

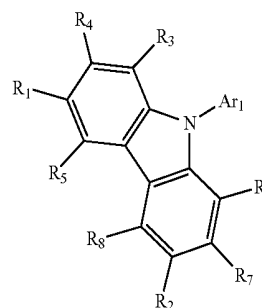


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(19) **United States**(12) **Patent Application Publication**
KIM et al.(10) **Pub. No.: US 2017/0098780 A1**(43) **Pub. Date: Apr. 6, 2017**(54) **CONDENSED CYCLIC COMPOUND AND
ORGANIC LIGHT-EMITTING DEVICE
INCLUDING THE SAME***C07D 209/88* (2006.01)*C09K 11/06* (2006.01)*C09K 11/02* (2006.01)(71) Applicants: **Samsung Electronics Co., Ltd.**,
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Ltd.**, Yongin-si (KR)(52) **U.S. Cl.**CPC *H01L 51/0072* (2013.01); *C09K 11/06*
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C07D 409/10 (2013.01); *H01L 51/0074*
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CHUNG**, Seoul (KR); **Dalho HUH**,
Suwon-si (KR); **Youngseok PARK**,
Yongin-si (KR); **Youngmok SON**,
Hwaseong-si (KR)(57) **ABSTRACT**

A condensed cyclic compound represented by Formula 1:

Formula 1

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Oct. 5, 2015 (KR) 10-2015-0139991

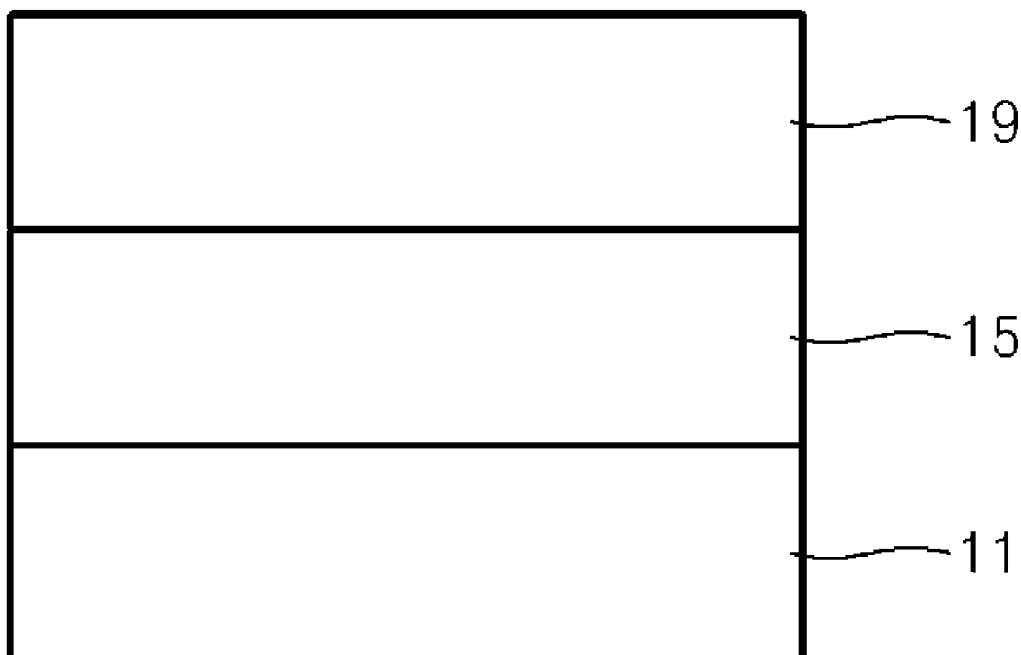
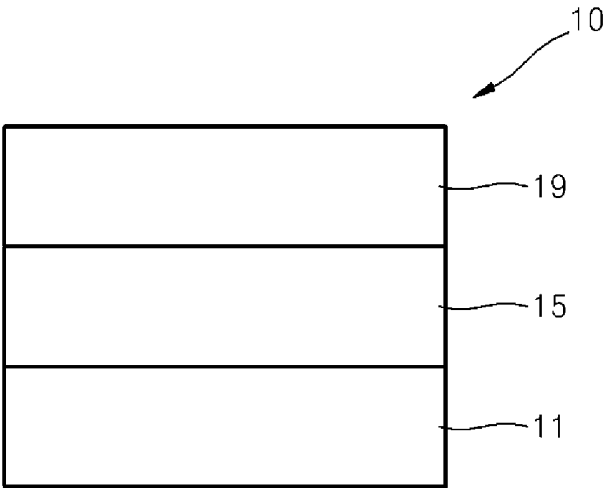
Publication Classification(51) **Int. Cl.***H01L 51/00* (2006.01)*C07D 409/10* (2006.01)wherein in Formula 1, Ar₁ and R₁ to R₈ are the same as
described in the specification.

FIG. 1



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

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2015-0139991, filed on Oct. 5, 2015, in the Korean Intellectual Property Office, the content of which is incorporated herein in its 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 excellent luminance, 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 the holes and the electrons are recombined in the emission layer to produce excitons. These excitons change from an excited state to a ground state, thereby generating light.

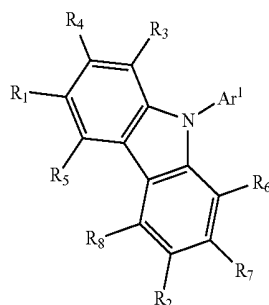
[0007] Different types of organic light emitting devices are known. However, there still remains a need in OLEDs having low driving voltage, high efficiency, high brightness, and long lifespan.

[0008] SUMMARY

[0009] Provided are a condensed cyclic compound and an organic light-emitting device including the same.

[0010] 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.

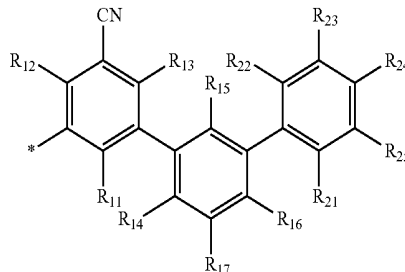
[0011] According to an exemplary embodiment, a condensed cyclic compound represented by Formula 1 is provided:



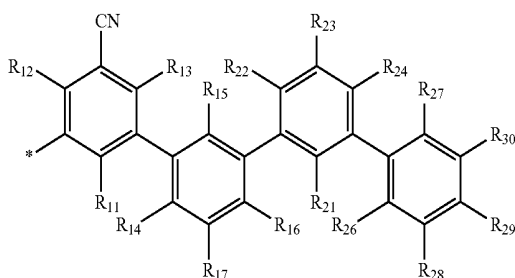
Formula 1

[0012] wherein in Formula 1, Ar₁ is selected from groups represented by Formulae 2A to 2C:

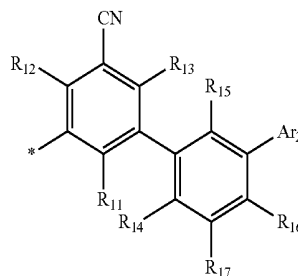
Formula 2A



Formula 2B



Formula 2C



[0013] wherein R₁₃ and R₁₅ in Formulae 2A to 2C are optionally connected to each other through *—O—*, *—S—*, *—C(R₃₁)(R₃₂)—*, or *—Si(R₃₁)(R₃₂)—* to form a 5-membered ring,

[0014] wherein R₁₁ and R₁₄ in Formulae 2A to 2C are optionally connected to each other through *—O—*, *—S—*, *—C(R₃₃)(R₃₄)—*, or *—Si(R₃₃)(R₃₄)—* to form a 5-membered ring,

[0015] wherein R₁₅ and R₂₂ in Formulae 2A and 2B are optionally connected to each other through *—O—*, *—S—*, *—C(R₃₅)(R₃₆)—*, or *—Si(R₃₅)(R₃₆)—* to form a 5-membered ring,

[0016] wherein R₁₆ and R₂₁ in Formulae 2A and 2B are optionally connected to each other through *—O—*, *—S—*, *—C(R₃₇)(R₃₈)—*, or *—Si(R₃₇)(R₃₈)—* to form a 5-membered ring,

[0017] wherein R₂₄ and R₂₇ in Formula 2B are optionally connected to each other through *—O—*, *—S—*, *—C(R₃₉)(R₄₀)—*, or *—Si(R₃₉)(R₄₀)—* to form a 5-membered ring,

[0018] wherein R₂₁ and R₂₆ in Formula 2B are optionally connected to each other through *—O—*, *—S—*, *—C(R₄₁)(R₄₂)—*, or *—Si(R₄₁)(R₄₂)—* to form a 5-membered ring,

[0019] wherein R₁ to R₈, R₁₁ to R₁₇, R₂₁ to R₃₀, and R₃₁ to R₄₂ in Formulae 1 and 2A to 2C are each independently selected from:

[0020] hydrogen, deuterium, a cyano group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a

biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group;

[0021] a C_1 - C_{20} alkyl group and C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium and a cyano group; and

[0022] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group, each substituted with at least one selected from deuterium, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group;

[0023] wherein Ar_2 in Formula 2C is selected from

[0024] a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group; and

[0025] a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group, each substituted with at least one selected from deuterium, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group;

[0026] wherein * indicates a binding site to an adjacent atom.

[0027] In various embodiments, an organic light-emitting device includes:

[0028] a first electrode;

[0029] a second electrode; and

[0030] an organic layer disposed between the first electrode and the second electrode,

[0031] wherein the organic layer includes an emission layer and at least one condensed cyclic compound represented by Formula 1.

BRIEF DESCRIPTION OF THE DRAWING

[0032] These and/or other aspects will become apparent and more readily appreciated from the following description of the exemplary embodiments, taken in conjunction with FIG. 1, which is a schematic cross-sectional view of an organic light-emitting device according to an exemplary embodiment.

DETAILED DESCRIPTION

[0033] 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.

[0034] 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.

[0035] 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.

[0036] 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.

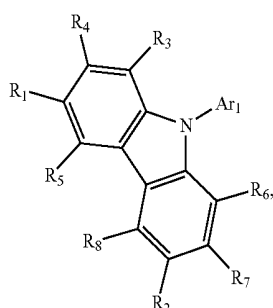
[0037] The term “or” means “and/or.” It will be further understood that the terms “comprises” and/or “comprising,” or “includes” and/or “including” when used in this specification, specify the presence of stated features, regions, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

[0038] 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.

[0039] 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.

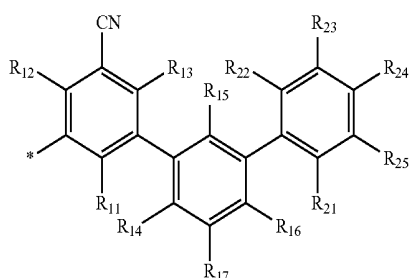
[0040] “About” or “approximately” as used herein is inclusive of the stated value and means within an acceptable range of deviation for the particular value as determined by one of ordinary skill in the art, considering the measurement in question and the error associated with measurement of the particular quantity (i.e., the limitations of the measurement system). For example, “about” can mean within one or more standard deviations, or within $\pm 30\%$, 20% , 10% , 5% of the stated value.

[0041] According to an exemplary embodiment, a condensed cyclic compound represented by Formula 1 is provided:

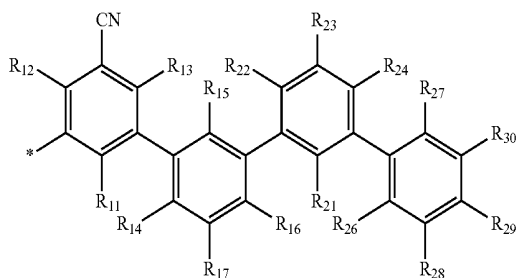


Formula 1

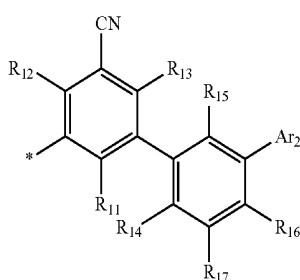
[0042] wherein Ar₁ in Formula 1 is selected from groups represented by Formulae 2A to 2C:



Formula 2A



Formula 2B



Formula 2C

[0043] wherein R₁₃ and R₁₅ in Formulae 2A to 2C are optionally connected to each other through *—O—*, *—S—*, *—C(R₃₁)(R₃₂)—*, or *—Si(R₃₁)(R₃₂)—* to form a 5-membered ring,

[0044] wherein R₁₁ and R₁₄ in Formulae 2A to 2C are optionally connected to each other through *—O—*, *—S—*, *—C(R₃₃)(R₃₄)—*, or *—Si(R₃₃)(R₃₄)—* to form a 5-membered ring,

[0045] wherein R₁₅ and R₂₂ in Formulae 2A and 2B are optionally connected to each other through *—O—*, *—S—*, *—C(R₃₅)(R₃₆)—*, or *—Si(R₃₅)(R₃₆)—* to form a 5-membered ring,

[0046] wherein R₁₆ and R₂₁ in Formulae 2A and 2B are optionally connected to each other through *—O—*, *—C

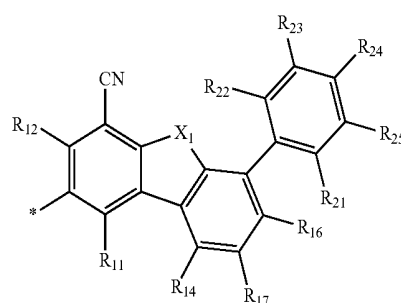
(R₃₇)(R₃₈)—*, or *—Si(R₃₇)(R₃₈)—* to form a 5-membered ring,

[0047] wherein R₂₄ and R₂₇ in Formula 2B are optionally connected to each other through *—O—*, *—C(R₃₉)(R₄₀)—*, or *—Si(R₃₉)(R₄₀)—* to form a 5-membered ring,

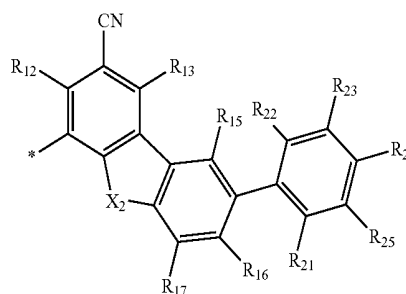
[0048] wherein R₂₁ and R₂₆ in Formula 2B are optionally connected to each other through *—O—*, *—C(R₄₁)(R₄₂)—*, or *—Si(R₄₁)(R₄₂)—* to form a 5-membered ring.

[0049] According to an exemplary embodiment, Ar₁ in Formula 1 may be selected from groups represented by Formulae 2A-1 to 2A-4:

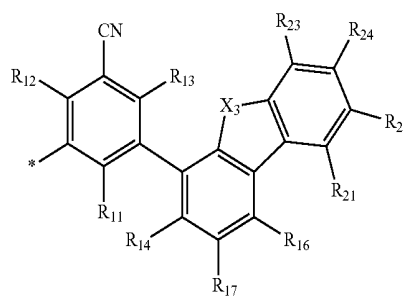
Formula 2A-1



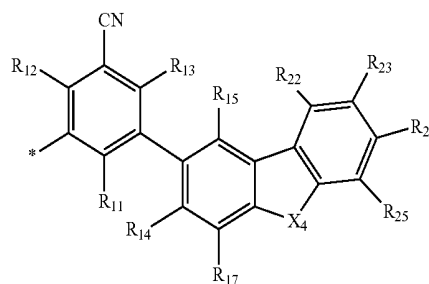
Formula 2A-2



Formula 2A-3



Formula 2A-4



[0050] wherein in Formulae 2A-1 to 2A-4,

[0051] X₁ is O, S, C(R₃₁)(R₃₂), or Si(R₃₁)(R₃₂),

[0052] X₂ is O, S, C(R₃₃)(R₃₄), or Si(R₃₃)(R₃₄),

[0053] X_3 is O, S, $C(R_{35})(R_{36})$, or $Si(R_{35})(R_{36})$,

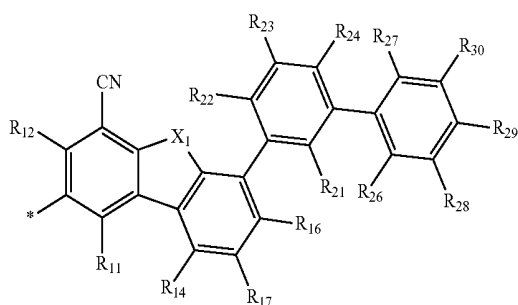
[0054] X_4 is O, S, $C(R_{37})(R_{38})$, or $Si(R_{37})(R_{38})$,

[0055] descriptions for R_{11} to R_{17} , R_{21} to R_{25} , and R_{31} to R_{38} are the same as described herein,

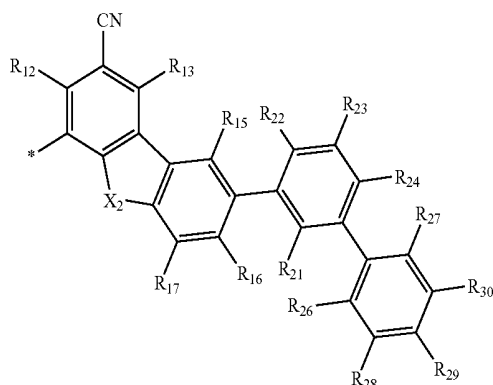
[0056] * indicates a binding site to an adjacent atom.

[0057] In various embodiments, Ar_1 in Formula 1 may be selected from groups represented by Formulae 2B-1 to 2B-6:

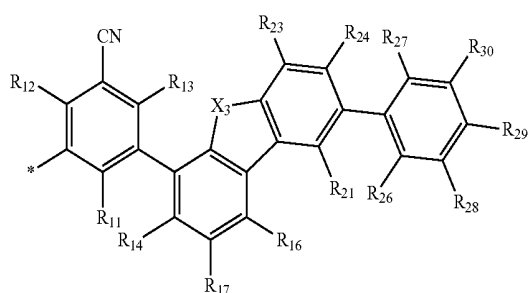
Formula 2B-1



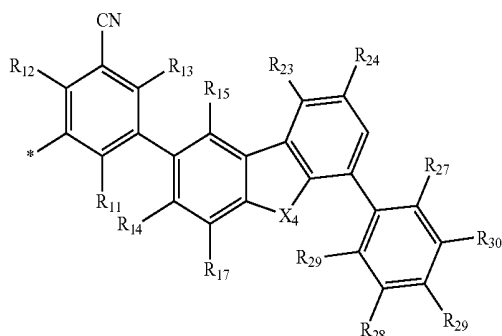
Formula 2B-2



Formula 2B-3

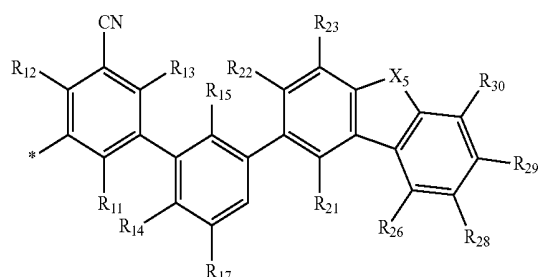


Formula 2B-4

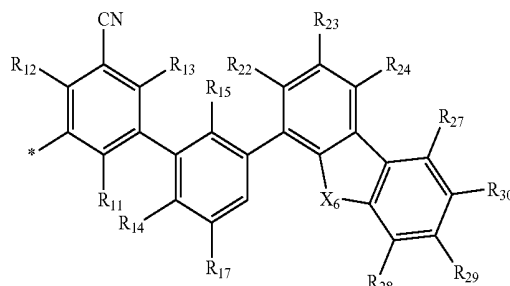


-continued

Formula 2B-5



Formula 2B-6



[0058] wherein in Formulae 2B-1 to 2B-6,

[0059] X_1 is O, S, $C(R_{31})(R_{32})$, or $Si(R_{31})(R_{32})$,

[0060] X_2 is O, S, $C(R_{33})(R_{34})$, or $Si(R_{33})(R_{34})$,

[0061] X_3 is O, S, $C(R_{35})(R_{36})$, or $Si(R_{35})(R_{36})$,

[0062] X_4 is O, S, $C(R_{37})(R_{38})$, or $Si(R_{37})(R_{38})$,

[0063] X_5 is O, S, $C(R_{39})(R_{40})$, or $Si(R_{39})(R_{40})$,

[0064] X_6 is O, S, $C(R_{41})(R_{42})$, or $Si(R_{41})(R_{42})$,

[0065] the descriptions for R_{11} to R_{17} , R_{21} to R_{30} , and R_{31} to R_{42} are the same as described herein,

[0066] * indicates a binding site to an adjacent atom.

[0067] According to some embodiments, Ar_1 in Formula 1 may be selected from groups represented by Formulae 2A to 2C, wherein R_{13} and R_{15} , R_{11} and R_{14} , R_{15} and R_{22} , R_{16} and R_{21} , R_{24} and R_{27} , and R_{21} and R_{26} in Formulae 2A to 2C may not be connected to each other.

[0068] R_1 to R_8 , R_{11} to R_{17} , R_{21} to R_{30} , and R_{31} to R_{42} in Formulae 1 and 2A to 2C may each independently be selected from

[0069] hydrogen, deuterium, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group;

[0070] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium and a cyano group; and

[0071] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group and a dibenzosilolyl group, each substituted with at least one selected from deuterium, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a

triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group;

[0072] Ar₂ in Formula 2A may be selected from

[0073] a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group; and

[0074] a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group, each substituted with at least one selected from deuterium, a cyano group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group,

[0075] * indicates a binding site to an adjacent atom.

[0076] For example, R₁ to R₈, R₁₁ to R₁₇, R₂₁ to R₃₀, and R₃₁ to R₄₂ in Formulae 1 and 2A to 2C may each independently be selected from

[0077] hydrogen, deuterium, a cyano group, a C₁-C₂₀ alkyl group, a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group;

[0078] a C₁-C₂₀ alkyl group substituted with at least one selected from deuterium and a cyano group; and

[0079] a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group, each substituted with at least one selected from deuterium, a cyano group, a C₁-C₂₀ alkyl group, a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group, but they are not limited thereto.

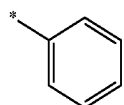
[0080] As another example, R₁ to R₈, R₁₁ to R₁₇, R₂₁ to R₃₀, and R₃₁ to R₄₂ in Formulae 1 and 2A to 2C may each independently be selected from hydrogen, deuterium, a cyano group, a C₁-C₂₀ alkyl group, a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group.

[0081] According to an exemplary embodiment, R₁ to R₈, R₁₁ to R₁₇, R₂₁ to R₃₀, and R₃₁ to R₄₂ in Formulae 1 and 2A to 2C may each independently be selected from

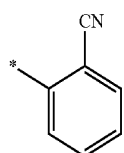
[0082] hydrogen, deuterium, and a cyano group; and

[0083] a phenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, a cyano group, and a phenyl group.

[0084] In various embodiments, R₁ to R₈, R₁₁ to R₁₇, R₂₁ to R₃₀, and R₃₁ to R₄₂ in Formulae 1 and 2A to 2C may each independently be selected from hydrogen, deuterium, a cyano group, and groups represented by Formulae 4-1 to 4-29, but they are not limited thereto:

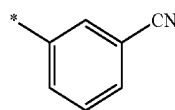


Formula 4-1

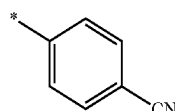


Formula 4-2

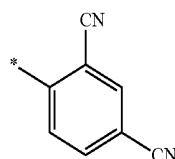
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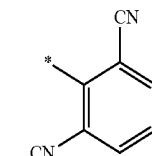
Formula 4-3



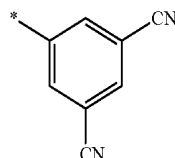
Formula 4-4



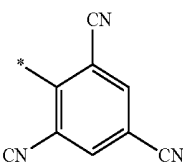
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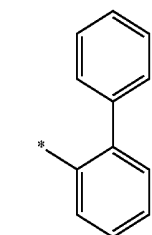
Formula 4-6



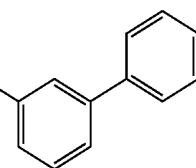
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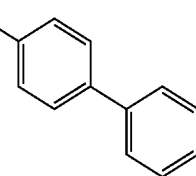
Formula 4-8



Formula 4-9

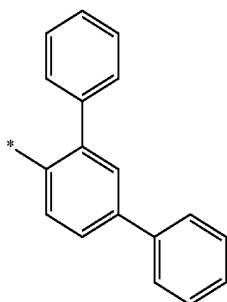


Formula 4-10

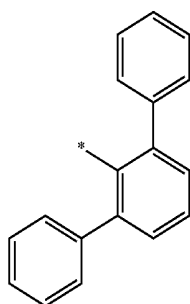


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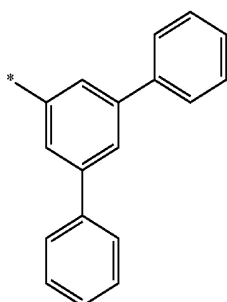
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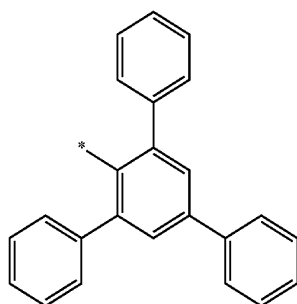
Formula 4-12



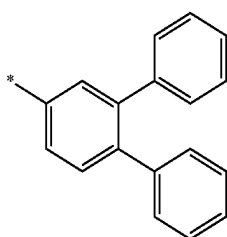
Formula 4-13



Formula 4-14

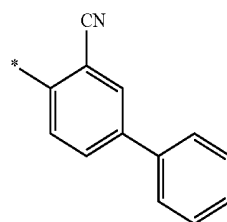


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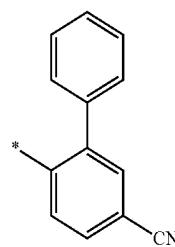


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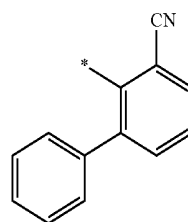
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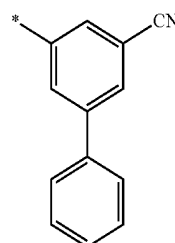
Formula 4-17



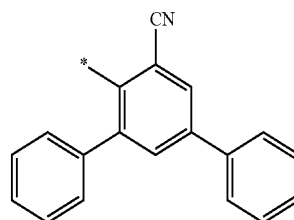
Formula 4-18



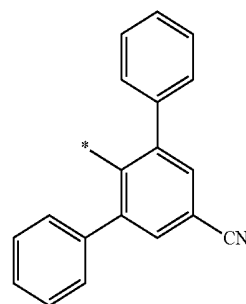
Formula 4-19



Formula 4-20

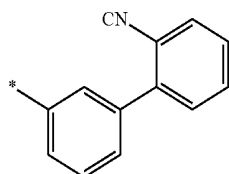


Formula 4-21

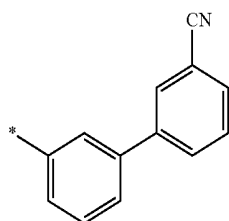


Formula 4-22

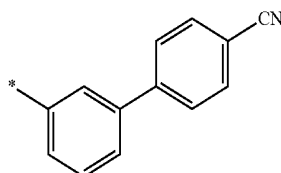
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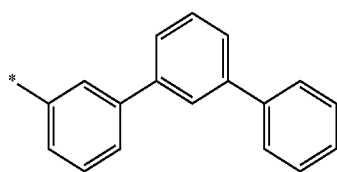
Formula 4-23



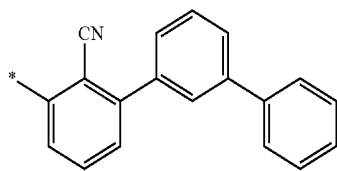
Formula 4-24



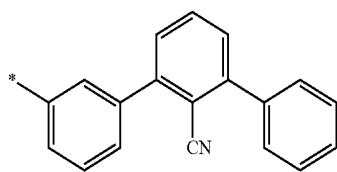
Formula 4-25



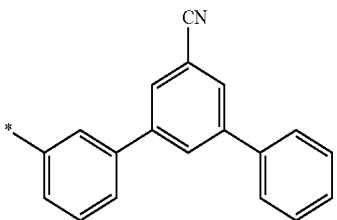
Formula 4-26



Formula 4-27



Formula 4-28



Formula 4-29

[0085] wherein in Formulae 4-1 to 4-29, * indicates a binding site to an adjacent atom.

[0086] According to an exemplary embodiment, at least one of R_1 and R_2 in Formula 1 may be a cyano group.

[0087] In various embodiments, R_1 in Formula 1 may be a cyano group, and R_2 to R_8 in Formula 1 may each independently be selected from

[0088] hydrogen, deuterium, and a cyano group; and

[0089] a phenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, a cyano group, and a phenyl group.

[0090] According to some embodiments, R_1 and R_2 in Formula 1 may be a cyano group, R_3 to R_8 in Formula 1 may each independently be selected from

[0091] hydrogen, deuterium, and a cyano group; and

[0092] a phenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, a cyano group, and a phenyl group.

[0093] According to some embodiments,

[0094] R_{11} to R_{17} and R_{21} to R_{25} in Formula 2A may all be hydrogen, or

[0095] at least one of R_{23} , R_{25} , and R_{15} to R_{17} in Formula 2A may each independently be selected from

[0096] deuterium and a cyano group; and

[0097] a phenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, a cyano group, and a phenyl group; or

[0098] R_{11} to R_{17} , R_{21} to R_{24} , and R_{26} to R_{30} in Formula 2B may all be hydrogen, or

[0099] at least one of R_{15} , R_{17} , R_{21} , R_{23} , R_{28} , and R_{30} in Formula 2B may each independently be selected from

[0100] deuterium and a cyano group; and

[0101] a phenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, a cyano group, and a phenyl group, or

[0102] R_{17} in Formula 2C may be a cyano group, a phenyl group, a biphenyl group or a terphenyl group, but they are not limited thereto.

[0103] According to some embodiments,

[0104] R_{11} to R_{17} and R_{21} to R_{25} of Formula 2A may all be hydrogen, or

[0105] at least one of R_{23} , R_{25} , and R_{15} to R_{17} in Formula 2A may each independently be selected from a cyano group and groups represented by Formulae 4-1 to 4-29, or

[0106] R_{11} to R_{17} , R_{21} to R_{24} , and R_{26} to R_{30} in Formula 2B may all be hydrogen, or

[0107] at least one of R_{15} , R_{17} , R_{21} , R_{23} , R_{28} , and R_{30} in Formula 2B may each independently be selected from a cyano group and groups represented by Formulae 4-1 to 4-29, or

[0108] R_{17} in Formula 2C may be a cyano group, a phenyl group, a biphenyl group or a terphenyl group, but they are not limited thereto.

[0109] According to some embodiments,

[0110] at least one of R_{23} , R_{25} , and R_{15} to R_{17} in Formula 2A may each independently be selected from a cyano group and groups represented by Formulae 4-1 to 4-29, and the other substituents in Formula 2A may all be hydrogen or deuterium, or

[0111] at least one of R_{15} , R_{17} , R_{21} , R_{23} , R_{28} and R_{30} in Formula 2B may each independently be selected from a cyano group and groups represented by Formulae 4-1 to 4-29, and the other substituents in Formula 2B may all be hydrogen or deuterium, but they are not limited thereto.

[0112] In various embodiments,

[0113] i) at least one of R_{17} and R_{25} in Formula 2A-1,

[0114] ii) at least one of R_{17} and R_{25} in Formula 2A-2,

[0115] iii) R_{17} in Formula 2A-3, and

[0116] iv) R_{17} in Formula 2A-4 may each independently be selected from

[0117] deuterium and a cyano group; and

[0118] a phenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, a cyano group, and a phenyl group.

[0119] In various embodiments,

[0120] i) at least one of R_{17} and R_{25} in Formula 2A-1,

[0121] ii) at least one of R_{17} and R_{25} in Formula 2A-2,

[0122] iii) R_{17} in Formula 2A-3, and

[0123] iv) R_{17} in Formula 2A-4 may each independently be selected from a cyano group and groups represented by Formulae 4-1 to 4-29. Alternatively, R_{11} to R_{17} and R_{21} to R_{25} in Formulae 2A-1 to 2A-4 may all be hydrogen.

[0124] In various embodiments,

[0125] i) R_{17} in Formula 2B-1,

[0126] ii) R_{17} in Formula 2B-2,

[0127] iii) one of R_{17} and R_{28} in Formula 2B-3,

[0128] iv) one of R_{17} and R_{28} in Formula 2B-4,

[0129] v) one of R_{23} , R_{28} , and R_{30} in Formula 2B-5, and

[0130] vi) one of R_{23} , R_{28} , and R_{30} in Formula 2B-6 may each independently be selected from

[0131] deuterium and a cyano group; and

[0132] a phenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, a cyano group, and a phenyl group.

[0133] In various embodiments,

[0134] i) R_{17} in Formula 2B-1,

[0135] ii) R_{17} in Formula 2B-2,

[0136] iii) one of R_{17} and R_{28} in Formula 2B-3,

[0137] iv) one of R_{17} and R_{28} in Formula 2B-4,

[0138] v) one of R_{23} , R_{28} , and R_{30} in Formula 2B-5, and

[0139] vi) one of R_{23} , R_{28} , and R_{30} in Formula 2B-6 may each independently be selected from a cyano group and groups represented by Formulae 4-1 to 4-29, but are not limited thereto. Alternatively, each of R_{11} to R_{17} , R_{21} to R_{24} , and R_{26} to R_{30} in Formulae 2B-1 to 2B-6 may simultaneously be hydrogen.

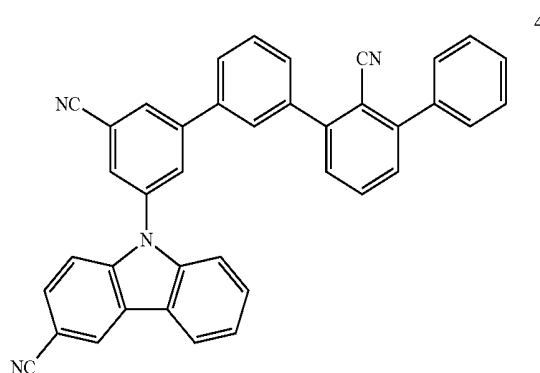
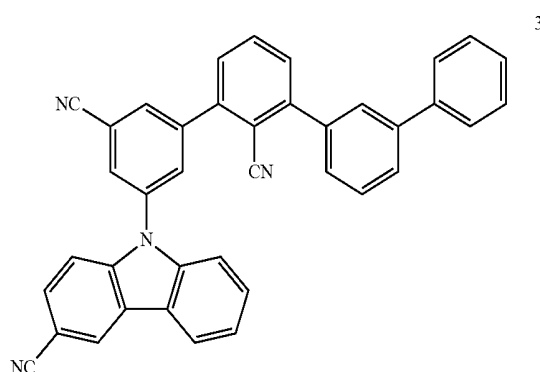
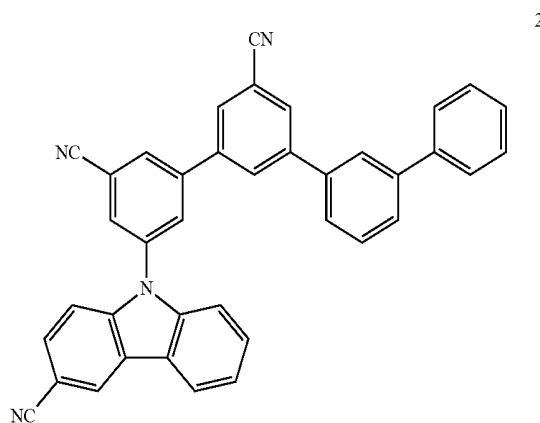
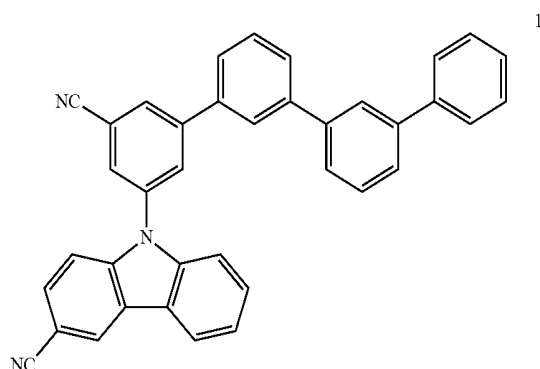
[0140] The number of cyano groups in each of Formulae 2A to 2C may be 1, 2, 3, or 4, for example, 2 or 3.

[0141] The number of cyano groups in Formula 1 may be 2, 3, or 4, or 2 or 3.

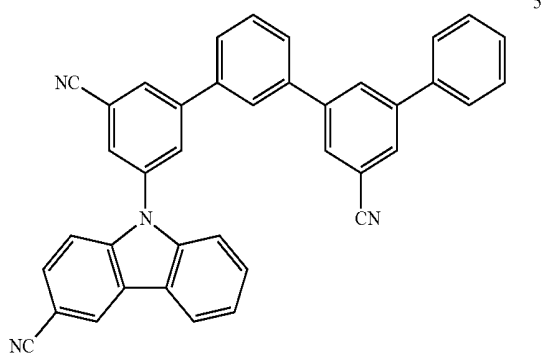
[0142] A difference between a triplet (T_1) energy level and a singlet (S_1) energy level of the condensed cyclic compound represented by Formula 1 may be in a range of 0.1 electron Volts (eV) to 0.6 eV. Accordingly, an electronic device (for example, an organic light-emitting device) including the condensed cyclic compound represented by Formula 1 may have an increased stability. Thus, the electronic device (for example, the organic light-emitting device) may have high efficiency and a long lifespan. In addition, the condensed cyclic compound represented by Formula 1 may be used as a thermally activated delayed fluorescence (TADF) emitter.

[0143] The triplet (T_1) energy level of the condensed cyclic compound represented by Formula 1 may be 2.9 eV to 3.1 eV. Accordingly, the condensed cyclic compound may be appropriately used as a host for emitting blue light of a high color purity.

