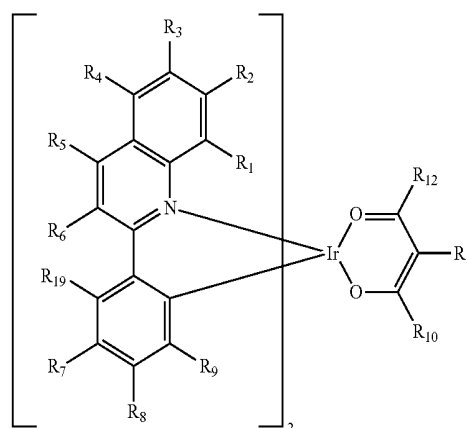




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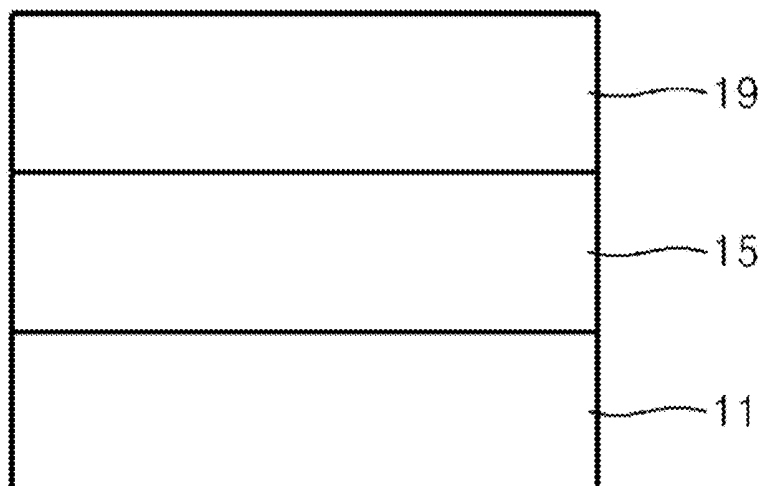
(19) **United States**(12) **Patent Application Publication**
KWAK et al.(10) **Pub. No.: US 2019/0326526 A1**(43) **Pub. Date: Oct. 24, 2019**(54) **ORGANOMETALLIC COMPOUND,
ORGANIC LIGHT-EMITTING DEVICE
INCLUDING THE ORGANOMETALLIC
COMPOUND, AND DIAGNOSTIC
COMPOSITION INCLUDING THE
ORGANOMETALLIC COMPOUND**(52) **U.S. Cl.**
CPC **H01L 51/0085** (2013.01); **H01L 51/5016**
(2013.01); **C09K 11/06** (2013.01); **C07F**
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ISHIHARA, Suwon-si (KR); **Yuri**
CHO, Suwon-si (KR); **Byoungki**
CHOI, Hwaseong-si (KR); **Seokhwan**
HONG, Seoul (KR)An organometallic compound represented by Formula 1, an
organic light-emitting device including the organometallic
compound, and a diagnostic composition including the
organometallic compound.

Formula 1

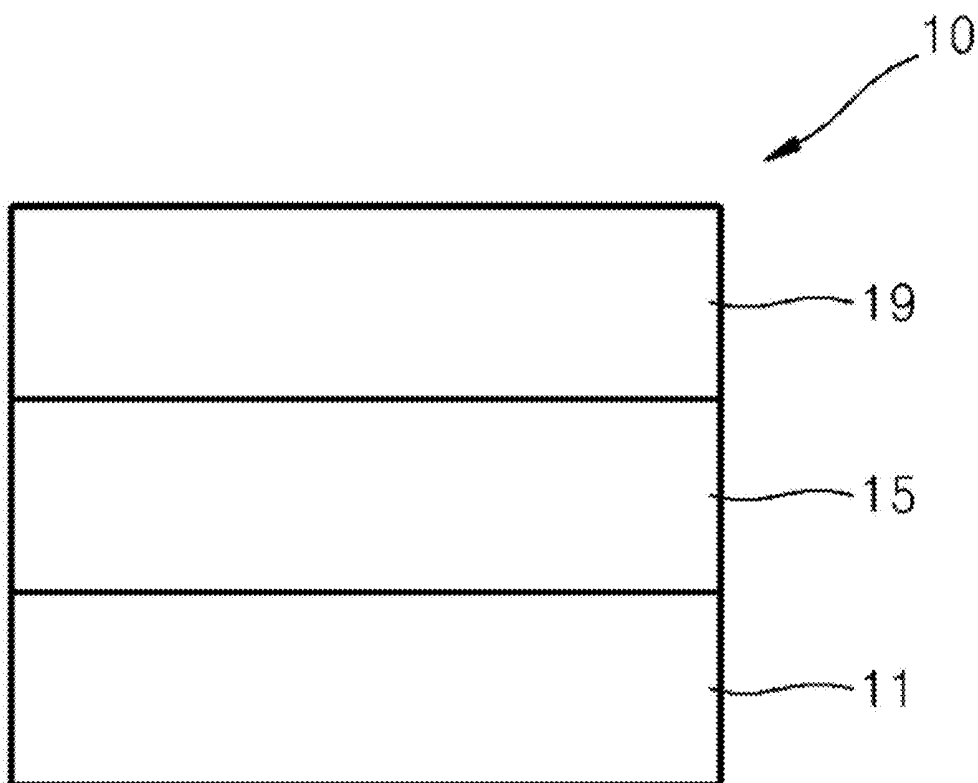
wherein, in Formula 1, R_1 to R_{12} and R_{19} are the same as
described in the specification.(21) Appl. No.: **16/391,808**(22) Filed: **Apr. 23, 2019**(30) **Foreign Application Priority Data**

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H01L 51/00 (2006.01)
C07F 15/00 (2006.01)
C09K 11/06 (2006.01)

FIGURE



**ORGANOMETALLIC COMPOUND,
ORGANIC LIGHT-EMITTING DEVICE
INCLUDING THE ORGANOMETALLIC
COMPOUND, AND DIAGNOSTIC
COMPOSITION INCLUDING THE
ORGANOMETALLIC COMPOUND**

**CROSS-REFERENCE TO RELATED
APPLICATION**

[0001] This application claims the benefit of Korean Patent Application Nos. 10-2018-0046990, filed on Apr. 23, 2018, and 10-2019-0046949, filed on Apr. 22, 2019, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND

1. Field

[0002] One or more embodiments relate to an organometallic compound, an organic light-emitting device including the organometallic compound, and a diagnostic composition including the organometallic compound.

2. Description of the Related Art

[0003] Organic light-emitting devices are self-emission devices, which have better characteristics in terms of a viewing angle, a response time, a brightness, a driving voltage, and a response speed, and produce full-color images.

[0004] In an example, an organic light-emitting device includes an anode, a cathode, and an organic layer between the anode and the cathode, wherein the organic layer includes an emission layer. A hole transport region may be between the anode and the emission layer, and an electron transport region may be 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. The holes and the electrons recombine in the emission layer to produce excitons. These excitons transit from an excited state to a ground state, thereby generating light.

[0005] Luminescent compounds may be used to monitor, sense, or detect a variety of biological materials including cells and proteins. An example of the luminescent compounds includes a phosphorescent luminescent compound.

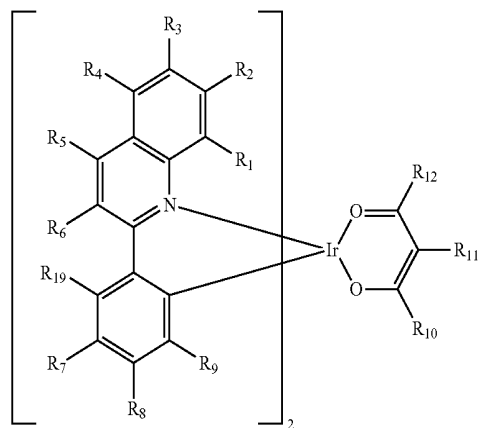
SUMMARY

[0006] Aspects of the present disclosure provide a novel organometallic compound and an organic light-emitting device and a diagnostic composition including the same.

[0007] Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments.

