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

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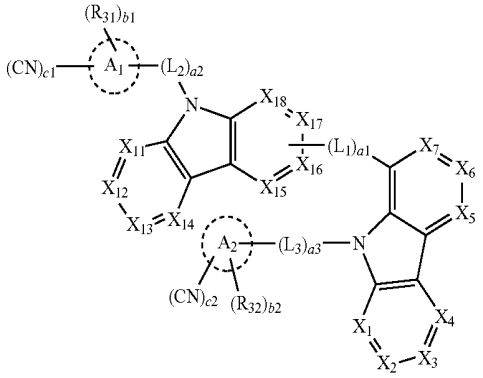
(57) **ABSTRACT**

A condensed cyclic compound represented by Formula 1:

Formula 1



wherein, in Formula 1, rings, groups and variables are the same as defined in the specification.

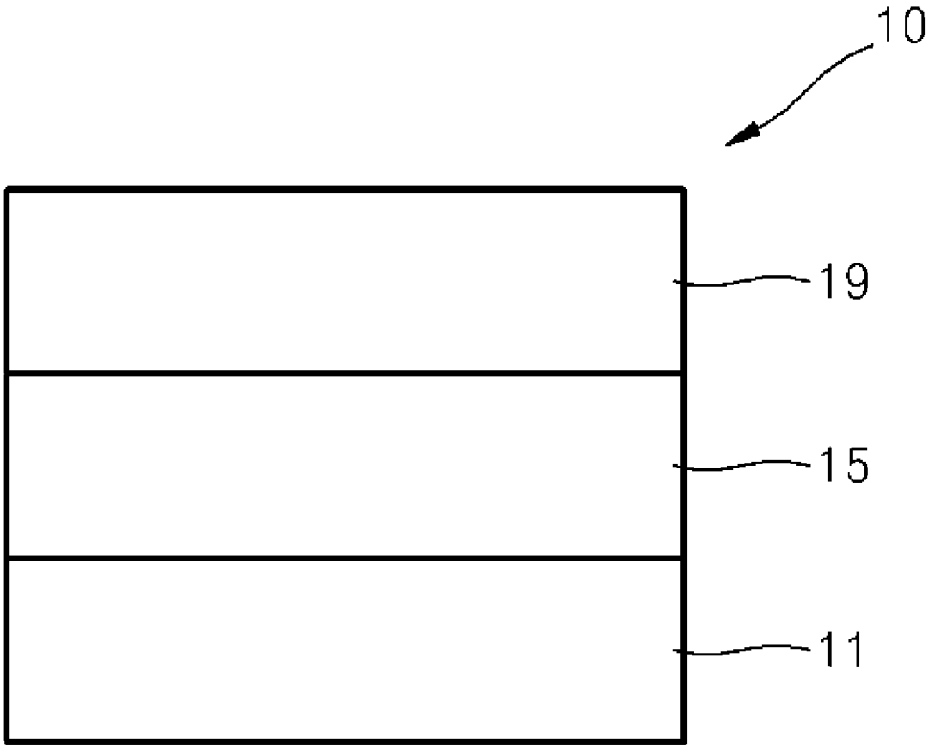
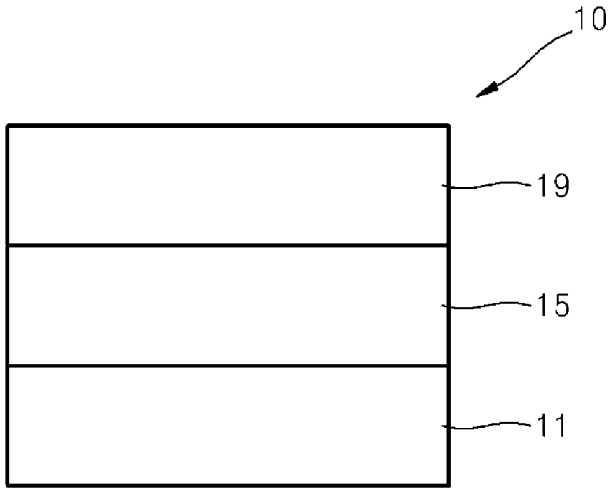


FIG. 1



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

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2015-0123657, filed on Sep. 1, 2015, and Korean Patent Application No. 10-2015-0089087, filed on Jun. 23, 2015 in the Korean Intellectual Property Office, the content of which are incorporated herein in their entirety by reference.

BACKGROUND

[0002] 1. Field

[0003] The present disclosure relates to a condensed cyclic compound and an organic light-emitting device including the same.

[0004] 2. Description of the Related Art

[0005] Organic light-emitting devices (OLEDs) are self-emission devices that have wide viewing angles, high contrast ratios, and short response times. In addition, the OLEDs exhibit high brightness, driving voltage, and response speed characteristics, and produce full-color images.

[0006] A typical organic light-emitting device includes an anode, a cathode, and an organic layer that is disposed between the anode and the cathode, wherein the organic layer includes an emission layer. A hole transport region may be disposed between the anode and the emission layer, and an electron transport region may be disposed between the emission layer and the cathode. Holes provided from the anode may move toward the emission layer through the hole transport region, and electrons provided from the cathode may move toward the emission layer through the electron transport region. Carriers, such as holes and electrons, are recombined in the emission layer to produce excitons. These excitons change from an excited state to a ground state, thereby generating light.

[0007] 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.

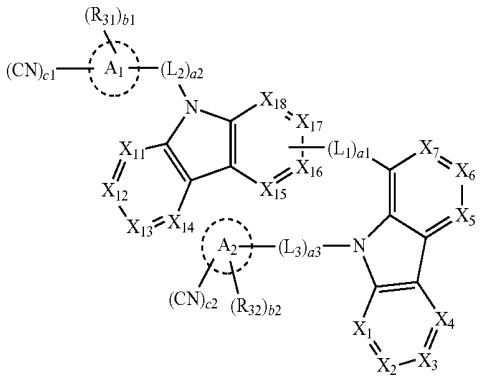
SUMMARY

[0008] Provided are a novel condensed cyclic compound and an organic light-emitting device including the same.

[0009] 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 exemplary embodiments.

[0010] According to an aspect of an exemplary embodiment, a condensed cyclic compound is represented by Formula 1:

Formula 1



[0011] wherein, in Formula 1,

[0012] X_1 is N or $C(R_1)$, X_2 is N or $C(R_2)$, X_3 is N or $C(R_3)$, X_4 is N or $C(R_4)$, X_5 is N or $C(R_5)$, X_6 is N or $C(R_6)$, X_7 is N or $C(R_7)$, X_{11} is N or $C(R_{11})$, X_{12} is N or $C(R_{12})$, X_{13} is N or $C(R_{13})$, X_{14} is N or $C(R_{14})$, X_{15} is N, $C(R_{15})$, or a carbon atom connected to $*\text{-}(L_1)_{a1}\text{-}*'$, X_{16} is N, $C(R_{16})$, or a carbon atom connected to $*\text{-}(L_1)_{a1}\text{-}*'$, X_{17} is N, $C(R_{17})$, or a carbon atom connected to $*\text{-}(L_1)_{a1}\text{-}*'$, and X_{18} is N, $C(R_{18})$, or a carbon atom connected to $*\text{-}(L_1)_{a1}\text{-}*'$, wherein one of X_{15} to X_{18} is connected to $*\text{-}(L_1)_{a1}\text{-}*'$,

[0013] ring A_1 and ring A_2 are each independently selected from a C_5-C_{60} carbocyclic group and a C_3-C_{60} heterocyclic group including at least one heteroatom selected from O, S, and Si,

[0014] L_1 to L_3 are each independently selected from

[0015] a phenylene group, a pyridinylene group, a pyrimidinylene group, a pyrazinylene group, a pyridazinylene group, a triazinylene group, a fluorenylene group, a dibenzofuranylene group, and a dibenzothiophenylene group; and a phenylene group, a pyridinylene group, a pyrimidinylene group, a pyrazinylene group, a pyridazinylene group, a triazinylene group, a fluorenylene group, a dibenzofuranylene group, and a dibenzothiophenylene group, each substituted with at least one 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 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, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and $—Si(Q_{11})(Q_{12})(Q_{13})$,

[0016] a1 to a3 are each independently an integer selected from 0 to 5, wherein when a1 is 2 or greater, two or more groups L_1 are identical to or different from each other, when a2 is 2 or greater, two or more groups L_2 are identical to or different from each other, and when a3 is 2 or greater, two or more groups L_3 are identical to or different from each other,

[0017] R_1 to R_7, R_{11} to R_{18}, R_{31}, and R_{32} are each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group (CN), 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 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_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-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_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and —$Si(Q_1)(Q_2)(Q_3)$,

[0018] b1 and b2 are each independently an integer selected from 0 to 4,

[0019] c1 is an integer selected from 1 to 4,

[0020] c2 is an integer selected from 0 to 4,

[0021] at least one selected from substituents of the 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_1-C_{10} heterocycloalkyl group, substituted C_3-C_{10} cycloalkenyl group, substituted C_1-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_1-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group is 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 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_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-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_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, and —$Si(Q_{21})(Q_{22})(Q_{23})$,

[0022] wherein Q_1 to Q_3, Q_{11} to Q_{13}, and Q_{21} to Q_{23} are each independently selected from a hydrogen, a deuterium, a C_1-C_{60} alkyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group,

[0023] in *-$(L_1)_{a1}$-*', * and *' are each a binding site to a neighboring atom.

[0024] According to another aspect of an exemplary embodiment, an organic light-emitting device includes:

[0025] a first electrode;

[0026] a second electrode; and

[0027] 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.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] These and/or other aspects will become apparent and more readily appreciated from the following description of the exemplary embodiments, taken in conjunction with the accompanying drawing in which:

[0029] FIG. **1** is a schematic cross-sectional view of an organic light-emitting device according to an embodiment.

DETAILED DESCRIPTION

[0030] Reference will now be made in detail to exemplary embodiments, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout. In this regard, the present exemplary embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the exemplary embodiments are merely described below, by referring to the figures, to explain aspects. 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.

[0031] 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.

[0032] 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.

[0033] 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.

[0034] 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.

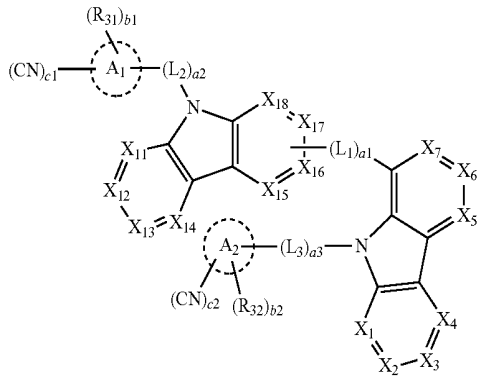
[0035] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this general inventive concept belongs. It will be further understood that terms, such as those defined in commonly 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.

[0036] "About" or "approximately" as used herein is inclusive of the stated value and means within an acceptable range of deviation for the particular value as determined by one of ordinary skill in the art, considering the measurement in question and the error associated with measurement of the particular quantity (i.e., the limitations of the measurement system). For example, "about" can mean within one or more standard deviations, or within ±30%, 20%, 10%, 5% of the stated value.

[0037] 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.

[0038] According to one or more exemplary embodiments, a condensed cyclic compound represented by Formula 1 is provided:

Formula 1



[0039] In Formula 1, X_1 may be N or $C(R_1)$, X_2 may be N or $C(R_2)$, X_3 may be N or $C(R_3)$, X_4 may be N or $C(R_4)$, X_5 may be N or $C(R_5)$, X_6 may be N or $C(R_6)$, X_7 may be N or $C(R_7)$, X_{11} may be N or $C(R_{11})$, X_{12} may be N or $C(R_{12})$, X_{13} may be N or $C(R_{13})$, X_{14} may be N or $C(R_{14})$, X_{15} may be N, $C(R_{15})$, or a carbon atom connected to $*\text{-}(L_1)_{a1}\text{-}*'$, X_{16} may be N, $C(R_{16})$, or a carbon atom connected to $*\text{-}(L_1)_{a1}\text{-}*'$, X_{17} may be N, $C(R_{17})$, or a carbon atom connected to $*\text{-}(L_1)_{a1}\text{-}*'$, and X_{18} may be N, $C(R_{18})$, or a carbon atom connected to $*\text{-}(L_1)_{a1}\text{-}*'$, wherein one of X_{15} to X_{18} may be connected to $*\text{-}(L_1)_{a1}\text{-}*'$.

[0040] For example, in Formula 1, X_1 may be $C(R_1)$, X_2 may be $C(R_2)$, X_3 may be $C(R_3)$, X_4 may be $C(R_4)$, X_5 may be $C(R_5)$, X_6 may be $C(R_6)$, X_7 may be $C(R_7)$, X_{11} may be $C(R_{11})$, X_{12} may be $C(R_{12})$, X_{13} may be $C(R_{13})$, X_{14} may be $C(R_{14})$, X_{15} may be $C(R_{15})$ or a carbon atom connected to $*\text{-}(L_1)_{a1}\text{-}*'$, X_{16} may be $C(R_{16})$ or a carbon atom connected to $*\text{-}(L_1)_{a1}\text{-}*'$, X_{17} may be $C(R_{17})$ or a carbon atom connected to $*\text{-}(L_1)_{a1}\text{-}*'$, and X_{18} may be $C(R_{18})$ or a carbon atom connected to $*\text{-}(L_1)_{a1}\text{-}*'$, wherein one of X_{15} to X_{18} may be connected to $*\text{-}(L_1)_{a1}\text{-}*'$.

[0041] In Formula 1, ring A_1 and ring A_2 may be each independently selected from a C_5-C_{60} carbocyclic group and a C_3-C_{60} heterocyclic group that includes at least one heteroatom selected from O, S, and Si. When ring A_1 and ring A_2 are each a C_3-C_{60} heterocyclic group, the C_3-C_{60} heterocyclic group includes at least one heteroatom selected from O, S, and Si as a ring-forming atom. That is, for example, ring A_1 and ring A_2 may not be a C_3-C_{60} heterocyclic group that includes N as a ring-forming atom. For example, ring A_1 and ring A_2 may not be a pyridine, a pyrimidine, a triazine, or a carbazole.

[0042] For example, in Formula 1, ring A_1 and ring A_2 may be each independently selected from a cyclopentyl group, a cyclohexyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthenyl group, a fluorenyl group, a spirobifluorenyl 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 furanyl group, a thiophenyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group.

[0043] According to an embodiment, in Formula 1, ring A_1 and ring A_2 may be each independently selected from a phenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, but embodiments are not limited thereto.

[0044] In Formula 1, L_1 to L_3 may be each independently selected from

[0045] a phenylene group, a pyridinylene group, a pyrimidinylene group, a pyrazinylene group, a pyridazinylene group, a triazinylene group, a fluorenylene group, a dibenzofuranylene group, and a dibenzothiophenylene group; and

[0046] a phenylene group, a pyridinylene group, a pyrimidinylene group, a pyrazinylene group, a pyridazinylene group, a triazinylene group, a fluorenylene group, a dibenzofuranylene group, and a dibenzothiophenylene group, each substituted with at least one 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 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, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and —$Si(Q_{11})(Q_{12})(Q_{13})$.

[0047] For example, in Formula 1, L_1 to L_3 may be each independently selected from

[0048] a phenylene group, a pyridinylene group, a pyrimidinylene group, a pyrazinylene group, a pyridazinylene group, a triazinylene group, a fluorenylene group, a dibenzofuranylene group, and a dibenzothiophenylene group; and

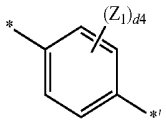
[0049] a phenylene group, a pyridinylene group, a pyrimidinylene group, a pyrazinylene group, a pyridazinylene group, a triazinylene group, a fluorenylene group, a dibenzofuranylene group, and a dibenzothiophenylene group, each substituted with at least one selected from a deuterium, a cyano group, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group,

a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and —$Si(Q_{11})(Q_{12})(Q_{13})$,

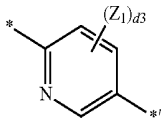
[0050] wherein Q_{11} to Q_{13} may be each independently selected from a hydrogen, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a pyridinyl group, a pyrimidinyl group, and a triazinyl group.

[0051] According to an embodiment, in Formula 1, L_1 to L_3 may be each independently selected from groups represented by Formulae 3-1 to 3-56:

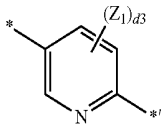
Formula 3-1



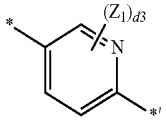
Formula 3-2



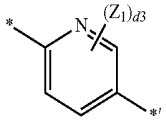
Formula 3-3



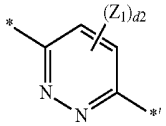
Formula 3-4



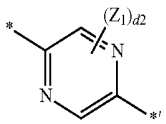
Formula 3-5



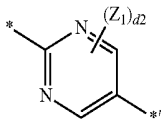
Formula 3-6



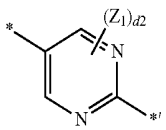
Formula 3-7



Formula 3-8

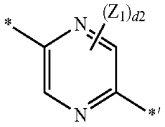


Formula 3-9



-continued

Formula 3-10



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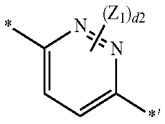

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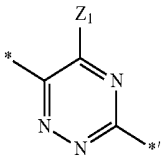

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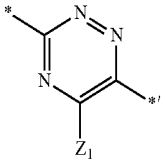

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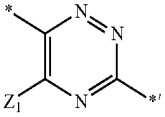

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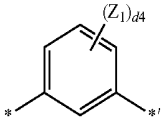

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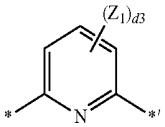

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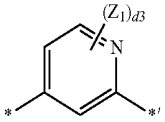

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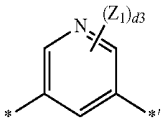

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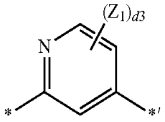

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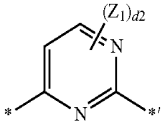

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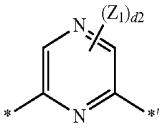

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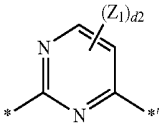

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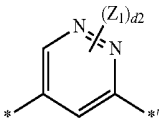

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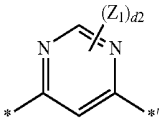

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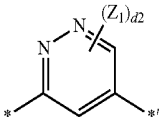

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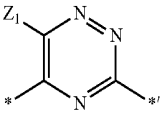

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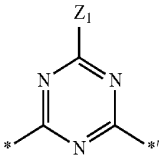

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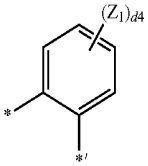

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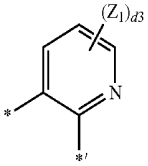

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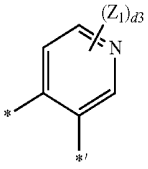

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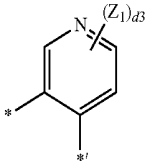

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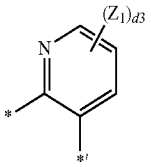

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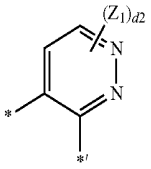

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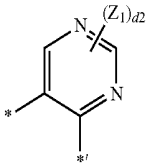

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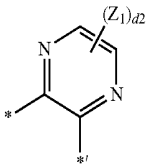

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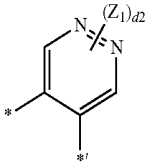

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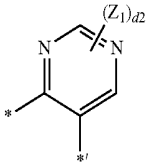

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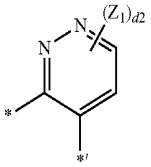

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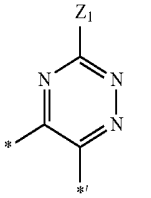

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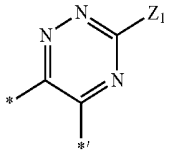
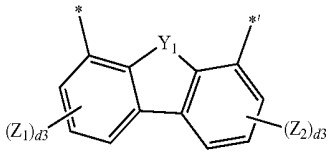
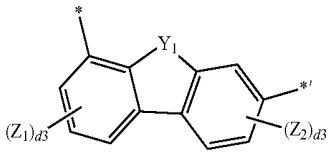


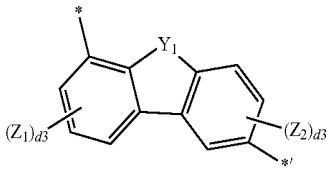
Formula 3-41



Formula 3-42



Formula 3-43



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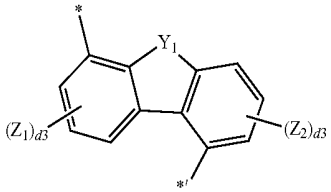

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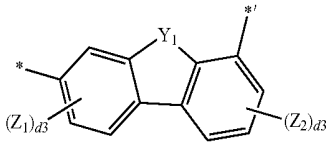

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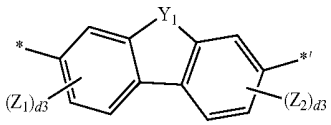

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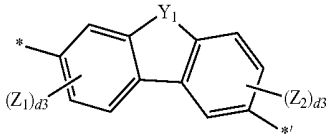

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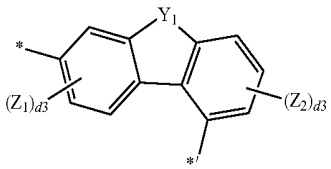

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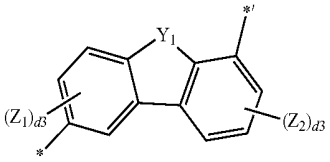
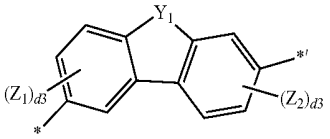


Formula 3-50



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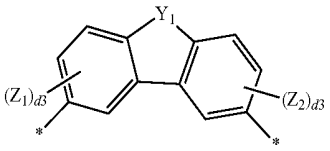

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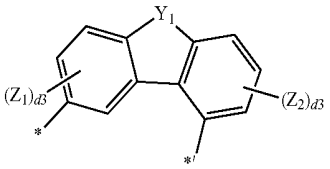
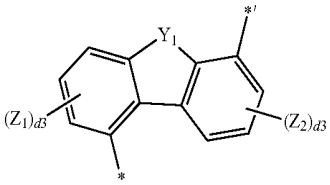
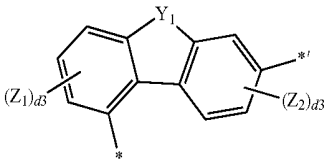


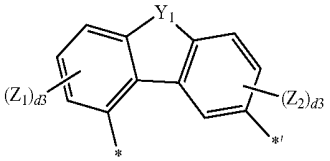
Formula 3-53



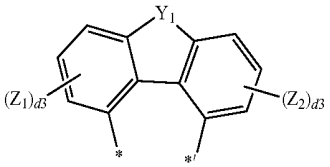
Formula 3-54



Formula 3-55



Formula 3-56



[0052] In Formulae 3-1 to 3-56,

[0053] Y_1 may be selected from O, S, and $C(Z_3)(Z_4)$,

[0054] Z_1 to Z_4 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, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl

group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and —Si(Q_{11})(Q_{12})(Q_{13}),

[0055] wherein Q_{11} to Q_{13} may be each independently selected from a hydrogen, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group,

[0056] d4 may be an integer selected from 0 to 4,

[0057] d3 may be an integer selected from 0 to 3,

[0058] d2 may be an integer selected from 0 to 2, and

[0059] * and *' may be each independently a binding site to a neighboring atom.

[0060] In Formula 1, a1 denotes the number of groups L_1, and is an integer selected from 0 to 5. When a1 is 0, *-$(L_1)_{a1}$-*' is a single bond, and when a1 is 2 or greater, two or more groups L_1 may be identical to or different from each other. Descriptions of a2 and a3 may be the same as defined for a1 in Formula 1.

[0061] In Formula 1, a1 to a3 may be each independently an integer selected from 0 to 5.

[0062] For example, in Formula 1, a1 to a3 may be each independently 0, 1, or 2, but embodiments are not limited thereto.

[0063] According to an embodiment, in Formula 1, a1 may be 0.

[0064] According to another embodiment, in Formula 1, when a1 is not 0, at least one of groups L_1 may be selected from groups represented by Formulae 3-15 to 3-56.

[0065] In some embodiments, in Formula 1, when a1 is not 0, all of groups L_1 may be each independently selected from groups represented by Formulae 3-15 to 3-56.

[0066] In some embodiments, in Formula 1,

[0067] L_1 may be selected from groups represented by Formulae 3-15, 3-28, 3-41, and 3-51,

[0068] L_2 and L_3 may be each independently selected from groups represented by Formulae 3-1, 3-15, 3-28, 3-41, and 3-51, and

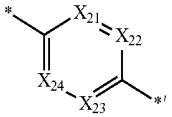
[0069] a1 to a3 may be each independently 0, 1, or 2,

[0070] but embodiments are not limited thereto.

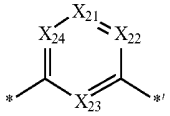
[0071] In Formula 1, a group represented by *-$(L_1)_{a1}$-*' may be selected from groups represented by Formulae 3-41 to 3-56.

[0072] In some embodiments, in Formula 1, a group represented by *-$(L_1)_{a1}$-*' may be selected from groups represented by Formulae 4-1 to 4-39:

Formula 4-1



Formula 4-2



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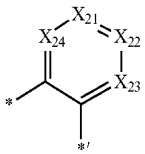
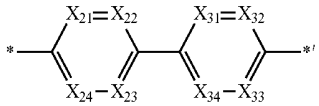
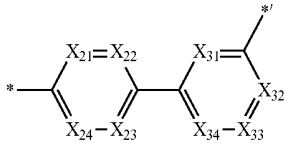
Formula 4-3



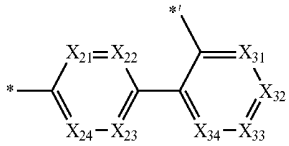
Formula 4-4



Formula 4-5



Formula 4-6



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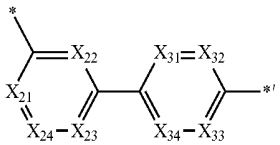

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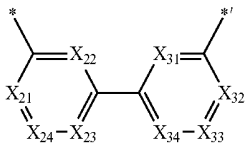

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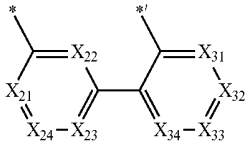
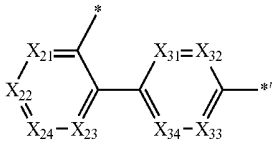


Formula 4-10



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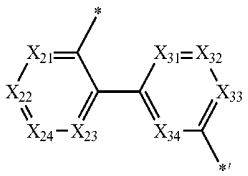

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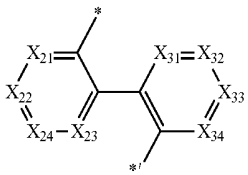

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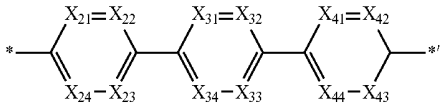

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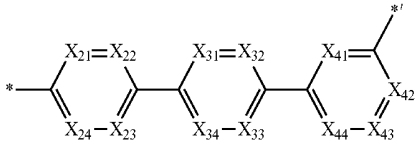

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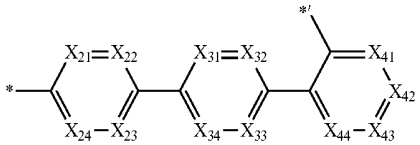

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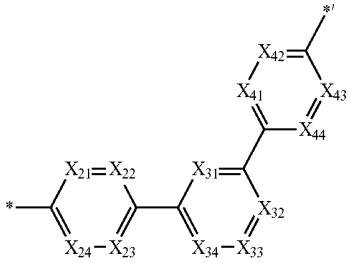

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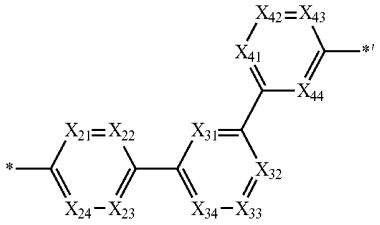

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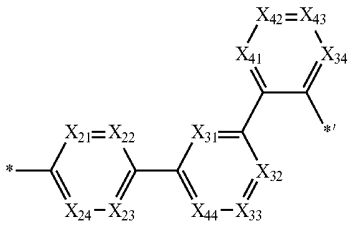

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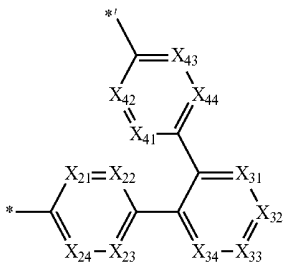

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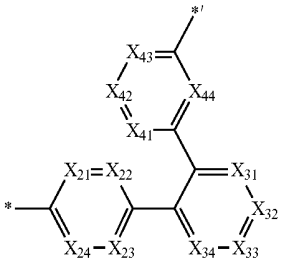

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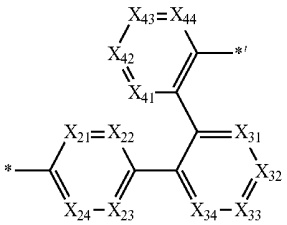

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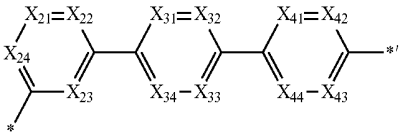

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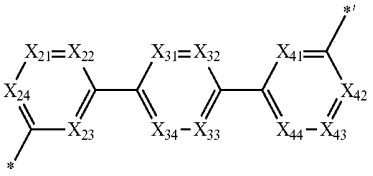

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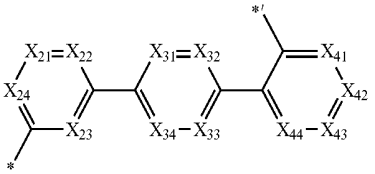

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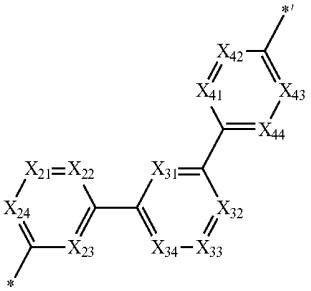

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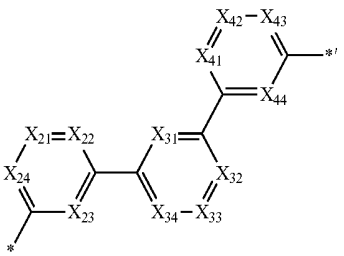

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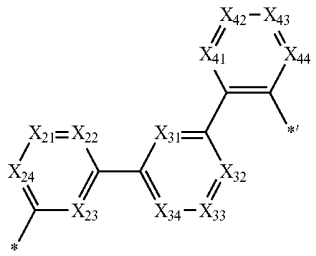

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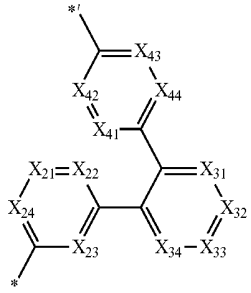

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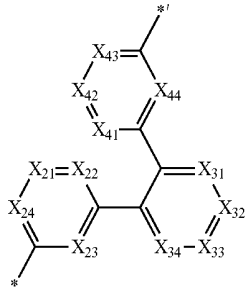
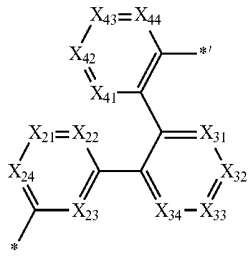
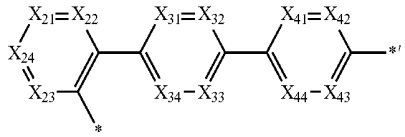


Formula 4-30



Formula 4-31



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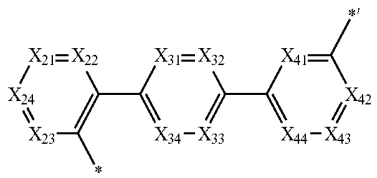

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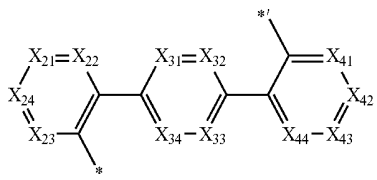

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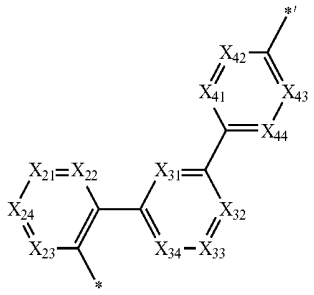
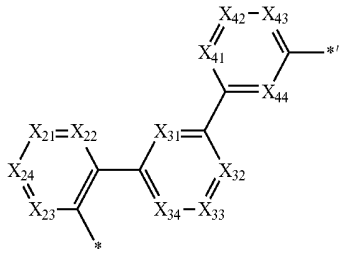
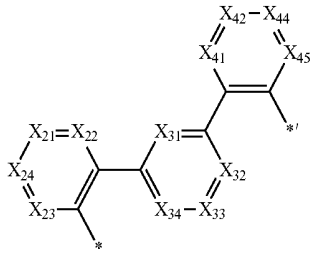
Formula 4-34



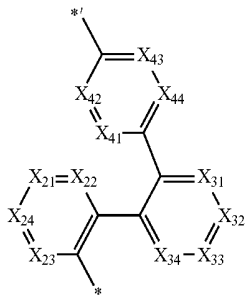
Formula 4-35



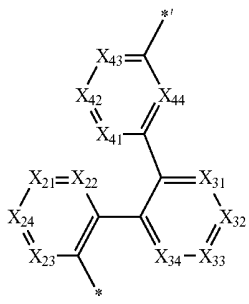
Formula 4-36



Formula 4-37



Formula 4-38



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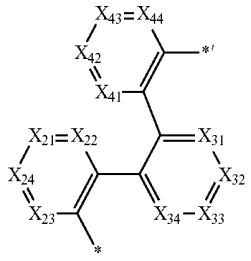
Formula 4-39



[0073] In Formulae 4-1 to 4-39, X_{21} may be N or $C(Z_{21})$, X_{22} may be N or $C(Z_{22})$, X_{23} may be N or $C(Z_{23})$, X_{24} may be N or $C(Z_{24})$, X_{31} may be N or $C(Z_{31})$, X_{32} may be N or $C(Z_{32})$, X_{33} may be N or $C(Z_{33})$, X_{34} may be N or $C(Z_{34})$, X_{41} may be N or $C(Z_{41})$, X_{42} may be N or $C(Z_{42})$, X_{43} may be N or $C(Z_{43})$, and X_{44} may be N or $C(Z_{44})$, provided that each of X_{21} to X_{24} are not simultaneously N, provided that each of X_{31} to X_{34} are not simultaneously N, and provided that each of X_{41} to X_{44} are not simultaneously N,

[0074] Z_{21} to Z_{24}, Z_{31} to Z_{34}, and Z_{41} to Z_{44} may be each independently selected from a hydrogen, a deuterium, a cyano group, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and —$Si(Q_{11})(Q_{12})(Q_{13})$,

[0075] wherein Q_{11} to Q_{13} may be each independently a hydrogen, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, and

[0076] * and *' may be each independently a binding site to a neighboring atom.

[0077] According to an embodiment, none, one, two, or three atoms among all ring-forming atoms in each of Formulae 4-1 to 4-39 may be nitrogen.

[0078] According to another embodiment, none, one, or two atoms among all ring-forming atoms in each of Formulae 4-1 to 4-39 may be nitrogen.

[0079] In some embodiments, none or one atom among all ring-forming atoms in each of Formulae 4-1 to 4-39 may be nitrogen.

[0080] In some embodiments, in each of Formulae 4-1 to 4-39, X_{21} may be $C(Z_{21})$, X_{22} may be $C(Z_{22})$, X_{23} may be $C(Z_{23})$, X_{24} may be $C(Z_{24})$, X_{31} may be $C(Z_{31})$, X_{32} may be $C(Z_{32})$, X_{33} may be $C(Z_{33})$, X_{34} may be $C(Z_{34})$, X_{41} may be $C(Z_{41})$, X_{42} may be $C(Z_{42})$, X_{43} may be $C(Z_{43})$, and X_{44} may be $C(Z_{44})$ (that is, none of the ring-forming atoms in each of Formulae 4-1 to 4-30 may be nitrogen).

[0081] In Formula 1, R_1 to R_7, R_{11} to R_{18}, and R_{31} and R_{32} may be each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group (—CN), 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 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_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-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_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and —$Si(Q_1)(Q_2)(Q_3)$.

[0082] For example, in Formula 1, R_1 to R_7, R_{11} to R_{18}, and R_{31} and R_{32} may be each independently selected from

[0083] 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_{20} alkyl group, and a C_1-C_{20} alkoxy group;

[0084] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one 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 group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, and a triazinyl group;

[0085] a cyclopentyl group, a cyclohexyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthenyl group, a fluorenyl group, a spiro-bifluorenyl 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 pyrrolyl group, an imidazolyl group, a pyrazolyl 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 phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzoimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a thazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group;

[0086] a cyclopentyl group, a cyclohexyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthenyl group, a fluorenyl group, a spiro-bifluorenyl 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 pyrrolyl group, an imidazolyl group, a pyrazolyl 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 quinoxalmyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzoimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group, each substituted with at least one 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 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_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl 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 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, a quinazolinyl group, and —$Si(Q_{21})(Q_{22})(Q_{23})$; and

—$Si(Q_1)(Q_2)(Q_3)$,

[0087] wherein Q_1 to Q_3 and Q_{21} to Q_{23} 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 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.

[0088] According to an embodiment, in Formula 1, R_1 to R_7, R_{11} to R_{18}, and R_{31} and R_{32} may be each independently

[0089] 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, and a C_1-C_{10} alkoxy group;

[0090] a C_1-C_{10} alkyl group and a C_1-C_{10} alkoxy group, each substituted with at least one 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 group or a salt thereof, a sulfonic acid group or a salt thereof, and a phosphoric acid group or a salt thereof;

[0091] a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

[0092] a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one 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 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, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and —$Si(Q_{21})(Q_{22})(Q_{23})$; and

—$Si(Q_1)(Q_2)(Q_3)$,

[0093] Q_1 to Q_3 and Q_{21} to Q_{23} may be each independently selected from a hydrogen, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group.

[0094] According to another embodiment, in Formula 1, R_1 to R_7, R_{11} to R_{18}, and R_{31} and R_{32} may be each independently selected from a hydrogen, a deuterium, —F, a cyano group, a C_1-C_{10} alkyl group, and a C_1-C_{10} alkoxy group;

[0095] a C_1-C_{10} alkyl group and a C_1-C_{10} alkoxy group, each substituted with at least one selected from a deuterium, —F, and a cyano group;

[0096] a phenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

[0097] a phenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from a deuterium, —F, a cyano group, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and —$Si(Q_{21})(Q_{22})(Q_{23})$; and

—$Si(Q_1)(Q_2)(Q_3)$,

[0098] wherein Q_1 to Q_3 and Q_{21} to Q_{23} may be each independently selected from a hydrogen, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group.

[0099] According to an embodiment, in Formula 1, at least one of X_3, X_6, X_{13}, and X_{16} may be C(CN).

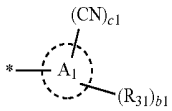
[0100] In Formula 1, b1 may denote the number of R_{31} which may be an integer selected from 0 to 4. When b1 is 2 or greater, two or more R_{31} may be identical to or different from each other. In Formula 1, b2 may denote the number of R_{32} which may be an integer selected from 0 to 4. When b2 is 2 or greater, two or more R_{32} may be identical to or different from each other.

[0101] In Formula 1, b1 and b2 may be each independently an integer selected from 0 to 4. For example, in Formula 1, b1 and b2 may be each independently 0, 1, or 2.

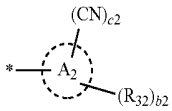
[0102] In Formula 1, c1 may be an integer selected from 1 to 4. That is, ring A_1 may essentially include at least one cyano group. For example, in Formula 1, c1 may be 1 or 2.

[0103] In Formula 1, c2 may be an integer selected from 0 to 4. For example, in Formula 1, c2 may be 0 or 1.

[0104] According to an embodiment, in Formula 1, a group represented by

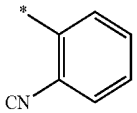


may be selected from groups represented by Formulae 5-1 to 5-60, and a group represented by

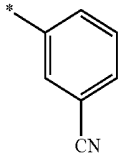


may be selected from groups represented by Formulae 5-1 to 5-69:

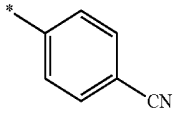
Formula 5-1



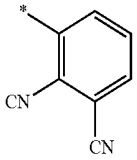
Formula 5-2



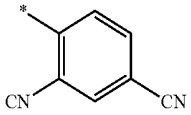
Formula 5-3



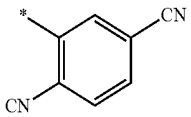
Formula 5-4



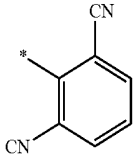
Formula 5-5



Formula 5-6



Formula 5-7



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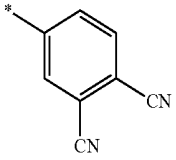
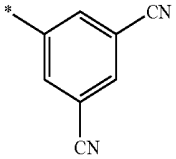
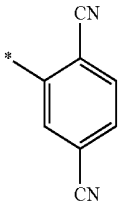
Formula 5-8



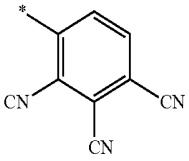
Formula 5-9



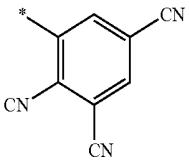
Formula 5-10



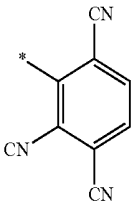
Formula 5-11



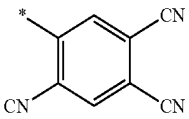
Formula 5-12



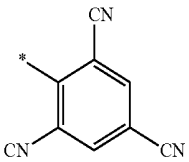
Formula 5-13



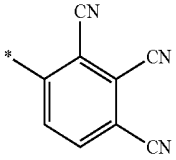
Formula 5-14



Formula 5-15



Formula 5-16



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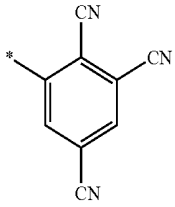
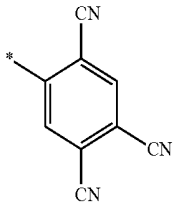
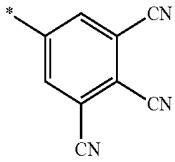
Formula 5-17



Formula 5-18



Formula 5-19



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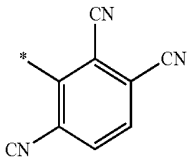

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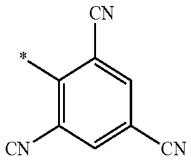
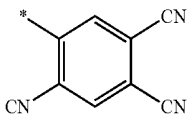
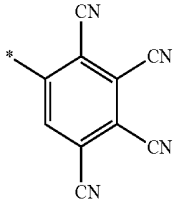


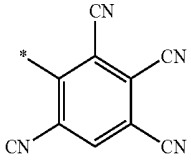
Formula 5-22



Formula 5-23



Formula 5-24



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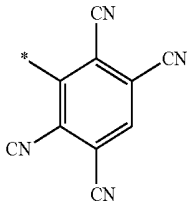
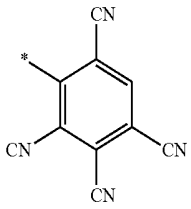
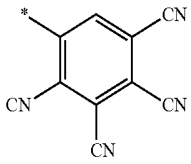
Formula 5-25



Formula 5-26



Formula 5-27



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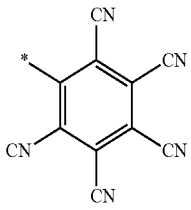

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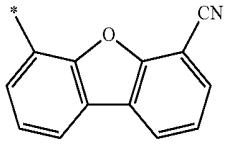
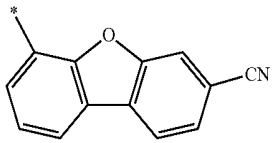
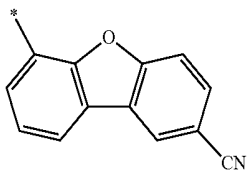


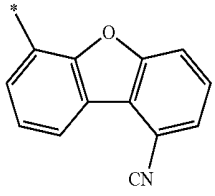
Formula 5-30



Formula 5-31



Formula 5-32



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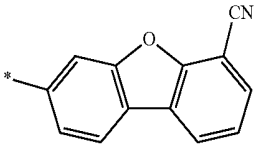
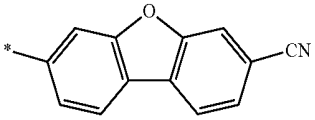
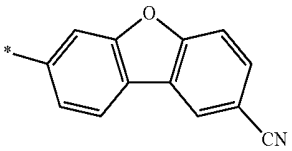
Formula 5-33



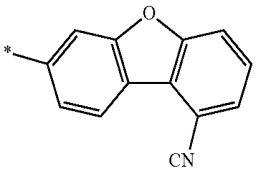
Formula 5-34



Formula 5-35



Formula 5-36



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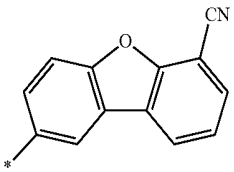
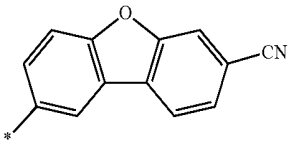
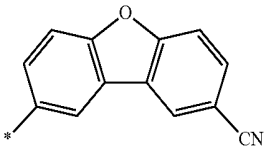


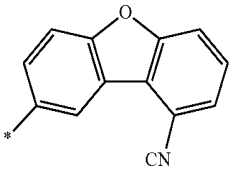
Formula 5-38



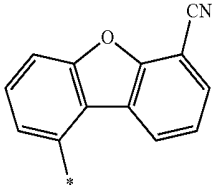
Formula 5-39



Formula 5-40



Formula 5-41



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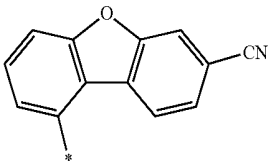
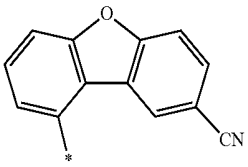
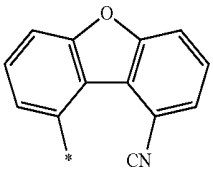
Formula 5-42



Formula 5-43



Formula 5-44



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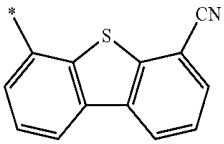
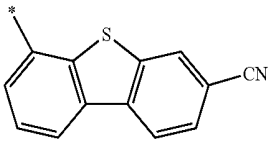
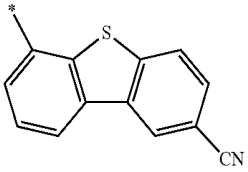


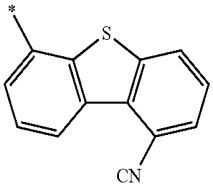
Formula 5-46



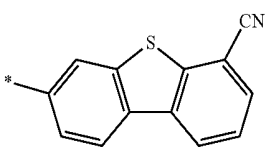
Formula 5-47



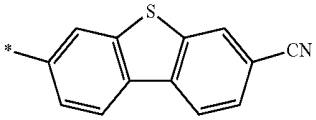
Formula 5-48



Formula 5-49



Formula 5-50



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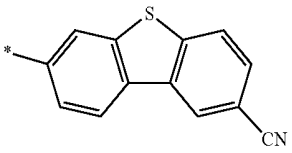

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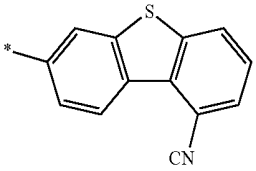

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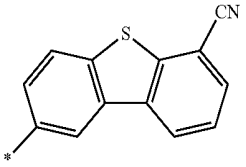

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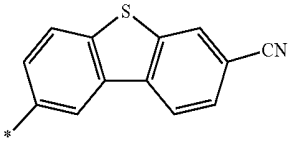

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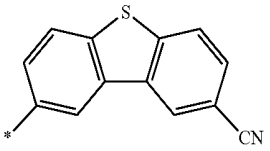

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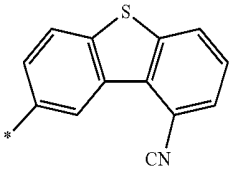

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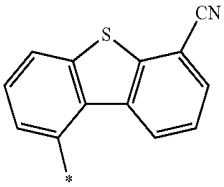

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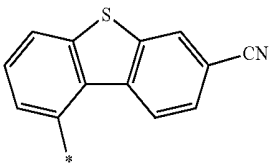
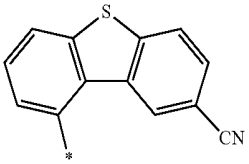


Formula 5-59



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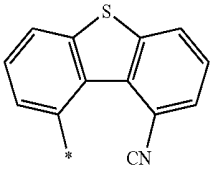
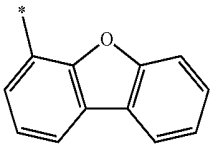
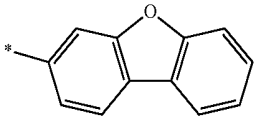


Formula 5-61



Formula 5-62



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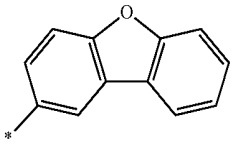
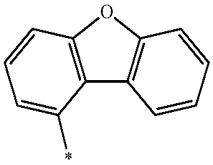
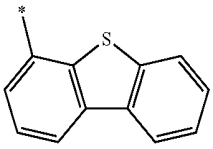


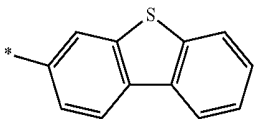
Formula 5-64



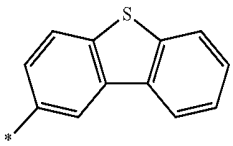
Formula 5-65



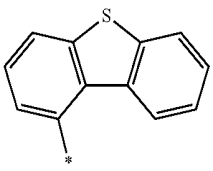
Formula 5-66



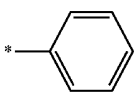
Formula 5-67



Formula 5-68

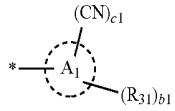


Formula 6-69

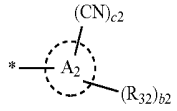


[0105] In Formulae 5-1 to 5-69, * may denote a binding site to a neighboring atom.

[0106] According to an embodiment, in Formula 1, a group represented by



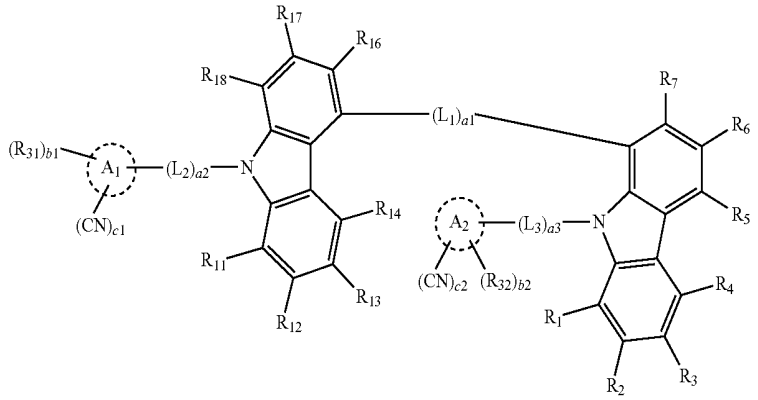
may be selected from groups represented by Formulae 5-1 to 5-3, 5-31, 5-39, 5-47, and 5-55, and a group represented by



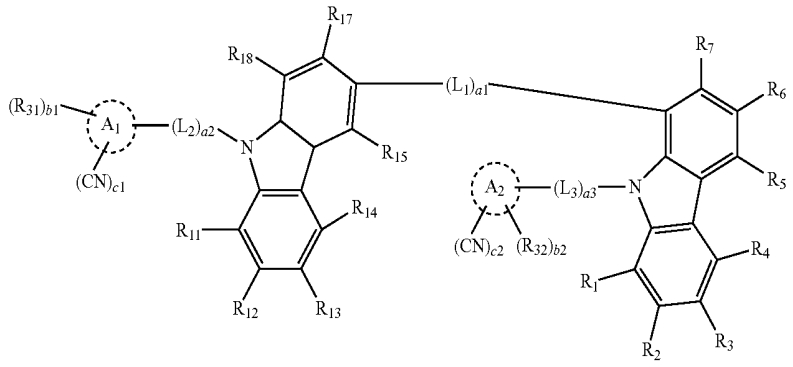
may be selected from groups represented by Formulae 5-1 to 5-3, 5-31, 5-39, 5-47, 5-55, 5-61, 5-63, 5-65, 5-67, and 5-69, but embodiments are not limited thereto.

[0107] A condensed cyclic compound represented by Formula 1 may be represented by one of Formulae 1A to 1D:

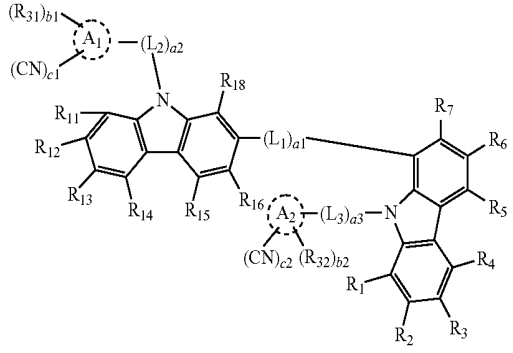
Formula 1A



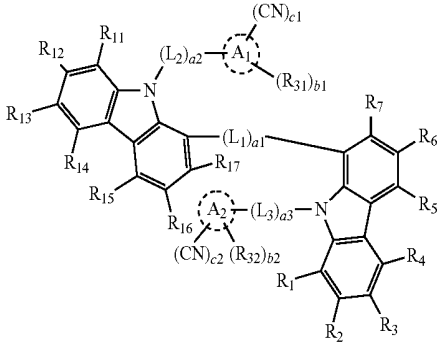
Formula 1B



Formula 1C



Formula 1D



[0108] In Formulae 1A to 1D, ring A_1, ring A_2, L_1 to L_3, a1 to a3, R_1 to R_7, R_{11} to R_{18}, R_{31}, R_{32}, b1, b2, c1, and c2 may be understood by referring to the description provided herein.

[0109] For example, in Formulae 1A to 1D, ring A_1 and ring A_2 may be each independently selected from a phenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group,

[0110] L_1 may be selected from groups represented by Formulae 3-15, 3-28, 3-41, and 3-51,

[0111] L_2 and L_3 may be each independently selected from groups represented by Formulae 3-1, 3-15, 3-28, 3-41, and 3-51,

[0112] a1 to a3 may be each independently selected from 0, 1, and 2,

[0113] R_1 to R_7, R_{11} to R_{18}, R_{31}, and R_{32} may be each independently selected from a hydrogen, a deuterium, —F, a cyano group, a C_1-C_{10} alkyl group, and a C_1-C_{10} alkoxy group;

[0114] a C_1-C_{10} alkyl group and a C_1-C_{10} alkoxy group, each substituted with at least one selected from a deuterium, —F, and a cyano group;

[0115] a phenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

[0116] a phenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from a deuterium, —F, a cyano group, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and —Si$(Q_{21})(Q_{22})(Q_{23})$; and

—Si$(Q_1)(Q_2)(Q_3)$,

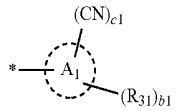
[0117] wherein Q_1 to Q_3 and Q_{21} to Q_{23} may be each independently selected from a hydrogen, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group,

[0118] b1 and b2 may be each independently 0 or 1,

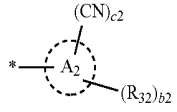
[0119] c1 may be 1 or 2, and

[0120] c2 may be 0, 1, or 2.

[0121] According to another embodiment, in Formulae 1A to 1D, a group represented by



may be selected from groups represented by Formulae 5-1 to 5-3, 5-31, 5-39, 5-47, and 5-55, and a group represented by



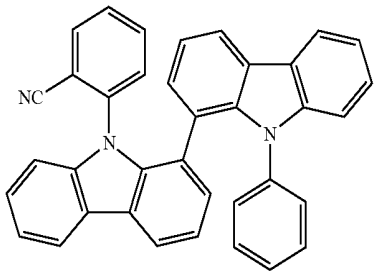
may be selected from groups represented by Formulae 5-1 to 5-3, 5-31, 5-39, 5-47, 5-55, 5-61, 5-63, 5-65, 5-67, and 5-69, but embodiments are not limited thereto.

[0122] In some embodiments, in Formulae 1A to 1D, at least one of R_3, R_6, R_{13}, and R_{16} may be a cyano group.

[0123] In some embodiments, the number of cyano groups in Formula 1 may be 1, 2, 3, or 4.