[0144] According to an exemplary embodiment, the condensed cyclic compound represented by Formula 1 may be selected from Compounds 1 to 116 below:

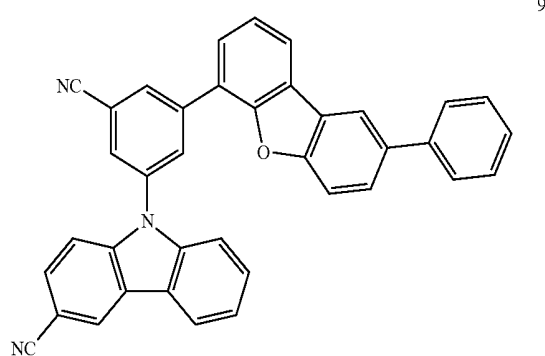


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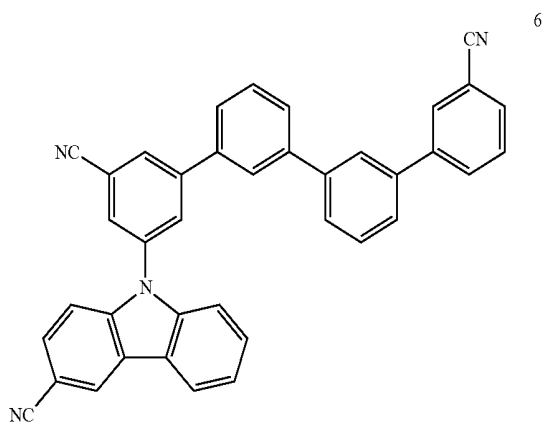


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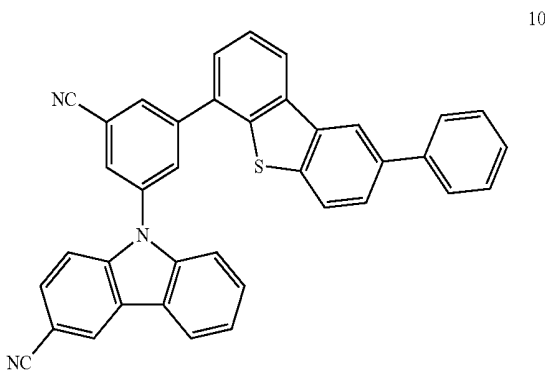
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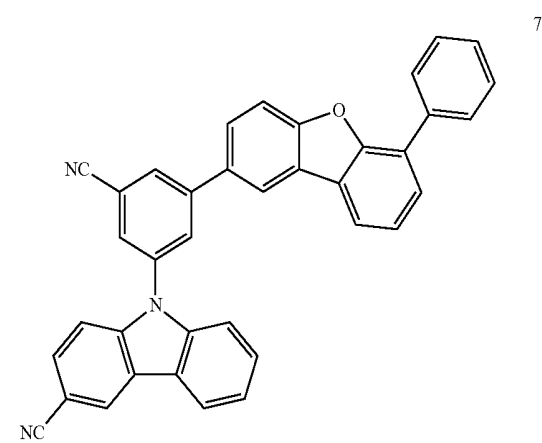
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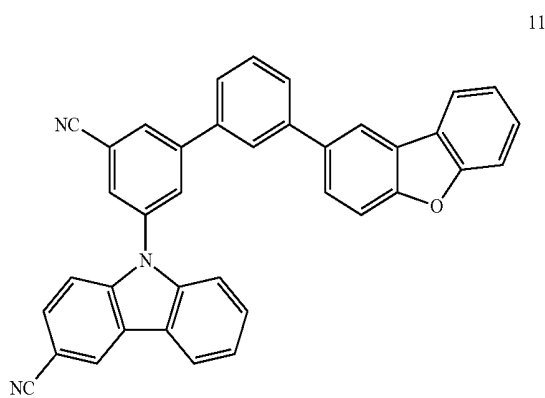
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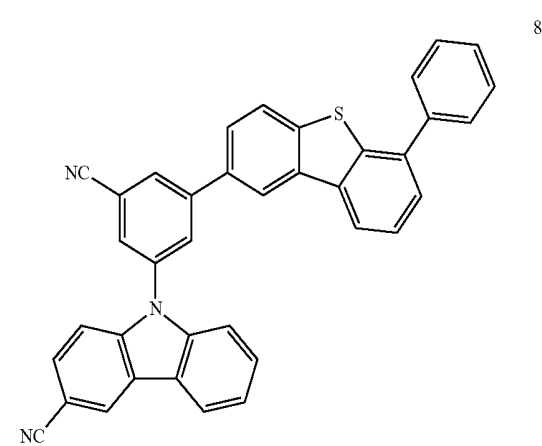
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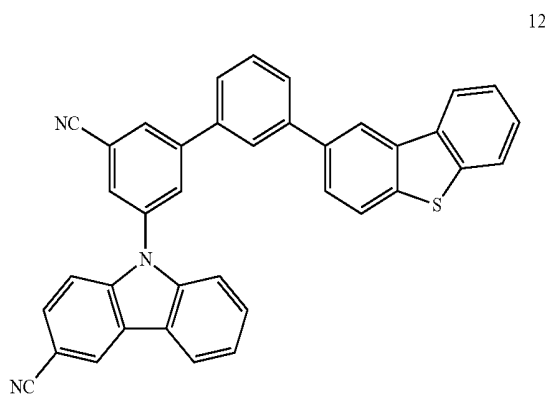
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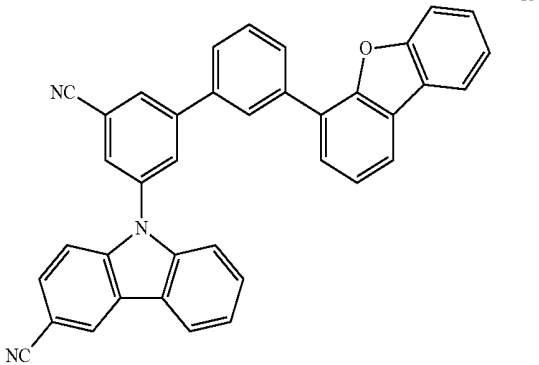


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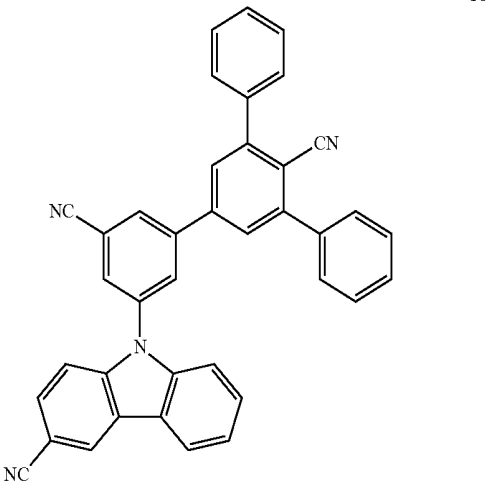


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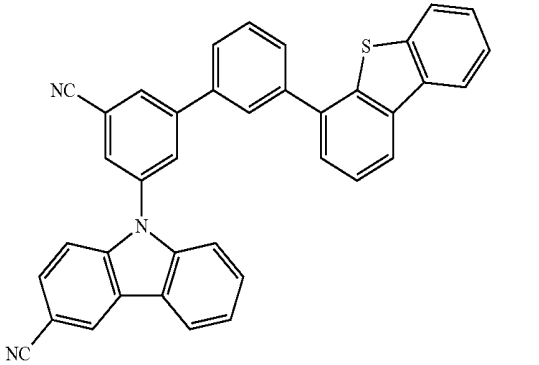
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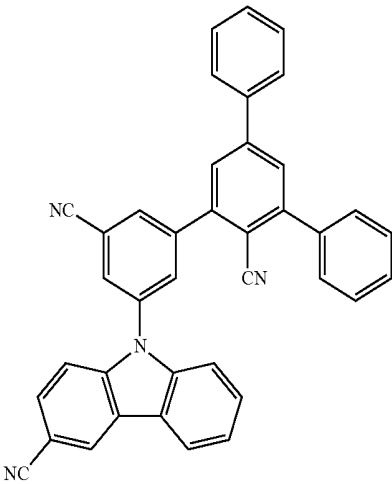
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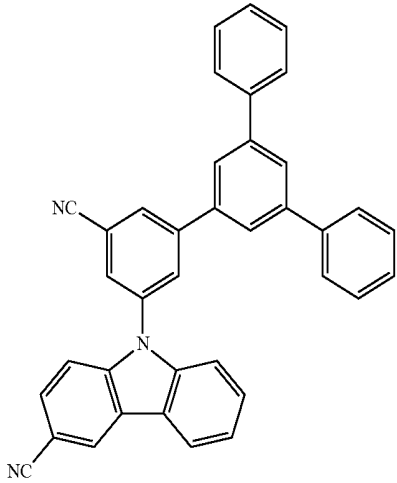
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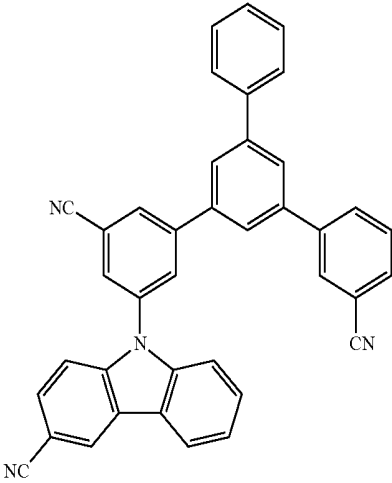
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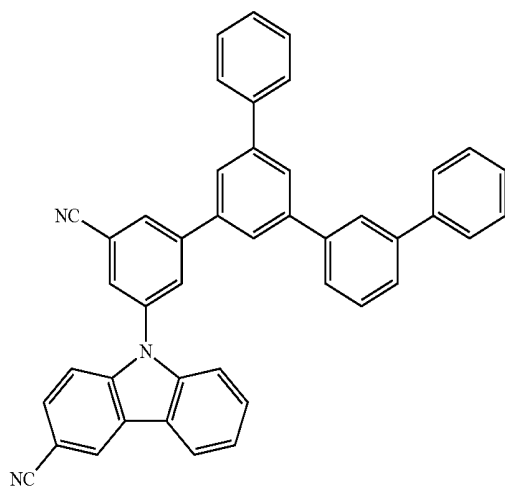


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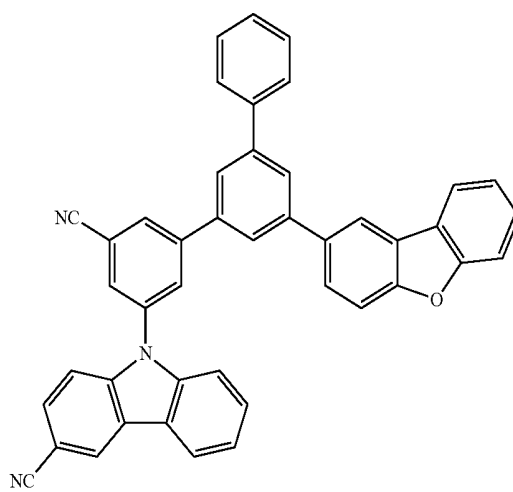
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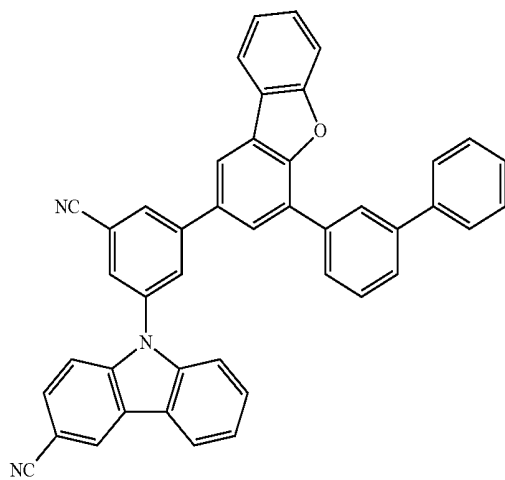


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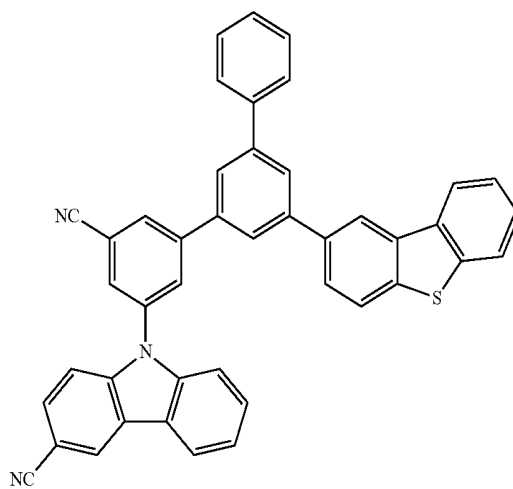
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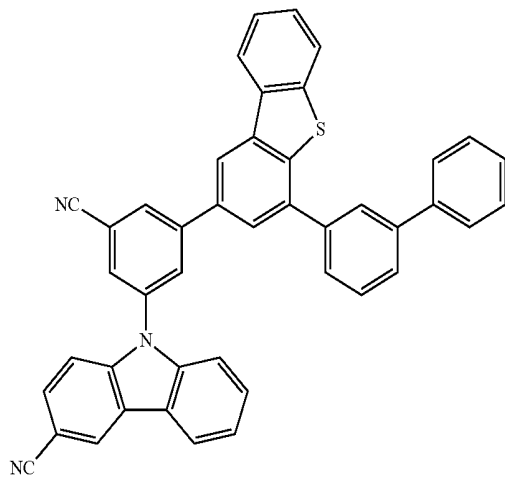
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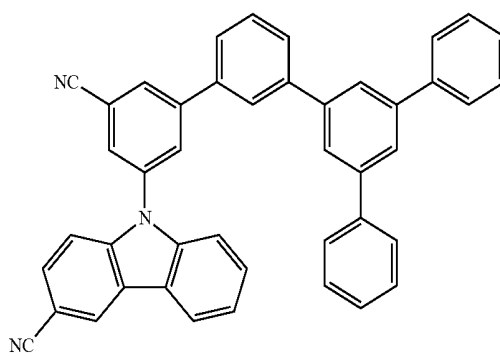
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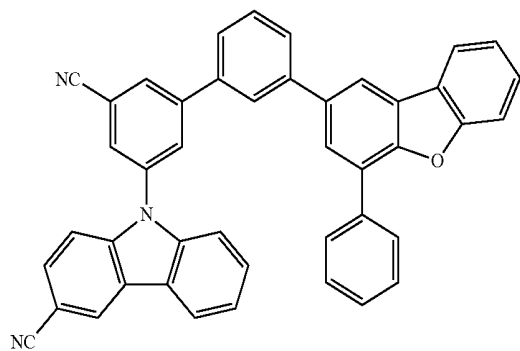


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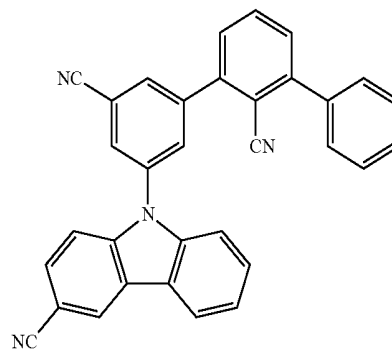
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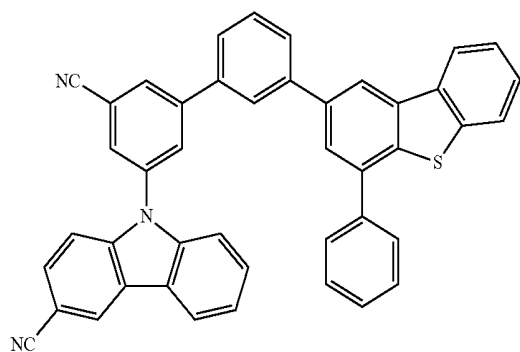


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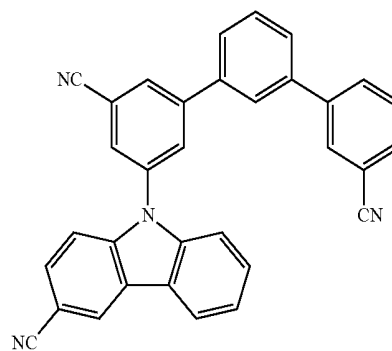
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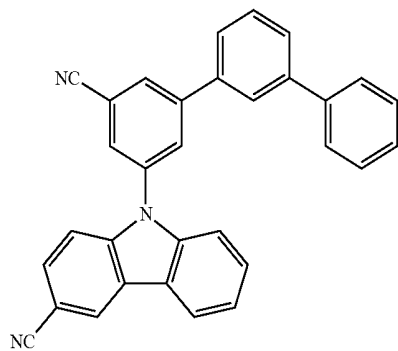
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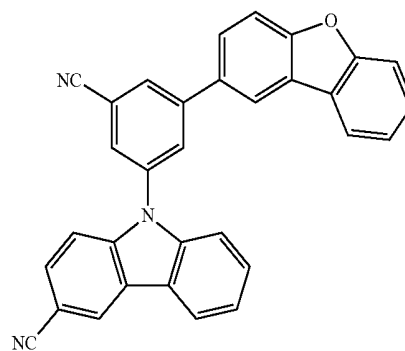
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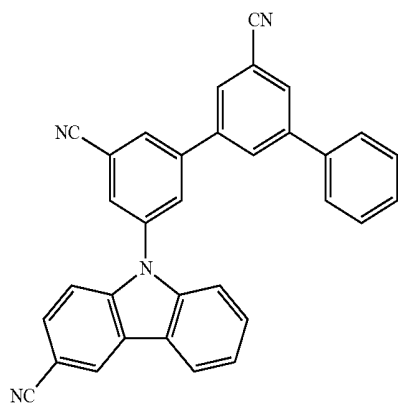
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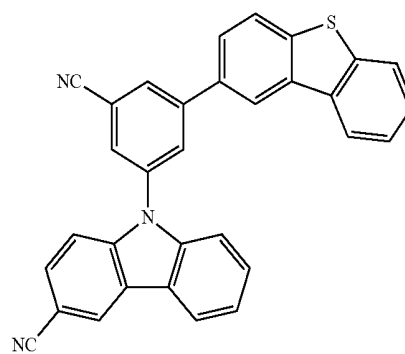
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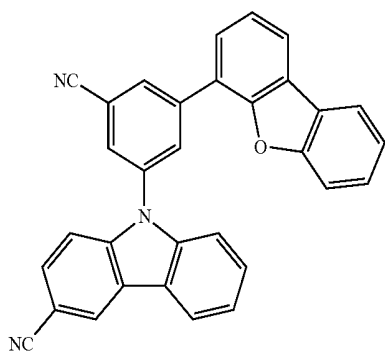
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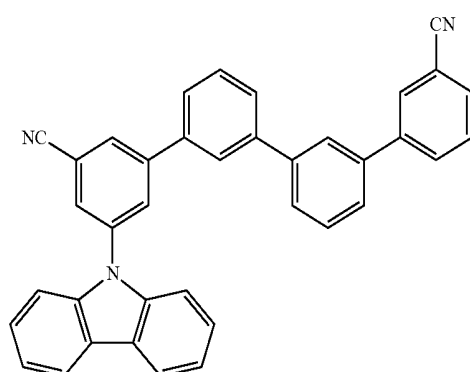
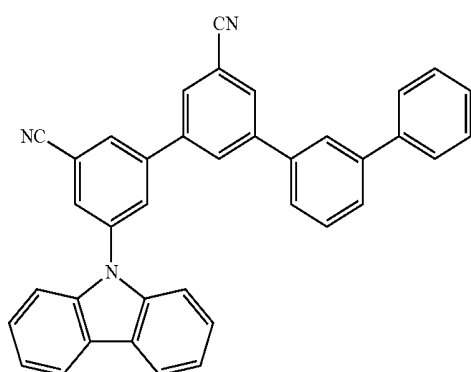
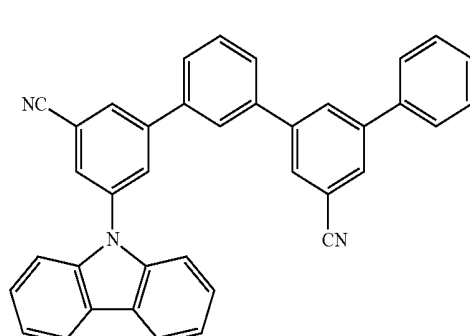
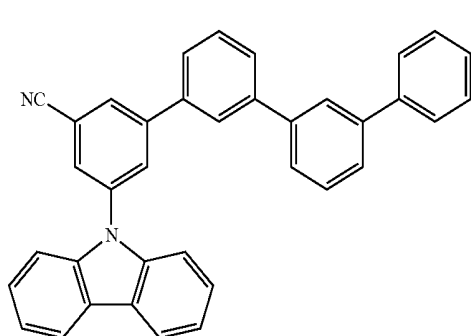
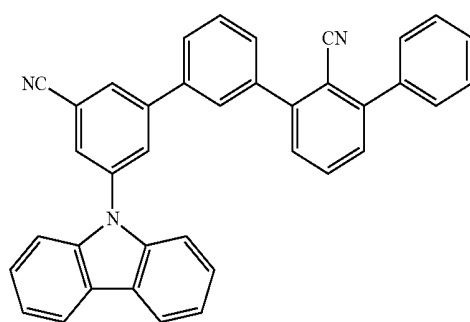
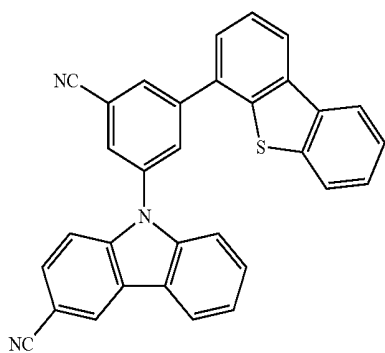
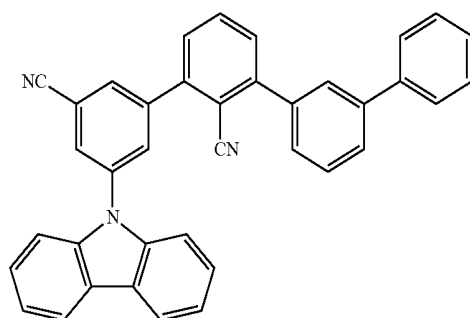
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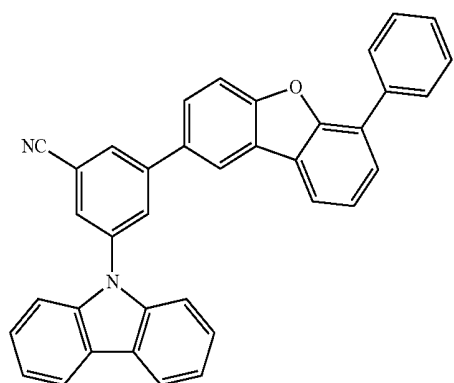
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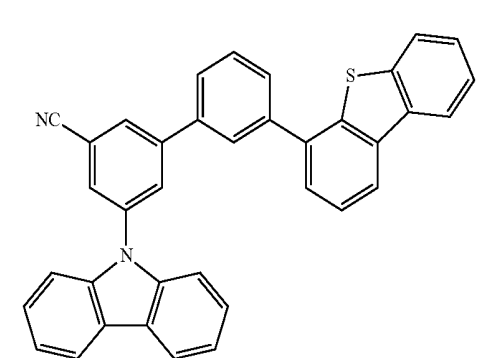
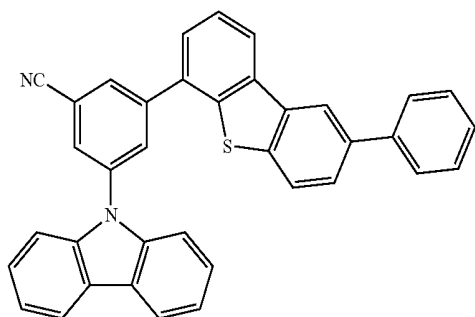
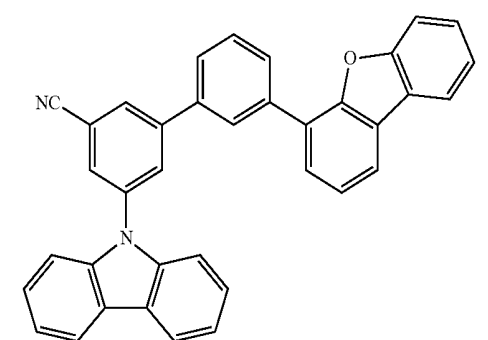
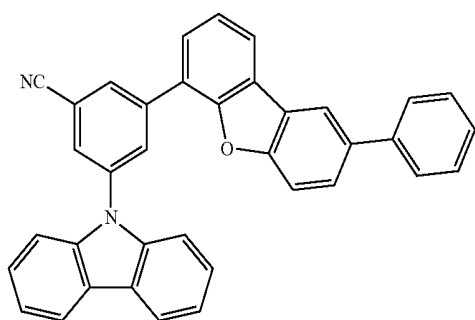
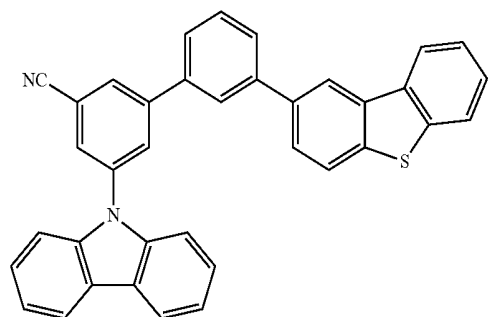
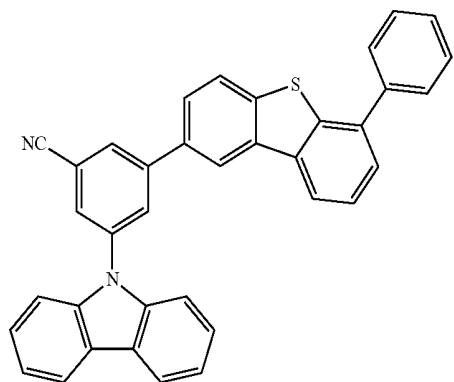
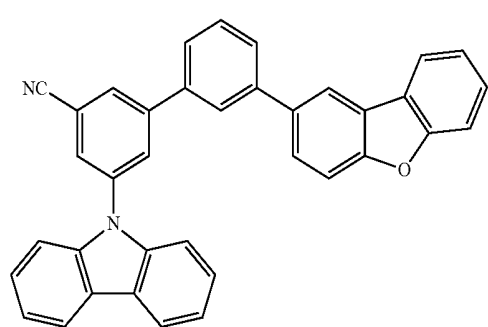
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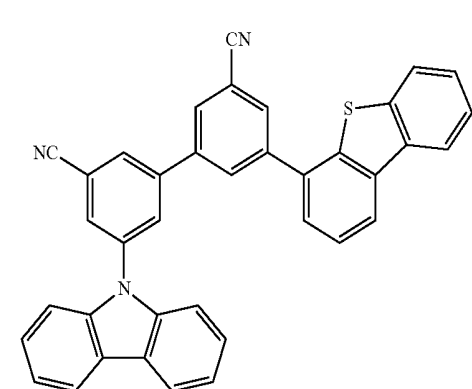
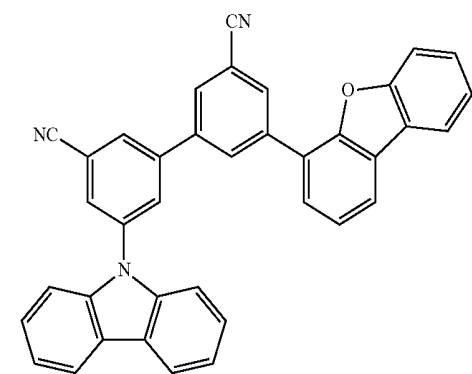
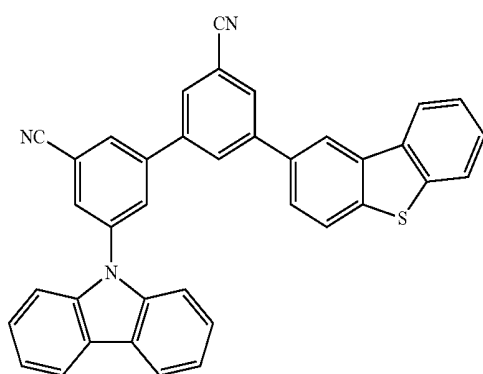
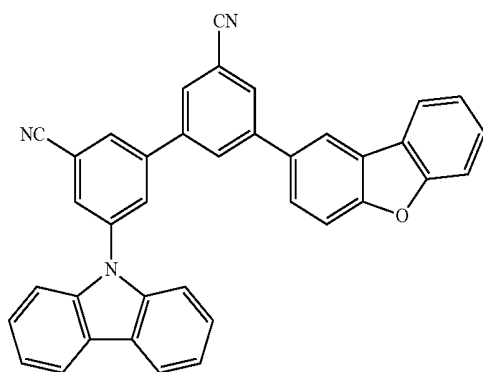
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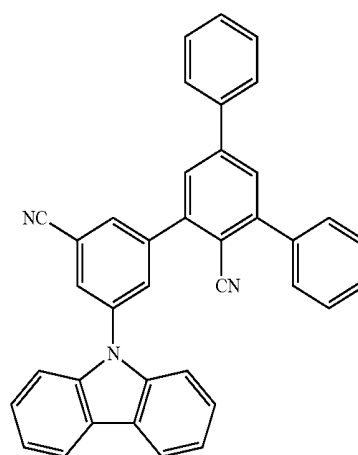
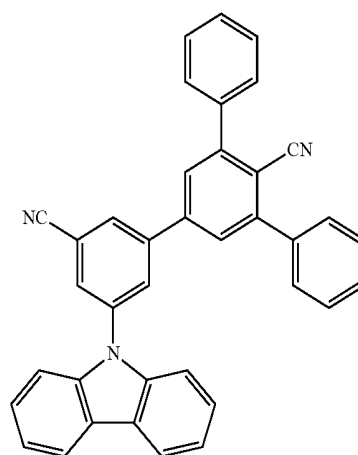
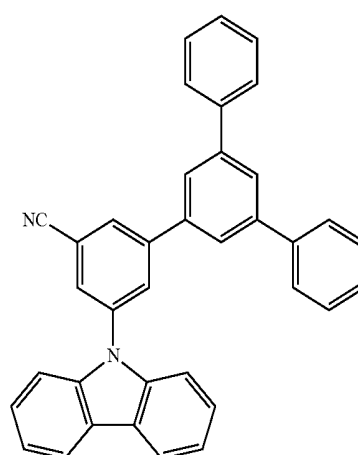
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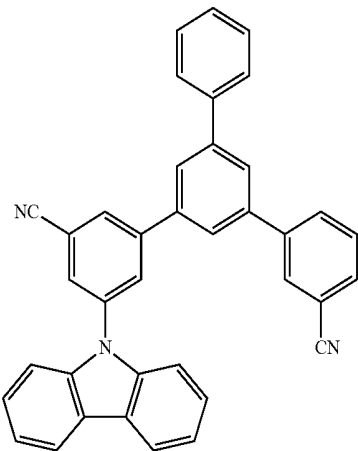
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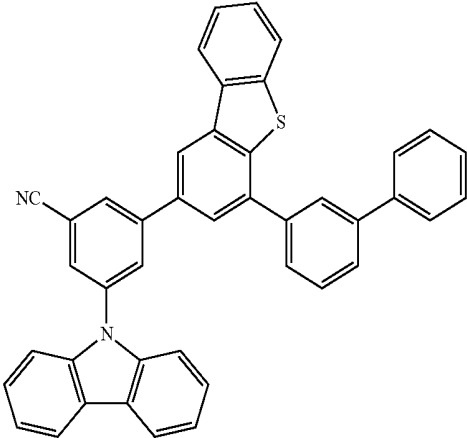


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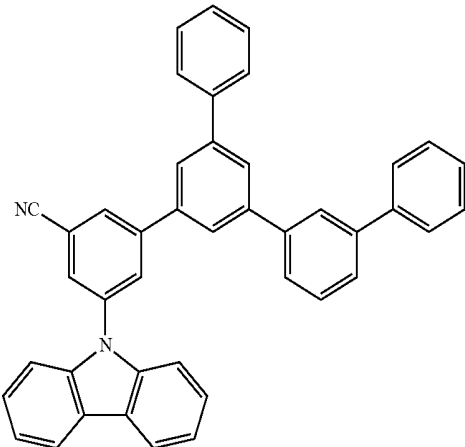


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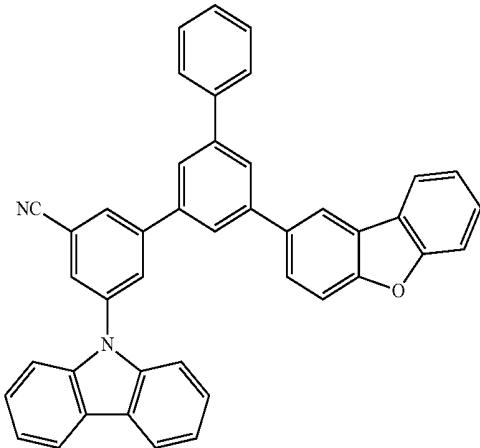
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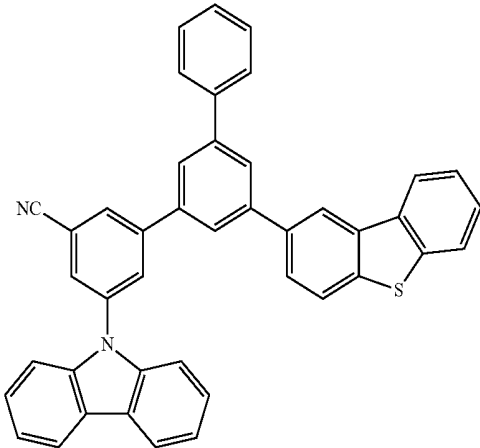
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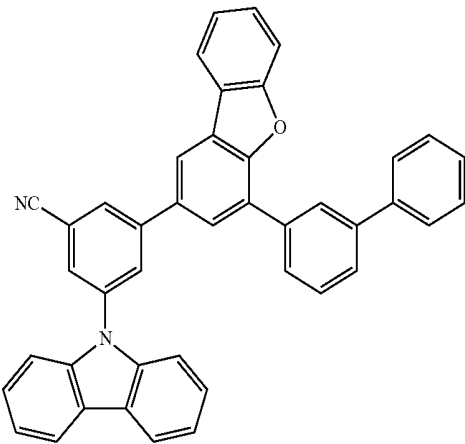
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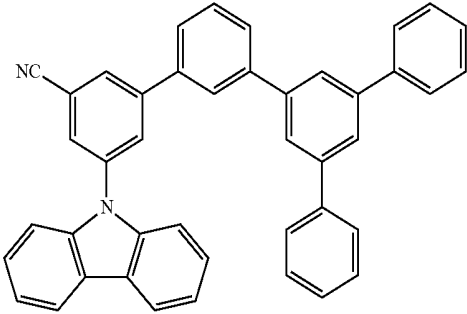
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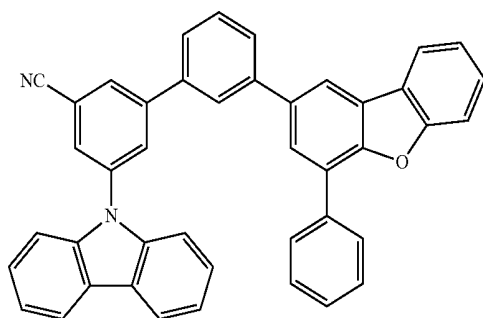


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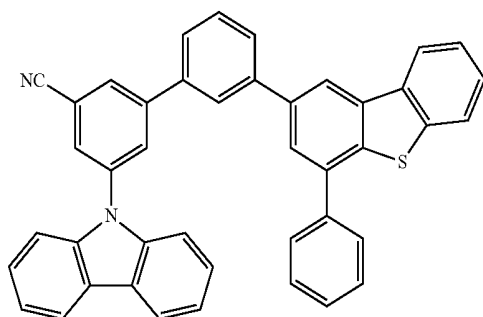


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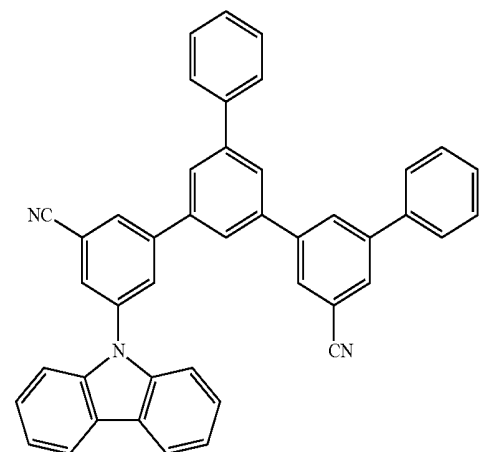
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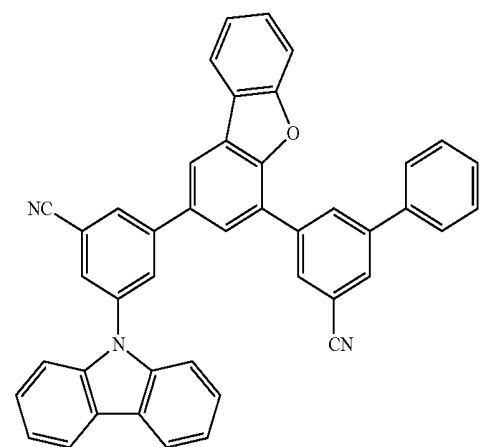
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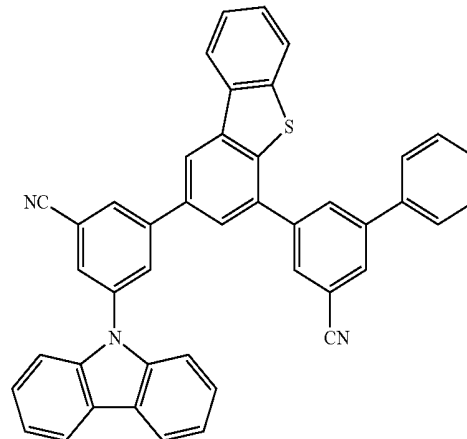
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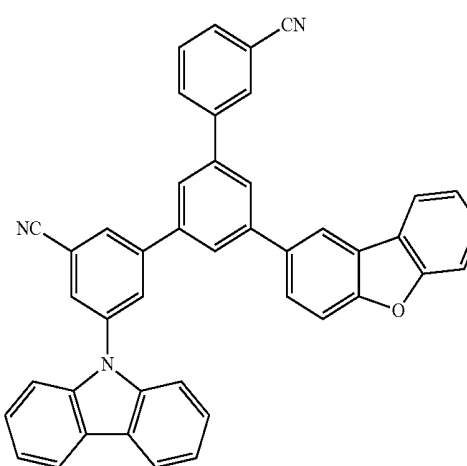


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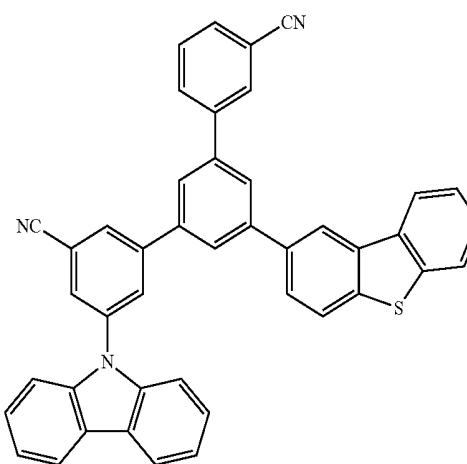


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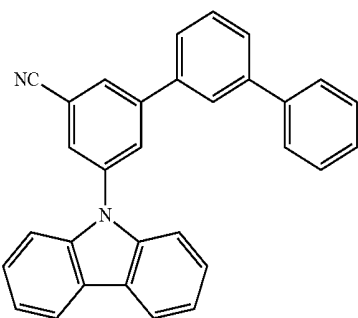
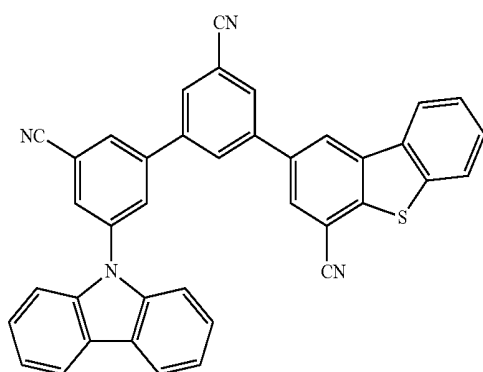
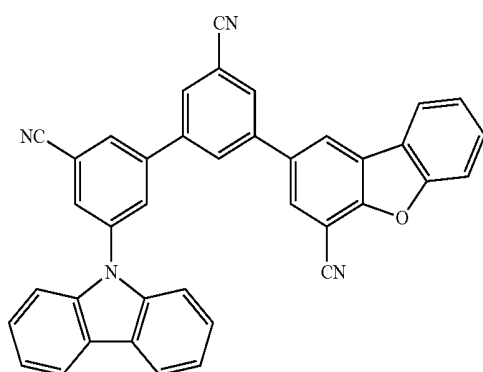
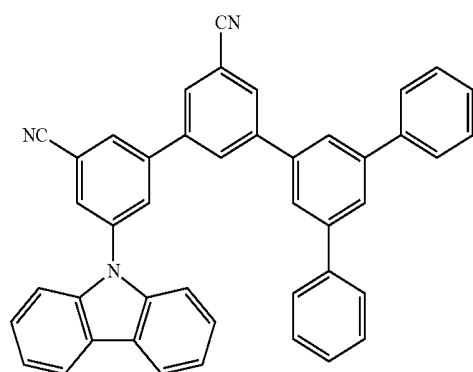
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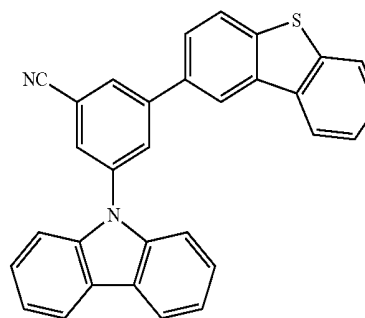
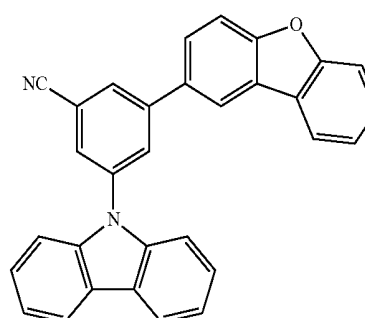
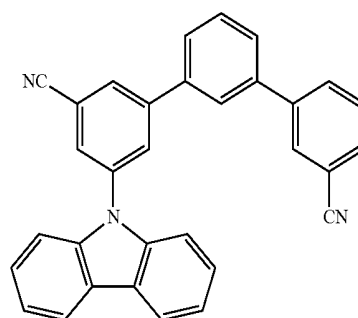
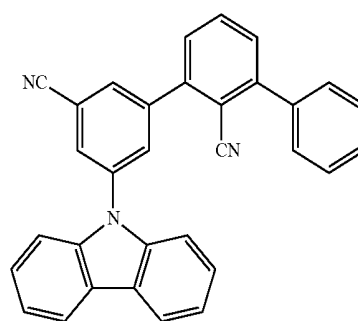
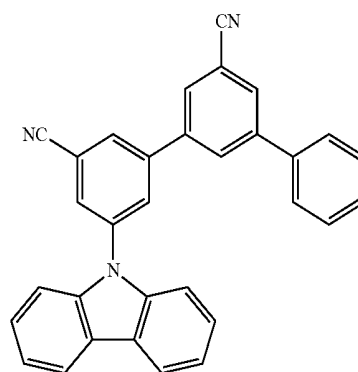
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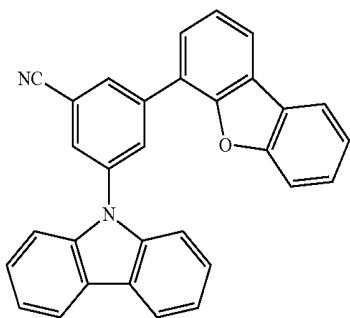
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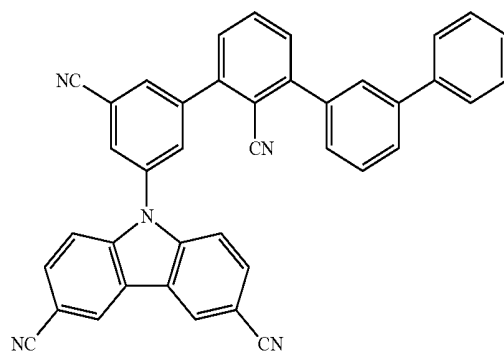


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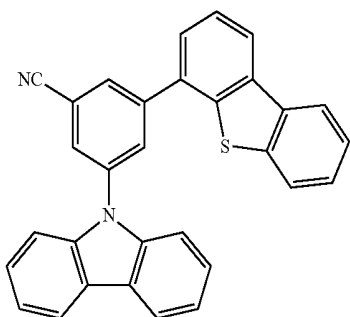


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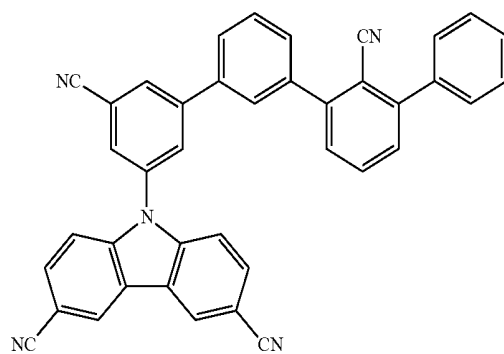
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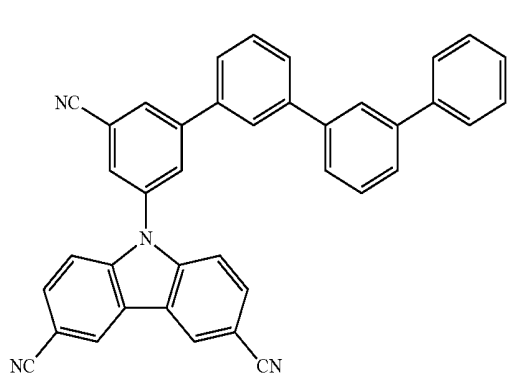
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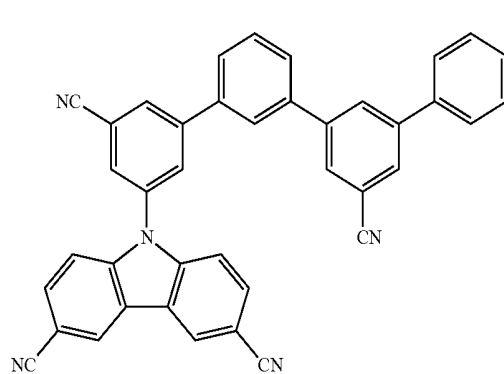
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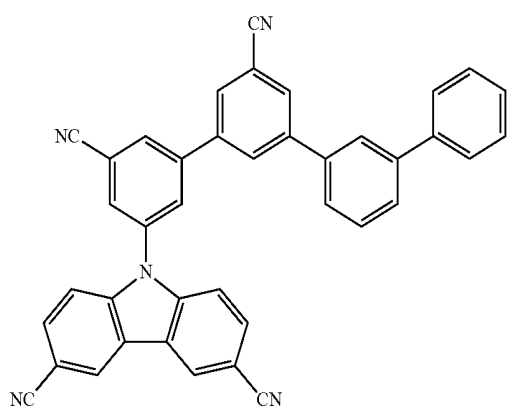
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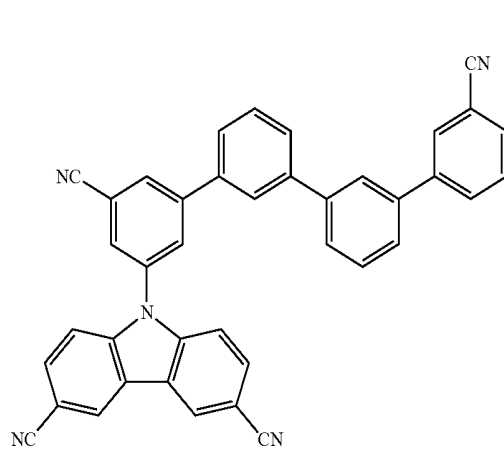
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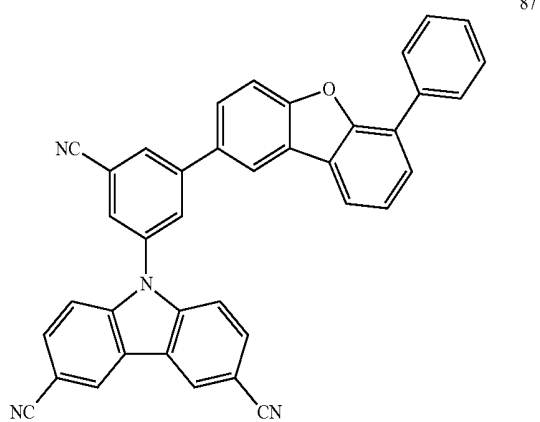


