US010158085B2

(12) **United States Patent**
Lee et al.

(10) **Patent No.: US 10,158,085 B2**
(45) **Date of Patent: Dec. 18, 2018**

(54) **CONDENSED CYCLIC COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 348 days.

(21) Appl. No.: **14/573,422**

(22) Filed: **Dec. 17, 2014**

(65) **Prior Publication Data**

US 2015/0171340 A1 Jun. 18, 2015

(30) **Foreign Application Priority Data**

Dec. 17, 2013 (KR) 10-2013-0157532

(51) **Int. Cl.**
H01L 51/00 (2006.01)
H01L 51/50 (2006.01)

(52) **U.S. Cl.**
CPC ***H01L 51/0067*** (2013.01); ***H01L 51/0072*** (2013.01); ***H01L 51/0073*** (2013.01);
(Continued)

(58) **Field of Classification Search**
None
See application file for complete search history.

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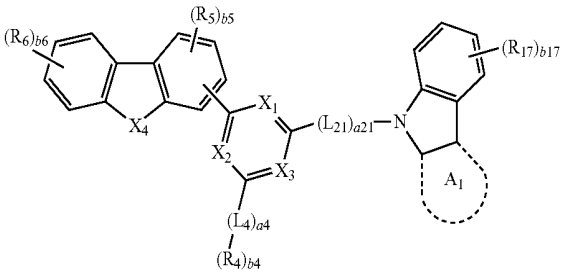
Primary Examiner — Jay Yang
(74) *Attorney, Agent, or Firm* — Cantor Colburn LLP

(57) **ABSTRACT**

A condensed-cyclic compound represented by Formula 1A or 1B:

Formula 1A



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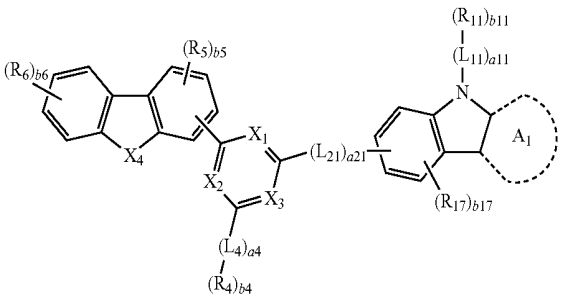
Formula 1B



wherein in Formulae 1A and 1B, groups, substituents, and variables are the same as defined in the specification.

13 Claims, 1 Drawing Sheet

(52) **U.S. Cl.**
CPC *H01L 51/0081* (2013.01); *H01L 51/0085* (2013.01); *H01L 51/5016* (2013.01)

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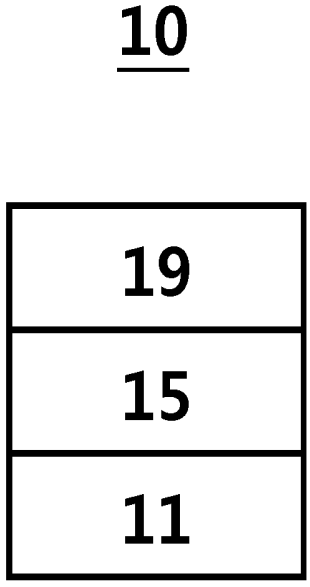
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CONDENSED CYCLIC COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to Korean Patent Application No. 10-2013-0157532, filed on Dec. 17, 2013, and all the benefits accruing therefrom under 35 U.S.C. § 119, the content of which is incorporated herein in its entirety by reference.

BACKGROUND

1. Field

One or more embodiments of the present disclosure relate to condensed-cyclic compounds and organic light-emitting devices including the condensed-cyclic compounds.

2. Description of the Related Art

Organic light-emitting devices (OLEDs) are self-emitting devices that have advantages such as wide viewing angles, excellent contrast ratios, and quick response times. In addition, OLEDs exhibit excellent brightness, driving voltage, and response speed characteristics, and can provide multi-colored images.

A typical OLED has a structure including an anode, a cathode, and an organic layer disposed between the anode and the cathode and including an emission layer. A hole transporting region may be disposed between the anode and the cathode, and an electron transporting region may be disposed between the emission layer and the cathode. Holes injected from the anode move to the EML via the hole transport region, and electrons injected from the cathode move to the EML via the electron transport region. Carriers such as holes and electrons recombine in the EML to generate excitons. When the excitons drop from an excited state to a ground state, light is emitted.

Different types of organic light emitting devices are known. However, there still remains a need in OLEDs having low driving voltage, high efficiency, high brightness, and long lifespan.

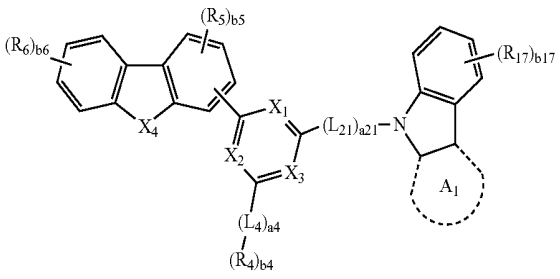
SUMMARY

One or more embodiments include novel condensed-cyclic compounds and organic light-emitting devices including the condensed-cyclic compounds.

Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments.

According to one or more embodiments, provided is a condensed-cyclic compound represented by Formula 1A or 1B:

Formula 1A



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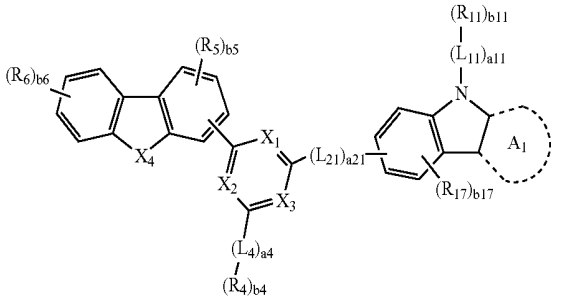
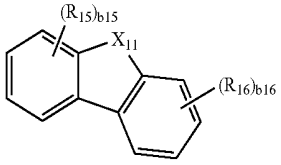
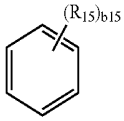
Formula 1B



Formula 1C



Formula 1D



In the Formulae above,

ring A_1 in Formulae 1A and 1B is represented by Formula 1C or 1D;

X_1 is N or C-[$(L_1)_{a1}$-$(R_1)_{b1}$],

X_2 is N or C-[$(L_2)_{a2}$-$(R_2)_{b2}$],

X_3 is N or C-[$(L_3)_{a3}$-$(R_3)_{b3}$], and

at least one of X_1 to X_3 is N;

X_4 is O or S;

X_{11} is selected from N-[$(L_{12})_{a12}$-$(R_{12})_{b12}$], S, O, S(=O), $S(=O)_2$, C(=O), $C(R_{13})(R_{14})$, $Si(R_{13})(R_{14})$, $P(R_{13})$, $P(=O)(R_{13})$, and $C=N(R_{12})$;

L_1 to L_4, L_{11}, L_{12} and L_{21} may be each independently selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_2-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_2-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_2-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic hetero-condensed polycyclic group;

a1 to a4, a11, a12, and a21 may be each independently selected from integers of 0 to 3;

R_1 to R_3, R_5, R_6, and R_{11} to R_{17} may be each independently selected from a hydrogen, a deuterium, —F (a fluoro group), —Cl (a chloro group), —Br (a bromo group), —I (an iodo group), a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_2-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_2-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or

unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_2-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic hetero-condensed polycyclic group, —$N(Q_1)(Q_2)$, —$Si(Q_3)(Q_4)(Q_5)$, and —$B(Q_6)(Q_7)$;

R_4 is selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_2-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_2-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_2-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic hetero-condensed polycyclic group;

b1 to b6 and b11 to b17 may be each independently selected from integers of 1 to 3;

at least one substituent of the substituted C_3-C_{10} cycloalkylene group, substituted C_2-C_{10} heterocycloalkylene group, substituted C_3-C_{10} cycloalkenylene group, substituted C_2-C_{10} heterocycloalkenylene group, substituted C_6-C_{60} arylene group, substituted C_2-C_{60} heteroarylene group, substituted divalent non-aromatic condensed polycyclic group, substituted divalent non-aromatic hetero-condensed polycyclic group, substituted C_1-C_{60} alkyl group, substituted C_2-C_{60} alkenyl group, substituted C_2-C_{60} alkynyl group, substituted C_1-C_{60} alkoxy group, substituted C_3-C_{10} cycloalkyl group, substituted C_2-C_{10} heterocycloalkyl group, substituted C_3-C_{10} cycloalkenyl group, substituted C_2-C_{10} heterocycloalkenyl group, substituted C_6-C_{60} aryl group, substituted C_6-C_{60} aryloxy group, substituted C_6-C_{60} arylthio group, substituted C_2-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic hetero-condensed polycyclic group may be selected from:

a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group;

a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic hetero-condensed polycyclic group, —$N(Q_{11})(Q_{12})$, —$Si(Q_{13})(Q_{14})(Q_{15})$ and —$B(Q_{16})(Q_{17})$;

a C_3-C_{10} cycloalkyl group, a C_2-010 heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic hetero-condensed polycyclic group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic hetero-condensed polycyclic group, —$N(Q_{21})(Q_{22})$, —$Si(Q_{23})(Q_{24})(Q_{25})$, and —$B(Q_{26})(Q_{27})$; and

—$N(Q_{31})(Q_{32})$, —$Si(Q_{33})(Q_{34})(Q_{35})$ and —$B(Q_{36})(Q_{37})$;

wherein Q_1 to Q_7, Q_{11} to Q_{17}, Q_{21} to Q_{27}, and Q_{31} to Q_{37} may be each independently selected from a hydrogen, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, monovalent a non-aromatic condensed polycyclic group, and a monovalent non-aromatic hetero-condensed polycyclic group.

According to one or more embodiments, provided is an organic light-emitting device including

a first electrode;

a second electrode; and

an organic layer disposed between the first electrode and the second electrode,

wherein the organic layer includes an emission layer and at least one condensed-cyclic compound represented by Formula 1.

The condensed-cyclic compound may be included in the emission layer, wherein the emission layer further includes a dopant, and the condensed-cyclic compound included in the emission layer may act as a host.

BRIEF DESCRIPTION OF THE DRAWING

These and/or other aspects will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompanying drawing in which:

The FIGURE is a schematic view showing an organic light-emitting device according to an embodiment.

DETAILED DESCRIPTION

Reference will now be made in detail to embodiments, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to the like elements throughout. In this regard, the present embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein.

Accordingly, the embodiments are merely described below, by referring to the figures, to explain aspects of the present description. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. Expressions such as "at least one of," when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

It will be understood that when an element is referred to as being "on" another element, it can be directly in contact with the other element or intervening elements may be present therebetween. In contrast, when an element is referred to as being "directly on" another element, there are no intervening elements present.

It will be understood that, although the terms first, second, third etc. may be used herein to describe various elements, components, regions, layers, and/or sections, these elements, components, regions, layers, and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer, or section from another element, component, region, layer, or section. Thus, a first element, component, region, layer, or section discussed below could be termed a second element, component, region, layer, or section without departing from the teachings of the present embodiments.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

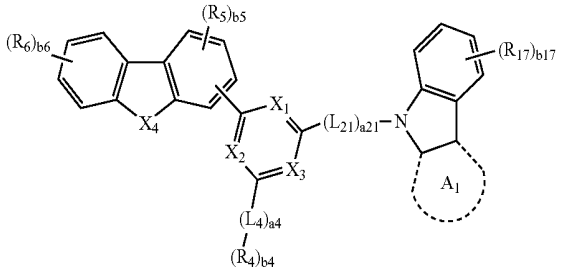
The term "or" means "and/or." It will be further understood that the terms "comprises" and/or "comprising," or "includes" and/or "including" when used in this specification, specify the presence of stated features, regions, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this general inventive concept belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and the present disclosure, and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

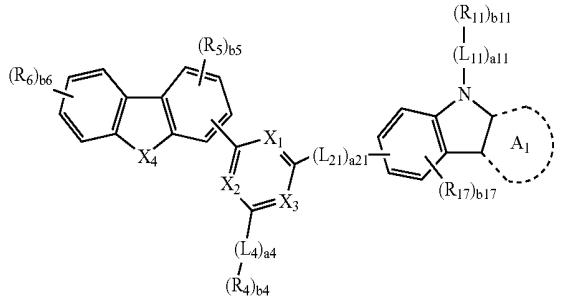
Exemplary embodiments are described herein with reference to cross section illustrations that are schematic illustrations of idealized embodiments. As such, variations from the shapes of the illustrations as a result, for example, of manufacturing techniques and/or tolerances, are to be expected. Thus, embodiments described herein should not be construed as limited to the particular shapes of regions as illustrated herein but are to include deviations in shapes that result, for example, from manufacturing. For example, a region illustrated or described as flat may, typically, have rough and/or nonlinear features. Moreover, sharp angles that are illustrated may be rounded. Thus, the regions illustrated in the figures are schematic in nature and their shapes are not intended to illustrate the precise shape of a region and are not intended to limit the scope of the present claims.

A condensed-cyclic compound according to an embodiment may be represented by Formula 1A or 1B:

Formula 1A

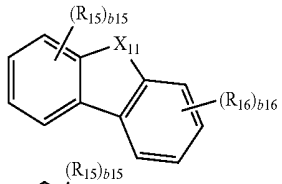


Formula 1B

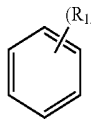


ring A_1 in Formula 1A and 1B may be represented by Formula 1C or 1D.

Formula 1C

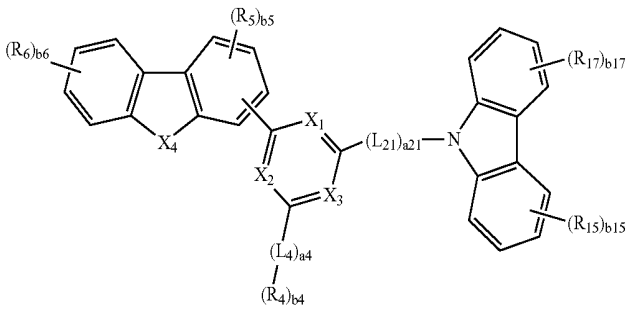


Formula 1D



In Formulae 1A and 1B, ring A_1 may be fused with an adjacent 5-membered cyclic ring by sharing the carbon atoms disposed therebetween. Accordingly, the condensed-cyclic compound represented by Formula 1A or 1B may be represented by any one of Formulae 1A-1 to 1A-7 and 1B-1 to 1B-4:

Formula 1A-1



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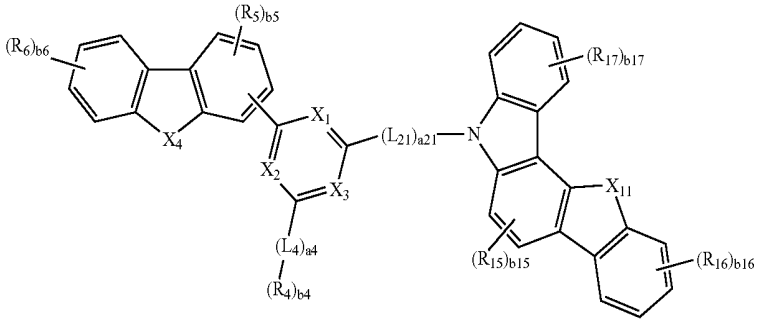
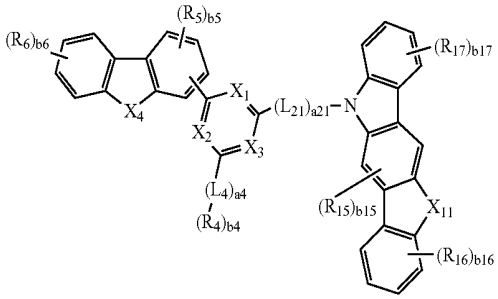
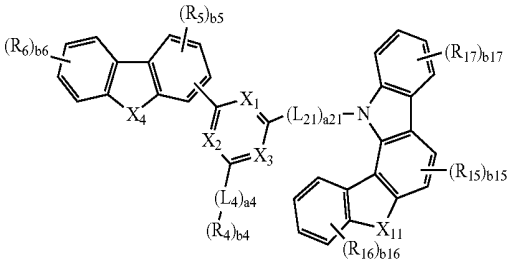
Formula 1A-2



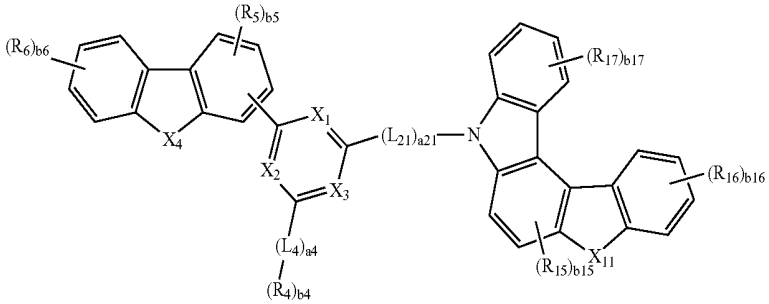
Formula 1A-3



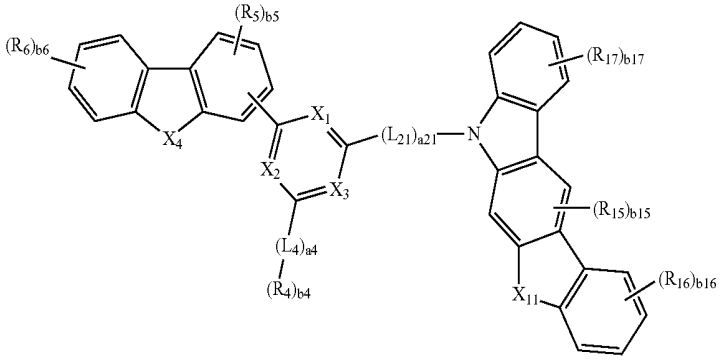
Formula 1A-4



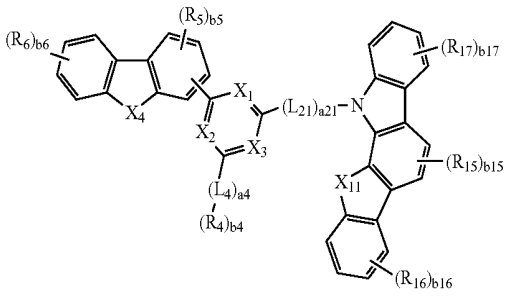
Formula 1A-5



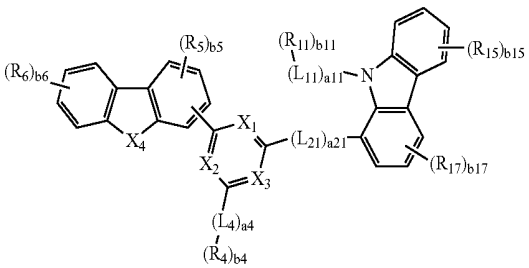
Formula 1A-6



Formula 1A-7



Formula 1B-1



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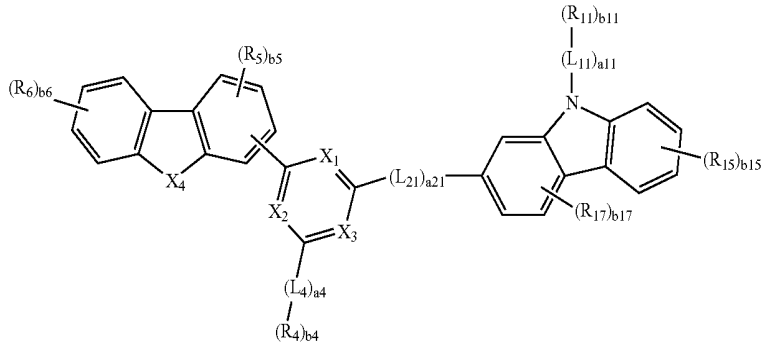
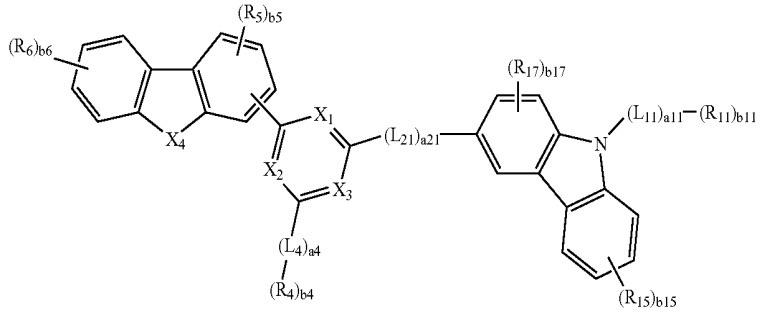
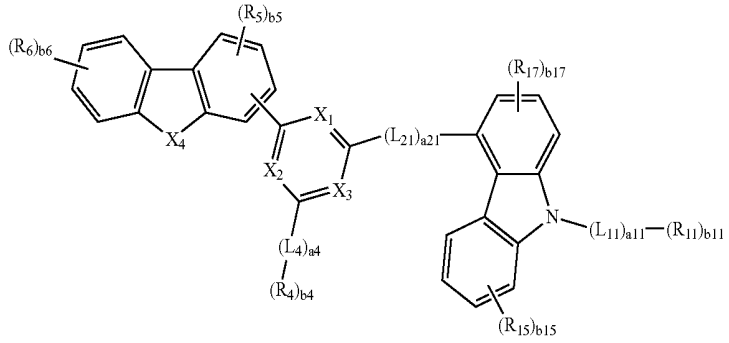
Formula 1B-2



Formula 1B-3



Formula 1B-4



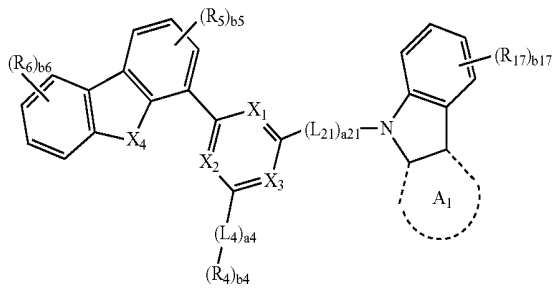
Descriptions of Formulae 1A-1 to 1A-7 and 1B-1 to 1B-4, X_1 to X_4, X_{11}, L_1 to L_4, L_{11}, L_{12}, L_{21}, a1 to a4, a11, a12, a21, R_1 to R_6, R_{11} to R_{17}, b1 to b6, and b11 to b17 are given below.

According to an embodiment, the condensed-cyclic compound may be represented by Formula 1A-1, 1A-2, 1A-3, 1B-1, 1B-2, 1B-3, or 1B-4, but it is not limited thereto.

According to another embodiment, the condensed-cyclic compound may be represented by Formula 1A-1 or 1A-2, but it is not limited thereto.

Formulae 1A and 1B may be represented by any one of Formulae 1A(1) to 1A(4) and 1B(1) to 1B(4), but they are not limited thereto:

Formula 1A(1)



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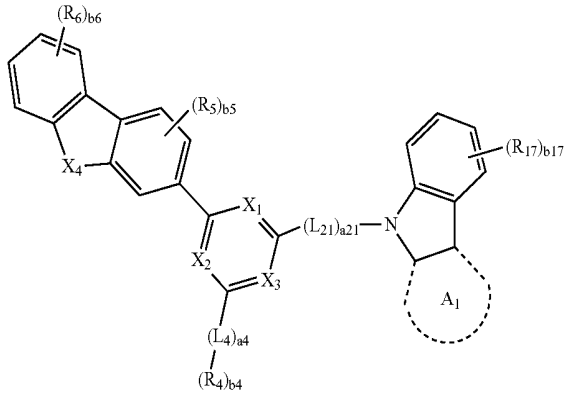
Formula 1A(2)



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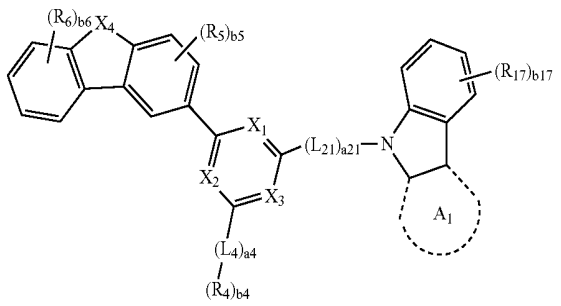
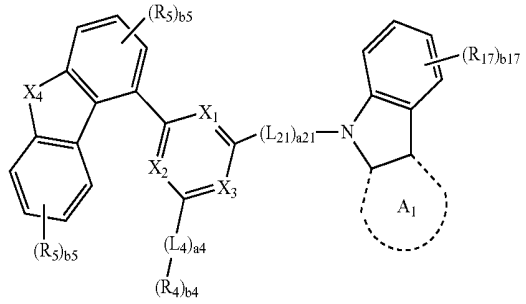
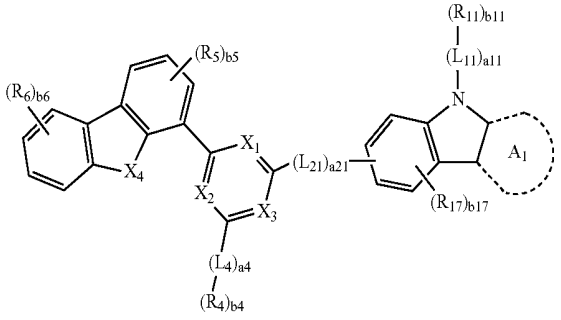
Formula 1A(3)



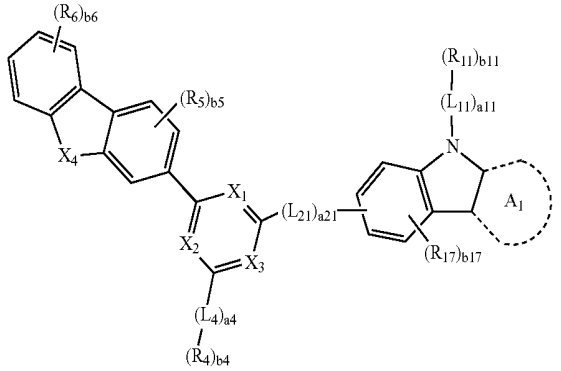
Formula 1A(4)



Formula 1B(1)



Formula 1B(2)



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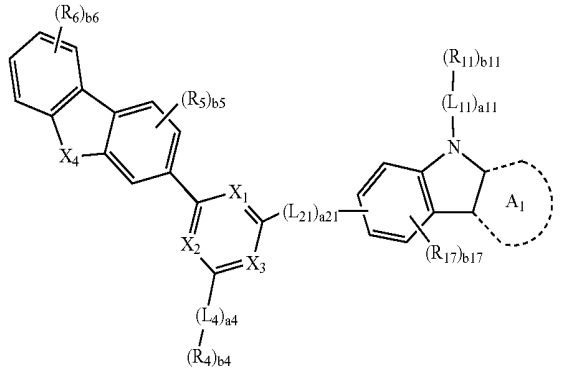
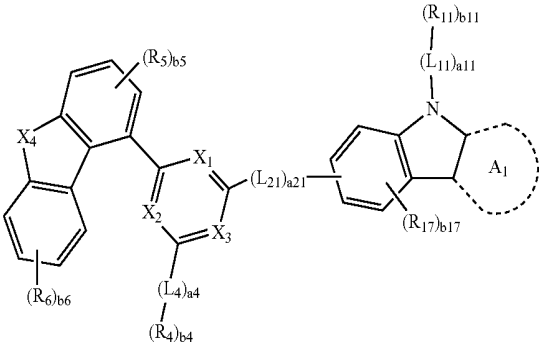
Formula 1B(3)



Formula 1B(4)



In Formulae 1A(1) to 1A(4) and 1B(1) to 1B(4), descriptions of ring A_1, X_1 to X_4, X_{11}, L_1 to L_4, L_{11}, L_{12}, L_{21}, a1 to a4, a11, a12, a21, R_1 to R_6, R_{11} to R_{17}, b1 to b6, and b11 to b17 are given below.

In Formula 1C, X_{11} is selected from N-[$(L_{12})_{a12}$-$(R_{12})_{b12}$], S, O, S(=O), S(=O)$_2$, C(=O), C(R_{13})(R_{14}), Si(R_{13})(R_{14}), P(R_{13}), P(=O)(R_{13}), and C=N(R_{12}). For example, in Formula 1C, X_{11} may be selected from N-[$(L_{12})_{a12}$-$(R_{12})_{b12}$], S, O, and C(R_{13})(R_{14}), but it is not limited thereto. Descriptions of L_{12}, a12, R_{12} to R_{14}, and b12 may be understood by referring to the description below.

In Formula 1A and 1B, X_1 is N or C-[$(L_1)_{a1}$-$(R_1)_{b1}$], X_2 is N or C-[$(L_2)_{a2}$-$(R_2)_{b2}$], X_3 is N or C-[$(L_3)_{a3}$-$(R_3)_{b3}$], and at least one of X_1 to X_3 is N.

For example, in Formulae 1A and 1B,

X_1 to X_3 may be N;

X_1 may be C-[$(L_1)_{a1}$-$(R_1)_{b1}$], X_2 and X_3 may be N;

X_1 may be N, X_2 may be C-[$(L_2)_{a2}$-$(R_2)_{b2}$], and X_3 may be N;

X_1 and X_2 may be N, and X_3 may be C-[$(L_3)_{a3}$-$(R_3)_{b3}$];

X_1 may be C-[$(L_1)_{a1}$-$(R_1)_{b1}$], X_2 may be N, and X_3 may be C-[$(L_3)_{a3}$-$(R_3)_{b3}$];

X_1 may be C-[$(L_1)_{a1}$-$(R_1)_{b1}$], X_2 may be C-[$(L_2)_{a2}$-$(R_2)_{b2}$], and X_3 may be N; or

X_1 may be N, X_2 may be C-[$(L_2)_{a2}$-$(R_2)_{b2}$], and X_3 may be C-[$(L_3)_{a3}$-$(R_3)_{b3}$].

According to an embodiment,

X_1 may be C-[$(L_1)_{a1}$-$(R_1)_{b1}$], X_2 and X_3 may be N; or

X_1 and X_2 may be N, and X_3 may be C-[$(L_3)_{a3}$-$(R_3)_{b3}$], but they are not limited thereto.

Descriptions of L_1 to L_3, a1 to a3, R_1 to R_3, and b1 to b3 may be understood by referring to the description below.

In Formulae 1A, 1B, and 1C, L_1 to L_4, L_{11}, L_{12}, and L_{21} may be each independently selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_2-C_{10} heterocycloalkylene group, a substi-

tuted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_2-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_2-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic hetero-condensed polycyclic group.

For example, in Formulae 1A, 1B, and 1C, L_1 to L_4, L_{11}, L_{12}, and L_{21} may be each independently selected from:

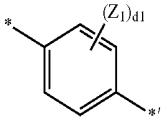
a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-fluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthrenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pyrrolylene group, an imidazolylene group, a pyrazolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an isoindolylene group, an indolylene group, an indazolylene group, a purinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a carbazolylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzooxazolylene group, a benzoimidazolylene group, a furanylene group, a benzofuranylene group, a thiophenylene group, a benzothiophenylene group, a thiazolylene group, a isothiazolylene group, a benzothiazolylene group, an isoxazolylene group, an oxazolylene group, a triazolylene group, a tetrazolylene group, an oxadiazolylene group, a triazinylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, an imidazopyrimidinylene group, and an imidazopyridinylene group; and

a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-fluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthrenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pyrrolylene group, an imidazolylene group, a pyrazolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an isoindolylene group, an indolylene group, an indazolylene group, a purinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a carbazolylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzooxazolylene group, a benzoimidazolylene group, a furanylene group, a benzofuranylene group, a thiophenylene group, a benzothiophenylene group, a thiazolylene group, a isothiazolylene group, a benzothiazolylene group, an isoxazolylene group, an oxazolylene group, a triazolylene group, a tetrazolylene group, an oxadiazolylene group, a triazinylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group an imidazopyrimidinylene group, and an imidazopyridinylene group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a C_6-C_{20} aryl group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic hetero-condensed cyclic group, and $—Si(Q_{33})(Q_{34})(Q_{35})$,

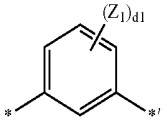
Q_{33} to Q_{35} may be each independently selected from a hydrogen, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group, but they are not limited thereto.

For example, in Formulae 1A, 1B, and 1C, L_1 to L_4, L_{11}, L_{12}, and L_{21} may be each independently selected from Formulae 2-1 to 2-34:

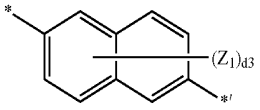
Formula 2-1



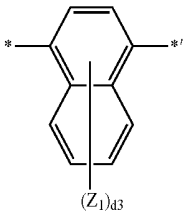
Formula 2-2



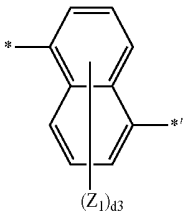
Formula 2-3



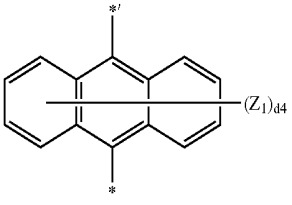
Formula 2-4



Formula 2-5



Formula 2-6



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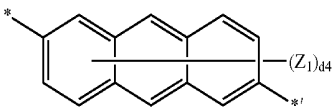
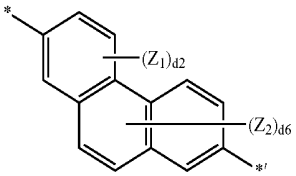
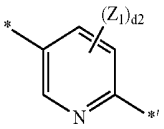


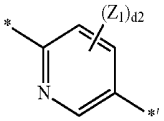
Formula 2-7



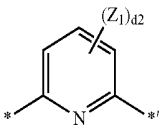
Formula 2-8



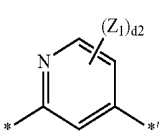
Formula 2-9



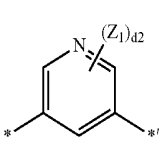
Formula 2-10



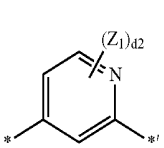
Formula 2-11



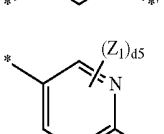
Formula 2-12



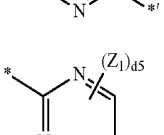
Formula 2-13



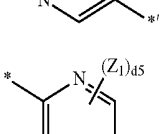
Formula 2-14



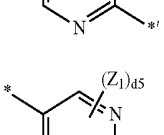
Formula 2-15



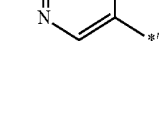
Formula 2-16



Formula 2-17



Formula 2-18



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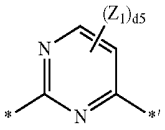
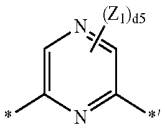
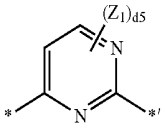
Formula 2-19



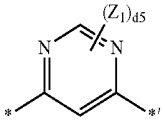
Formula 2-20



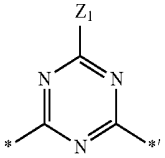
Formula 2-21



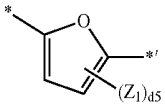
Formula 2-22



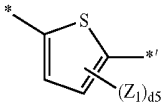
Formula 2-23



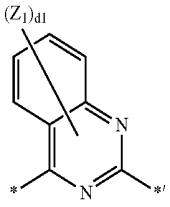
Formula 2-24



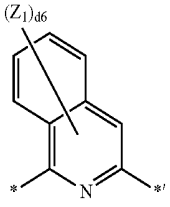
Formula 2-25



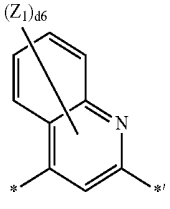
Formula 2-26



Formula 2-27

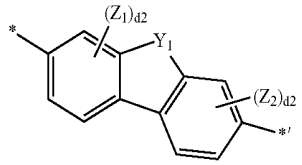


Formula 2-28

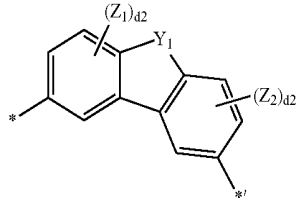


-continued

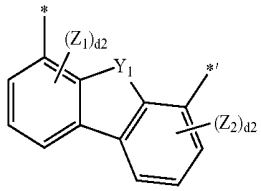
Formula 2-29



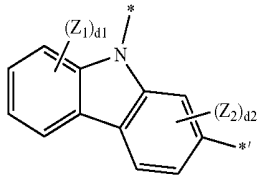
Formula 2-30



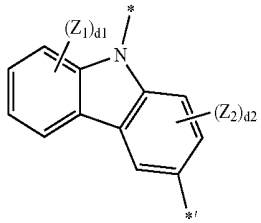
Formula 2-31



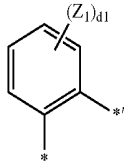
Formula 2-32



Formula 2-33



Formula 2-34



In Formula 2-1 to 2-34,

Y_1 may be selected from O, S, S(=O), S(=O)$_2$, C(Z_3)(Z_4), N(Z_5), or Si(Z_6)(Z_7);

Z_1 to Z_7 may be each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, a quinoxalinyl group, a biphenyl group, and —Si(Q_{33})(Q_{34})(Q_{35});

wherein Q_{33} to Q_{35} may be each independently selected from a hydrogen, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group;

d1 is selected from integers of 1 to 4,

d2 is selected from integers of 1 to 3,

d3 is selected from integers of 1 to 6,

d4 is selected from integers of 1 to 8,

d5 is 1 or 2,

d6 is selected from integers of 1 to 5, and

each of * and *' indicates a bonding site to neighboring atoms.

For example, in Formulae 2-1 to 2-34, *' indicates a bonding site to neighboring atoms of L_1 to L_4, L_{11}, L_{12}, and L_{21} or bonding site to each of R_1 to R_4, R_{11}, R_{12}, and R_{21}.

According to an embodiment, in Formulae 1A and 1B, L_1 to L_4, L_{11}, L_{12}, and L_{21} may be each independently selected from Formulae 2-1 to 2-5, 2-9 to 2-23, and 2-34, but they are not limited thereto.

According to another embodiment, in Formulae 1A and 1B, L_1 to L_4, L_{11}, L_{12}, and L_{21} may be each independently selected from:

a phenylene group and a naphthylene group; and

a phenylene group and a naphthylene group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, a quinoxalinyl group, a biphenyl group, and —Si(Q_{33})(Q_{34})(Q_{35}) (wherein Q_{33} to Q_{35} may be each independently selected from a hydrogen, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group, but they are not limited thereto.

In Formula 1A, a1 represents the number of groups L_1, which may be 0, 1, 2, or 3, for example, 0, 1, or 2, or may be 0 or 1. When a1 is 0, -(L_1)$_{a1}$- is a single bond. When a1 is 2 or greater, two or more groups L_1 may be the same or different. Descriptions of a2 to a4, a11, a12, and a21 may be understood by referring to the description of a1 and structures of Formulae 1A and 1B.

According to an embodiment, in Formulae above, a1 to a4, a11, a12, and a21 may be each independently, 0, 1, or 2.

According to another embodiment, in Formulae above, a21 may be 1, but it is not limited thereto.

In Formulae 1A, 1B, 1C, and 1D, R_1 to R_3, R_5, R_6, and R_{11} to R_{17} may be each independently selected from a hydrogen, a deuterium, —F (a fluoro group), —Cl (a chloro group), —Br (a bromo group), —I (an iodo group), a

hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_2-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_2-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_2-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic hetero-condensed polycyclic group, —$N(Q_1)(Q_2)$, —$Si(Q_3)(Q_4)(Q_5)$, and —$B(Q_6)(Q_7)$. Here, descriptions of Q_1 to Q_7 are as described below.

In Formulae 1A and 1B, R_4 is selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_2-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_2-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_2-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic hetero-condensed polycyclic group. For example, R_4 may be selected from a substituted or unsubstituted C_6-C_{20} aryl group, a substituted or unsubstituted C_2-C_{30} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic hetero-condensed polycyclic group, but it is not limited thereto.

According to an embodiment, in Formulae 1A and 1B, R_{11} and R_{12} may be each independently selected from a substituted or unsubstituted C_6-C_{30} aryl group, a substituted or unsubstituted C_2-C_{30} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic hetero-condensed polycyclic group.

For example, in Formulae 1A, 1B, 1C, and 1D, R_1 to R_3, R_5, R_6, and R_{13} to R_{17} may be each independently selected from:

a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;

a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof and a phosphoric acid or a salt thereof;

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group;

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, —$Si(Q_{33})(Q_{34})(Q_{35})$, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group,

an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and a biphenyl group; and

$—Si(Q_3)(Q_4)(Q_5)$ (provided that, R_{13} and R_{14} are not $—Si(Q_3)(Q_4)(Q_5)$);

wherein Q_3 to Q_5 and Q_{33} to Q_{35} may be each independently selected from a hydrogen, C_1-C_{20} alkyl group, C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group, but they are not limited thereto.

According to another embodiment, in Formulae 1A, 1B, 1C, and 1D, R_1 to R_3, R_5, R_6, and R_{13} to R_{17} may be each independently selected from:

a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;

a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, and a phosphoric acid or a salt thereof;

a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group;

a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, $—Si(Q_{33})(Q_{34})(Q_{35})$, a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group; and

$—Si(Q_3)(Q_4)(Q_5)$, provided that R_{13} and R_{14} are not $—Si(Q_3)(Q_4)(Q_5)$;

wherein Q_3 to Q_5 and Q_{33} to Q_{35} may be each independently selected from a hydrogen, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group.

Meanwhile, in Formulae 1A and 1B, R_4, R_{11}, and R_{12} may be each independently selected from:

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a

naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group and an imidazopyrimidinyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, —$Si(Q_{33})(Q_{34})(Q_{35})$, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and a biphenyl group; and

Q_{33} to Q_{35} may be each independently selected from a hydrogen, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group.

According to another embodiment, in Formulae 1A, 1B, 1C, and 1 D, R_1 to R_3, R_5, R_6, and R_{13} to R_{17} may be each independently selected from:

a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group;

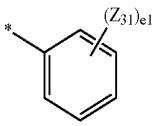
a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, and a phosphoric acid or a salt thereof;

Formulae 4-1 to 4-31 below (for example, Formulae 4-1 to 4-3 and 4-6 to 4-13); and

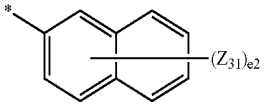
—$Si(Q_3)(Q_4)(Q_5)$ (provided that, R_{13} and R_{14} are not —$Si(Q_3)(Q_4)(Q_5)$);

wherein, R_4, R_{11}, and R_{12} may be each independently selected from Formulae 4-1 to 4-31 (for example, Formulae 4-1 to 4-3 and 4-6 to 4-13), but they are not limited thereto.

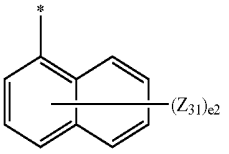
Formula 4-1



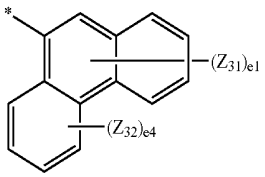
Formula 4-2



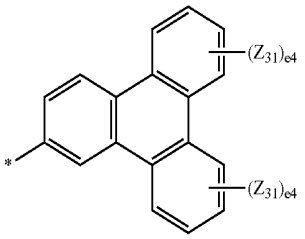
Formula 4-3



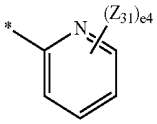
Formula 4-4



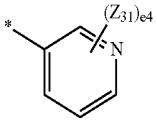
Formula 4-5



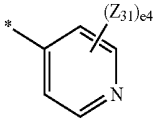
Formula 4-6



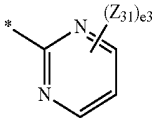
Formula 4-7



Formula 4-8

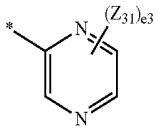


Formula 4-9

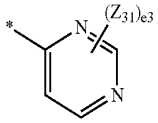


-continued

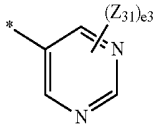
Formula 4-10



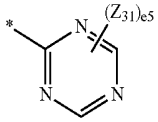
Formula 4-11



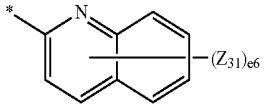
Formula 4-12



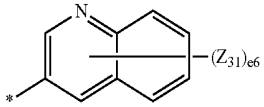
Formula 4-13



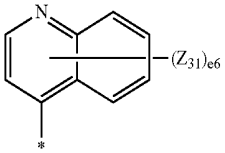
Formula 4-14



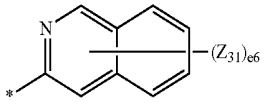
Formula 4-15



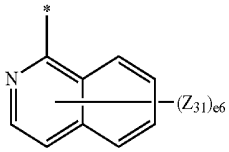
Formula 4-16



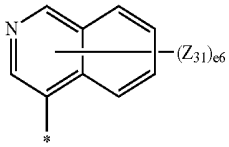
Formula 4-17



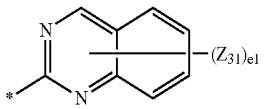
Formula 4-18



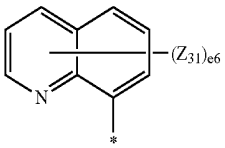
Formula 4-19



Formula 4-20



Formula 4-21



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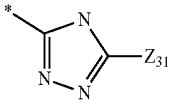
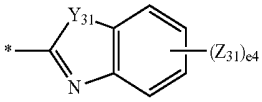
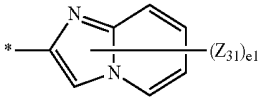
Formula 4-22



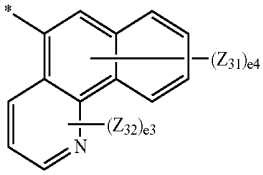
Formula 4-23



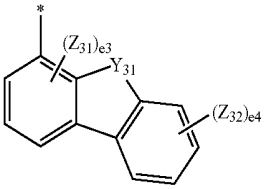
Formula 4-24



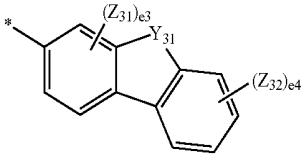
Formula 4-25



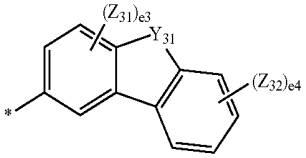
Formula 4-26



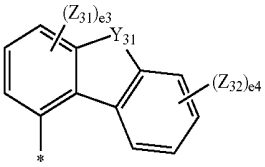
Formula 4-27



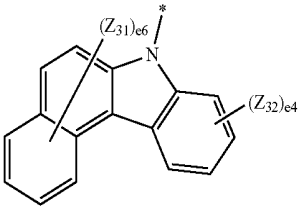
Formula 4-28



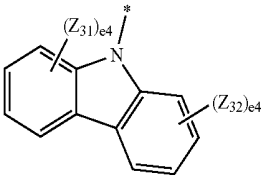
Formula 4-29



Formula 4-30



Formula 4-31



In Formulae 4-1 to 4-31,

Y_{31} may be O, S, $C(Z_{33})(Z_{34})$, $N(Z_{35})$ or $Si(Z_{36})(Z_{37})$;

Z_{31} to Z_{37} may be each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, C_1-C_{20} alkyl group, C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, a quinoxalinyl group, a biphenyl group, and $—Si(Q_{33})(Q_{34})(Q_{35})$;

Q_3 to Q_5 and Q_{33} to Q_{35} may be each independently selected from a hydrogen, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group;

e1 may be selected from integers of 1 to 5,

e2 is selected from integers of 1 to 7,

e3 is selected from integers of 1 to 3,

e4 is selected from integers of 1 to 4,

e5 is 1 or 2,

e6 is selected from integers of 1 to 6, and

* indicates a bonding site to a neighboring atom.

According to another embodiment, R_1 to R_3, R_5, R_6, and R_{13} to R_{17} may be each independently selected from:

a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;

a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, and a phosphoric acid or a salt thereof;

a phenyl group and a naphthyl group;

a phenyl group and a naphthyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, and a naphthyl group; and

$—Si(Q_3)(Q_4)(Q_5)$ (provided that, R_{13} and R_{14} are not $—Si(Q_3)(Q_4)(Q_5)$ and Q_3 to Q_5 are each independently selected from a hydrogen, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, and a naphthyl group);

R_4, R_{11}, and R_{12} are each independently selected from:

a phenyl group and a naphthyl group; and

a phenyl group and a naphthyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, and a naphthyl group; but, they are not limited thereto.

According to another embodiment, R_5, R_6, and R_{15} to R_{17} may all be hydrogen, but they are not limited thereto.

In Formulae 1A and 1B, b1 represents the number of groups R_1 and may be selected from integers of 1 to 3. For example, b1 may be 1 or 2. In greater detail, b1 may be 1. When b1 is 2 or greater, two or more of groups R_1 may be the same or different. Descriptions of b2 to b6 and b11 to b17 may be understood by referring to the description of b1 and structures of Formulae 1A, 1B, 1C, and 1D.

According to an embodiment, at least one substituent of the substituted C_3-C_{10} cycloalkylene group, substituted C_2-C_{10} heterocycloalkylene group, substituted C_3-C_{10} cycloalkenylene group, substituted C_2-C_{10} heterocycloalkenylene group, substituted C_6-C_{60} arylene group, substituted C_2-C_{60} heteroarylene group, substituted divalent non-aromatic condensed polycyclic group, substituted divalent non-aromatic hetero-condensed polycyclic group, substituted C_1-C_{60} alkyl group, substituted C_2-C_{60} alkenyl group, substituted C_2-C_{60} alkynyl group, substituted C_1-C_{60} alkoxy group, substituted C_3-C_{10} cycloalkyl group, substituted C_2-C_{10} heterocycloalkyl group, substituted C_3-C_{10} cycloalkenyl group, substituted C_2-C_{10} heterocycloalkenyl group, substituted C_6-C_{60} aryl group, substituted C_6-C_{60} aryloxy group, substituted C_6-C_{60} arylthio group, substituted C_2-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic hetero-condensed polycyclic group may be selected from:

a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group;

a C_1-C_{60} alkyl group, C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic hetero-condensed polycyclic group, $—N(Q_{11})(Q_{12})$, $—Si(Q_{13})(Q_{14})(Q_{15})$ and $—B(Q_{16})(Q_{17})$;

a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic hetero-condensed polycyclic group; a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic hetero-condensed polycyclic group, each substituted with at least one of a deuterium, —F,

—Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic hetero-condensed polycyclic group, —$N(Q_{21})(Q_{22})$, —$Si(Q_{23})(Q_{24})(Q_{25})$, and —$B(Q_{26})(Q_{27})$; and

—$N(Q_{31})(Q_{32})$, —$Si(Q_{33})(Q_{34})(Q_{35})$ and —$B(Q_{36})(Q_{37})$;

wherein Q_1 to Q_7, Q_{11} to Q_{17}, Q_{21} to Q_{27} and Q_{31} to Q_{37} may be each independently selected from a hydrogen, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic hetero-condensed polycyclic group.

The condensed-cyclic compound may be any one of Compounds 1 to 824, but it is not limited thereto:

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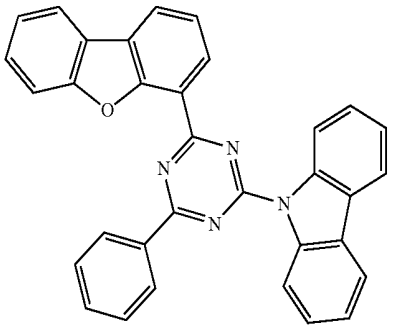

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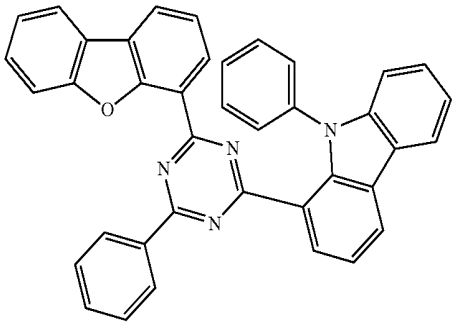

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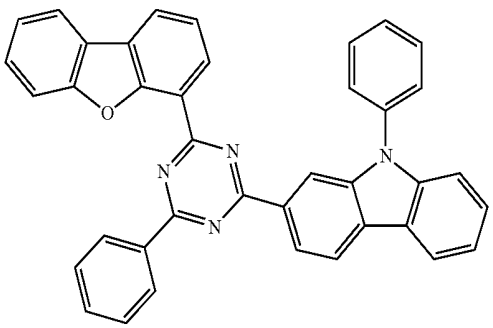

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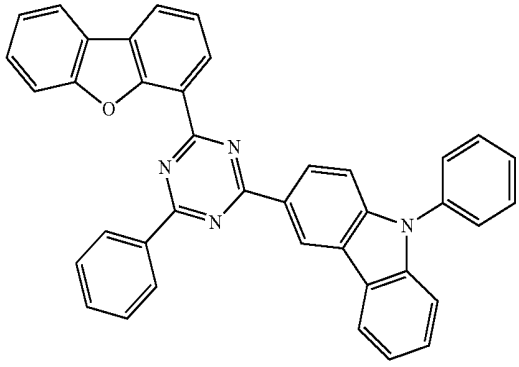

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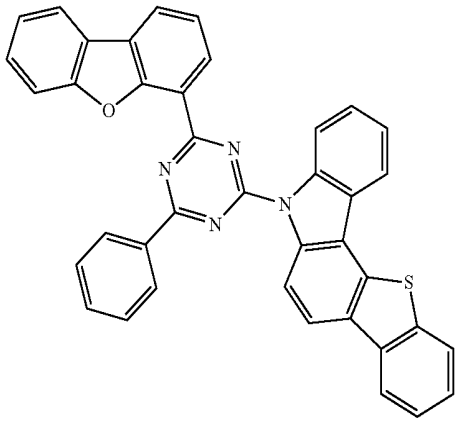

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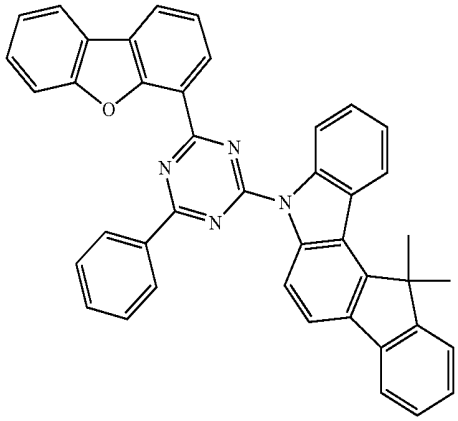

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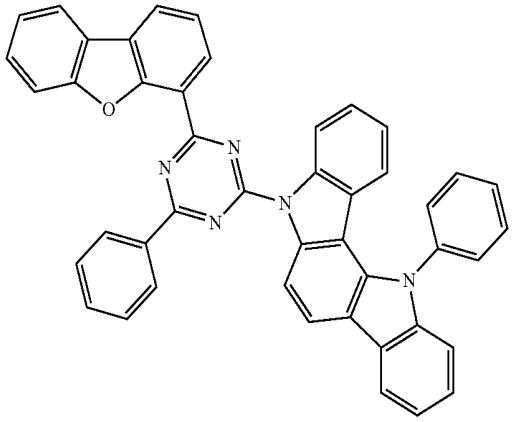

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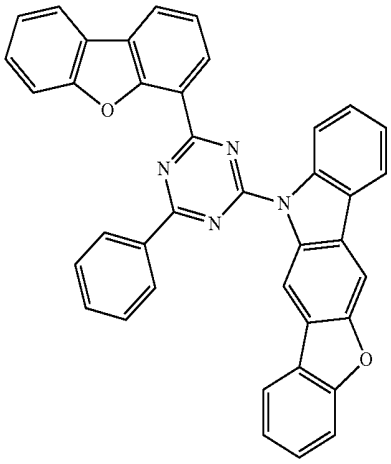

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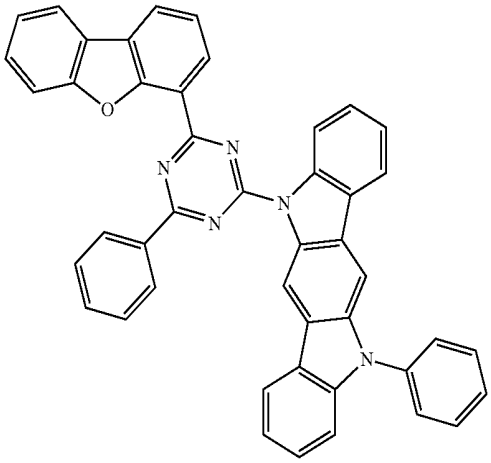

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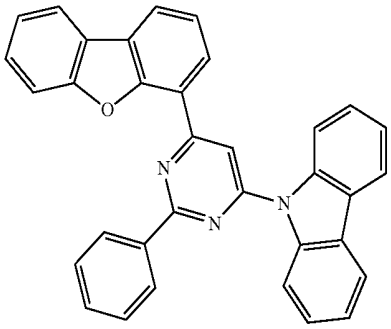

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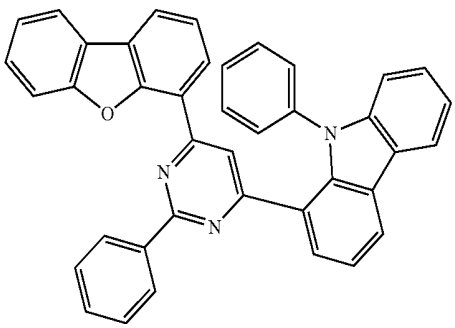

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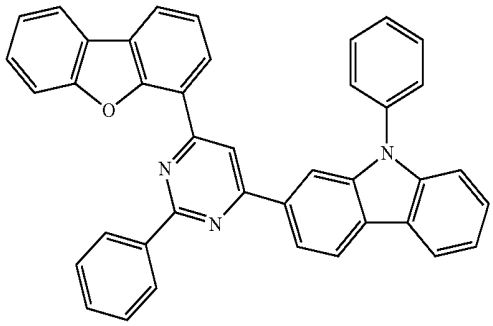

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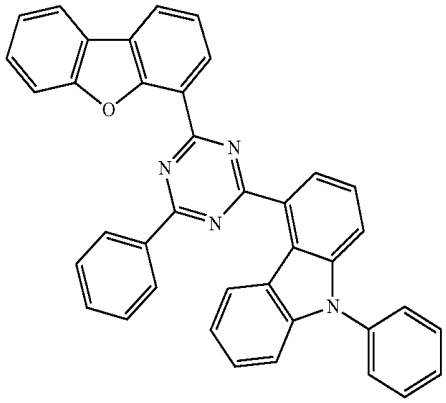

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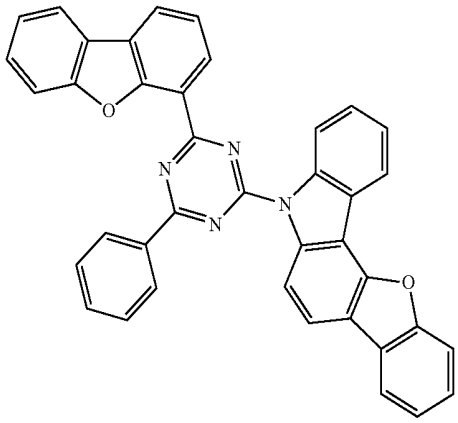

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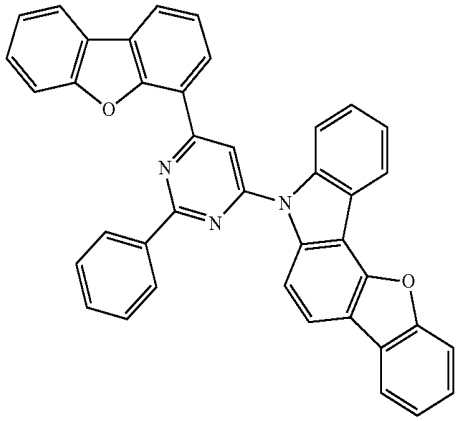

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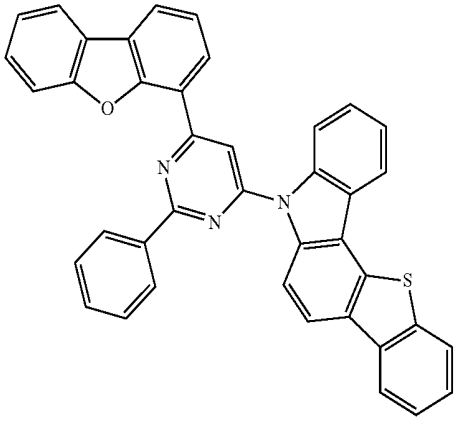

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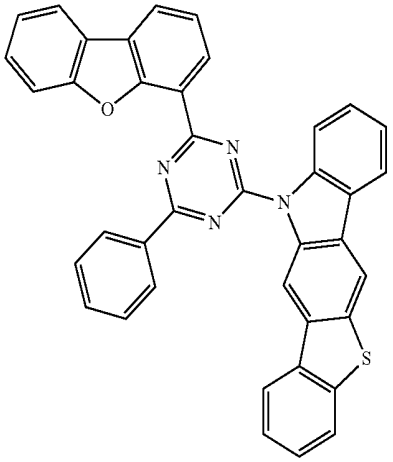

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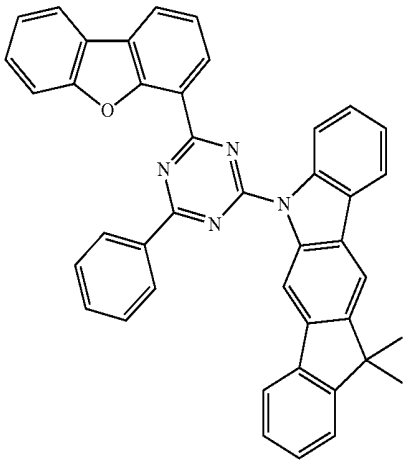

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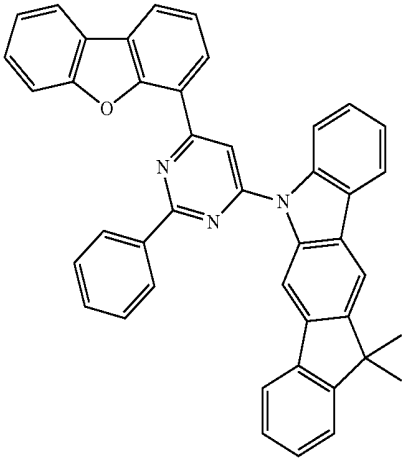

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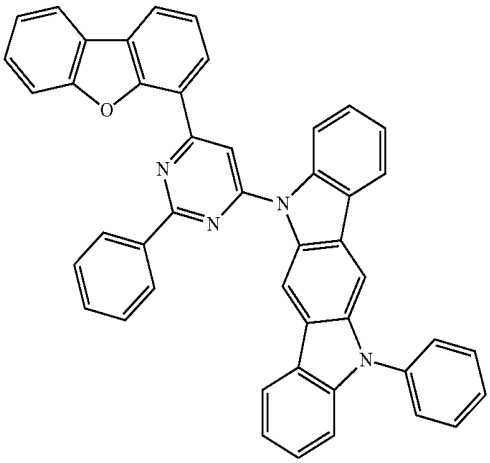

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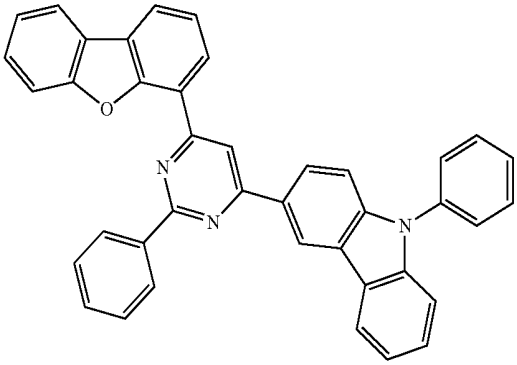

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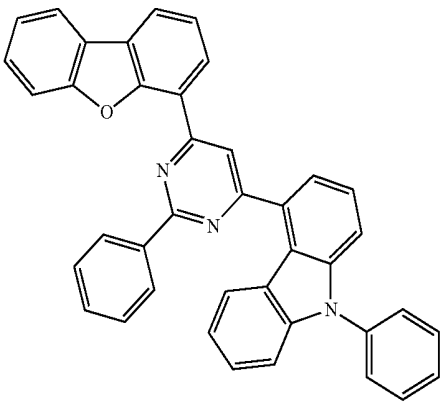

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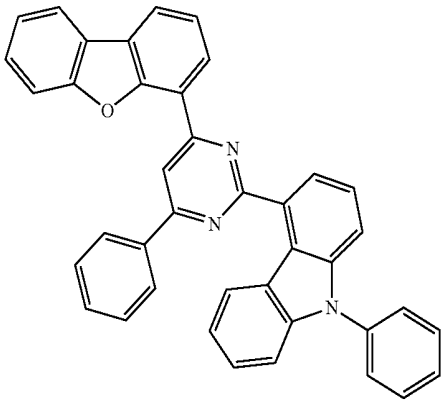

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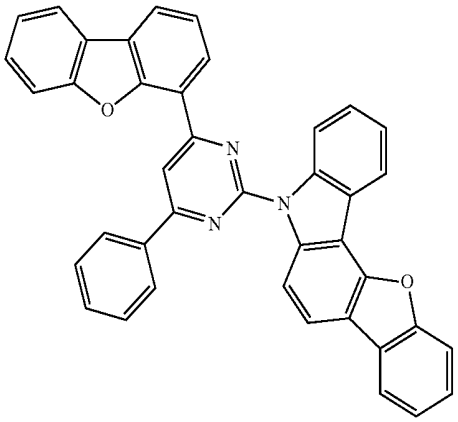

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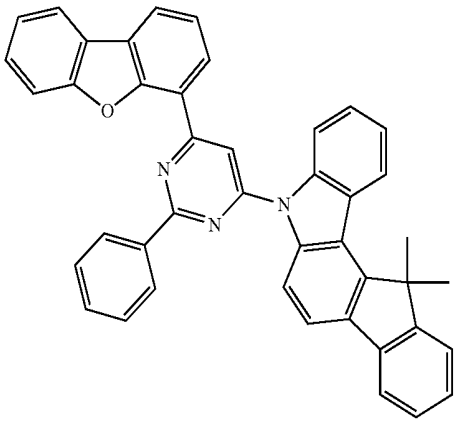

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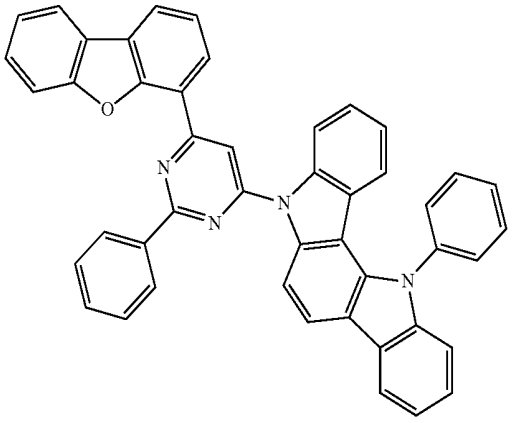

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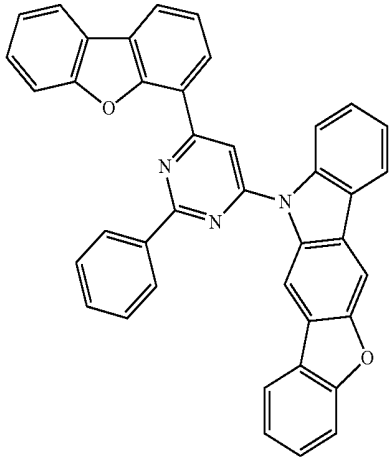

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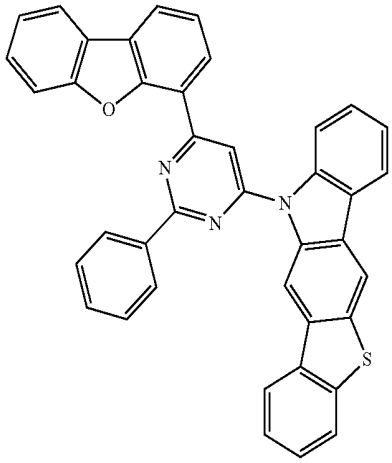

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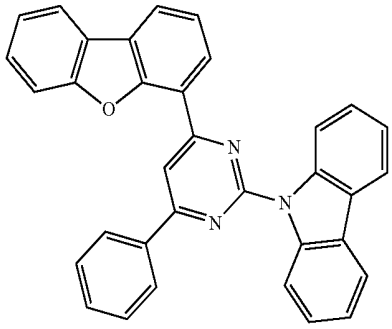

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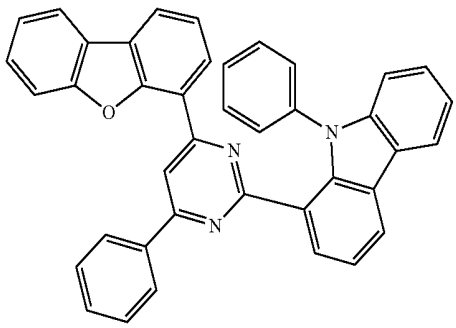

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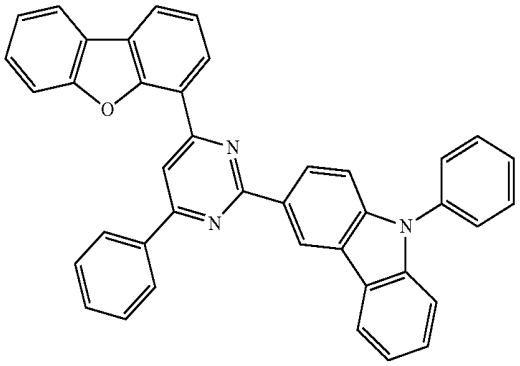

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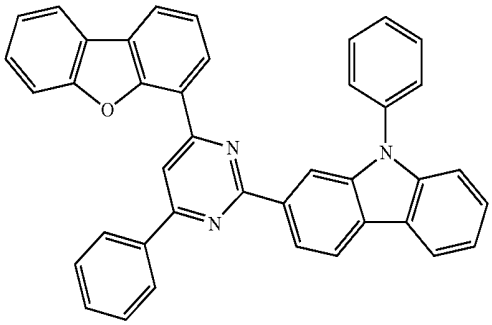

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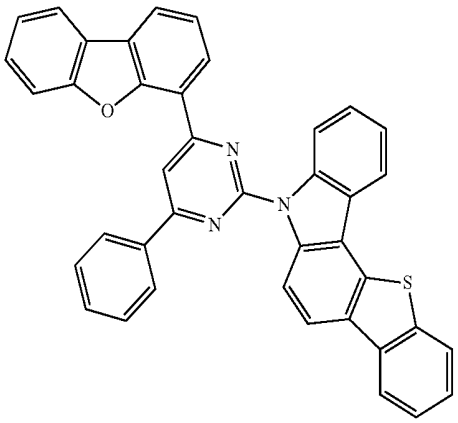

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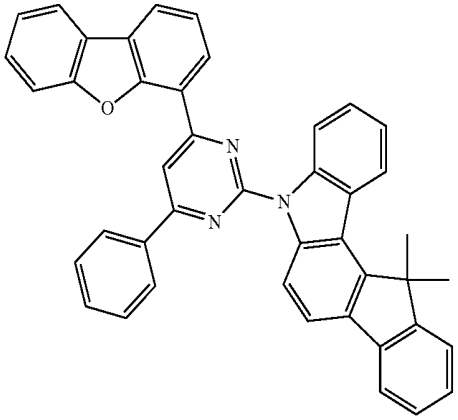

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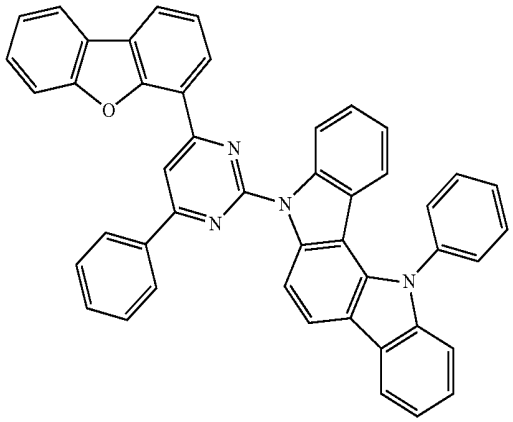

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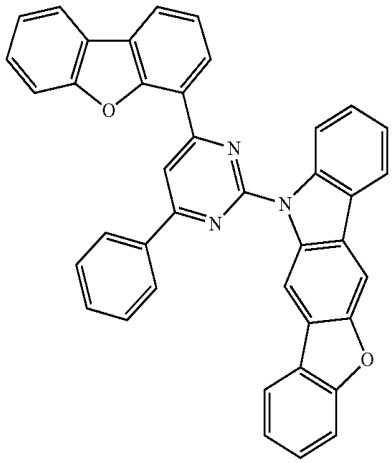

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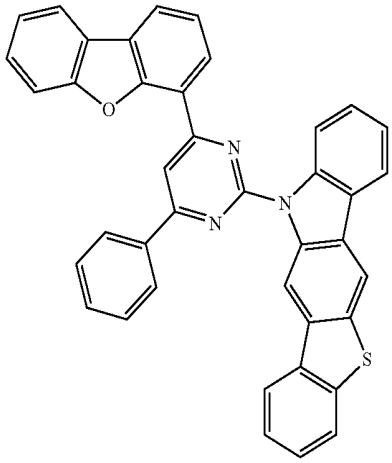

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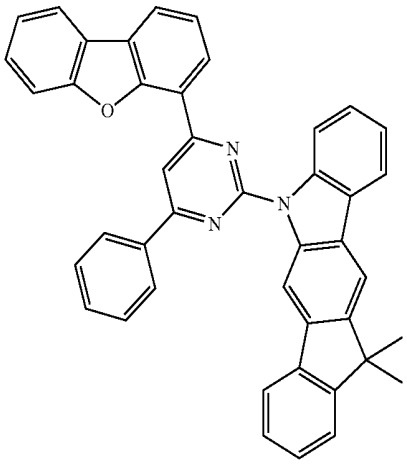

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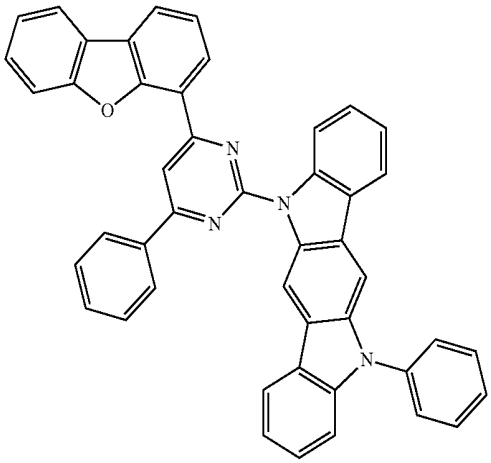

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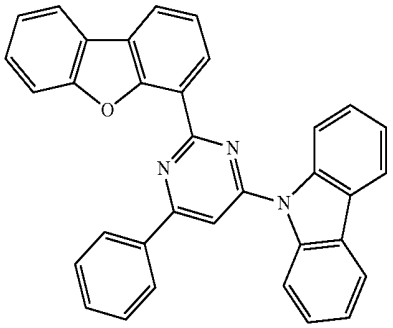

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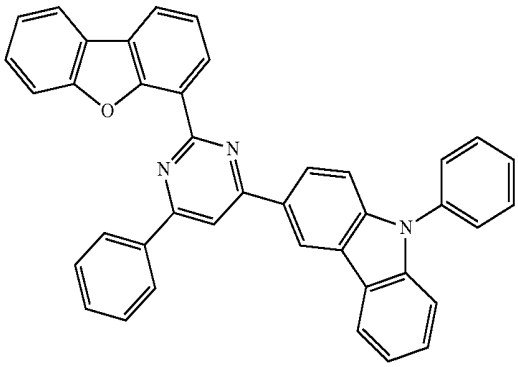

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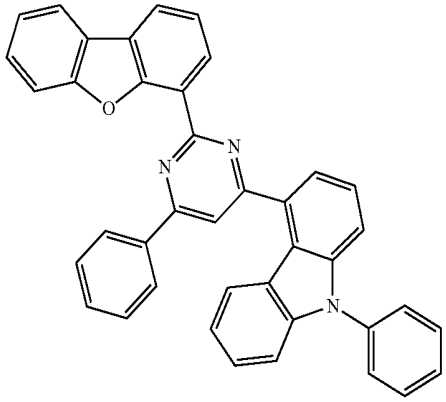

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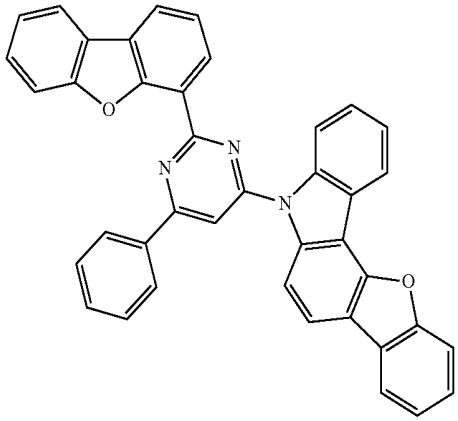

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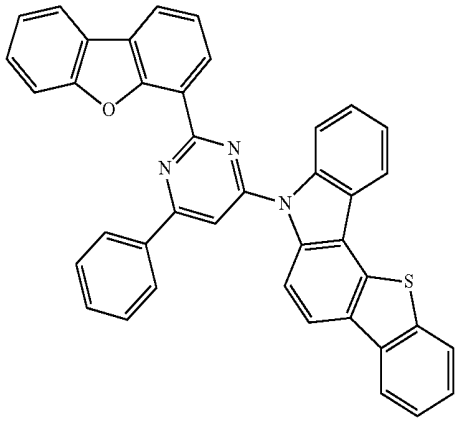

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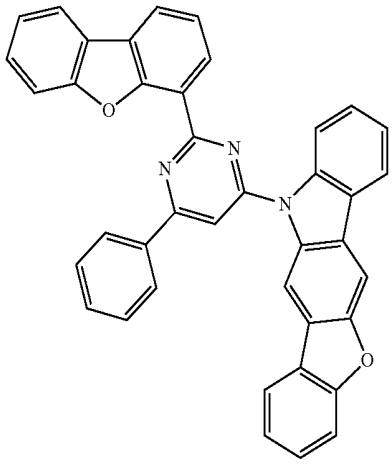

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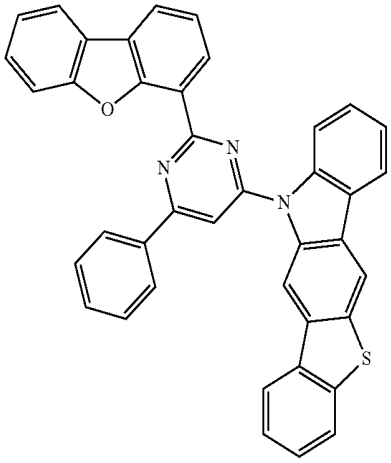

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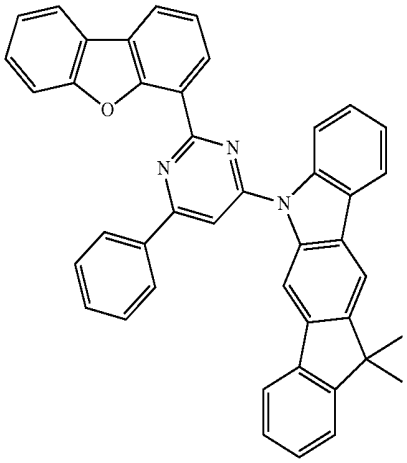

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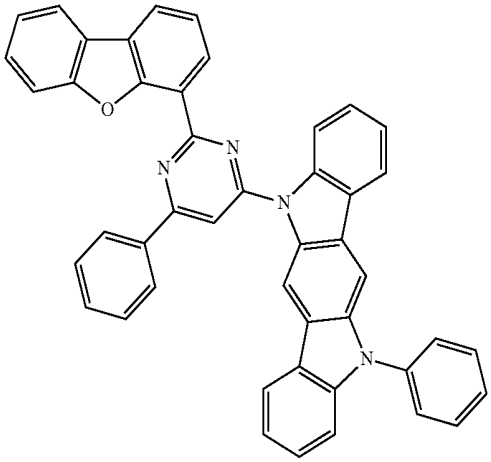

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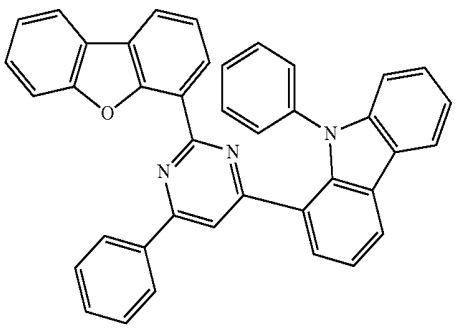

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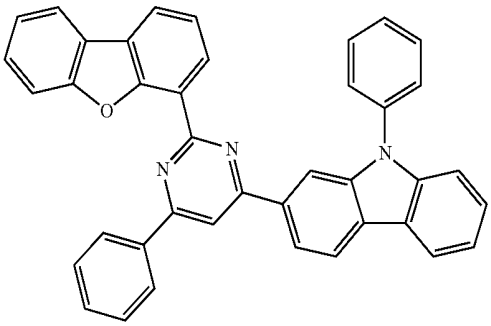

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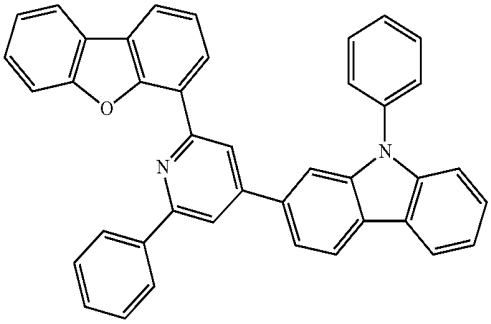

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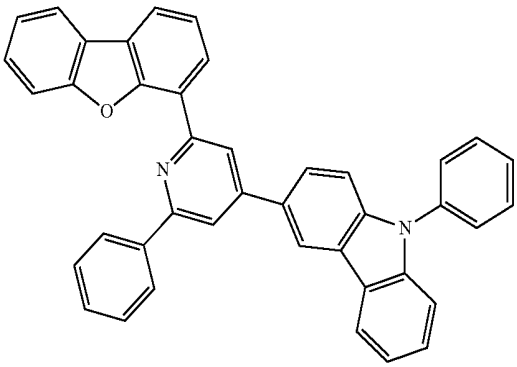

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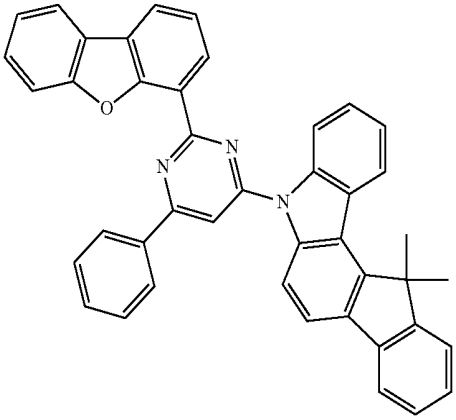

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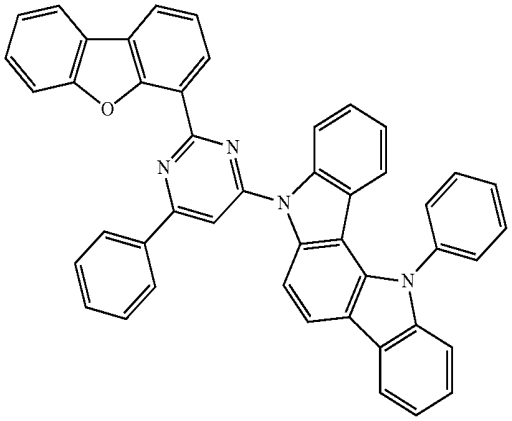

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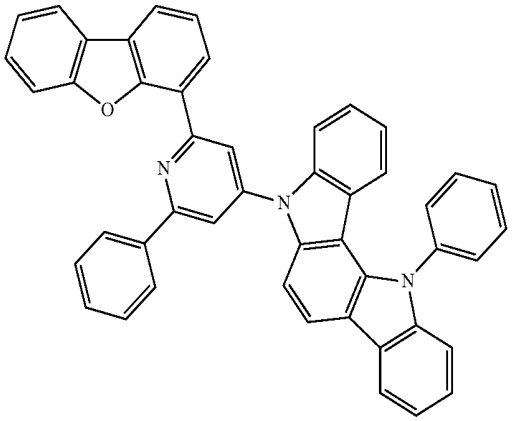

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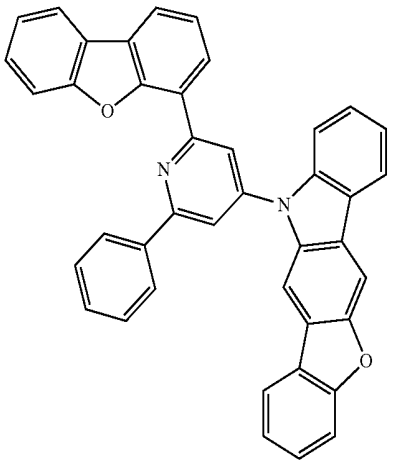

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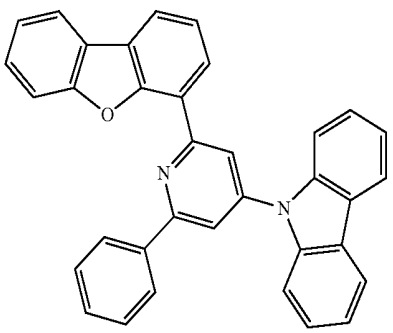

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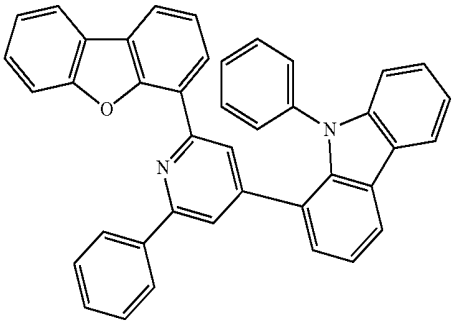

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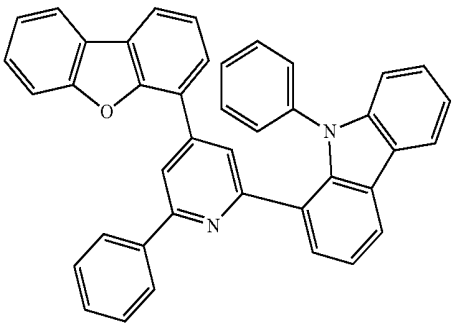

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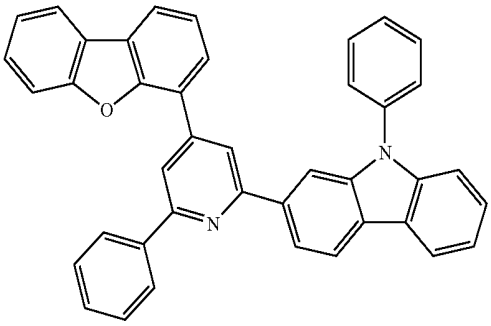

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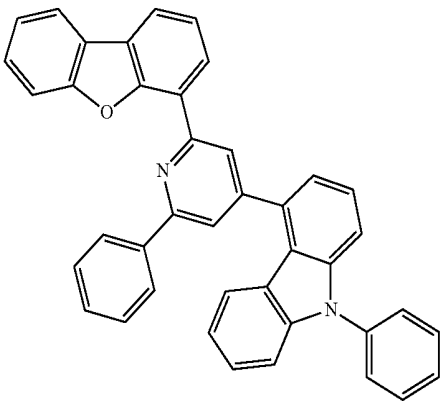

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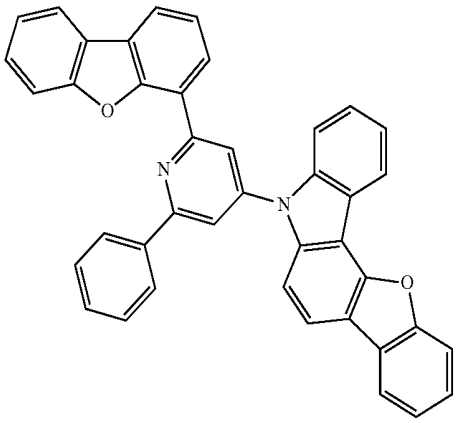

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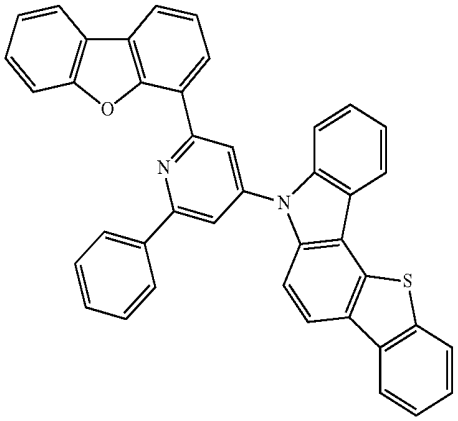

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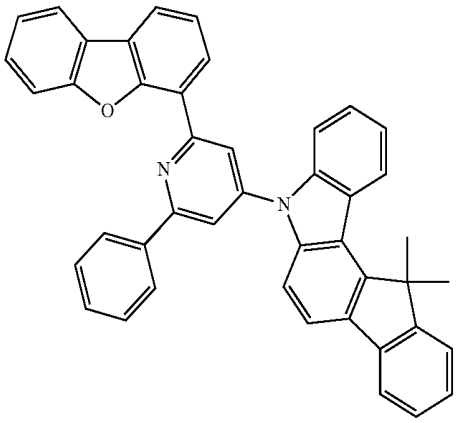

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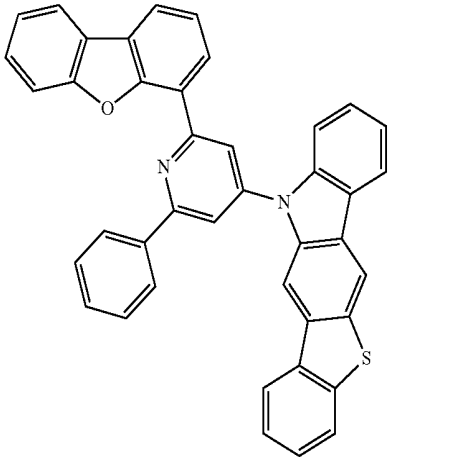

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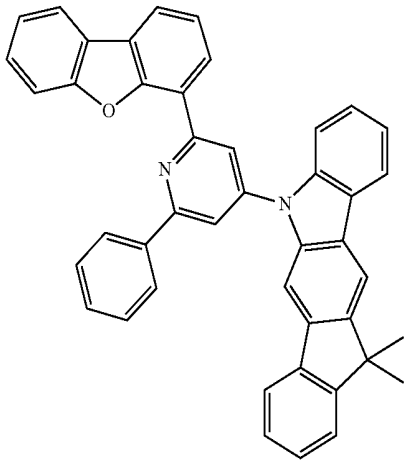

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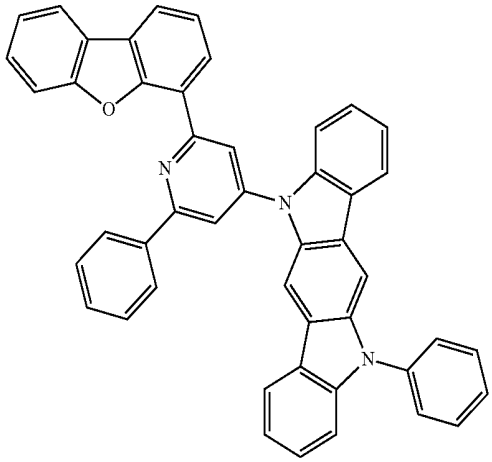

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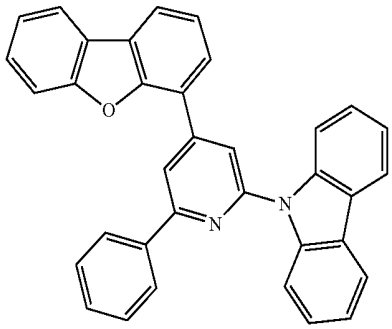

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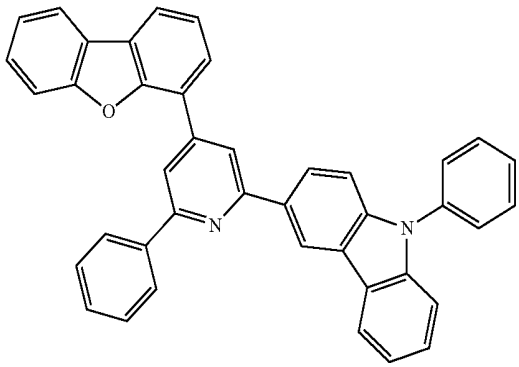

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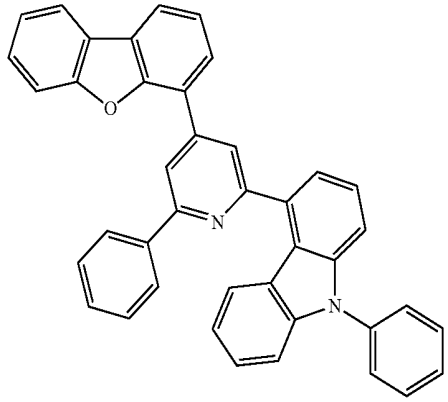

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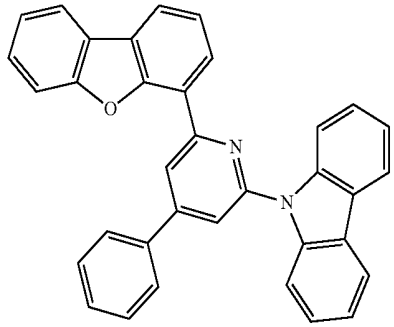

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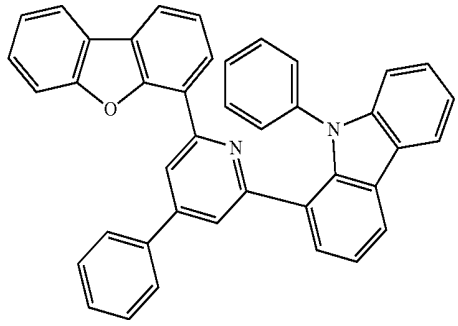

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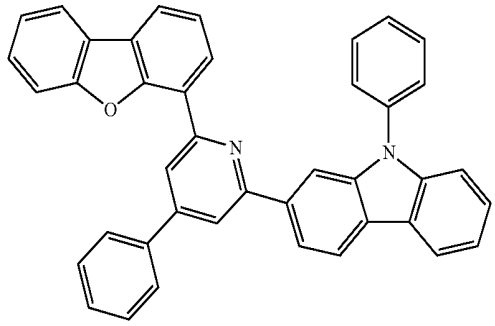

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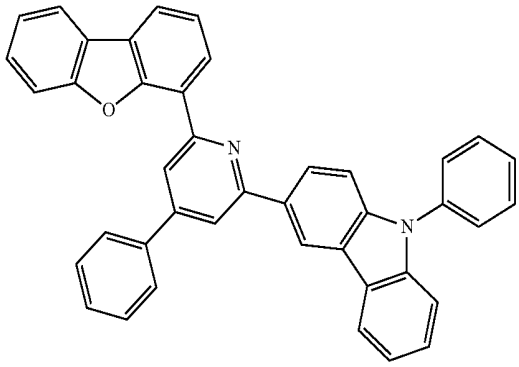

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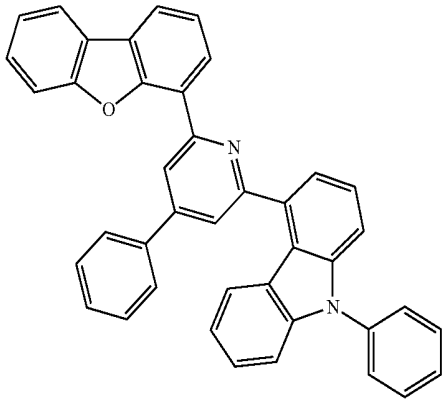

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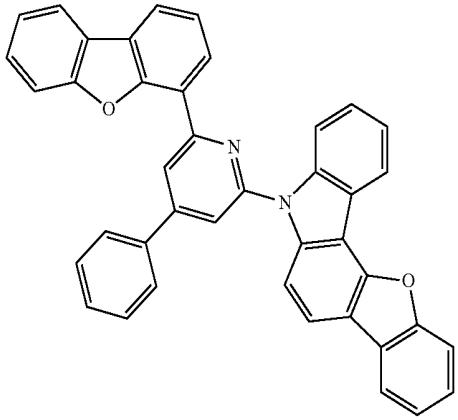

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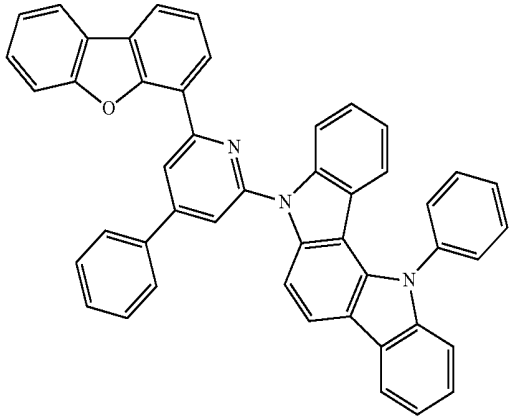