[0008] An aspect of the present disclosure provides an organometallic compound represented by Formula 1 below:

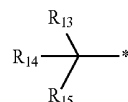
Formula 1



[0009] In Formula 1, R₁ to R₁₂ and R₁₉ may each independently be hydrogen, deuterium, —F, —Cl, —Br, —I, —SF₅, 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 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, —N(Q₁)(Q₂), —Si(Q₃)(Q₄)(Q₅), —Ge(Q₃)(Q₄)(Q₅), —B(Q₆)(Q₇), —P(=O)(Q₈)(Q₉), or —P(Q₈)(Q₉), and

[0010] at least one of R₁ to R₆ may each independently be a group represented by Formula 2:

Formula 2



[0011] The number of carbon atoms included in Formula 2 may be 4 or more,

[0012] R₁₃ in Formula 2 may be hydrogen, deuterium, a C₁-C₂₀ alkyl group, a deuterium-containing C₁-C₂₀ alkyl group, a C₃-C₁₀ cycloalkyl group, or a deuterium-containing C₃-C₁₀ cycloalkyl group,

[0013] R₁₄ and R₁₅ in Formula 2 may each independently be a C₁-C₂₀ alkyl group, a deuterium-containing

- C₁-C₂₀ alkyl group, a C₃-C₁₀ cycloalkyl group, or a deuterium-containing C₃-C₁₀ cycloalkyl group,
- [0014] provided that, R₁₃, R₁₄ and R₁₅ may not be a methyl group, simultaneously,
- [0015] * indicates a binding site to a neighboring atom,
- [0016] two or more of R₁ to R₉ and R₁₉ in Formula 1 may optionally be linked to form a C₅-C₃₀ carbocyclic group that is unsubstituted or substituted with R_{1a}, a C₂-C₃₀ heterocyclic group that is unsubstituted or substituted with R_{1a}, or a combination thereof,
- [0017] R_{1a} may be the same as described in connection with R₇,
- [0018] a substituent of the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, or the substituted monovalent non-aromatic condensed heteropolycyclic group may be:
- [0019] 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-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, or a combination thereof;
- [0020] a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, or a combination thereof, each substituted with 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 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, —N(Q₁₁)(Q₁₂), —Si(Q₁₃)(Q₁₄)(Q₁₅), —Ge(Q₁₃)(Q₁₄)(Q₁₅), —B(Q₁₆)(Q₁₇), —P(=O)(Q₁₈)(Q₁₉), —P(Q₁₈)(Q₁₉), or a combination thereof;
- [0021] 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, or a combination thereof;
- [0022] 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, or a combination thereof, each substituted with 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 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, —N(Q₂₁)(Q₂₂), —Si(Q₂₃)(Q₂₄)(Q₂₅), —Ge(Q₂₃)(Q₂₄)(Q₂₅), —B(Q₂₆)(Q₂₇), —P(=O)(Q₂₈)(Q₂₉), —P(Q₂₈)(Q₂₉), or a combination thereof;
- [0023] —N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₅), —Ge(Q₃₃)(Q₃₄)(Q₃₅), —B(Q₃₆)(Q₃₇), —P(=O)(Q₃₈)(Q₃₉), or —P(Q₃₈)(Q₃₉); or
- [0024] a combination thereof, and
- [0025] Q₁ to Q₉, Q₁₁ to Q₁₉, Q₂₁ to Q₂₉, and Q₃₁ to Q₃₉ may each independently be 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-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, or a combination thereof.
- [0026] Another aspect of the present disclosure provides an organic light-emitting device includes: a first electrode, a second electrode, and an organic layer between the first electrode and the second electrode and including an emission layer, wherein the organic layer includes an organometallic compound described above.
- [0027] The organometallic compound in the emission layer of the organic layer may act as a dopant.
- [0028] Still another aspect of the present disclosure provides a diagnostic composition including an organometallic compound described above.

BRIEF DESCRIPTION OF THE DRAWING

[0029] These and/or other aspects will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with FIGURE which is a schematic view of an organic light-emitting device according to an embodiment.

DETAILED DESCRIPTION

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

[0031] Accordingly, the embodiments are merely described below, by referring to the figures, to explain aspects of the present description. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items. Expressions such as “at least one of,” when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

[0032] It will be understood that when an element is referred to as being “on” another element, it can be directly on 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.

[0033] 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 herein.

[0034] 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, including “at least one,” unless the content clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” or “includes” and/or “including” when used in this specification, specify the presence of stated features, regions, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

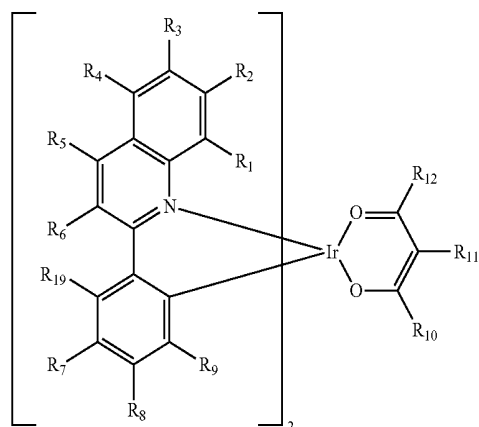
[0035] “About” or “approximately” as used herein is inclusive of the stated value and means within an acceptable range of deviation for the particular value as determined by one of ordinary skill in the art, considering the measurement in question and the error associated with measurement of the particular quantity (i.e., the limitations of the measurement system). In an exemplary embodiment, “about” can mean within one or more standard deviations, or within $\pm 30\%$, 20% , 10% or 5% of the stated value.

[0036] 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 disclosure 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.

[0037] Exemplary embodiments are described herein with reference to cross section illustrations that are schematic illustrations of idealized embodiments. As such, variations from the shapes of the illustrations as a result, for example, of manufacturing techniques and/or tolerances, are to be expected. Thus, embodiments described herein should not be construed as limited to the particular shapes of regions as illustrated herein but are to include deviations in shapes that result, for example, from manufacturing. In an exemplary embodiment, a region illustrated or described as flat may, typically, have rough and/or nonlinear features. Moreover, sharp angles that are illustrated may be rounded. Thus, the regions illustrated in the figures are schematic in nature and their shapes are not intended to illustrate the precise shape of a region and are not intended to limit the scope of the present claims.

[0038] An organometallic compound according to an embodiment is represented by Formula 1 below:

Formula 1



[0039] In Formula 1, R_1 to R_{12} and R_{19} may each independently be hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, $-SF_5$, 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 substituted or unsubstituted C_1 - C_{60} alkyl group, a substituted or unsubstituted C_2 - C_{60} alkenyl group, a substituted or unsubstituted C_2 - C_{60} alkynyl group, a substituted or unsubstituted C_1 - C_{60} alkoxy group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $-N(Q_1)(Q_2)$, $-Si(Q_3)(Q_4)(Q_5)$, $-Ge(Q_3)(Q_4)(Q_5)$, $-B(Q_6)(Q_7)$, $-P(=O)(Q_8)(Q_9)$, or $-P(Q_8)(Q_9)$. Formulae 2 and 3 and Q_1 to Q_9 are the same as described above.

[0040] In an exemplary embodiment, R_1 to R_{12} and R_{19} may each independently be:

[0041] 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, $-SF_5$, a C_1 - C_{20} alkyl group, or a C_1 - C_{20} alkoxy group;

[0042] a C_1 - C_{20} alkyl group or a C_1 - C_{20} alkoxy group, each substituted with deuterium, $-F$, $-Cl$, $-Br$, $-I$, $-CD_3$, $-CD_2H$, $-CDH_2$, $-CF_3$, $-CF_2H$, $-CFH_2$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{10} alkyl group, a 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, bicyclo[1.1.1]pentyl, bicyclo[2.1.1]hexyl, bicyclo[2.2.1]heptyl, a bicyclo[2.2.2]octyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, or a combination thereof;

[0043] 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, bicyclo[1.1.1]pentyl, bicyclo[2.1.1]hexyl, bicyclo[2.2.1]heptyl, a bicyclo[2.2.2]octyl group, a phenyl group, a biphenyl group, a terphenyl 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 quinolynyl group, an isoquinolynyl group, a benzoquinolynyl group, a quinoxalynyl group, a quinazolinyl group, a cinnolynyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranlyl 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 dibenzofuranlyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, or an imidazopyrimidinyl group;