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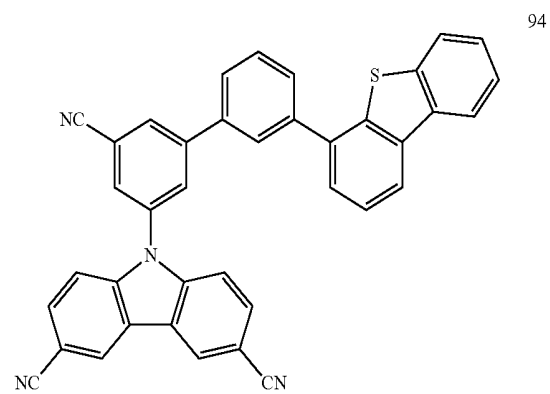
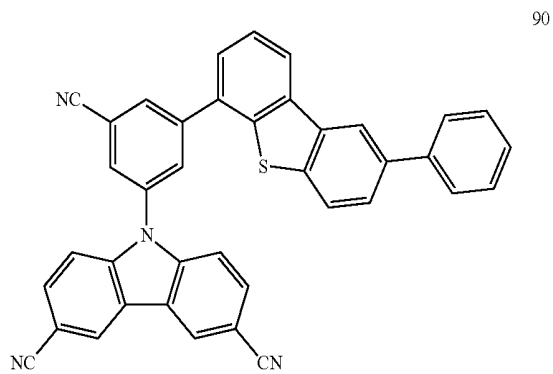
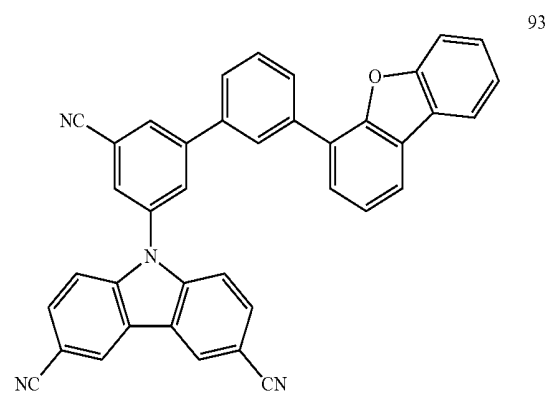
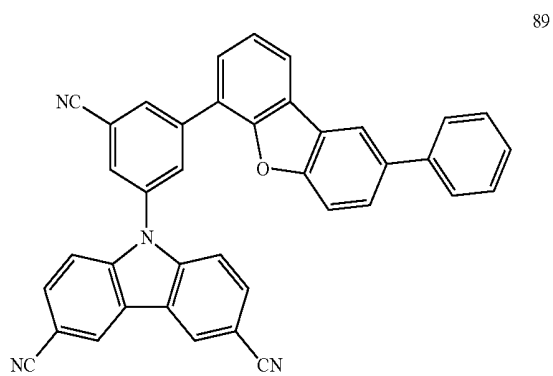
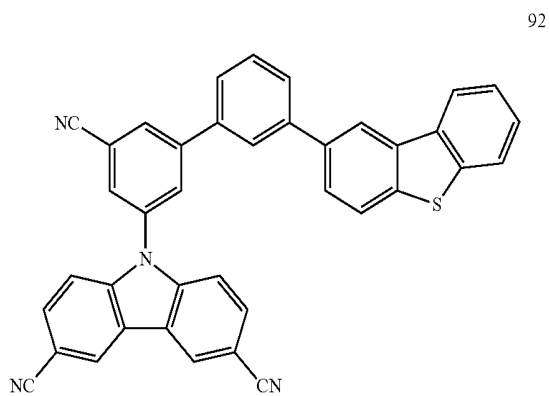
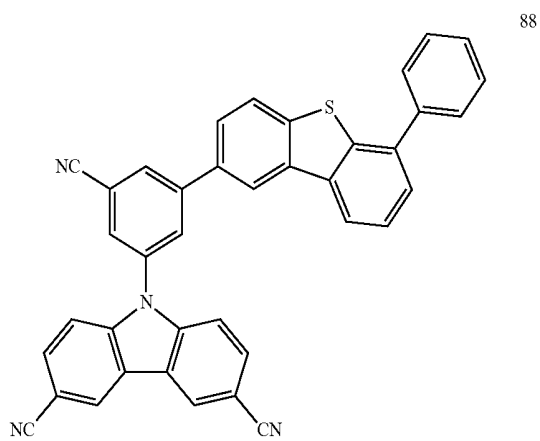
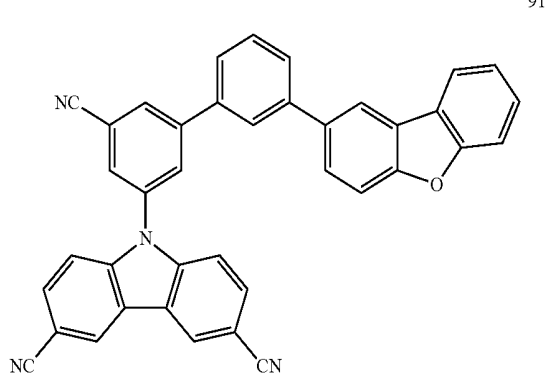


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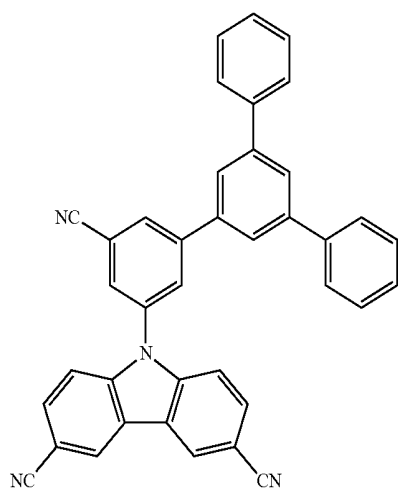
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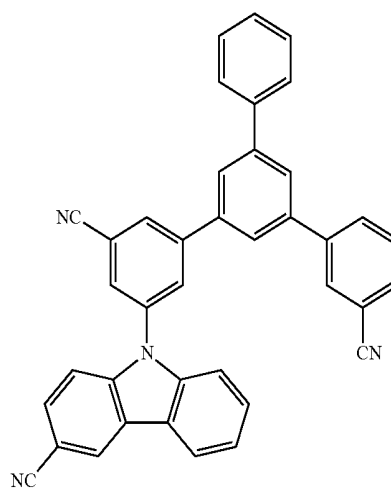


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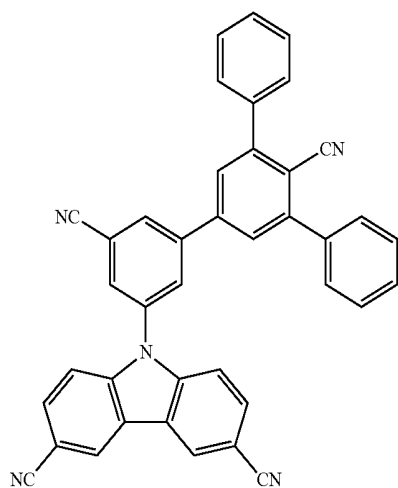


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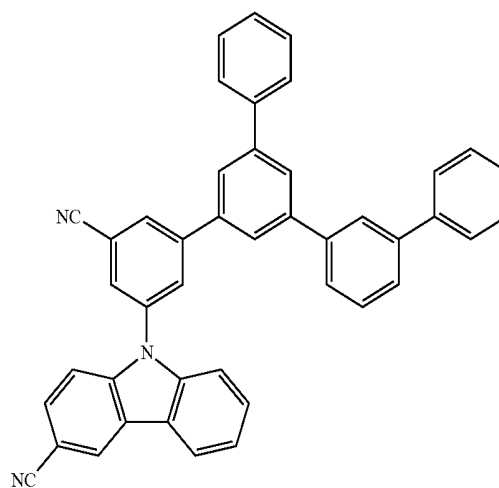
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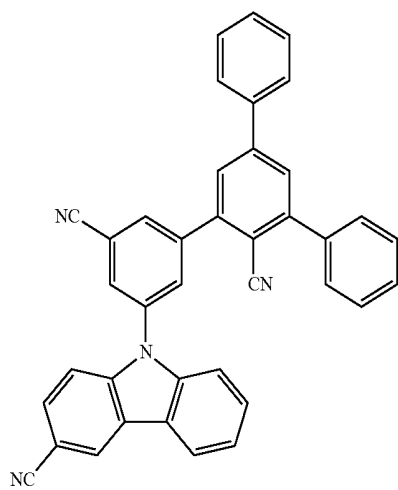
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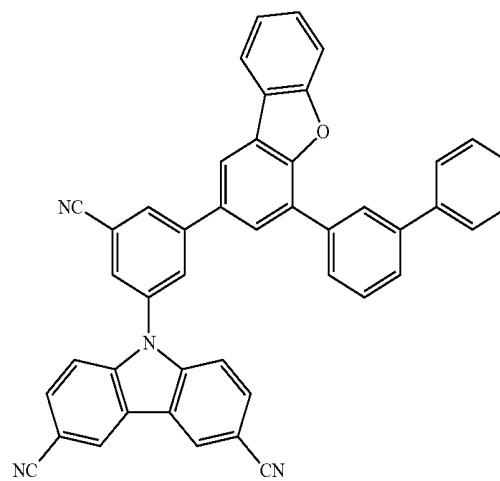
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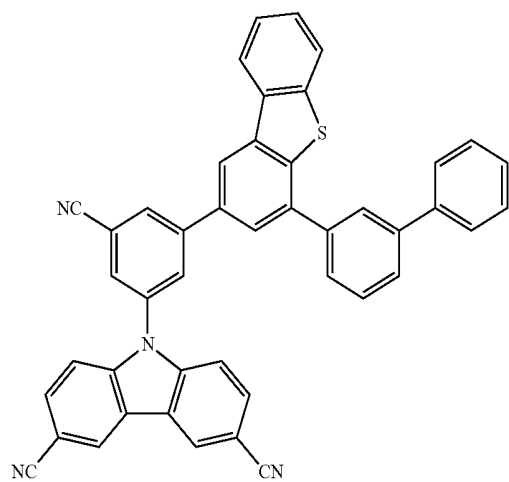
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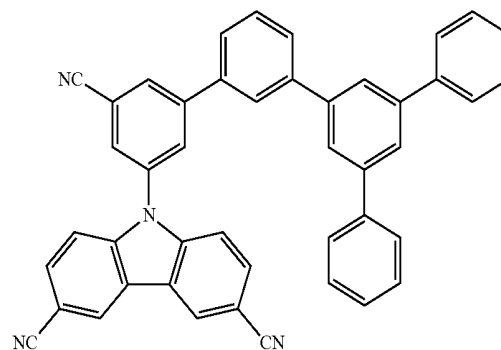
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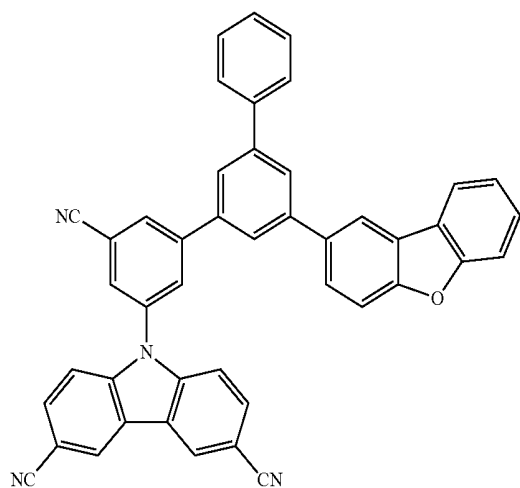


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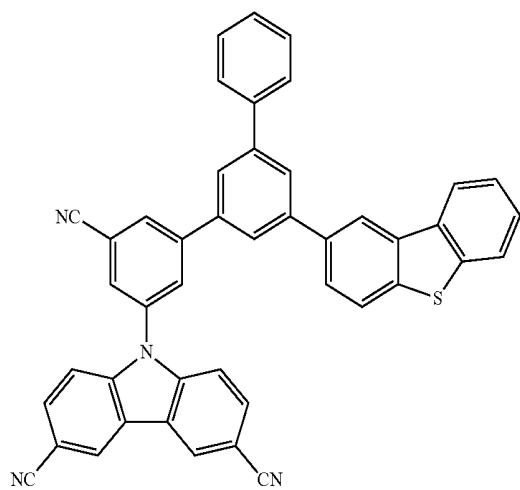
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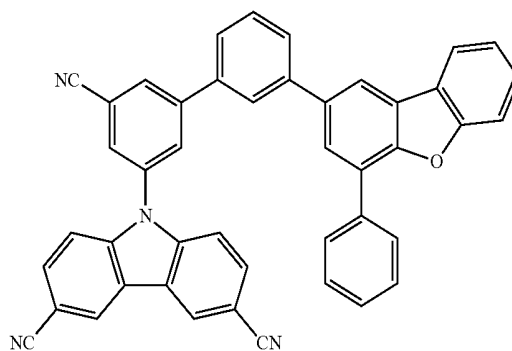
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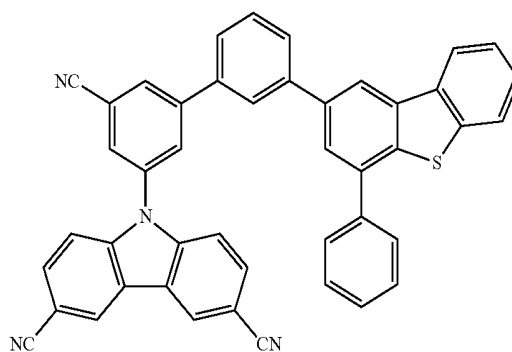
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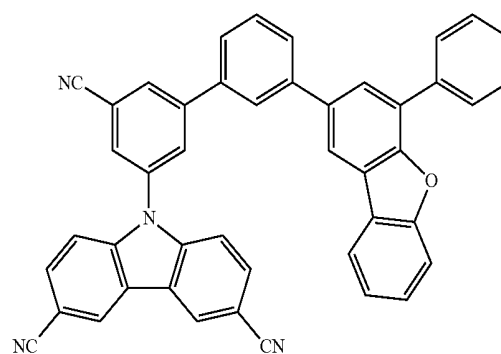
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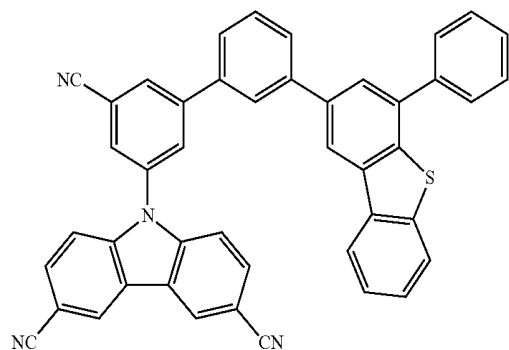


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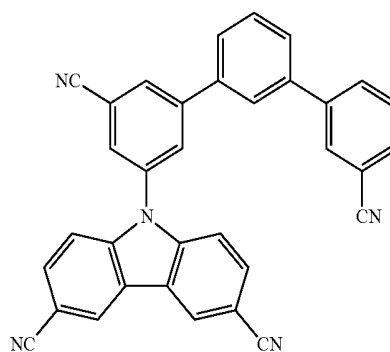
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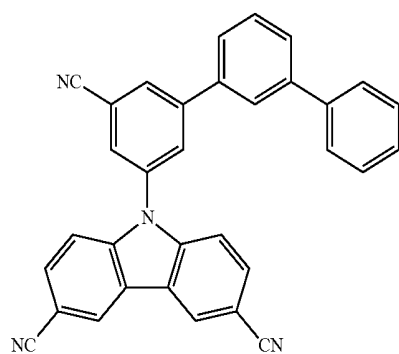


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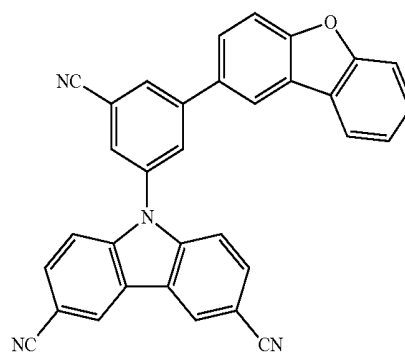
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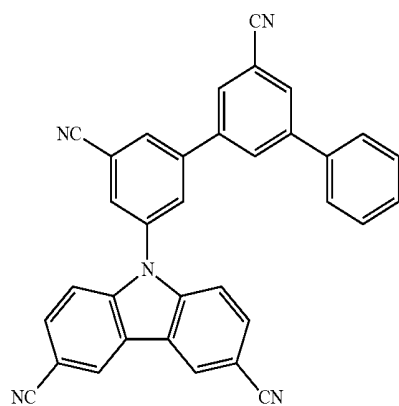
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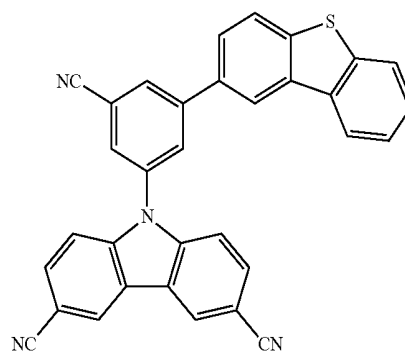
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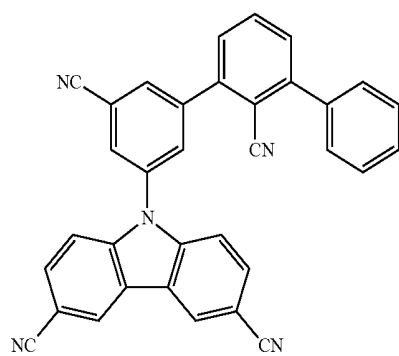
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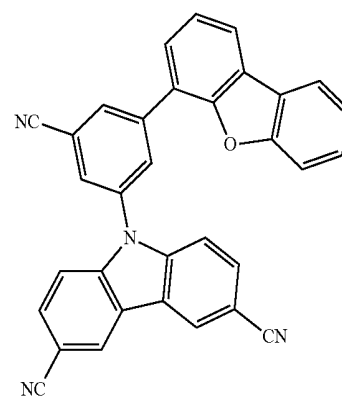
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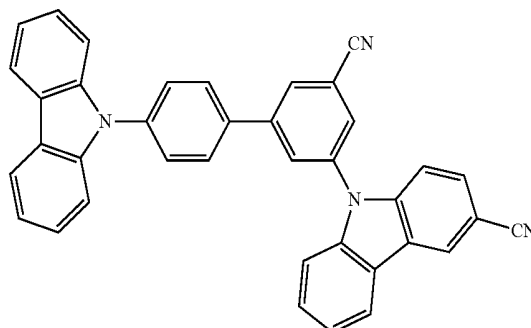
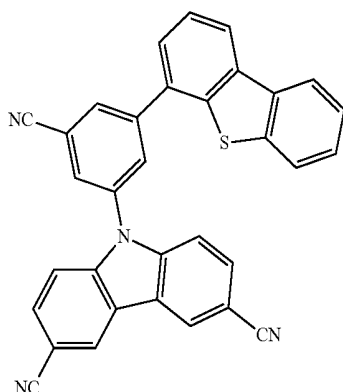
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B



[0145] Ar_1 in the condensed cyclic compound represented by Formula 1 is selected from groups represented by Formulae 2A to 2C, and Formulae 2A to 2C include at least one cyano group. Furthermore, Formulae 2A to 2C include two or more phenylene groups or derivatives thereof, linked to each other in meta-position. Accordingly, the condensed cyclic compound represented by Formula 1 may have a relatively high triplet (T_1) energy level, and a relatively low energy band gap between a highest occupied molecular orbital (HOMO) and a lowest unoccupied molecular orbital (LUMO) to thereby contribute to easy transportation of holes and electrons. Also, by introducing at least one cyano group to Formulae 2A to 2C, the condensed cyclic compound may maintain a high triplet (T_1) and have excellent heat resistance with respect to molecular weight. Accordingly, an electronic device including the condensed cyclic compound, for example, an organic light-emitting device including the condensed cyclic compound may have a high efficiency and a long lifespan.

[0146] A HOMO energy level, a LUMO energy level, a triplet (T_1) energy level, and a singlet (S_1) energy level, and a difference between T_1 and S_1 of Compounds 1 to 16 and Compound B were evaluated by using a Density Functional Theory (DFT) method of a Gaussian program structure-optimized at the level of B3LYP/6-31G(d,p). Results thereof are shown in Table 1:

TABLE 1

Compound No.	HOMO (eV)	LUMO (eV)	T_1 (eV)	S_1 (eV)	$S_1 - T_1$
1	-5.648	-1.811	2.992	3.243	0.251
2	-5.777	-2.335	2.975	3.108	0.133
3	-6.175	-2.232	3.001	3.361	0.360
4	-6.067	-1.958	3.037	3.507	0.470
5	-6.068	-1.958	3.012	3.508	0.496
6	-6.065	-1.948	3.001	3.516	0.515
7	-6.071	-1.966	3.036	3.505	0.469
8	-6.068	-1.938	3.043	3.526	0.483
9	-5.989	-1.94	3.014	3.515	0.501
10	-6.064	-1.98	2.991	3.485	0.494
11	-6.041	-1.918	2.958	3.526	0.568
12	-6.055	-1.958	2.916	3.499	0.583
13	-6.071	-1.966	3.036	3.505	0.469
14	-5.989	-1.94	3.014	3.515	0.501
15	-6.059	-1.967	2.9	3.494	0.594
16	-5.998	-1.977	3.001	3.501	0.500
B	-5.652	-2.065	2.839	3.187	0.348

[0147] Referring to Table 1, as Compounds 1 to 16 have a higher T_1 energy level than Compound B including phenylene groups linked in para-position, one can see that Compounds 1 to 16 are suitable for a material to be used in an electronic device, for example, in an organic light-emitting device (e.g., as a host in an emission layer).

[0148] 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.

[0149] Therefore, the condensed cyclic compound represented by Formula 1 may be appropriate to be used in an organic layer of an organic light-emitting device, for example as a host in an emission layer of the organic layer or as an emitter (for example, a TADF emitter). Thus, according to another aspect, provided is an organic light-emitting device that may include:

[0150] a first electrode;

[0151] a second electrode; and

[0152] an organic layer that is disposed between the first electrode and the second electrode,

[0153] wherein the organic layer includes an emission layer and at least one condensed cyclic compound represented by Formula 1.

[0154] Since the organic light-emitting device has an 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 emission efficiency, and long lifespan.

[0155] The condensed cyclic compound represented by Formula 1 may be included 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 a hole injection layer, a hole transport layer, an electron blocking layer, or any combination thereof) disposed between the first electrode and the emission layer, and an electron transport region (for example, including a hole blocking layer, an electron transport layer, an electron injection layer, or any combination thereof) disposed between the emission layer and the second electrode.

[0156] For example, 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 serve as a host, and the emission layer may further include a dopant (a fluorescent dopant or a

phosphorescent dopant). The emission layer may be a green emission layer that emits green light or a blue emission layer that emits blue light. According to an exemplary embodiment, the condensed cyclic compound represented by Formula 1 may be included in the emission layer, and the emission layer may further include a phosphorescent dopant, and the emission layer may emit blue light.

[0157] Alternatively, 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 only the condensed cyclic compound represented by Formula 1 or may further include a host and/or a dopant in addition to the condensed cyclic compound represented by Formula 1.

[0158] As used herein, the expression the “(organic layer) includes at least one condensed cyclic compound” may be construed as meaning the “(organic layer) may include one condensed cyclic compound within the scope in Formula 1 or two or more different condensed cyclic compounds within the scope of Formula 1”.

[0159] 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. Alternatively, 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 may be respectively included in different layers.

[0160] 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.

[0161] For example, the first electrode may be an anode, the second electrode may be a cathode, and the organic layer may include:

[0162] i) a hole transport region disposed between the first electrode and the emission layer, wherein the hole transport region includes a hole injection layer, a hole-transport layer, an electron blocking layer, or any combination thereof; and

[0163] ii) an electron transport region disposed between the emission layer and the second electrode, wherein the electron transport region includes a hole blocking layer, an electron transport layer, an electron injection layer, or any combination thereof.

[0164] As used herein, the term the “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.

[0165] FIG. 1 is a schematic view of an organic light-emitting device 10 according to an exemplary embodiment. Hereinafter, a structure and a method of manufacturing the organic light-emitting device according to an exemplary 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.

[0166] 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.

[0167] The first electrode 11 may be formed by depositing or sputtering a material for forming the first electrode on the substrate. The first electrode 11 may be an anode. The material for the first electrode 11 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 material for the first electrode 11 may be selected from indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO₂), and zinc oxide (ZnO). Alternatively, a metal such as magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), and magnesium-silver (Mg—Ag) may be used as the material for the first electrode 11.

[0168] The first electrode 11 may have a single layer structure or a multi-layer structure including two or more layers. For example, the first electrode 11 may have a triple-layer structure of ITO/Ag/ITO, but it is not limited thereto.

[0169] The organic layer 15 is disposed on the first electrode 11.

[0170] The organic layer 15 may include a hole transport region, an emission layer, and an electron transport region.

[0171] The hole transport region may be disposed between the first electrode 11 and the emission layer.

[0172] The hole transport region may include a hole injection layer, a hole transport layer, an electron blocking layer, a buffer layer, or any combination thereof.

[0173] 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.

[0174] When the hole transport region includes a hole injection layer, the hole injection layer (HIL) may be formed on the first electrode 11 by using various methods such as vacuum-deposition, spin coating, casting, and Langmuir-Blodgett (LB) method.

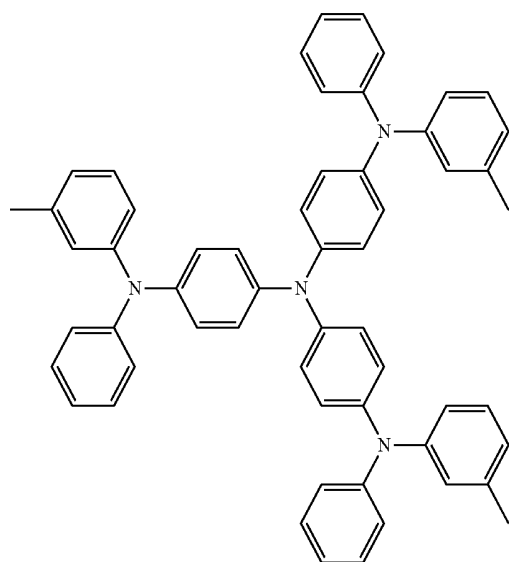
[0175] When a hole injection layer is formed by vacuum-deposition, for example, the vacuum-deposition may be performed at a deposition temperature in a range of about 100° C. to about 500° C., at a vacuum degree in a range of about 10⁻⁸ to about 10⁻³ torr, and at a deposition rate in a range of about 0.01 Angstroms per second (Å/sec) to about 100 Å/sec, though the conditions may vary depending on a compound that is used as a hole injection material and a structure and thermal properties of a desired hole injection layer, but it is not limited thereto.

[0176] When a hole injection layer is formed by spin coating, the spin coating may be performed at a coating rate in a range of about 2,000 revolutions per minute (rpm) to about 5,000 rpm, and at a temperature in a range of about 80° C. to 200° C. for removing a solvent after the spin coating, though the conditions may vary depending on a

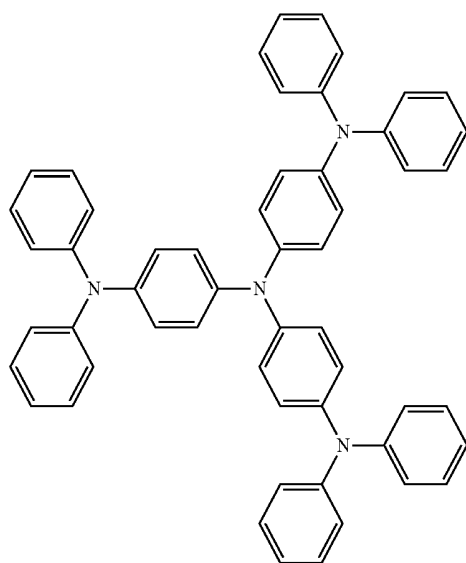
compound that is used as a hole injection material and a structure and thermal properties of a desired HIL, but is not limited thereto.

[0177] The conditions for forming a hole transport layer and an electron blocking layer may be understood based on the description of the conditions for forming the hole injection layer.

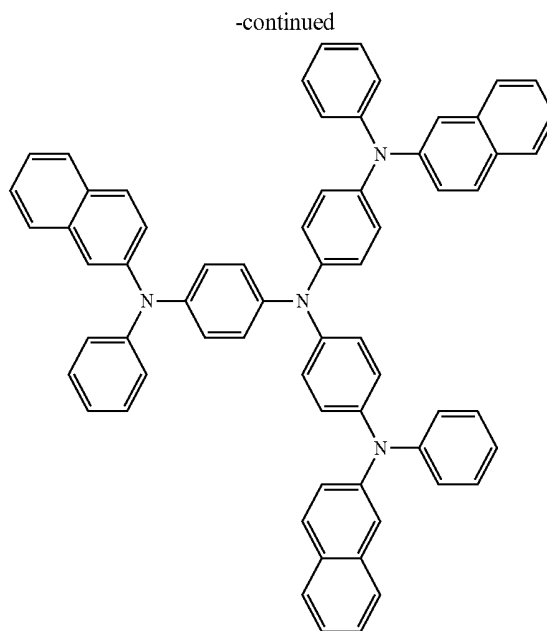
[0178] The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB, β -NPB, TPD, a spiro-TPD, a spiro-NPB, methylated-NPB, TAPC, HMTPD, 4,4',4''-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (Pani/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (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:



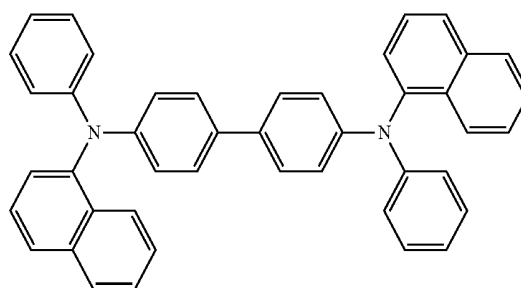
m-MTDATA



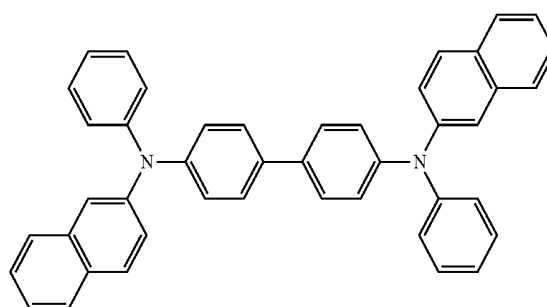
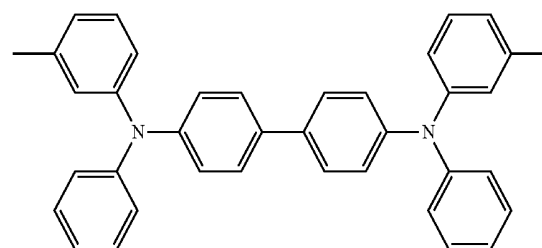
TDATA



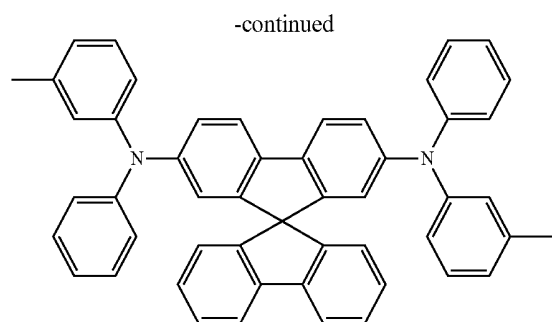
2-TNATA



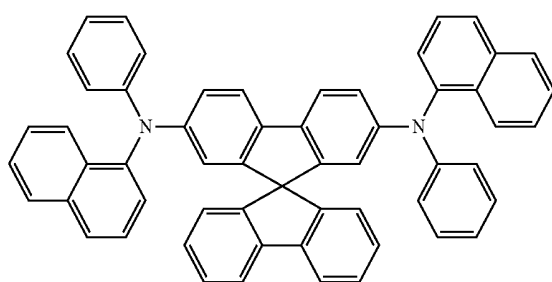
NPB

 β -NPB

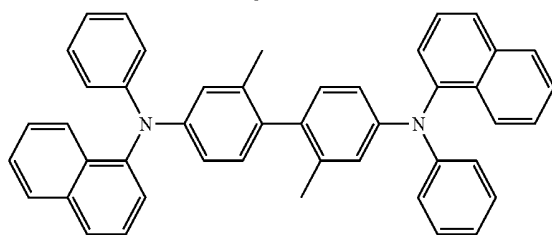
TPD



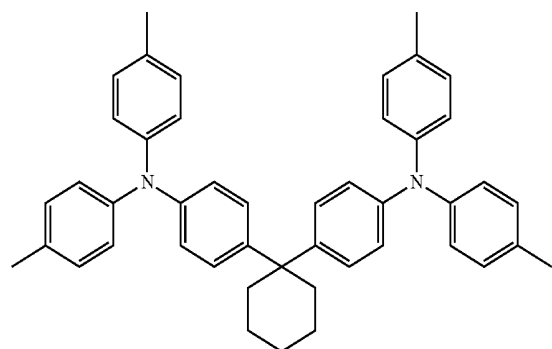
Spiro-TPD



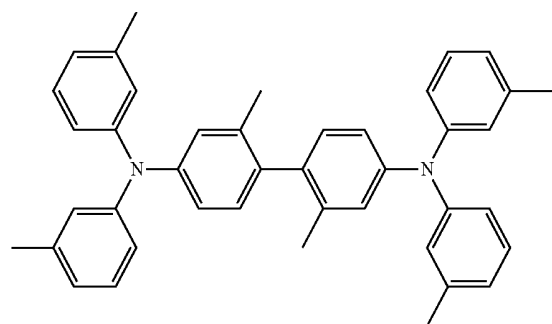
Spiro-NPB



methylated NPB



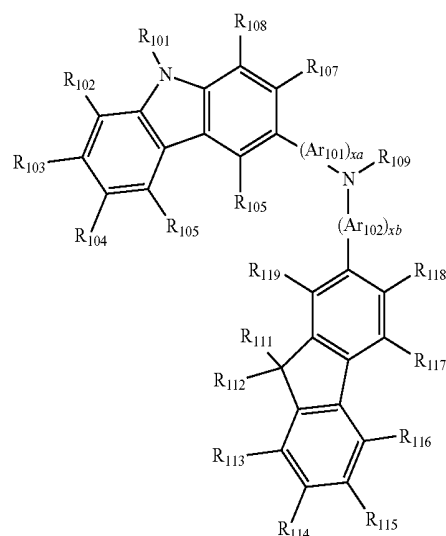
TAPC



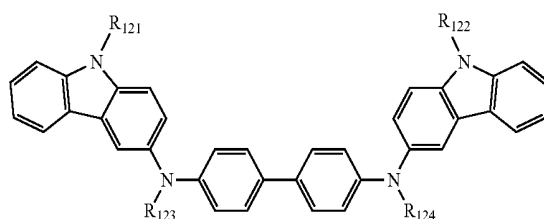
HMTPD

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Formula 201



Formula 202



[0179] In Formula 201, Ar₁₀₁ and Ar₁₀₂ may each independently be selected from

[0180] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an acenaphthylene group, a fluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, and a pentacenylene group; and

[0181] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an acenaphthylene group, a fluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, and a pentacenylene group, each substituted with at least one selected from 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 C₁-C₆₀ alkyl group, a C₂-C₆₀

alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

[0182] In Formula 201, xa and xb may each independently be 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 they are not limited thereto.

[0183] In Formulae 201 and 202, R₁₀₁ to R₁₀₈, R₁₁₁ to R₁₁₉, and R₁₂₁ to R₁₂₄ may each independently be selected from

[0184] hydrogen, 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 C₁-C₁₀ alkyl group (for example, a methyl group, an ethyl group, a propyl group, a butyl group, pentyl group, or a hexyl group), and a C₁-C₁₀ alkoxy group (for example, a methoxy group, an ethoxy group, a propoxy group, butoxy group, or a pentoxy group);

[0185] a C₁-C₁₀ alkyl group and a C₁-C₁₀ alkoxy group, each substituted with at least one selected from 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;

[0186] a phenyl group, a naphthyl group, an anthracenyl group, a fluorenyl group, and a pyrenyl group; and

[0187] a phenyl group, a naphthyl group, an anthracenyl group, a fluorenyl group, and a pyrenyl group, each substituted with at least one selected from 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 C₁-C₁₀ alkyl group, and a C₁-C₁₀ alkoxy group, but they are not limited thereto.

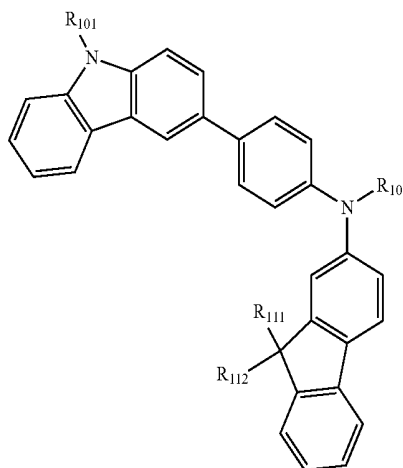
[0188] In Formula 201, R₁₀₉ may be selected from

[0189] a phenyl group, a naphthyl group, an anthracenyl group and a pyridinyl group; and

[0190] a phenyl group, a naphthyl group, an anthracenyl group, and a pyridinyl group, each substituted with at least one selected from 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 C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, and a pyridinyl group.

[0191] According to an exemplary embodiment, the compound represented by Formula 201 may be represented by Formula 201A, but it is not limited thereto:

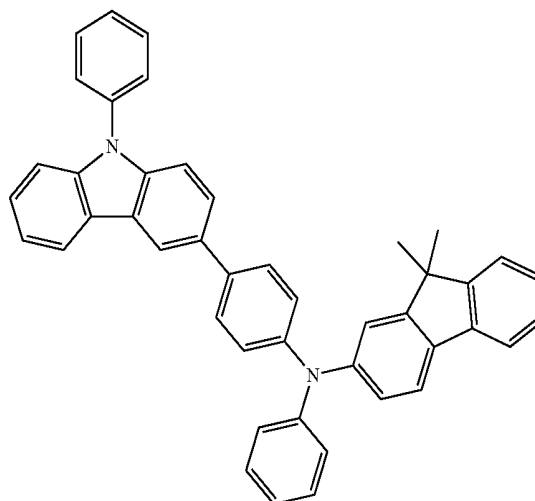
Formula 201A



[0192] Descriptions for R₁₀₁, R₁₁₁, R₁₁₂, and R₁₀₉ in Formula 201A are the same as described above.