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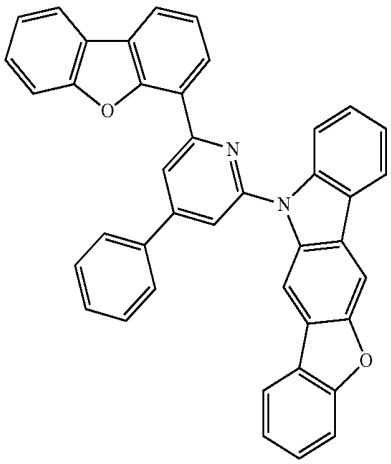

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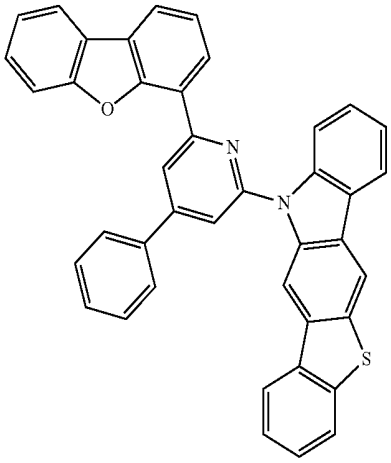

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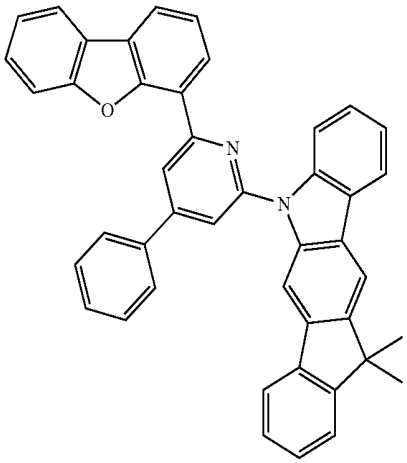

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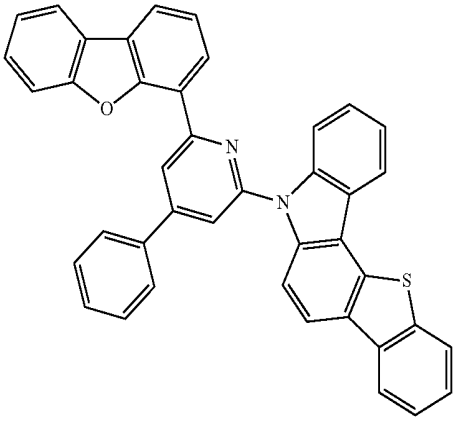

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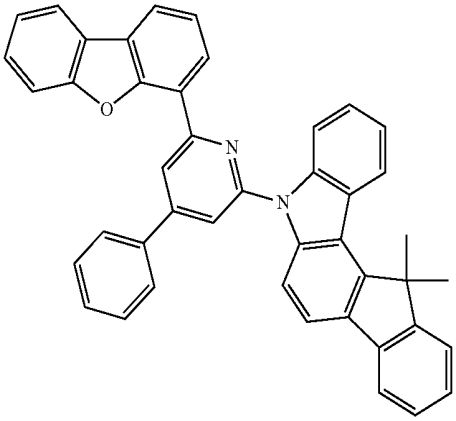

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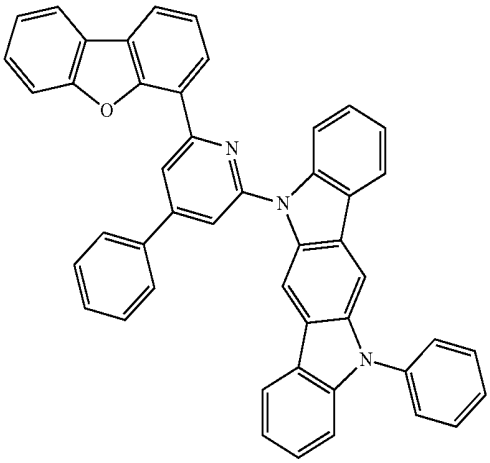

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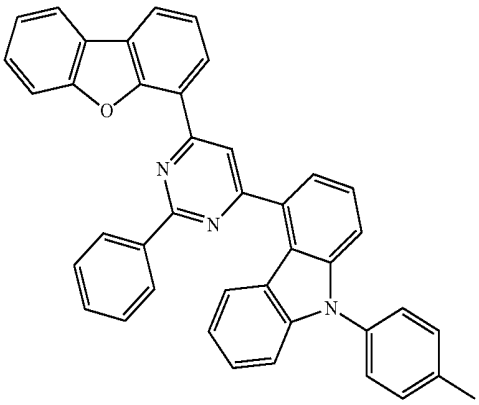

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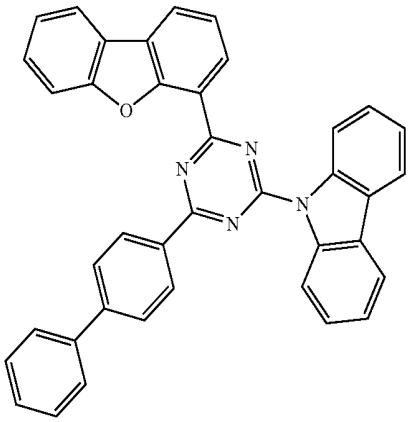

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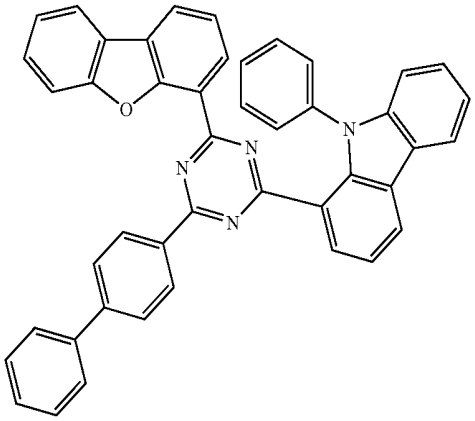

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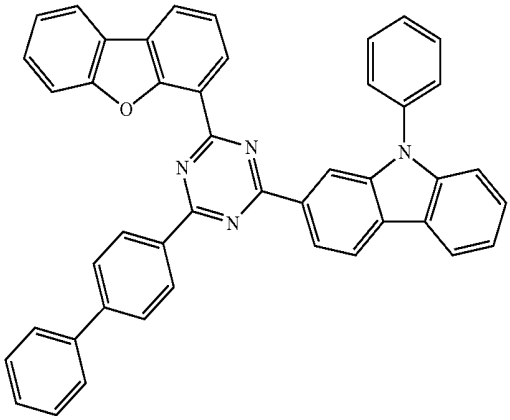

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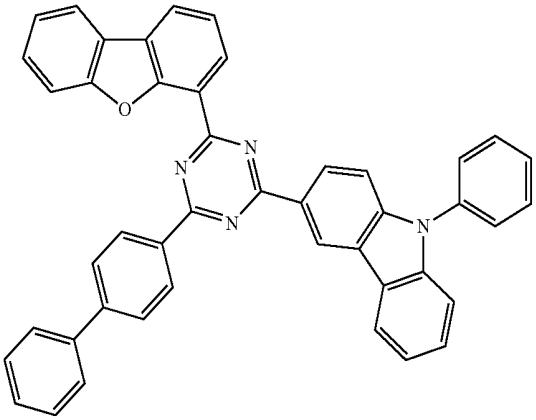

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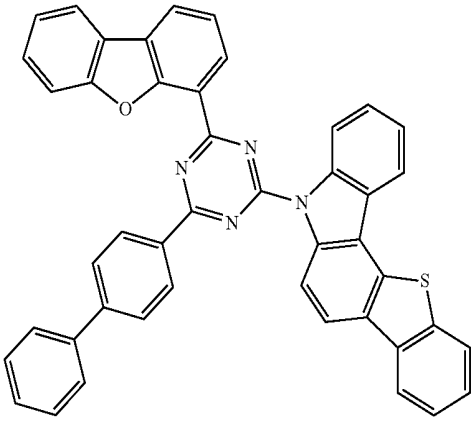

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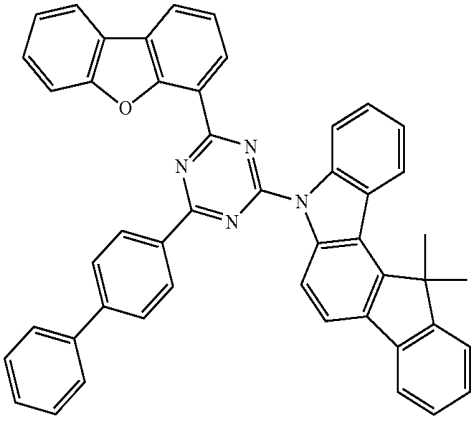

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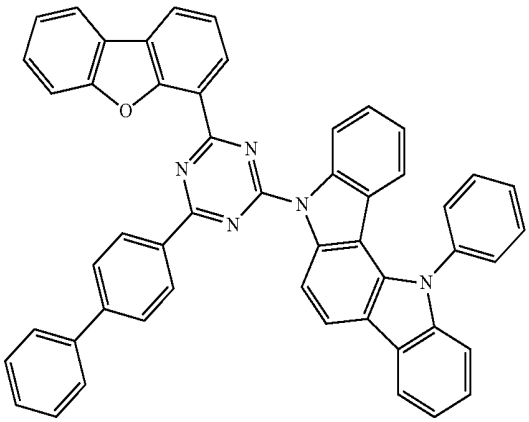

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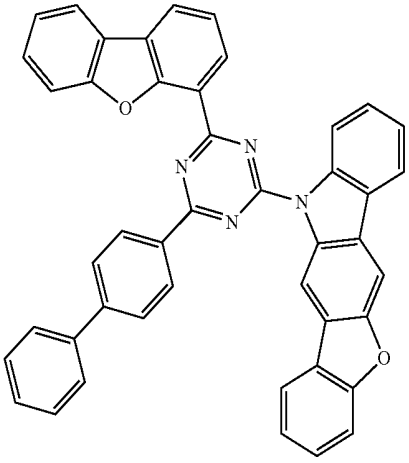

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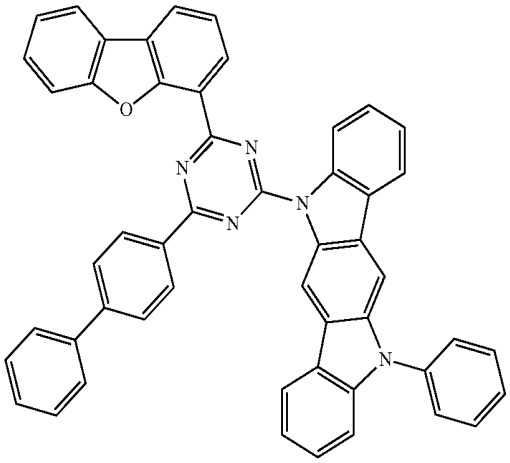

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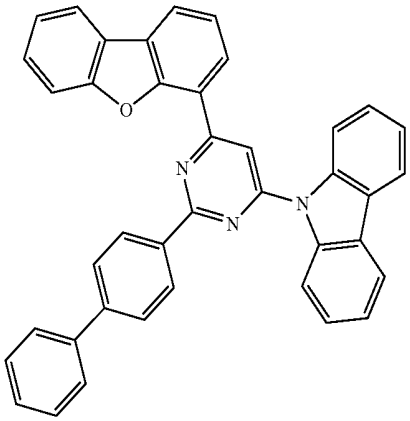

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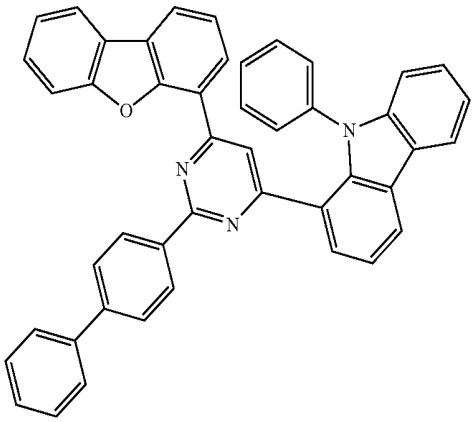

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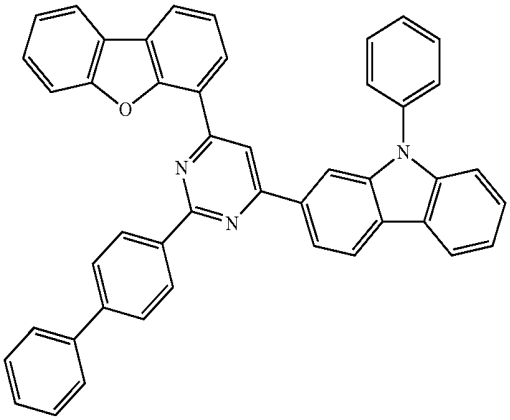

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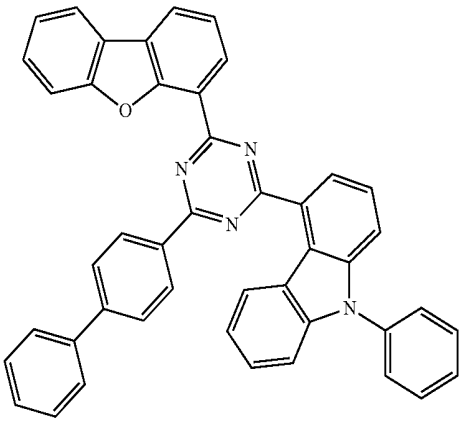

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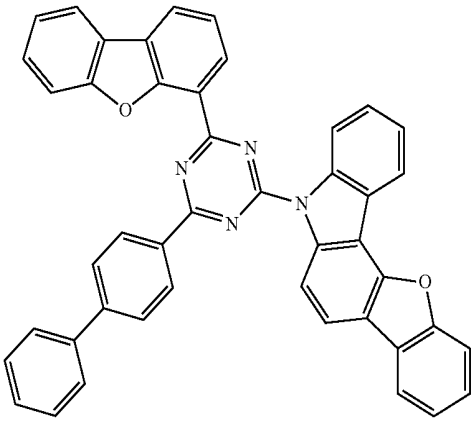

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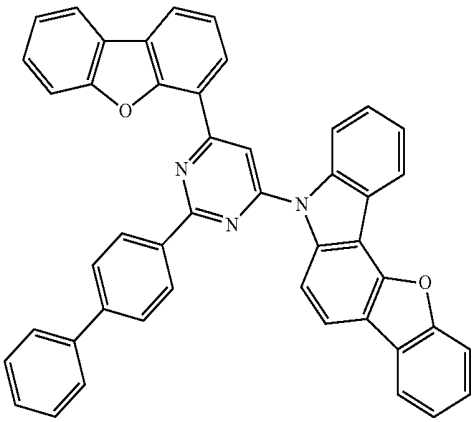

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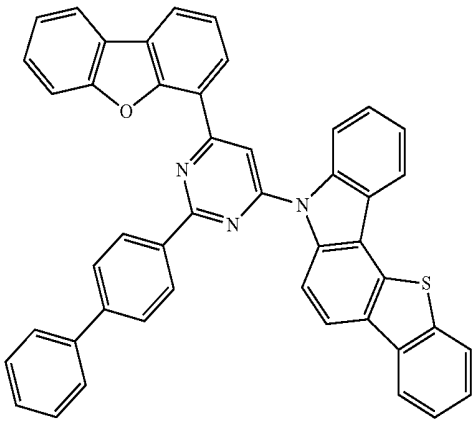

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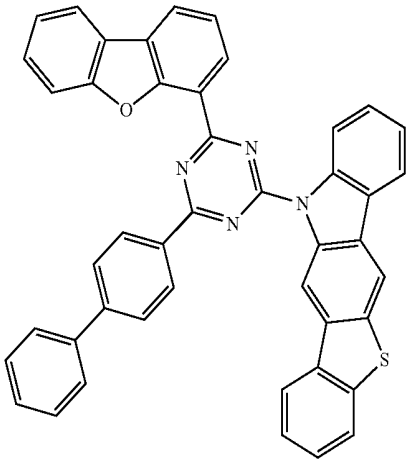

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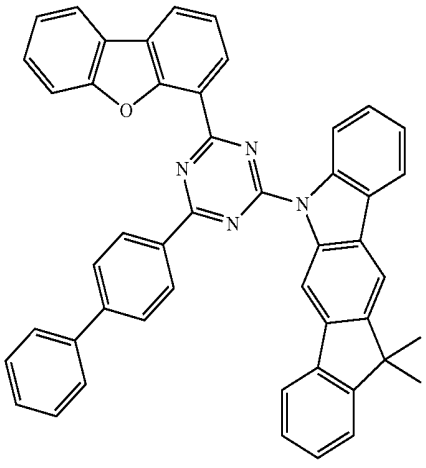

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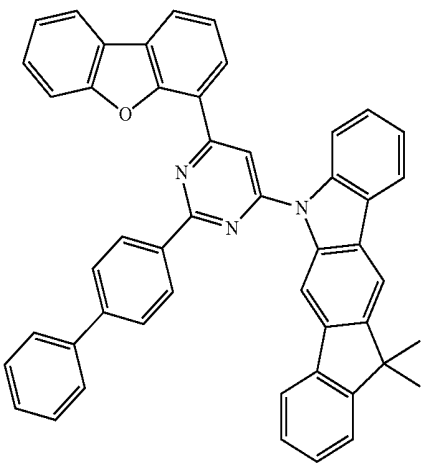

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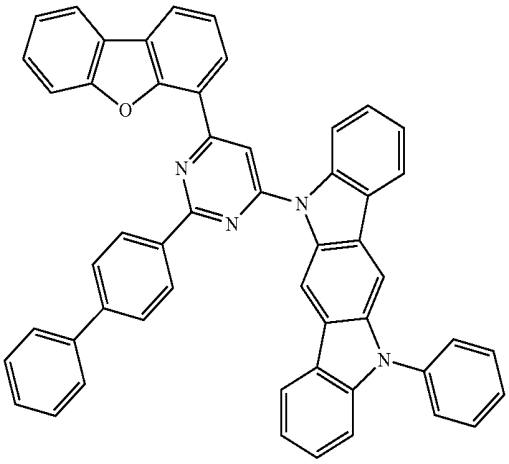

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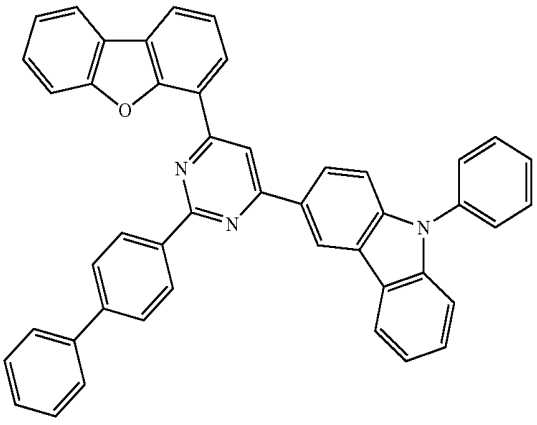

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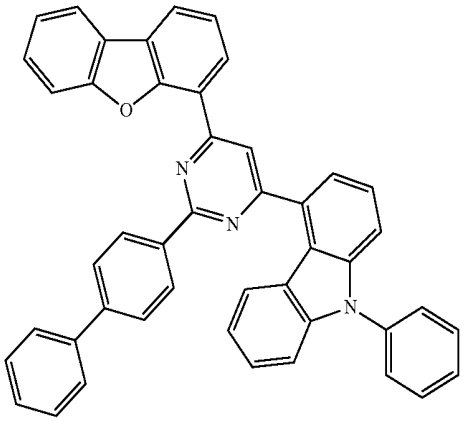

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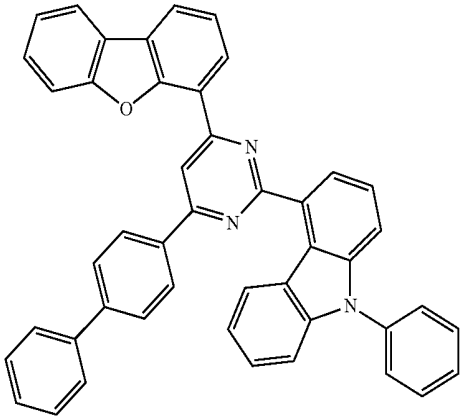

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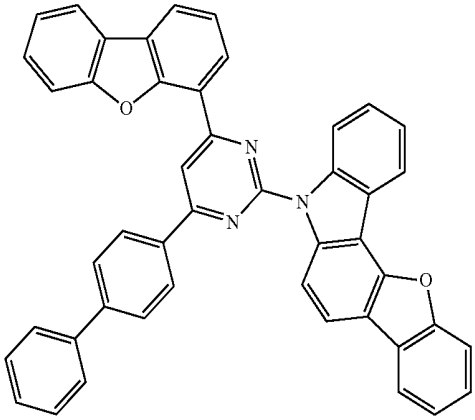

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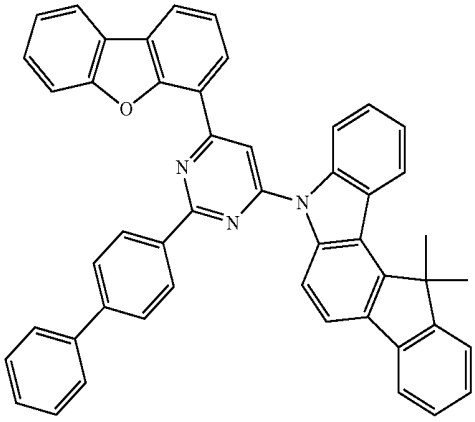

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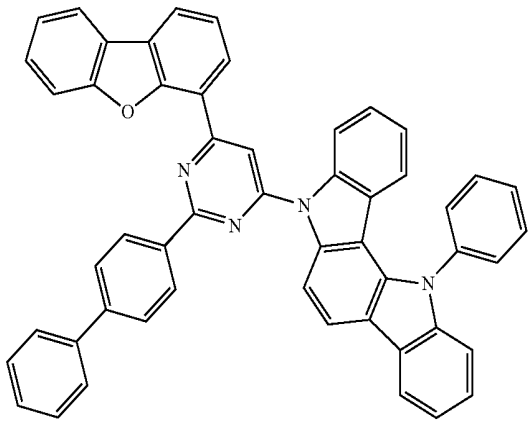

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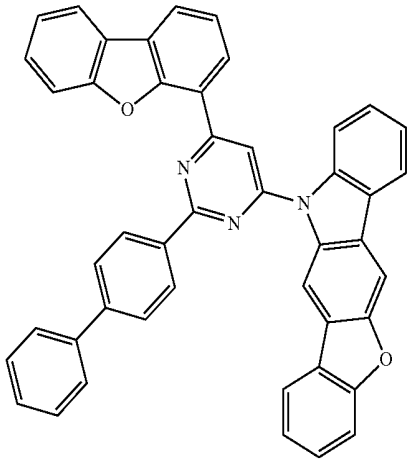

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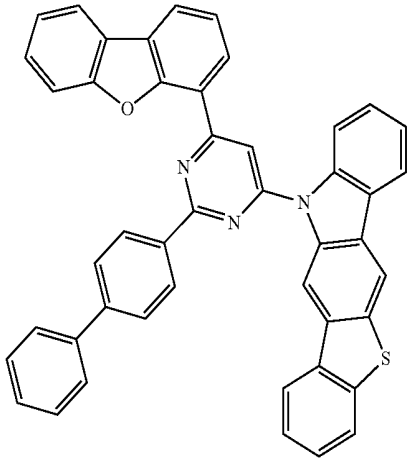

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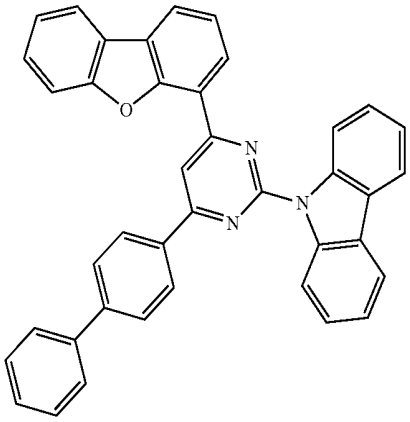

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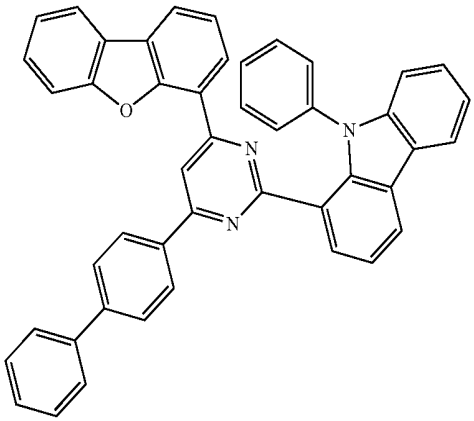

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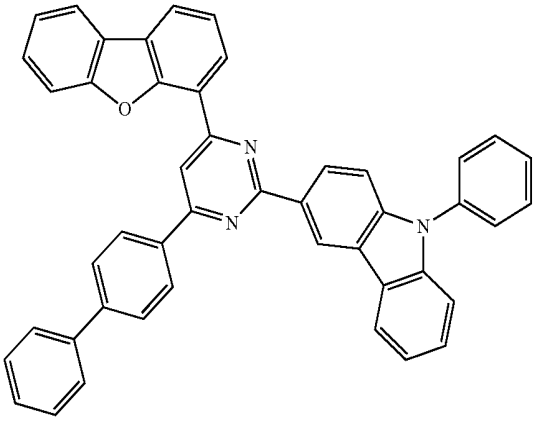

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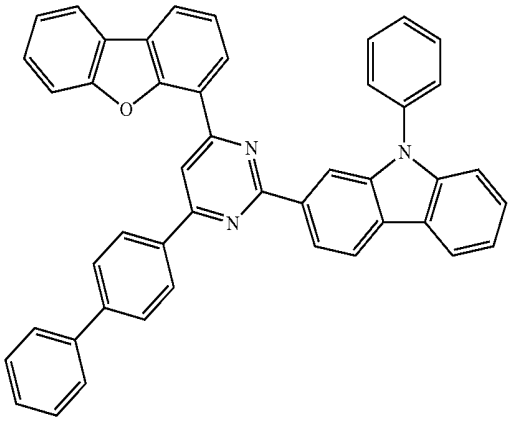

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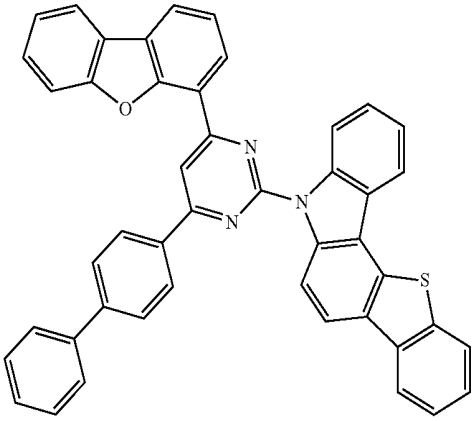

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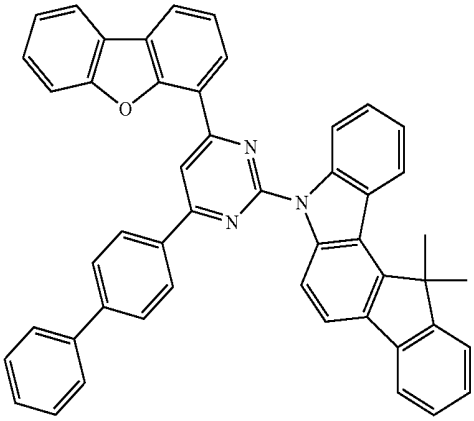

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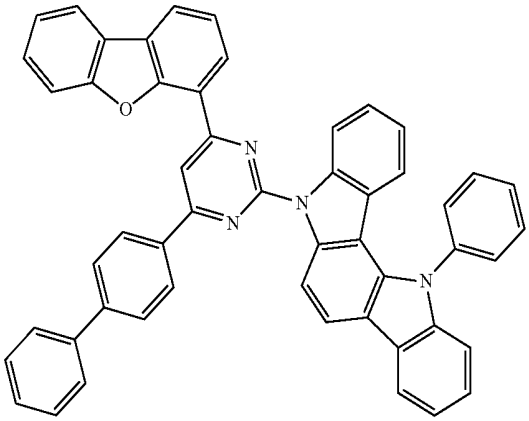

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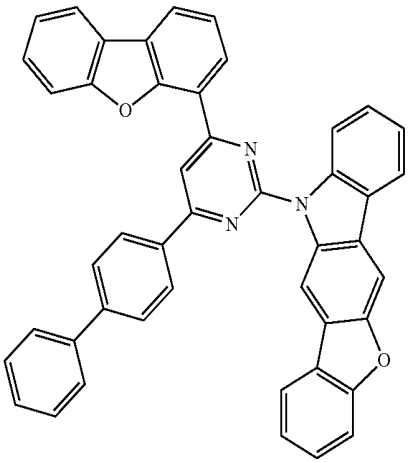

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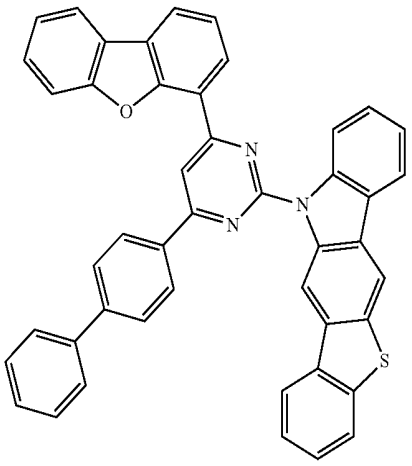

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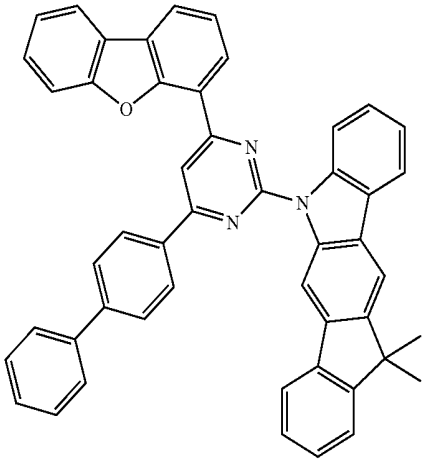

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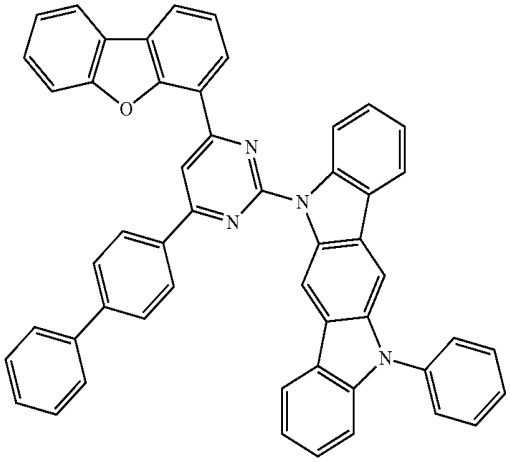

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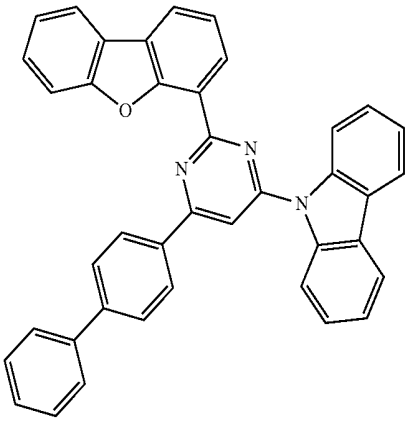

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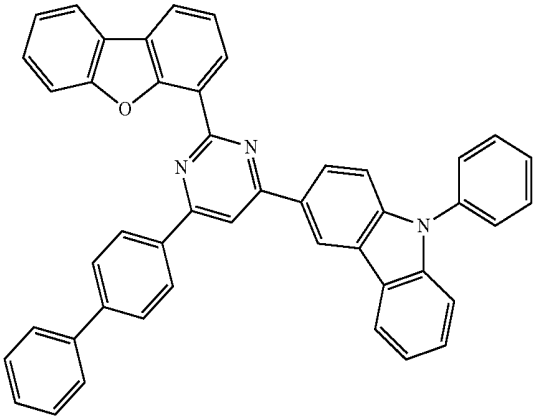

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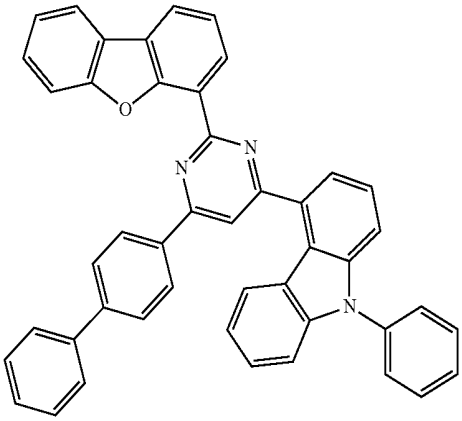

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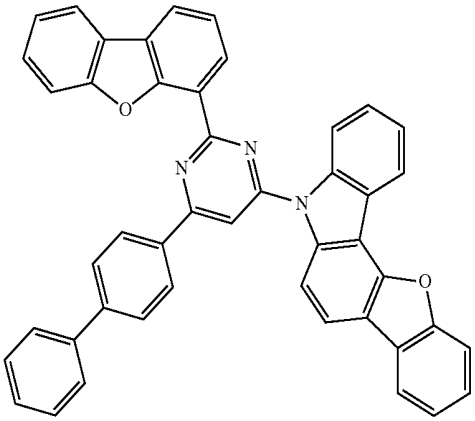

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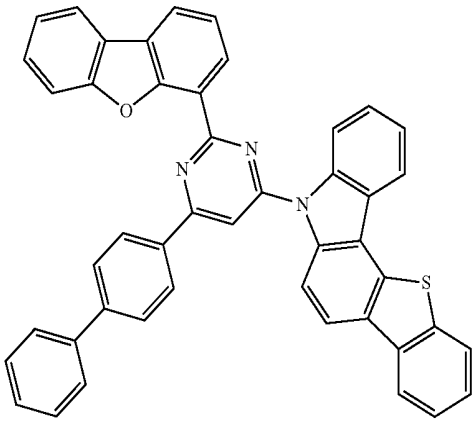

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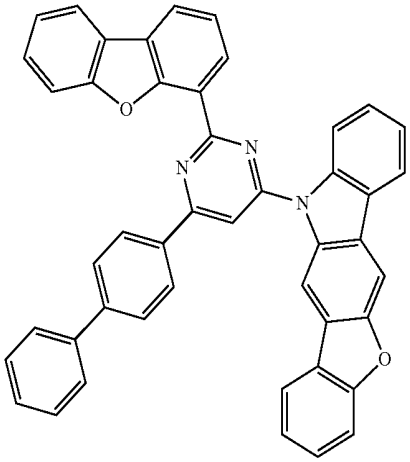

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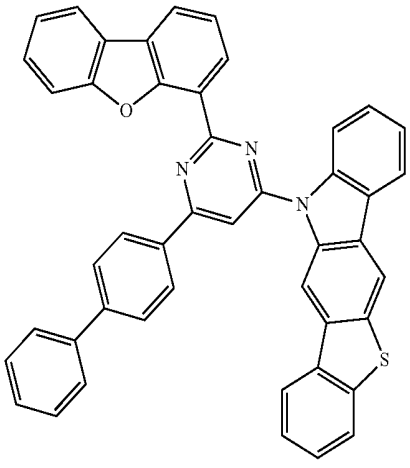

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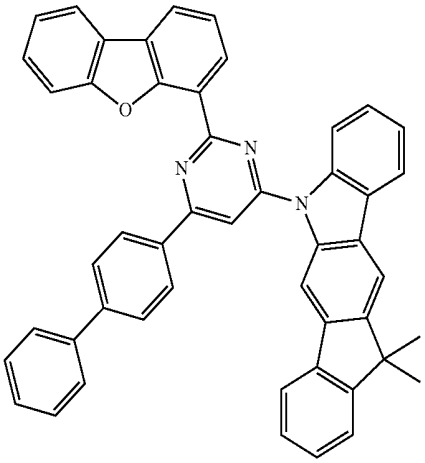

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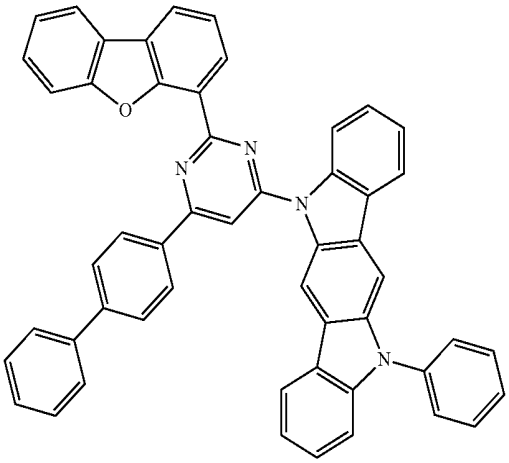

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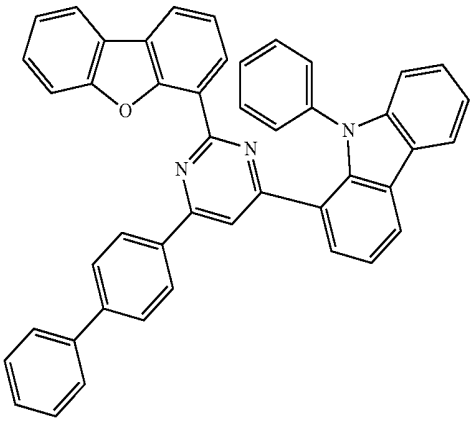

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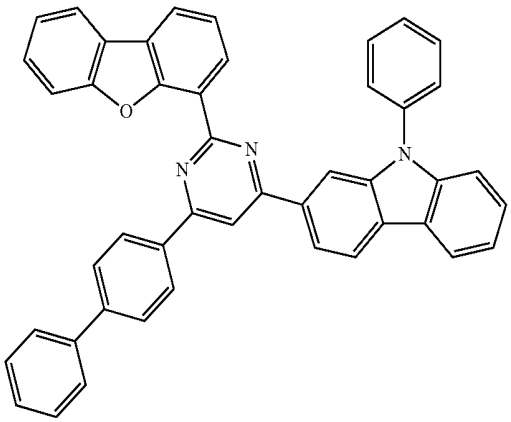

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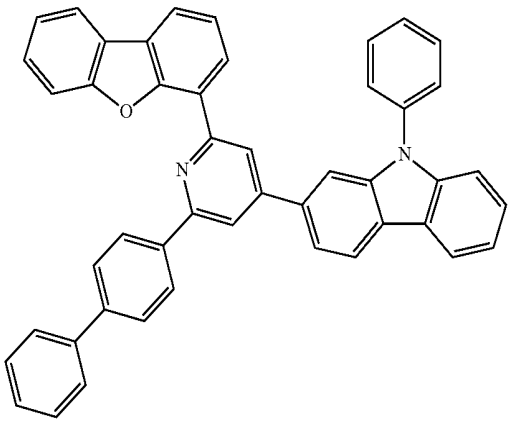

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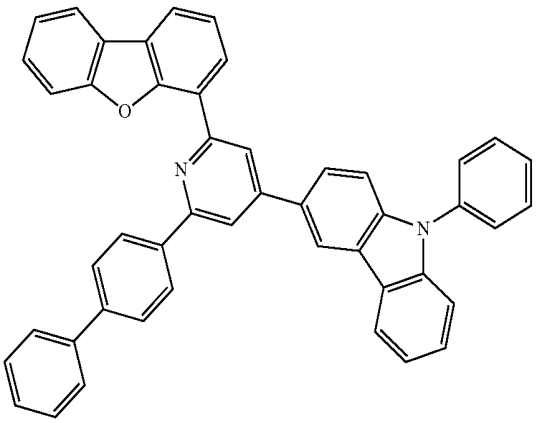

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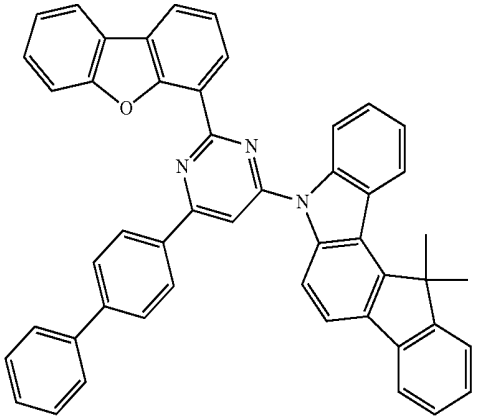

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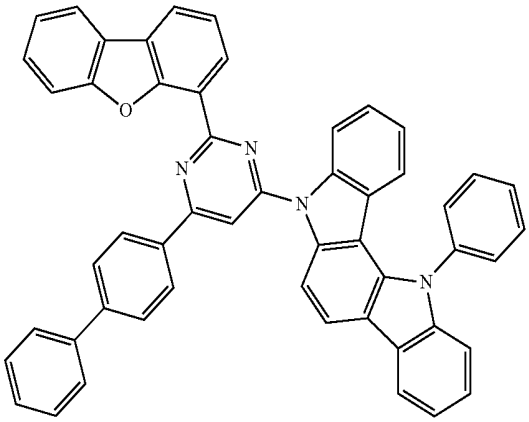

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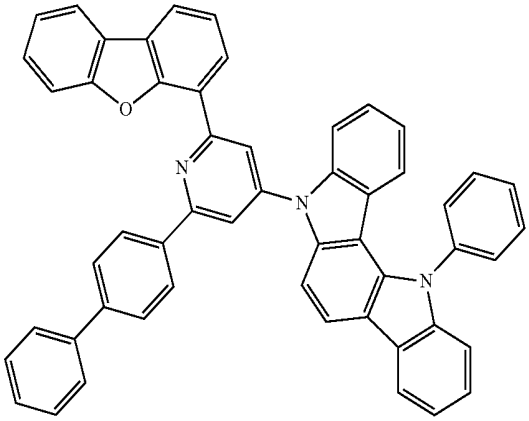

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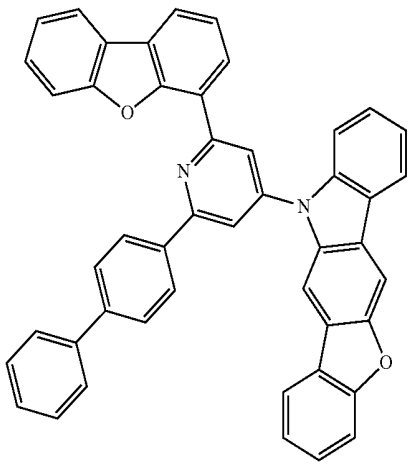

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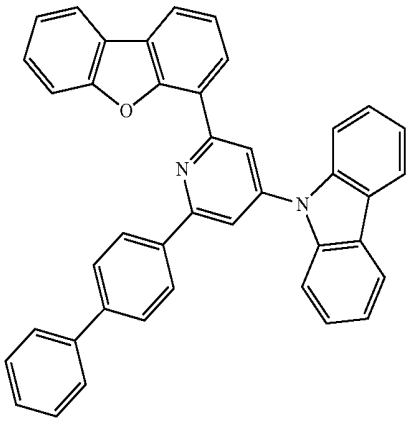

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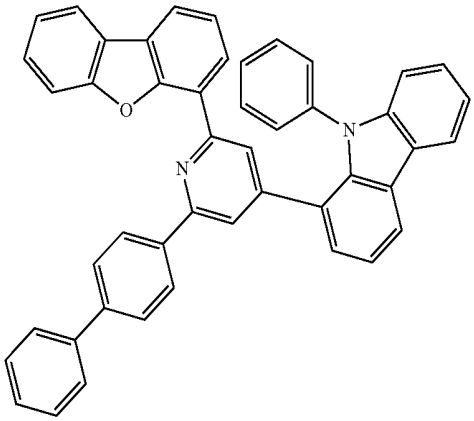

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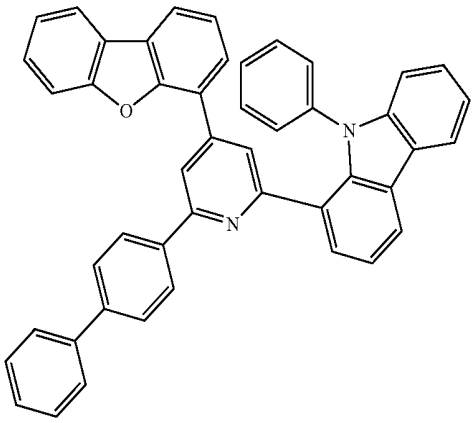

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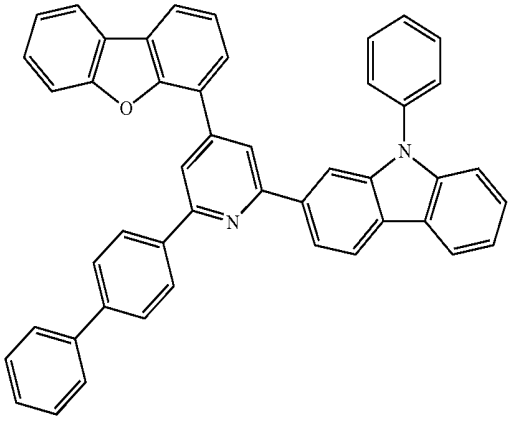

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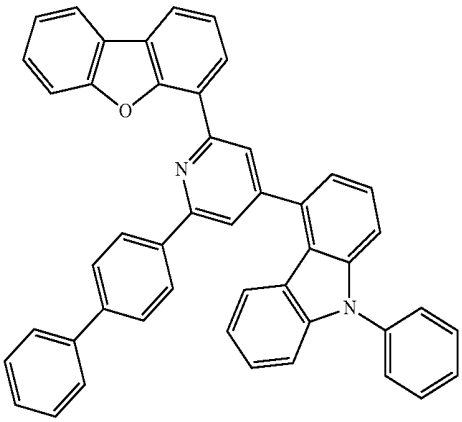

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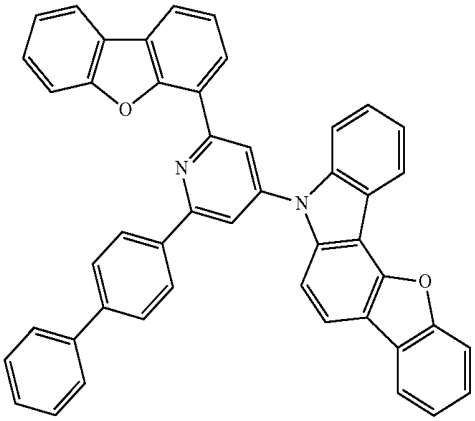

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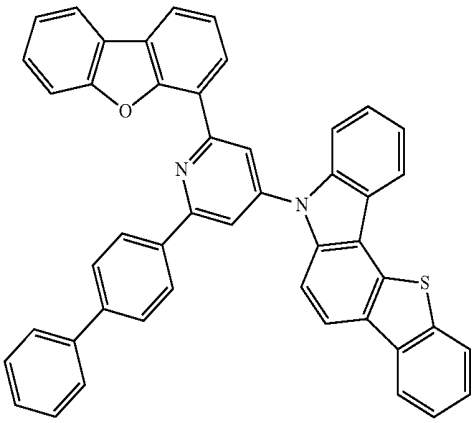

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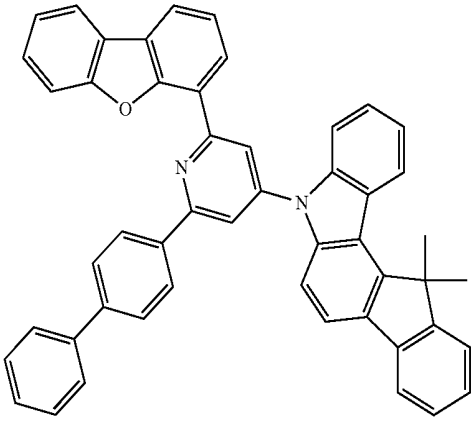

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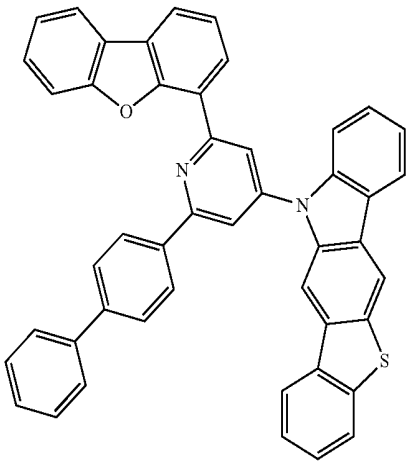

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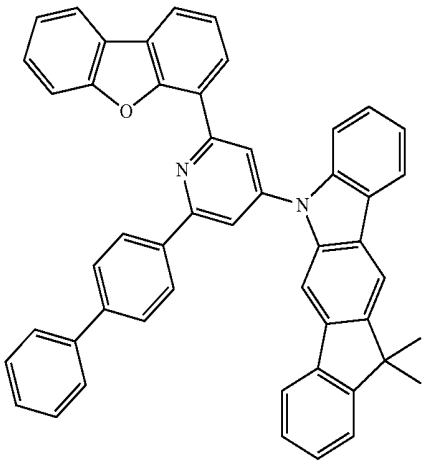

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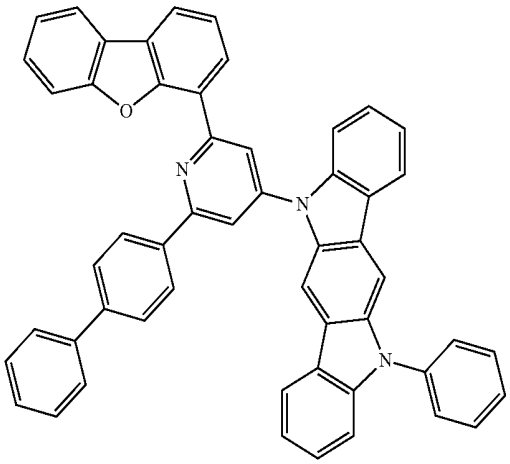

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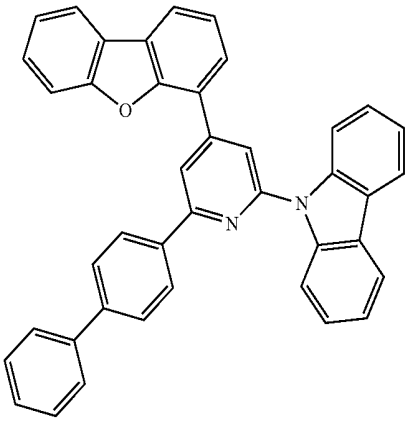

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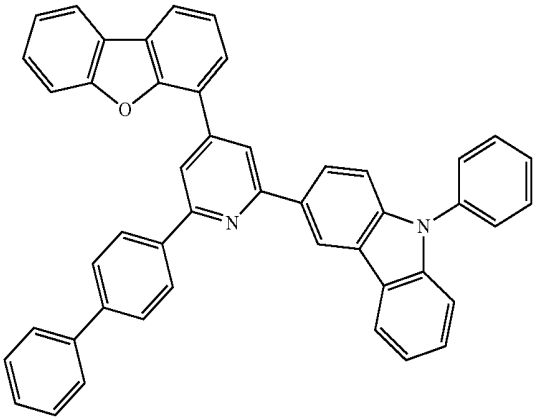

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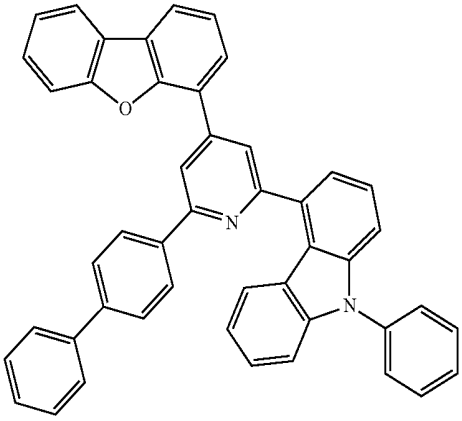

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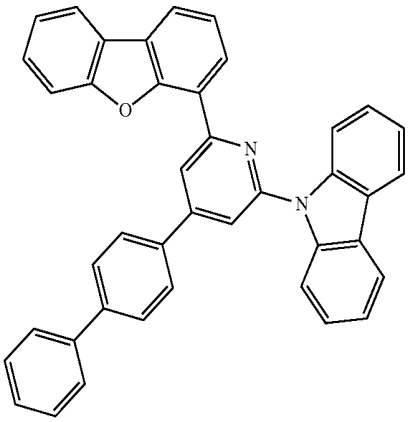

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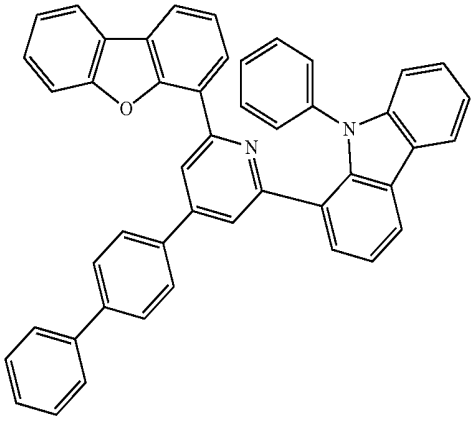

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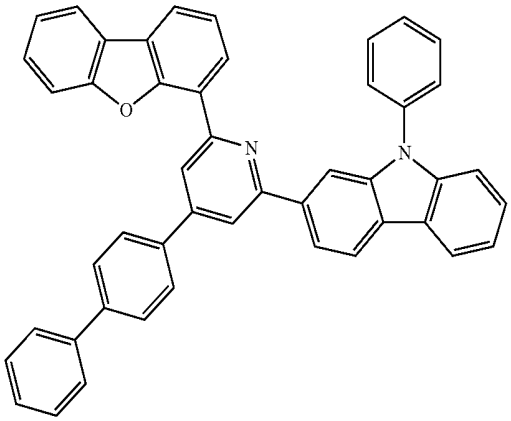

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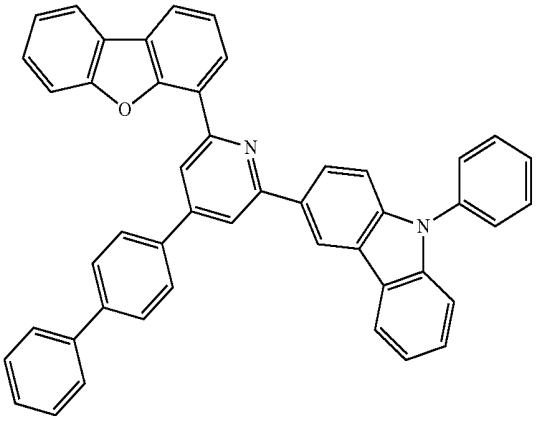

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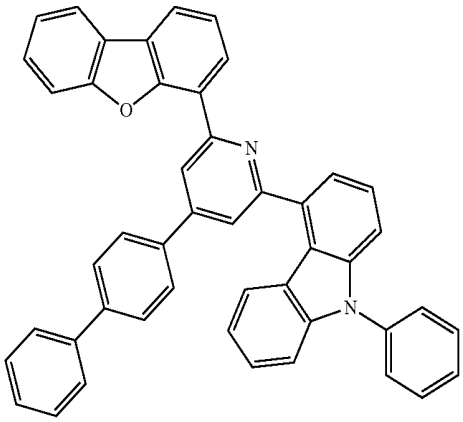

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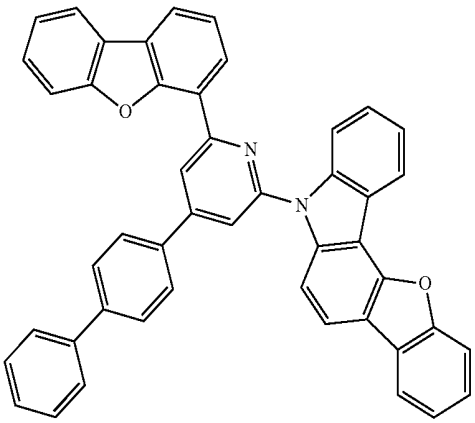

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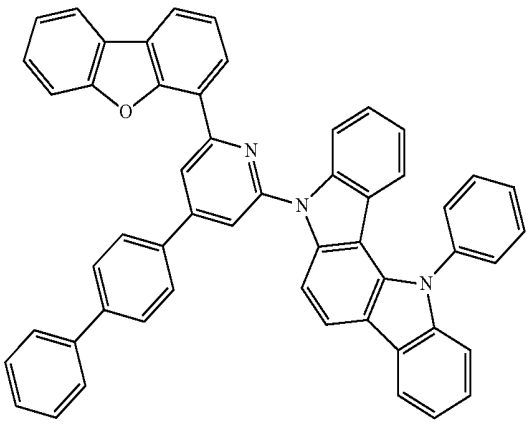

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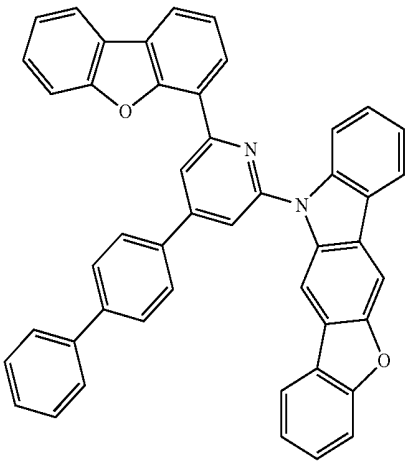

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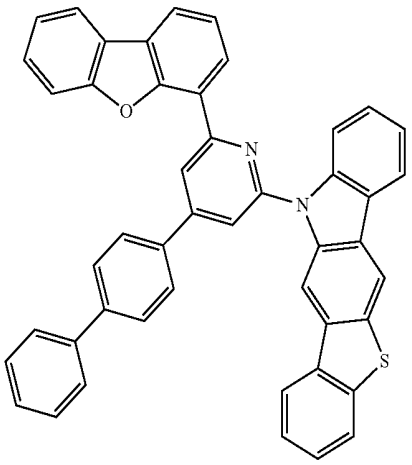

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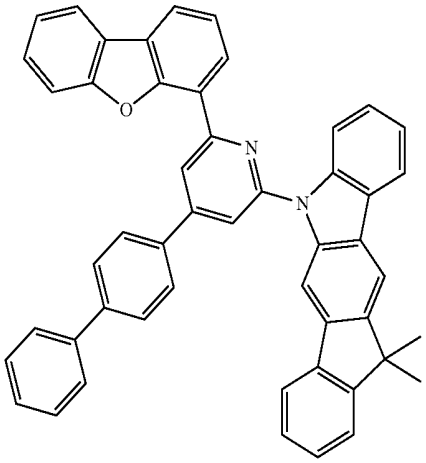

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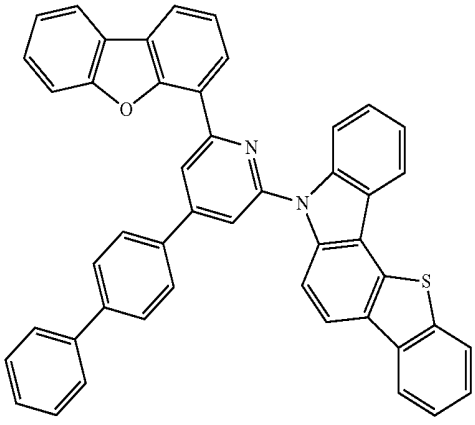

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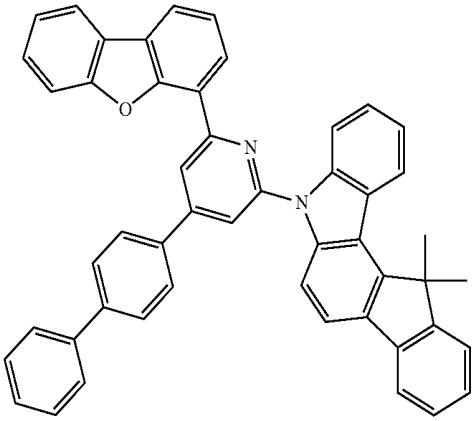

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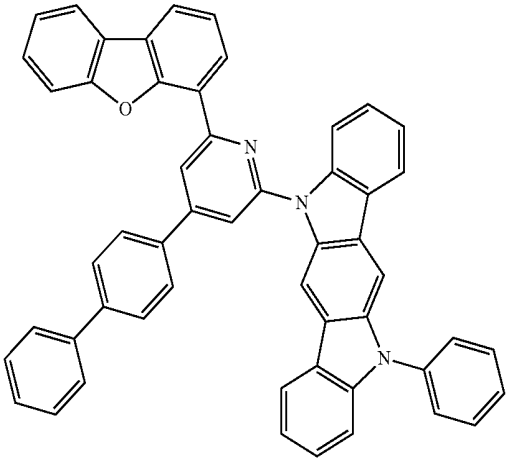

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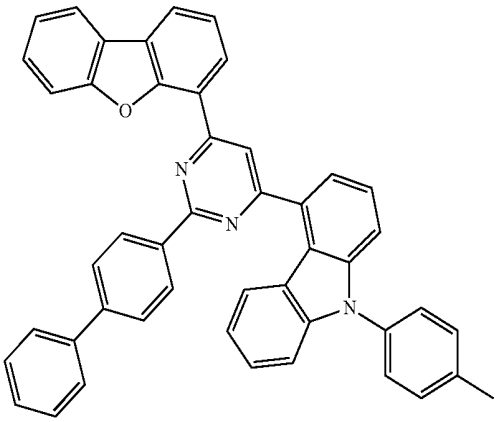

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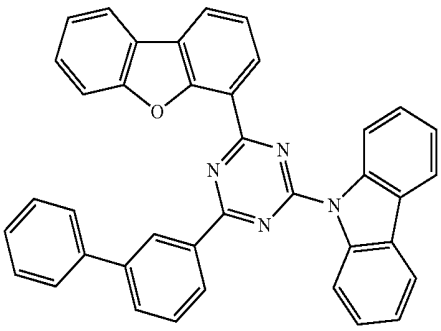

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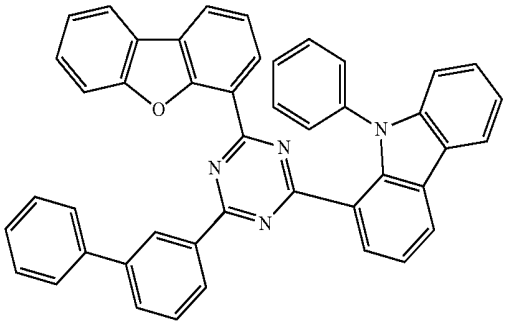

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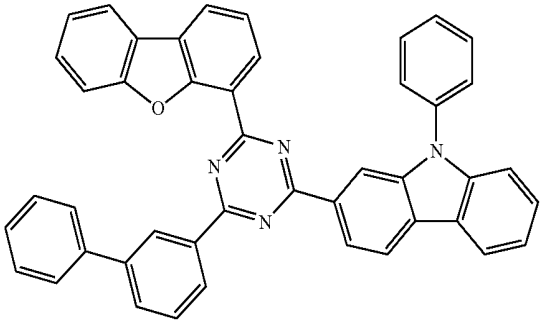

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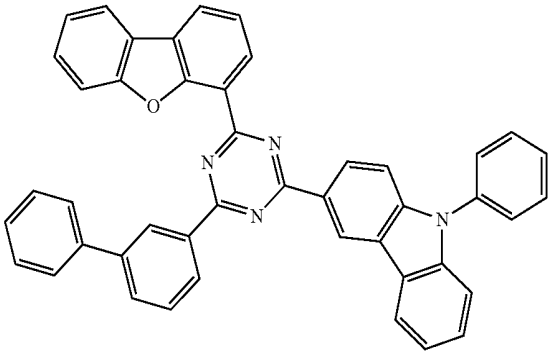

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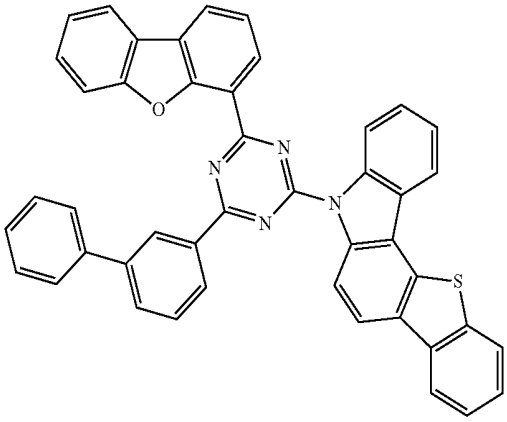

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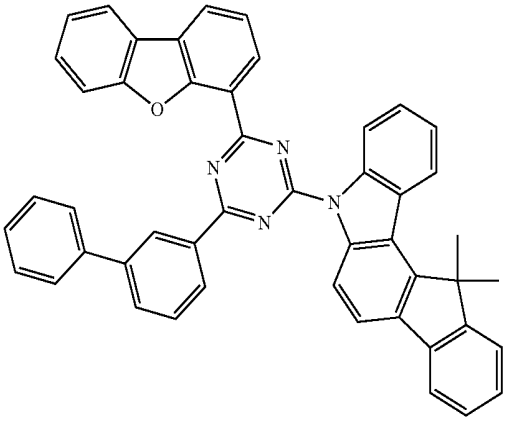

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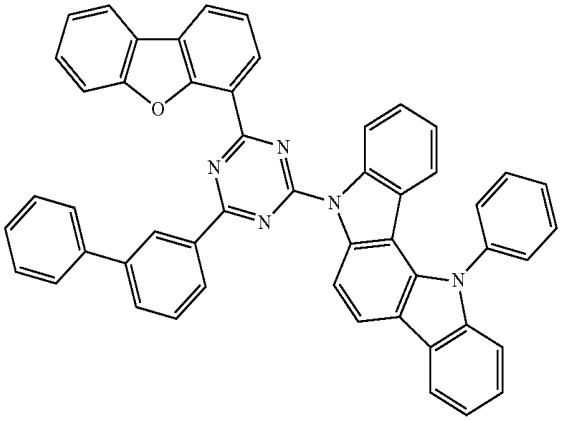

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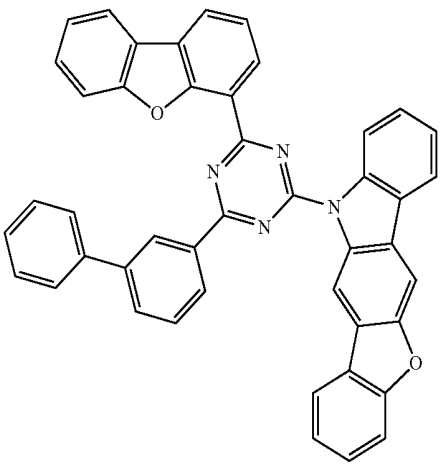

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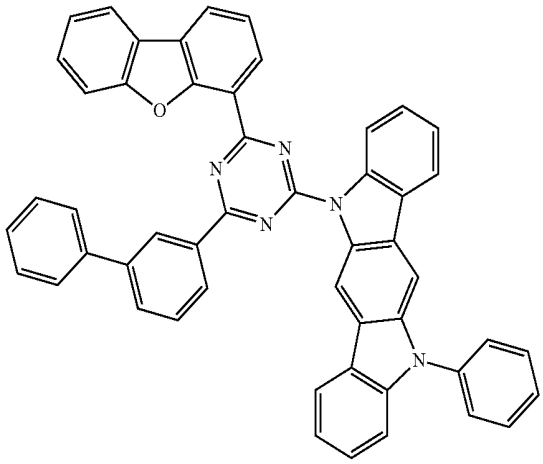

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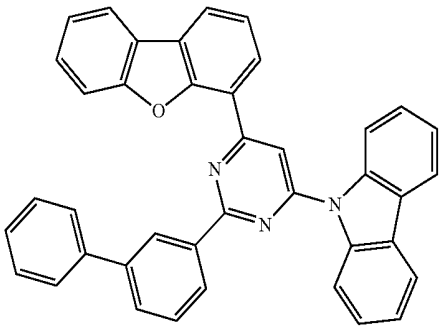

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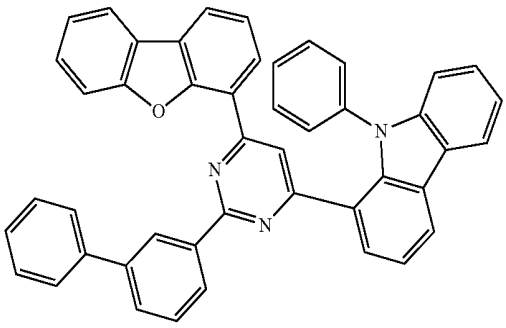

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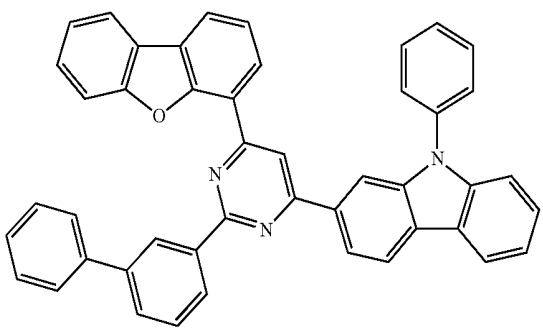

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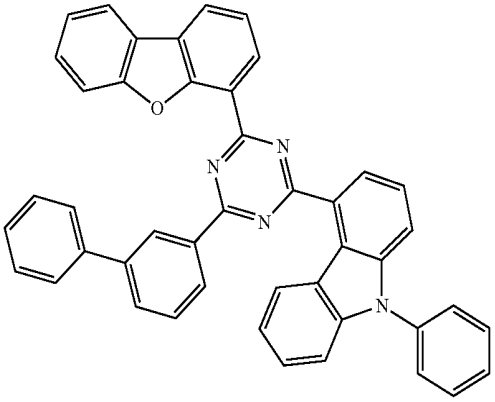

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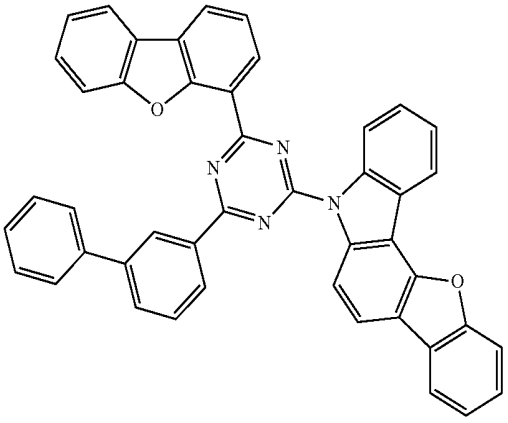

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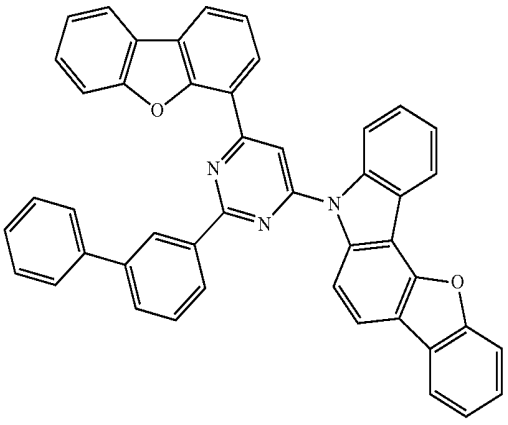

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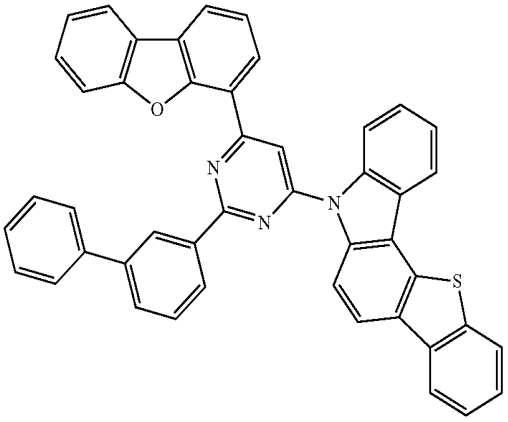

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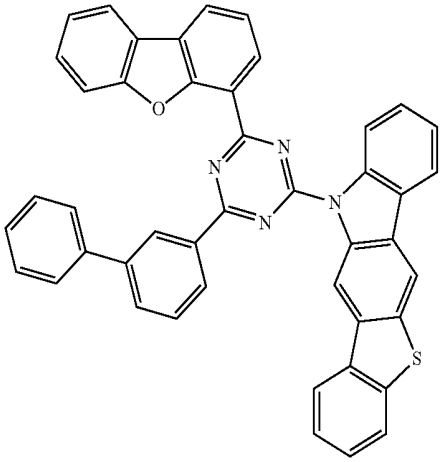

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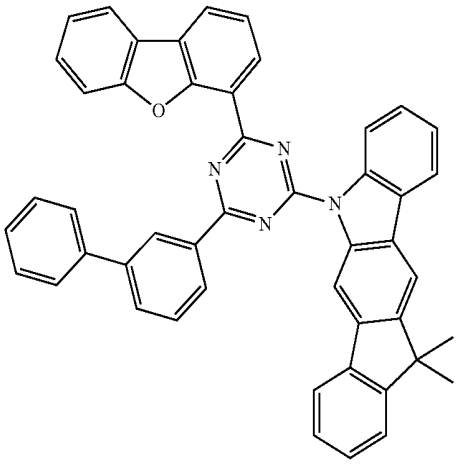

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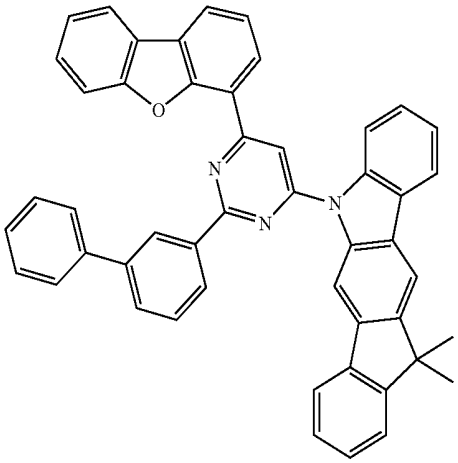

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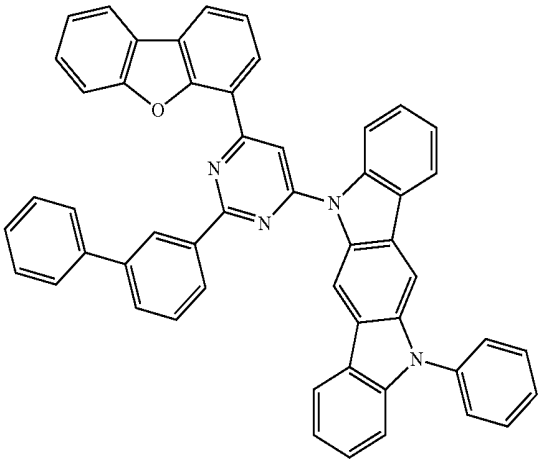

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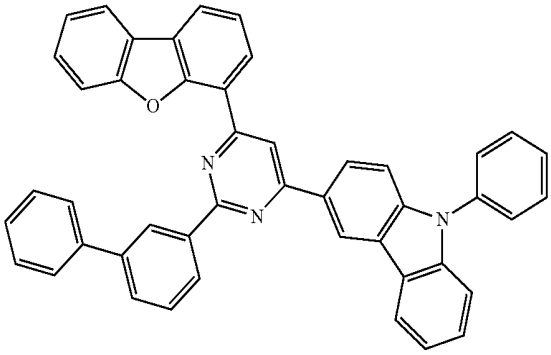

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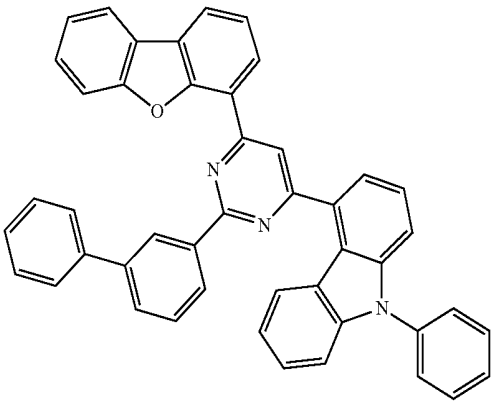

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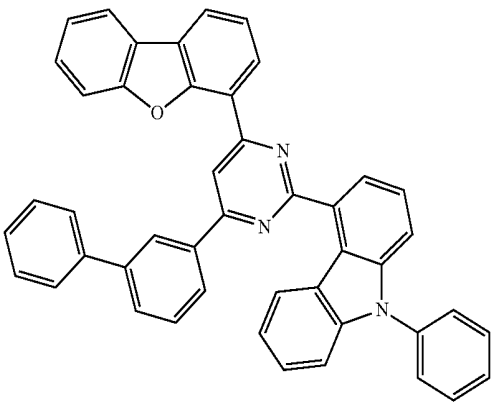

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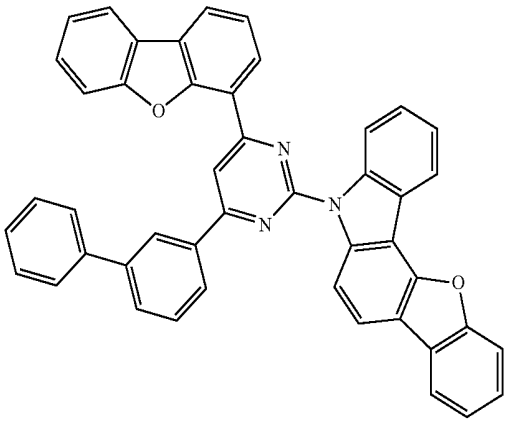

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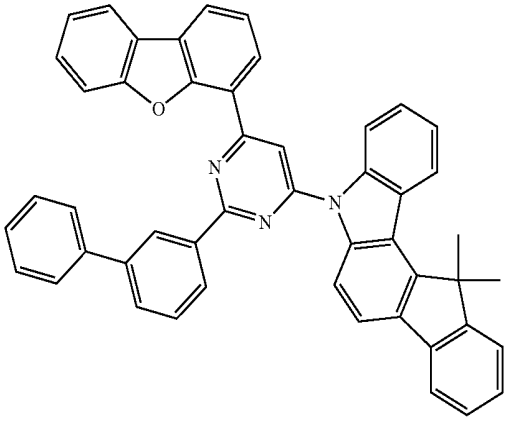

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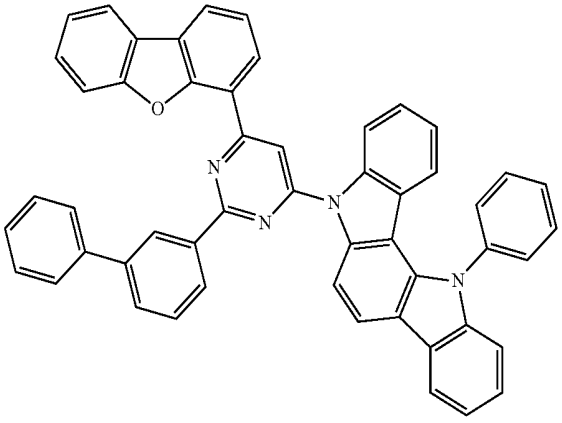

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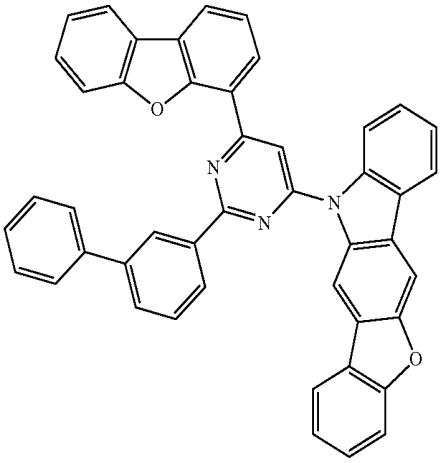

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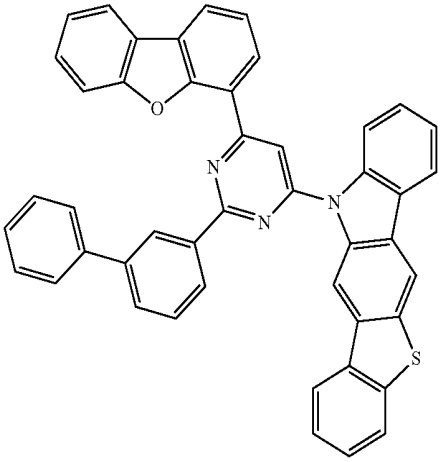

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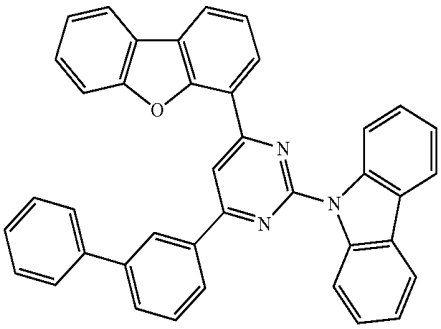

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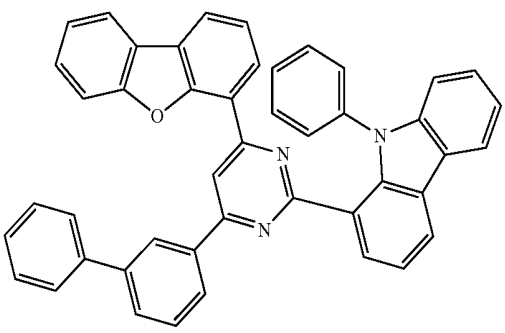

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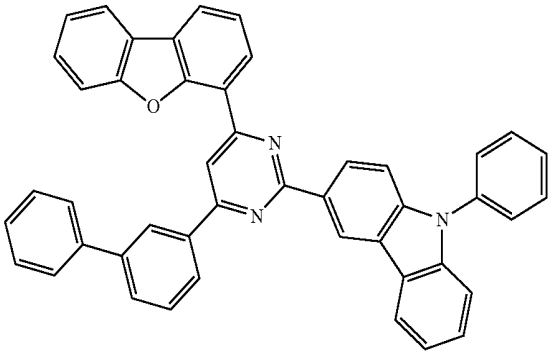

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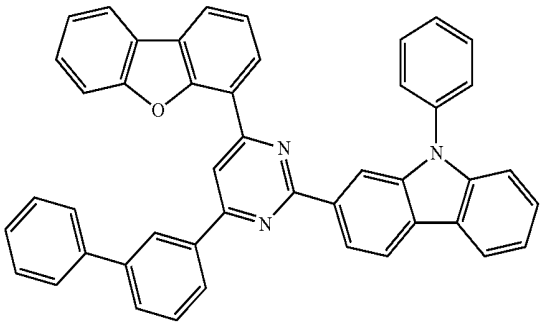

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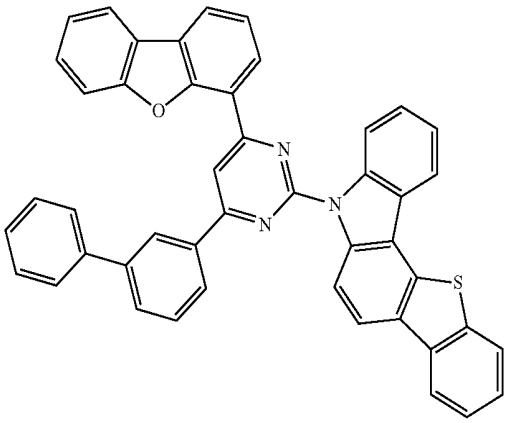

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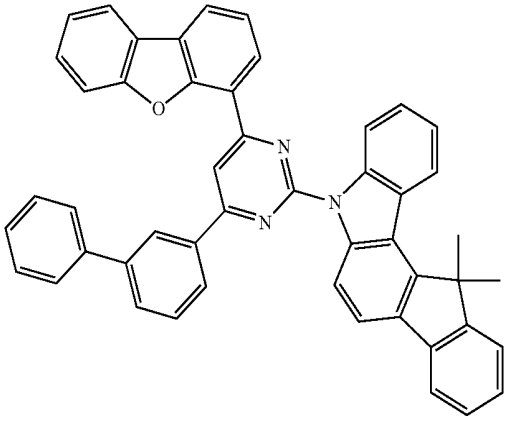

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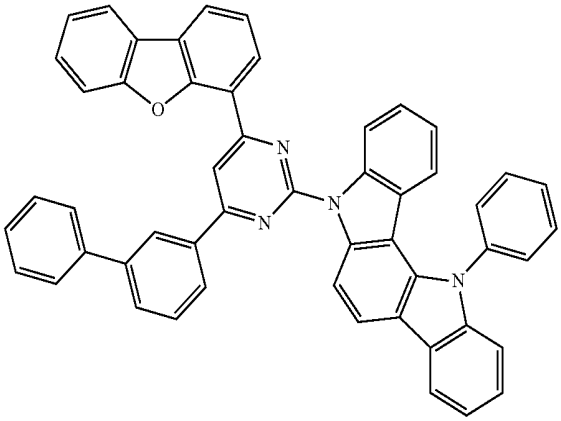

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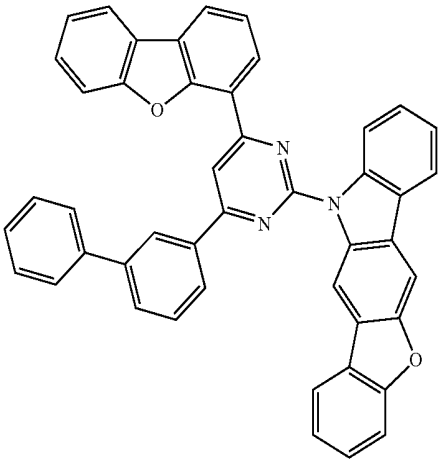

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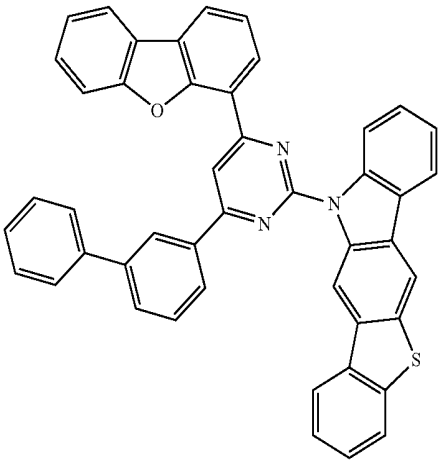

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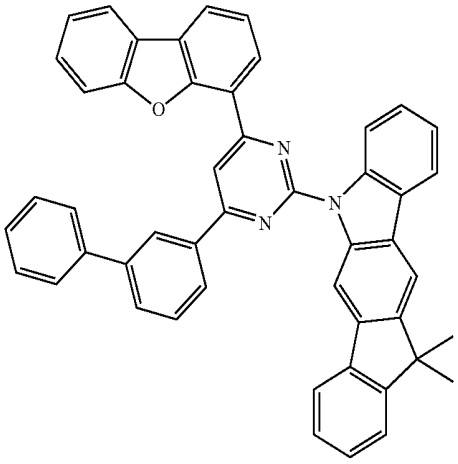

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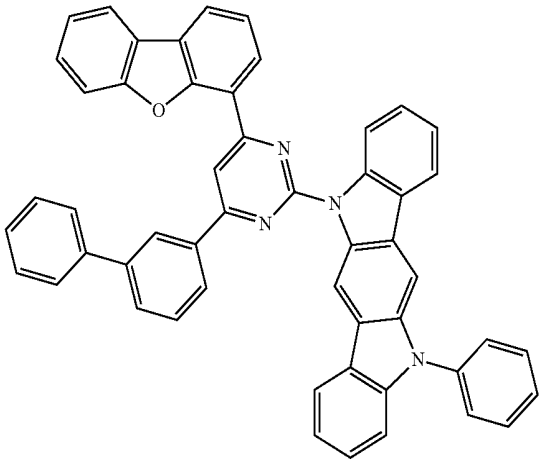

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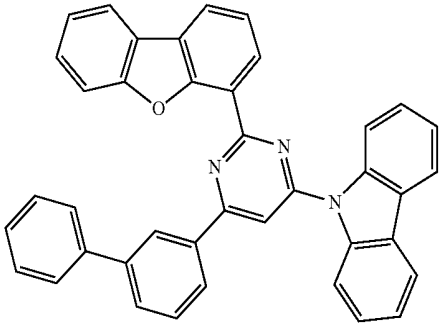

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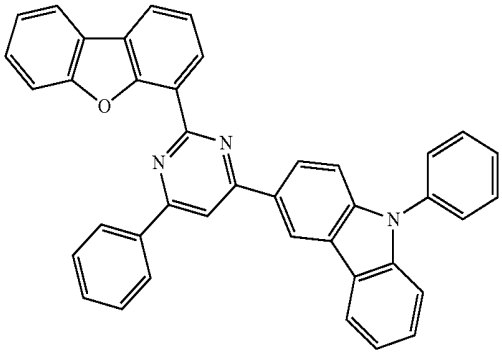

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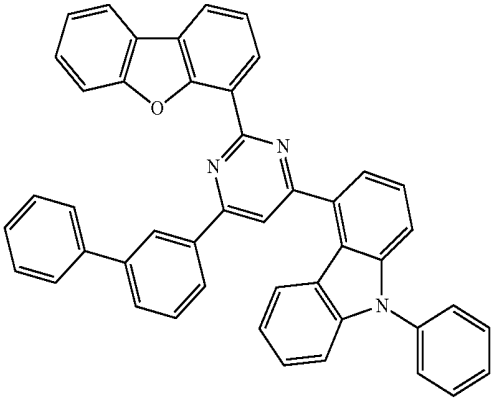

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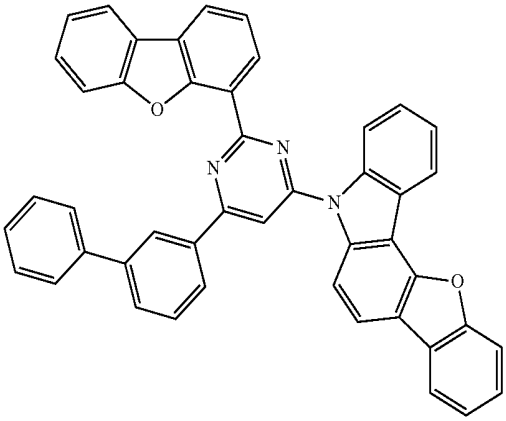

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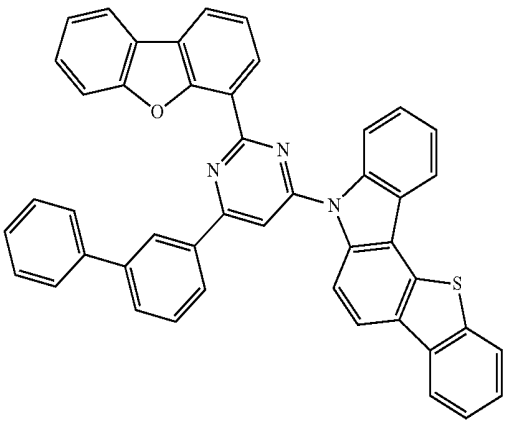

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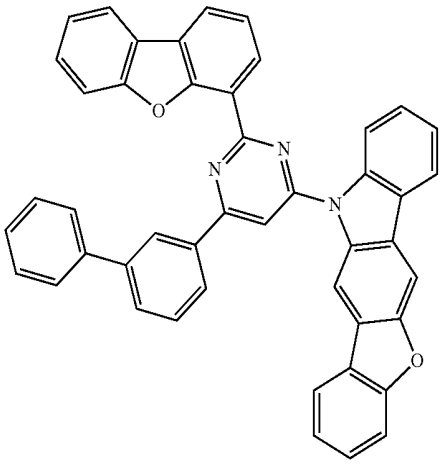

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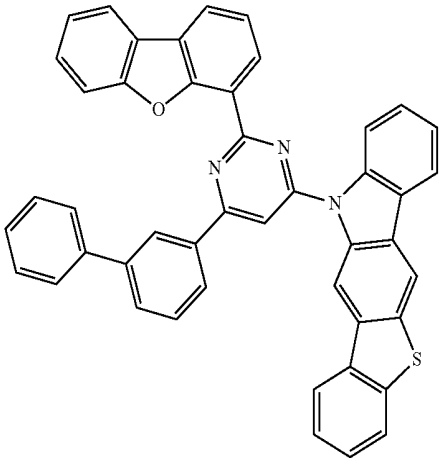

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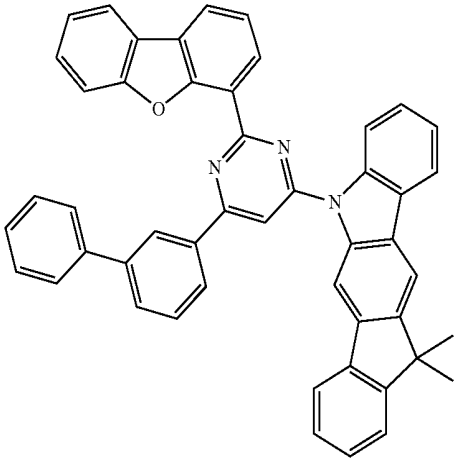

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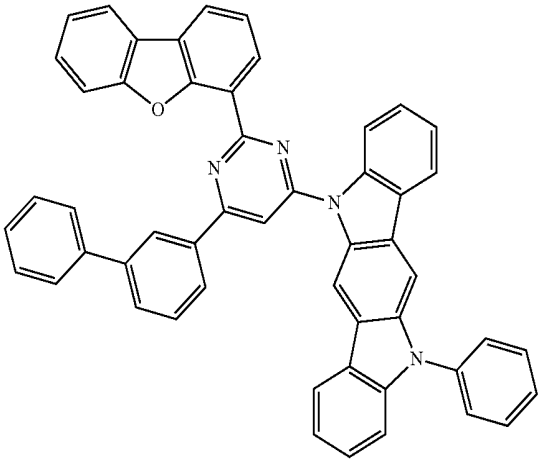

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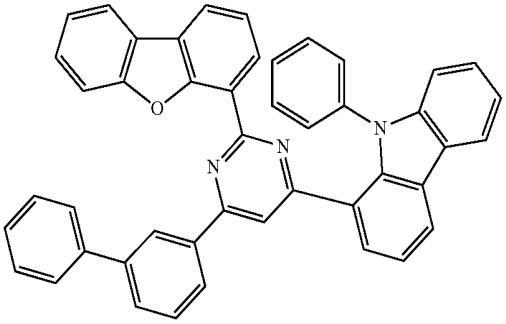

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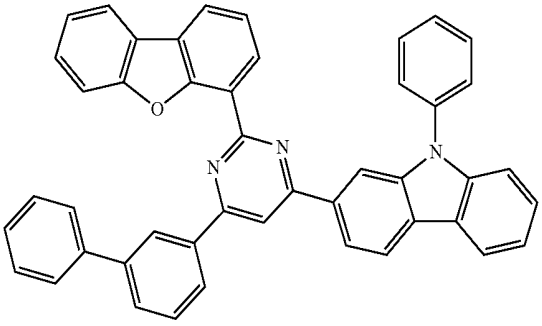

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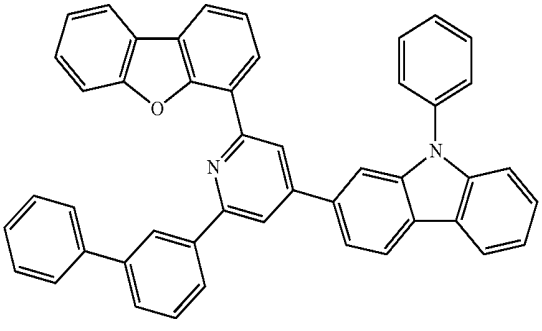

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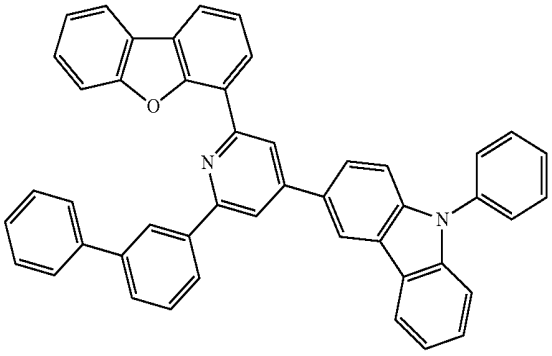

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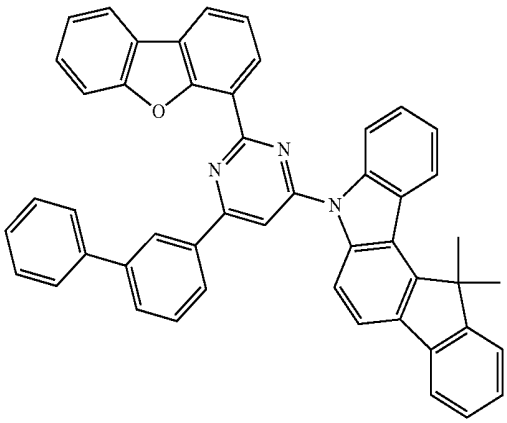

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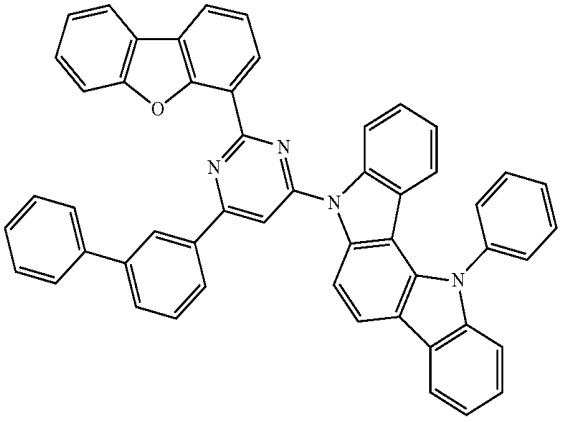