[0044] 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, bicyclo[1.1.1]pentyl, bicyclo[2.1.1]hexyl, bicyclo[2.2.1]heptyl, a bicyclo[2.2.2]octyl group, a phenyl group, a biphenyl group, a terphenyl 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 quinolynyl group, an isoquinolynyl group, a benzoquinolynyl group, a quinoxalynyl group, a quinazolinyl group, a cinnolynyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranlyl 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 dibenzofuranlyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, or an imidazopyrimidinyl group, each substituted with deuterium, $-F$, $-Cl$, $-Br$, $-I$, $-CD_3$, $-CD_2H$, $-CDH_2$, $-CF_3$, $-CF_2H$, $-CFH_2$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a 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, bicyclo[1.1.1]pentyl, bicyclo[2.1.1]hexyl, bicyclo[2.2.1]heptyl, a bicyclo[2.2.2]octyl group, a phenyl group, a biphenyl group, a terphenyl 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 quinolynyl group, an isoquinolynyl group, a benzoquinolynyl group, a quinoxalynyl group, a quinazolinyl group, a cinnolynyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranlyl 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 dibenzofuranlyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, $-Si(Q_{33})(Q_{34})(Q_{35})$, or a combination thereof; or

[0045] $-N(Q_1)(Q_2)$, $-Si(Q_3)(Q_4)(Q_5)$, $-Ge(Q_3)(Q_4)(Q_5)$, $-B(Q_6)(Q_7)$, $-P(=O)(Q_8)(Q_9)$, or $-P(Q_8)(Q_9)$, and

[0046] Q_1 to Q_9 and Q_{33} to Q_{35} may each independently be:

[0047] $-CH_3$, $-CD_3$, $-CD_2H$, $-CDH_2$, $-CH_2CH_3$, $-CH_2CD_3$, $-CH_2CD_2H$, $-CH_2CDH_2$, $-CHDCH_3$, $-CHDCD_2H$, $-CHDCDH_2$, $-CHDCD_3$, $-CD_2CD_3$, $-CD_2CD_2H$, or $-CD_2CDH_2$;

[0048] an n-propyl group, an isopropyl 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, or a naphthyl group; or

[0049] an n-propyl group, an isopropyl 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, or a naphthyl group, each substituted with deuterium, a C₁-C₁₀ alkyl group, a phenyl group, or a combination thereof.

[0050] In one embodiment, R₁ to R₉ and R₁₉ may each independently be hydrogen, deuterium, a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, or —Si(Q₃)(Q₄)(Q₅). Q₃ to Q₅ are the same as described in this disclosure.

[0051] In one or more embodiments, R₁ to R₁₂ and R₁₉ may each independently be:

[0052] hydrogen, deuterium, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neopentyl group, an iso-pentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl 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, bicyclo[1.1.1]pentyl, bicyclo[2.1.1]hexyl, bicyclo[2.2.1]heptyl, a bicyclo[2.2.2]octyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a carbazolyl group, a fluorenyl group, a dibenzosilolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, or —Si(Q₃)(Q₄)(Q₅);

[0053] a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neopentyl group, an iso-pentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl 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, or a tert-decyl group, each substituted with deuterium; or

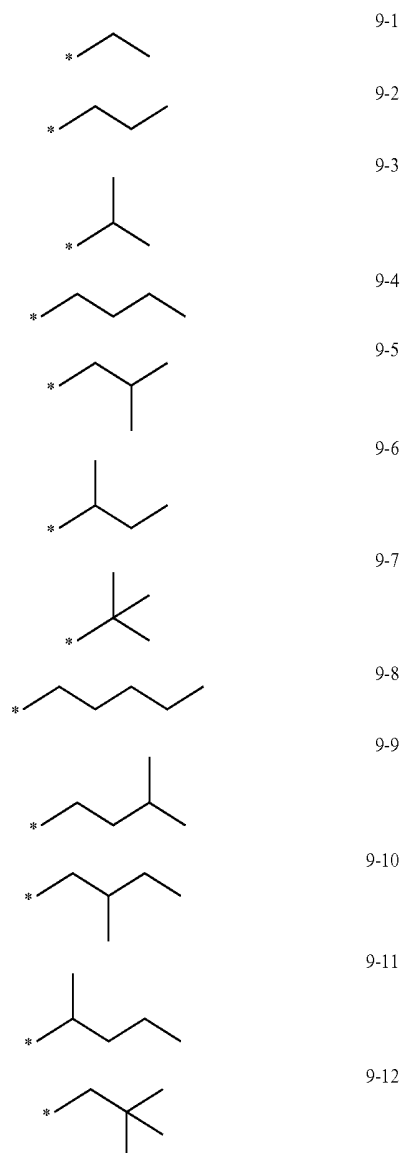
[0054] a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, bicyclo[1.1.1]pentyl, bicyclo[2.1.1]hexyl, bicyclo[2.2.1]heptyl, a bicyclo[2.2.2]octyl group, a phenyl group, a biphenyl

group, a terphenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a carbazolyl group, a fluorenyl group, a dibenzosilolyl group, a dibenzofuranyl group, or a dibenzothiophenyl group, each substituted with deuterium, a C₁-C₁₀₀ alkyl group, or a combination thereof, and

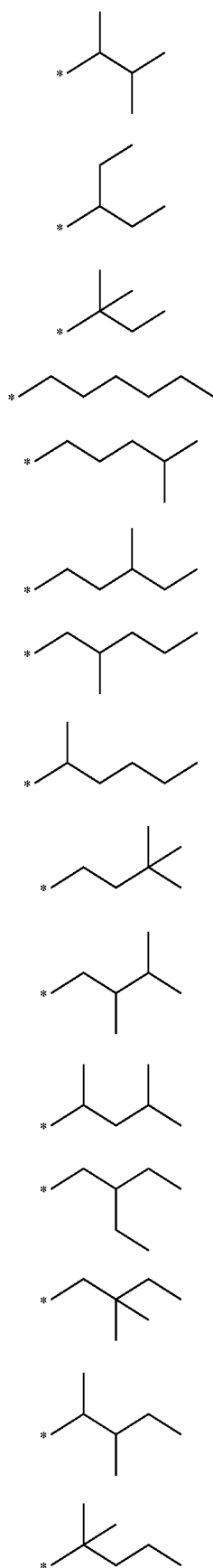
[0055] Q₃ to Q₅ are the same as described above.

[0056] In one or more embodiments, R₁ to R₁₂ and R₁₉ may each independently be:

[0057] hydrogen, deuterium, —F, a cyano group, a nitro group, —SF₅, —CH₃, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, groups represented by Formulae 9-1 to 9-66, groups represented by Formulae 9-1 to 9-66 in which a hydrogen is substituted with deuterium, groups represented by Formulae 10-1 to 10-249, groups represented by Formulae 10-1 to 10-249 in which a hydrogen is substituted with deuterium, or —Si(Q₃)(Q₄)(Q₅) (wherein Q₃ to Q₅ are the same as described above), but embodiments of the present disclosure are not limited thereto:



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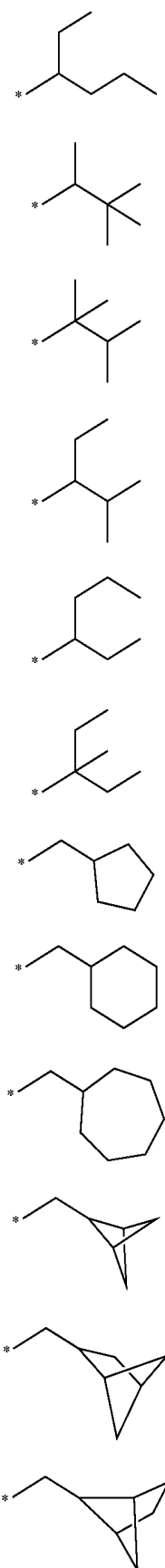
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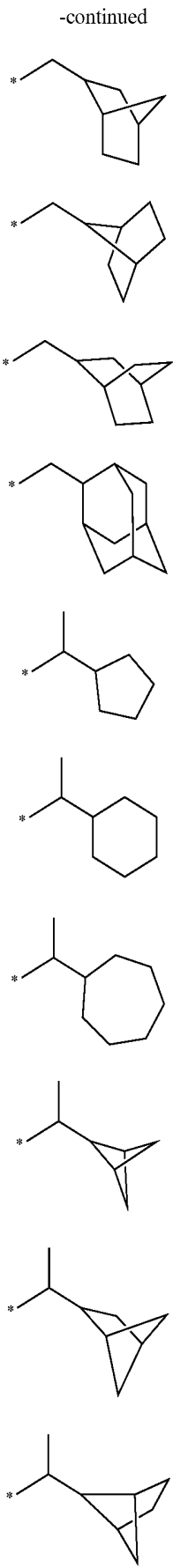
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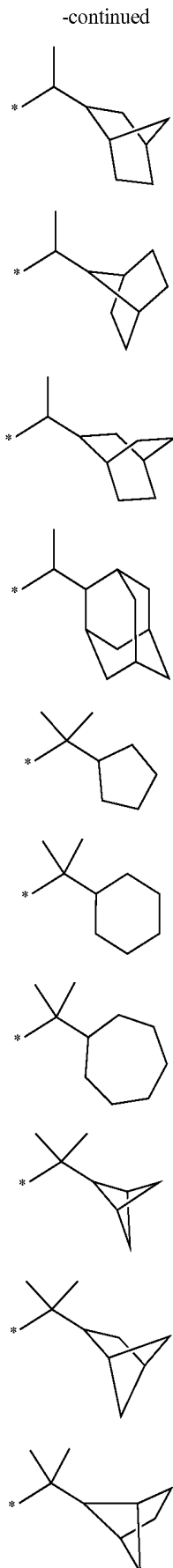
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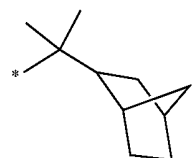