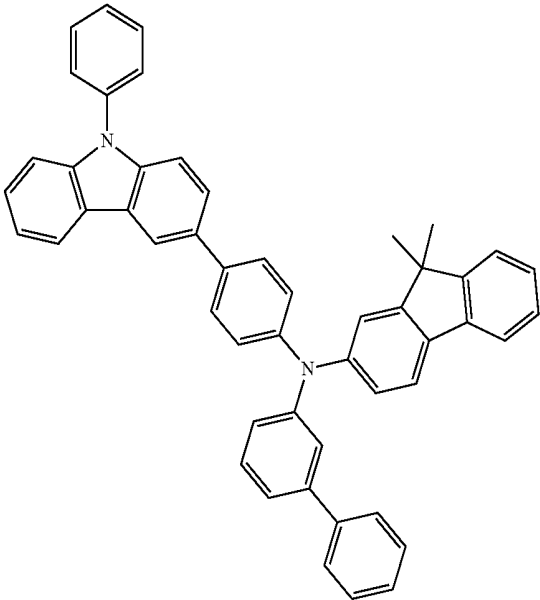
[0193] For example, the compound represented by Formula 201 and the compound represented by Formula 202 may include Compounds HT1 to HT20, but they are not limited thereto:

HT1



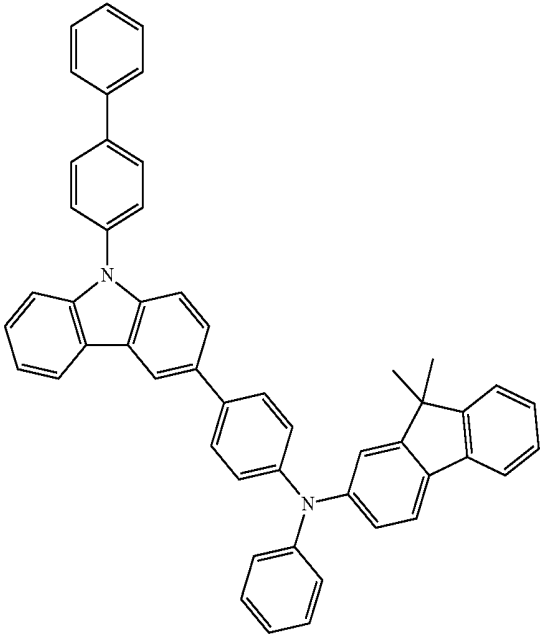
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HT2

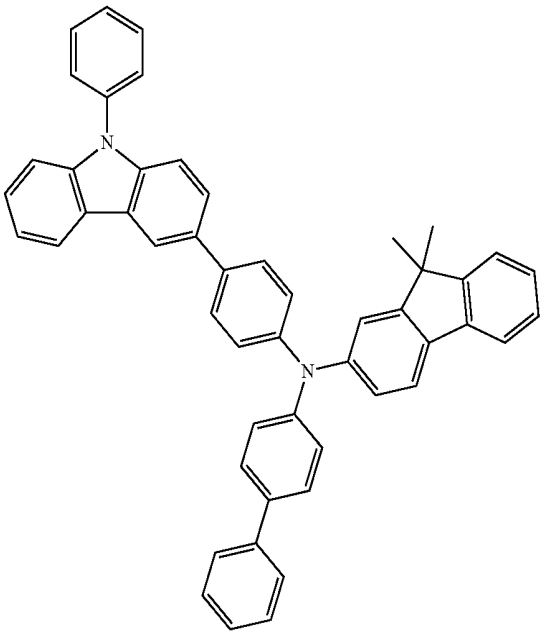


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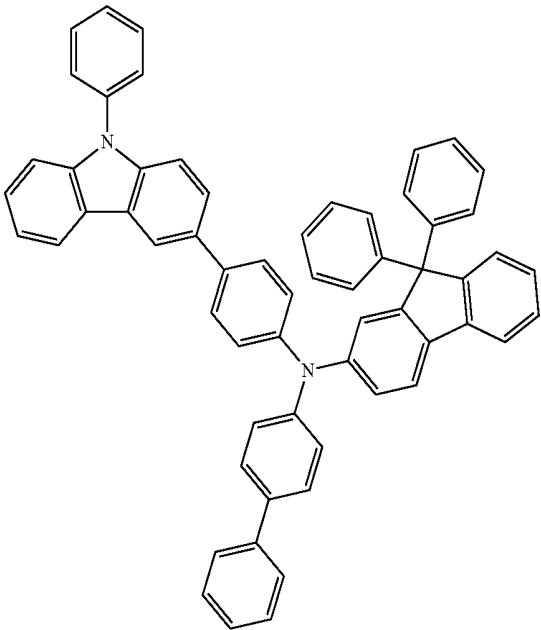
HT4



HT3

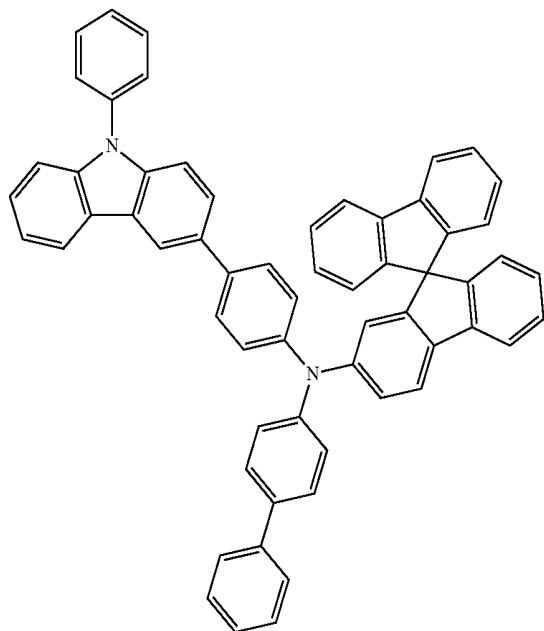


HT5



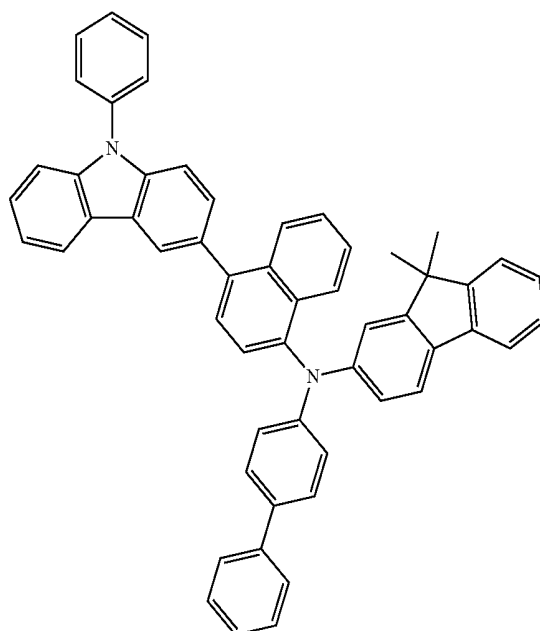
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HT6

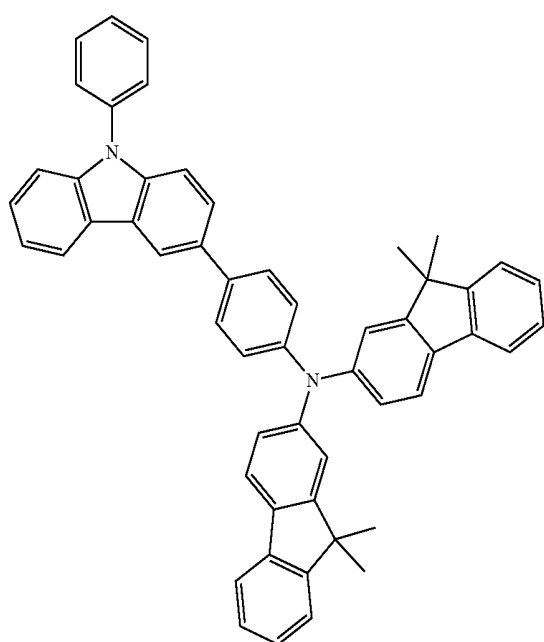


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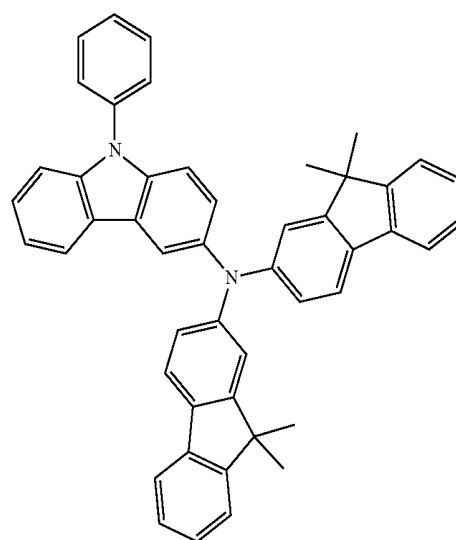
HT8



HT7

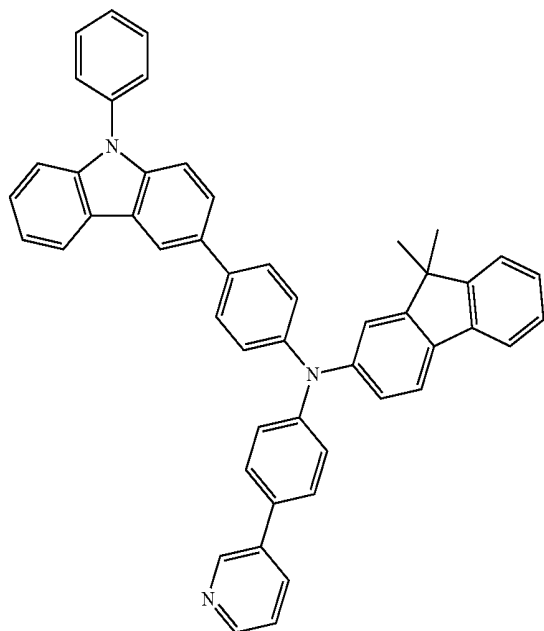


HT9



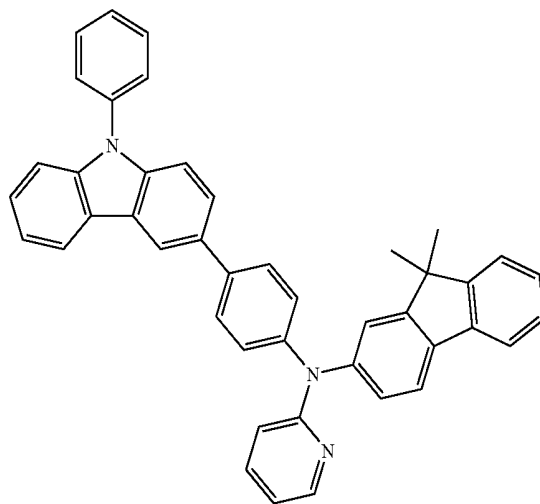
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HT10

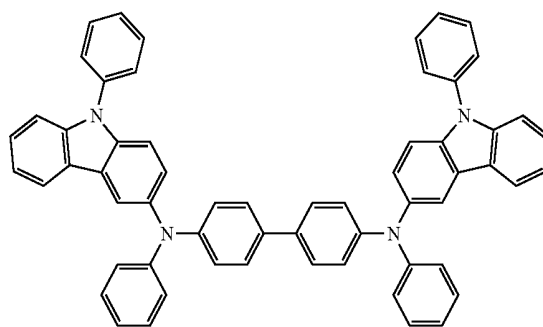


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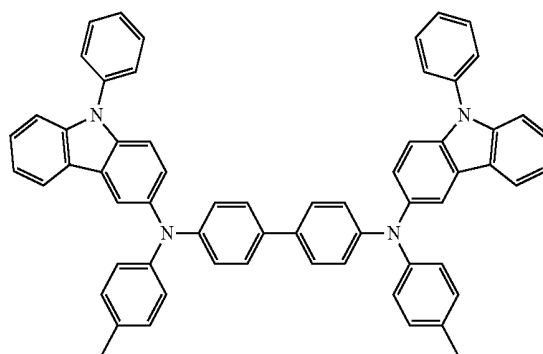
HT12



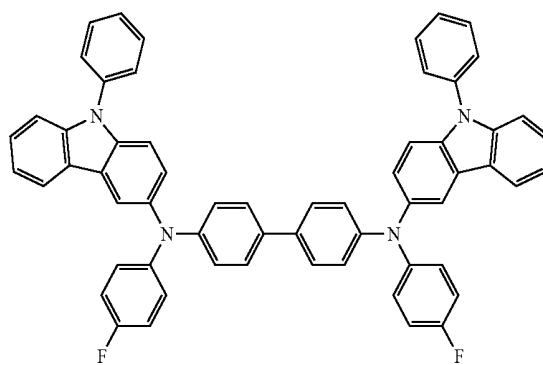
HT13



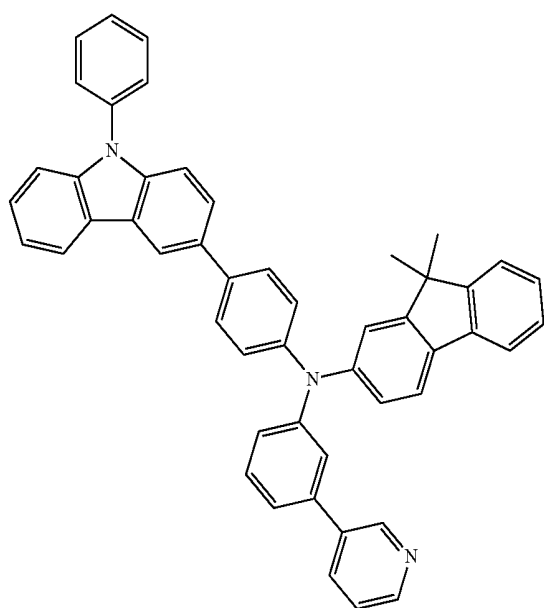
HT14



HT15

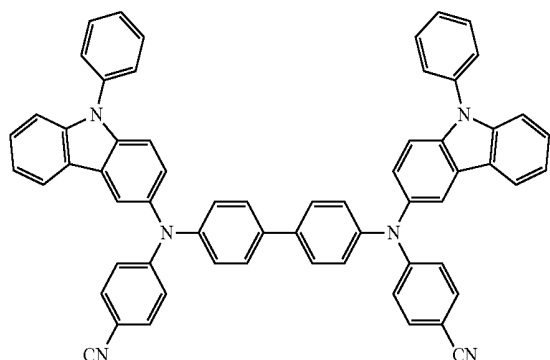


HT11



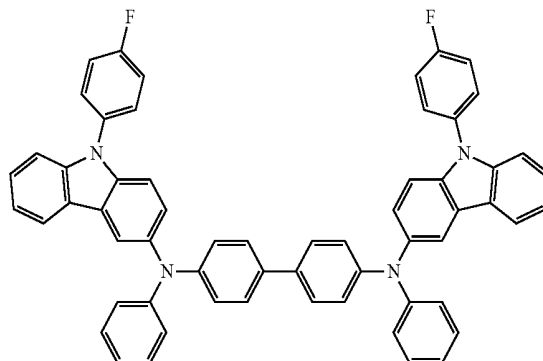
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HT16

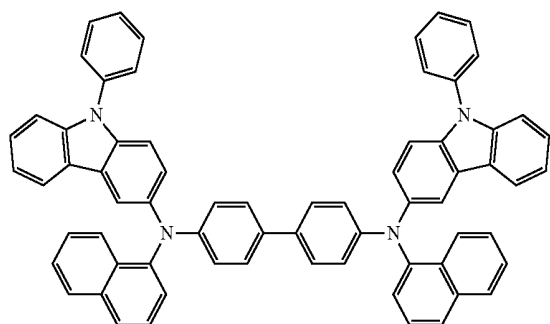


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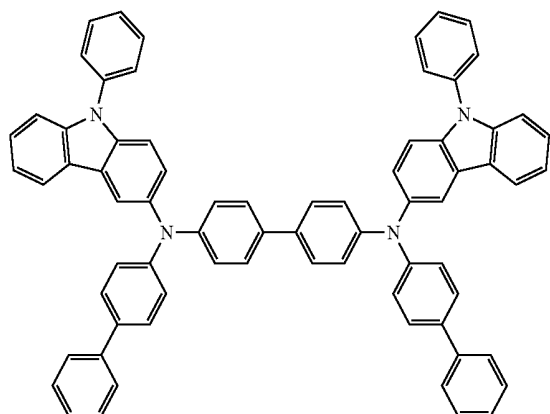
HT20



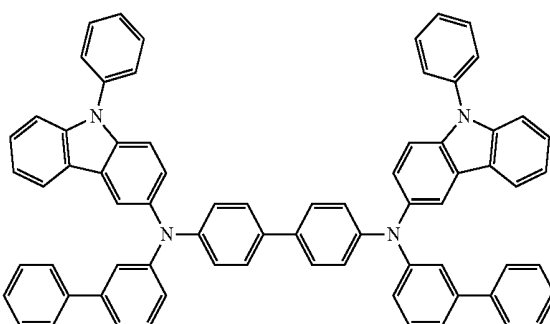
HT17



HT18



HT19

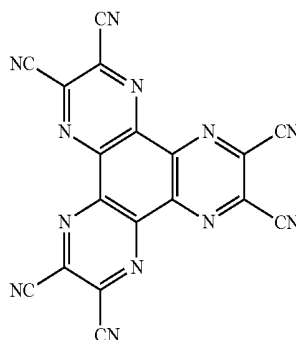


[0194] A thickness of the hole transport region may be in a range of about 100 Angstroms (Å) to about 10,000 Å, for example, about 100 Å to about 1,000 Å. When the hole transport region includes at least one of a hole injection layer and a hole transport layer, a thickness of the hole injection layer may be in a range of about 100 Å to about 10,000 Å, for example, about 100 Å to about 1,000 Å, and a thickness of the hole transport layer may be in a range of about 50 Å to about 2,000 Å, for example, about 100 Å to about 1,500 Å. While not wishing to be bound by 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, excellent hole transport characteristics may be obtained without a substantial increase in driving voltage.

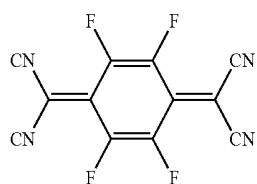
[0195] The hole transport region may further include, in addition to the above-described materials, a charge-generating material to improve conductive properties. The charge-generating material may be homogeneously or non-homogeneously dispersed throughout the hole transport region.

[0196] 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 is not limited thereto. For example, non-limiting examples of the p-dopant may include a quinone derivative, such as tetracyanoquinonodimethane (TCNQ) or 2,3,5,6-tetrafluoro-tetracyano-1,4-benzoquinonodimethane (F4-TCNQ); a metal oxide, such as a tungsten oxide or a molybdenum oxide; and a compound containing a cyano group, such as Compound HT-D1 or Compound HP-1 illustrated below, but they are not limited thereto.

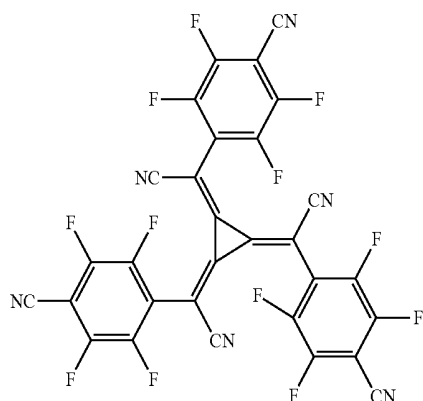
Compound HT-D1



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F4-TCNQ



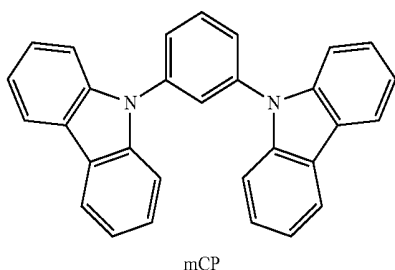
HP-1

[0197] The hole transport region may further include a buffer layer.

[0198] 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.

[0199] An emission layer (EML) may be formed on the hole transport region by using various methods, such as vacuum-deposition, spin coating, casting, or an LB method. When the emission layer is formed by vacuum-deposition or spin coating, vacuum-deposition and coating conditions for the emission layer may be generally similar to the conditions for forming a hole injection layer, though the conditions may vary depending on the compound used.

[0200] The hole transport region may further include an electron blocking layer. The electron blocking layer may include a well-known material such as mCP, but is not limited thereto.



mCP

[0201] 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.

[0202] 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 of a phosphorescent dopant and a fluorescent dopant.

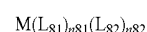
[0203] Alternatively, the emission layer may include only the condensed cyclic compound represented by Formula 1, and the condensed cyclic compound may be a TADF emitter.

[0204] Alternatively, the emission layer may include only the condensed cyclic compound represented by Formula 1, and the condensed cyclic compound may be a TADF emitter, and the emission layer may further include a host.

[0205] For example, the host in the emission layer may include the condensed cyclic compound represented by Formula 1.

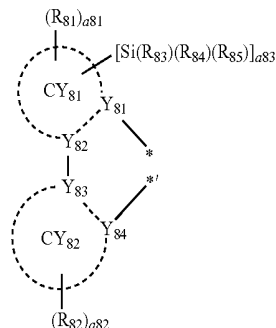
[0206] The dopant in the emission layer may include a fluorescent dopant which emits light according to a fluorescent emission mechanism or a phosphorescent dopant which emits light according to a phosphorescent emission mechanism.

[0207] According to an exemplary 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

Formula 81A



[0208] wherein in Formulae 81 and 81A,

[0209] M is selected from iridium (Ir), platinum (Pt), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), thulium (Tm), and rhodium (Rh),

[0210] L_{81} is a ligand represented by Formula 81A, n_{81} is an integer selected from 1 to 3, provided that when n_{81} is 2 or greater, two or more groups L_{81} are identical to or different from each other,

[0211] L_{82} is an organic ligand, n_{82} is an integer selected from 0 to 4, provided that when n_{82} is 2 or greater, two or more groups L_{82} are identical to or different from each other,

[0212] Y_{81} to Y_{84} are each independently carbon(C) or nitrogen(N),

[0213] Y_{81} and Y_{82} are connected to each other via a single bond or a double bond, and Y_{83} and Y_{84} are connected to each other via a single bond or a double bond,

[0214] CY_{81} and CY_{82} are each independently selected from a C_5 - C_{30} carbocyclic group and a C_3 - C_{30} heterocarbocyclic group,

[0215] CY_{81} and CY_{82} may be optionally further linked to each other via an organic linking group,

[0216] R_{81} to R_{85} are each independently selected from hydrogen, 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, —SF₅, a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₂-C₆₀ alkenyl group, a substituted or unsubstituted C₂-C₆₀ alkynyl group, a substituted or unsubstituted C₁-C₆₀ alkoxy group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₈₁)(Q₈₂)(Q₈₃), —N(Q₈₄)(Q₈₅), —B(Q₈₆)(Q₈₇), and —P(=O)(Q₈₈)(Q₈₉).

[0217] a₈₁ to a₈₃ are each independently selected from integers of 0 to 5, provided that

[0218] when a₈₁ is 2 or greater, two or more groups R_{81} are identical to or different from each other,

[0219] when a₈₂ is 2 or greater, two or more groups R_{82} are identical to or different from each other,

[0220] when a₈₁ is 2 or greater, adjacent groups R_{81} may be optionally linked to each other to form a saturated or unsaturated ring,

[0221] when a₈₂ is 2 or greater, adjacent groups R_{82} may be optionally linked to each other to form a saturated or unsaturated ring,

[0222] * and * in Formula 81A each indicate a binding site to M in Formula 81,

[0223] at least one of substituents of the substituted C₁-C₆₀ alkyl group, substituted C₂-C₆₀ alkenyl group, substituted C₂-C₆₀ alkynyl group, substituted C₁-C₆₀ alkoxy group, substituted C₃-C₁₀ cycloalkyl group, substituted C₁-C₁₀ heterocycloalkyl group, substituted C₃-C₁₀ cycloalkenyl group, substituted C₁-C₁₀ heterocycloalkenyl group, substituted C₆-C₆₀ aryl group, substituted C₆-C₆₀ aryloxy group, substituted C₆-C₆₀ arylthio group, substituted C₁-C₆₀ heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group and substituted monovalent non-aromatic condensed heteropolycyclic group is selected from [0224] 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 C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, and —Si(Q₉₁)(Q₉₂)(Q₉₃).

[0225] Q_{81} to Q_{89} and Q_{91} to Q_{93} are each independently selected from hydrogen, deuterium, a C₁-C₆₀ alkyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a

C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

[0226] According to an exemplary embodiment, in Formula 81A,

[0227] a₈₃ is 1 or 2,

[0228] R_{83} to R_{85} may each independently be selected from

[0229] —CH₃, —CD₃, —CD₂H, —CDH₂, —CH₂CH₃, —CH₂CD₃, —CH₂CD₂H, —CH₂CDH₂, —CHDC₂H₃, —CHDCD₂H, —CHDCD₂H₂, —CHDCD₃, —CD₂CD₃, —CD₂CD₂H, and —CD₂CDH₂;

[0230] an n-propyl group, an iso-propyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

[0231] an n-propyl group, an iso-propyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C₁-C₁₀ alkyl group, and a phenyl group, but are not limited thereto.

[0232] In various embodiments, in Formula 81A,

[0233] Y_{81} may be nitrogen, Y_{82} and Y_{83} may each be carbon, Y_{84} may be nitrogen or carbon,

[0234] CY_{81} and CY_{82} may each independently be selected from a cyclopentadiene, a benzene, a heptalene, an indene, a naphthalene, an azulene, an indacene, an acenaphthylene, a fluorene, a spiro-bifluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentacene, a hexacene, a pentaphene, a rubicene, a coronene, an ovalene, a pyrrole, an isoindole, an indole, an indazole, a pyrazole, an imidazole, a triazole, an oxazole, an isoxazole, an oxadiazole, a thiazole, an isothiazole, a thiadiazole, a purine, a furan, a thiophene, a pyridine, a pyrimidine, a quinoline, an isoquinoline, a benzoquinoline, a phthalazine, a naphthyridine, a quinoxaline, a quinazoline, a cinnoline, a phenanthridine, an acridine, a phenanthroline, a phenazine, a benzoimidazole, a benzofuran, a benzothiophene, an isobenzothiazole, a benzoxazole, an isobenzoxazole, a benzocarbazole, a dibenzocarbazole, an imidazopyridine, an imidazopyrimidine, a dibenzofuran, a dibenzothiophene, a dibenzothiophene sulfone, a carbazole, a dibenzosilole, and a 2,3-dihydro-1H-imidazole.

[0235] According to some embodiments, in Formula 81A, Y_{81} may be nitrogen, Y_{82} to Y_{84} may each be carbon, CY_{81} may be selected from a 5-membered ring including two nitrogen atoms as ring-forming atoms, and CY_{82} may be selected from a benzene, a naphthalene, a fluorene, a dibenzofuran, and a dibenzothiophene, but they are not limited thereto.

[0236] According to some embodiments, in Formula 81A, Y_{81} may be nitrogen, Y_{82} to Y_{84} may each be carbon, CY_{81} may be an imidazole or a 2,3-dihydro-1H-imidazole, and CY_{82} may be selected from a benzene, a naphthalene, a fluorene, a dibenzofuran, and a dibenzothiophene, but they are not limited thereto.

group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

[0251] an n-propyl group, an iso-propyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, a C₁-C₁₀ alkyl group, and a phenyl group.

[0252] According to some embodiments, in Formula 81A, R₈₁ and R₈₂ may each independently be selected from

[0253] hydrogen, deuterium, —F, a cyano group, a nitro group, —SF₅, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an iso-hexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an iso-heptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an iso-octyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an iso-nonyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an iso-decyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

[0254] a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an iso-hexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an iso-heptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an iso-octyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an iso-nonyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an iso-decyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group, each substituted with at least one selected from deuterium, —F, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, a cyano group, a nitro group, a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group; and

[0255] —B(Q₈₆)(Q₈₇) and —P(=O)(Q₈₈)(Q₈₉),

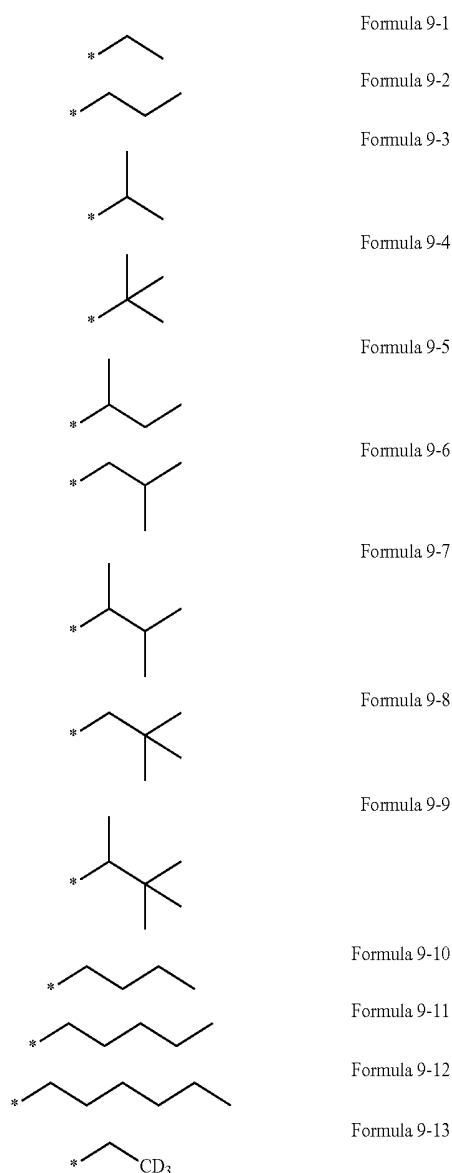
[0256] Q₈₆ to Q₈₉ may each independently be selected from

[0257] —CH₃, —CD₃, —CD₂H, —CDH₂, —CH₂CH₃, —CH₂CD₃, —CH₂CD₂H, —CH₂CDH₂, —CHDCH₃, —CHDCD₂H, —CHDCD₂H, —CHDCD₃, —CD₂CD₃, —CD₂CD₂H, and —CD₂CDH₂;

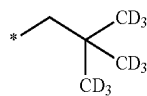
[0258] an n-propyl group, an iso-propyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

[0259] an n-propyl group, an iso-propyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, a C₁-C₁₀ alkyl group, and a phenyl group.

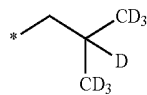
[0260] According to some embodiments, in Formula 81A, R₈₁ and R₈₂ may each independently be selected from hydrogen, deuterium, —F, a cyano group, a nitro group, —SF₅, —CH₃, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, groups represented by Formulae 9-1 to 9-19, and groups represented by Formulae 10-1 to 10-30, but are not limited thereto:



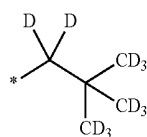
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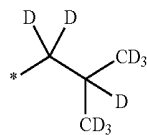
Formula 9-14



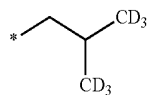
Formula 9-15



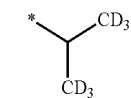
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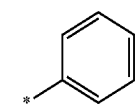
Formula 9-17



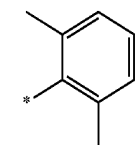
Formula 9-18



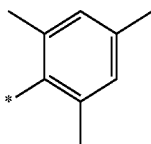
Formula 9-19



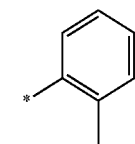
Formula 10-1



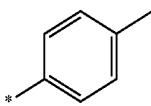
Formula 10-2



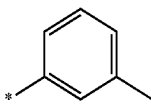
Formula 10-3



Formula 10-4

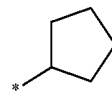


Formula 10-5

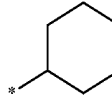


Formula 10-6

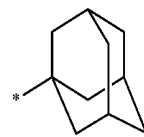
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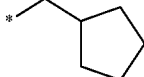
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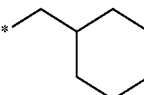
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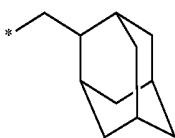
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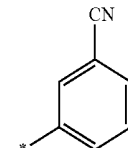
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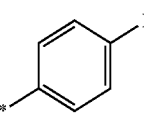
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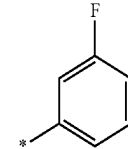
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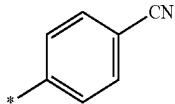
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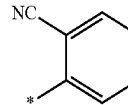
Formula 10-14



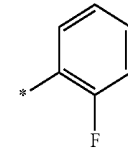
Formula 10-15



Formula 10-16

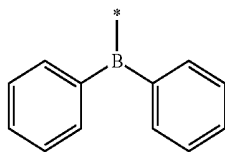


Formula 10-17

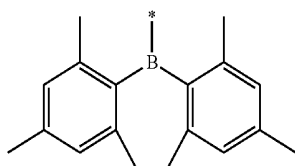


Formula 10-18

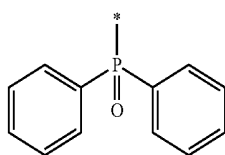
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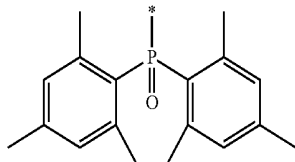
Formula 10-19



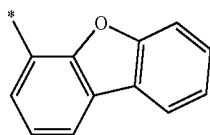
Formula 10-20



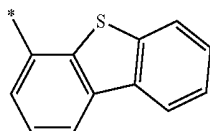
Formula 10-22



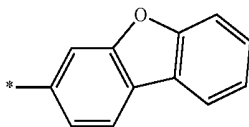
Formula 10-23



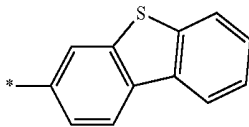
Formula 10-24



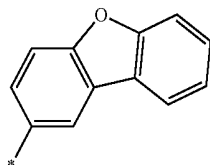
Formula 10-25



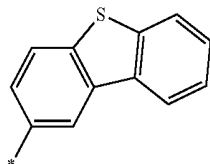
Formula 10-26



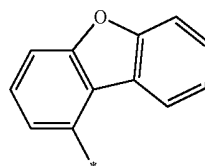
Formula 10-27



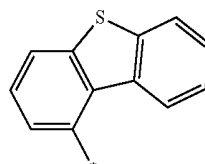
Formula 10-28



-continued



Formula 10-29



Formula 10-30

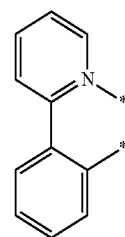
[0261] In Formulae 9-1 to 9-17 and 10-1 to 10-30, * indicates a binding site to an adjacent atom.

[0262] According to some embodiments, a₈₁+a₈₂ in Formula 81A may be equal to or greater than 1, and at least one selected from a₈₁ number of groups R₈₁ and a₈₂ number of groups R₈₂ may be a cyano group.

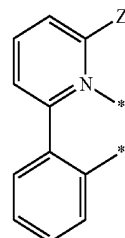
[0263] According to some embodiments, a₈₂ in Formula 81A may be equal to or greater than 1, and at least one of a₈₂ number of groups R₈₂ may be a cyano group.

[0264] According to some embodiments, at least one selected from a₈₁ number of groups R₈₁ and a₈₂ number of groups R₈₂ in Formula 81A may be deuterium. According to some embodiments, L₈₂ in Formula 81 may be selected from ligands represented by Formulae 3-1(1) to 3-1(60), 3-1(61) to 3-1(69), 3-1(71) to 3-1(79), 3-1(81) to 3-1(88), 3-1(91) to 3-1(98), and 3-1(101) to 3-1(114):

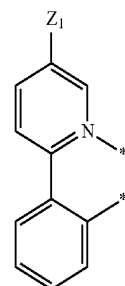
Formula 3-1(1)



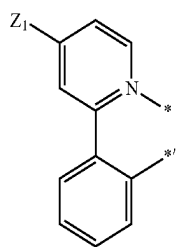
Formula 3-1(2)



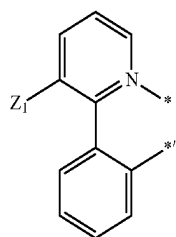
Formula 3-1(3)



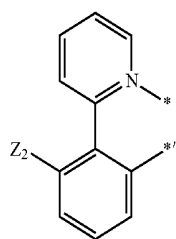
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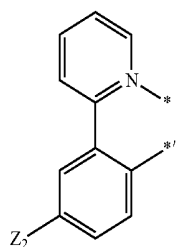
Formula 3-1(4)



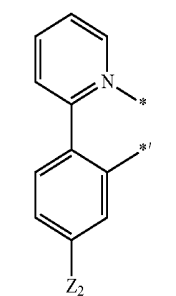
Formula 3-1(5)



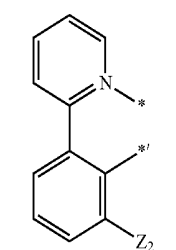
Formula 3-1(6)



Formula 3-1(7)

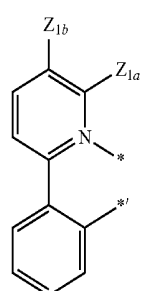


Formula 3-1(8)

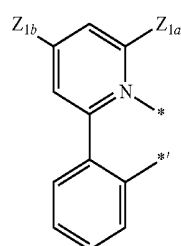


Formula 3-1(9)

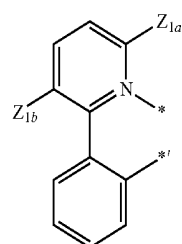
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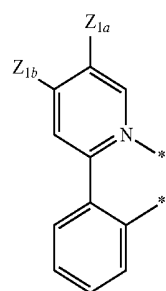
Formula 3-1(10)



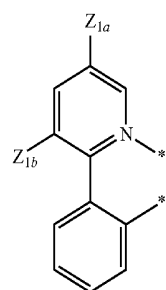
Formula 3-1(11)



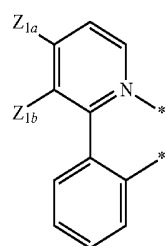
Formula 3-1(12)



Formula 3-1(13)

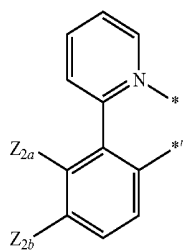


Formula 3-1(14)

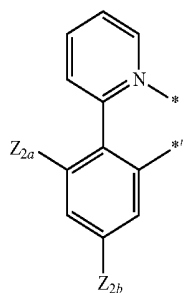


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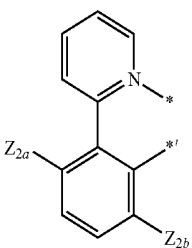
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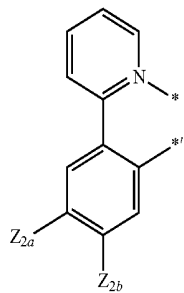
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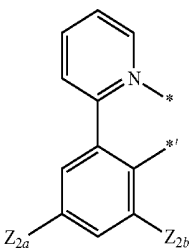
Formula 3-1(17)



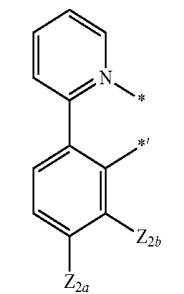
Formula 3-1(18)



Formula 3-1(19)

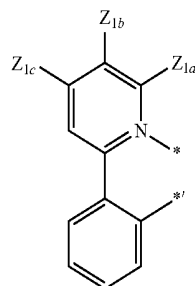


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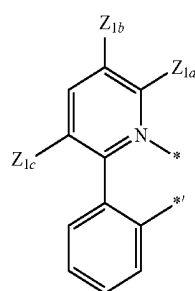


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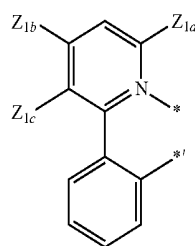
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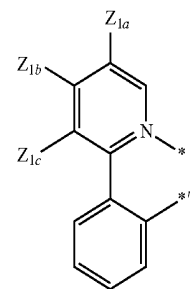
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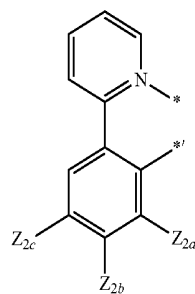
Formula 3-1(23)



Formula 3-1(24)

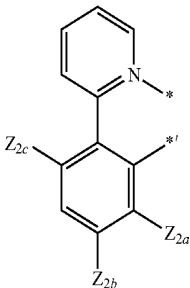


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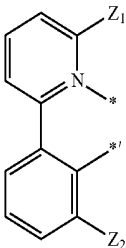
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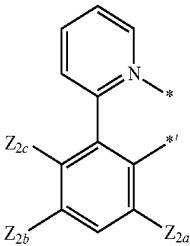


Formula 3-1(27)

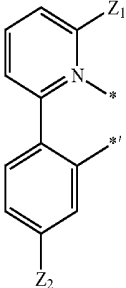
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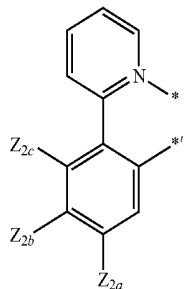
Formula 3-1(32)



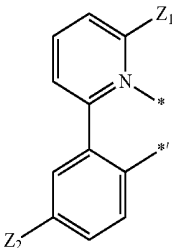
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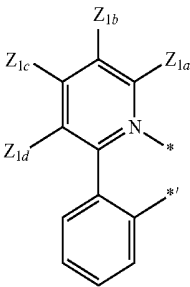
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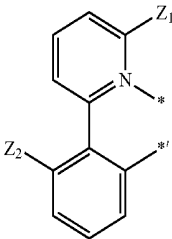
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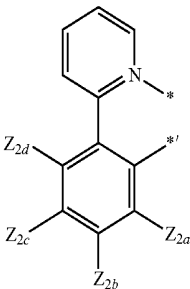
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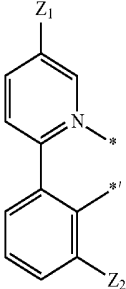
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Formula 3-1(35)

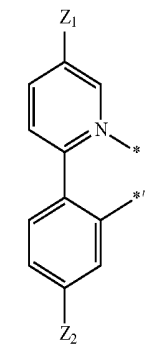


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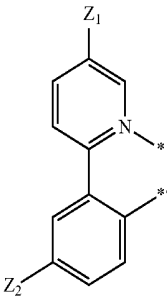


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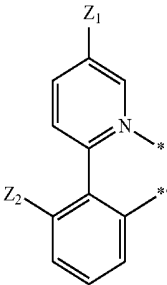
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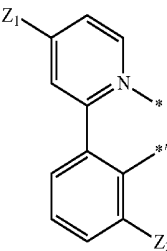
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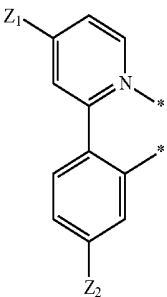
Formula 3-1(38)



Formula 3-1(39)

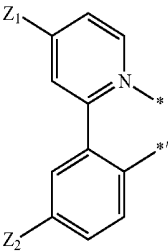


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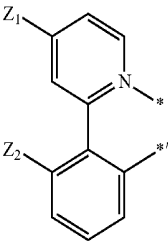


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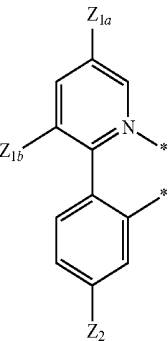
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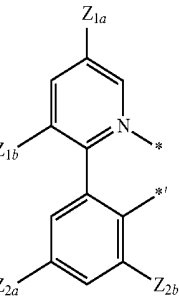
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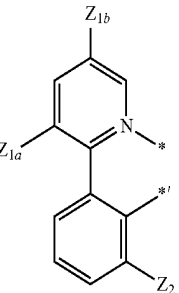
Formula 3-1(43)



Formula 3-1(44)

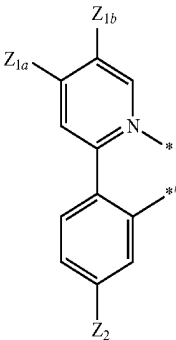


Formula 3-1(45)



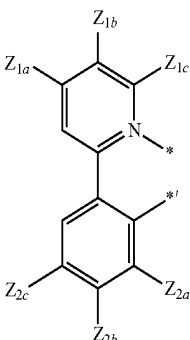
Formula 3-1(46)

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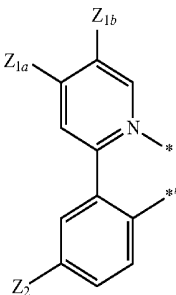


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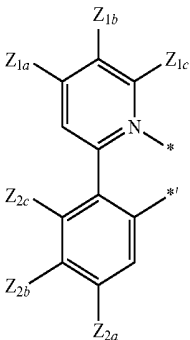
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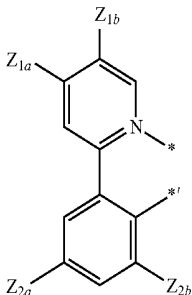
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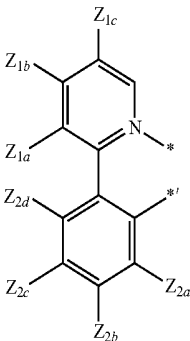
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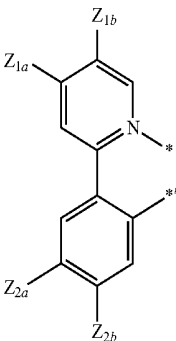
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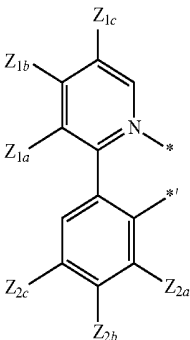
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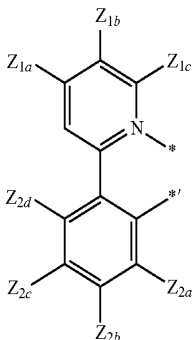
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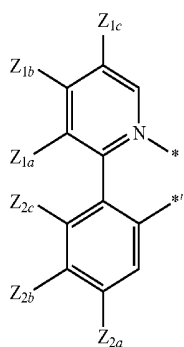


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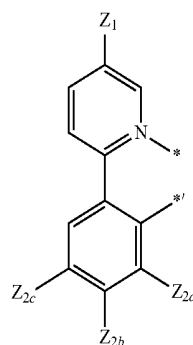
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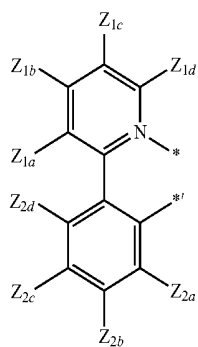


Formula 3-1(56)

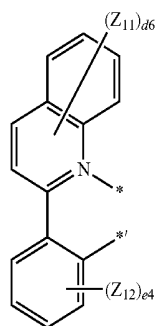
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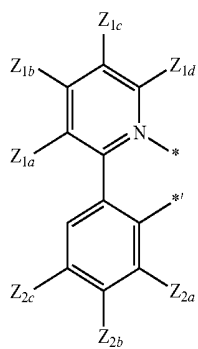
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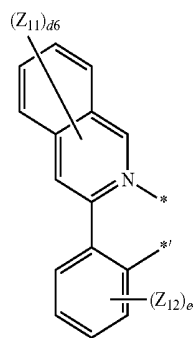
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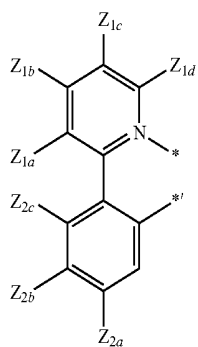
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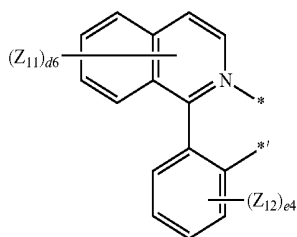
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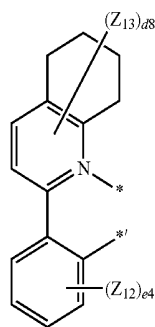
Formula 3-1(62)



Formula 3-1(59)

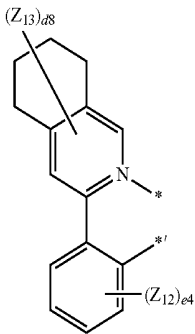


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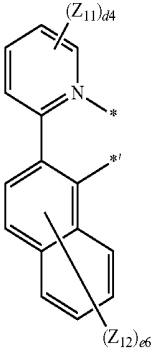
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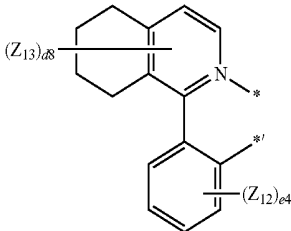


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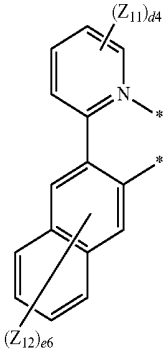
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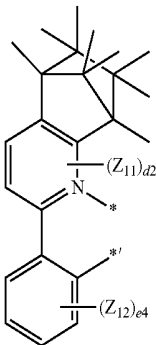
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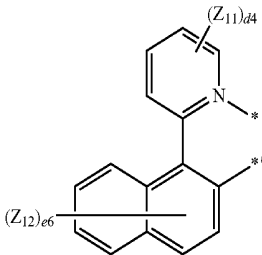
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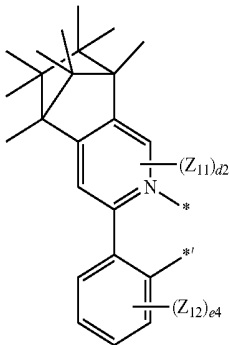
Formula 3-1(72)



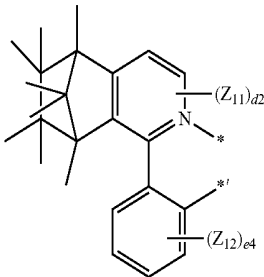
Formula 3-1(67)



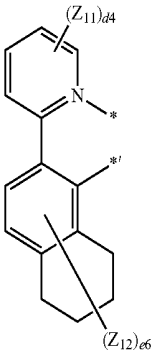
Formula 3-1(73)



Formula 3-1(68)

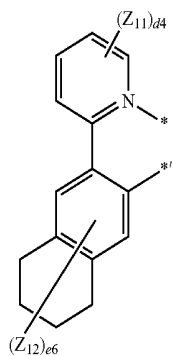


Formula 3-1(69)



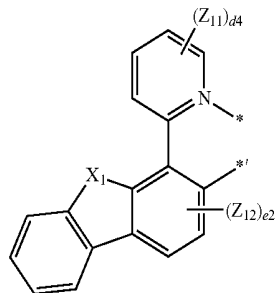
Formula 3-1(74)