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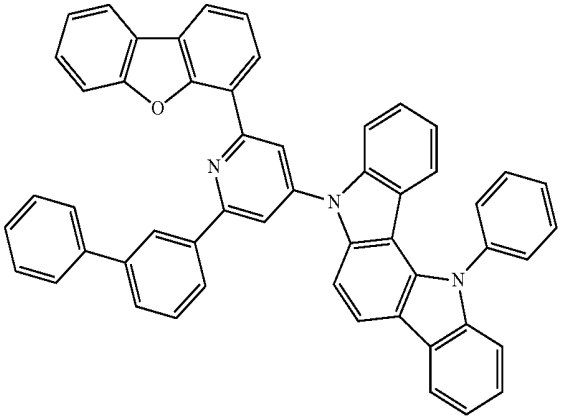

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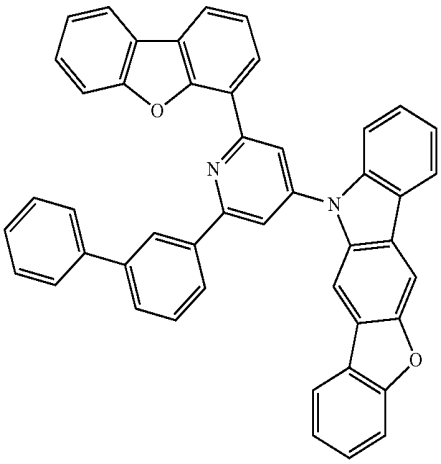

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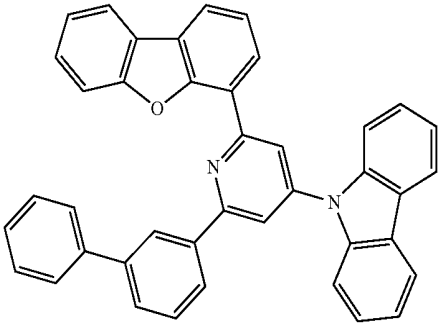

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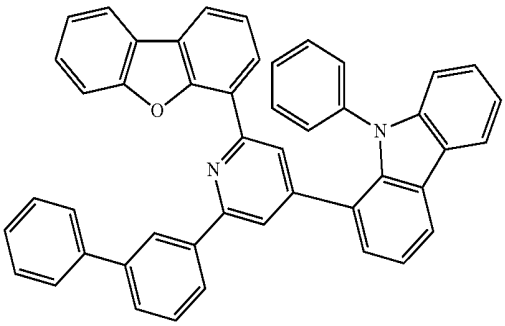

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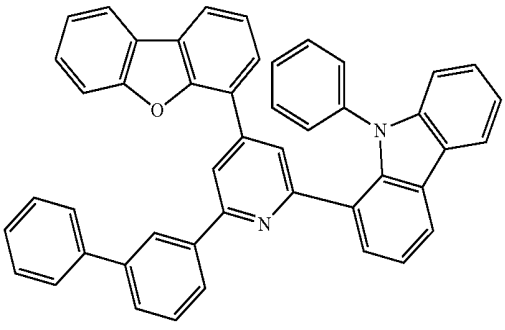

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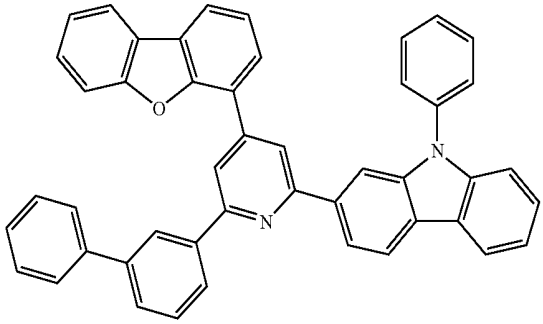

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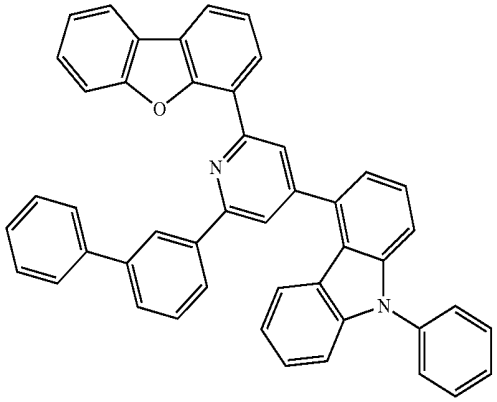

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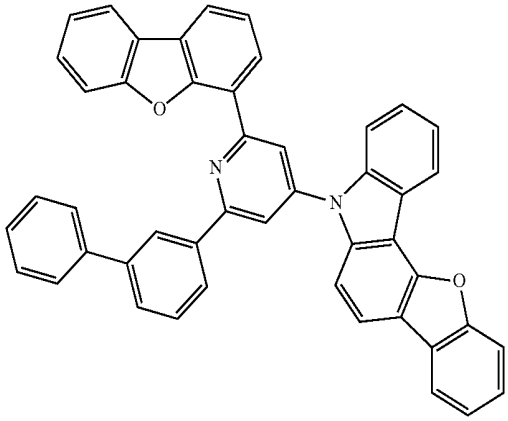

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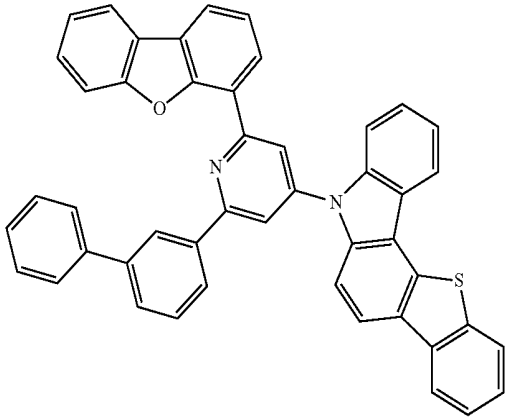

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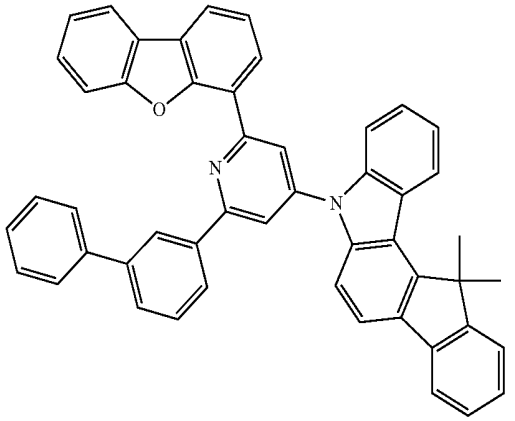

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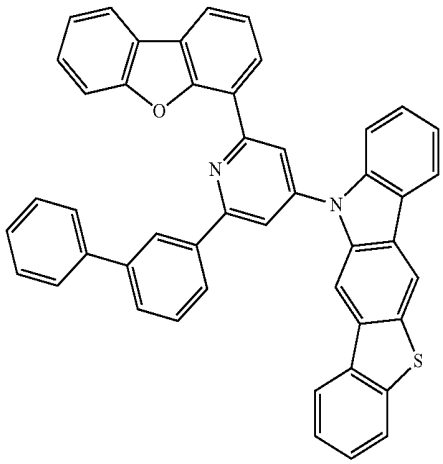

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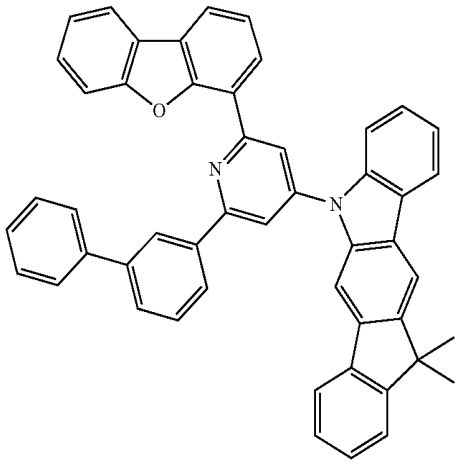

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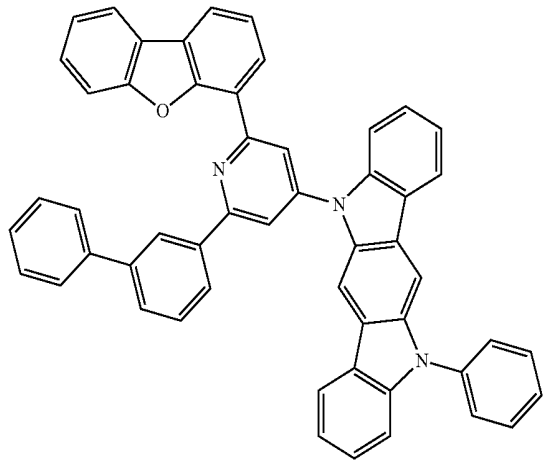

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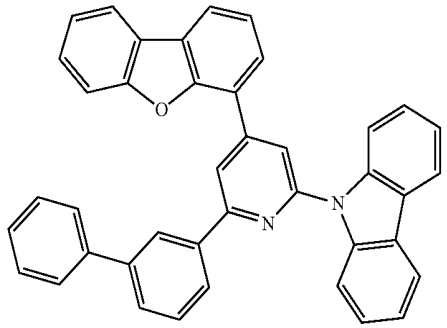

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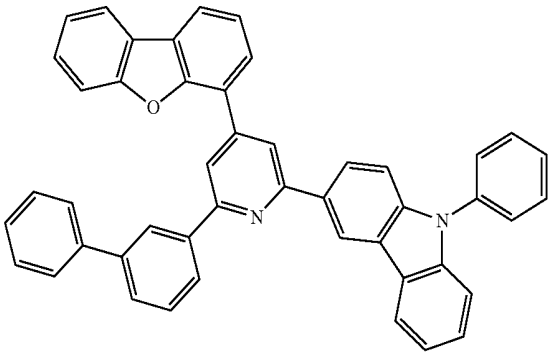

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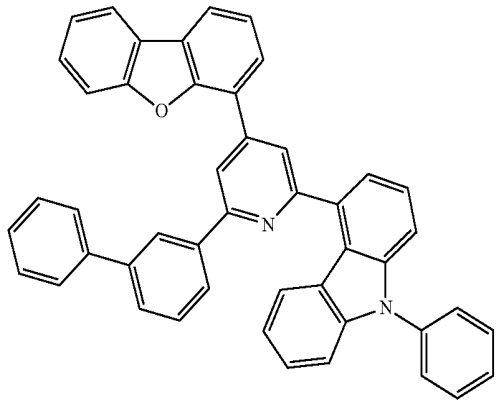

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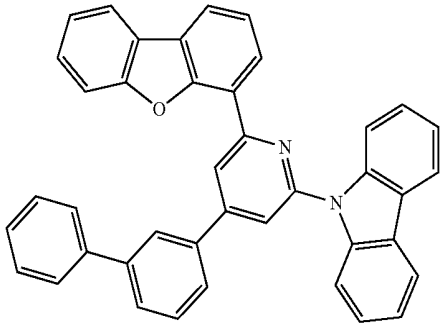

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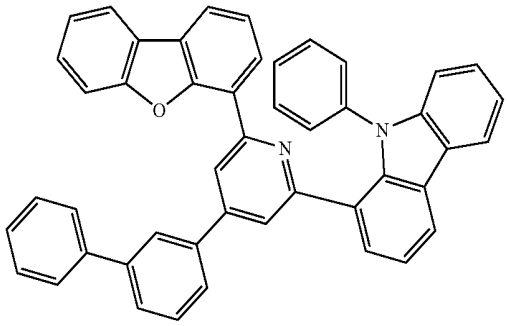

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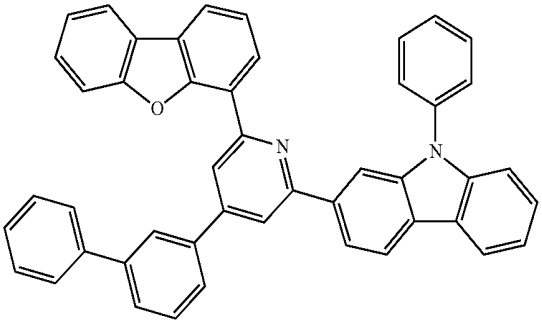

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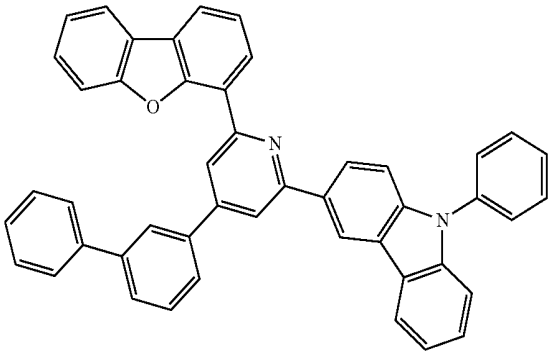

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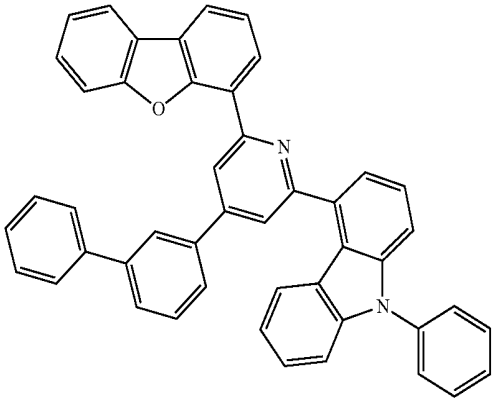

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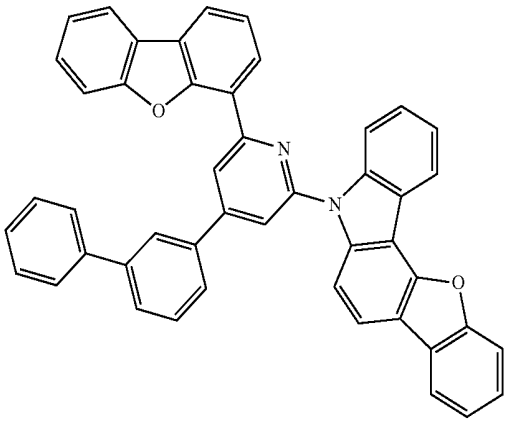

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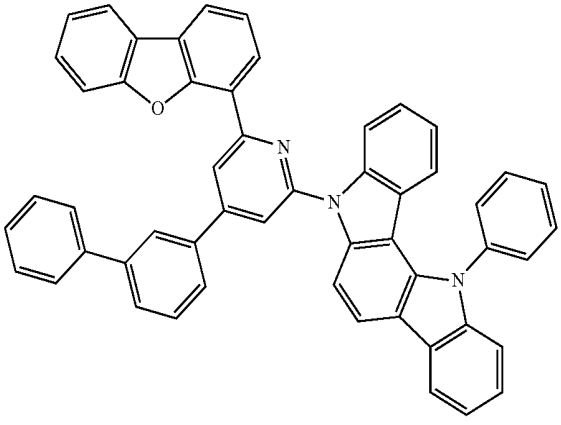

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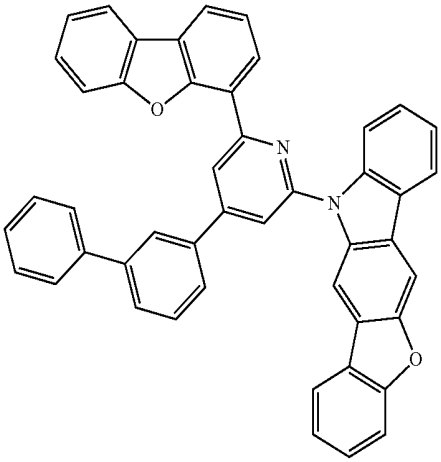

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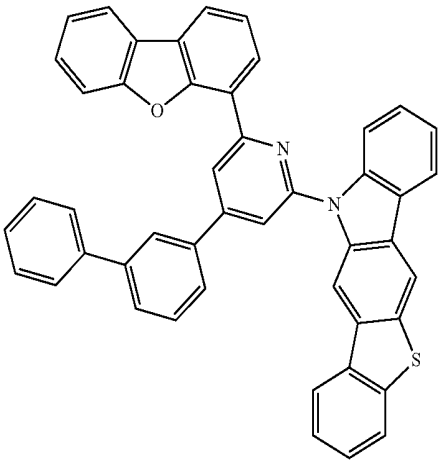

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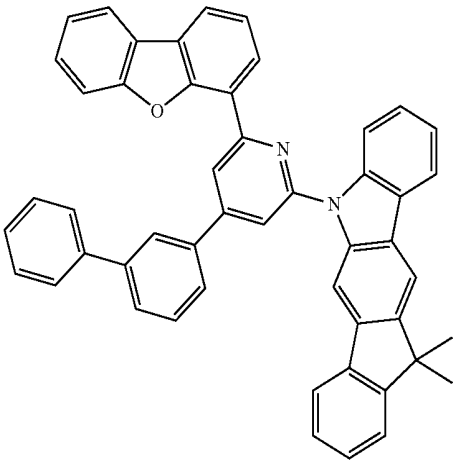

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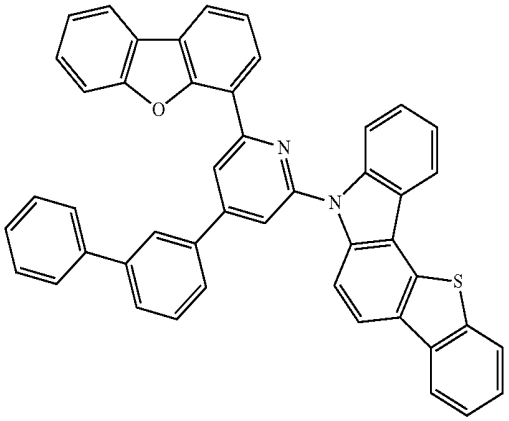

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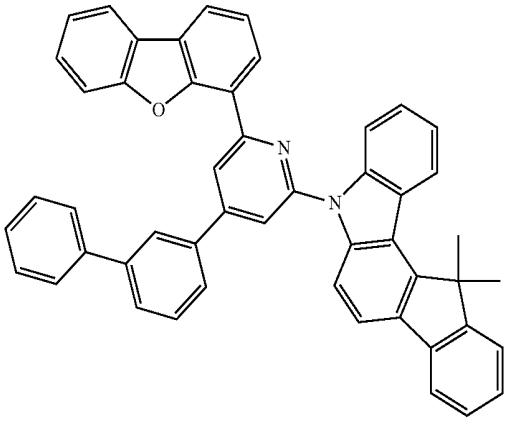

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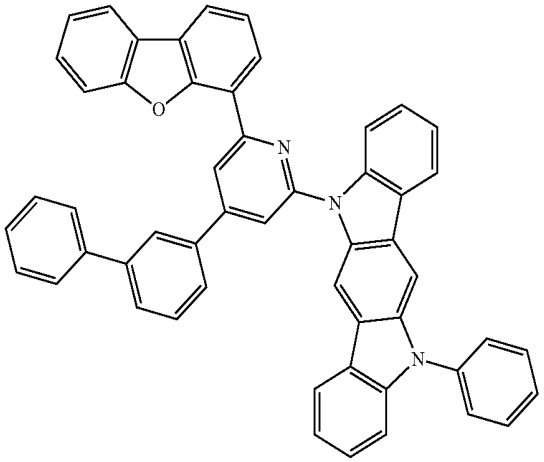

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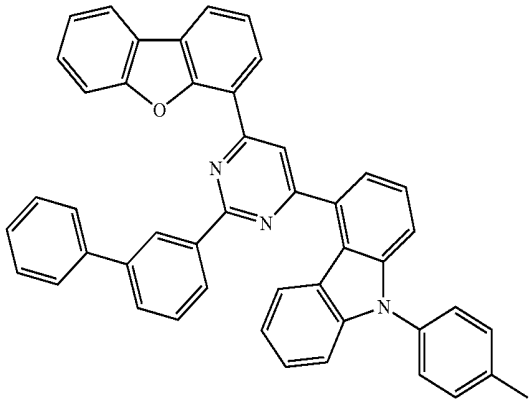

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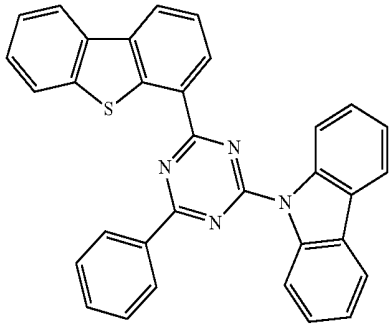

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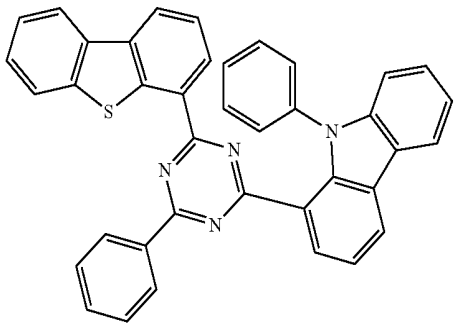

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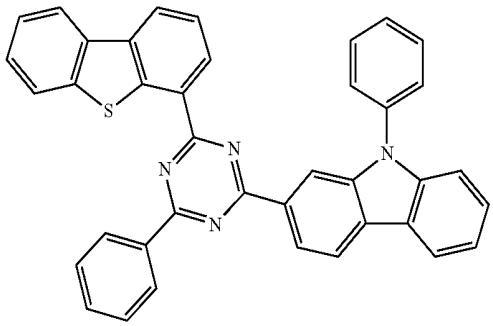

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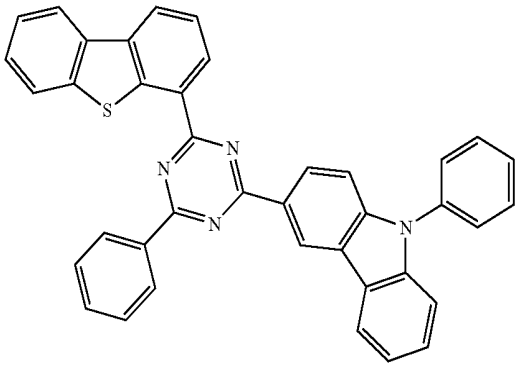

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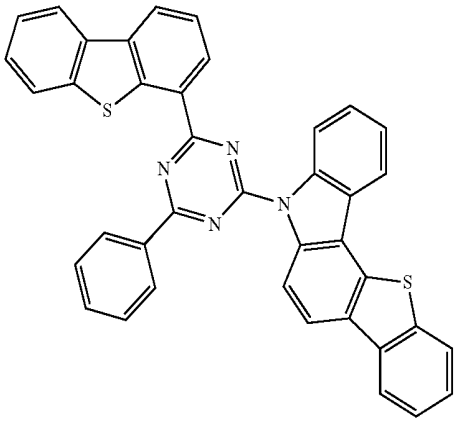

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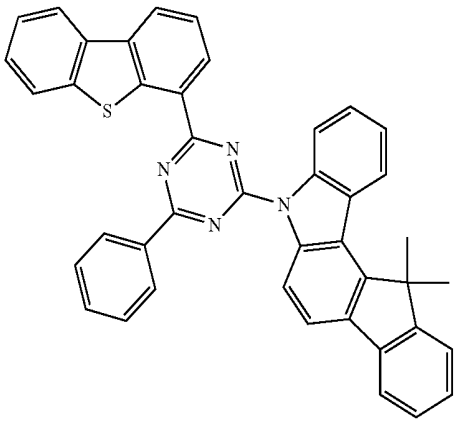

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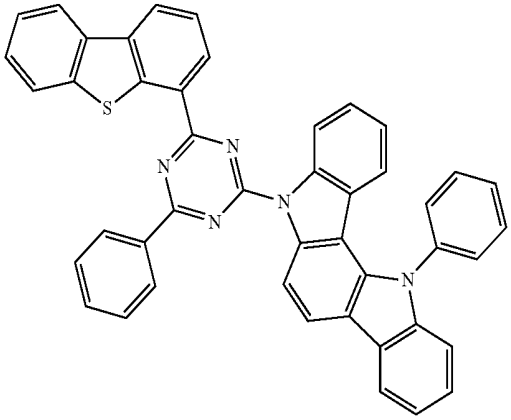

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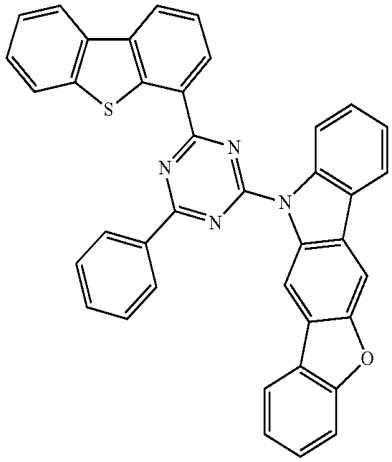

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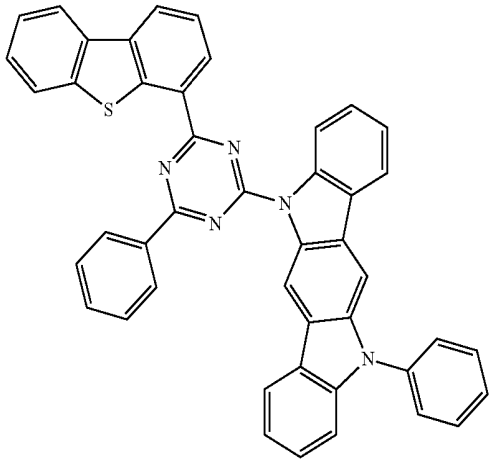

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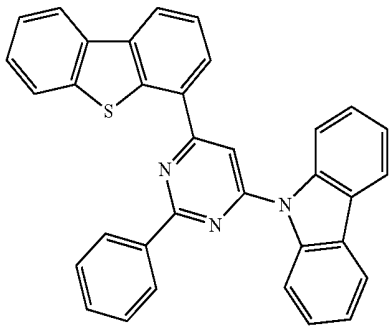

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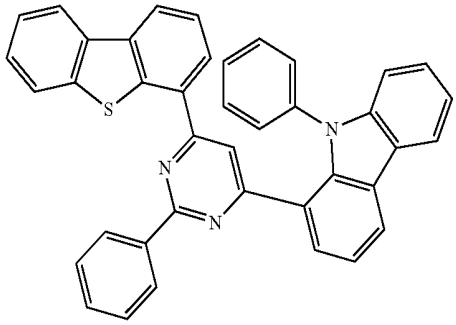

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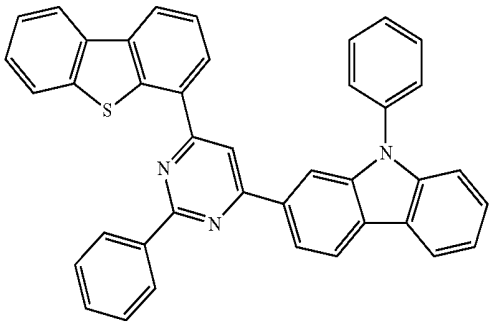

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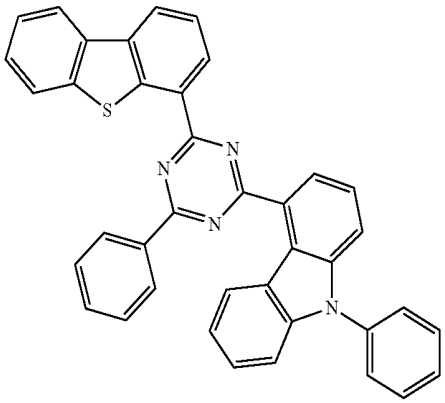

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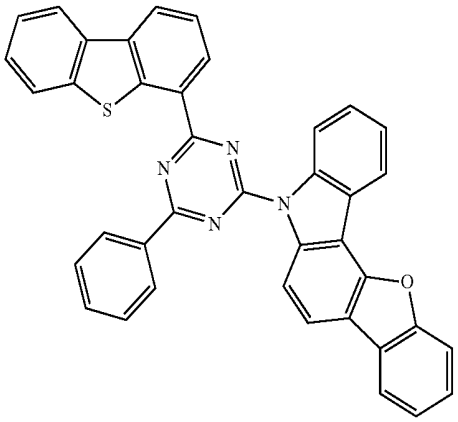

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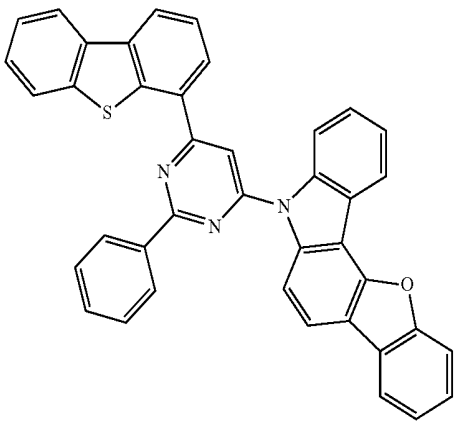

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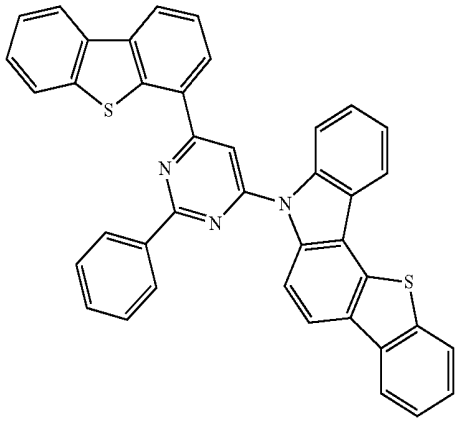

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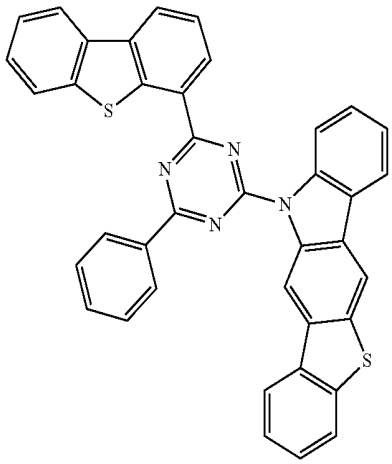

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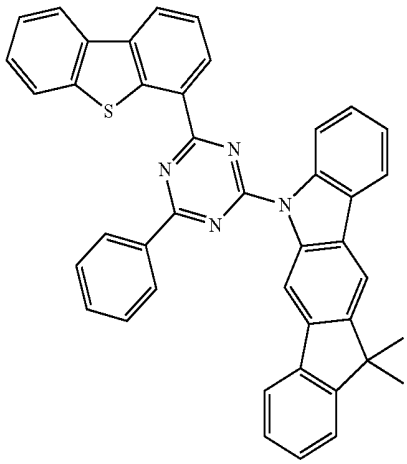

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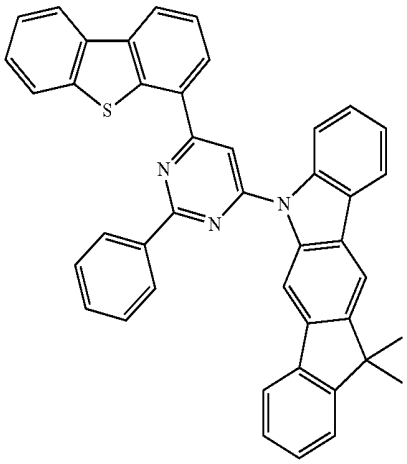

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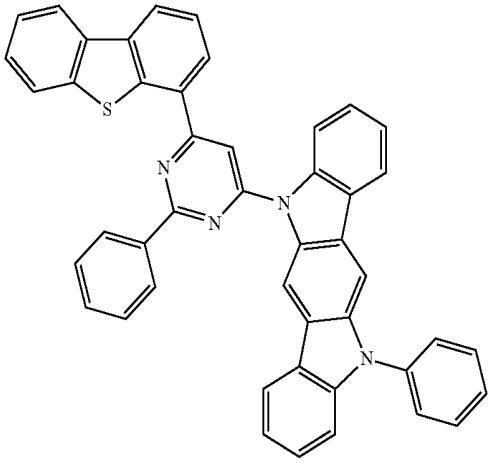

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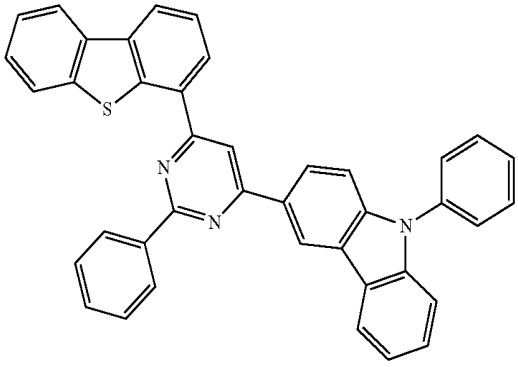

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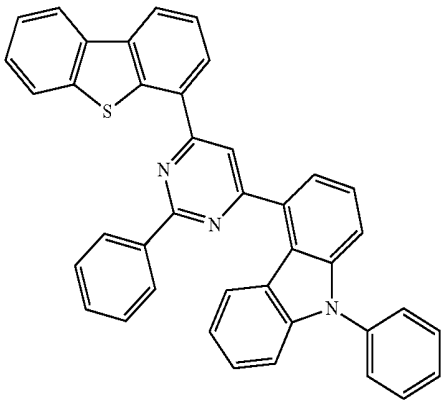

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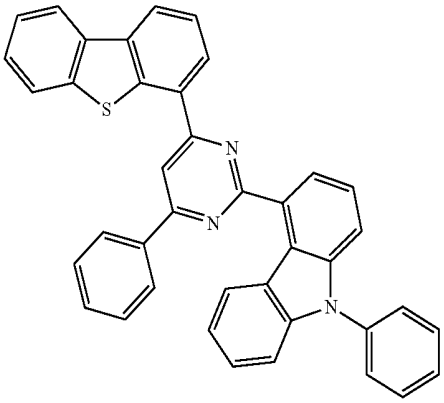

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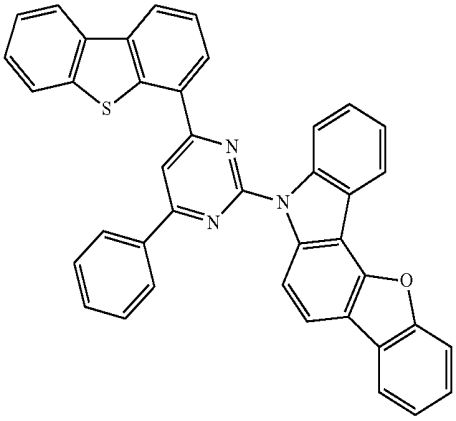

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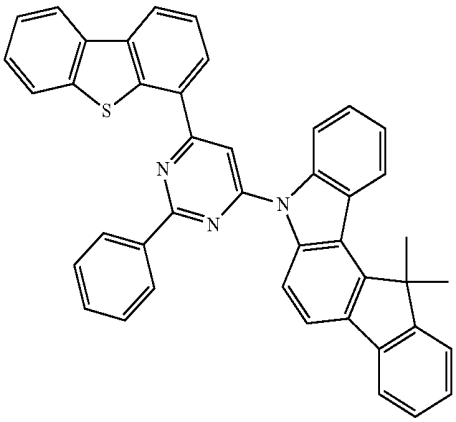

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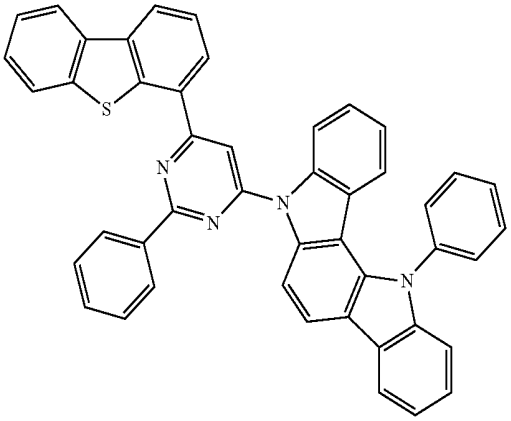

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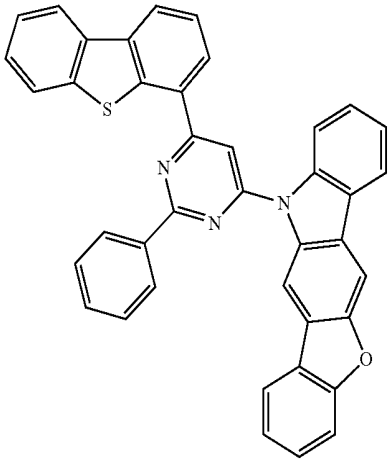

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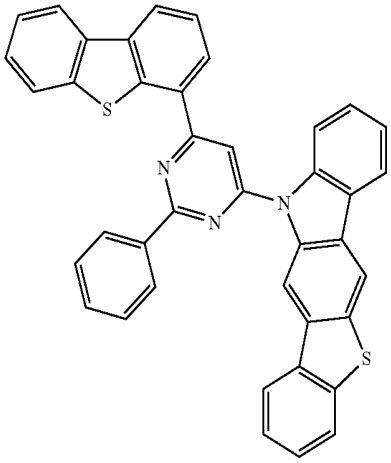

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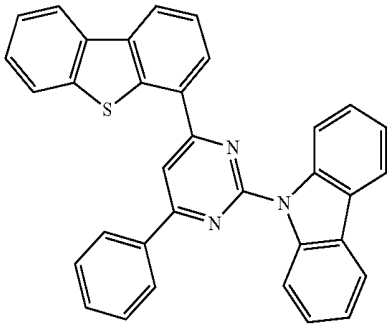

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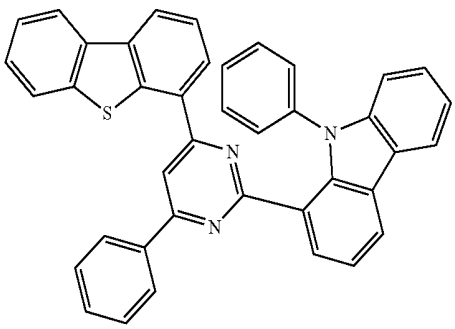

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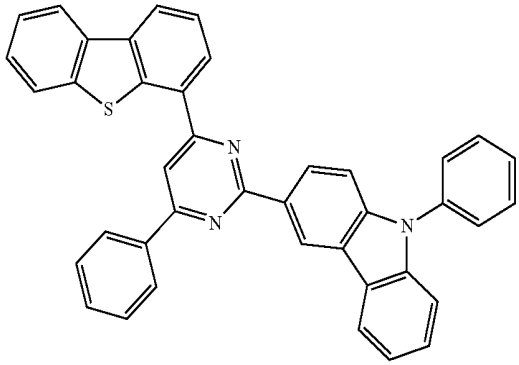

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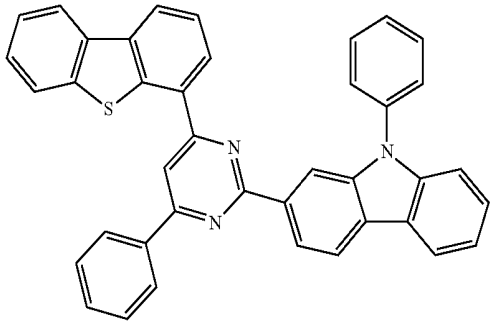

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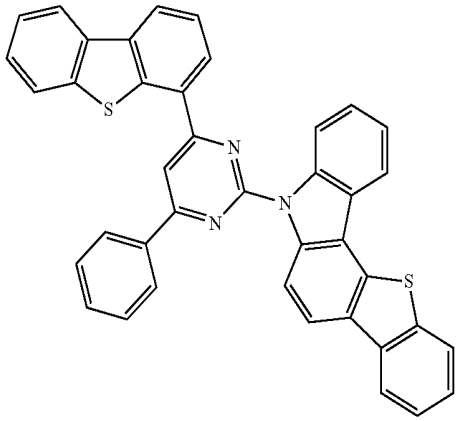

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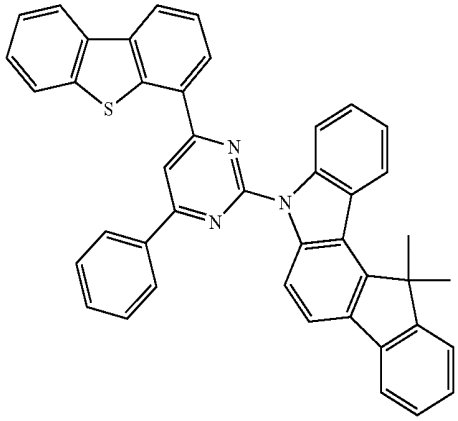

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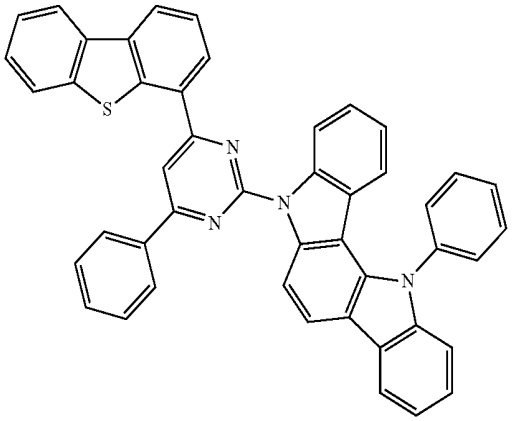

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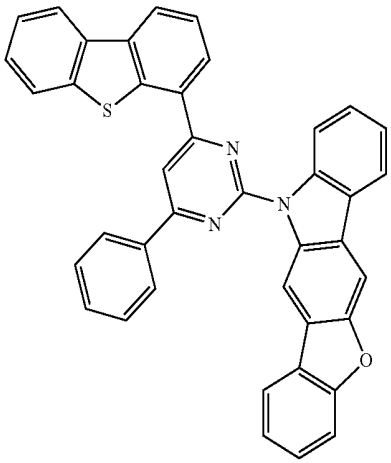

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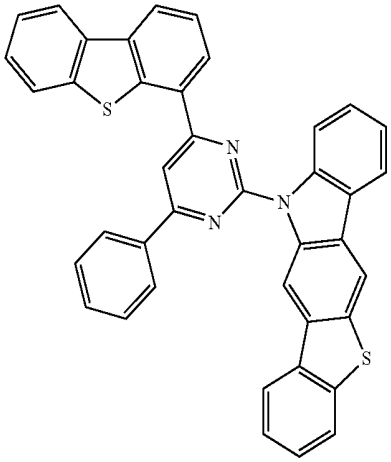

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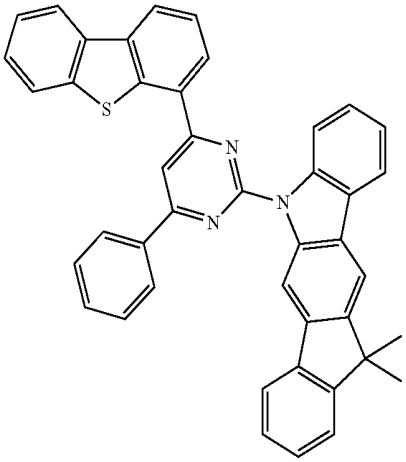

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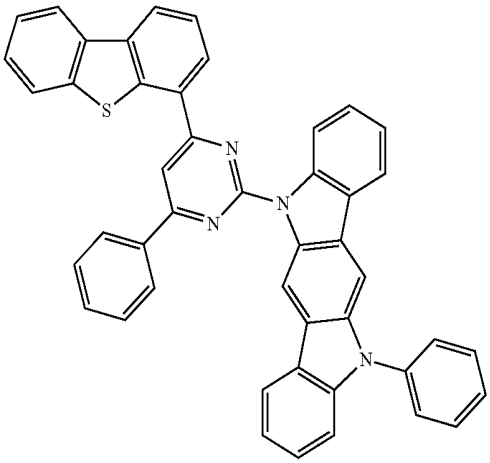

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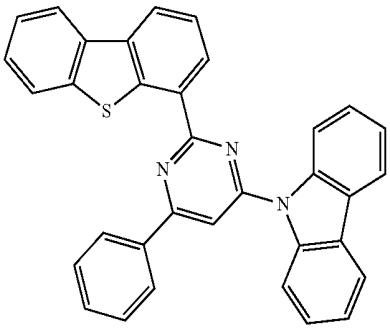

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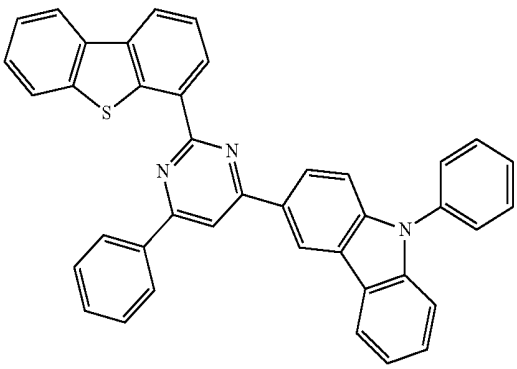

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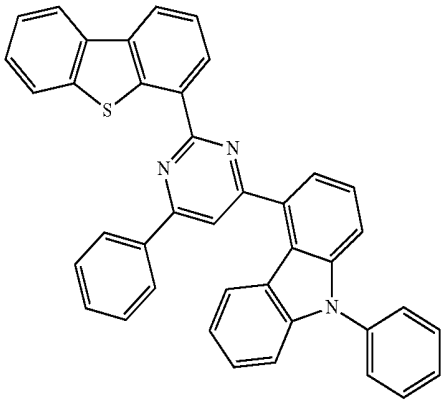

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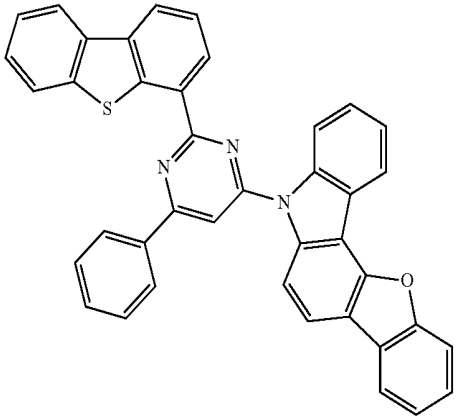

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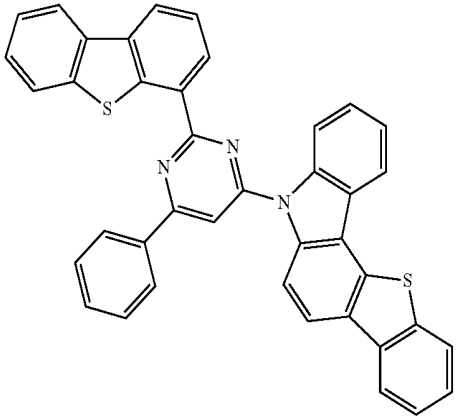

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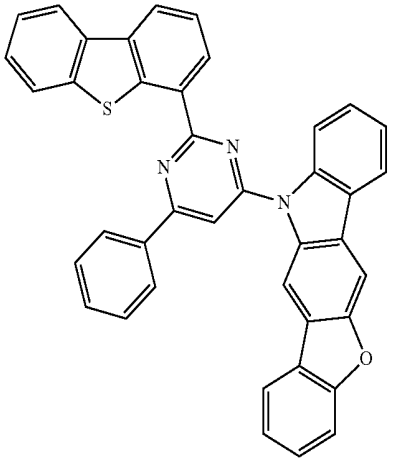

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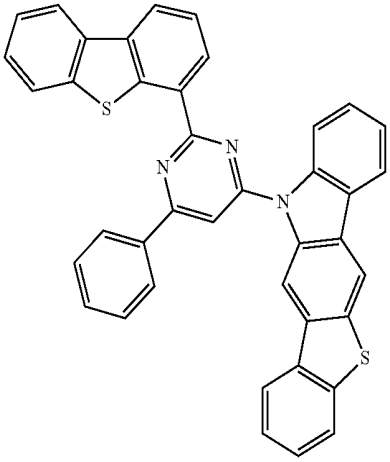

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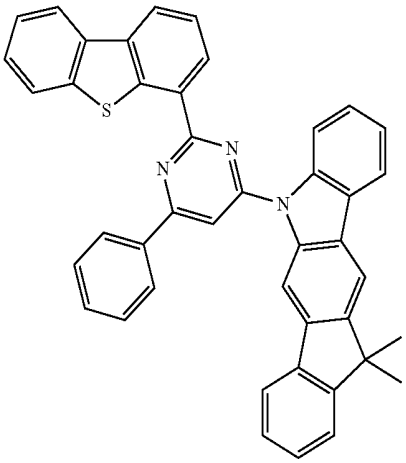

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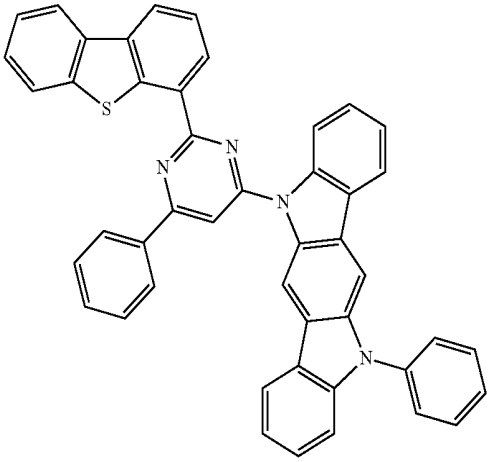

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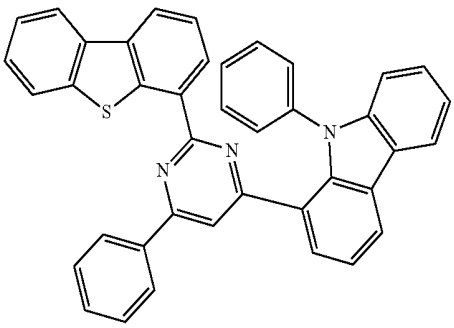

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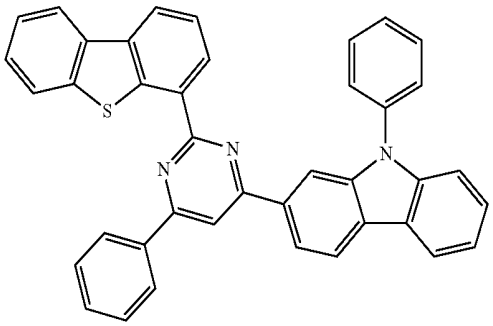

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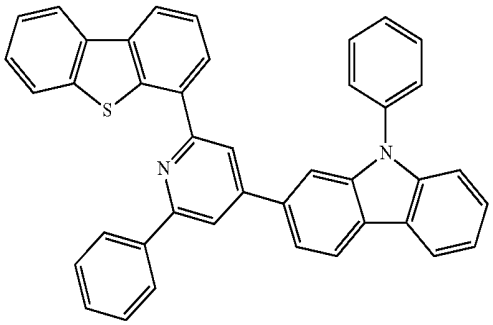

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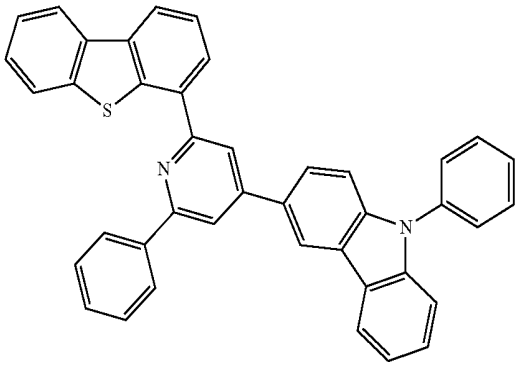

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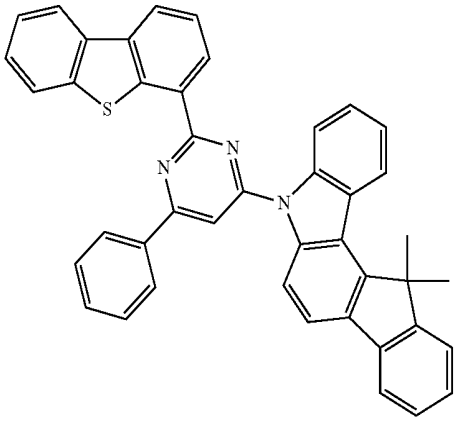

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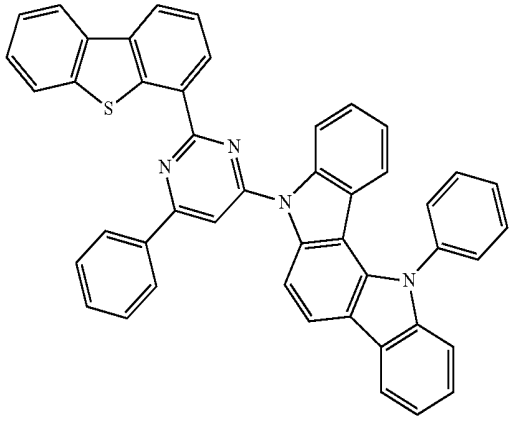

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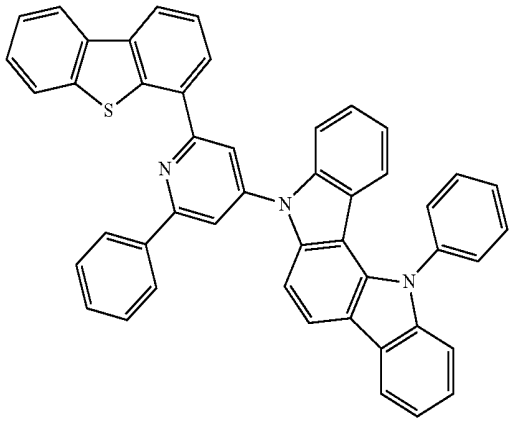

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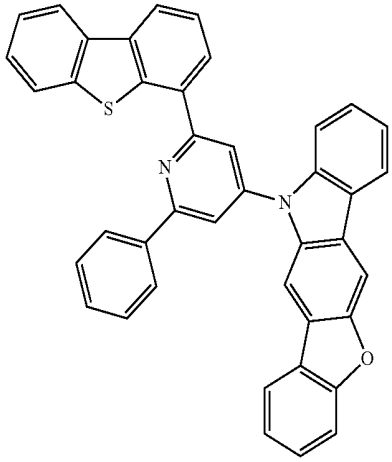

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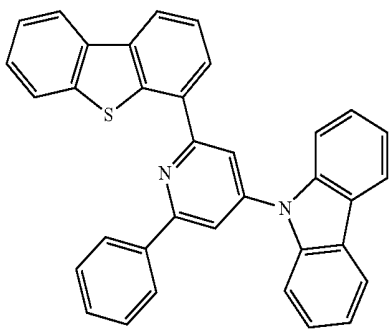

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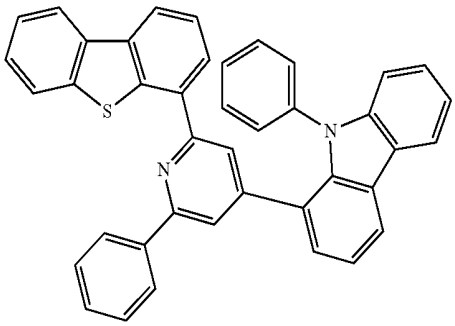

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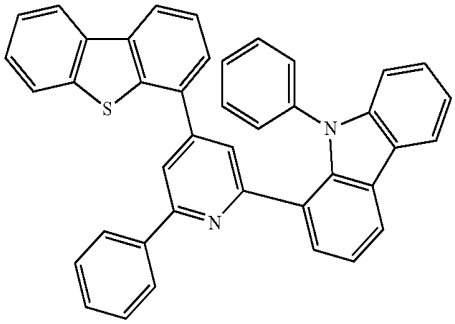

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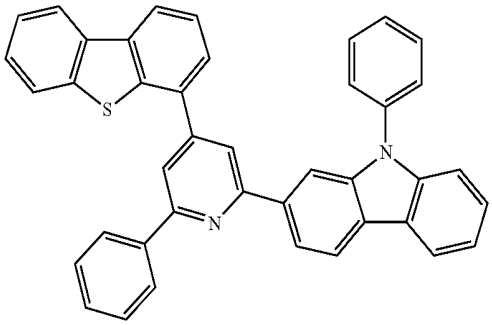

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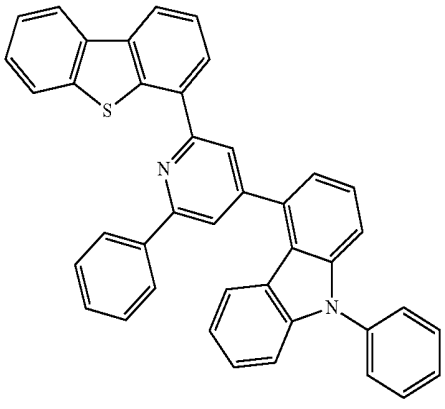

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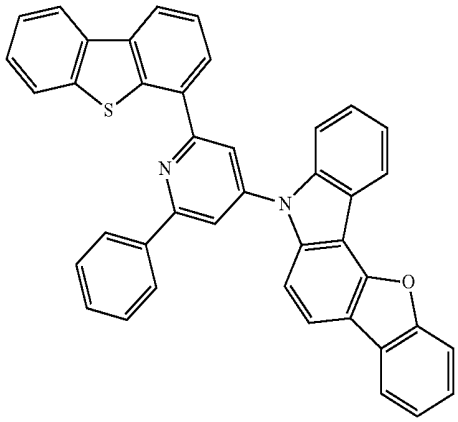

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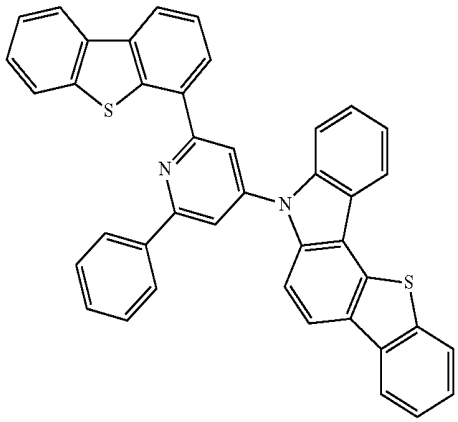

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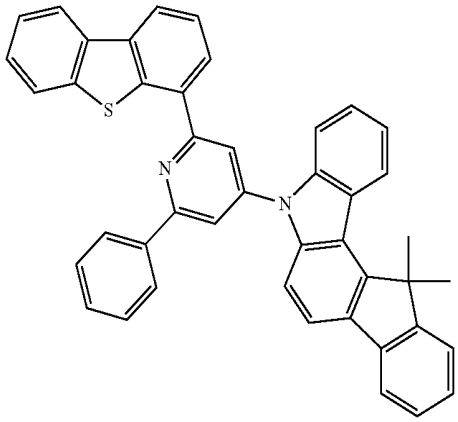

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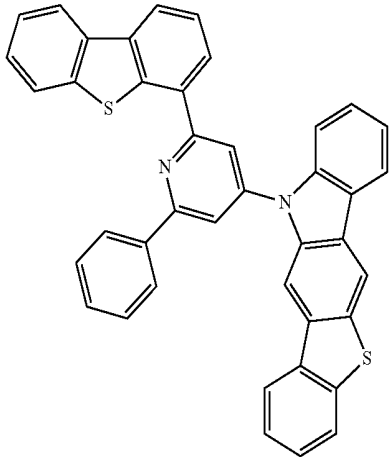

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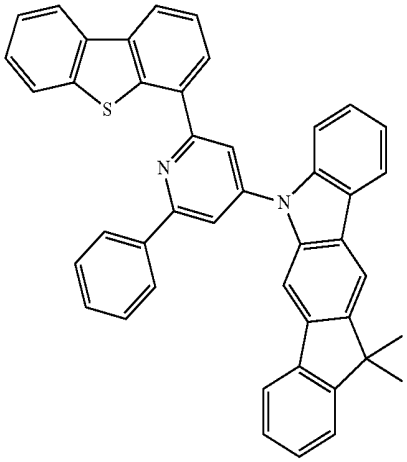

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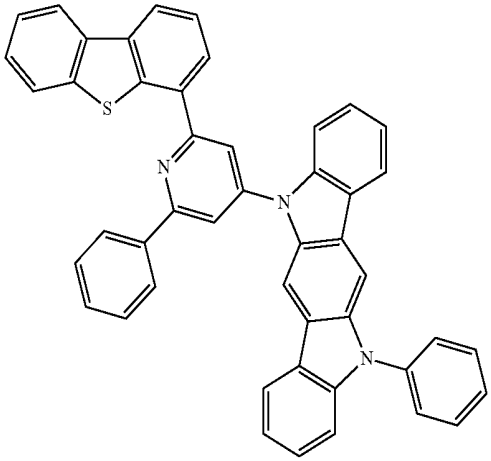

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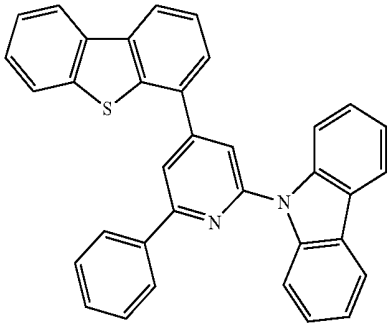

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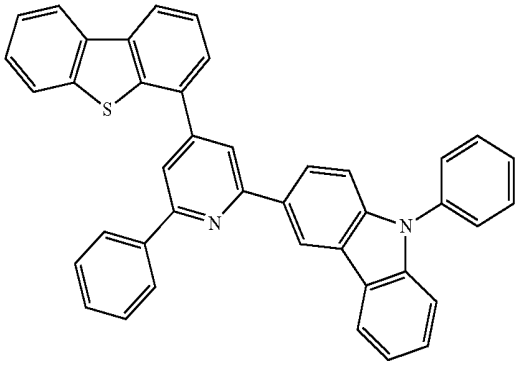

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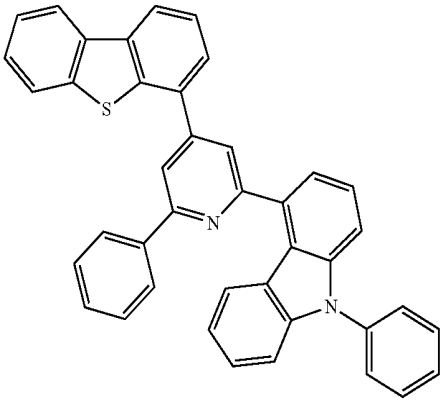

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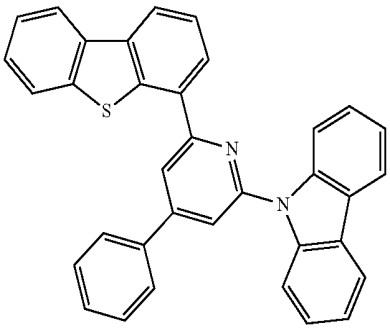

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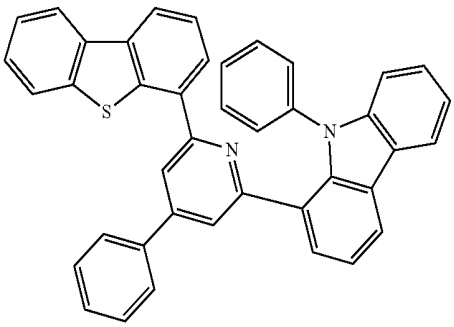

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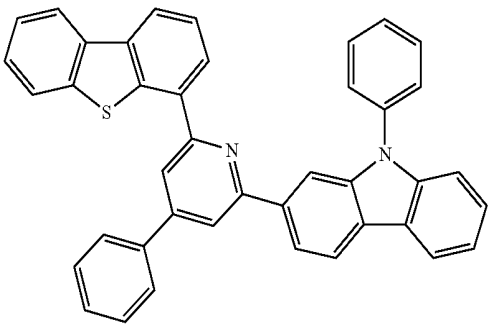

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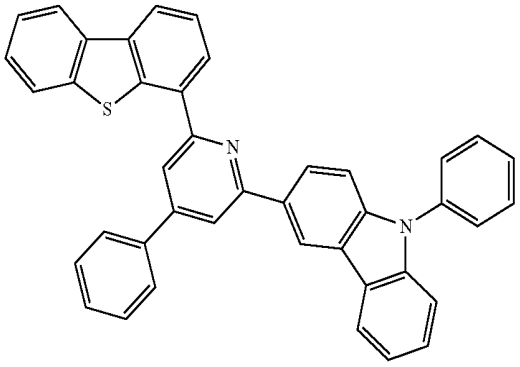

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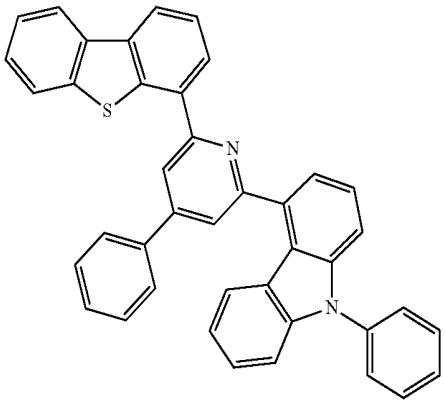

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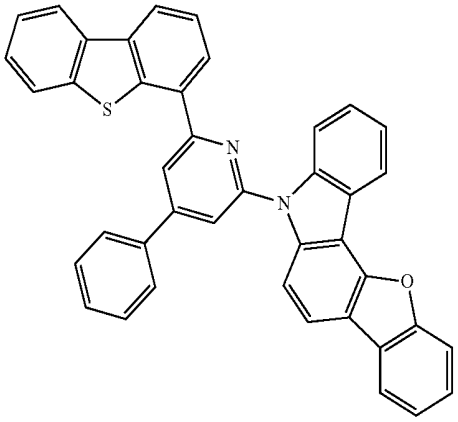

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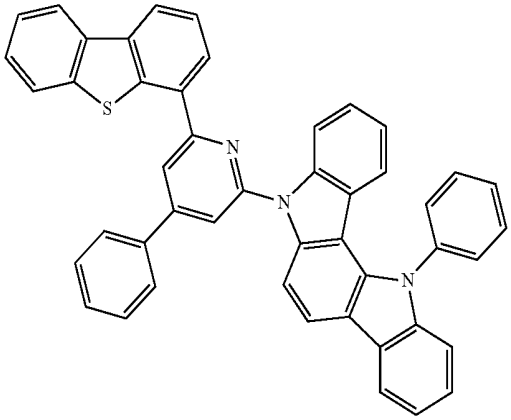

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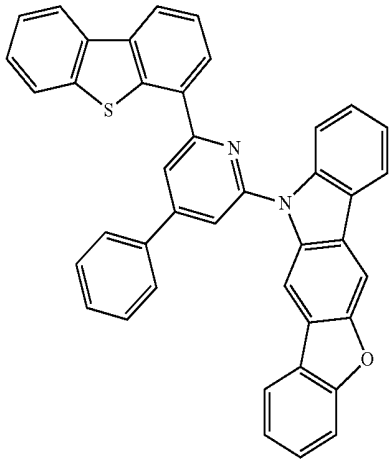

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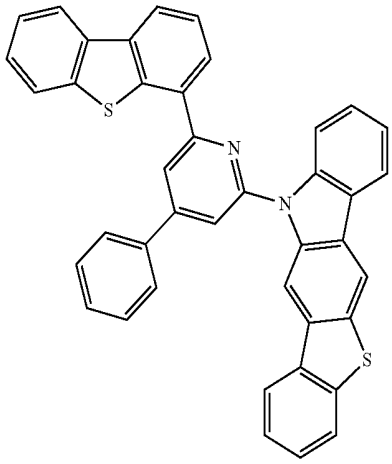

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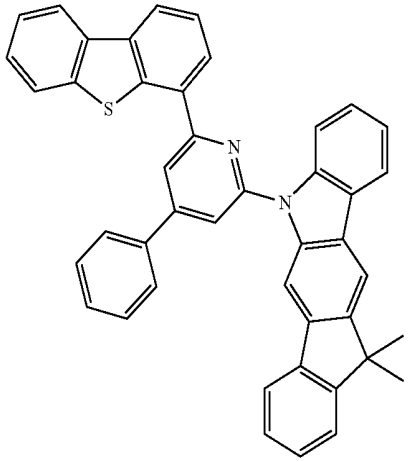

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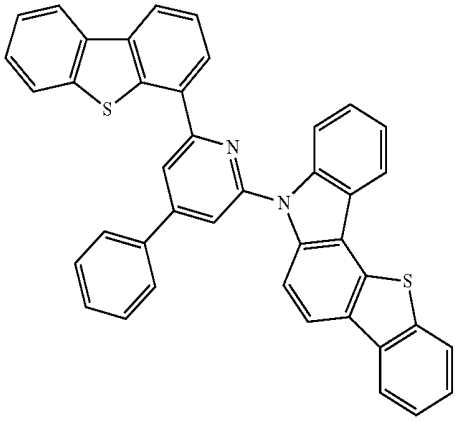

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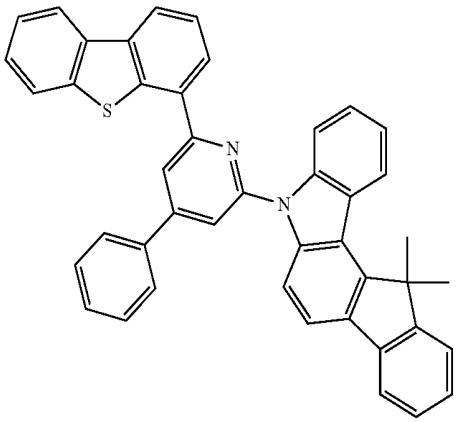

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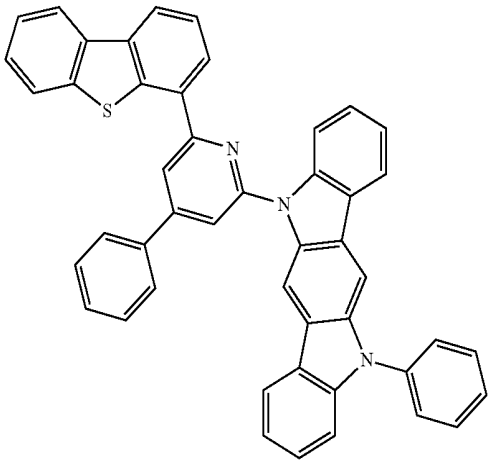

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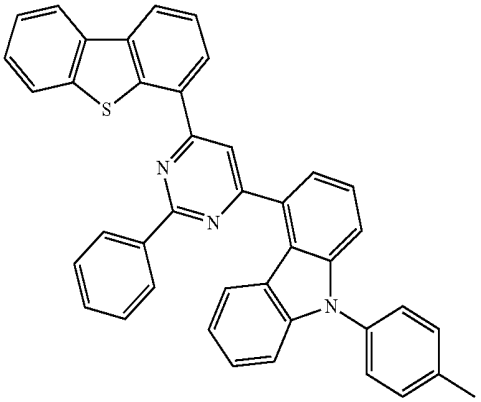

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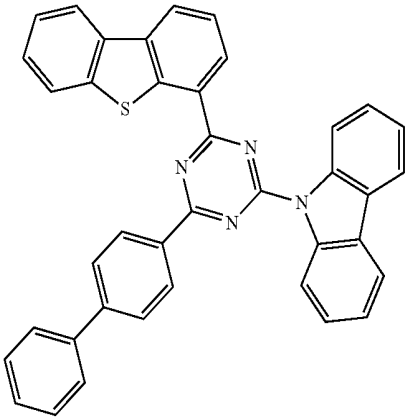

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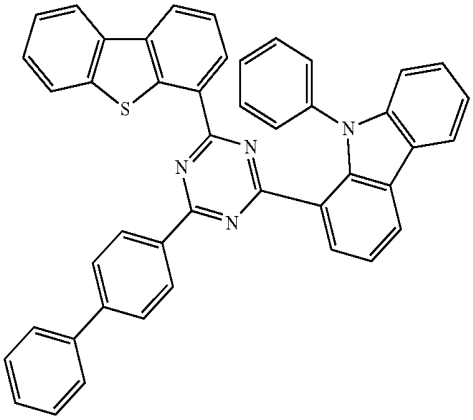

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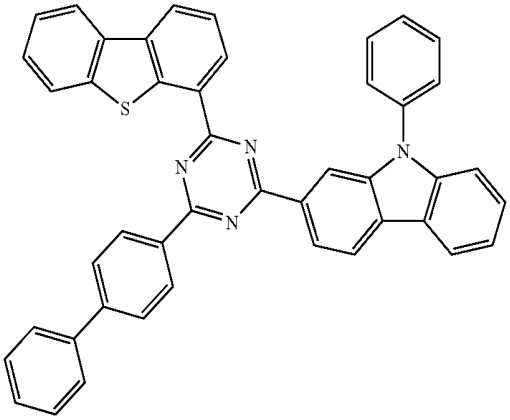

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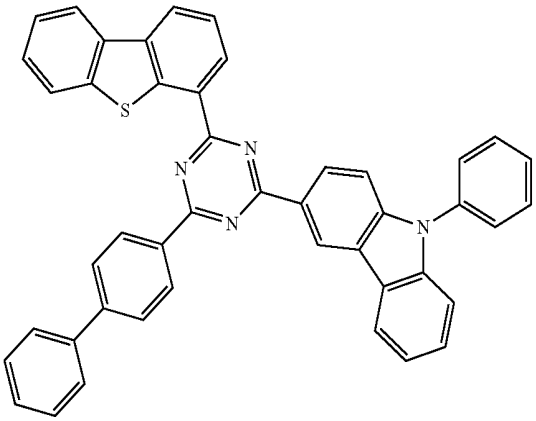

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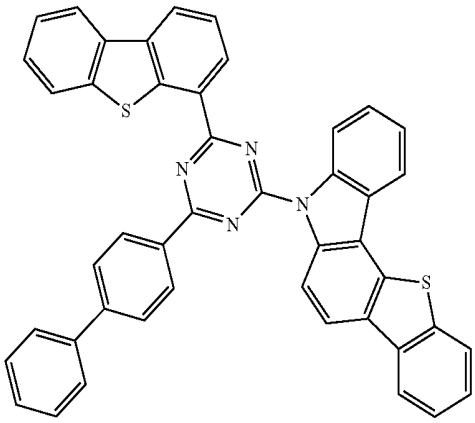

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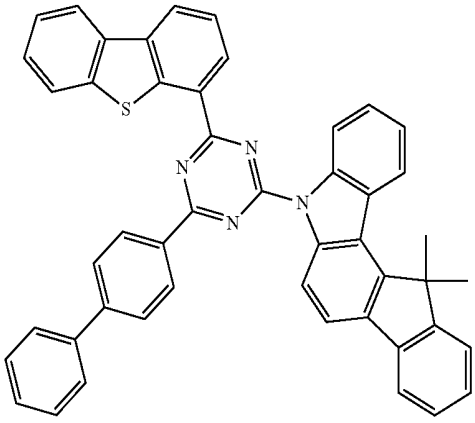

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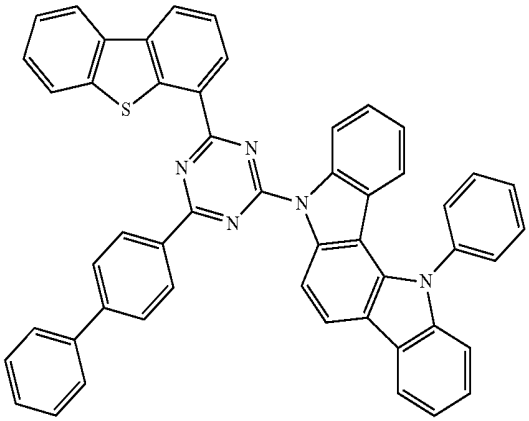

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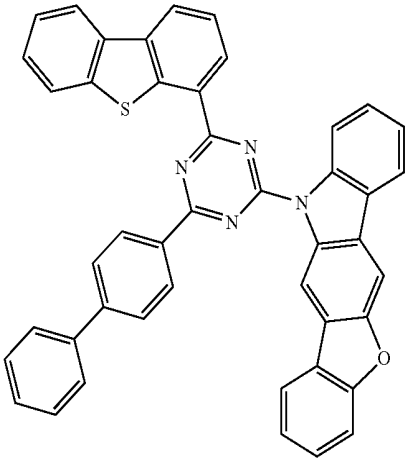

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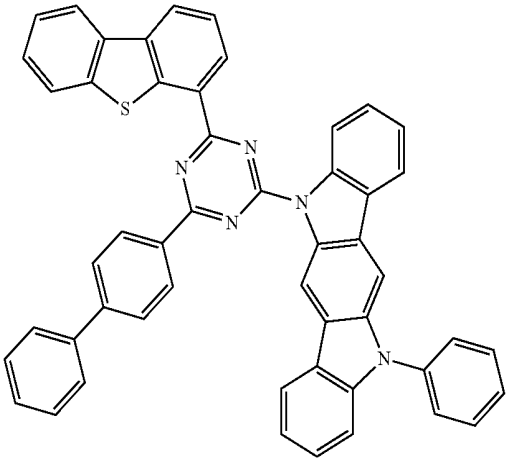

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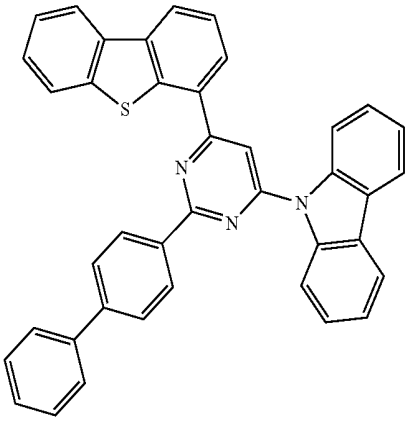

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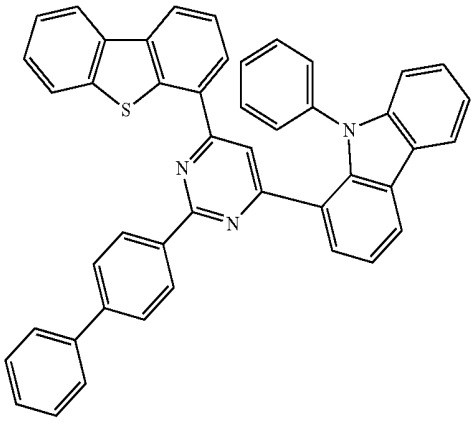

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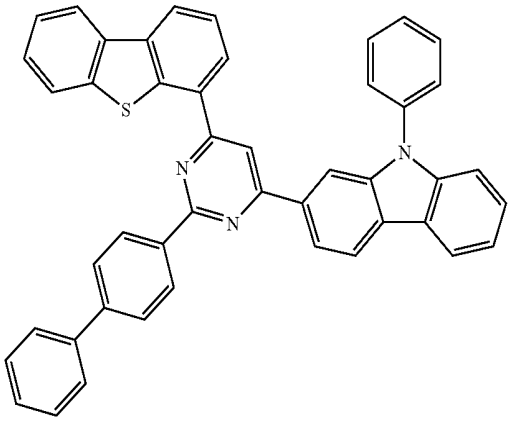

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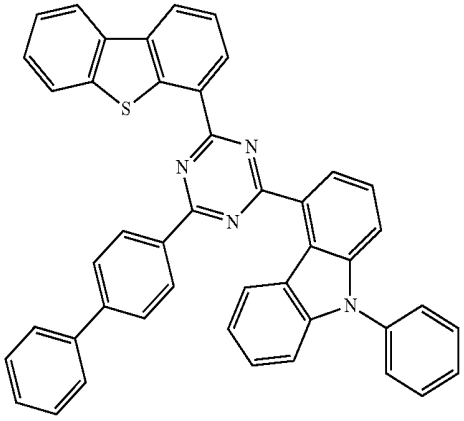

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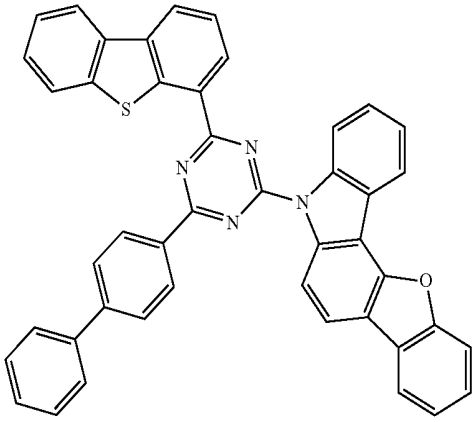

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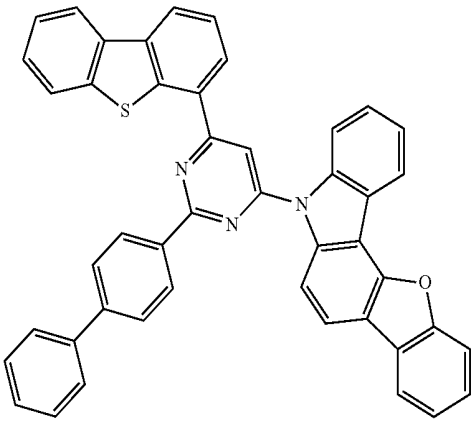

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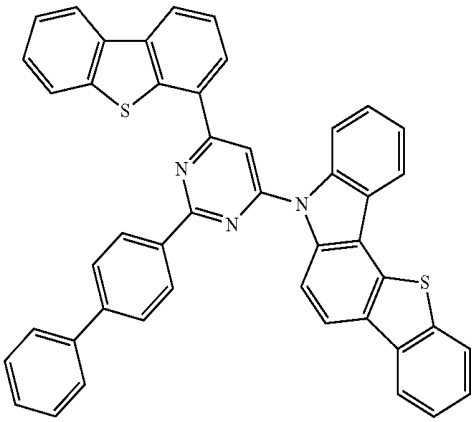

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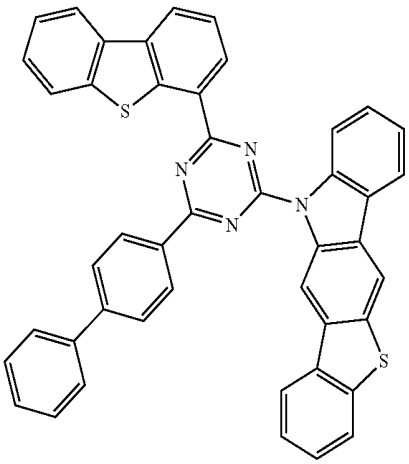

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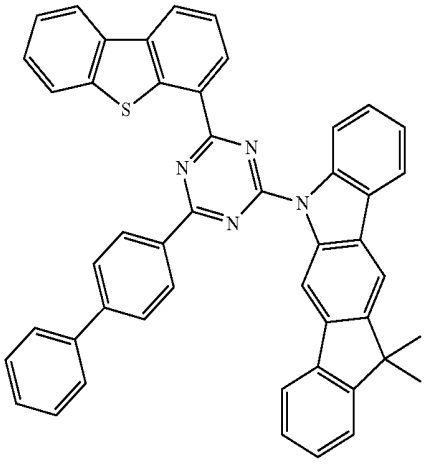

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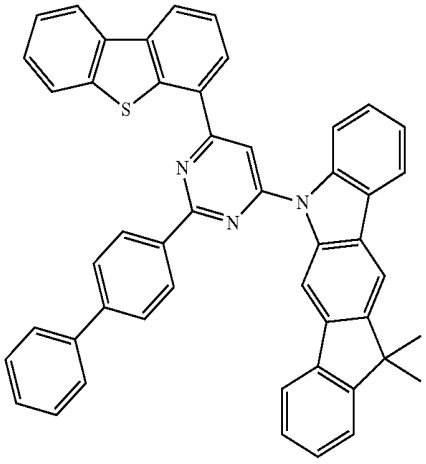

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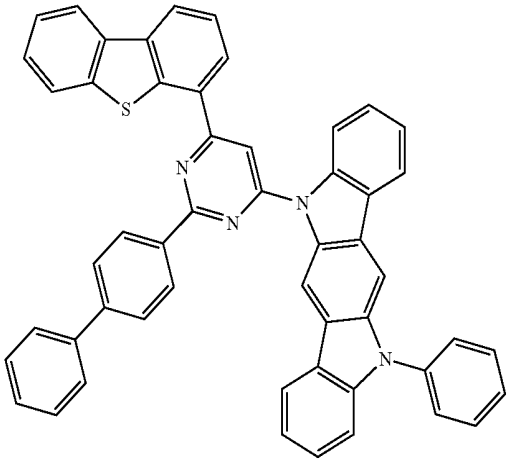

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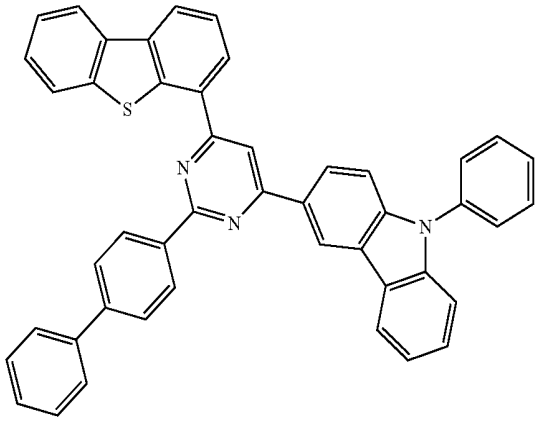

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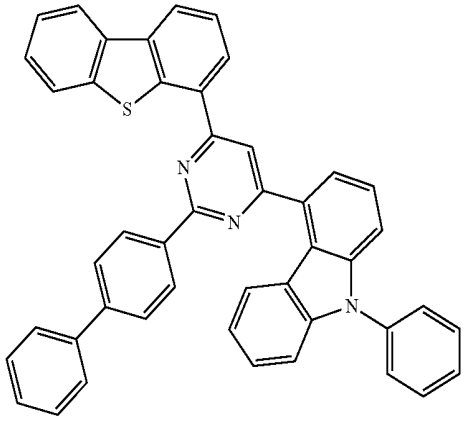

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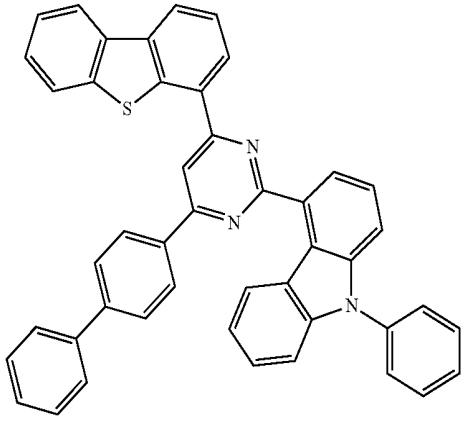

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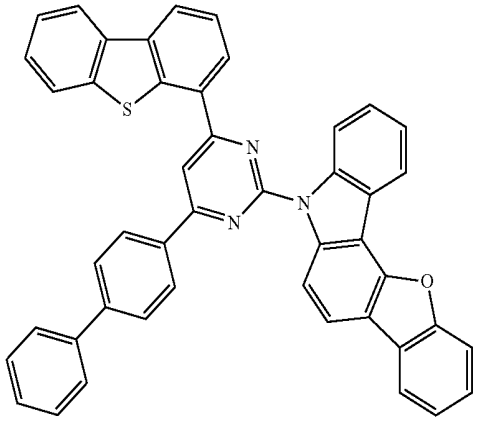

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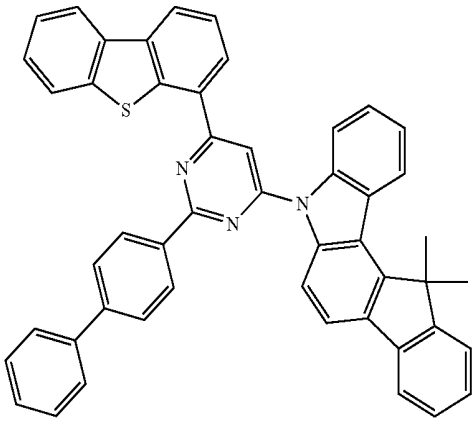

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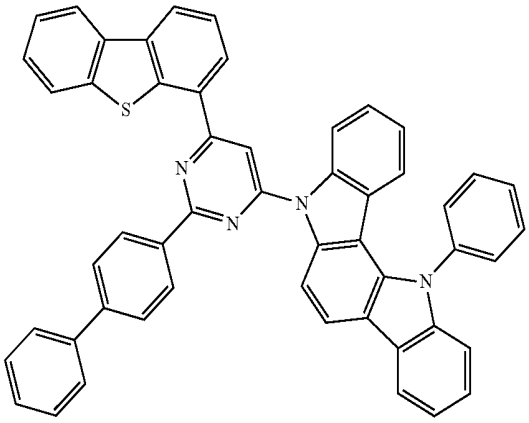

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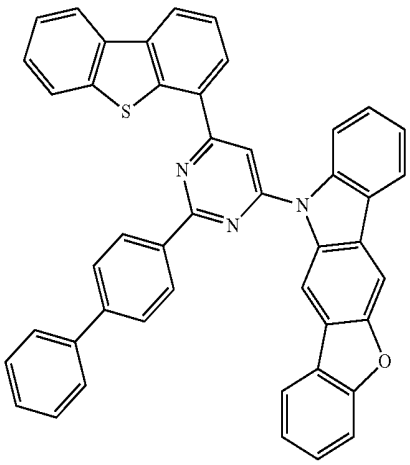

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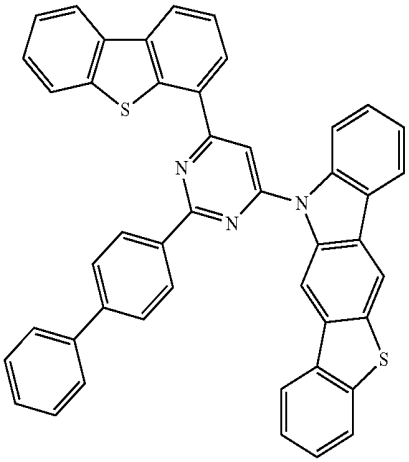

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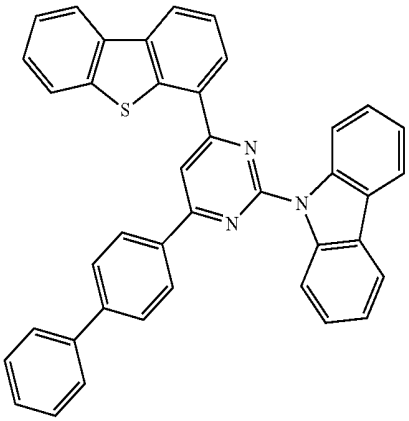

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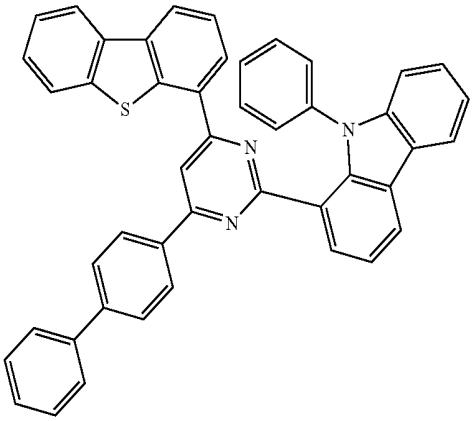

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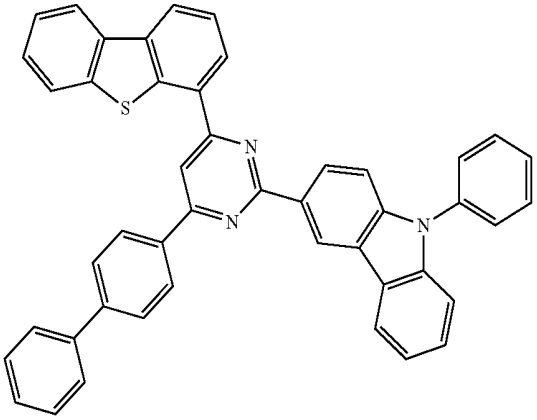

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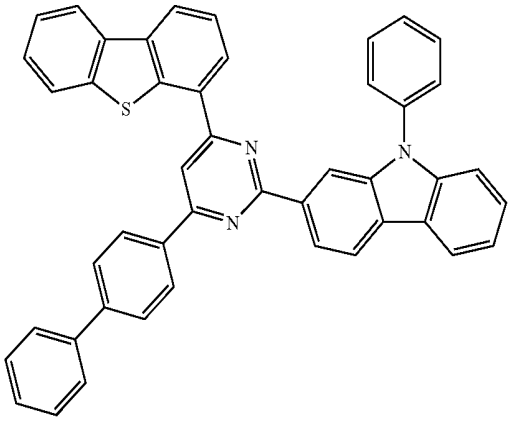

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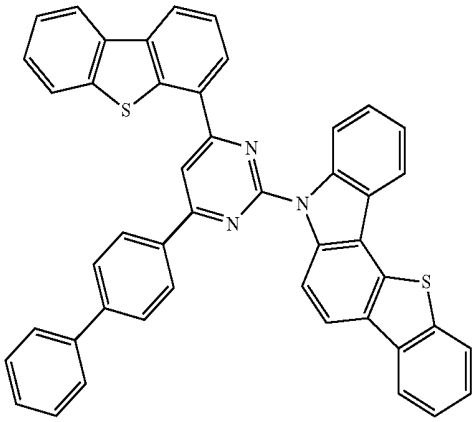

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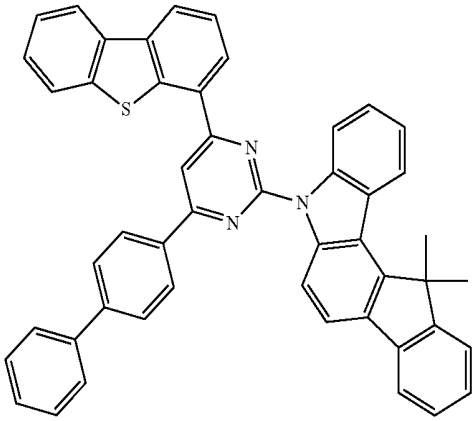

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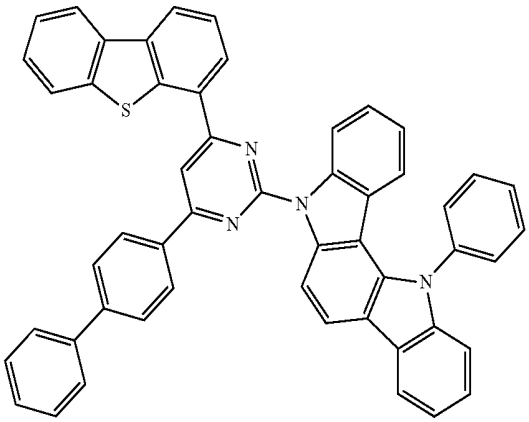

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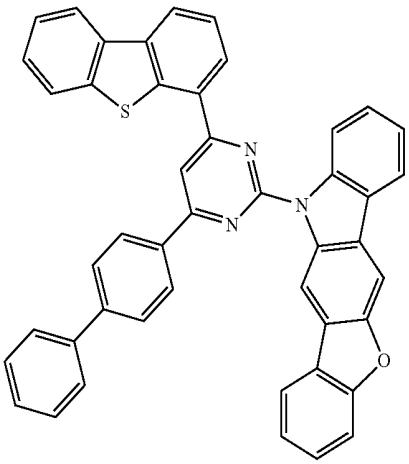

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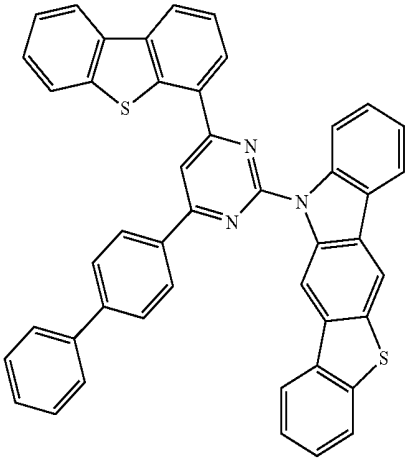

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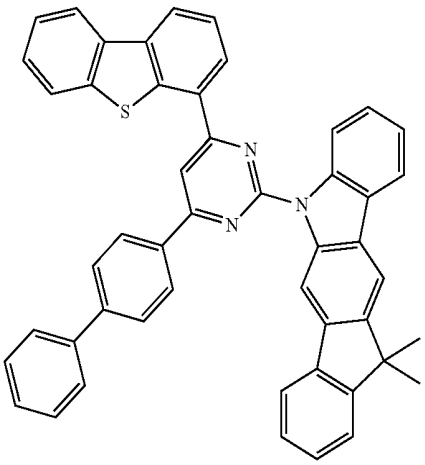

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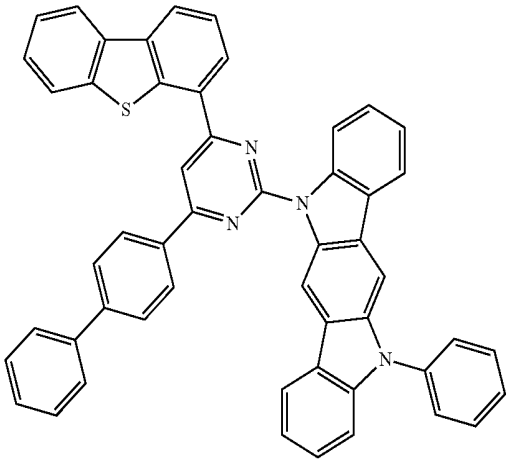

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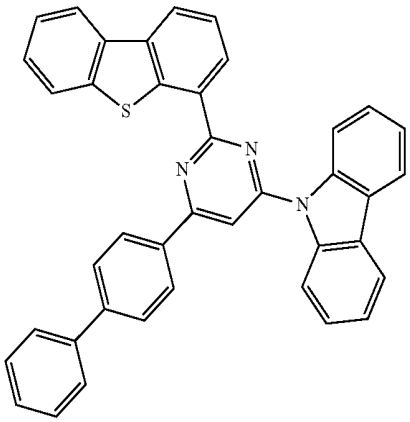