[0124] A compound represented by Formula 1 may be one of Compounds 1 to 271, but embodiments are not limited thereto:

1



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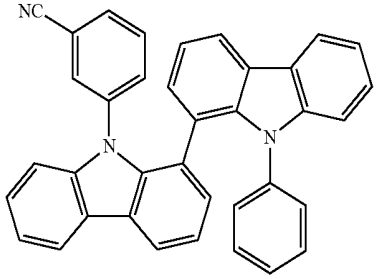

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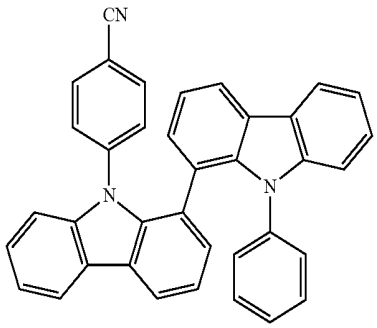

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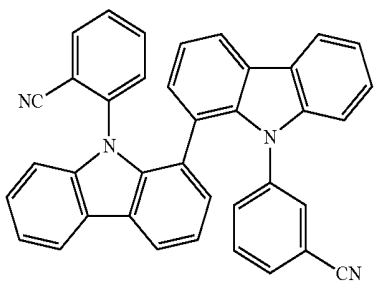

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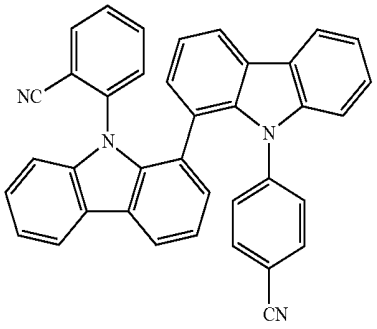

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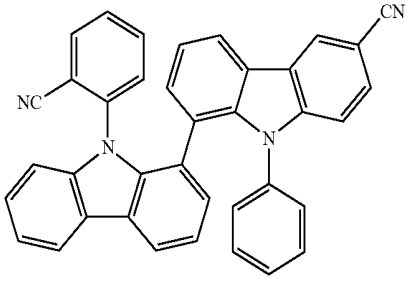

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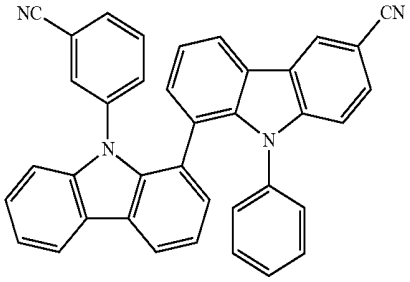

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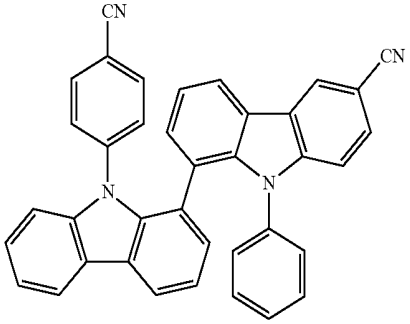

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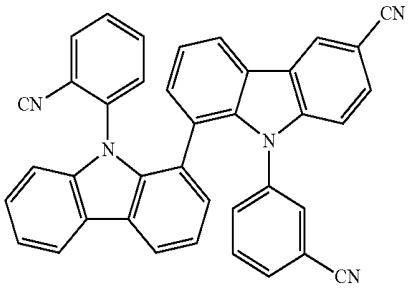

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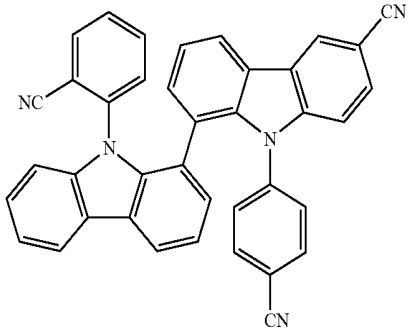

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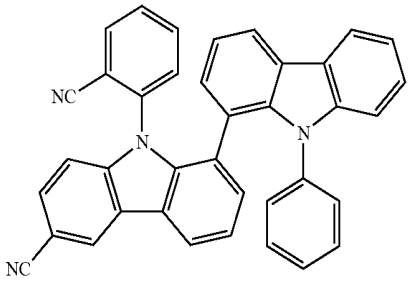

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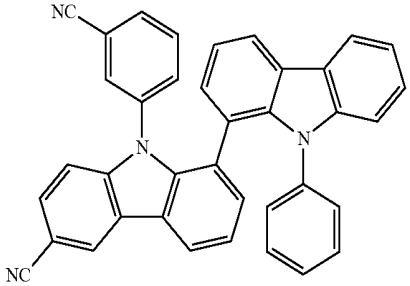

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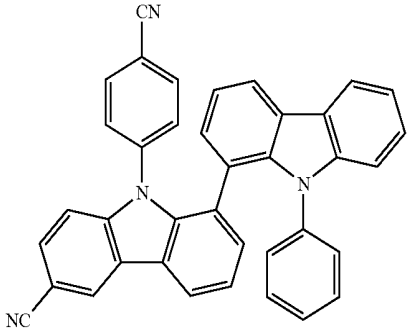

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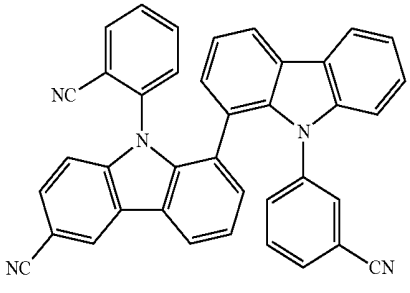

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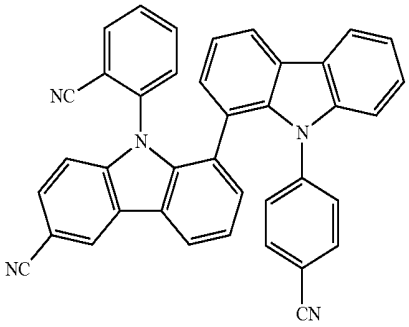

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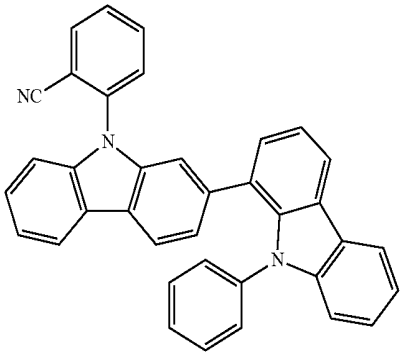

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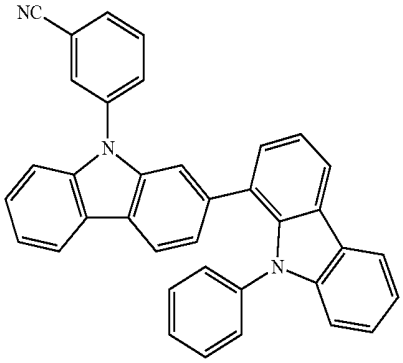

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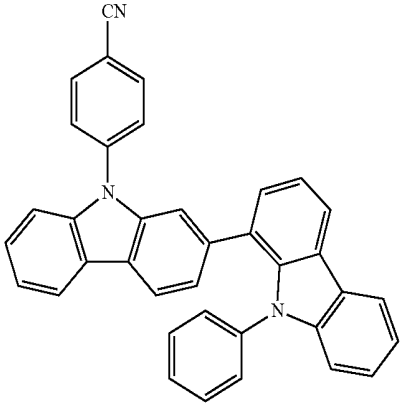

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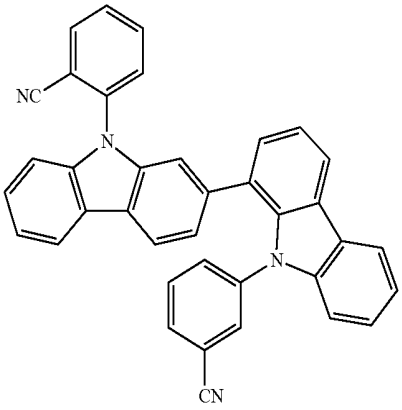

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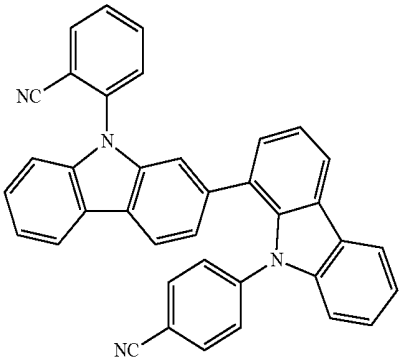

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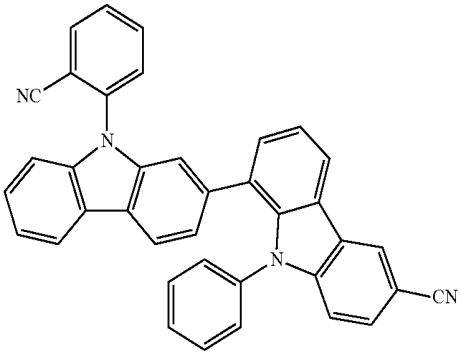

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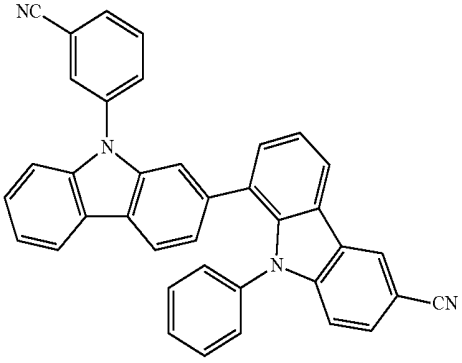

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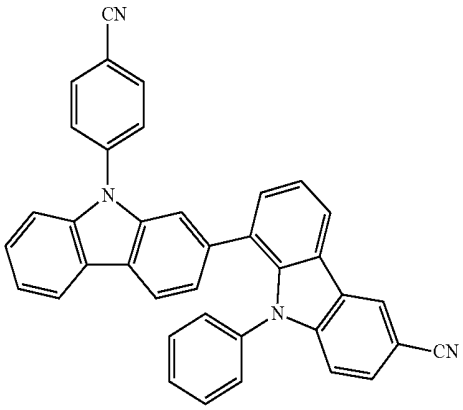

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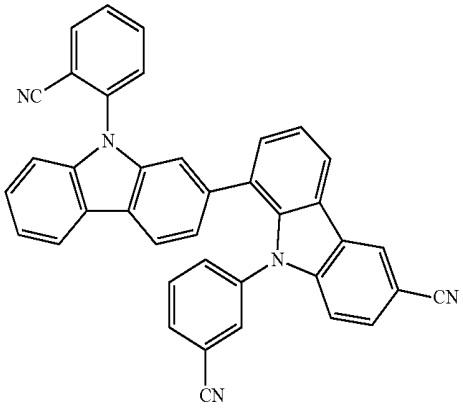

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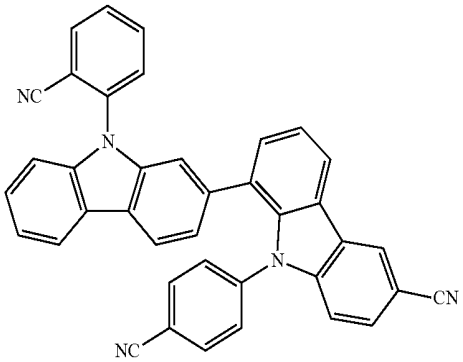

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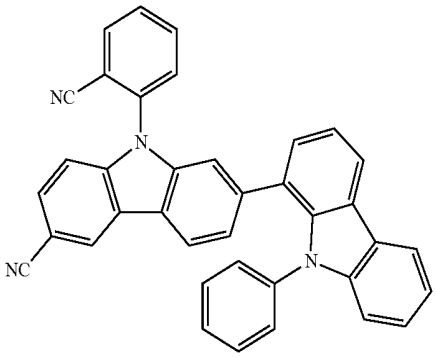

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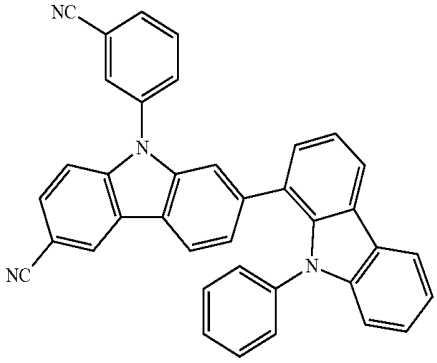

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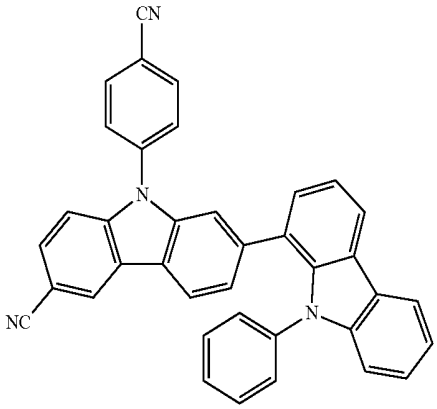

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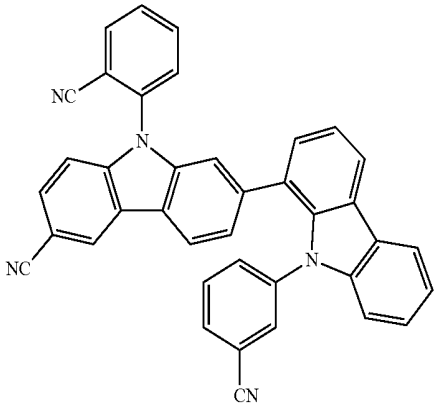

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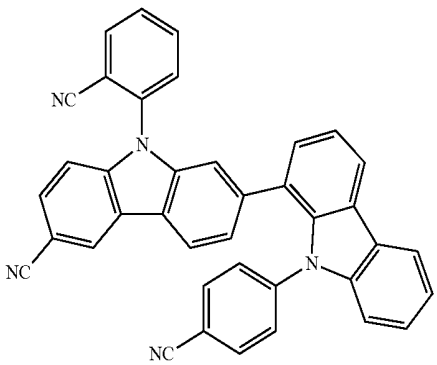

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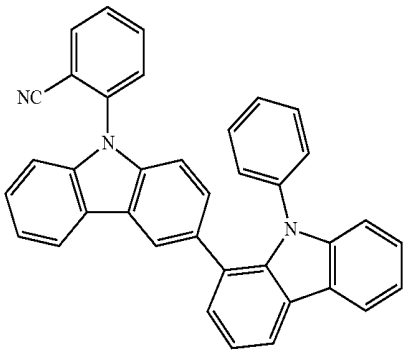

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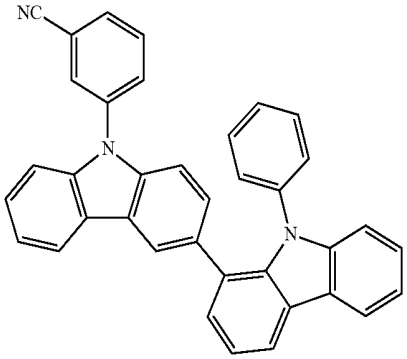

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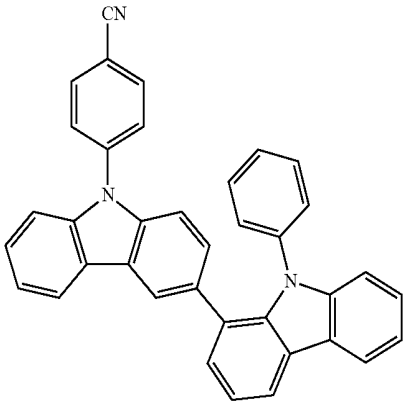

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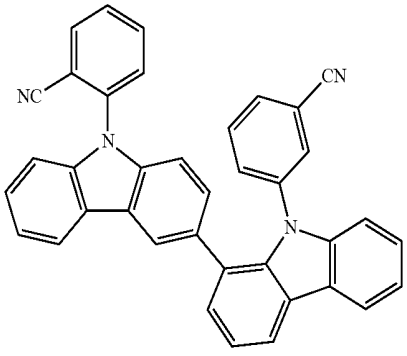

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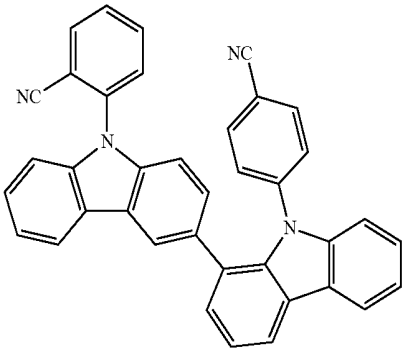

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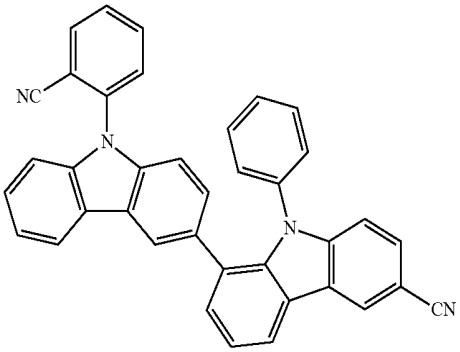

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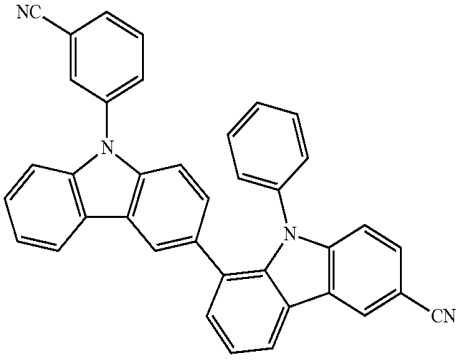

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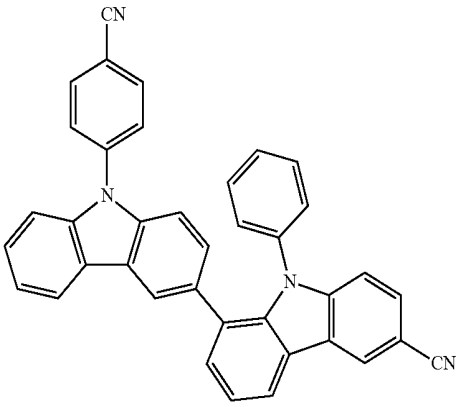

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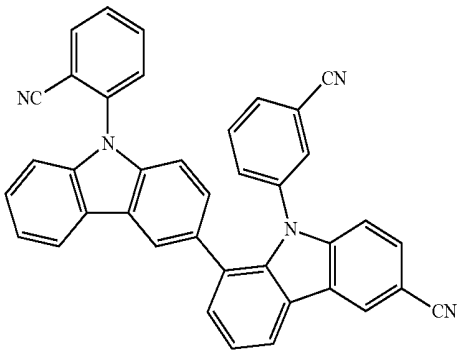

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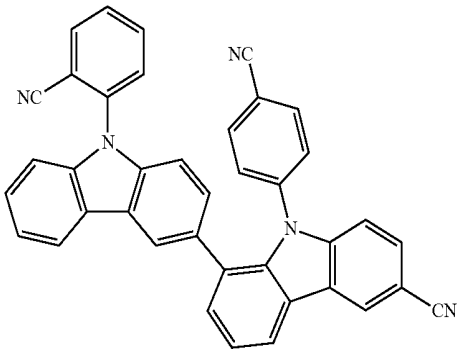

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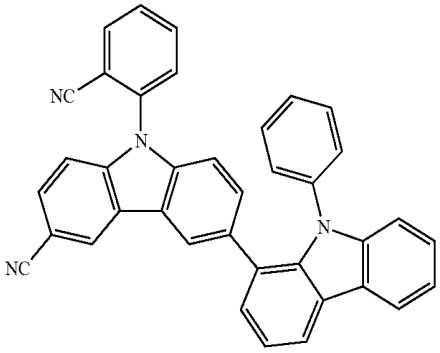

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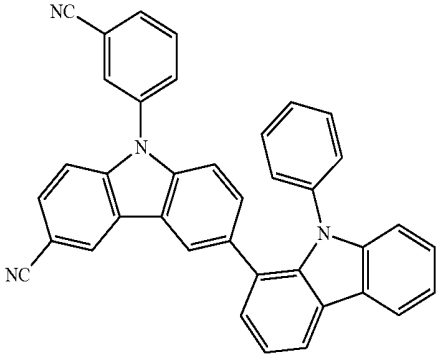

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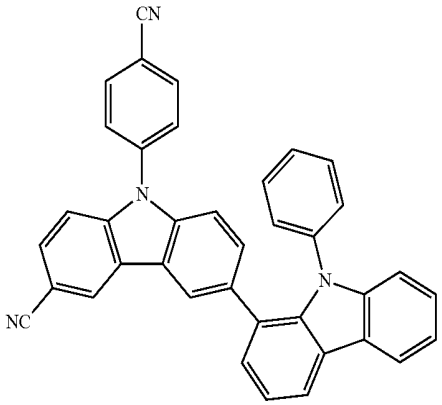

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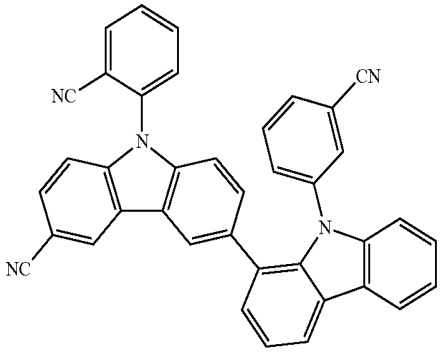

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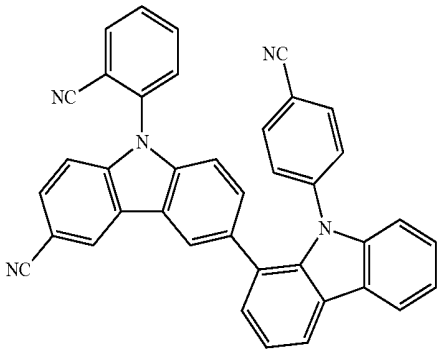

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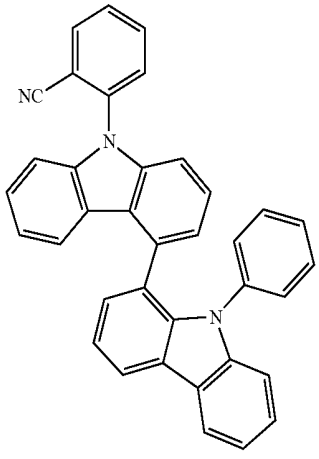

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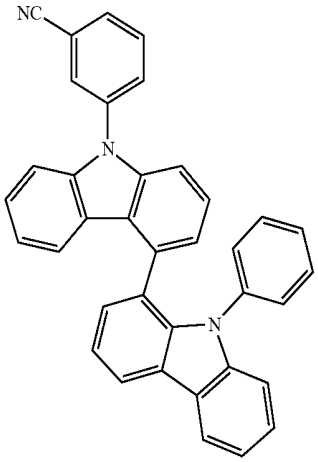

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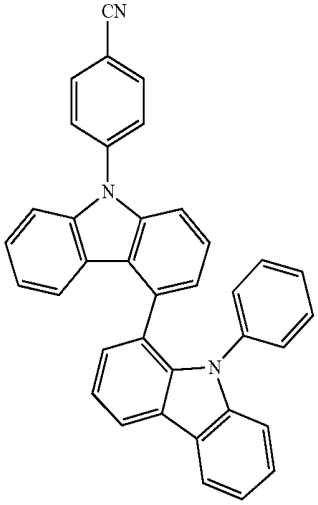

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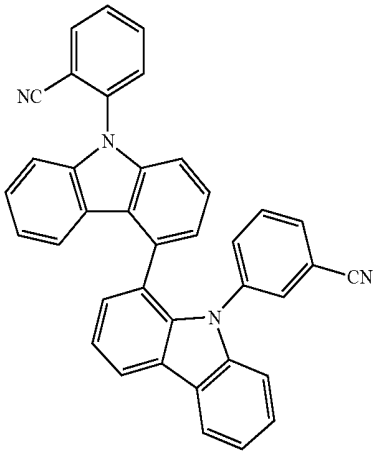

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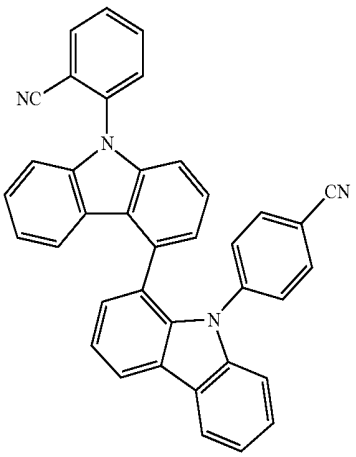

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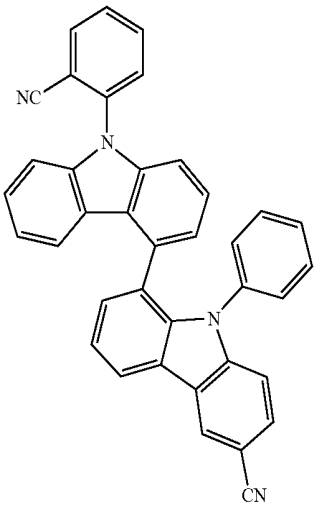

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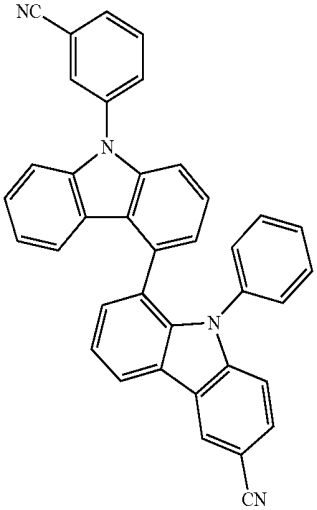

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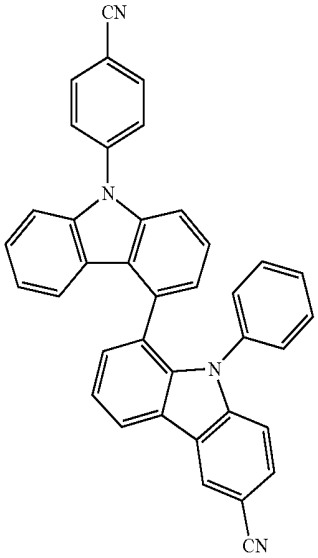

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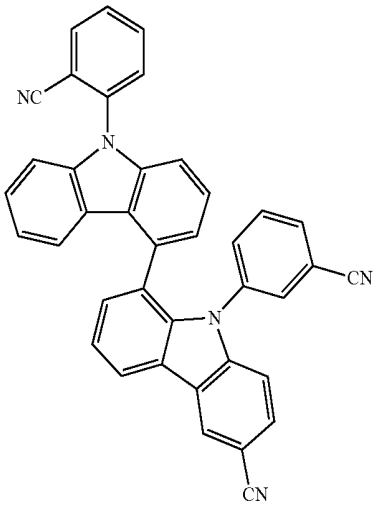

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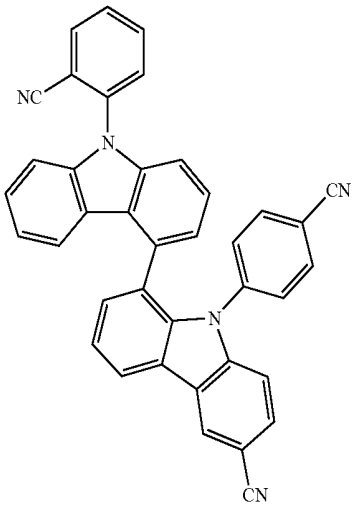

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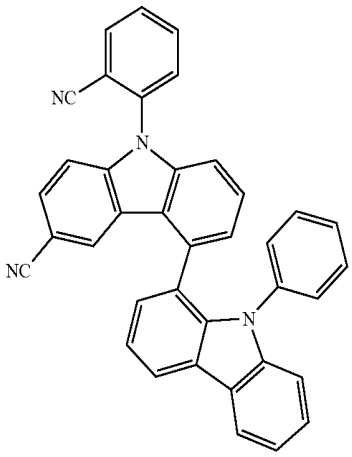

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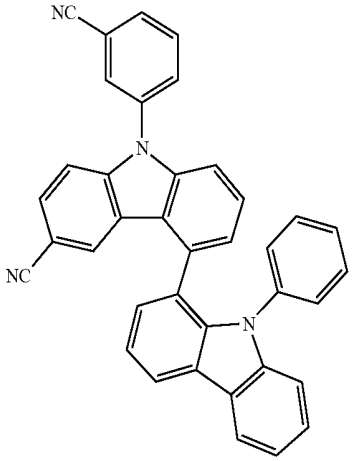

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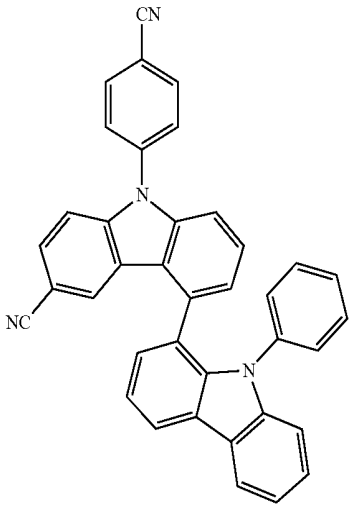

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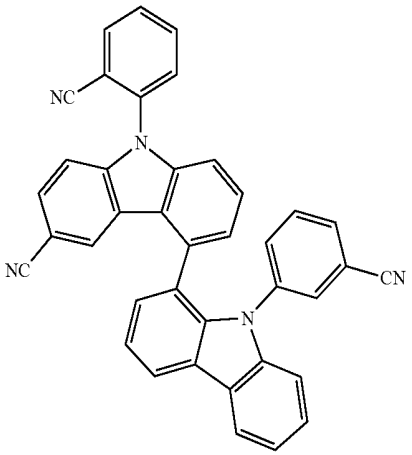

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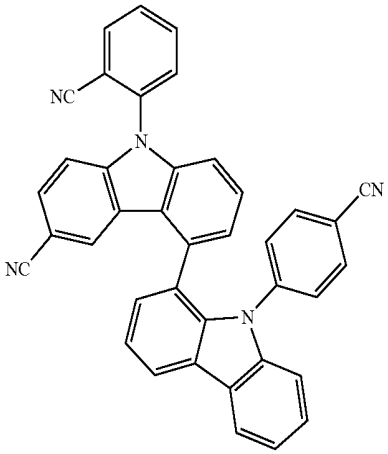

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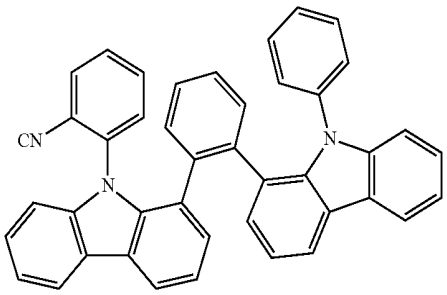

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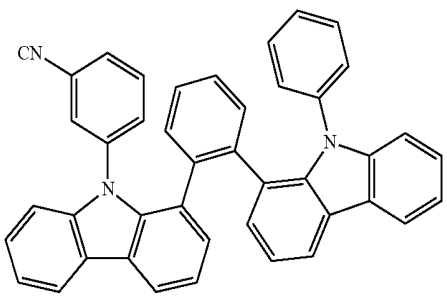

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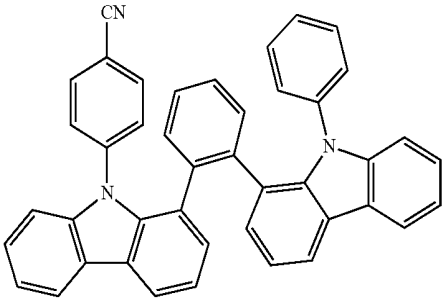

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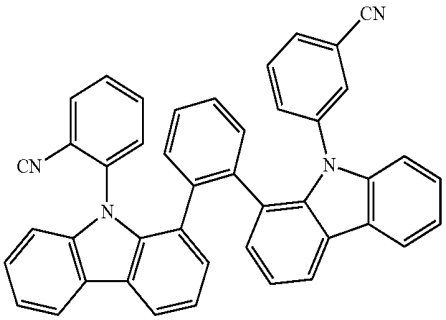

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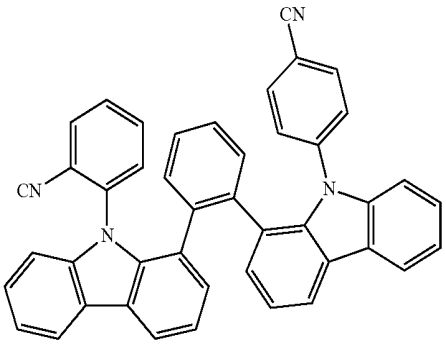

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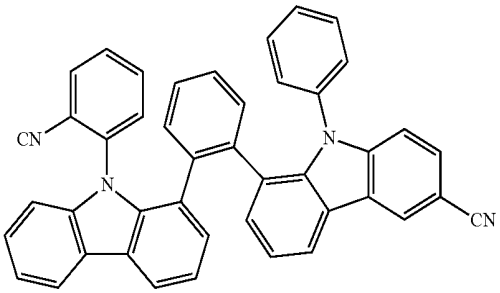

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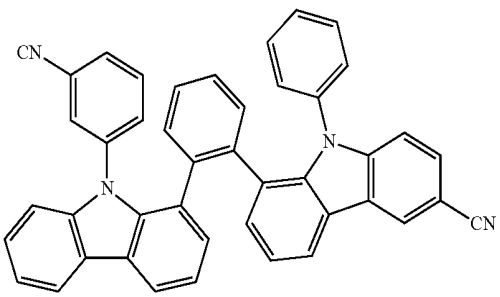

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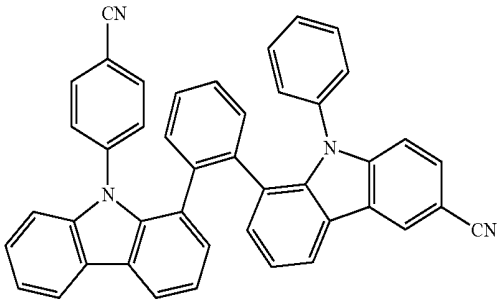

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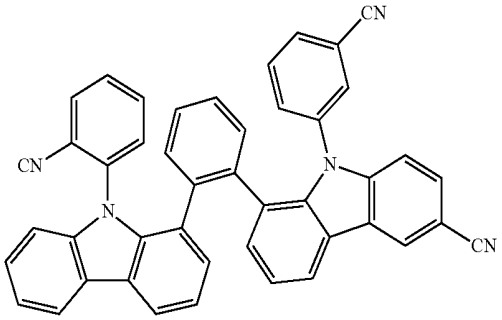

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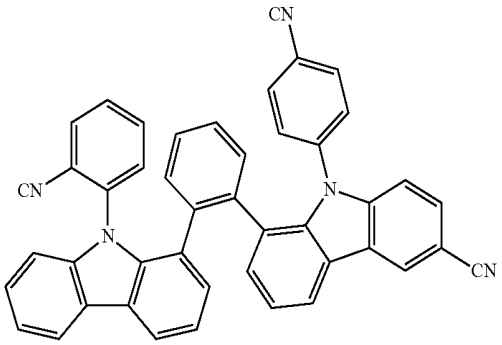

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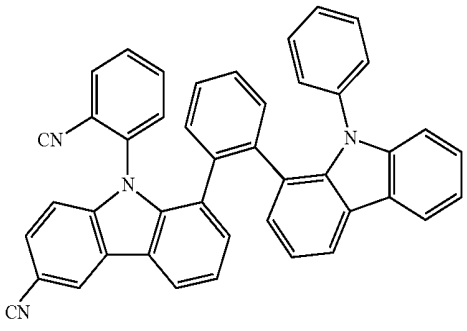

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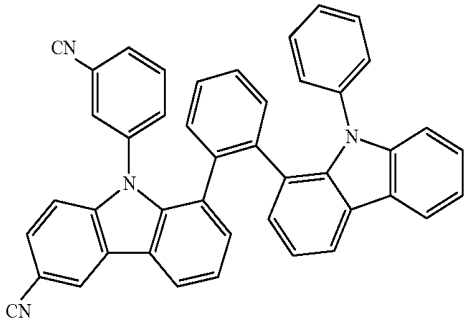

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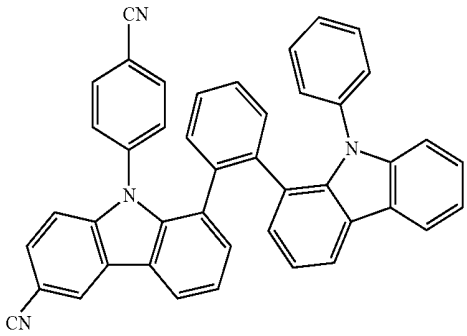

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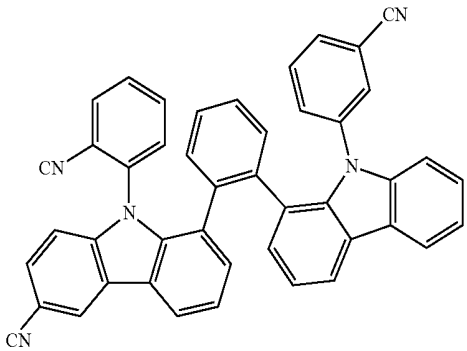

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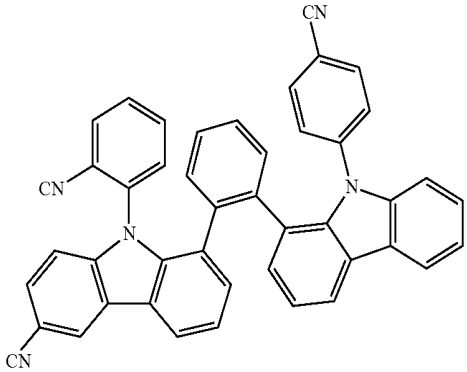

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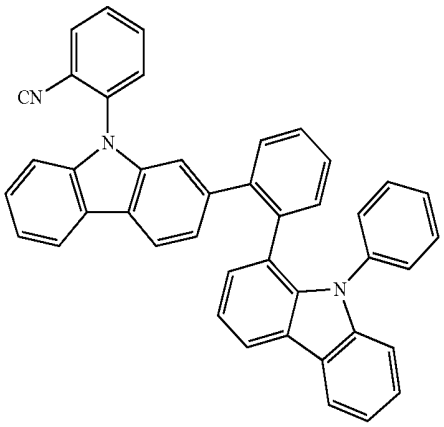

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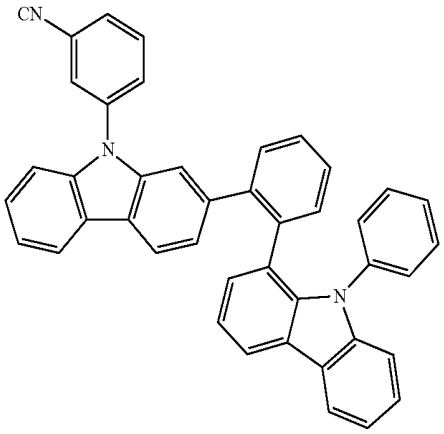

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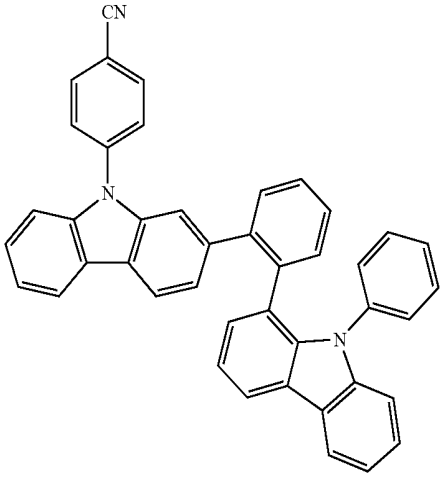

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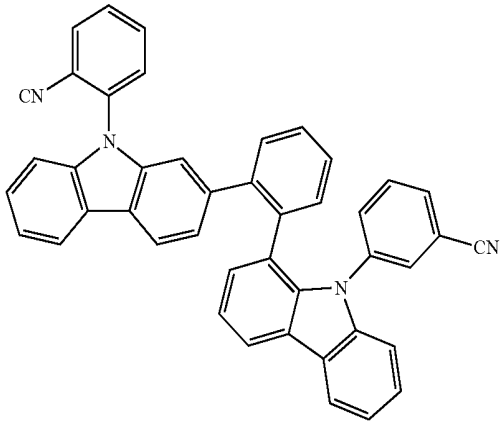

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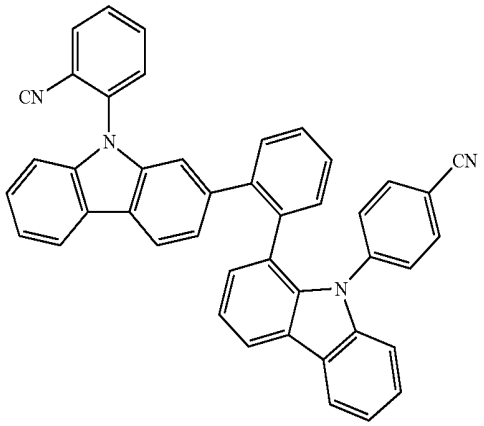

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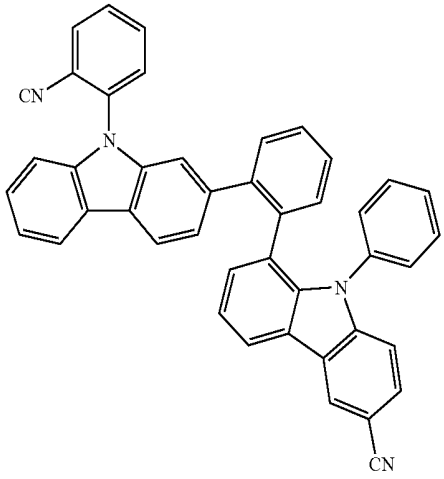

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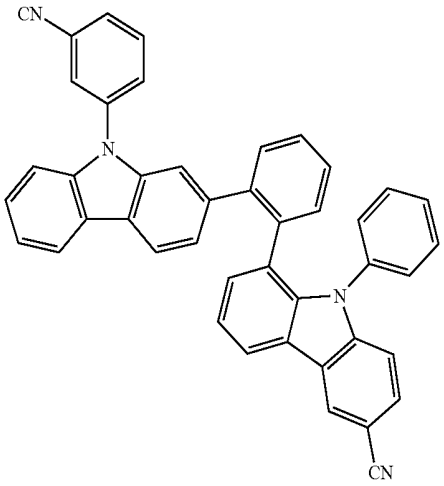

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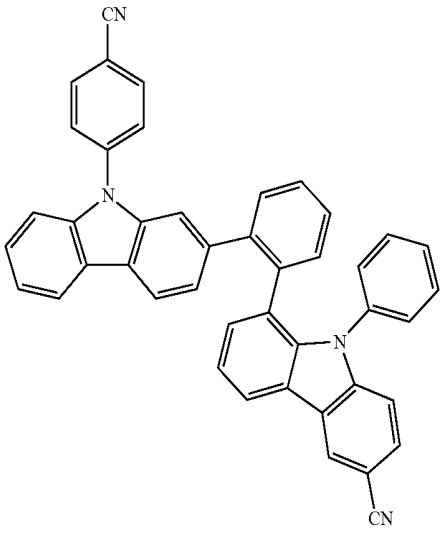

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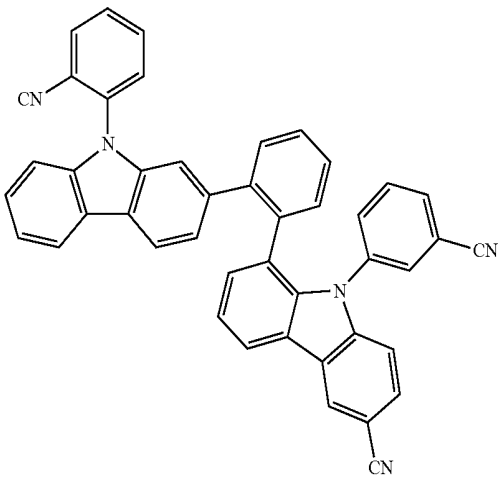

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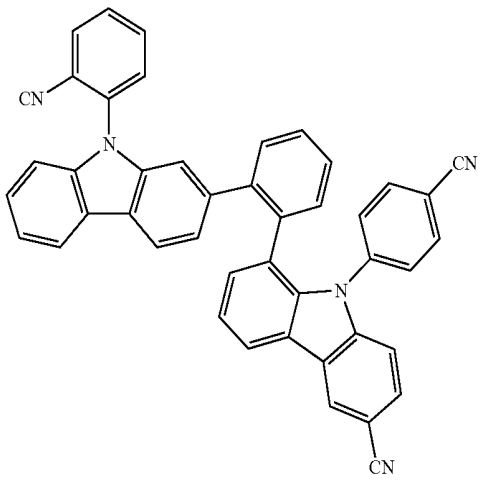

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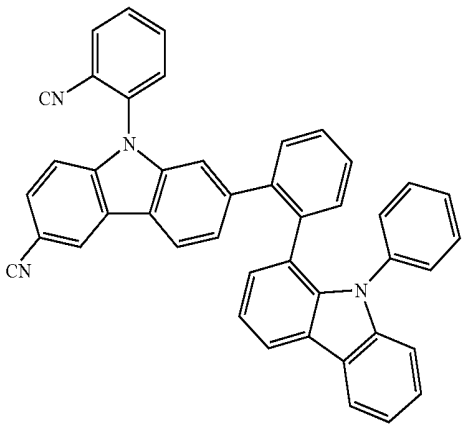

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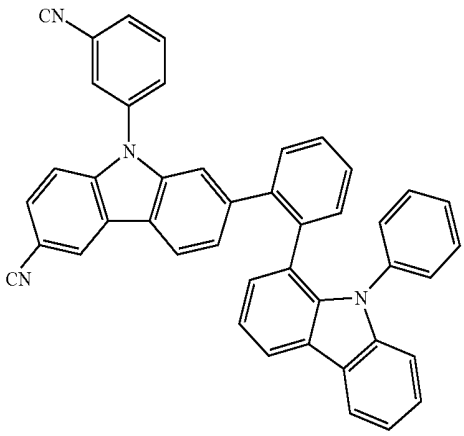

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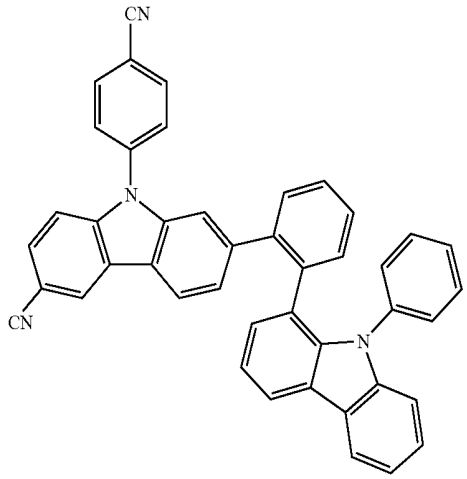

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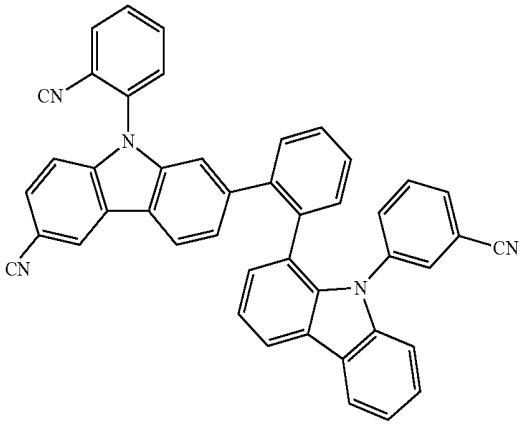

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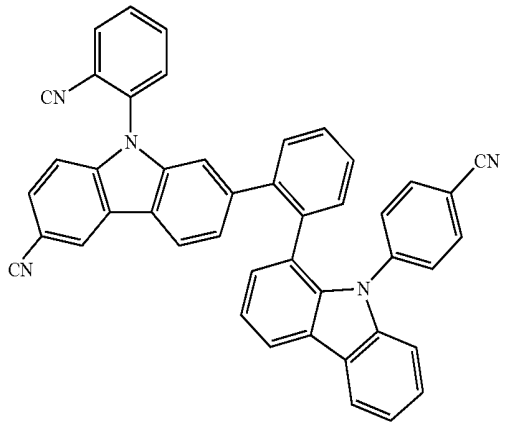

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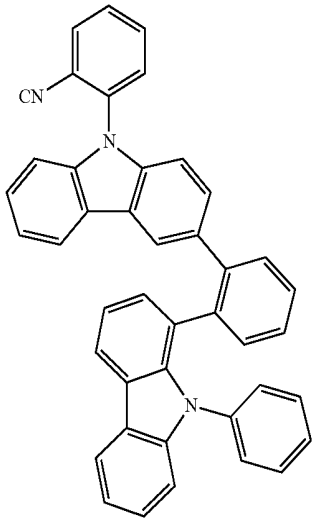

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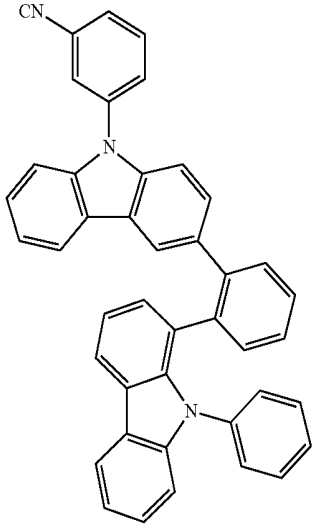

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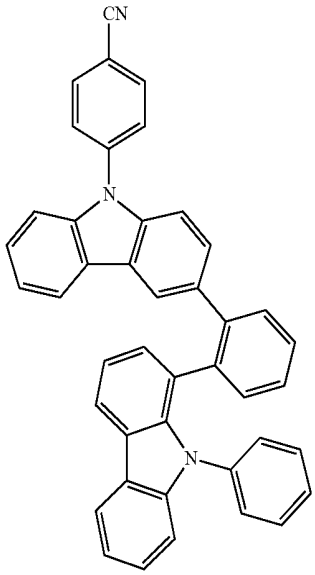

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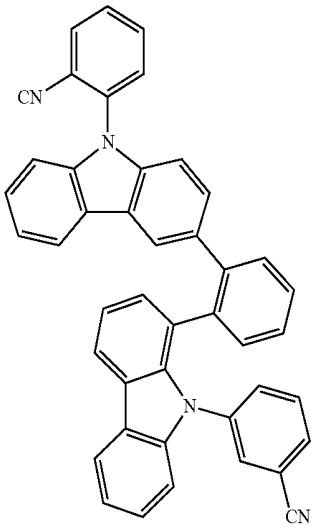

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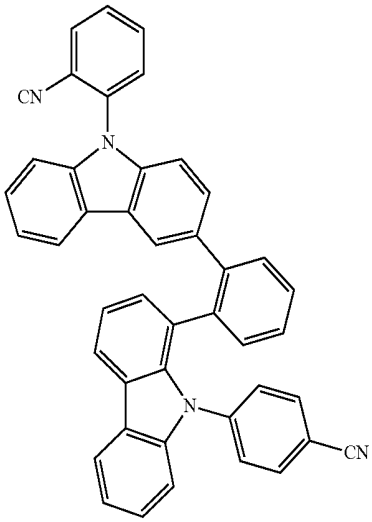

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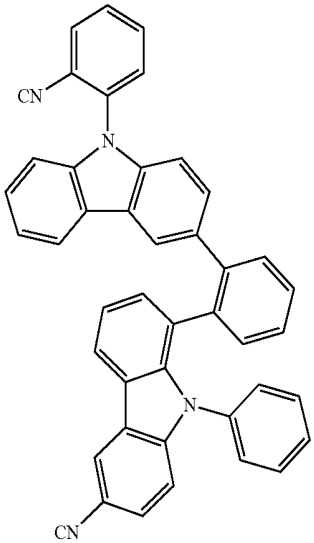

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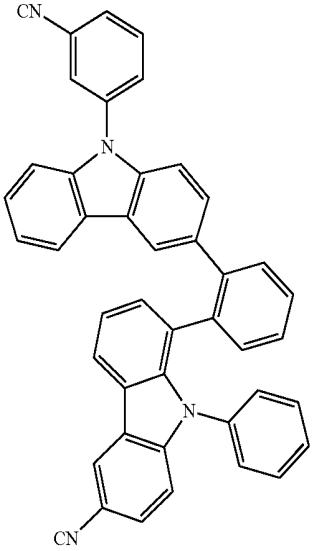

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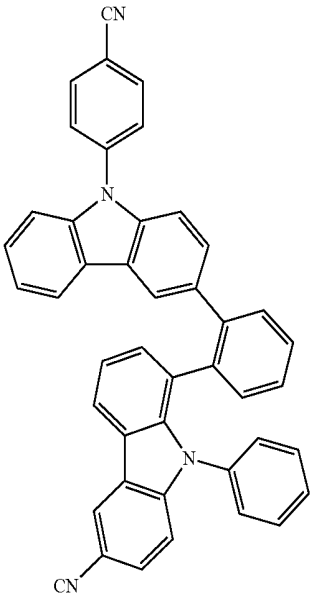

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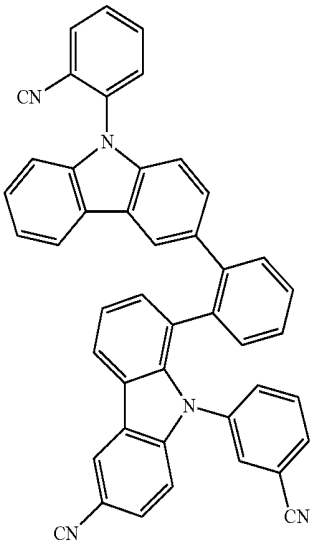

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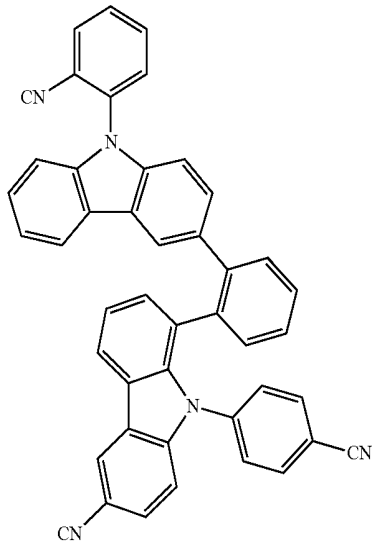

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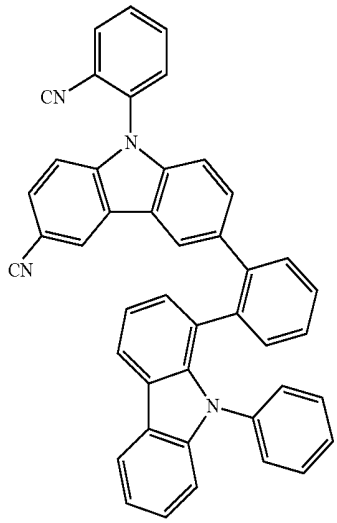

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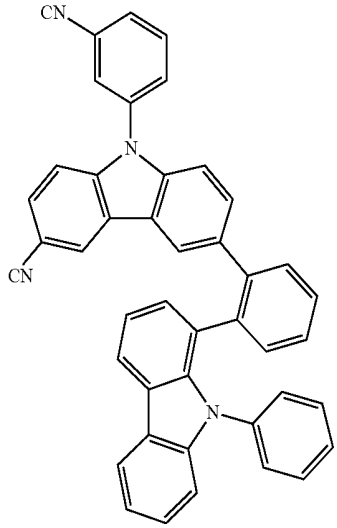

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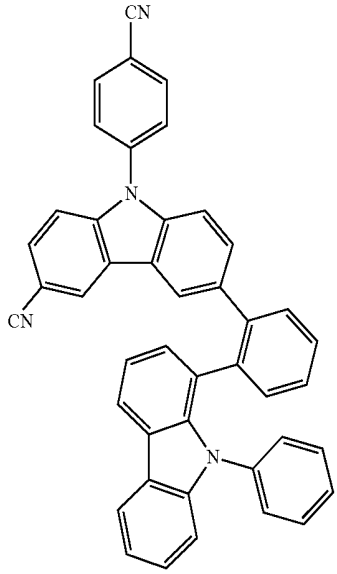

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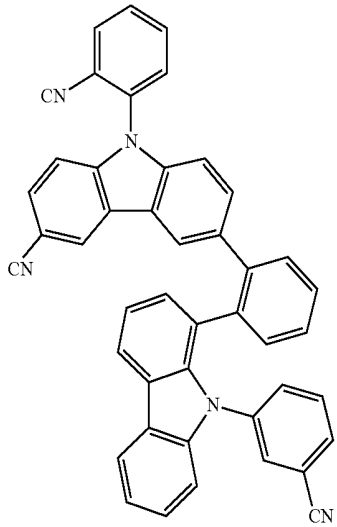

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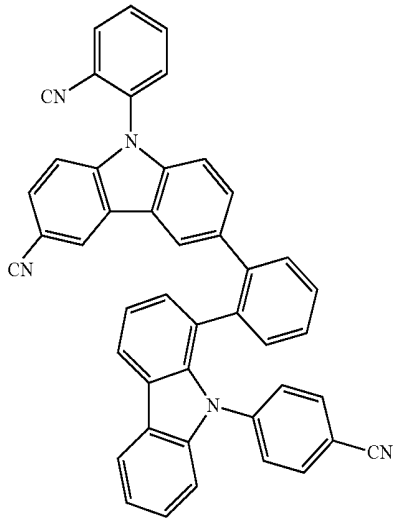

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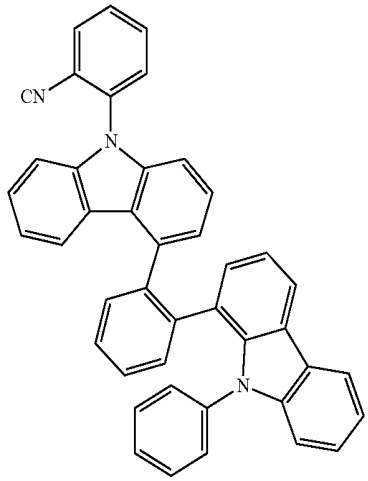

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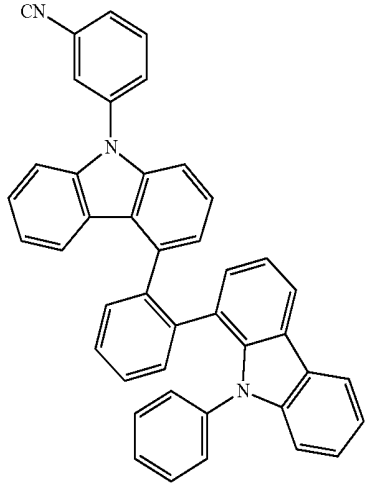

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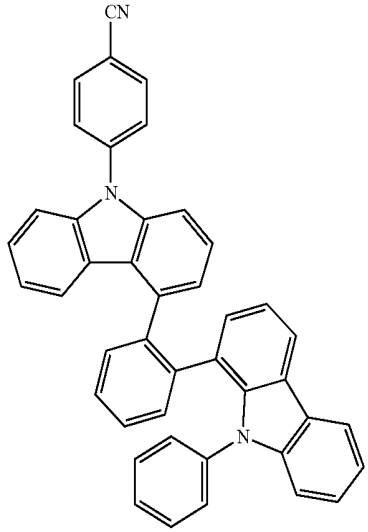

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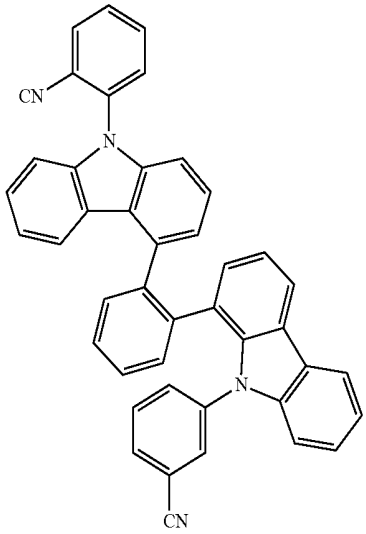

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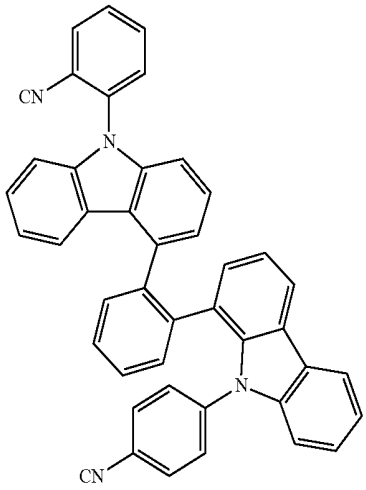

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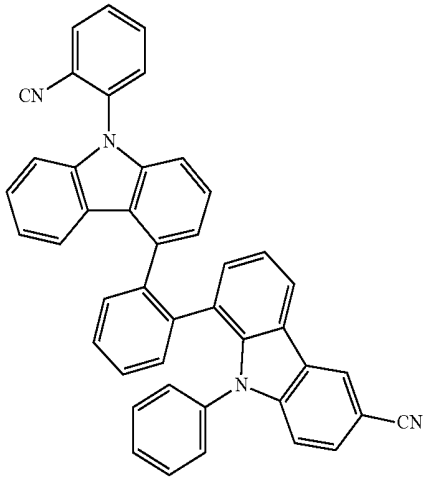

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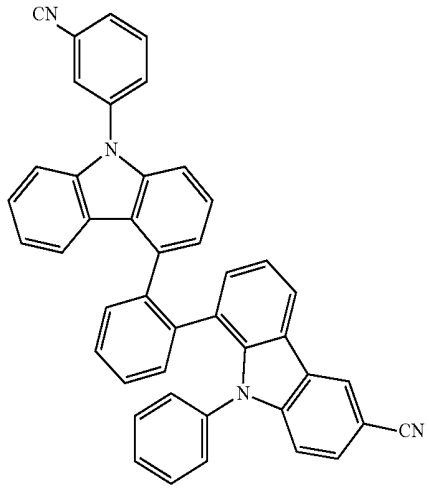

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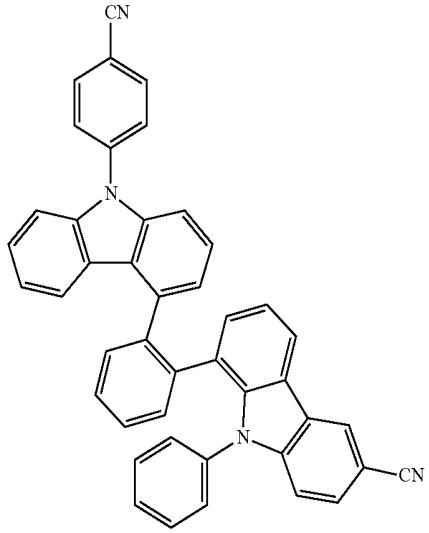

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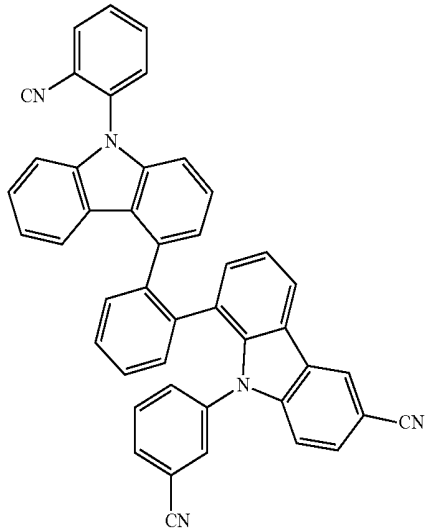

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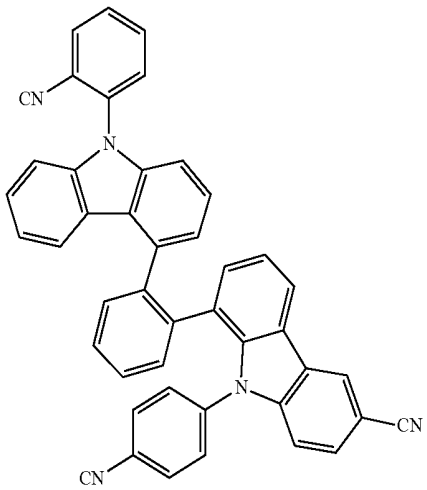

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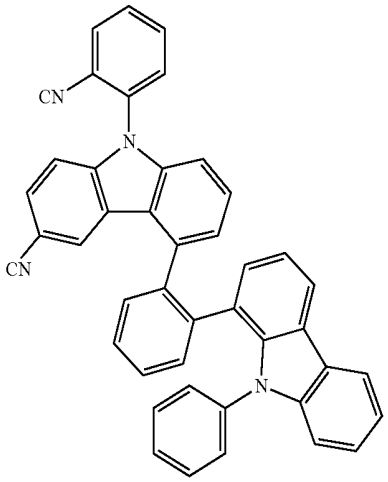

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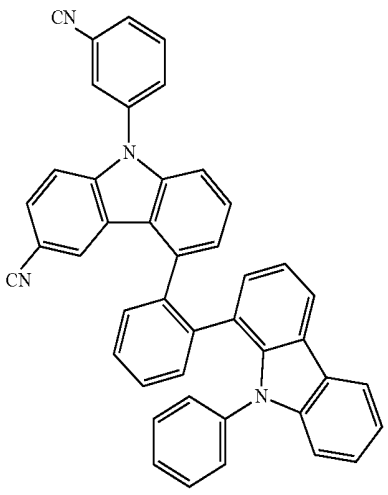

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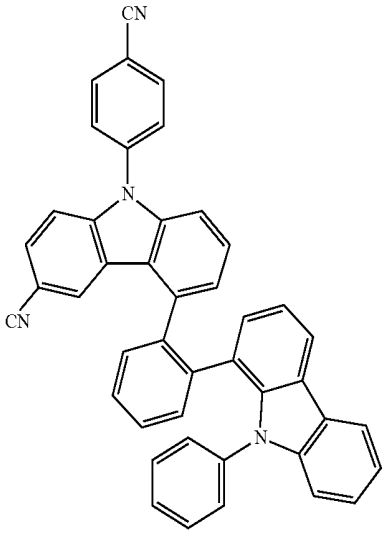

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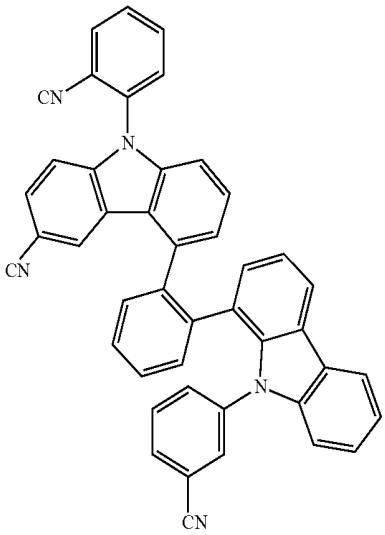

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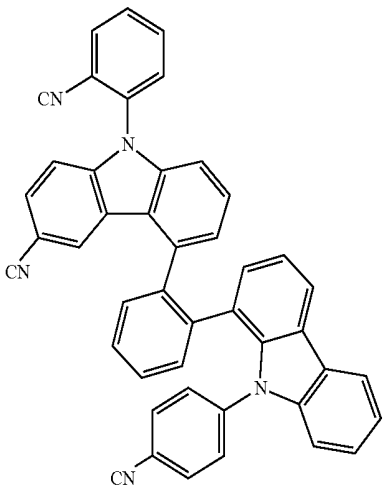

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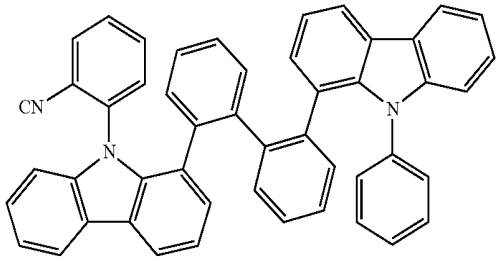

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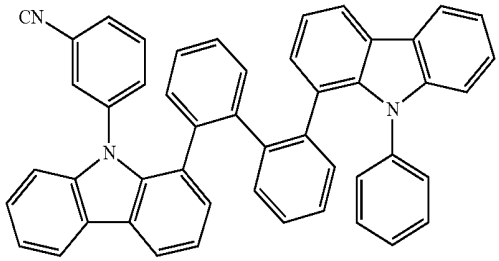

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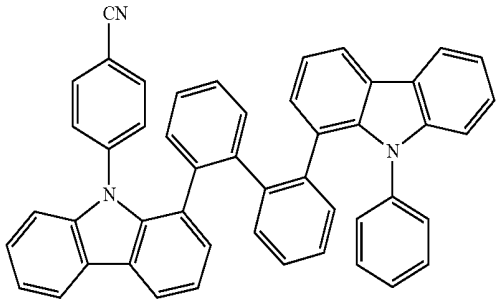

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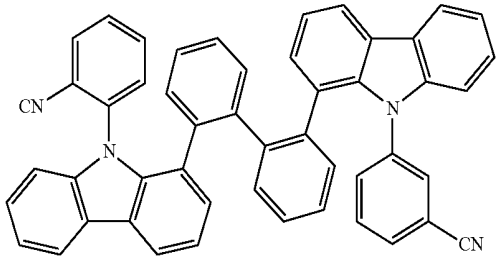

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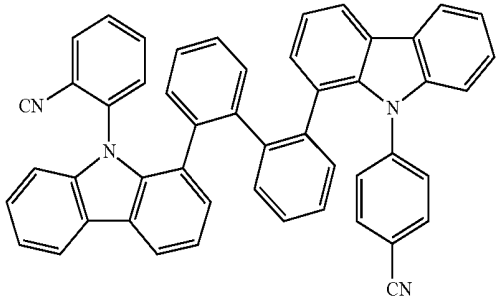

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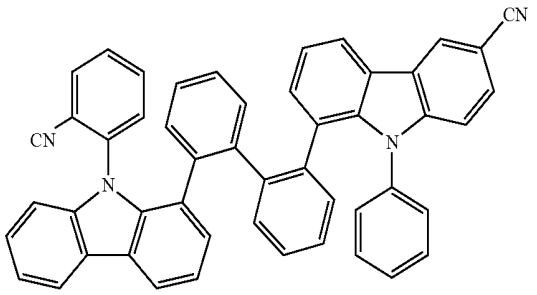

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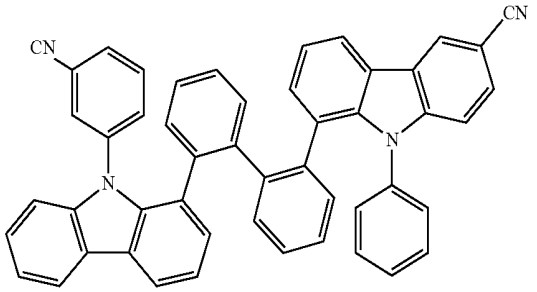

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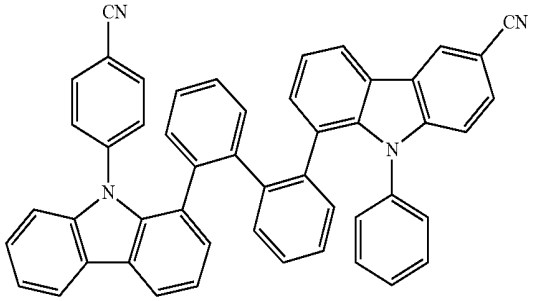

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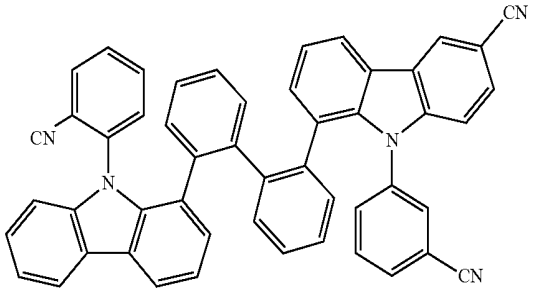

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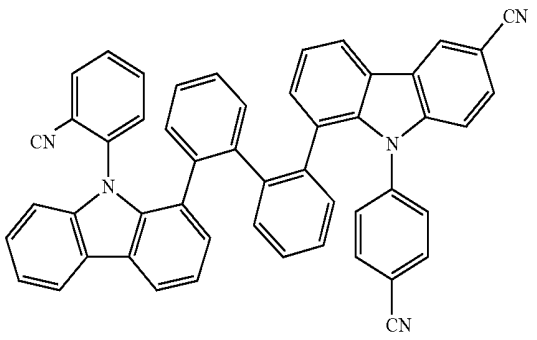

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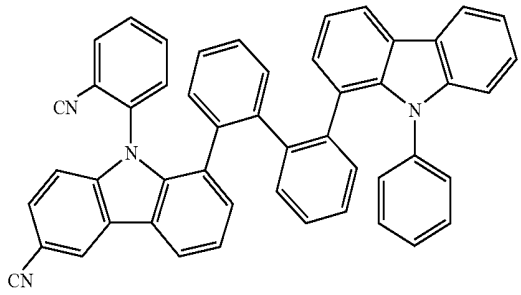

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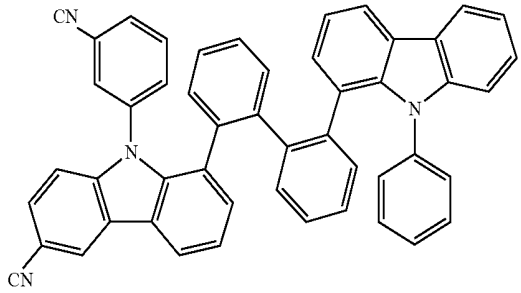

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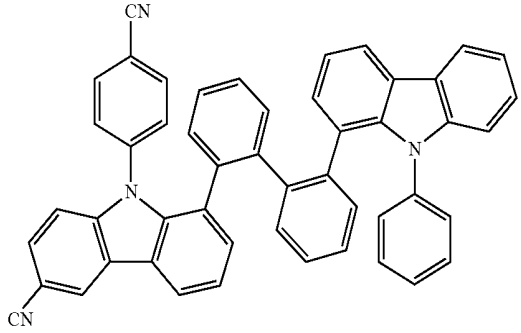

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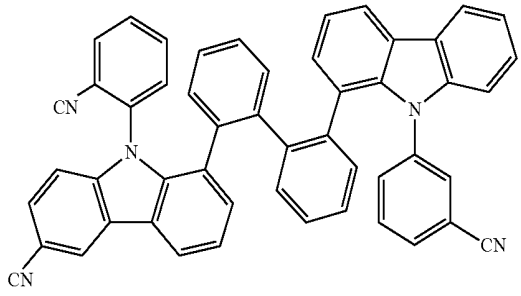

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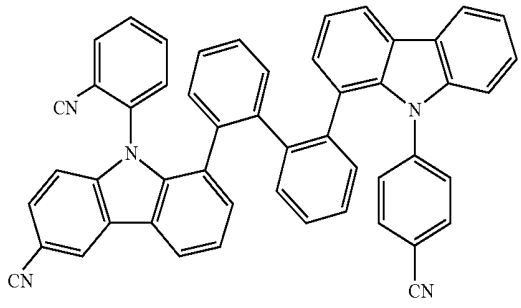