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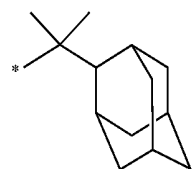
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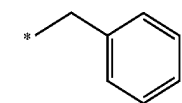
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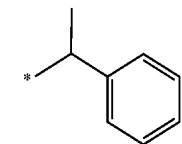
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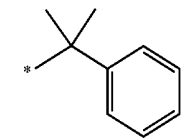
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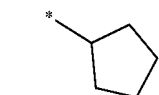
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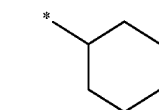
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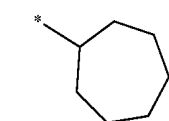
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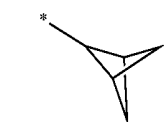
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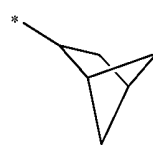


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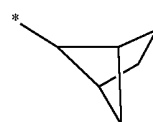


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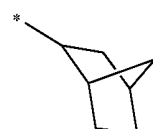
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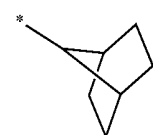
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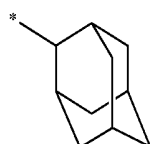
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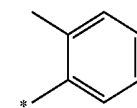
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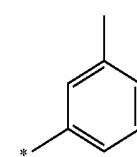
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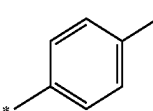
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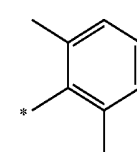
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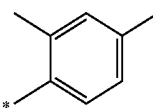
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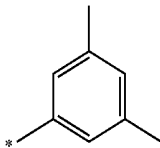


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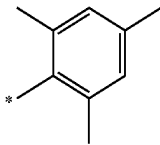


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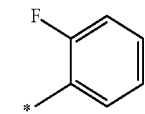
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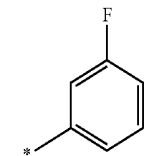
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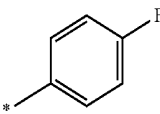
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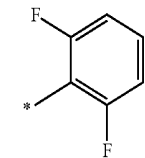
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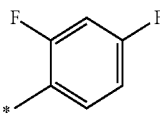
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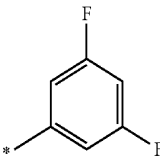
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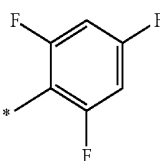
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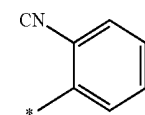
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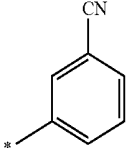


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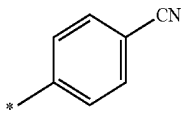


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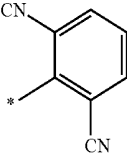
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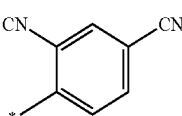
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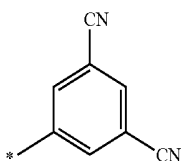
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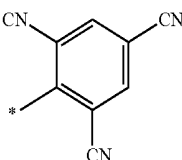
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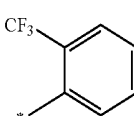
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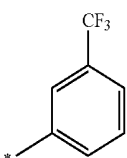
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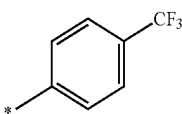
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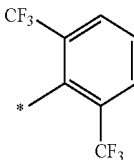
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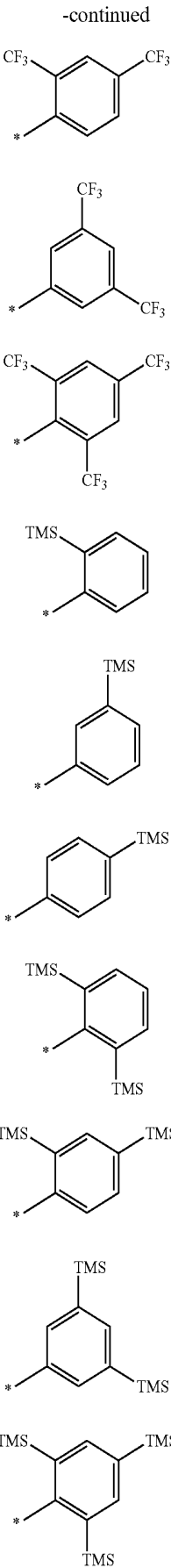
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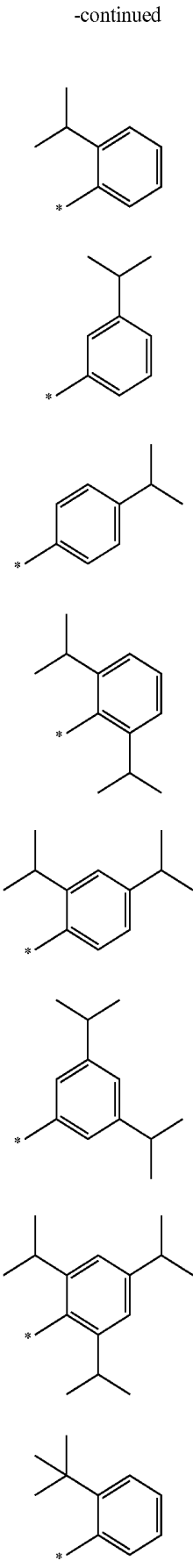
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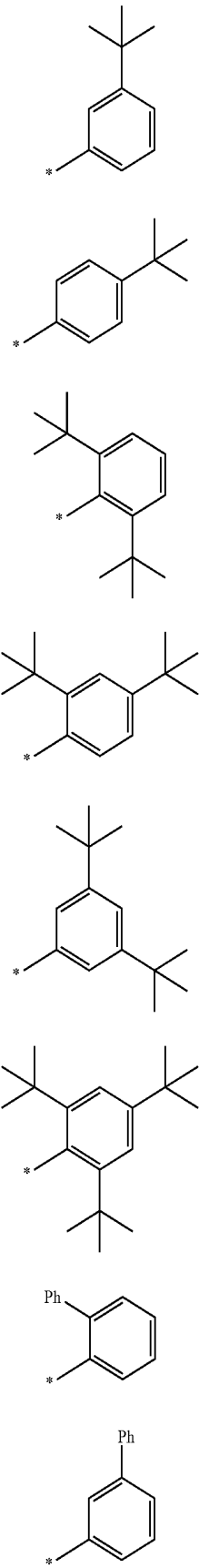