-continued



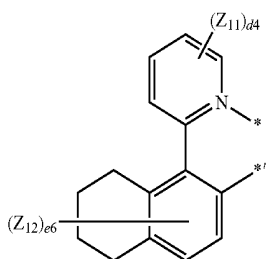
Formula 3-1(75)

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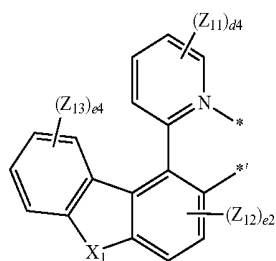


Formula 3-1(81)

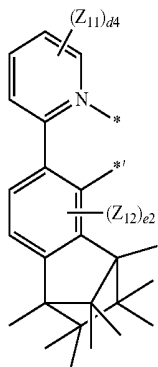
Formula 3-1(76)



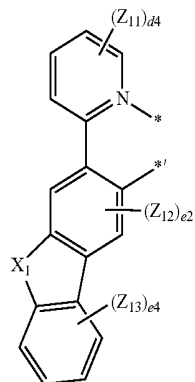
Formula 3-1(77)



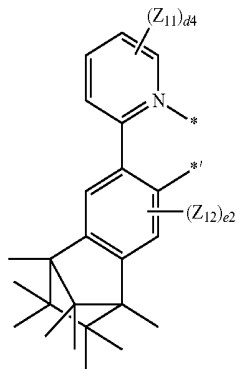
Formula 3-1(82)



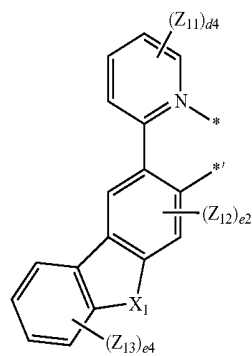
Formula 3-1(78)



Formula 3-1(83)

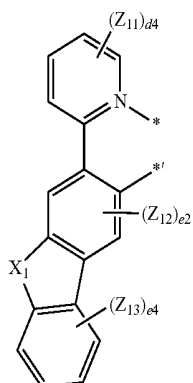


Formula 3-1(79)



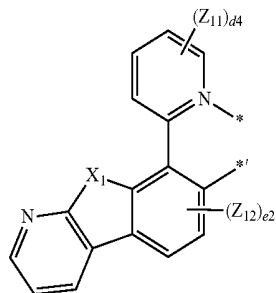
Formula 3-1(84)

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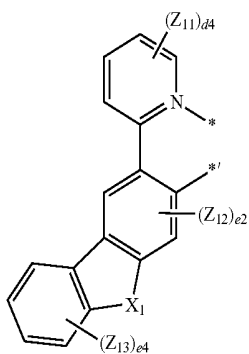
Formula 3-1(85)

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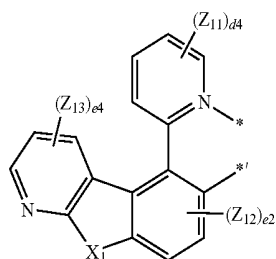


Formula 3-1(91)

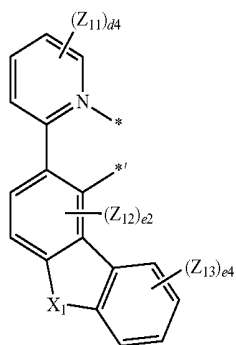
Formula 3-1(86)



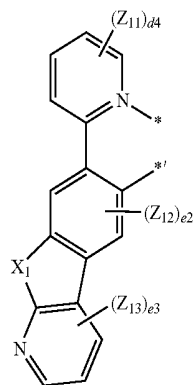
Formula 3-1(92)



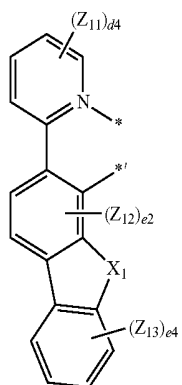
Formula 3-1(87)



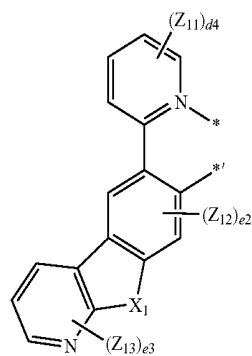
Formula 3-1(93)



Formula 3-1(88)

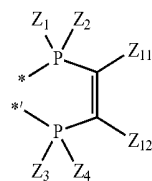


Formula 3-1(94)

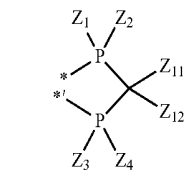


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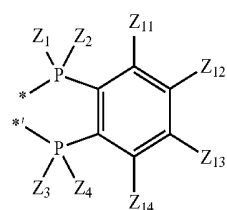
Formula 3-1(102)



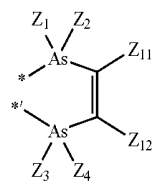
Formula 3-1(103)



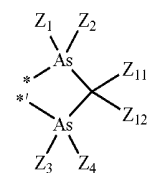
Formula 3-1(104)



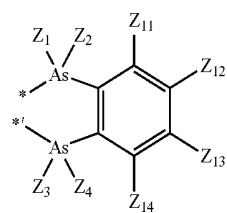
Formula 3-1(105)



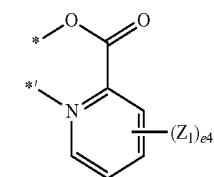
Formula 3-1(106)



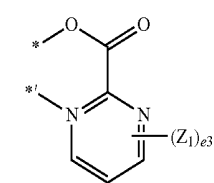
Formula 3-1(107)



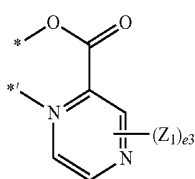
Formula 3-1(108)



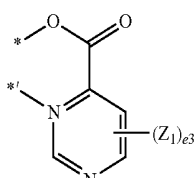
Formula 3-1(109)



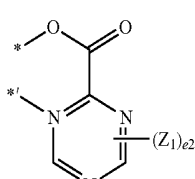
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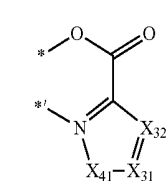
Formula 3-1(110)



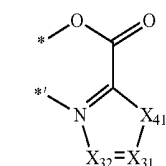
Formula 3-1(111)



Formula 3-1(112)



Formula 3-1(113)



Formula 3-1(114)

[0265] In Formulae 3-1(1) to 3-1(60), 3-1(61) to 3-1(69), 3-1(71) to 3-1(79), 3-1(81) to 3-1(88), 3-1(91) to 3-1(98), and 3-1(101) to 3-1(114),

[0266] X_1 is O, S, $C(Z_{21})(Z_{22})$, or $N(Z_{23})$,

[0267] X_{31} is N or $C(Z_{1a})$, X_{32} is N or $C(Z_{1b})$,

[0268] X_{41} is O, S, $N(Z_{1a})$, or $C(Z_{1a})(Z_{1b})$,

[0269] Z_1 to Z_4 , Z_{1a} , Z_{1b} , Z_{1c} , Z_{1d} , Z_{2a} , Z_{2b} , Z_{2c} , Z_{2d} , Z_{11} to Z_{14} , and Z_{21} to Z_{23} are each independently selected from:

[0270] hydrogen, 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, —SF₅, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group;

[0271] a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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 C₁-C₁₀ alkyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclo-

hexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

[0272] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl 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 quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group;

[0273] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl 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 quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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, C₁-C₂₀ alkyl group, C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an

oxazolyl group, an isoxazolyl 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 quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and

[0274] $-\text{B}(\text{Q}_{86})(\text{Q}_{87})$ and $-\text{P}(=\text{O})(\text{Q}_{88})(\text{Q}_{89})$, wherein

[0275] Q_{86} to Q_{89} may each independently be selected from $-\text{CH}_3$, $-\text{CD}_3$, $-\text{CD}_2\text{H}$, $-\text{CDH}_2$, $-\text{CH}_2\text{CH}_3$, $-\text{CH}_2\text{CD}_3$, $-\text{CH}_2\text{CD}_2\text{H}$, $-\text{CH}_2\text{CDH}_2$, $-\text{CHDCD}_3$, $-\text{CHDCD}_2\text{H}$, $-\text{CHDCDH}_2$, $-\text{CHDCD}_3$, $-\text{CD}_2\text{CD}_2\text{H}$, and $-\text{CD}_2\text{CDH}_2$;

[0276] an n-propyl group, an iso-propyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

[0277] an n-propyl group, an iso-propyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C_1 - C_{10} alkyl group, and a phenyl group,

[0278] d2 and e2 may each independently be 0 or 2,

[0279] e3 may be an integer selected from 0 to 3,

[0280] d4 and e4 may each independently be an integer selected from 0 to 4,

[0281] d6 and e6 may each independently be an integer selected from 0 to 6,

[0282] d8 and e8 may each independently be an integer selected from 0 to 8,

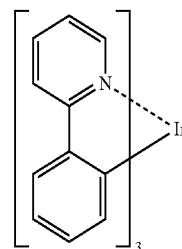
[0283] * and *' each indicate a binding site to M in Formula 1.

[0284] For example, Z_1 to Z_4 , Z_{1a} , Z_{1b} , Z_{1c} , Z_{1d} , Z_{2a} , Z_{2b} , Z_{2c} , Z_{2d} , Z_{11} to Z_{14} , and Z_{21} to Z_{23} may each independently be selected from hydrogen, deuterium, $-\text{F}$, a cyano group, a nitro group, $-\text{SF}_5$, $-\text{CH}_3$, $-\text{CD}_3$, $-\text{CD}_2\text{H}$, $-\text{CDH}_2$, $-\text{CF}_3$, $-\text{CF}_2\text{H}$, $-\text{CFH}_2$, groups represented by Formulae 9-1 to 9-19, and groups represented by Formulae 10-1 to 10-30, but are not limited thereto.

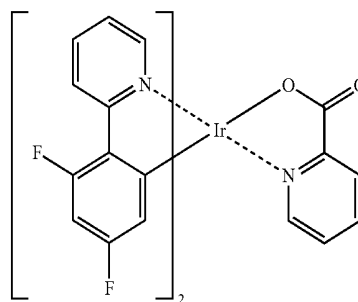
[0285] According to some embodiments, M in Formula 81 may be Ir, n81+n82 may be 3; or M may be Pt, and n81+n82 may be 2.

[0286] According to some embodiments, an organometallic compound represented by Formula 81 may not be a salt consisting of a pair of a cation and an anion, but may be neutral.

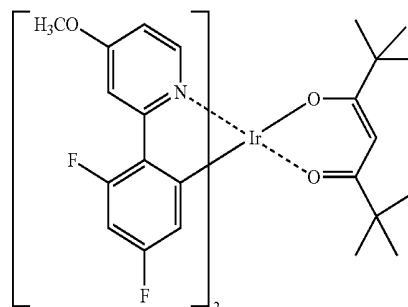
[0287] The phosphorescent dopant may include at least one selected from Compounds PD1 to PD78 and FIr6 below, but it is not limited thereto:



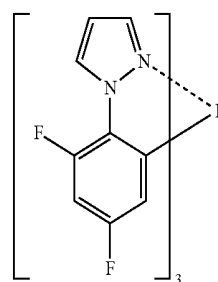
PD1



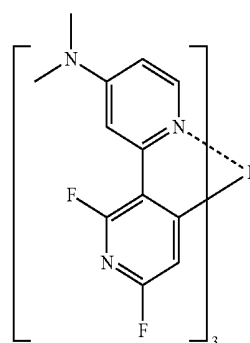
PD2



PD3

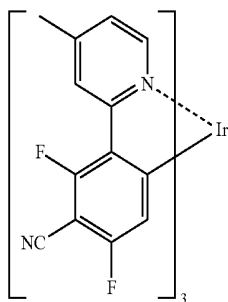
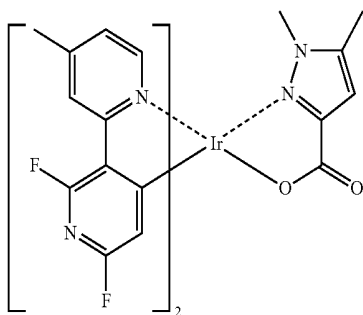
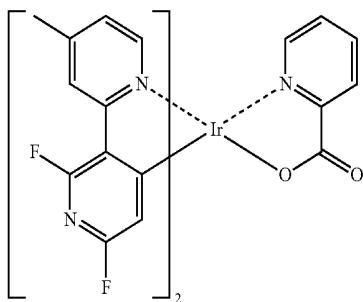
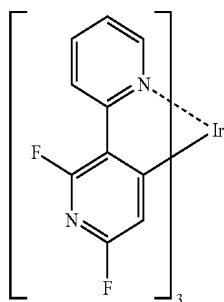
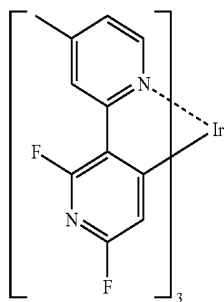


PD4



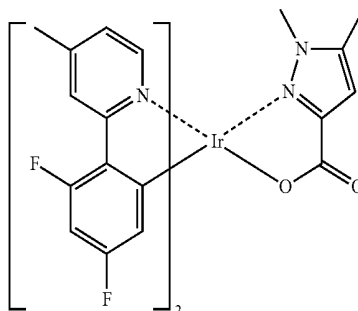
PD5

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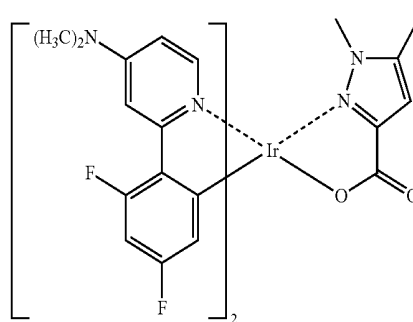
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PD6



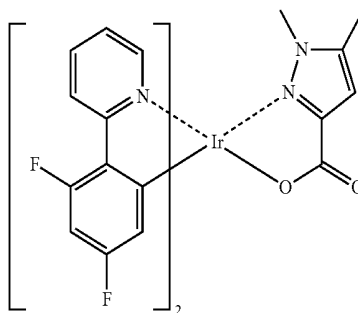
PD11

PD7



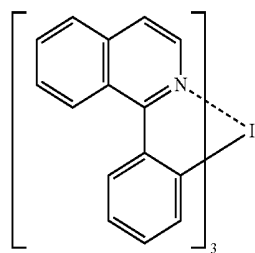
PD12

PD8



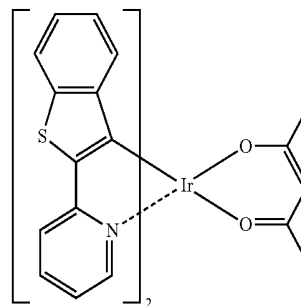
PD13

PD9



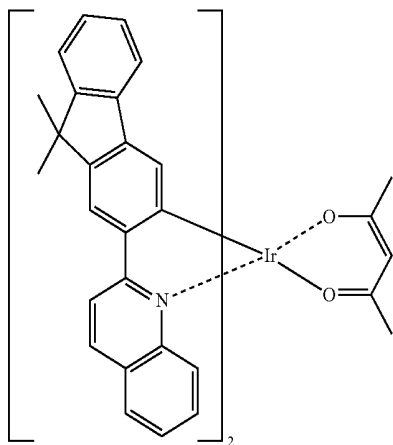
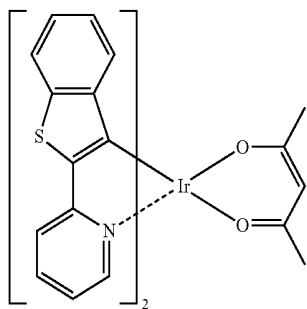
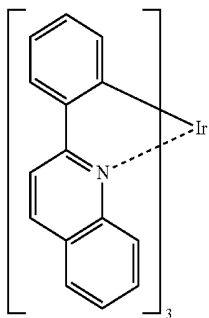
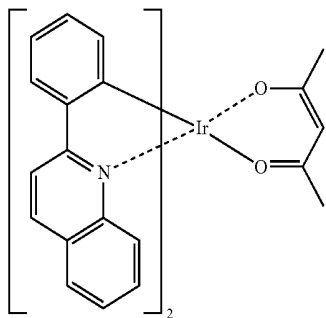
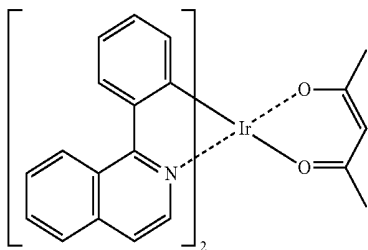
PD14

PD10



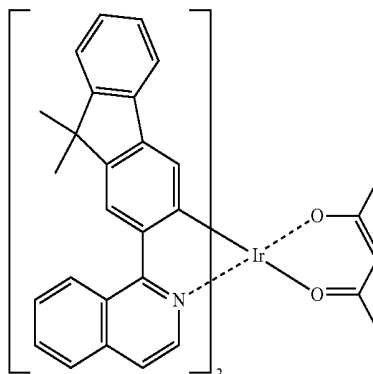
PD15

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PD16

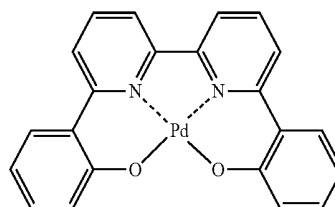
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PD21

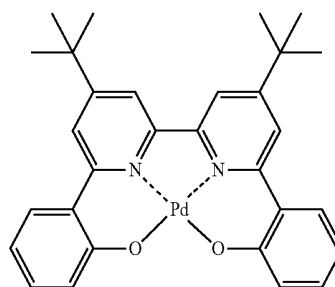
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PD18



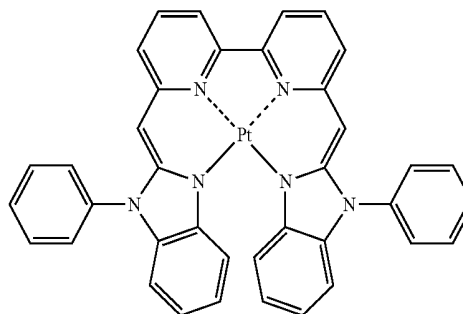
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PD19



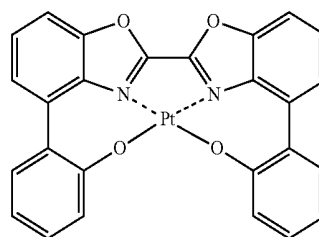
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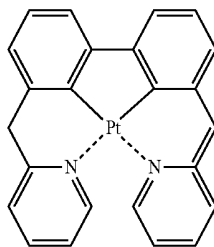


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PD25

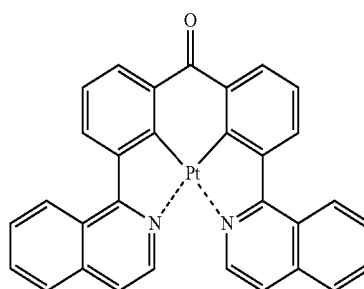


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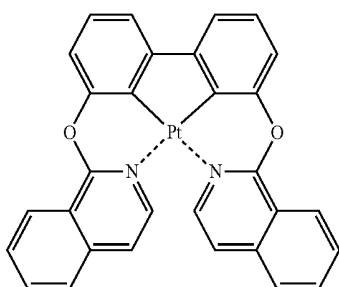
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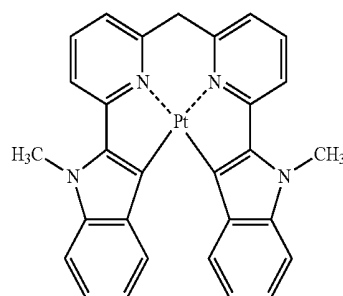


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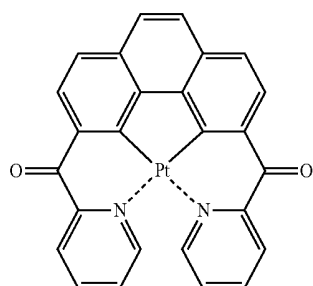
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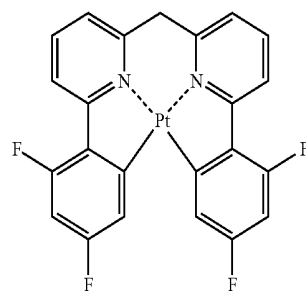
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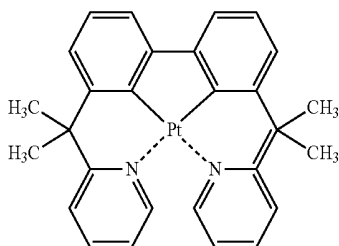
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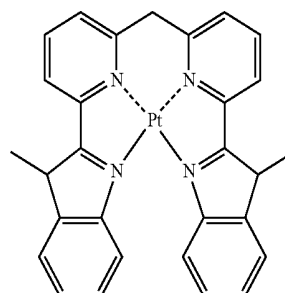
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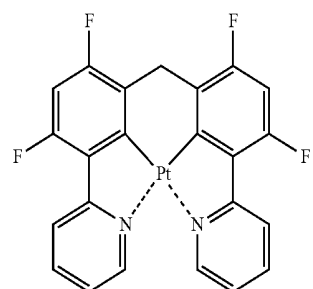
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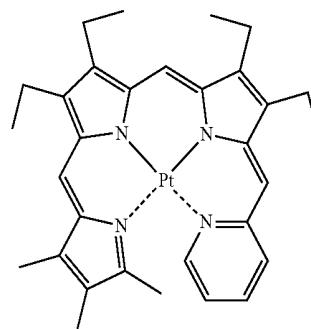
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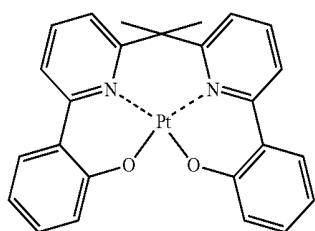
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PD35

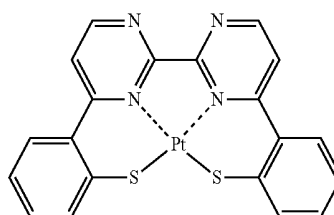


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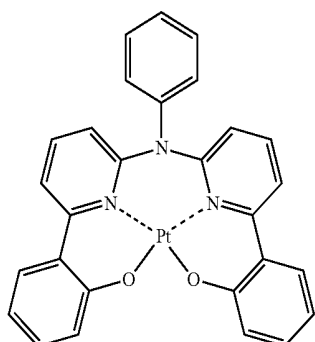


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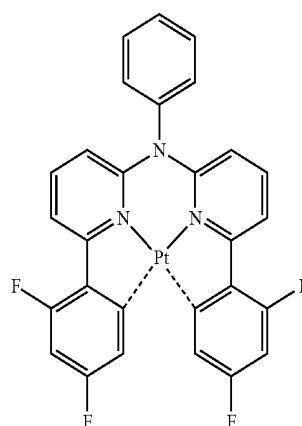
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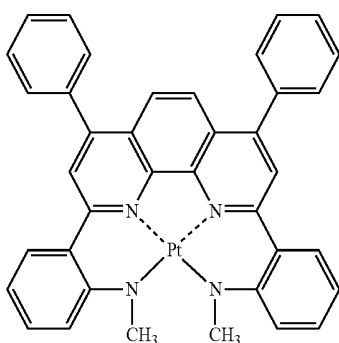
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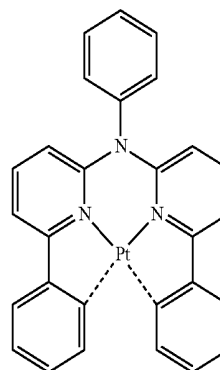
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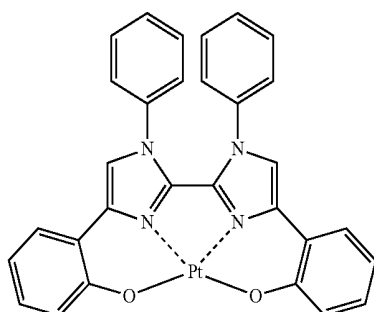
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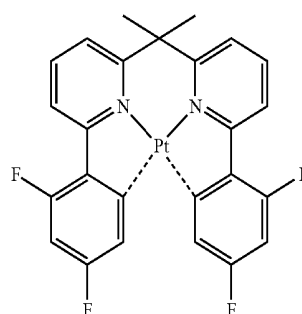
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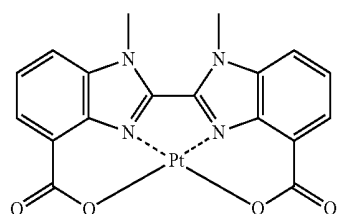
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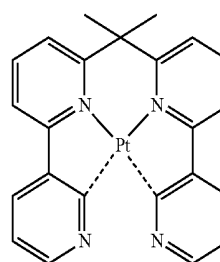
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PD44

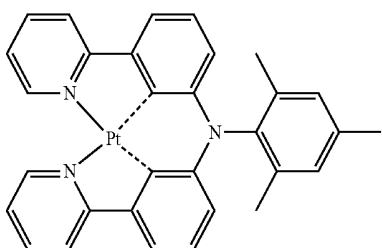
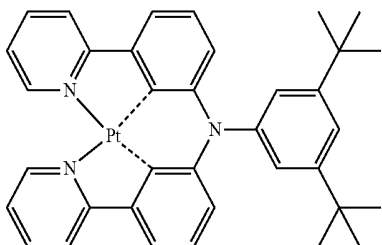
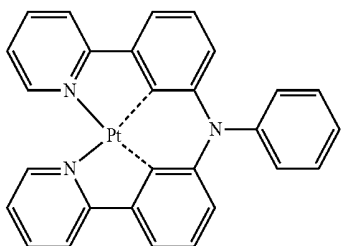
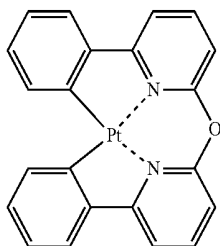
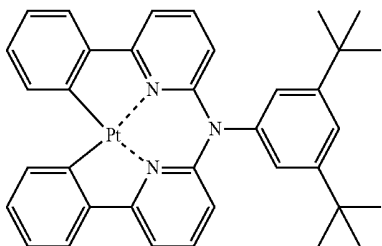
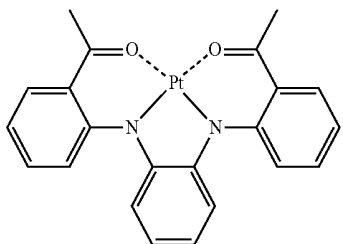


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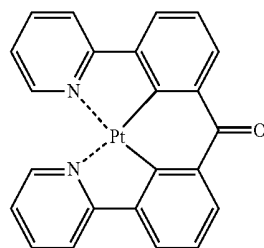
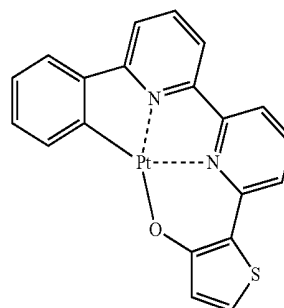
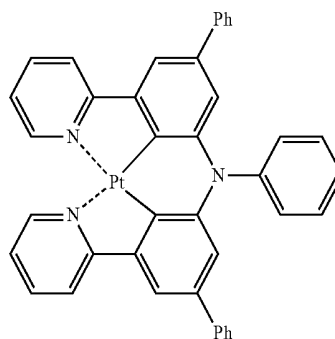
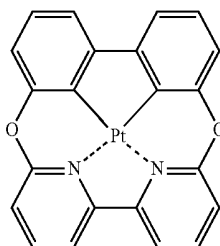
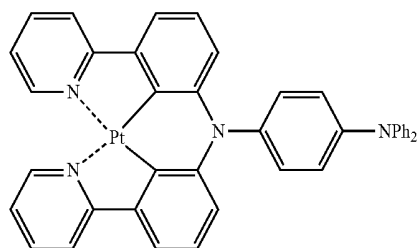
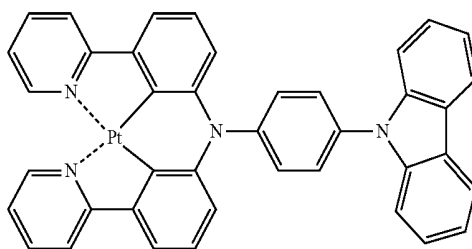


PD45

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PD46

PD47

PD48

PD49

PD50

PD51

PD52

PD53

PD54

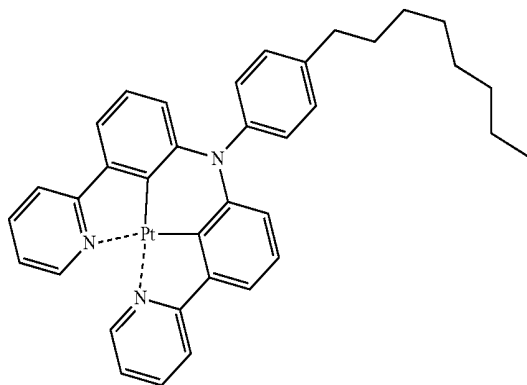
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PD56

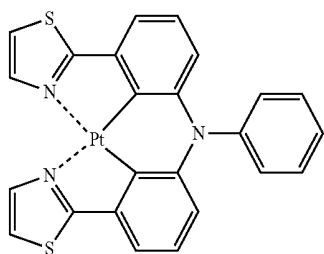
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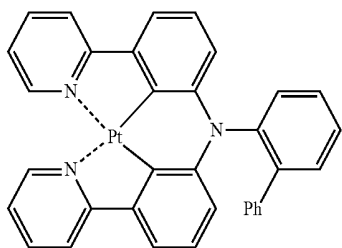
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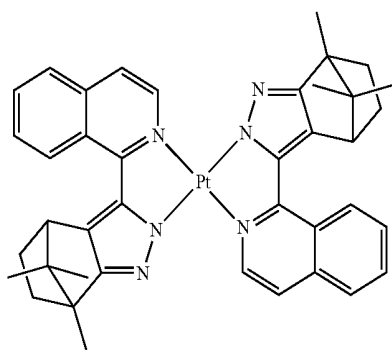
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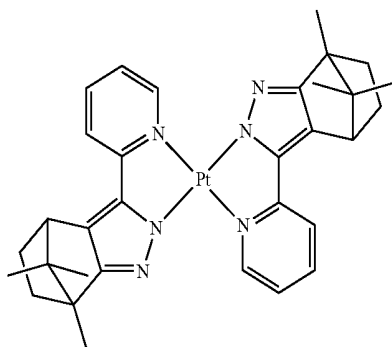
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PD61

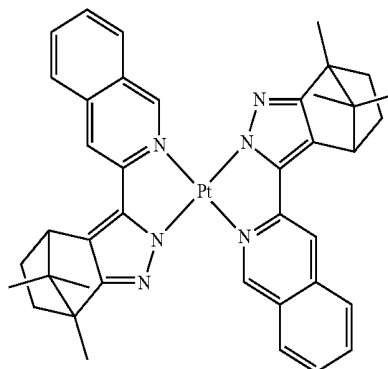


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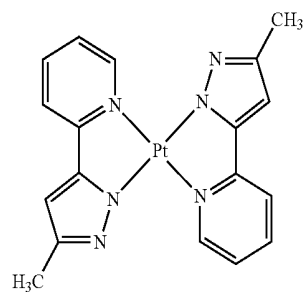


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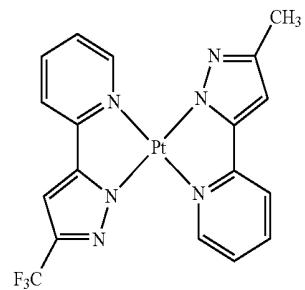
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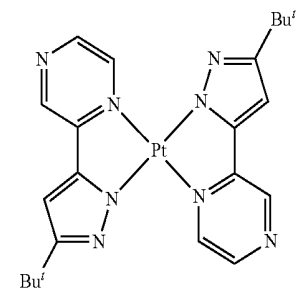
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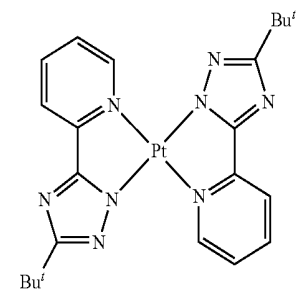
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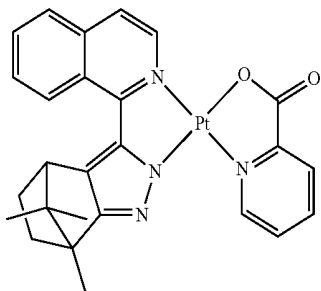
PD66



PD67

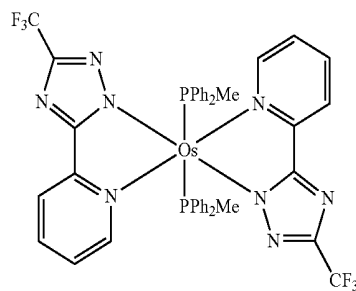


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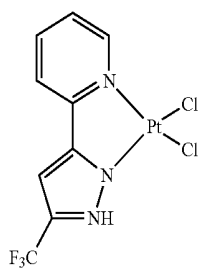
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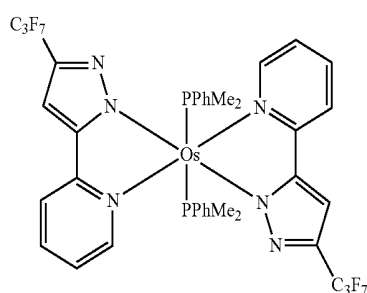


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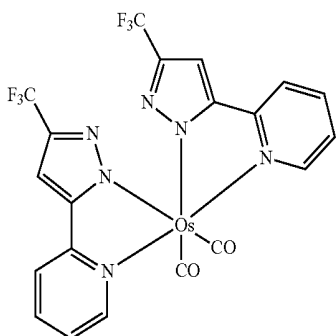
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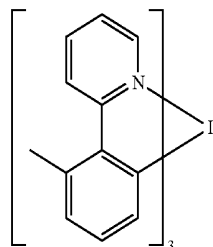
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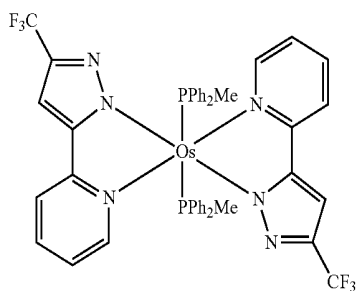
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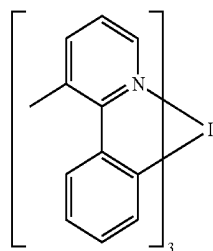
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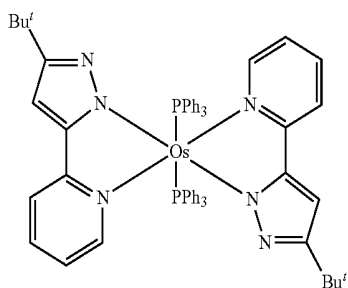
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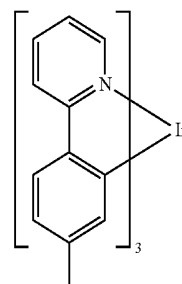
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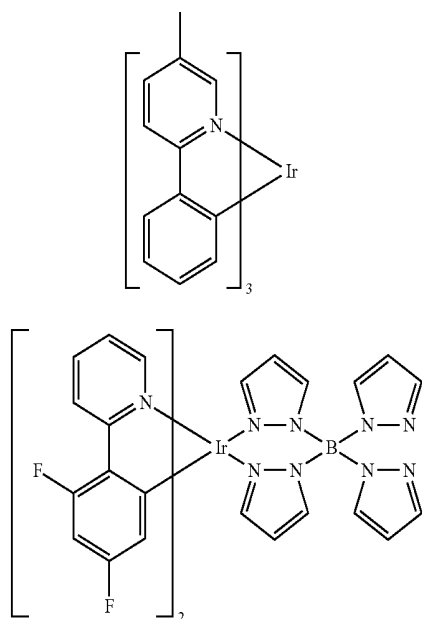
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PD77



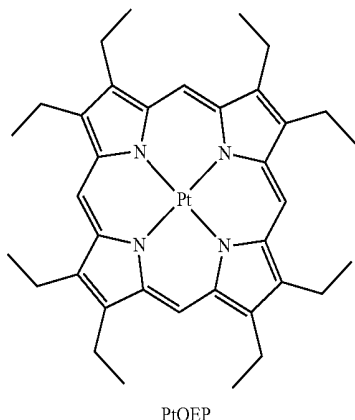
-continued



PD78

Flr6

[0288] Alternatively, the phosphorescent dopant may include PtOEP below:



PtOEP

[0289] When the emission layer includes the host and the dopant, an amount of the dopant may be selected from in a range of about 0.01 to about 20 parts by weight based on about 100 parts by weight of the host, but the amount is not limited thereto.

[0290] 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 theory, it is understood that when the thickness of the emission layer is within this range, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

[0291] Then, an electron transport region may be disposed on the emission layer.

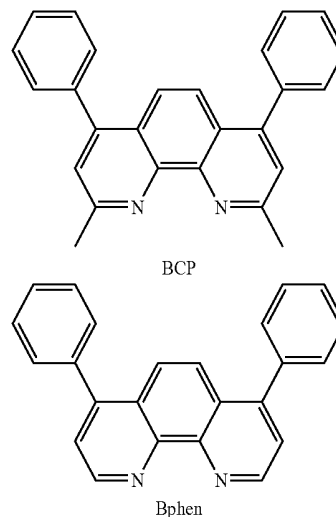
[0292] The electron transport region may include a hole blocking layer, an electron transport layer, an electron injection layer, or any combination thereof.

[0293] For example, the electron transport region may have a structure of a hole blocking layer/an electron trans-

port layer/an electron injection layer or an electron transport layer/an electron injection layer, but it is not limited thereto. The electron transport layer may have a single layer structure or a multi-layer structure including two or more different materials.

[0294] 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.

[0295] When the electron transport region includes a hole blocking layer, the hole blocking layer may include, for example, at least one of BCP and Bphen, but it is not limited thereto.

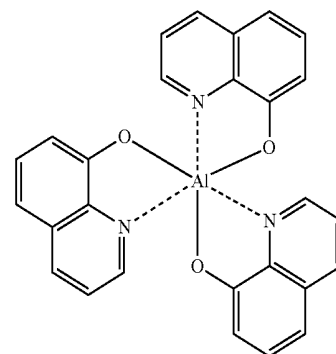


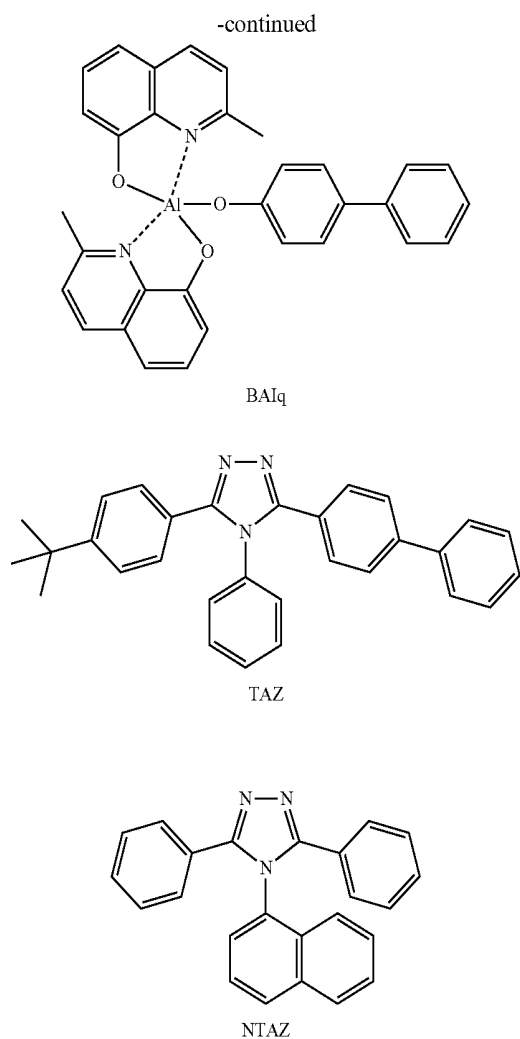
BCP

Bphen

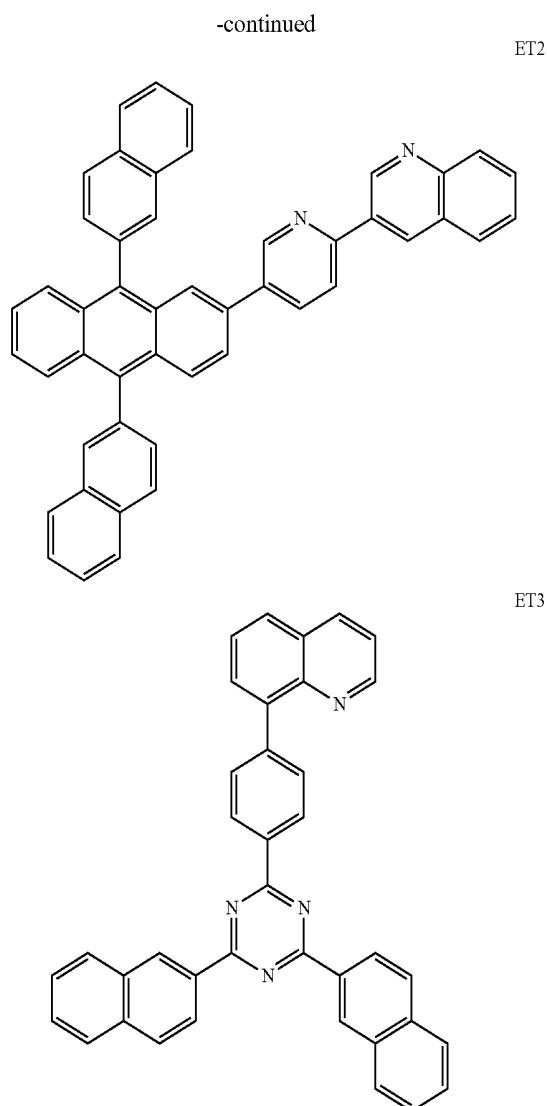
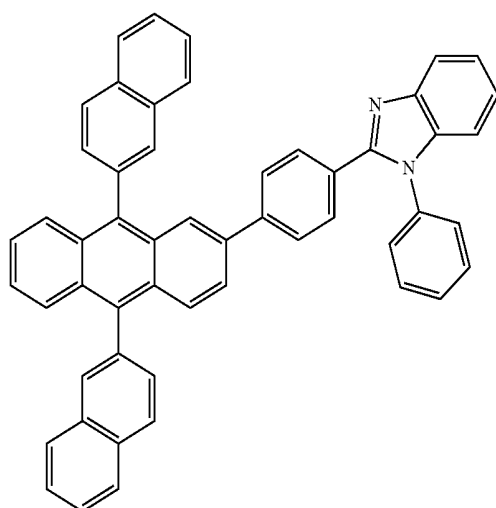
[0296] A thickness of the hole blocking layer may be in a range of about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. While not wishing to be bound by theory, it is understood that when the thickness of the hole blocking layer is within this range, excellent hole blocking characteristics may be obtained without a substantial increase in driving voltage.

[0297] The electron transport layer may further include at least one selected from BCP, Bphen, Alq₃, BALq, TAZ, and NTAZ.

Alq₃



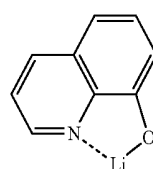
[0298] Alternatively, the electron transport layer may include at least one selected from Compounds ET1, ET2, and ET3, but it is not limited thereto.



[0299] 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 theory, it is understood that when the thickness of the electron transport layer is within this range, excellent electron transport characteristics may be obtained without a substantial increase in driving voltage.

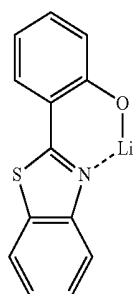
[0300] The electron transport layer may further include a metal-containing material in addition to the materials described above.

[0301] 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.



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ET-D2



[0302] The electron transport region may include an electron injection layer (EIL) that facilitates electron injection from the second electrode 19.