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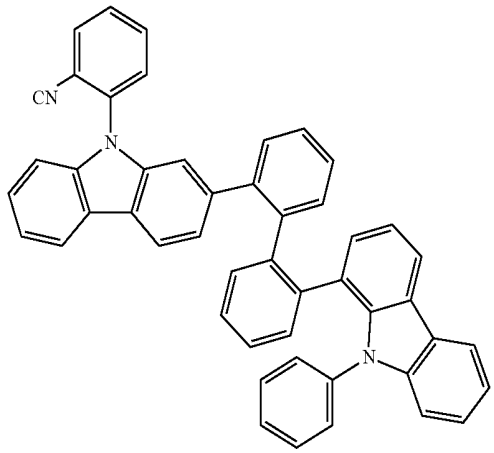

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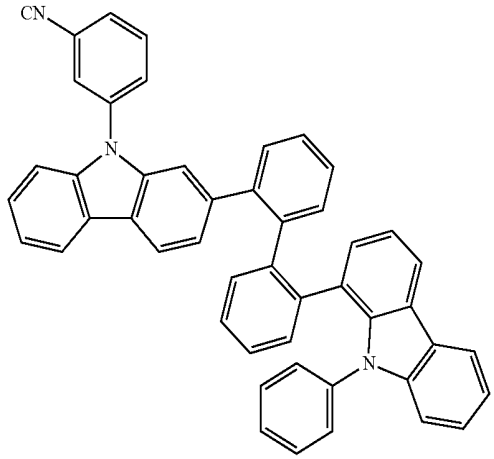

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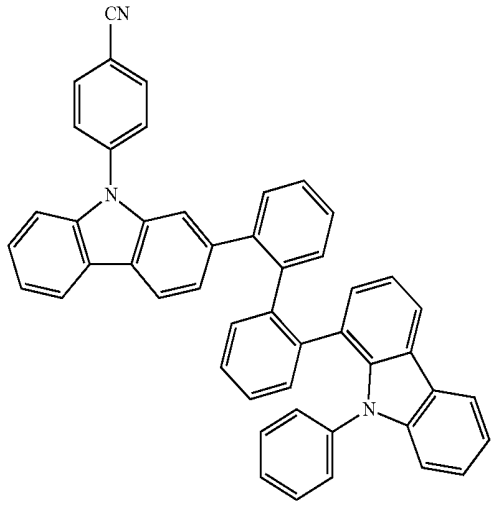

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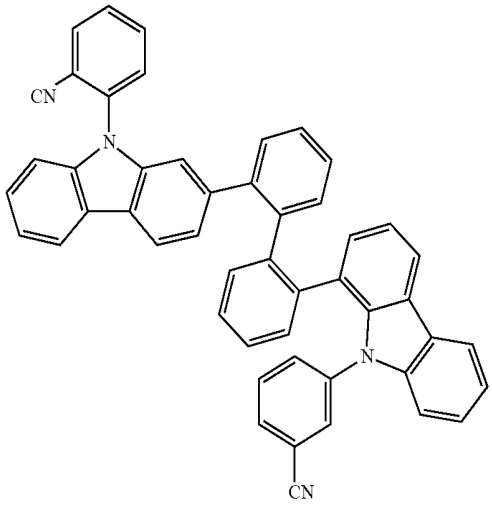

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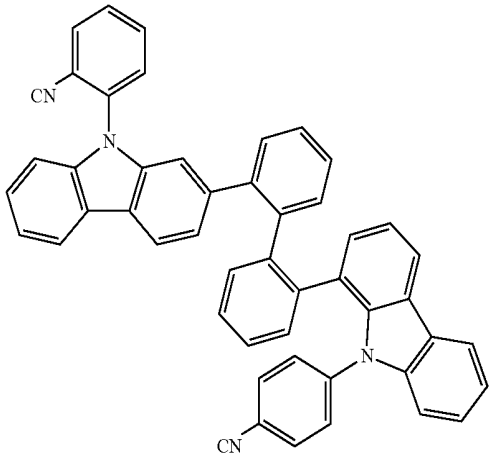

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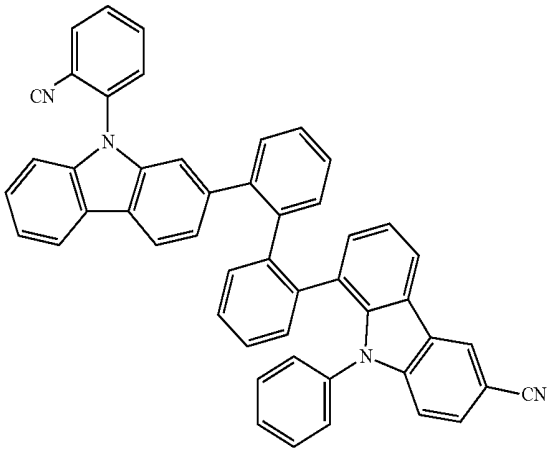

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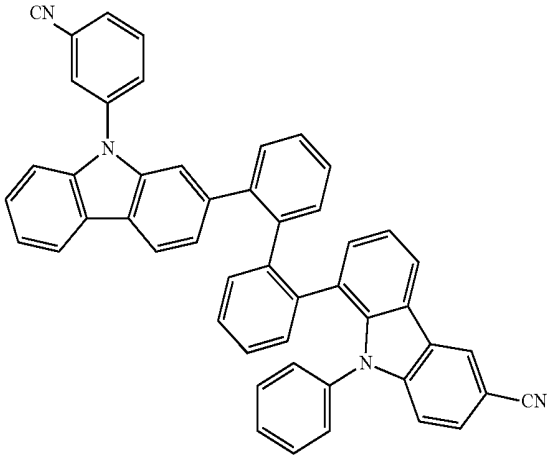

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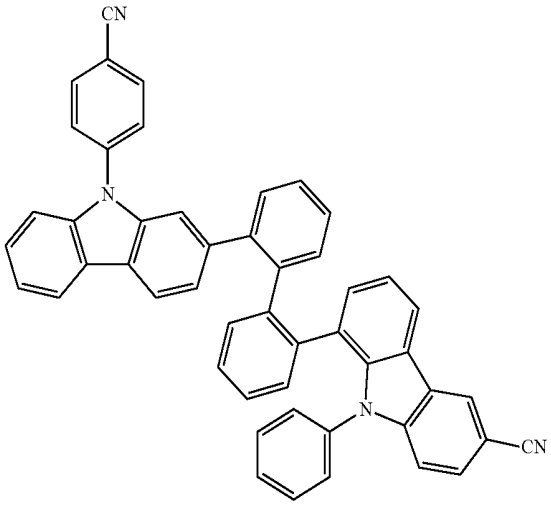

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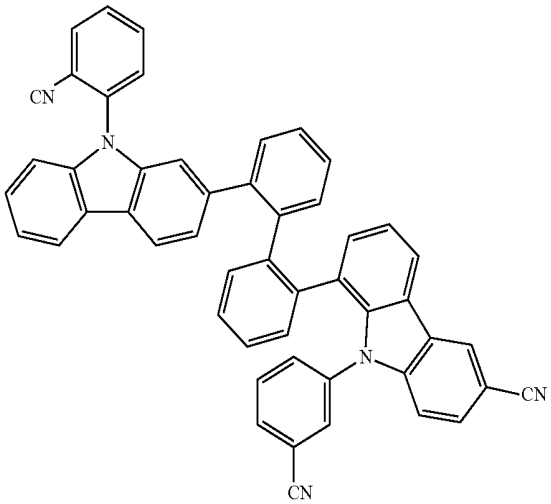

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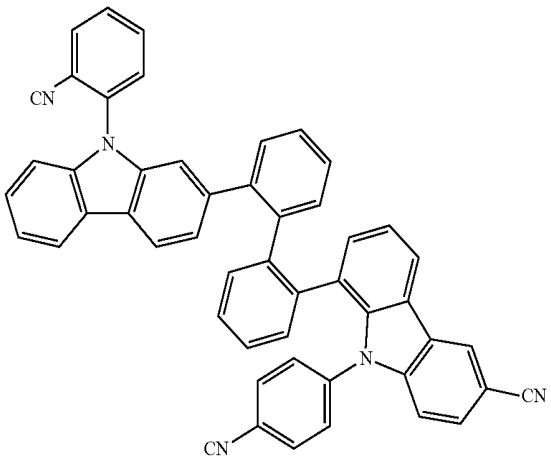

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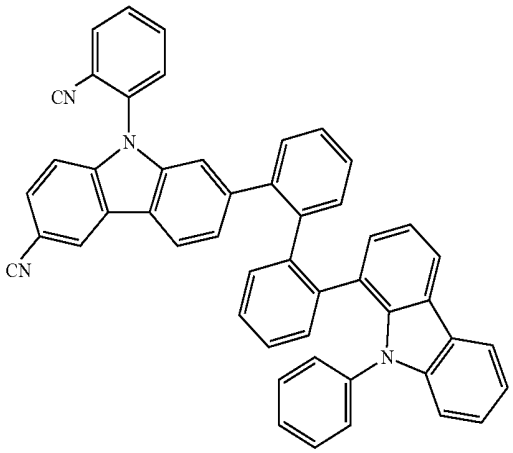

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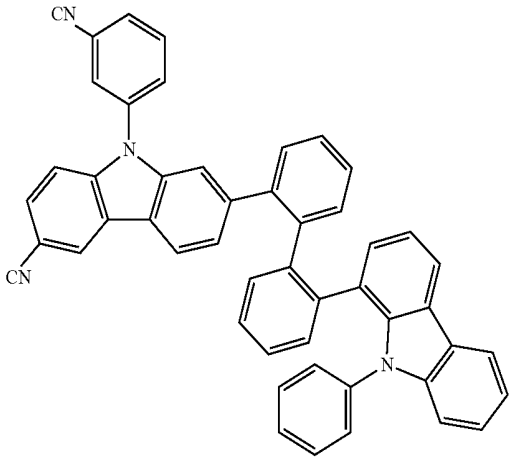

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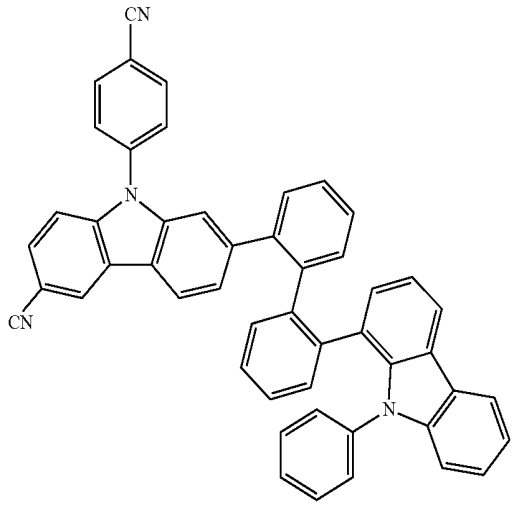

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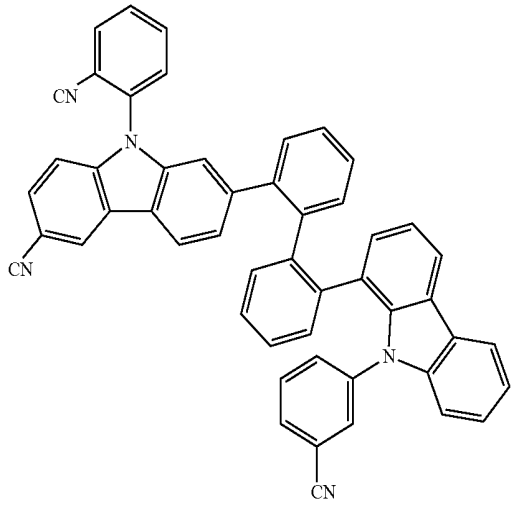

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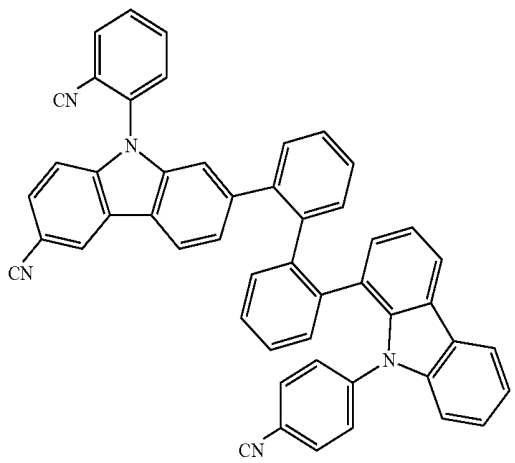

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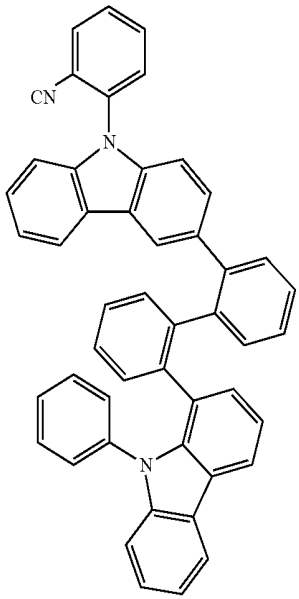

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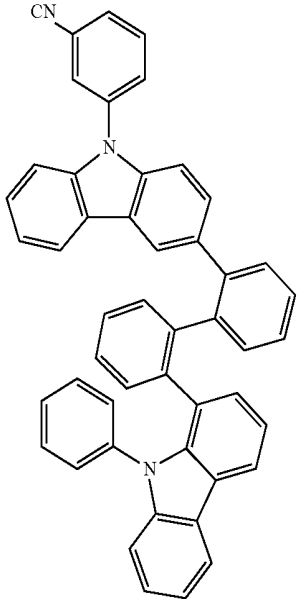

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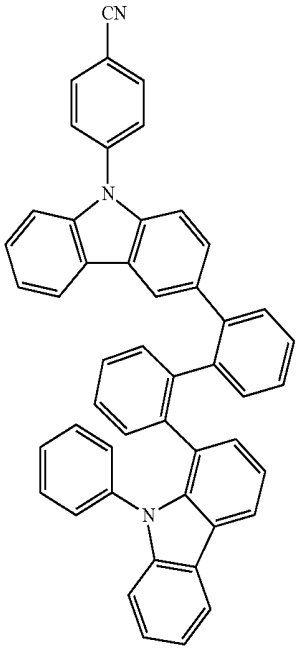

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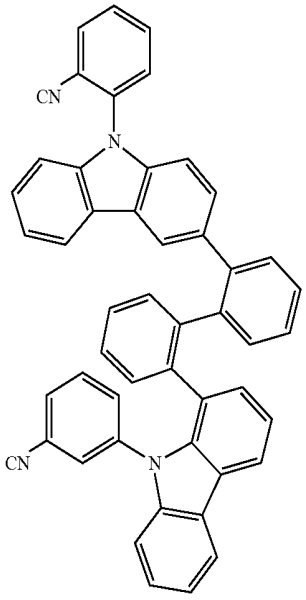

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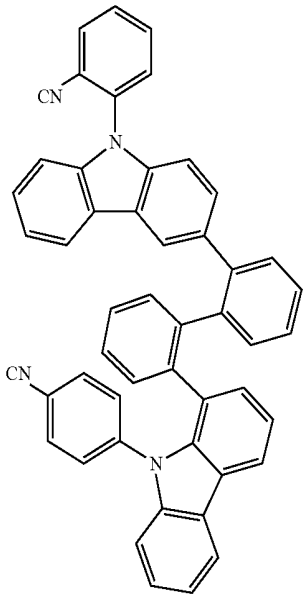

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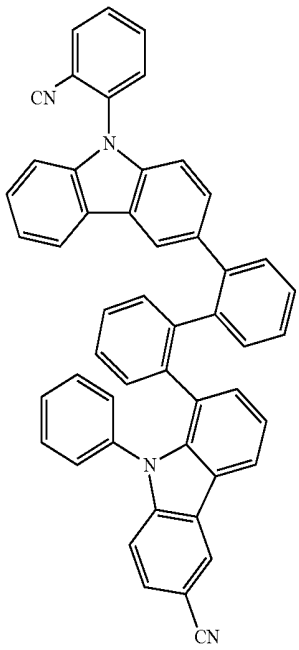

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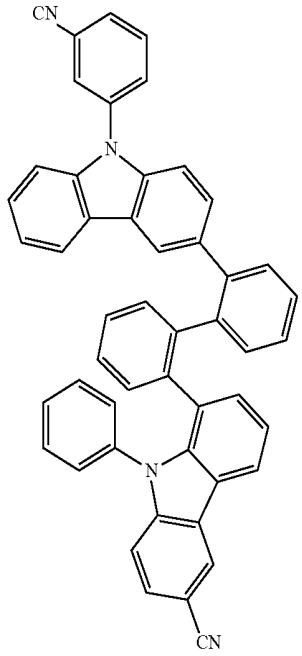

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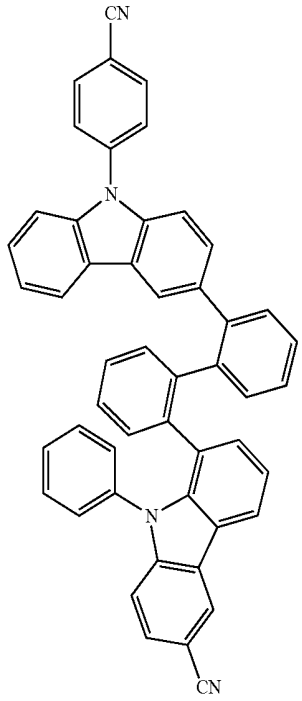

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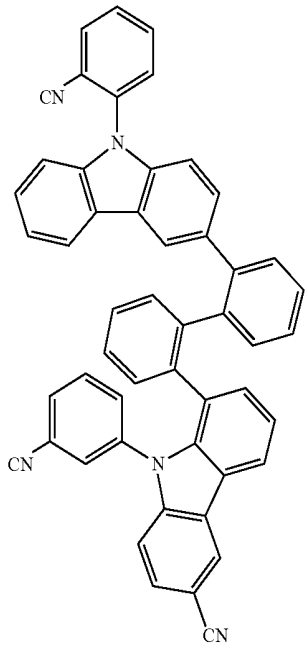

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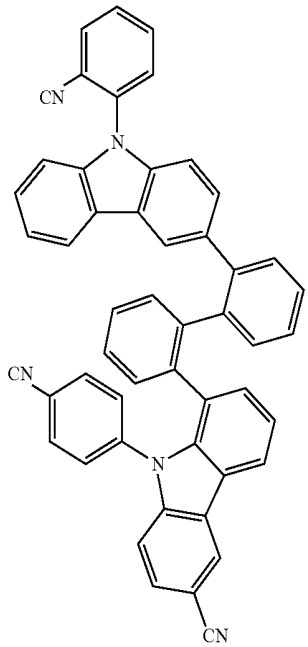

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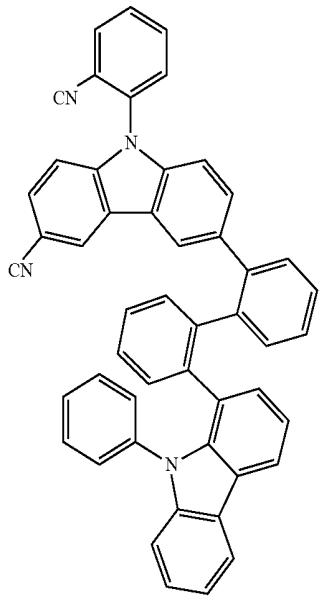

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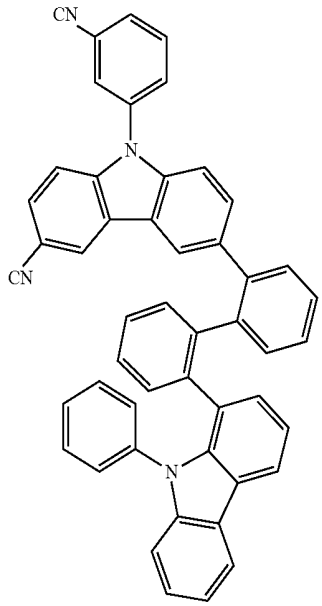

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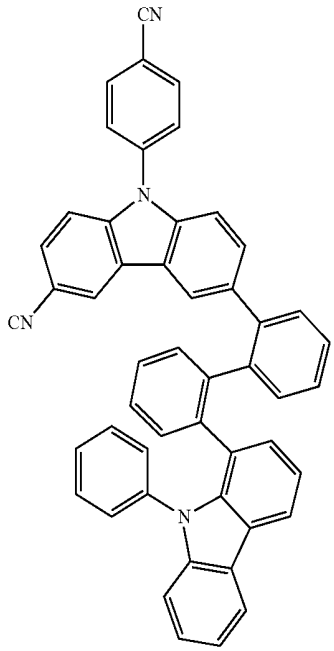

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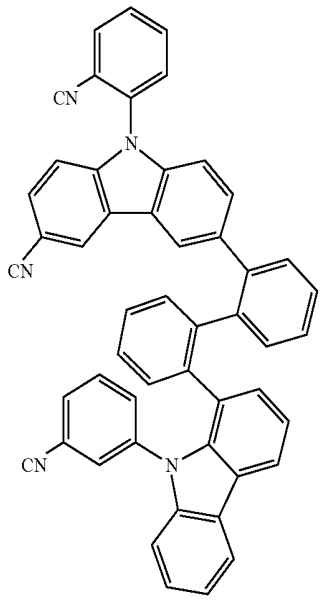

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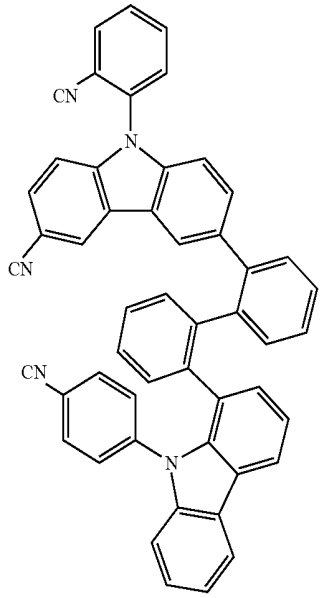

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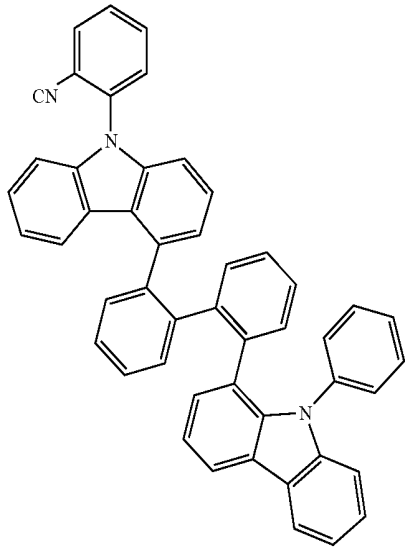

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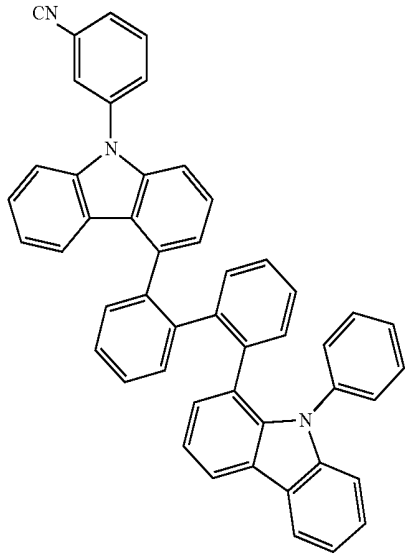

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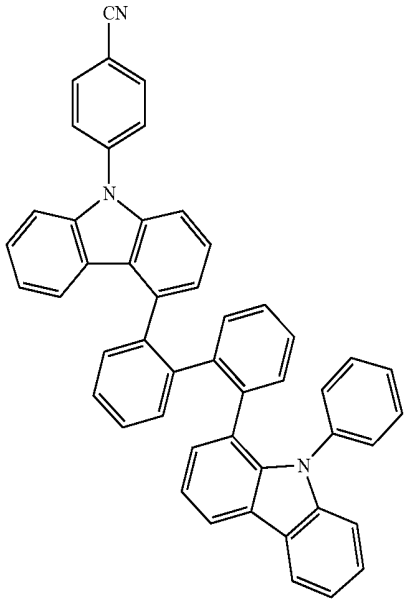

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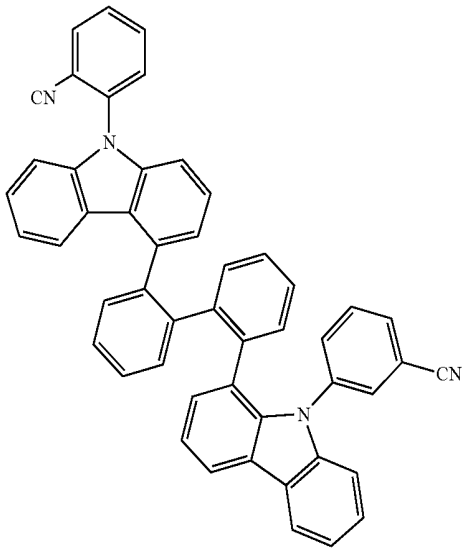

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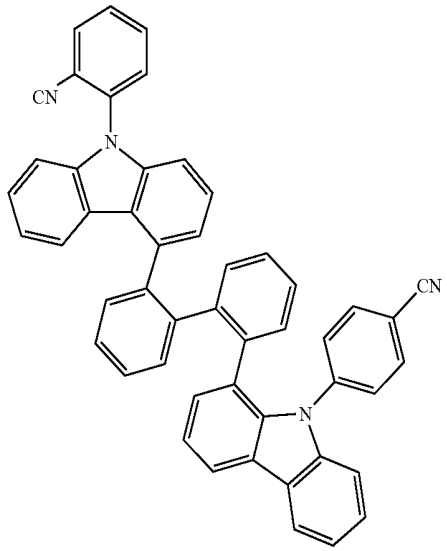

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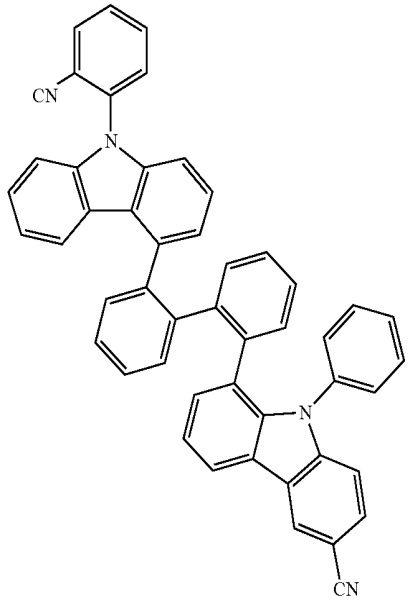

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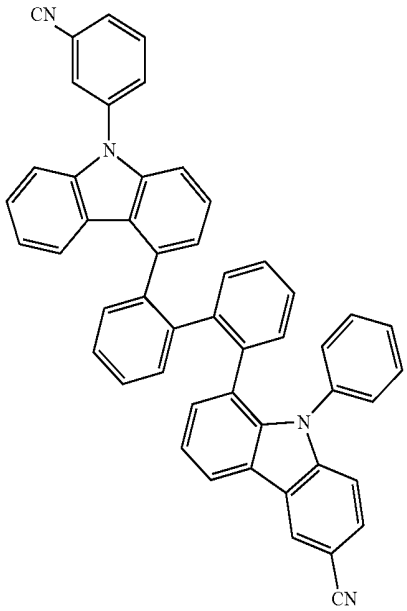

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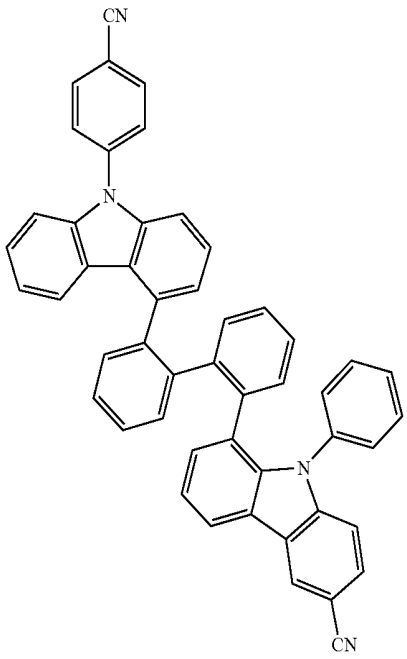

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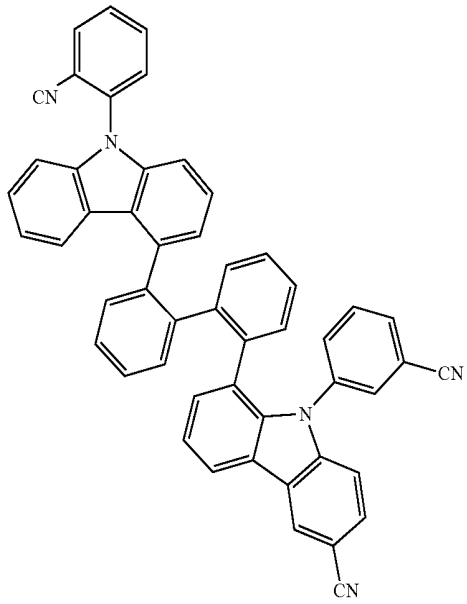

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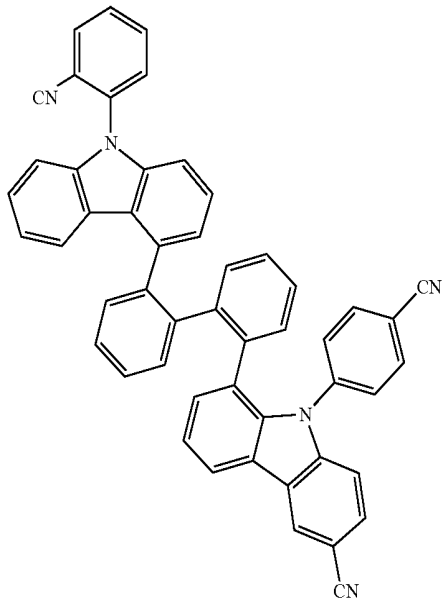

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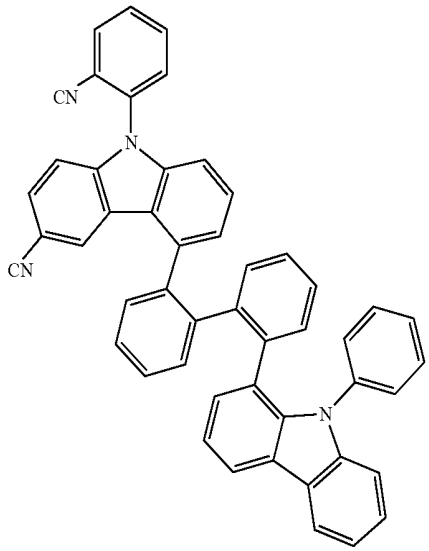

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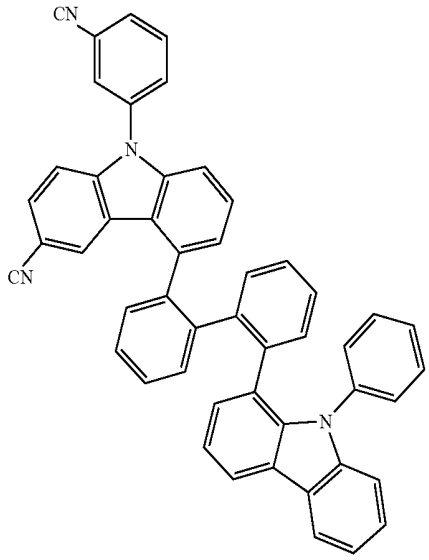

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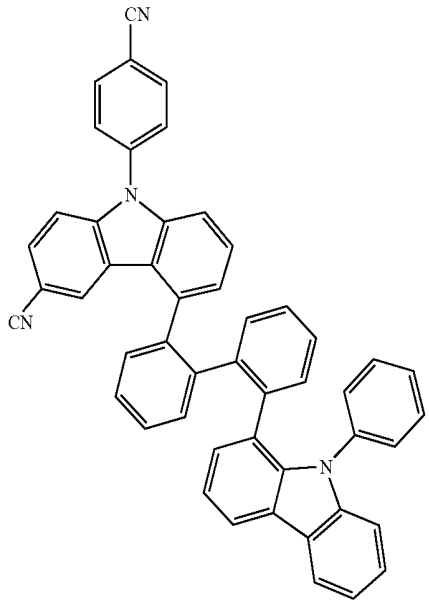

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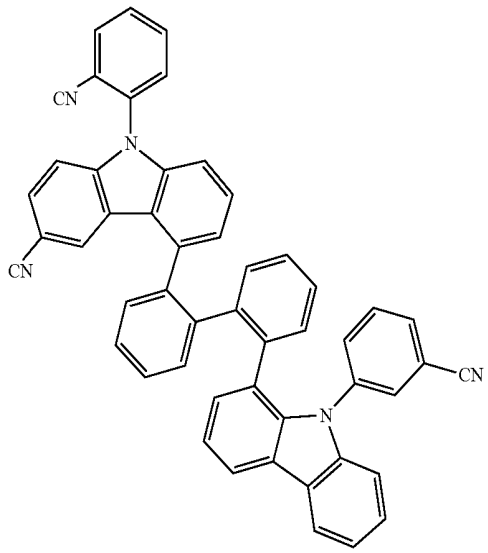

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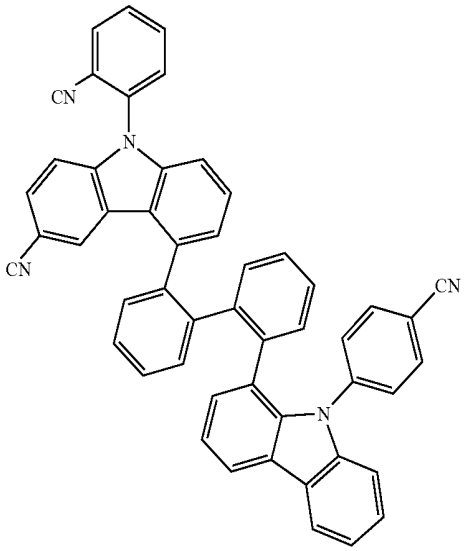

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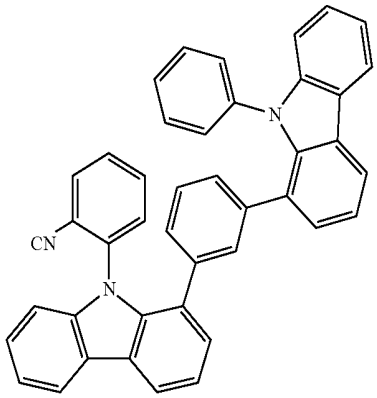

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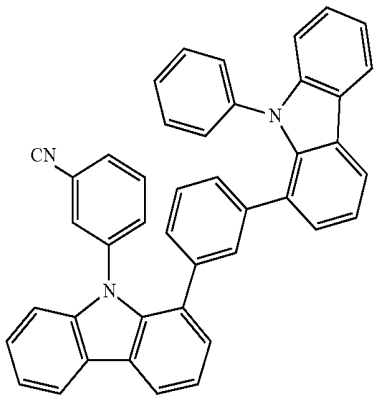

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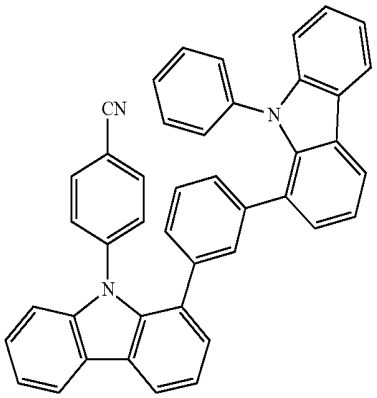

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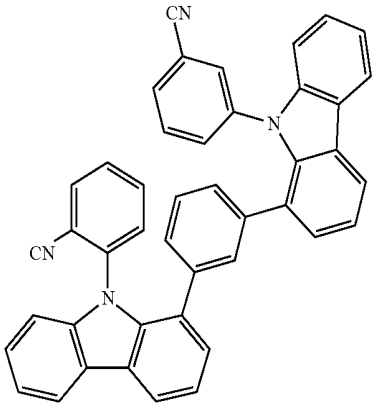

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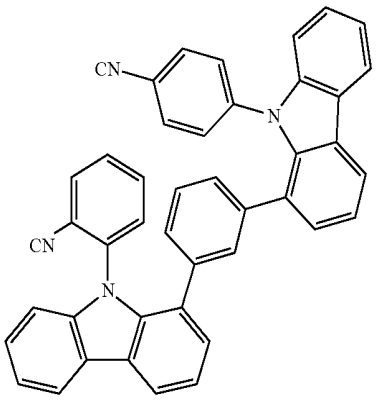

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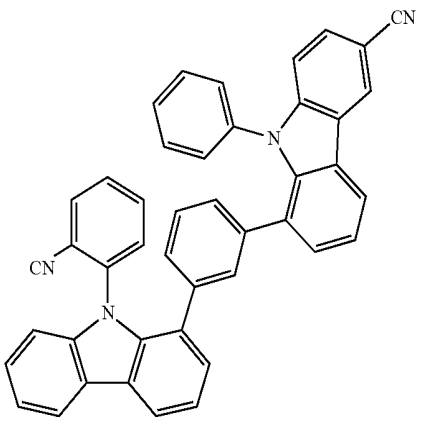

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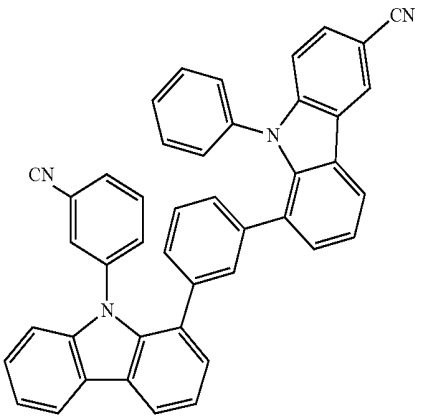

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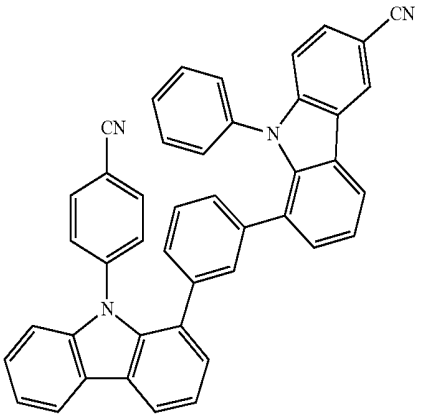

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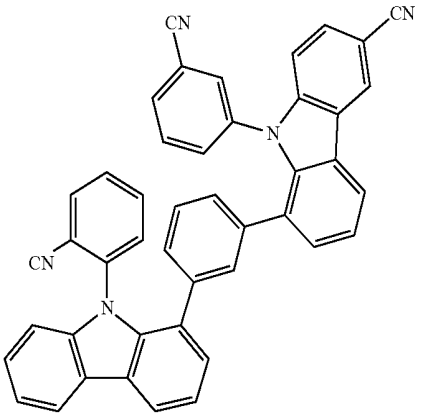

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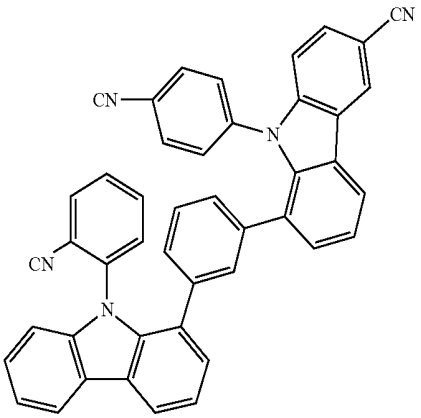

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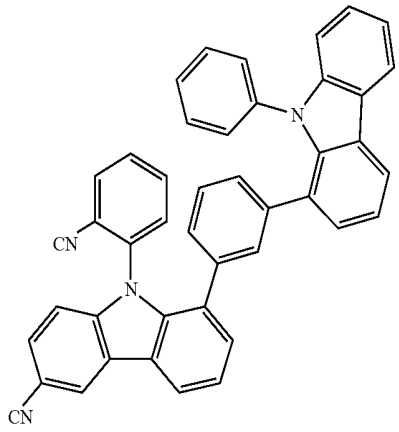

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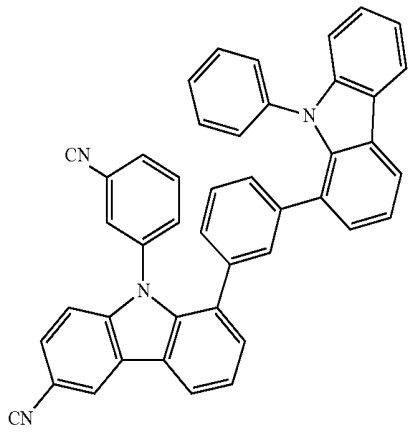

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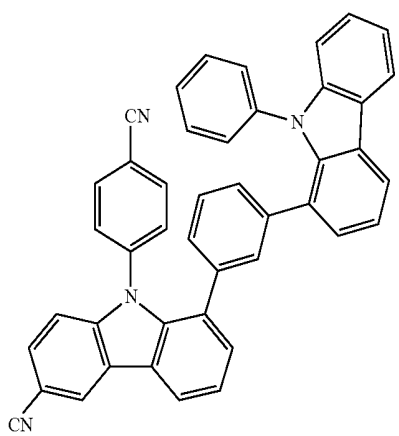

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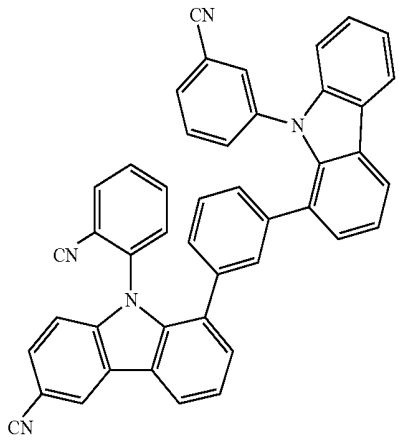

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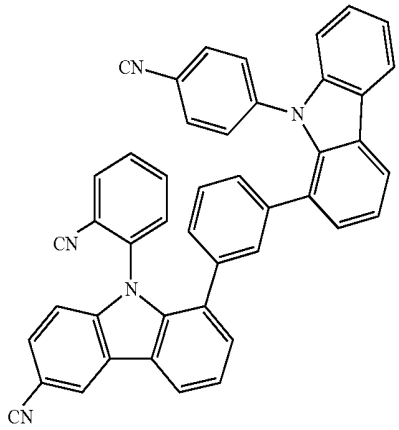

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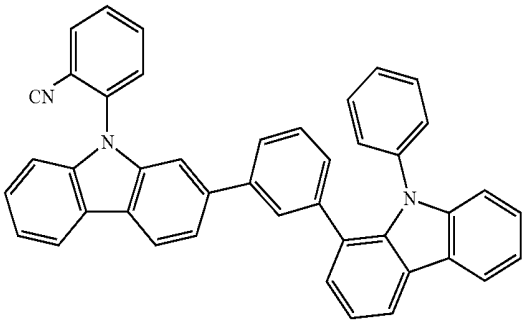

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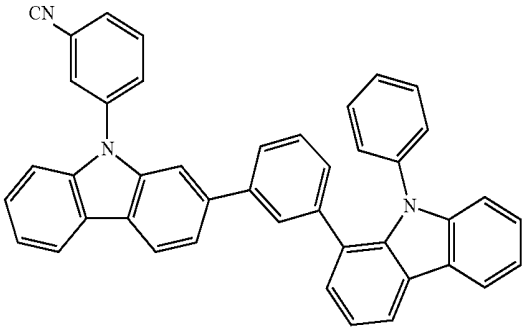

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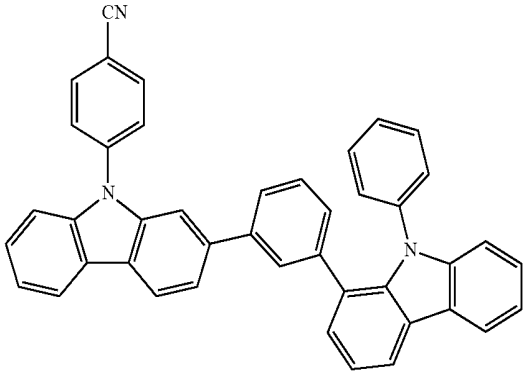

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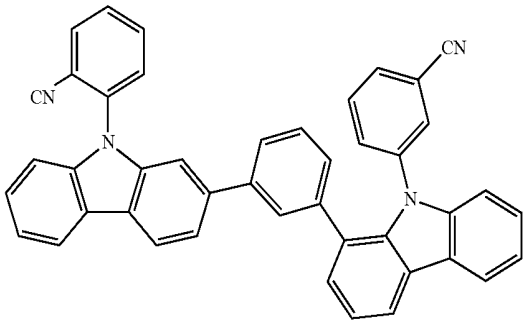

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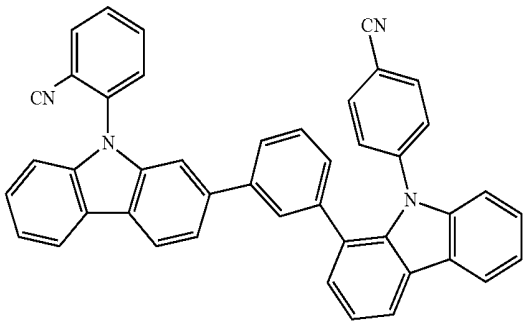

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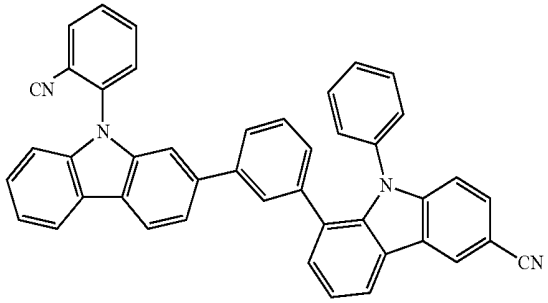

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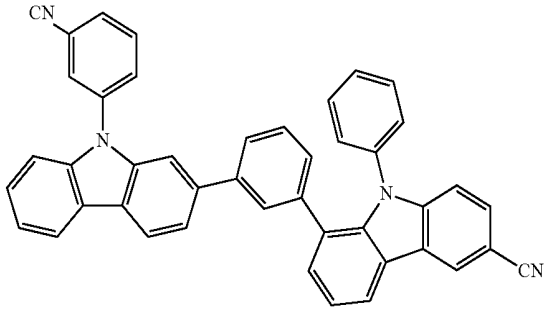

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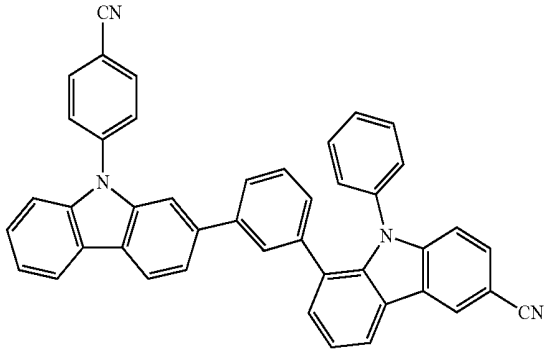

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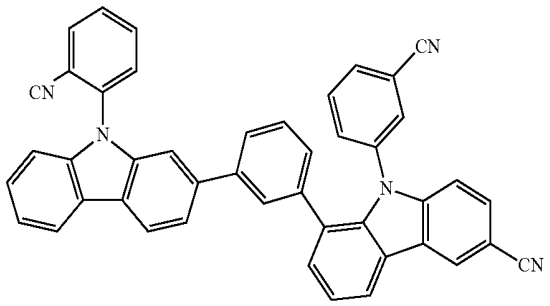

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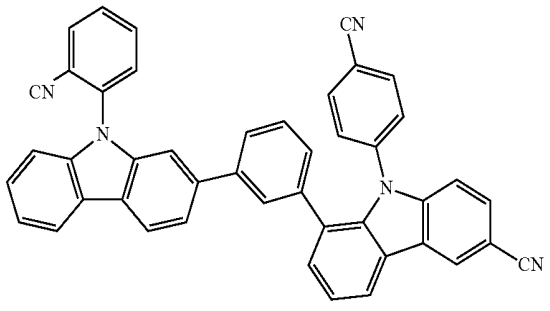

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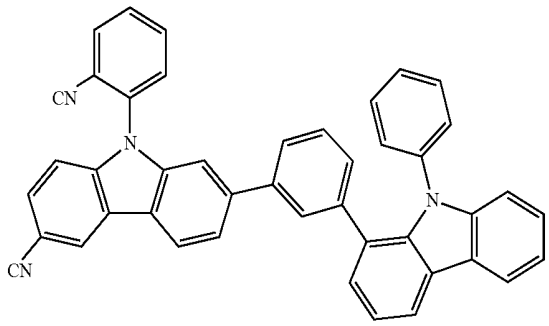

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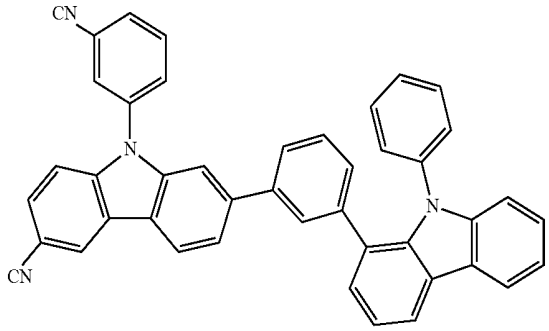

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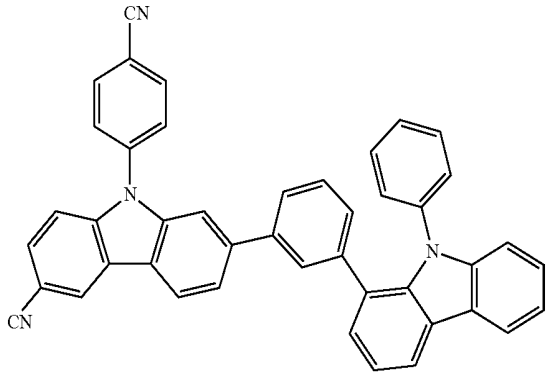

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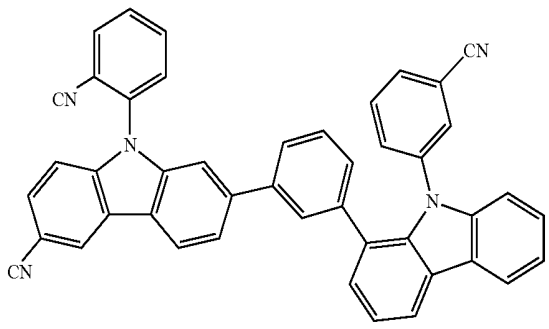

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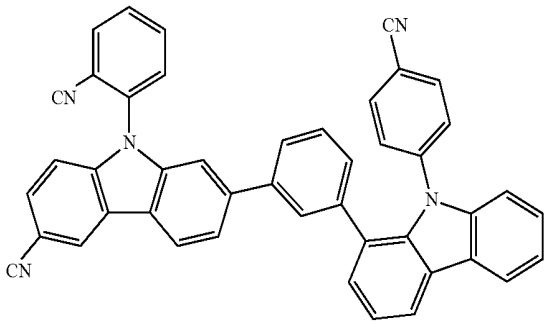

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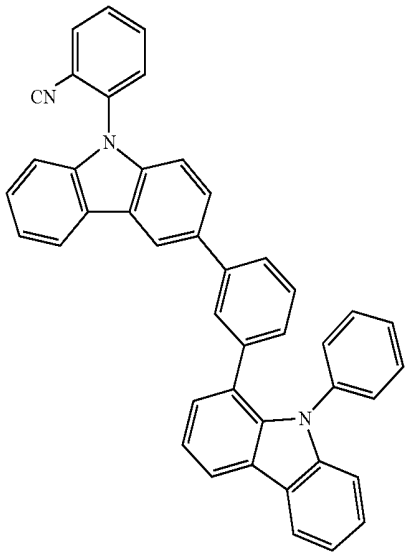

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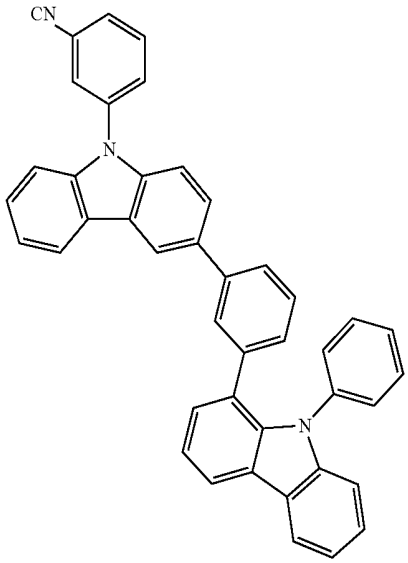

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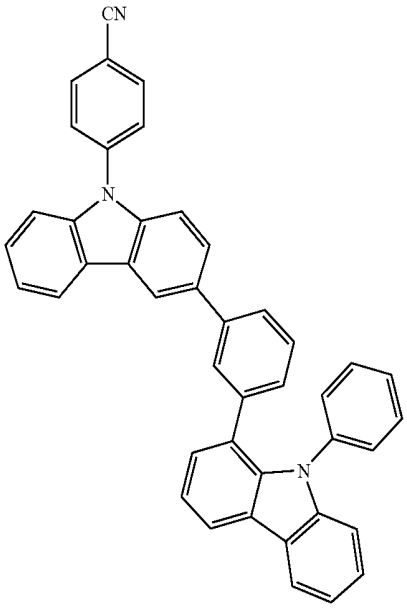

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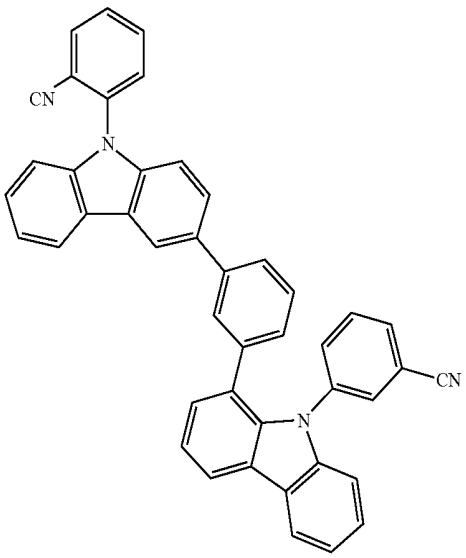

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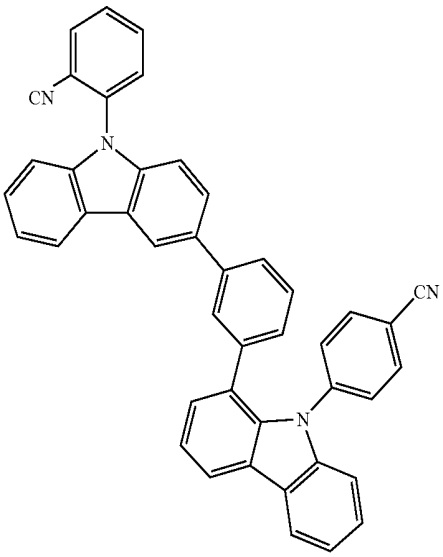

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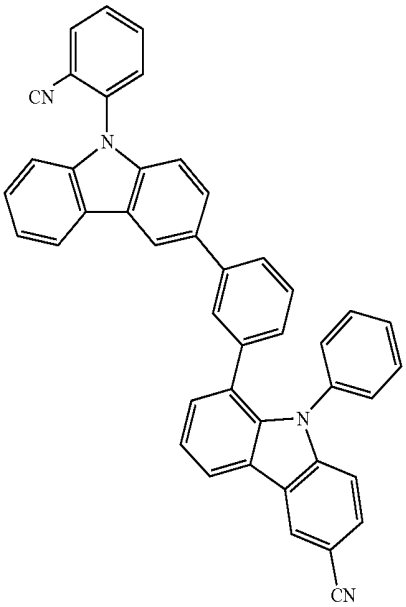

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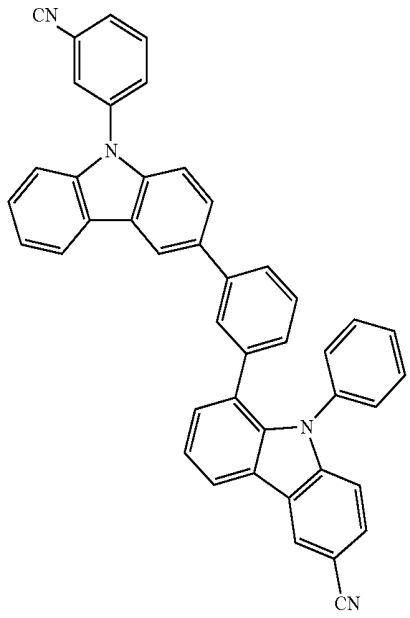

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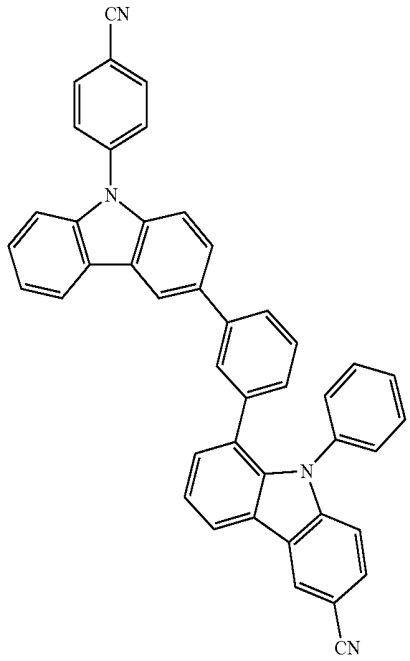

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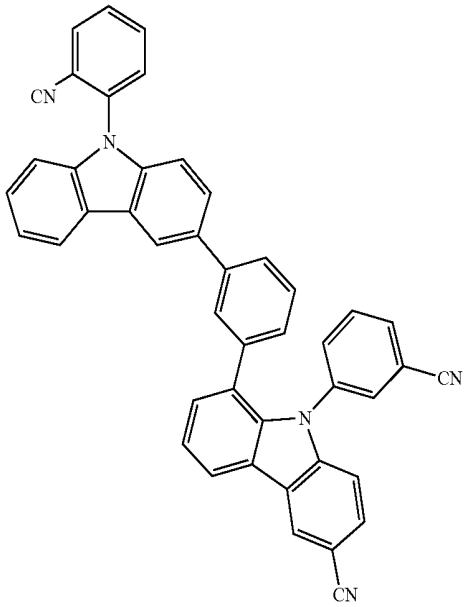

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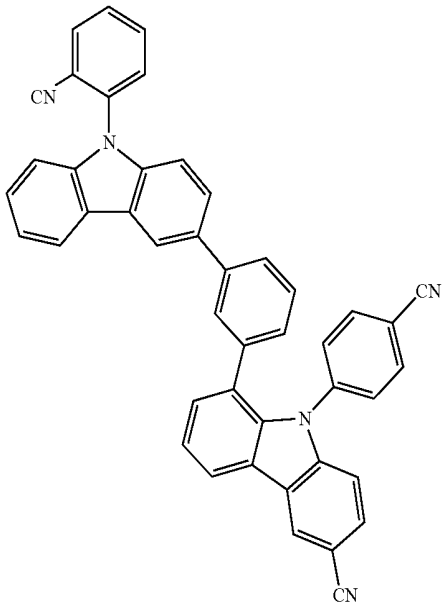

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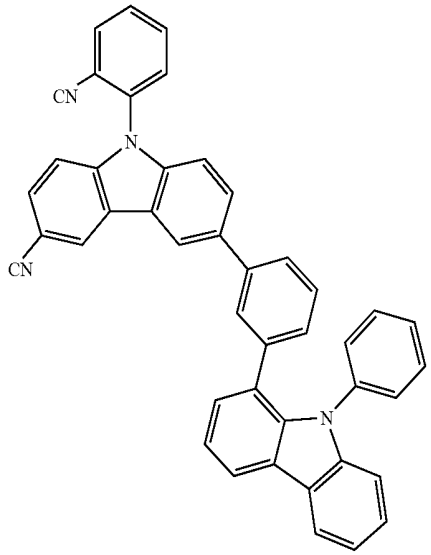

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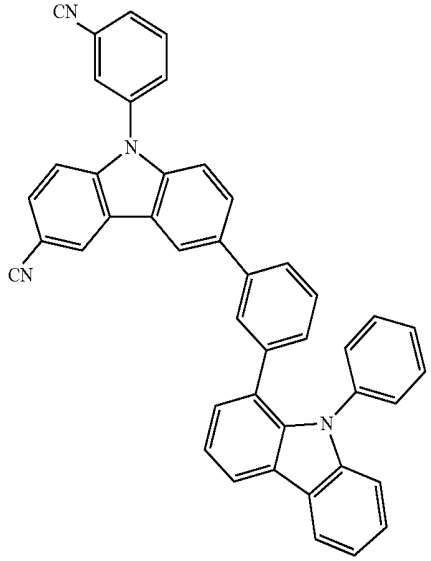

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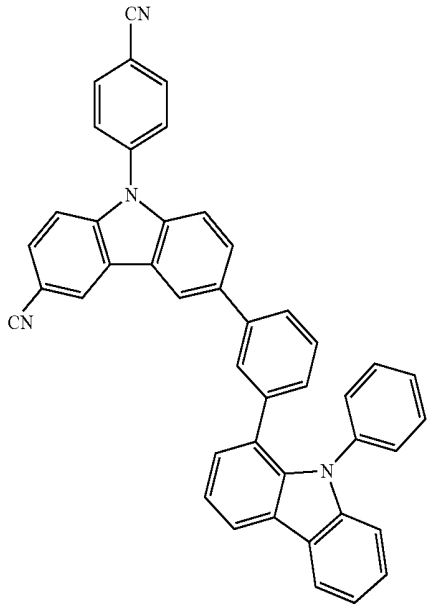

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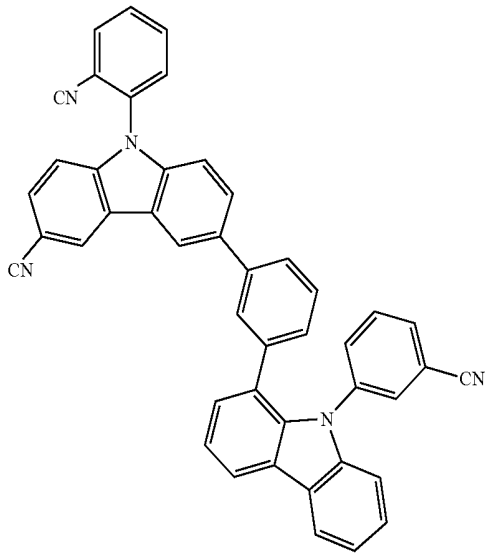

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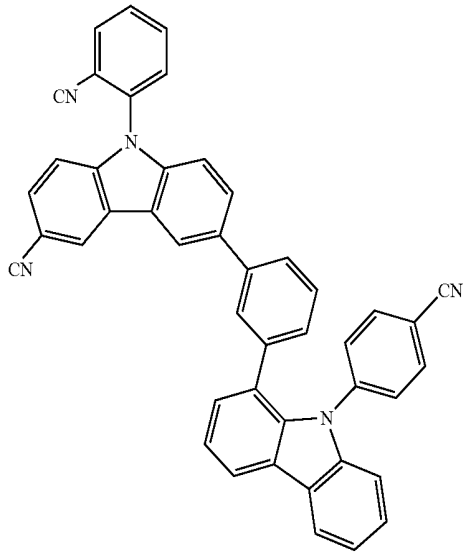

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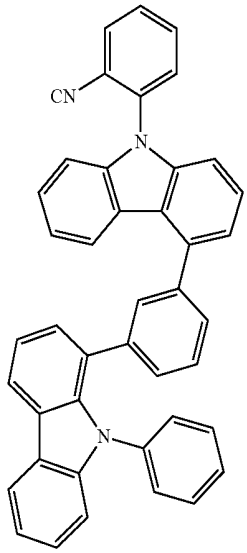

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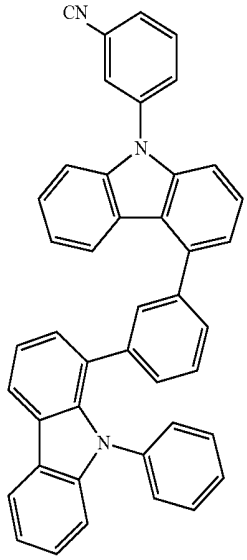

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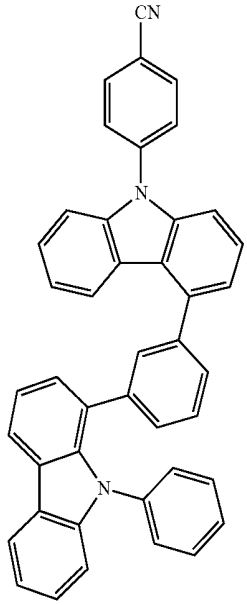

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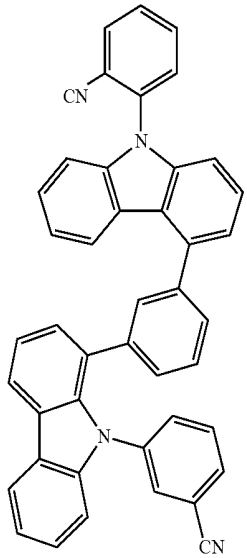

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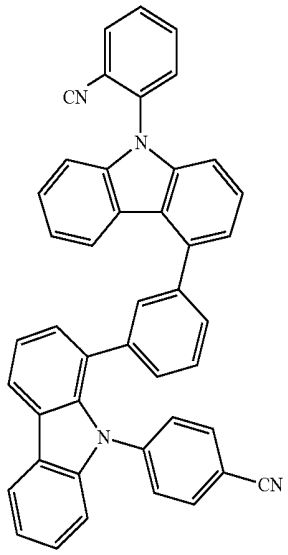