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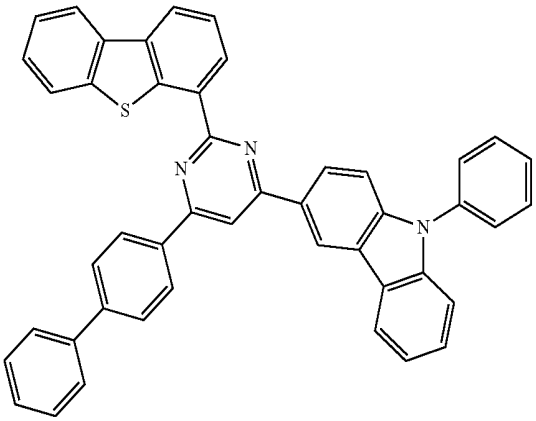

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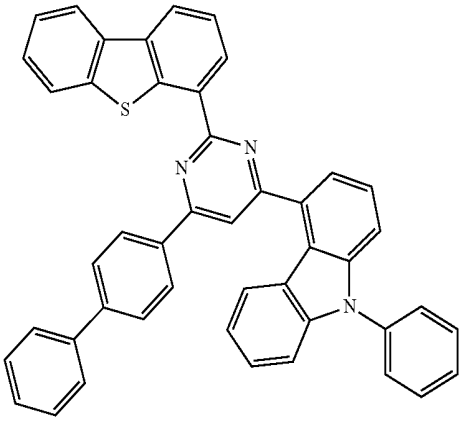

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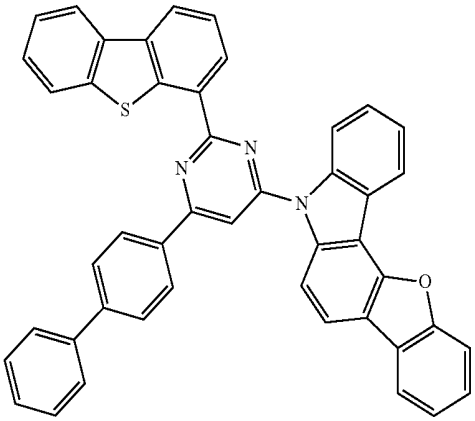

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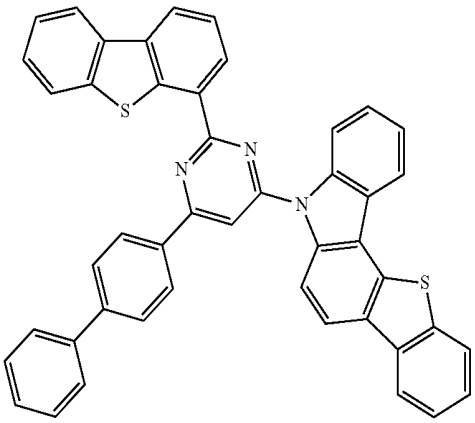

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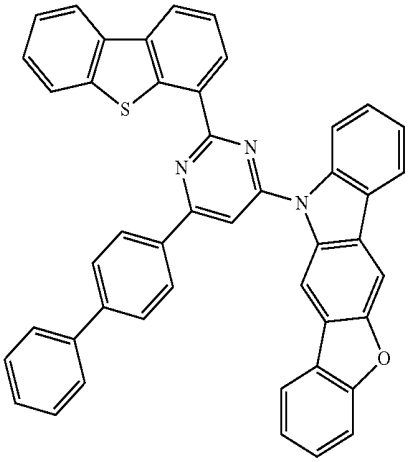

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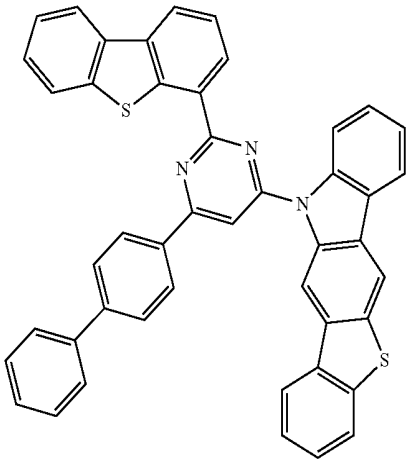

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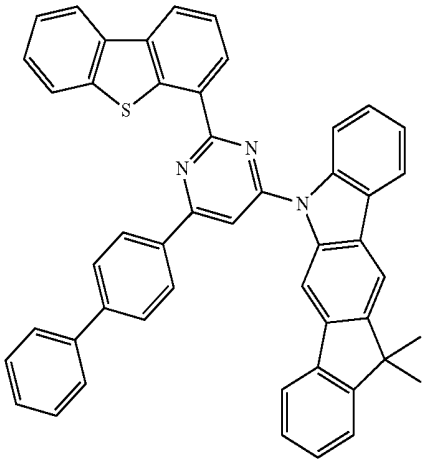

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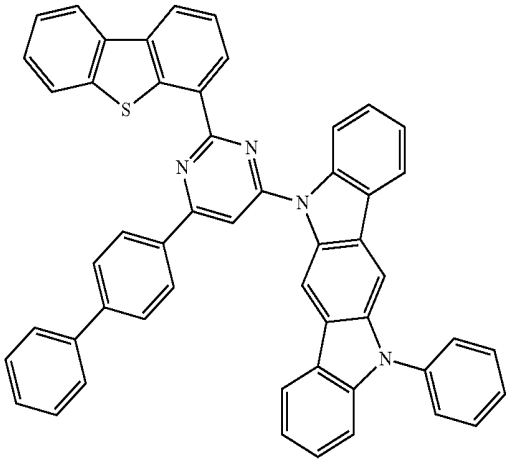

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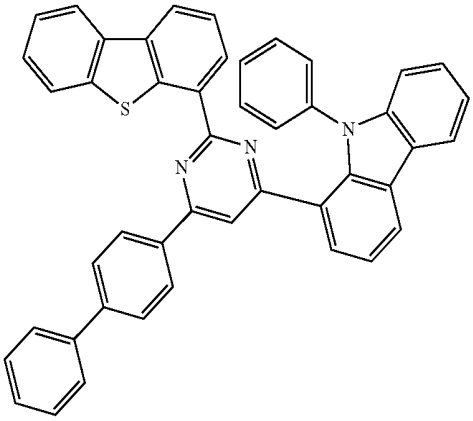

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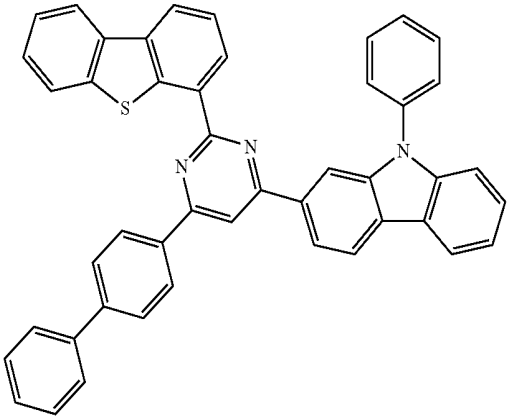

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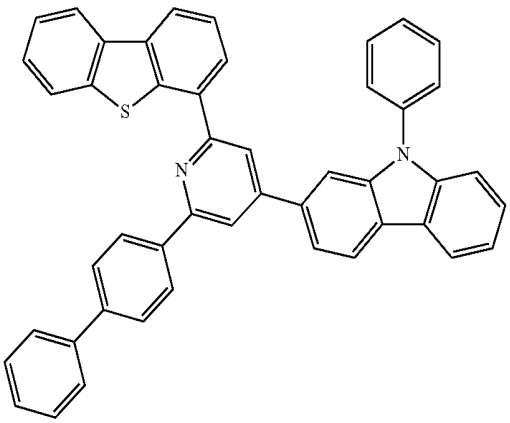

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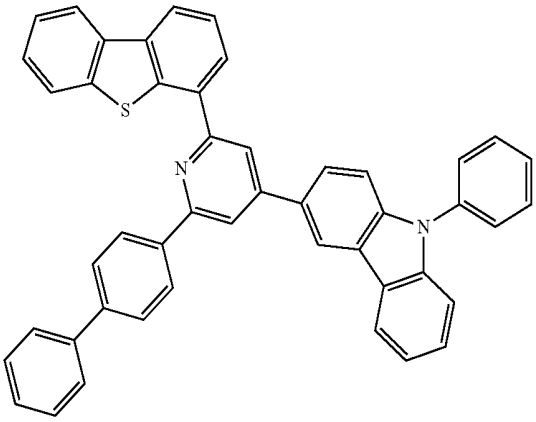

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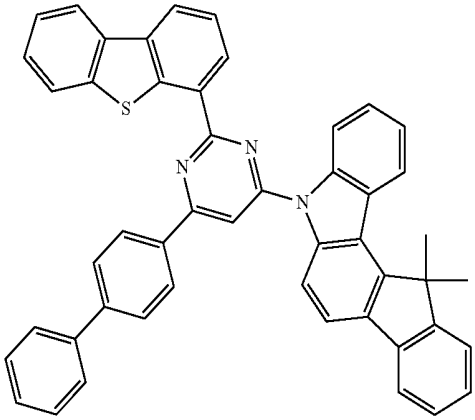

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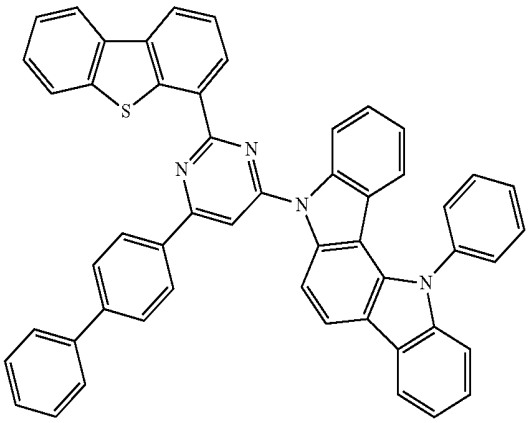

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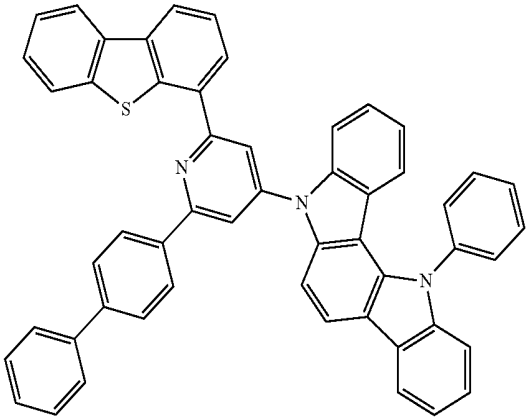

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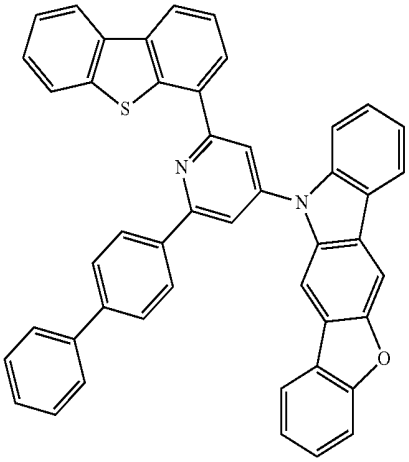

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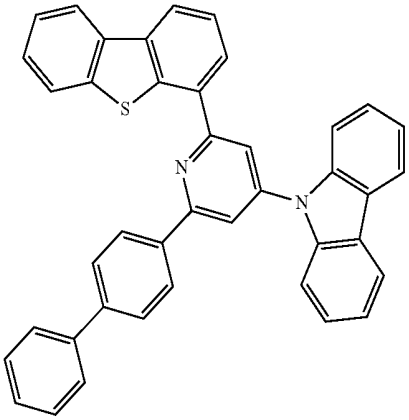

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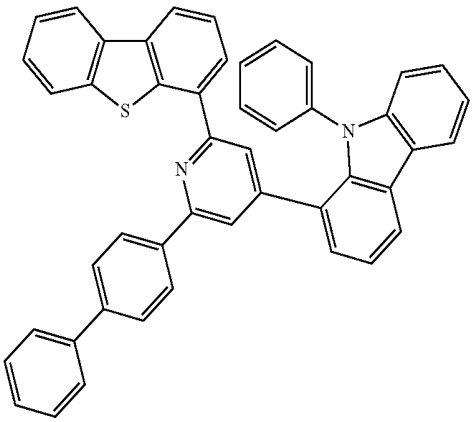

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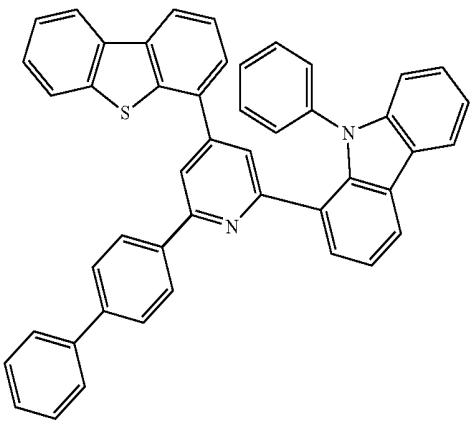

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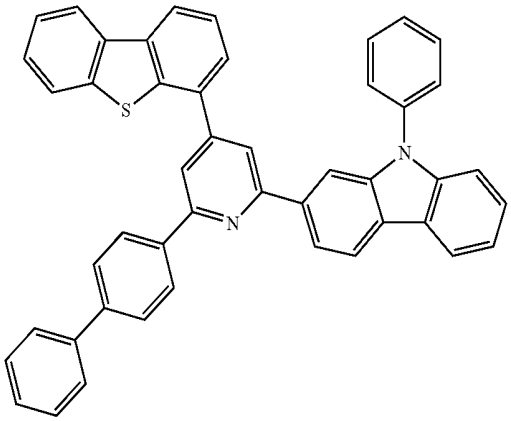

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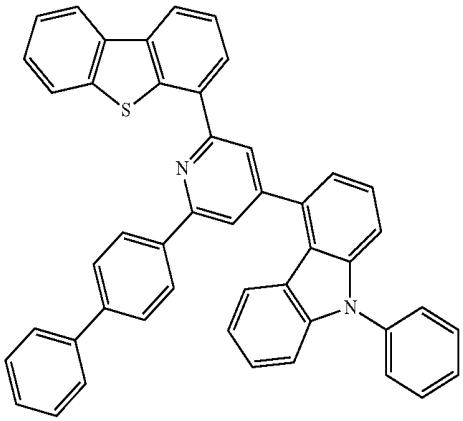

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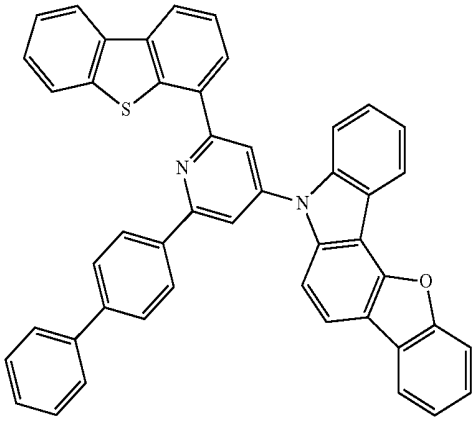

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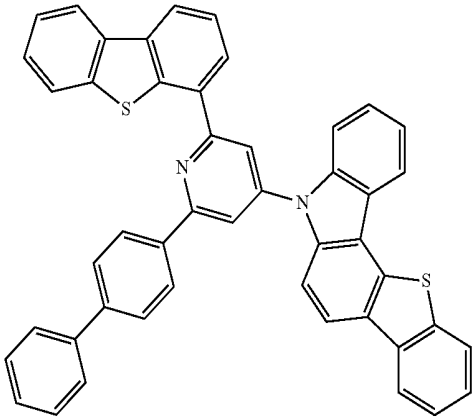

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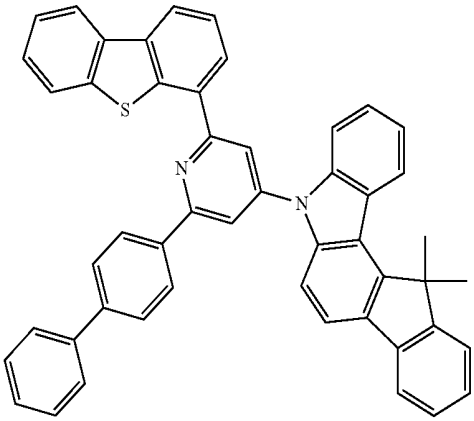

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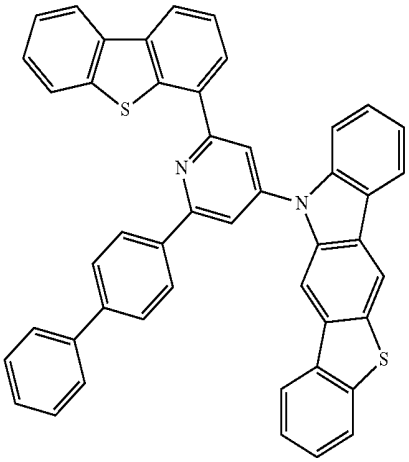

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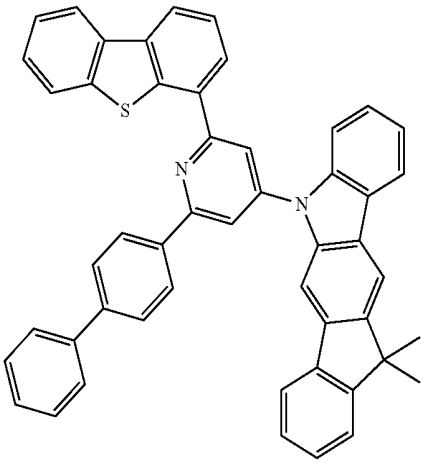

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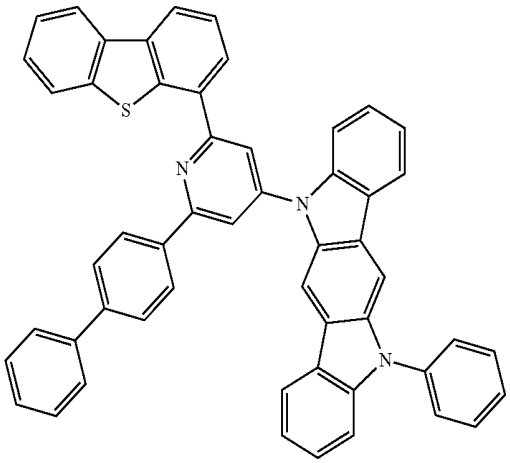

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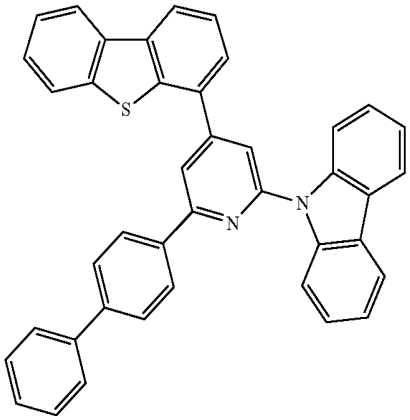

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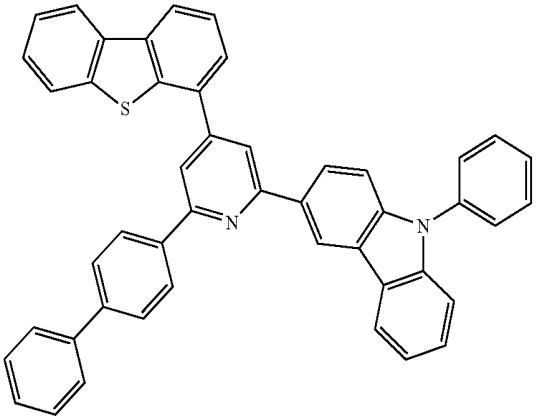

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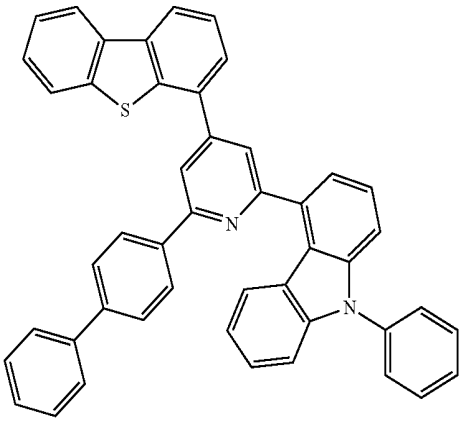

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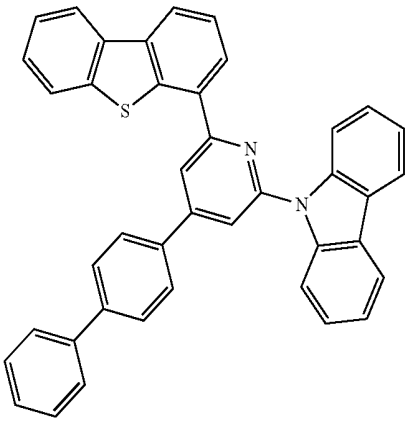

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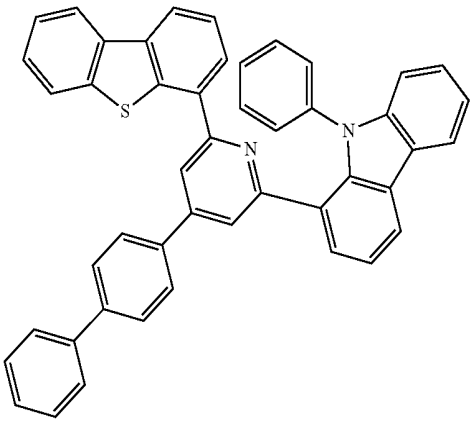

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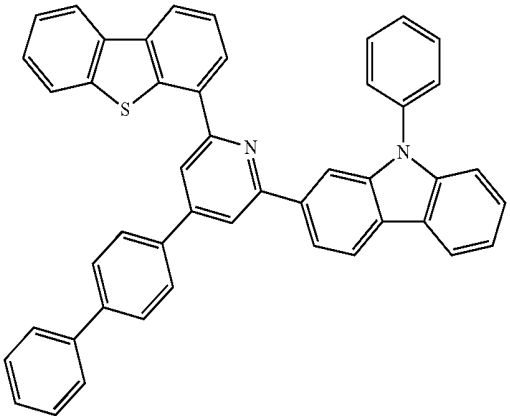

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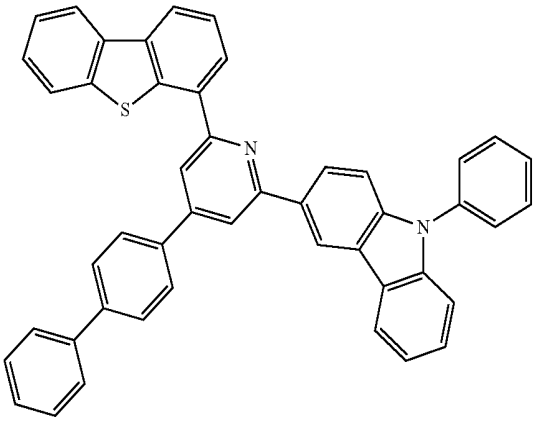

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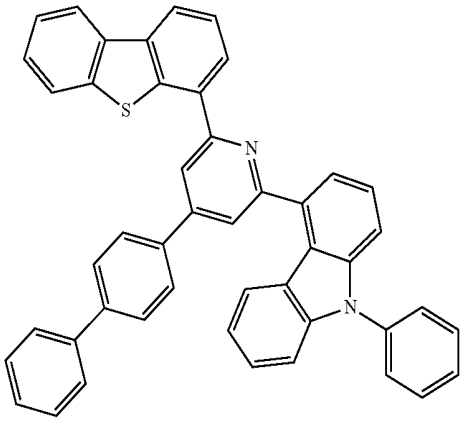

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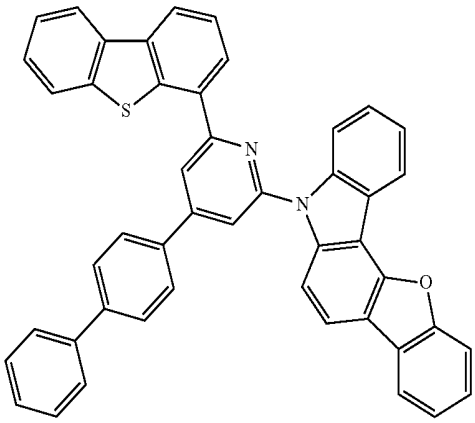

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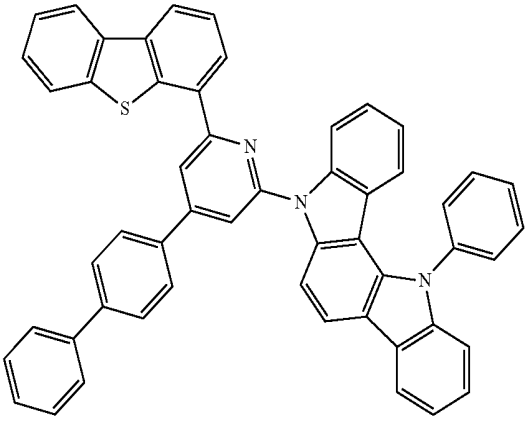

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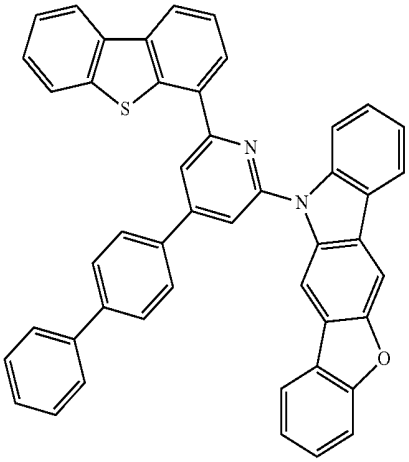

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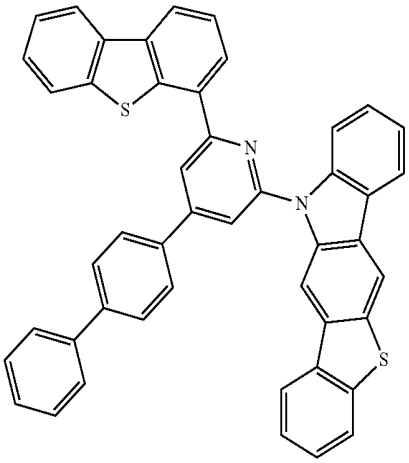

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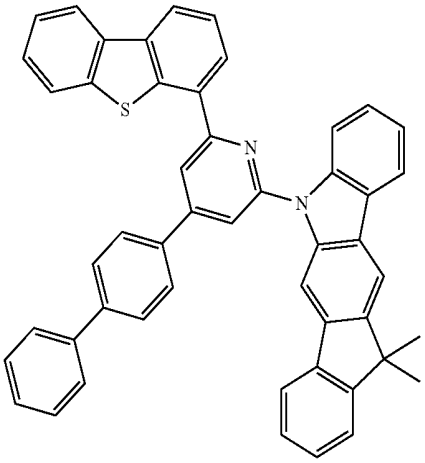

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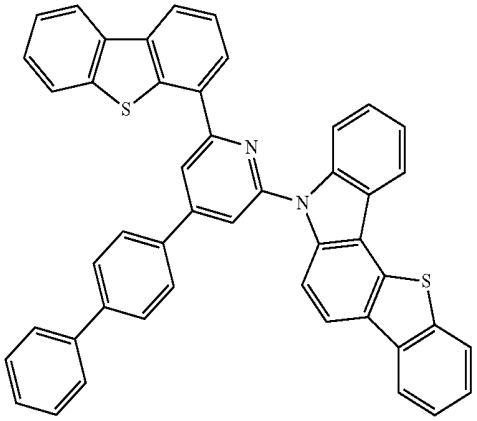

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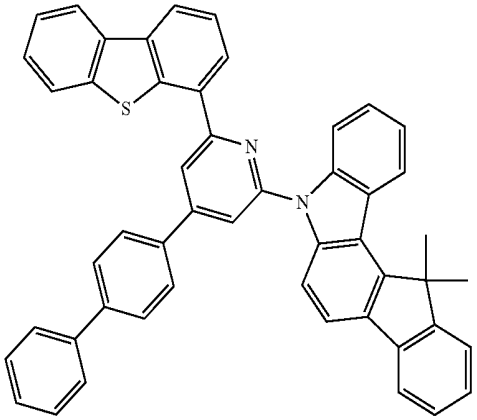

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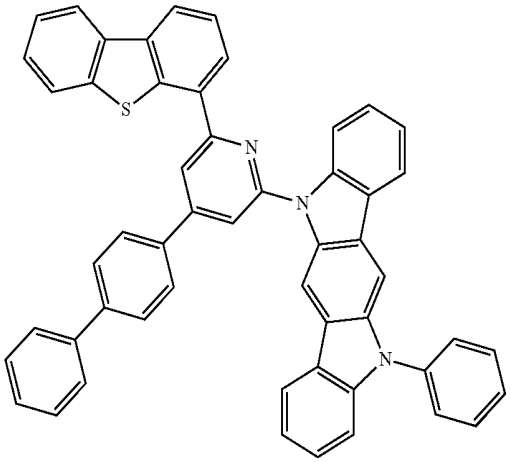

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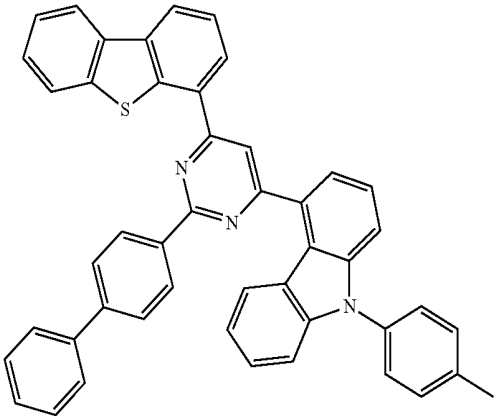

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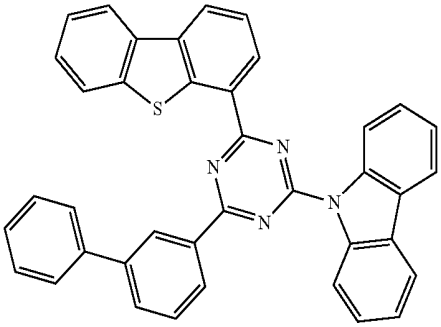

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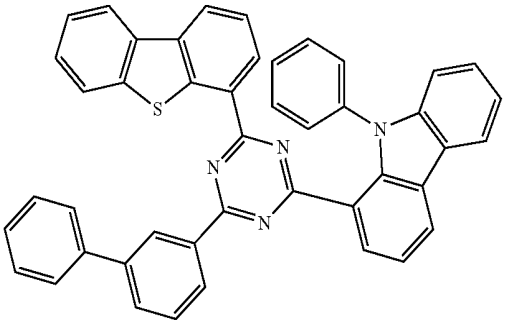

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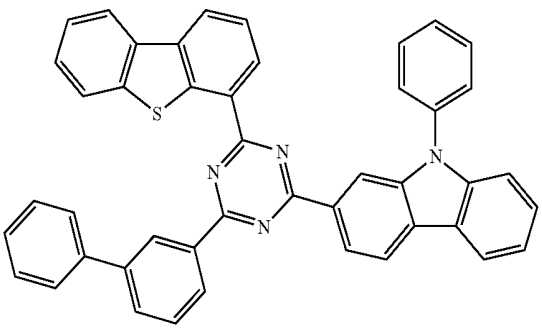

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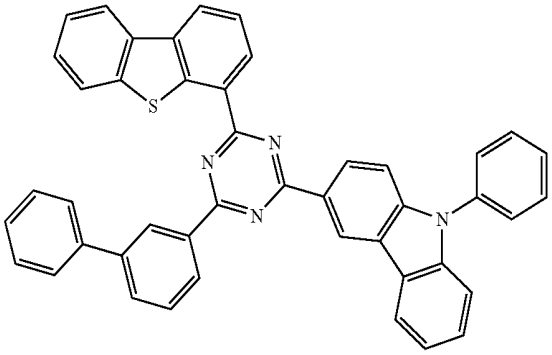

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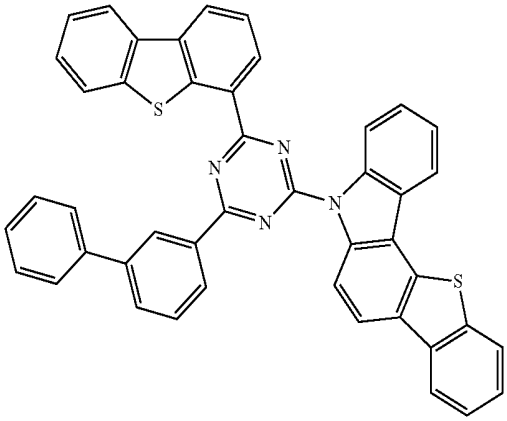

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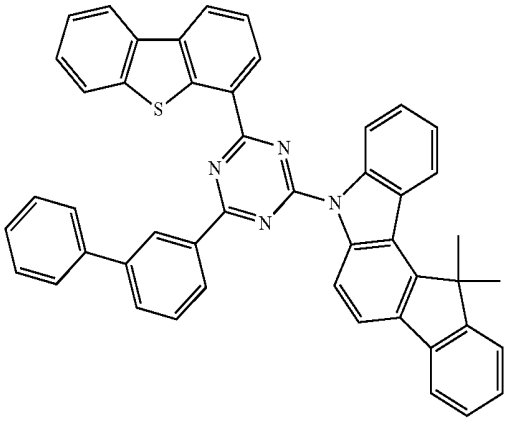

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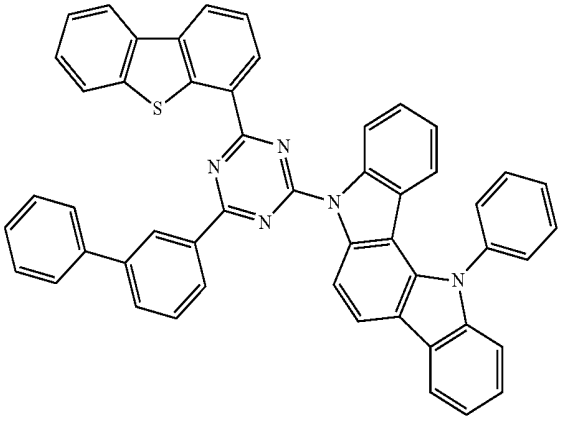

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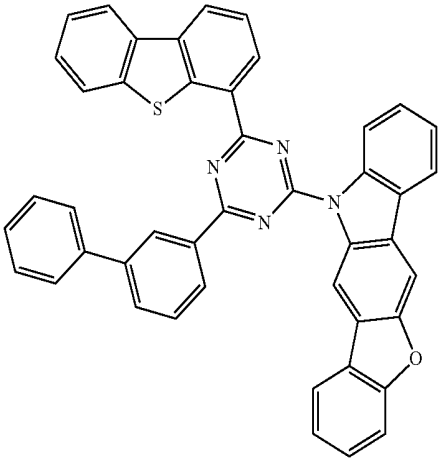

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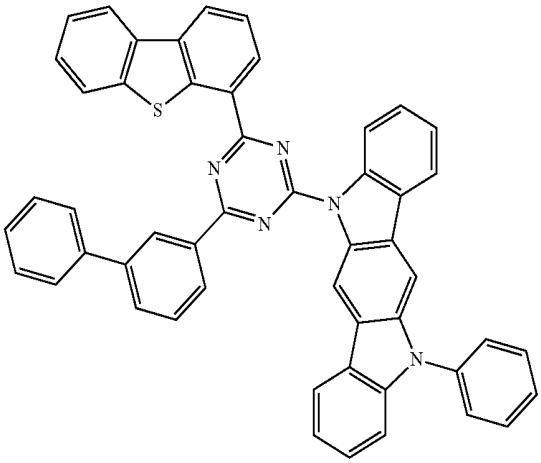

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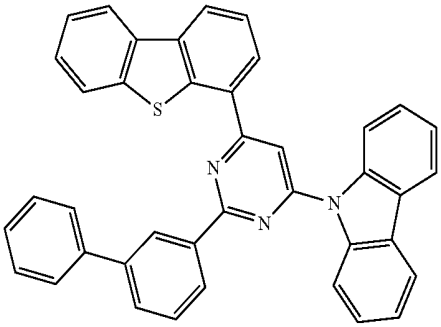

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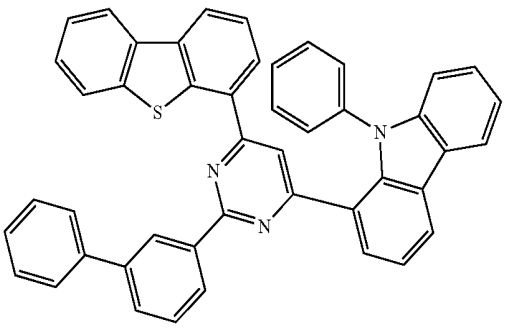

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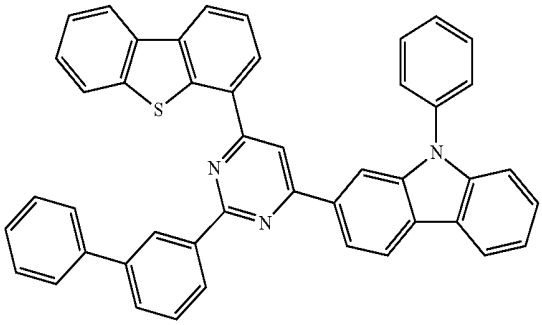

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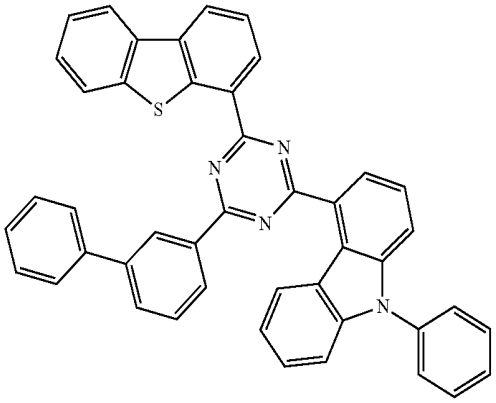

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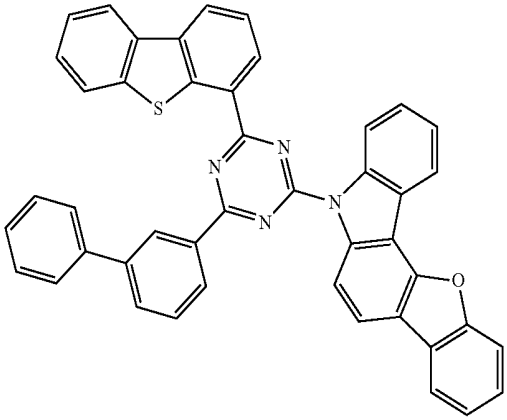

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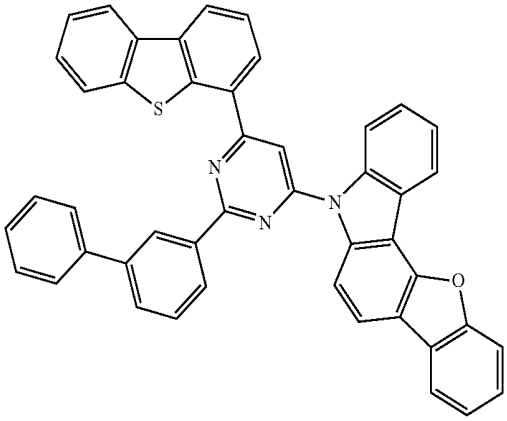

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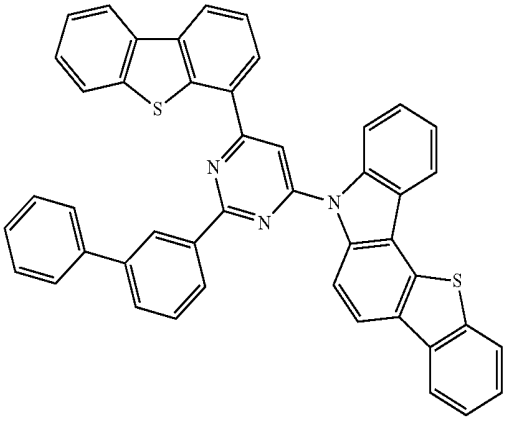

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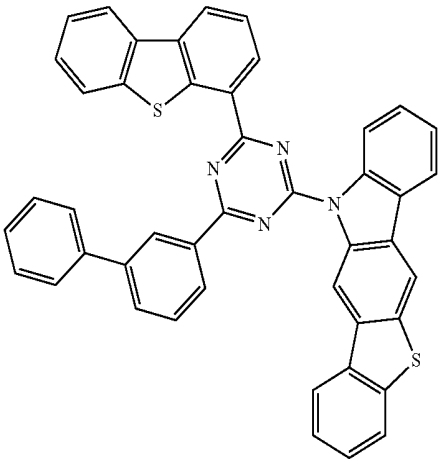

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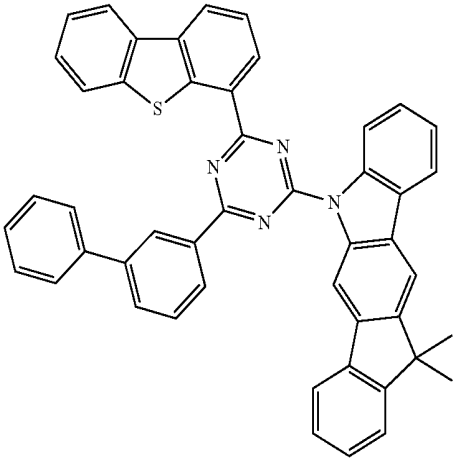

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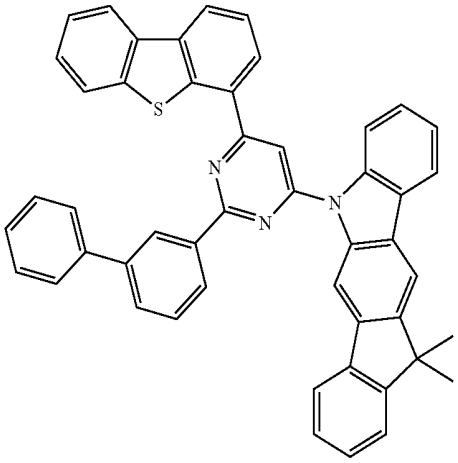

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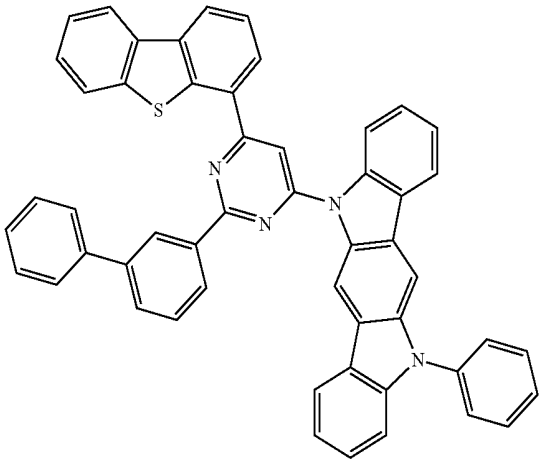

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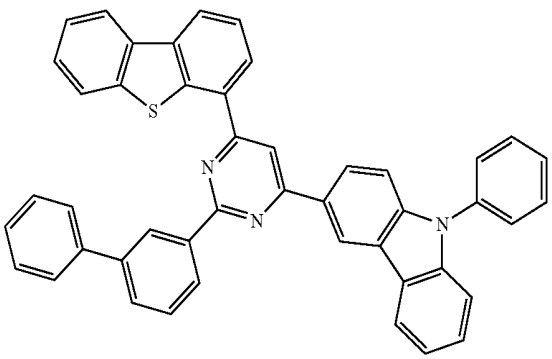

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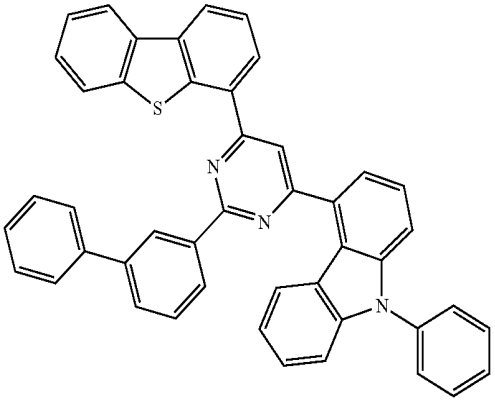

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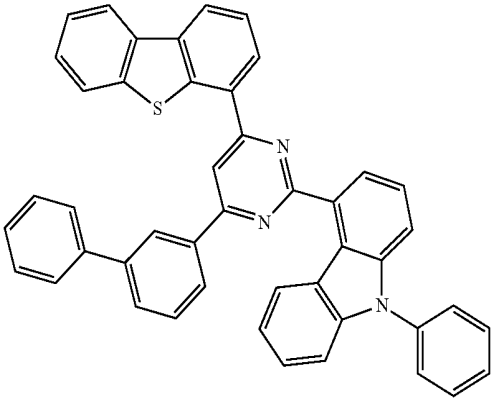

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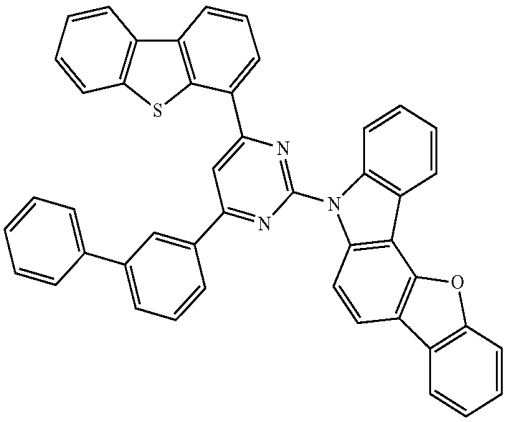

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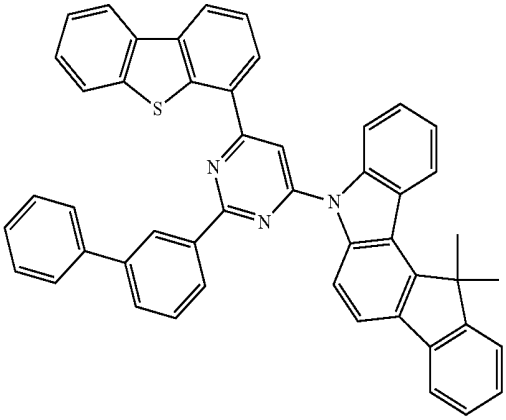

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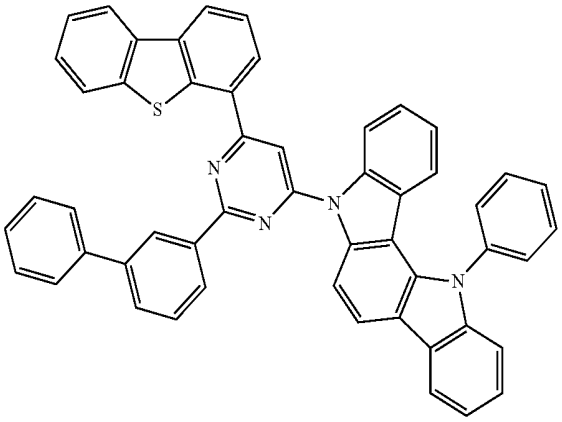

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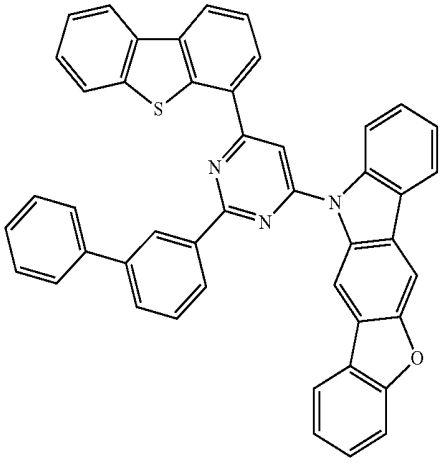

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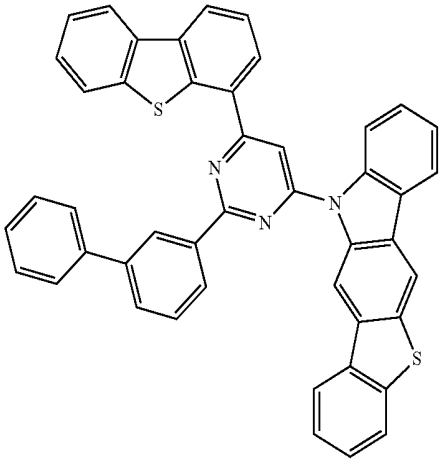

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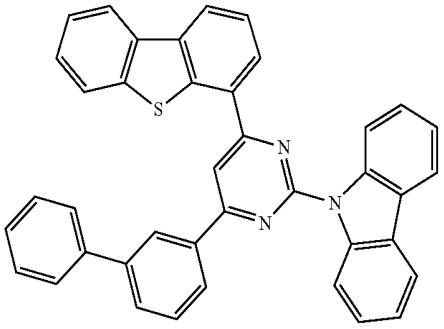

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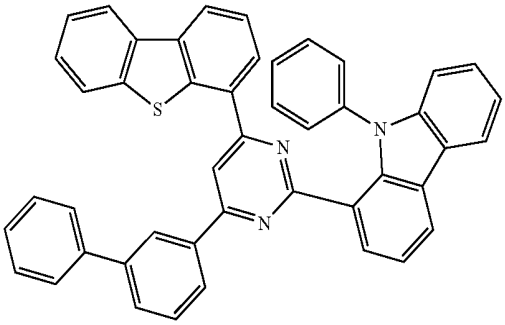

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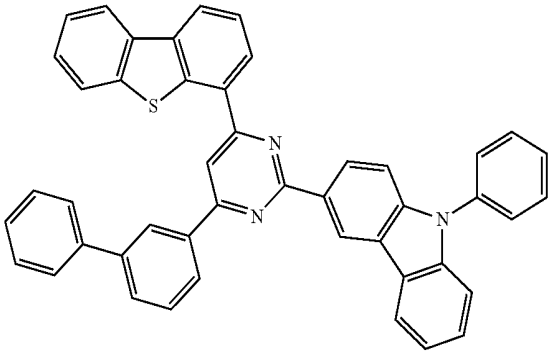

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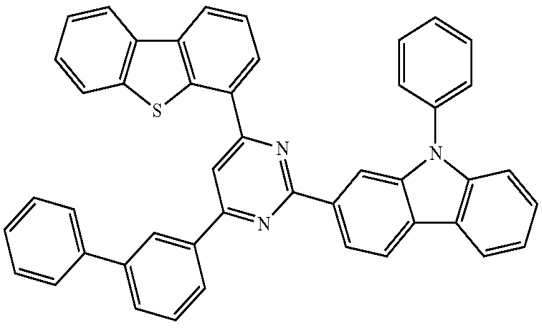

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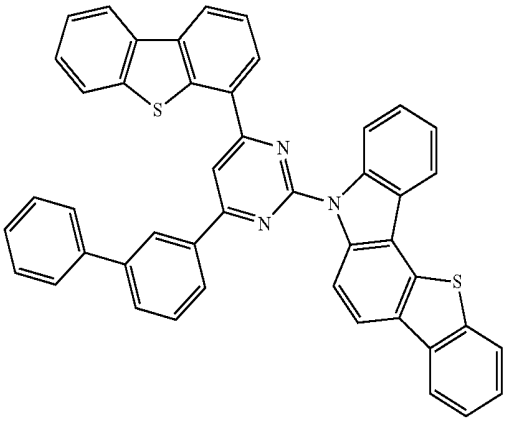

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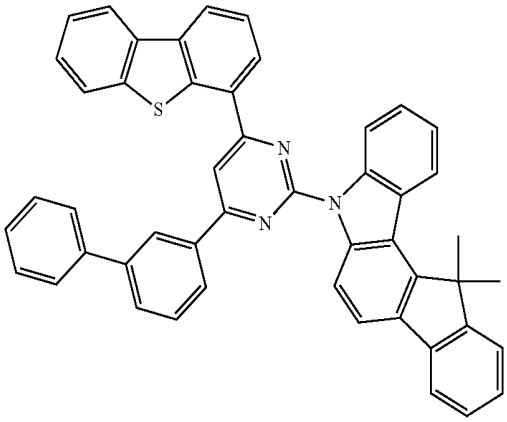

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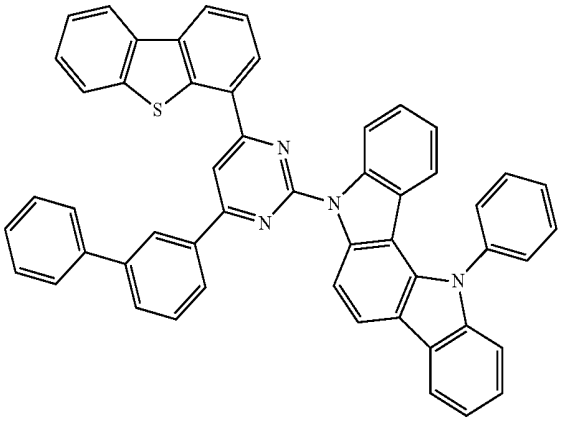

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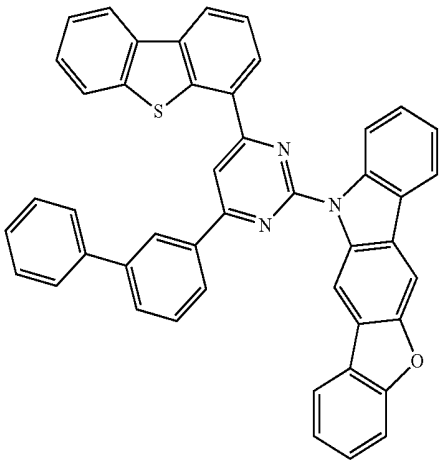

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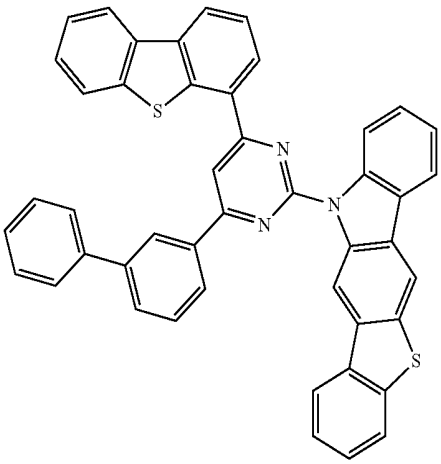

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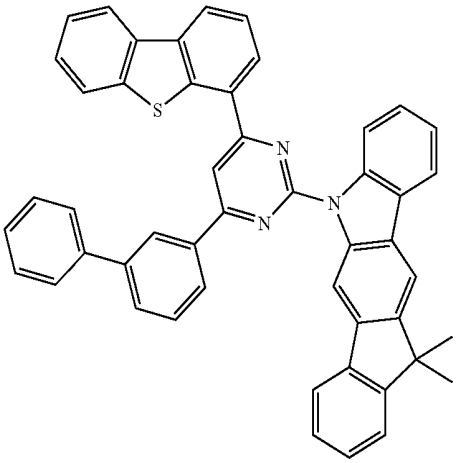

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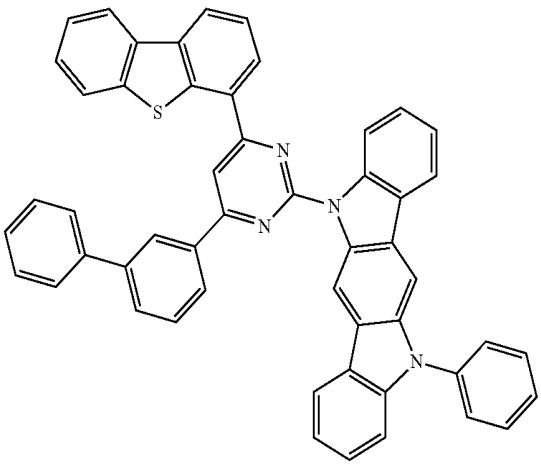

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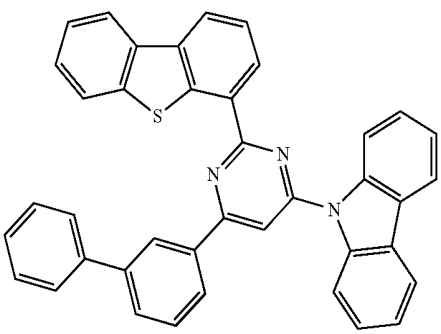

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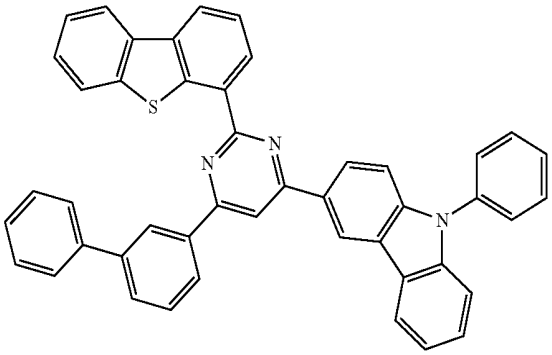

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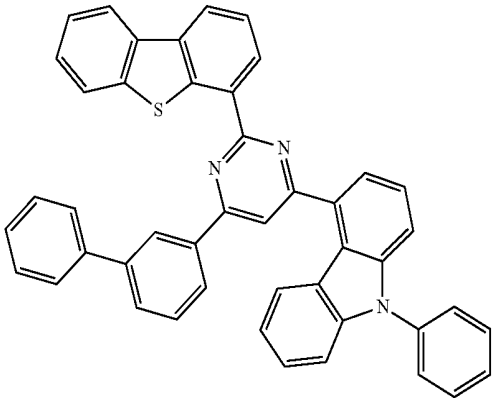

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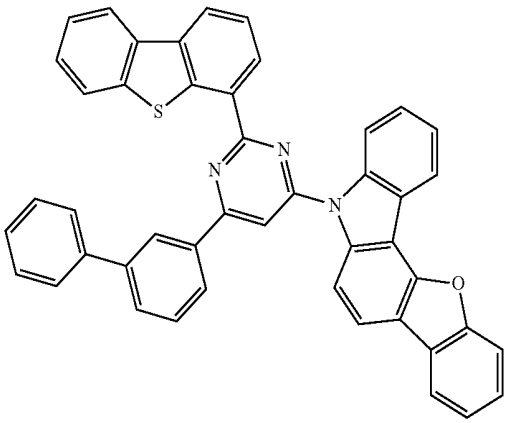

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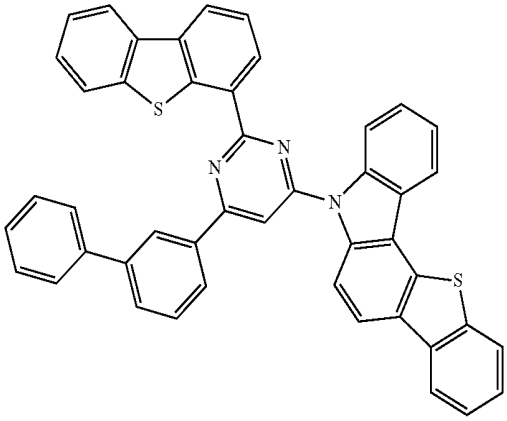

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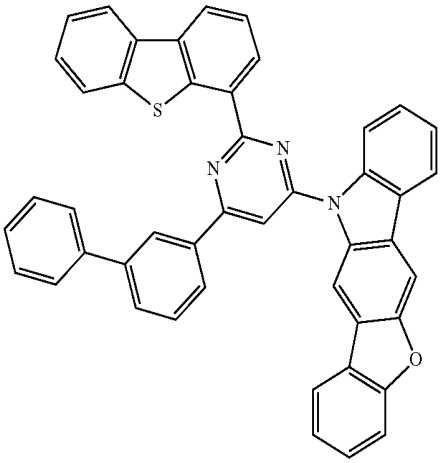

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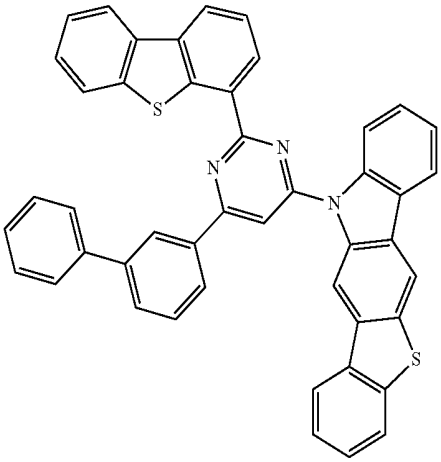

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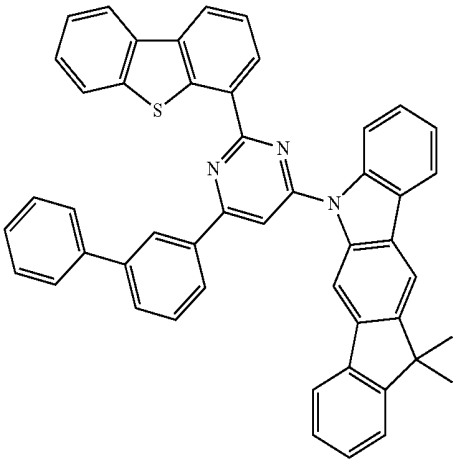

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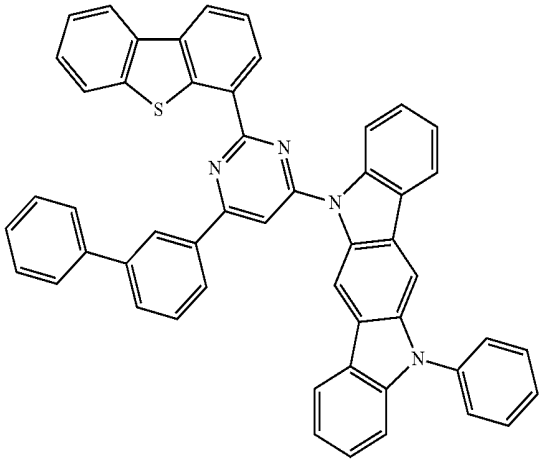

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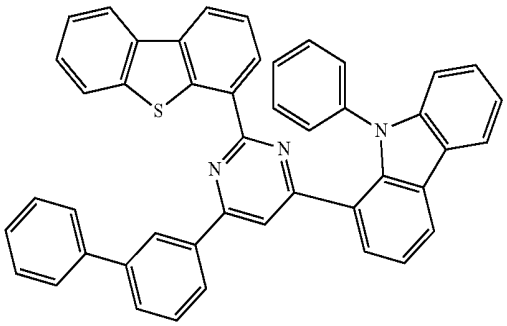

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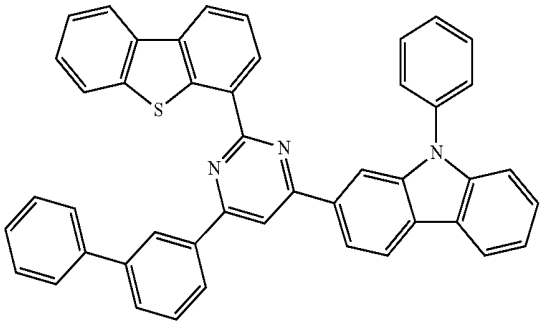

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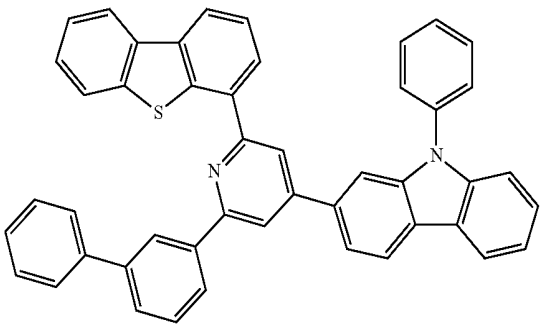

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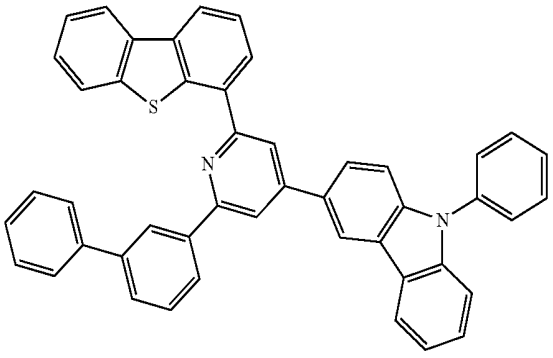

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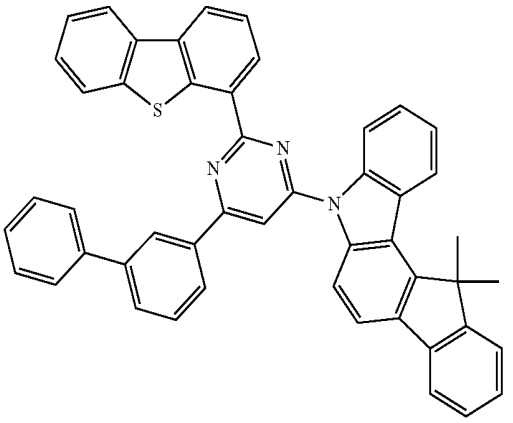

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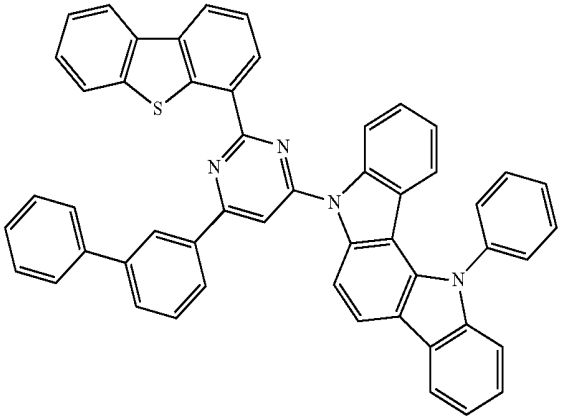

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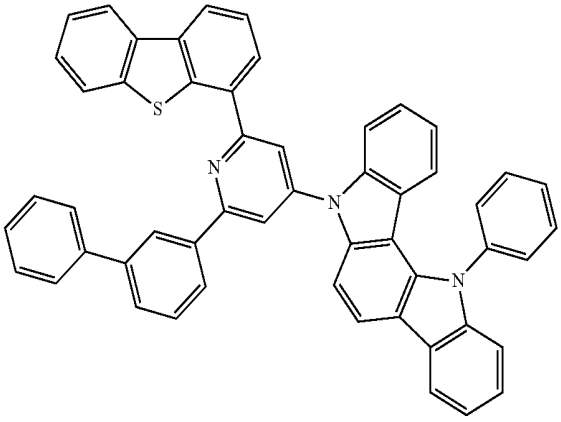

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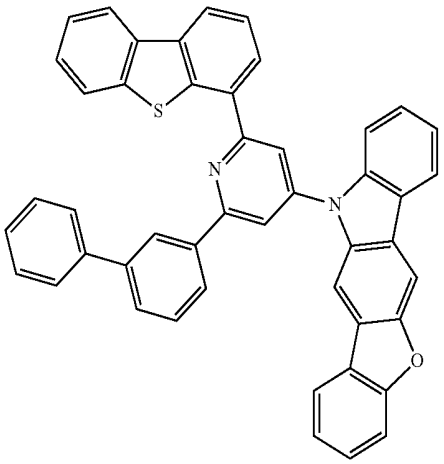

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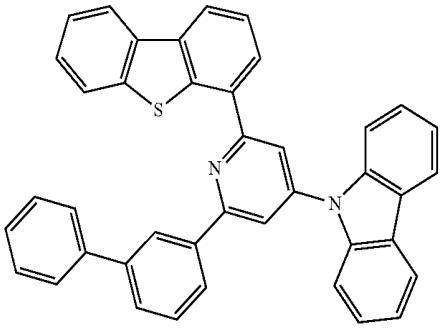

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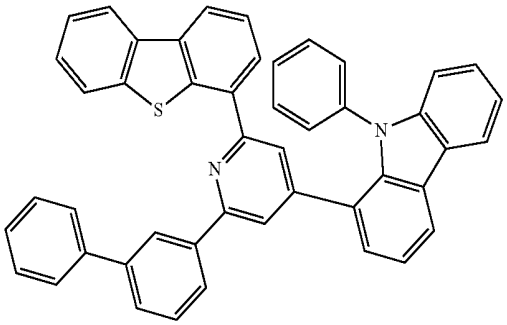

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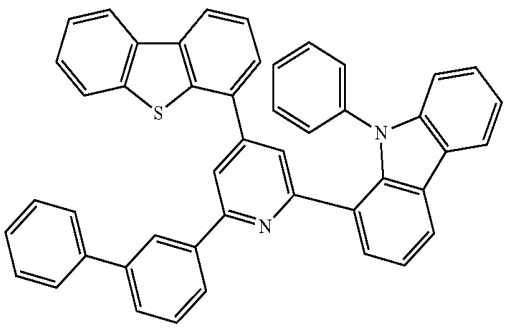

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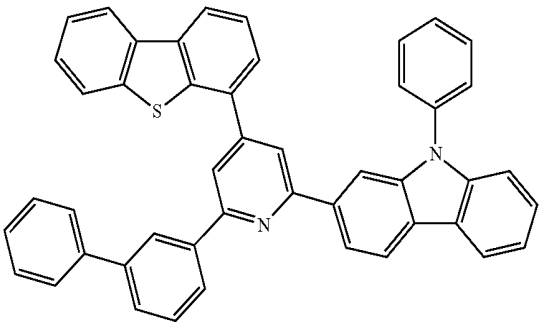

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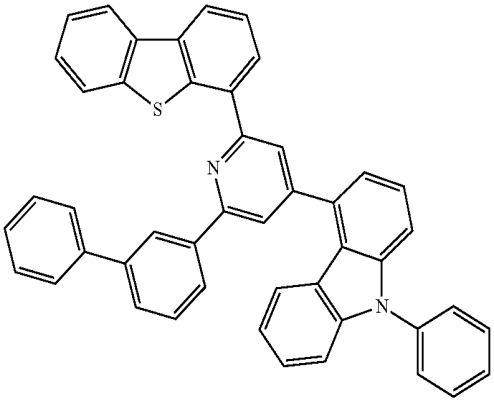

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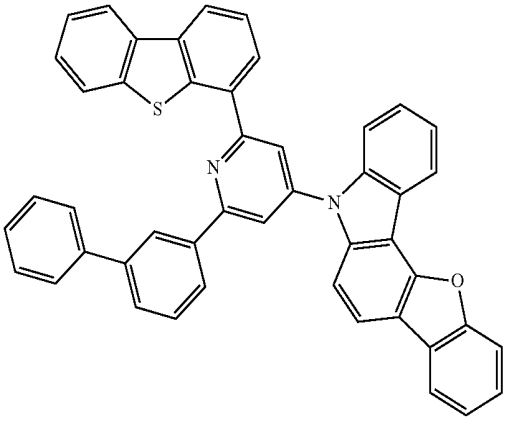

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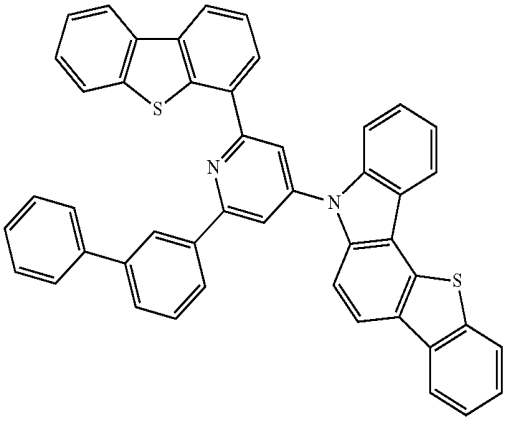

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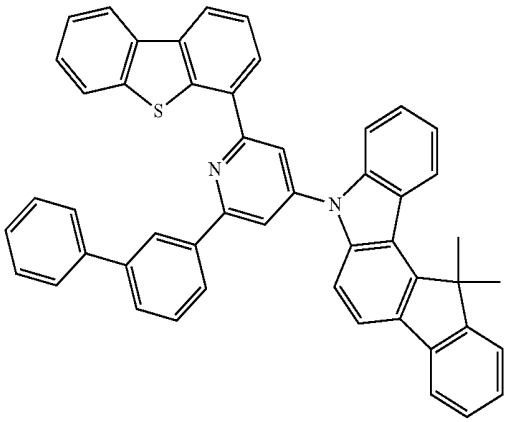

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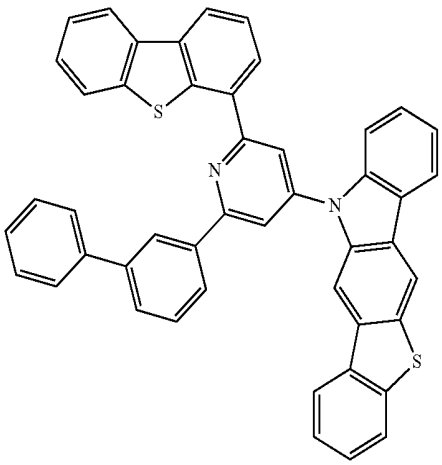

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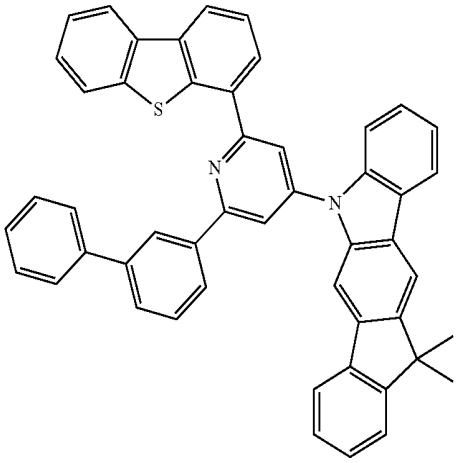

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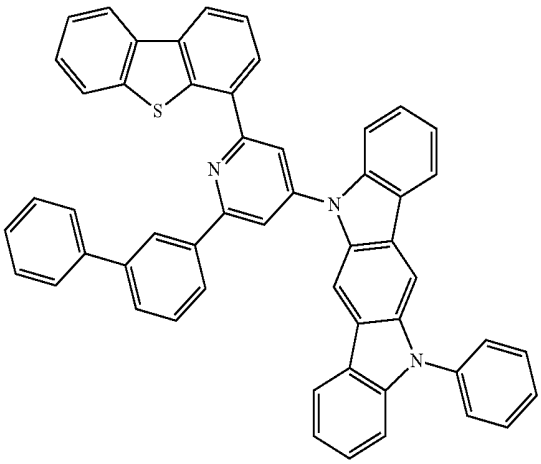

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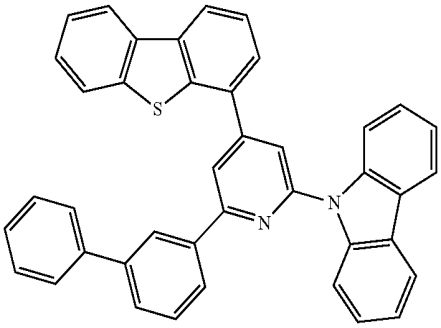

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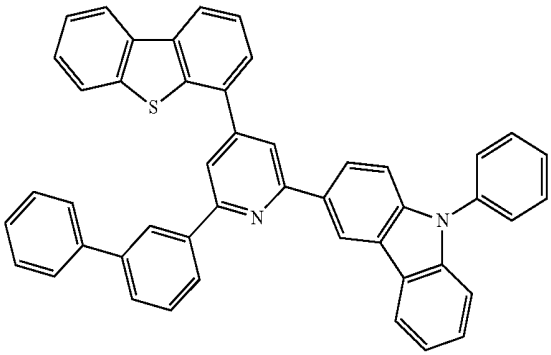

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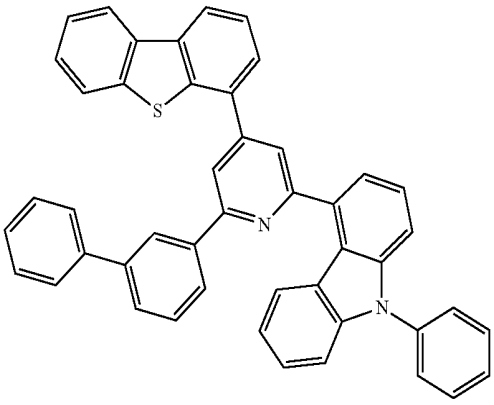

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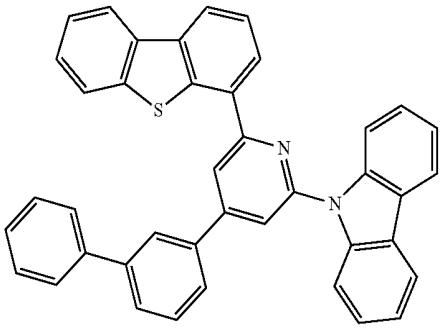

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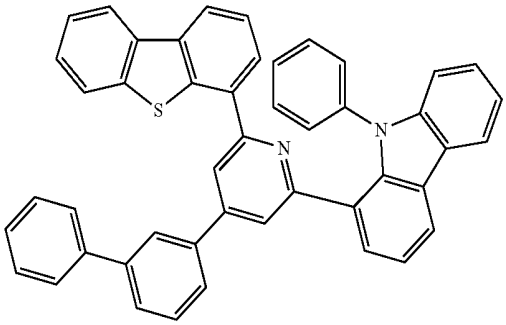

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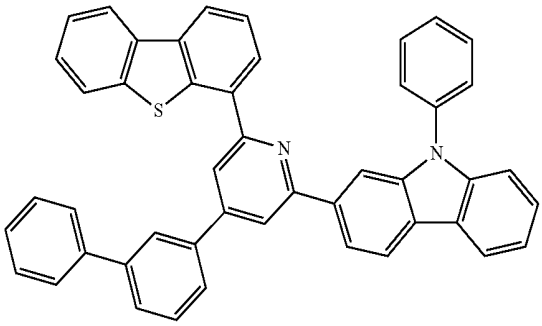

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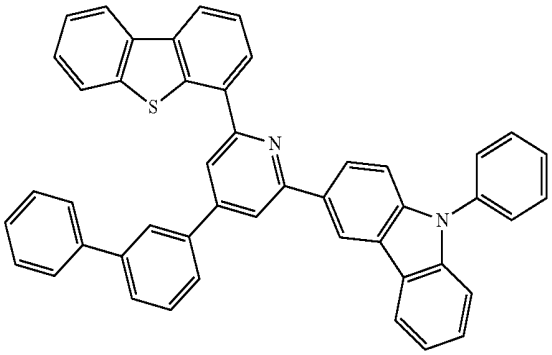

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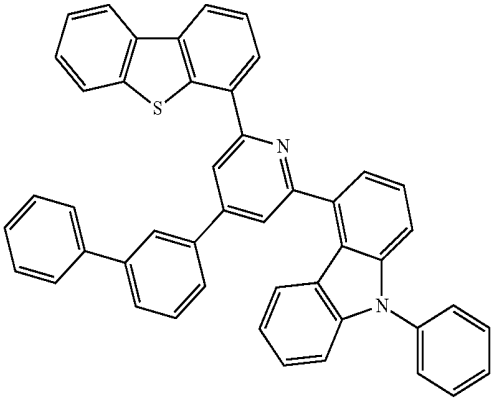

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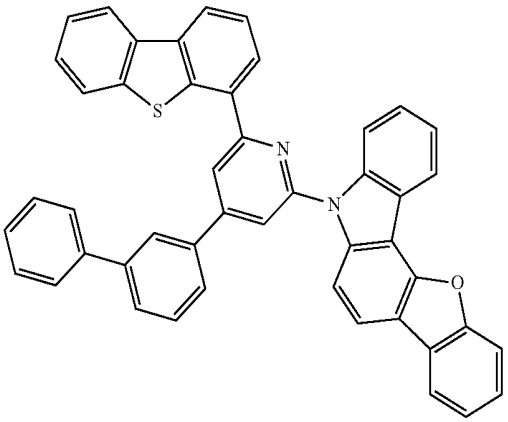

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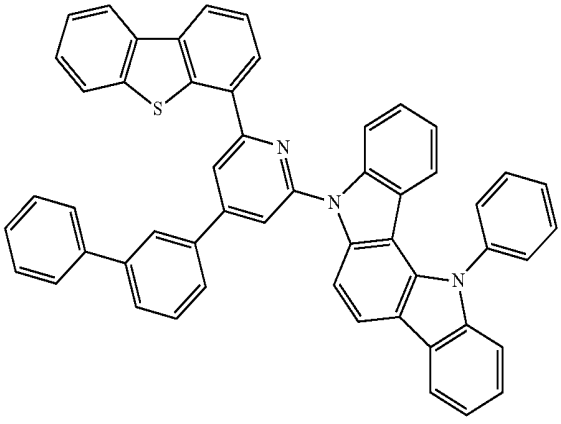

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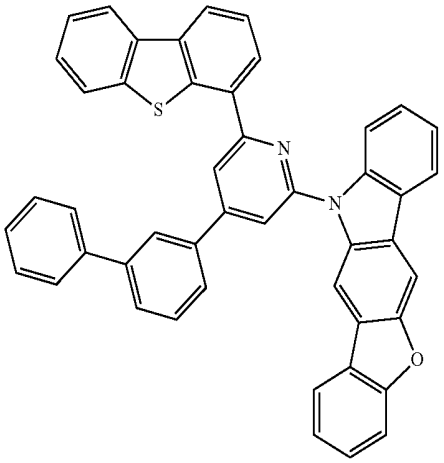

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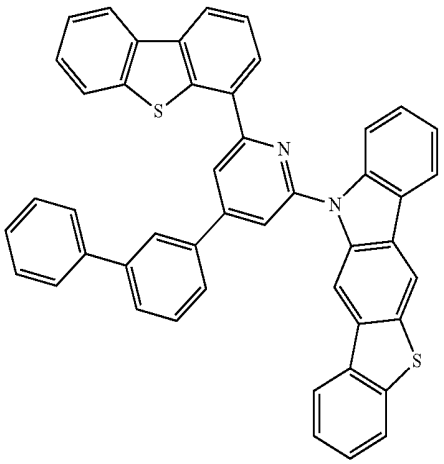

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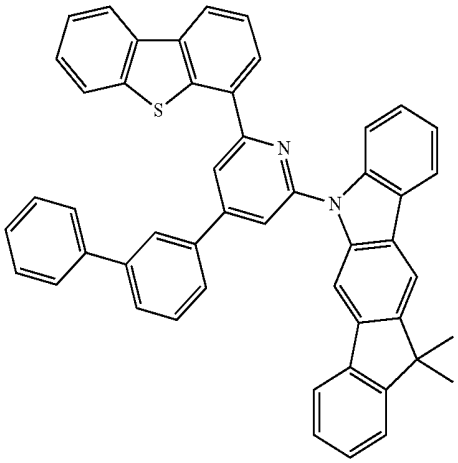

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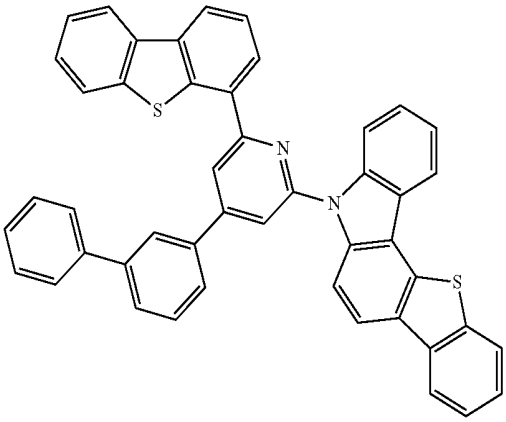

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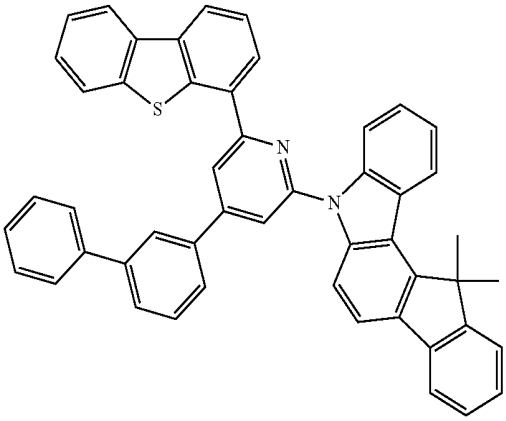

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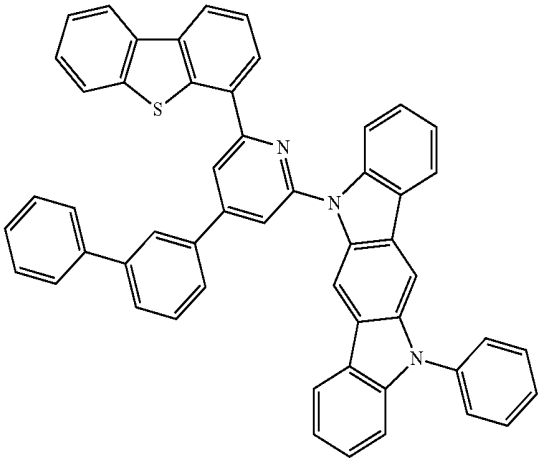

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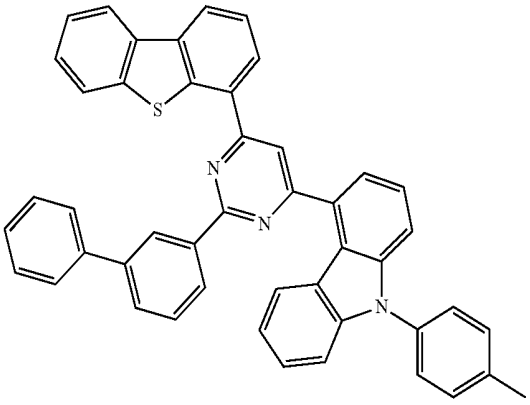

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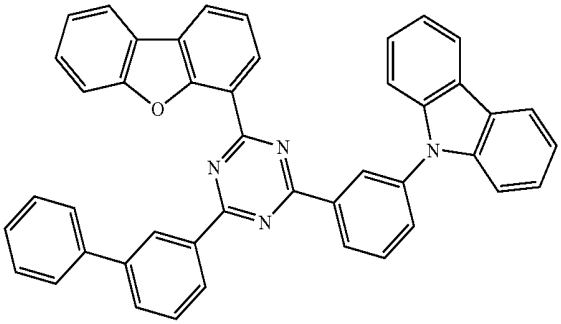

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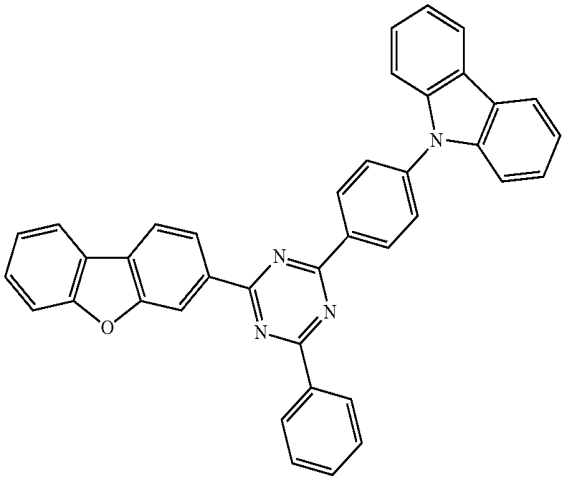

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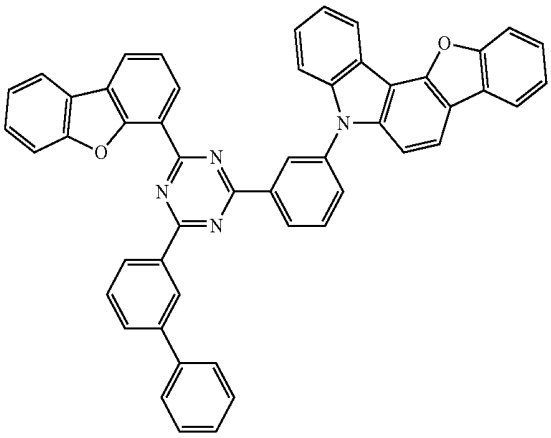

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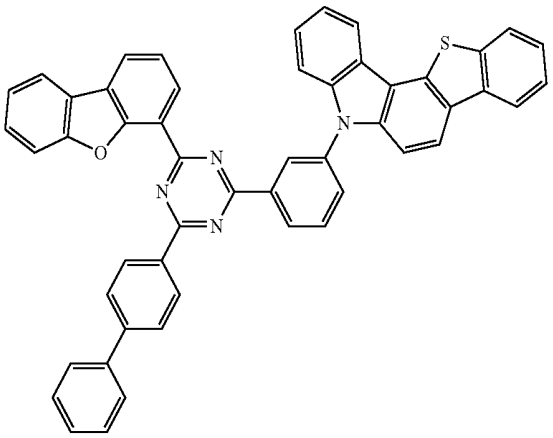

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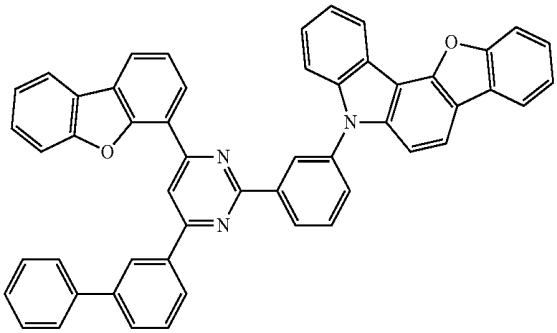

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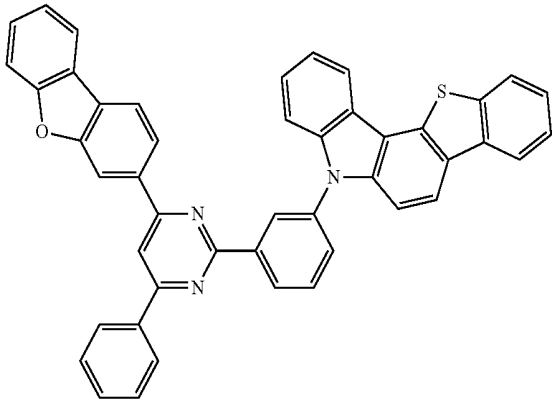

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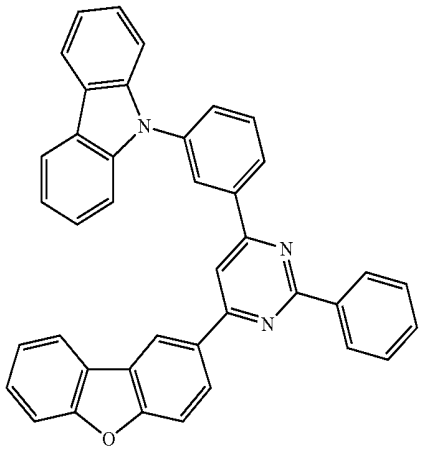

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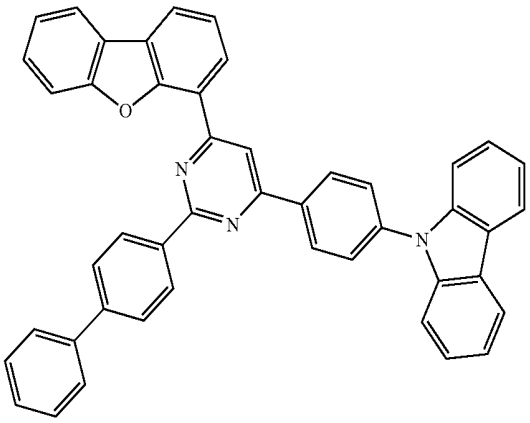

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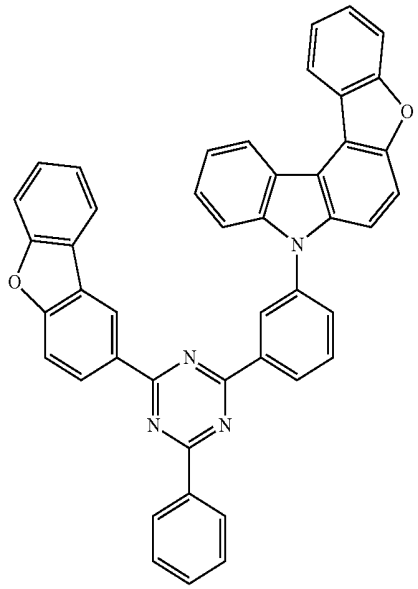

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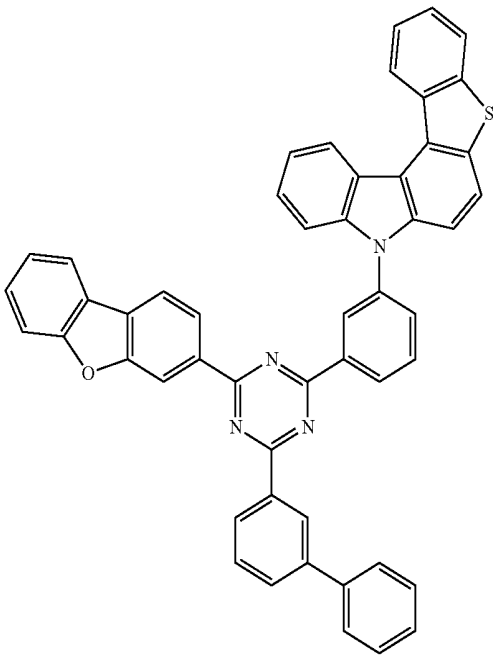

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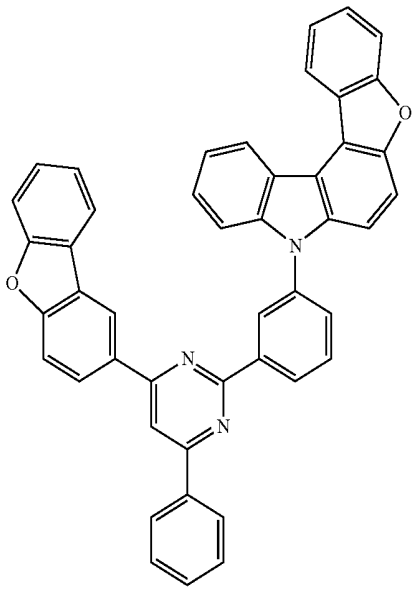

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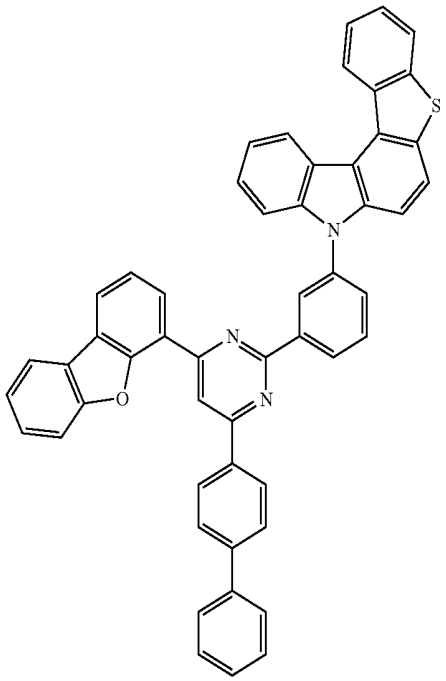

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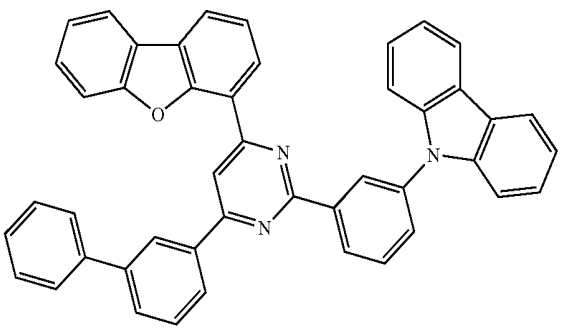

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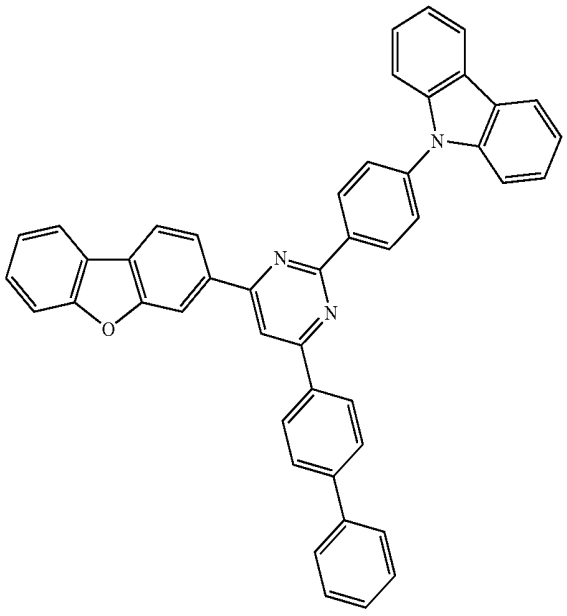

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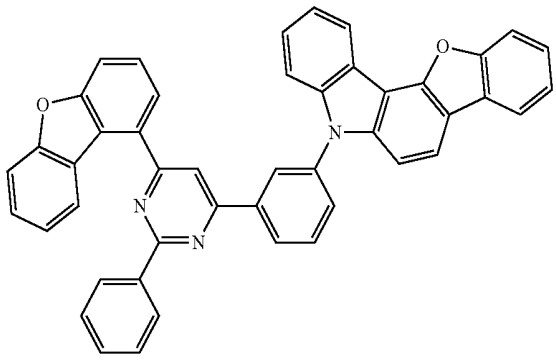