[0303] The electron injection layer may include at least one selected from, LiF, NaCl, CsF, Li₂O, and BaO.

[0304] 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 theory, it is understood that when the thickness of the electron injection layer is within this range, excellent electron injection characteristics may be obtained without a substantial increase in driving voltage.

[0305] The second electrode 19 is disposed on the organic layer 15. The second electrode 19 may be a cathode. A material for the second electrode 19 may be a material having a relatively low work function, such as a metal, an alloy, an electrically conductive compound, and a mixture thereof. Detailed examples of the material for forming the second electrode 19 are lithium (Li), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), and magnesium-silver (Mg—Ag). Alternatively, ITO or IZO may be used to form a transmissive second electrode 19 to manufacture a top emission light-emitting device, and such a variation may be possible.

[0306] Hereinbefore, the organic light-emitting device has been described with reference to FIG. 1, but is not limited thereto.

[0307] A C₁-C₆₀ alkyl group as used herein refers to a linear or branched aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms. Detailed examples thereof are a methyl group, an ethyl group, a propyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. A C₁-C₆₀ alkylene group as used herein refers to a divalent group having the same structure as the C₁-C₆₀ alkyl group.

[0308] A C₁-C₆₀ alkoxy group as used herein refers to a monovalent group represented by -OA₁₀₁ (wherein A₁₀₁ is the C₁-C₆₀ alkyl group). Detailed examples thereof are a methoxy group, an ethoxy group, and an iso-propyloxy group.

[0309] A C₂-C₆₀ alkenyl group as used herein refers to a group formed by including at least one carbon double bond in the middle or at the terminal of the C₂-C₆₀ alkyl group. Detailed examples thereof are an ethenyl group, a propenyl group, and a butenyl group. A C₂-C₆₀ alkenylene group as used herein refers to a divalent group having the same structure as a C₂-C₆₀ alkenyl group.

[0310] A C₂-C₆₀ alkynyl group as used herein refers to a group formed by including at least one carbon triple bond in the middle or at the terminal of the C₂-C₆₀ alkyl group.

Detailed examples thereof are an ethynyl group and a propynyl group. A C₂-C₆₀ alkynylene group as used herein refers to a divalent group having the same structure as a C₂-C₆₀ alkynyl group.

[0311] A C₃-C₁₀ 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 C₃-C₁₀ cycloalkylene group as used herein refers to a divalent group having the same structure as a C₃-C₁₀ cycloalkyl group.

[0312] A C₁-C₁₀ heterocycloalkyl group as used herein refers to a monovalent 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 C₁-C₁₀ heterocycloalkylene group as used herein refers to a divalent group having the same structure as a C₁-C₁₀ heterocycloalkyl group.

[0313] A C₃-C₁₀ cycloalkenyl group as used herein refers to a monovalent monocyclic group including 3 to 10 carbon atoms and at least one double bond in the ring thereof, which does not have aromaticity. Detailed examples thereof are a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. A C₃-C₁₀ cycloalkenylene group as used herein refers to a divalent group having the same structure as a C₃-C₁₀ cycloalkenyl group.

[0314] A C₁-C₁₀ heterocycloalkenyl group as used herein refers to a monovalent monocyclic group including at least one hetero atom 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 C₂-C₁₀ heterocycloalkenyl group are a 2,3-dihydrofuranyl group and a 2,3-dihydrothiophenyl group. A C₁-C₁₀ heterocycloalkenylene group as used herein refers to a divalent group having the same structure as a C₁-C₁₀ heterocycloalkenyl group.

[0315] A C₆-C₆₀ aryl group as used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and a C₆-C₆₀ 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 C₆-C₆₀ aryl group are a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C₆-C₆₀ aryl group and the C₆-C₆₀ arylene group each include two or more rings, the rings may be fused to each other or may be connected to each other by a single bond.

[0316] A C₁-C₆₀ heteroaryl group as used herein refers to a monovalent group having a carbocyclic aromatic system having 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 C₁-C₆₀ heteroarylene group as used herein refers to a divalent group having a carbocyclic aromatic system having at least one hetero atom selected from N, O, P, Si, and S as a ring-forming atom and 1 to 60 carbon atoms. Detailed examples of the C₁-C₆₀ 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 C₁-C₆₀ heteroaryl group and the C₁-C₆₀ heteroarylene group each include two or more rings, the rings may be fused to each other or may be connected to each other by a single bond.

[0317] A C_6 - C_{60} aryloxy group as used herein indicates -OA₁₀₂ (wherein A₁₀₂ is the C_6 - C_{60} aryl group), and a C_6 - C_{60} arylthio group as used herein indicates -SA₁₀₃ (wherein A₁₀₃ is the C_6 - C_{60} aryl group).

[0318] 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, and 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. Detailed examples of the non-aromatic condensed polycyclic group include 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.

[0319] A monovalent non-aromatic condensed heteropolycyclic group as used herein refers to a monovalent group that has two or more rings condensed with each other, and 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. Detailed examples of the monovalent non-aromatic condensed heteropolycyclic group include 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.

[0320] At least one substituent as used herein in 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, a substituted divalent non-aromatic condensed polycyclic group, a substituted 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_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 or substituted monovalent non-aromatic condensed heteropolycyclic group is selected from 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(Q₃₁)(Q₃₂)(Q₃₃).

[0321] Q₁ to Q₃, Q₁₁ to Q₁₃, Q₂₁ to Q₂₃, and Q₃₁ to Q₃₃ are each independently selected from 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.

[0322] A biphenyl group as used herein refers to a monovalent group including two benzenes linked to each other via a single bond.

[0323] A terphenyl group as used herein refers to a monovalent group including three benzenes linked to one another via a single bond.

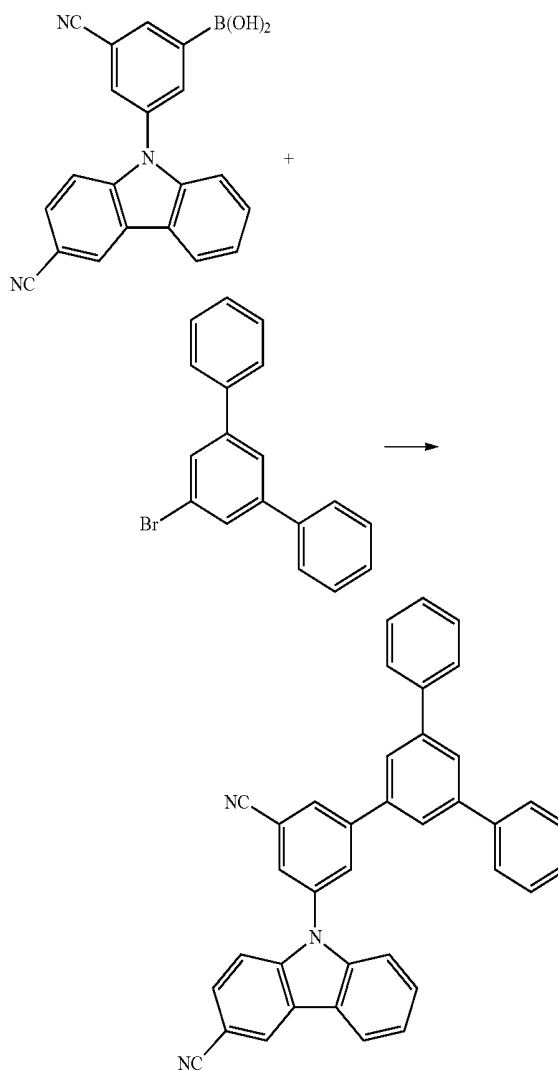
[0324] Hereinafter, a compound and an organic light-emitting device according to an exemplary embodiment will be described in detail with reference to Synthesis Examples and Examples. However, the inventive concept is not limited to Synthesis Examples and Examples. The wording "B was used instead of A" used in describing Synthesis Examples means that an amount of B used was identical to an amount of A used based on molar equivalence.

EXAMPLE

Synthesis Example 1

Synthesis of Compound 15

[0325]



Compound 15

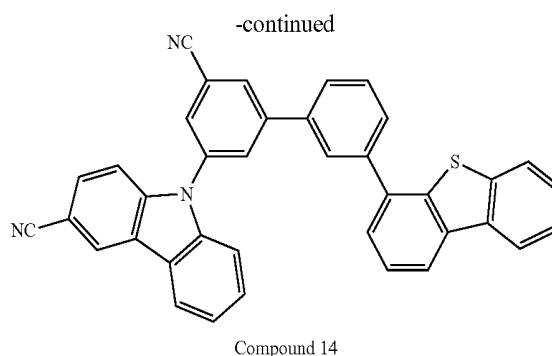
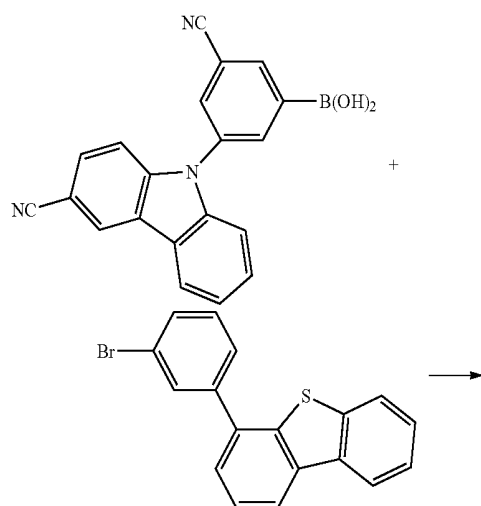
[0326] 13.084 grams (g) (38.81 millimoles (mmol)) of [3-cyano-5-(3-cyano-9H-fluorene-9-yl)phenyl]boronic acid, 10 g (32.34 mmol) of 1-bromo-3,5-diphenylbenzene, 3.737 g (3.23 mmol) of tetrakis(triphenylphosphine)palladium [Pd(PPh₃)₄], and 8.940 g (64.68 mmol) of potassium carbonate were added to 40 milliliters (mL) of tetrahydrofuran (THF) and 40 mL of distilled water in a round bottom flask, and the reaction mixture was heated under reflux for about 12 hours. Once the reaction was complete, the resultant was cooled to room temperature, and the THF and distilled water were separated. The separated THF was added dropwise to 100 mL of methanol for crystallization. The obtained solid therefrom was separated by filtering, and was subsequently washed with water and methanol. The resulting solid was dried in a vacuum oven to obtain 11.4 g of Compound 15 (yield: 68%).

[0327] MS(m/z, [M+H]⁺): 521.62

Synthesis Example 2

Synthesis of Compound 14

[0328]



[0329] 9.838 g (29.18 mmol) of [3-cyano-5-(3-cyano-9H-fluorene-9-yl)phenyl]boronic acid, 8.25 g (24.32 mmol) of 3-bromophenyl-4-dibenzothiophene, 2.810 g (2.43 mmol) of tetrakis(triphenylphosphine)palladium [Pd(PPh₃)₄], and 6.722 g (48.64 mmol) of potassium carbonate were added to 20 mL of THF and 20 mL of distilled water in a round bottom flask, and the reaction mixture was heated under reflux for about 12 hours. Once the reaction was complete, the resultant was cooled to room temperature, and the THF and distilled water were separated. The separated THF was added dropwise to 60 mL of methanol for crystallization. The obtained solid therefrom was separated by filtering, and was subsequently washed with water and methanol. The resulting solid was dried in a vacuum oven to obtain 8.24 g of Compound 14 (yield: 61%).

[0330] MS(m/z, [M+H]⁺): 551.67

Evaluation Example 1

Evaluation on HOMO, LUMO, T₁, and S₁ Energy Levels

[0331] HOMO, LUMO, T₁, and S₁ energy levels of Compounds 15 and 14 were evaluated using the method of Table 2. The results thereof are shown in Table 3.

TABLE 2

HOMO energy level evaluation method	A potential (Volts, V) versus current (Amperes, A) graph of each compound was obtained by using cyclic voltammetry (CV) (electrolyte: 0.1 molar (M) Bu ₄ NClO ₄ / solvent: CH ₂ Cl ₂ / electrode: 3-electrode system (working electrode: GC, reference electrode: Ag/AgCl, auxiliary electrode: Pt)). Subsequently, 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 a 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.
T ₁ energy level evaluation method	A mixture (each compound was dissolved in an amount of 1 milligram (mg) in 3 cubic centimeters (cc) of 2-MeTHF) of 2-MeTHF and each compound was loaded into a quartz cell. Subsequently, the resultant quartz cell was loaded into liquid nitrogen (77 Kelvins (K)), and a photoluminescence spectrum thereof was measured by using a device for measuring photoluminescence. T ₁ energy level was calculated from the start wavelength of the short-wavelength side of the photoluminescence spectrum.
S ₁ energy level evaluation method	A mixture (each compound was dissolved at a concentration of 10 ⁻⁴ [M] in 2-MeTHF) of 2-MeTHF and each compound was loaded into a quartz cell. A fluorescence spectrum was measured at room temperature by using a device for measuring photoluminescence (F7000, available from Hitachi). S ₁ energy level was calculated from the start wavelength of the short-wavelength side.

TABLE 3

Compound No.	HOMO (eV) (found)	LUMO (eV) (found)	T ₁ (eV)	S ₁ (eV)
15	-5.99	-2.25	2.95	3.57
14	-5.95	-2.38	2.93	3.27

[0332] Referring to Table 3, it was found that Compounds 15 and 14 had electric characteristics that are suitable as a material for forming an organic light-emitting device.

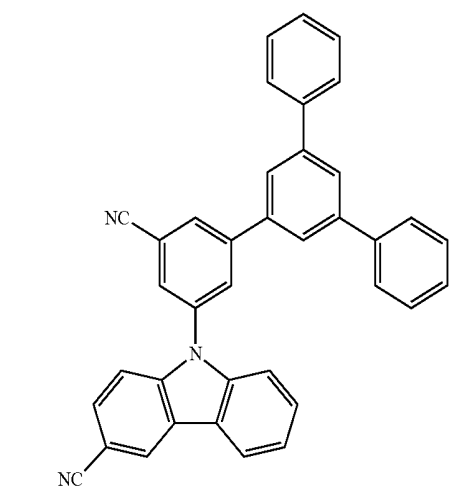
Evaluation Example 2

Thermal Characteristics Evaluation

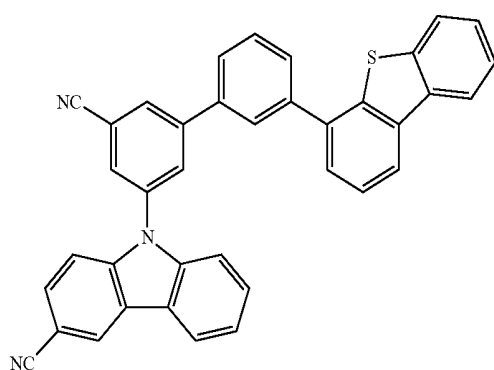
[0333] Thermal analysis (N₂ atmosphere, temperature range: from room temperature to 800° C. (10° C./min)-TGA, from room temperature to 400° C.-DSC, Pan Type: Pt Pan in disposable Al Pan (TGA) and disposable Al pan (DSC)) was performed on Compounds 15, 14, and A by using thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). The evaluation results are shown in Table 4. Referring to Table 4, it was found that Compounds 15 and 14 had excellent thermal stability, as compared with Compound A.

TABLE 4

Compound No.	Tg (° C.)
15	124
14	133
Compound A	72



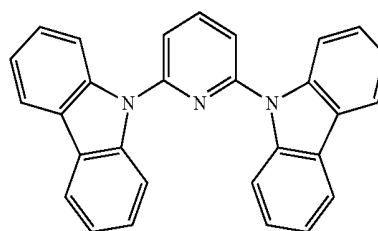
15



14

-continued

A



Example 1

[0334] A glass substrate with an ITO electrode (first electrode, anode) having a thickness of 1,500 Å formed thereon was washed with distilled water in the presence of ultrasound waves. Once the washing with distilled water was complete, ultrasound wave washing was performed on the substrate by using a solvent, such as isopropyl alcohol, acetone, or methanol. Subsequently, the substrate was dried, transferred to a plasma washer, washed for 5 minutes using oxygen plasma, and mounted in a vacuum depositor.

[0335] Compound HT3 and Compound HP-1 were co-deposited on the ITO electrode of the glass substrate to form a hole injection layer having a thickness of about 100 Å. Subsequently, Compound HT3 was deposited on the hole injection layer to form a hole transport layer having a thickness of about 1,300 Å. mCP was next deposited on the hole transport layer to form an electron blocking layer having a thickness of about 150 Å, thereby forming a hole transport region.

[0336] Subsequently, Compound 15 (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 about 300 Å.

[0337] BCP was vacuum deposited on the emission layer to form a hole blocking layer having a thickness of about 100 Å. Compound ET3 and Liq were then co-deposited on the hole blocking layer to form an electron transport layer having a thickness of about 250 Å. Next, Liq was deposited on the electron transport layer to form an electron injection layer having a thickness of about 5 Å, and then, aluminum (Al) second electrode (a 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 Examples 1 and 2

[0338] Organic light-emitting devices were manufactured in the same manner as in Example 1, except that the compounds shown in Table 5 were used instead of Compound 15 as a host in the formation of an emission layer.

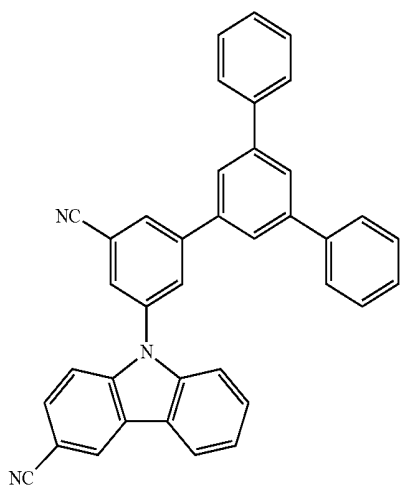
Evaluation Example 3: Evaluation of Characteristics of Organic Light-Emitting Device

[0339] The driving voltage, current density, efficiency, power efficiency, quantum efficiency, and lifespan of the organic light-emitting devices manufactured in Examples 1 and 2 and Comparative Examples 1 and 2 were measured by using a current voltmeter (Keithley 2400) and a luminance meter (Minolta Cs-1000A). The evaluation results are shown in Table 5. In Table 5, T₉₅ is lifespan data evaluating a period taken for the luminance (at 500 candelas per square meter (cd/m²)) to reach 95% with respect to 100% of the initial luminance.

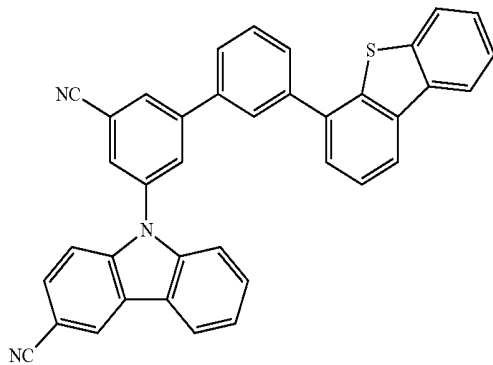
TABLE 5

	Host	Driving voltage (V)	Efficiency (cd/A)	Power (lm/W)	Quantum efficiency (%)	T ₉₅ (hours)
Example 1	Compound 15	3.49	18.56	16.73	13	3.2
Example 2	Compound 14	3.62	20.22	17.55	12	4.55
Comparative Example 1	Compound A	6.71	14.80	6.95	8.1	0.47
Comparative Example 2	mCP	5.85	19.4	13.73	16.3	0.18

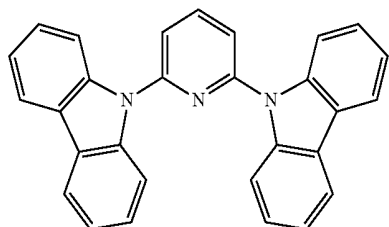
15



14



A



mCP

[0340] Referring to Table 5, the organic light-emitting device manufactured in Examples 1 and 2 had a low driving voltage, high efficiency, high power, high quantum emission efficiency, and long lifespan, as compared with the organic light-emitting devices manufactured in Comparative Examples 1 and 2.

[0341] As described above, according to the one or more of the above exemplary embodiments, the condensed cyclic compound according has excellent electric characteristics and thermal stability. Accordingly, an organic light-emitting device including the condensed cyclic compound may have a low driving voltage, high efficiency, high power characteristics, high quantum light-emitting efficiency, and a long lifespan.

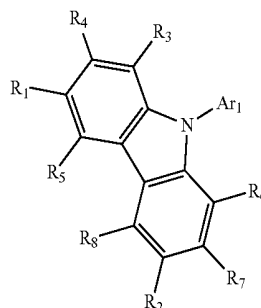
[0342] It should be understood that exemplary embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each exemplary embodiment should typically be considered as available for other similar features or aspects in other exemplary embodiments.

[0343] 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 inventive concept as defined by the following claims.

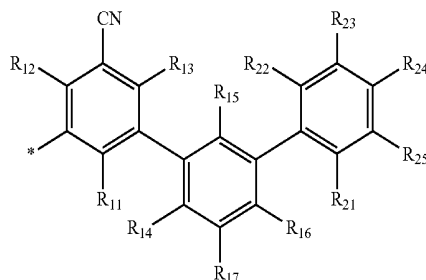
What is claimed is:

1. A condensed cyclic compound represented by Formula 1:

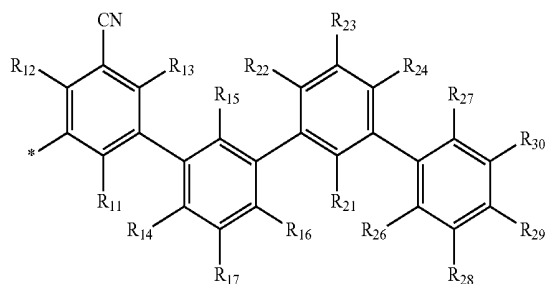
Formula 1



Formula 2A

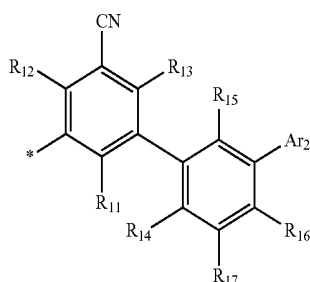


Formula 2B



-continued

Formula 2C



wherein Ar₁ in Formula 1 is selected from groups represented by Formulae 2A to 2C,

R₁₃ and R₁₅ in Formulae 2A to 2C are optionally connected to each other through *—O—*, *—S—*, *—C(R₃₁)(R₃₂)—*, or *—Si(R₃₁)(R₃₂)—* to form a 5-membered ring,

R₁₁ and R₁₄ in Formulae 2A to 2C are optionally connected to each other through *—O—*, *—S—*, *—C(R₃₃)(R₃₄)—*, or *—Si(R₃₃)(R₃₄)—* to form a 5-membered ring,

R₁₅ and R₂₂ in Formulae 2A and 2B are optionally connected to each other through *—O—*, *—S—*, *—C(R₃₅)(R₃₆)—*, or *—Si(R₃₅)(R₃₆)—* to form a 5-membered ring,

R₁₆ and R₂₁ in Formulae 2A and 2B are optionally connected to each other through *—O—*, *—S—*, *—C(R₃₇)(R₃₈)—*, or *—Si(R₃₇)(R₃₈)—* to form a 5-membered ring,

R₂₄ and R₂₇ in Formula 2B are optionally connected to each other through *—O—*, *—S—*, *—C(R₃₉)(R₄₀)—*, or *—Si(R₃₉)(R₄₀)—* to form a 5-membered ring,

R₂₁ and R₂₆ in Formula 2B are optionally connected to each other through *—O—*, *—S—*, *—C(R₄₁)(R₄₂)—*, or *—Si(R₄₁)(R₄₂)—* to form a 5-membered ring,

R₁ to R₈, R₁₁ to R₁₇, R₂₁ to R₃₀, and R₃₁ to R₄₂ in Formulae 1 and 2A to 2C are each independently selected from:

hydrogen, deuterium, a cyano group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group;

a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group, each substituted with at least one selected from deuterium and a cyano group; and

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group and a dibenzosilolyl group, each substituted with at least one of deuterium, a cyano group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group;

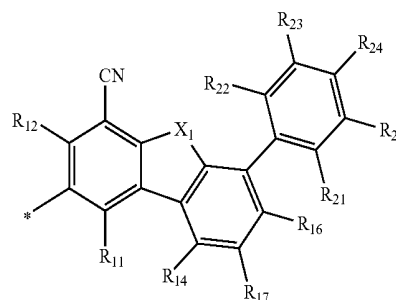
Ar₂ in Formula 2C is selected from

a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group; and

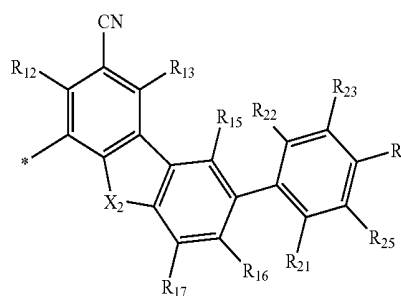
a dibenzofuranyl group, a dibenzothiophenyl group and a dibenzosilolyl group, each substituted with at least one selected from deuterium, a cyano group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group, and
* indicates a binding site to an adjacent atom.

2. The condensed cyclic compound of claim 1, wherein Ar₁ is selected from groups represented by Formulae 2A-1 to 2A-4:

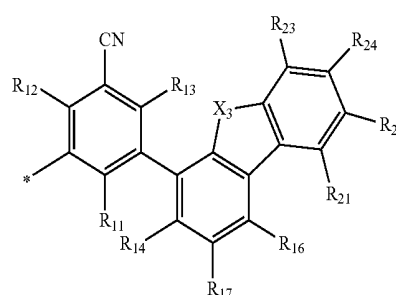
Formula 2A-1



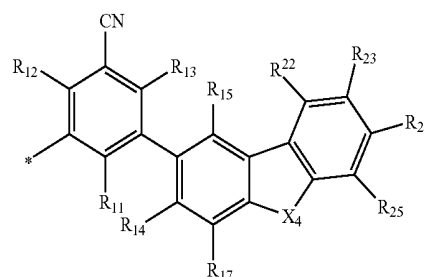
Formula 2A-2



Formula 2A-3



Formula 2A-4



wherein, in Formulae 2A-1 to 2A-4,

X₁ is O, S, C(R₃₁)(R₃₂), or Si(R₃₁)(R₃₂),

X₂ is O, S, C(R₃₃)(R₃₄), or Si(R₃₃)(R₃₄),

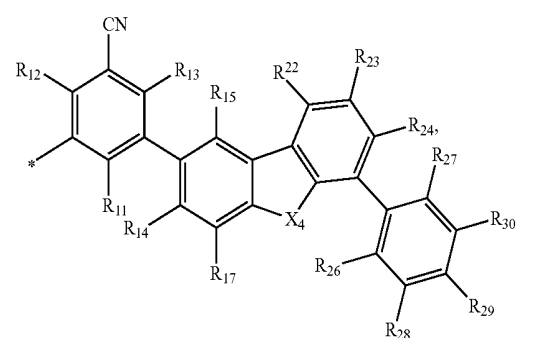
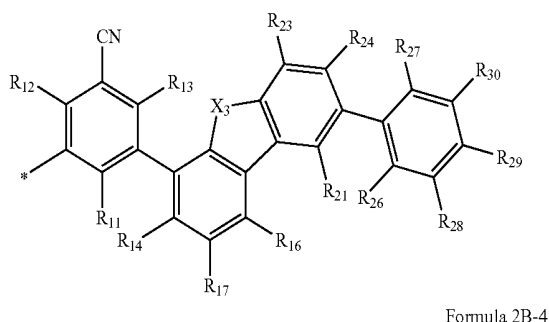
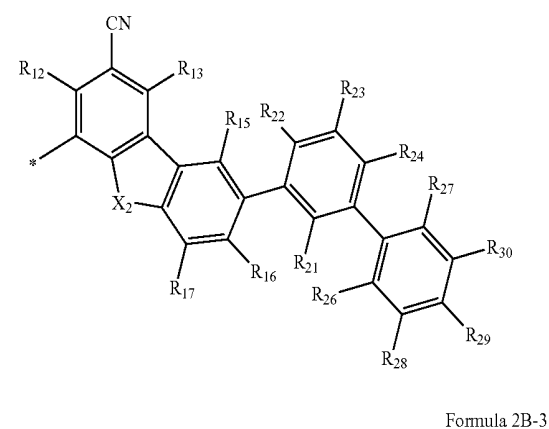
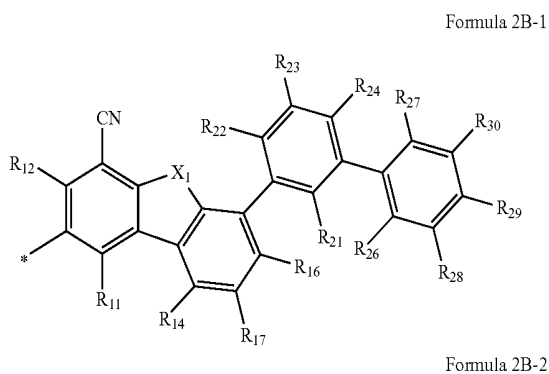
X_3 is O, S, $C(R_{35})(R_{36})$, or $Si(R_{35})(R_{36})$,

X_4 is O, S, $C(R_{37})(R_{38})$, or $Si(R_{37})(R_{38})$,

R_{11} to R_{17} , R_{21} to R_{25} , and R_{31} to R_{38} are the same as in claim 1, and

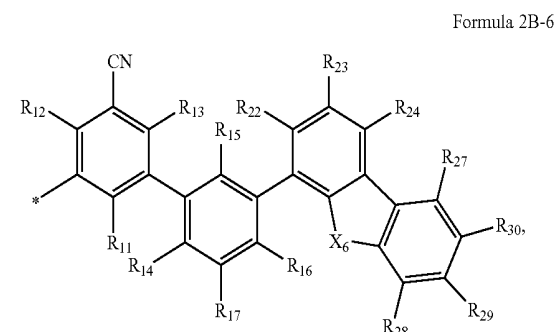
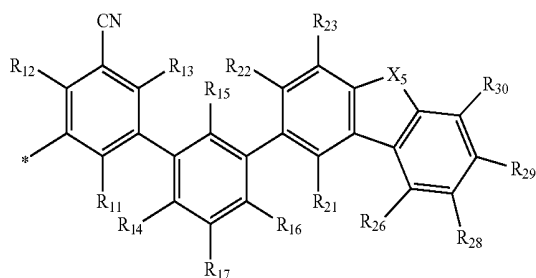
* indicates a binding site to an adjacent atom.

3. The condensed cyclic compound of claim 1, wherein Ar_1 is selected from groups represented by Formulae 2B-1 to 2B-6:



-continued

Formula 2B-5



wherein, in Formulae 2B-1 to 2B-6,

X_1 is O, S, $C(R_{31})(R_{32})$, or $Si(R_{31})(R_{32})$,

X_2 is O, S, $C(R_{33})(R_{34})$, or $Si(R_{33})(R_{34})$,

X_3 is O, S, $C(R_{35})(R_{36})$, or $Si(R_{35})(R_{36})$,

X_4 is O, S, $C(R_{37})(R_{38})$, or $Si(R_{37})(R_{38})$,

X_5 is O, S, $C(R_{39})(R_{40})$, or $Si(R_{39})(R_{40})$,

X_6 is O, S, $C(R_{41})(R_{42})$, or $Si(R_{41})(R_{42})$,

R_{11} to R_{17} , R_{21} to R_{30} , and R_{31} to R_{42} are the same as in claim 1, and

* indicates a binding site to an adjacent atom.

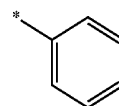
4. The condensed cyclic compound of claim 1, wherein R_1 to R_8 , R_{11} to R_{17} , R_{21} to R_{30} , and R_{31} to R_{42} are each independently selected from

hydrogen, deuterium, a cyano group, a C_1 - C_{20} alkyl group, a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group;

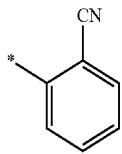
a C_1 - C_{20} alkyl group substituted with at least one of deuterium and a cyano group; and

a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group, each substituted with at least one selected from deuterium, a cyano group, a C_1 - C_{20} alkyl group, a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a dibenzosilolyl group.

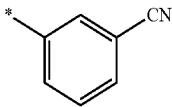
5. The condensed cyclic compound of claim 1, wherein R_1 to R_8 , R_{11} to R_{17} , R_{21} to R_{30} , and R_{31} to R_{42} are each independently selected from hydrogen, deuterium, a cyano group, and groups represented by Formulae 4-1 to 4-29:



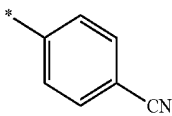
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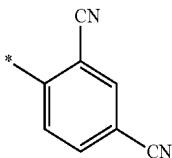
Formula 4-2



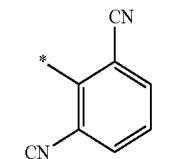
Formula 4-3



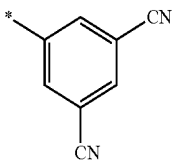
Formula 4-4



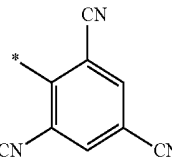
Formula 4-5



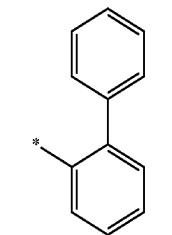
Formula 4-6



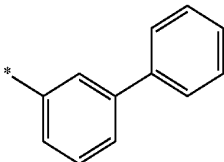
Formula 4-7



Formula 4-8

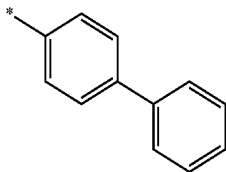


Formula 4-9

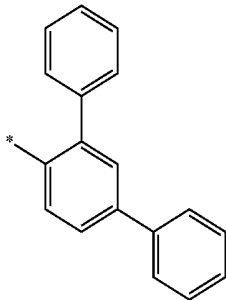


Formula 4-10

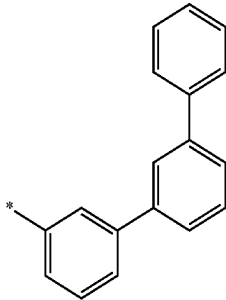
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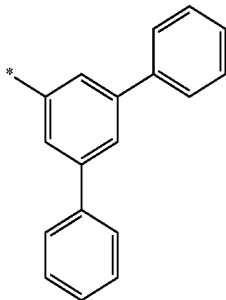
Formula 4-11



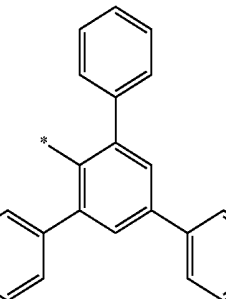
Formula 4-12



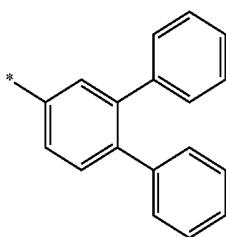
Formula 4-13



Formula 4-14

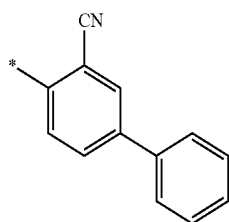


Formula 4-15



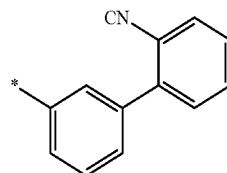
Formula 4-16

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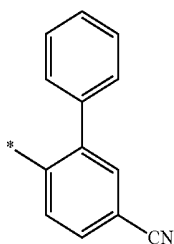
Formula 4-17

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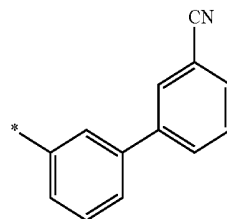


Formula 4-23

Formula 4-18

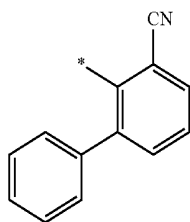


Formula 4-24

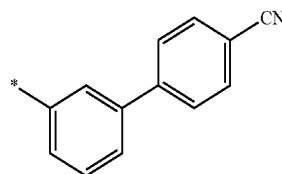


Formula 4-25

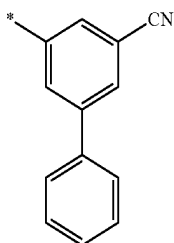
Formula 4-19



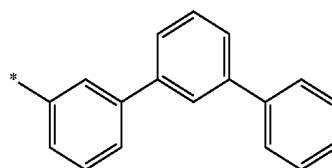
Formula 4-26



Formula 4-20

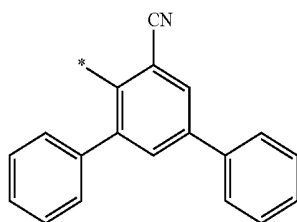


Formula 4-27

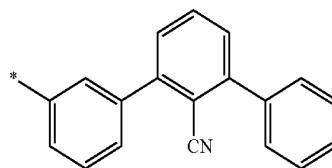


Formula 4-28

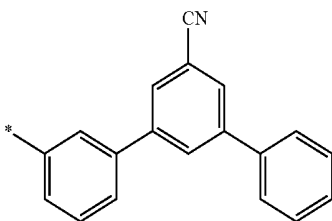
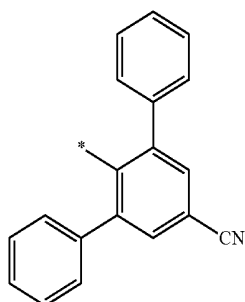
Formula 4-21



Formula 4-29



Formula 4-22

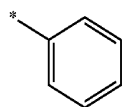


wherein * in Formulae 4-1 to 4-29 indicates a binding site to an adjacent atom.

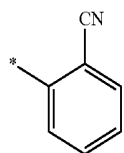
6. The condensed cyclic compound of claim 1, wherein at least one of R_1 and R_2 in Formula 1 is a cyano group.

7. The condensed cyclic compound of claim 1, wherein each of R_{11} to R_{17} and R_{21} to R_{25} in Formula 2A is simultaneously hydrogen, or

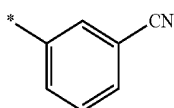
at least one of R_{23} , R_{25} , and R_{15} to R_{17} in Formula 2A is each independently selected from a cyano group and groups represented by Formulae 4-1 to 4-29, or each of R_{11} to R_{17} , R_{21} to R_{24} , and R_{26} to R_{30} in Formula 2B is simultaneously hydrogen, or at least one of R_{15} , R_{17} , R_{21} , R_{23} , R_{28} , and R_{30} in Formula 2B is each independently selected from a cyano group and groups represented by Formulae 4-1 to 4-29, or R_{17} in Formula 2C is a cyano group, a phenyl group, a biphenyl group or a terphenyl group,



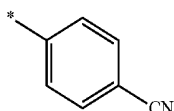
Formula 4-1



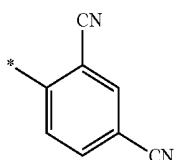
Formula 4-2



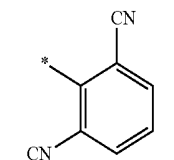
Formula 4-3



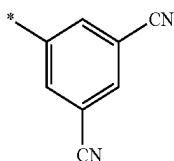
Formula 4-4



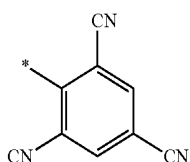
Formula 4-5



Formula 4-6

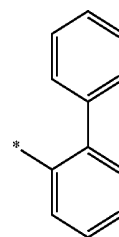


Formula 4-7

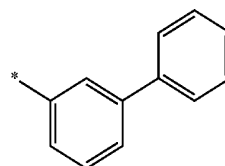


Formula 4-8

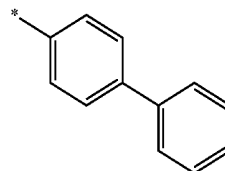
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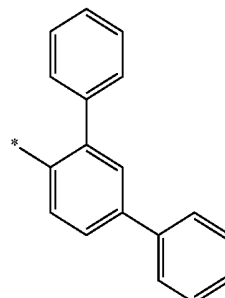
Formula 4-9



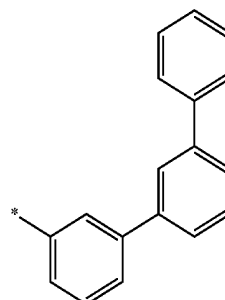
Formula 4-10



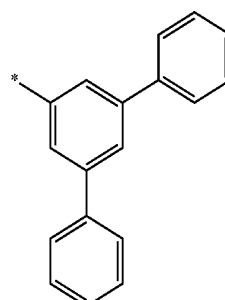
Formula 4-11



Formula 4-12

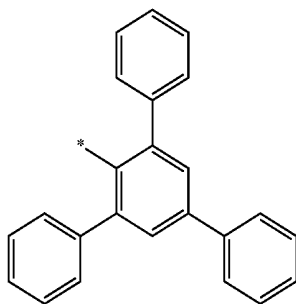


Formula 4-13

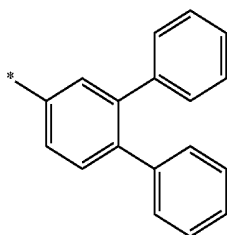


Formula 4-14

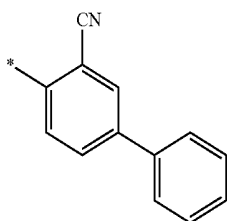
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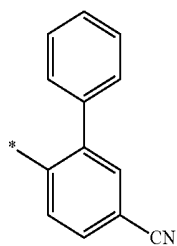
Formula 4-15



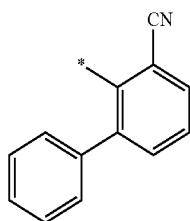
Formula 4-16



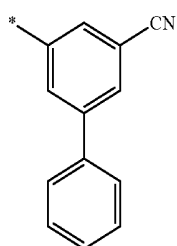
Formula 4-17



Formula 4-18

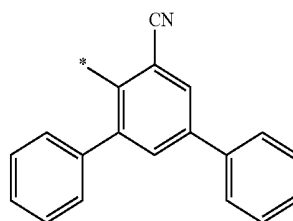


Formula 4-19

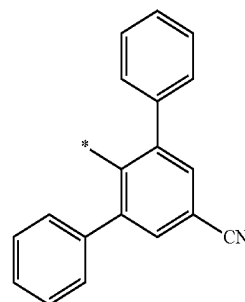


Formula 4-20

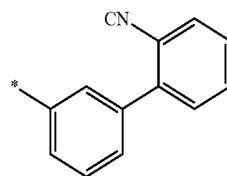
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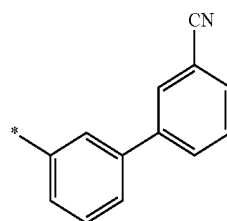
Formula 4-21



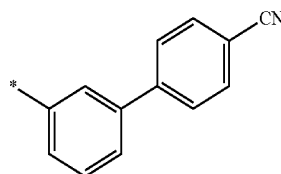
Formula 4-22



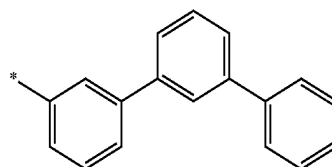
Formula 4-23



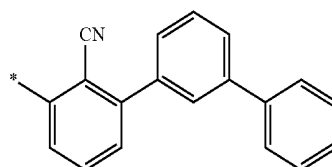
Formula 4-24



Formula 4-25

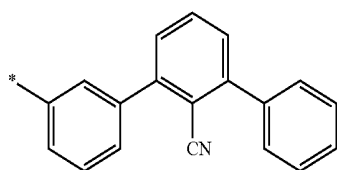


Formula 4-26



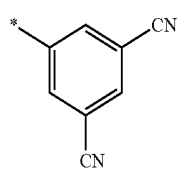
Formula 4-27

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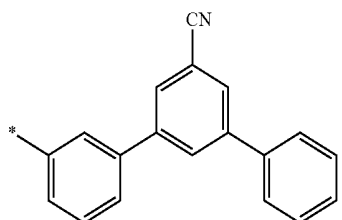
Formula 4-28

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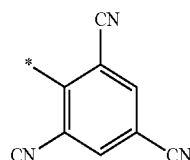


Formula 4-7

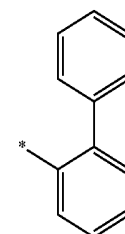
Formula 4-29



Formula 4-8



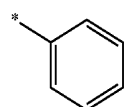
Formula 4-9



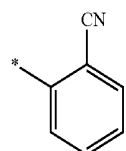
Formula 4-10

wherein, in Formulae 4-1 to 4-29, * indicates a binding site to an adjacent atom.