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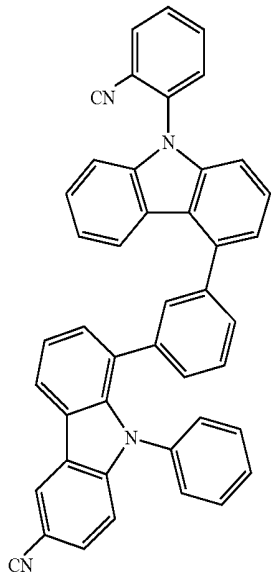

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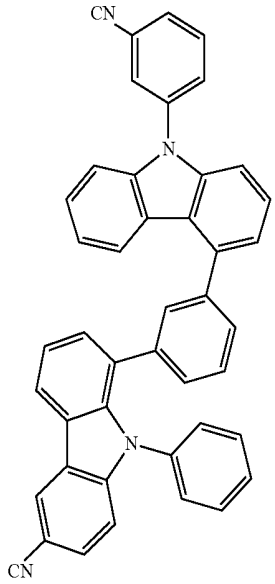

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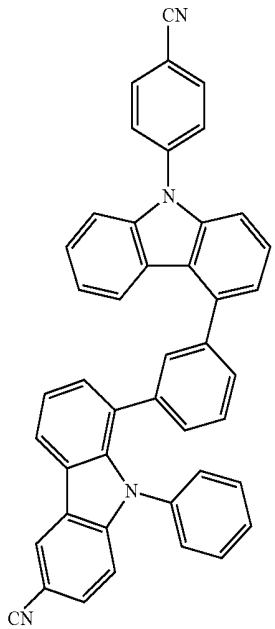

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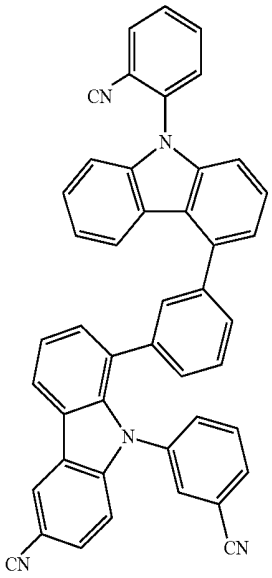

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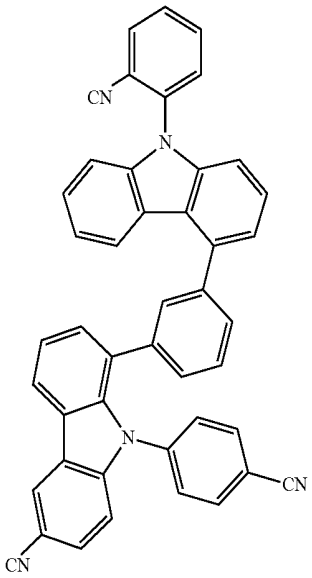

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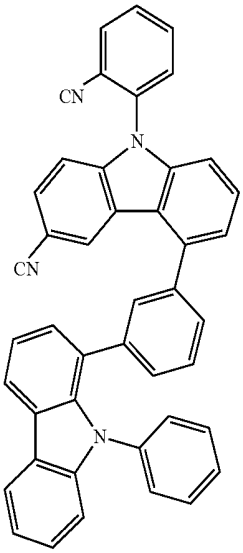

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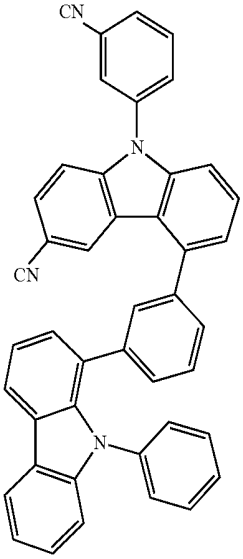

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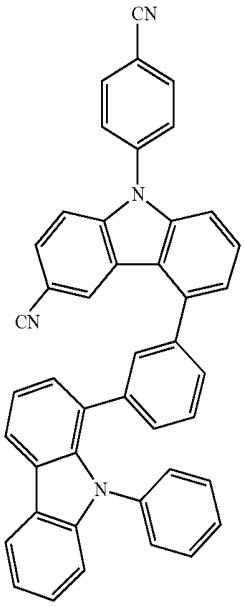

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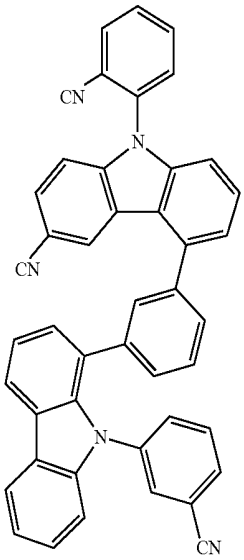

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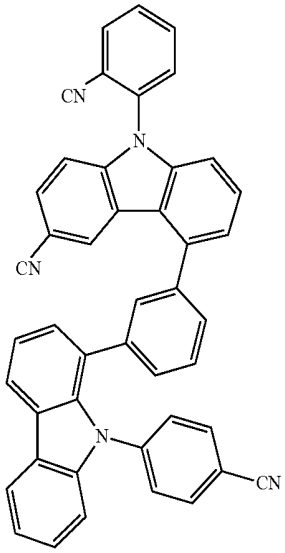

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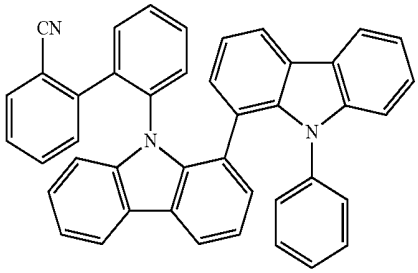

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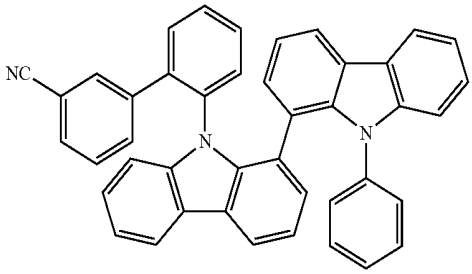

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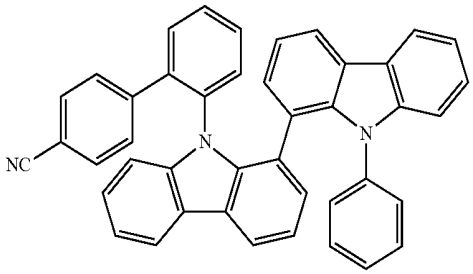

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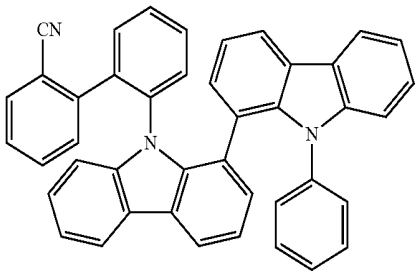

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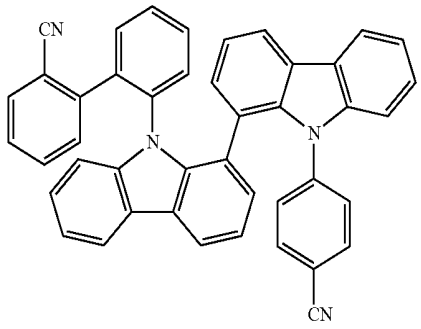

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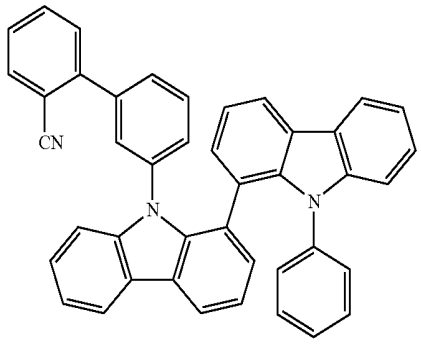

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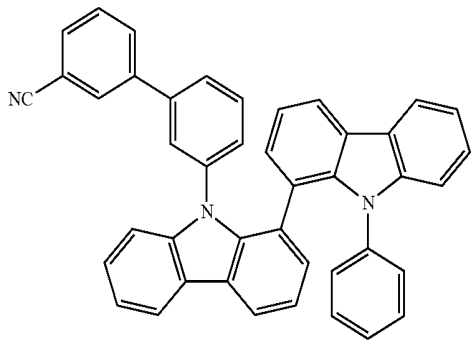

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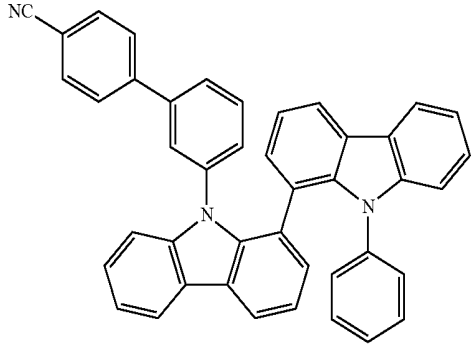

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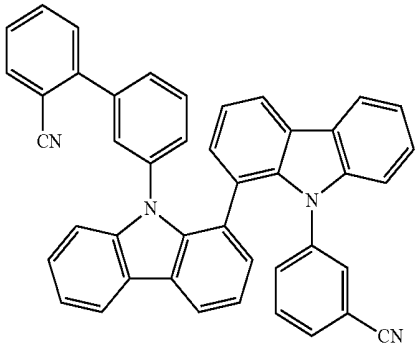

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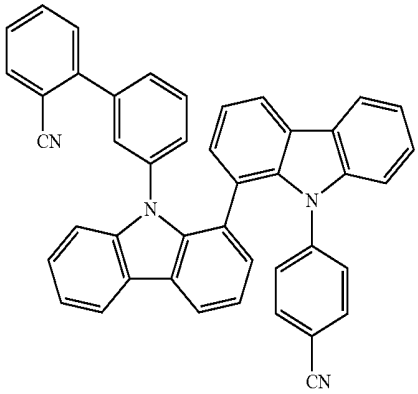

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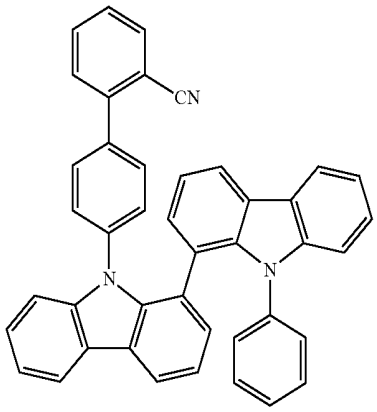

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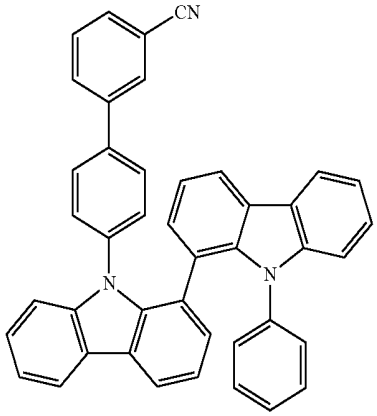

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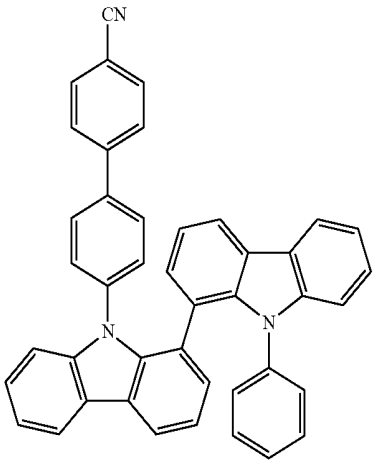

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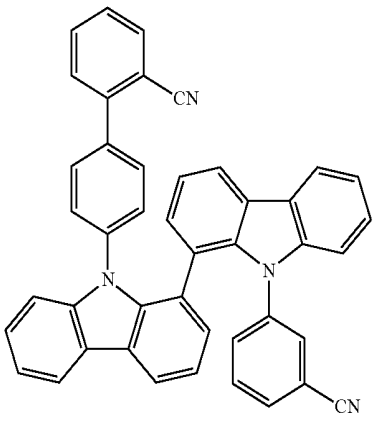

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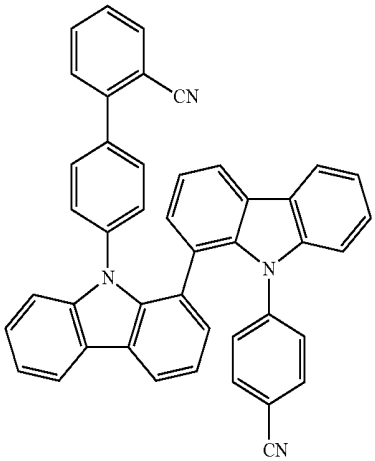

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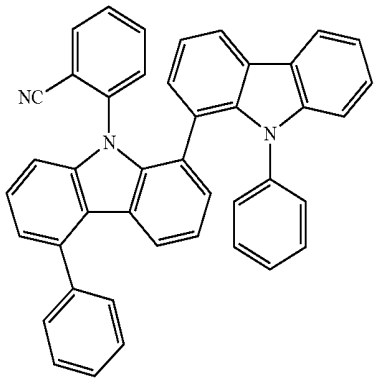

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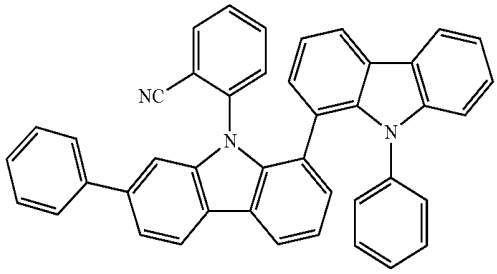

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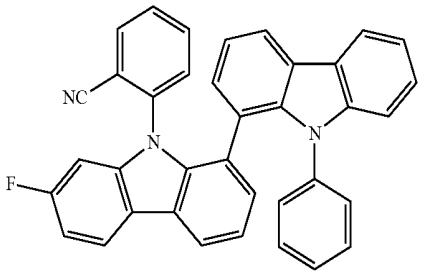

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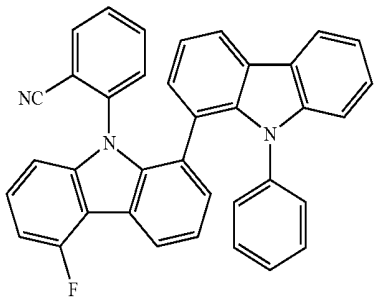

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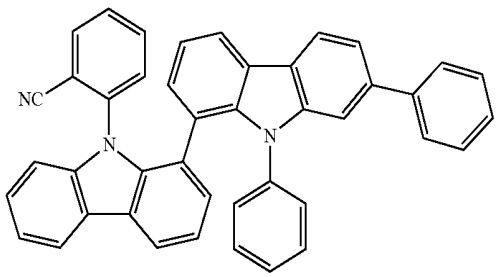

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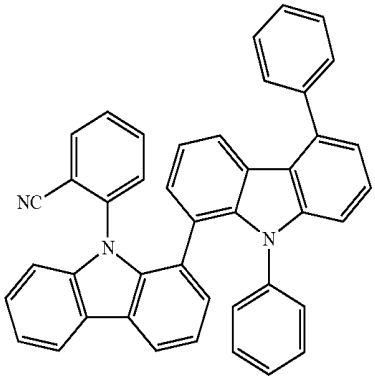

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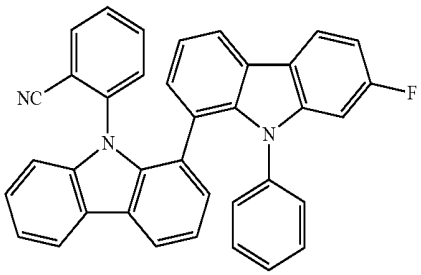

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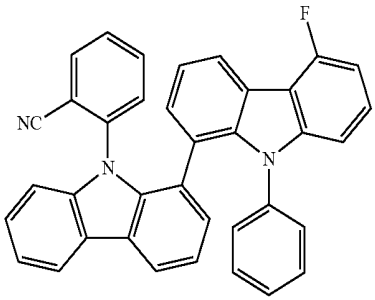

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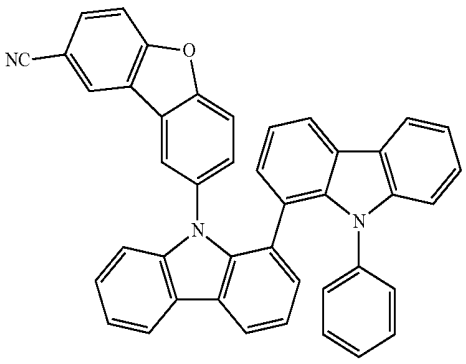

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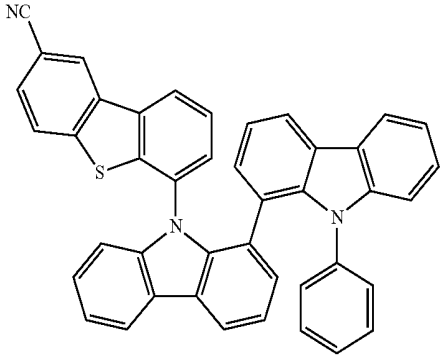

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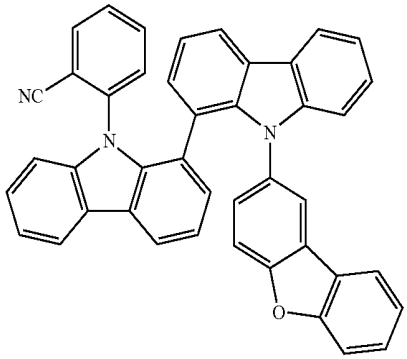

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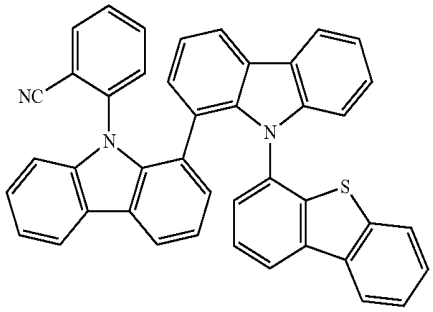

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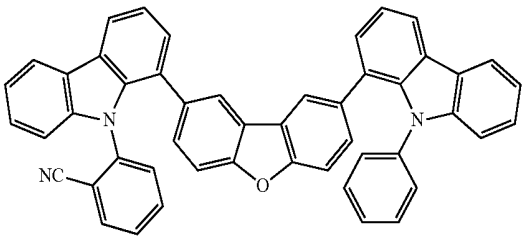

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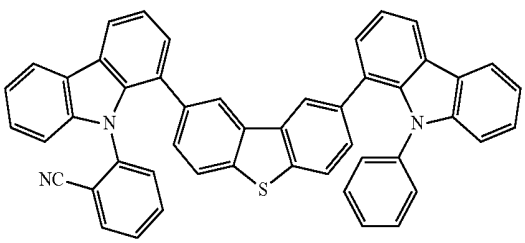

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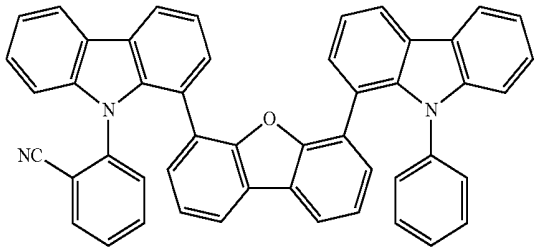

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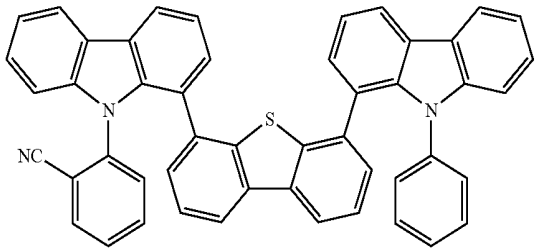
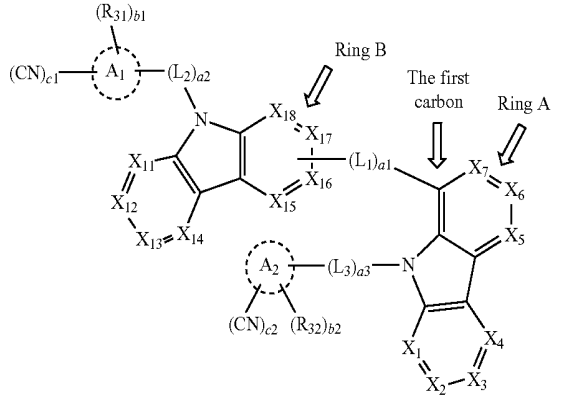


[0125] In Formula 1, "ring B" is bonded to the first carbon of "ring A" via *-$(L_1)_{a1}$-*' (see Formula 1').

[0126] In this regard, the condensed cyclic compound represented by Formula 1 may have a high triplet (T_1) energy level. For example, although not limited to a particular theory, the condensed cyclic compound represented by Formula 1 may have a T_1 energy level that is at least about 0.05 electron volts (eV) higher than that of a virtual compound having the same structure as the condensed cyclic compound represented by Formula 1 except that "ring B" bonded to the third carbon of "ring A" via *-$(L_1)_{a1}$-*'.

Formula 1'



[0127] Also, in Formula 1, c1 may be an integer selected from 1 to 4. That is, in Formula 1, ring A_1 essentially includes at least one cyano group. Thus, in the condensed cyclic compound represented by Formula 1, ring A_1 essentially including at least one cyano group is connected with "N" of "ring B" via *-$(L_2)_{a2}$-*' and has a structure in which one of X_{15} to X_{18} of "ring B" is essentially connected to the first carbon of "ring A" via *-$(L_1)_{a1}$-*'.

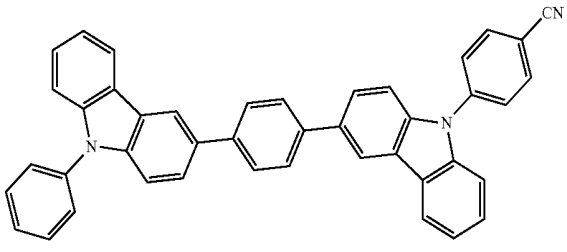
[0128] In this regard, the condensed cyclic compound represented by Formula 1 may have a high T_1 energy level, where the HOMO and LUMO energy levels of the condensed cyclic compound represented by Formula 1 may be suitable for an organic light-emitting device material, such as, a phosphorescent host material. For example, the condensed cyclic compound represented by Formula 1 having c1, which is an integer selected from 1 to 4, may have an energy band gap and a singlet (S_1) energy level that are suitable for a material of a single host for an organic light-emitting device. For example, although not limited to a particular theory, a virtual compound having the same structure as the condensed cyclic compound represented by Formula 1 except that c1 is 0 may have an energy band gap that is broader than that of the condensed cyclic compound represented by Formula 1 and a relatively high S_1 energy level, and thus the virtual compound may be improper for using as an organic light-emitting device material, such as a single host material and may have a relatively low optical stability.

[0129] Also, a difference between S_1 (singlet) energy level and T_1 (triplet) energy level of the condensed cyclic compound represented by Formula 1 may be relatively small. In this regard, the condensed cyclic compound represented by Formula 1 may be used as a thermally activated delayed fluorescence (TADF) emitter.

[0130] For example, the results of HOMO, LUMO, T_1, and S_1 energy levels of Compounds 1 to 8, 11 to 13, 16, 31 and 136 and Compounds B and C simulated and measured by using a density functional theory ("DFT") method of Gaussian program (structurally optimized at a level of B3LYP, 6-31 G(d,p)) are shown in Table 1.

TABLE 1

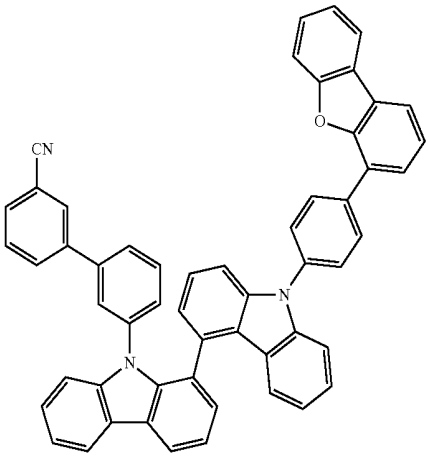
Compound No.	HOMO (eV)	LUMO (eV)	T_1 (eV)	S_1 (eV)
1	−5.4	−1.48	3.09	3.28
2	−5.524	−1.513	3.104	3.433
3	−5.501	−1.531	3.08	3.395
4	−5.613	−1.626	3.082	3.317
5	−5.662	−1.76	3.087	3.203
6	−5.688	−1.697	3.074	3.311
7	−5.769	−1.72	3.077	3.432
8	−5.786	−1.715	3.075	3.439
11	−5.641	−1.766	3.067	3.275
12	−5.71	−1.792	3.075	3.386
13	−5.7	−1.813	3.07	3.346
16	−5.181	−1.754	3.061	3.122
31	−5.253	−1.679	3.034	3.195
136	−5.421	−1.516	3.054	3.347
Compound B	−5.19	−1.65	2.8	3.212
Compound C	−5.34	−1.43	2.9	3.444



Compound B

TABLE 1-continued

Compound No.	HOMO (eV)	LUMO (eV)	T_1 (eV)	S_1 (eV)



Compound C

[0131] A method of synthesizing the condensed cyclic compound represented by Formula 1 may be understood by one of ordinary skill in the art by referring to Synthesis Examples described below.

[0132] Therefore, the condensed cyclic compound represented by Formula 1 may be suitable for use as an organic layer of an organic light-emitting device or, for example, as a host or an emitter (e.g., a TADF emitter) of an emission layer in the organic layer. According to another aspect of an embodiment, an organic light-emitting device includes:

[0133] a first electrode;

[0134] a second electrode; and

[0135] an organic layer that is disposed between the first electrode and the second electrode, wherein the organic layer includes an emission layer and at least one condensed cyclic compounds represented by Formula 1.

[0136] While not wishing to be bound by a theory, it is understood that when the organic light-emitting device includes the organic layer including the condensed cyclic compound represented by Formula 1, the organic light-emitting device may have a low driving voltage, high efficiency, high luminance, high quantum efficiency, and long lifespan.

[0137] The condensed cyclic compound represented by Formula 1 may be included in between a pair of electrodes of the organic light-emitting device. In some embodiments, the condensed cyclic compound may be included in at least one selected from the emission layer, a hole transport region (for example, including at least one selected from a hole injection layer, a hole transport layer, and an electron blocking layer) disposed between the first electrode and the emission layer, and an electron transport region (for example, including at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer) disposed between the emission layer and the second electrode.

[0138] In some embodiments, the condensed cyclic compound represented by Formula 1 may be included in the emission layer. Here, the condensed cyclic compound included in the emission layer may be a host, and the emission layer may further include a dopant (a fluorescent dopant or a phosphorescent dopant), wherein a weight of the condensed cyclic compound is greater than a weight of the dopant. The emission layer may be a green emission layer or a blue emission layer that emits green light or blue light. According to an embodiment, the condensed cyclic compound represented by Formula 1 may be included in the emission layer, the emission layer may further include a phosphorescent dopant, and the emission layer may emit blue light.

[0139] In some embodiments, the condensed cyclic compound represented by Formula 1 may be included in the emission layer, and the condensed cyclic compound may be a TADF emitter. Here, the emission layer may include the condensed cyclic compound represented by Formula 1 only or may further include a host and/or a dopant in addition to the condensed cyclic compound represented by Formula 1.

[0140] As used herein, the expression "(an organic layer) includes at least one condensed cyclic compound" may include an embodiment in which (an organic layer) includes one condensed cyclic compounds represented by Formula 1 and an embodiment in which (an organic layer) includes two or more different condensed cyclic compounds represented by Formula 1.

[0141] For example, the organic layer may include only Compound 1 as the condensed cyclic compound. In this regard, Compound 1 may be included in the emission layer of the organic light-emitting device. In some embodiments, the organic layer may include Compound 1 and Compound 2 as the condensed cyclic compounds. In this regard, Compound 1 and Compound 2 may be included in the same layer (for example, both Compound 1 and Compound 2 may be included in the emission layer) or in different layers, respectively.

[0142] The first electrode may be an anode, which is a hole injection electrode, and the second electrode may be a cathode, which is an electron injection electrode. Alternatively, the first electrode may be a cathode, which is an electron injection electrode, and the second electrode may be an anode, which is a hole injection electrode.

[0143] For example, the first electrode may be an anode, the second electrode may be a cathode, and the organic layer may include:

[0144] i) a hole transport region disposed between the first electrode and the emission layer, wherein the hole transport region includes at least one selected from a hole injection layer, a hole transport layer, and an electron blocking layer; and

[0145] ii) an electron transport region disposed between the emission layer and the second electrode, wherein the electron transport region includes at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer.

[0146] As used herein, the term "organic layer" refers to a single and/or a plurality of layers disposed between the first electrode and the second electrode in an organic light-emitting device. The "organic layer" may include not only organic compounds but also organometallic complexes including metals.

[0147] FIG. **1** is a schematic view of an organic light-emitting device **10** according to an embodiment. Hereinafter, a structure and a method of manufacturing an organic light-emitting device, according to an embodiment, will be described with reference to FIG. **1**. The organic light-

emitting device **10** includes a first electrode **11**, an organic layer **15**, and a second electrode **19**, which are sequentially layered in the stated order.

[0148] A substrate may be additionally disposed under the first electrode **11** or on the second electrode **19**. The substrate may be a conventional substrate that is used in an organic light-emitting device, such as a glass substrate or a transparent plastic substrate, each having excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water repellency.

[0149] The first electrode **11** may be formed by depositing or sputtering a first electrode material on the substrate. The first electrode **11** may be an anode. The first electrode material may be selected from materials with a high work function to facilitate hole injection. The first electrode **11** may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. The first electrode material may be selected from indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), and zinc oxide (ZnO). In some embodiments, a metal such as magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), or magnesium-silver (Mg—Ag) may be used as the first electrode material.

[0150] The first electrode **11** may have a single layer structure or a multi-layer structure including a plurality of layers. For example, the first electrode **11** may have a triple-layer structure of ITO/Ag/ITO, but embodiments are not limited thereto.

[0151] The organic layer **15** is disposed on the first electrode **11**.

[0152] The organic layer **15** may include a hole transport region, an emission layer, and an electron transport region.

[0153] The hole transport region may be disposed between the first electrode **11** and the emission layer.

[0154] The hole transport region may include at least one selected from a hole injection layer, a hole transport layer, an electron blocking layer, and a buffer layer.

[0155] The hole transport region may only include a hole injection layer or a hole transport layer. Alternatively, the hole transport region may include a structure in which a hole injection layer/a hole transport layer or a hole injection layer/a hole transport layer/an electron blocking layer are sequentially layered on the first electrode **11**.

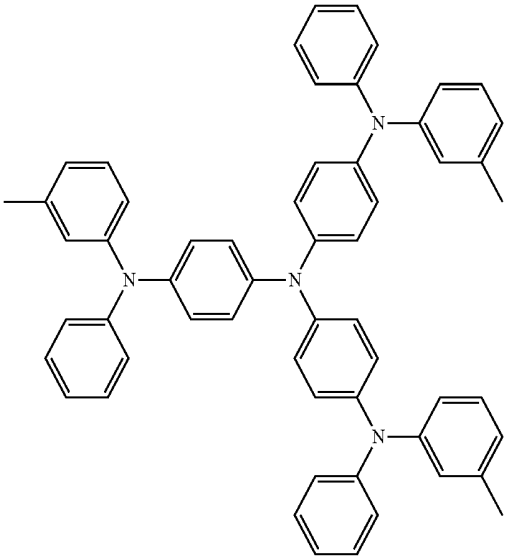
[0156] When the hole transport region includes a hole injection layer, the hole injection layer may be formed on the first electrode **11** by using various methods such as vacuum deposition, spin coating, casting, and Langmuir-Blodgett (LB) method.

[0157] When a hole injection layer is formed by vacuum deposition, the deposition conditions may vary according to a material that is used to form the hole injection layer and the structure and thermal characteristics of the hole injection layer. For example, the deposition conditions may include a deposition temperature of about 100° C. to about 500° C., a vacuum pressure of about 10^{-8} torr to about 10^{-3} torr, and a deposition rate of about 0.01 Angstroms per second (Å/sec) to about 100 Å/sec. However, the deposition conditions are not limited thereto.

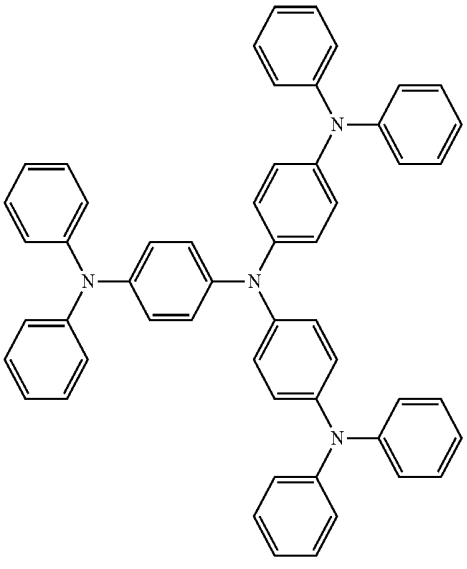
[0158] When the hole injection layer is formed by spin coating, the coating conditions may vary according to a material used to form the hole injection layer and the structure and thermal characteristics of the hole injection layer. For example, a coating rate may be from about 2,000 revolutions per minute (rpm) to about 5,000 rpm, and a temperature at which a heat treatment is performed to remove a solvent after coating may be from about 80° C. to about 200° C. However, the coating conditions are not limited thereto.

[0159] The conditions for forming a hole transport layer and an electron blocking layer may be inferred based on the conditions for forming the hole injection layer.

[0160] The hole transport region may include at least one 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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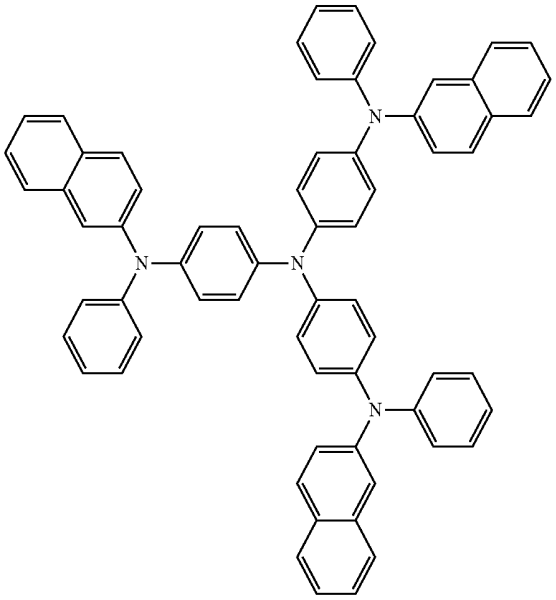
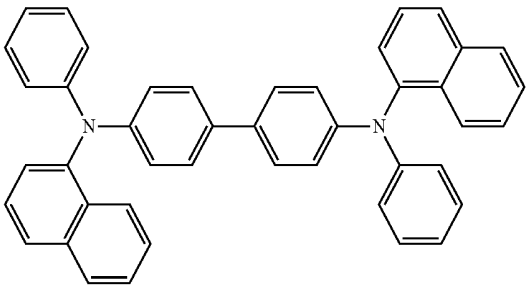
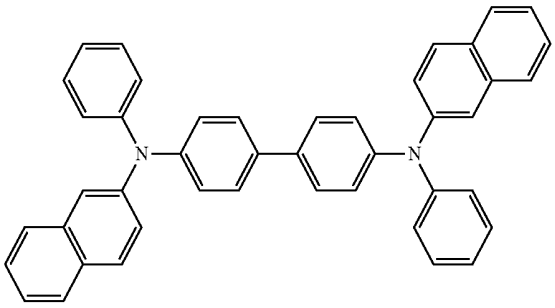


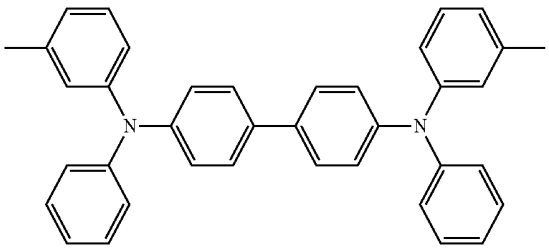
2-TNATA



NPB



β-NPB



TPD

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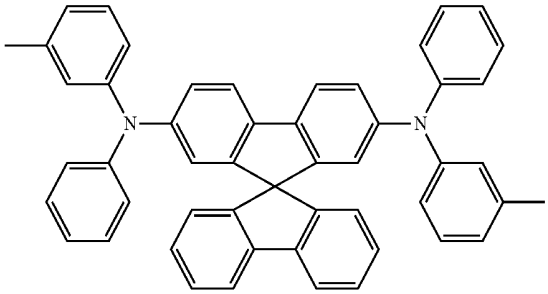
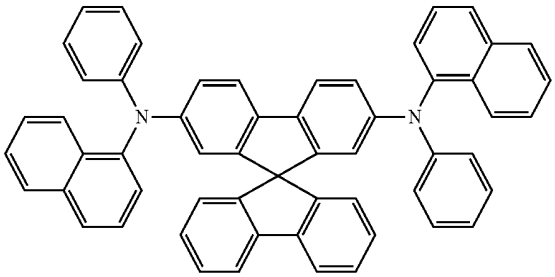


Spiro-TPD



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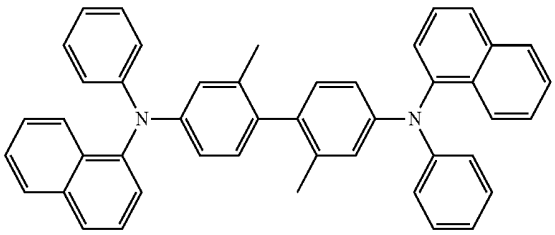
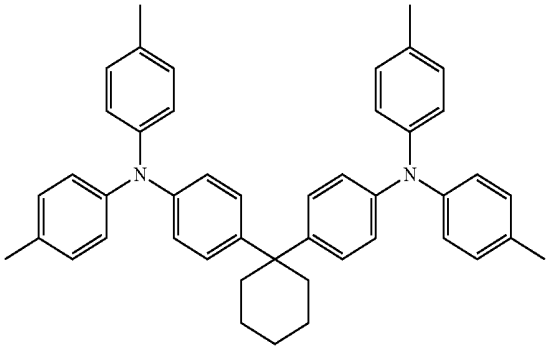
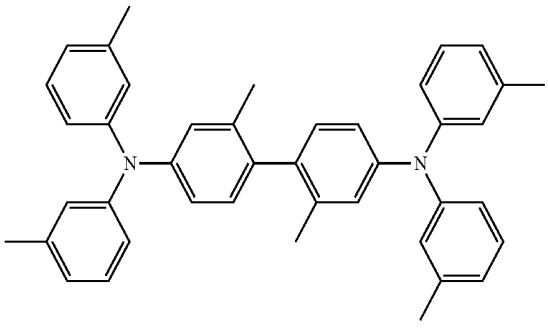


methylated NPB



TAPC



HMTPD

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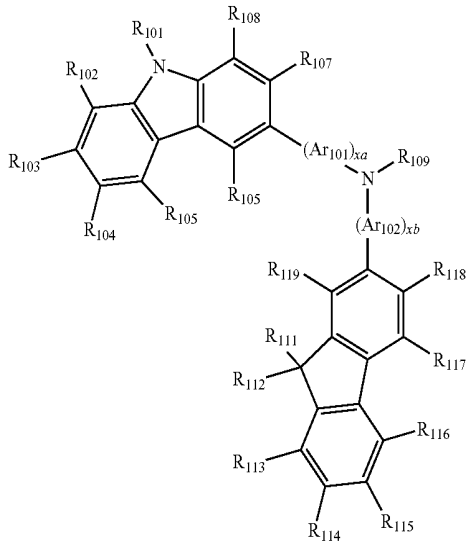
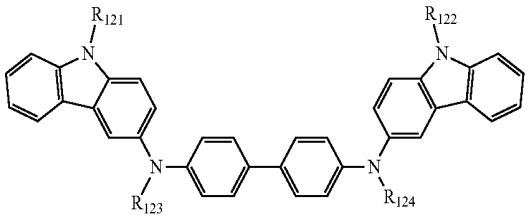
Formula 201



Formula 202



[0161] 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 acenaphthenylene 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 acenaphthenylene 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 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 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_1-C_{10} heterocycloalkyl group, a C_1-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_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

[0162] In Formula 201, xa and xb may be each independently an integer selected from 0 to 5 or may be 0, 1, or 2. For example, xa may be 1, and xb may be 0, but embodiments are not limited thereto.

[0163] 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 (e.g., a methyl group, an ethyl group, a propyl group, a butyl group, pentyl group, or a hexyl group), and a C_1-C_{10} alkoxy group (e.g., a methoxy group, an ethoxy group, a propoxy group, a butoxy group, or a pentoxy group);

[0164] a C_1-C_{10} alkyl group and a C_1-C_{10} alkoxy group, each substituted with at least one 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 group or a salt thereof, a sulfonic acid group or a salt thereof, and a phosphoric acid group or a salt thereof;

[0165] a phenyl group, a naphthyl group, an anthracenyl group, a fluorenyl group, and a pyrenyl group; and

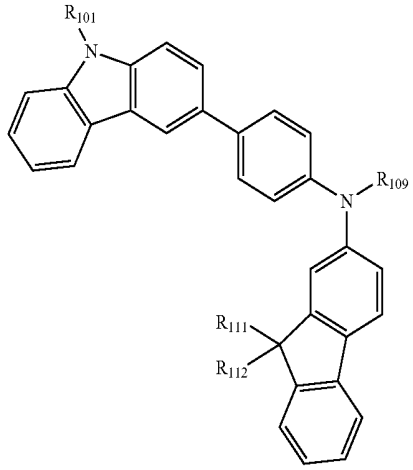
[0166] a phenyl group, a naphthyl group, an anthracenyl group, a fluorenyl group, and a pyrenyl group, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid 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 embodiments are not limited thereto.

[0167] In Formula 201, R_{109} may be selected from a phenyl group, a naphthyl group, an anthracenyl group, and a pyridinyl group; and

[0168] a phenyl group, a naphthyl group, an anthracenyl group, and a pyridinyl group, each substituted with at least one 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 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 phenyl group, a naphthyl group, an anthracenyl group, and a pyridinyl group.

[0169] According to an embodiment, a compound represented by Formula 201 may be represented by Formula 201A, but embodiments are not limited thereto:

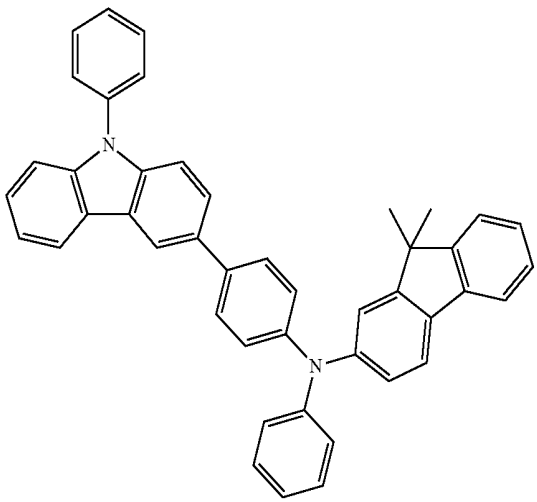
Formula 201A



[0170] In Formula 201A, R_{101}, R_{111}, R_{112}, and R_{109} may be understood by referring to the description provided herein.

[0171] For example, the compound represented by Formula 201 and the compound represented by Formula 202 may include Compounds HT1 to HT20, but embodiments are not limited thereto:

HT1



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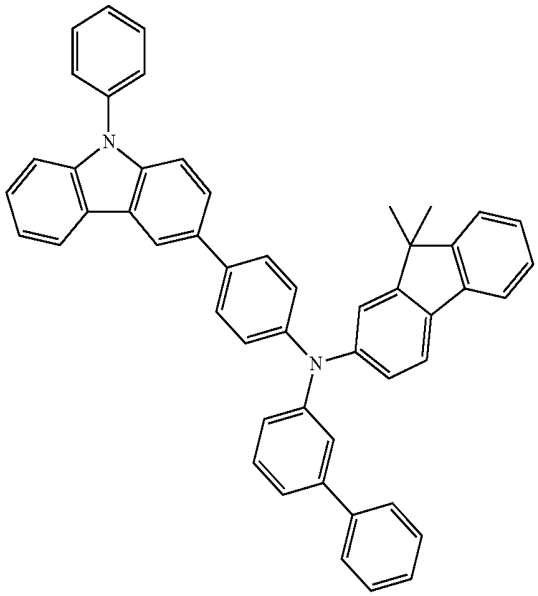
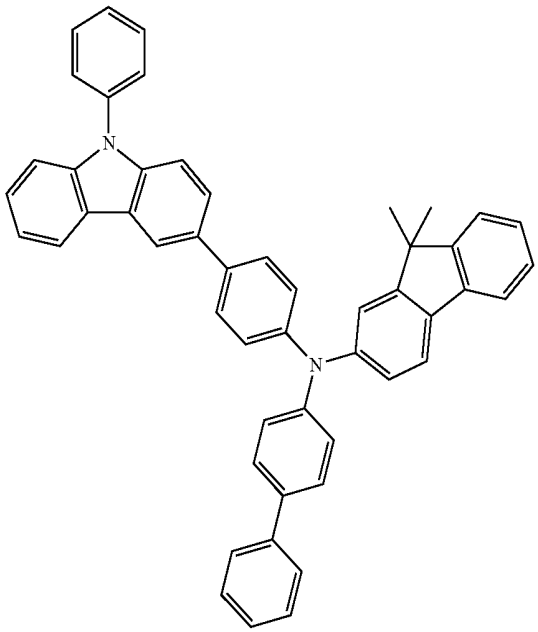
HT2



HT3



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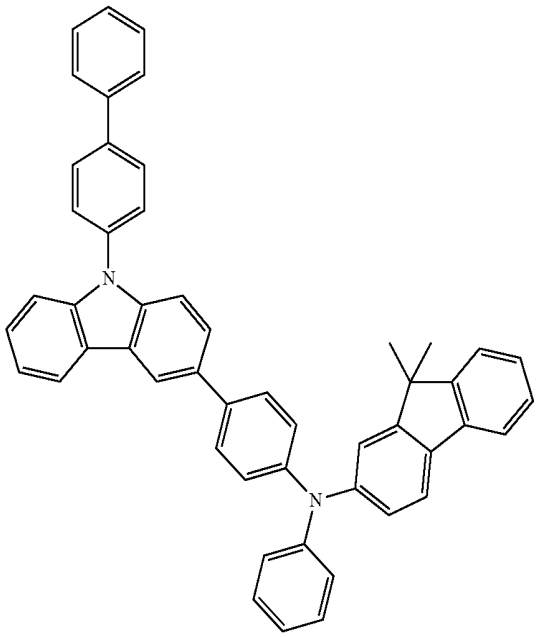
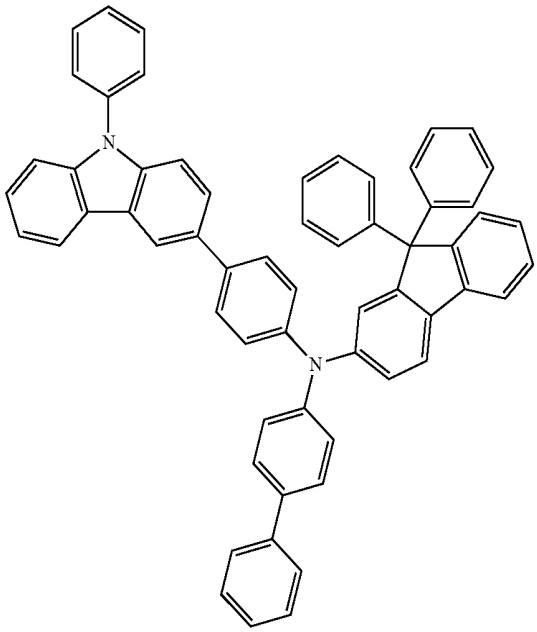
HT-4



HT-5



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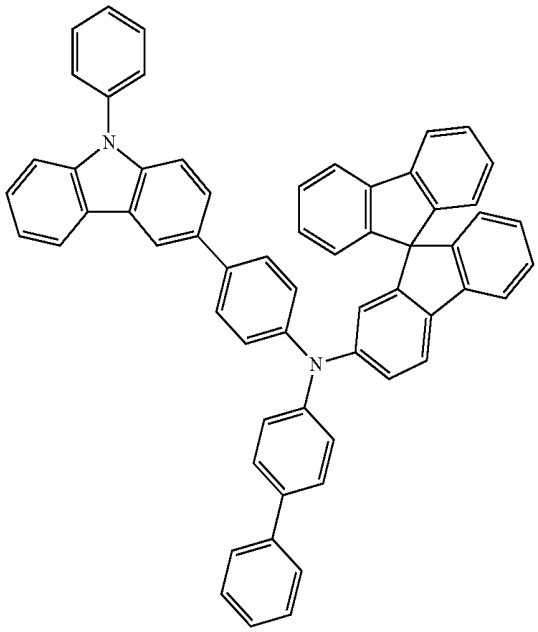
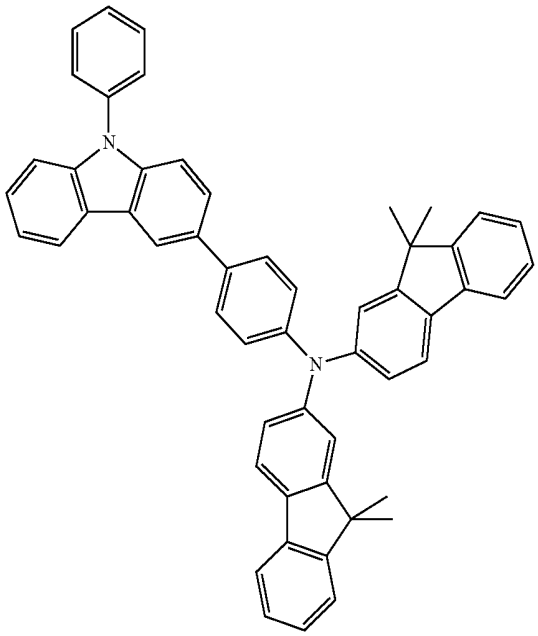
HT6



HT7



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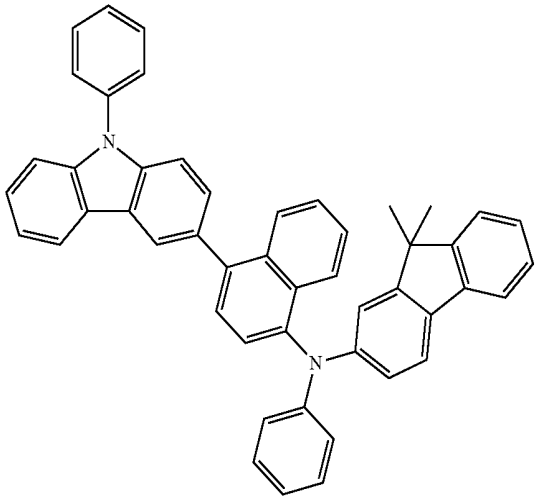
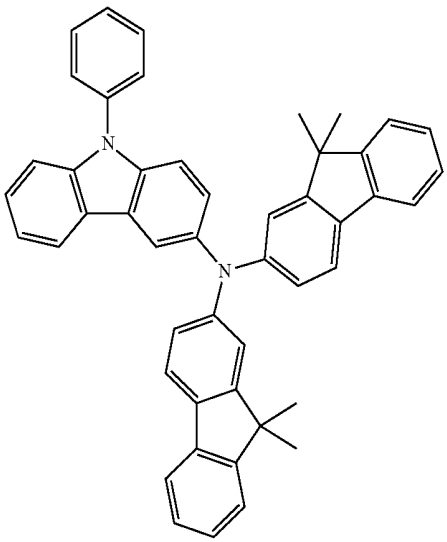
HT8



HT9



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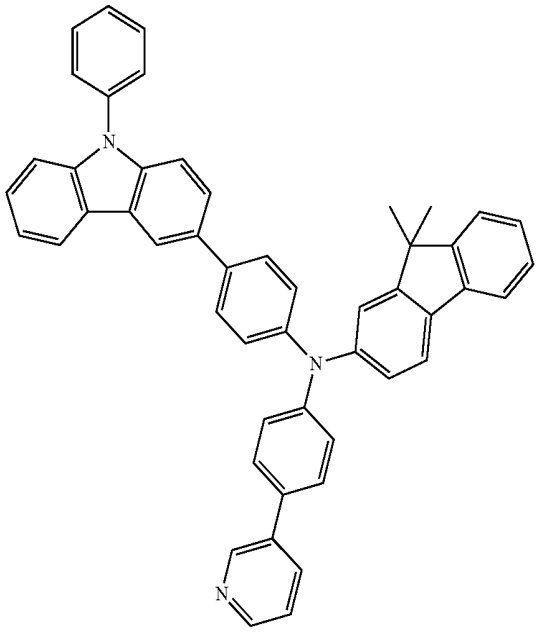
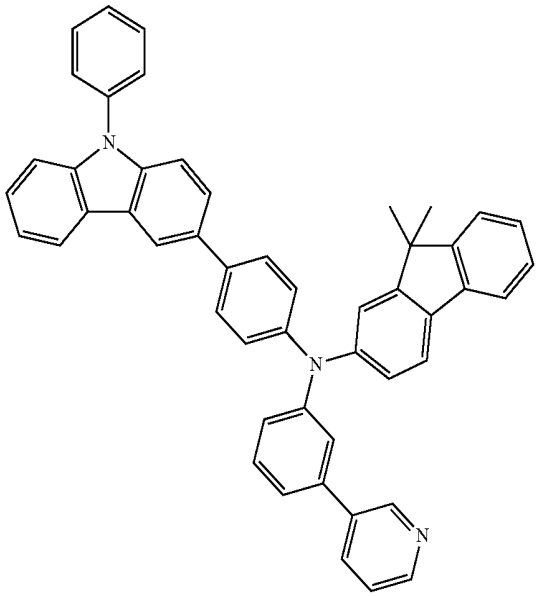
HT10



HT11



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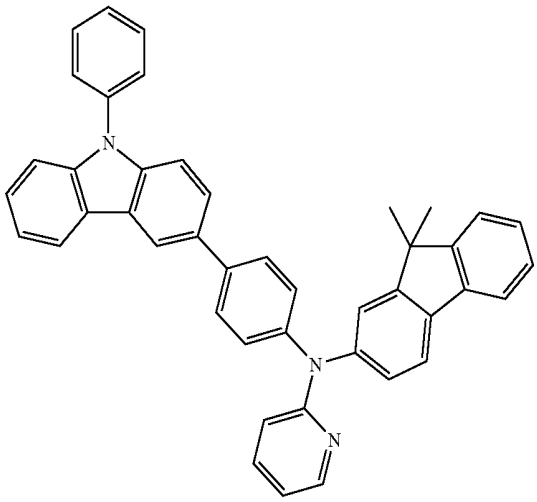
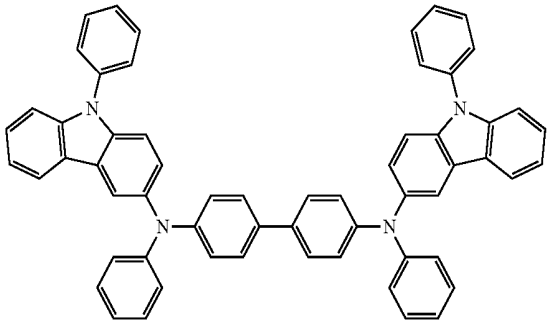
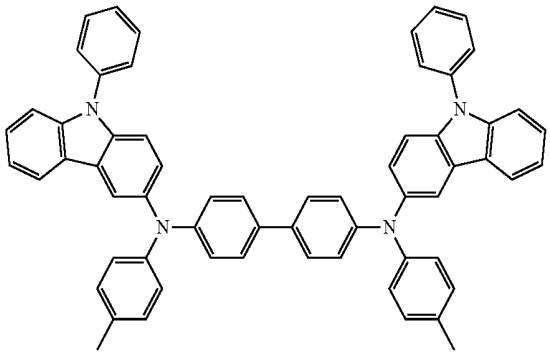
HT12



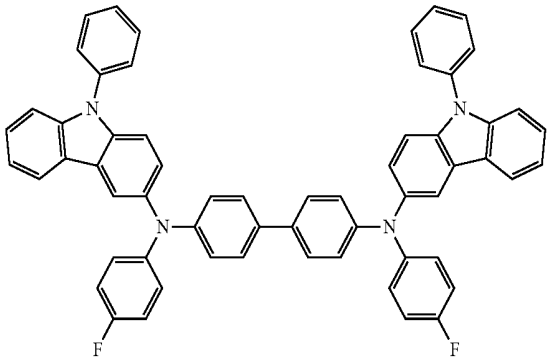
HT13



HT14



HT15



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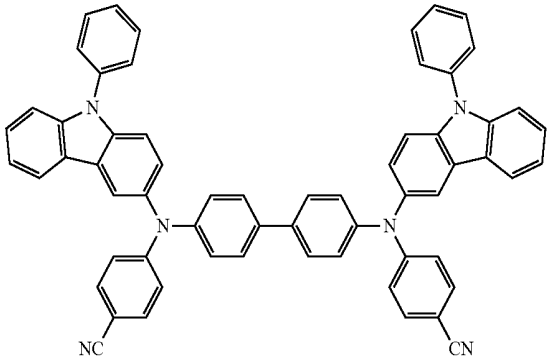
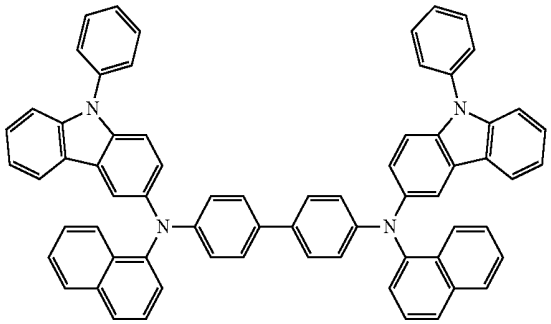
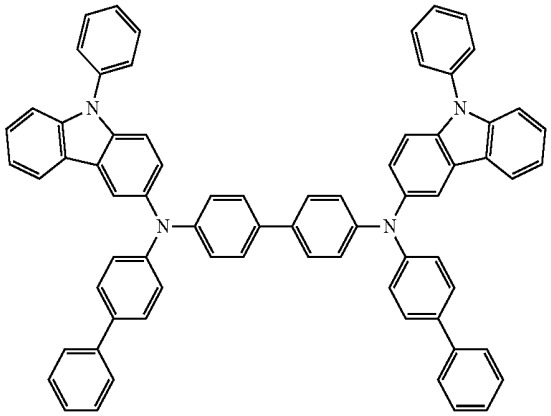
HT16



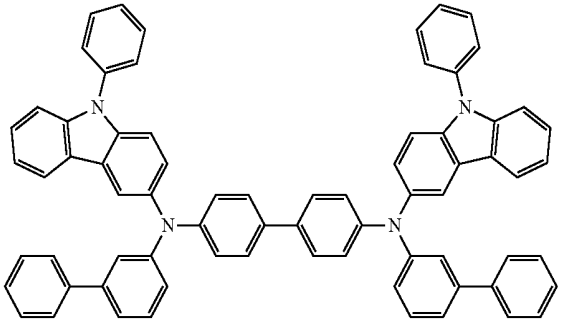
HT17



HT18



HT19



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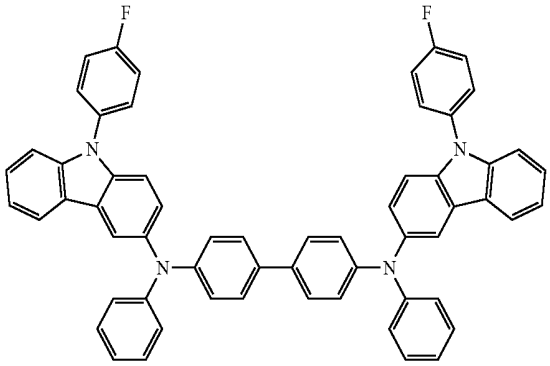
HT20

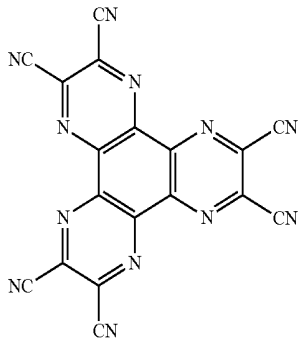


[0172] A thickness of the hole transport region may be in a range of about 100 Å to about 10,000 Å, for example, about 100 Å to about 1,000 Å. When the hole transport region includes at least one of a hole injection layer and a hole transport layer, the thickness of the hole injection layer may be in a range of about 100 Å to about 10,000 Å, and for example, about 100 Å to about 1,000 Å, and the thickness of the hole transport layer may be in a range of about 50 Å to about 2,000 Å, and for example, about 100 Å to about 1,500 Å. While not wishing to be bound by a theory, it is understood that when the thicknesses of the hole transport region, the hole injection layer, and the hole transport layer are within these ranges, hole transporting characteristics may be satisfactory without a substantial increase in driving voltage.

[0173] The hole transport region may further include, in addition to the mentioned materials above, a charge-generating material to improve conductive properties. The charge-generating material may be homogeneously or non-homogeneously dispersed throughout the hole transport region.

[0174] The charge-generating material may be, for example, a p-dopant. The p-dopant may be one selected from a quinone derivative, a metal oxide, and a cyano group-containing compound, but embodiments are not limited thereto. 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 a cyano group-containing compound, such as Compound HT-D1 or HP-1, but embodiments are not limited thereto.

Compound HT-D1



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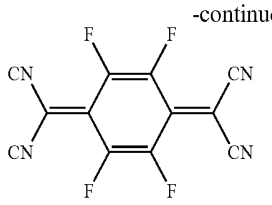
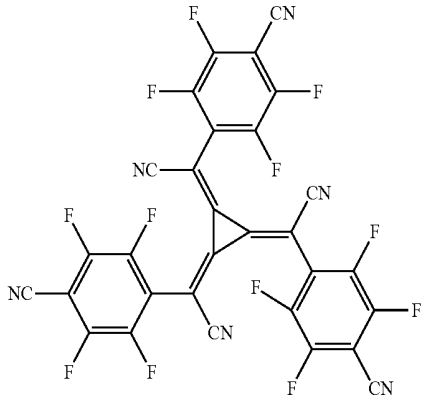


F4-TCNQ

HP-1

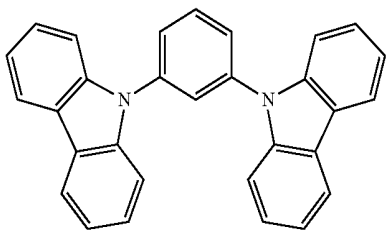


[0175] The hole transport region may further include a buffer layer.

[0176] The buffer layer may compensate for an optical resonance distance according to a wavelength of light emitted from the emission layer to improve the efficiency of an organic light-emitting device.

[0177] Then, an emission layer may be formed on the hole transport region by vacuum deposition, spin coating, casting, LB deposition, or the like. When the emission layer is formed by vacuum deposition or spin coating, the deposition or coating conditions may be similar to those applied to form the hole injection layer although the deposition or coating conditions may vary depending on the material that is used to form the emission layer.

[0178] The hole transport region may further include an electron blocking layer. The electron blocking layer may include, for example, mCP, but embodiments are not limited thereto.



mCP

[0179] When the organic light-emitting device is a full color organic light-emitting device, the emission layer may be patterned into a red emission layer, a green emission layer, and a blue emission layer. Alternatively, the emission layer may have a structure in which the red emission layer, the green emission layer, and/or the blue emission layer are layered to emit white light or other various embodiments are possible.

[0180] The emission layer may include the condensed cyclic compound represented by Formula 1. The emission layer may further include a dopant. The dopant may include at least one selected from a fluorescent dopant and a phosphorescent dopant.

[0181] In some embodiments, the emission layer may include the condensed cyclic compound represented by Formula 1 only, and the condensed cyclic compound may be a TADF emitter.

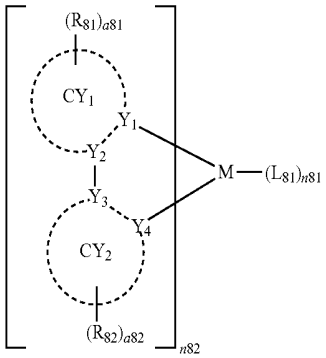
[0182] In some embodiments, the emission layer may include the condensed cyclic compound represented by Formula 1, the condensed cyclic compound may be a TADF emitter, and the emission layer may further include any host not being the condensed cyclic compound represented by Formula 1.

[0183] For example, a host in the emission layer may include the condensed cyclic compound represented by Formula 1.

[0184] The dopant in the emission layer may include a fluorescent dopant which emits light according to a fluorescent emission mechanism or a phosphorescent dopant which emits light according to a phosphorescent emission mechanism.