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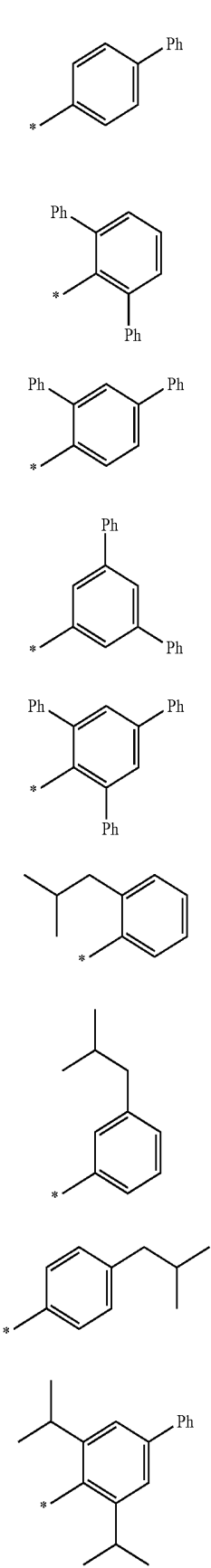


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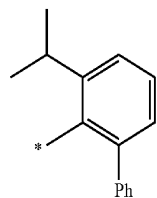
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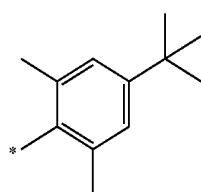
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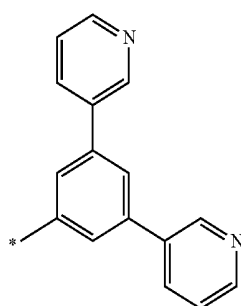
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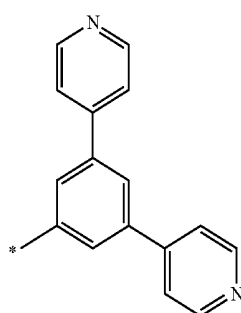
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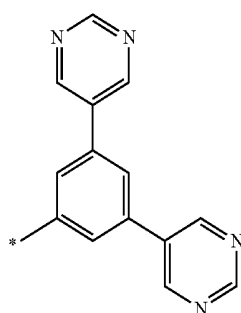
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10-73

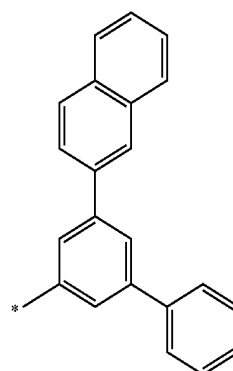


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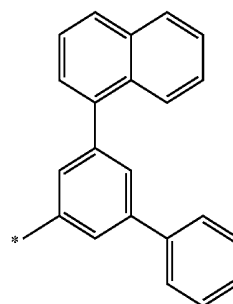


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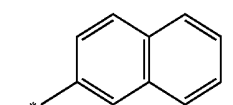
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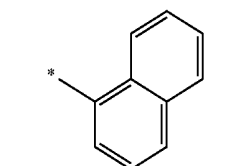
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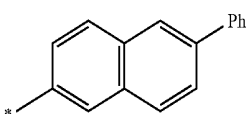
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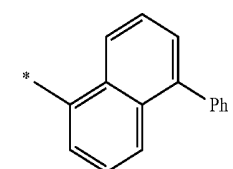
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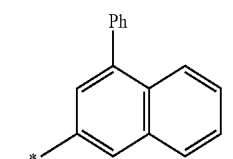
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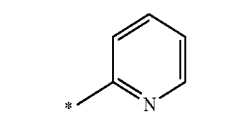
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10-81

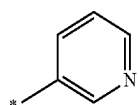


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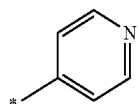


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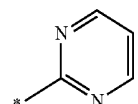
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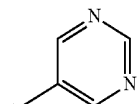
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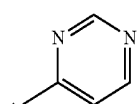
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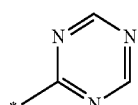
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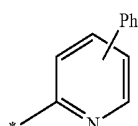
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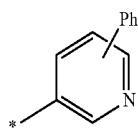
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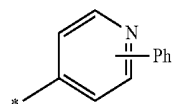
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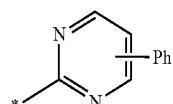
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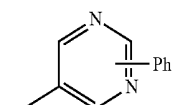
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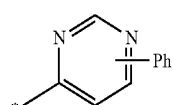
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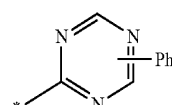


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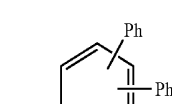


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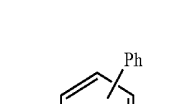
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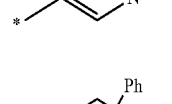
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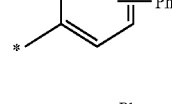
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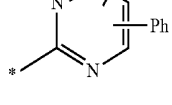
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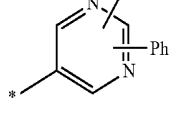
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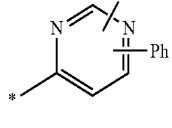
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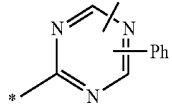
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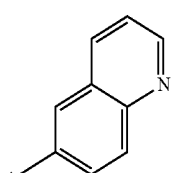
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10-103

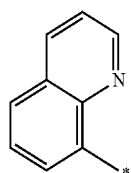


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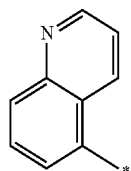


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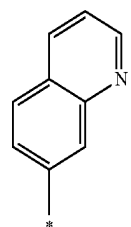
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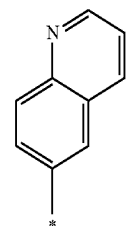
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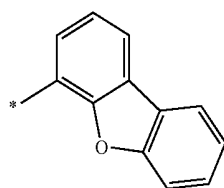
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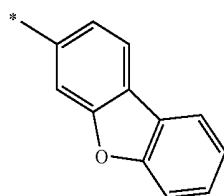
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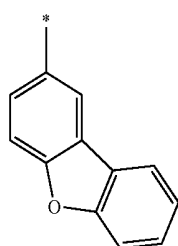
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10-110

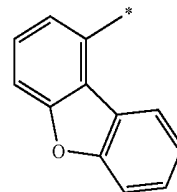


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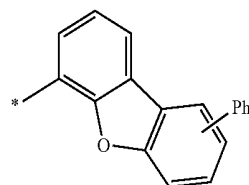


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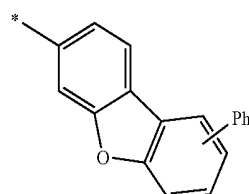
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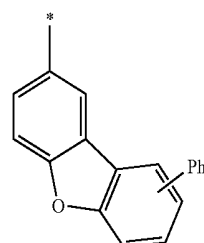
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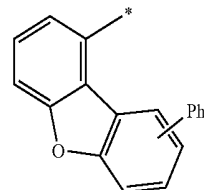
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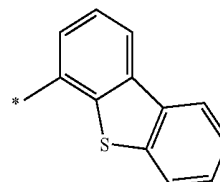
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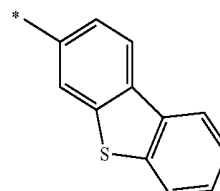
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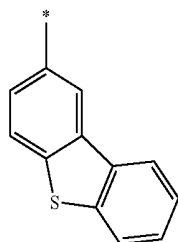
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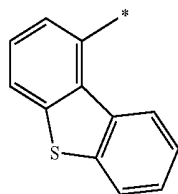
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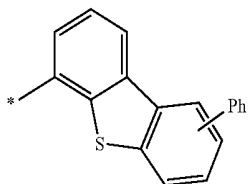
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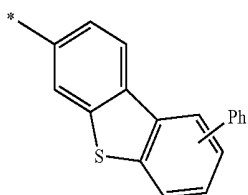
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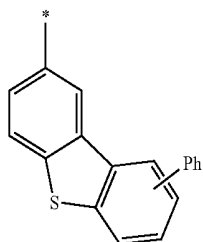
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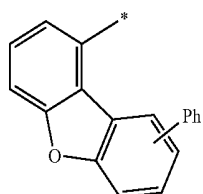
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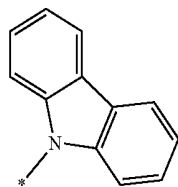
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10-125

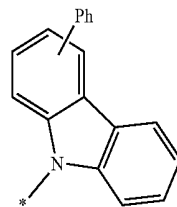


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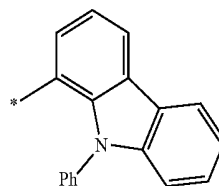