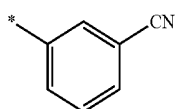
8. The condensed cyclic compound of claim 2, wherein
- i) at least one of R_{17} and R_{25} in Formula 2A-1,
 - ii) at least one of R_{17} and R_{25} in Formula 2A-2,
 - iii) R_{17} in Formula 2A-3, and
 - iv) R_{17} in Formula 2A-4 are each independently selected from a cyano group and groups represented by Formulae 4-1 to 4-29:



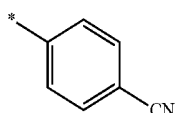
Formula 4-1



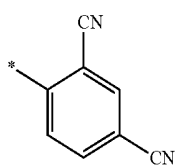
Formula 4-2



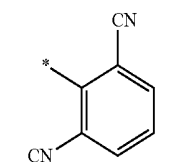
Formula 4-3



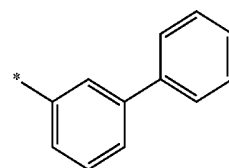
Formula 4-4



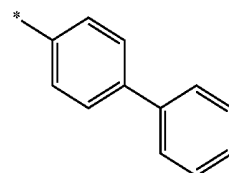
Formula 4-5



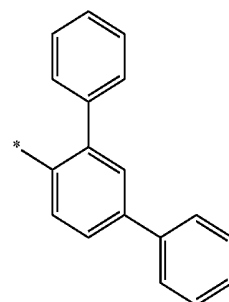
Formula 4-6



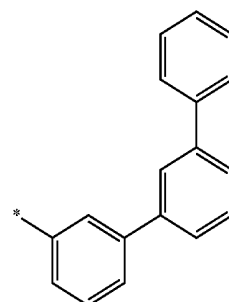
Formula 4-11



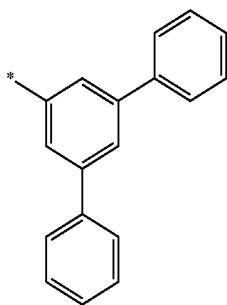
Formula 4-12



Formula 4-13

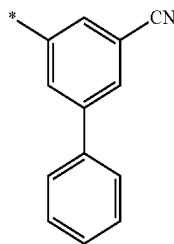


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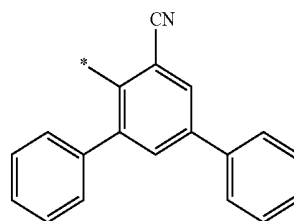
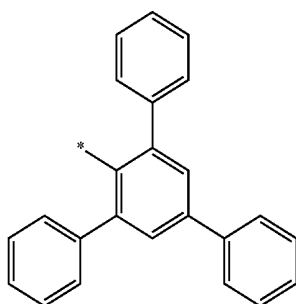
Formula 4-14

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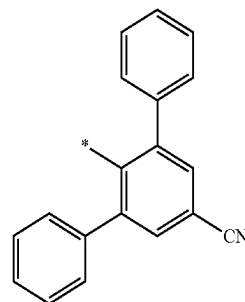
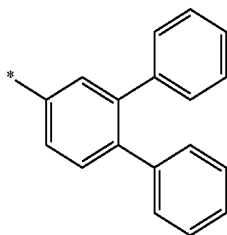
Formula 4-20

Formula 4-15



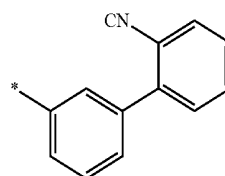
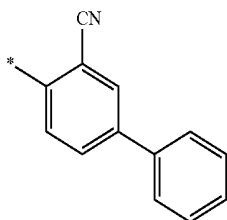
Formula 4-21

Formula 4-16



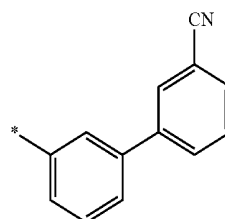
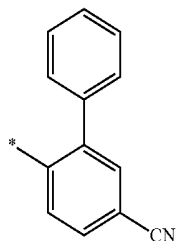
Formula 4-22

Formula 4-17



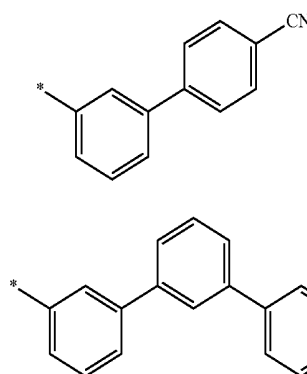
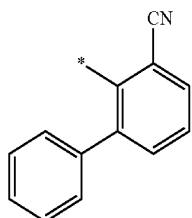
Formula 4-23

Formula 4-18



Formula 4-24

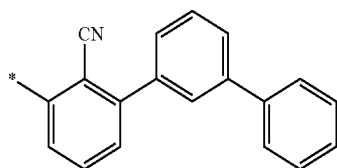
Formula 4-19



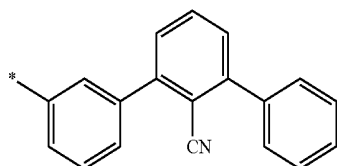
Formula 4-25

Formula 4-26

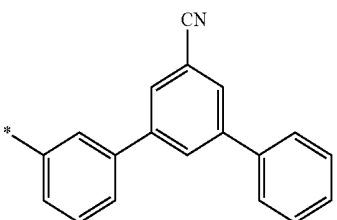
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Formula 4-27



Formula 4-28

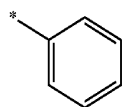


Formula 4-29

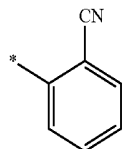
wherein, in Formula 4-1 to 4-29, * indicates a binding site to an adjacent atom.

9. The condensed cyclic compound of claim 3, wherein

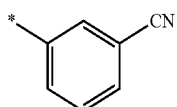
- i) R_{17} in Formula 2B-1,
- ii) R_{17} in Formula 2B-2,
- iii) one of R_{17} and R_{28} in Formula 2B-3,
- iv) one of R_{17} and R_{28} in Formula 2B-4,
- v) one of R_{23} , R_{28} , and R_{30} in Formula 2B-5, and
- vi) one of R_{23} , R_{28} , and R_{30} in Formula 2B-6 are each independently selected from a cyano group and groups represented by Formulae 4-1 to 4-29:



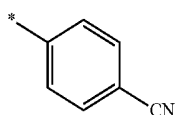
Formula 4-1



Formula 4-2

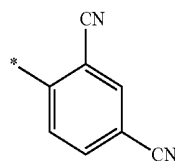


Formula 4-3

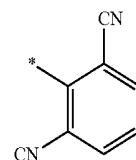


Formula 4-4

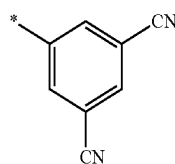
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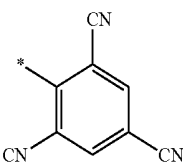
Formula 4-5



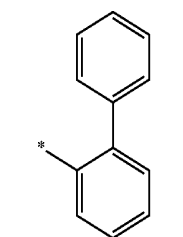
Formula 4-6



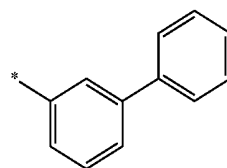
Formula 4-7



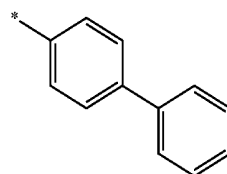
Formula 4-8



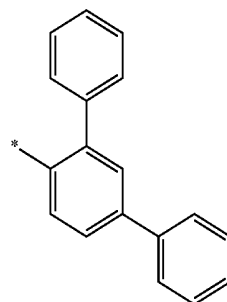
Formula 4-9



Formula 4-10

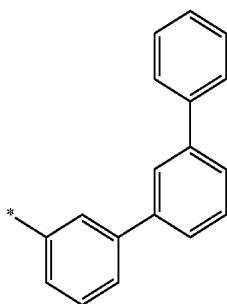


Formula 4-11

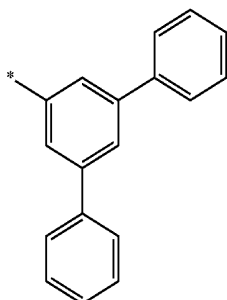


Formula 4-12

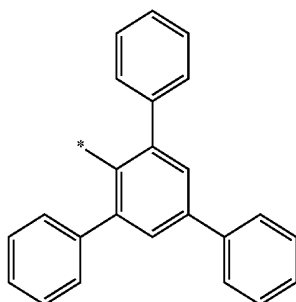
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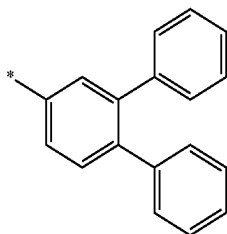
Formula 4-13



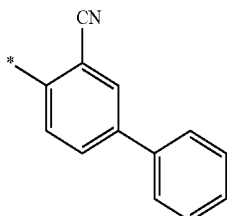
Formula 4-14



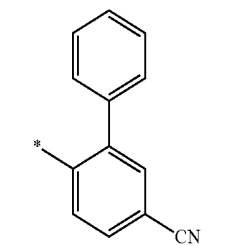
Formula 4-15



Formula 4-16

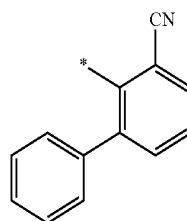


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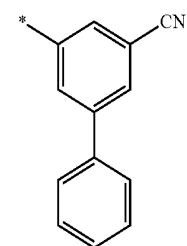


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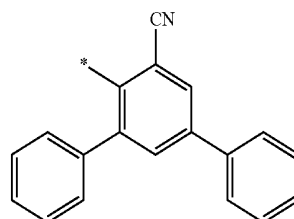
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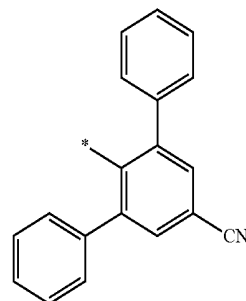
Formula 4-19



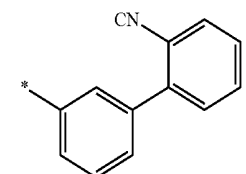
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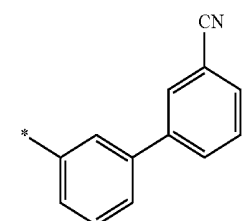
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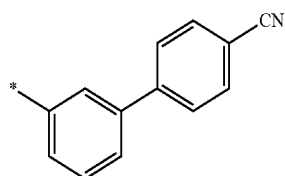
Formula 4-22



Formula 4-23

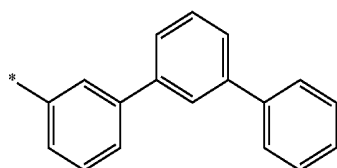


Formula 4-24

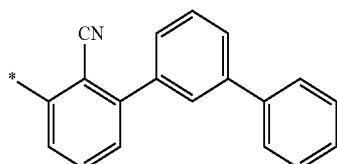


Formula 4-25

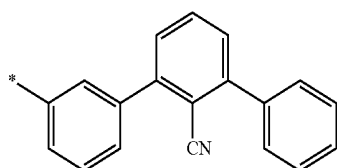
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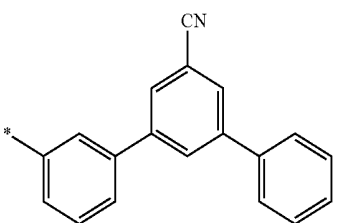
Formula 4-26



Formula 4-27



Formula 4-28



Formula 4-29

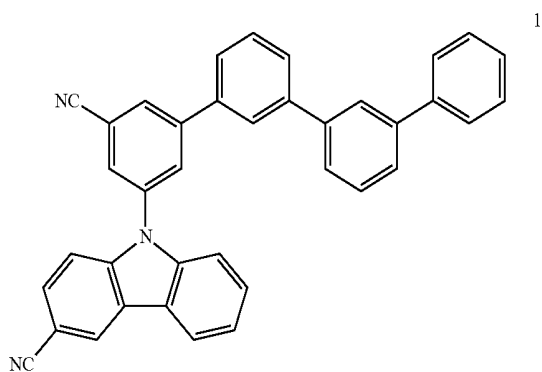
wherein, in Formulae 4-1 to 4-29, * indicates a binding site to an adjacent atom.

10. The condensed cyclic compound of claim 1, wherein the number of cyano groups in each of Formulae 2A to 2C is 1, 2, 3, or 4.

11. The condensed cyclic compound of claim 1, wherein the condensed cyclic compound has a difference between a triplet (T_1) energy level and a singlet (S_1) energy level in a range from about 0.1 electron Volts to about 0.6 electron Volts.

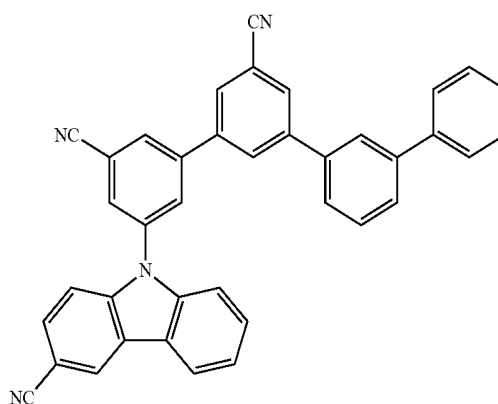
12. The condensed cyclic compound of claim 1, wherein the condensed cyclic compound has a triplet (T_1) energy level in a range from about 2.9 electron Volts to about 3.1 electron Volts.

13. The condensed cyclic compound of claim 1, wherein the condensed cyclic compound is one selected from Compounds 1 to 116:

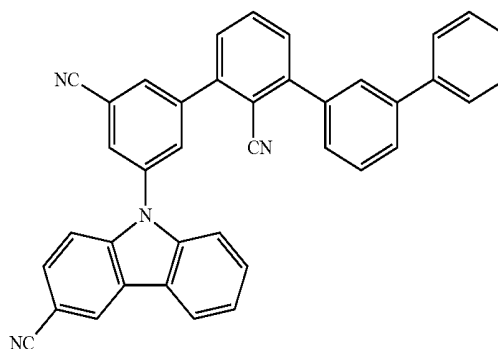


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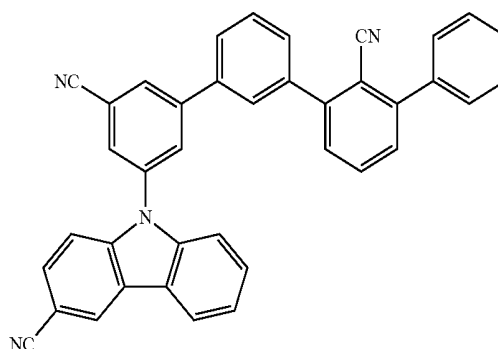
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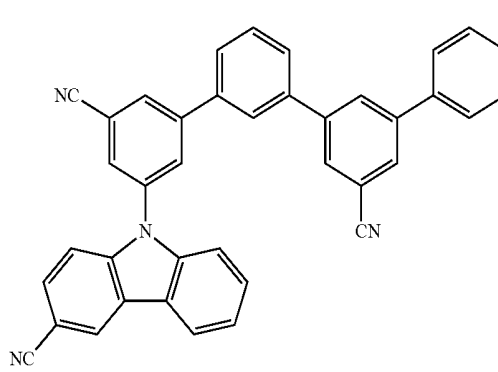
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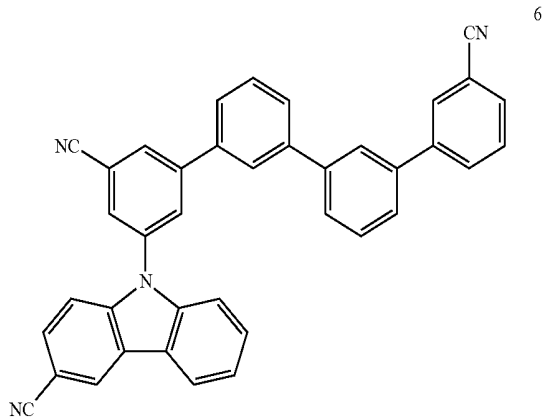


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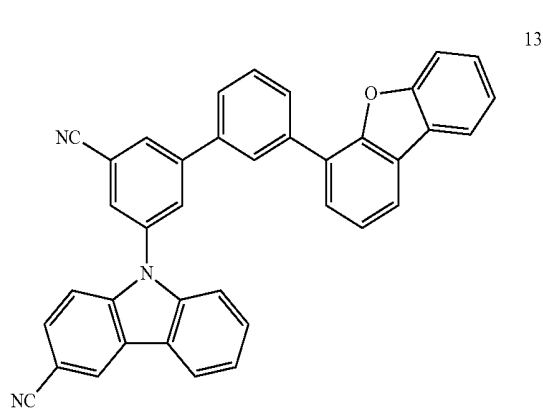
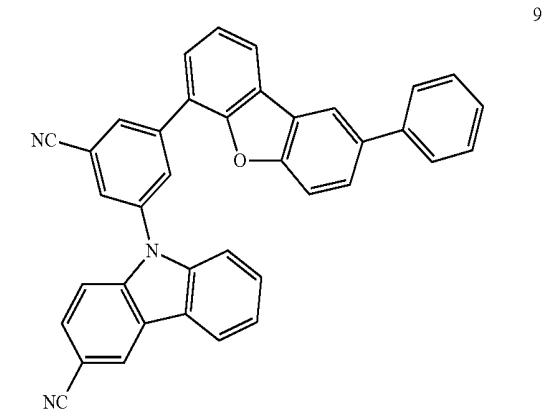
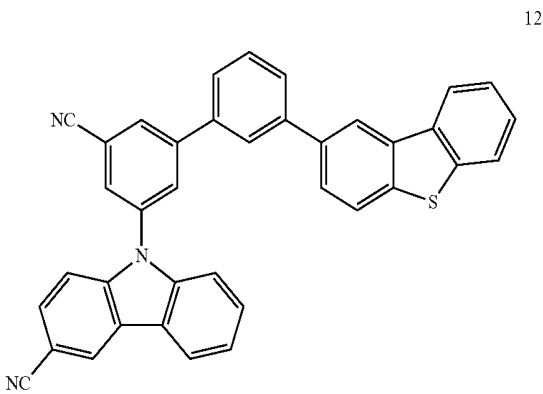
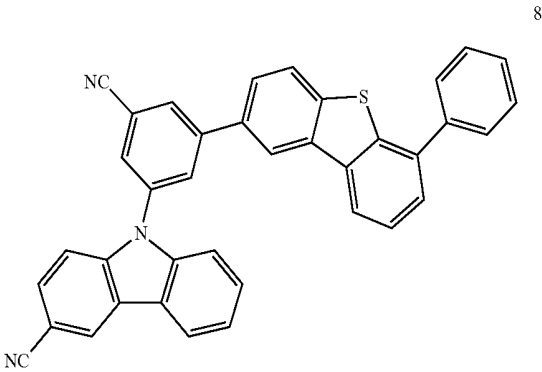
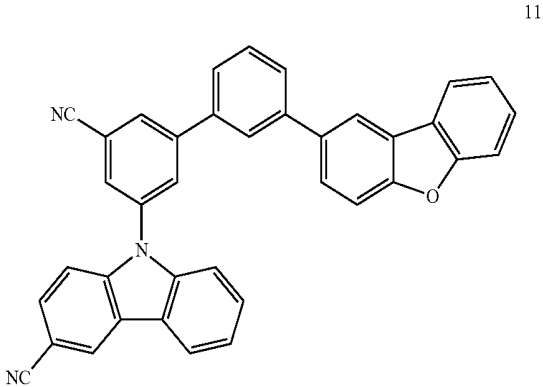
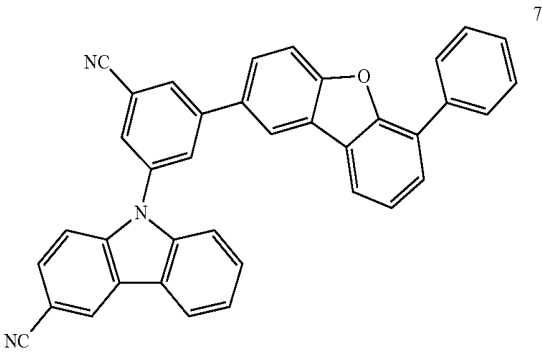
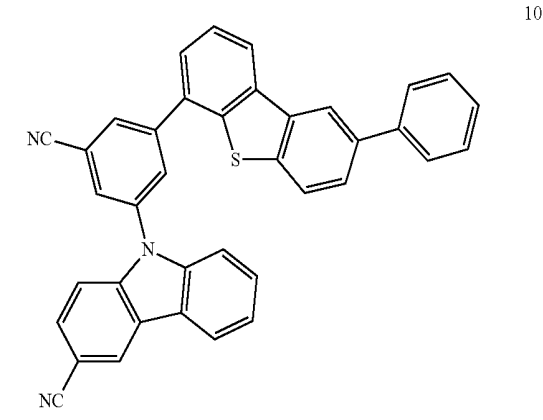


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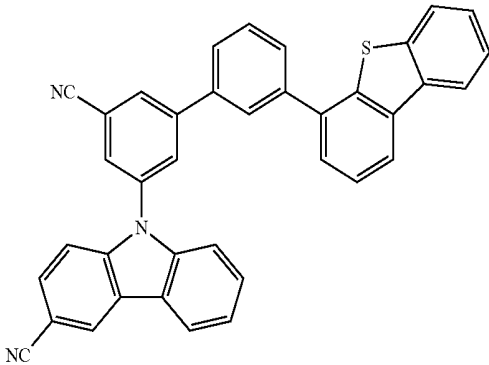
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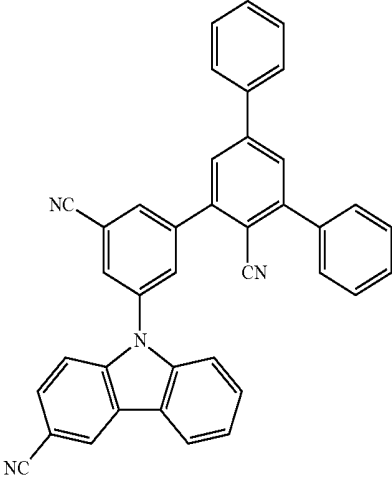


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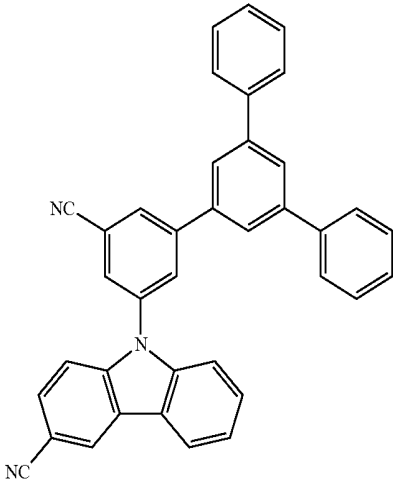
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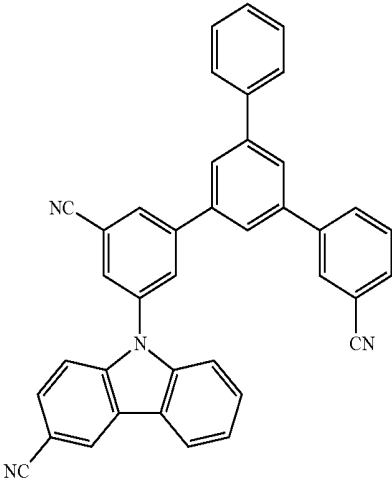


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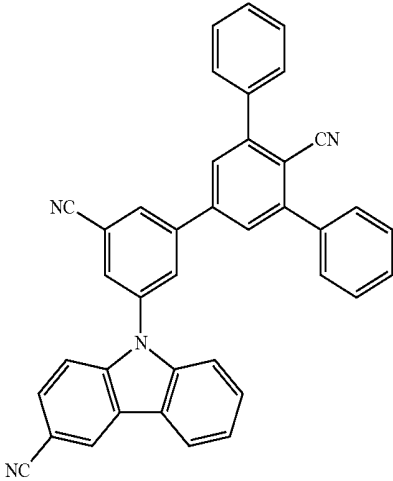
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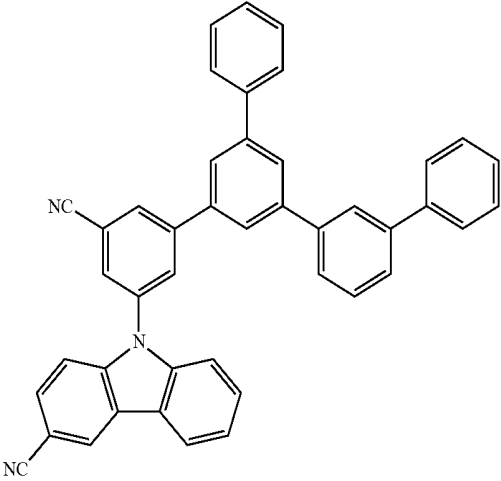
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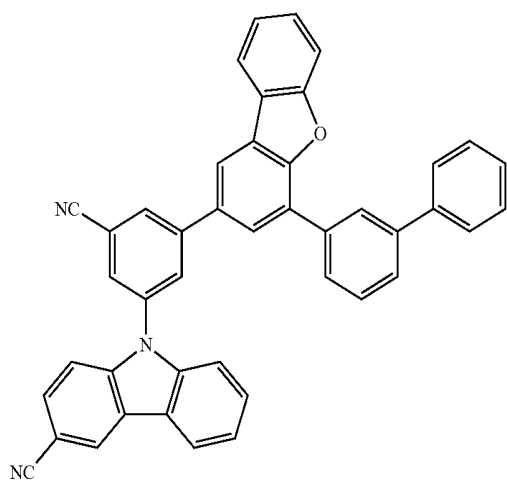
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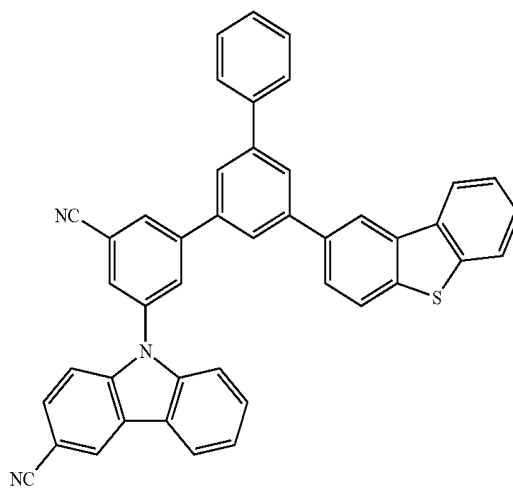
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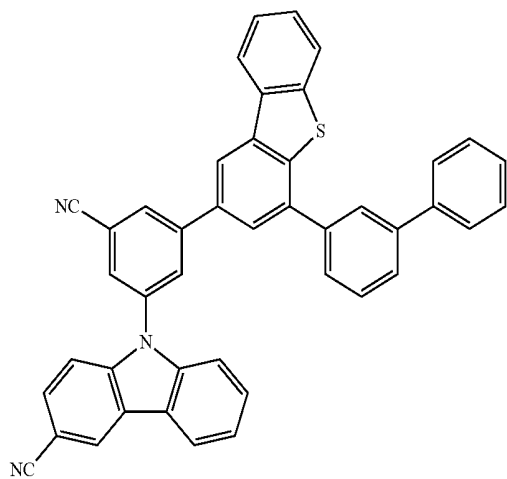
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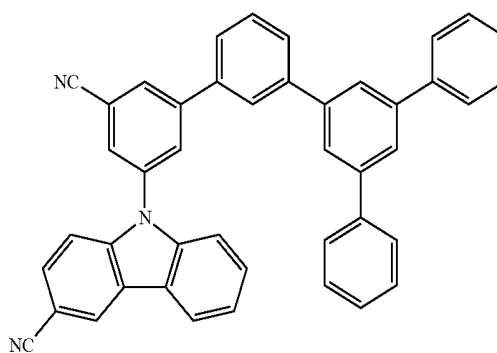
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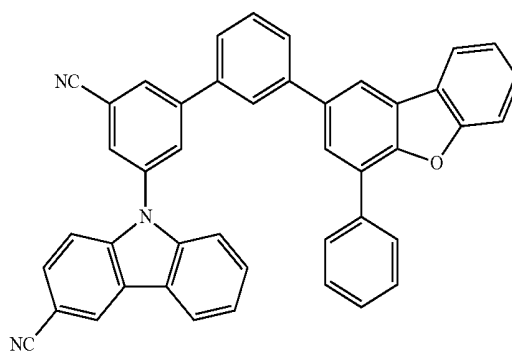
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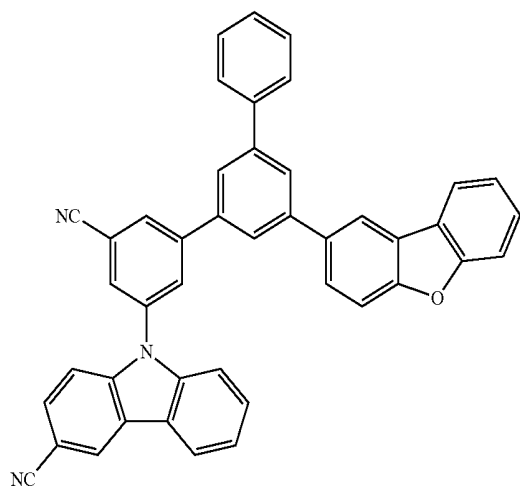
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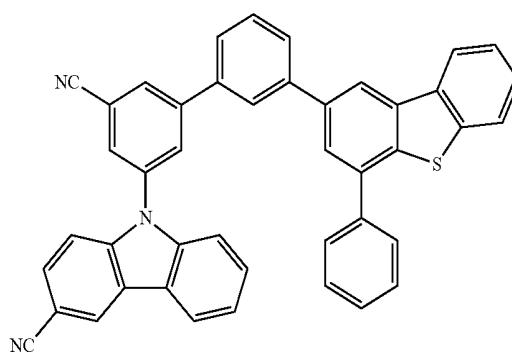
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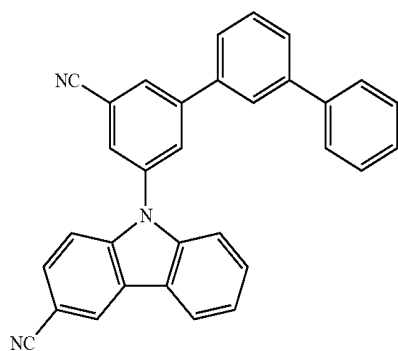
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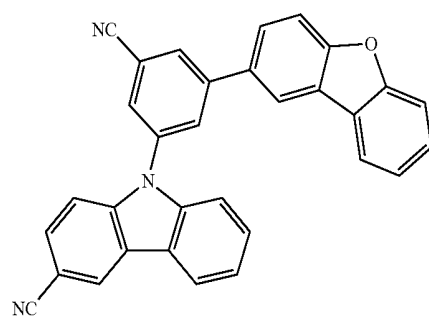


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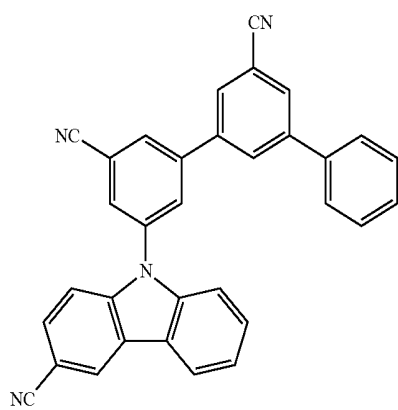


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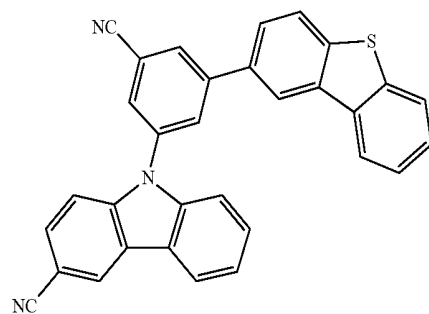
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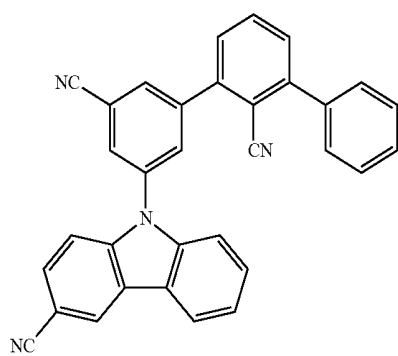
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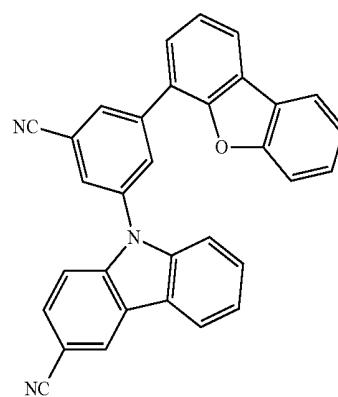
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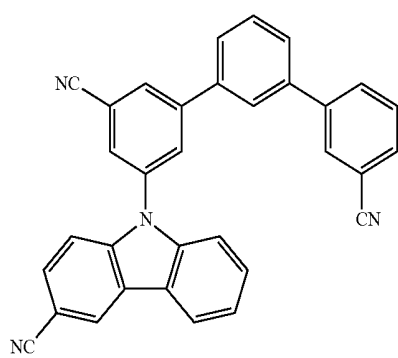
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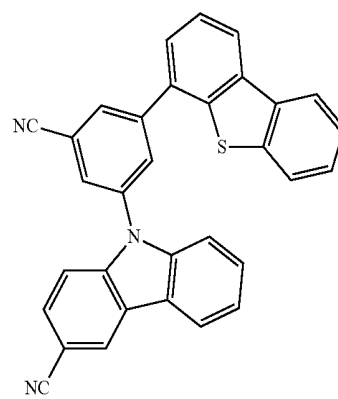
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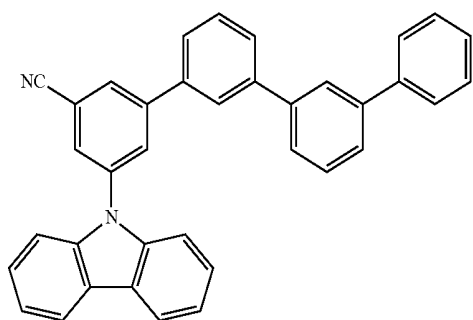


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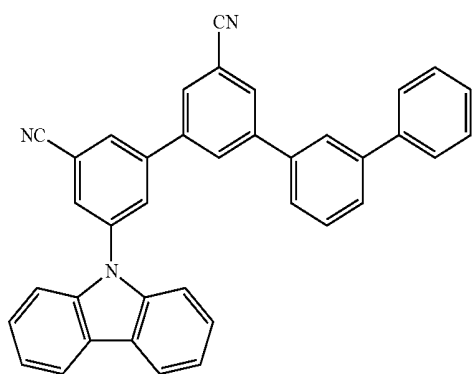


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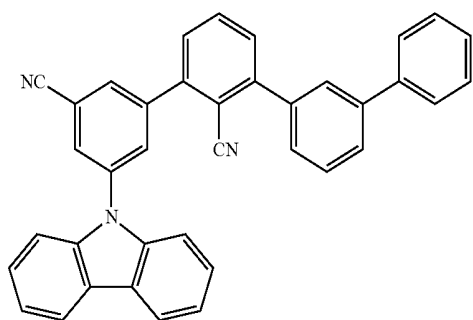
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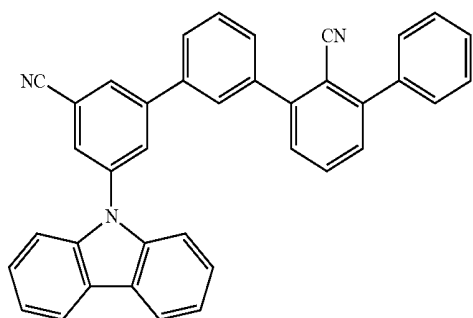
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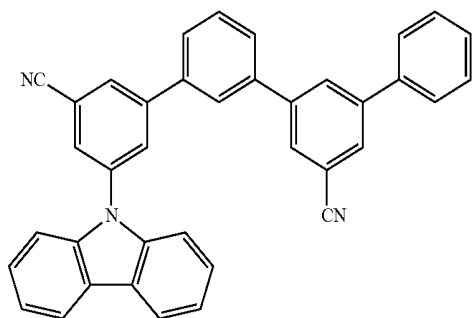
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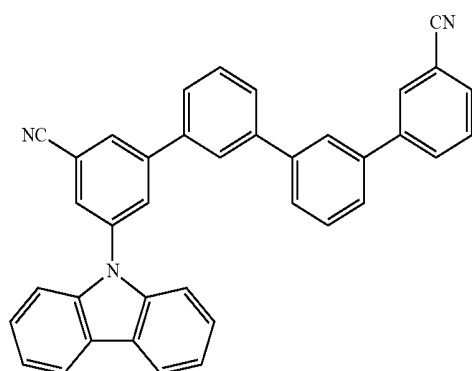


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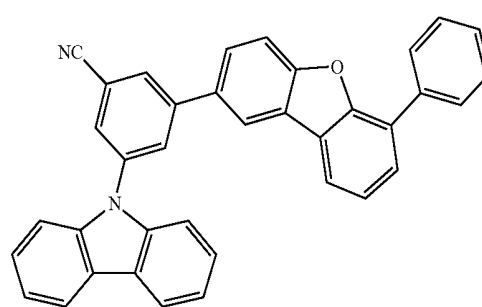


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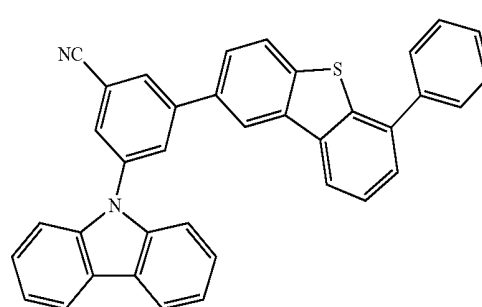
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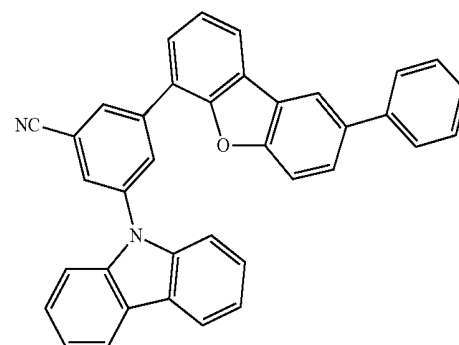
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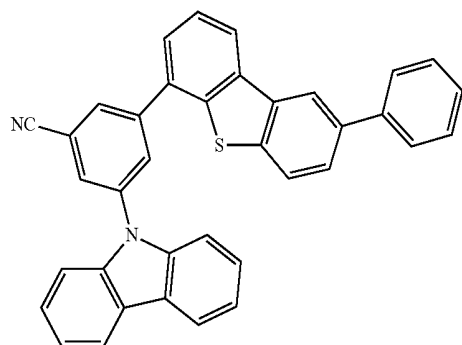


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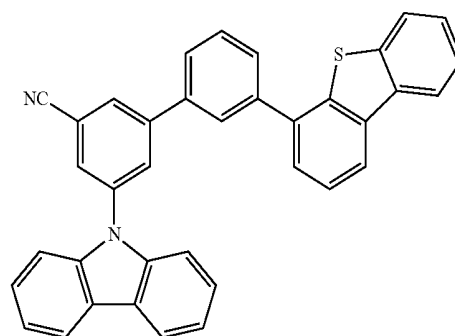
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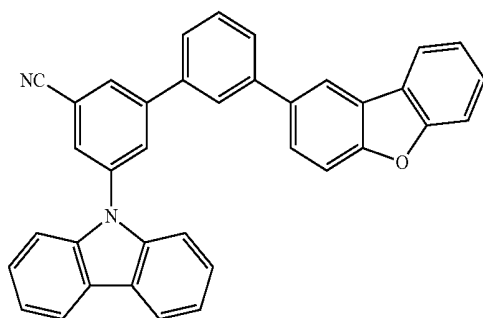