[0185] According to an embodiment, the dopant in the emission layer may be a phosphorescent dopant, and the phosphorescent dopant may include an organometallic compound represented by Formula 81:

Formula 81



[0186] wherein, in Formula 81,

[0187] M may be selected from iridium (Ir), platinum (Pt), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), and thulium (Tm),

[0188] Y_1 to Y_4 may be each independently carbon (C) or nitrogen (N),

[0189] Y_1 and Y_2 are linked via a single bond or a double bond, and Y_3 and Y_4 are linked via a single bond or a double bond,

[0190] CY_1 and CY_2 may be each independently selected from a benzene ring, a naphthalene ring, a fluorene ring, a spiro-fluorene ring, an indene ring, a pyrrole ring, a thiophene ring, a furan ring, an imidazole ring, a pyrazole ring, a thiazole ring, an isothiazole ring, an oxazole ring, an isoxazole ring, a pyridine ring, a pyrazine ring, a pyrimidine ring, a pyridazine ring, a quinoline ring, an isoquinoline ring, a benzoquinoline ring, a quinoxaline ring, a quinazoline ring, a carbazole ring, a benzoimidazole ring, a benzofuran ring, a benzothiophene ring, an isobenzothiophene ring, a benzoxazole ring, an isobenzoxazole ring, a triazole ring, a tetrazole ring, an oxadiazole ring, a triazine ring, a dibenzofuran ring, or a dibenzothiophene ring, and CY_1 and CY_2 are optionally further linked to each other through an organic linking group,

[0191] R_{81} and R_{82} 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, $—SF_5$, 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_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-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_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $—N(Q_1)(Q_2)$, $—Si(Q_3)(Q_4)(Q_5)$, and $—B(Q_6)(Q_7)$,

[0192] a81 and a82 may be each independently an integer selected from 1 to 5,

[0193] n81 may be an integer selected from 0 to 4,

[0194] n82 may be 1, 2, or 3, and

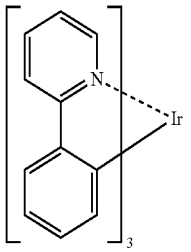
[0195] L_{81} may be a monovalent organic ligand, a divalent organic ligand, or a trivalent organic ligand, and

[0196] Q_1 to Q_7 may have the same definitions as Q_1 to Q_3 in $—Si(Q_1)(Q_2)(Q_3)$ in Formula

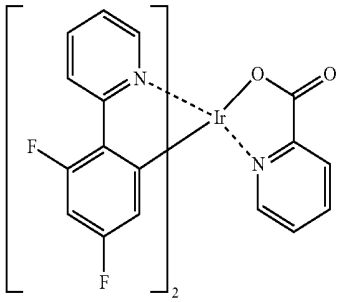
[0197] R_{81} and R_{82} may be understood by referring to the description provided herein in connection with R_{11}.

[0198] The phosphorescent dopant may include at least one selected from Compounds PD1 to PD78, and FIr_6, but embodiments are not limited thereto:

PD1



PD2



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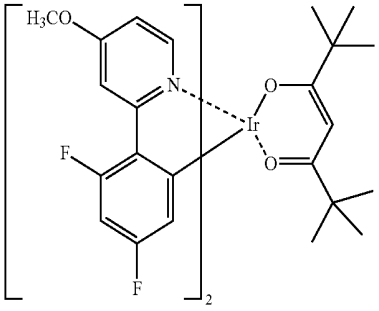
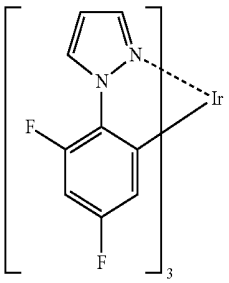
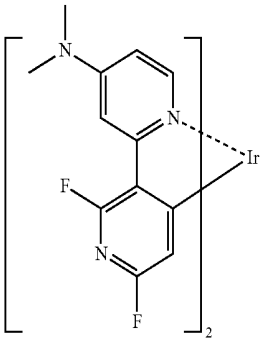
PD3



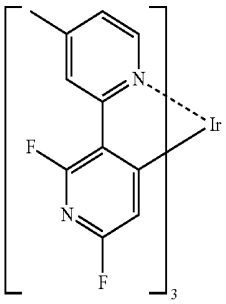
PD4



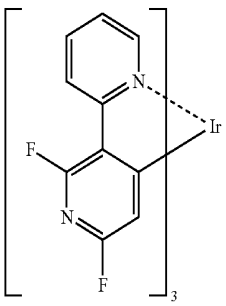
PD5



PD6



PD7



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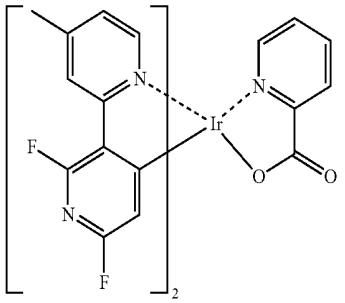
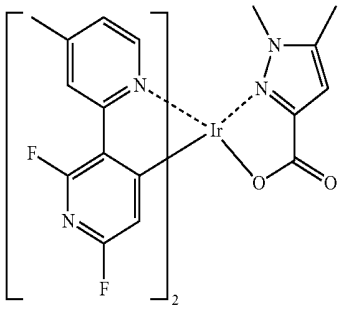
PD8



PD9



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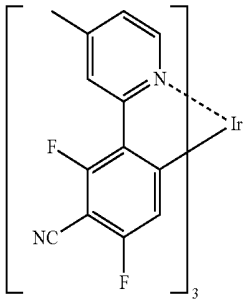

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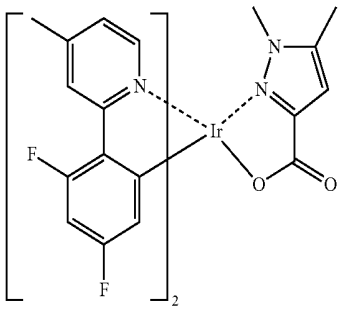

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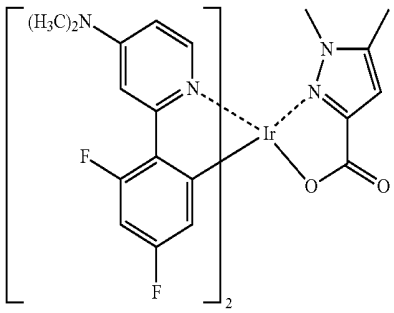

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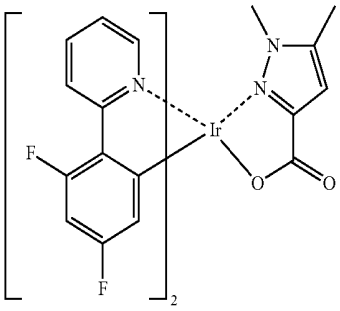

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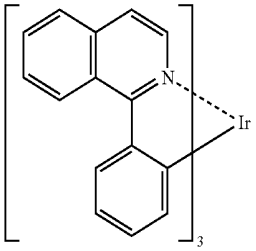

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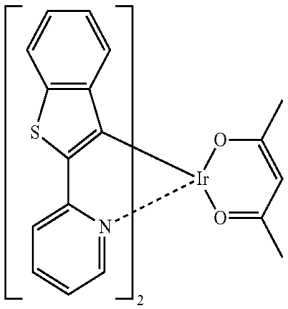

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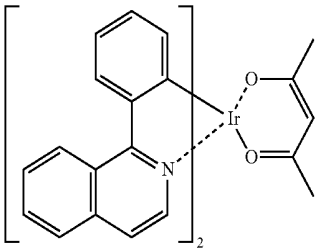

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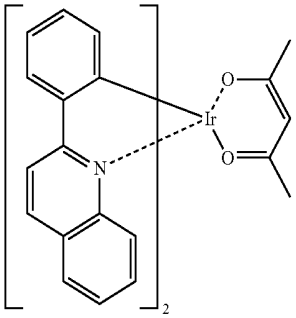

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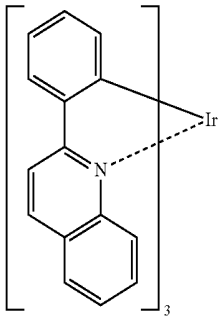

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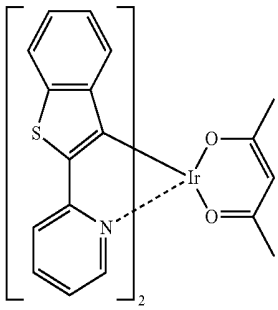

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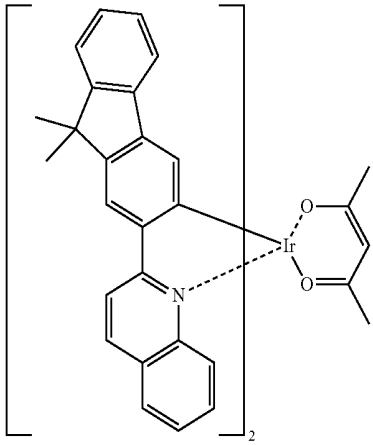

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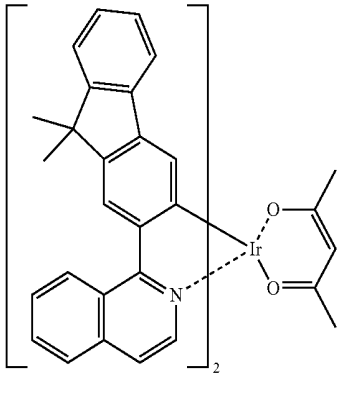

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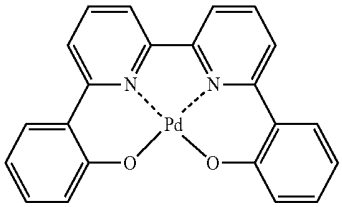

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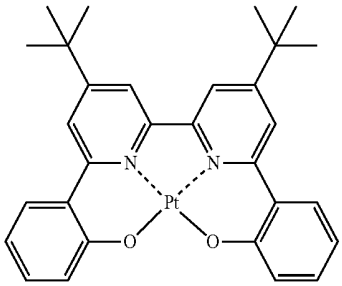

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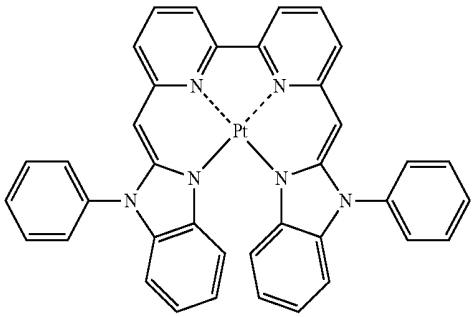

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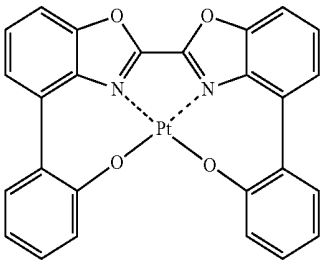

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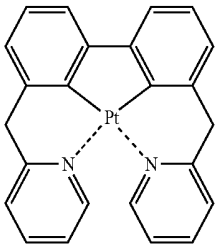

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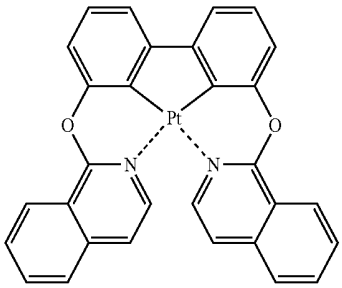

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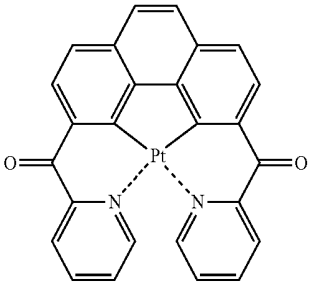

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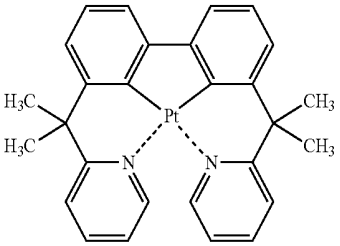

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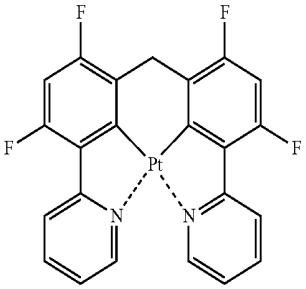

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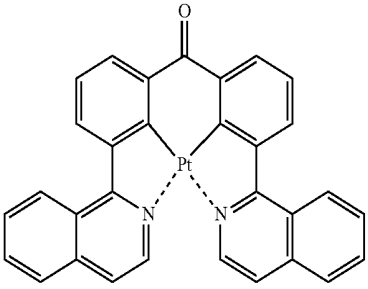

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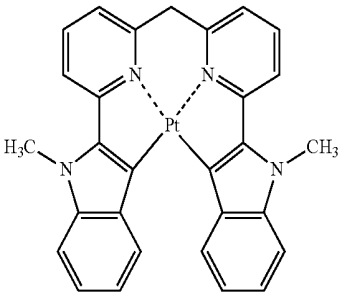

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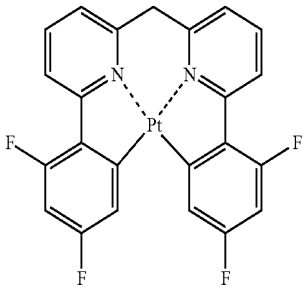

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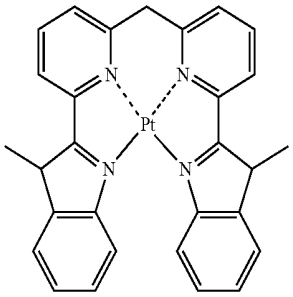

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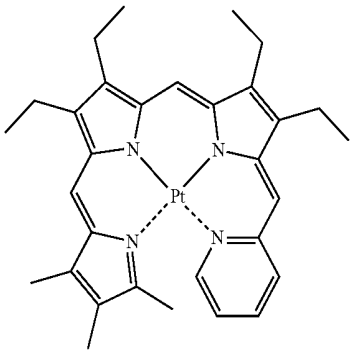

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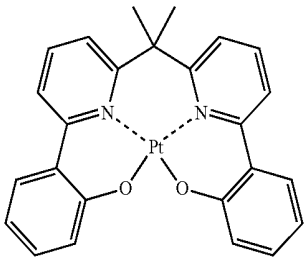

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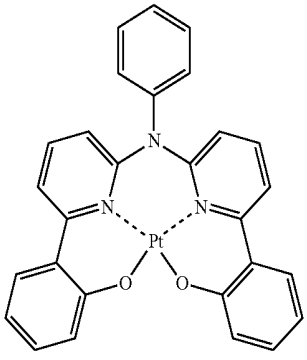

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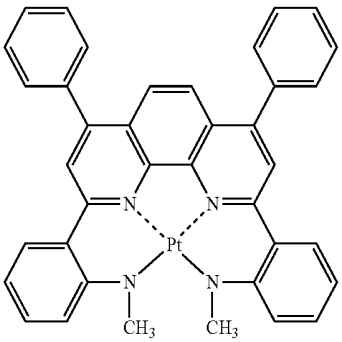

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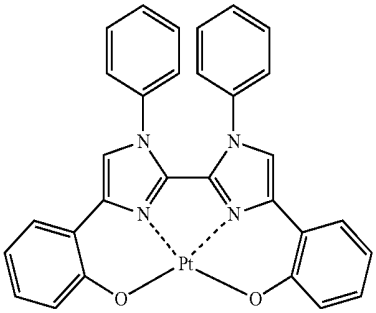

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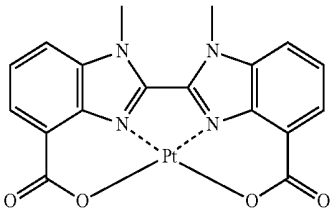

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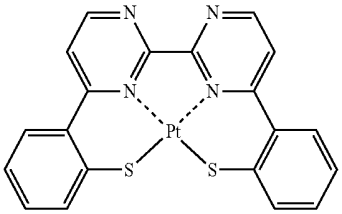

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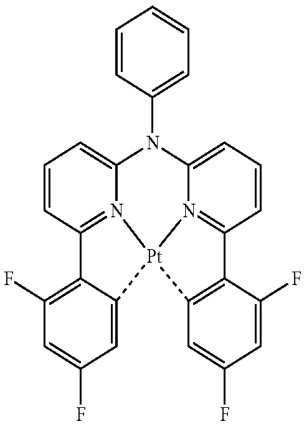

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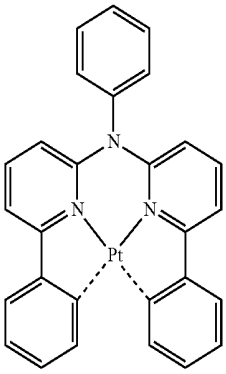

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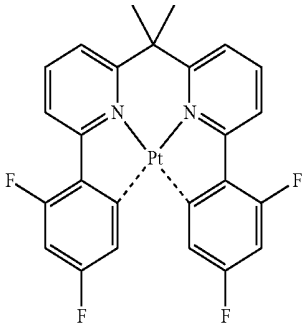

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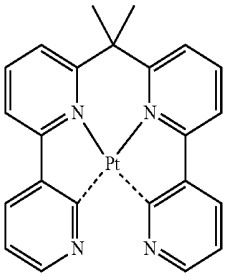

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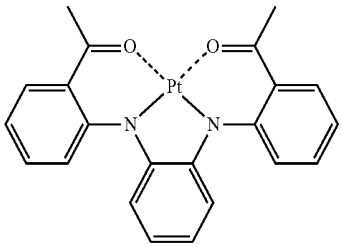

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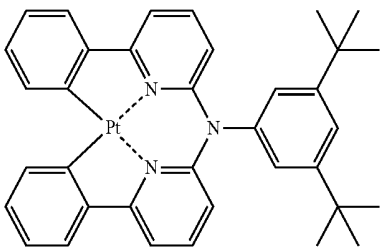

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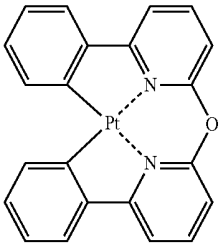

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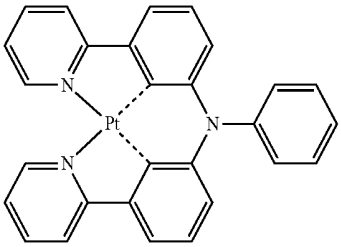

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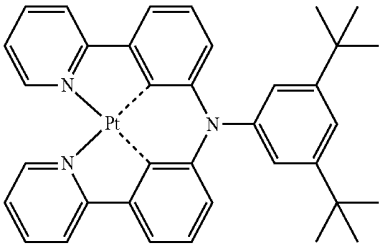

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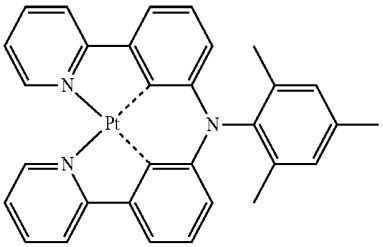

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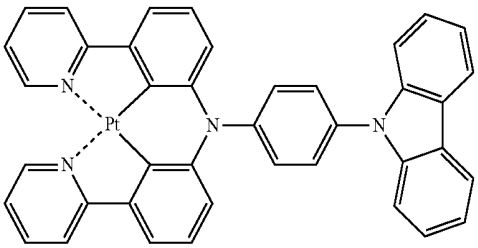

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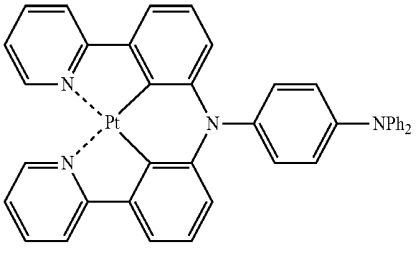

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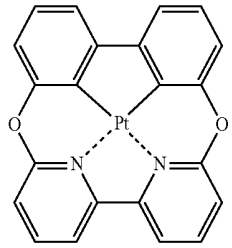

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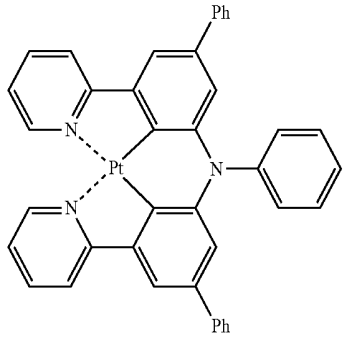

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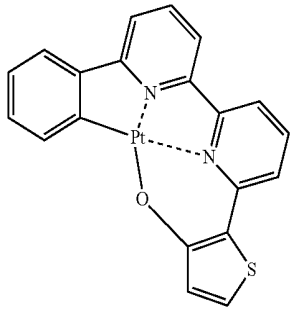

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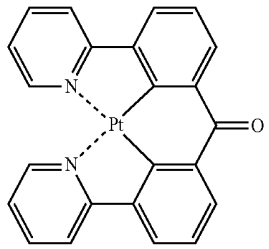

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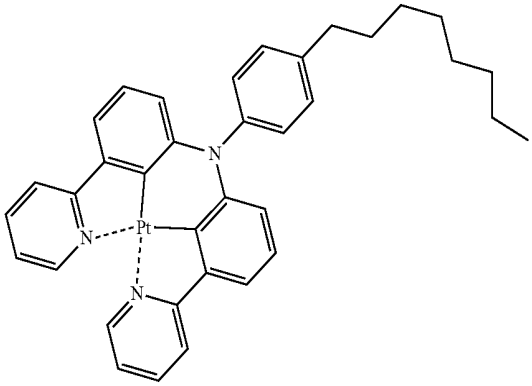

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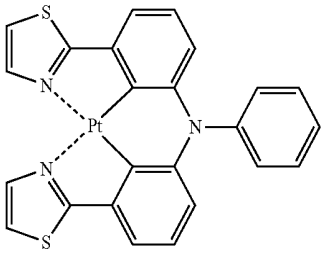

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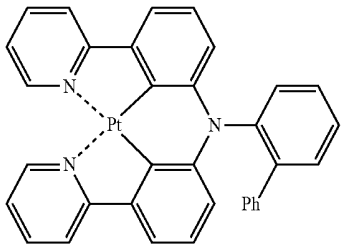

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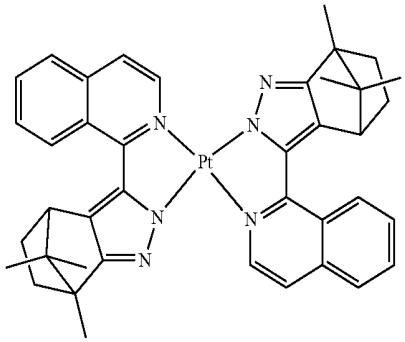

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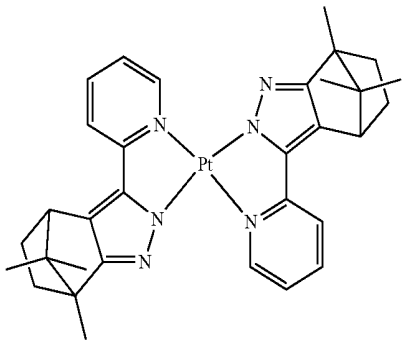

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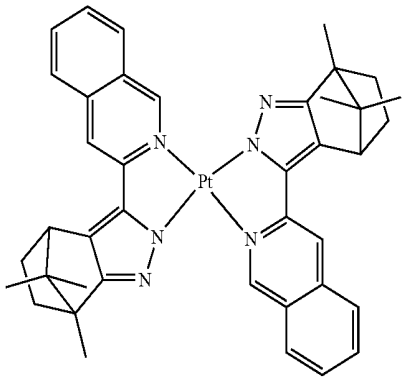

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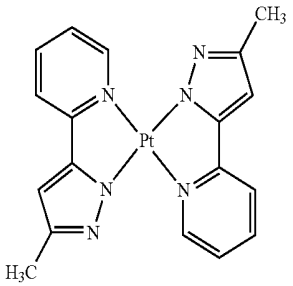

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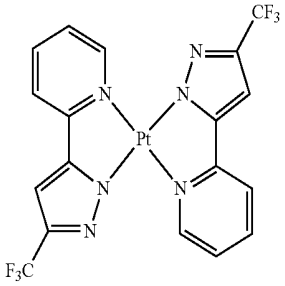

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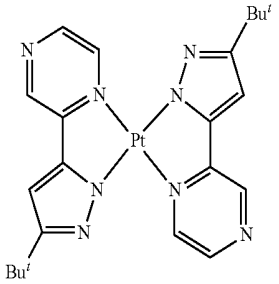

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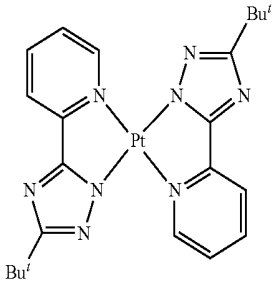
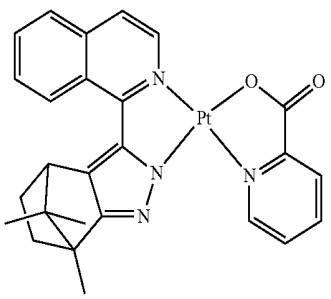


PD68



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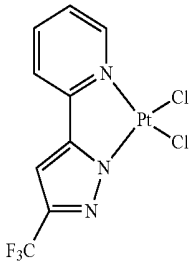

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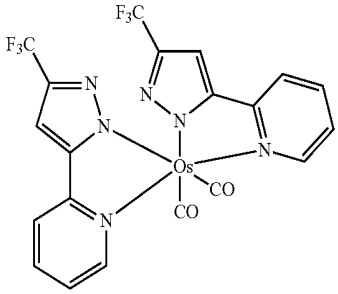

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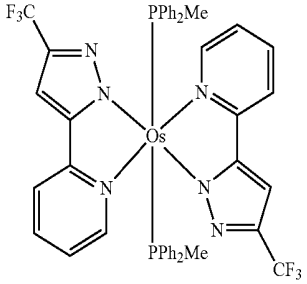

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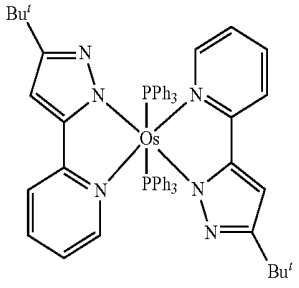
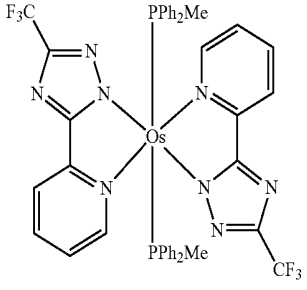


PD73



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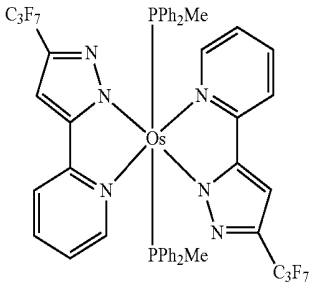

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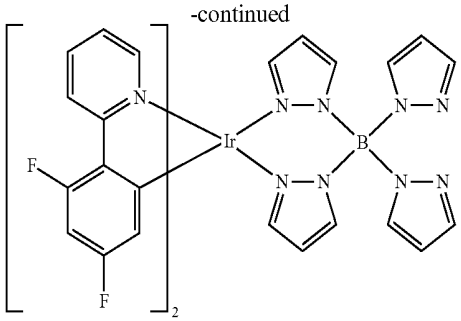
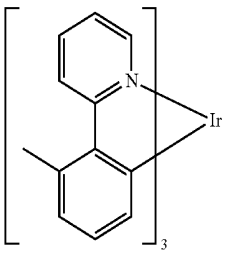


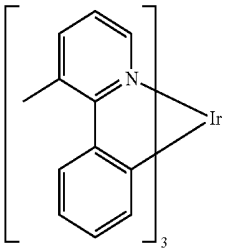
Flr6

[0199] In some embodiments, the phosphorescent dopant may include PtOEP:

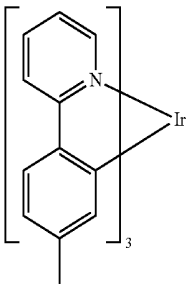
PD75



PD76



PD77



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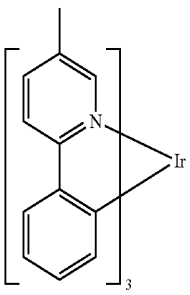
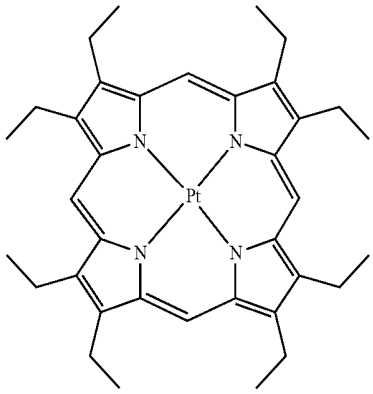




PtOEP

[0200] When the emission layer includes a host and a dopant, an amount of the dopant may be in a range of about 0.01 part to about 20 parts by weight based on 100 parts by weight of the host, but embodiments are not limited thereto.

[0201] A thickness of the emission layer may be in a range of about 100 Å to about 1,000 Å, for example, about 200 Å to about 600 Å. While not wishing to be bound by a theory, it is understood that when the thickness of the emission layer is within this range, light-emission characteristics may be excellent without a substantial increase in driving voltage.

[0202] Then, an electron transport region may be disposed on the emission layer.

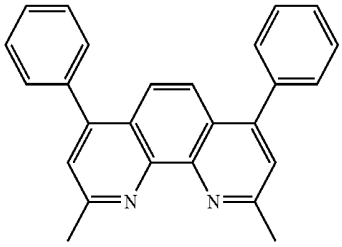
[0203] The electron transport region may include at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer, but embodiments not limited thereto.

[0204] For example, the electron transport region may have a structure of a hole blocking layer/an electron transport layer/an electron injection layer or an electron transport layer/an electron injection layer, but embodiments are not limited thereto. The electron transport layer may have a single layer structure or a multi-layer structure including two or more different materials.

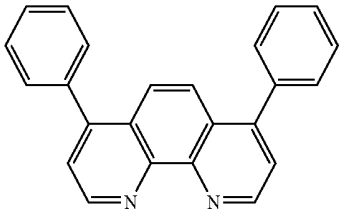
[0205] The conditions for forming a hole blocking layer, an electron transport layer, and an electron injection layer may be inferred based on the conditions for forming the hole injection layer.

[0206] When the electron transport region includes a hole blocking layer, the hole blocking layer may include, for

example, at least one selected from BCP and Bphen, but embodiments are not limited thereto.



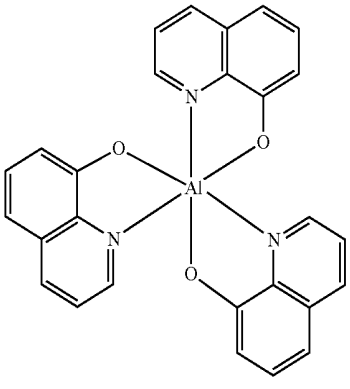
BCP



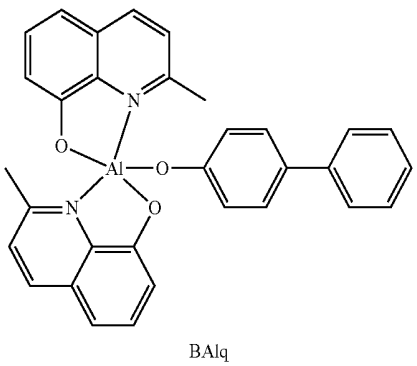
Bphen

[0207] A thickness of the hole blocking layer may be in a range of about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. While not wishing to be bound by a theory, it is understood that when the thickness of the hole blocking layer is within these ranges, the hole blocking layer may have improved hole blocking ability without a substantial increase in driving voltage.

[0208] The electron transport layer may further include at least one selected from BCP, BPhen, Alq_3, BAlq, TAZ, and NTAZ.



Alq_3



BAlq

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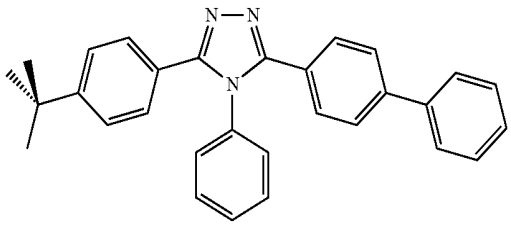
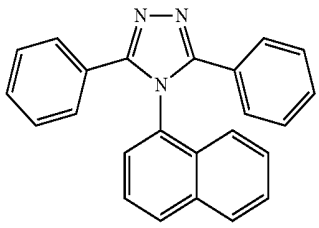


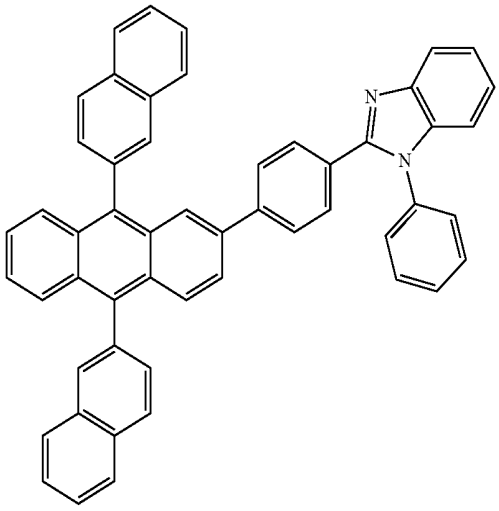
TAZ



NTAZ

[0209] In some embodiments, the electron transport layer may include at least one selected from Compounds ET1, ET2, and ET3, but embodiments are not limited thereto.

ET1



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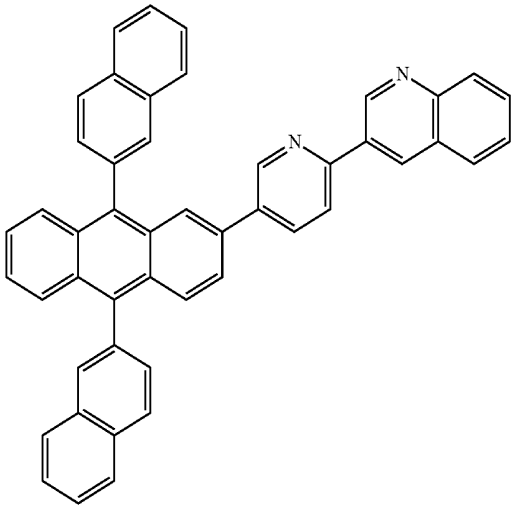
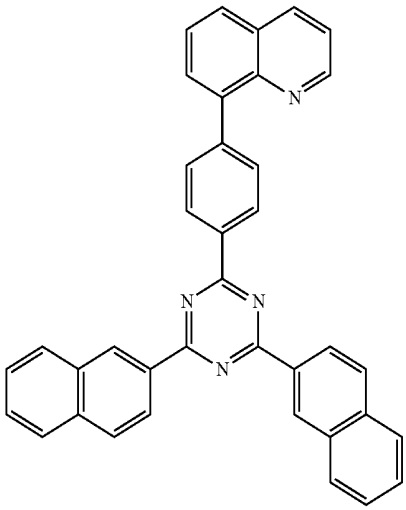
ET2



ET3

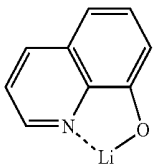


[0210] A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, for example, about 150 Å to about 500 Å. While not wishing to be bound by a theory, it is understood that when the thickness of the electron transport layer is within the range described above, the electron transport layer may have satisfactory electron transport characteristics without a substantial increase in driving voltage.

[0211] The electron transport layer may further include a metal-containing material in addition to the materials described above.

[0212] 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



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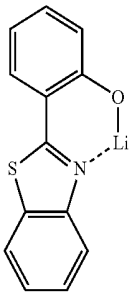
ET-D2



[0213] The electron transport region may include an electron injection layer that allows electrons to be easily provided from a second electrode **19**.

[0214] The electron injection layer may include at least one selected from, LiF, NaCl, CsF, Li_2O, and BaO.

[0215] A thickness of the electron injection layer may be in a range of about 1 Å to about 100 Å, for example, about 3 Å to about 90 Å. While not wishing to be bound by a theory, it is understood that when the thickness of the electron injection layer is within the range described above, the electron injection layer may have satisfactory electron injection characteristics without a substantial increase in driving voltage.

[0216] The second electrode **19** is disposed on the organic layer **15**. The second electrode **19** may be a cathode. A second electrode material may be selected from a metal, an alloy, an electrically conductive compound, and a combination thereof, which have a relatively low work function. For example, lithium (Li), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), or magnesium-silver (Mg—Ag) may be formed as second electrode material. To manufacture a top emission type light-emitting device, a transmissive electrode formed using ITO or IZO may be used as the second electrode **19**.

[0217] Hereinbefore, the organic light-emitting device has been described with reference to FIG. **1**, but embodiments are not limited thereto.

[0218] A C_1-C_{60} alkyl group as used herein refers to a linear or branched aliphatic saturated 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 group as used herein refers to a divalent group having the same structure as the C_1-C_{60} alkyl group.

[0219] A C_1-C_{60} alkoxy group as 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.

[0220] A C_2-C_{60} alkenyl group as used herein refers to a hydrocarbon group formed by placing at least one carbon-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 as used herein refers to a divalent group having the same structure as the C_2-C_{60} alkenyl group.

[0221] A C_2-C_{60} alkynyl group as used herein refers to a hydrocarbon group formed by placing at least one carbon-

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 as used herein refers to a divalent group having the same structure as the C_2-C_{60} alkynyl group.

[0222] A C_3-C_{10} cycloalkyl group as used herein refers to a monovalent monocyclic saturated hydrocarbon group including 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 as used herein refers to a divalent group having the same structure as a C_3-C_{10} cycloalkyl group.

[0223] A C_1-C_{10} heterocycloalkyl group as used herein refers to a monovalent saturated monocyclic group including at least one hetero atom selected from N, O, P, Si and S as a ring-forming atom and 1 to 10 carbon atoms. Detailed examples thereof are a tetrahydrofuranyl group and a tetrahydrothiophenyl group. A C_1-C_{10} heterocycloalkylene group as used herein refers to a divalent group having the same structure as a C_1-C_{10} heterocycloalkyl group.

[0224] A C_3-C_{10} cycloalkenyl group as 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 which is not aromatic. Detailed examples thereof are a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. A C_3-C_{10} cycloalkenylene group as used herein refers to a divalent group having the same structure as the C_3-C_{10} cycloalkenyl group.

[0225] A C_1-C_{10} heterocycloalkenyl group as used herein refers to a monovalent monocyclic group including at least one heteroatom selected from N, O, P, Si, and S as a ring-forming atom, 1 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_1-C_{10} heterocycloalkenylene group as used herein refers to a divalent group having the same structure as a C_1-C_{10} heterocycloalkenyl group.

[0226] A C_6-C_{60} aryl group as 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 as 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.

[0227] A C_1-C_{60} heteroaryl group as used herein refers to a monovalent group having a heterocyclic aromatic system that has at least one hetero atom selected from N, O, P, Si and S as a ring-forming atom, and 1 to 60 carbon atoms. A C_1-C_{60} heteroarylene group as used herein refers to a divalent group having a heterocyclic aromatic system that has at least one hetero atom selected from N, O, P, Si and S as a ring-forming atom, and 1 to 60 carbon atoms. Examples of the C_1-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_1-C_{60} heteroaryl group and the C_1-C_{60} heteroarylene group each include two or more rings, the rings may be fused to each other.

[0228] A C_6-C_{60} aryloxy group as used herein indicates —OA_{102} (wherein A_{102} is the C_6-C_{60} aryl group), and a C_6-C_{60} arylthio group as used herein indicates —SA_{103} (wherein A_{103} is the C_6-C_{60} aryl group).

[0229] A monovalent non-aromatic condensed polycyclic group as used herein refers to a monovalent group that has two or more rings condensed to each other, only carbon atoms (for example, the number of carbon atoms may be in a range of 8 to 60) as ring-forming atoms, wherein the molecular structure as a whole is non-aromatic in the entire molecular structure. Detailed example of the non-aromatic condensed polycyclic group includes a fluorenyl group. A divalent non-aromatic condensed polycyclic group as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed polycyclic group.

[0230] A monovalent non-aromatic condensed heteropolycyclic group as used herein refers to a monovalent group that has a plurality of rings condensed with each other, has a hetero atom selected from N, O, P, Si and S, other than carbon atoms (for example, the number of carbon atoms may be in a range of 1 to 60), as ring-forming atoms, wherein the molecular structure as a whole is non-aromatic in the entire molecular structure. The monovalent non-aromatic condensed heteropolycyclic group includes a carbazolyl group. A divalent non-aromatic condensed hetero-polycyclic group as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

[0231] At least one substituent of the substituted C_3-C_{10} cycloalkylene group, substituted C_1-C_{10} heterocycloalkylene group, substituted C_3-C_{10} cycloalkenylene group, substituted C_1-C_{10} heterocycloalkenylene group, substituted C_6-C_{60} arylene group, substituted C_1-C_{60} heteroarylene group, substituted a divalent non-aromatic condensed polycyclic group, substituted a divalent non-aromatic condensed heteropolycyclic 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_1-C_{10} heterocycloalkyl group, substituted C_3-C_{10} cycloalkenyl group, substituted C_1-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_1-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic 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 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_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-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_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group (where, a carbazolyl group is excepted from the monovalent non-aromatic condensed heteropolycyclic group) and —$Si(Q_{31})(Q_{32})(Q_{33})$,

[0232] wherein Q_1 to Q_3, Q_{11} to Q_{13}, Q_{21} to Q_{23}, and Q_{31} to Q_{33} may be each independently selected from a hydrogen,

a C_1-C_{60} alkyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group (where, a carbazolyl group is excepted from the monovalent non-aromatic condensed heteropolycyclic group).

[0233] When a group containing a specified number of carbon atoms is substituted with any of the substituents listed above, the number of carbon atoms in the resulting "substituted" group may be the number of atoms contained in the original (base) group plus the number of carbon atoms (if any) contained in the substituent. For example, the "substituted C_1-C_{30} alkyl" may refer to a C_1-C_{30} alkyl group substituted with C_{6-60} aryl group, in which the total number of carbon atoms may be C_7-C_{90}.

[0234] The "biphenyl group" as used herein refers to "a phenyl group substituted with a phenyl group".

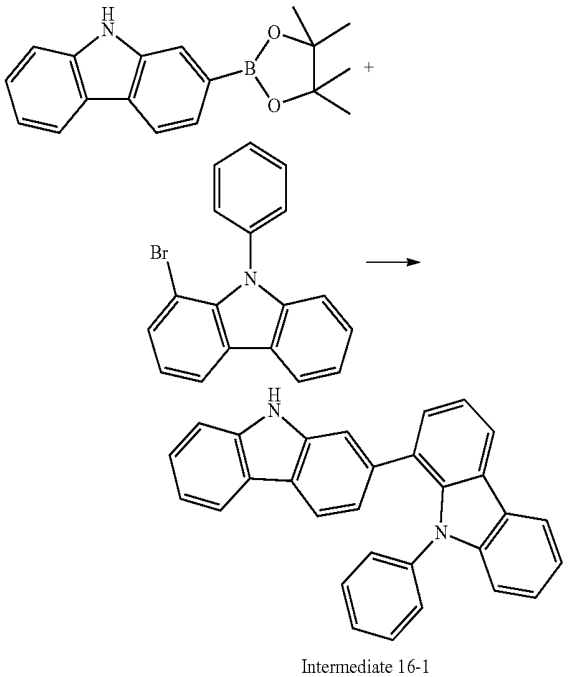
[0235] Hereinafter, a compound and an organic light-emitting device according to embodiments are described in detail with reference to Synthesis Example and Examples. However, the organic light-emitting device is not limited thereto. The wording "B was used instead of A" used in describing Synthesis Examples means that an amount of A used was identical to an amount of B used, in terms of a molar equivalent.

EXAMPLE

Synthesis Example 1

Synthesis of Compound 16

[0236]



Intermediate 16-1

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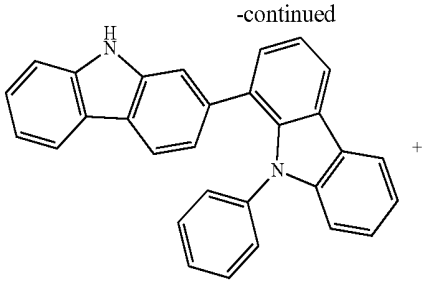
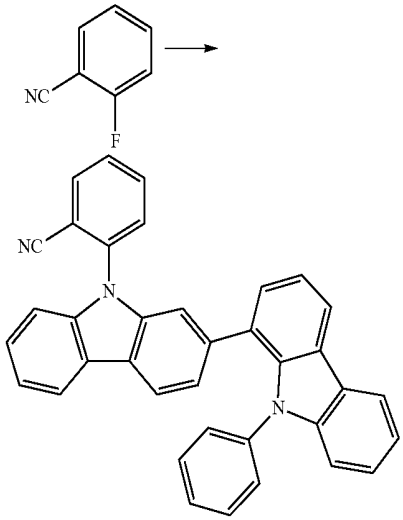


Intermediate 16-1



Compound 16

Synthesis of Intermediate 16-1

[0237] 21.838 grams (g) (74.49 millimoles (mmol)) of 2-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-9H-carbazole, 20 g (61.07 mmol) of 1-bromo-9-phenyl-9H-carbazole, 14.346 g (12.41 mmol) of tetrakis(triphenylphosphine)palladium [$Pd(PPh_3)_4$], and 27.863 g (496.59 mmol) of potassium hydroxide were added to 200 milliliters (mL) of THF and 100 mL of distilled water in a round-bottomed flask, and the mixture was heated under reflux for 12 hours. Once the reaction was completed, the reaction product was cooled to room temperature, and THF was separated from distilled water. Next, the THF layer separated therefrom was added dropwise to 600 mL of methanol and crystallized. The solid was filtered and washed with water and methanol. The resultant solid was dried in a vacuum oven to obtain Intermediate 16-1 (21 g, the yield of 85%).

Synthesis of Compound 16

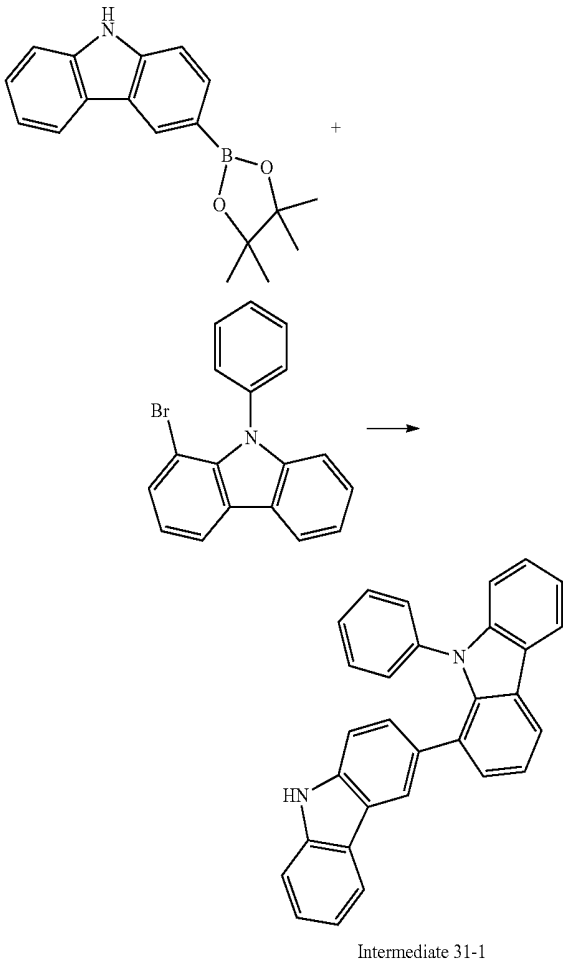
[0238] 12.3 g (30.11 mmol) of Intermediate 16-1, 3.27 mL (30.11 mmol) of 2-fluorobenzonitrile, and 1.566 g (39.14 mmol) of sodium hydride were added to 200 mL of DMF in a round-bottomed flask, and the mixture was heated under reflux for 12 hours. Once the reaction was completed, the reaction product was cooled to room temperature, and added dropwise to 600 mL of methanol and crystallized. The solid was filtered, and washed with water and methanol. The resultant solid was dried in a vacuum oven to obtain Compound 16 (10.74 g, the yield of 70%).

[0239] 1H NMR (400 MHz, $CDCl_3$): δ 8.23 (d, 1H), 8.20 (d, 1H), 7.97 (d, 1H), 7.92 (d, 1H), 7.84 (t, 1H), 7.71 (s, 1H), 7.64 (t, 1H), 7.53 (d, 1H), 7.47 (d, 1H), 7.43 (m, 4H), 7.32 (m, 4H), 7.16 (t, 3H), 6.82 (d, 2H), 6.74 (t, 1H). MS (m/z, [M]+): 509.06

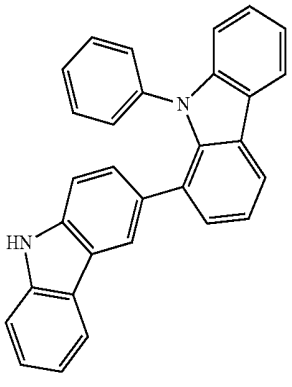
Synthesis Example 2

Synthesis of Compound 31

[0240]

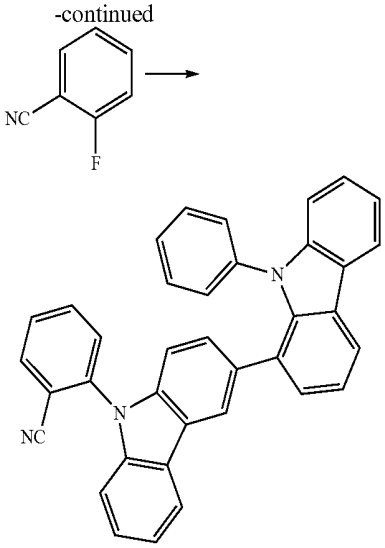


Intermediate 31-1



Intermediate 31-1

-continued



Compound 31

Synthesis of Intermediate 31-1

[0241] 16.378 g (55.87 mmol) of 3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-9H-carbazole, 15 g (46.55 mmol) of 1-bromo-9-phenyl-9H-carbazole, 10.759 g (9.31 mmol) of tetrakis(triphenylphosphine)palladium [$Pd(PPh_3)_4$], and 20.898 g (372.44 mmol) of potassium hydroxide were added to 200 mL THF and 100 mL of distilled water in a round-bottomed flask, and the mixture was heated under refluxed for 12 hours. Once the reaction was completed, the temperature was decreased to room temperature, and THF was separated from distilled water. The THF separated therefrom was added dropwise to 600 mL of methanol and crystallized. The solid was filtered, and washed with water and methanol. The resultant solid obtained therefrom was dried in a vacuum oven to obtain Intermediate 31-1 (13 g, the yield of 68%).

Synthesis of Compound 31

[0242] 10 g (24.48 mmol) of Intermediate 31-1, 2.66 mL (24.48 mmol) of 2-fluorobenzonitrile, and 1.27 g (31.82 mmol) of sodium hydride were added to 150 mL of DMF in a round-bottomed flask, and the mixture was heated under reflux for 12 hours. Once the reaction was completed, the reaction product was cooled to room temperature, and added dropwise to 600 mL of methanol and crystallized. The solid was filtered, and washed with water and methanol. The resultant solid was dried in a vacuum oven to obtain Compound 31 (8.98 g, the yield of 72%).

[0243] 1H NMR (400 MHz, $CDCl_3$): δ 8.20 (d, 1H), 8.17 (d, 1H), 8.07 (d, 1H), 7.79 (t, 1H), 7.72 (d, 1H), 7.59 (m, 3H), 7.40 (m, 7H), 7.22 (t, 2H), 7.03 (d, 2H), 6.90 (t, 4H). MS (m/z, [M]+): 509.06

Evaluation Example 1

Evaluation on HOMO and LUMO Energy Levels

[0244] HOMO and LUMO energy levels of Compounds 16 and 31 were evaluated according to the method indicated in Table 2, and results thereof are shown in Table 3.

TABLE 2

HOMO energy level evaluation method	A potential (V)-current (A) graph of each compound was obtained by using cyclic voltammetry (CV) (electrolyte: 0.1 molar (M) Bu_4NClO_4/solvent: CH_2Cl_2/electrode: 3 electrode system (working electrode: GC, reference electrode: Ag/AgCl, auxiliary electrode: Pt)). From oxidation onset of the graph, a HOMO energy level of the compound was calculated.
LUMO energy level evaluation method	Each compound was diluted at a concentration of 1×10^{-5}M in $CHCl_3$, and an UV absorption spectrum thereof was measured at room temperature by using Shimadzu UV-350 Spectrometer. A LUMO energy level thereof was calculated by using an optical band gap (E_g) from an edge of the absorption spectrum and a HOMO energy level.

TABLE 3

Compound No.	HOMO (eV) (found)	LUMO (eV) (found)
16	−5.63	−2.19
31	−5.61	−2.15

[0245] From Table 3, it is confirmed that Compounds 16 and 31 have electric characteristics that are suitable for use as a material for forming an organic light-emitting device.

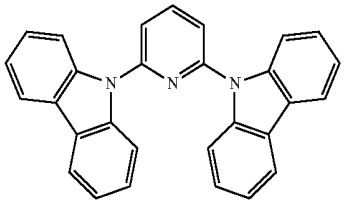
Evaluation Example 2

Thermal Characteristics Evaluation

[0246] Each of Compounds 16, 31, and A was subjected to thermal analysis (N_2 atmosphere, temperature range: room temperature to 800° C. (10° C./min)-TGA, room temperature to 400° C.-DSC, Pan Type: Pt Pan in disposable Al Pan(TGA), disposable Al pan(DSC)) using thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC), and obtained results are shown in Table 4 below. Based on the data in Table 4, it was confirmed that Compounds 16 and 31 had excellent thermal stability than that of Compound A.

TABLE 4

Compound No.	T_g(° C.)
16	115
31	114
Compound A	72



Compound A

Example 1

[0247] A glass substrate with a 1,500 Angstrom (Å)-thick ITO (Indium tin oxide) electrode (first electrode, anode) formed thereon was washed with distilled water and ultrasonic waves. When the washing with distilled water was completed, sonification washing was performed using a solvent, such as isopropyl alcohol, acetone, or methanol. The resultant was dried and transferred to a plasma washer. The resultant substrate was washed with oxygen plasma for 5 minutes and transferred to a vacuum depositor.

[0248] Compound HT3 and Compound HP-1 were co-deposited on the ITO electrode on the glass substrate to form a hole injection layer having a thickness of 100 Å, and Compound HT3 was deposited on the hole injection layer to form a hole transport layer having a thickness of 1,300 Å. mCP was deposited on the hole transport layer to form an electron blocking layer having a thickness of 150 Å, thereby completing the manufacture of a hole transport region.

[0249] Compound 16 (host) and FIr6 (dopant, 10 percent by weight (wt %)) were co-deposited on the hole transport region to form an emission layer having a thickness of 300 Å.

[0250] BCP was vacuum deposited on the emission layer to form a hole blocking layer having a thickness of 100 Å, Compound ET3 and Liq were vacuum deposited on the hole blocking layer to form an electron transport layer having a thickness of 250 Å. Then, Liq was deposited on the electron transport layer to form an electron injection layer having a thickness of 5 Å, and Al second electrode (cathode) having a thickness of 1,000 Å was formed on the electron injection layer, thereby completing the manufacture of an organic light-emitting device.

Example 2 and Comparative Example 1

[0251] Organic light-emitting devices were manufactured in the same manner as in Example 1, except that the compounds shown in Table 4 were used, as a host, instead of Compound 16 in the formation of the emission layer.

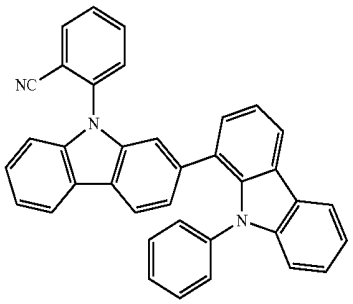
Evaluation Example 3

Evaluation on Characteristics of Organic Light-Emitting Devices

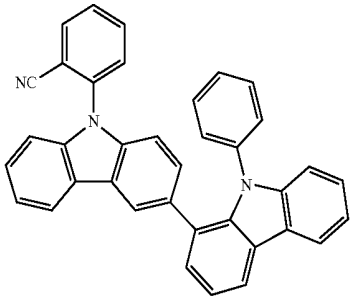
[0252] The driving voltage, current density, efficiency, power efficiency, quantum efficiency, and lifespan of the organic light-emitting devices of Examples 1 and 2 and Comparative Example 1 were measured by using a current-voltage meter (Keithley 2400) and a luminance meter (Minolta Cs-1000A), and results thereof are shown in Table 5. T_{95} (at 500 candelas per square meter (cd/m^2)) in Table 5 indicates an amount of time that lapsed when 100% of the initial luminance was decreased to 95%.

TABLE 5

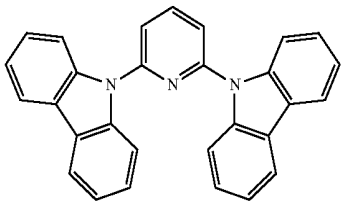
	Host	Driving voltage (V)	Efficiency (cd/A)	Power Efficiency (lm/W)	Quantum Efficiency (%)	T_{95} (hr)
Example 1	Compound 16	5.03	35.15	21.95	19.1	3.66
Example 2	Compound 31	5.12	39.25	24.16	19.5	2.24
Comparative Example 1	Compound A	6.85	15.27	7.03	8.9	0.54



16



31



Compound A

[0253] Referring to Table 5, it was confirmed that the organic light-emitting devices of Examples 1 and 2 have a lower driving voltage, a higher efficiency, a higher power efficiency, a higher quantum luminescent efficiency, and a longer lifespan than the organic light-emitting device of Comparative Example 1.

[0254] As described above, according to the one or more of the above embodiments of the present inventive concept, a condensed cyclic compound has excellent electric characteristics and thermal stability, and thus an organic light-emitting device including the condensed cyclic compound may have a low driving voltage, high efficiency, high power efficiency, high quantum luminescent efficiency, and long lifespan characteristics.

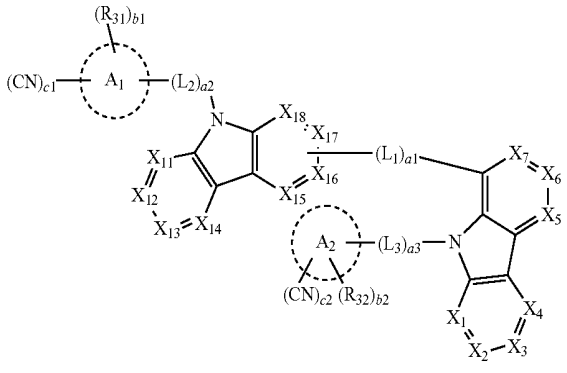
[0255] It should be understood that exemplary embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each exemplary embodiment should typically be considered as available for other similar features or aspects in other exemplary embodiments.

[0256] While one or more exemplary 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 1:

Formula 1



wherein, in Formula 1,

X_1 is N or $C(R_1)$, X_2 is N or $C(R_2)$, X_3 is N or $C(R_3)$, X_4 is N or $C(R_4)$, X_5 is N or $C(R_5)$, X_6 is N or $C(R_6)$, X_7 is N or $C(R_7)$, X_{11} is N or $C(R_{11})$, X_{12} is N or $C(R_{12})$, X_{13} is N or $C(R_{13})$, X_{14} is N or $C(R_{14})$, X_{15} is N, $C(R_{15})$, or a carbon atom connected to $*-(L_1)_{a1}-*'$, X_{16} is N, $C(R_{16})$, or a carbon atom connected to $*-(L_1)_{a1}-*'$, X_{17} is N, $C(R_{17})$, or a carbon atom connected to $*-(L_1)_{a1}-*'$, and X_{18} is N, $C(R_{18})$, or a carbon atom connected to $*-(L_1)_{a1}-*'$, wherein one of X_{15} to X_{18} is connected to $*-(L_1)_{a1}-*'$,

ring A_1 and ring A_2 are each independently selected from a C_5-C_{60} carbocyclic group and a C_3-C_{60} heterocyclic group comprising at least one heteroatom selected from O, S, and Si,

L_1 to L_3 are each independently selected from

a phenylene group, a pyridinylene group, a pyrimidinylene group, a pyrazinylene group, a pyridazinylene group, a triazinylene group, a fluorenylene group, a dibenzofuranylene group, and a dibenzothiophenylene group; and

a phenylene group, a pyridinylene group, a pyrimidinylene group, a pyrazinylene group, a pyridazinylene group, a triazinylene group, a fluorenylene group, a dibenzofuranylene group, and a dibenzothiophenylene group, each substituted with at least one 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 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, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and $—Si(Q_{11})(Q_{12})(Q_{13})$,

a1 to a3 are each independently an integer selected from 0 to 5, wherein when a1 is 2 or greater, two or more groups L_1 are identical to or different from each other, when a2 is 2 or greater, two or more groups L_2 are identical to or different from each other, and when a3 is 2 or greater, two or more groups L_3 are identical to or different from each other,

R_1 to R_7, R_{11} to R_{18}, R_{31}, and R_{32} are each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group (CN), 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 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_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-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_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and $—Si(Q_1)(Q_2)(Q_3)$,

b1 and b2 are each independently an integer selected from 0 to 4,

c1 is an integer selected from 1 to 4,

c2 is an integer selected from 0 to 4,

at least one selected from substituents of the 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_1-C_{10} heterocycloalkyl group, substituted C_3-C_{10} cycloalkenyl group, substituted C_1-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_1-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group is 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 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_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-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_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, and $—Si(Q_{21})(Q_{22})(Q_{23})$,

wherein Q_1 to Q_3, Q_{11} to Q_{13}, and Q_{21} to Q_{23} are each independently selected from a hydrogen, a deuterium, a C_1-C_{60} alkyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group,

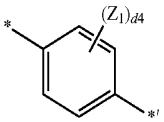
in $*-(L_1)_{a1}-*'$, * and *' are each a binding site to a neighboring atom.

2. The condensed cyclic compound of claim **1**, wherein ring A_1 and ring A_2 are each independently selected from a cyclopentyl group, a cyclohexyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthenyl group, a fluorenyl group, a spirobifluorenyl 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 furanyl group, a thiophenyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group.

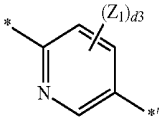
3. The condensed cyclic compound of claim 1, wherein ring A_1 and ring A_2 are each independently selected from a phenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group.

4. The condensed cyclic compound of claim 1, wherein L_1 to L_3 are each independently selected from groups represented by Formulae 3-1 to 3-56:

Formula 3-1



Formula 3-2



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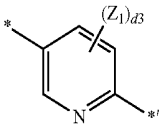
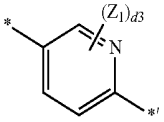


Formula 3-4



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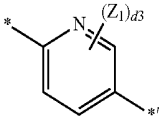

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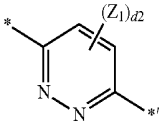

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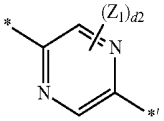

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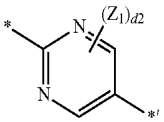

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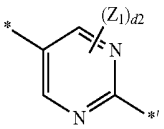

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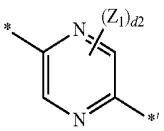

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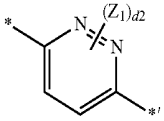
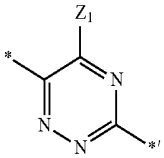
Formula 3-11



Formula 3-12



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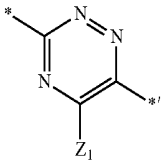

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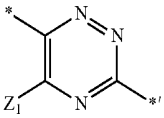
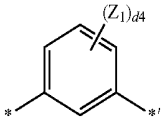
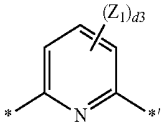


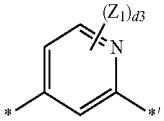
Formula 3-15



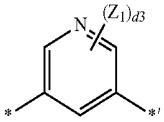
Formula 3-16



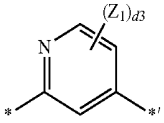
Formula 3-17



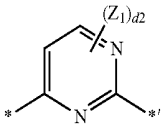
Formula 3-18



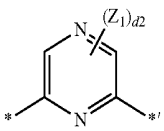
Formula 3-19



Formula 3-20



Formula 3-21



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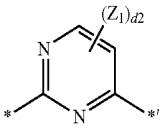
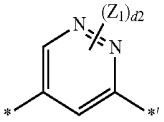
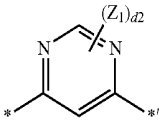
Formula 3-22



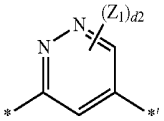
Formula 3-23



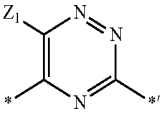
Formula 3-24



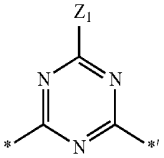
Formula 3-25



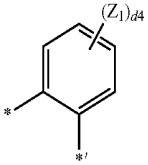
Formula 3-26



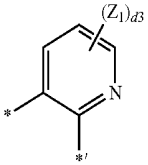
Formula 3-27



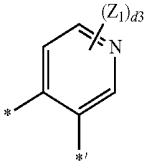
Formula 3-28



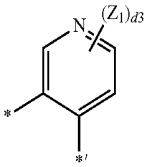
Formula 3-29



Formula 3-30



Formula 3-31



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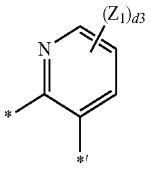
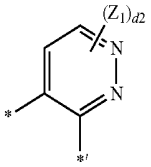
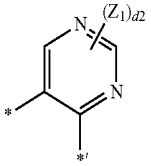
Formula 3-32



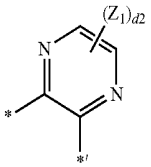
Formula 3-33



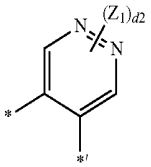
Formula 3-34



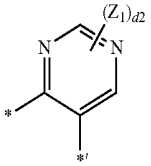
Formula 3-35



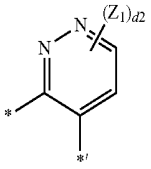
Formula 3-36



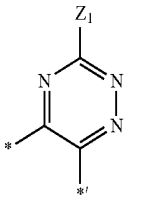
Formula 3-37



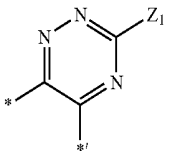
Formula 3-38



Formula 3-39



Formula 3-40



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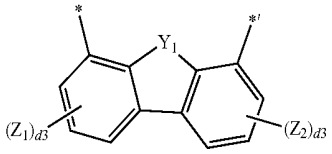
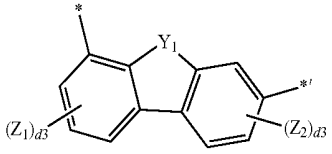
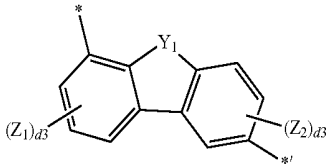
Formula 3-41



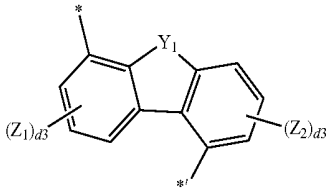
Formula 3-42



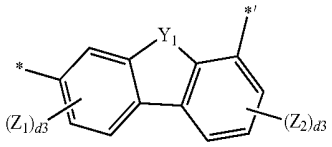
Formula 3-43



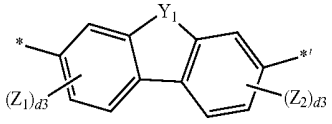
Formula 3-44



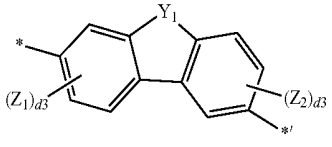
Formula 3-45



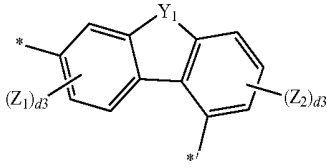
Formula 3-46



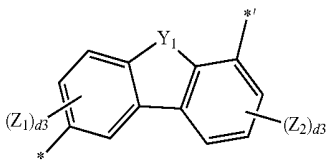
Formula 3-47



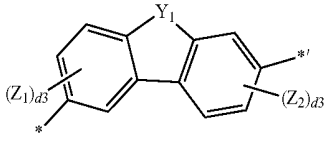
Formula 3-48



Formula 3-49



Formula 3-50



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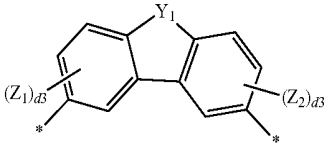
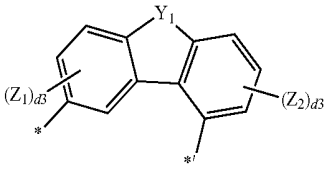
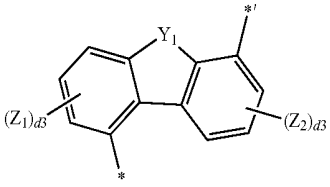
Formula 3-51



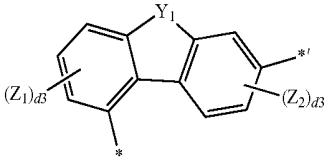
Formula 3-52



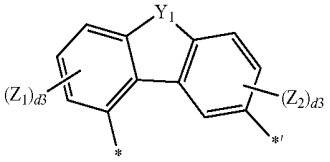
Formula 3-53



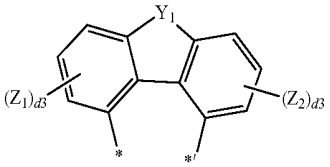
Formula 3-54



Formula 3-55



Formula 3-56



wherein, in Formulae 3-1 to 3-56,

Y_1 is selected from O, S, and $C(Z_3)(Z_4)$,

Z_1 to Z_4 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 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, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and —Si$(Q_{11})(Q_{12})(Q_{13})$,

wherein Q_{11} to Q_{13} are each independently selected from a hydrogen, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group,

d4 is an integer selected from 0 to 4,

d3 is an integer selected from 0 to 3,

d2 is an integer selected from 0 to 2, and

* and *' are each a binding site to a neighboring atom.