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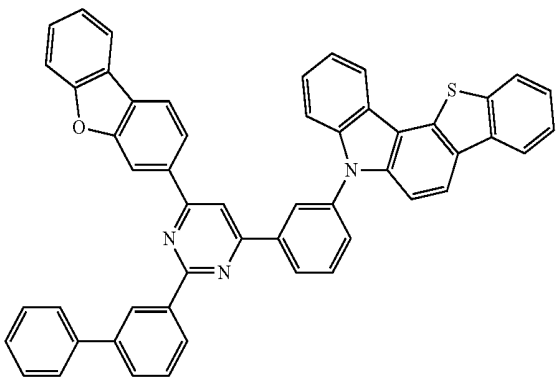

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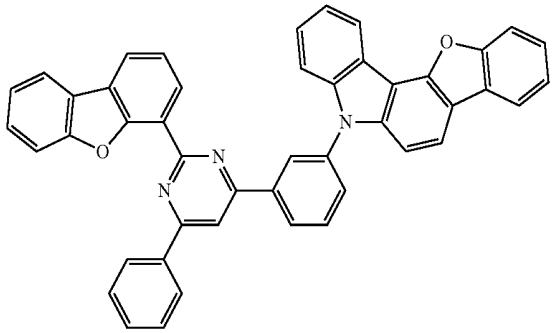

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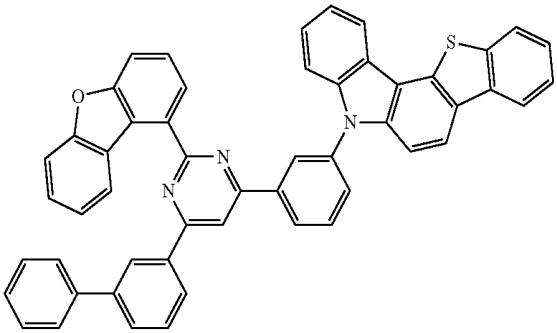

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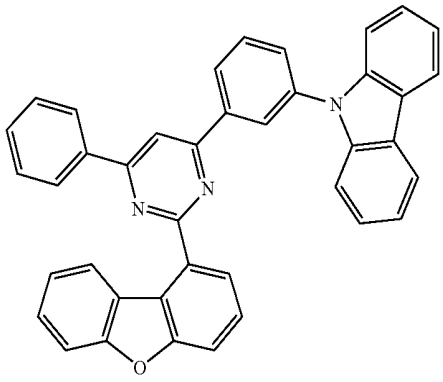

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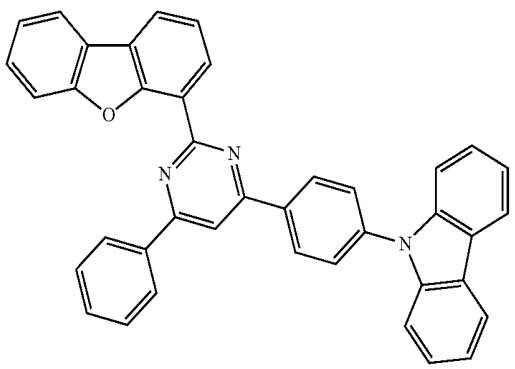

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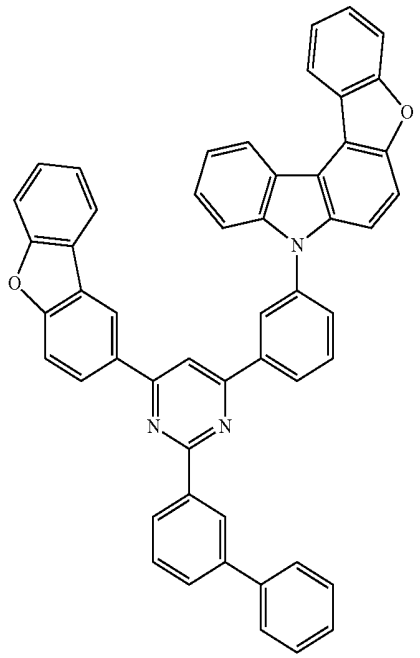

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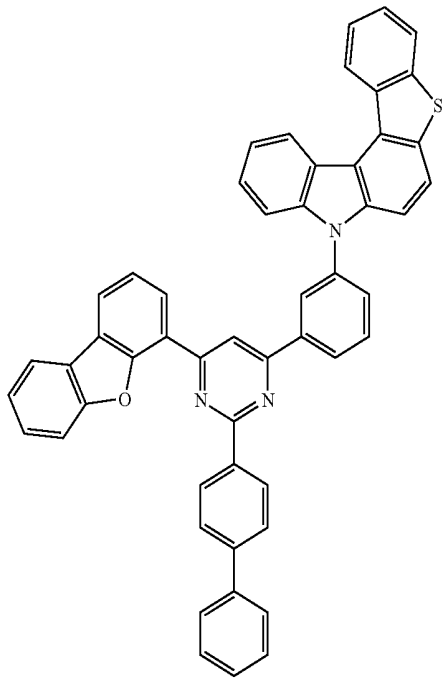

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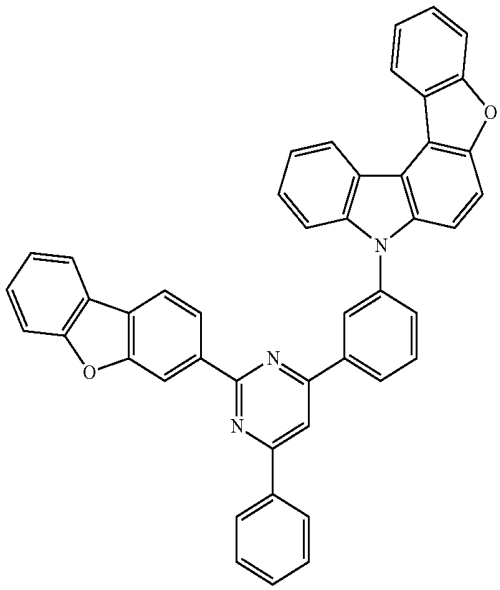

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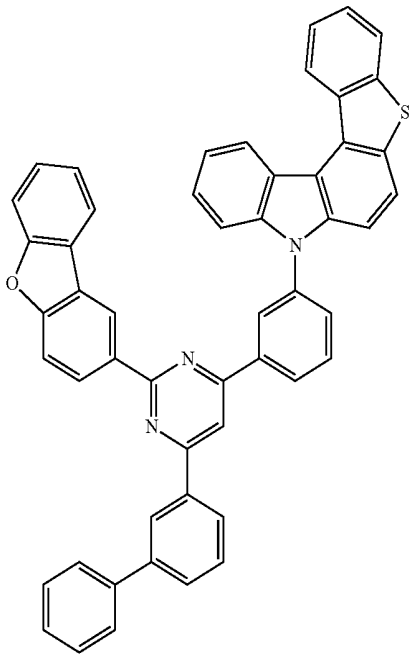

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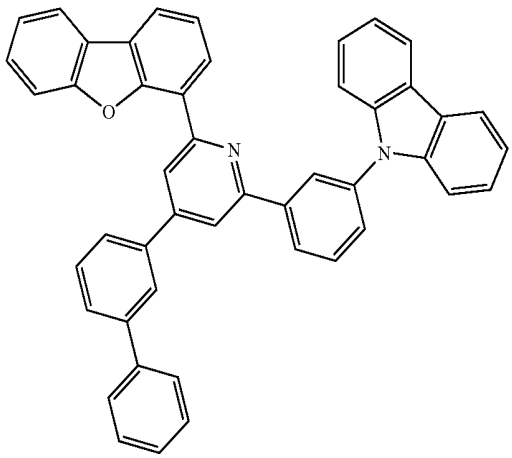

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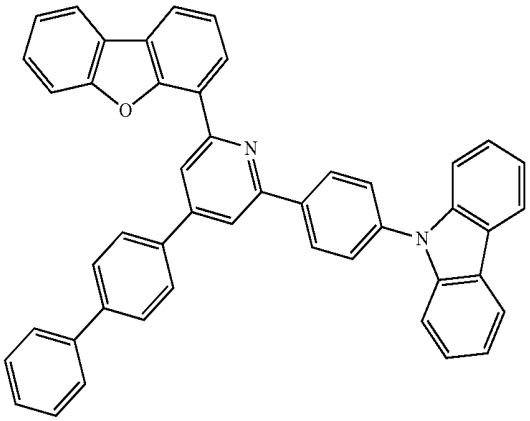

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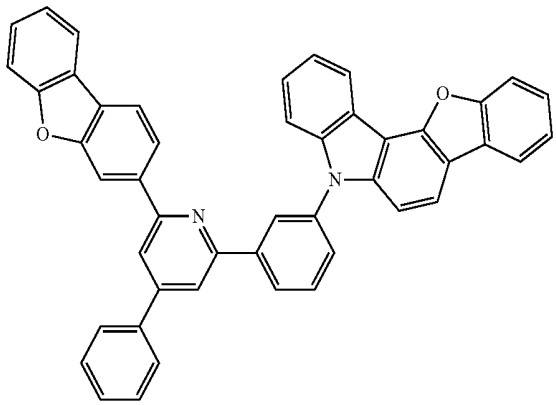

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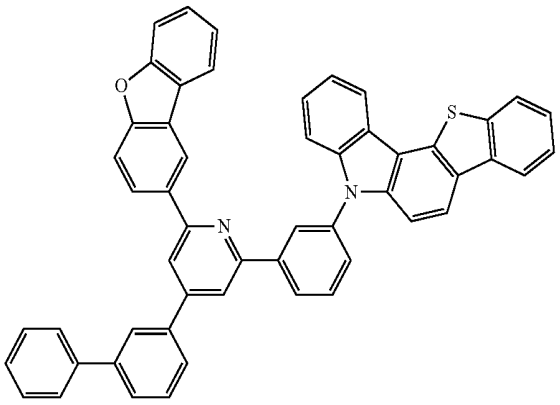

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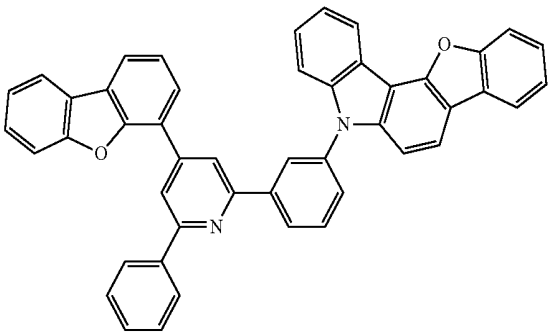

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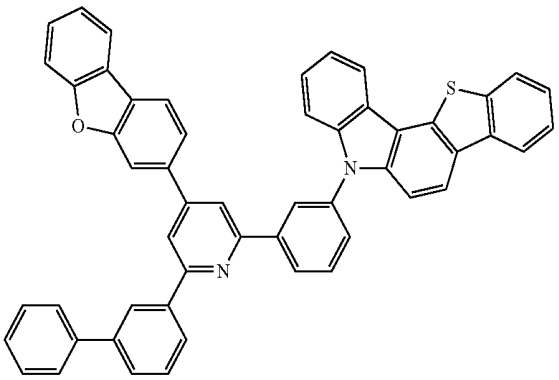

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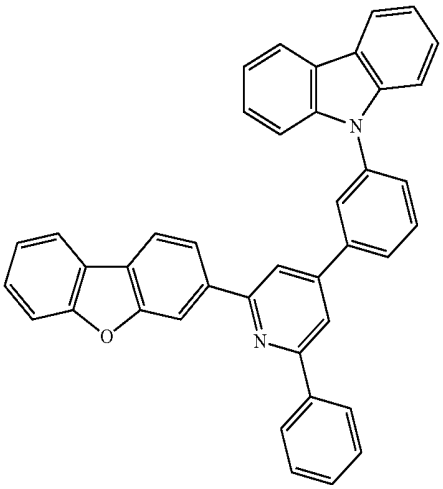

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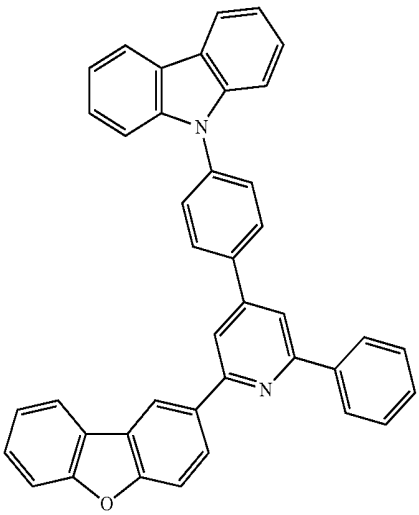

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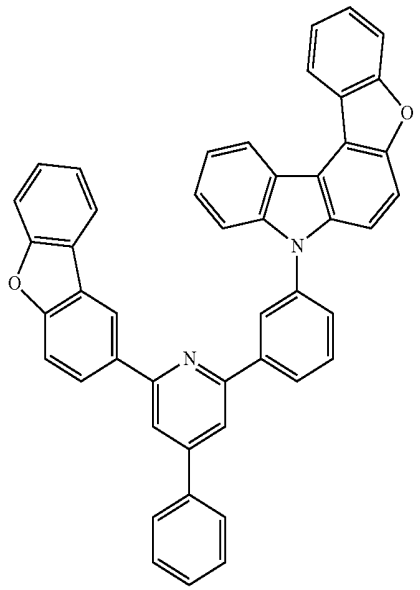

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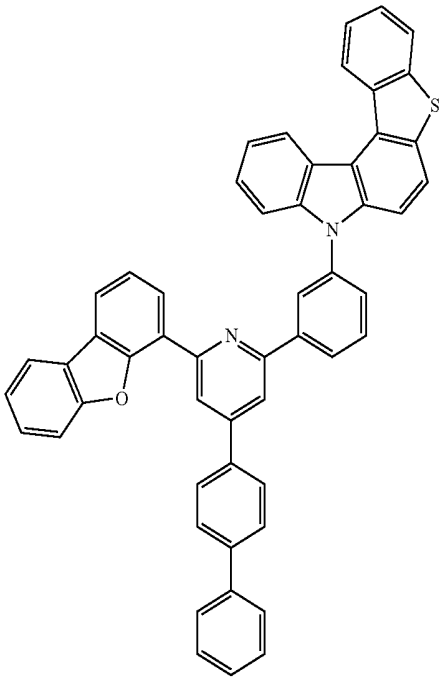

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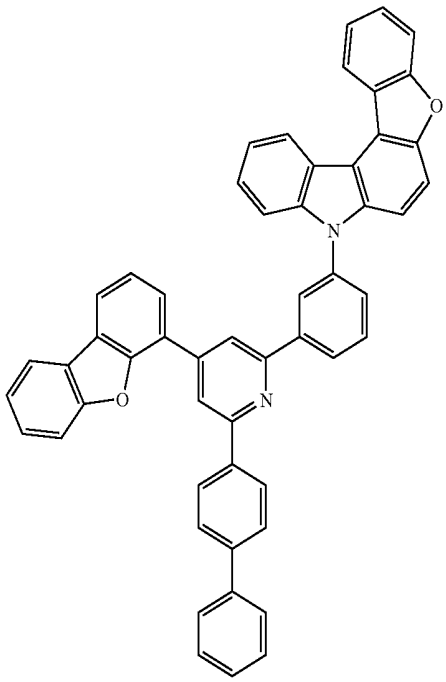

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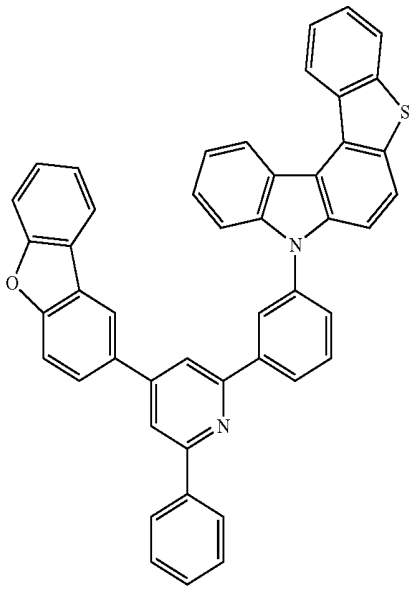

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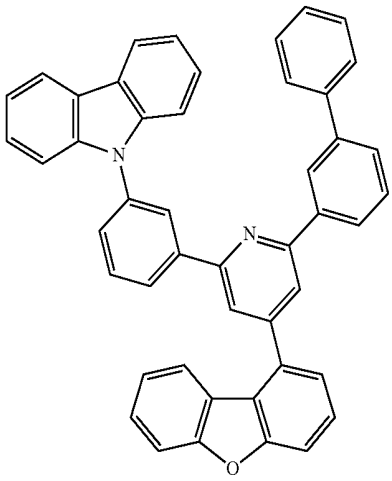

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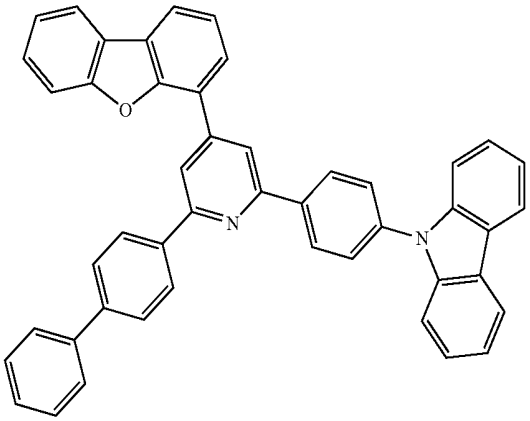

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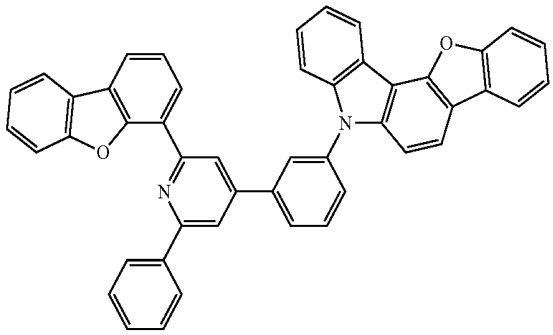

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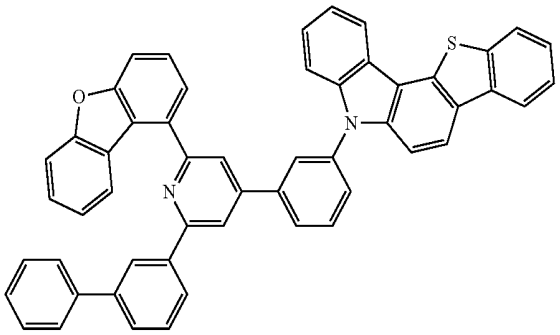

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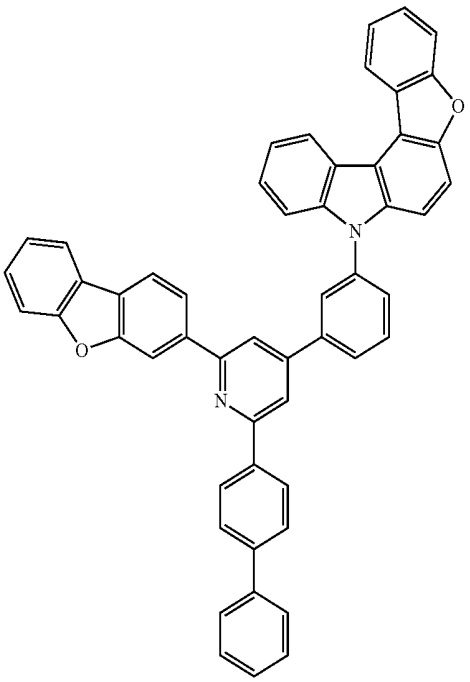

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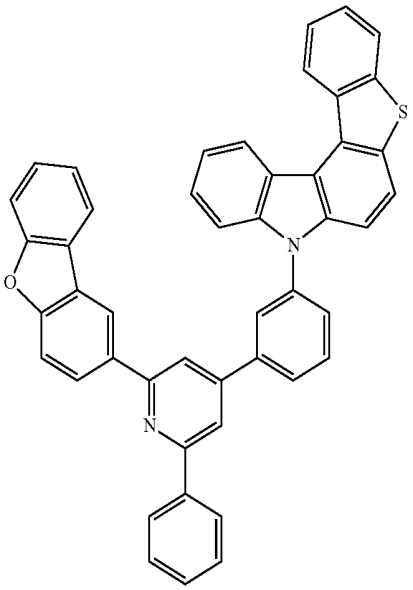

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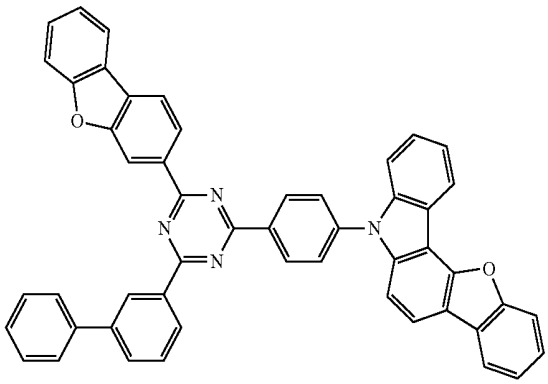

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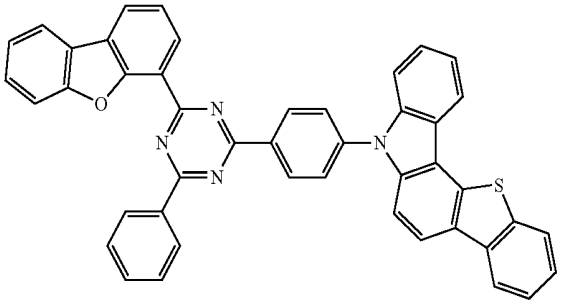

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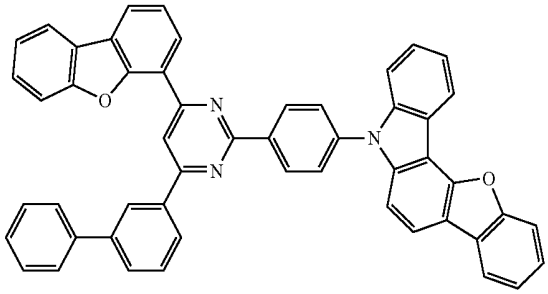

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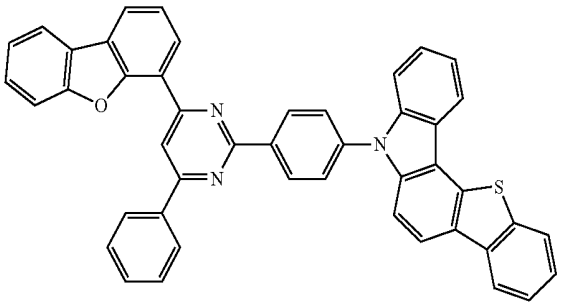

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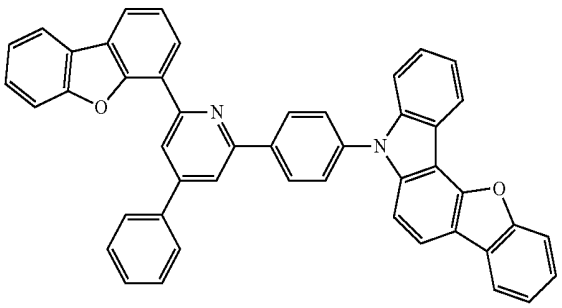

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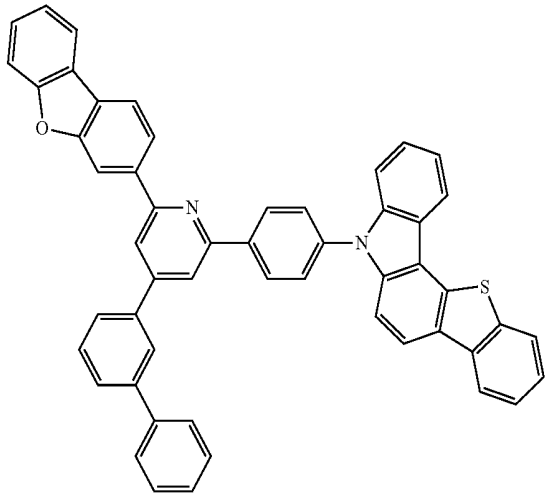

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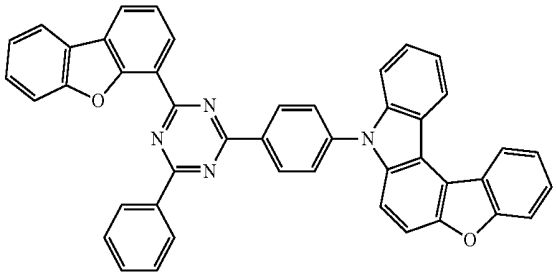

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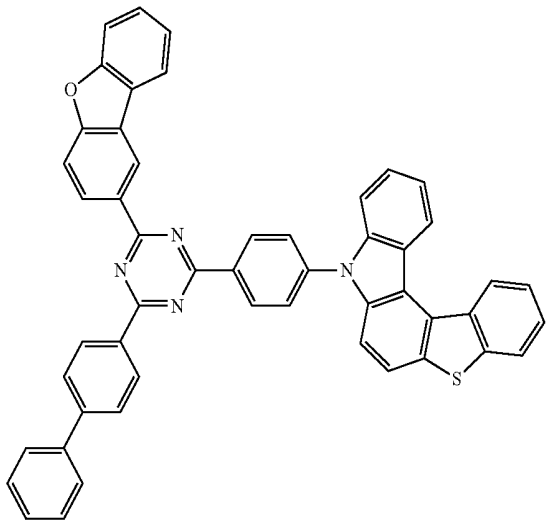

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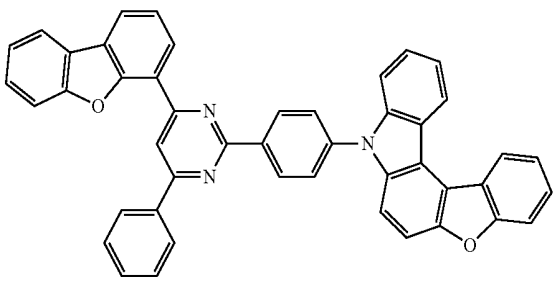

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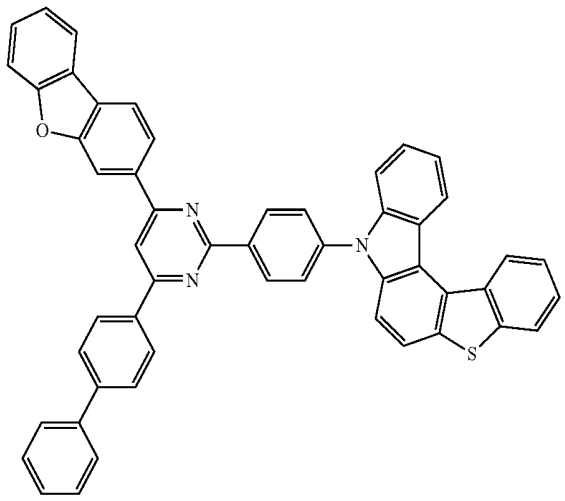

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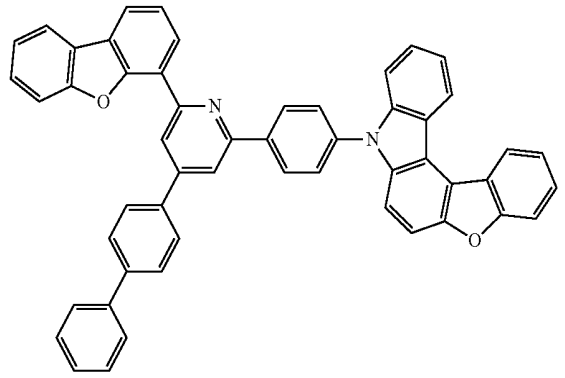

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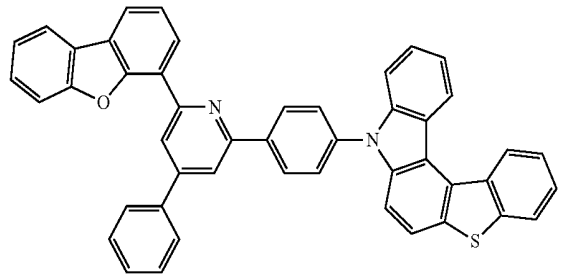

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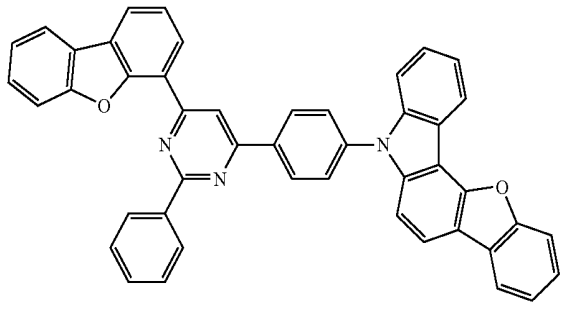

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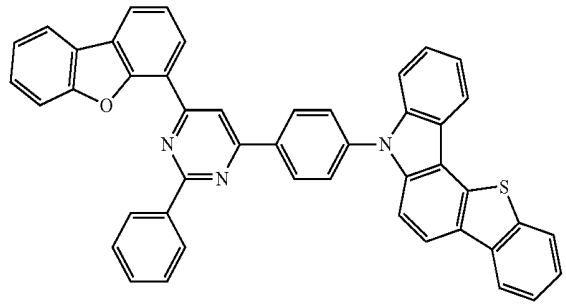

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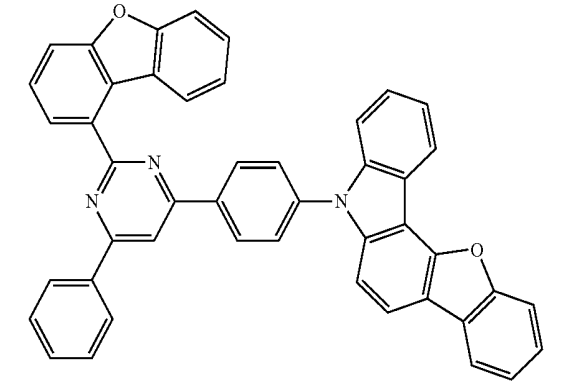

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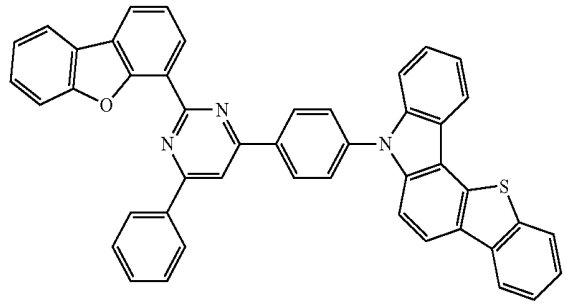

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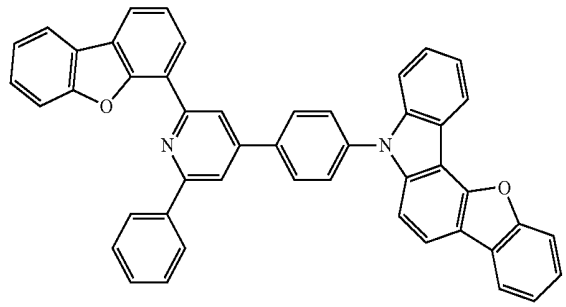

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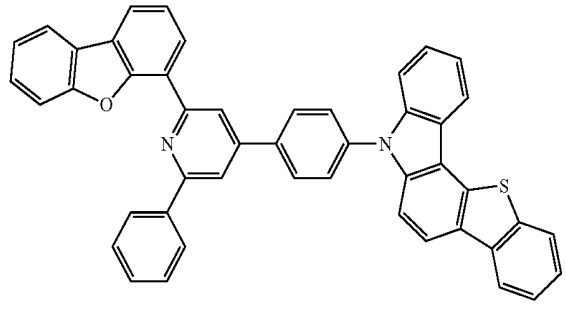

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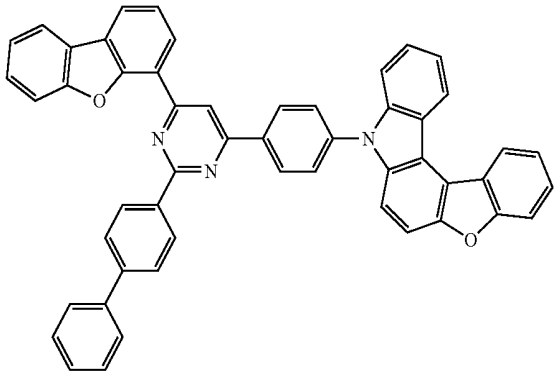

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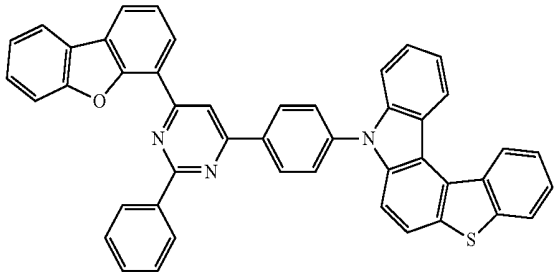

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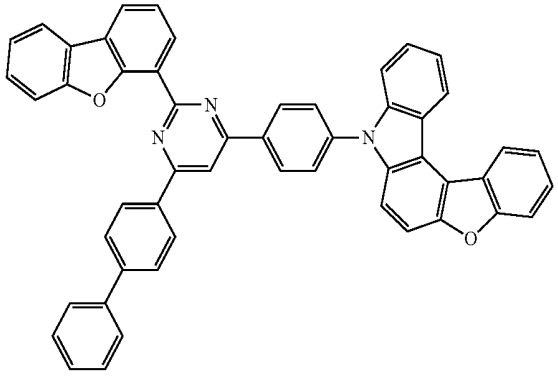

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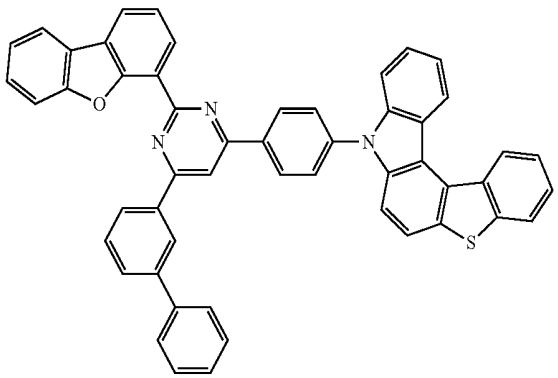

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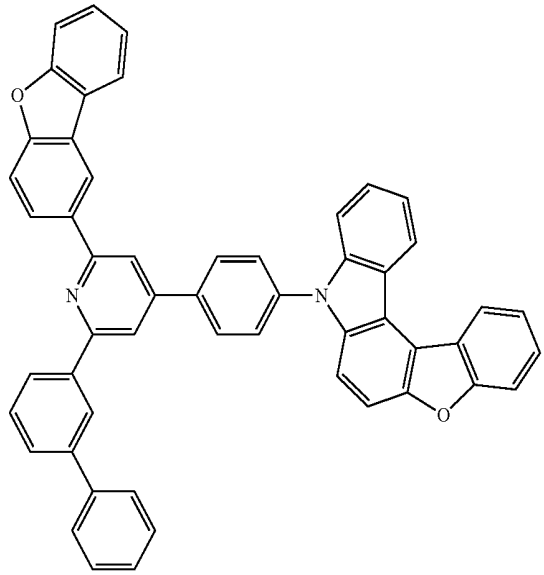

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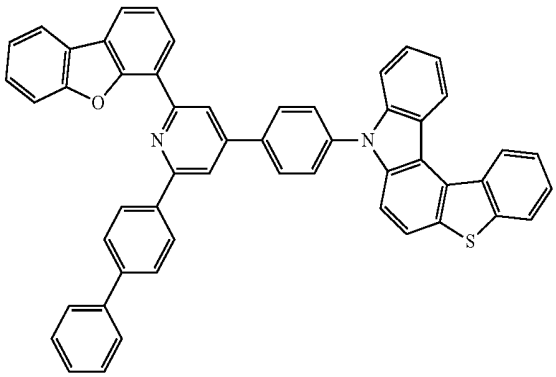

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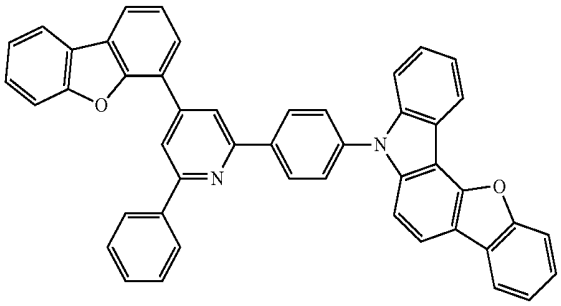

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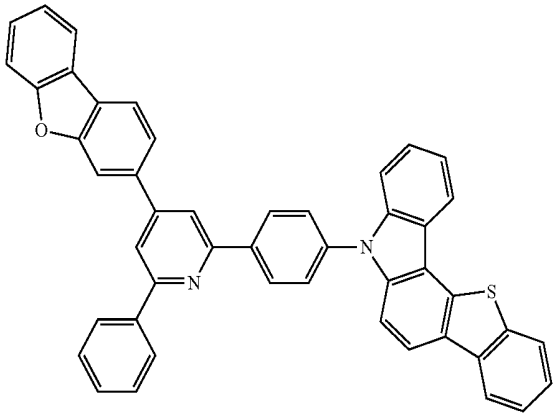

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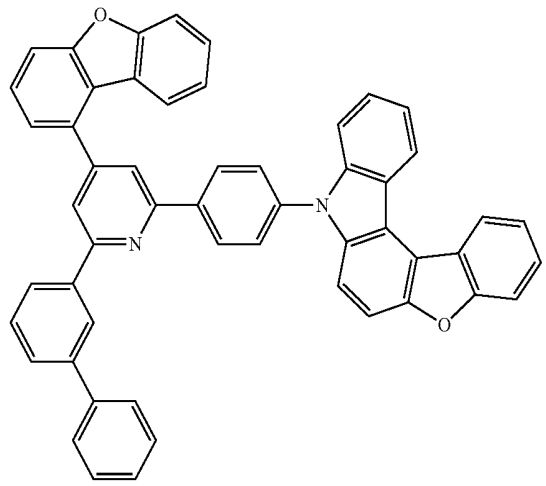

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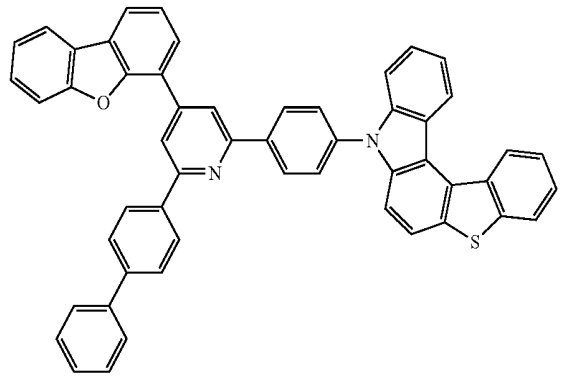

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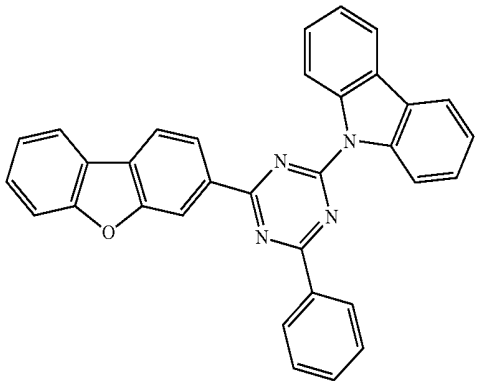

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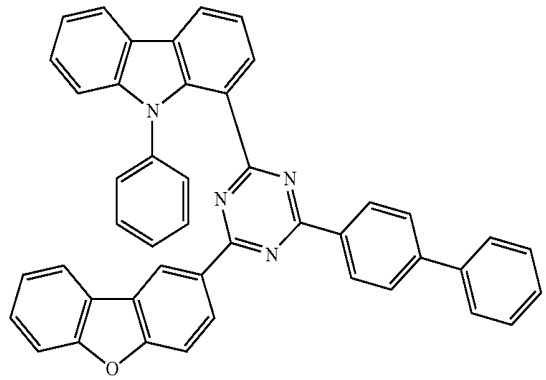

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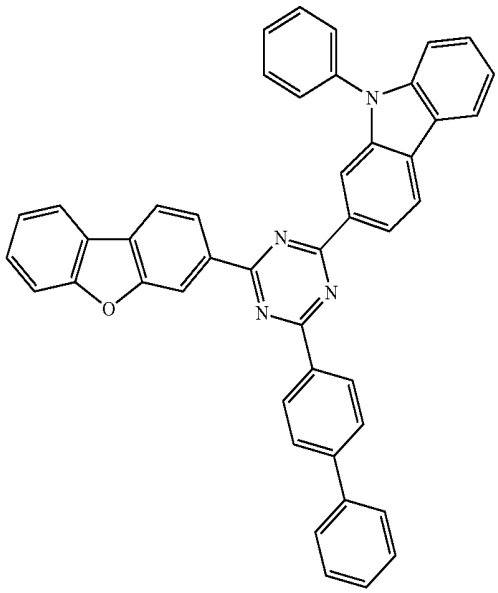

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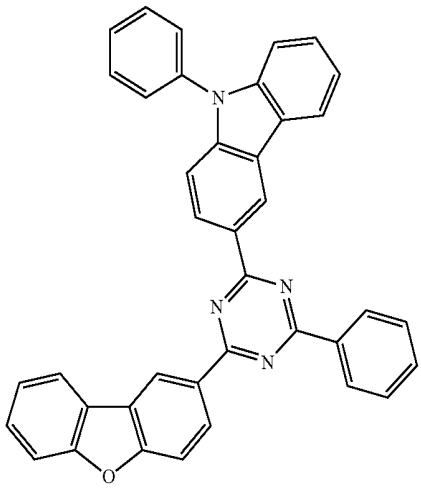

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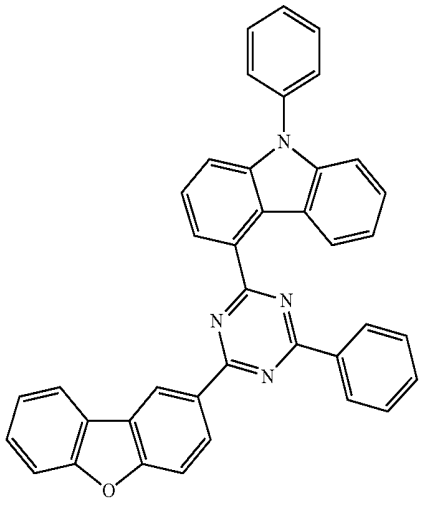

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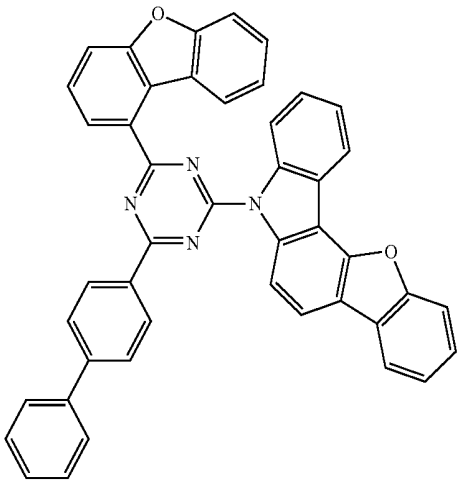

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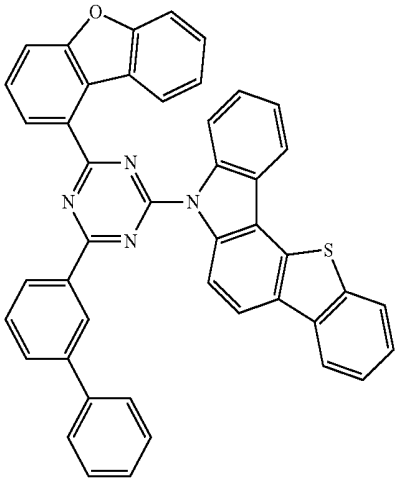

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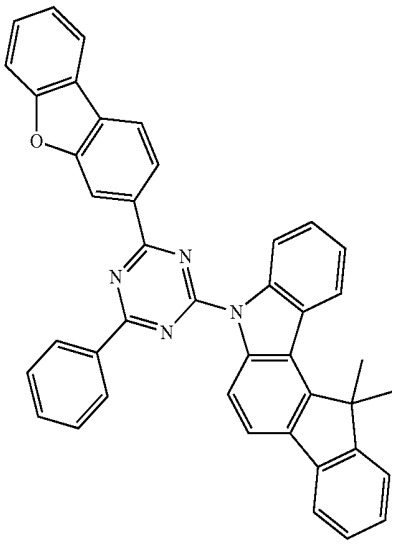

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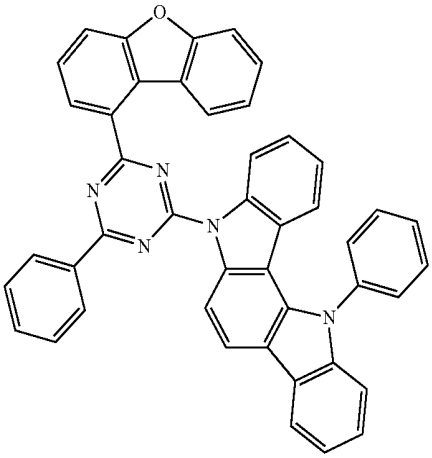

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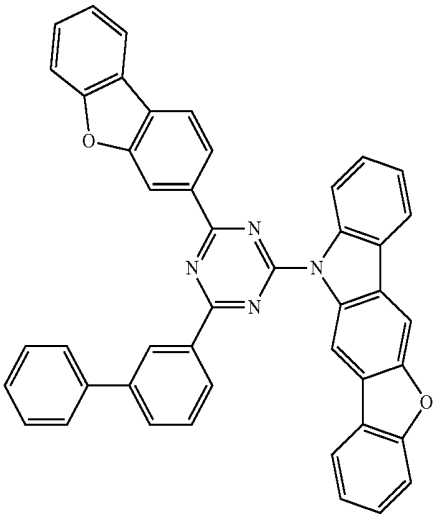

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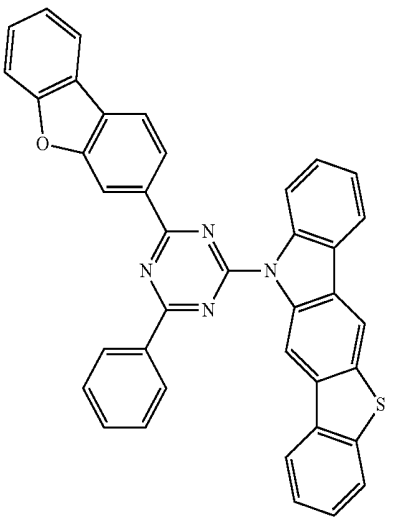

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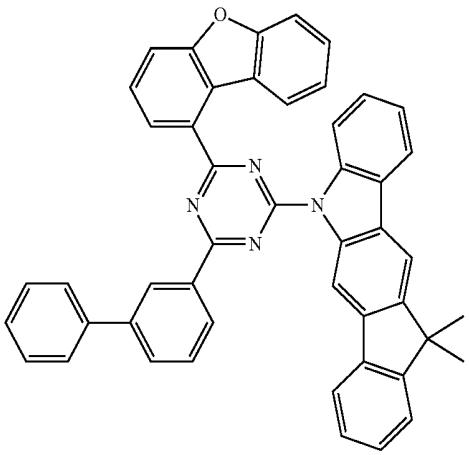

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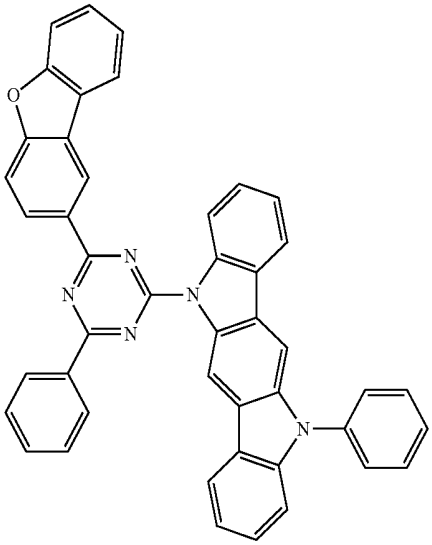

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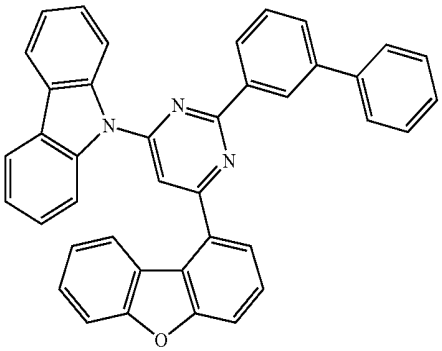

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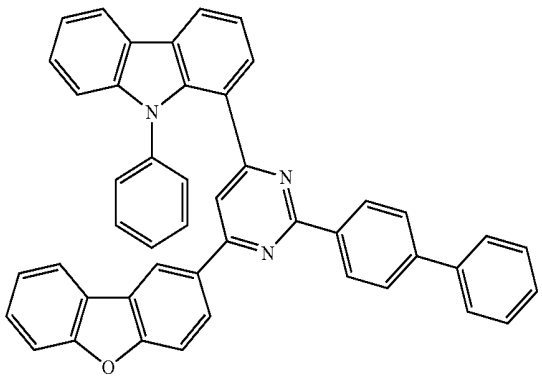

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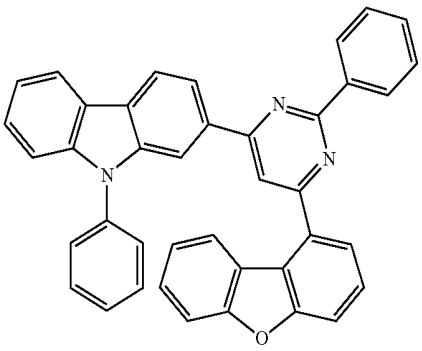

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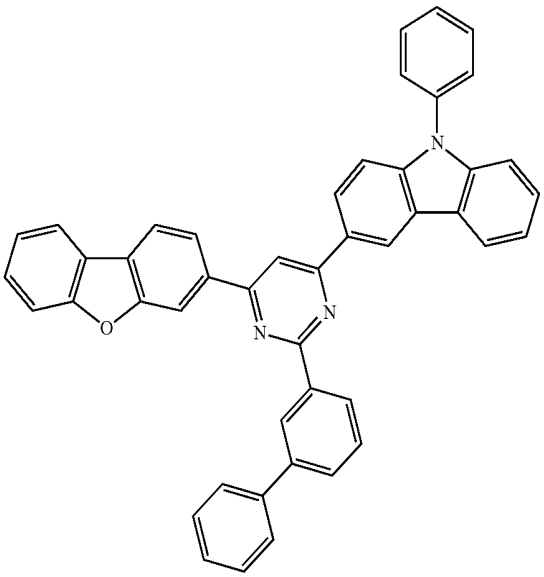

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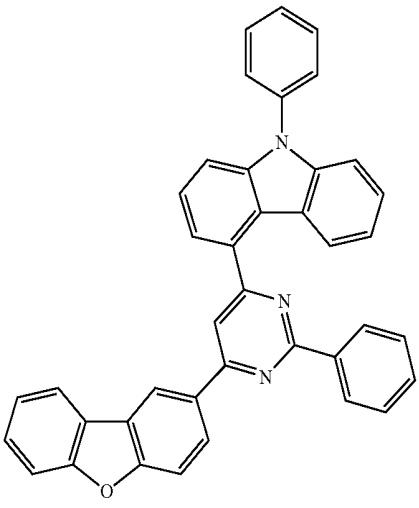

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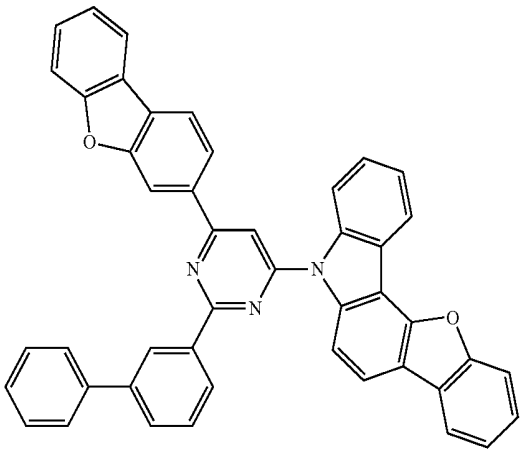

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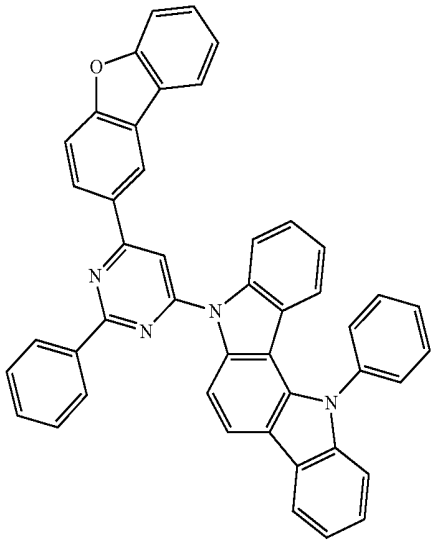

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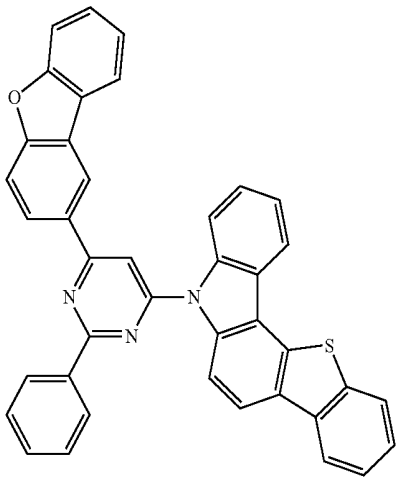

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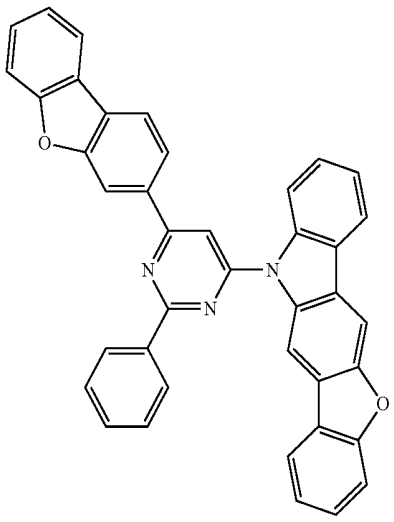

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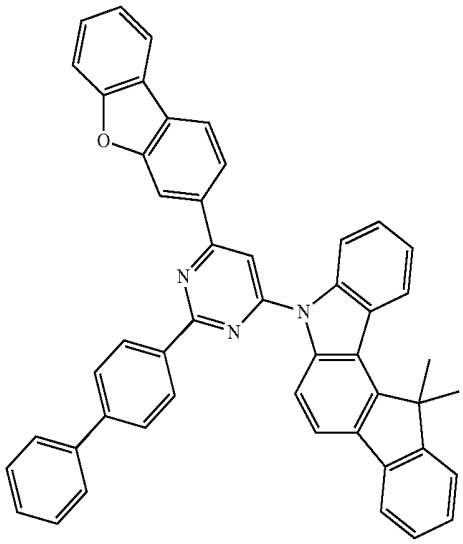

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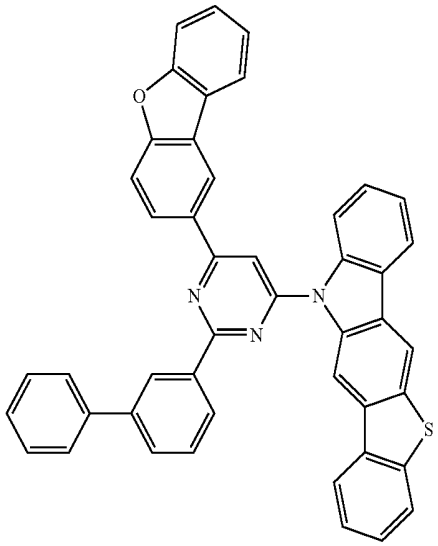

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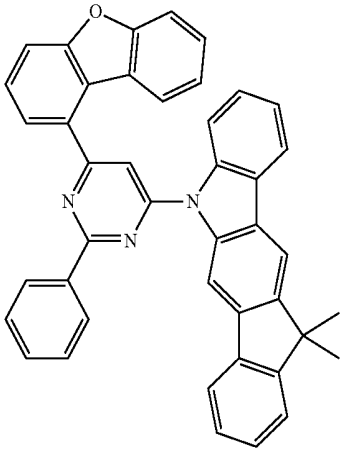

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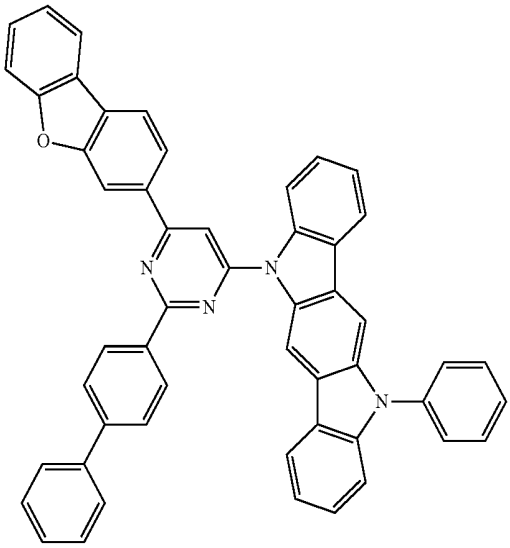

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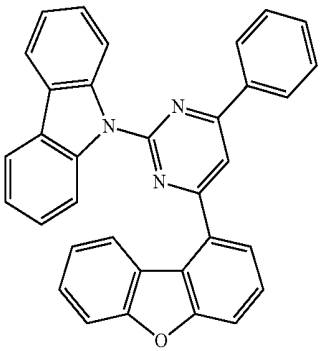

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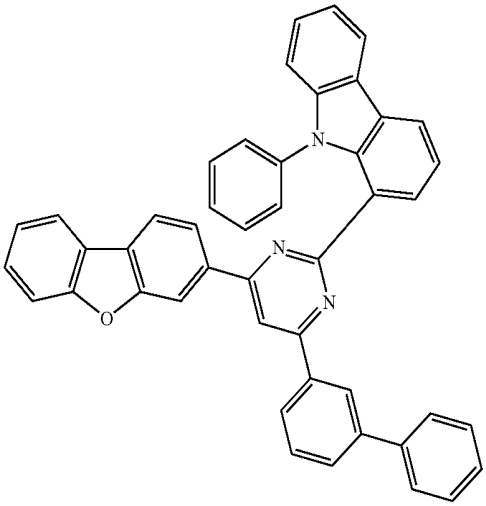

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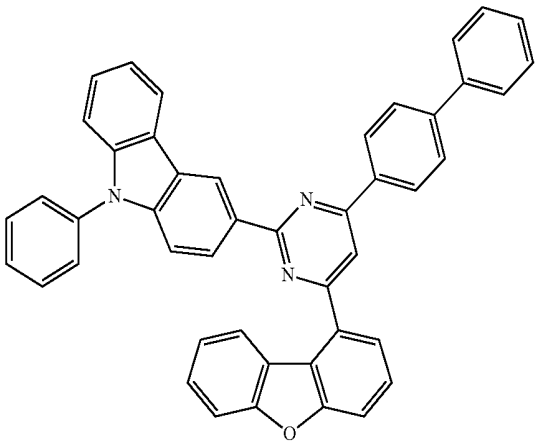

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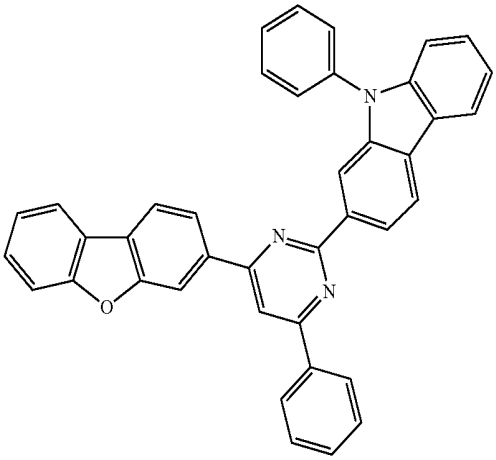

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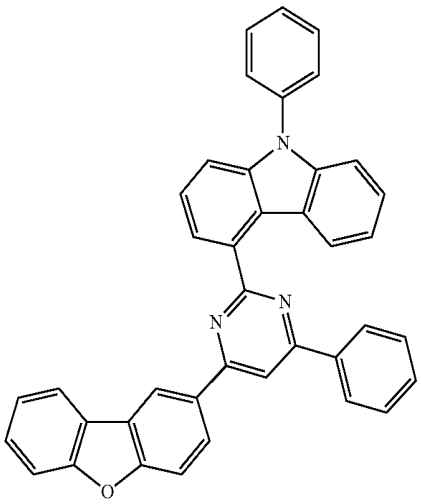

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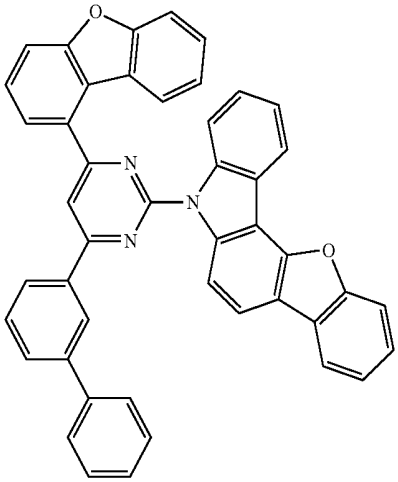

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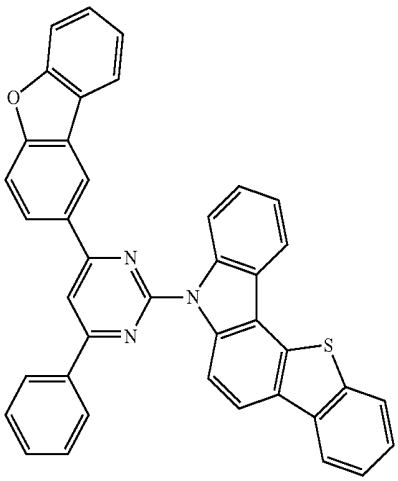

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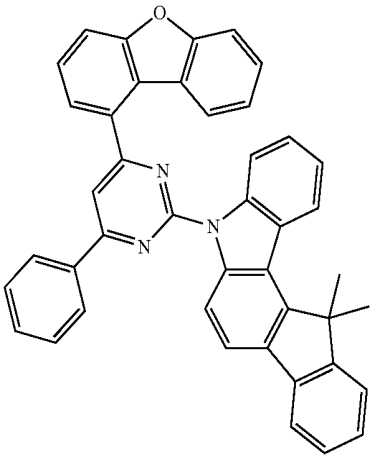

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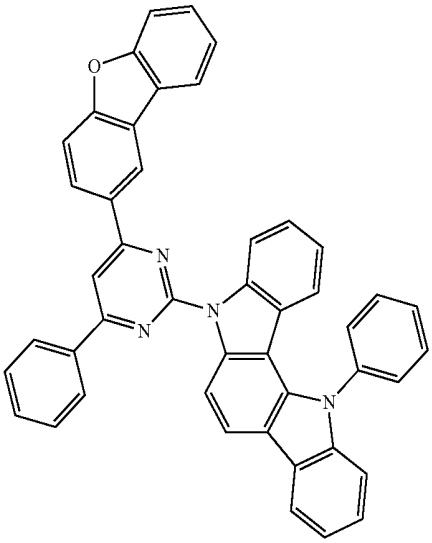

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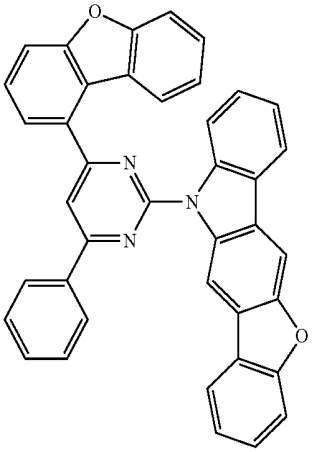

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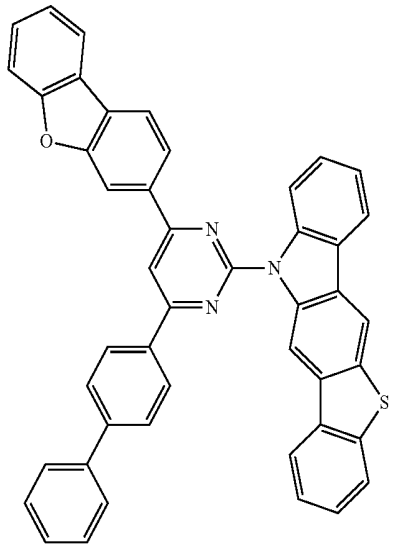

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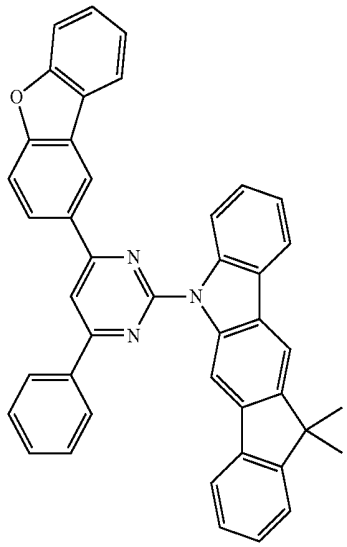

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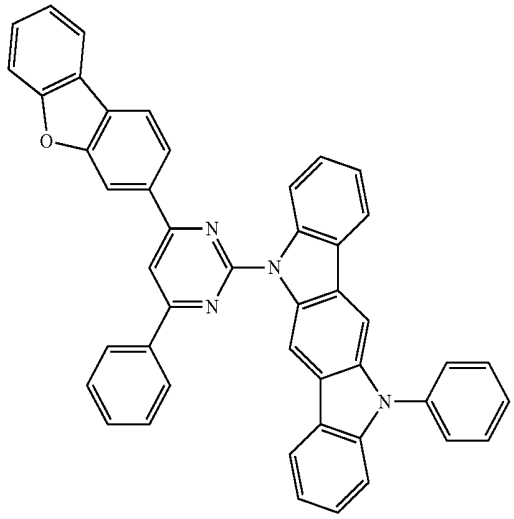

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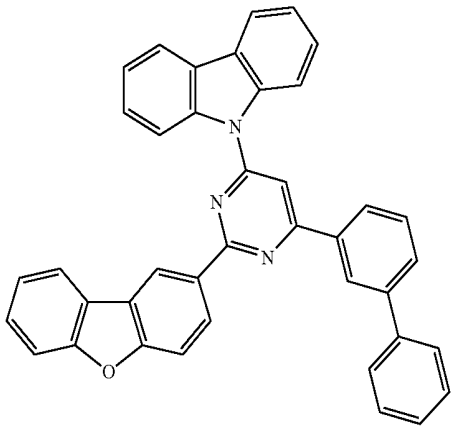

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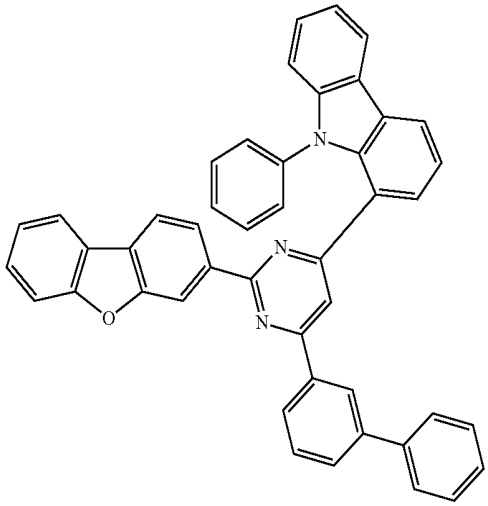

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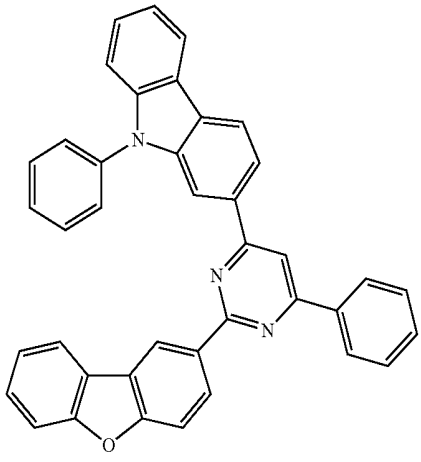

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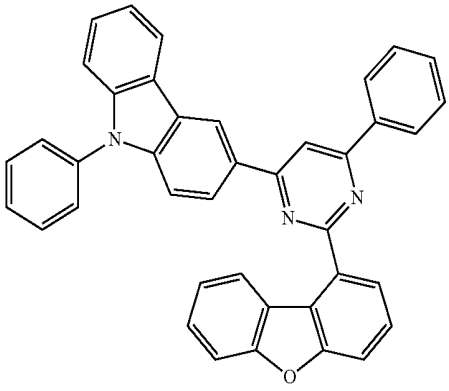

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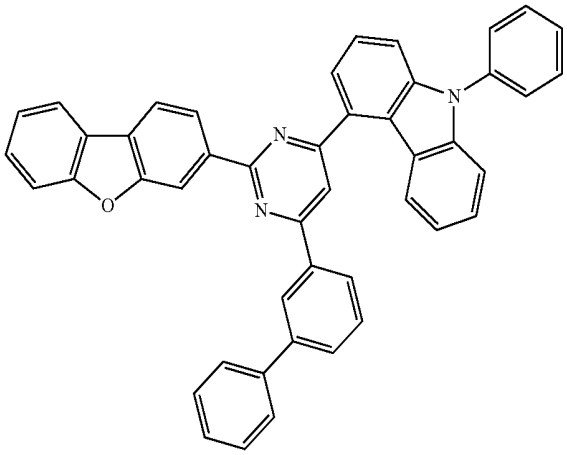

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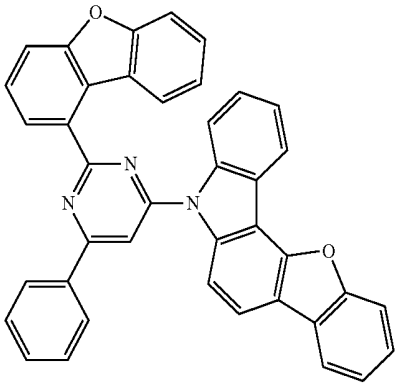

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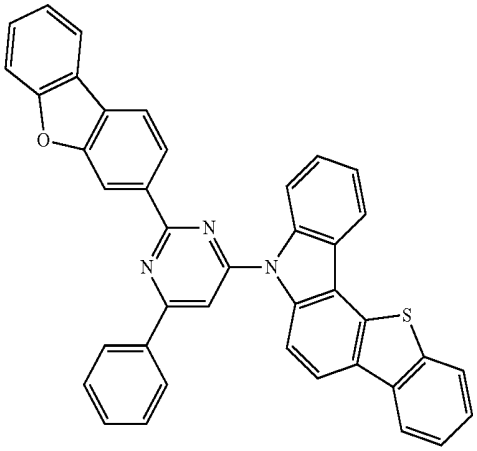

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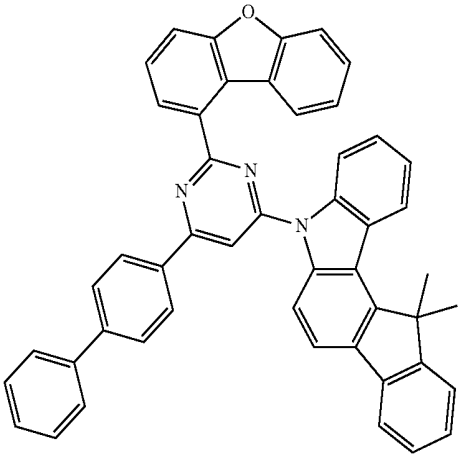

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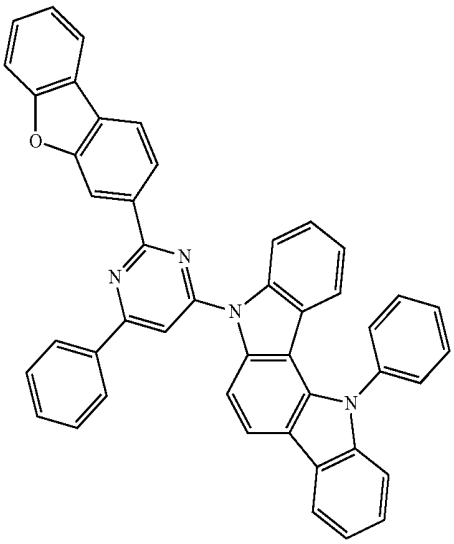

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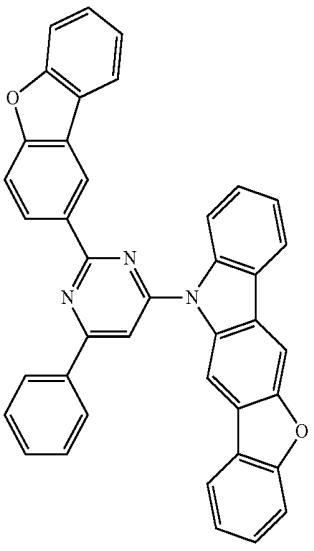

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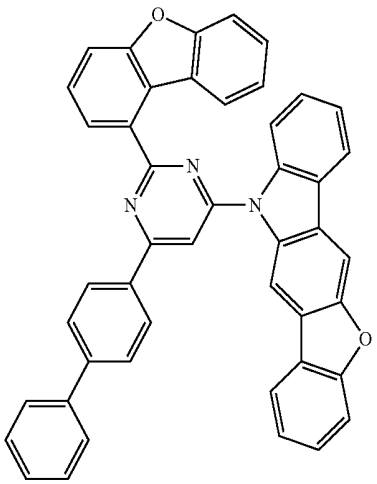

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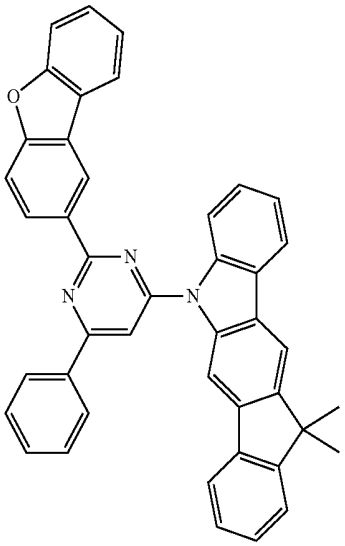

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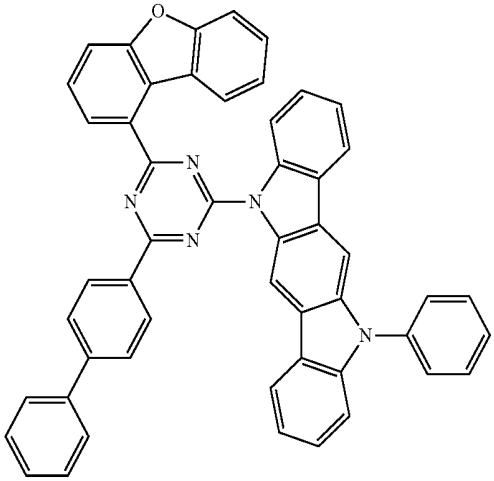

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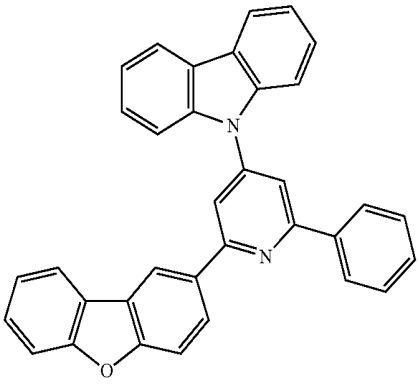

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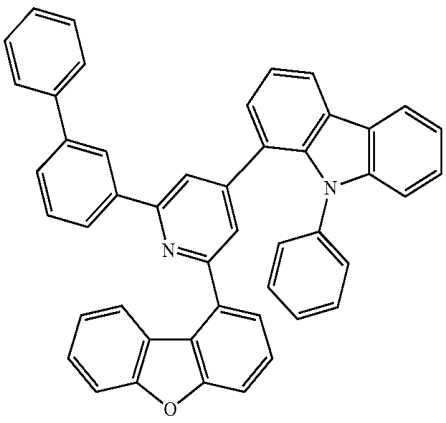

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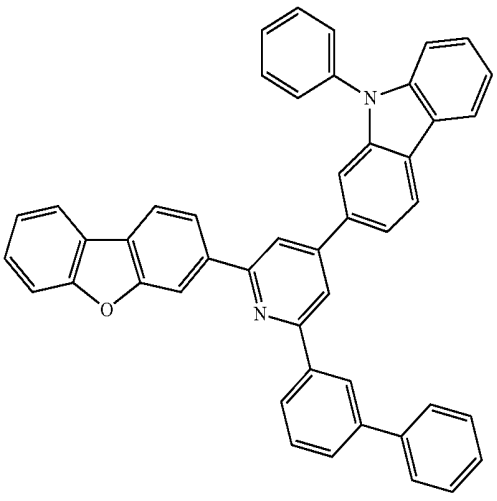

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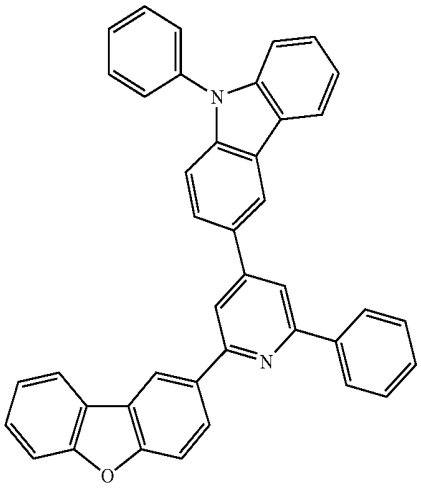

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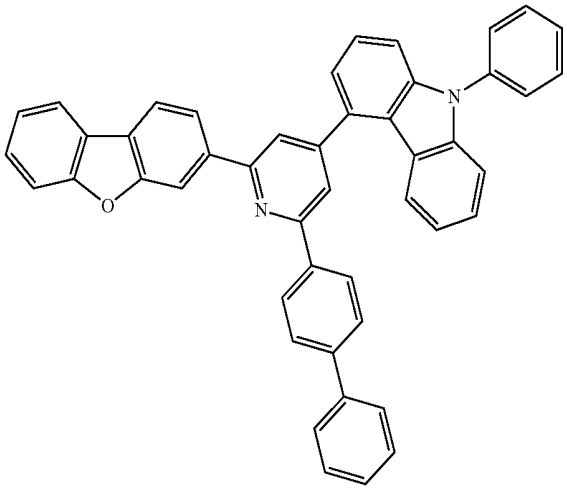

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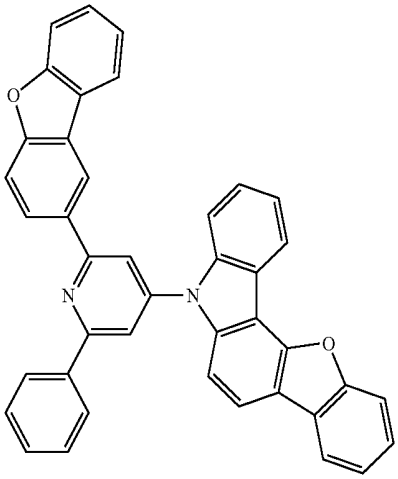

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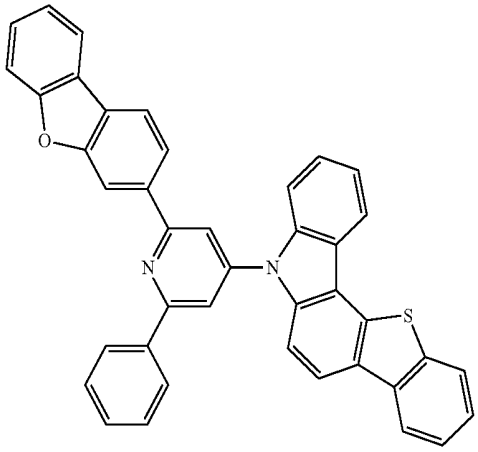

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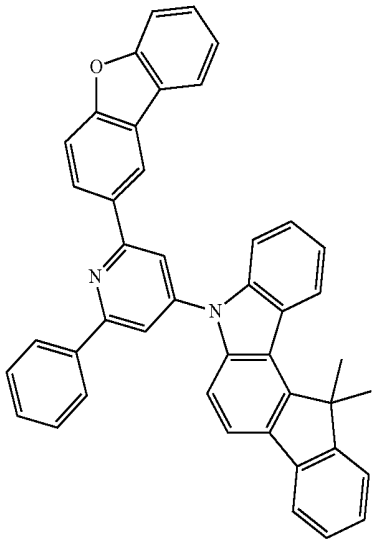

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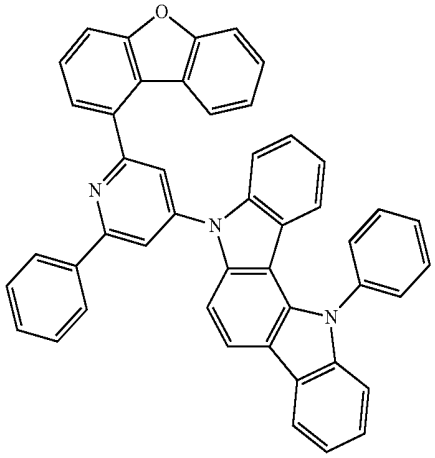

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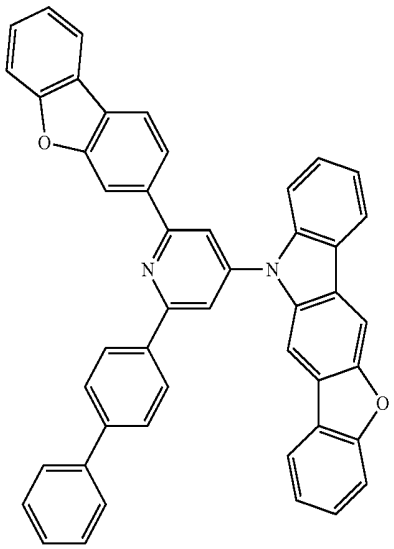

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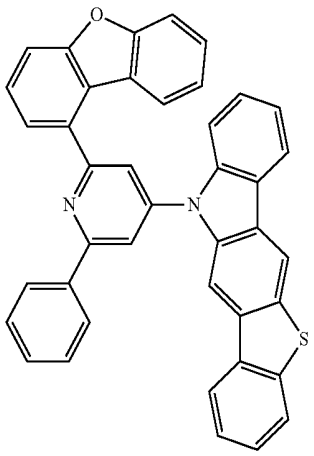

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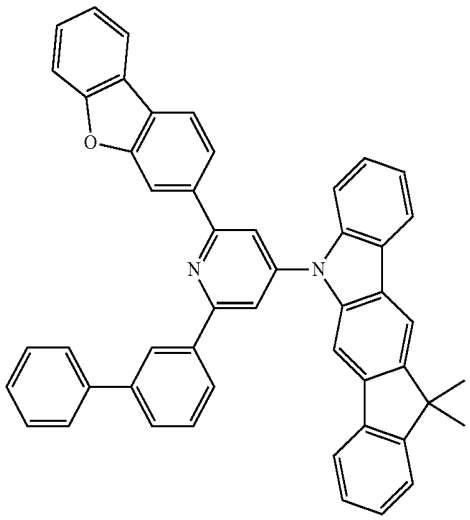

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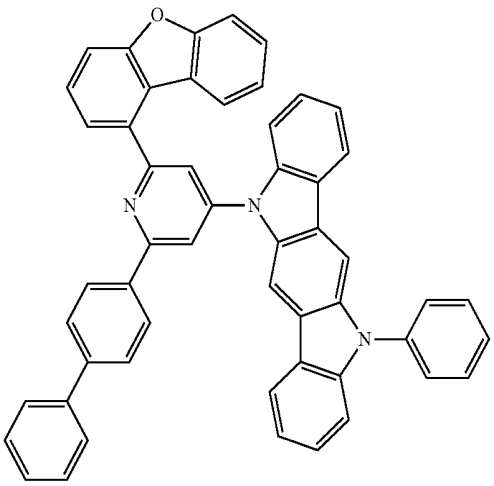

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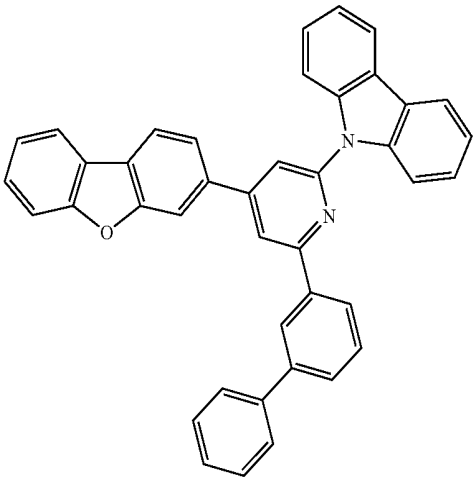

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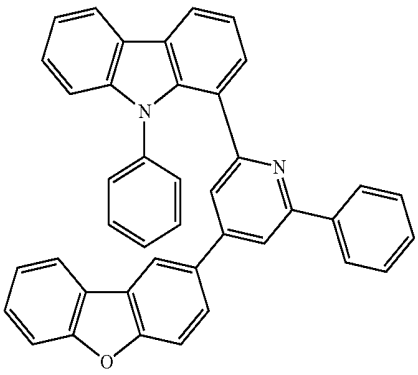

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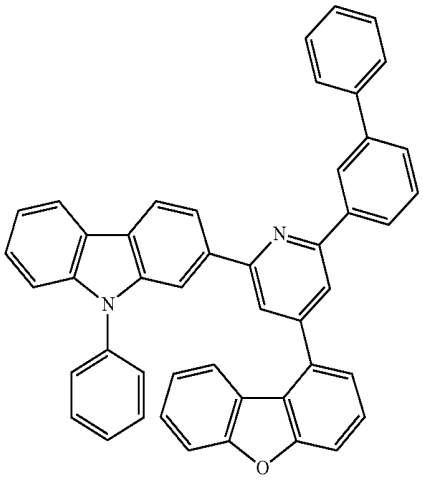

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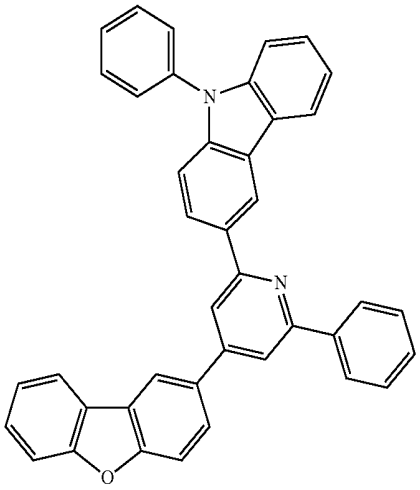

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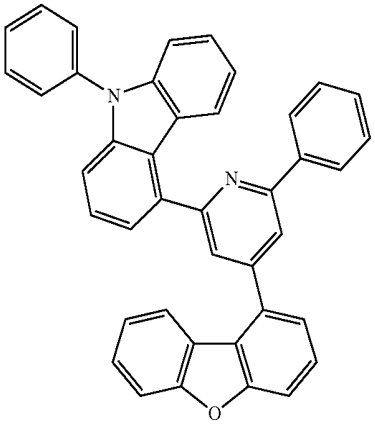

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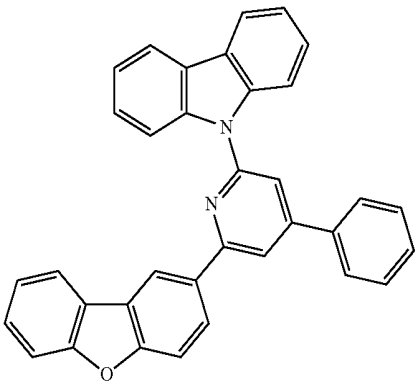

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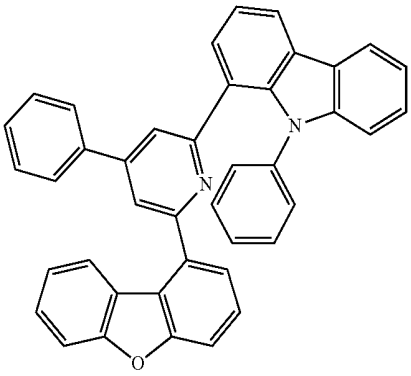

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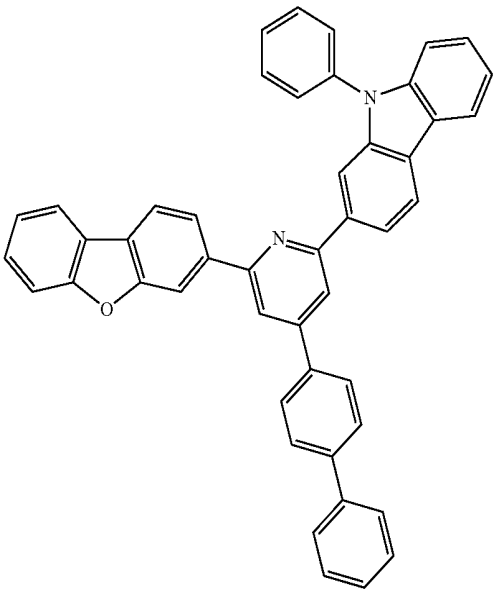

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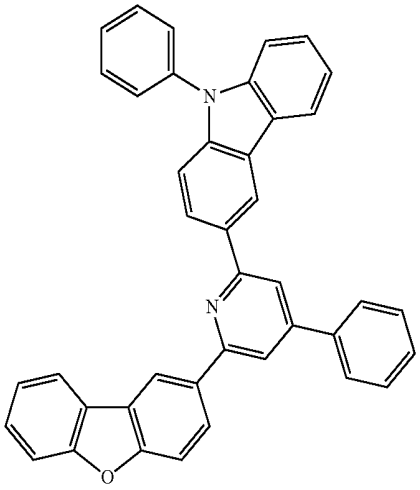

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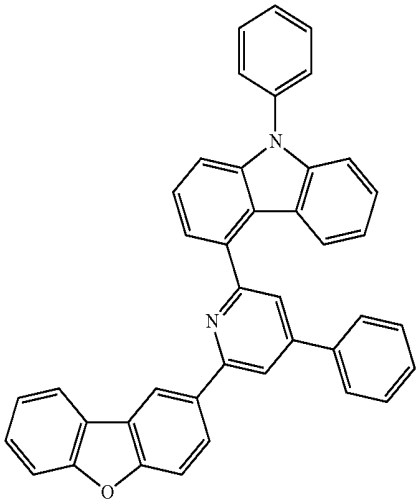

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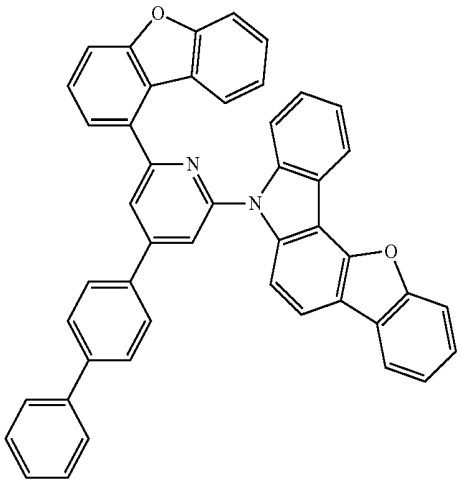

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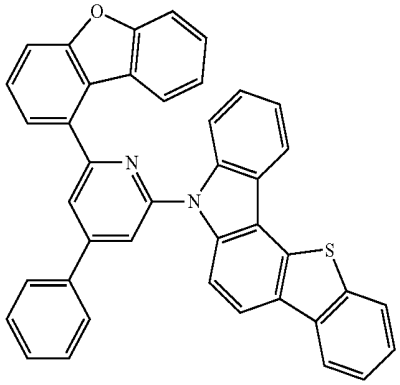

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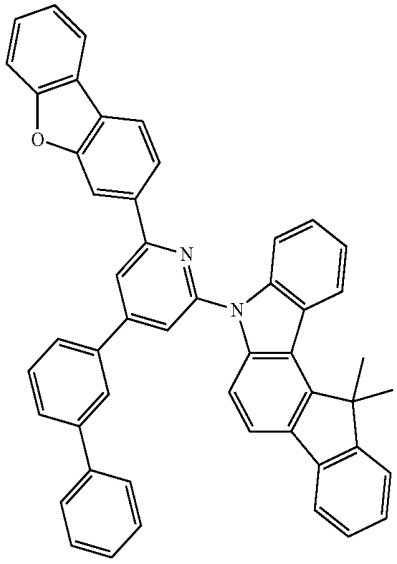

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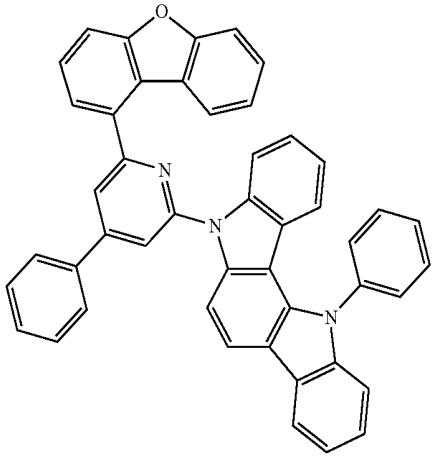

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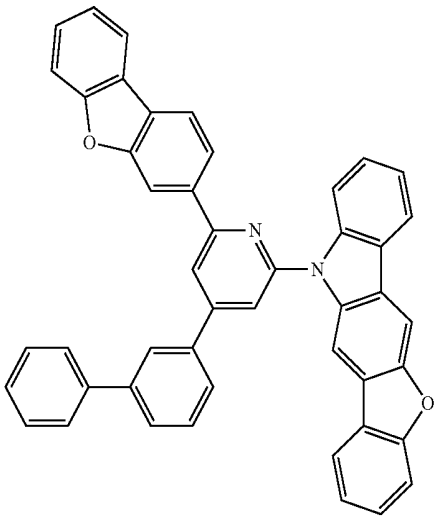

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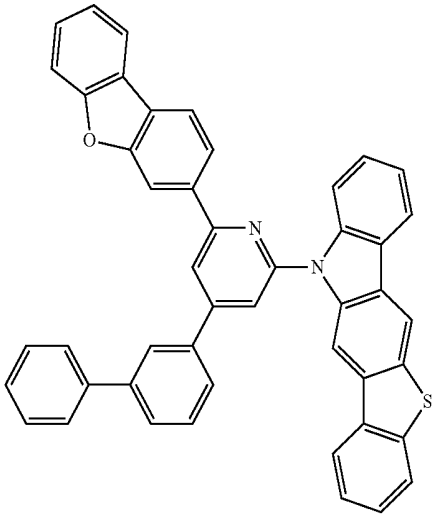

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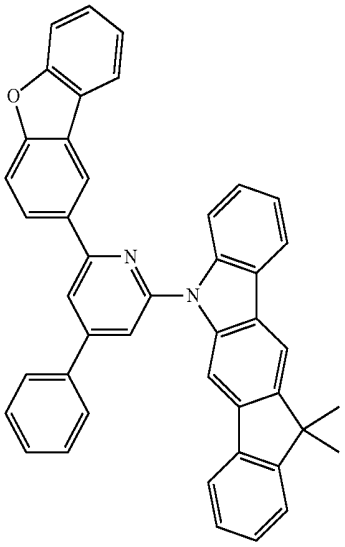

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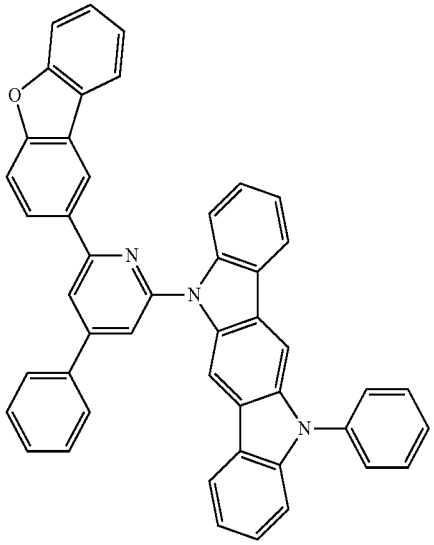

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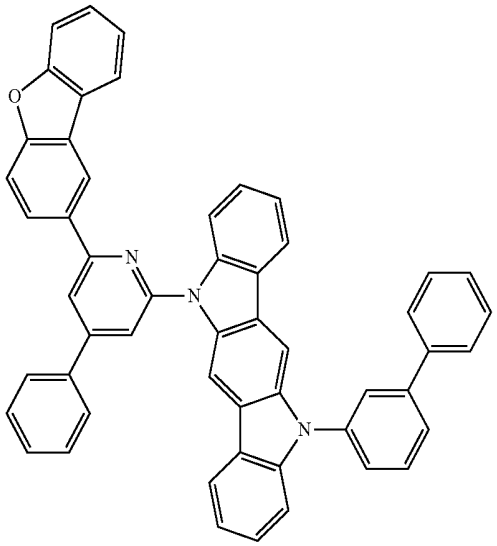