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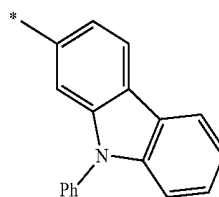
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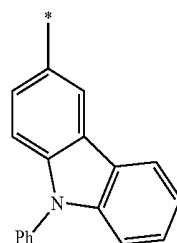
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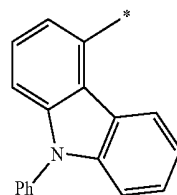
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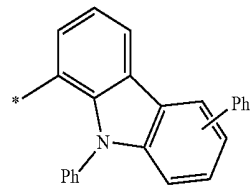
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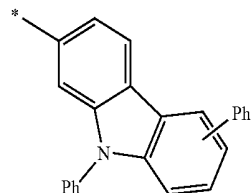
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10-132

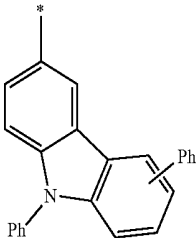


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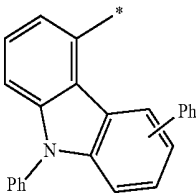


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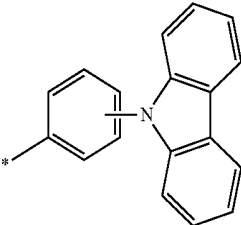
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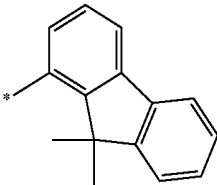
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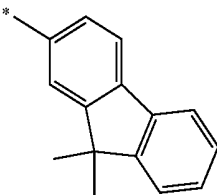
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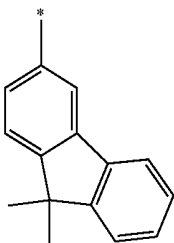
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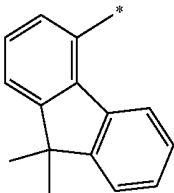
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10-139

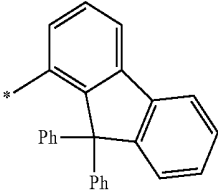


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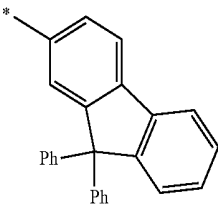


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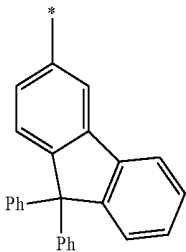
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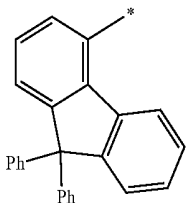
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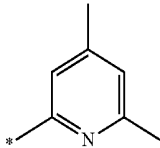
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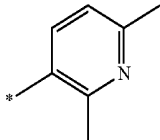
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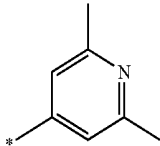
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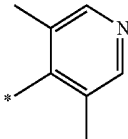
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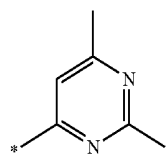
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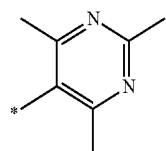
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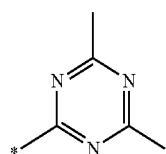
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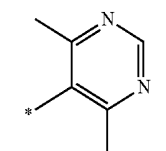
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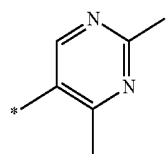
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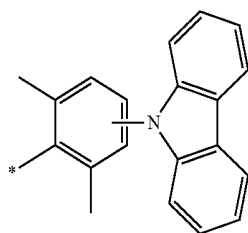
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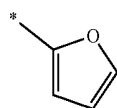
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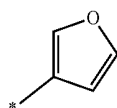
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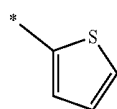
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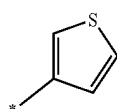
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10-156

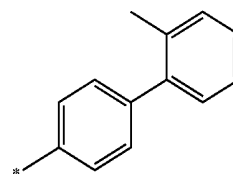


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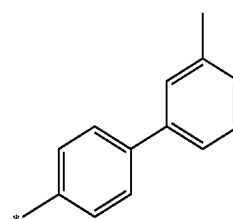


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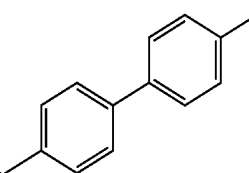
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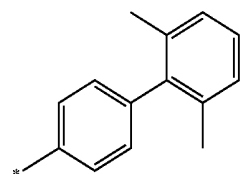
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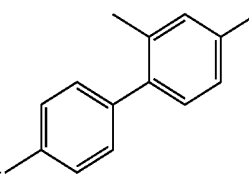
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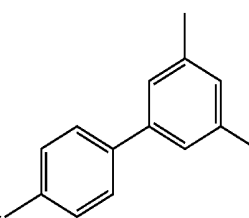
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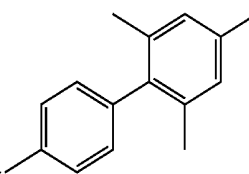
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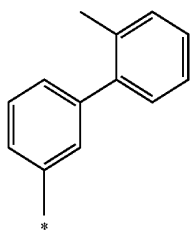


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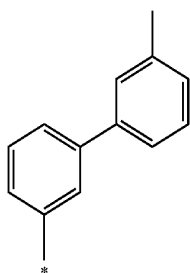


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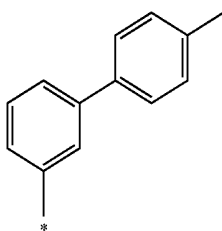
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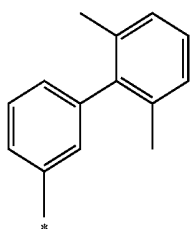
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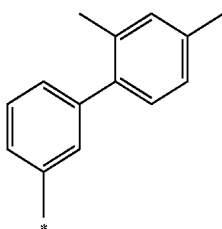
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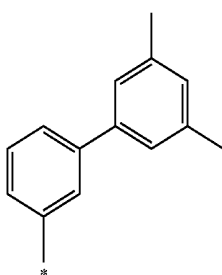
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10-169

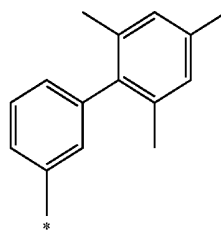


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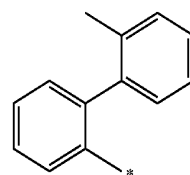


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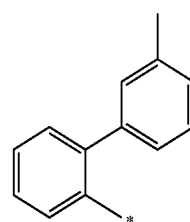
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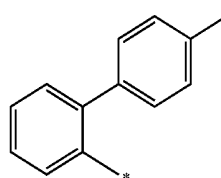
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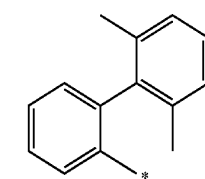
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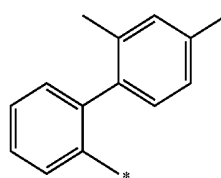
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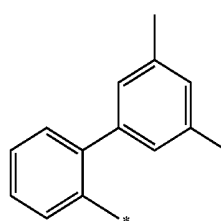
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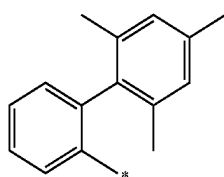


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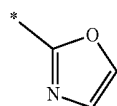


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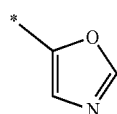
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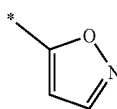
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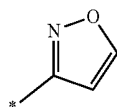
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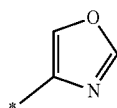
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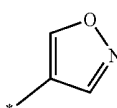
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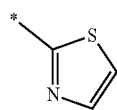
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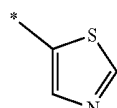
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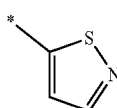
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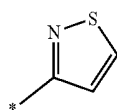
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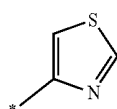
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10-188

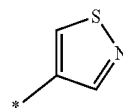


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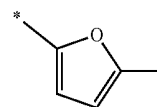