5. The condensed cyclic compound of claim **4**, wherein

i) a1 is 0; or

ii) when a1 is not 0, at least one of groups L_1 is selected from groups represented by Formulae 3-15 to 3-56.

6. The condensed cyclic compound of claim **4**, wherein

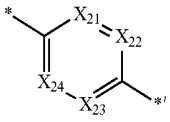
L_1 is selected from groups represented by Formulae 3-15, 3-28, 3-41, and 3-51,

L_2 and L_3 are each independently selected from groups represented by Formulae 3-1, 3-15, 3-28, 3-41, and 3-51, and

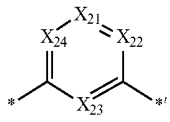
a1 to a3 are each independently 0, 1, or 2.

7. The condensed cyclic compound of claim **1**, wherein a group represented by *-$(L_1)_{a1}$-*' is selected from groups represented by Formulae 4-1 to 4-39:

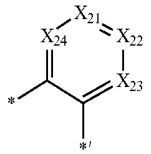
Formula 4-1



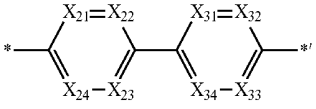
Formula 4-2



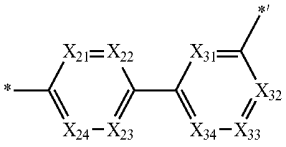
Formula 4-3



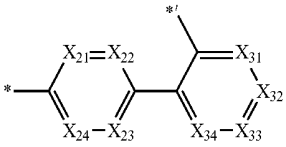
Formula 4-4



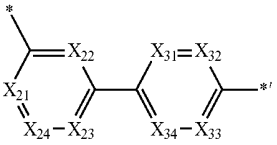
Formula 4-5



Formula 4-6



Formula 4-7



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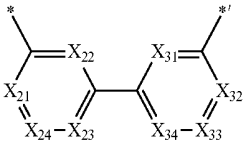
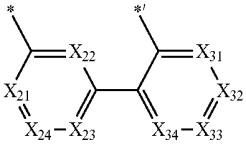
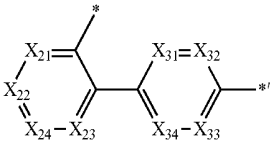
Formula 4-8



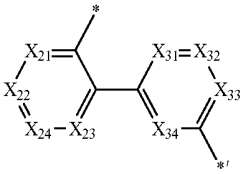
Formula 4-9



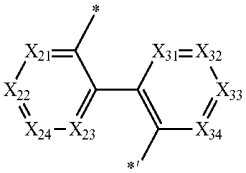
Formula 4-10



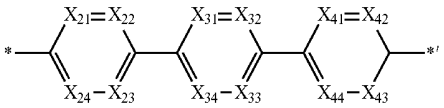
Formula 4-11



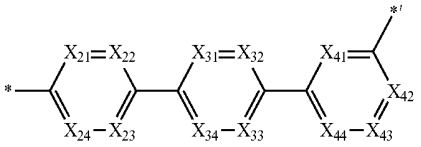
Formula 4-12



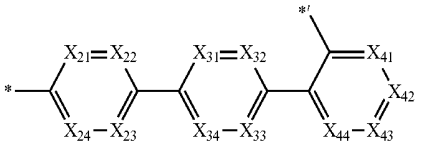
Formula 4-13



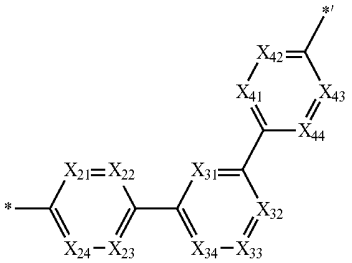
Formula 4-14



Formula 4-15



Formula 4-16



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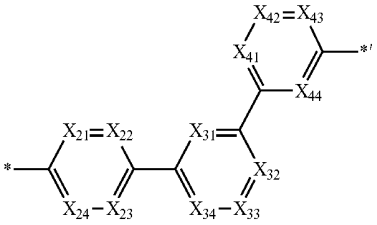
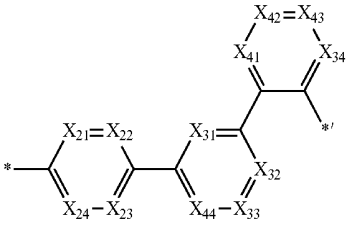
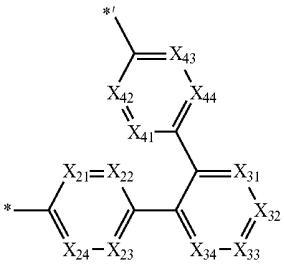
Formula 4-17



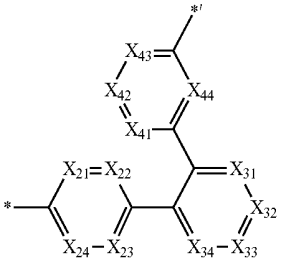
Formula 4-18



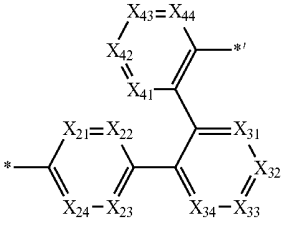
Formula 4-19



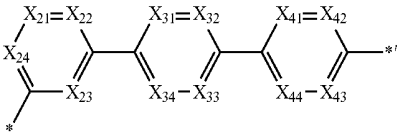
Formula 4-20



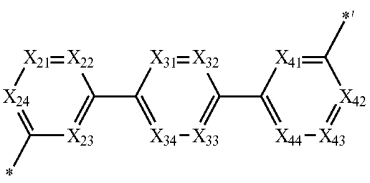
Formula 4-21



Formula 4-22



Formula 4-23



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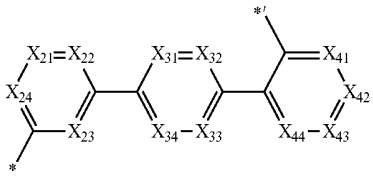
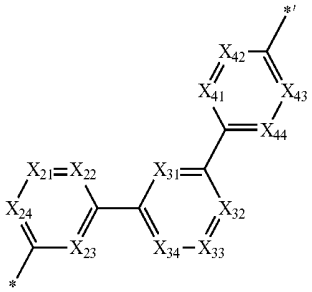
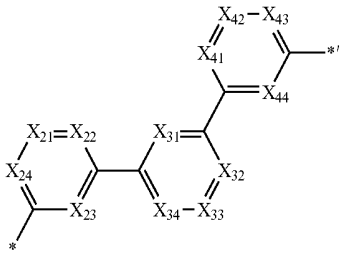
Formula 4-24



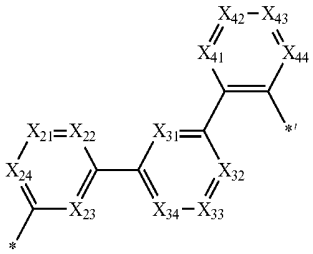
Formula 4-25



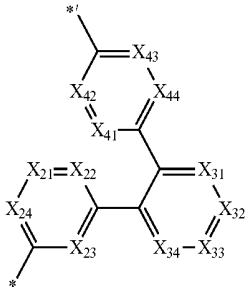
Formula 4-26



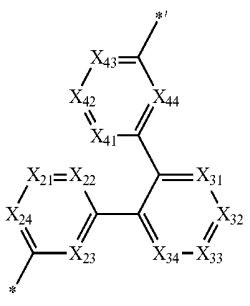
Formula 4-27



Formula 4-28



Formula 4-29



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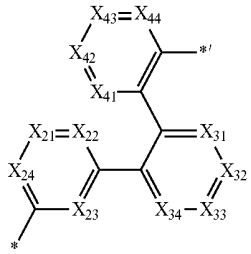
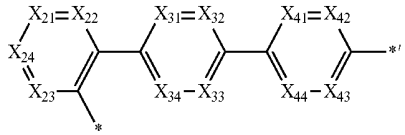
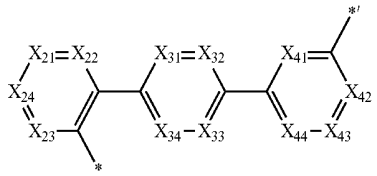
Formula 4-30



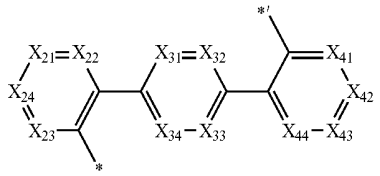
Formula 4-31



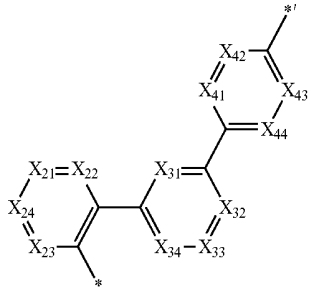
Formula 4-32



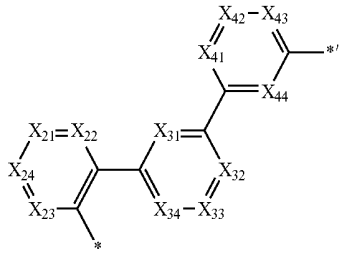
Formula 4-33



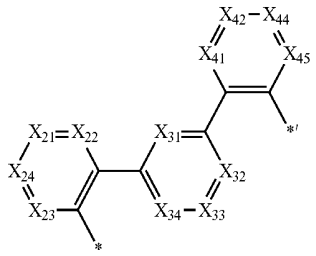
Formula 4-34



Formula 4-35



Formula 4-36



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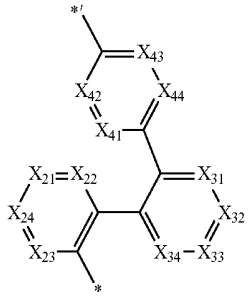
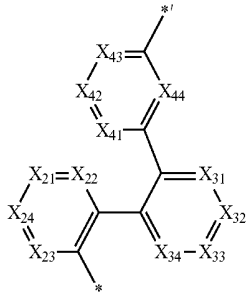
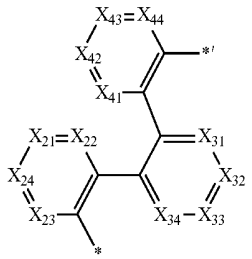
Formula 4-37



Formula 4-38



Formula 4-39



wherein, in Formulae 4-1 to 4-39,

X_{21} is N or $C(Z_{21})$, X_{22} is N or $C(Z_{22})$, X_{23} is N or $C(Z_{23})$, X_{24} is N or $C(Z_{24})$, X_{31} is N or $C(Z_{31})$, X_{32} is N or $C(Z_{32})$, X_{33} is N or $C(Z_{33})$, X_{34} is N or $C(Z_{34})$, X_{41} is N or $C(Z_{41})$, X_{42} is N or $C(Z_{42})$, X_{43} is N or $C(Z_{43})$, and X_{44} is N or $C(Z_{44})$, provided that each of X_{21} to X_{24} is not simultaneously N, provided that each of X_{31} to X_{34} is not simultaneously N, and provided that each of X_{41} to X_{44} is not simultaneously N,

Z_{21} to Z_{24}, Z_{31} to Z_{34}, and Z_{41} to Z_{44} are each independently selected from a hydrogen, a deuterium, a cyano group, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and —Si$(Q_{11})(Q_{12})(Q_{13})$,

wherein Q_{11} to Q_{13} are each independently a hydrogen, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, and

* and *' are each a binding site to a neighboring atom.

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

R_1 to R_7, R_{11} to R_{18}, R_{31}, and R_{32} 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 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;

a C_1-C_{10} alkyl group and a C_1-C_{10} alkoxy group, each substituted with at least one 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 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, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one 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 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, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and $—Si(Q_{21})(Q_{22})(Q_{23})$; and

$—Si(Q_1)(Q_2)(Q_3)$,

wherein Q_1 to Q_3 and Q_{21} to Q_{23} are each independently selected from a hydrogen, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group.

9. The condensed cyclic compound of claim **1**, wherein R_1 to R_7, R_{11} to R_{18}, and R_{31} and R_{32} are each independently selected from

a hydrogen, a deuterium, —F, a cyano group, a C_1-C_{10} alkyl group, and a C_1-C_{10} alkoxy group;

a C_1-C_{10} alkyl group and a C_1-C_{10} alkoxy group, each substituted with at least one selected from a deuterium, —F, and a cyano group;

a phenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

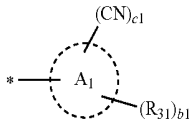
a phenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from a deuterium, —F, a cyano group, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and $—Si(Q_{21})(Q_{22})(Q_{23})$; and

$—Si(Q_1)(Q_2)(Q_3)$,

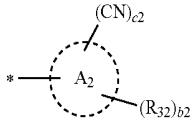
Q_1 to Q_3 and Q_{21} to Q_{23} are each independently a hydrogen, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group.

10. The condensed cyclic compound of claim **1**, wherein at least one of X_3, X_6, X_{13}, and X_{16} is C(CN).

11. The condensed cyclic compound of claim **1**, wherein a group represented by

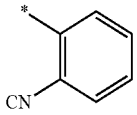


is selected from groups represented by Formulae 5-1 to 5-60, and a group represented by

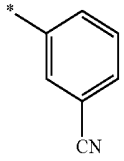


is selected from groups represented by Formulae 5-1 to 5-69:

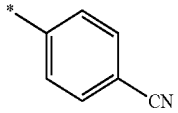
Formula 5-1



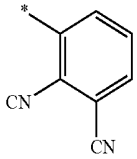
Formula 5-2



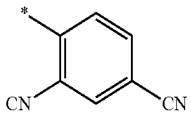
Formula 5-3



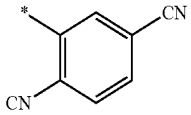
Formula 5-4



Formula 5-5



Formula 5-6



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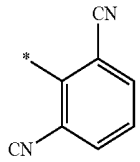
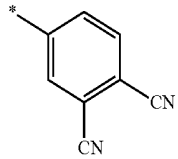
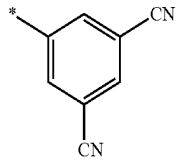
Formula 5-7



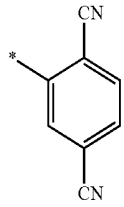
Formula 5-8



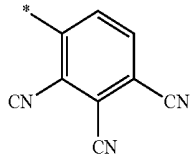
Formula 5-9



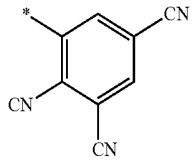
Formula 5-10



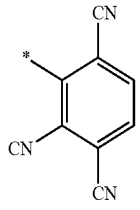
Formula 5-11



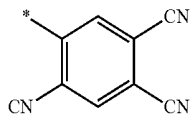
Formula 5-12



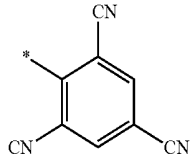
Formula 5-13



Formula 5-14



Formula 5-15



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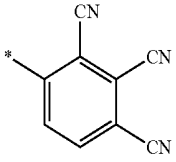
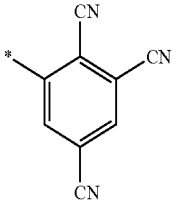
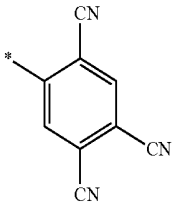
Formula 5-16



Formula 5-17



Formula 5-18



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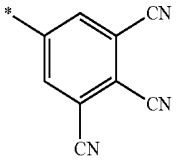

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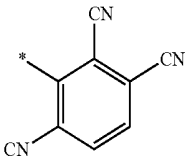

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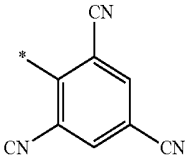

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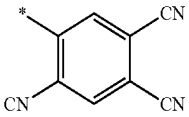

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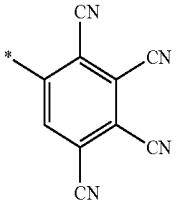

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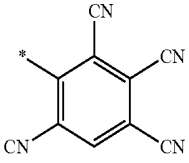

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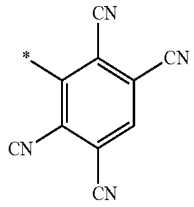

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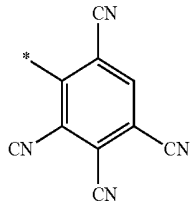

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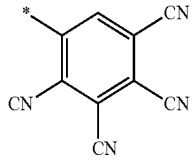

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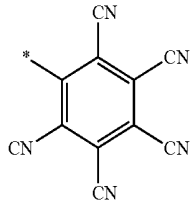

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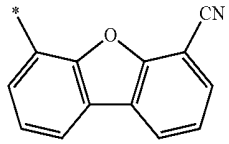
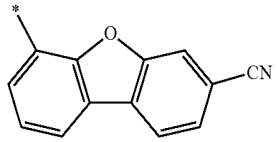


Formula 5-30



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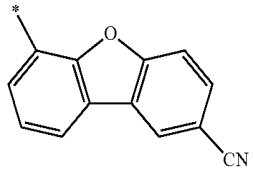

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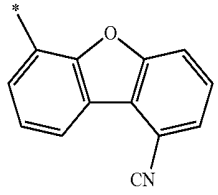

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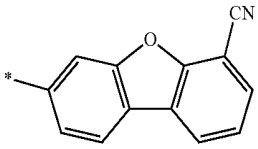

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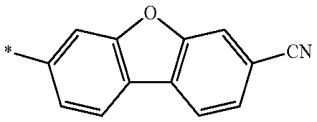

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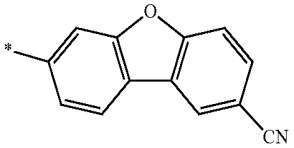
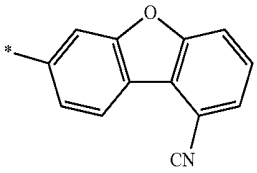


Formula 5-36



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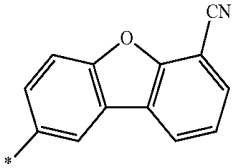

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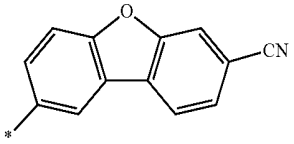

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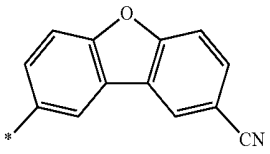

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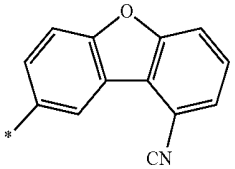

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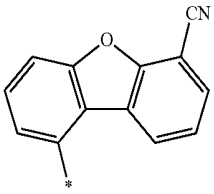

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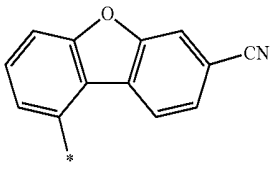
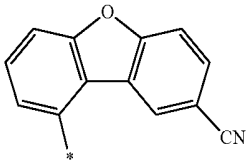
Formula 5-42



Formula 5-43



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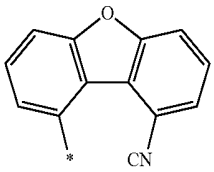
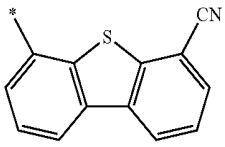
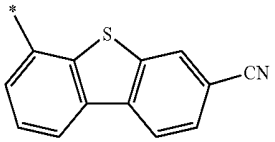


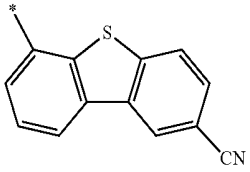
Formula 5-45



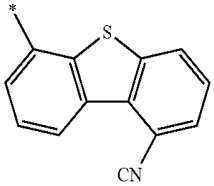
Formula 5-46



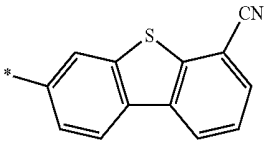
Formula 5-47



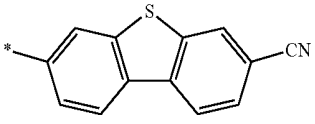
Formula 5-48



Formula 5-49



Formula 5-50



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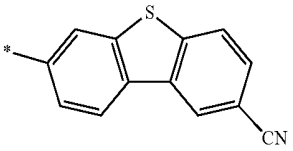
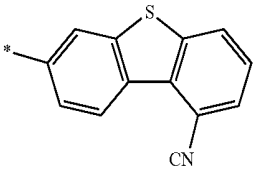
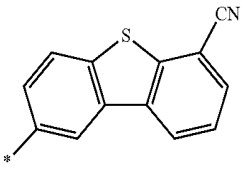


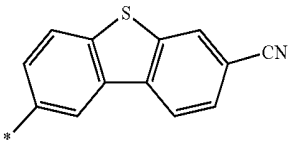
Formula 5-52



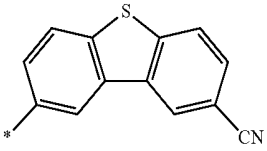
Formula 5-53



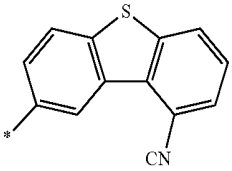
Formula 5-54



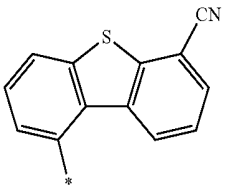
Formula 5-55



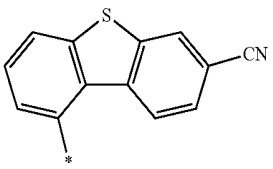
Formula 5-56



Formula 5-57



Formula 5-58



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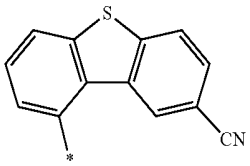
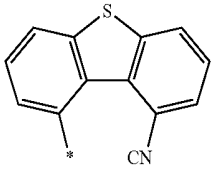
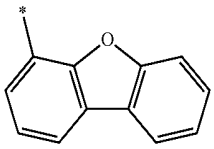
Formula 5-59



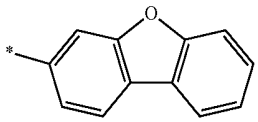
Formula 5-60



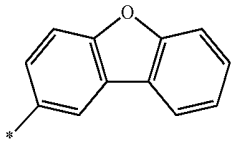
Formula 5-61



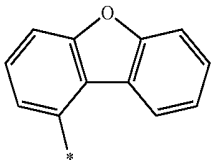
Formula 5-62



Formula 5-63



Formula 5-64



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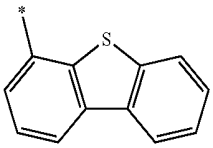
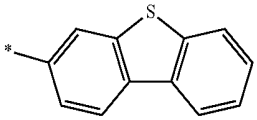
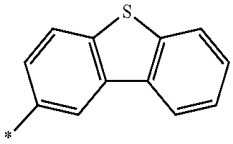
Formula 5-65



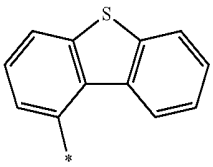
Formula 5-66



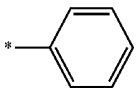
Formula 5-67



Formula 5-68



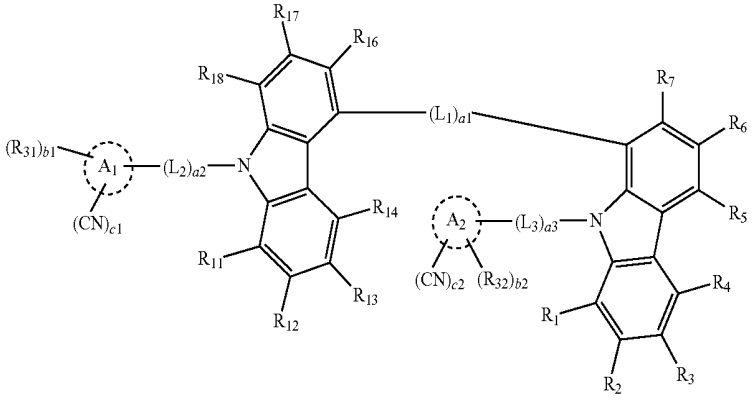
Formula 6-69



wherein, in Formulae 5-1 to 5-69, * is a binding site to a neighboring atom.

12. The condensed cyclic compound of claim **1** represented by one of Formulae 1A to 1D:

Formula 1A



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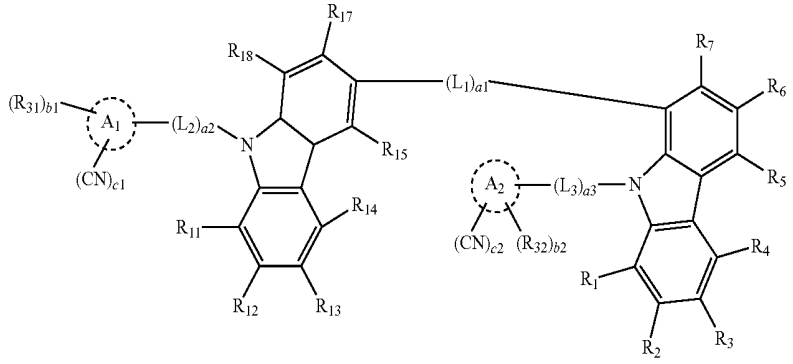
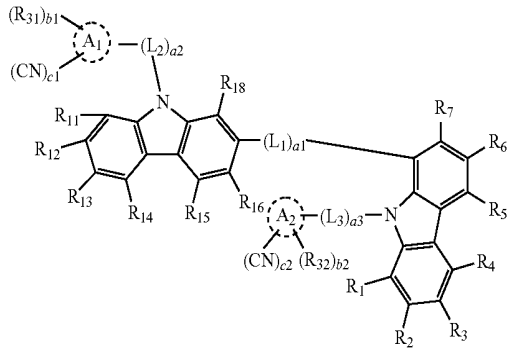
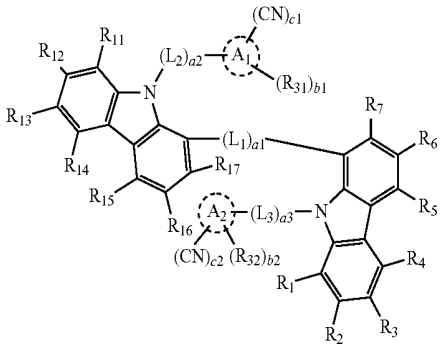
Formula 1B



Formula 1C



Formula 1D



wherein, in Formulae 1A to 1D,

ring A_1 and ring A_2 are each independently selected from a phenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group,

L_1 is selected from groups represented by Formulae 3-15, 3-28, 3-41, and 3-51,

L_2 and L_3 are each independently selected from groups represented by Formulae 3-1, 3-15, 3-28, 3-41, and 3-51,

a1 to a3 are each independently selected from 0, 1, and 2,

R_1 to R_7, R_{11} to R_{18}, R_{31}, and R_{32} are each independently selected from

a hydrogen, a deuterium, —F, a cyano group, a C_1-C_{10} alkyl group, and a C_1-C_{10} alkoxy group;

a C_1-C_{10} alkyl group and a C_1-C_{10} alkoxy group, each substituted with at least one selected from a deuterium, —F, and a cyano group;

a phenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

a phenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from a deuterium, —F, a cyano group, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and —$Si(Q_{21})(Q_{22})(Q_{23})$; and

—$Si(Q_1)(Q_2)(Q_3)$,

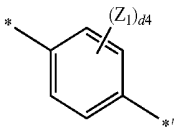
wherein Q_1 to Q_3 and Q_{21} to Q_{23} are each independently selected from a hydrogen, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group,

b1 and b2 are each independently 0 or 1,

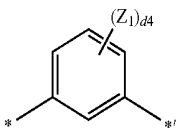
c1 is 1 or 2, and

c2 is 0, 1, or 2

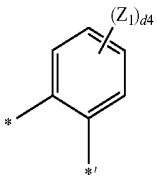
Formula 3-1



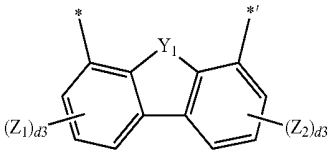
Formula 3-15



Formula 3-28



Formula 3-41



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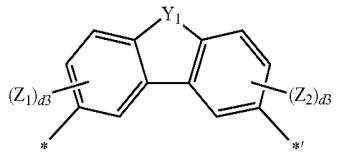
Formula 3-51



wherein, in Formulae 3-1, 3-15, 3-28, 3-41, and 3-51,

Y_1 is selected from O, S, and $C(Z_3)(Z_4)$,

Z_1 to Z_4 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 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, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and —$Si(Q_{11})(Q_{12})(Q_{13})$,

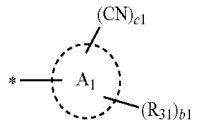
wherein Q_{11} to Q_{13} are each independently selected from a hydrogen, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group,

d4 is an integer selected from 0 to 4,

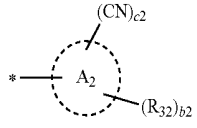
d3 is an integer selected from 0 to 3, and

* and *' are each a binding site to a neighboring atom.

13. The condensed cyclic compound of claim **12**, wherein a group represented by

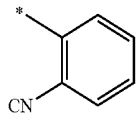


is selected from groups represented by Formulae 5-1 to 5-3, 5-31, 5-39, 5-47, and 5-55, and a group represented by



is selected from groups represented by Formulae 5-1 to 5-3, 5-31, 5-39, 5-47, 5-55, 5-61, 5-63, 5-65, 5-67, and 5-69:

Formula 5-1



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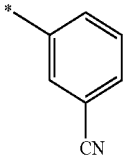
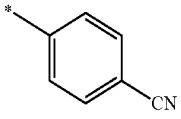
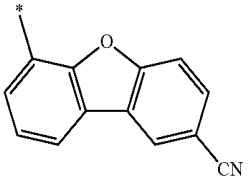
Formula 5-2



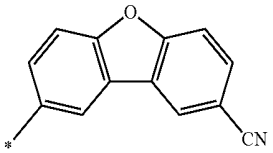
Formula 5-3



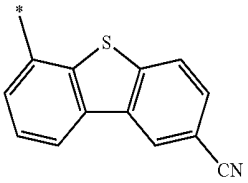
Formula 5-31



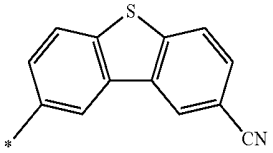
Formula 5-39



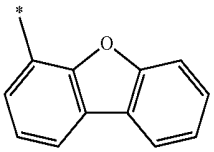
Formula 5-47



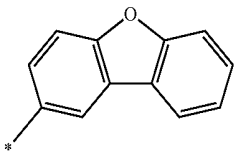
Formula 5-55



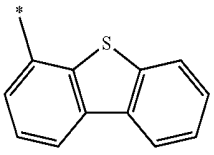
Formula 5-61



Formula 5-63



Formula 5-65



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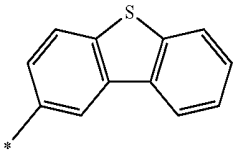
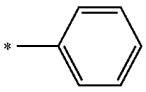
Formula 5-67



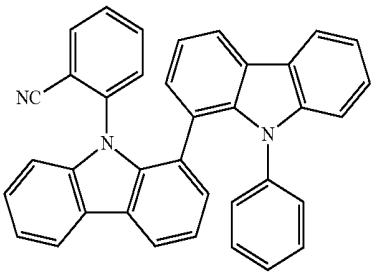
Formula 5-69



wherein * is a binding site to a neighboring atom.

14. The condensed cyclic compound of claim **1**, being one of Compounds 1 to 271:

1



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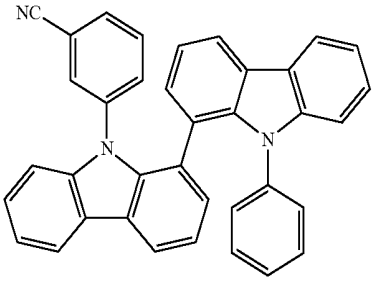

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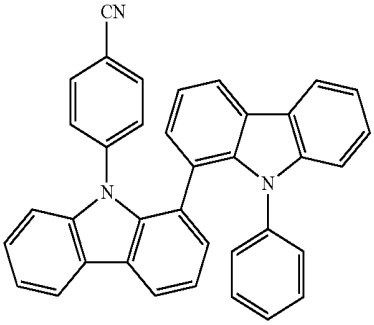

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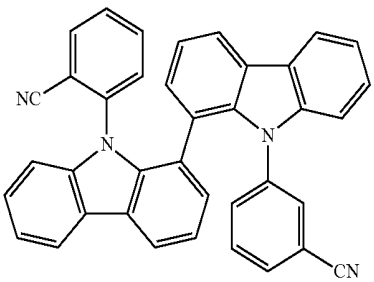

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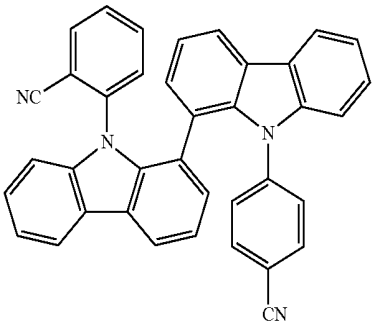

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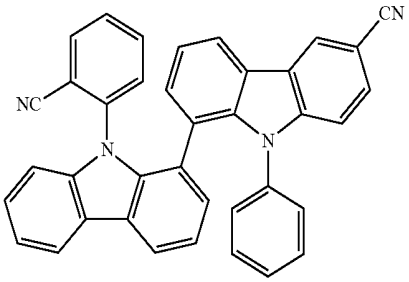

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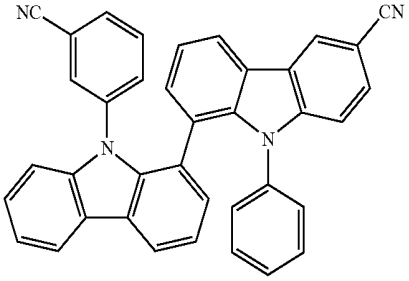

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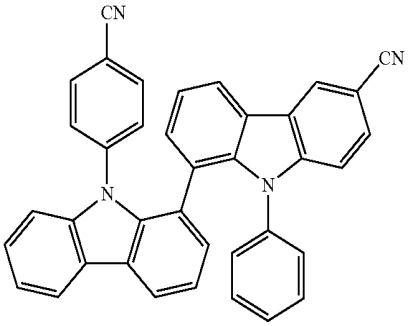

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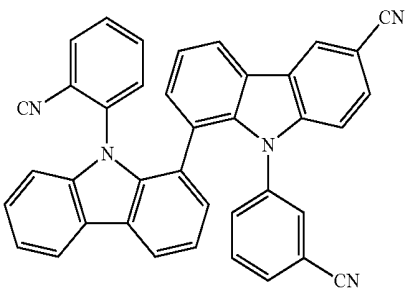

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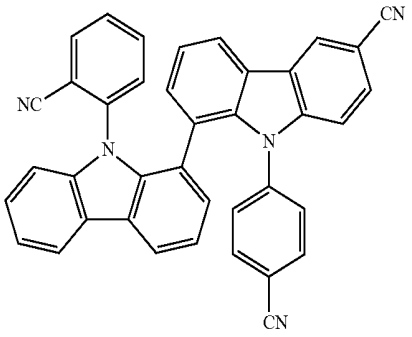

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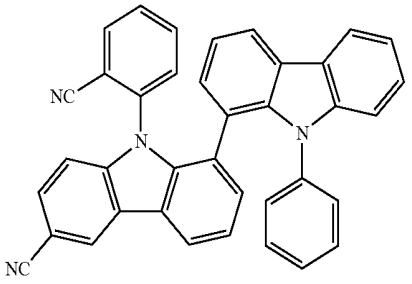

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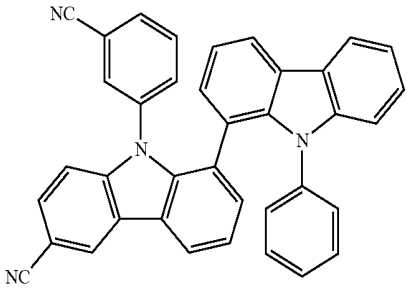

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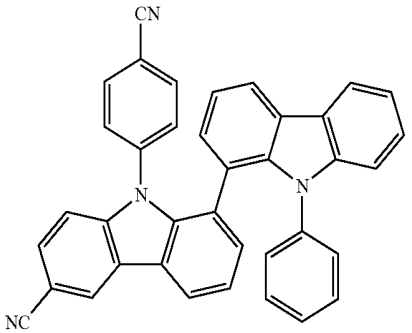

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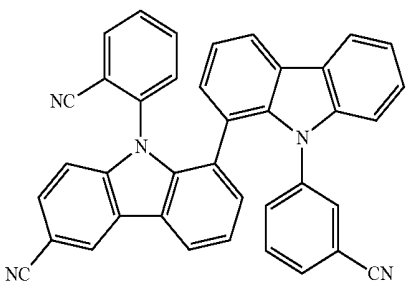

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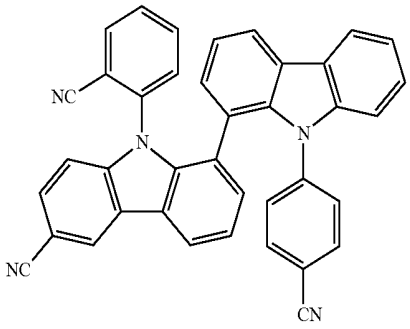

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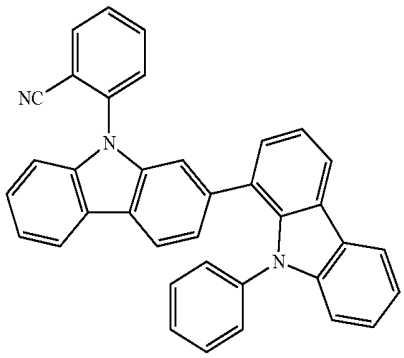

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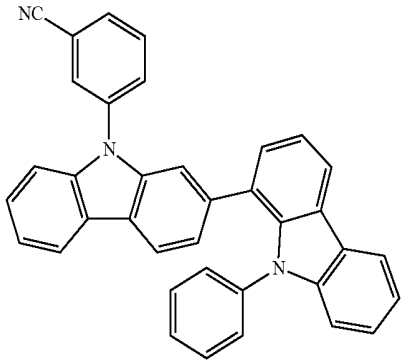

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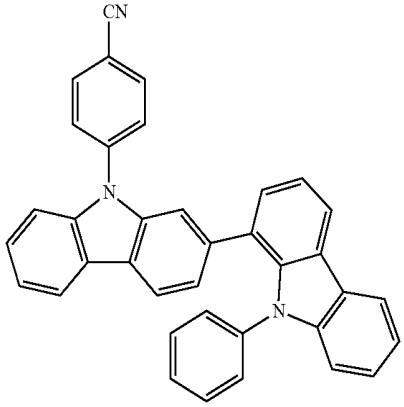

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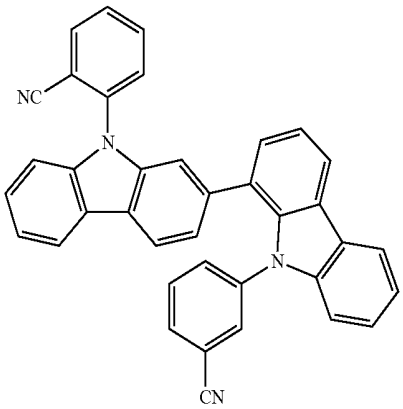

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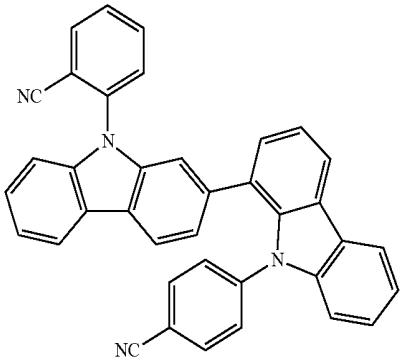

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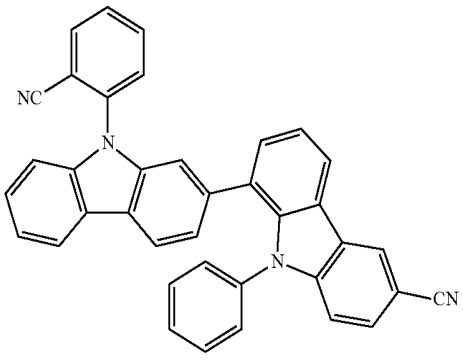

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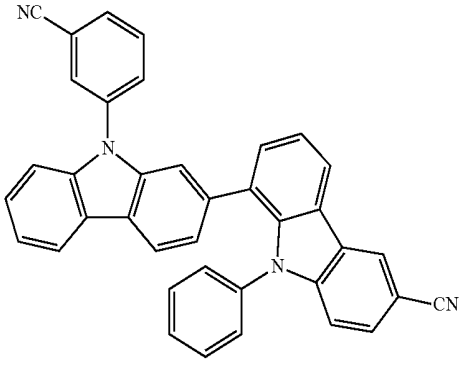

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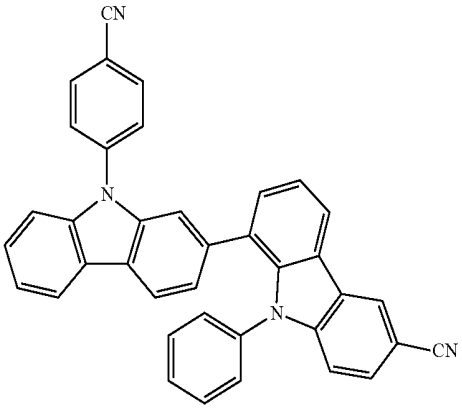

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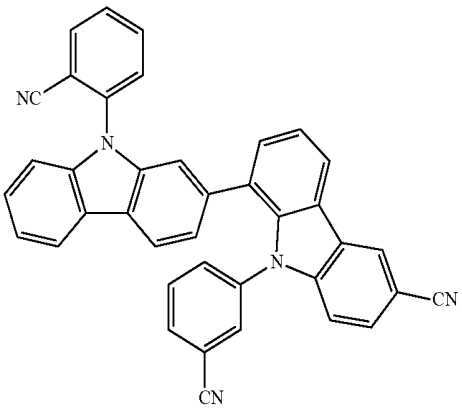

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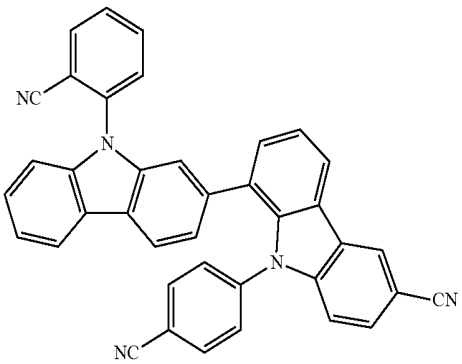

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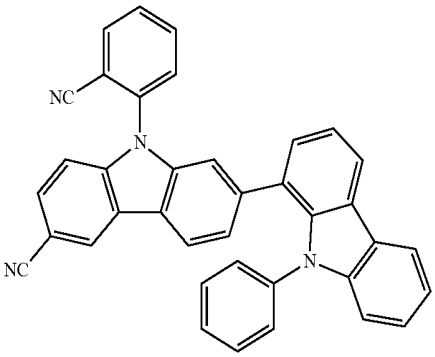

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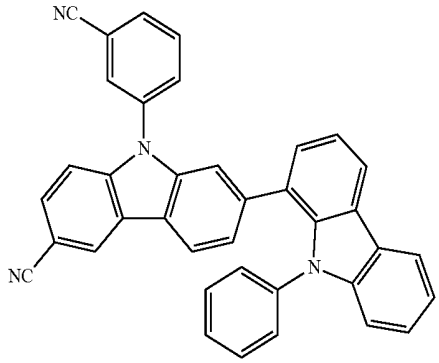
27



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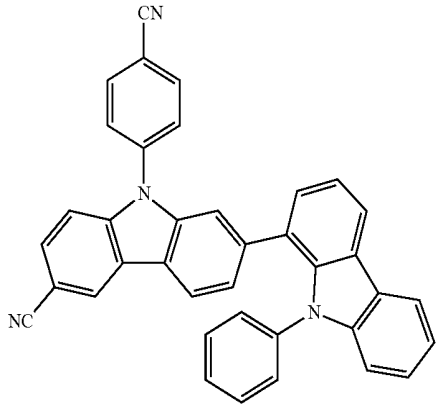

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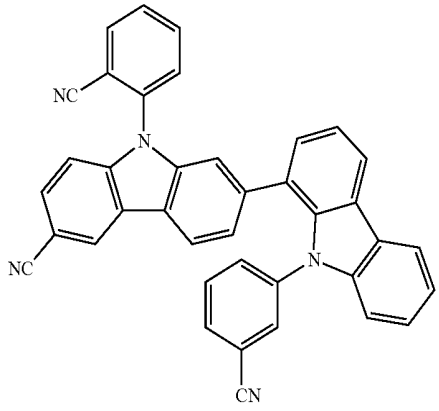

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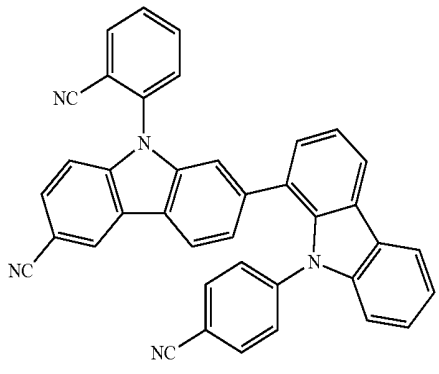

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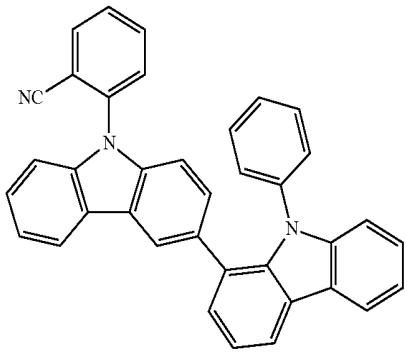

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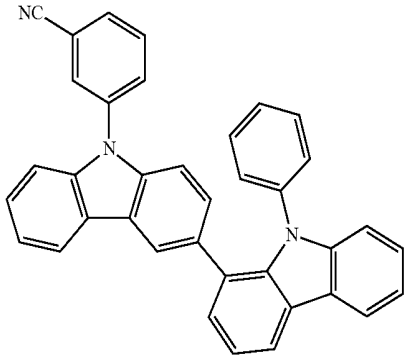

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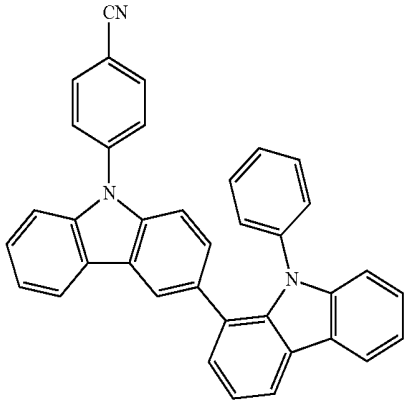

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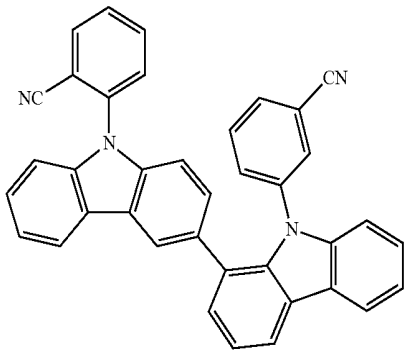

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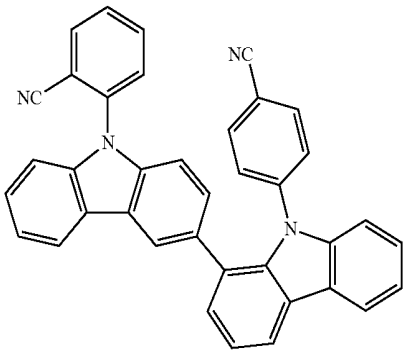

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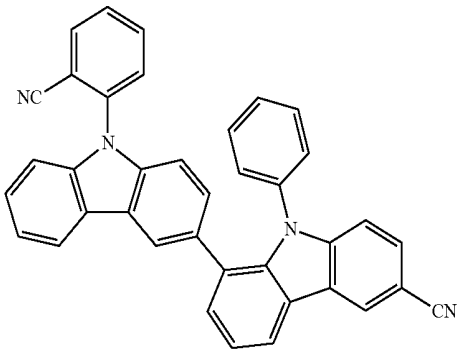

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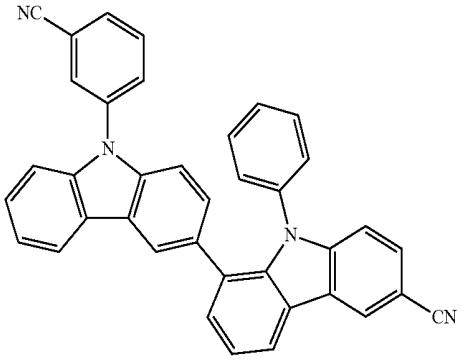

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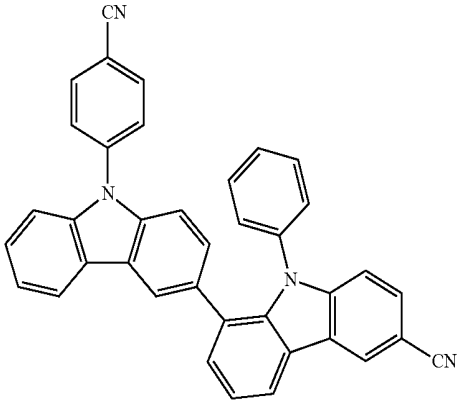

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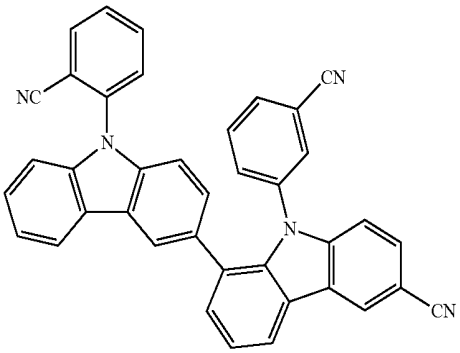

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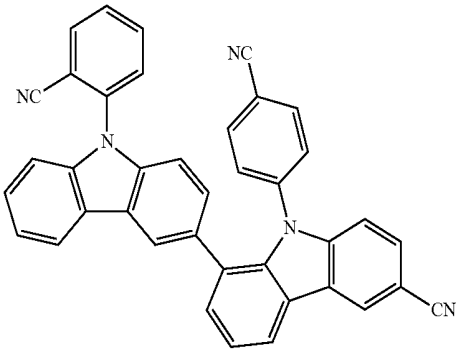

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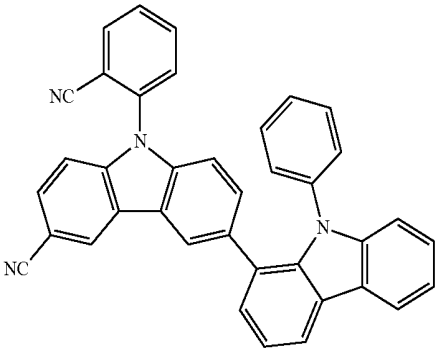

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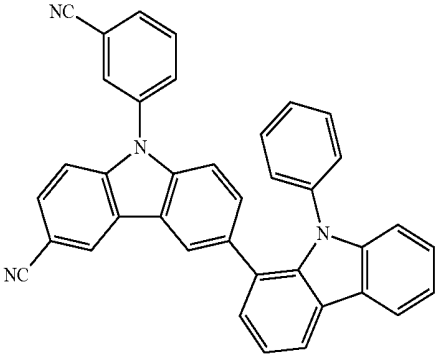

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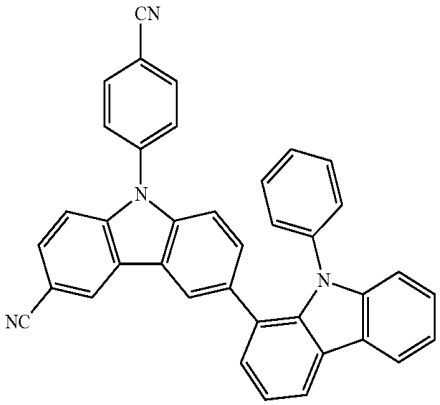

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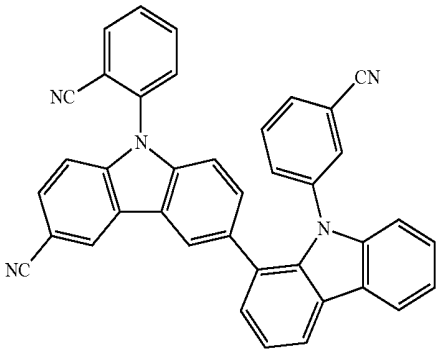

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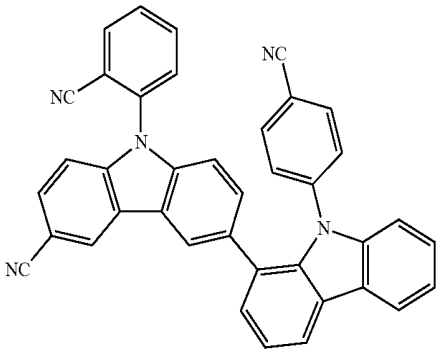

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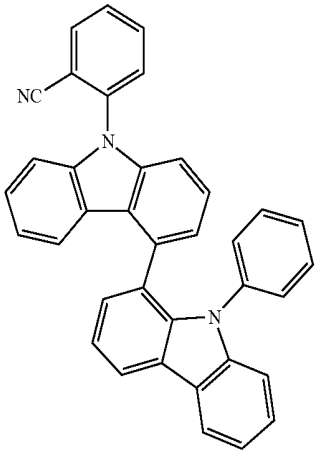

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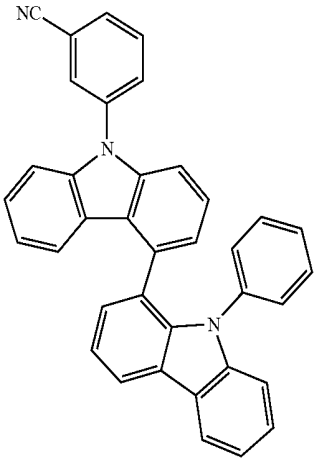

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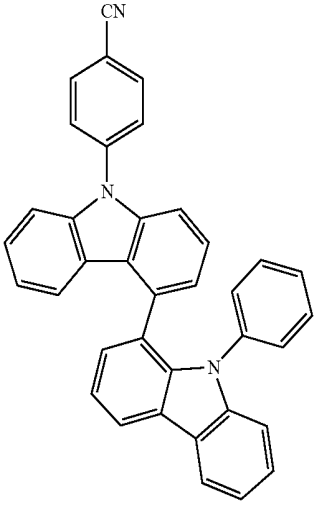

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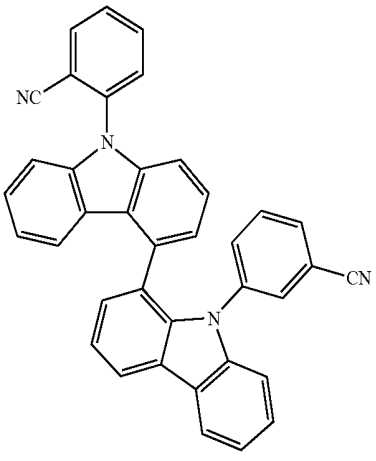

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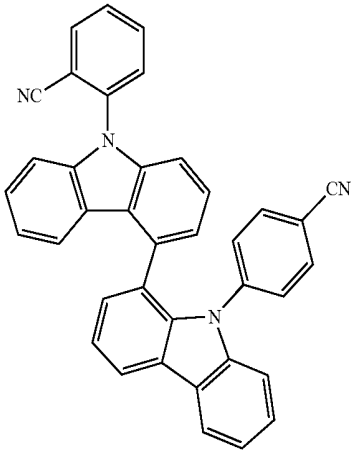

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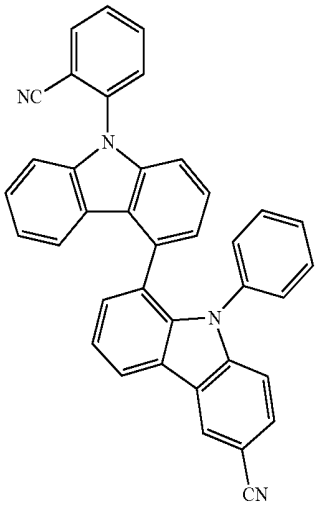

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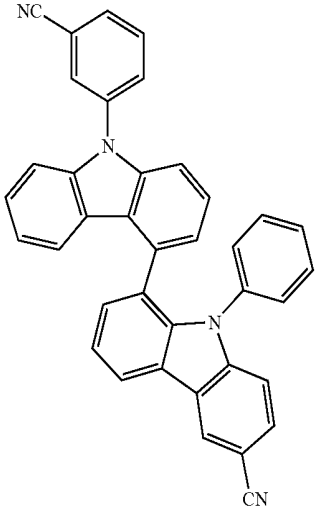

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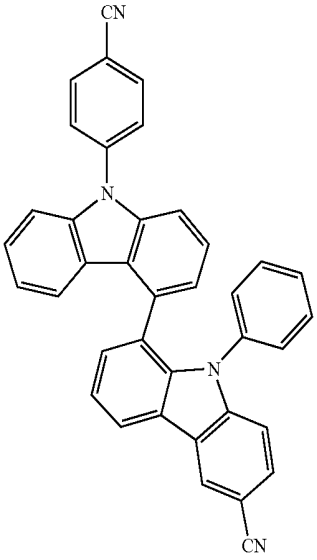

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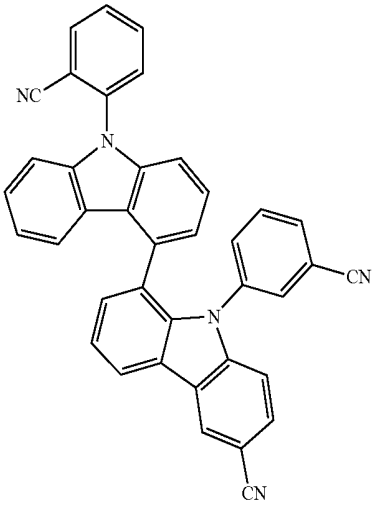

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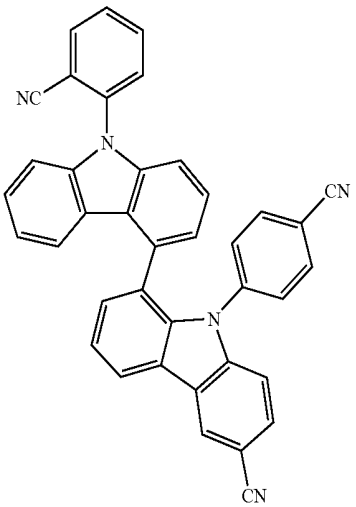

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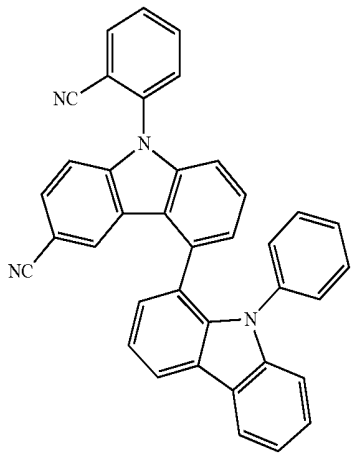

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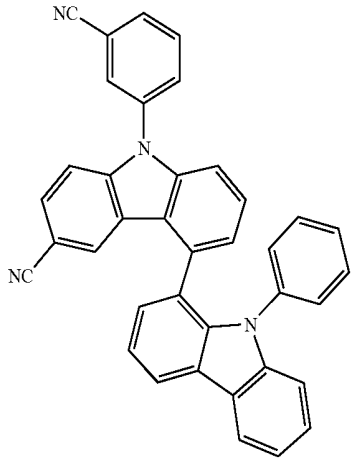

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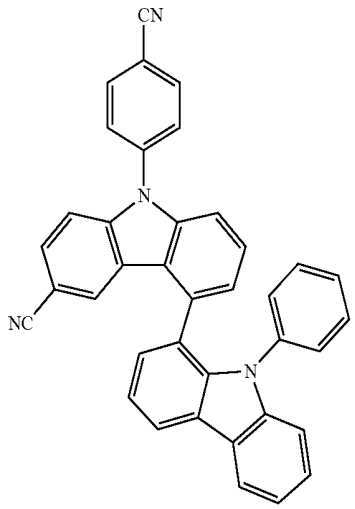

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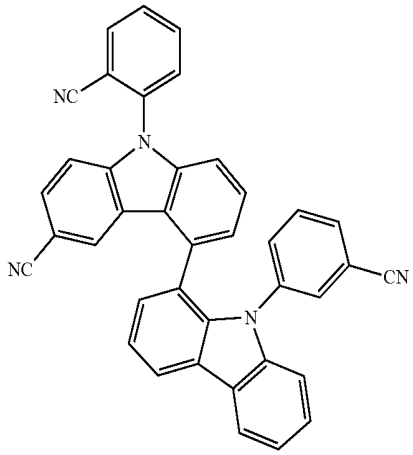

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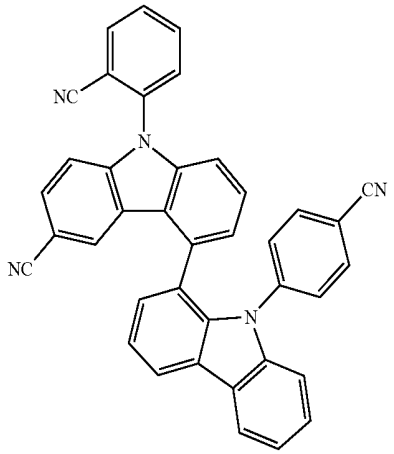

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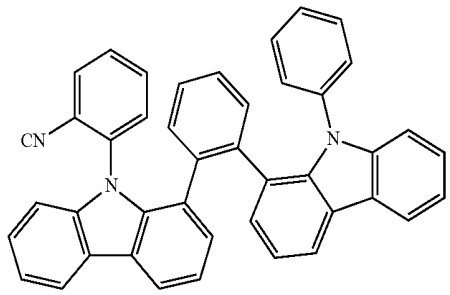

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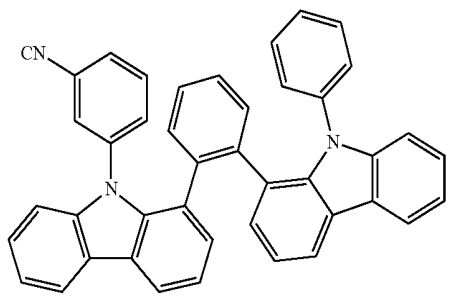

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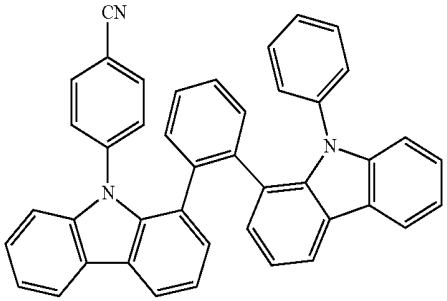