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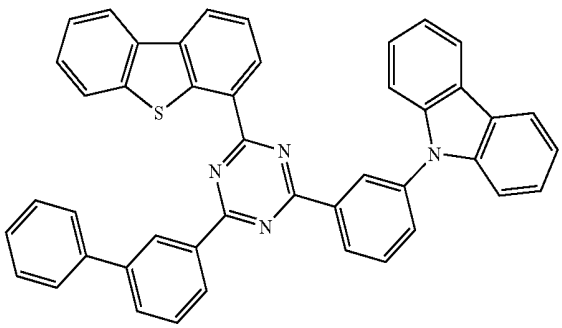

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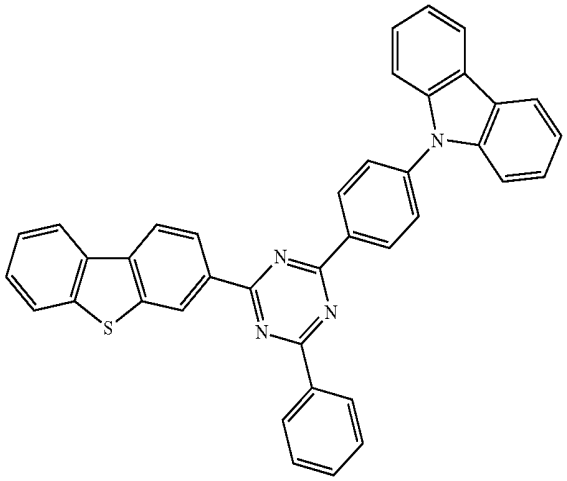

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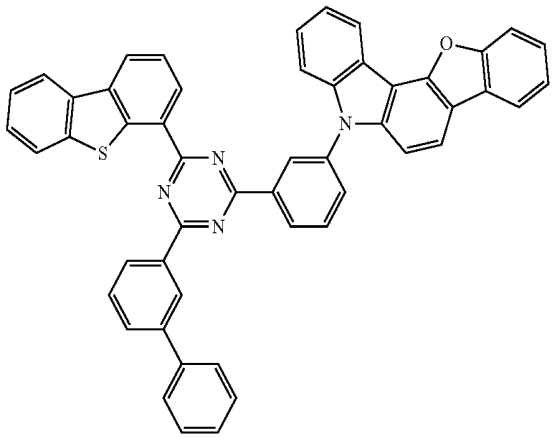

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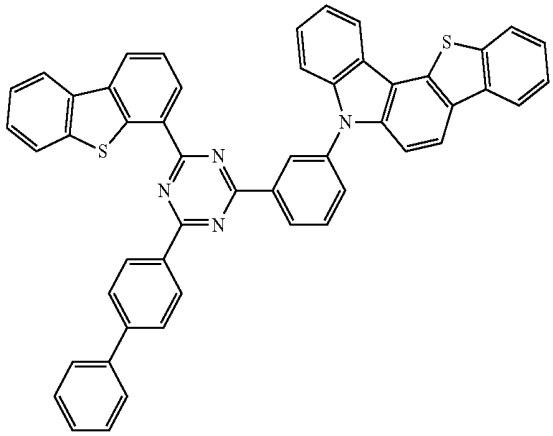

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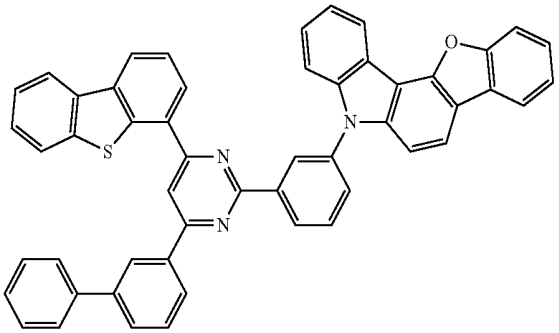

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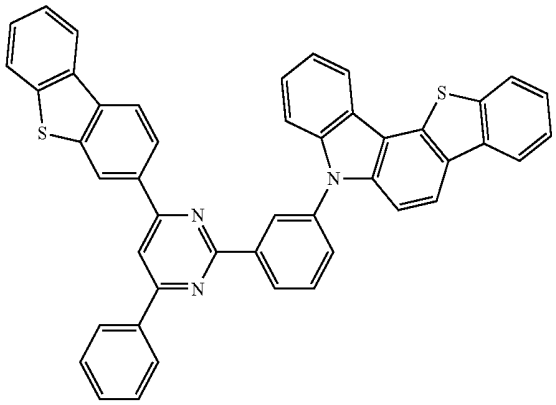

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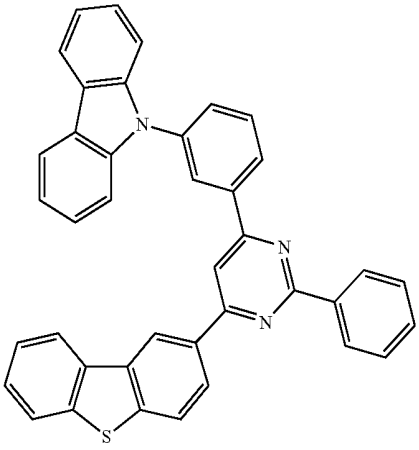

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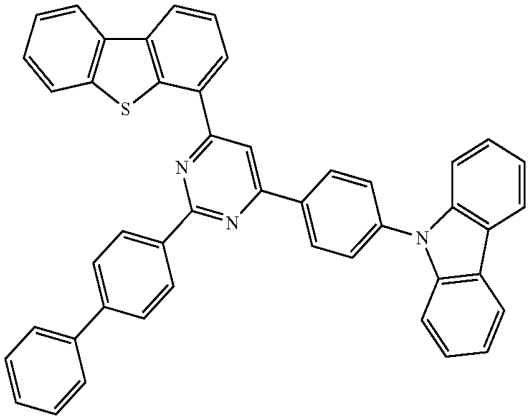

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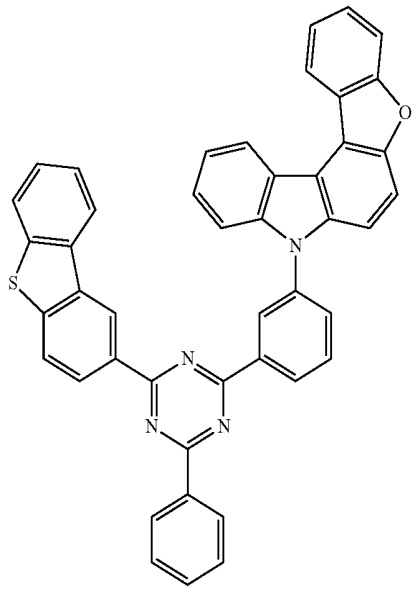

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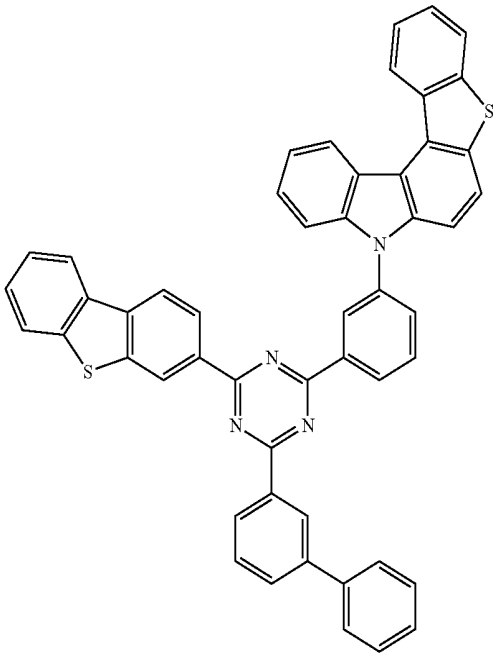

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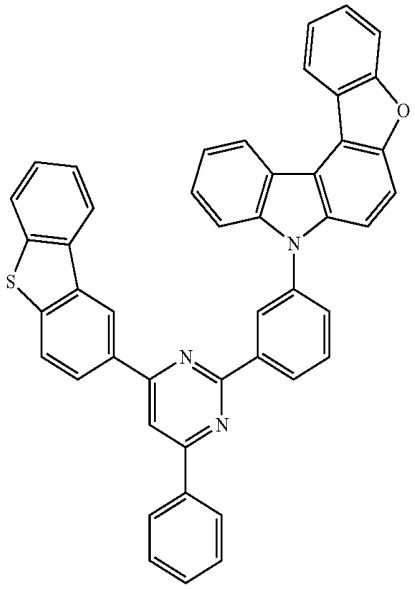

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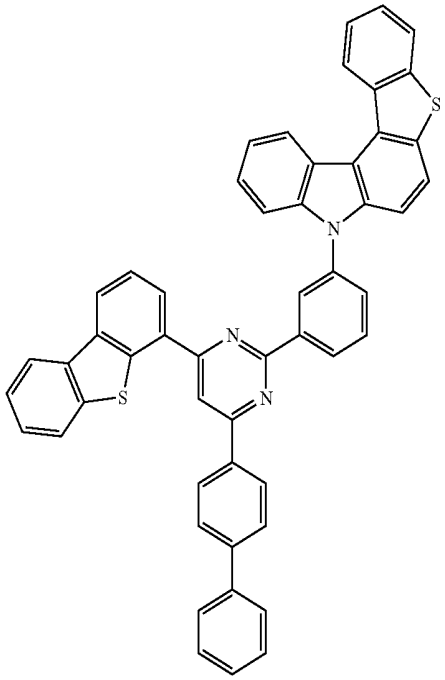

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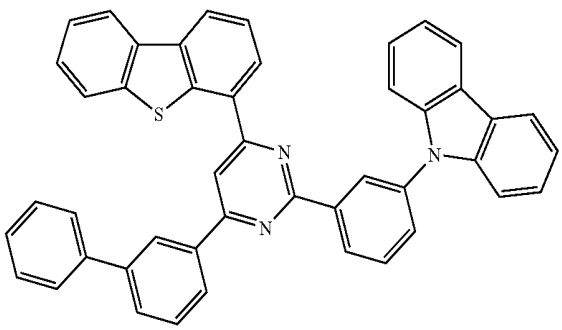

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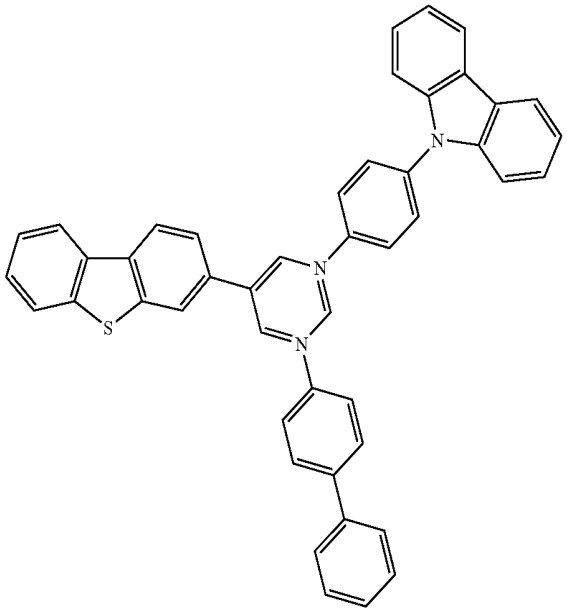

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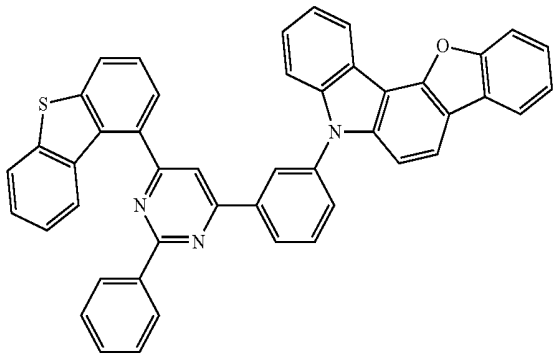

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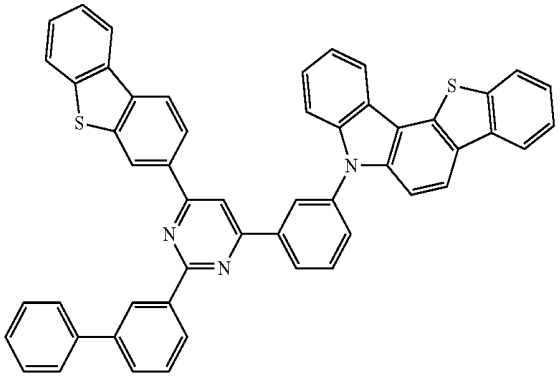

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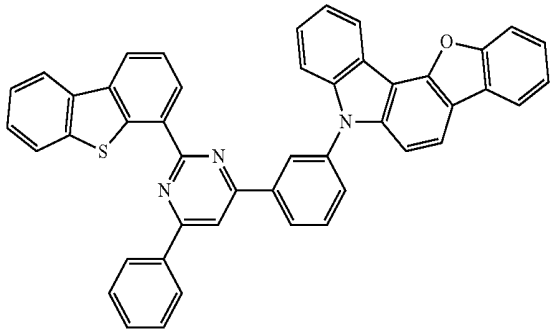

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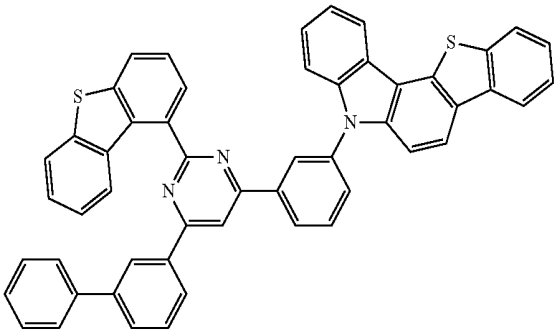

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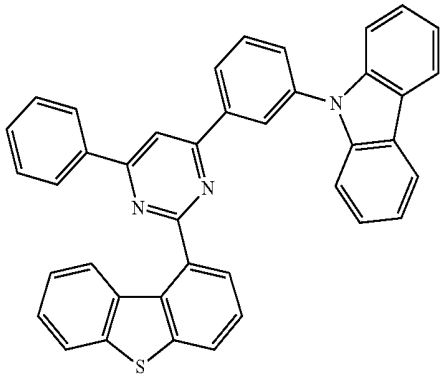

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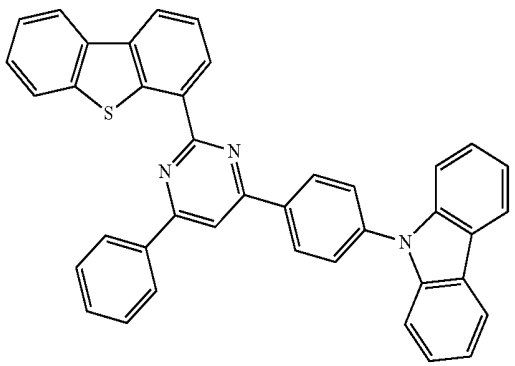

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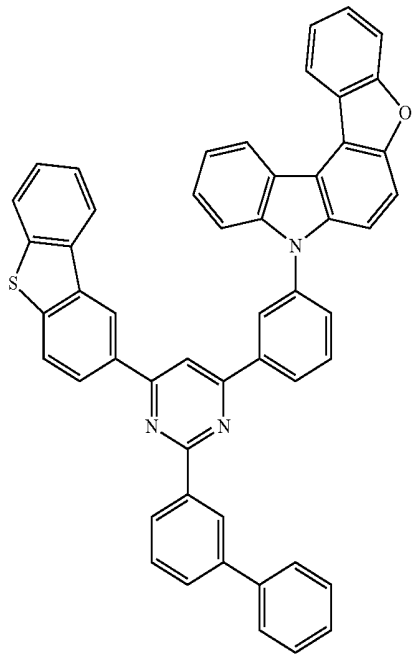

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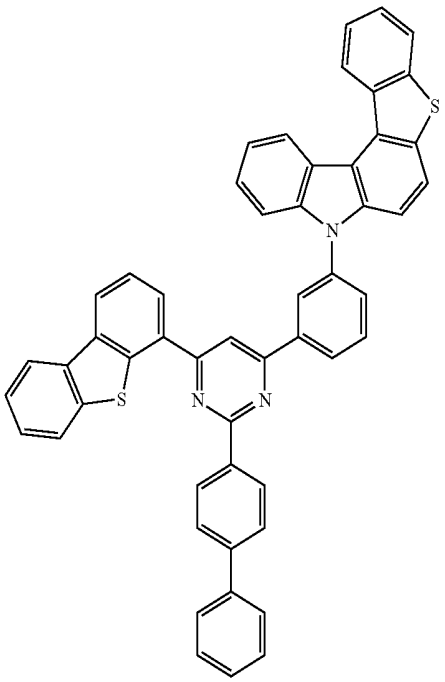

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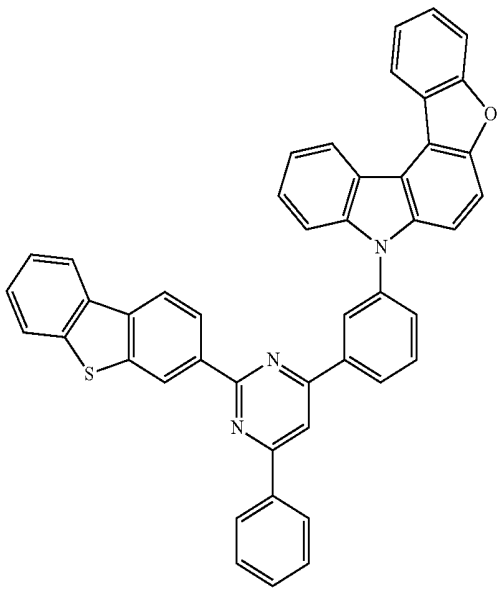

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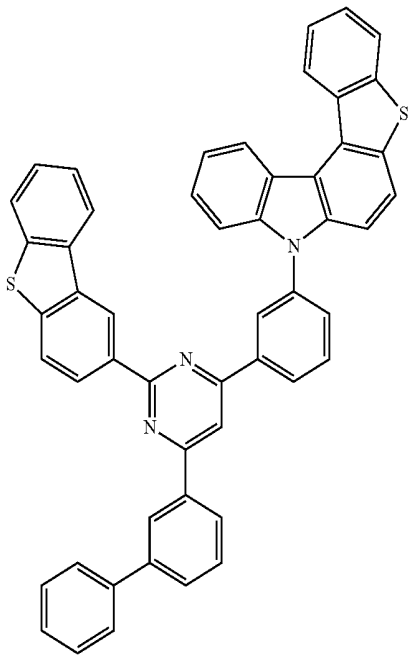

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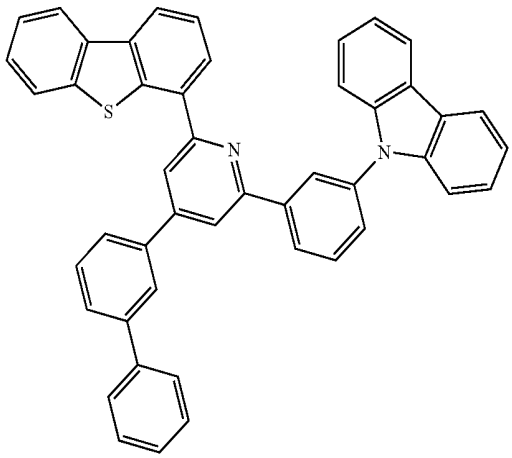

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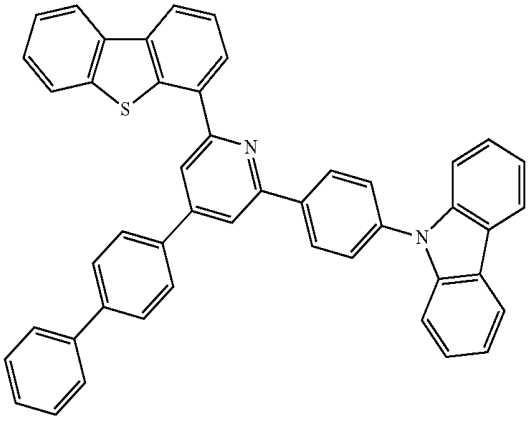

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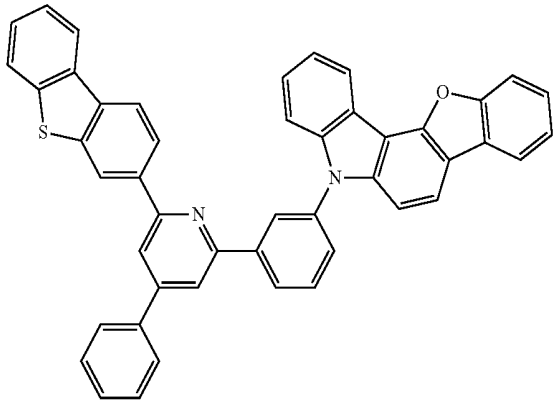

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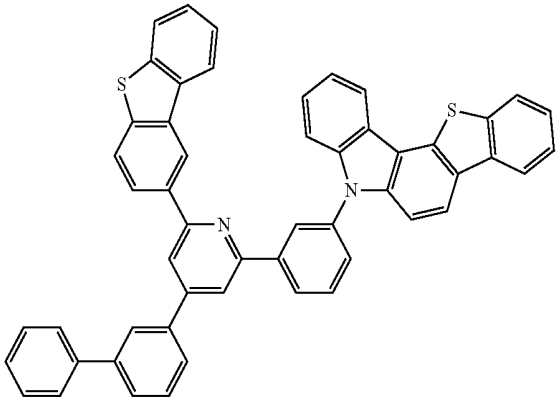

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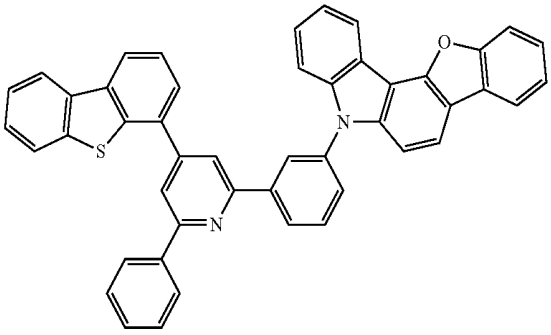

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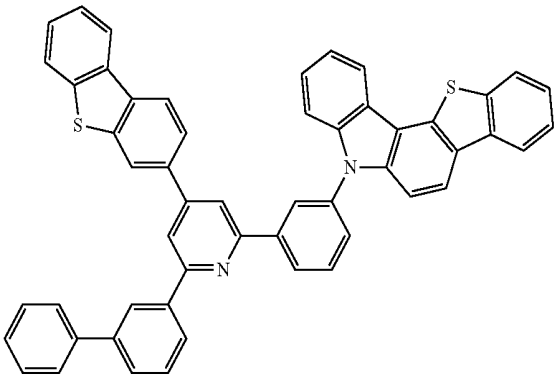

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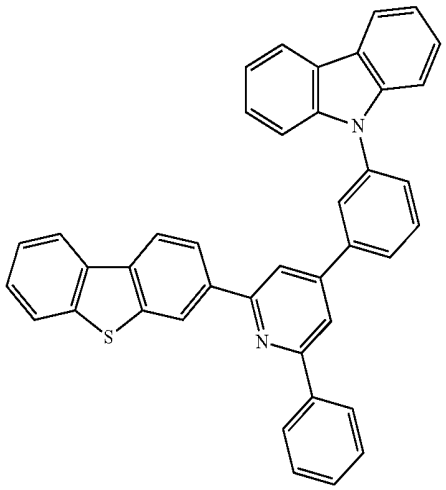

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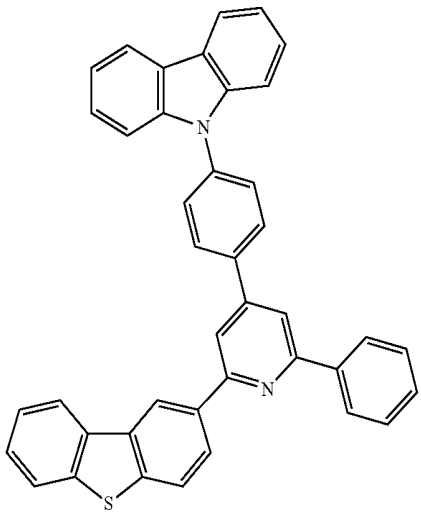

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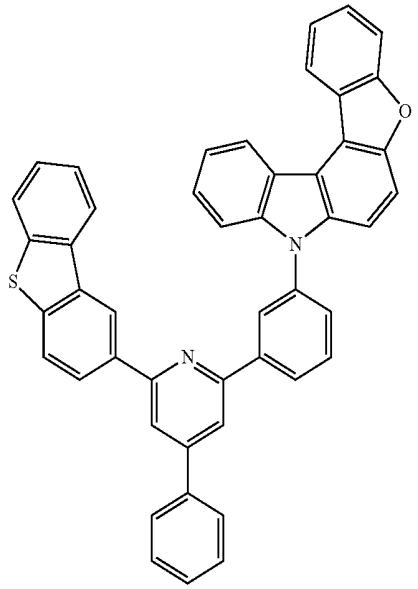

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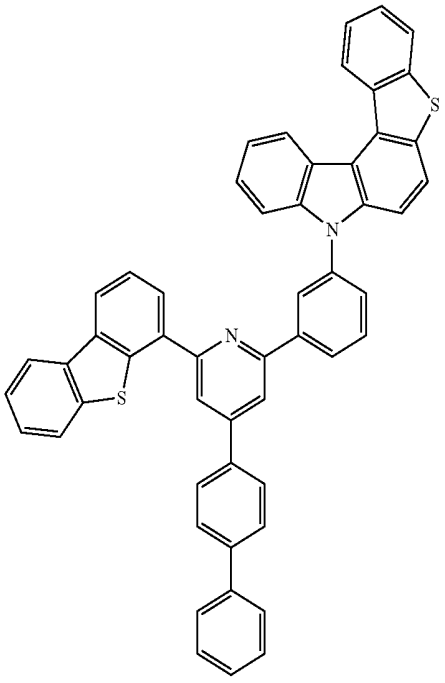

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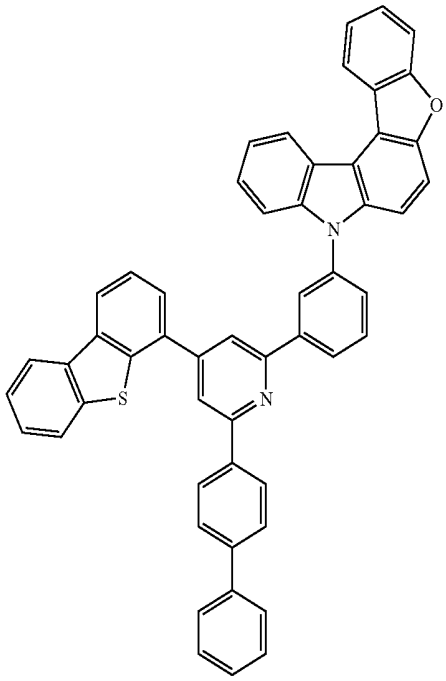

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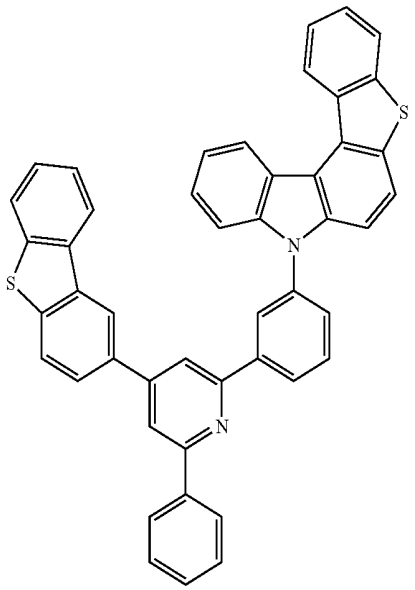

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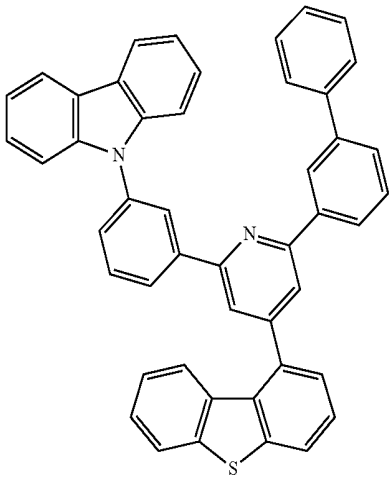

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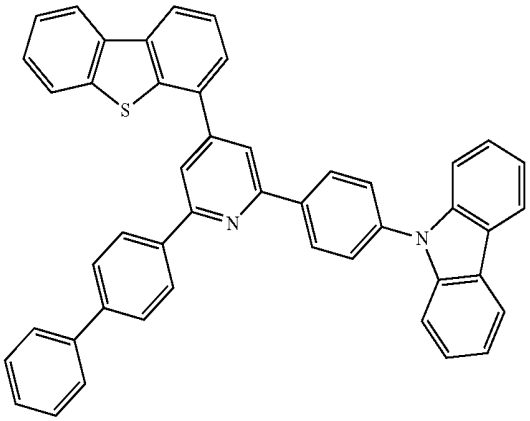

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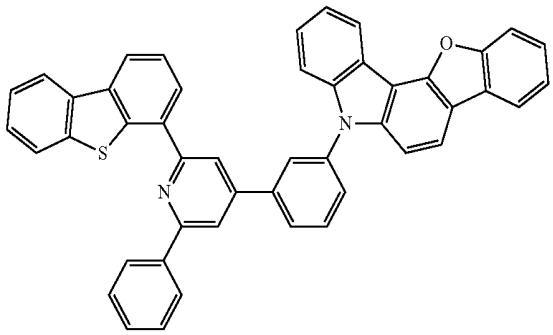

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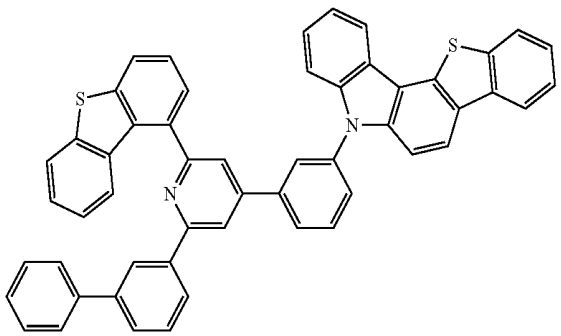

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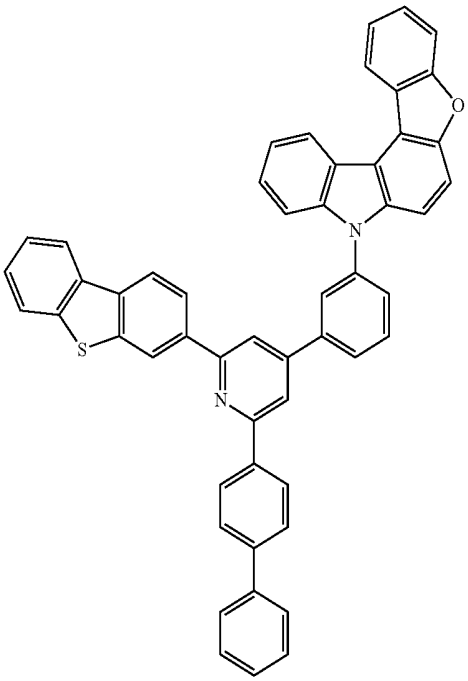

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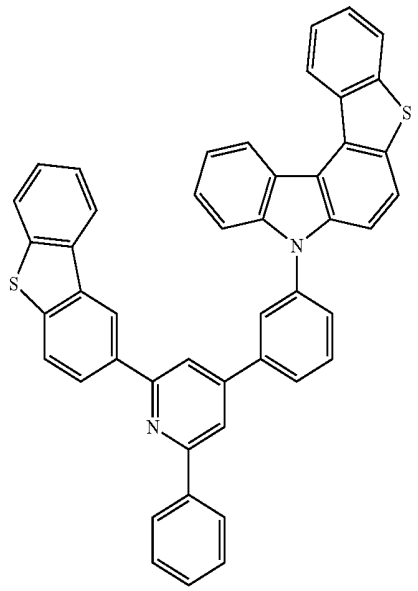

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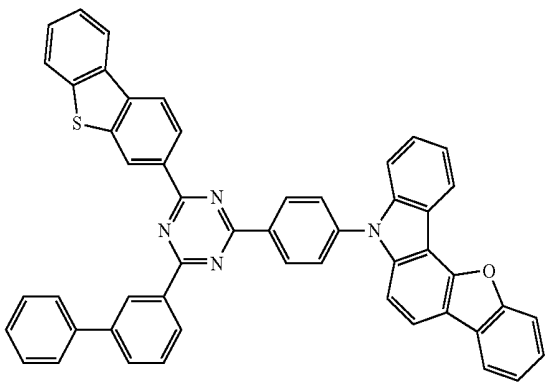

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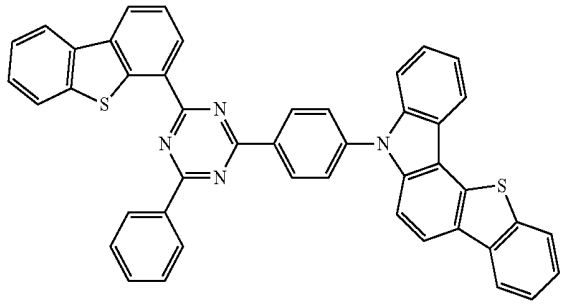

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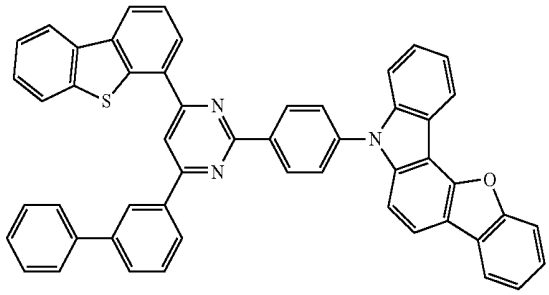

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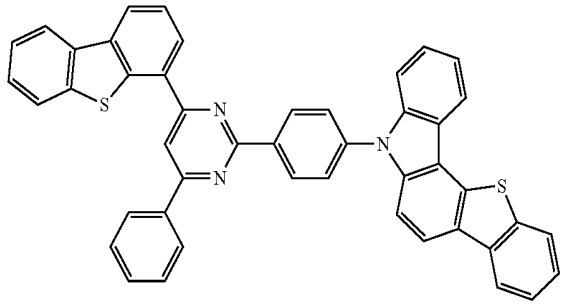

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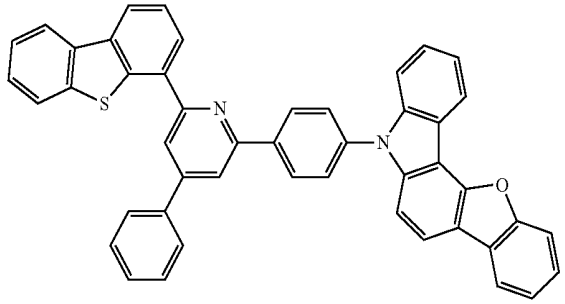

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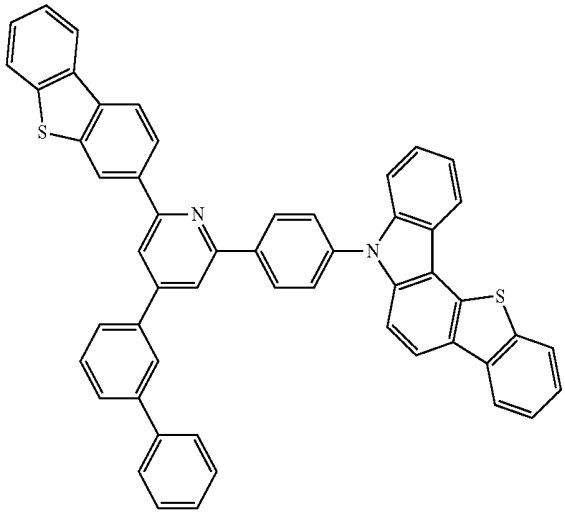

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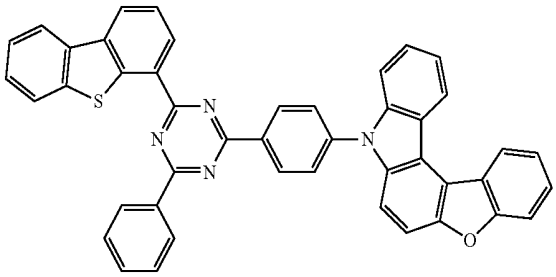

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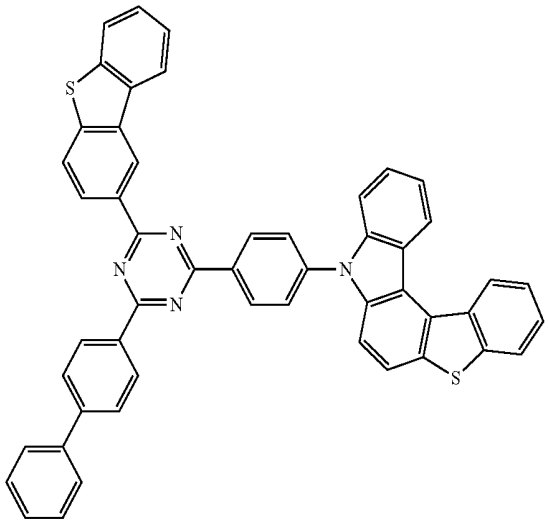

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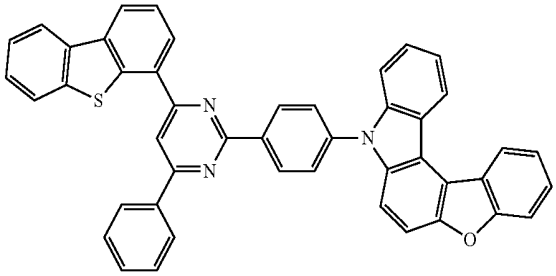

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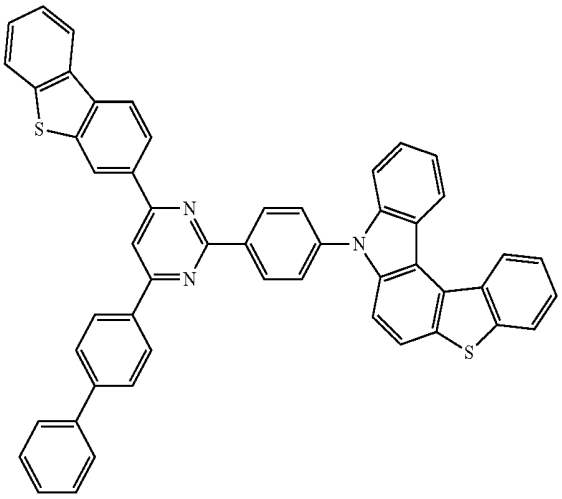

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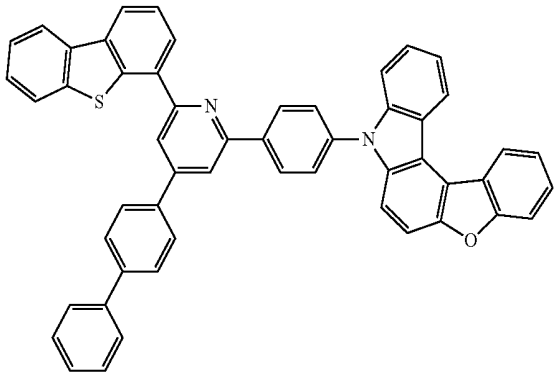

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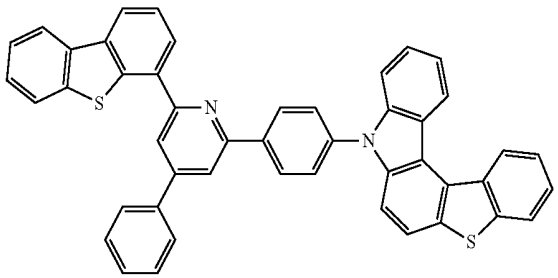

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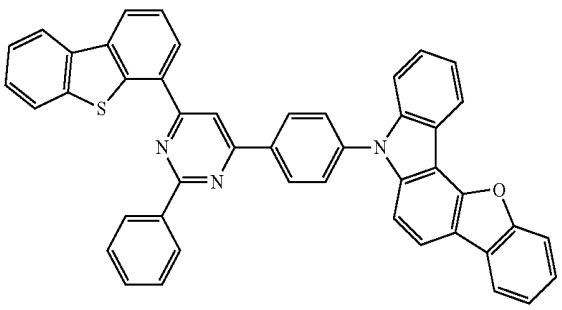

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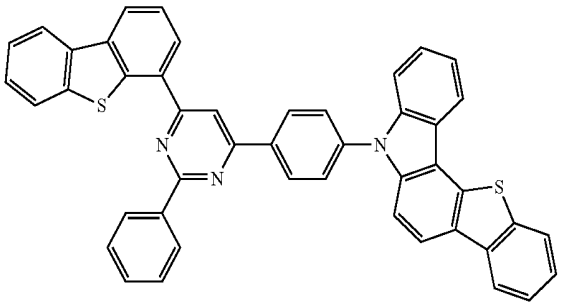

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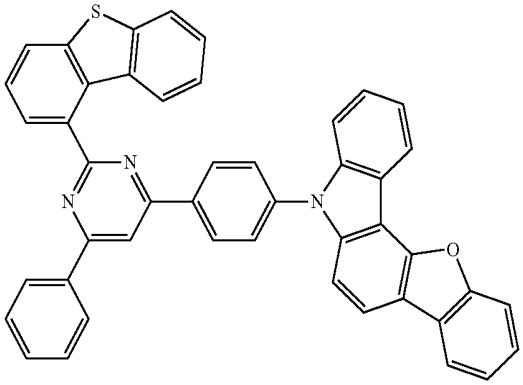

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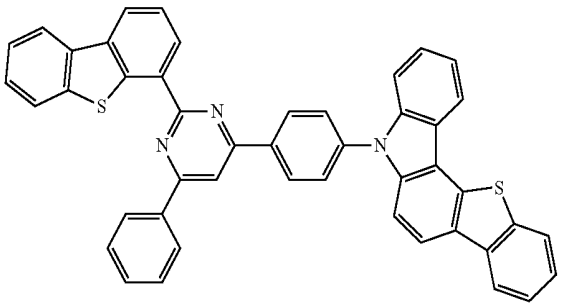

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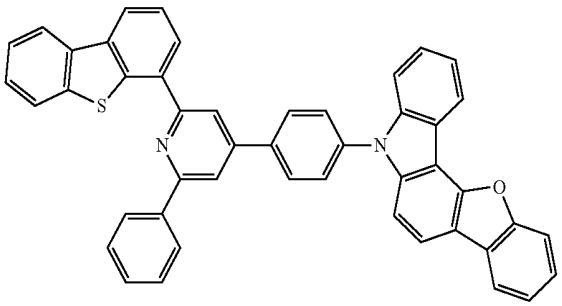

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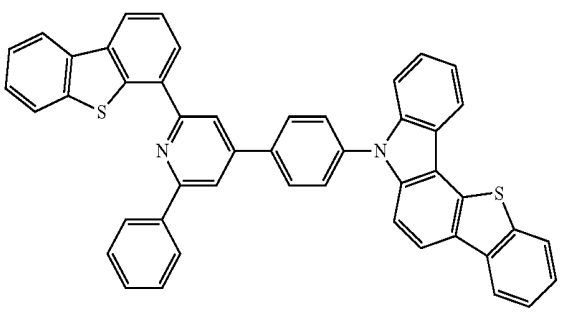

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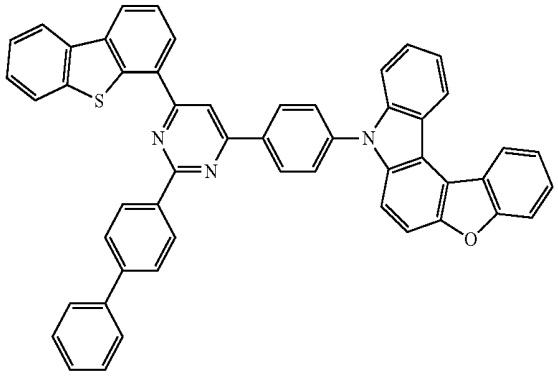

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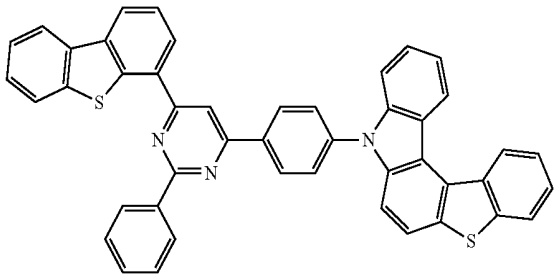

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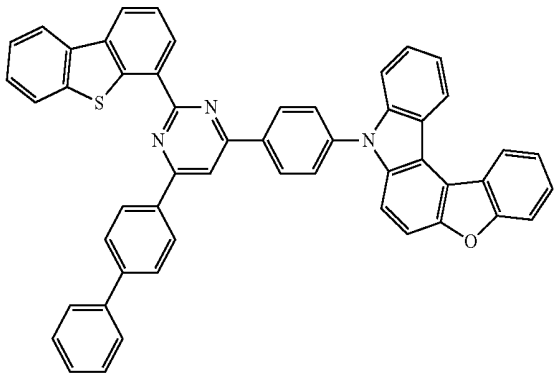

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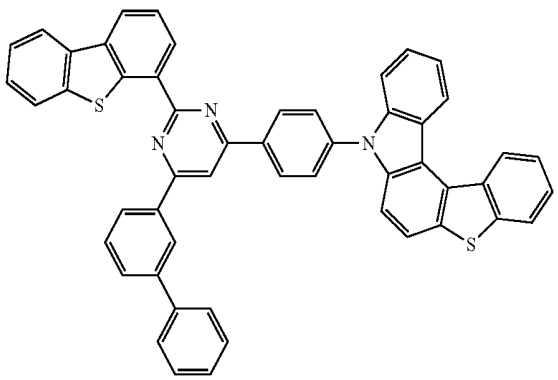

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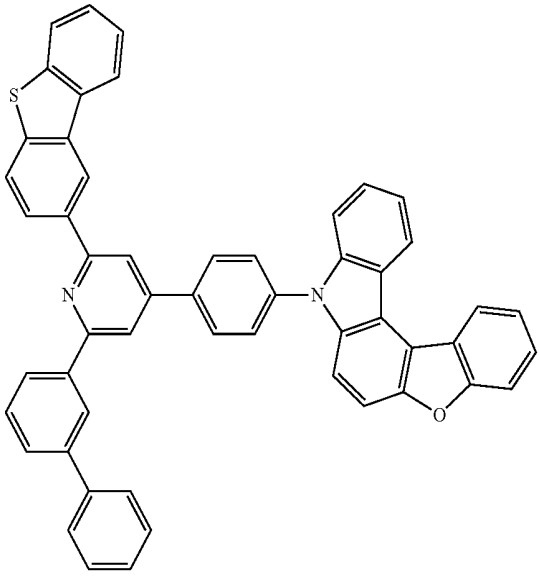

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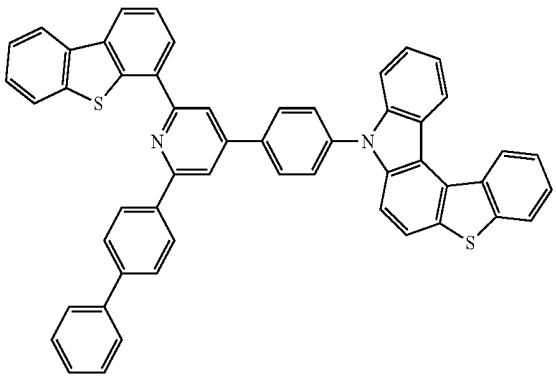

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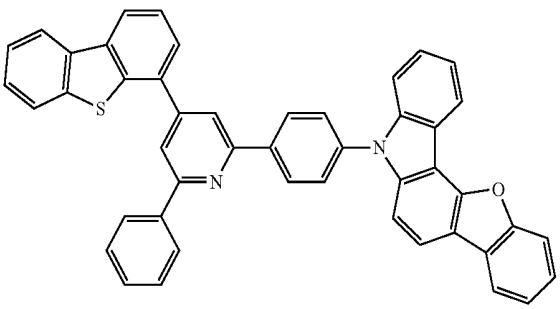

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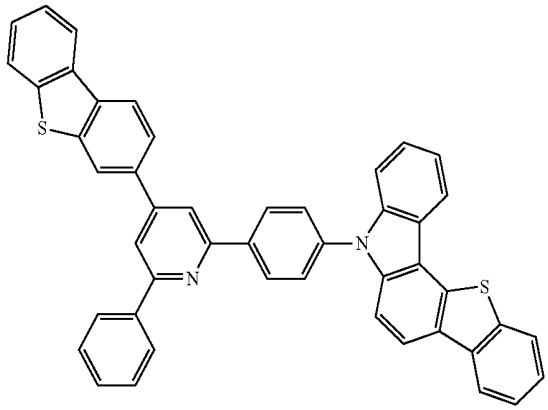

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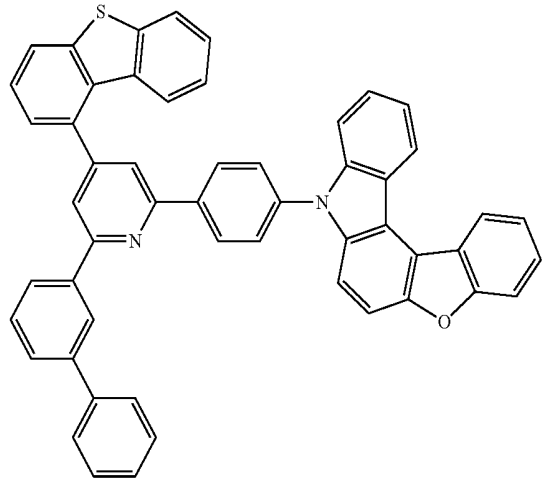

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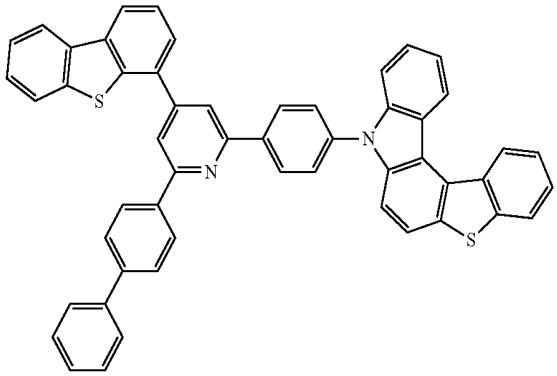

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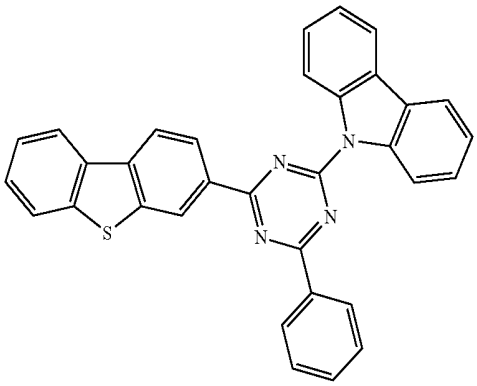

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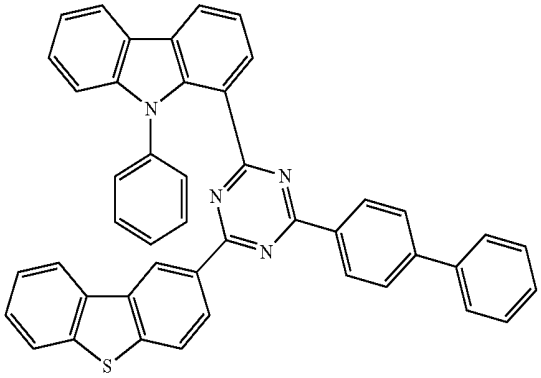

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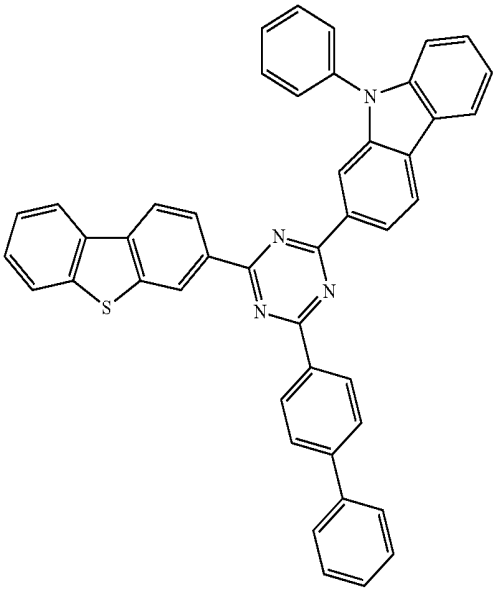

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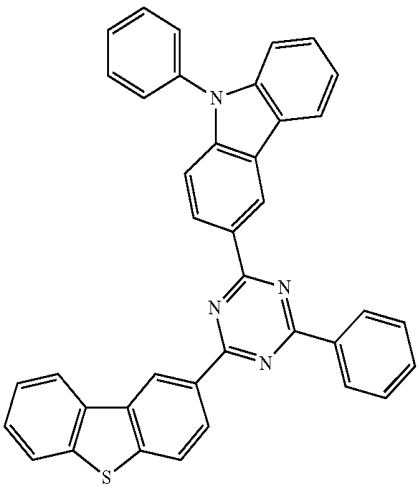

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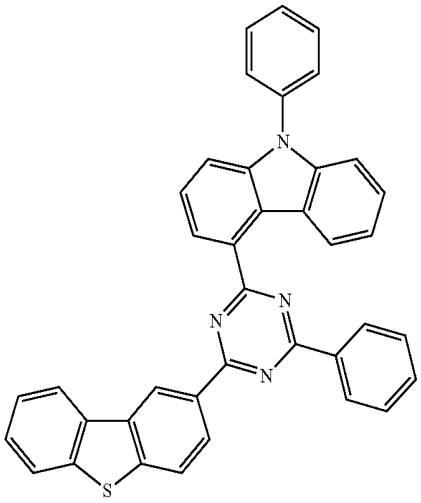

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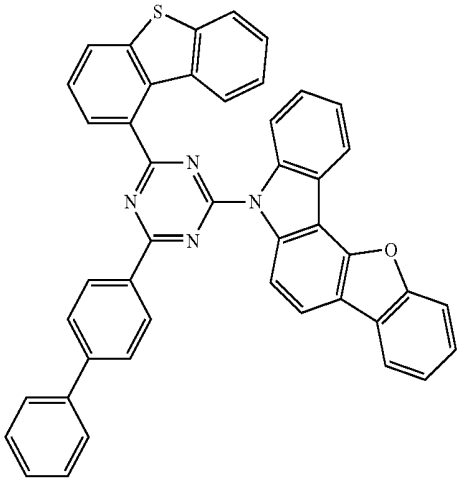

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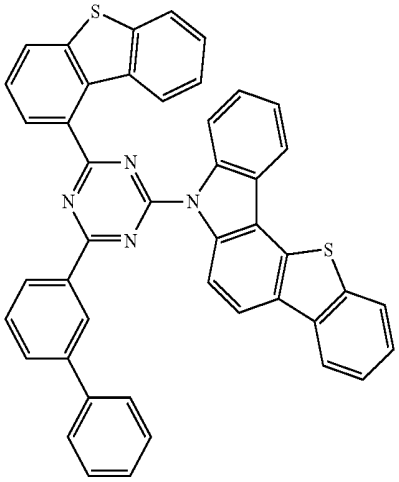

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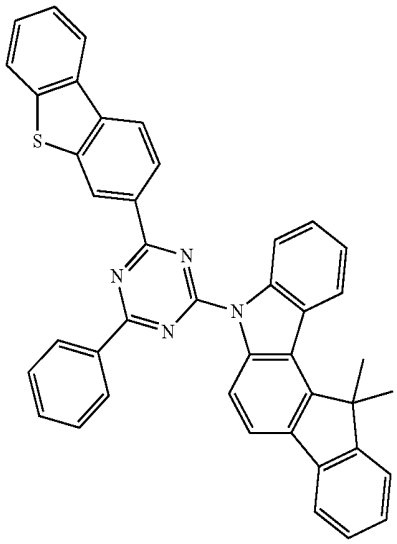

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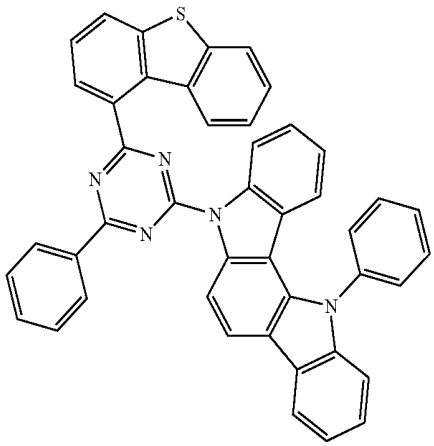

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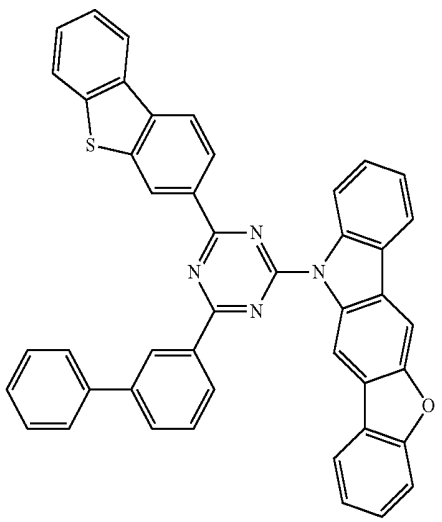

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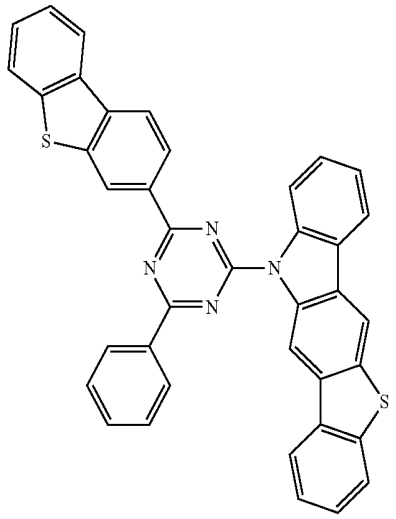

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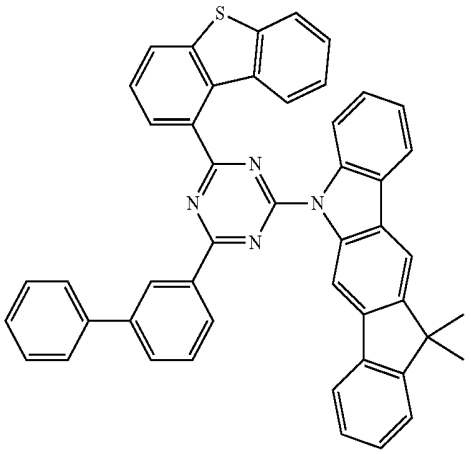

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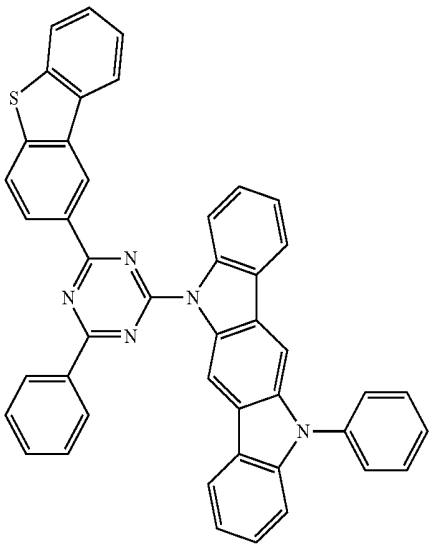

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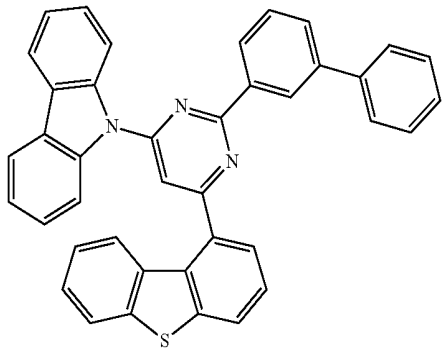

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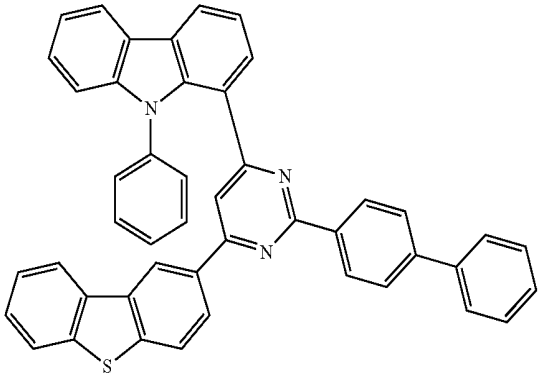

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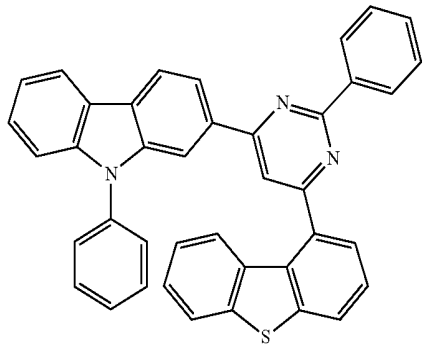

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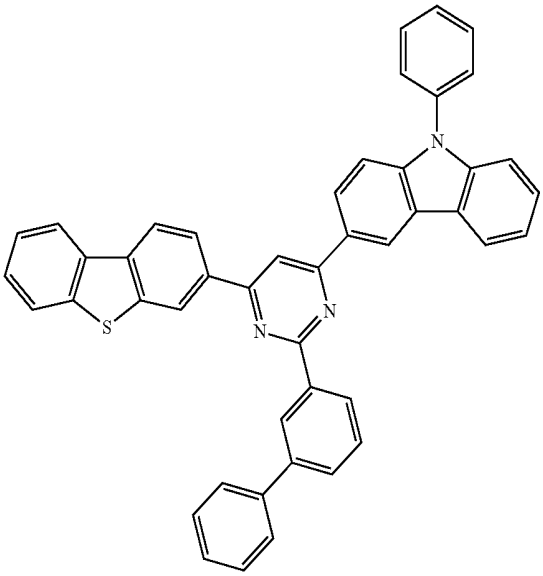

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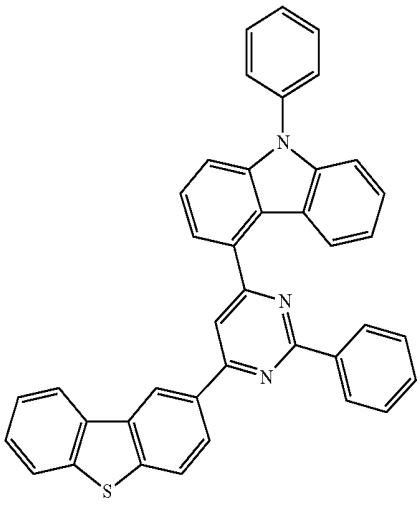

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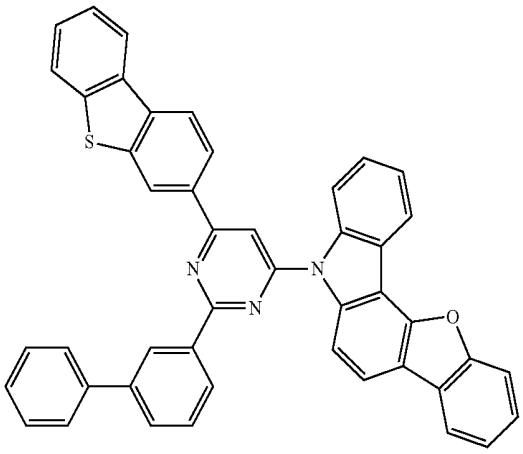

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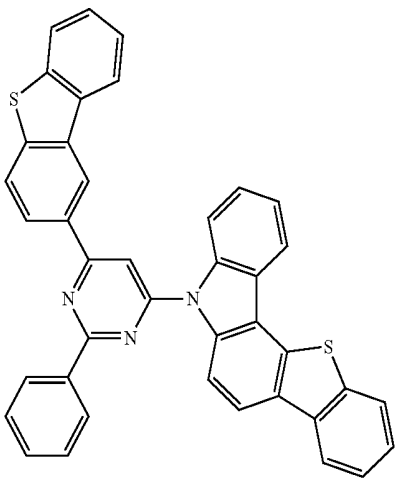

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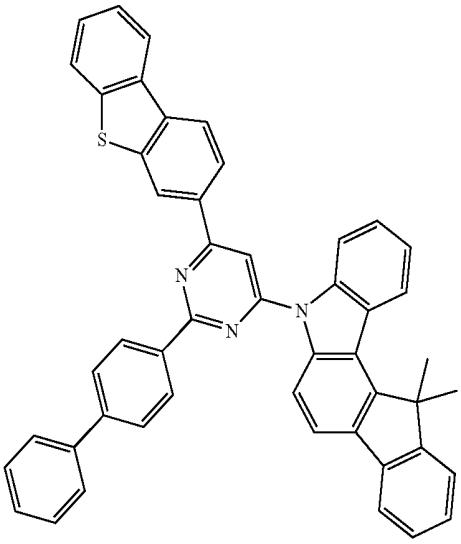

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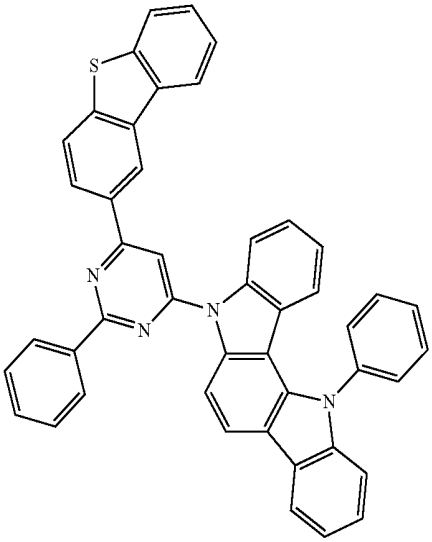

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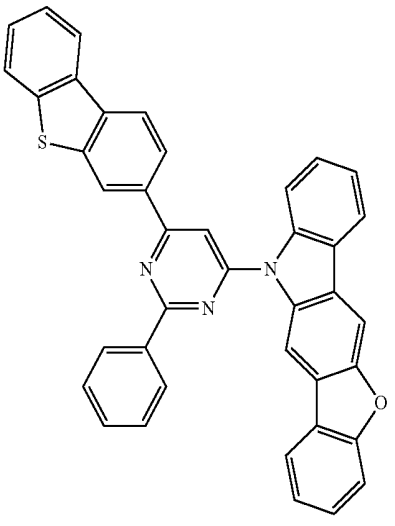

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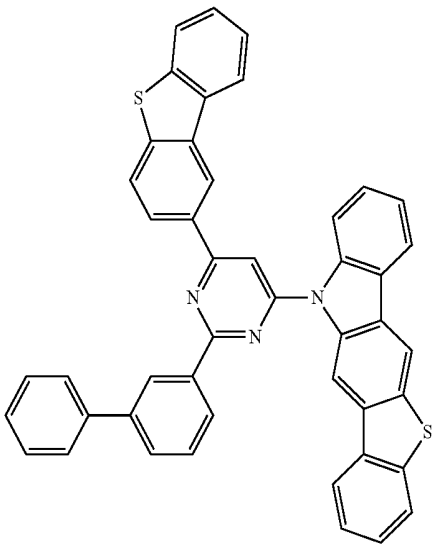

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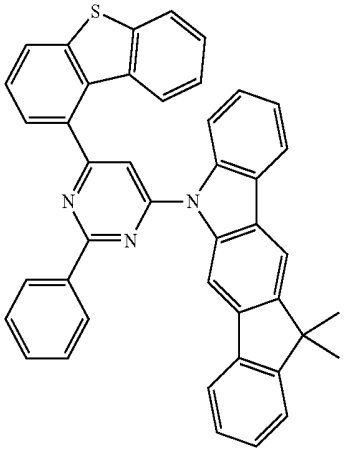

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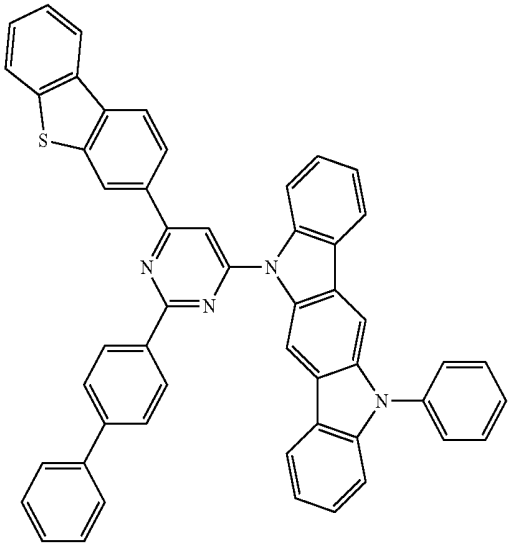

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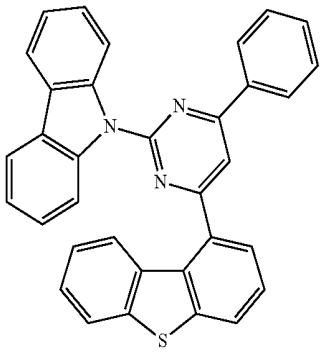

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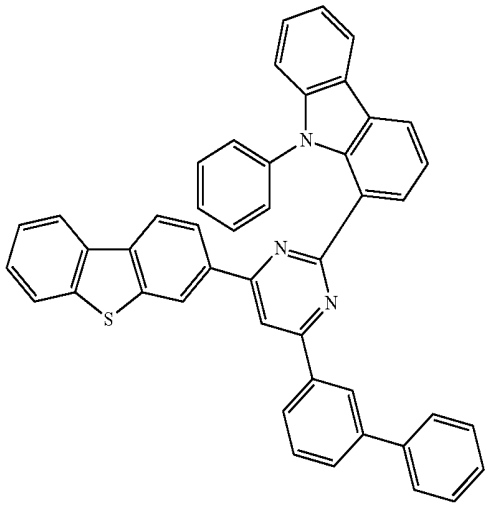

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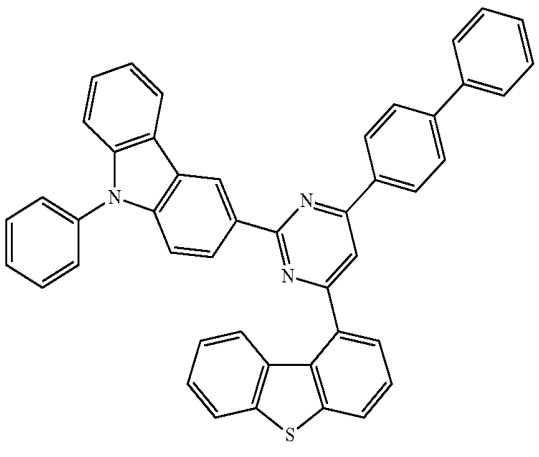

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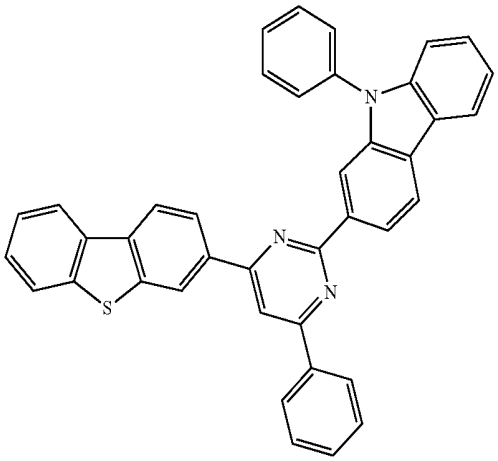

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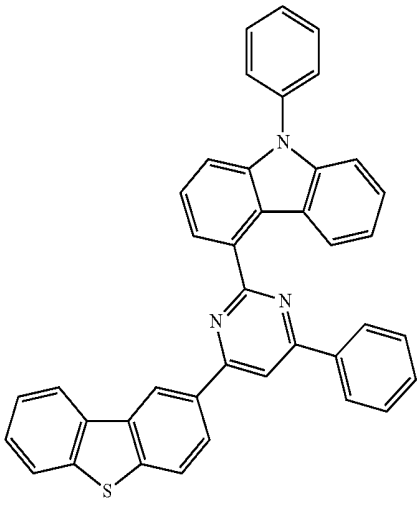

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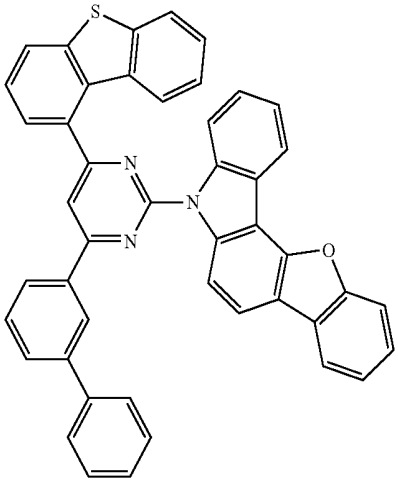

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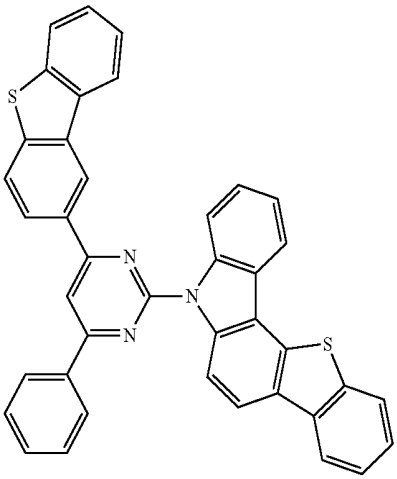

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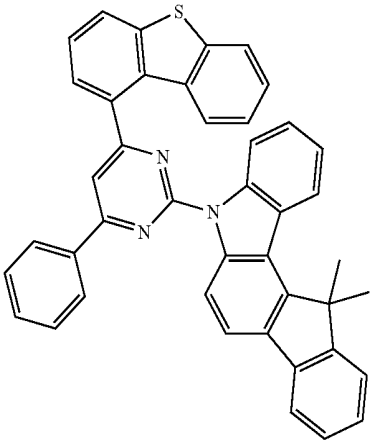

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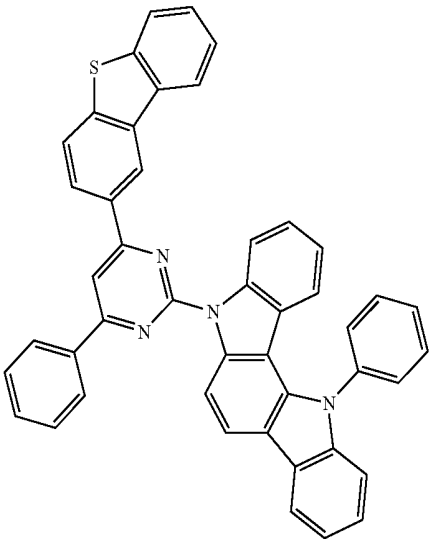

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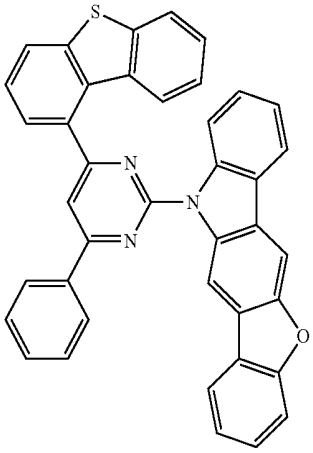

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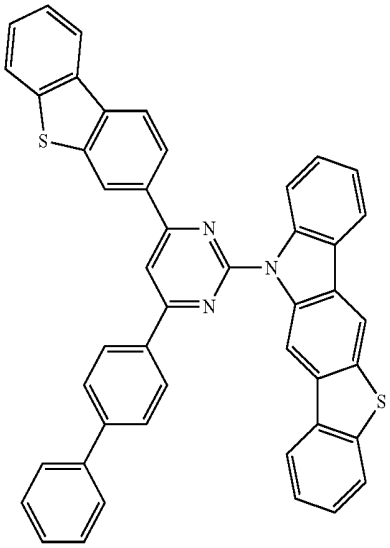

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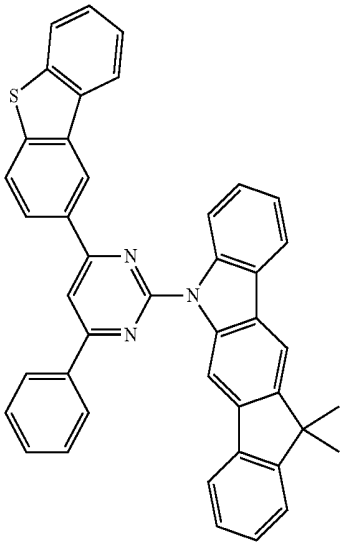

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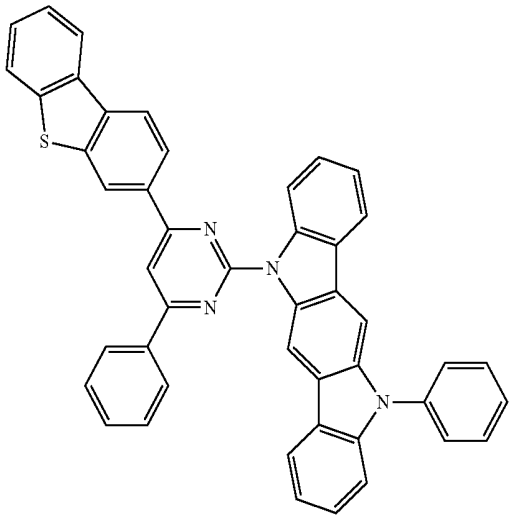

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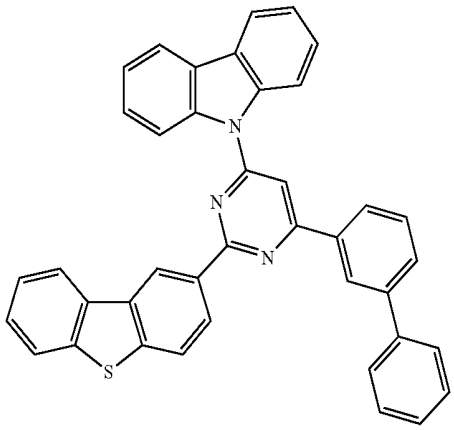

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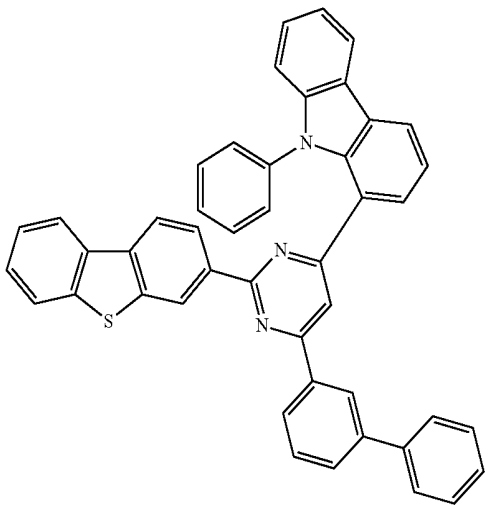

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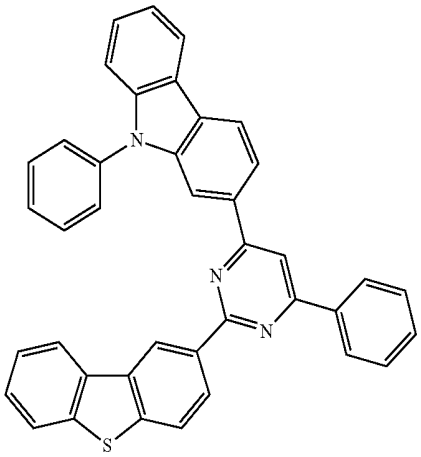

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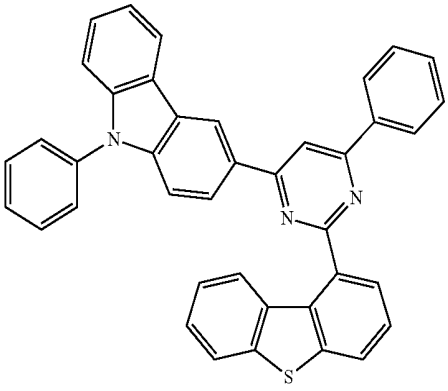

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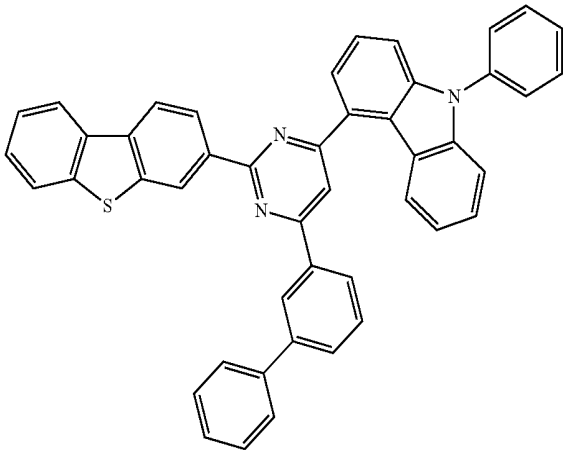

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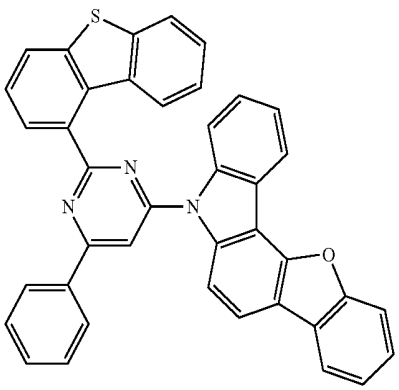

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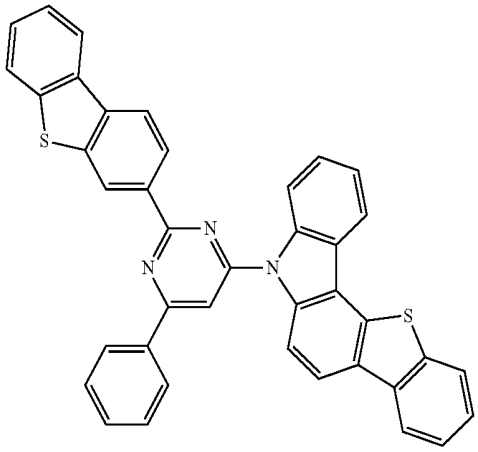

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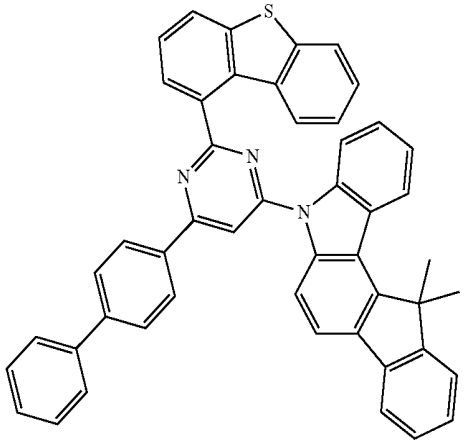

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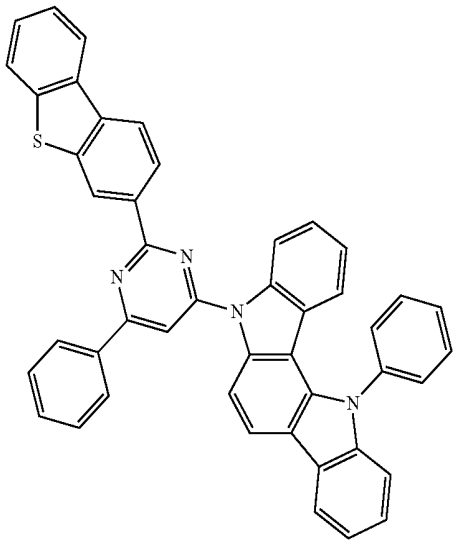

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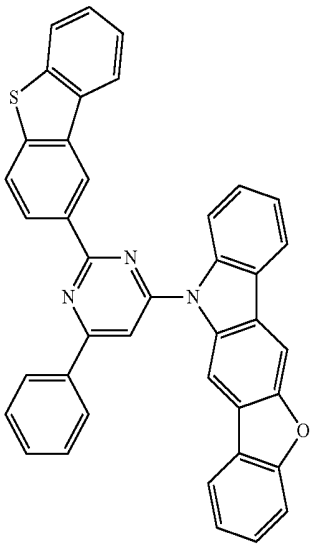

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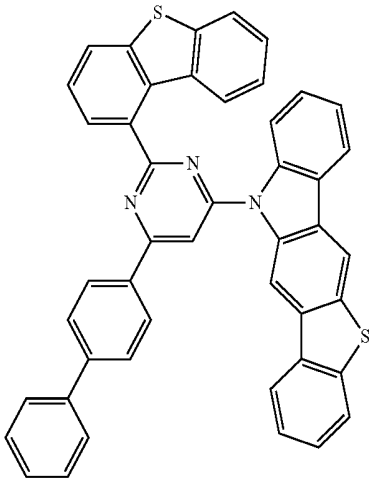

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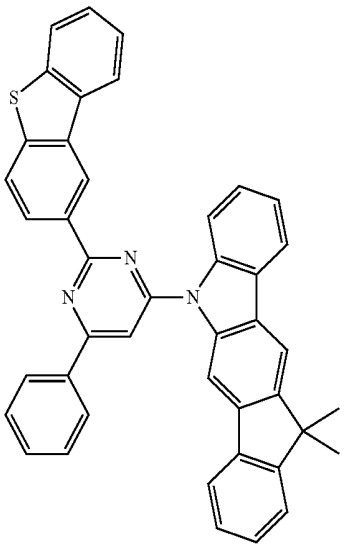

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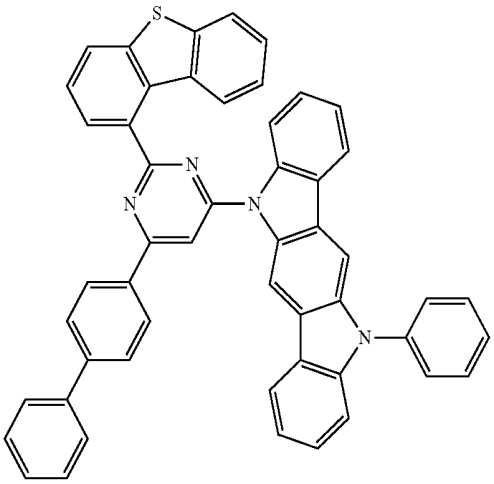

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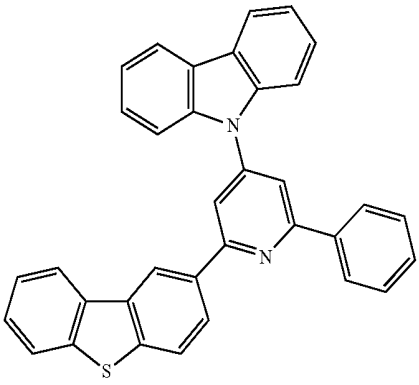

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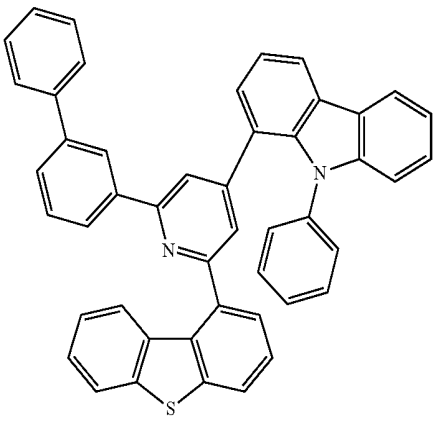

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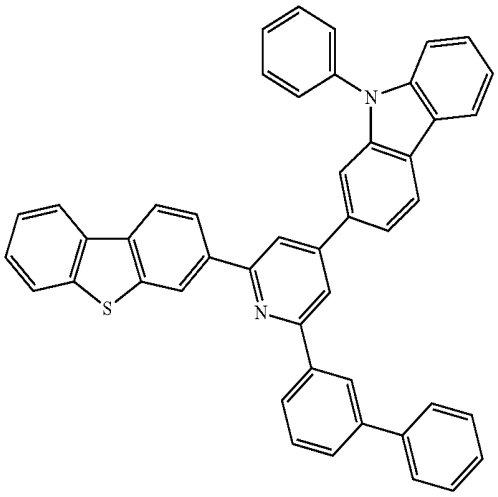

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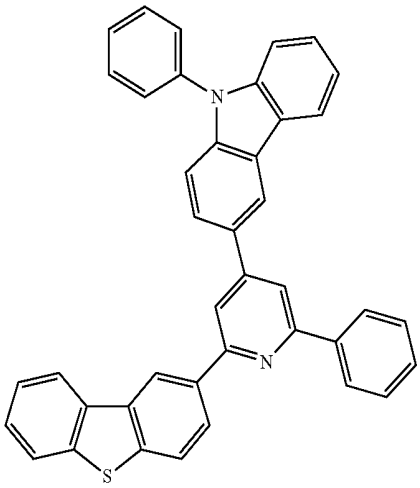

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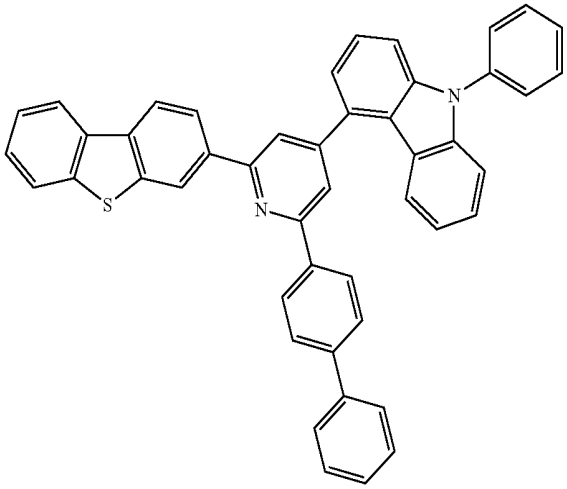

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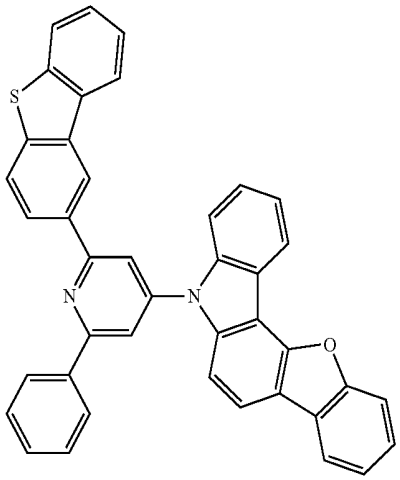

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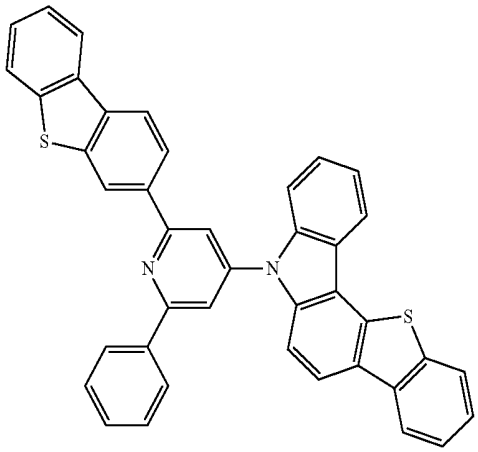

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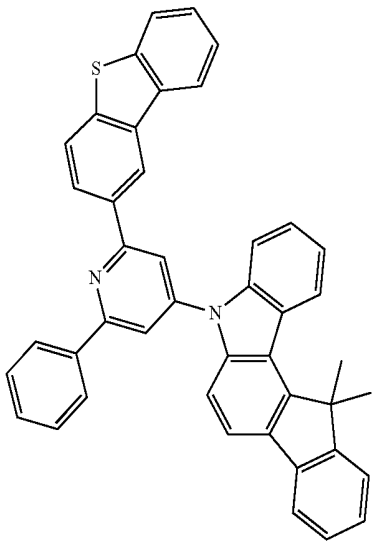

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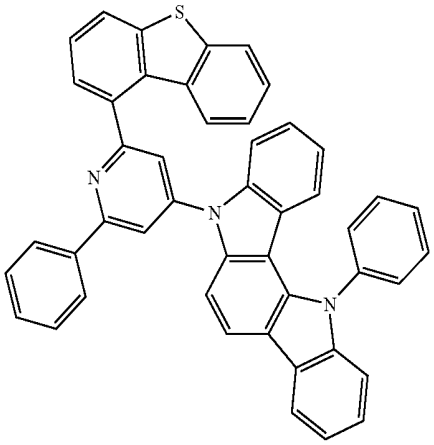

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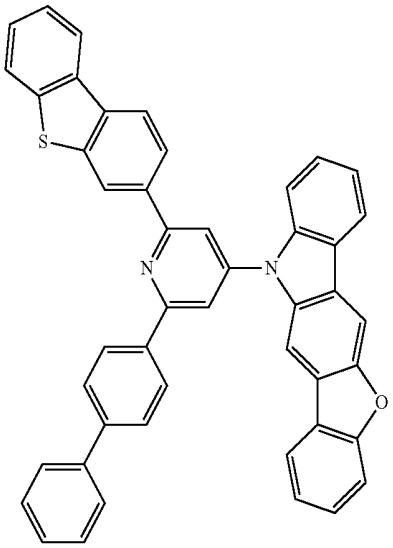

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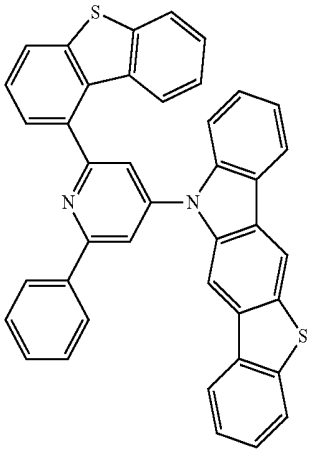

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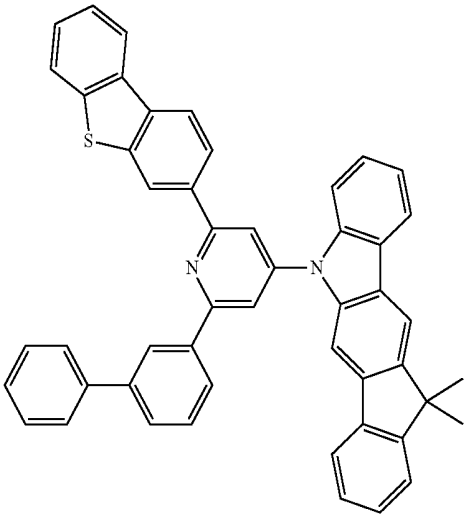

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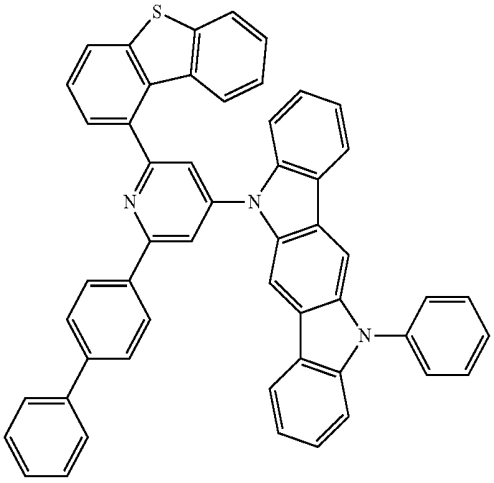

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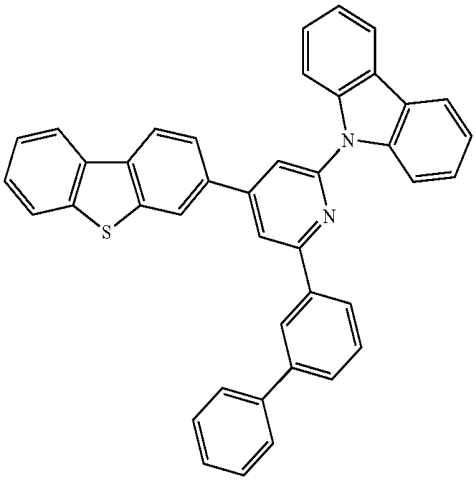

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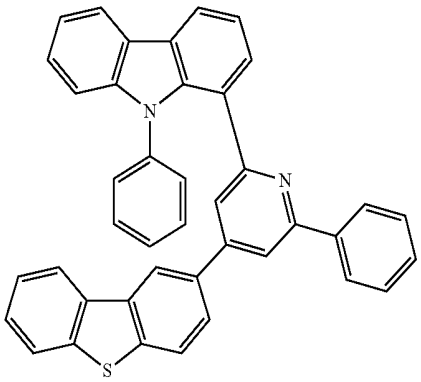

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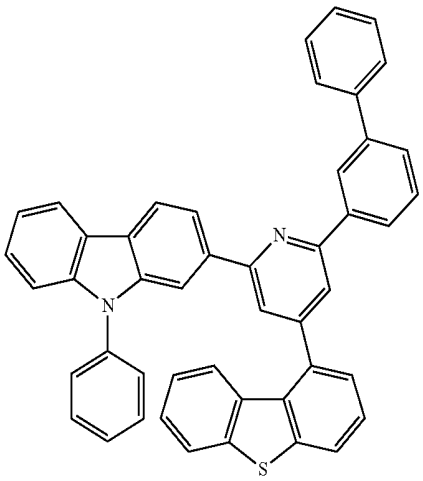