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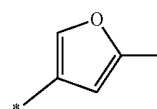
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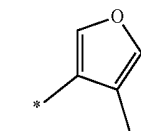
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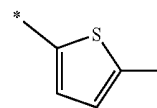
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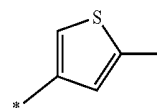
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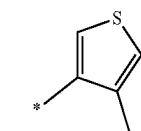
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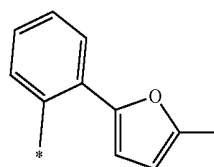
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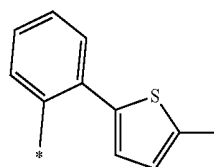
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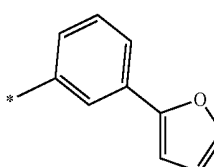
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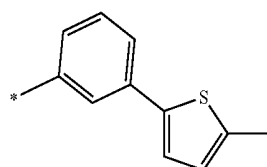


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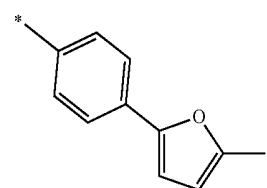


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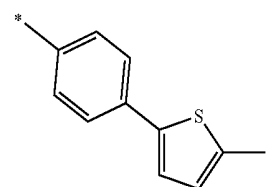
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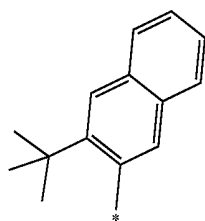
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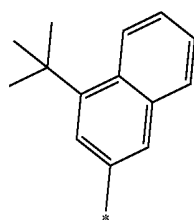
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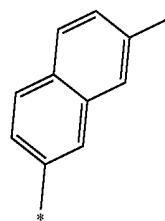
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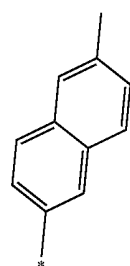
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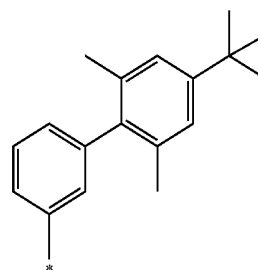


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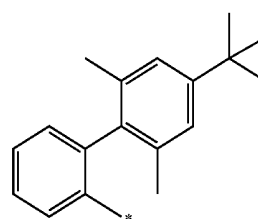


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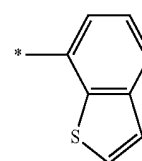
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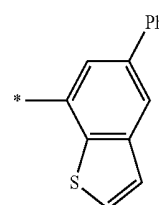
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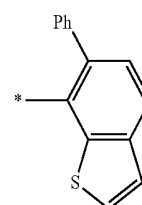
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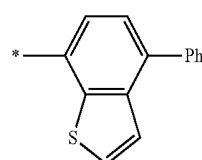
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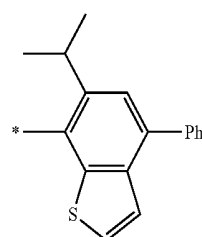
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10-212

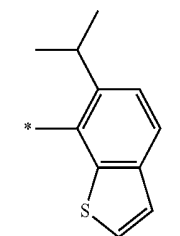


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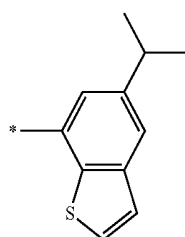


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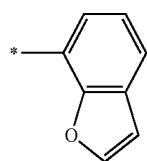
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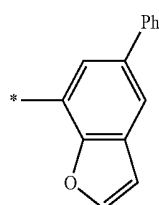
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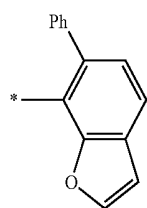
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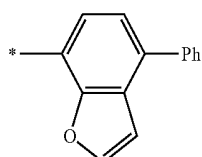
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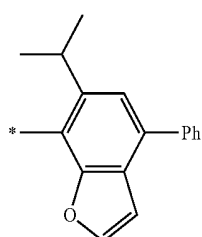
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10-219

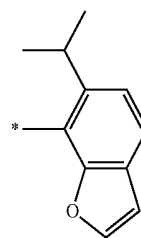


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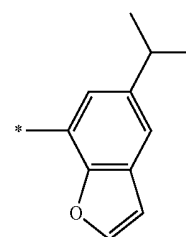


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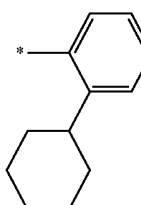
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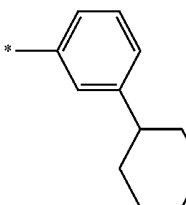
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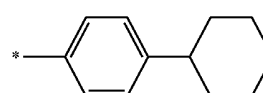
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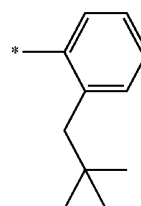
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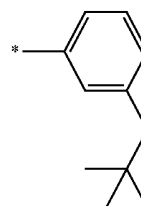
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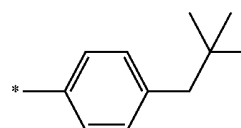
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10-227

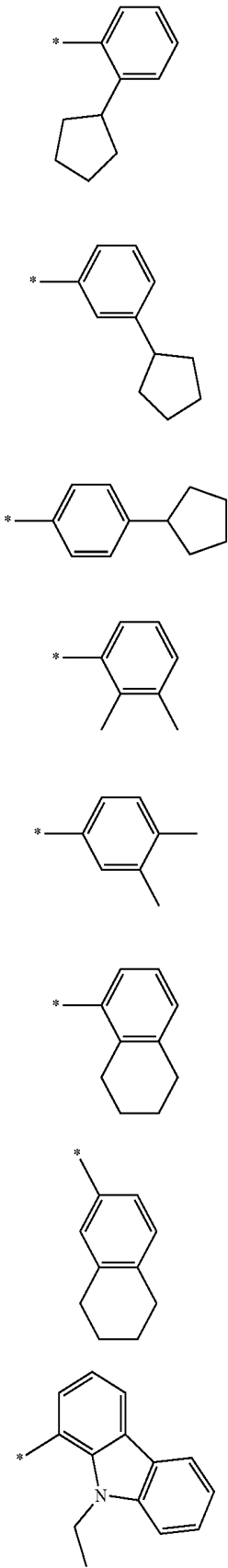


10-228



10-229

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10-230

10-231

10-232

10-233

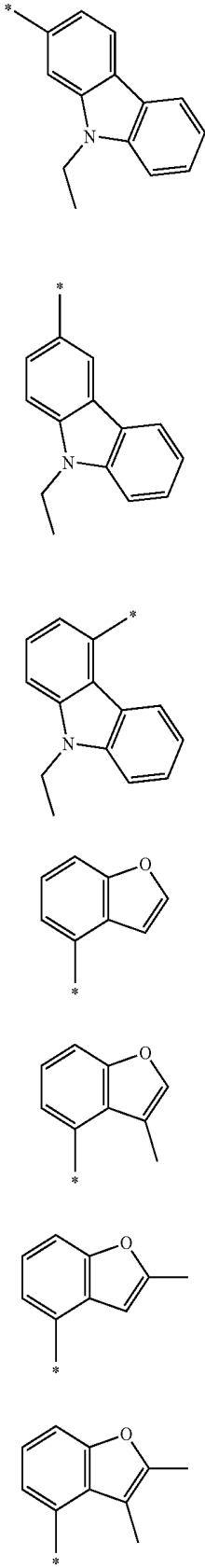
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10-235

10-236

10-237

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10-238

10-239

10-240

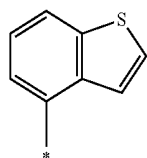
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10-242

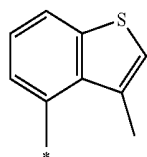
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10-244

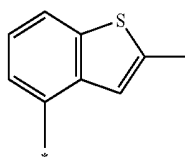
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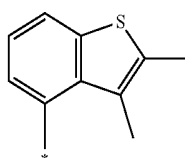
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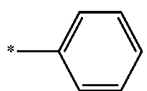
10-246



10-247



10-248



10-249

[0058] In Formulae 9-1 to 9-66 and 10-1 to 10-249, * indicates a binding site to a neighboring atom, Ph indicates a phenyl group, and TMS indicates a trimethylsilyl group.