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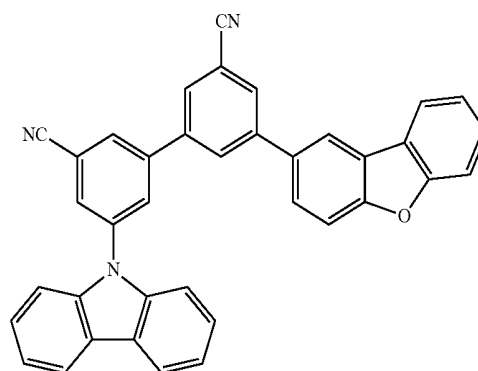
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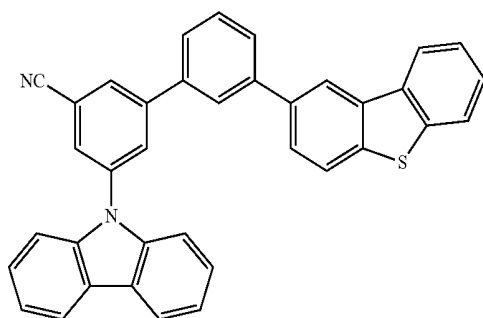
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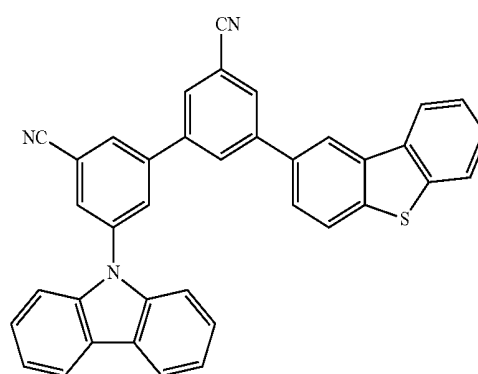
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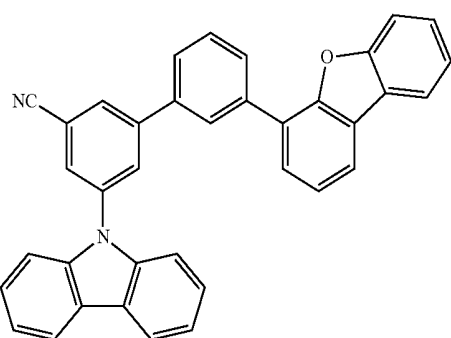
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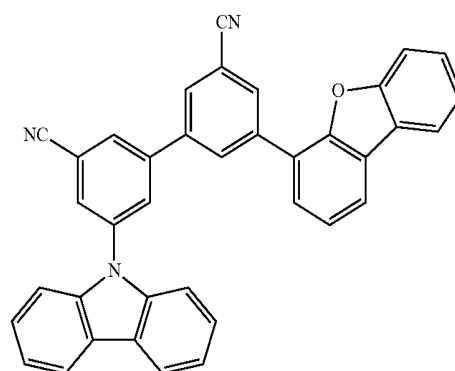
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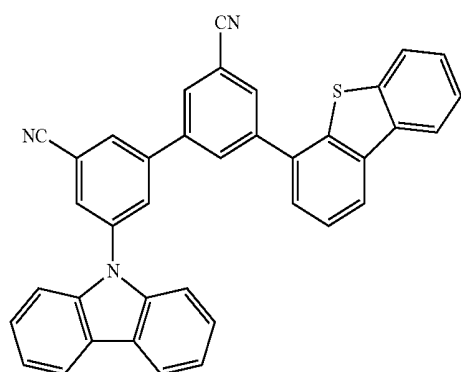
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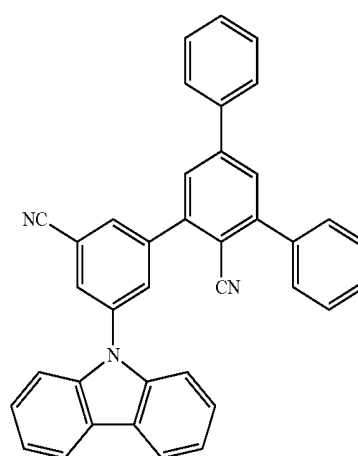
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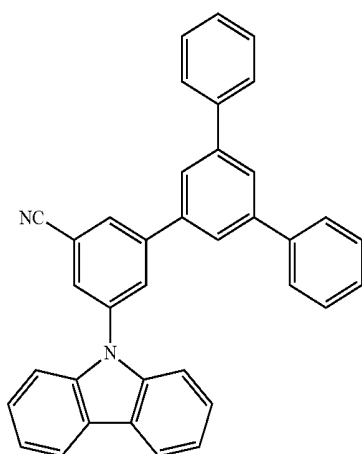
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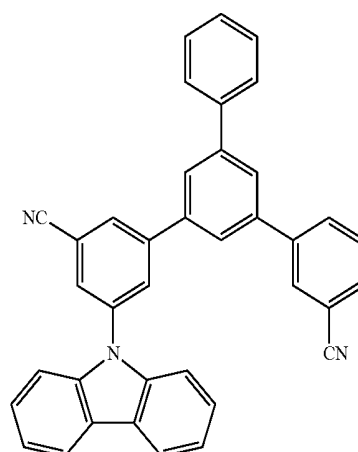
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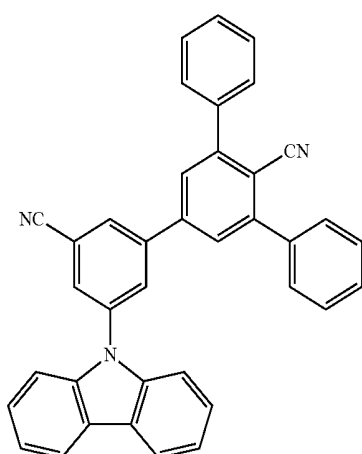
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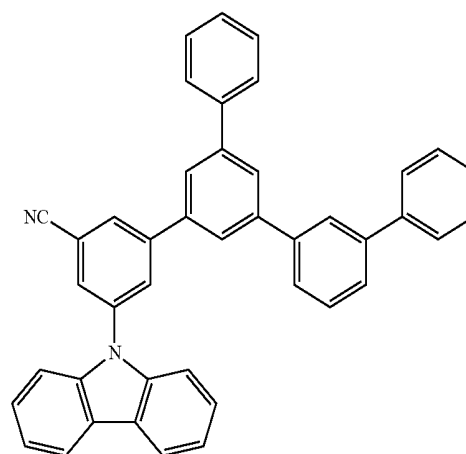
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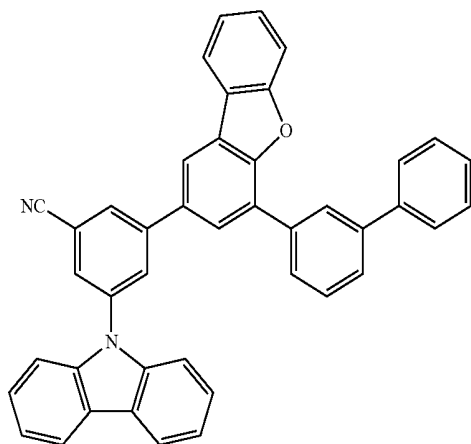
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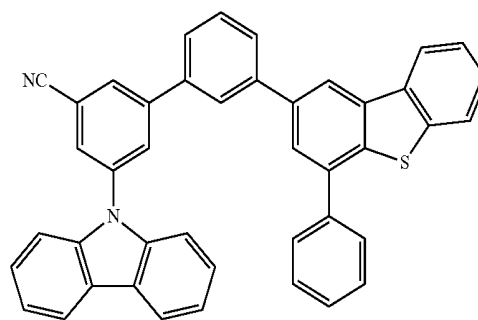
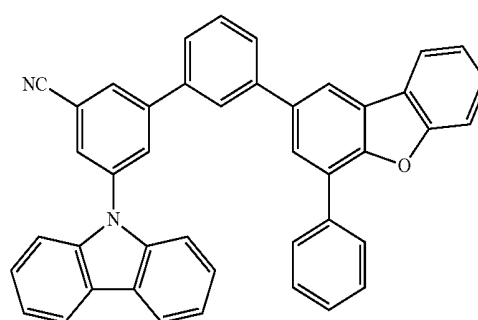
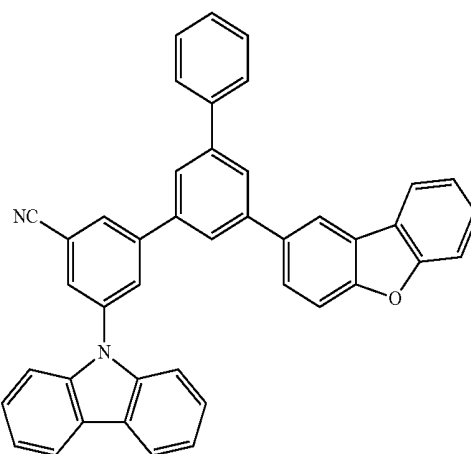
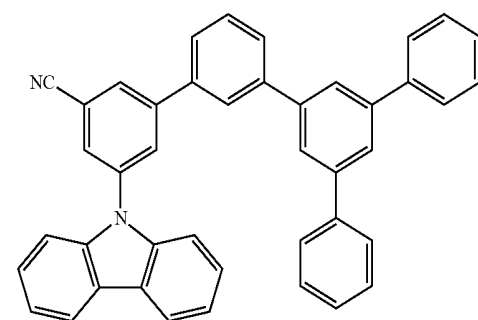
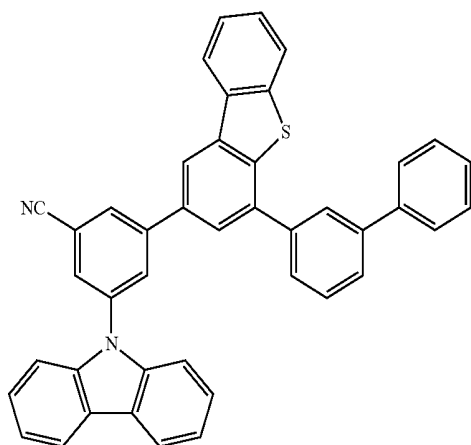
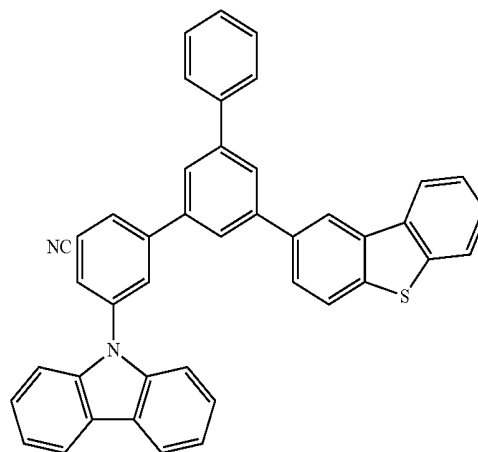
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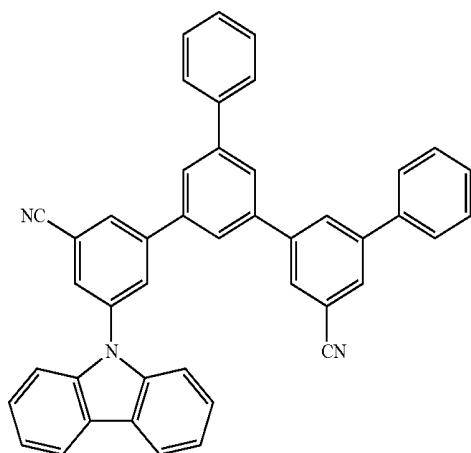
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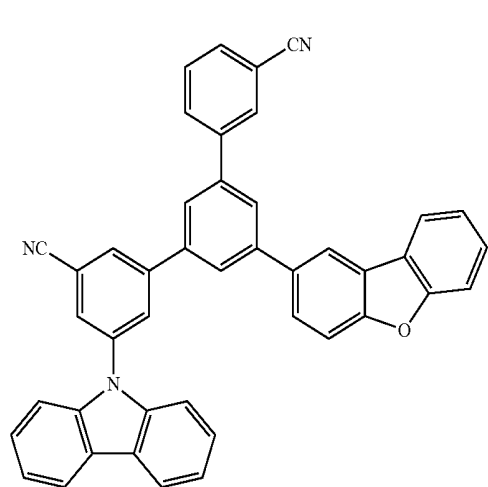
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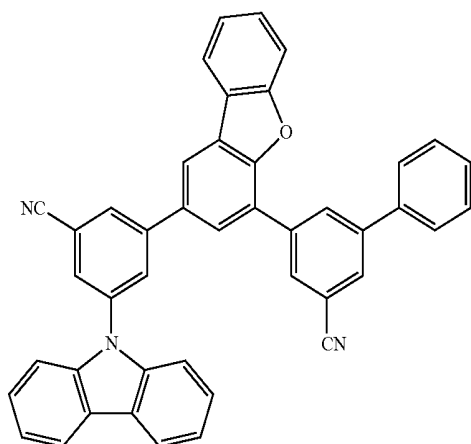
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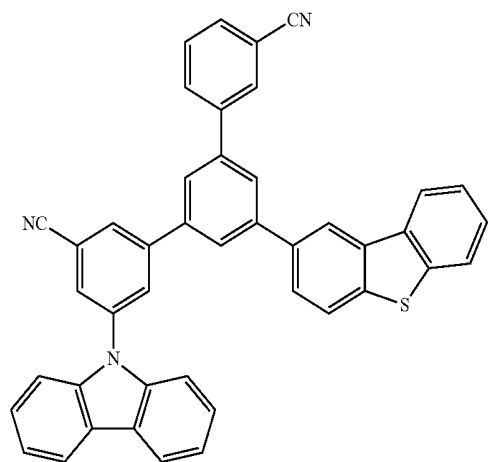
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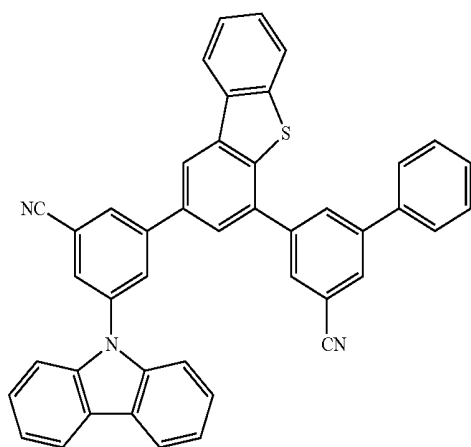
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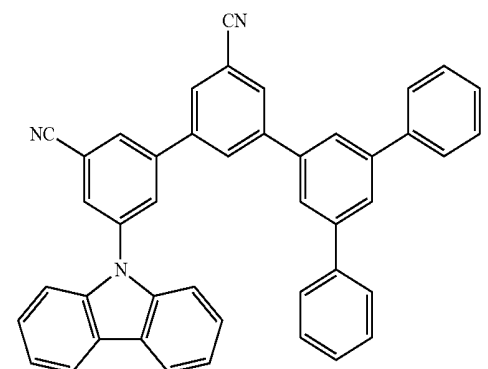
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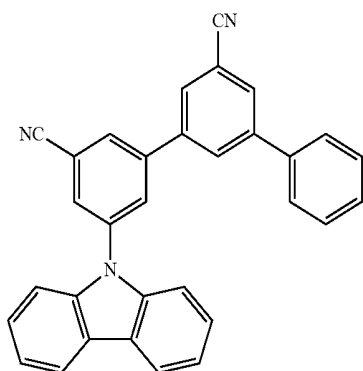
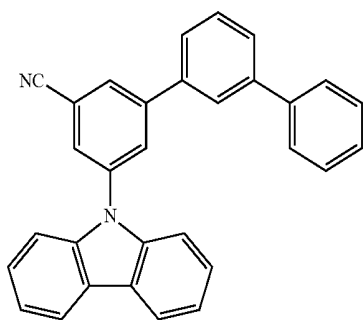
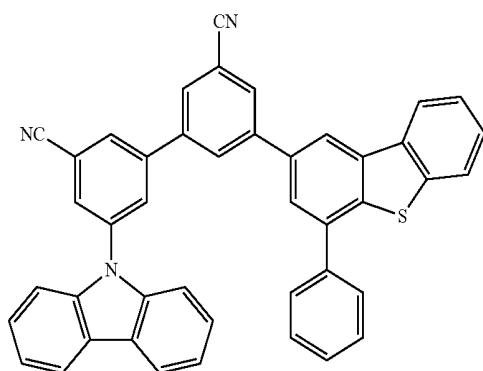
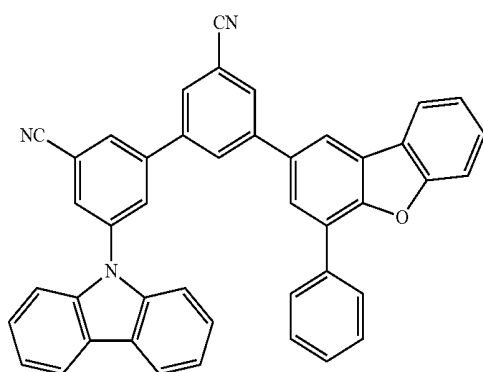
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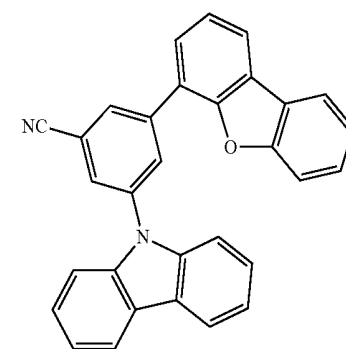
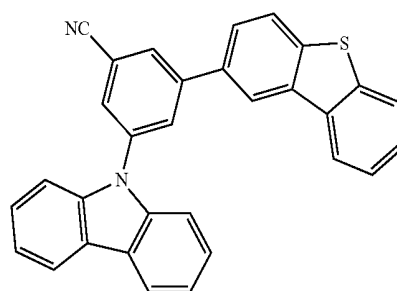
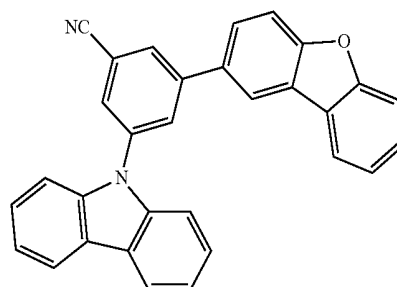
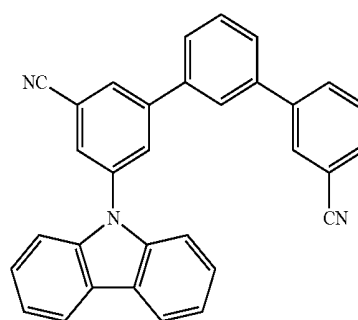
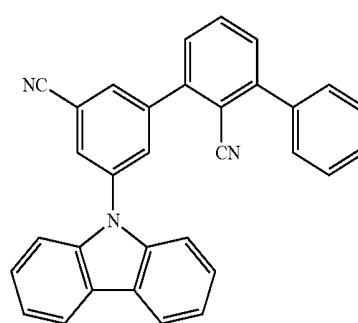
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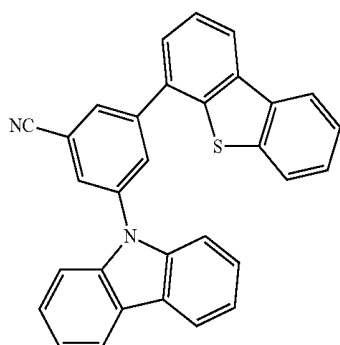


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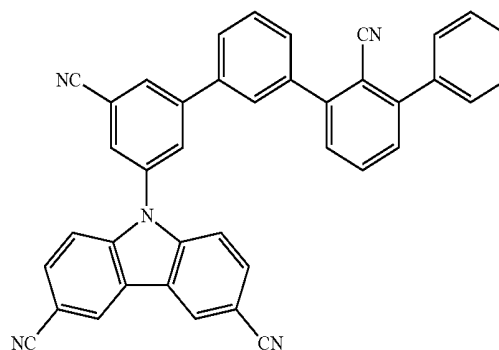
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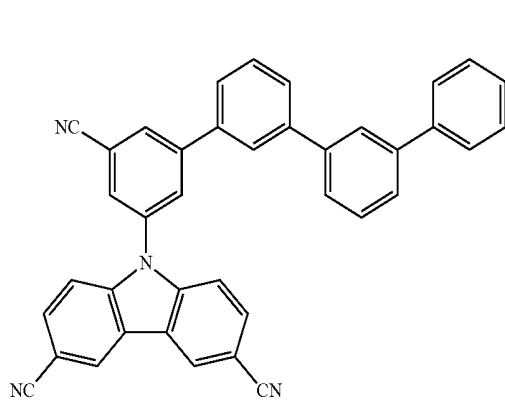


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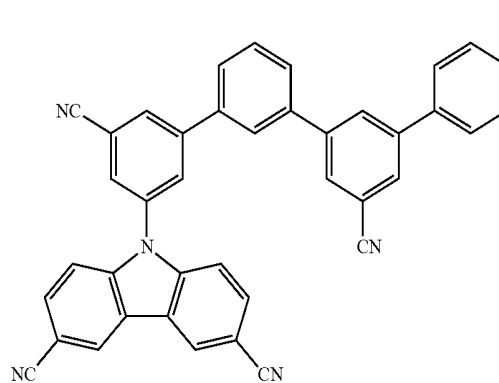
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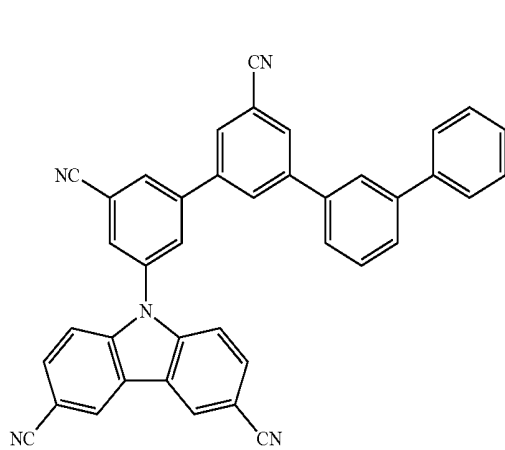
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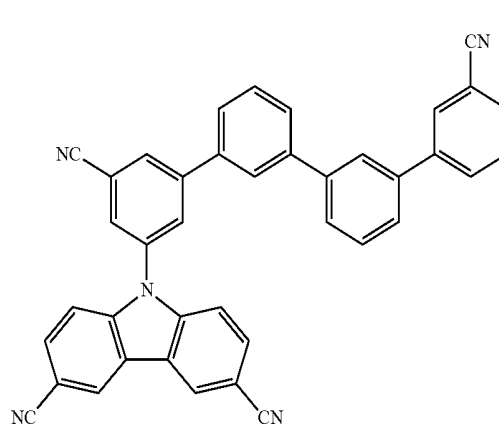
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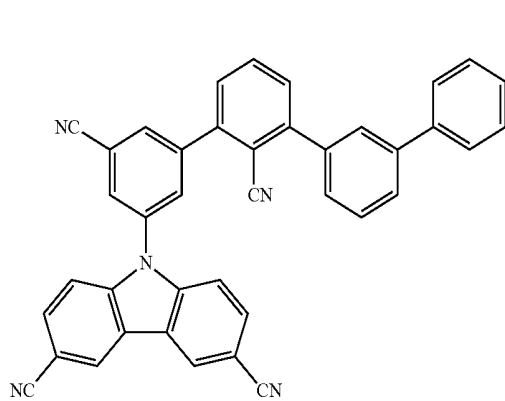
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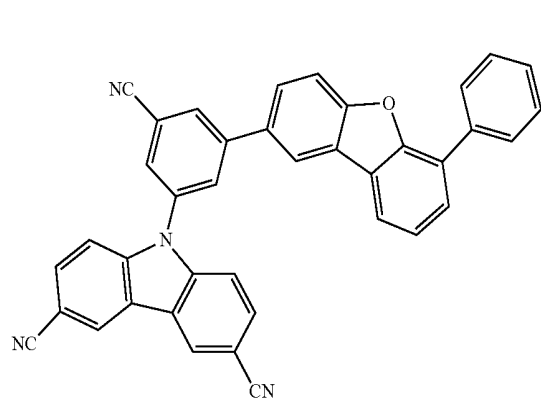
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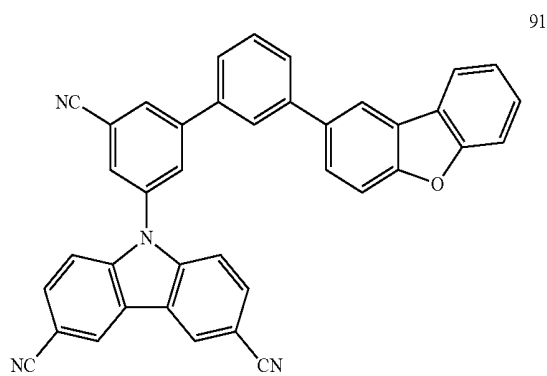
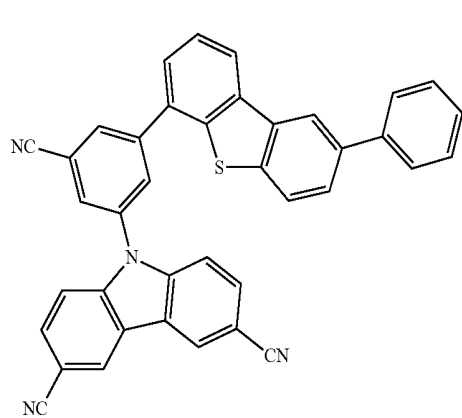
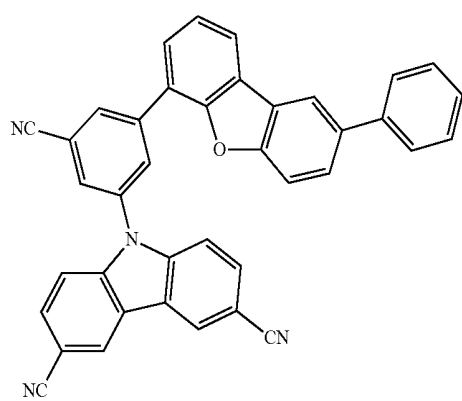
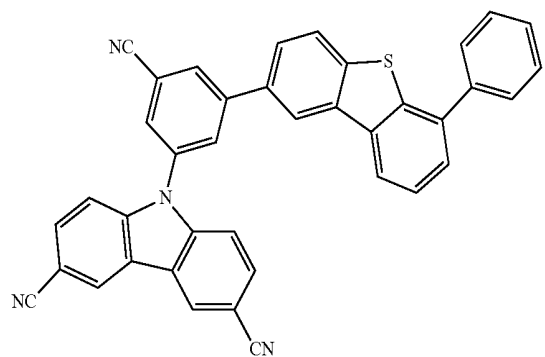


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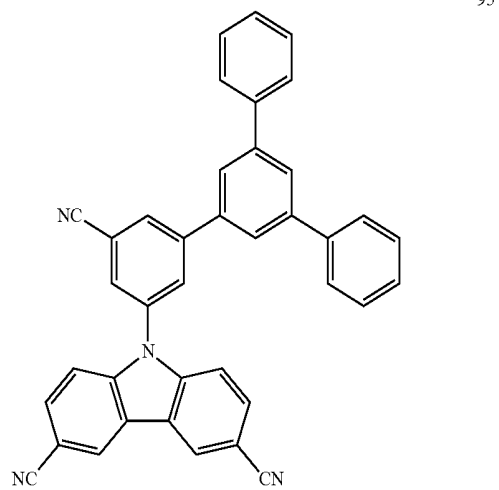
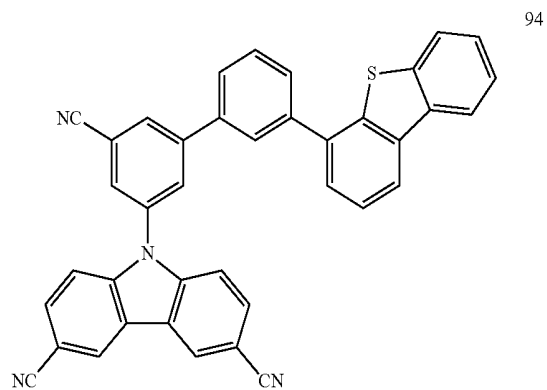
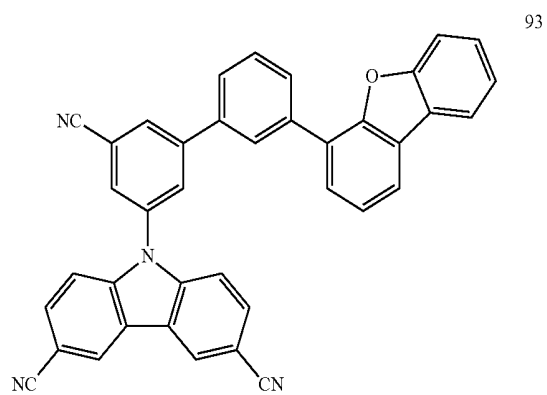
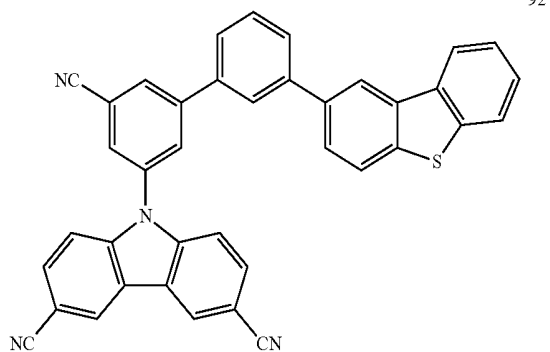


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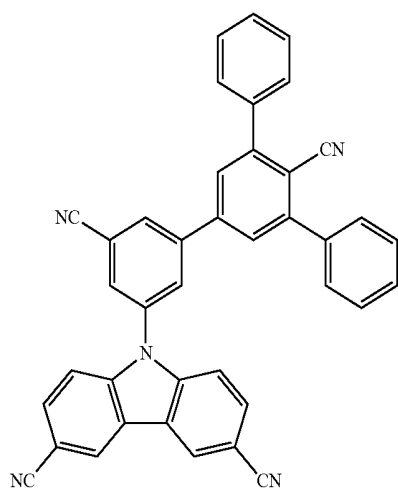
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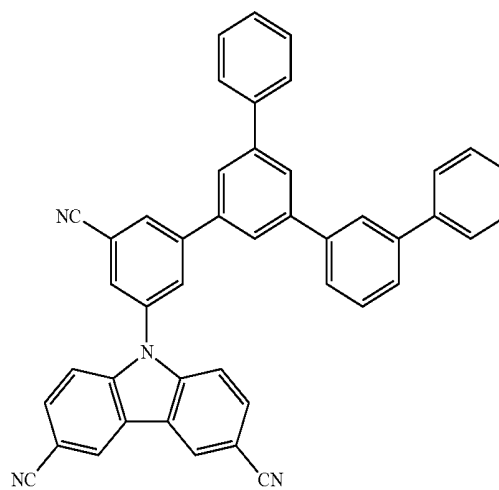


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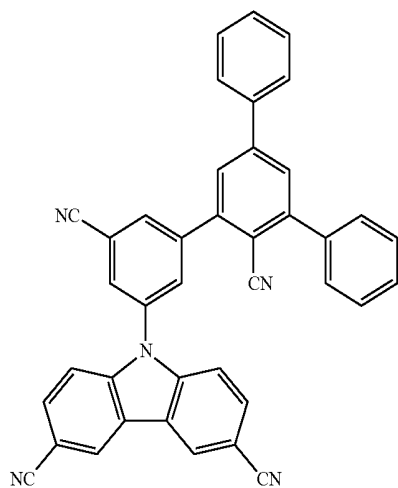
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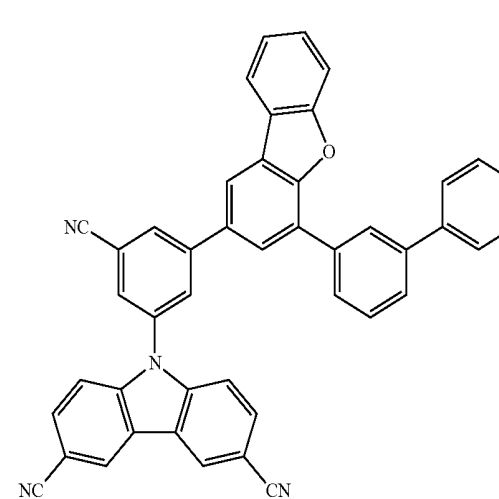


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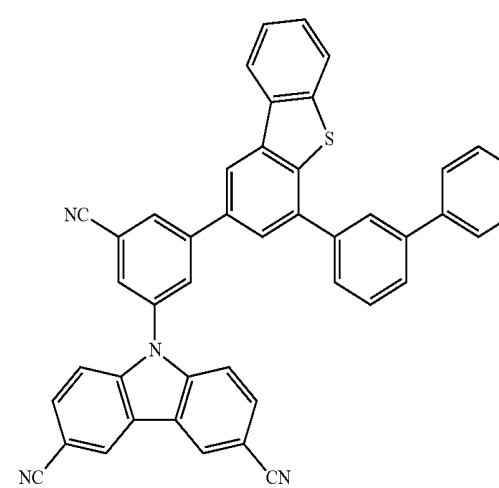
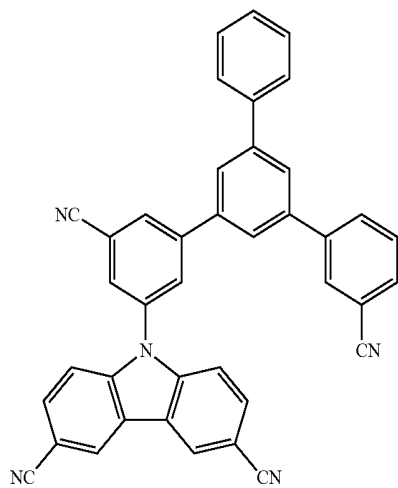
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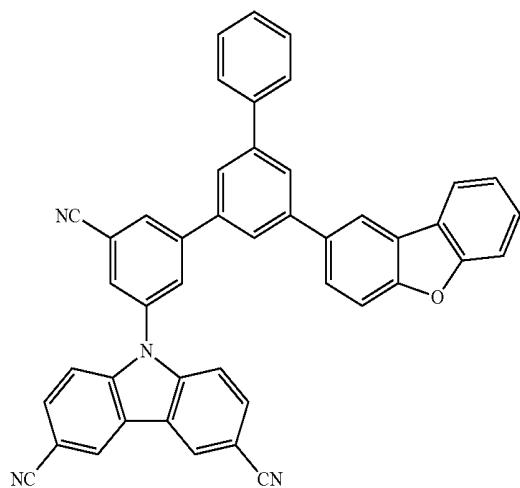
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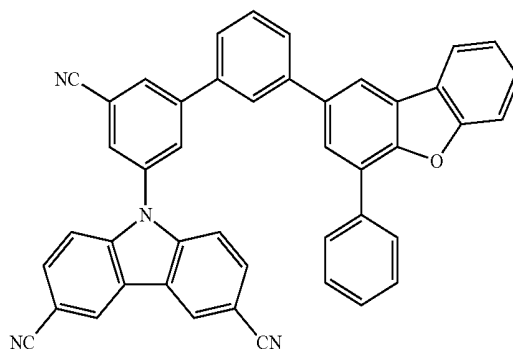
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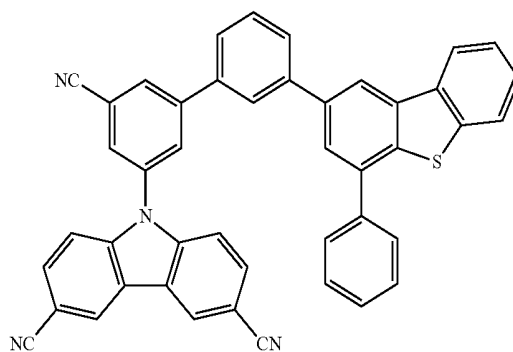


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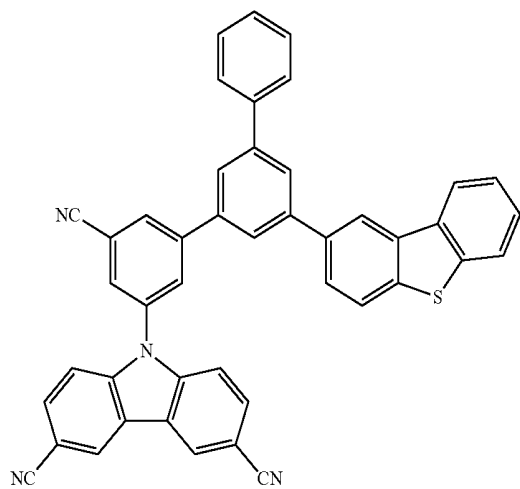
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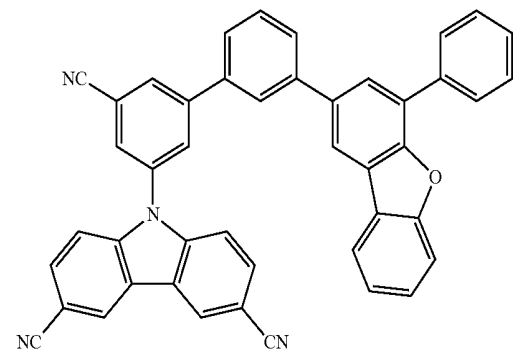
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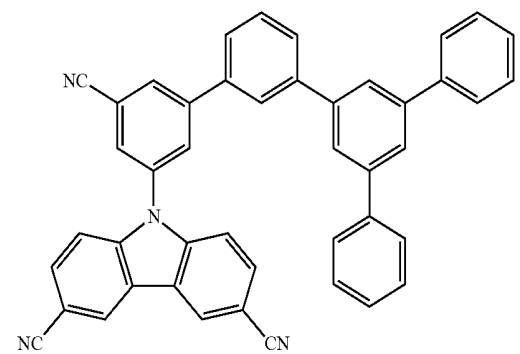
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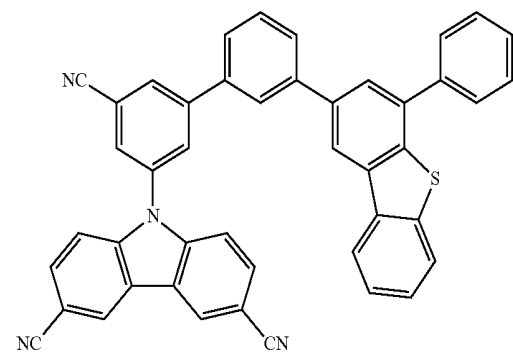
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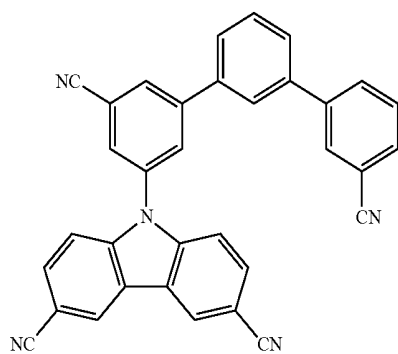
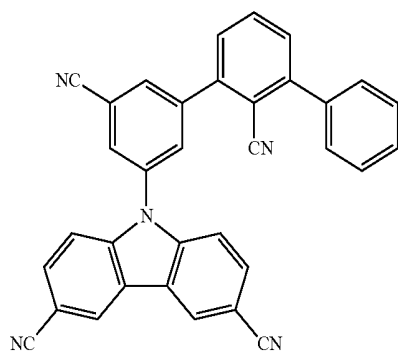
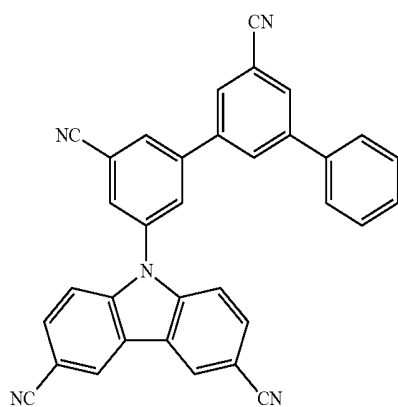
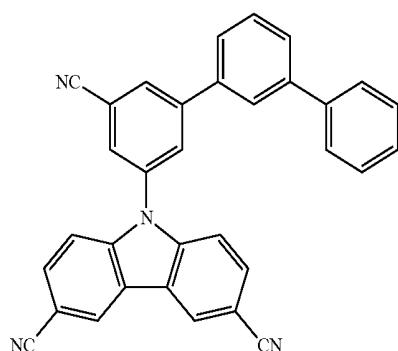
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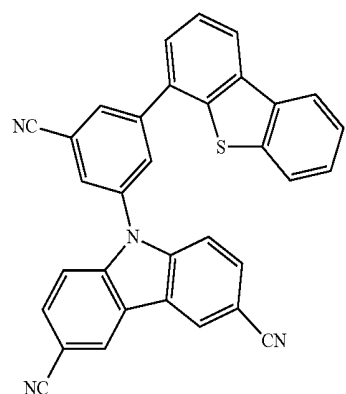
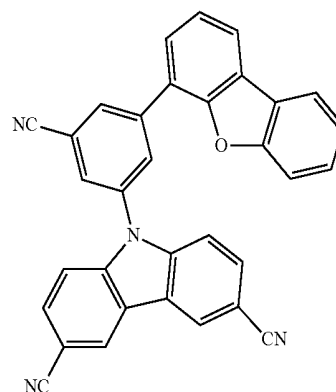
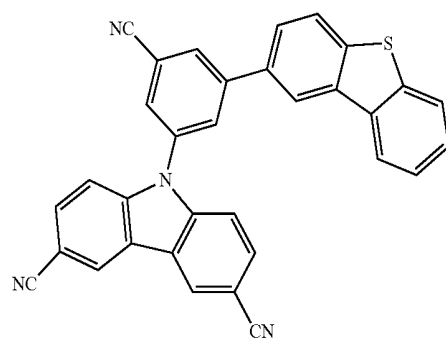
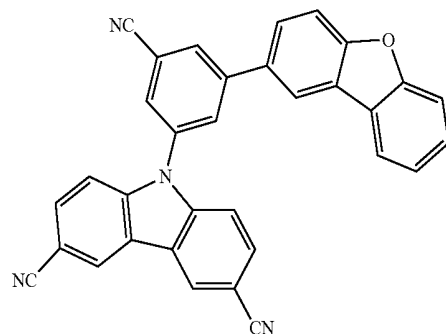
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**14. An organic light-emitting device comprising:**

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.

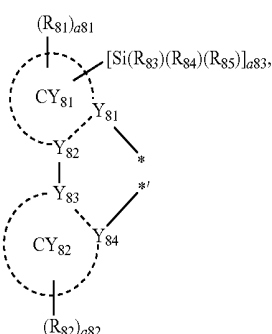
15. The organic light-emitting device of claim 14, wherein the first electrode is an anode, the second electrode is a cathode, and the organic layer comprises

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

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.

16. The organic light-emitting device of claim 14, wherein the emission layer comprises the at least one condensed cyclic compound represented by Formula 1.

17. The organic light-emitting device of claim 16, wherein the emission layer further comprises a phosphorescent dopant comprising an organometallic compound represented by Formula 81:



wherein, in Formulae 81 and 81A,

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

L₈₁ is a ligand represented by Formula 81A,

n_{81} is an integer selected from 1 to 3, provided that when n_{81} is 2 or greater, two or more groups L_{81} are identical to or different from each other,

L_{82} is an organic ligand,

n_{82} is an integer selected from 0 to 4, provided that when n_{82} is 2 or greater, two or more groups L_{82} are identical to or different from each other,

Y_{81} to Y_{84} are each independently C or N,

Y_{81} and Y_{82} are linked to each other via a single bond or a double bond, and Y_{83} and Y_{84} are linked to each other via a single bond or a double bond.

CY₈₁ and CY₈₂ are each independently selected from a C₅-C₃₀ carbocyclic group and a C₃-C₃₀ hetero carbocyclic group.

CY₈₁ and CY₈₂ are optionally further linked to each other via an organic linking group,

R₈₁ to R₈₅ are each independently selected from hydrogen, 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, $-\text{SF}_5$, a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ alkyl group, a substituted or unsubstituted $\text{C}_2\text{-C}_{60}$ alkenyl group, a substituted or unsubstituted $\text{C}_2\text{-C}_{60}$ alkynyl group, a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ alkoxy group, a substituted or unsubstituted $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a substituted or unsubstituted $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a substituted or unsubstituted $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a substituted or unsubstituted $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a substituted or unsubstituted $\text{C}_6\text{-C}_{60}$ aryl group, a substituted or unsubstituted $\text{C}_6\text{-C}_{60}$ aryloxy group, a substituted or unsubstituted $\text{C}_6\text{-C}_{60}$ arylthio group, a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $-\text{Si}(\text{Q}_{81})(\text{Q}_{82})(\text{Q}_{83})$, $-\text{N}(\text{Q}_{84})(\text{Q}_{85})$, $-\text{B}(\text{Q}_{86})(\text{Q}_{87})$, and $-\text{P}(=\text{O})(\text{Q}_{88})(\text{Q}_{89})$,

a81 to a83 are each independently an integer selected from 0 to 5, provided that

when a_{81} is 2 or greater, two or more groups R_{81} are identical to or different from each other.

when a82 is 2 or greater, two or more groups R_{82} are identical to or different from each other.

when a81 is 2 or greater, adjacent groups R_{81} are optionally linked to each other to form a saturated or unsaturated ring,

when a82 is 2 or greater, adjacent groups R₈₂ are optionally linked to each other to form a saturated or unsaturated ring,

wherein in Formula 81A, * and *' each indicate a binding site to M in Formula 81,

wherein at least one of 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_7 - 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_{80} 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 :

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 C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, and —Si(Q₉₁)(Q₉₂)(Q₉₃).

wherein Q₈₁ to Q₈₉ and Q₉₁ to Q₉₃ are each independently selected from hydrogen, deuterium, a C₁-C₆₀ alkyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀

cycloalkenyl group, a C_7 - 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.

18. The organic light-emitting device of claim 17, wherein Y_{81} is N, Y_{82} and Y_{83} are each C, and Y_{84} is N or C,

wherein CY_{81} and CY_{82} are each independently selected from a cyclopentadiene, a benzene, a heptalene, an indene, a naphthalene, an azulene, an indacene, an acenaphthylene, a fluorene, a spiro-bifluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentacene, a hexacene, a pentaphene, a rubicene, a coronene, an ovalene, a pyrrole, an isoindole, an indole, an indazole, a pyrazole, an imidazole, a triazole, an oxazole, an isoxazole, an oxadiazole, a thiazole, an

isothiazole, a thiadiazole, a purine, a furan, a thiophene, a pyridine, a pyrimidine, a quinoline, an isoquinoline, a benzoquinoline, a phthalazine, a naphthyridine, a quinoxaline, a quinazoline, a cinnoline, a phenanthridine, an acridine, a phenanthroline, a phenazine, a benzoimidazole, a benzofuran, a benzothiophene, an isobenzothiazole, a benzoxazole, an isobenzoxazole, a benzocarbazole, a dibenzocarbazole, an imidazopyridine, an imidazopyrimidine, a dibenzofuran, a dibenzothiophene, a dibenzothiophene sulfone, a carbazole, a dibenzosilole, and a 2,3-dihydro-1 H-imidazole.

19. The organic light-emitting device of claim 17, wherein in Formula 81A, at least one selected from a81 number of groups R_{81} and a82 number of groups R_{82} is a cyano group or deuterium.

20. The organic light-emitting device of claim 16, wherein the emission layer emits blue light.

* * * * *

专利名称(译)	冷凝循环化合物和有机发光装置，包括相同的装置		
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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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摘要(译)

由式1表示的稠合环状化合物：其中在式1中，Ar 1 且R 1 至R 8 与说明书中描述的相同。