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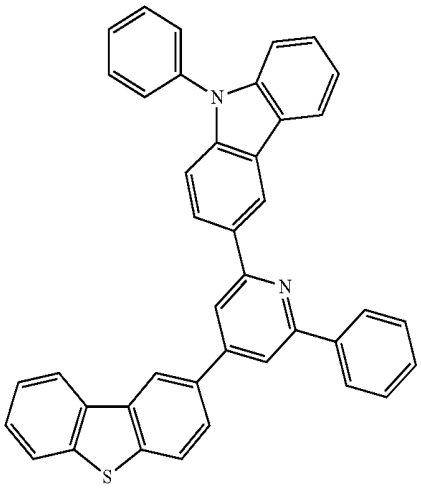

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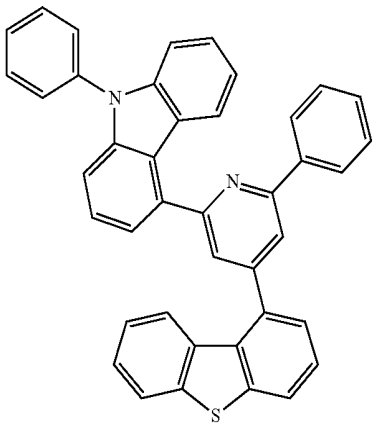

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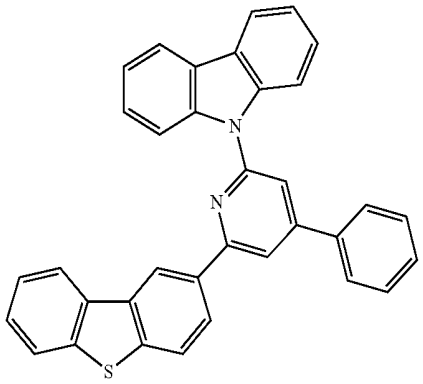

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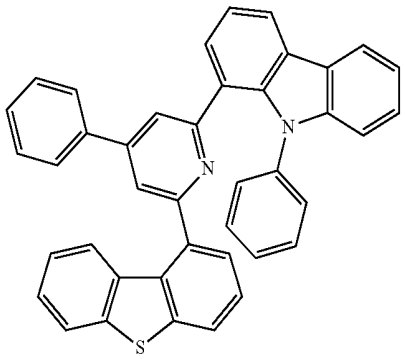

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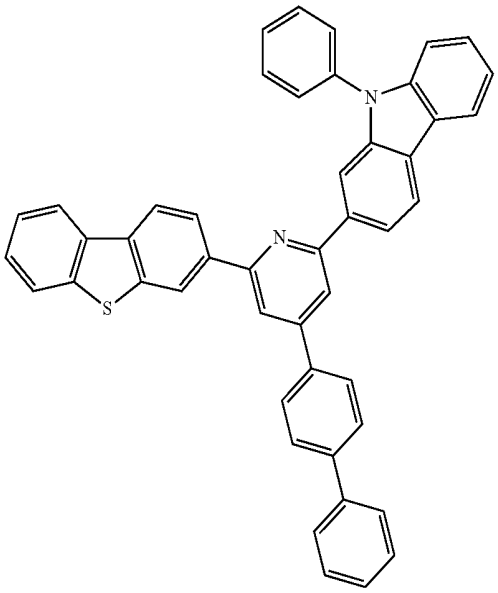

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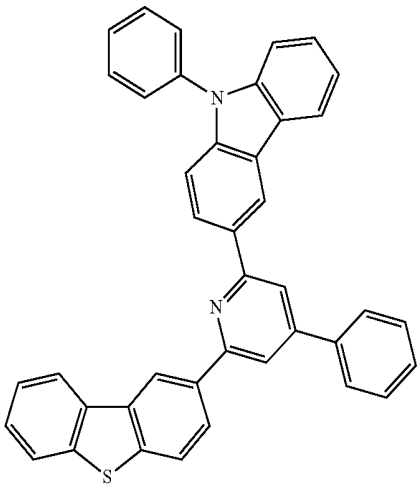

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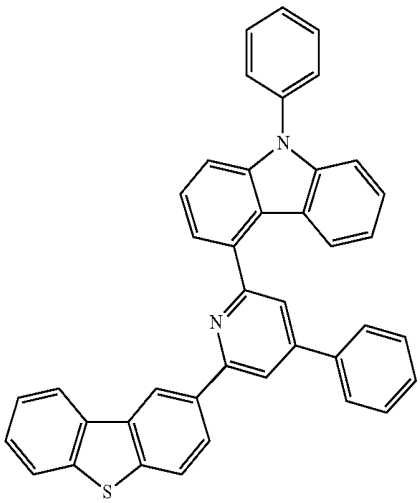

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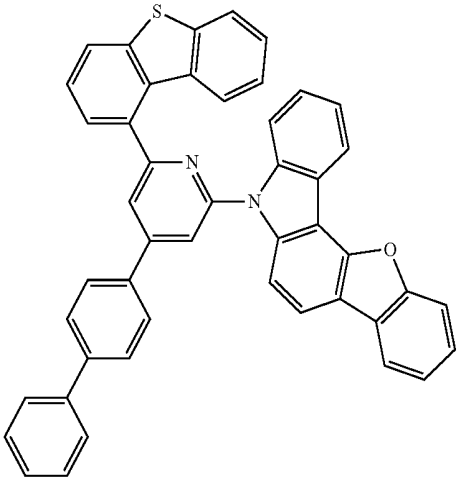

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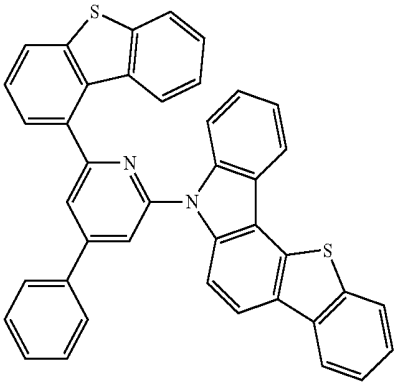

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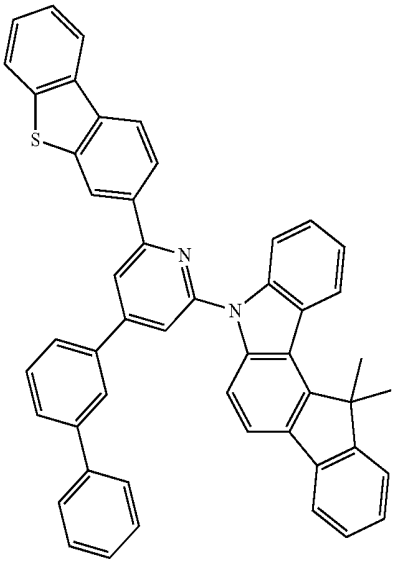

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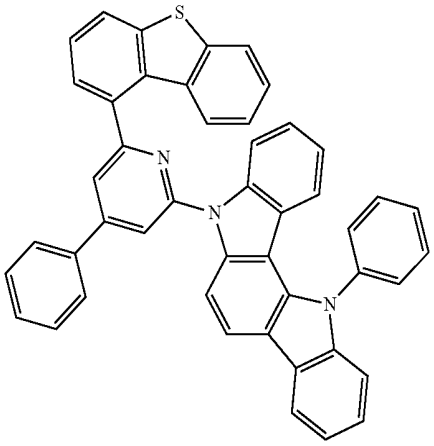

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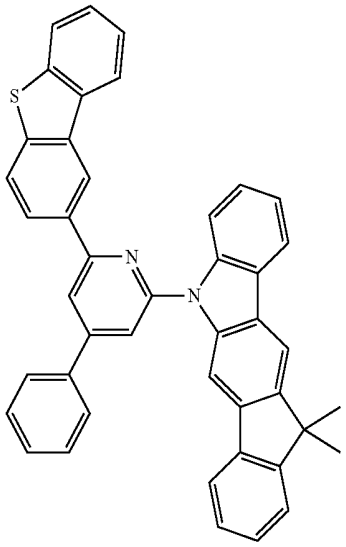

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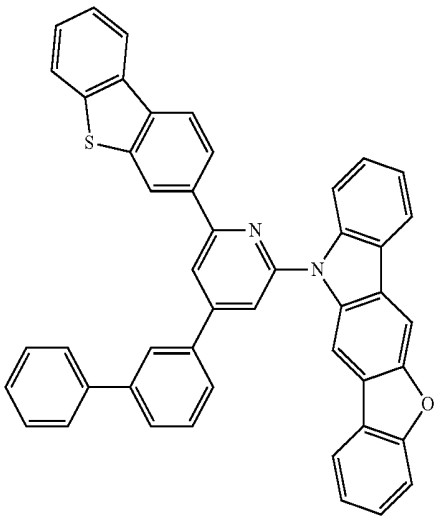

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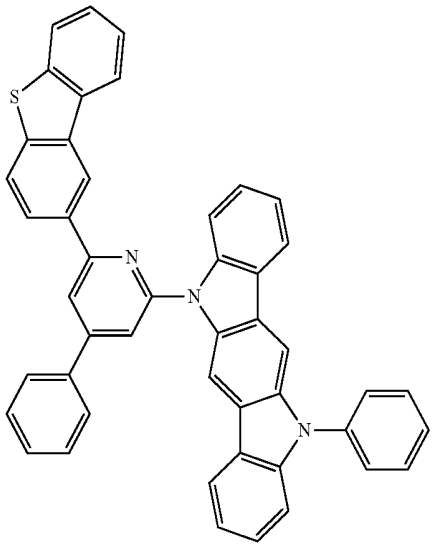

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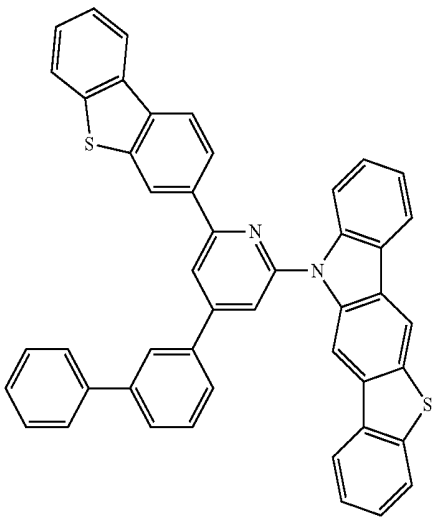

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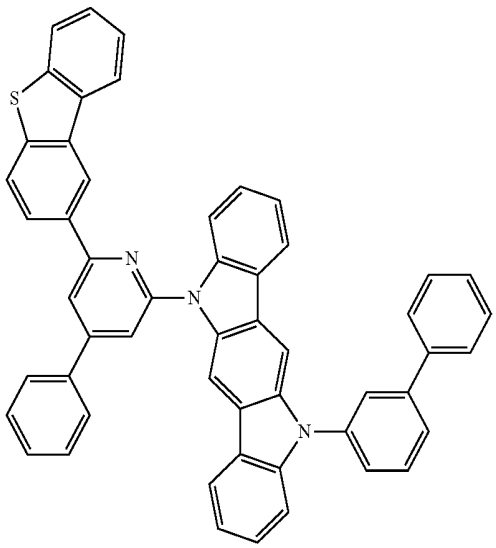

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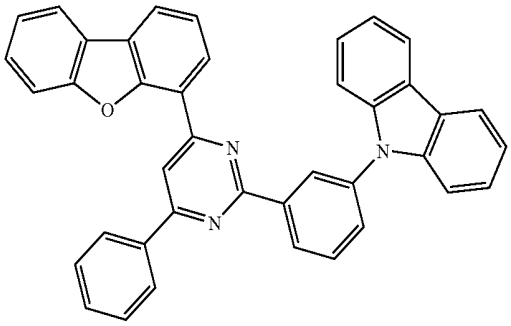

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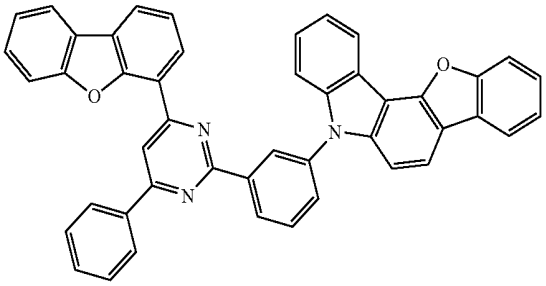

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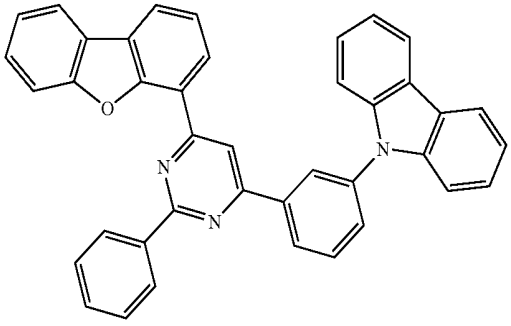

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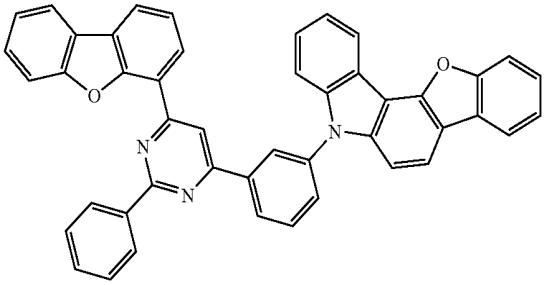

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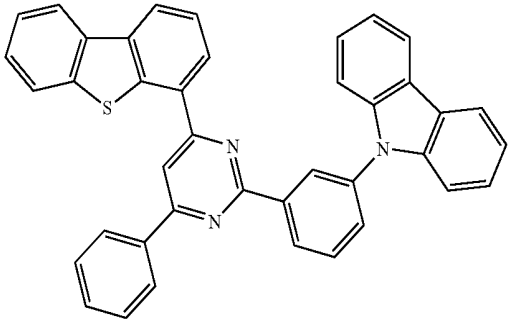

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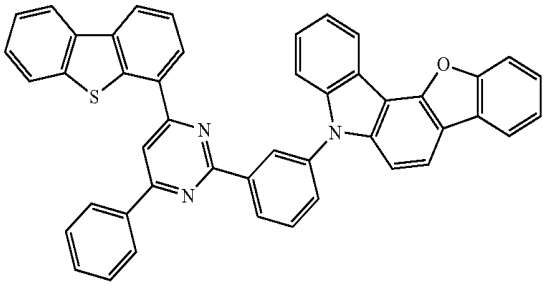

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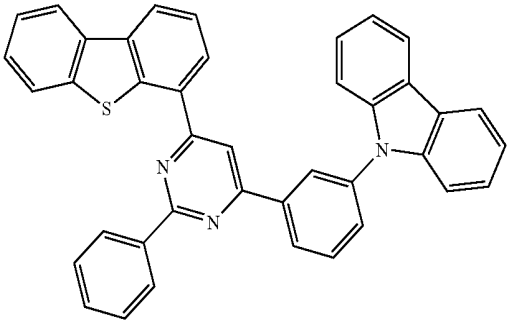

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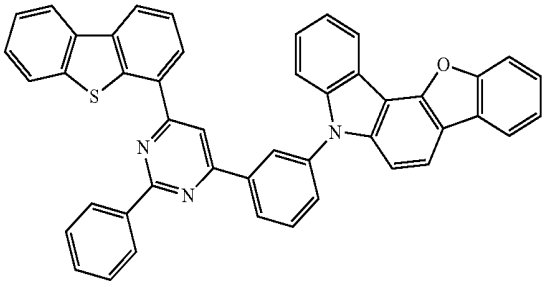

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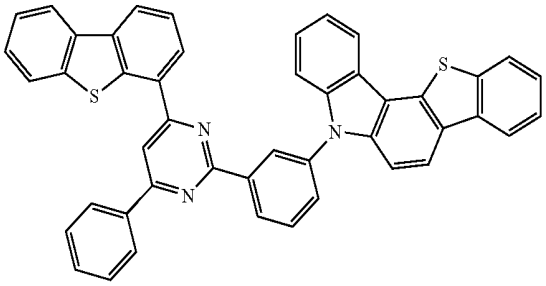

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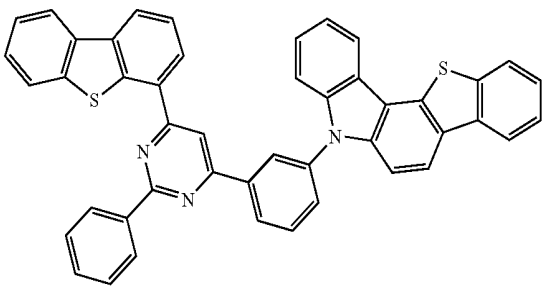

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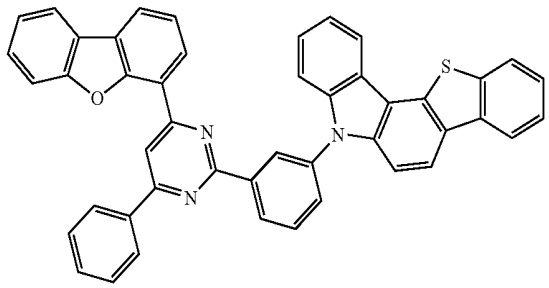

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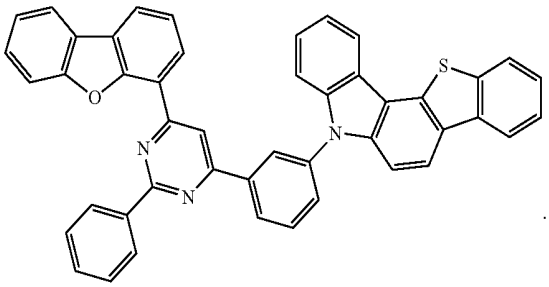
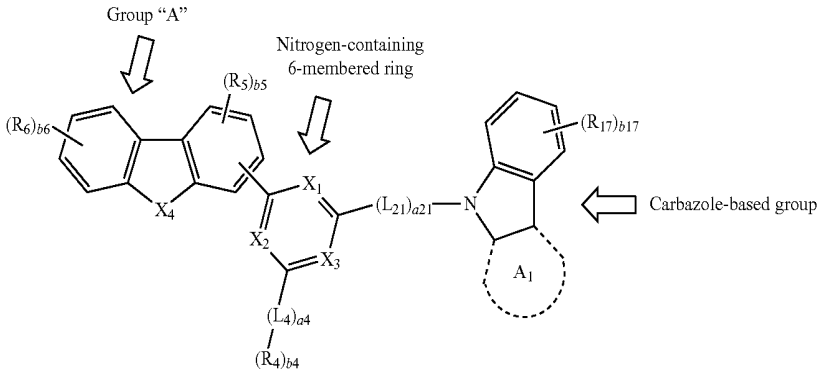


In the condensed-cyclic compound represented by Formula 1A or 1B, R_4 is selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_2-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_2-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_2-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic hetero-condensed polycyclic group.

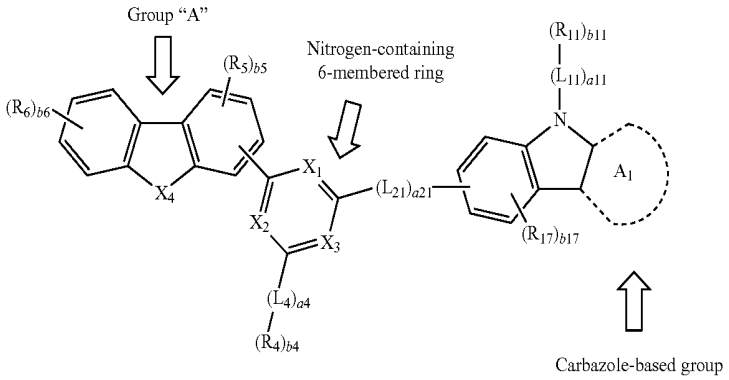
In other words, in Formula 1A and 1B, R_4 necessarily includes a ring structure. As a result, the condensed-cyclic compound represented by Formula 1A or 1B is chemically and structurally stable and may actually have a spherical molecular structure. Accordingly, the condensed-cyclic compound represented by Formula 1A or 1B may have excellent thermal stability, which may increase deposition temperature. As a result, efficiency and lifespan of an organic light-emitting device including the condensed-cyclic compound may be improved to improve formability of the organic light-emitting device during the manufacturing process thereof.

Also, because both group "A" and the "carbazole-based" group in Formulae 1A and 1B are bound to a "nitrogen-containing 6-membered ring" (see Formulae 1A' and 1B'), hole injection and hole transport and electron injection and electron transport may occur thoroughly and Formulae 1A and 1B may each actually have a spherical molecular structure. Accordingly, the condensed-cyclic compound may simultaneously have excellent charge-transporting ability and thermal stability, such that the organic light-emitting device including the condensed-cyclic compound may have increased emission efficiency, reduced driving voltage, and a long lifespan.

Formula 1A'



Formula 1B'



A method of synthesizing the condensed-cyclic compound represented by Formula 1A or 1B may be understood by one of ordinary skill in the art by referring to the embodiments described below.

Accordingly, the condensed-cyclic compound represented by Formula 1A or 1B may be suitable as a material for an organic layer (for example, a host of an EML) in an organic light-emitting device. According to another embodiment, provided is an organic light-emitting device including

a first electrode;

a second electrode; and

an organic layer disposed between the first electrode and the second electrode,

wherein the organic layer includes the EML, which includes at least one condensed-cyclic compound represented by Formula 1A or 1B.

The organic light-emitting device including an organic layer including the condensed-cyclic compound represented by Formula 1A or 1B has low driving voltage, high efficiency, high brightness, and a long lifespan.

The condensed-cyclic compound represented by Formula 1A or 1B may be used between a pair of electrodes in the organic light-emitting device. For example, the condensed-cyclic compound may be included in at least one of an EML, a hole-transport region disposed between the first electrode and the EML (for example, the hole transport region may include at least one of a hole-injecting layer (HIL), a hole-transporting layer (HTL), and an electron-blocking layer (EBL)), and an electron-transport region disposed between the EML and the second electrode (for example, the electron transport region may include at least one of a hole-blocking layer (HBL), an electron-transporting layer (ETL), and an electron-injecting layer (EIL)). For example, the condensed-cyclic compound represented by Formula 1A or 1B may be included in the EML. In this regard, the EML further includes a dopant and the condensed-cyclic compound included in the EML may act as a host. The EML may be a green EML emitting green light and the dopant may be a phosphorescent dopant.

As used herein, the term "(the organic layer) includes at least one condensed-cyclic compound" may be understood as "(the organic layer) may include at least one condensed-cyclic compound belonging to the group of Formula 1A or 1B or two different condensed-cyclic compounds belonging to the group of Formula 1A or 1B".

For example, the organic layer may only include Compound 1 as the condensed-cyclic compound. In this regard, Compound 1 may be situated in the EML of the organic light-emitting device. Alternatively, the organic layer may include Compound 1 and Compound 2 as the condensed-cyclic compound. In this regard, Compound 1 and Compound 2 may be present on the same layer (for example, Compound 1 and Compound 2 may all be present on the EML) or on different layers.

The organic layer includes

i) a hole transport region that is disposed between the first electrode and the EML and includes at least one of an HIL, an HTL, a buffer layer, and an EBL, and

ii) an electron transport region that is disposed between the EML and the second electrode and includes at least one layer selected from a HBL, an ETL, and an EIL.

The expression "organic layer", as used herein refers to a single layer and/or a plurality of layers disposed between the first and second electrodes of an organic light-emitting device. A material of the "organic layer" is not limited to an organic material and may include an organic metal complex including a metal.

The FIGURE is a schematic view of an organic light-emitting device **10** according to an embodiment. Hereinafter, a structure and a method of manufacturing the organic light-emitting device according to an embodiment will be described with reference to the FIGURE. The organic light-emitting device **10** includes a first electrode **11**, an organic layer **15**, and a second electrode **19**, which are sequentially stacked in the stated order.

A substrate may be additionally disposed under the first electrode **11** or on the second electrode **19**. The substrate may be a conventional glass substrate or a transparent plastic substrate, each with excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water repellency.

The first electrode **11** may be formed by depositing or sputtering a material for forming the first electrode **11** on the substrate. When the first electrode **11** is an anode, the material for the first electrode **11** may be selected from materials with a high work function for an easy hole injection. The first electrode **11** may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. The material for the first electrode **110** may be selected from indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), and zinc oxide (ZnO). Alternatively, a metal such as magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), and magnesium-silver (Mg—Ag).

The first electrode **11** may have a single-layer structure or a multi-layer structure including two or more layers.

The organic layer **15** is disposed on the first electrode **11**.

The organic layer **15** may include a hole transport region; an EML; and an electron transport region.

The hole transport region may be disposed between the first electrode **1** and the EML.

The hole transport region may include at least one of the HIL, HTL, EBL, and buffer layer.

The hole transport region may only include the HIL or HTL. Alternatively, the hole transport region may have an HIL/HTL structure or an HIL/HTL/EBL structure, wherein layers of each structure are sequentially stacked on the first electrode **11** in this stated order, but it is not limited thereto.

When the hole transport region includes an HIL, the HIL may be formed on the first electrode **11** by using various methods, such as vacuum deposition, spin coating, casting, a Langmuir-Blodgett (LB) method, or the like.

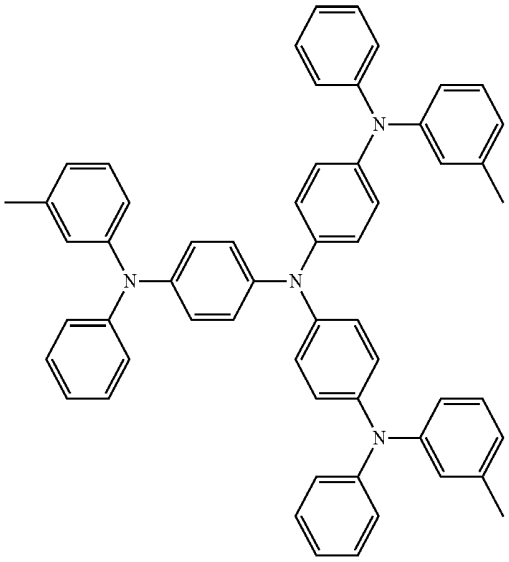
When an HIL is formed by vacuum deposition, for example, the vacuum deposition may be performed at a deposition temperature of about 100 to about 500° C., at a vacuum degree of about 10^{-8} to about 10^{-3} torr, and at a deposition rate of about 0.01 Angstrom per second (Å/sec) to about 100 Å/sec in consideration of a compound for an HIL to be deposited, and the structure of an HIL to be formed, but the conditions are not limited thereto.

When an HIL is formed by spin coating, the spin coating may be performed at a coating rate of about 2,000 revolutions per minute (rpm) to about 5,000 rpm, and at a temperature of about 80° C. to 200° C. for removing a solvent after the spin coating, in consideration of a compound for an HIL to be deposited, and the structure of an HIL to be formed, but the conditions are not limited thereto.

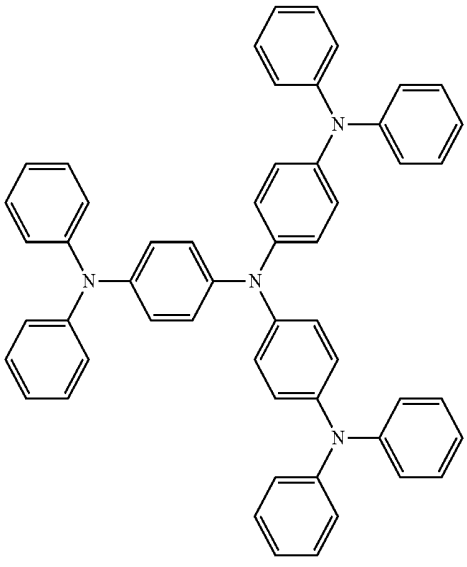
The conditions for forming the HTL and EBL may be inferred based on the conditions for forming the HIL.

The hole transport region may include at least one compound selected from m-MTDATA, TDATA, 2-TNATA, NPB, β-NPB, TPD, Spiro-TPD, Spiro-NPB, methylated NPB, TAPC, HMTPD, 4,4',4"-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic

acid (Pani/DBSA), poly(3,4-ethylenedioxythiophene)/poly (4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonic acid (Pani/CSA), (polyaniline)/poly(4-styrenesulfonate) (PANI/PSS), a compound represented by Formula 201 below, and a compound represented by Formula 202 below:



m-MTDATA



TDATA

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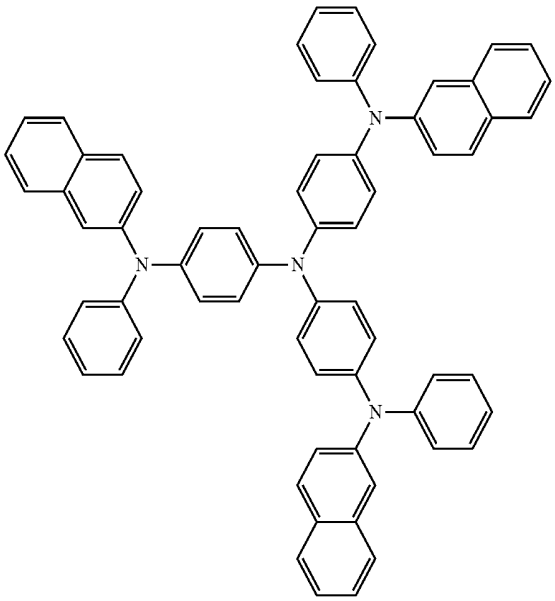
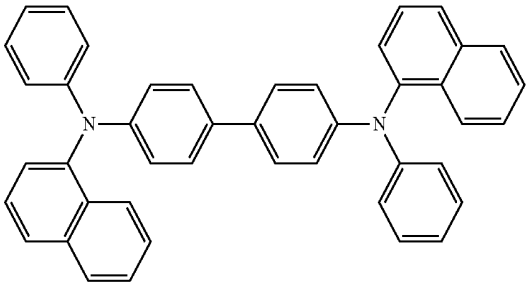
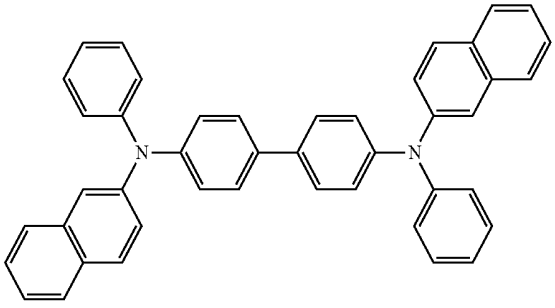


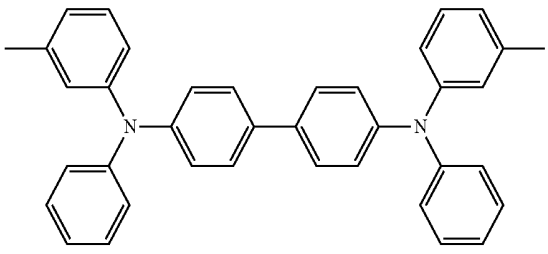
2-TNATA



NPB



β-NPB



TPD

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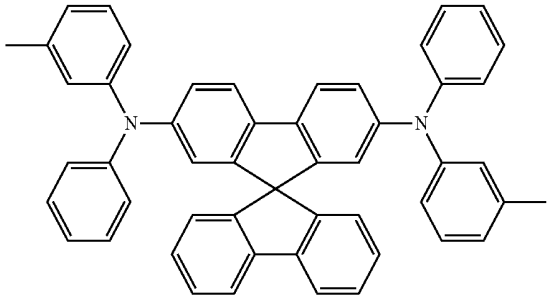
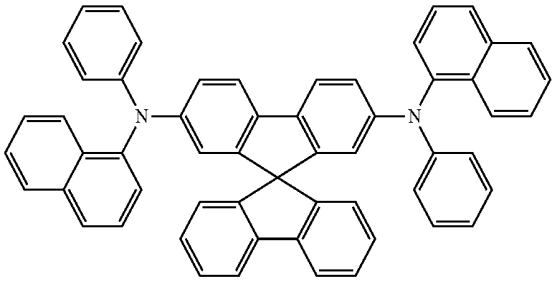
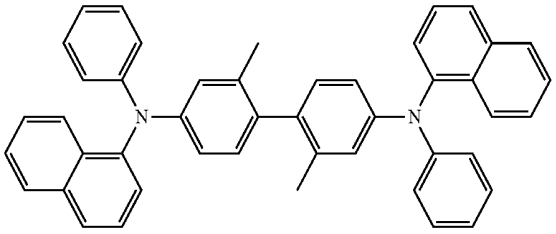


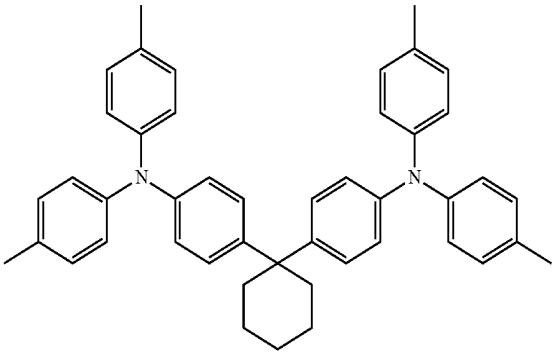
Spiro-TPD



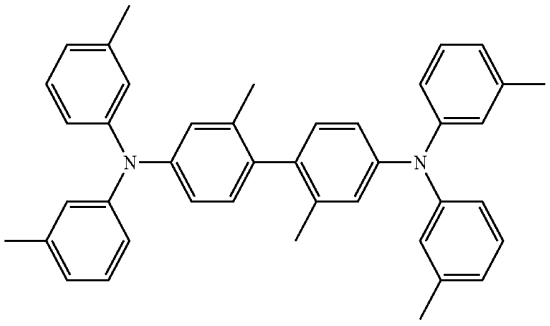
Spiro-NPB



methylated NPB



TAPC



HMTPD

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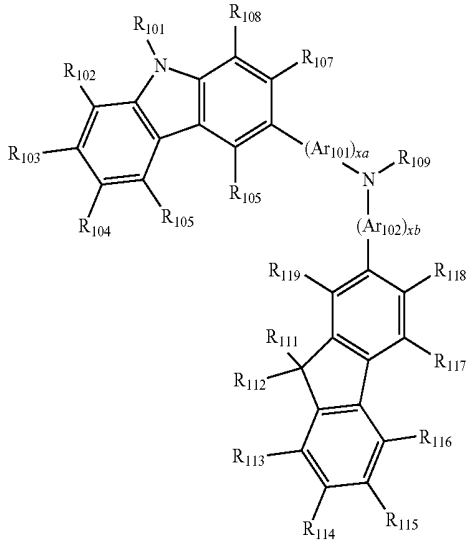
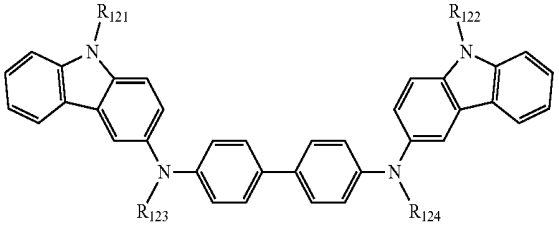
Formula 201



Formula 202



In Formula 201, Ar_{101} and Ar_{102} may be each independently selected from:

a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an acenaphthylene group, a fluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, and a pentacenylene group; and

a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an acenaphthylene group, a fluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, and a pentacenylene group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic hetero-condensed polycyclic group.

In Formula 201, xa and xb may be each independently integers of 0 to 5, or 0, 1, or 2. For example, xa may be 1 and xb may be 0, but they are not limited thereto.

In Formulae 201 and 202, R_{101} to R_{108}, R_{111} to R_{119}, and R_{121} to R_{124} may be each independently selected from:

a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{10} alkyl group (for example, a methyl group, an ethyl group, a propyl group, a butyl group, a pentyl group, and a hexyl group) and a C_1-C_{10} alkoxy group (for example, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, and a pentoxy group);

a C_1-C_{10} alkyl group and a C_1-C_{10} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, and a phosphoric acid group or a salt thereof;

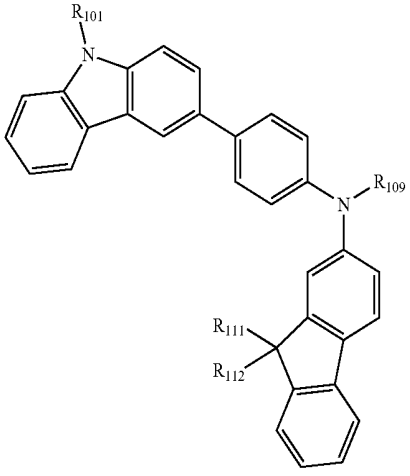
a phenyl group, a naphthyl group, an anthracenyl group, a fluorenyl group, and a pyrenyl group; and

a phenyl group, a naphthyl group, an anthracenyl group, a fluorenyl group, and a pyrenyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{10} alkyl group, and a C_1-C_{10} alkoxy group, but they are not limited thereto.

In Formula 201, R_{109} may be any one of a phenyl group, a naphthyl group, an anthracenyl group and a pyridinyl group; a phenyl group, a naphthyl group, an anthracenyl group, and a pyridinyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group.

According to an embodiment, the compound represented by Formula 201 may be represented by Formula 201A, but it is not limited thereto:

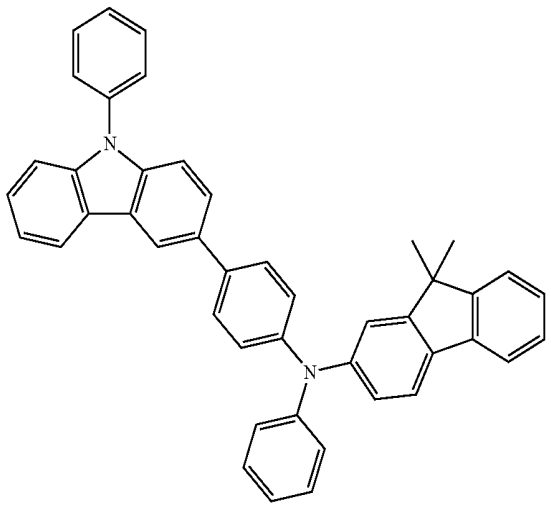
Formula 201A



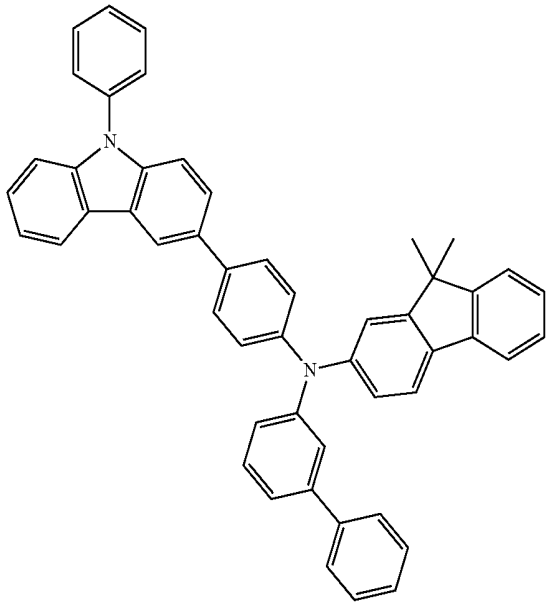
In Formula 201A, detailed descriptions of R_{101}, R_{111}, R_{112}, and R_{109} may be the same as described herein.

For example, the compound represented by Formula 201 and the compound represented by Formula 202 may include Compounds HT1 to HT20, but the compound is not limited thereto:

HT1



HT2



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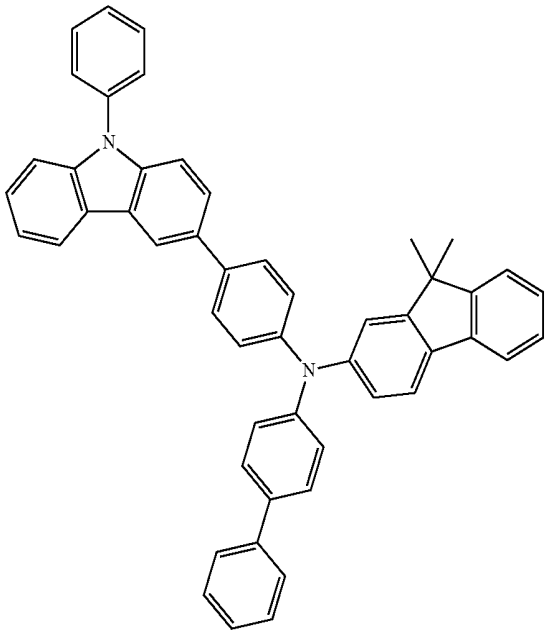
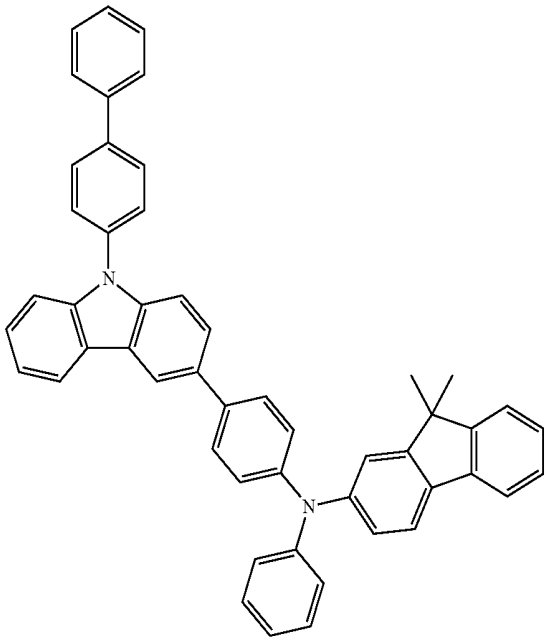
HT3



HT4



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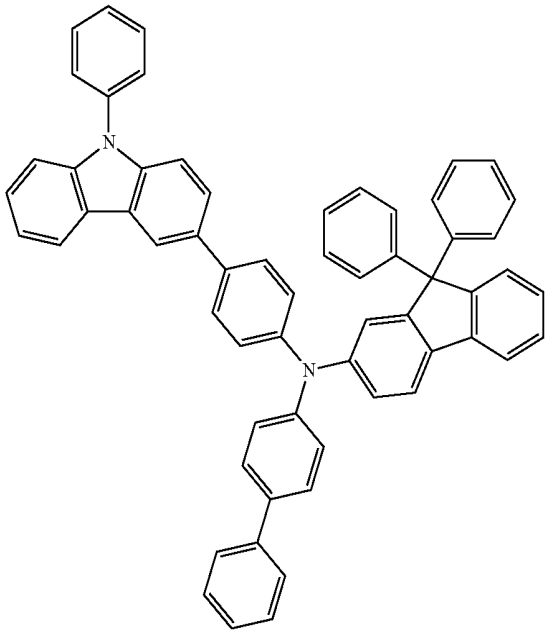
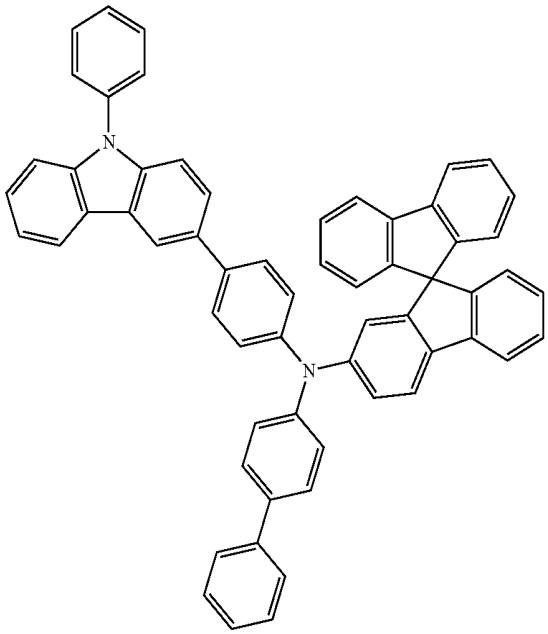
HT5



HT6



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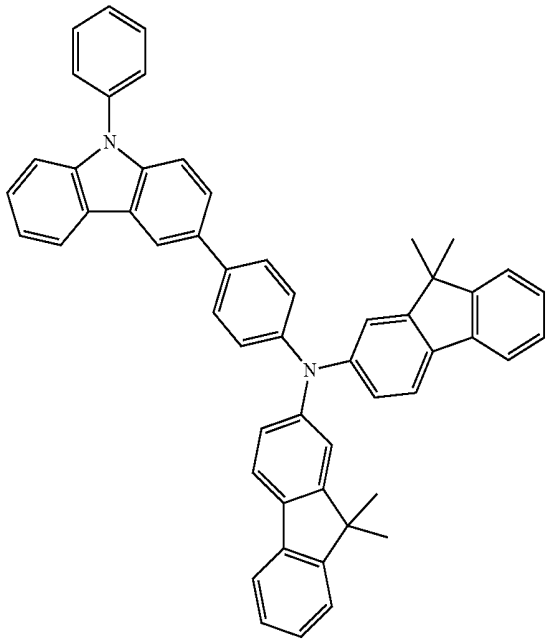
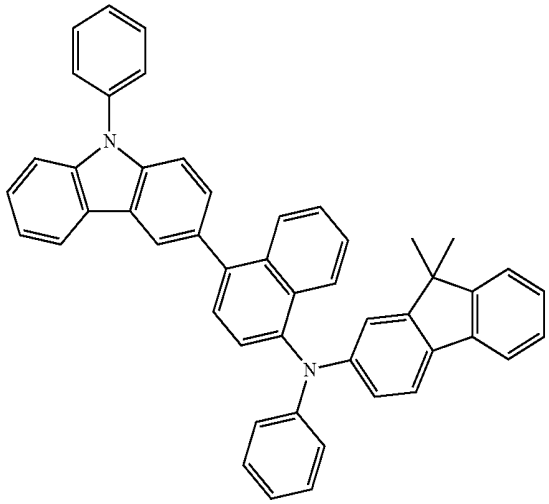
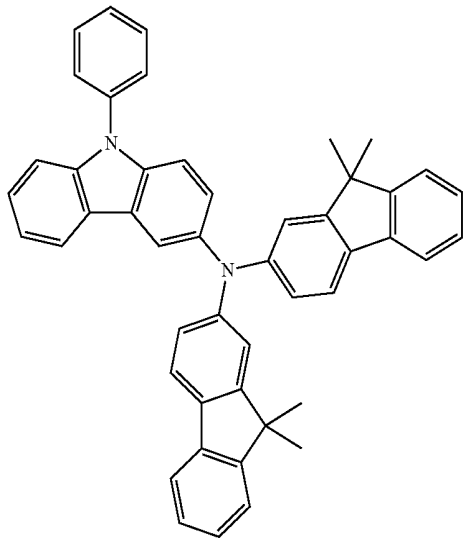
HT7



HT8



HT9



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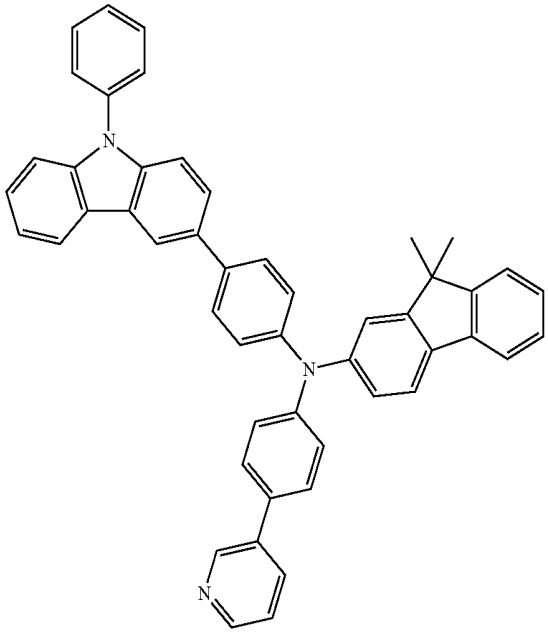

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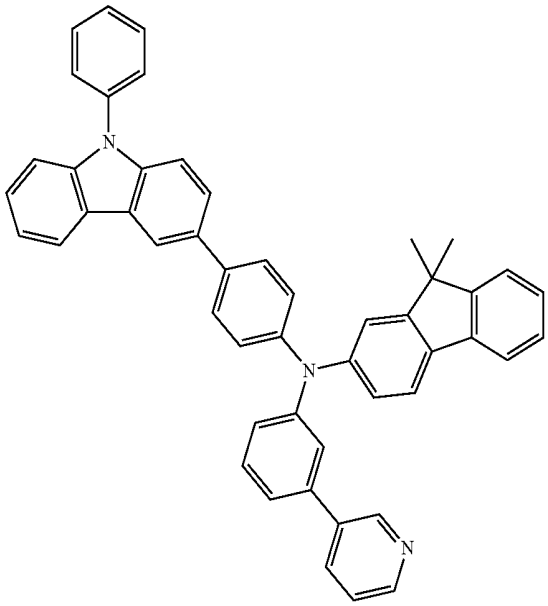

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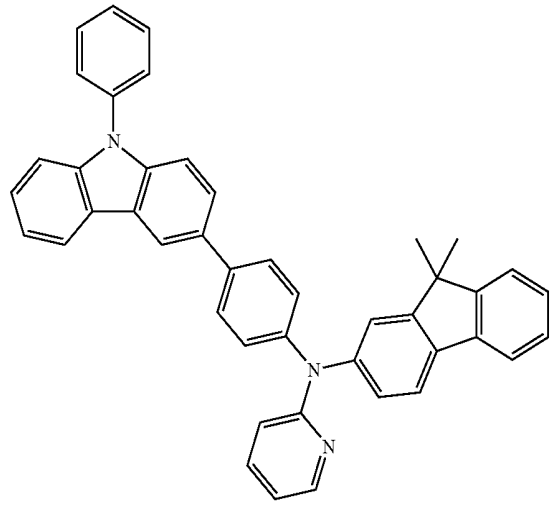
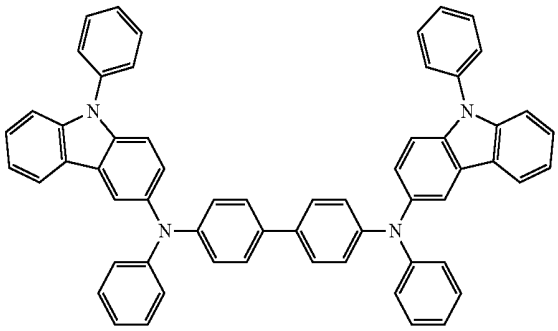


HT13



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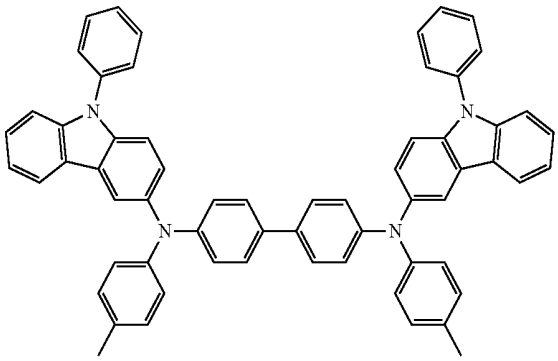

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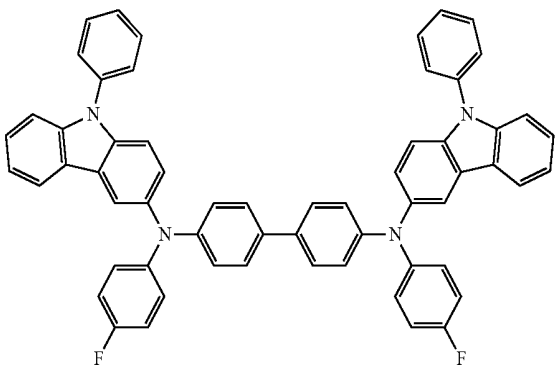

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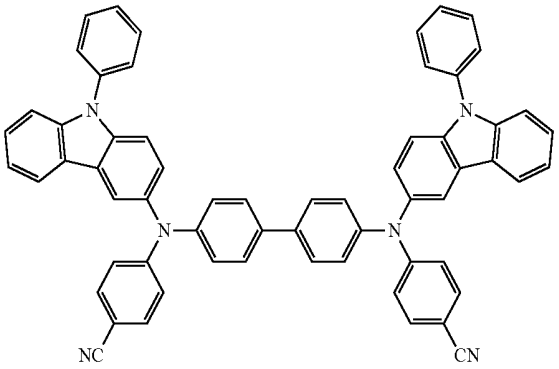
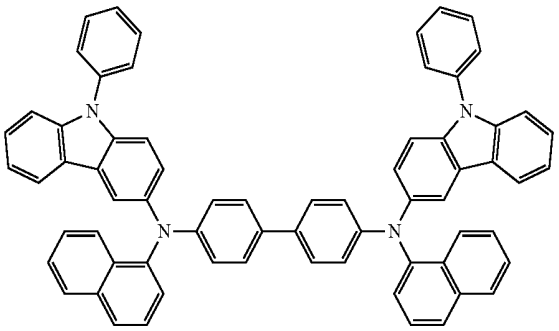


HT17



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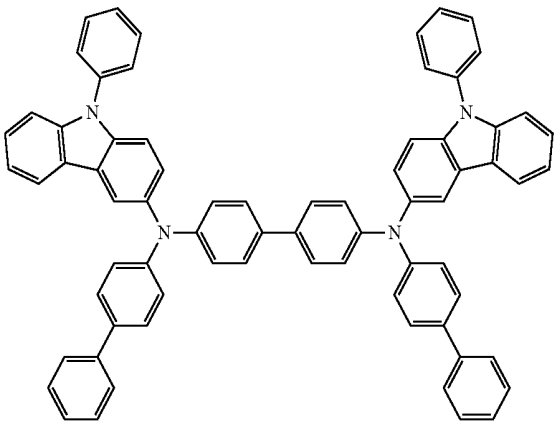

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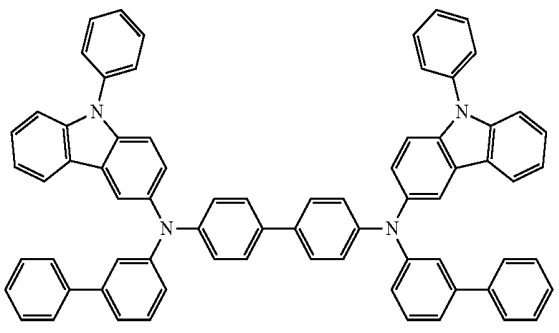

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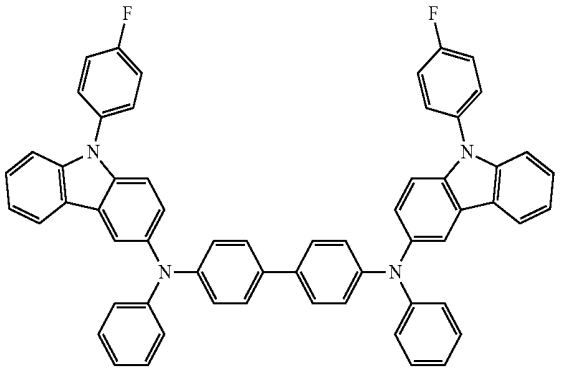
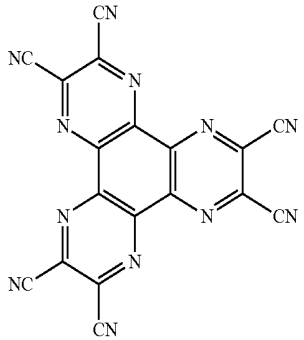
HT20



A thickness of the hole transport region may be in a range of about 100 Angstrom (Å) to about 10,000 Å, for example, about 100 Å to about 1,000 Å. When the hole transport region includes an HIL and a HTL, a thickness of the HIL may be in a range of about 100 Å to about 10,000 Å, for example, about 100 Å to about 1,000 Å, and a thickness of the HTL may be in a range of about 50 Å to about 2,000 Å, for example, about 100 Å to about 1,500 Å. When the thicknesses of the hole transport region, the HIL, and the HTL are within these ranges, satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.

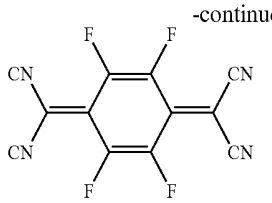
The hole transport region may further include, in addition to the abovementioned materials, a charge-generating material for the improvement of conductive properties. The charge-generating material may be homogeneously or non-homogeneously dispersed throughout the hole transport region.

The charge-generating material may be, for example, a p-dopant. The p-dopant may be one of a quinone derivative, a metal oxide, and a cyano group-containing compound, but is not limited thereto. For example, non-limiting examples of the p-dopant are a quinone derivative, such as tetracyanoquinonedimethane (TCNQ) or 2,3,5,6-tetrafluoro-tetracyano-1,4-benzoquinonedimethane (F4-TCNQ); a metal oxide, such as a tungsten oxide or a molybdenum oxide; and Compound HT-D1 illustrated below, but are not limited thereto.



Compound HT-D1

-continued



F4-TCNQ

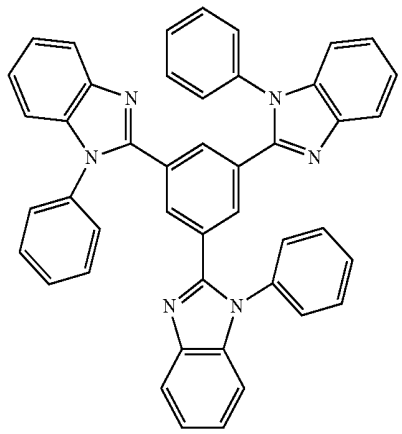
The hole transport region may further include a buffer layer.

The buffer layer may compensate for an optical resonance distance according to a wavelength of light emitted from the EML, and thus, efficiency of an organic light-emitting device may be improved.

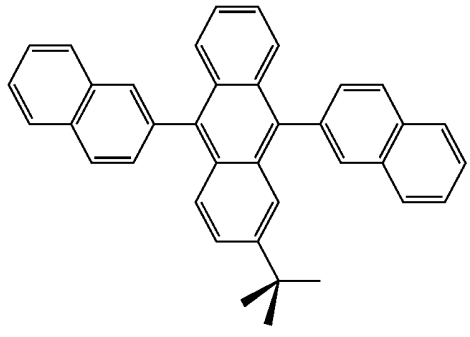
An EML may be formed on the hole transport region by using various methods, such as vacuum deposition, spin coating, casting, or an LB method. When the EML is formed by vacuum deposition or spin coating, deposition and coating conditions for the EML may be determined by referring to the deposition and coating conditions for the HIL.

The EML may include a host and a dopant. The host may include at least one condensed-cyclic compound represented by Formula 1A or 1B.

The host may include at least one compound selected from TPBi, TBADN, ADN (also referred to as "DNA"), CBP, CDBP, and TCP:



TPBi



TBADN

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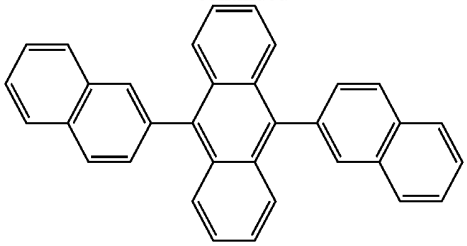
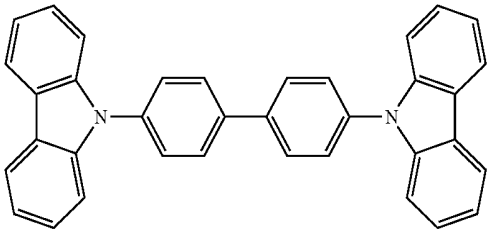
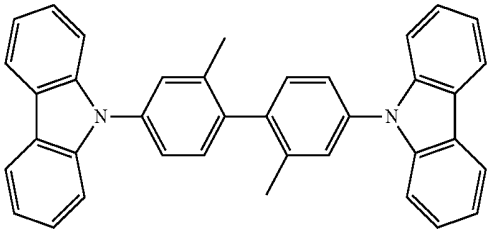


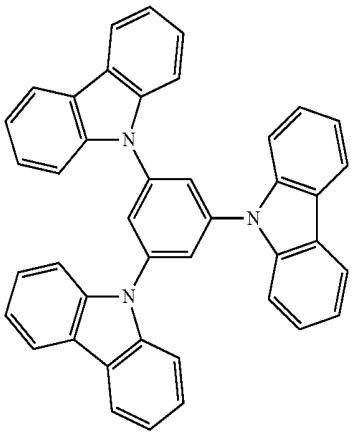
ADN



CBP



CDBP



TCP

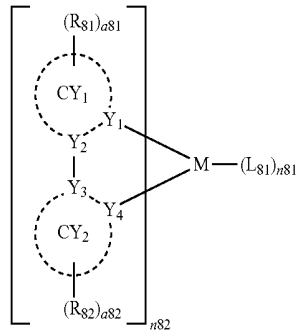
When the organic light-emitting device **10** is a full color organic light-emitting device, the EML may be patterned into a red EML, a green EML, and a blue EML. In some embodiments, the EML may have a stacked structure of a red EML, a green EML, and/or a blue EML to emit white light. The host in the red EML, green EML, and blue EML may include the condensed-cyclic compound represented by Formula 1. According to an embodiment, the host in the green EML may include the condensed-cyclic compound represented by Formula 1A or 1B.

The EML may include a fluorescent dopant that emits light according to a fluorescent light emission mechanism or a phosphorescent dopant that emits light according to a phosphorescent light emission mechanism.

According to an embodiment, the EML may include a fluorescent and a phosphorescent dopant including the condensed-cyclic compound represented by Formula 1A or 1B. The phosphorescent dopant may include an organic metal complex including a transition metal (for example, iridium (Ir), platinum (Pt), osmium (Os), rhodium (Rh), or the like).

The phosphorescent compound may include an organometallic compound represented by Formula 81:

Formula 81



In Formula 81,

M may be selected from Iridium (Ir), platinum (Pt), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), and thulium (Tm);

Y_1 to Y_4 may be each independently carbon (C) or nitrogen (N);

Y_1 and Y_2 may be connected by a single bond or a double bond, and Y_3 and Y_4 may be connected by a single bond or a double bond;

CY_1 and CY_2 may be each independently selected from a benzene, a naphthalene, a fluorene, a spiro-fluorene, an indene, a pyrrole, a thiophene, a furan, an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isooxazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, a quinoline, an isoquinoline, a benzoquinoline, a quinoxaline, a quinazoline, a carbazole, a benzoimidazole, benzofuran, a benzothiophene, an isobenzothiophene, a benzooxazole, an isobenzooxazole, a triazole, a tetrazole, an oxadiazole, a triazine, a dibenzofuran, and a dibenzothiophene, wherein CY_1 and CY_2 are optionally bound to each other via a single bond or an organic linking group;

R_{81} and R_{82} are each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, —SF_5, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_2-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_2-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_2-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic hetero-condensed polycyclic group, —$N(Q_1)(Q_2)$, —$Si(Q_3)(Q_4)(Q_5)$, and —$B(Q_6)(Q_7)$;

a81 and a82 are each independently selected from integers of 1 to 5;

n81 is selected from integers of 0 to 4;

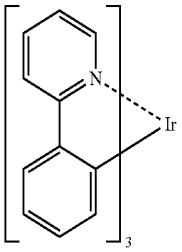
n82 is 1, 2, or 3; and

L_{81} is selected from a monovalent organic ligand, a divalent organic ligand, and a trivalent organic ligand.

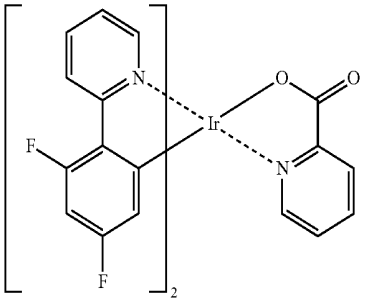
Descriptions of R_{81} and R_{82} may be the same as the description of R_5.

The phosphorescent dopant may include at least one of Compounds PD1 to PD74, but it is not limited thereto:

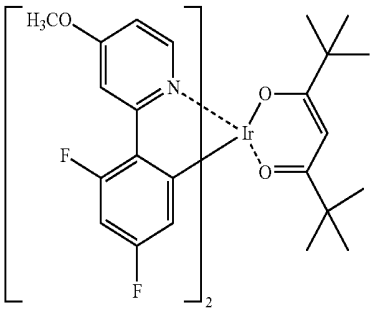
PD1



PD2



PD3



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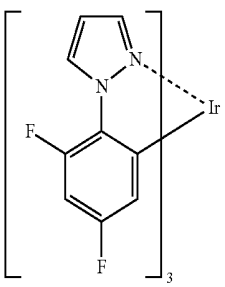

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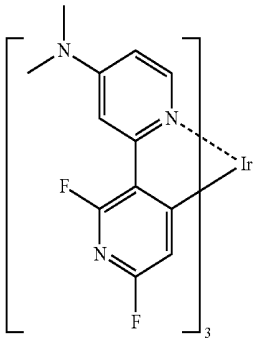
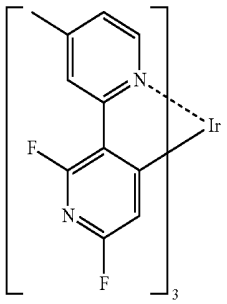
PD5



PD6



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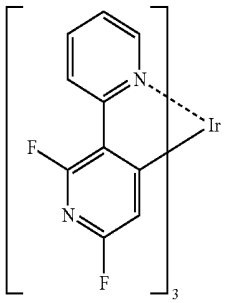

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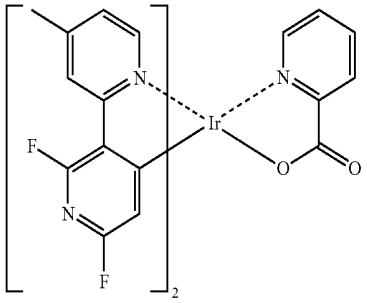

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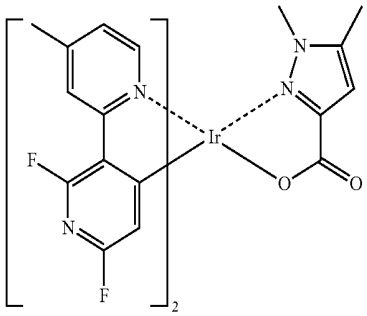

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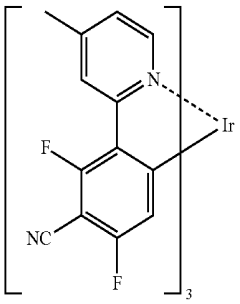
PD10



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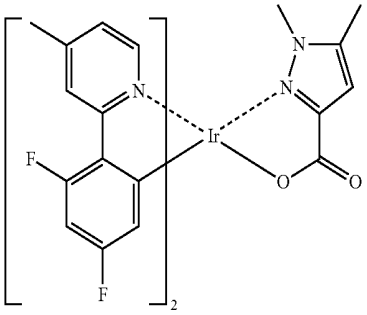

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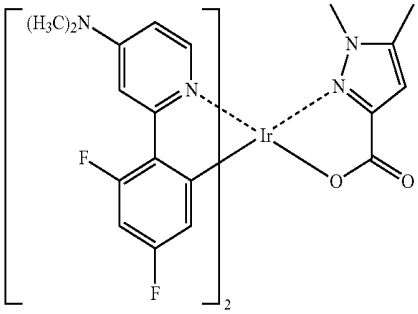

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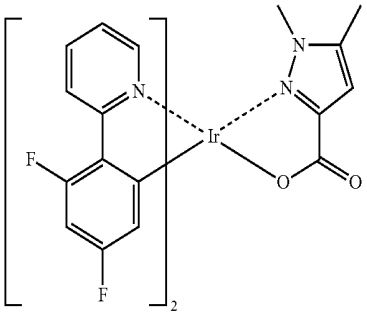

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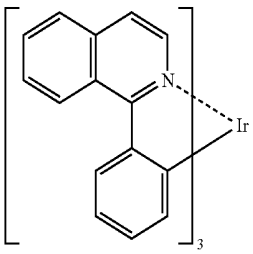

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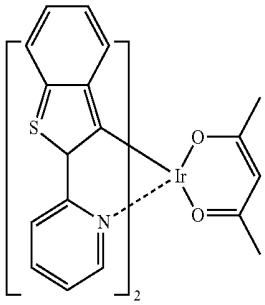

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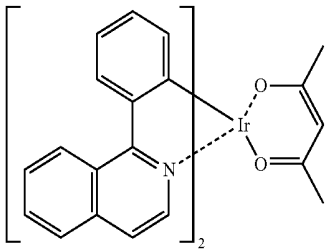

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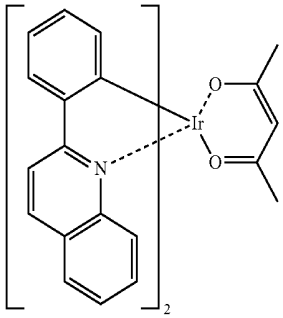

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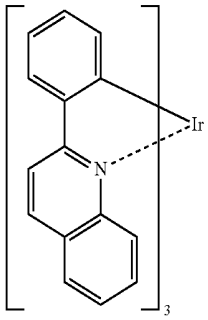

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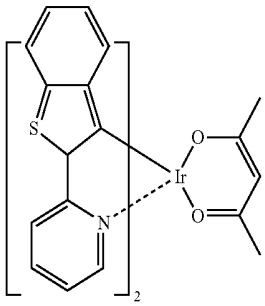

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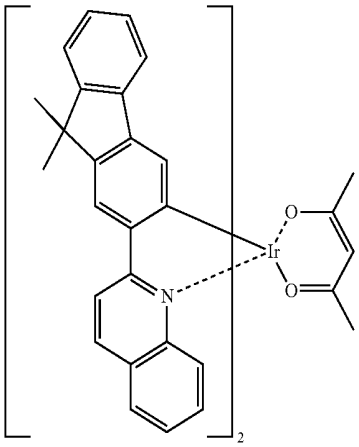
PD20



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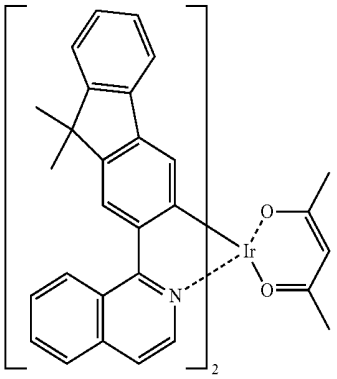

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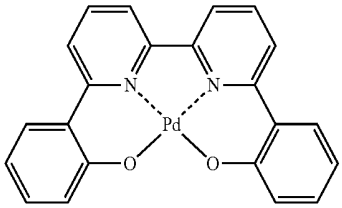

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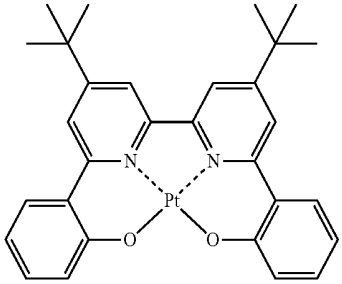

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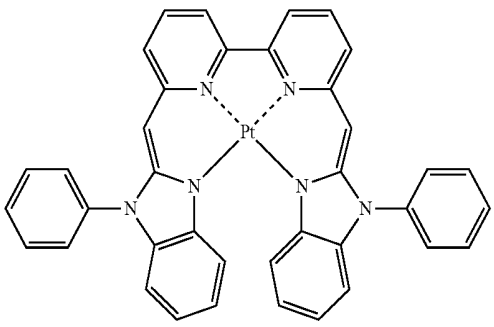

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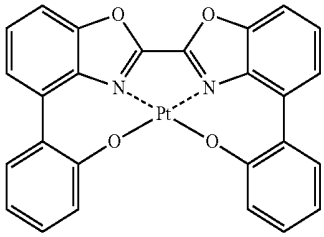
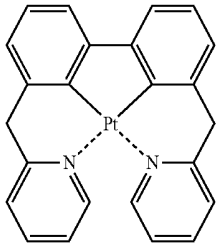
PD25



PD26



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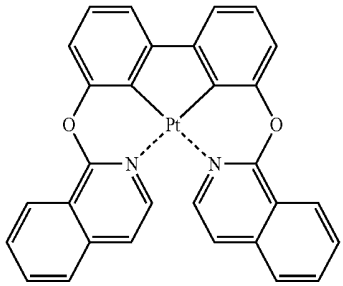

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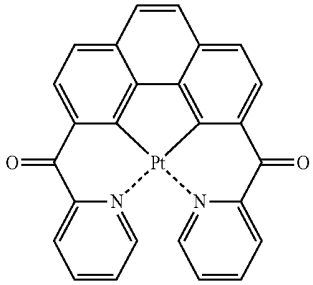

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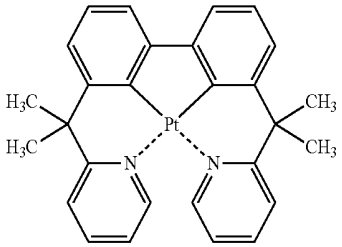

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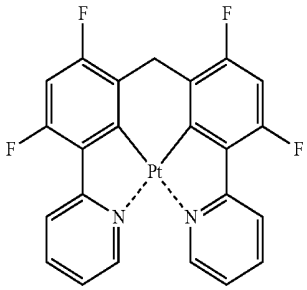

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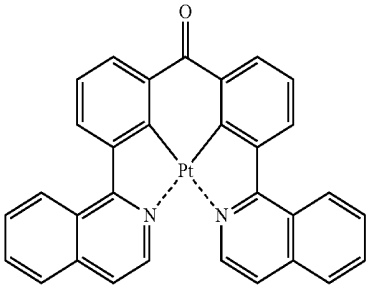

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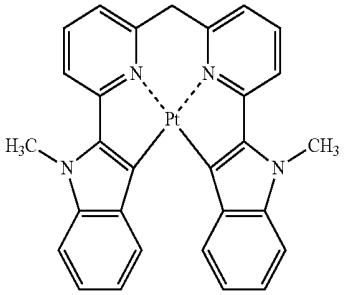

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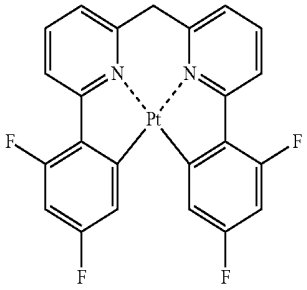

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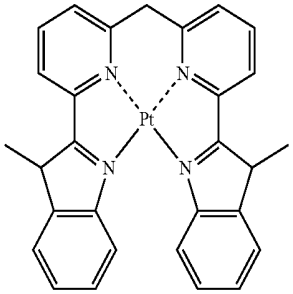

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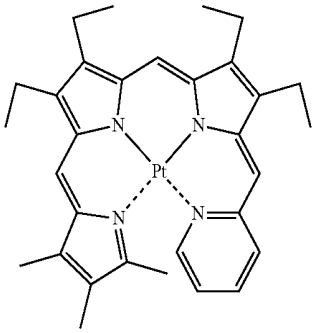

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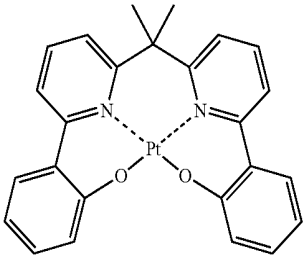

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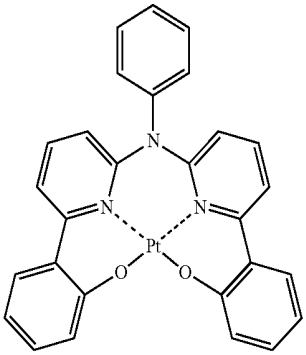

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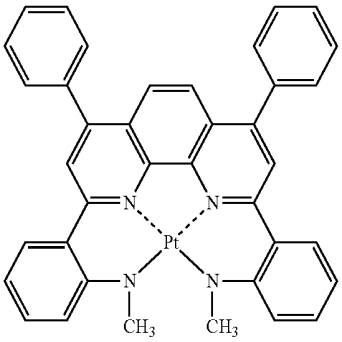

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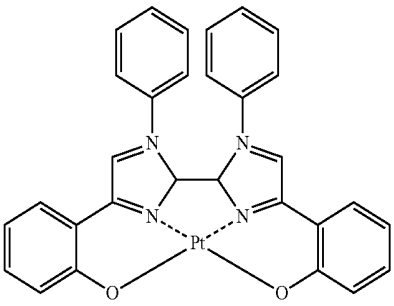

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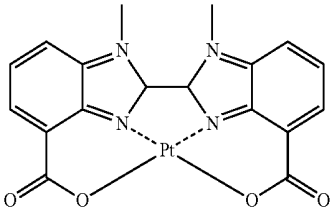

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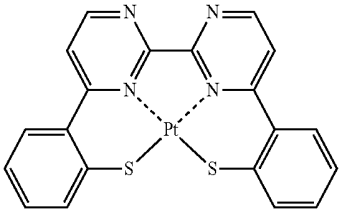

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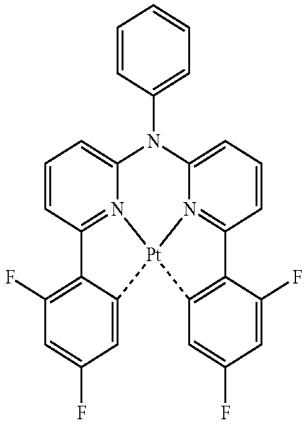

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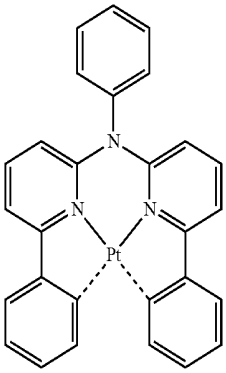

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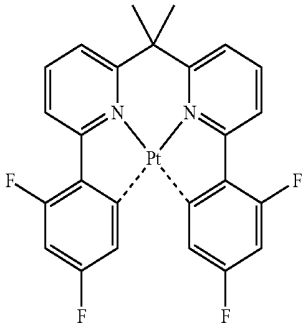

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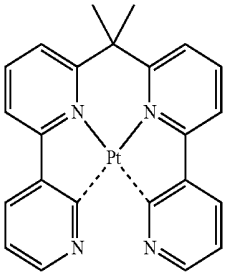

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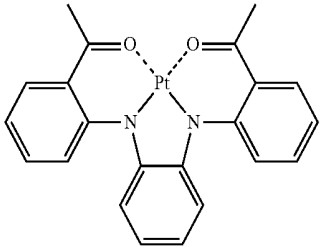

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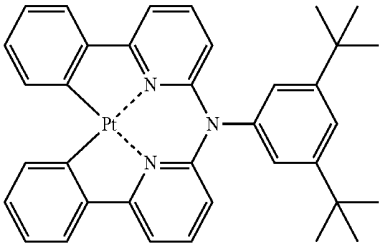

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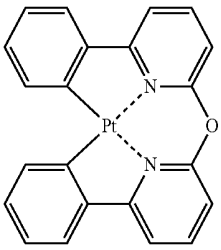

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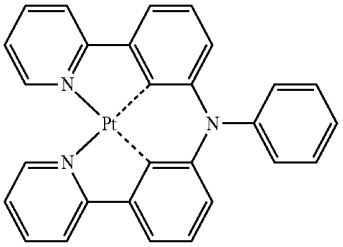

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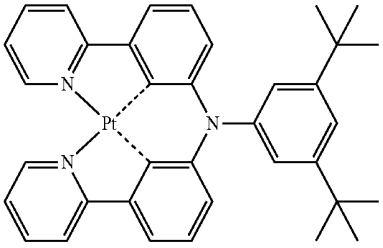

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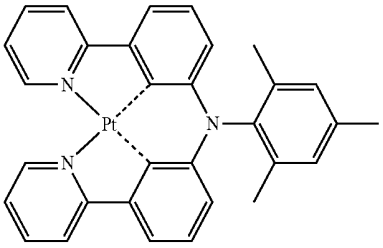

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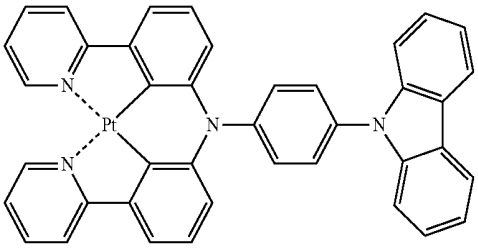

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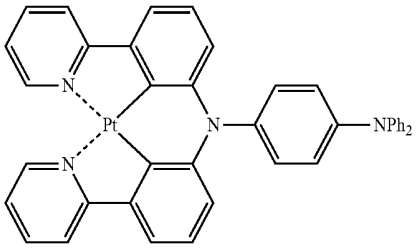

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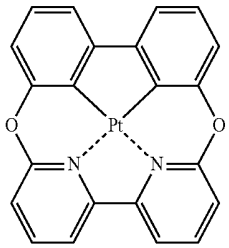

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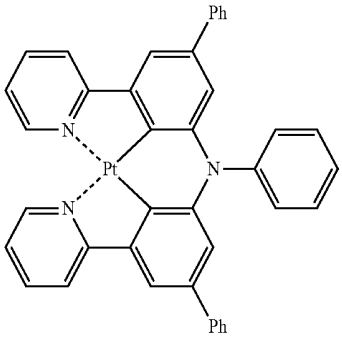

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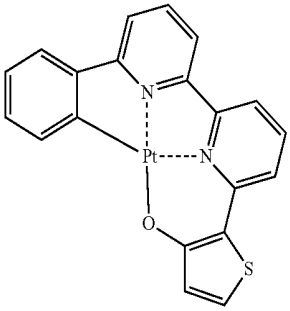

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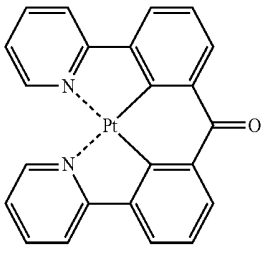

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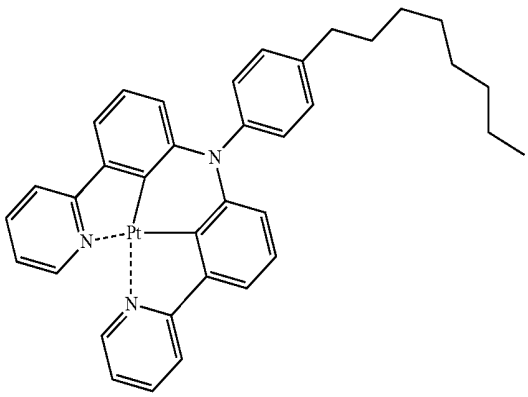

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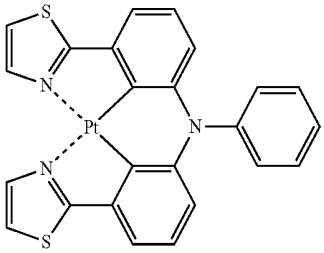

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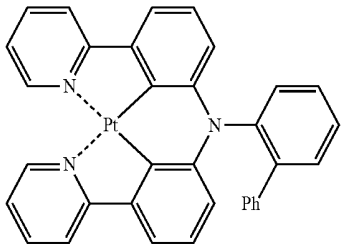

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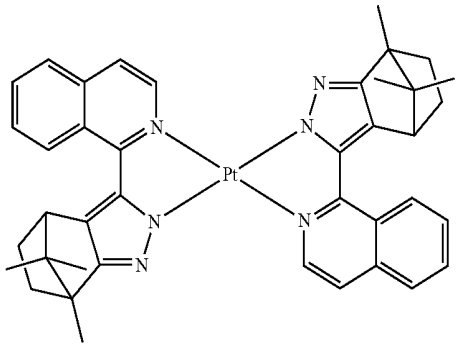

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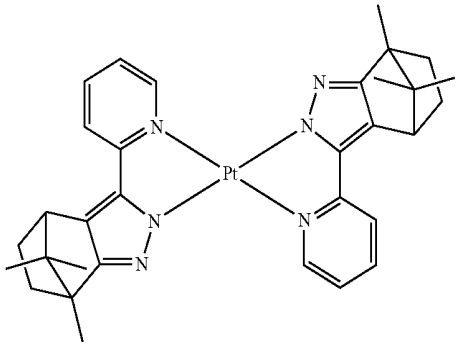

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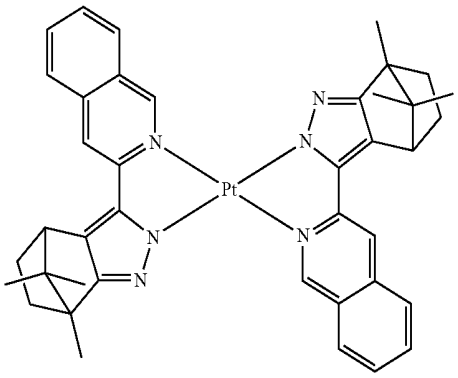

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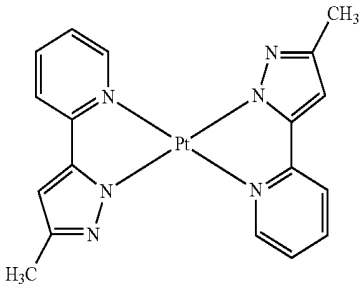

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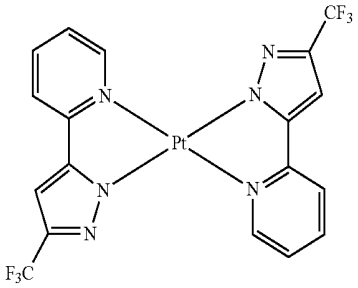

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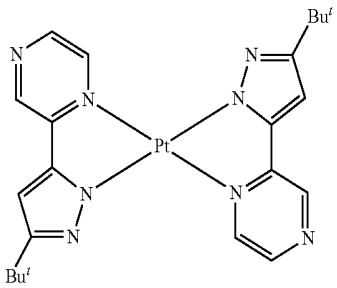

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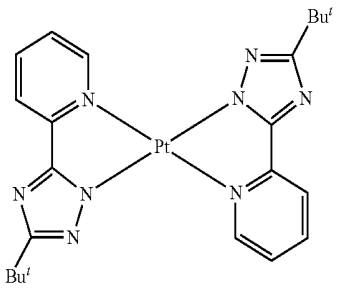

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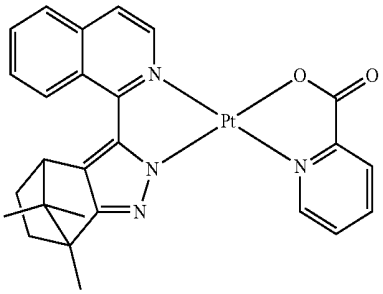

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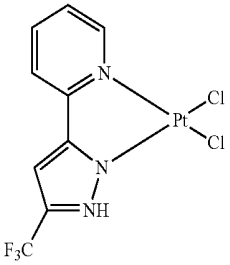

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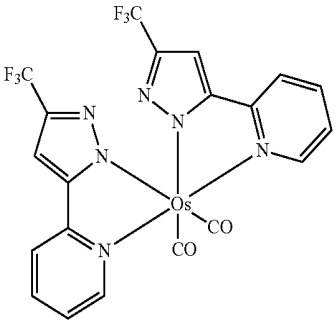

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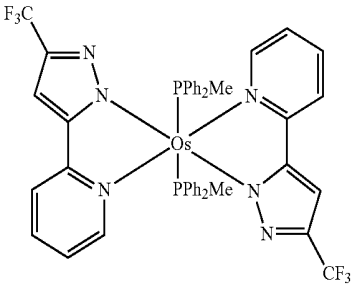

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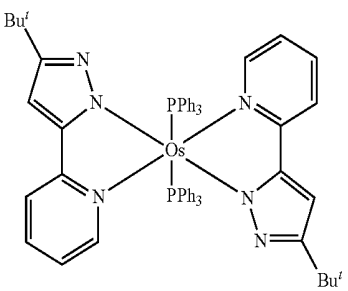

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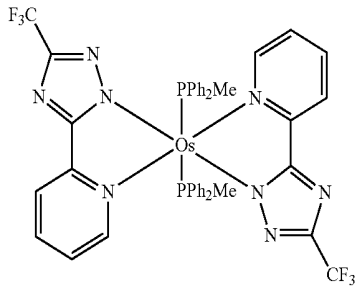
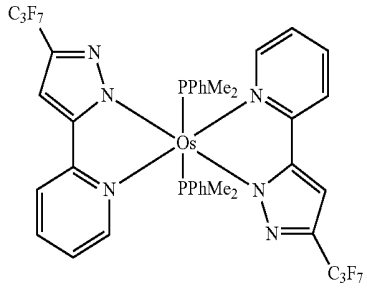
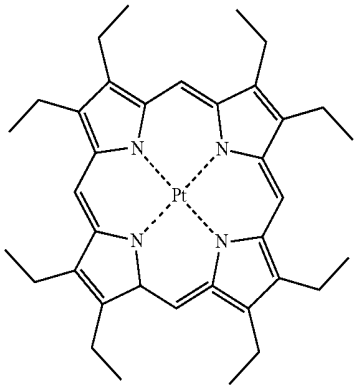
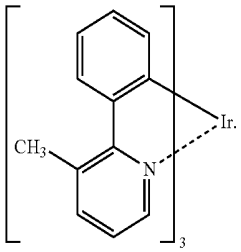




Alternatively, the phosphorescent dopant may include PtOEP or compound PhGD:



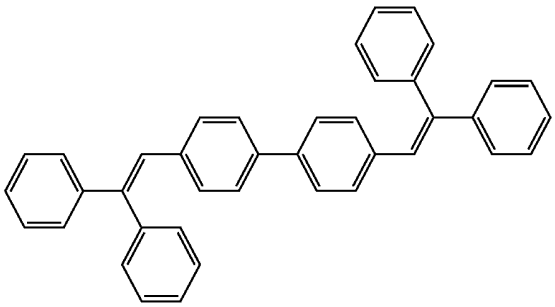
PtOEP



PhGD

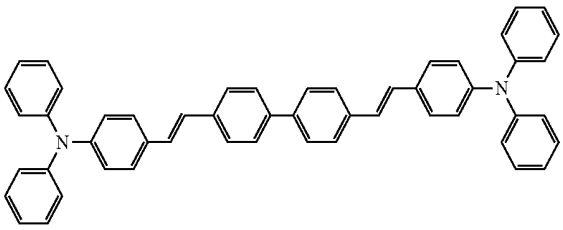
The fluorescent dopant may include at least one of DPVBi, DPAVBi, TBPe, DCM, DCJTB, Coumarin 6, and C545T.

PD73

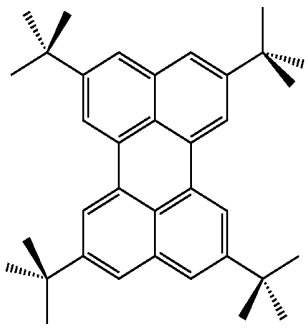


DPVBi

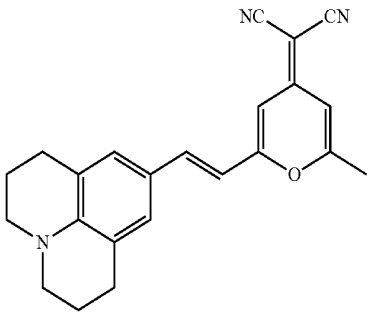
PD74



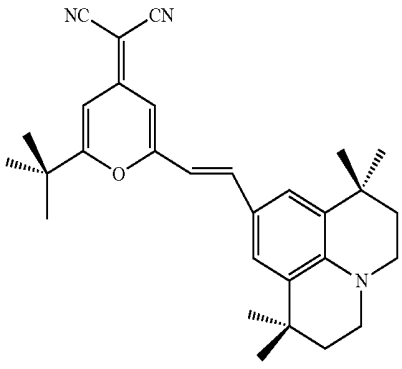
DPAVBi



TBPe



DCM



DCJTB

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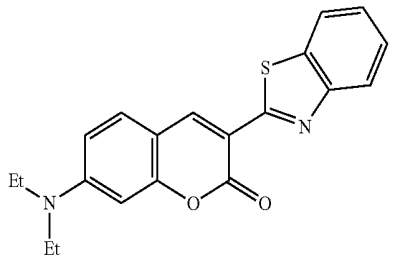
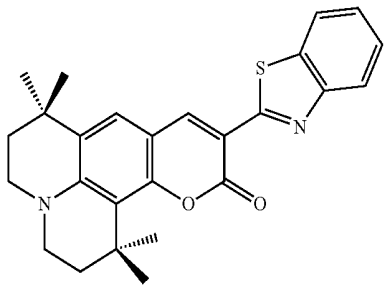


Coumarin 6



C545T

When the EML includes the host and the dopant, an amount of the dopant may be selected from a range of about 0.01 parts by weight to about 15 parts by weight based on 100 parts by weight of the host, but the amount is not limited thereto.

A thickness of the EML may be about 100 Å to about 1,000 Å, for example, about 200 Å to about 600 Å. When the thickness of the EML is within this range, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

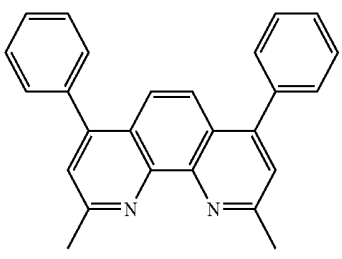
Then, an electron transport region may be disposed on the EML.

The electron transport region may include at least one layer selected from a HBL, an ETL, and an EIL, but is not limited thereto.

For example, the electron transport region may have an HBL/ETL/EIL structure or an ETL/EIL structure, wherein layers of each structure are sequentially stacked from the EML in the stated order, but is not limited thereto. The ETL may have a single layer or a multi-layer structure including two or more different materials.

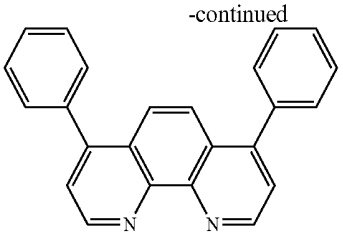
The conditions for forming the HBL, ETL, and EIL may be understood by referring to the conditions for forming the HIL.

When the electron transport region includes the HBL, the HBL may include, for example, at least one of BCP and Bphen, but it is not limited thereto.



BCP

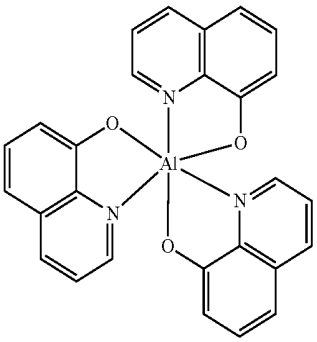
-continued



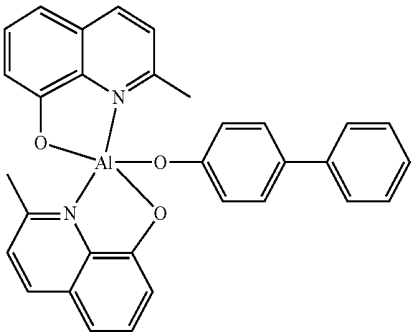
Bphen

A thickness of the HBL may be in a range of about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. When the thickness of the HBL is within the range described above, the HBL may have excellent hole blocking characteristics without a substantial increase in driving voltage.

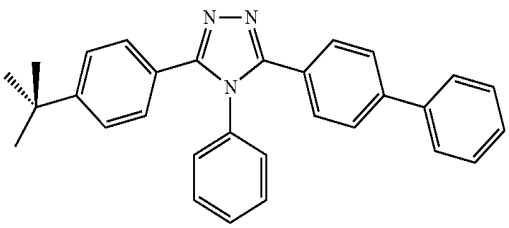
The ETL may include at least one of BCP and Bphen, and may further include at least one of Alq_3, Balq, TAZ, and NTAZ.



Alq_3

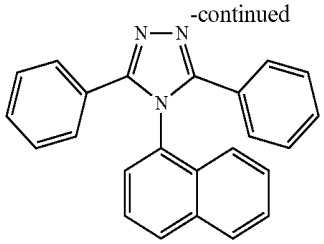


BAlq



TAZ

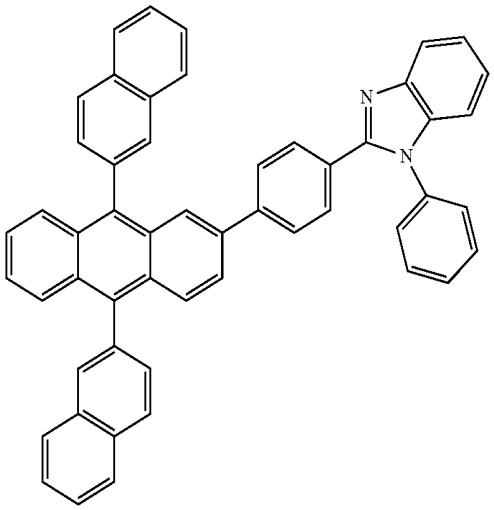
-continued



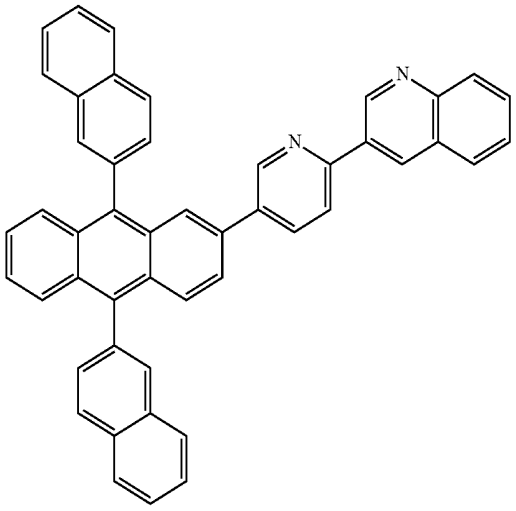
NTAZ

Alternatively, the ETL may include at least one of Compound ET1 and ET2, but it is not limited thereto.