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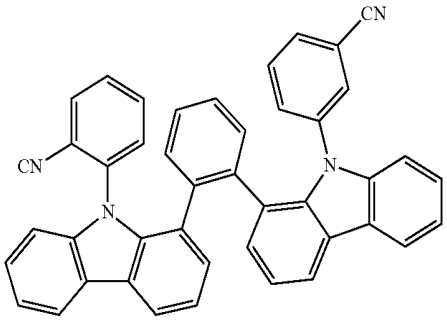

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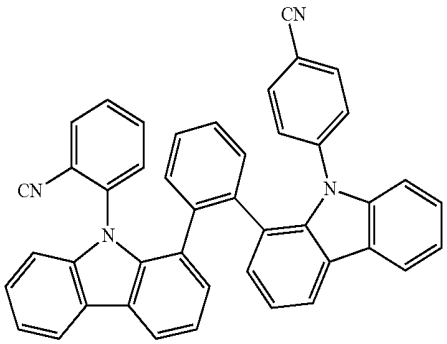

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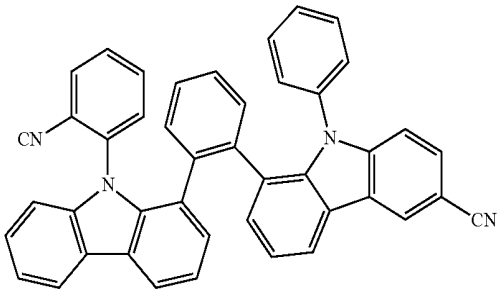

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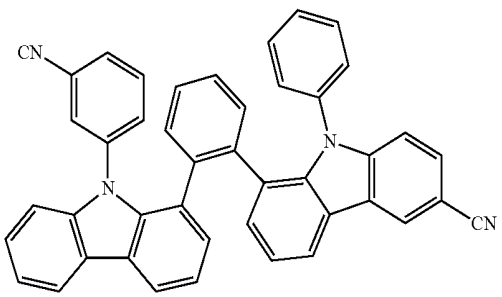

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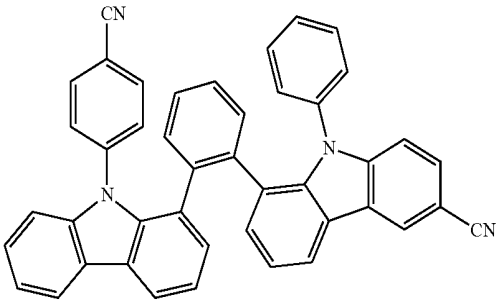

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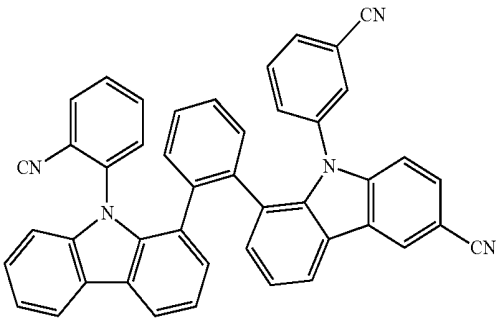

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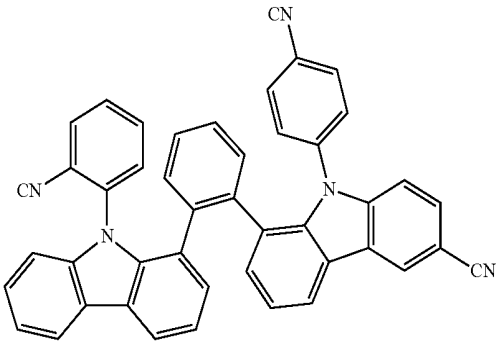

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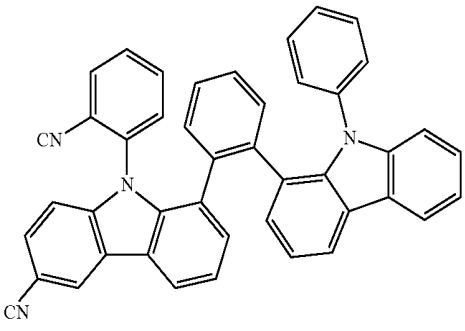

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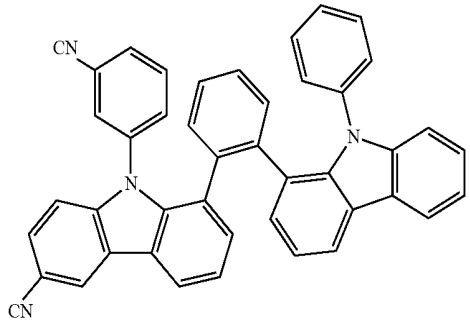

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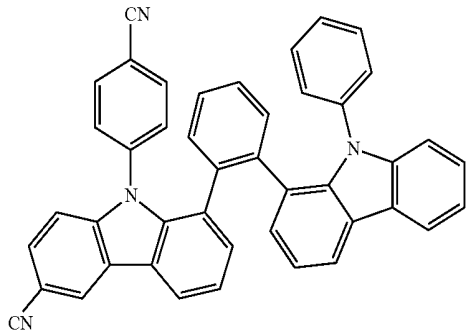

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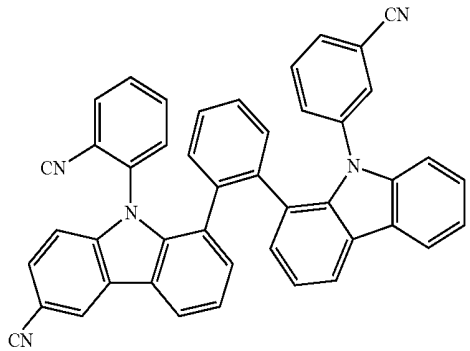

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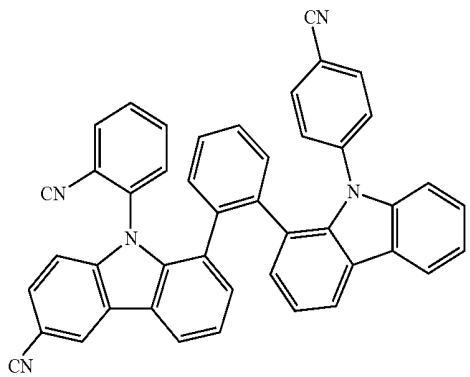

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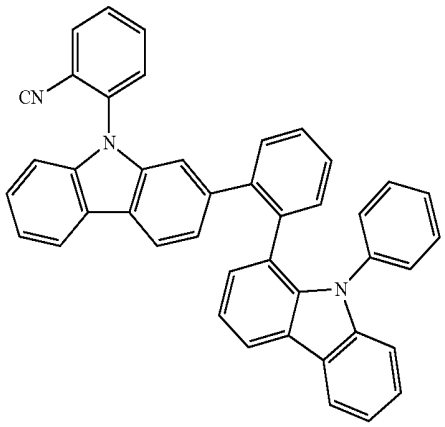

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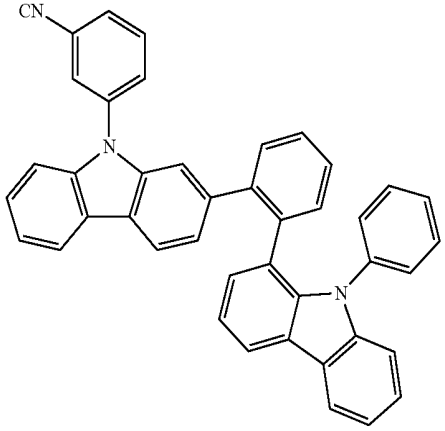

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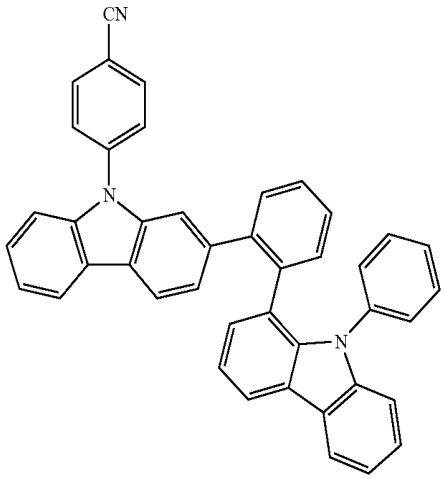

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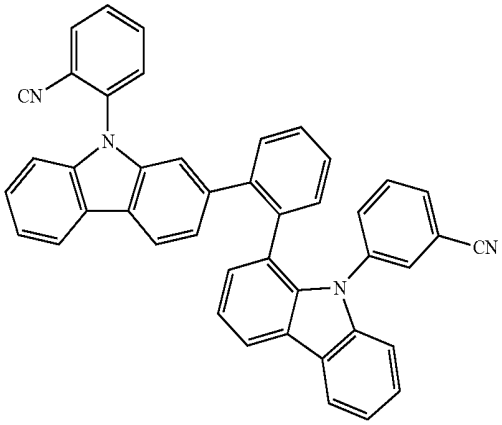

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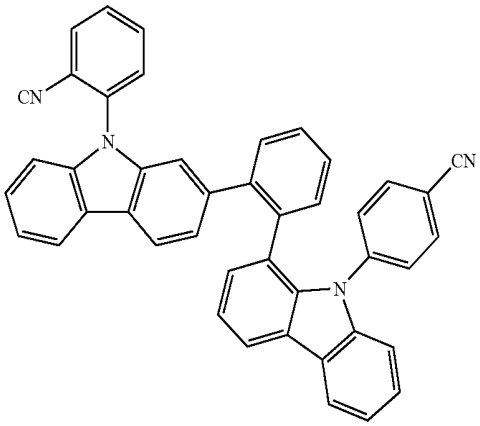

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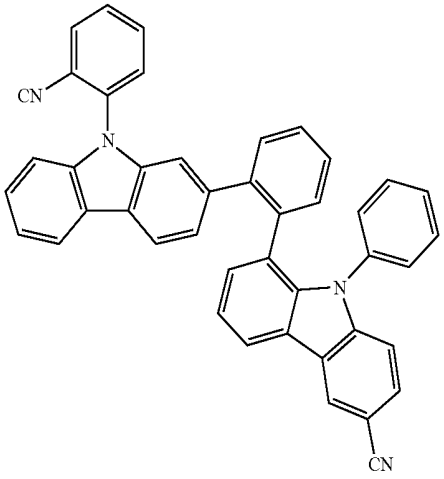

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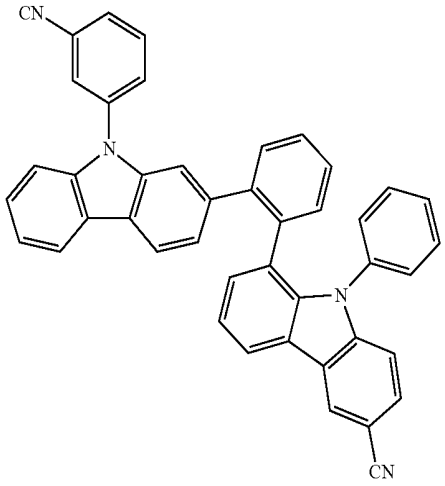

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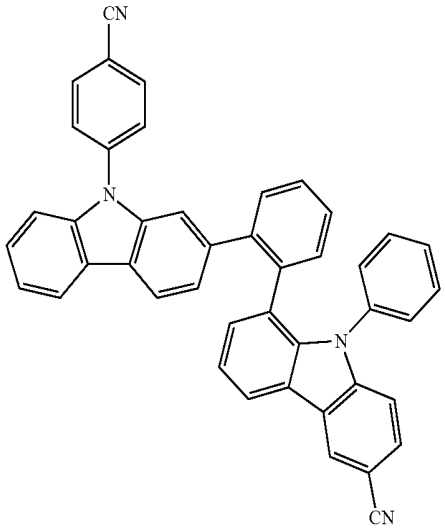

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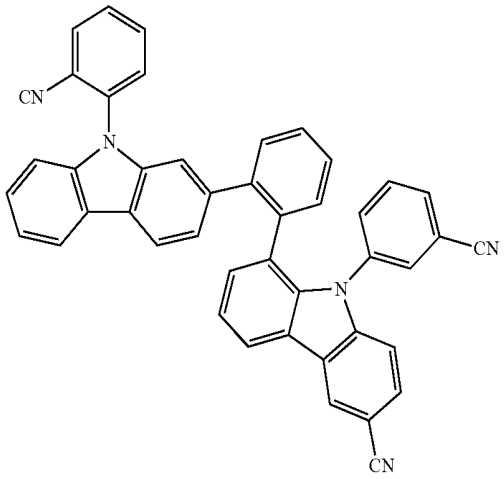

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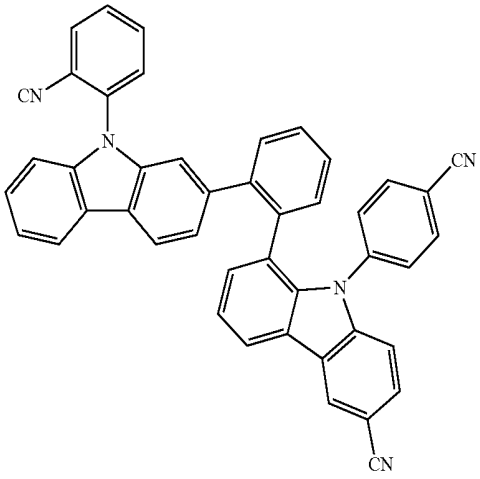

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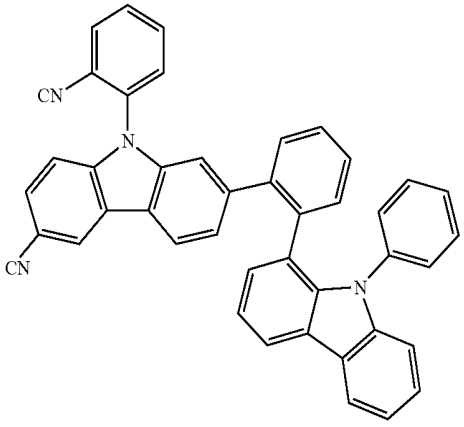

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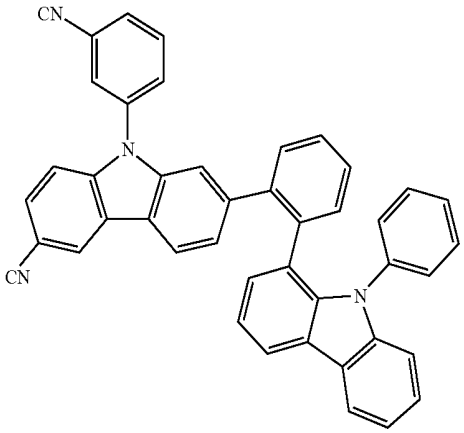

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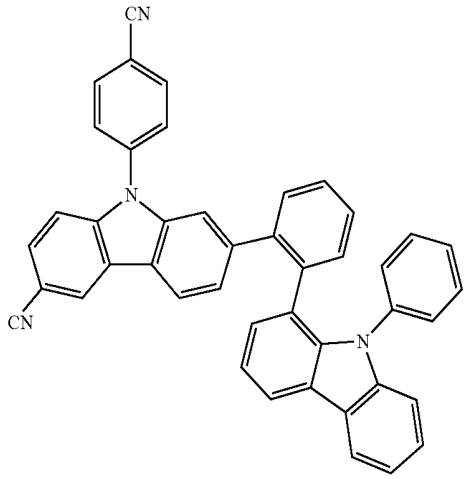

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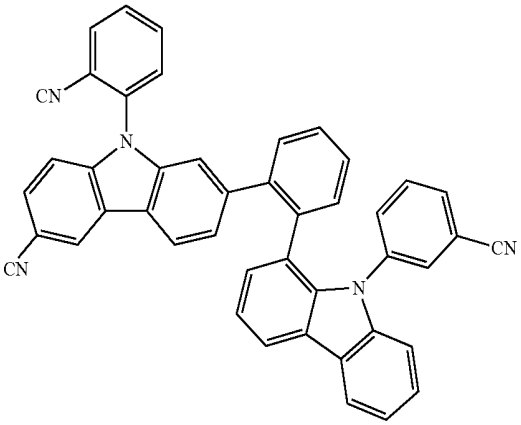

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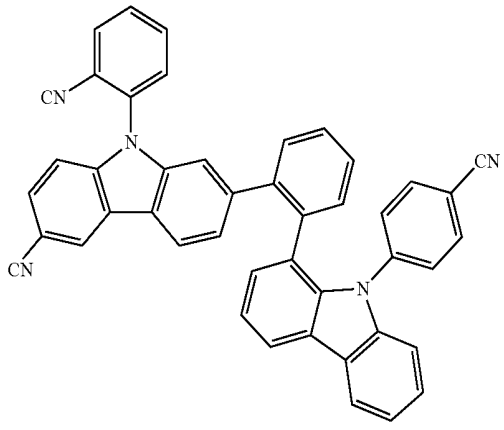

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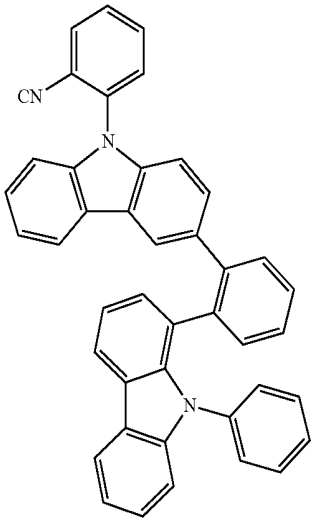

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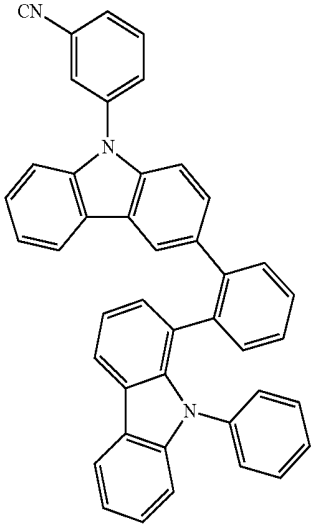

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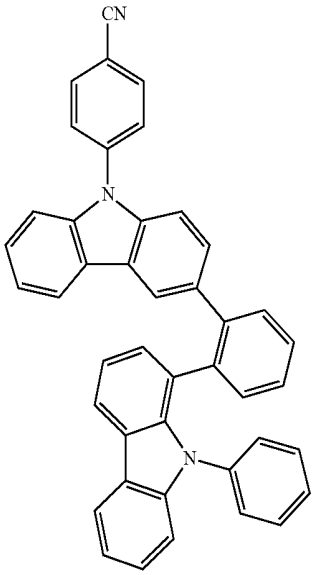

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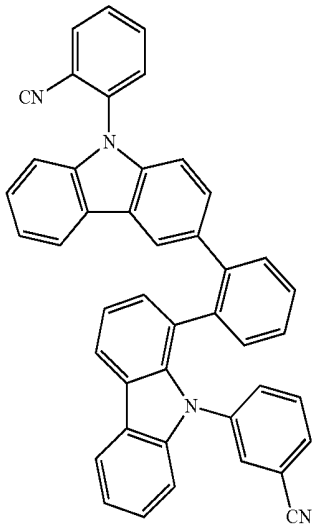

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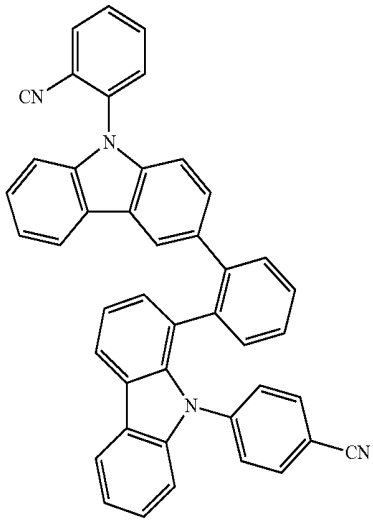

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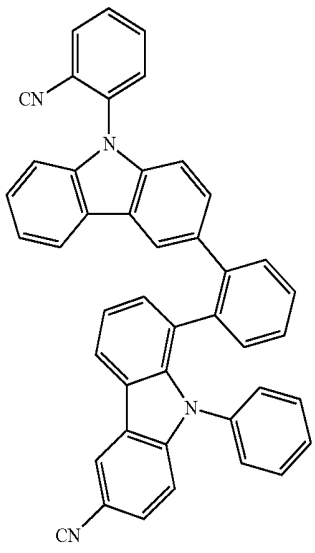

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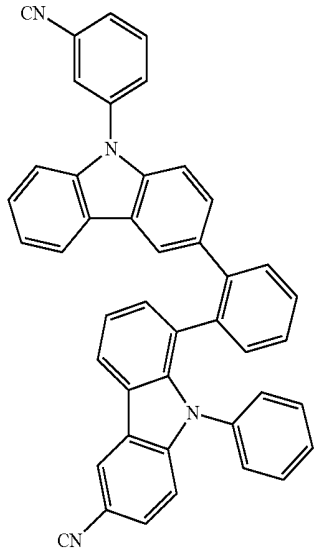

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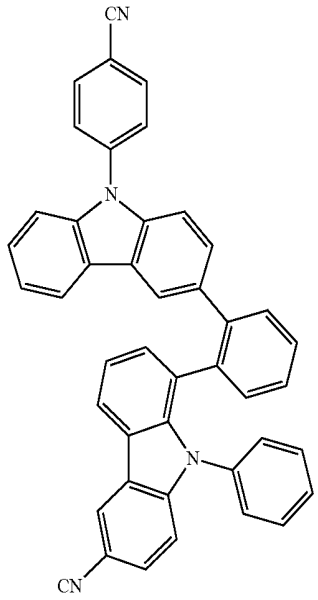

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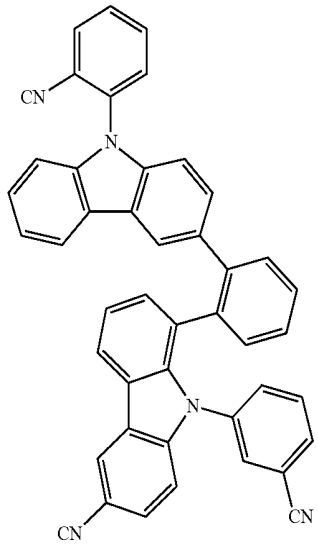

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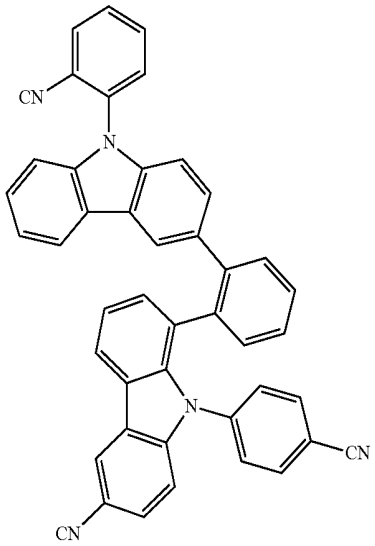

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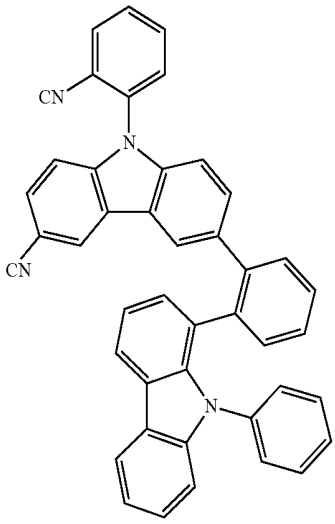

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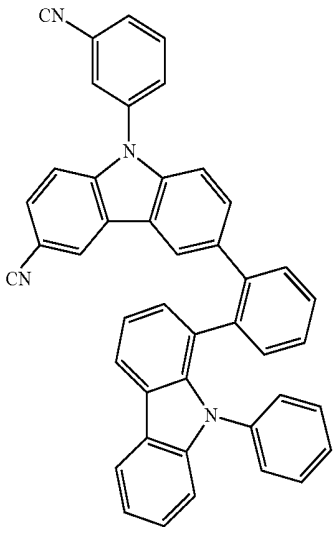

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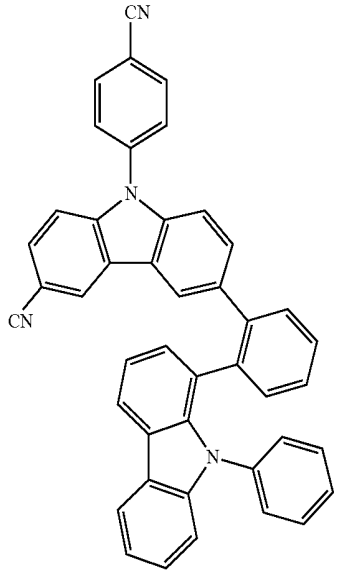

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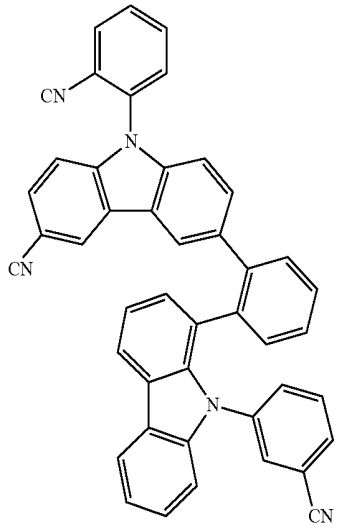

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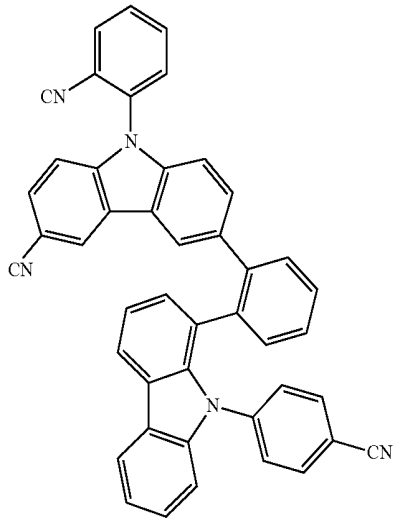

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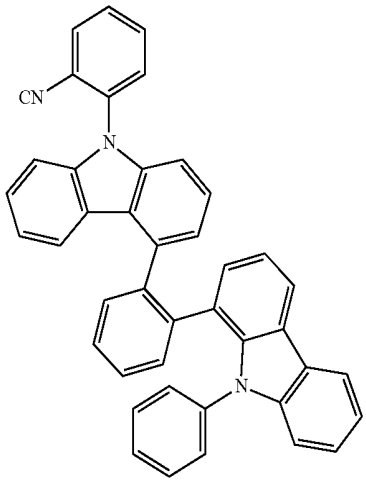

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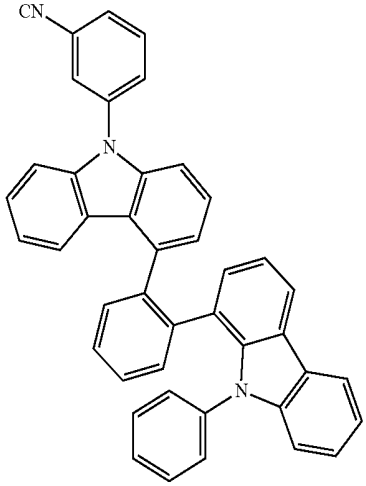

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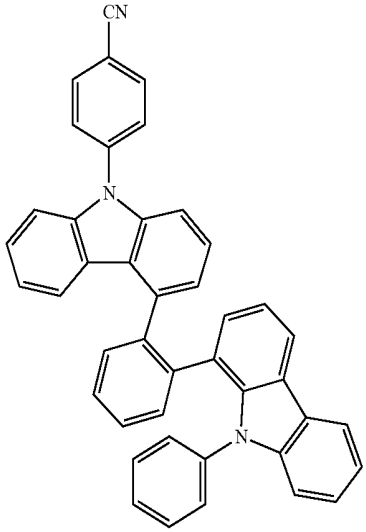

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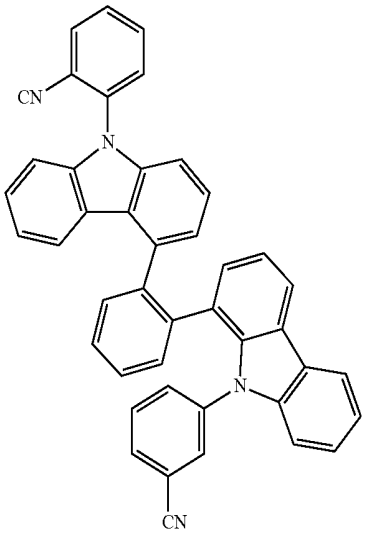

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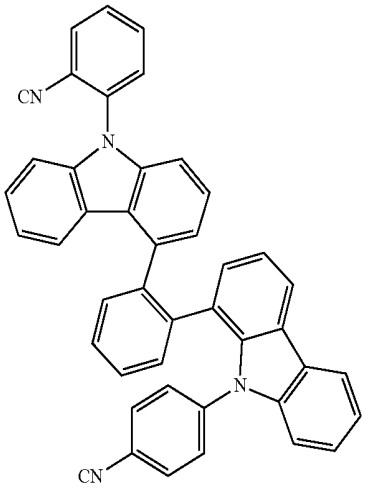

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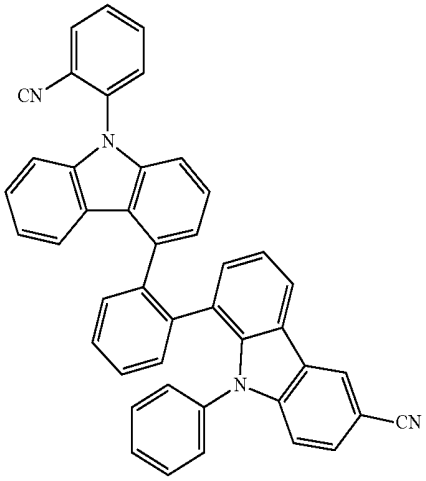

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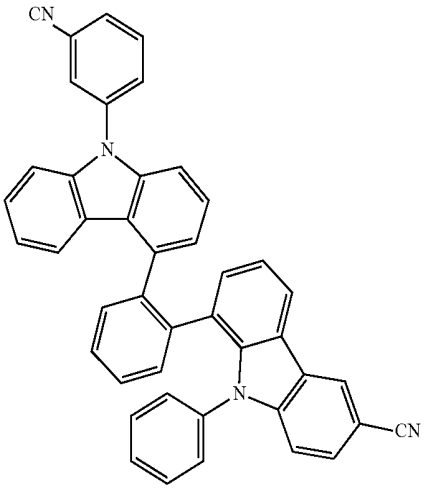

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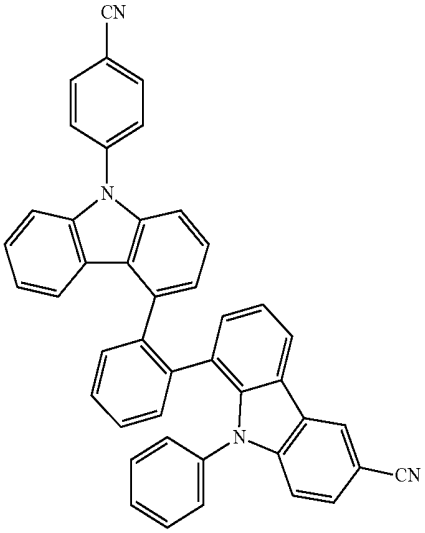

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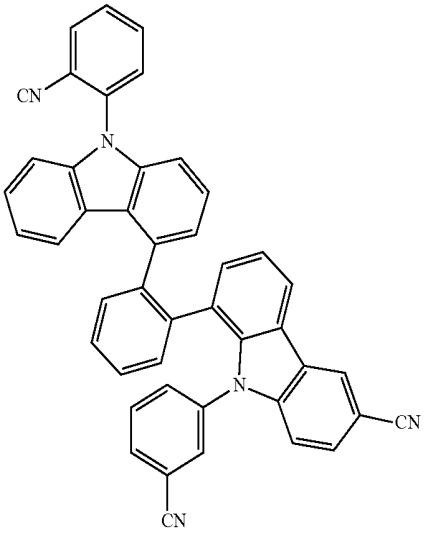

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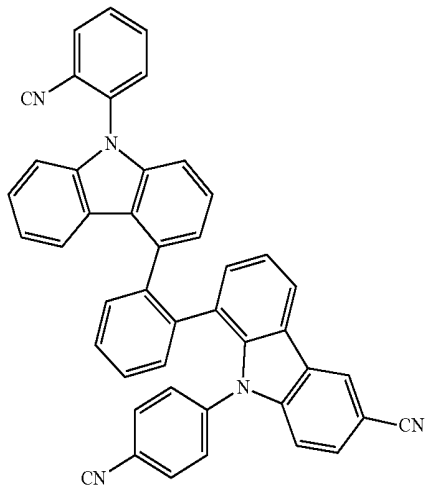

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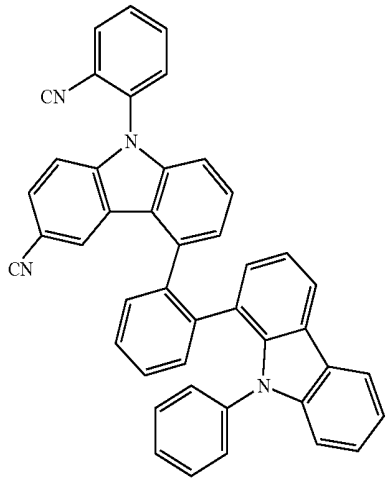

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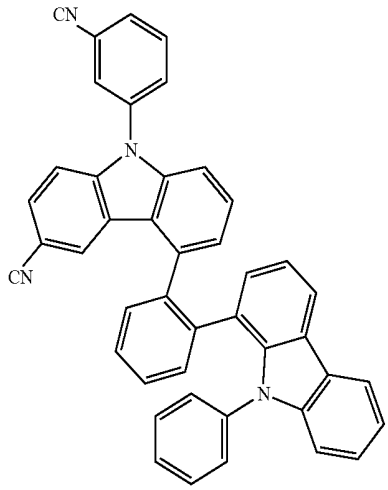

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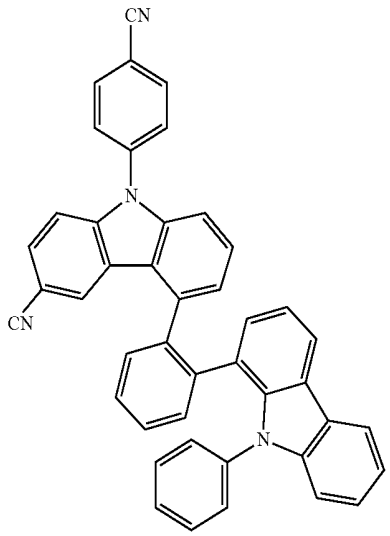

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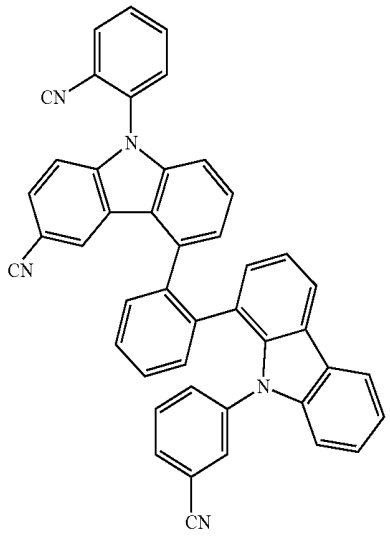

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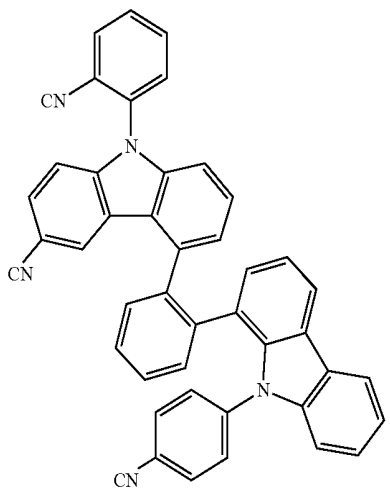

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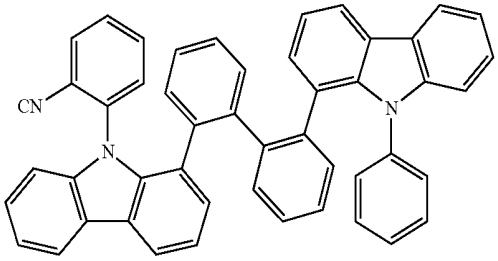

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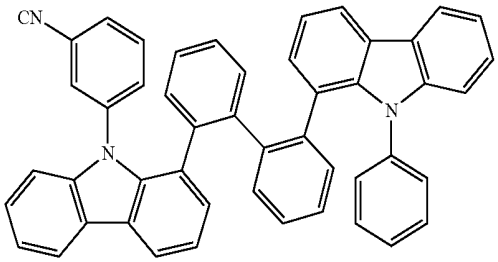

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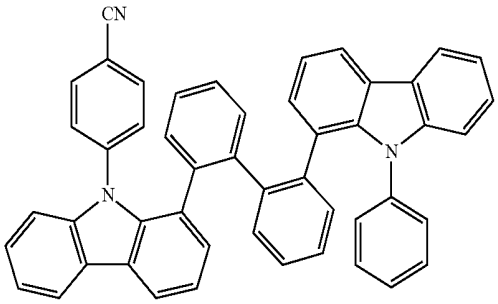

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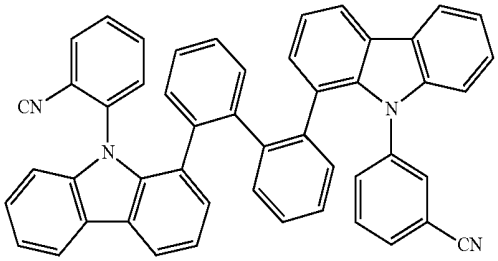

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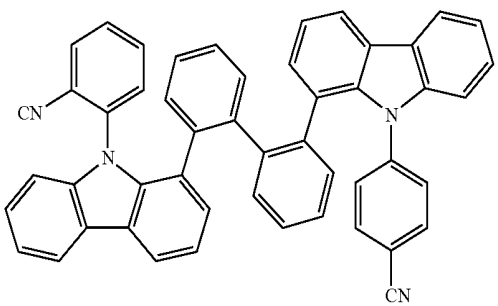

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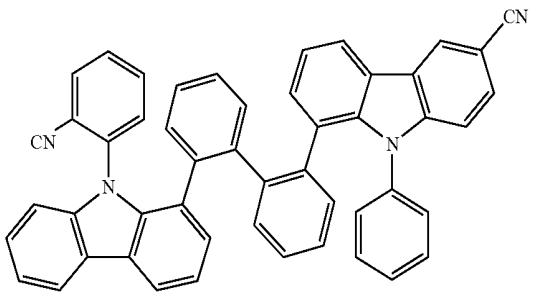

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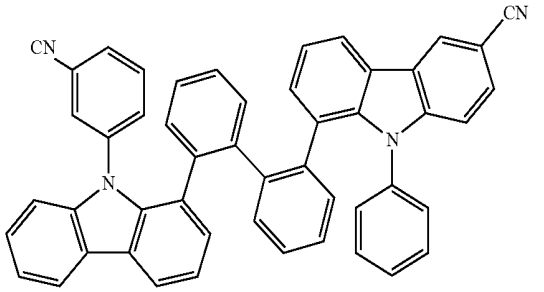

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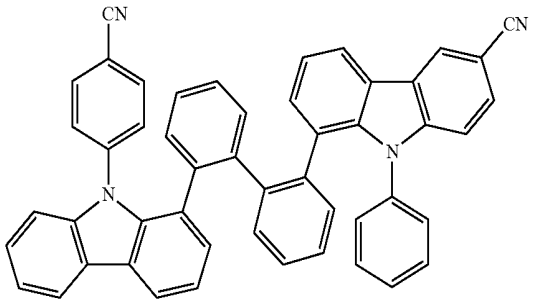

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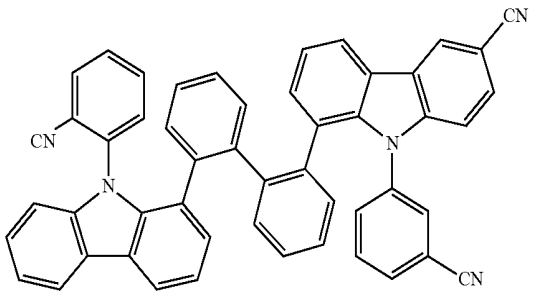

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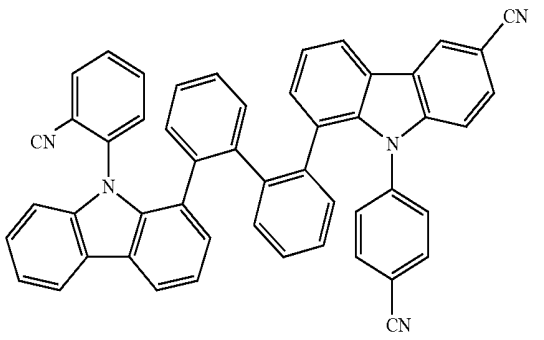

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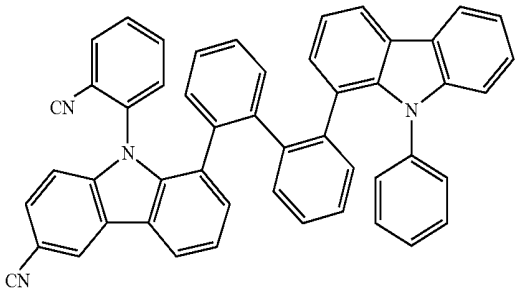

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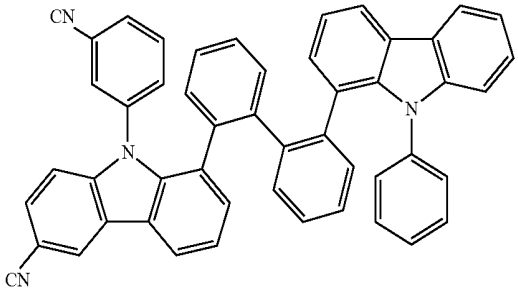

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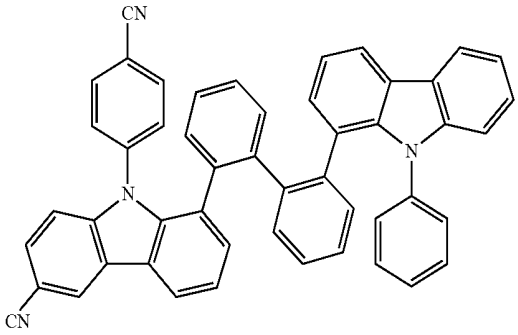

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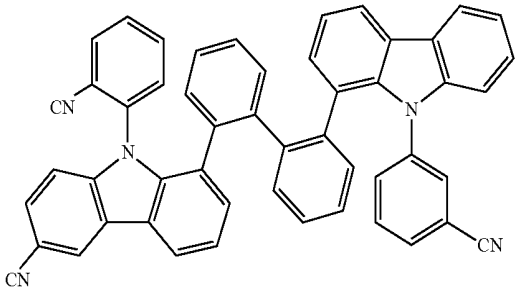

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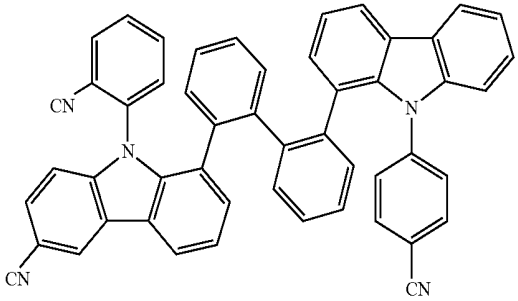

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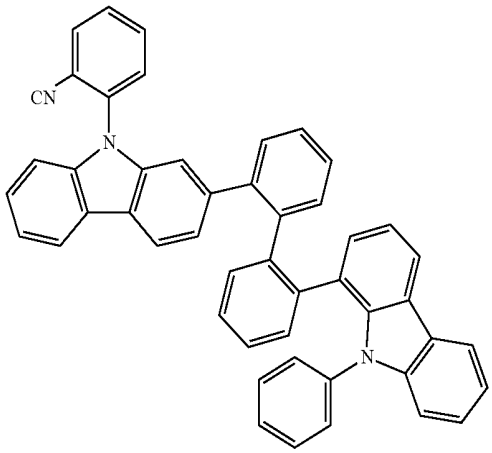

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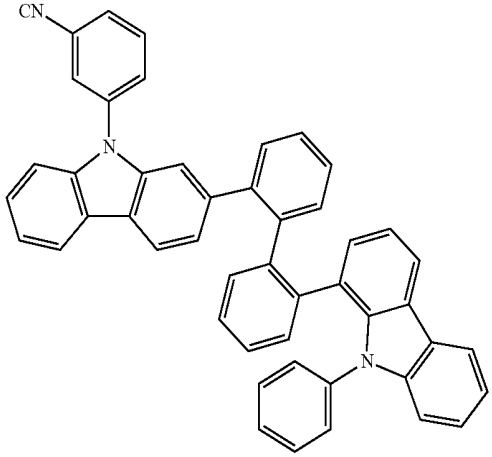

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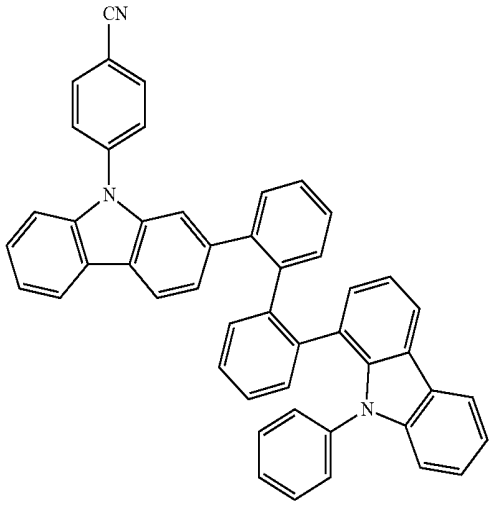

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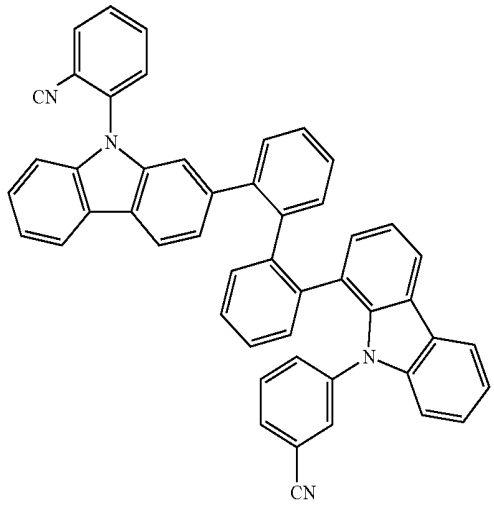

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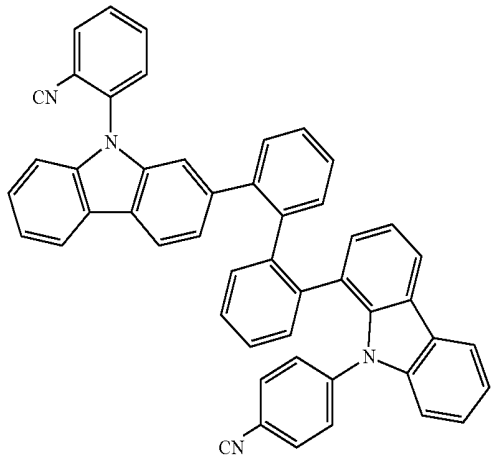

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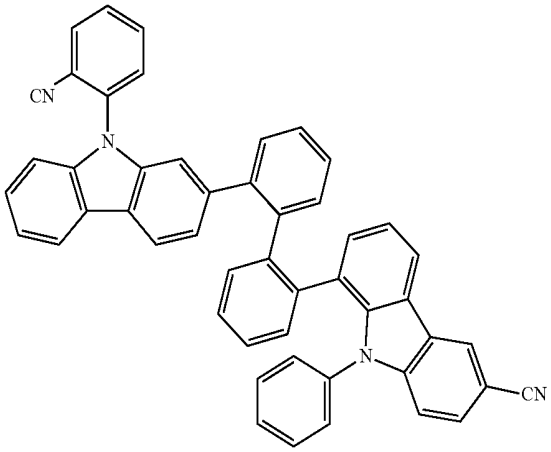

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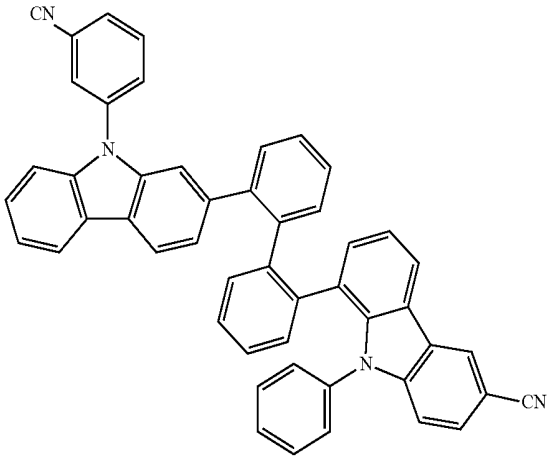

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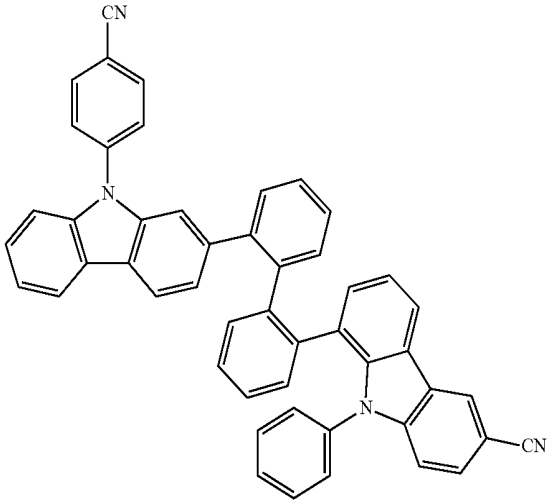

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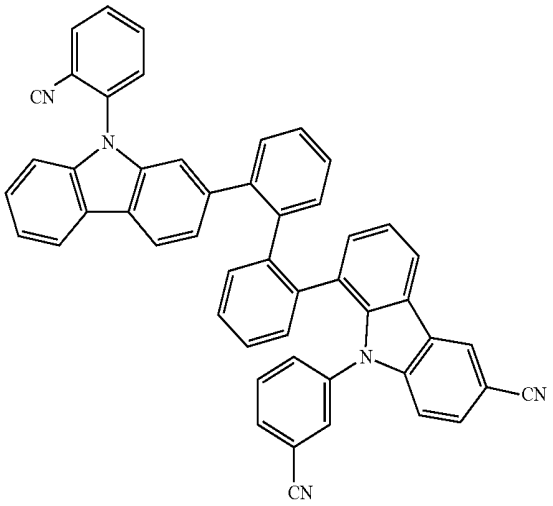

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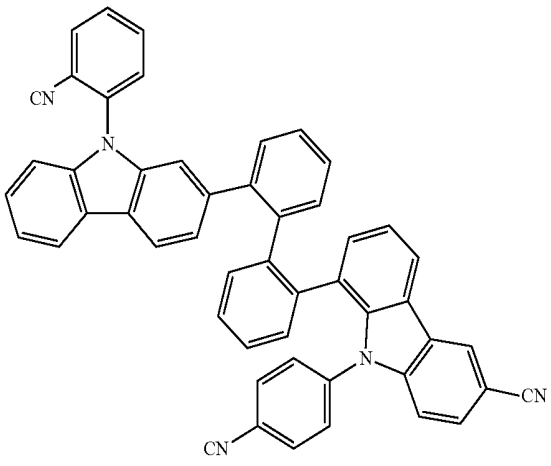

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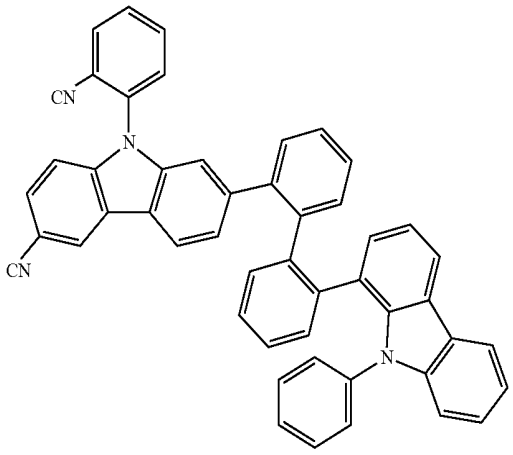

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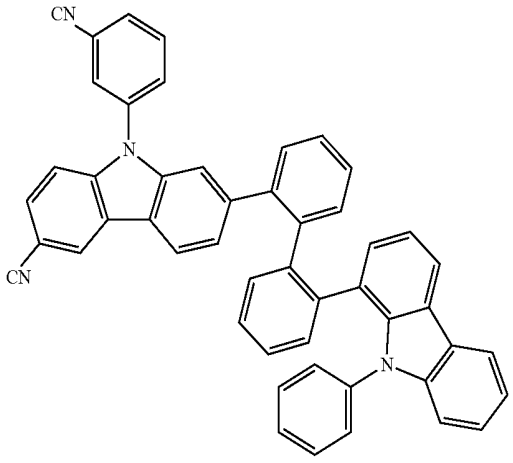

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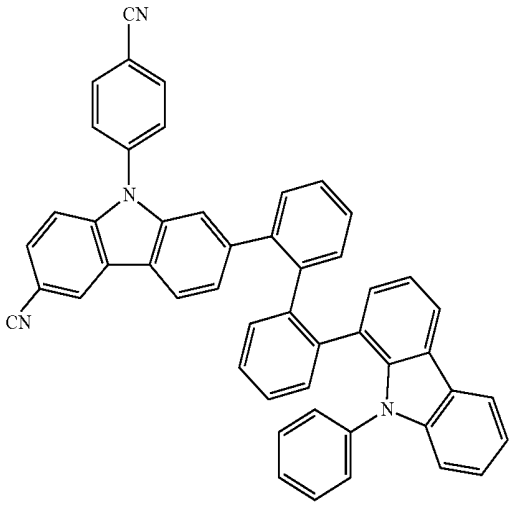

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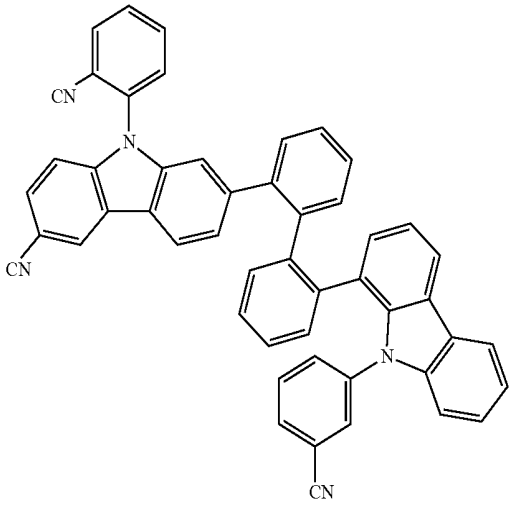

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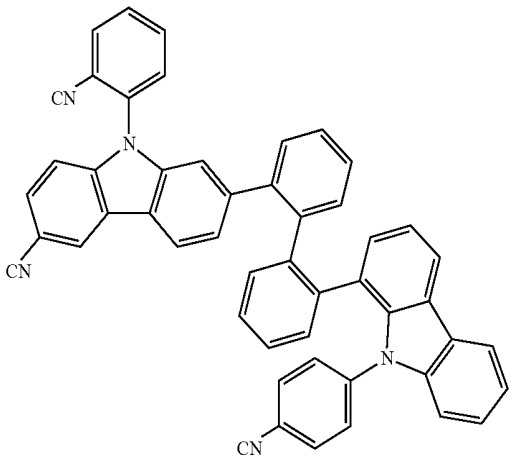

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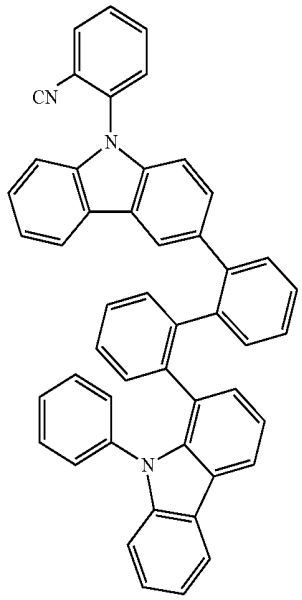

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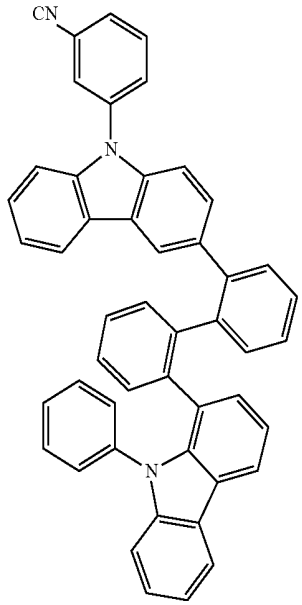

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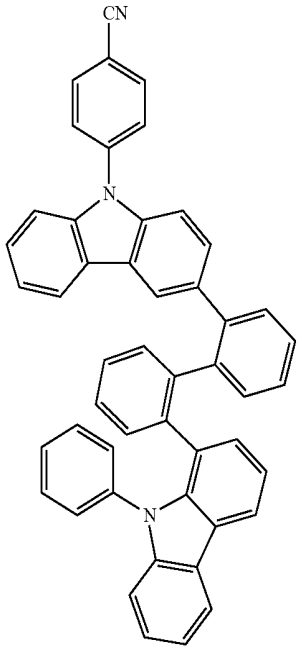

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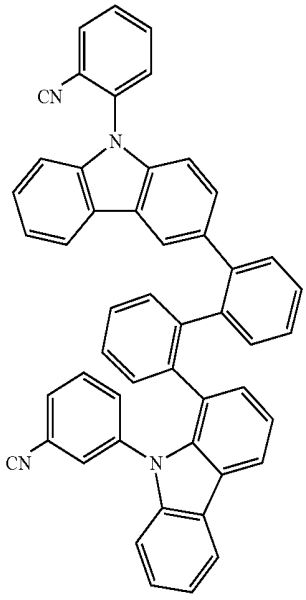

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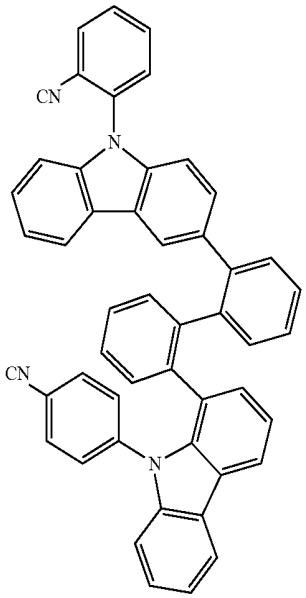

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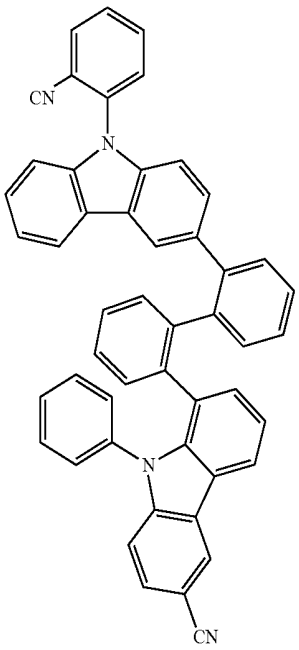

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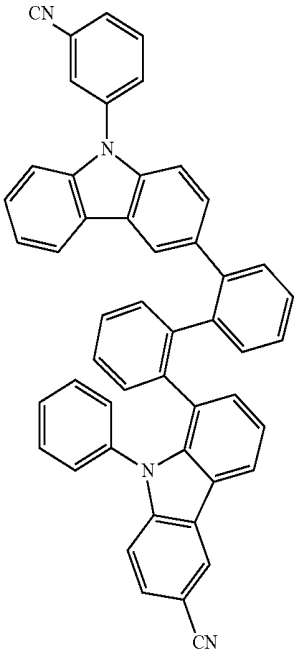

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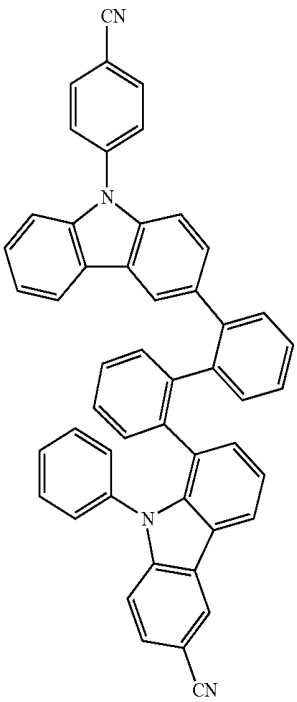

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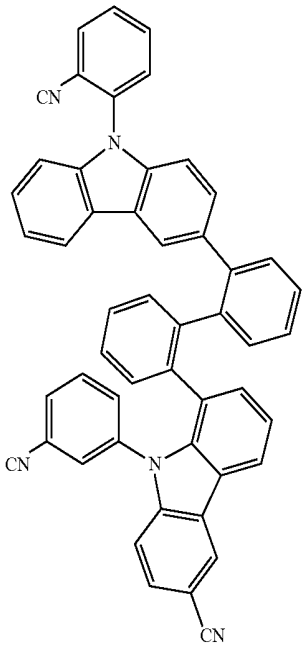

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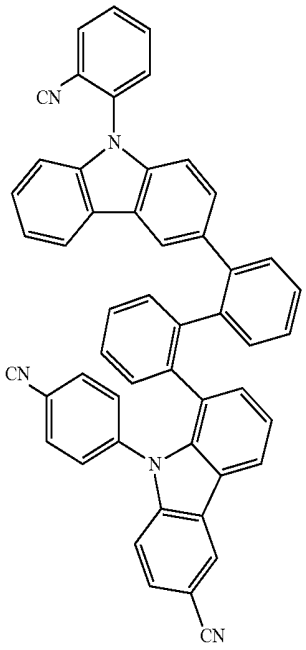

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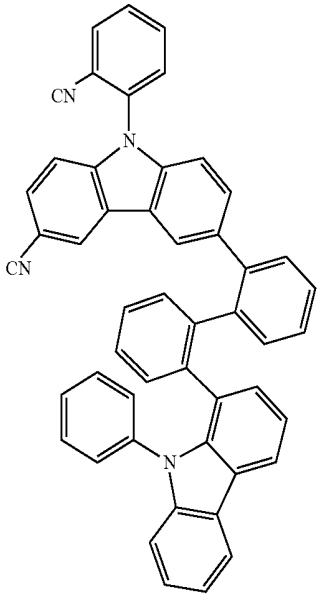

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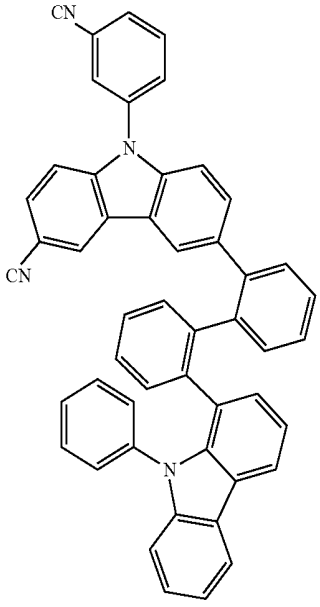

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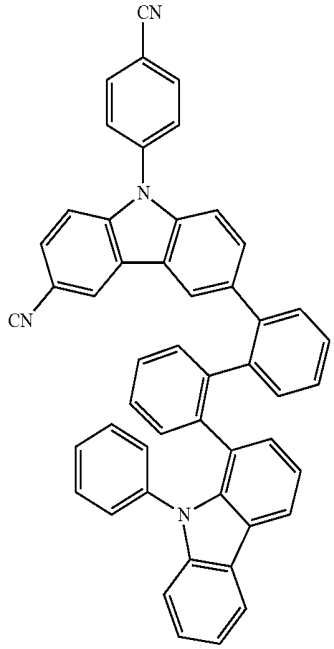

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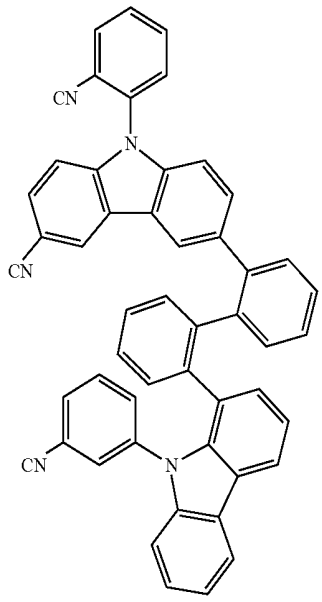

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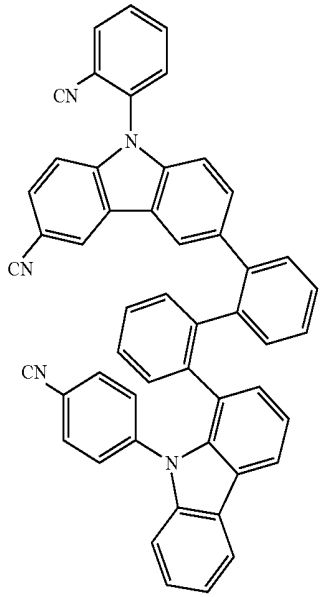

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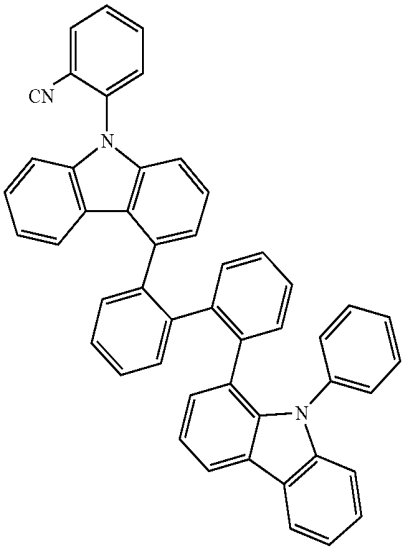

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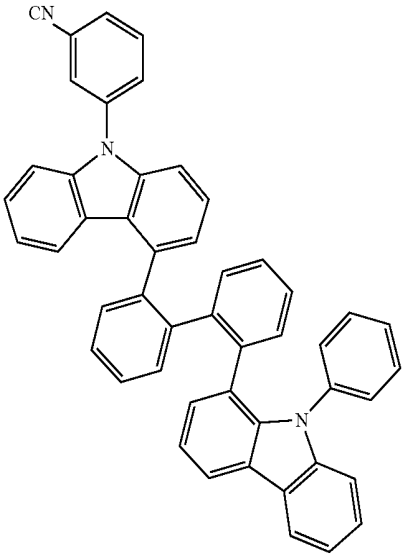

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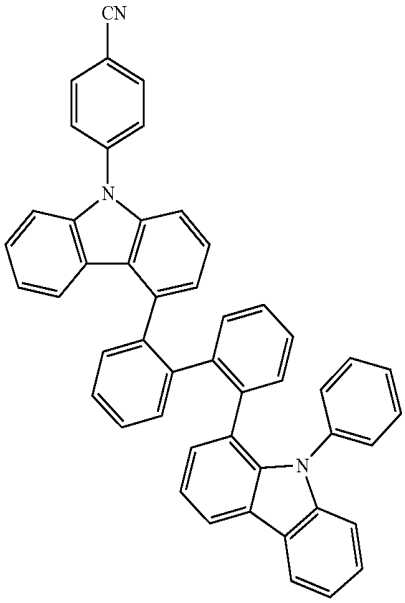

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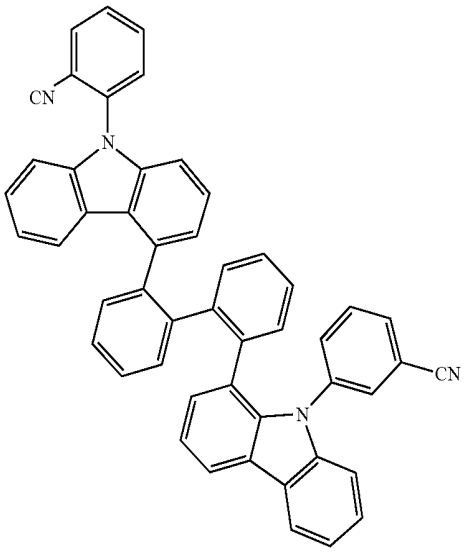

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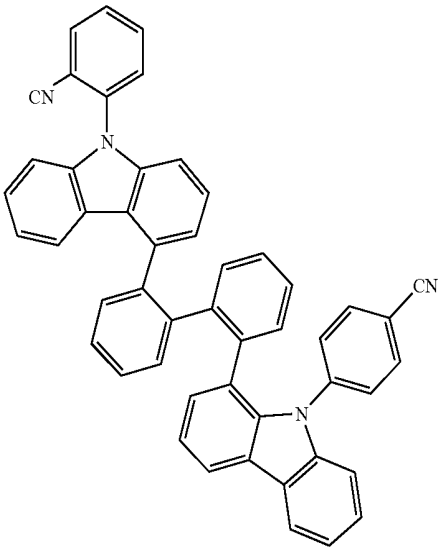

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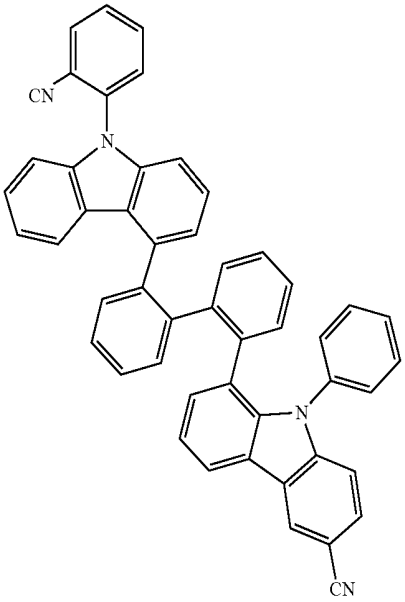

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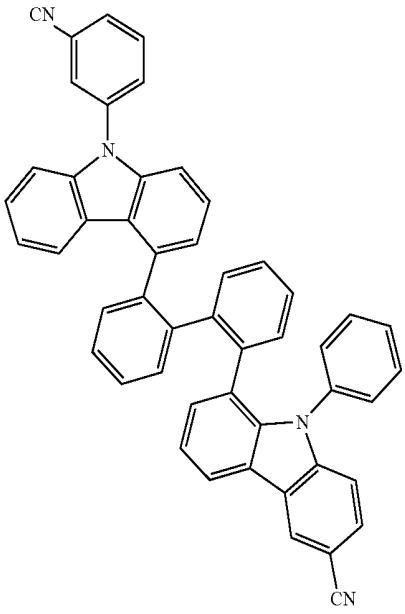

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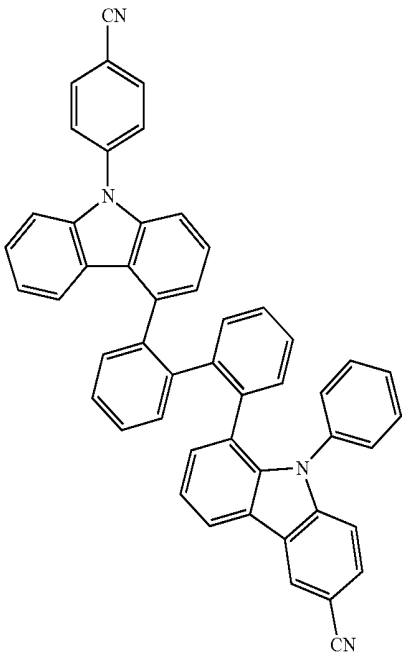

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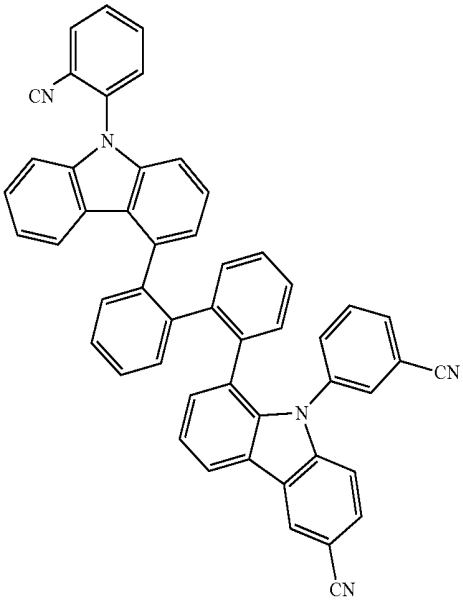

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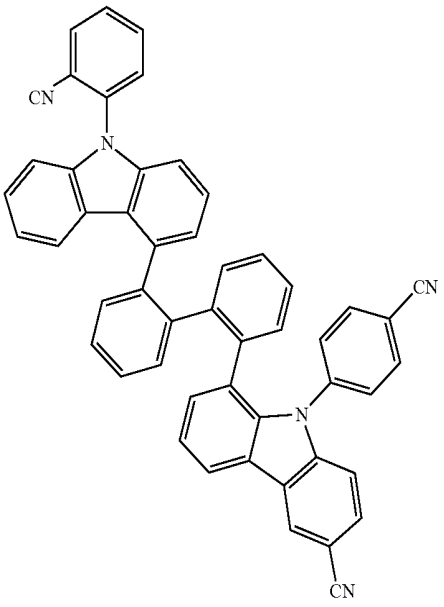

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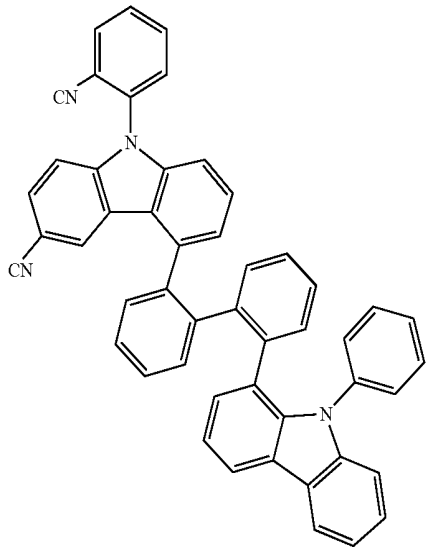

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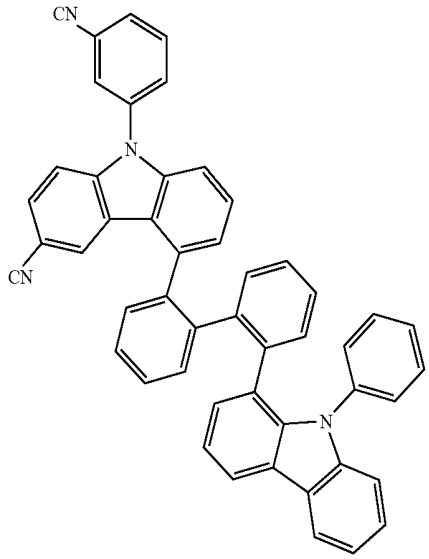

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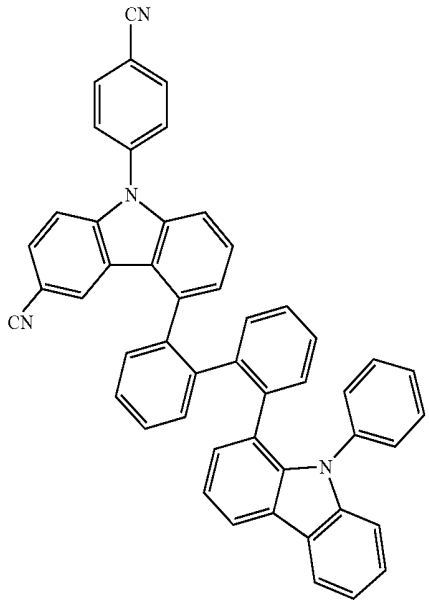

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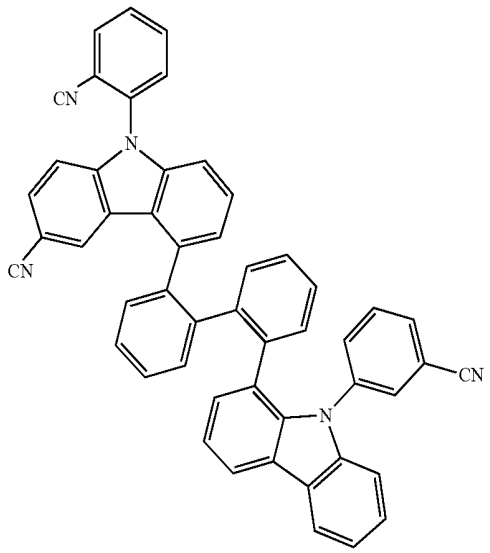

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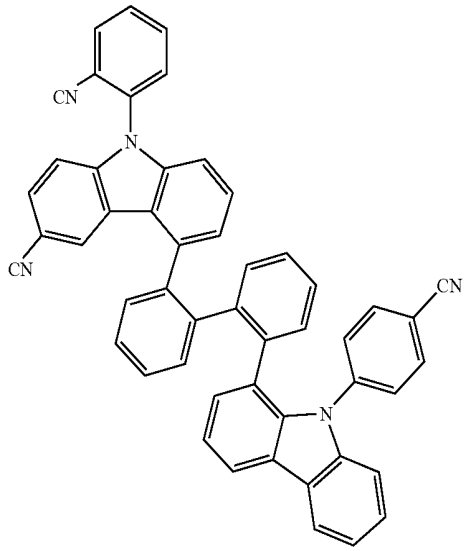

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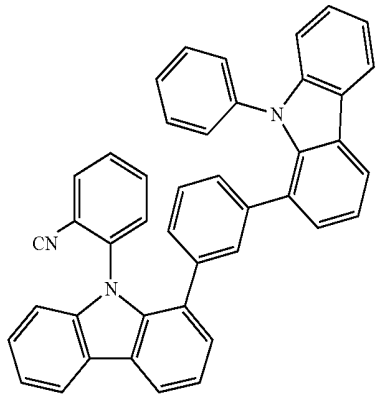

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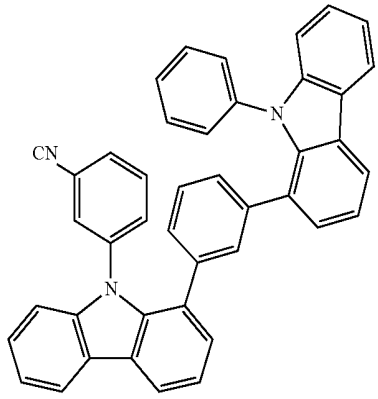

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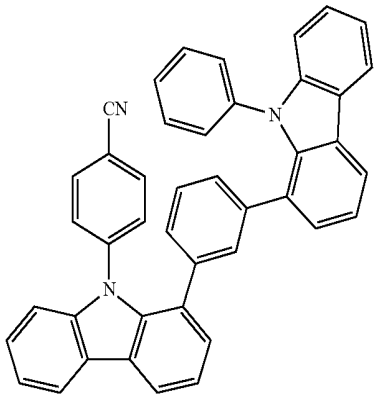

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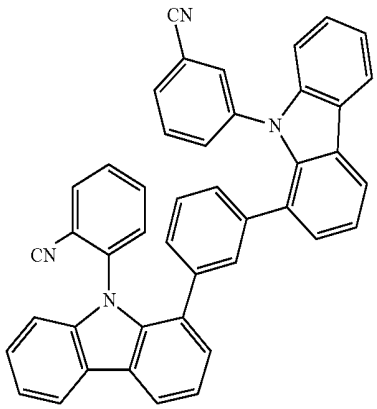

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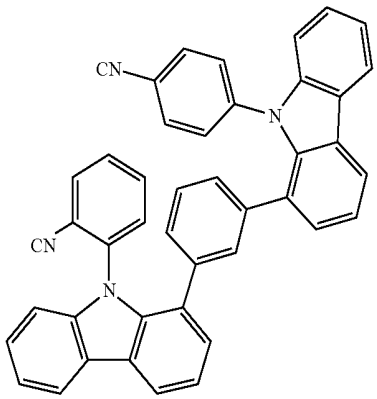

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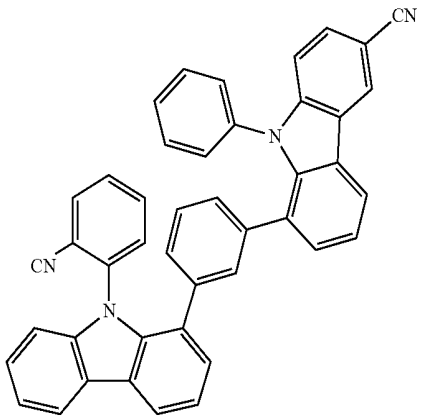

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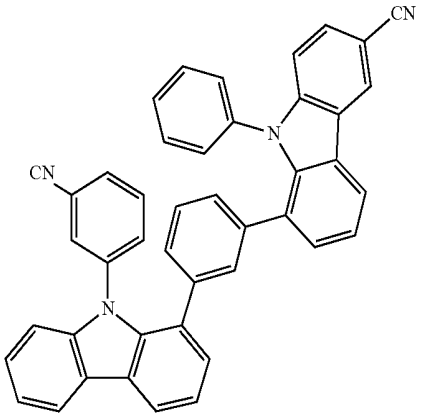

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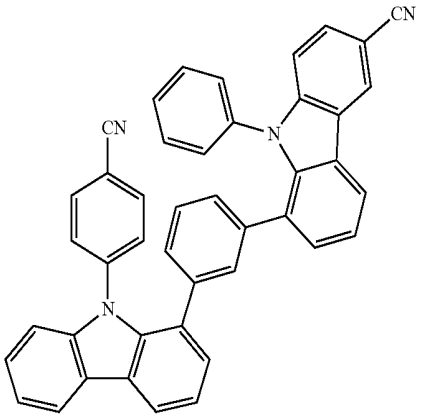

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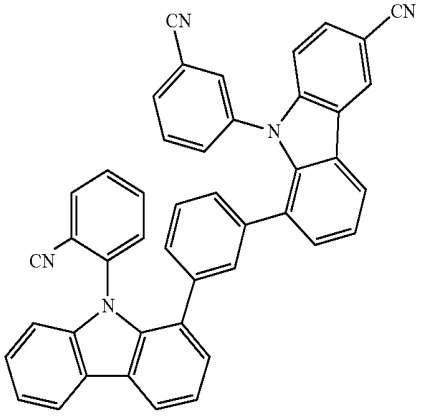

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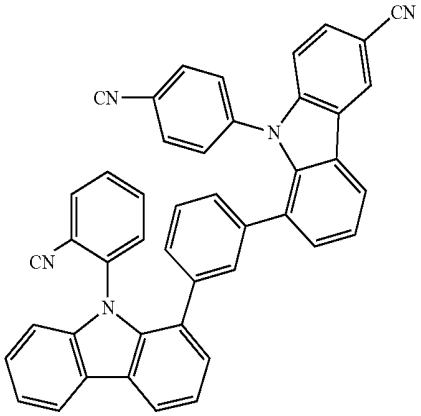

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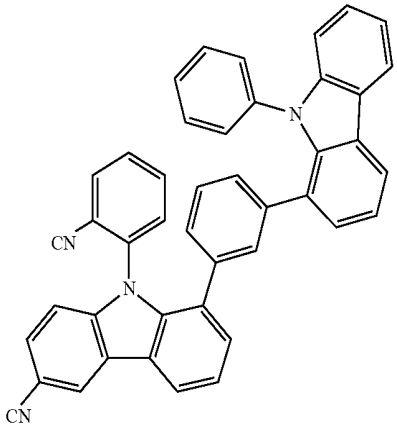

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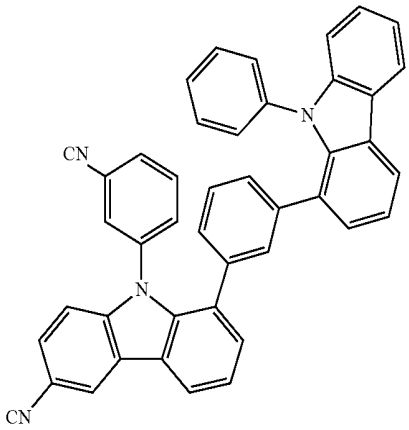

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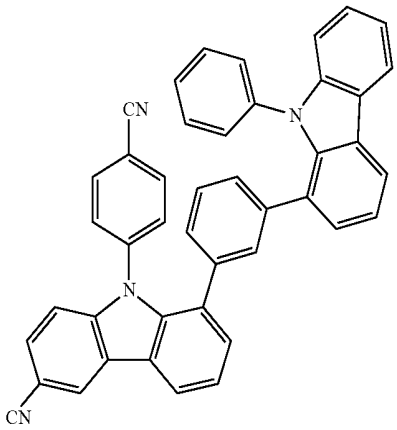

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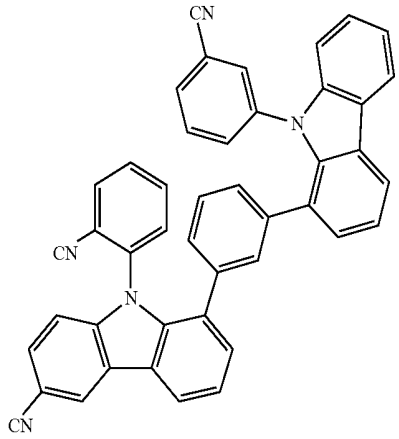

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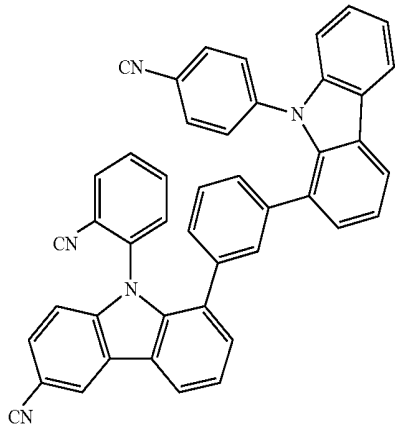

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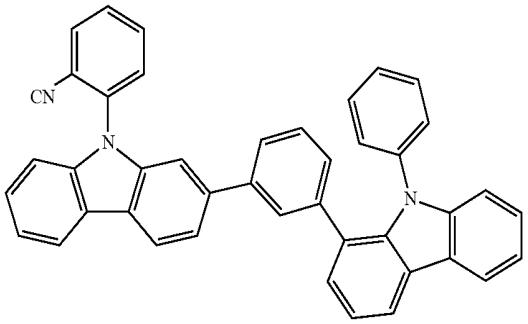

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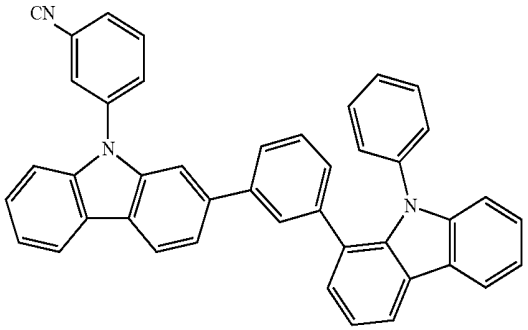

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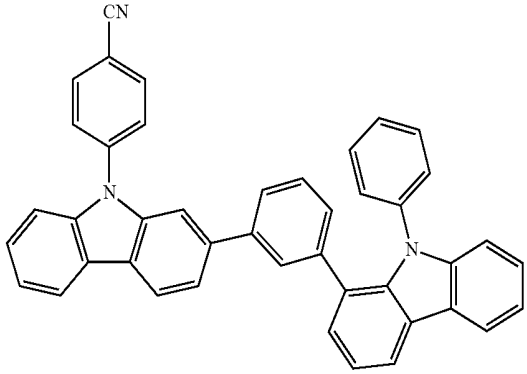

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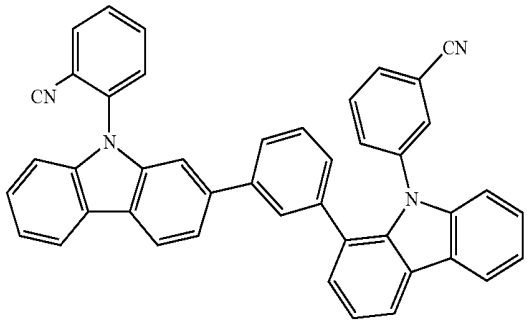

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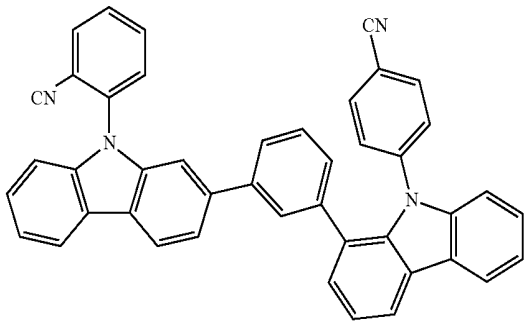

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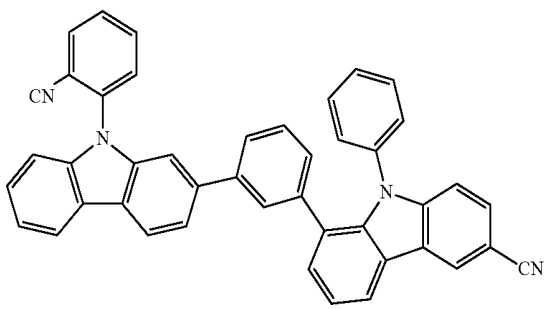

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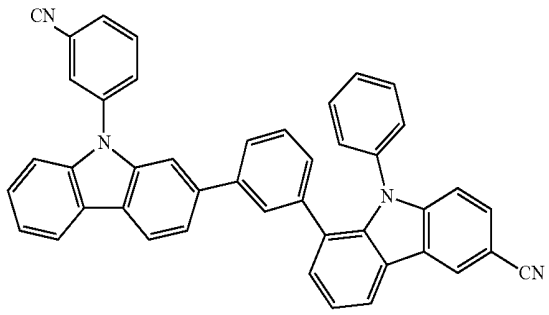

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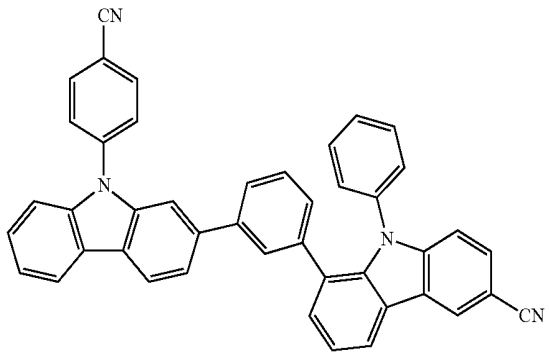

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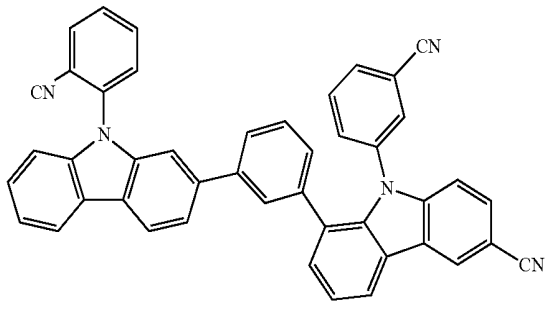

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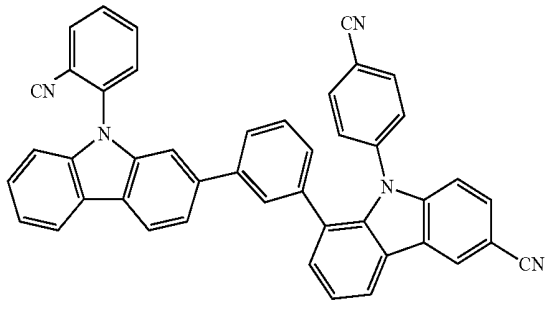

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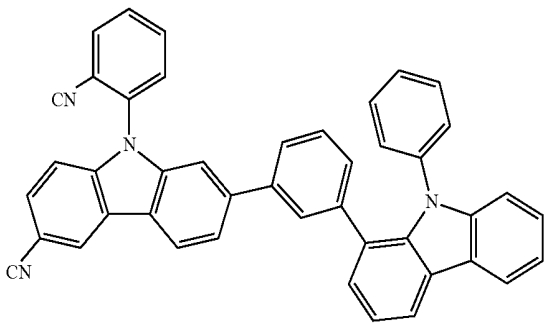

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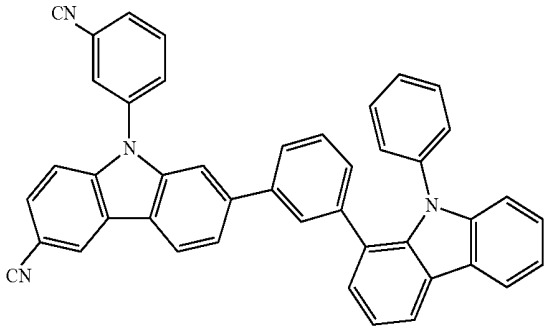

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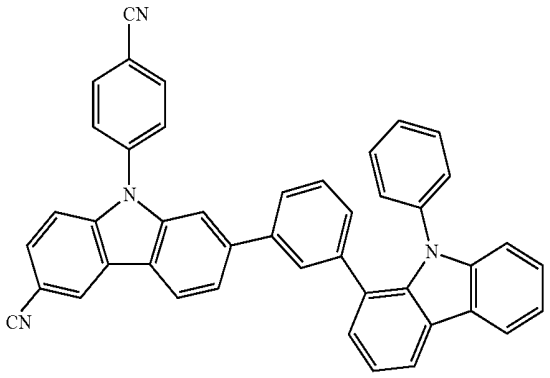

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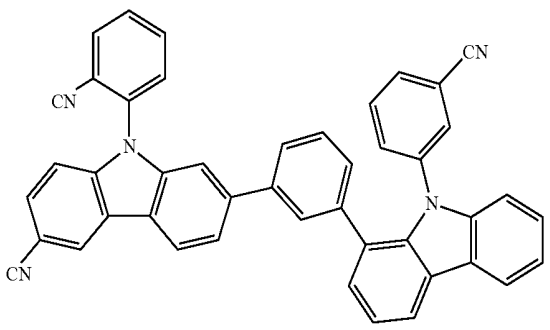

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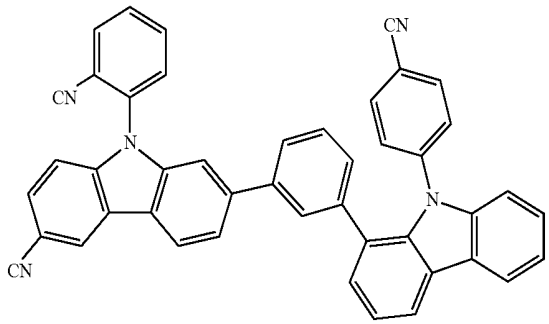

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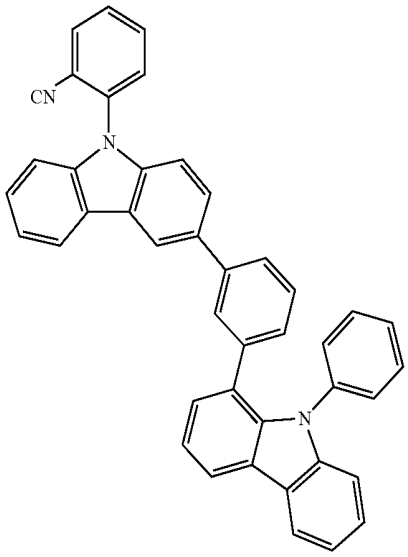

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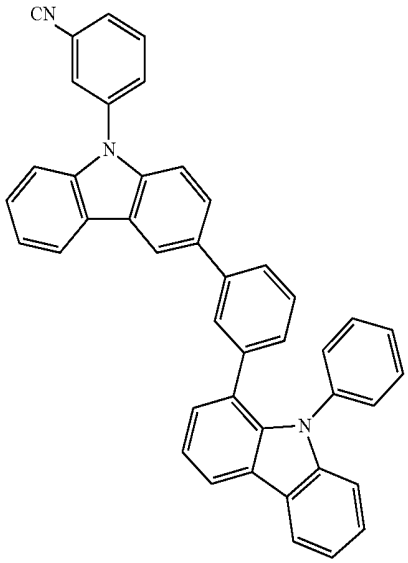

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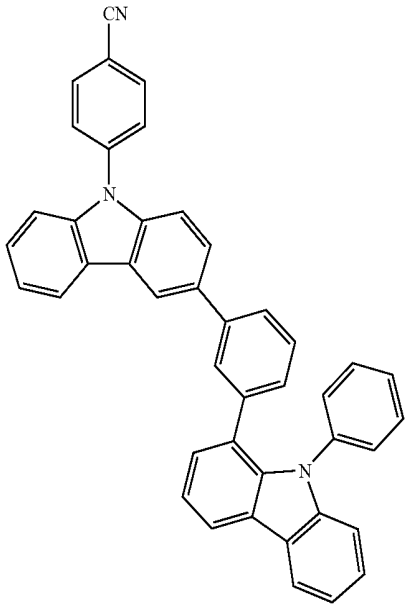

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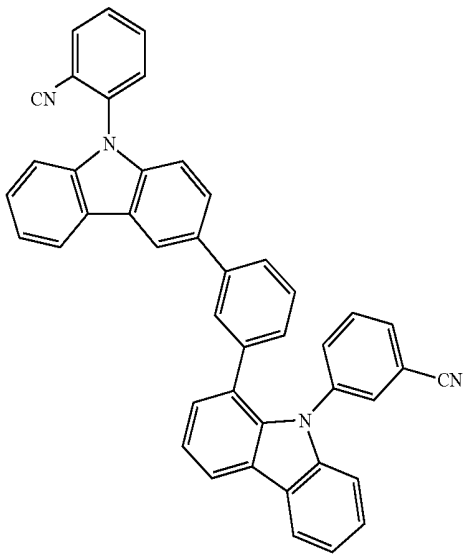

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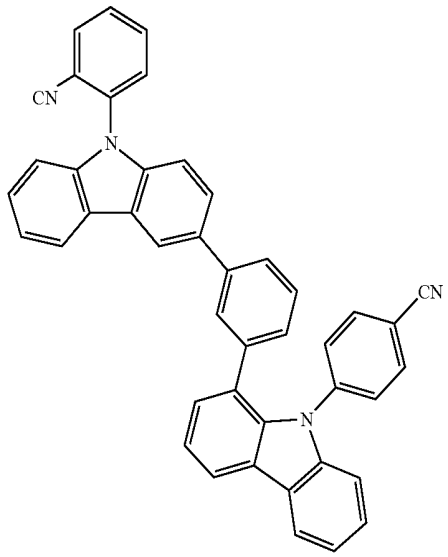

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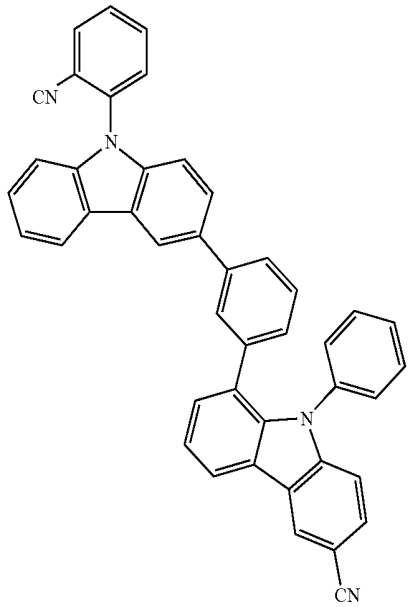

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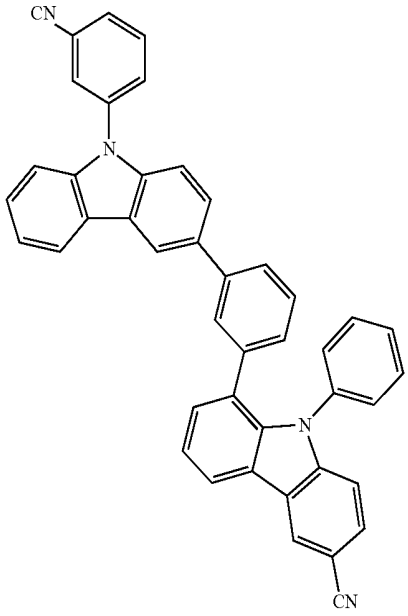

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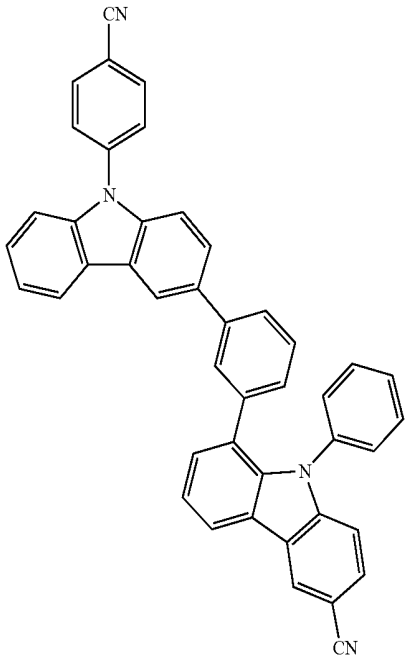

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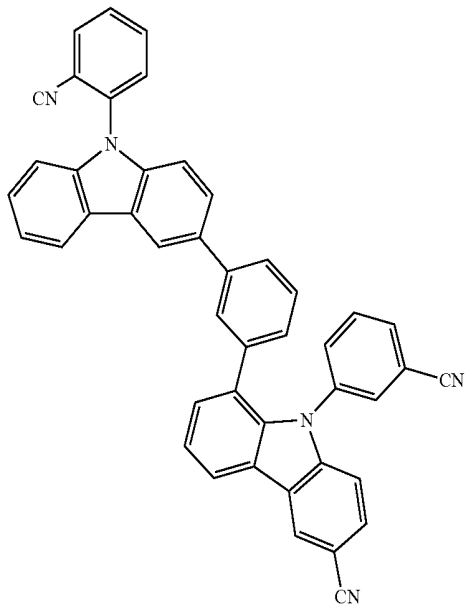

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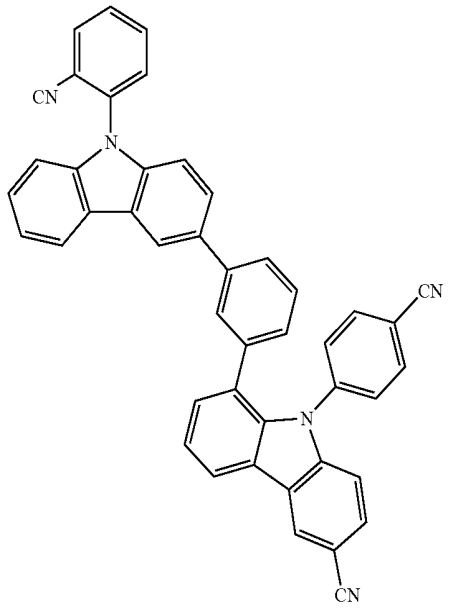

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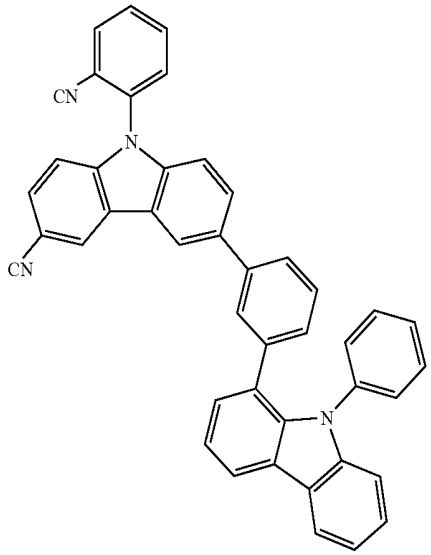

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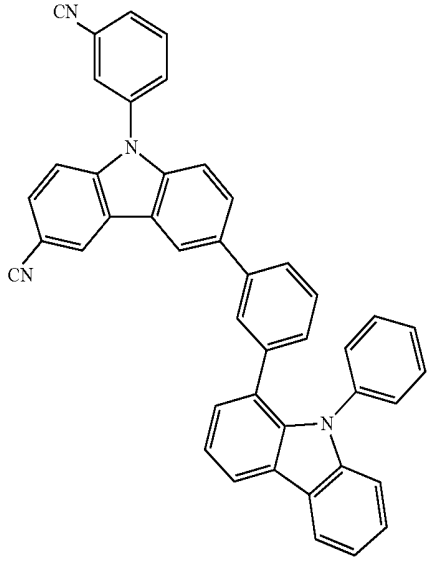

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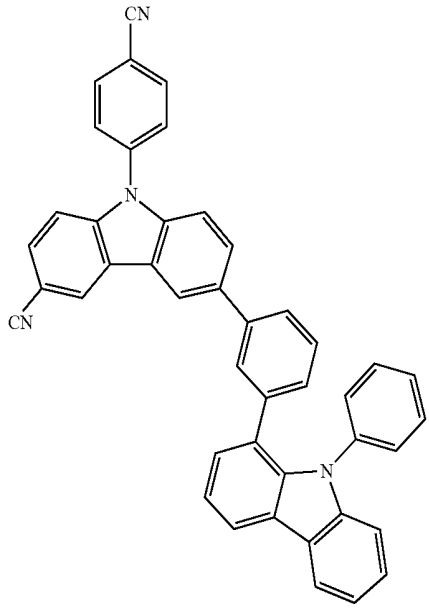

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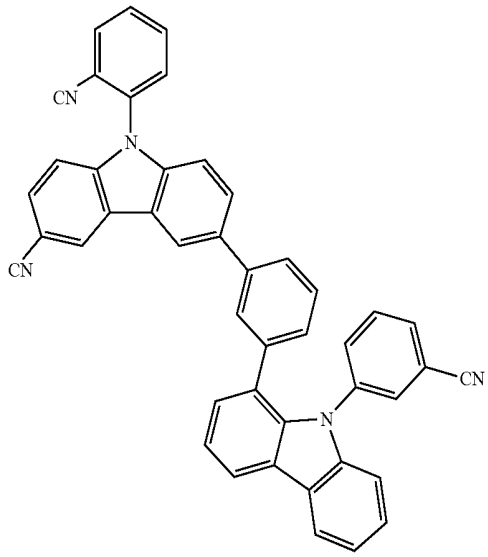

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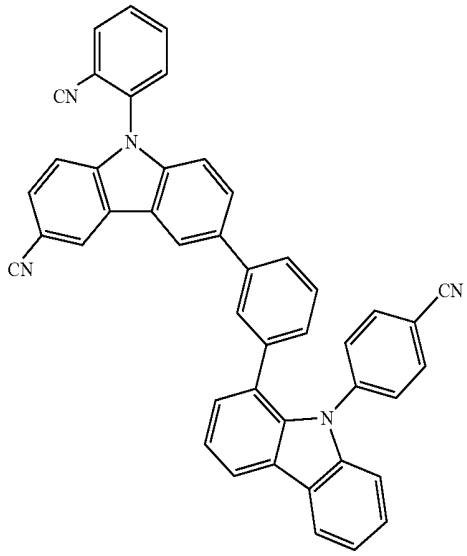

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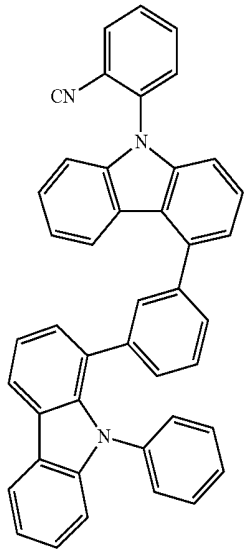

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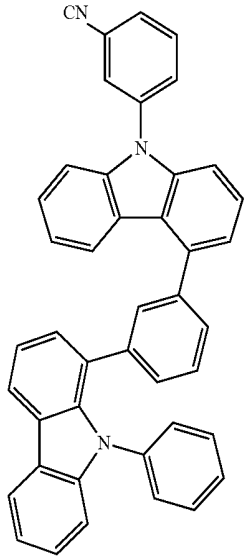

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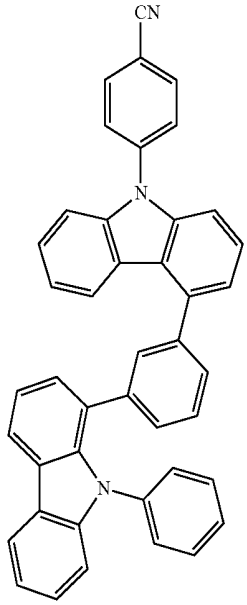

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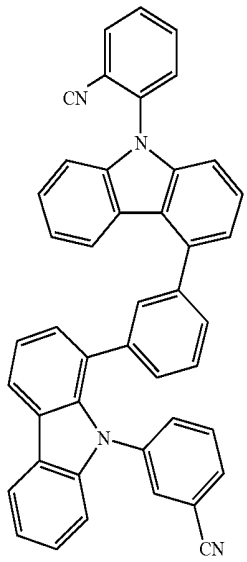

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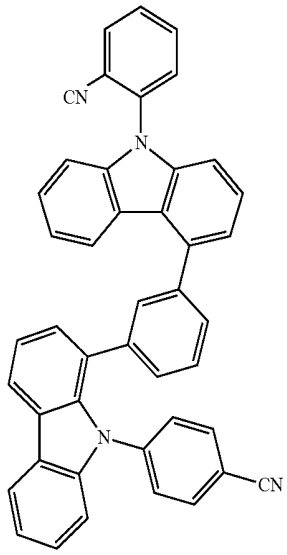

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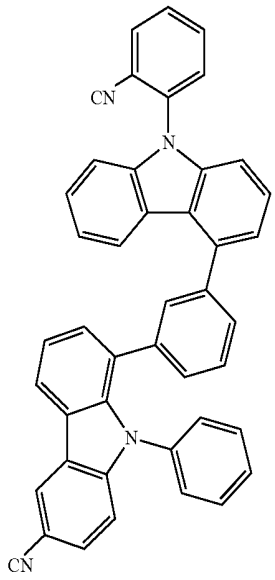

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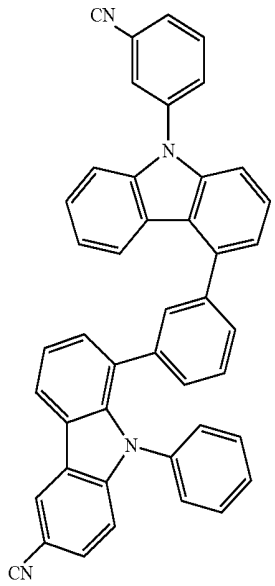

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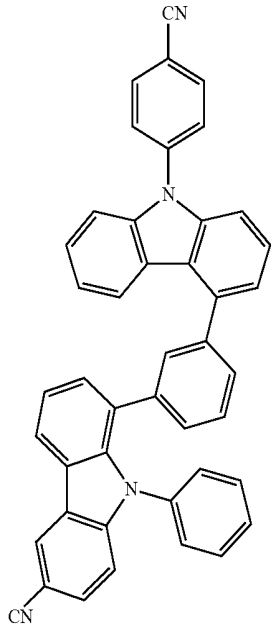

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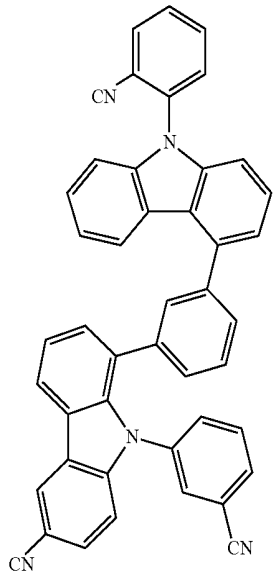

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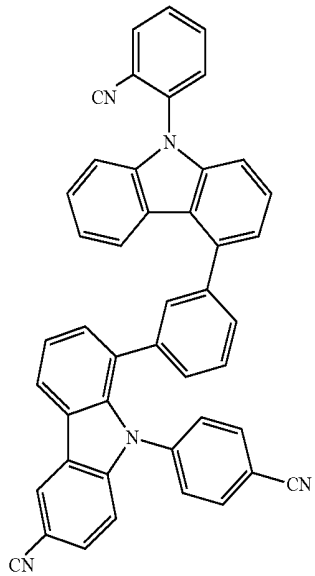

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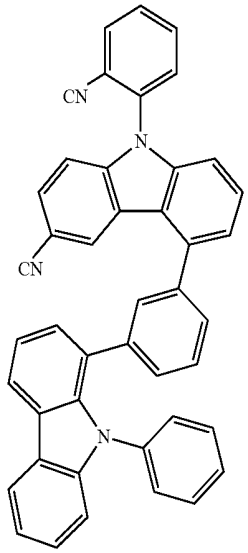

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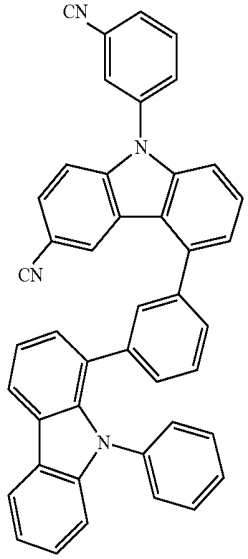

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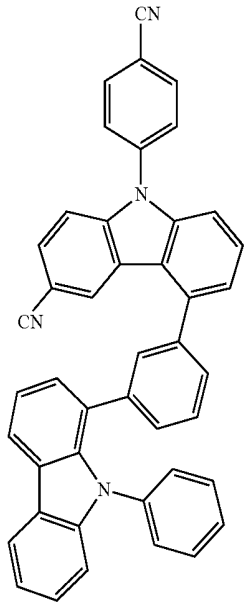

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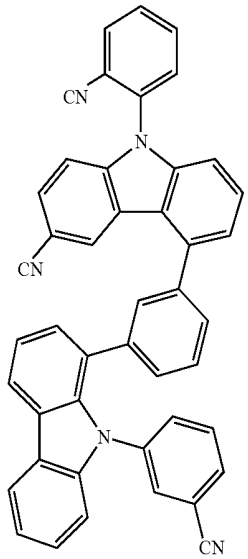

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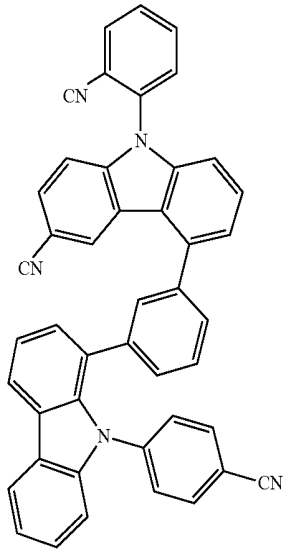

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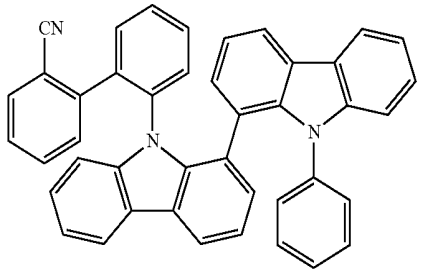

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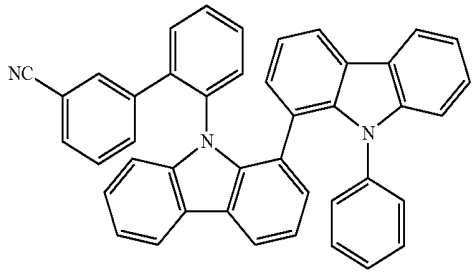

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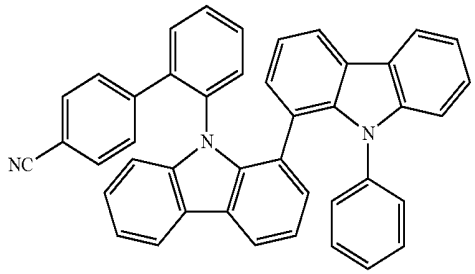

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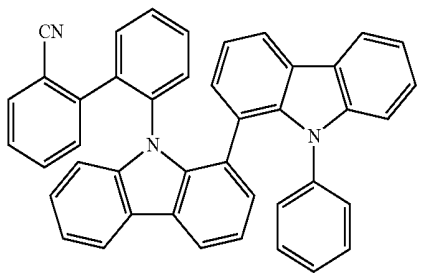

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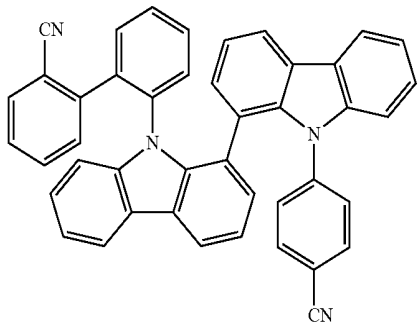

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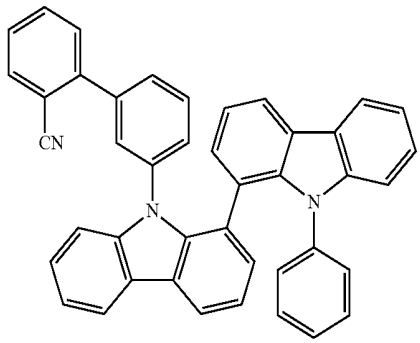

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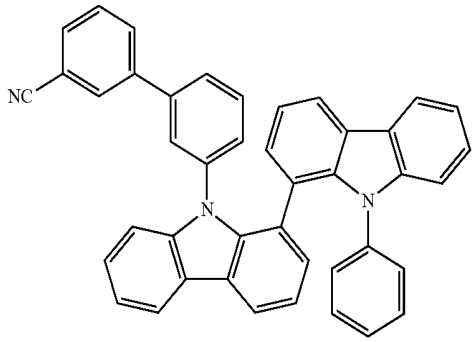

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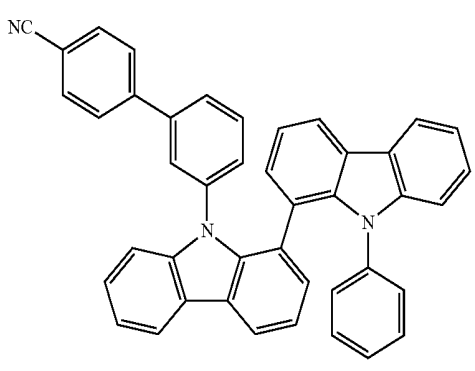

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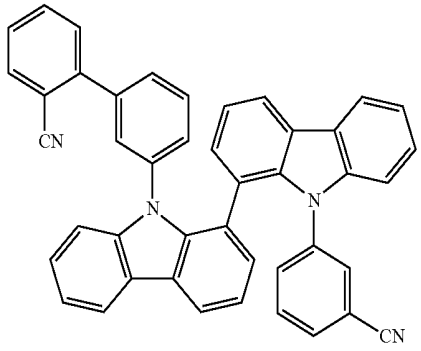

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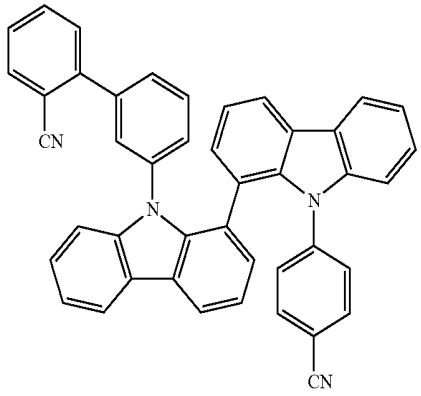

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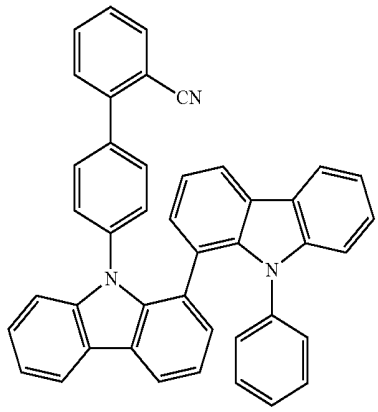

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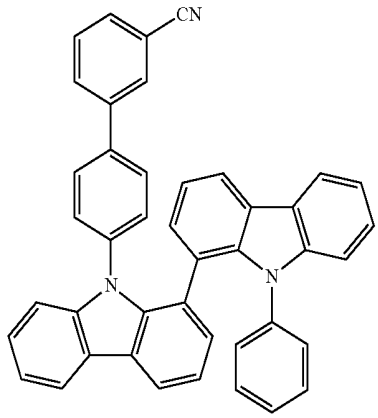

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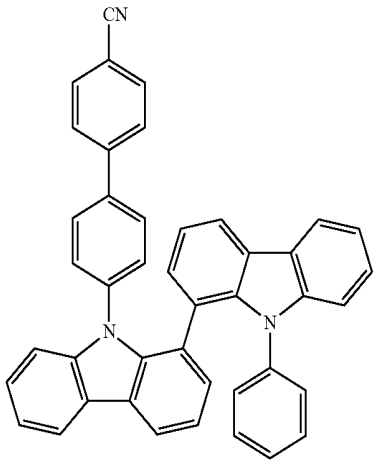

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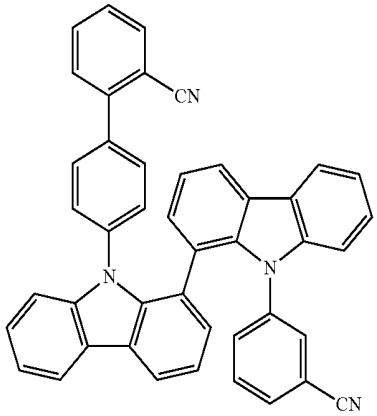

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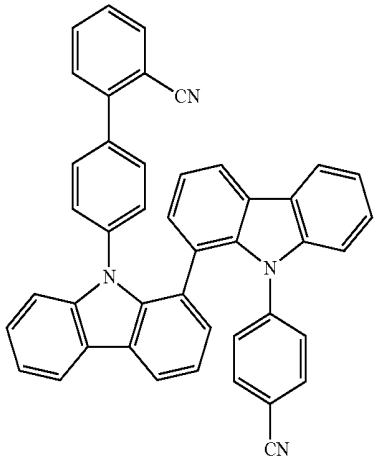

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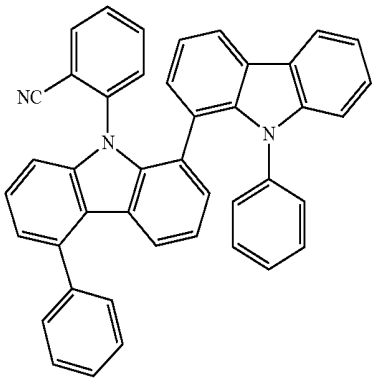

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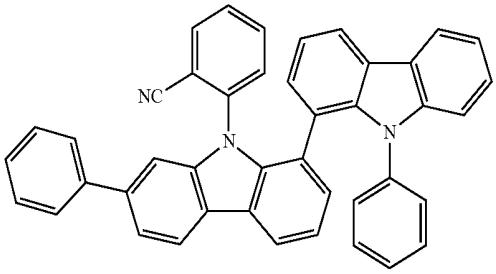

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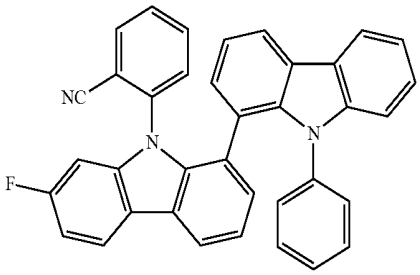

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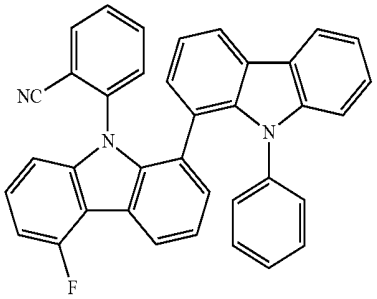

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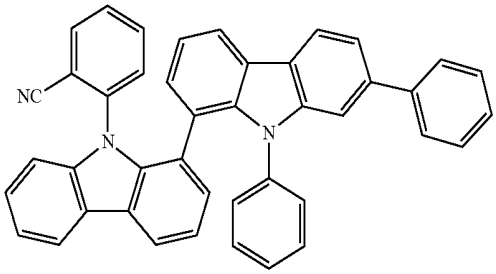

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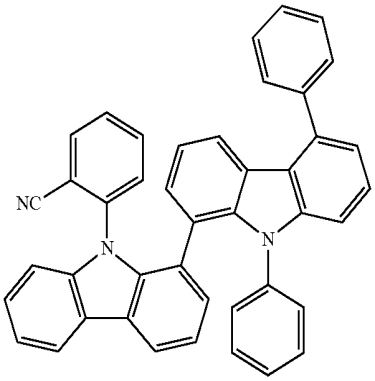

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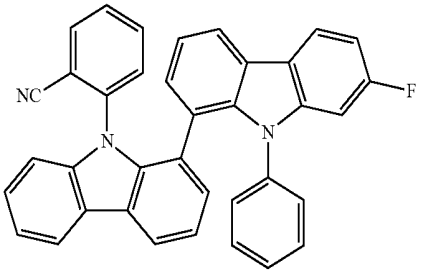

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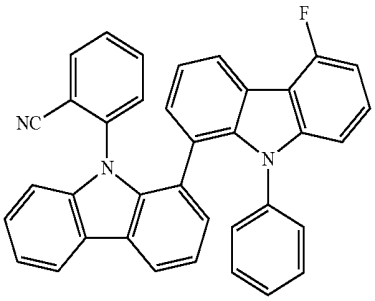

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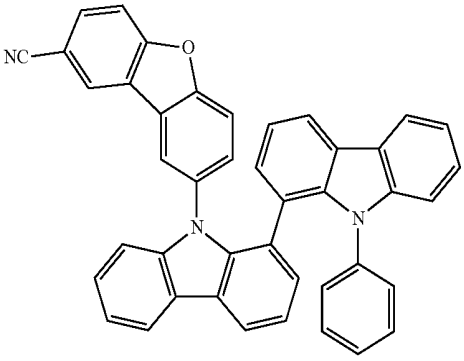

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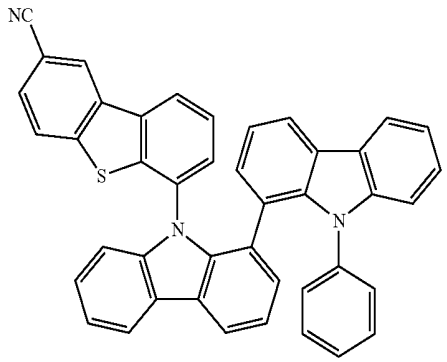

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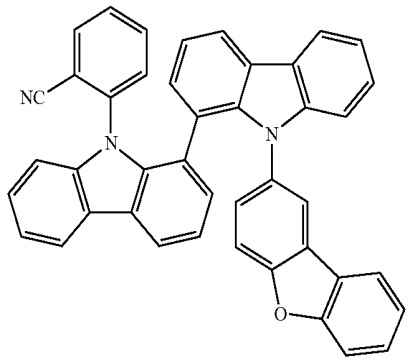

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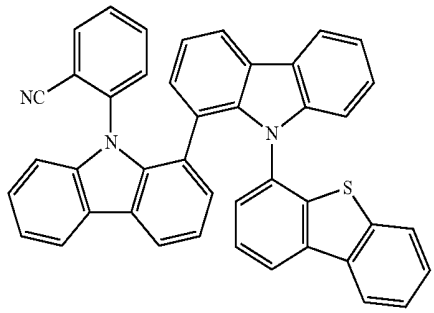

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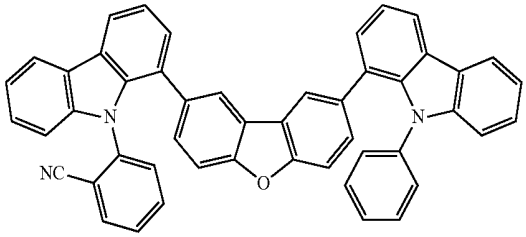

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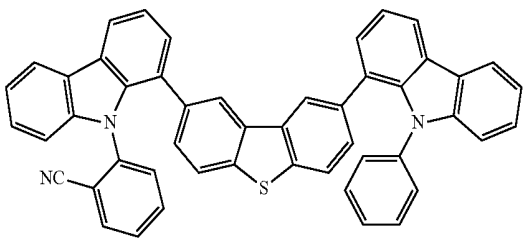

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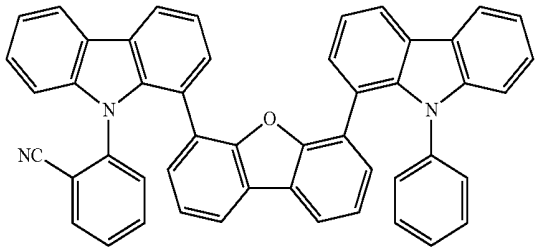

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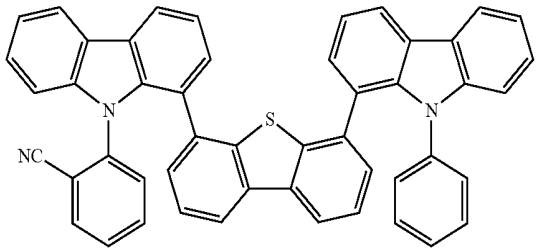

15. An organic light-emitting device comprising:
a first electrode;
a second electrode; and
an organic layer disposed between the first electrode and the second electrode,
wherein the organic layer comprises an emission layer and at least one condensed cyclic compound represented by Formula 1 of claim **1**.

16. The organic light-emitting device of claim **15**, wherein
the first electrode is an anode,
the second electrode is a cathode, and
the organic layer comprises:
i) a hole transport region disposed between the first electrode and the emission layer, wherein the hole transport region comprises a hole injection layer, a hole transport layer, an electron blocking layer, or any combination thereof; and
ii) an electron transport region disposed between the emission layer and the second electrode, wherein the electron transport region comprises a hole blocking layer, an electron transport layer, an electron injection layer, or any combination thereof.

17. The organic light-emitting device of claim **15**, wherein the emission layer comprises the condensed cyclic compound represented by Formula 1.

18. The organic light-emitting device of claim **15**, wherein the emission layer comprises the condensed cyclic compound represented by Formula 1 and a phosphorescent dopant,
wherein an amount of the condensed cyclic compound is greater than an amount of the phosphorescent dopant.

19. The organic light-emitting device of claim **17**, wherein the emission layer emits blue light.

20. The organic light-emitting device of claim **15**, wherein the emission layer comprises the condensed cyclic compound represented by Formula 1, and wherein the condensed cyclic compound represented by Formula 1 is a thermally activated delayed fluorescence emitter.

* * * * *

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	US20160380209A1	公开(公告)日	2016-12-29
申请号	US15/012266	申请日	2016-02-01
[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.		
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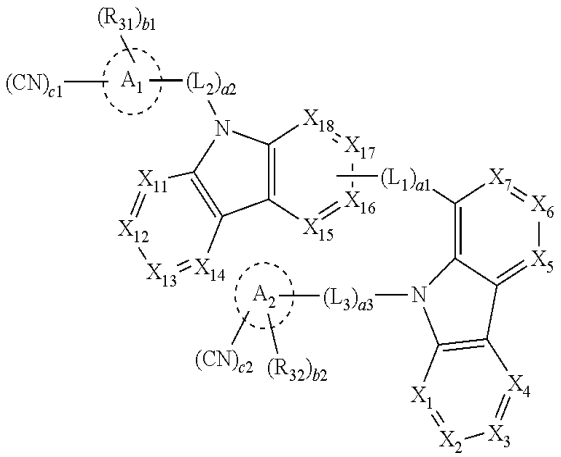
CPC分类号	H01L51/5004 C09K11/06 H01L51/5016 C09K2211/1007 C09K2211/1022 C09K2211/1044 C09K2211/185 C09K2211/1029 H01L51/0072 H01L51/009 H01L51/008 H01L51/0085 C07D209/86 C09K11/025 H01L2251/552		
优先权	1020150089087 2015-06-23 KR 1020150123657 2015-09-01 KR		
其他公开文献	US10367151		
外部链接	Espacenet USPTO		

摘要(译)

由式1表示的稠合环状化合物： 其中，在式1中，环，基团和变量与说明书中定义的相同。

Formula 1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