ET1



ET2

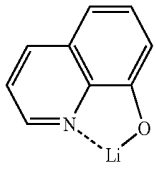


A thickness of the ETL may be in a range of about 100 Å to about 1,000 Å, for example, about 150 Å to about 500 Å. When the thickness of the ETL is within the range described above, the ETL may have satisfactory electron transportation characteristics without a substantial increase in driving voltage.

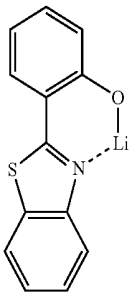
Also, the ETL may further include, in addition to the materials described above, a metal-containing material.

The metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (lithium quinolate, LiQ) or ET-D2.

ET-D1



ET-D2



The electron transport region may include an EIL that allows electrons to be easily provided from the second electrode 19.

The EIL may include at least one compound selected from LiF, NaCl, CsF, Li_2O, and BaO.

A thickness of the EIL may be in a range of about 1 Å to about 100 Å, for example, about 3 Å to about 90 Å. When the thickness of the EIL is within the range described above, the EIL may have satisfactory electron transportation characteristics without a substantial increase in driving voltage.

The second electrode 19 is disposed on the organic layer 15 having the structure described above. The second electrode 19 may be a cathode that is an electron injection electrode, and in this regard, a material for forming the second electrode 19 may be a material having a low work function, and such a material may be a metal, an alloy, an electrically conductive compound, or a mixture thereof. Detailed examples of the material for forming second electrode 19 are lithium (Li), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), and magnesium-silver (Mg—Ag). Alternatively, ITO or IZO may be may be used to form a transmissive second electrode 19 to manufacture a top emission light-emitting device.

Hereinbefore, the organic light-emitting device has been described with reference to the FIGURE, but is not limited thereto.

A C_1-C_{60} alkyl group used herein refers to a linear or branched aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms. Detailed examples thereof are a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. A C_1-C_{60} alkylene used herein refers to a divalent group having the same structure as the C_1-C_{60} alkyl group.

A C_1-C_{60} alkoxy group used herein refers to a monovalent group represented by —OA_{101} (wherein A_{101} is the C_1-C_{60} alkyl group). Detailed examples thereof are a methoxy group, an ethoxy group, and an isopropyloxy group.

A C_2-C_{60} alkenyl group used herein refers to a hydrocarbon group formed by substituting at least one carbon double bond in the middle or at the terminal of the C_2-C_{60} alkyl group. Detailed examples thereof are an ethenyl group, a propenyl group, and a butenyl group. A C_2-C_{60} alkenylene group used herein refers to a divalent group having the same structure as the C_2-C_{60} alkenyl group.

A C_2-C_{60} alkynyl group used herein refers to a hydrocarbon group formed by substituting at least one carbon triple bond in the middle or at the terminal of the C_2-C_{60} alkyl group. Detailed examples thereof are an ethynyl group and a propynyl group. A C_2-C_{60} alkynylene group used herein refers to a divalent group having the same structure as the C_2-C_{60} alkynyl group.

A C_3-C_{10} cycloalkyl group used herein refers to a monovalent hydrocarbon monocyclic group having 3 to 10 carbon atoms. Detailed examples thereof are a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. A C_3-C_{10} cycloalkylene group used herein refers to a divalent group having the same structure as the C_3-C_{10} cycloalkyl group.

A C_3-C_{10} heterocycloalkyl group used herein refers to a monovalent monocyclic group having at least one heteroatom selected from N, O, P, and S as a ring-forming atom and 3 to 10 carbon atoms. Detailed examples thereof are tetrahydrofuranyl and tetrahydrothiophenyl. A C_3-C_{10} heterocycloalkylene group used herein refers to a divalent group having the same structure as the C_3-C_{10} heterocycloalkyl group.

A C_3-C_{10} cycloalkenyl group used herein refers to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one double bond in the ring thereof and does not have aromaticity. Detailed examples thereof are a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. A C_3-C_{10} cycloalkenylene group used herein refers to a divalent group having the same structure as the C_3-C_{10} cycloalkenyl group.

A C_2-C_{10} heterocycloalkenyl group used herein refers to a monovalent monocyclic group that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom, 2 to 10 carbon atoms, and at least one double bond in its ring. Detailed examples of the C_2-C_{10} heterocycloalkenyl group are a 2,3-dihydrofuranyl group and a 2,3-dihydrothiophenyl group. A C_2-C_{10} heterocycloalkenylene group used herein refers to a divalent group having the same structure as the C_2-C_{10} heterocycloalkenyl group.

A C_6-C_{60} aryl group used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and a C_6-C_{60} arylene group used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Detailed examples of the C_6-C_{60} aryl group are a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C_6-C_{60} aryl group and the C_6-C_{60} arylene group each include two or more rings, the rings may be fused to each other.

A C_2-C_{60} heteroaryl group used herein refers to a monovalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom, and 2 to 60 carbon atoms. A C_2-C_{60} heteroarylene group used herein refers to a divalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom, and 2 to 60 carbon atoms. Detailed examples of the C_2-C_{60} heteroaryl group are a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the C_2-C_{60} heteroaryl group and the C_2-C_{60} heteroarylene group each include two or more rings, the rings may be fused to each other.

A C_6-C_{60} aryloxy group used herein indicates —OA_{102} (wherein A_{102} is the C_6-C_{60} aryl) and a C_6-C_{60} arylthio group used herein indicates —SA_{103} (wherein A_{103} is the C_6-C_{60} aryl group).

A monovalent non-aromatic condensed polycyclic group (for example, having 8 to 60 carbon atoms) used herein refers to a monovalent group that has two or more rings condensed to each other, only carbon atoms as ring-forming atoms, wherein the molecular structure as a whole is non-aromatic. A detailed example of the monovalent non-aromatic condensed polycyclic group is a fluorenyl group. A divalent non-aromatic condensed polycyclic group used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed polycyclic group.

A monovalent non-aromatic condensed heteropolycyclic group (for example, having 2 to 60 carbon atoms) used herein refers to a monovalent group that has two or more rings condensed to each other, has a heteroatom selected from N, O P, and S, other than carbon atoms, as a ring forming atom, wherein the molecular structure as a whole is non-aromatic. Detailed examples of the monovalent non-aromatic condensed heteropolycyclic group are a carbazolyl group. A divalent non-aromatic condensed heteropolycyclic group used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

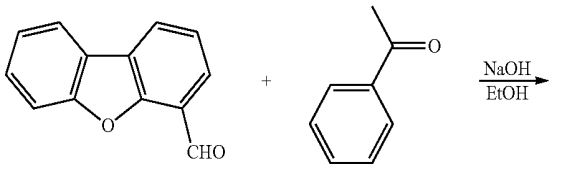
Hereinafter, an organic light-emitting device according to an embodiment will be described in detail with reference to Synthesis Examples and Examples. The wording "B was used instead of A" used in describing Synthesis Examples means that a molar equivalent of A was identical to a molar equivalent of B.

EXAMPLE

Synthesis Example 1

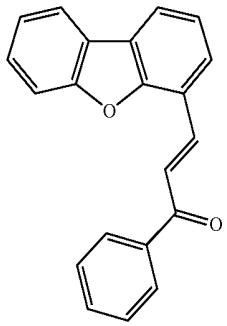
Synthesis of Compound 813

Synthesis of Intermediate B



Molecular Weight: 196.20
Intermediate A

Molecular Weight:
120.15



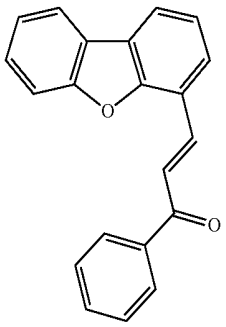
Molecular Weight: 298.33
Intermediate B

44.0 g (224.3 mmol) of Intermediate A, 126.9 g (224.3 mmol) of acetophenone, and 9.0 g (224.3 mmol) of sodium hydroxide were added in 670 mL of ethanol in a 1,000 mL

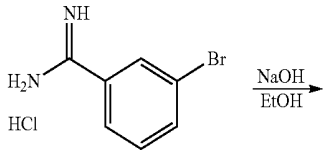
round bottom flask and then stirred in nitrogen atmosphere for 2 hours at room temperature to prepare a mixture. Crystallized solids in the mixture were filtered to obtain Intermediate B (59.2. g and yield 88.0%). Element analysis results of Intermediate B are as follows.

calcd. $C_{21}H_{14}O_2$: C, 84.54; H, 4.73; O, 10.73. found: C, 84.51; H, 4.75; O, 10.71.

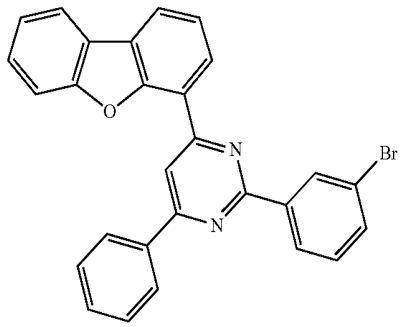
Synthesis of Intermediate C



Molecular Weight: 298.33
Intermediate B



Molecular Weight: 235.51

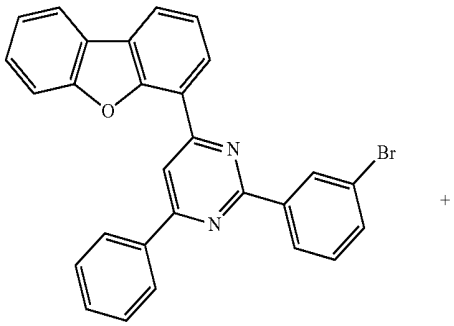


Molecular Weight: 477.35
Intermediate C

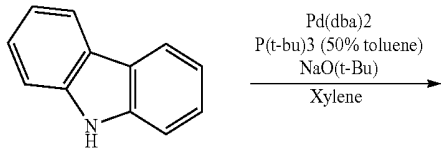
13.0 g (106.2 mmol) of Intermediate B, 30.0 g (127.4 mmol) of 3-bromobenzimidamide, and 8.5 g (212.3 mmol) of sodium hydroxide were added in 500 ml of ethanol in a 1,000 mL round bottom flask, heated in a nitrogen atmosphere for 15 hours to reflux the same to prepare a mixture. Crystallized solids in the mixture were stirred with water and then filtered. The crystallized solids were stirred again by using ethanol and then filtered to obtain Intermediate C (23.8 g, yield 47%). Element analysis results of the Intermediate C are as follows.

calcd. $C_{28}H_{17}BrN_2O$: C, 70.45; H, 3.59; Br, 16.74; N, 5.87; O, 3.35. found C, 70.43; H, 3.60; Br, 16.72; N, 5.85; O, 3.36.

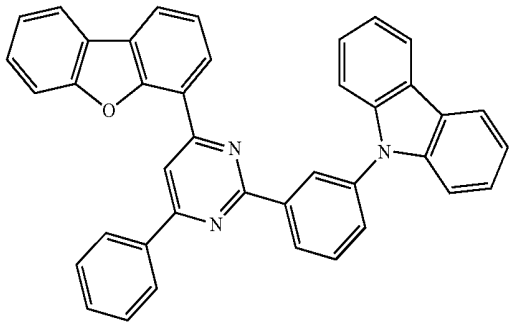
Synthesis of Compound 813



Molecular Weight: 477.35
Intermediate C



Molecular Weight: 167.21



Molecular Weight: 563.65
Compound 813

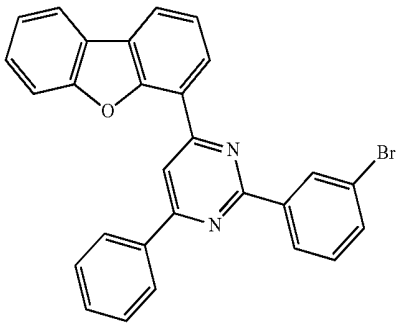
23.8 g (49.9 mmol) of Intermediate C, 7.0 g (41.6 mmol) of 9H-carbazole, 8.0 g (83.1 mmol) of sodium t-butoxide, 3.8 g (4.2 mmol) of $Pd(dba)_2$, and 4.2 mL (8.3 mmol) of tri-t-butyl phosphine (50% in toluene solution) were added to 166.2 mL of xylene in a 500 mL round bottom flask, and heated in a nitrogen atmosphere for 15 hours to reflux the same to prepare a mixture. The mixture was added to 1,000 mL of methanol to filter crystallized solids, dissolved in monochlorobenzene to filter the same by using a silica gel/celite, a suitable amount of organic solvent was removed therefrom, and then the same was recrystallized with methanol to obtain Compound 813 (11.7 g and yield 50%). Element analysis results and NMR analysis results of Compound 813 are as follows.

calcd. $C_{40}H_{25}N_3O$: C, 85.24; H, 4.47; N, 7.46; O, 2.84. found C, 85.22; H, 4.46; N, 7.47; O, 2.83.

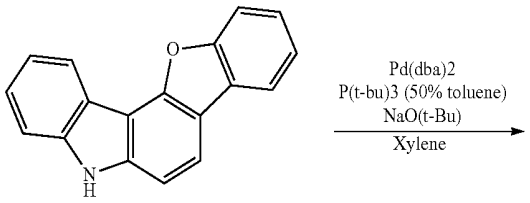
300 MHz ($CDCl_3$, ppm): δ 8.960 (m, 1H), 8.865 (m, 2H), 8.657 (dd, 1H), 8.359 (dd, 2H), 8.196 (d, 2H), 8.081 (dd, 1H), 7.999 (d, 1H), 7.816 (t, 1H), 7.659~7.727 (m, 2H), 7.381~7.601 (m, 10H), 7.316 (t, 2H)

Synthesis Example 2

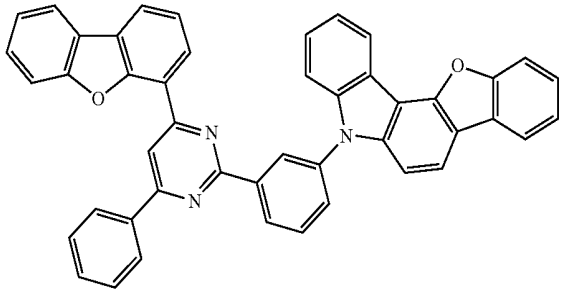
Synthesis of Compound 814



Molecular Weight: 477.35
Intermediate C



Molecular Weight: 257.29



Molecular Weight: 653.73
Compound 814

15.0 g (31.4 mmol) of Intermediate C, 9.7 g (37.7 mmol) of 5H-benzofuro[3,2-c]carbazole, 6.0 g (62.9 mmol) of sodium t-butoxide, 2.9 g (3.1 mmol) of $Pd(dba)_2$, and 3.1 mL (6.3 mmol) of tri-t-butyl phosphine (50% in toluene solution) were added to 125.7 mL of xylene in a 500 mL round bottom flask, and heated in a nitrogen atmosphere for 15 hours to reflux the same to prepare a mixture. The mixture was added to 1,000 mL of methanol to filter crystallized solids, dissolved in dichlorobenzene to filter the same by using a silica gel/celite, a suitable amount of organic solvent was removed therefrom, and then the same was recrystallized with methanol to obtain Compound 814 (11.8 g, yield 57%). Element analysis results and NMR analysis results of Compound 814 are as follows.

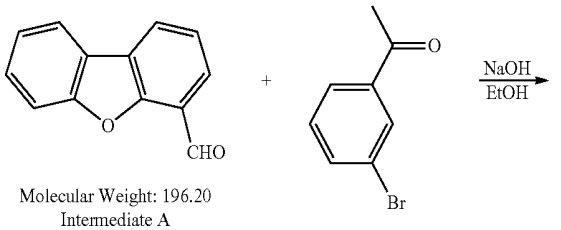
calcd. $C_{46}H_{27}N_3O_2$: C, 84.51; H, 4.16; N, 6.43; O, 4.89.
found C, 84.49; H, 4.17; N, 6.44; O, 4.87

300 MHz ($CDCl_3$, ppm): δ 9.023 (t, 1H), 8.905~8.959 (m, 2H), 8.797 (dd, 1H), 8.666 (dd, 1H), 8.392 (m, 2H), 8.110 (dd, 1H), 8.012 (m, 3H), 7.684-7.884 (t, 4H), 7.362~7.627 (m, 12H)

Synthesis Example 3

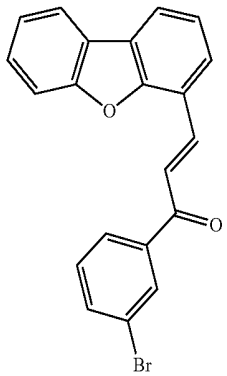
Synthesis of Compound 815

Synthesis of Intermediate D



Molecular Weight: 196.20
Intermediate A

Molecular Weight: 199.04

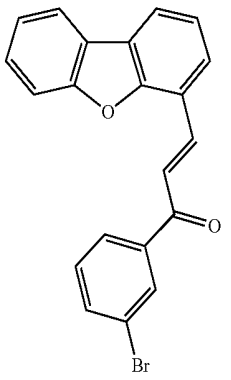


Molecular Weight: 377.23
Intermediate D

30.0 g (152.9 mmol) of Intermediate A, 30.4 g (152.9 mmol) of 1-(3-bromophenyl)ethanone, and 6.1 g (152.9 mmol) of sodium hydroxide were added to 458.7 mL of ethanol in a 1,000 mL round bottom flask and then stirred in a nitrogen current for 2 hours at room temperature to prepare a mixture. Crystallized solids in the mixture were filtered to obtain Intermediate D (46.2 g, yield 80.0%). Element analysis results of Intermediate D are as follows.

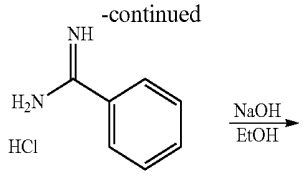
calcd. $C_{21}H_{13}BrO_2$: C, 66.86; H, 3.47; Br, 21.18; O, 8.48.
found C, 66.83; H, 3.45; Br, 21.17; O, 8.49.

Synthesis of Intermediate E

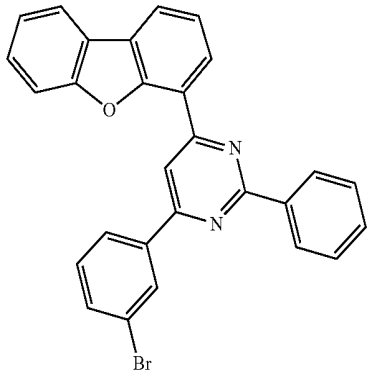


Molecular Weight: 377.23
Intermediate D

-continued



Molecular Weight: 156.61

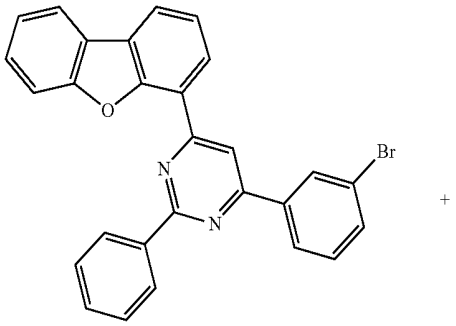


Molecular Weight: 477.35
Intermediate E

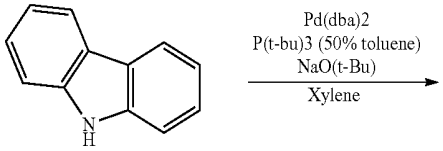
80.3 g (212.9 mmol) of Intermediate D, 40.0 g (255.4 mmol) of benzimidamide, and 17 g (425.7 mmol) of sodium hydroxide were added to 1,000 ml of ethanol in a 2,000 mL round bottom flask and then heated in a nitrogen atmosphere for 15 hours to reflux the same to prepare a mixture. Crystallized solids in the mixture were filtered and then stirred with water to filter the same. The crystallized solids were stirred again with ethanol and then filtered to obtain Intermediate E (45.8 g, yield 45%). Element analysis results of Intermediate E are as follows.

calcd. $C_{28}H_{17}BrN_2O$: C, 70.45; H, 3.59; Br, 16.74; N, 5.87; O, 3.35. found C, 70.44; H, 3.61; Br, 16.71; N, 5.84; O, 3.35.

Synthesis of Compound 815

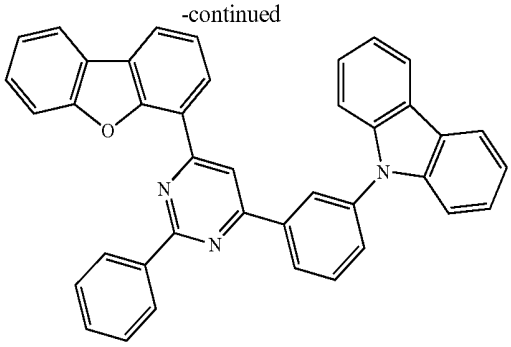


Molecular Weight: 477.35
Intermediate E



Molecular Weight: 167.21

-continued



Molecular Weight: 563.65
Compound 815

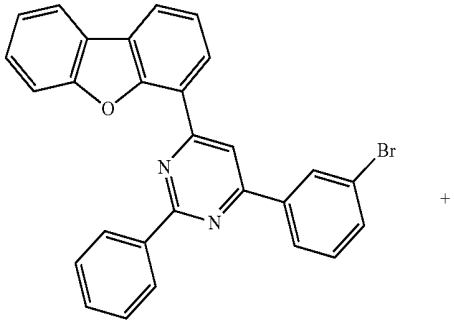
34.3. g (71.8 mmol) of Intermediate E, 10.0 g (60.0 mmol) of 9H-carbazole, 11.5 g (119.6 mmol) of sodium t-butoxide, 5.5 g (6.0 mmol) of $Pd(dba)_2$, and 2.9 mL (12.0 mmol) of tri-t-butyl phosphine (50% in toluene solution) were added to 239.2 mL of xylene in a 500 mL round bottom flask and then heated in a nitrogen atmosphere for 15 hours to reflux the same to prepare a mixture. The mixture was added to 1,000 mL of methanol to filter crystallized solids, which were dissolved in monochlorobenzene to be filtered by using a silica gel/celite, a suitable amount of organic solvent was removed therefrom and then recrystallized with methanol to obtain Compound 815 (22.2 g, yield 66%). Element analysis results and NMR analysis results of Compound 815 are as follows.

calcd. $C_{40}H_{25}N_3O$: C, 85.24; H, 4.47; N, 7.46; O, 2.84. found C, 85.21; H, 4.47; N, 7.48; O, 2.86;

300 MHz ($CDCl_3$, ppm): δ 8.905 (s, 1H), 8.745 (m, 3H), 8.635 (t, 1H), 8.473 (tt, 1H), 8.208 (d, 2H), 8.120 (dd, 1H), 8.016 (d, 1H), 7.802~7.885 (m, 2H), 7.317~7.600 (m, 13H)

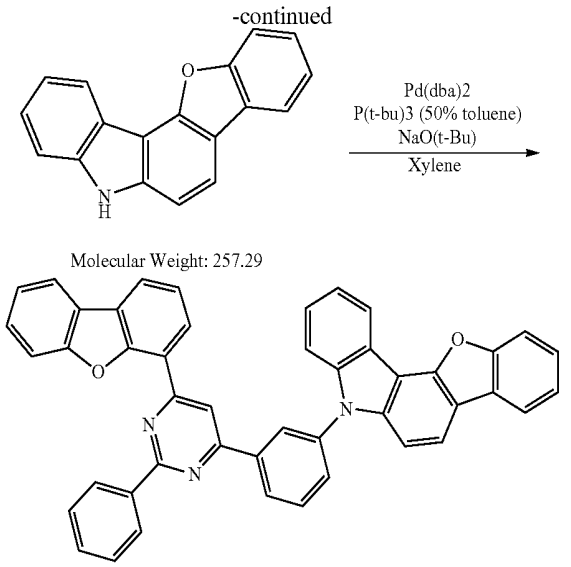
Synthesis Example 4

Synthesis of Compound 816



Molecular Weight: 477.35
Intermediate E

-continued



Molecular Weight: 257.29

Molecular Weight: 653.73
Compound 816

19.0 g (56.0 mmol) of Intermediate E, 12.0 g (46.6 mmol) of 5H-benzofuro[3,2-c]carbazole, 6.7 g (70.0 mmol) of sodium t-butoxide, 1.3 g (1.4 mmol) of $Pd(dba)_2$, and 2.1 mL (4.2 mmol) tri t-butylphosphine (50% in toluene) were added to 182.9 mL of xylene in a 500 mL round bottom flask and then heated in a nitrogen atmosphere for 15 hours to reflux the same to prepare a mixture. The mixture was added to 1,000 mL of methanol to filter crystallized solids, dissolved in dichlorobenzene to filter the same by using a silica gel/celite, a suitable amount of organic solvent was removed therefrom, and then the same was recrystallized with methanol to obtain Compound 816 (14.7 g, yield 48%). Element analysis results and NMR analysis results of Compound 816 are as follows.

calcd. $C_{46}H_{27}N_3O_2$: C, 84.51; H, 4.16; N, 6.43; O, 4.89. found C, 84.53; H, 4.18; N, 6.42; O, 4.87.

300 MHz ($CDCl_3$, ppm): δ 8.903 (s, 1H), 8.739 (d, 3H), 8.641 (t, 2H), 8.506 (d, 1H), 8.096 (d, 1H), 7.976 (m, 3H), 7.868 (m, 2H), 7.763 (d, 1H), 7.347~7.634 (m, 13H)

Evaluation Example 1

Evaluation of HOMO, LUMO, and Triplet (T1) Energy Levels of Compounds

HOMO, LUMO, and triplet (T1) energy levels of Compounds 813 to 824 were evaluated by using a DFT method of a Gaussian program (optimized at B3LYP and 6-31G(d,p) levels) and the results obtained therefrom are shown in Table 1 below.

TABLE 1

Compound No.	HOMO (eV)	LUMO (eV)	T_1 energy level (eV)
813	−5.236	−1.880	2.994
815	−5.355	−1.802	3.096
817	−5.252	−1.877	3.002
819	−5.435	−1.894	3.089
814	−5.150	−1.894	2.9
816	−5.344	−1.909	3.02
820	−5.303	−1.925	2.959
818	−5.139	−1.885	2.904
821	−5.188	−1.893	2.945
822	−5.350	−1.934	2.997
823	−5.206	−1.897	2.951
824	−5.394	−1.913	3.063

Thereafter, HOMO, LUMO, S1 energy level, and T1 energy level of Compounds 813 to 816 obtained according to the method in Table 2 and the results thereof are shown in Table 3.

TABLE 2

An evaluation method of a HOMO energy level	Each compound was diluted in $CHCl_3$ at a concentration of 1×10^{-5}M to measure UV absorption spectrum by using a Shimadzu UV-350 Spectrometer at room temperature and then a HOMO energy level was calculated by using an optical band gap (Eg) from an edge of the absorption spectrum.
An evaluation method of a LUMO energy level	Cyclic voltammetry (CV) (electrolyte: 0.1M Bu_4NClO_4/solvent: CH_2Cl_2/ electrode: a 3-electrode system (working electrode: GC, standard electrode: Ag/AgCl, and supply electrode: Pt)) was used to obtain a voltage (V)-current (A) graph for each compound and a LUMO energy level was calculated from a reduction onset of the graph.
An evaluation method of evT1 energy level	A mixture of toluene and each compound (1 mg of each compound was dissolved in 3 cc of toluene) was added to a quartz cell and liquid nitrogen (77 K) was added thereto, a photoluminescence measurement device was used to measure photoluminescence spectrum, which was compared to a conventional room temperature photoluminescence spectrum to only analyze the peak observed only at low temperature and calculate a T1 energy level.

TABLE 3

Compound No.	HOMO (eV)	LUMO (eV)	T1 energy level (eV)
813	−5.432	−1.901	2.994
815	−5.665	−1.972	3.096
814	−5.451	−1.998	2.9
816	−5.643	−1.942	3.02

It may be concluded from Tables 1 and 3 that the condensed-cyclic compounds have suitable electrical properties to be used as a material for an organic light-emitting device.

Evaluation Example 2

Evaluation of Thermal Properties of Synthesized Compounds

compounds 813 to 816 were subjected to thermal analyses by using Thermo Gravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC) (N_2 atmosphere and

temperature range for TGA: room temperature ~800° C. (10° C./min), for DSC: from room temperature to 400° C., Pan Type: for TGA: Pt Pan in a disposable Al Pan, for DSC: a disposable Al pan) and results obtained therefrom are shown in Table 4. From Table 4, it may be concluded that Compounds 813 to 816 have excellent thermal stabilities.

TABLE 4

Compound No.	Tc (° C.)	Tm (° C.)	Tg (° C.)
813	—	—	101.21
815	218.72	241.72	102.57
814	—	312.38	—
816	—	—	139.38

Example 1

An ITO glass substrate was cut to a size of 50 mm×50 mm×0.5 mm, and the ITO glass substrate was ultrasonically washed using isopropyl alcohol and pure water for 15 minutes each, followed by irradiation of UV and exposure to ozone for cleaning for about 30 minutes.

m-MTDATA was vacuum deposited on the ITO glass substrate to form an HIL having a thickness of 600 Å, and α-NPB was vacuum deposited at a rate of 1 Å/sec on the HIL to form an EML having a thickness of 300 Å. Thereafter, $Ir(ppy)_3$ (dopant) and Compound 813 (host) were co-deposited at a rate of 0.1 Å/sec and 1 Å/sec, respectively, on the HTL to form an EML having a thickness of 400 Å. BAlq was vacuum deposited on the EML at a rate of 1 Å/sec to form an HBL having a thickness of 50 Å and then Alq_3 was vacuum deposited on the HBL to form an ETL having a thickness of 300 Å. Then, LiF 10 Å (EIL) and Al 2000 Å (cathode) were sequentially vacuum deposited on the ETL to manufacture an organic light-emitting device.

Example 2

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 815 was used as a host instead of Compound 813 when forming an EML.

Example 3

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 814 was used as a host instead of Compound 813 when forming an EML.

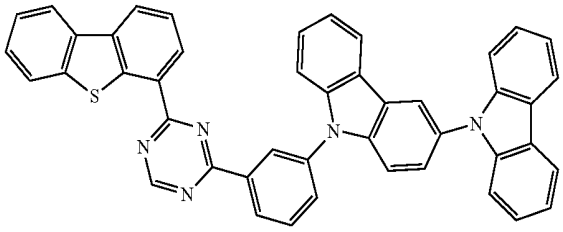
Example 4

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 816 was used as a host instead of Compound 813 when forming an EML.

Comparative Example 1

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound A was used as a host instead of Compound 813 when forming an EML.

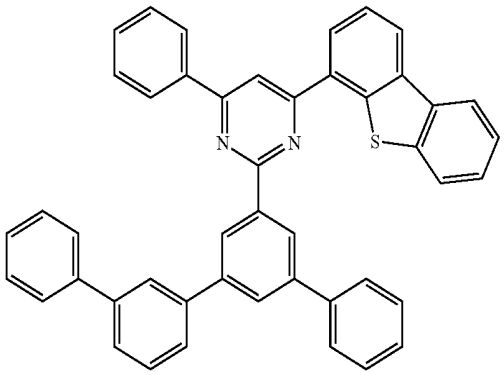
Compound A



Comparative Example 2

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound B was used as a host instead of Compound 813 when forming an EML.

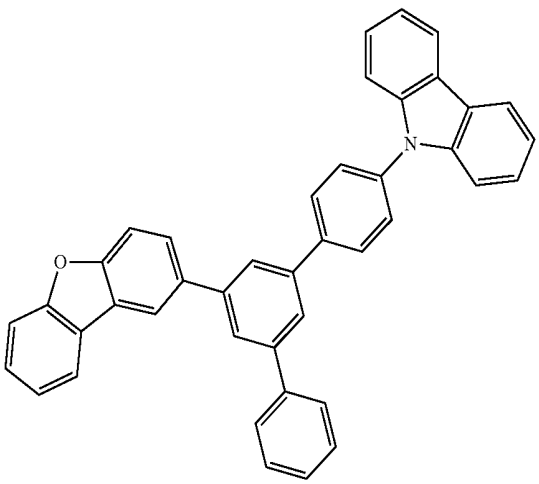
Compound B



Comparative Example 3

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound C was used as a host instead of Compound 813 when forming an EML.

Compound C



Evaluation Example 2

Evaluation of Characteristics of Organic Light-Emitting Device

Changes in current density and brightness, and emission efficiency of each organic light-emitting device manufactured in Examples 1 to 4 and Comparative Examples 1 to 3 were measured. A detailed method of measurement is as described below and results obtained therefrom are shown in Table 5 below:

(1) Measurement of Changes in Current Density According to Changes in Voltage

For each organic light-emitting device, voltage was increased from 0 volts (V) to 10 V to measure current that flows through a unit cell therein by using a voltage-current meter (Keithley 2400) and the current was divided by surface area to obtain a current density.

(2) Measurement of Changes in Brightness According to Changes in Voltage

For each organic light-emitting device, brightness was measured while increasing voltage from 0 V to 10 V to by using Cs-1000A (a product of Minolta).

(3) Measurement of Emission Efficiency

Brightness, current density, and voltage measured from (1) and (2) were used to calculate current efficiency (candelas per ampere (cd/A)) at the same current density (10 milliamperes per square centimeter (mA/cm^2)).

TABLE 5

	Host	Dopant	Driving voltage (V)	Current density (cd/A)	Brightness (cd/m^2)
Example 1	Compound 813	$Ir(ppy)_3$	3.7	40.3	3500
Example 2	Compound 815	$Ir(ppy)_3$	3.4	46.2	3500
Example 3	Compound 814	$Ir(ppy)_3$	4.1	36.1	3500
Example 4	Compound 816	$Ir(ppy)_3$	3.8	33.8	3500
Comparative Example 1	Compound A	$Ir(ppy)_3$	4.4	32.6	3500
Comparative Example 2	Compound B	$Ir(ppy)_3$	4.3	31.5	3500
Comparative Example 3	Compound C	$Ir(ppy)_3$	4.2	32.9	3500

From Table 5, it may be concluded that the organic light-emitting devices of Examples 1 to 4 have lower driving voltage, high efficiency, and high brightness compared the organic light-emitting devices of Comparative Examples 1 to 3.

As described above, according to the one or more of the above embodiments, the condensed-cyclic compound have excellent electrical properties and thermal stability and thus, an organic light-emitting device including the condensed-cyclic compound may have low driving voltage, high efficiency, high brightness, and a long lifespan.

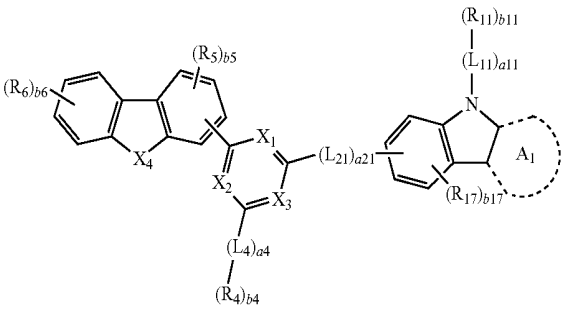
It should be understood that the exemplary embodiments described therein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each embodiment should typically be considered as available for other similar features or aspects in other embodiments.

While one or more embodiments have been described with reference to the figures, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present disclosure as defined by the following claims.

What is claimed is:

1. A condensed-cyclic compound represented by Formula 1B:

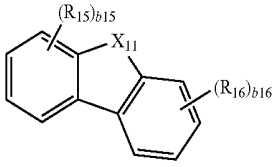
Formula 1B



wherein in Formula 1B,

ring A_1 is represented by Formula 1C;

Formula 1C



X_1 is N or C-[$(L_1)_{a1}$-$(R_1)_{b1}$],

X_2 is N or C-[$(L_2)_{a2}$-$(R_2)_{b2}$],

X_3 is N or C-[$(L_3)_{a3}$-$(R_3)_{b3}$], and

at least one of X_1 to X_3 is N;

X_4 is O or S;

X_{11} is selected from N-[$(L_{12})_{a12}$-$(R_{12})_{b12}$], S, O, S(=O), $S(=O)_2$, C(=O), $C(R_{13})(R_{14})$, $Si(R_{13})(R_{14})$, $P(R_{13})$, $P(=O)(R_{13})$, and $C=N(R_{12})$;

L_1 to L_4, L_{11}, L_{12}, and L_{21} are each independently selected from Formulae 2-1 to 2-34;

a1 to a4, a11, a12, and a21 are each independently selected from integers of 0 to 3;

R_1 to R_3, R_5, R_6, and R_{13} to R_{17} are each independently selected from:

a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;

a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, and a phosphoric acid or a salt thereof;

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group,

a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group and an imidazopyrimidinyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, —$Si(Q_{33})(Q_{34})(Q_{35})$, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and a biphenyl group,

R_4, R_{11}, and R_{12} are each independently selected from:

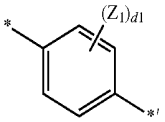
a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacencyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imida-

zolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyranzinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, —$Si(Q_{33})(Q_{34})(Q_{35})$, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and a biphenyl group,

b1 to b6 and b11 to b17 are each independently selected from integers of 1 to 3;

Formula 2-1



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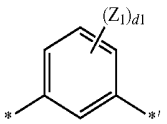
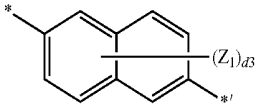
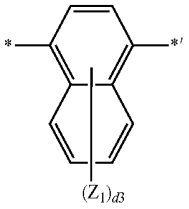
Formula 2-2



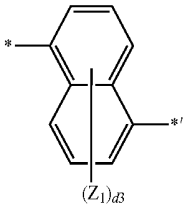
Formula 2-3



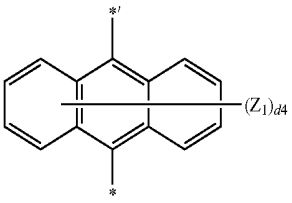
Formula 2-4



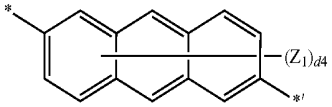
Formula 2-5



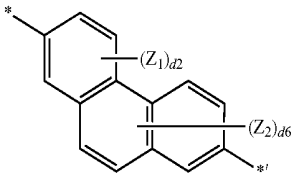
Formula 2-6



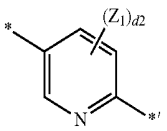
Formula 2-7



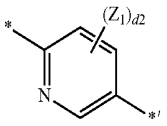
Formula 2-8



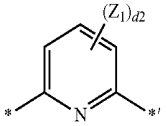
Formula 2-9



Formula 2-10



Formula 2-11



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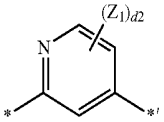
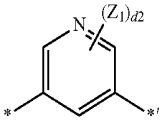
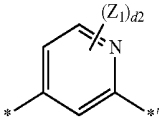
Formula 2-12



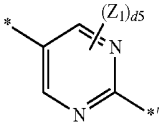
Formula 2-13



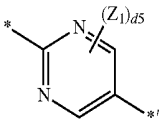
Formula 2-14



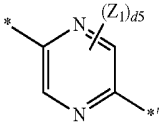
Formula 2-15



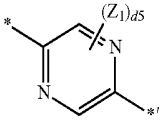
Formula 2-16



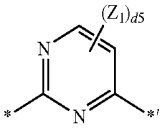
Formula 2-17



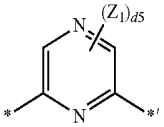
Formula 2-18



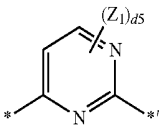
Formula 2-19



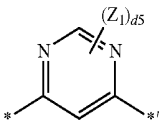
Formula 2-20



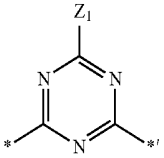
Formula 2-21



Formula 2-22



Formula 2-23



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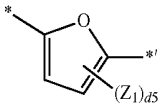
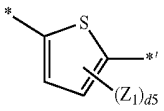
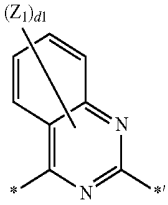
Formula 2-24



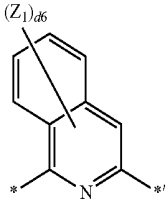
Formula 2-25



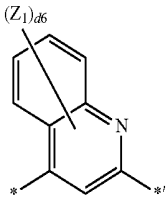
Formula 2-26



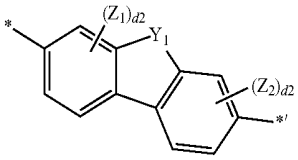
Formula 2-27



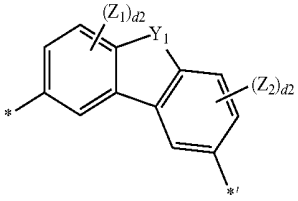
Formula 2-28



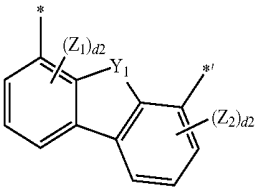
Formula 2-29



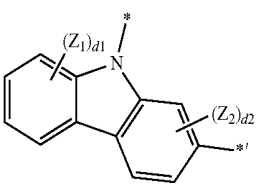
Formula 2-30



Formula 2-31



Formula 2-32



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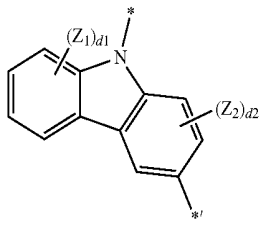
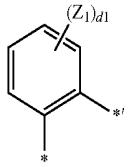
Formula 2-33



Formula 2-34



wherein in Formulae 2-1 to 2-34,

Y_1 is O, S, S(=O), S(=O)$_2$, C(Z_3)(Z_4), N(Z_5) or Si(Z_6)(Z_7);

Z_1 to Z_7 are each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, a quinoxalinyl group, a biphenyl group, and —Si(Q_{33})(Q_{34})(Q_{35}),

wherein Q_{33} to Q_{35} are each independently selected from a hydrogen, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group; and

d1 is selected from integers of 1 to 4,

d2 is selected from integers of 1 to 3,

d3 is selected from integers of 1 to 6,

d4 is selected from integers of 1 to 8,

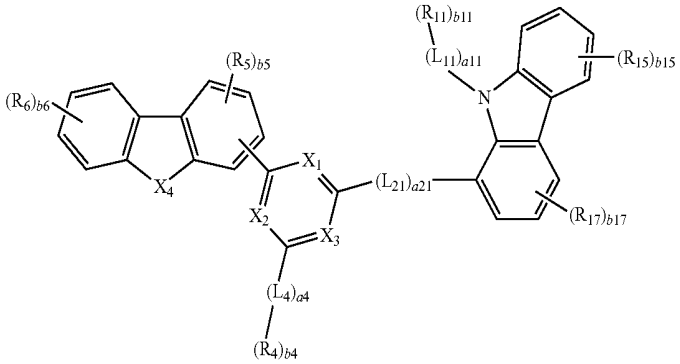
d5 is 1 or 2,

d6 is selected from integers of 1 to 5, and

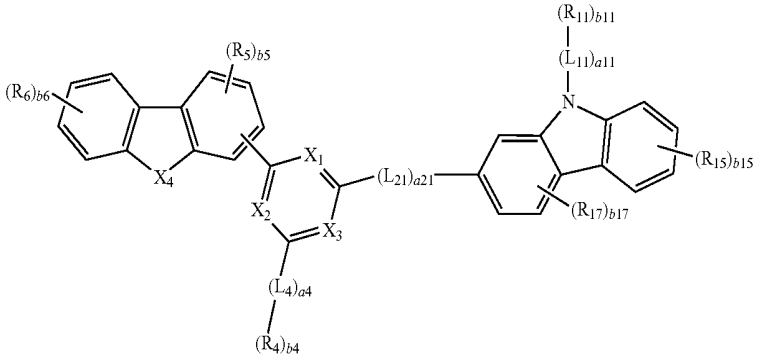
each of * and *' indicates a binding site to a neighboring atom.

2. The condensed-cyclic compound of claim **1**, wherein the condensed-cyclic compound is represented by one of Formulae and 1 B-1 to 1 B-4:

Formula 1B-1



Formula 1B-2



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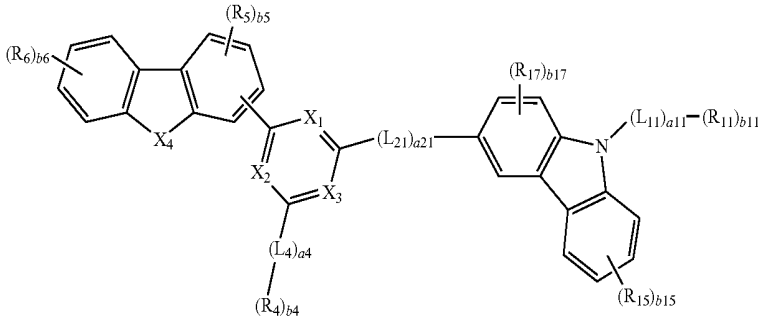
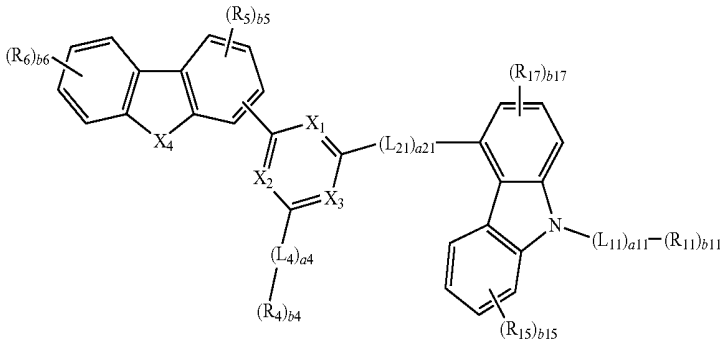
Formula 1B-3



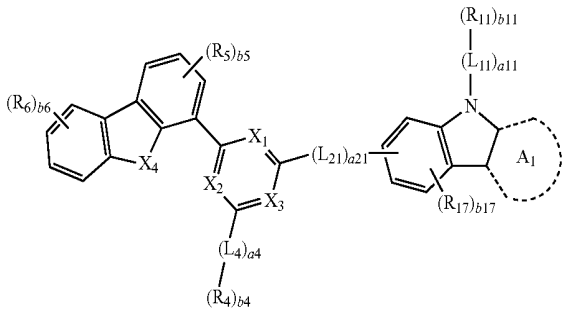
Formula 1B-4



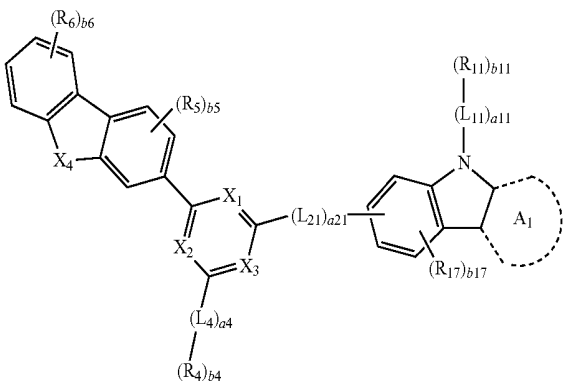
wherein in Formulae 1B-1 to 1B-4, X_1 to X_4, X_{11}, L_1 to L_4, L_{11}, L_{12}, L_{21}, a1 to a4, a11, a12, a21, R_1 to R_6, R_{11} to R_{17}, b1 to b6, and b11 to b17 are the same as described in claim **1**.

3. The condensed-cyclic compound of claim **1**, wherein the condensed-cyclic compound is represented by one of Formulae 1B(1), 1B(2), and 1B(4):

Formula 1B(1)



Formula 1B(2)



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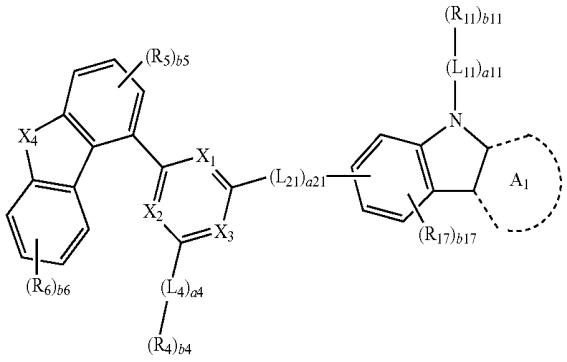
Formula 1B(4)



wherein in Formulae 1B(1), 1B(2), and 1B(4), the ring A_1 is represented by Formula 1C and descriptions of X_1 to X_4, X_{11}, L_1 to L_4, L_{11}, L_{12}, L_{21}, a1 to a4, a11, a12, a21, R_1 to R_6, R_{11} to R_{17}, b1 to b6, and b11 to b17 are the same as described in claim **1**.

4. The condensed-cyclic compound of claim **1**, wherein

X_1 to X_3 is N;

X_1 is C-[$(L_1)_{a1}$-$(R_1)_{b1}$] and X_2 and X_3 are N;

X_1 is N, X_2 is C-[$(L_2)_{a2}$-$(R_2)_{b2}$], and X_3 is N;

X_1 and X_2 are N and X_3 is C-[$(L_3)_{a3}$-$(R_3)_{b3}$];

X_1 is C-[$(L_1)_{a1}$-$(R_1)_{b1}$], X_2 is N, and X_3 is C-[$(L_3)_{a3}$-$(R_3)_{b3}$];

X_1 is C-[$(L_1)_{a1}$-$(R_1)_{b1}$], X_2 is C-[$(L_2)_{a2}$-$(R_2)_{b2}$], and X_3 is N; or

X_1 is N, X_2 is C-[$(L_2)_{a2}$-$(R_2)_{b2}$], and X_3 is C-[$(L_3)_{a3}$-$(R_3)_{b3}$].

5. The condensed-cyclic compound of claim **1**, wherein

X_1 is C-[$(L_1)_{a1}$-$(R_1)_{b1}$] and X_2 and X_3 are N; or

X_1 and X_2 are N, and X_3 is C-[$(L_3)_{a3}$-$(R_3)_{b3}$].

6. The condensed-cyclic compound of claim **1**, wherein a21 is 1.

7. The condensed-cyclic compound of claim 1, wherein R_1 to R_3, R_5, R_6, and R_{13} to R_{17} are each independently selected from:

a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;

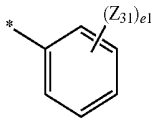
a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, and a phosphoric acid or a salt thereof;

Formulae 4-1 to 4-31; and

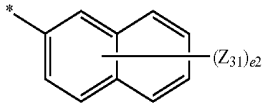
$—Si(Q_3)(Q_4)(Q_5)$, provided that R_{13} and R_{14} are not $—Si(Q_3)(Q_4)(Q_5)$,

R_4, R_{11}, and R_{12} are each independently selected from Formulae 4-1 to 4-31:

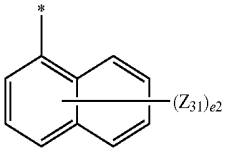
Formula 4-1



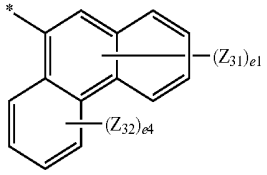
Formula 4-2



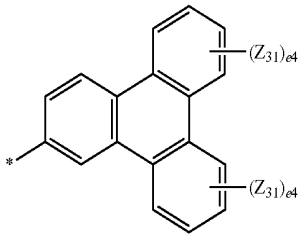
Formula 4-3



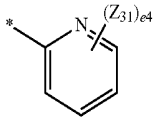
Formula 4-4



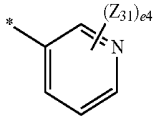
Formula 4-5



Formula 4-6



Formula 4-7



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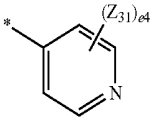
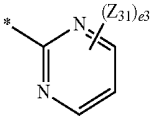
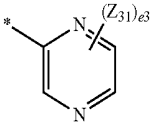
Formula 4-8



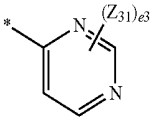
Formula 4-9



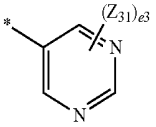
Formula 4-10



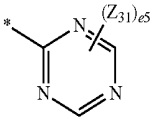
Formula 4-11



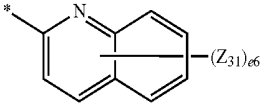
Formula 4-12



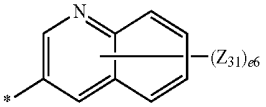
Formula 4-13



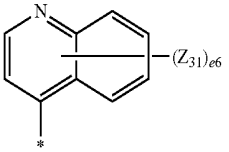
Formula 4-14



Formula 4-15



Formula 4-16



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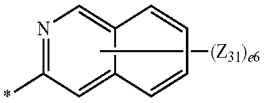
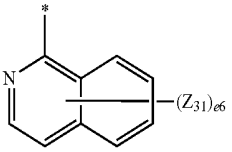
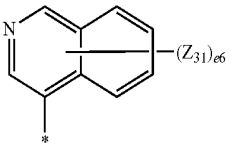


Formula 4-18



Formula 4-19



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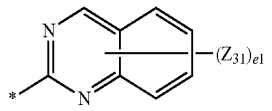
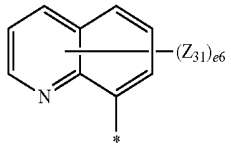
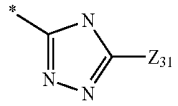
Formula 4-20



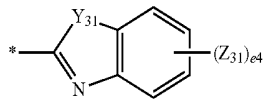
Formula 4-21



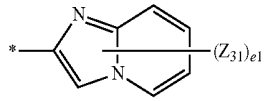
Formula 4-22



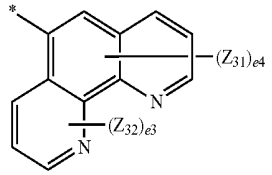
Formula 4-23



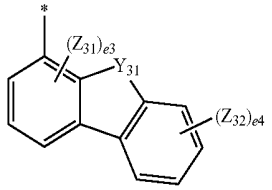
Formula 4-24



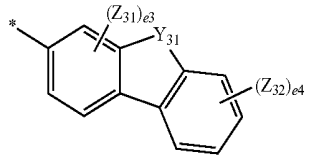
Formula 4-25



Formula 4-26



Formula 4-27



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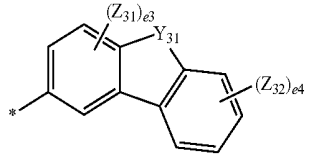
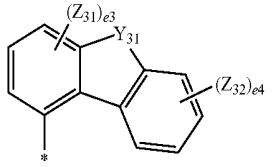


Formula 4-29



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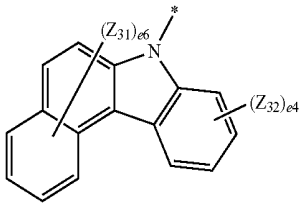
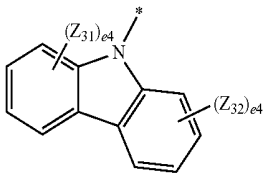
Formula 4-30



Formula 4-31



in Formula 4-1 to 4-31,

Y_{31} is O, S, $C(Z_{33})(Z_{34})$, $N(Z_{35})$ or $Si(Z_{36})(Z_{37})$;

Z_{31} to Z_{37} are each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, a quinoxalinyl group, a biphenyl group, and $—Si(Q_{33})(Q_{34})(Q_{35})$;

Q_3 to Q_5 and Q_{33} to Q_{35} are each independently selected from a hydrogen, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group;

e1 is selected from integers of 1 to 5,

e2 is selected from integers of 1 to 7,

e3 is selected from integers of 1 to 3,

e4 is selected from integers of 1 to 4,

e5 is 1 or 2, and

e6 is selected from integers of 1 to 6, and

* indicates a bonding site to a neighboring atom.

8. The condensed-cyclic compound of claim **1**, wherein

R_1 to R_3, R_5, R_6, and R_{13} to R_{17} are each independently selected from:

a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;

a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine

group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, and a phosphoric acid or a salt thereof;

a phenyl group and a naphthyl group; and

a phenyl group and a naphthyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, and a naphthyl group; and

R_4 , R_{11} , and R_{12} are each independently selected from:

a phenyl group and a naphthyl group; and

a phenyl group and a naphthyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, and a naphthyl group.

9. An organic light-emitting device comprising

a first electrode;

a second electrode; and

an organic layer disposed between the first electrode and the second electrode,

wherein the organic layer comprises an emission layer and the condensed-cyclic compound of claim **1**.

10. The organic light-emitting device of claim **9**, wherein

the first electrode is an anode and

the second electrode is a cathode,

wherein the organic layer comprises

i) a hole transport region disposed between the first electrode and the emission layer,

wherein the hole transport region comprises at least one of a hole-injection layer, a hole-transporting layer, and an electron-blocking layer; and

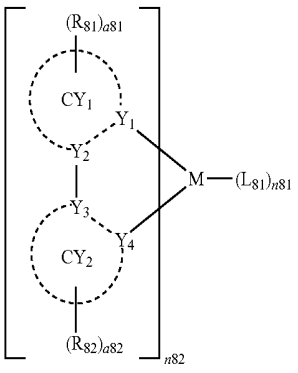
ii) an electron transport region disposed between the emission layer and the second electrode,

wherein the electron transport region comprises at least one layer selected from a hole-blocking layer, an electron-transporting layer, and an electron-injecting layer.

11. The organic light-emitting device of claim **9**, wherein the emission layer comprises the condensed-cyclic compound.

12. The organic light-emitting device of claim **11**, wherein the emission layer further comprises an organometallic compound represented by Formula 81:

Formula 81



wherein in Formula 81,

M is selected from Ir, Pt, Os, Ti, Zr, Hf, Eu, Tb, and Tm;

Y_1 to Y_4 are each independently C or N;

Y_1 and Y_2 are connected by a single bond or a double bond and

Y_3 and Y_4 are connected by a single bond or a double bond;

CY_1 and CY_2 are each independently selected from a benzene, a naphthalene, a fluorene, a spiro-fluorene, an indene, a pyrrole, a thiophene, a furan, an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isooxazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, a quinoline, an isoquinoline, a benzoquinoline, a quinoxaline, a quinazoline, a carbazole, a benzoimidazole, a benzofuran, a benzothiophene, an isobenzothiophene, a benzooxazole, an isobenzooxazole, a triazole, a tetrazole, an oxadiazole, a triazine, a dibenzofuran, and a dibenzothiophene, wherein CY_1 and CY_2 are optionally bound to each other by a single bond or an organic linking group;

R_{81} and R_{82} are each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, $—SF_5$, a substituted or unsubstituted C_1 -C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_2-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_2-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_2-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic hetero-condensed polycyclic group, $—N(Q_1)(O_2)$, $—Si(Q_3)(O_4)(Q_5)$, and $—B(Q_6)(Q_7)$;

a81 and a82 are each independently selected from integers of 1 to 5;

n81 is selected from integers of 0 to 4;

n82 is 1, 2, or 3; and

L81 is selected from a monovalent organic ligand, a divalent organic ligand, and a trivalent organic ligand.

13. A condensed-cyclic compound being one of the following compounds:

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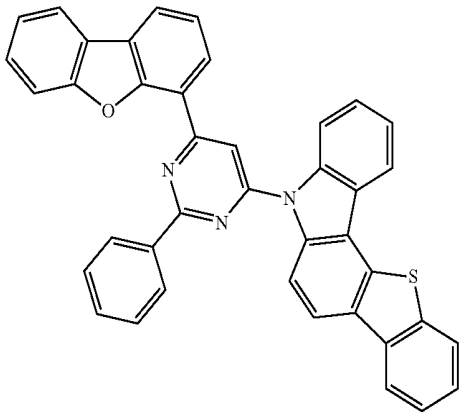

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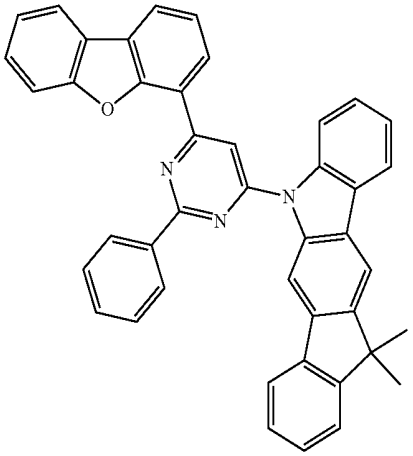

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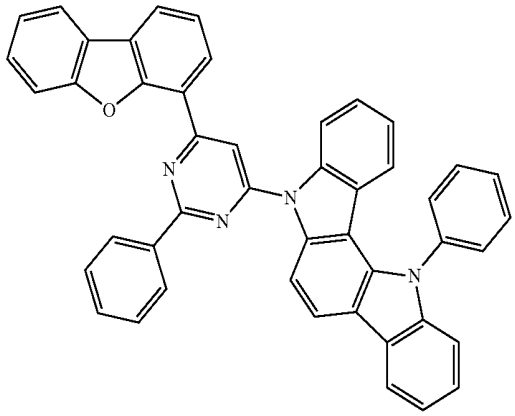

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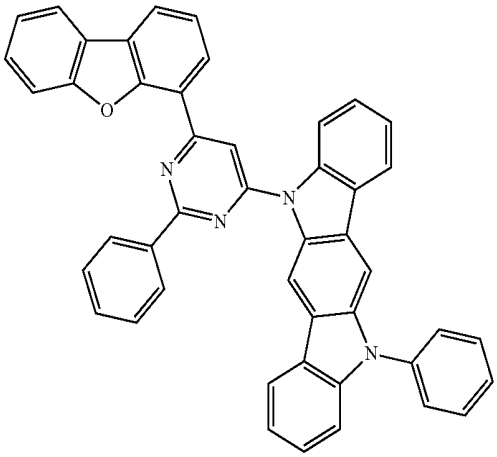

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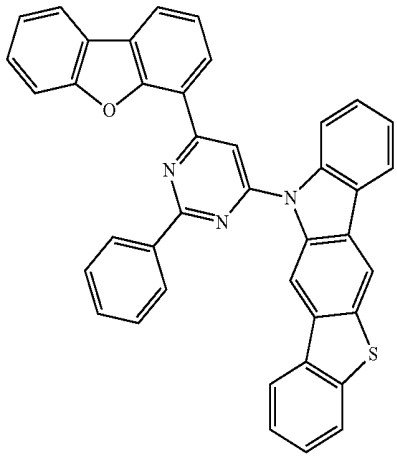

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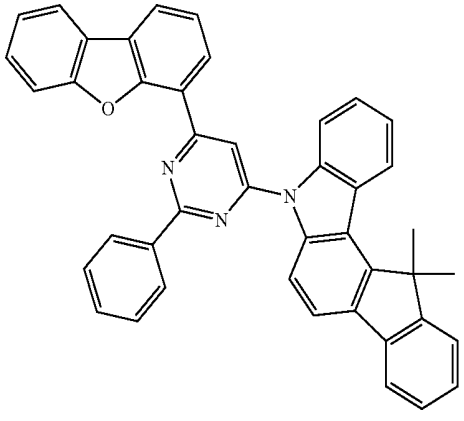

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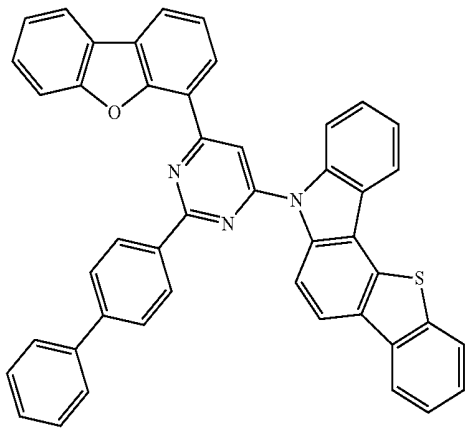

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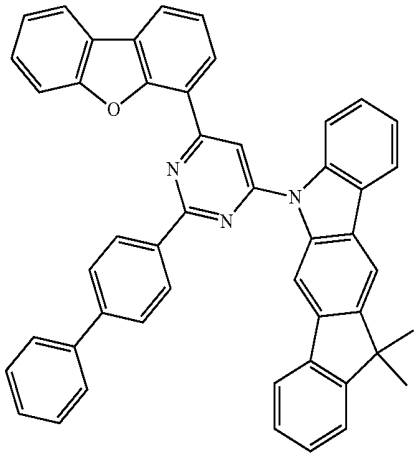

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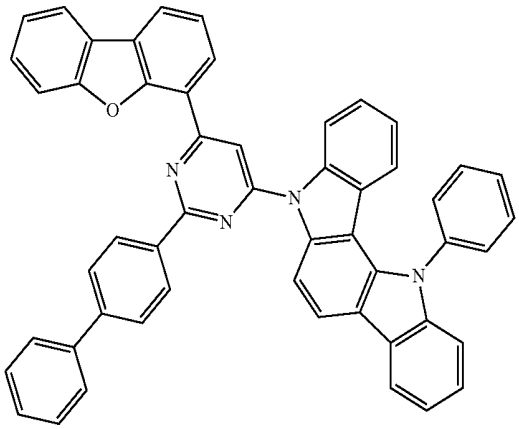

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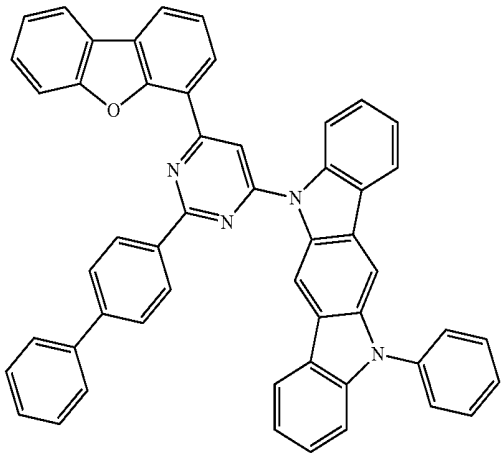

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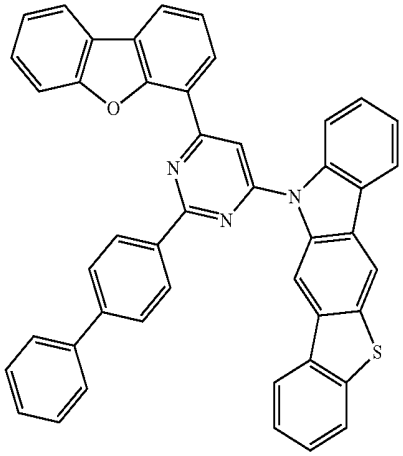

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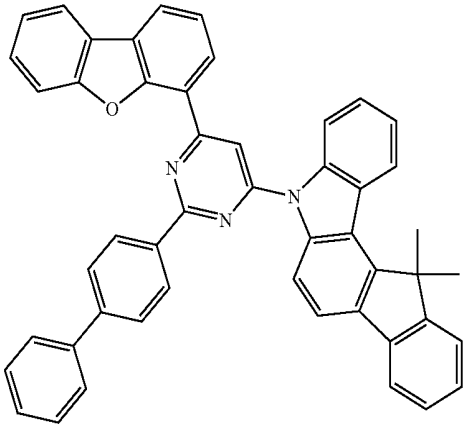

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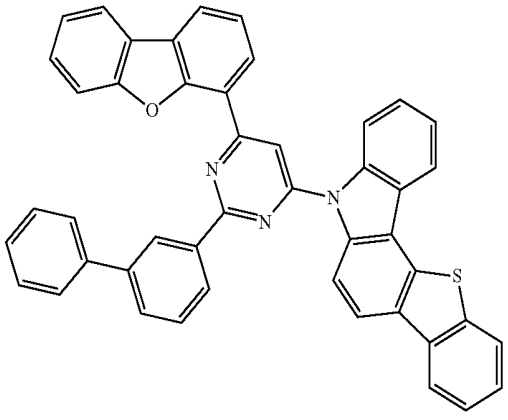

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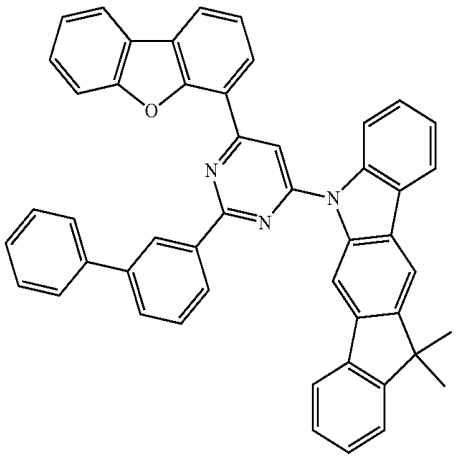

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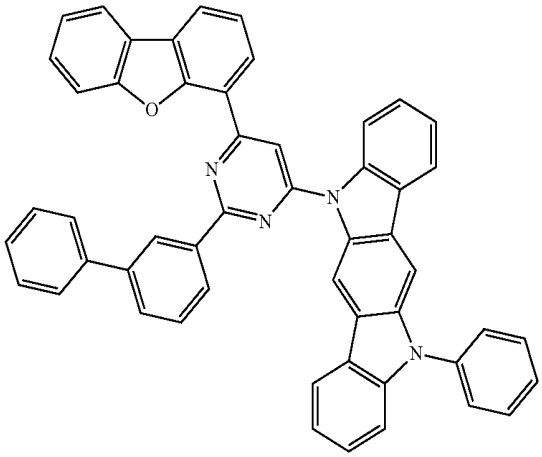

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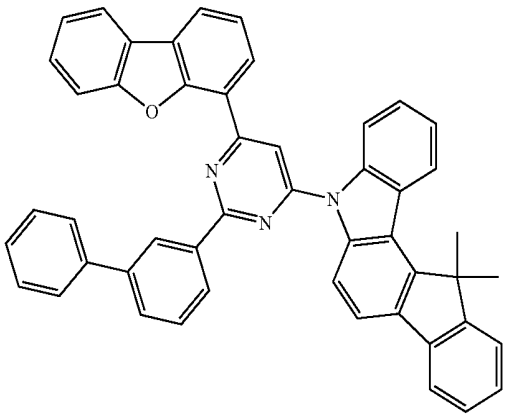

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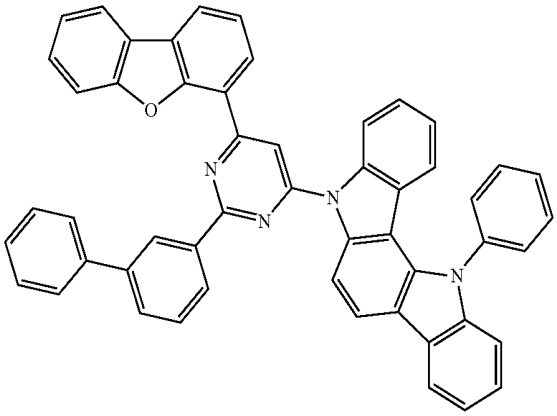

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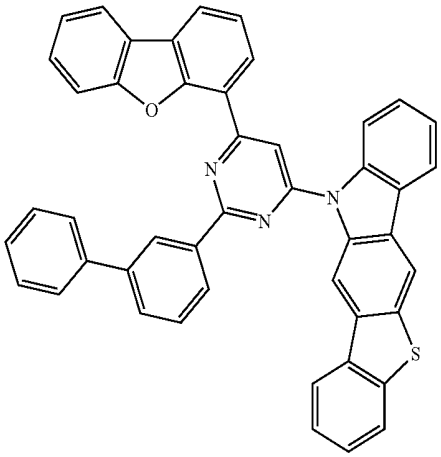

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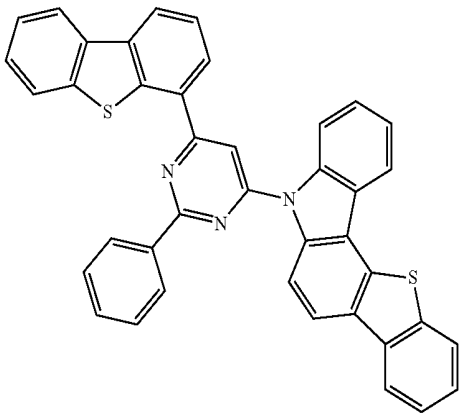

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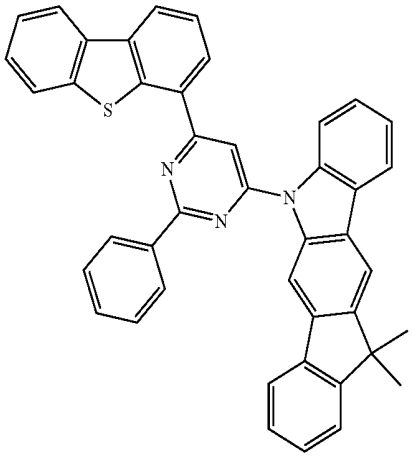

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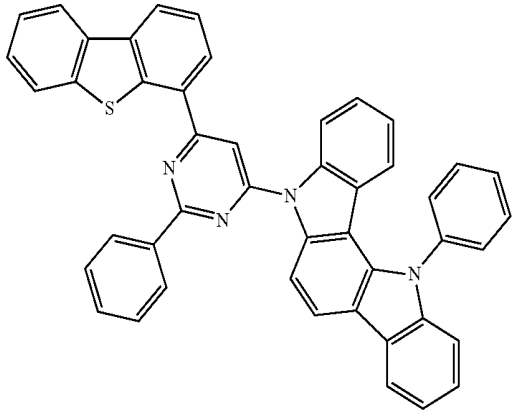

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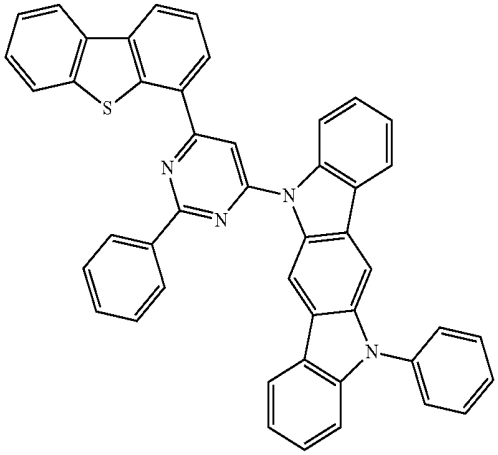

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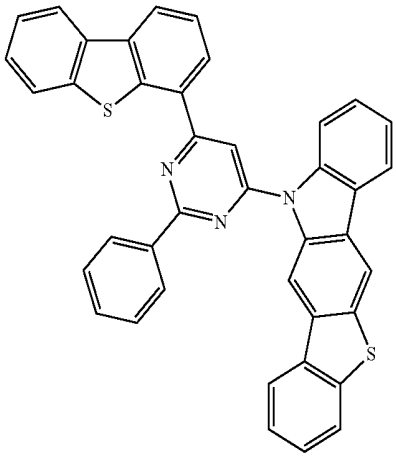

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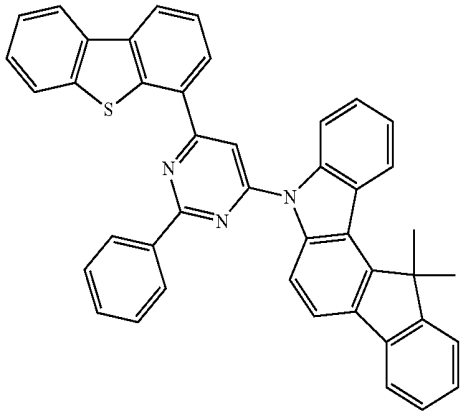

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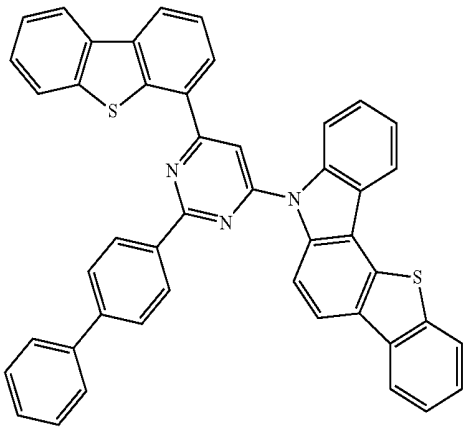

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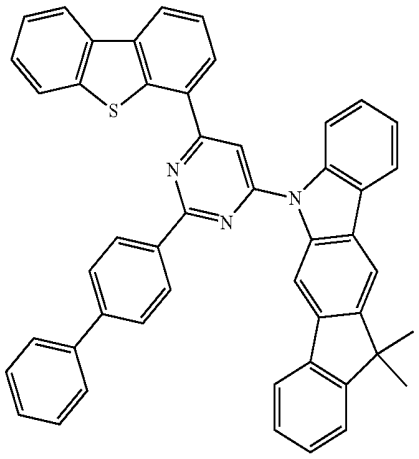

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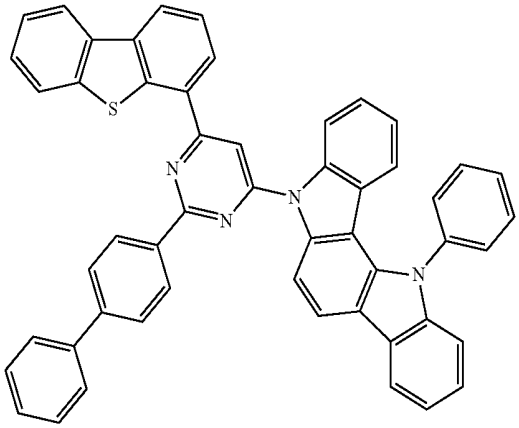

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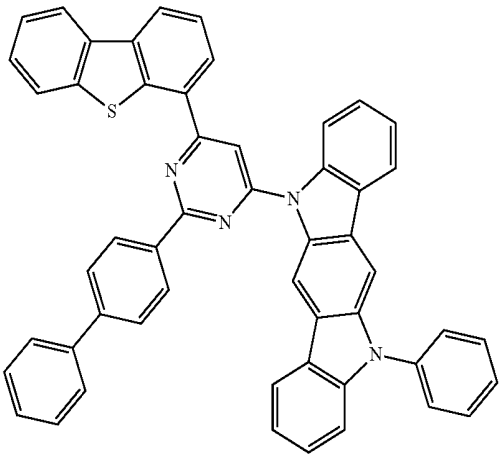

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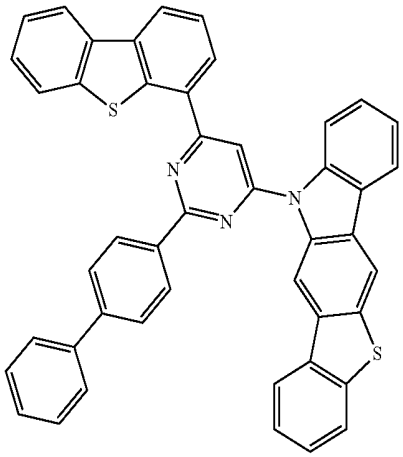

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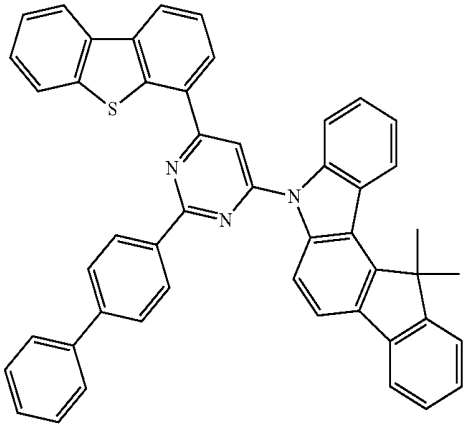

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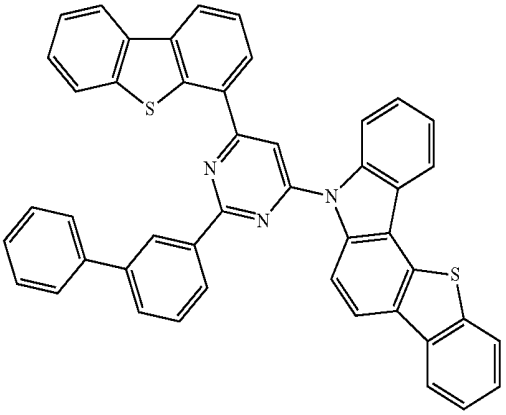

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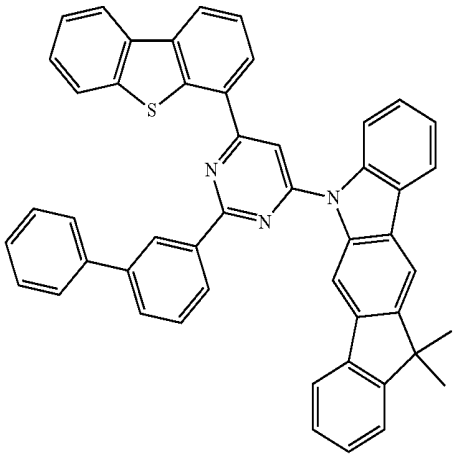

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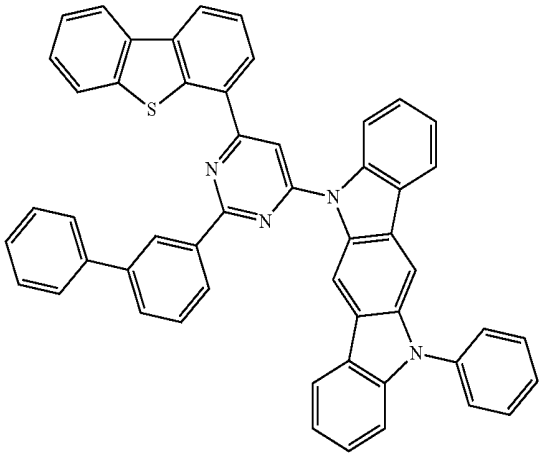

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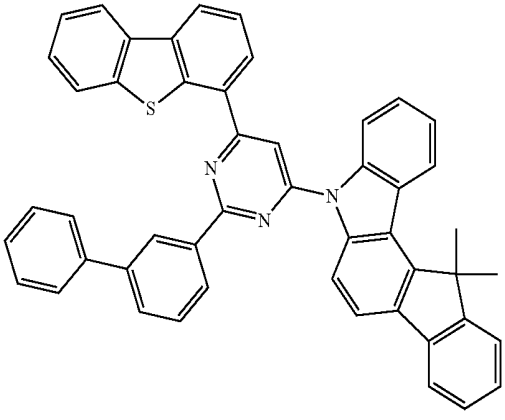

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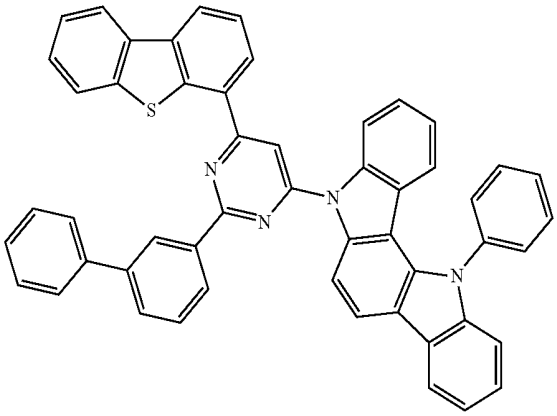

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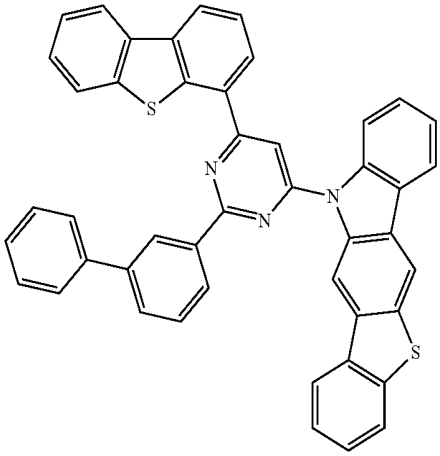

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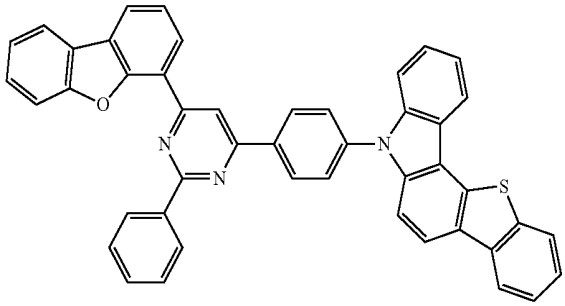

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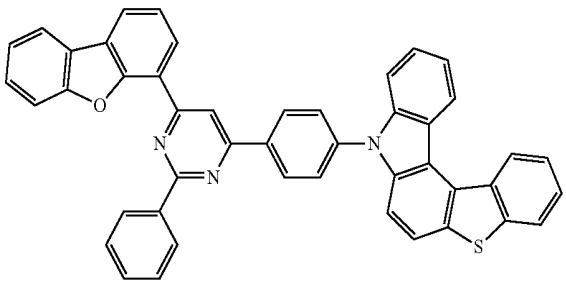

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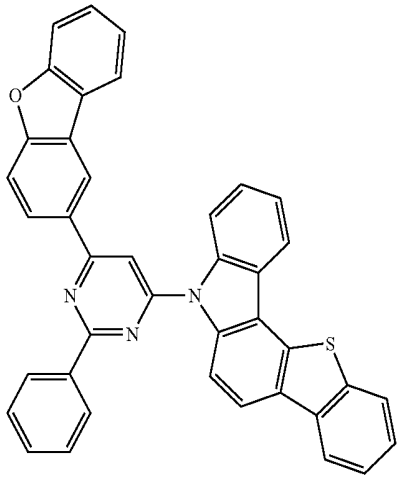

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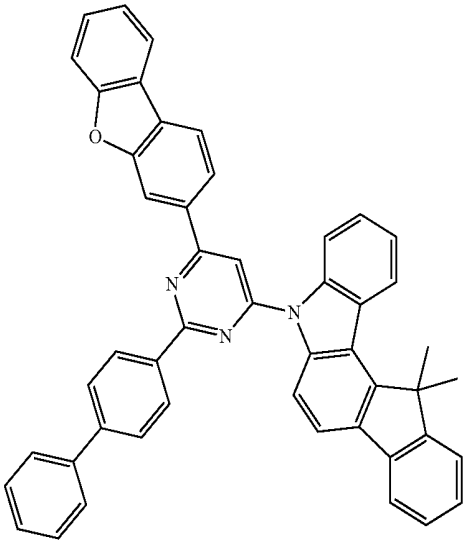

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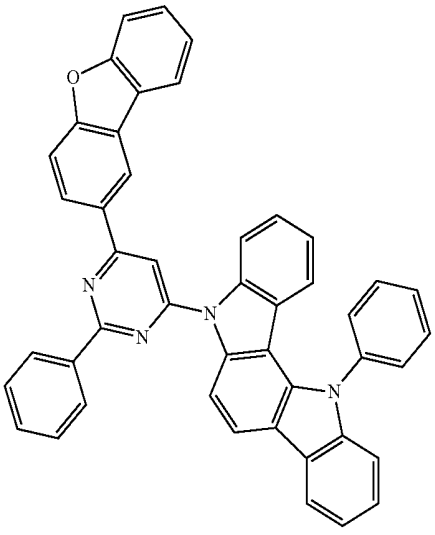

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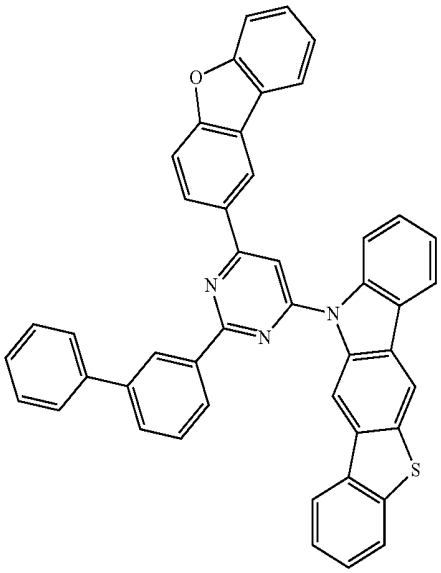

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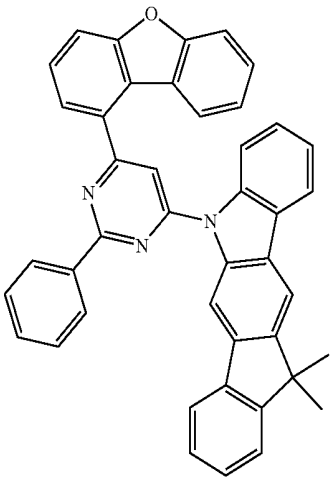

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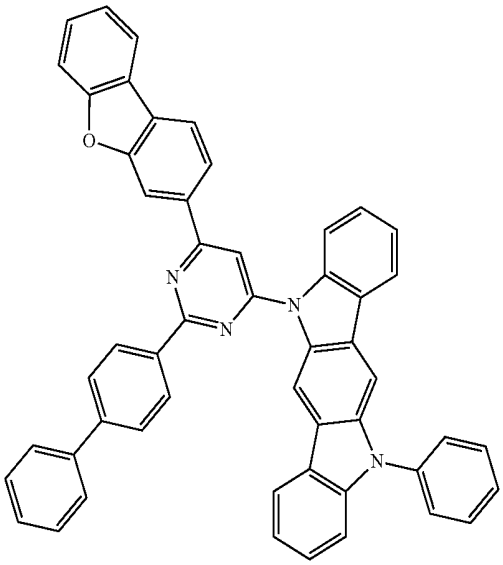

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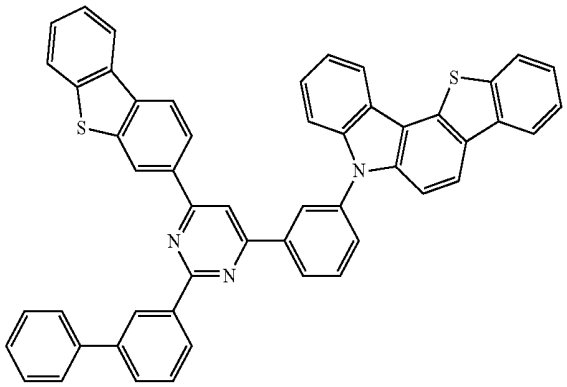

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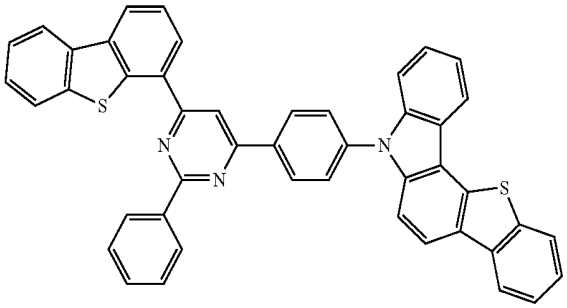

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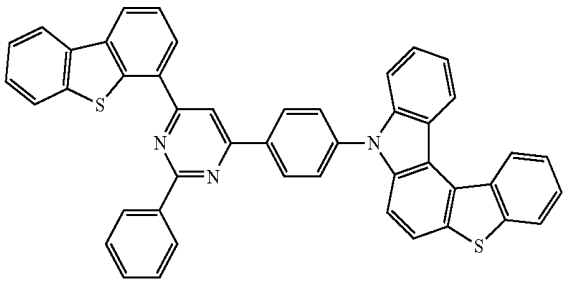

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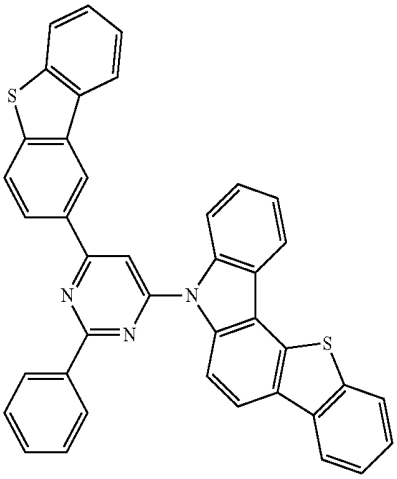

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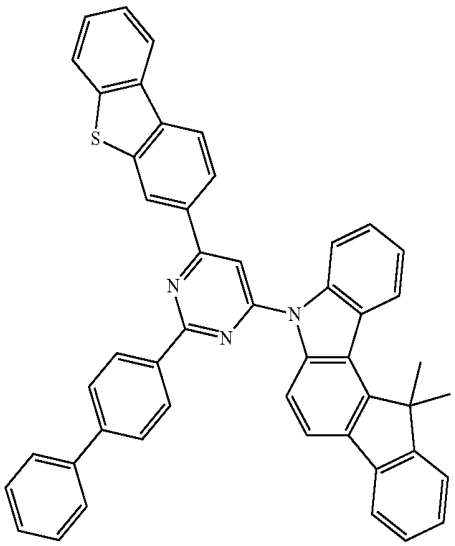

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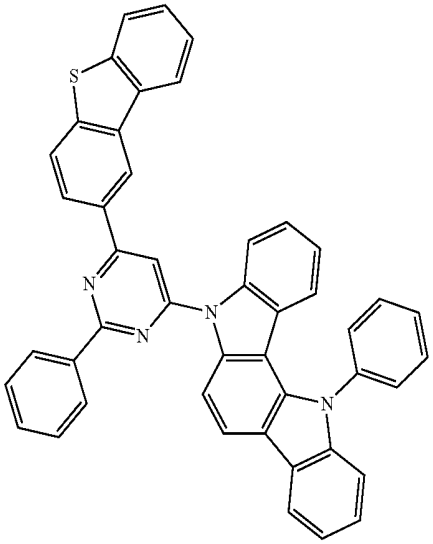

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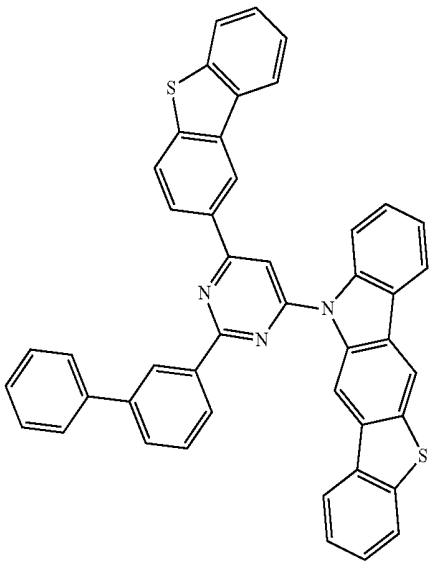

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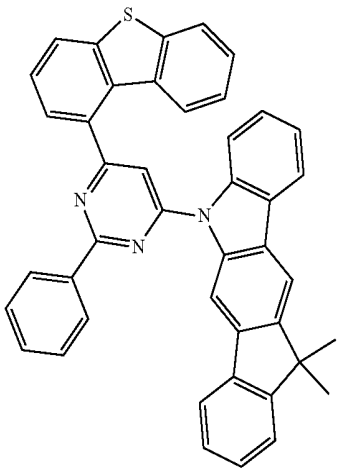

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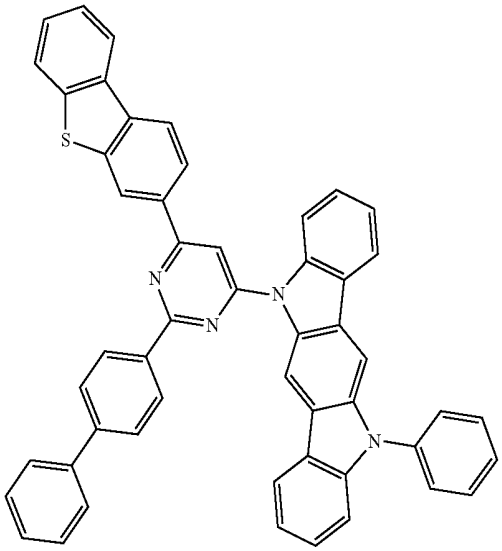

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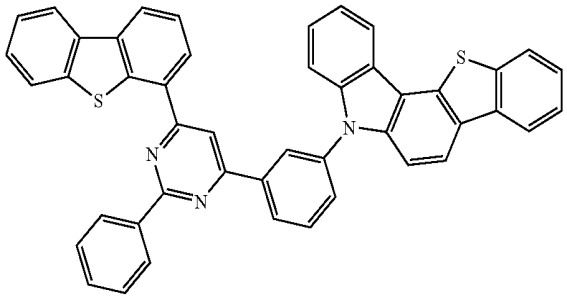

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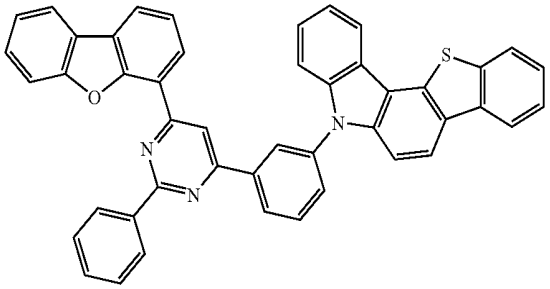

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专利名称(译)	缩合环状化合物和包括其的有机发光器件		
公开(公告)号	US10158085	公开(公告)日	2018-12-18
申请号	US14/573422	申请日	2014-12-17
[标]申请(专利权)人(译)	三星电子株式会社		
申请(专利权)人(译)	SAMSUNG ELECTRONICS CO.，LTD. 三星SDI CO.，LTD.		
当前申请(专利权)人(译)	SAMSUNG ELECTRONICS CO.，LTD. 三星SDI CO.，LTD.		
[标]发明人	LEE SEUNGJAE KIM BYUNGKU KIM YOUNGKWON KIM CHANGWOO KIM HYUNGSUN SHIN CHANGJU YU EUNSUN CHOI BYOUNGKI HWANG KYUYOUNG		
发明人	LEE, SEUNGJAE KIM, BYUNGKU KIM, YOUNGKWON KIM, CHANGWOO KIM, HYUNGSUN SHIN, CHANGJU YU, EUNSUN CHOI, BYOUNGKI HWANG, KYUYOUNG		
IPC分类号	H01L51/00 H01L51/50		
CPC分类号	H01L51/0067 H01L51/0072 H01L51/0073 H01L51/5016 H01L51/0081 H01L51/0085		
代理机构(译)	康托科尔伯恩LLP		
审查员(译)	杨，JAY		
优先权	1020130157532 2013-12-17 KR		
其他公开文献	US20150171340A1		
外部链接	Espacenet		

摘要(译)

由式1A或1B表示的稠环化合物： 其中在式1A和1B中，基团，取代基和变量与说明书中定义的相同。

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