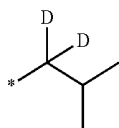
[0059] The “groups represented by Formulae 9-1 to 9-66 in which a hydrogen is substituted with deuterium” may refer to, for example, groups represented by Formulae 9-501 to 9-552:



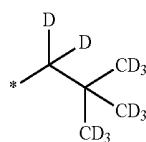
9-501



9-502

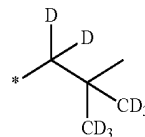


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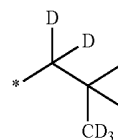


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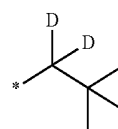
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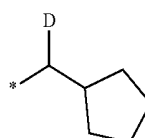
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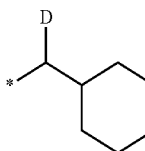
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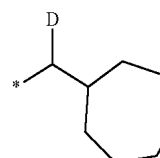
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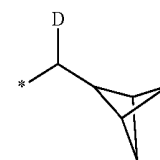
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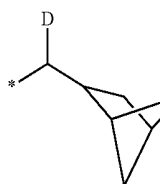
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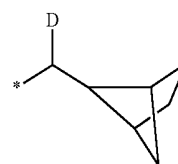
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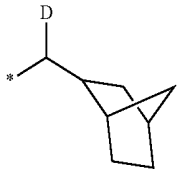


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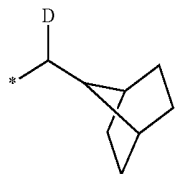


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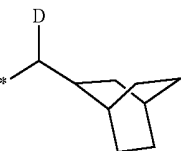
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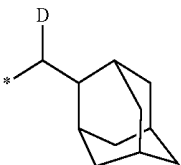
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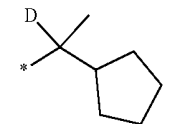
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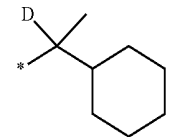
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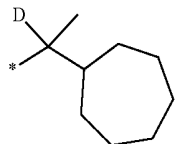
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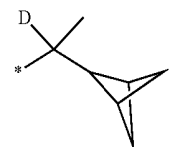
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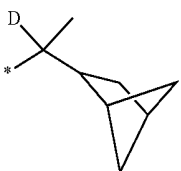
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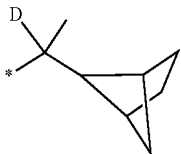


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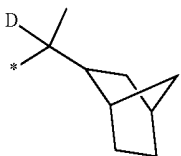


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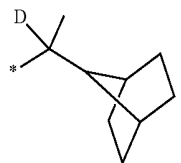
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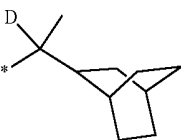
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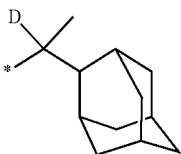
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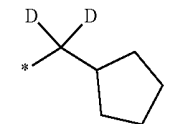
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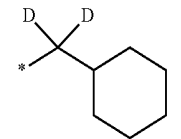
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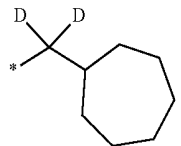
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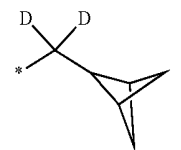
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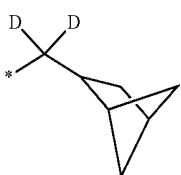
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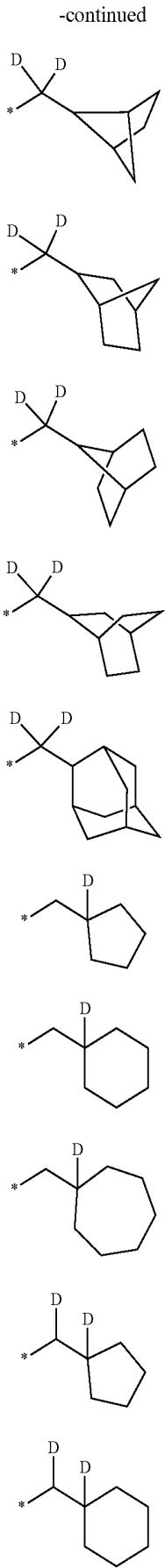
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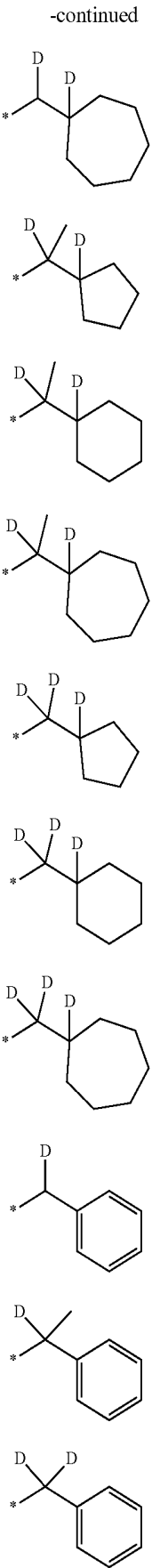
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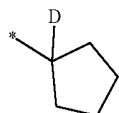


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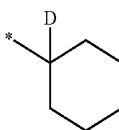


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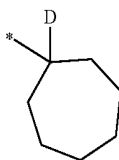
[0060] The “groups represented by Formulae 10-1 to 10-249 in which a hydrogen is substituted deuterium” may refer to, for example, groups represented by Formulae 10-501 to 10-510:



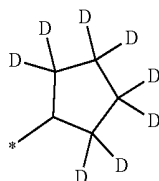
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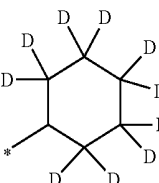
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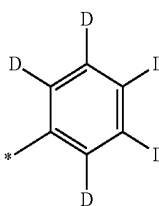
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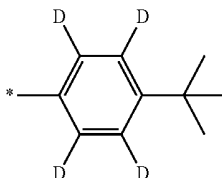
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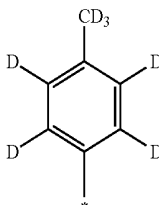
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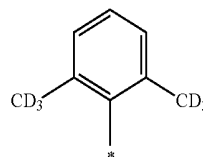
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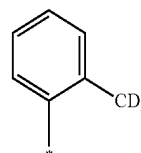
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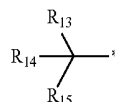


10-510



[0061] At least one of R_1 to R_6 may each independently be a group represented by Formula 2:

Formula 2



[0062] The number of carbon atoms included in Formula 2 may be 4 or more (for example, 4 to 20, 4 to 15 or 4 to 10),

[0063] R_{13} in Formula 2 may be hydrogen, deuterium, a C_1 - C_{20} alkyl group, a deuterium-containing C_1 - C_{20} alkyl group, a C_3 - C_{10} cycloalkyl group, or a deuterium-containing C_3 - C_{10} cycloalkyl group,

[0064] R_{14} and R_{15} in Formula 2 may each independently be a C_1 - C_{20} alkyl group, a deuterium-containing C_1 - C_{20} alkyl group, a C_3 - C_{10} cycloalkyl group, or a deuterium-containing C_3 - C_{10} cycloalkyl group, and

[0065] * indicates a binding site to a neighboring atom.

[0066] The terms “deuterium-containing C_1 - C_{20} alkyl group” and “deuterium-containing C_3 - C_{10} cycloalkyl group” as used herein refer to a C_1 - C_{20} alkyl group or a C_3 - C_{10} cycloalkyl group, each substituted with a deuterium. In an exemplary embodiment, the deuterium-containing methyl group refers to $-CDH_2$, $-CD_2H$, and $-CD_3$.

[0067] The term “ C_1 - C_{20} alkyl group” as used herein refers to, for example, a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, a sec-butyl group, an isobutyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neopentyl group, an isopentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an isoheptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an isooctyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an isononyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an isodecyl group, a sec-decyl group, or a tert-decyl group, but embodiments of the present disclosure are not limited thereto.

[0068] The term “ C_3 - C_{10} cycloalkyl group” as used herein refers to, for example, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a bicyclo[1.1.1]pentyl group, a bicyclo[2.1.1]hexyl group, a bicyclo[2.2.1]heptyl

group, or a bicyclo[2.2.2]octyl group, but embodiments of the present disclosure are not limited thereto.

[0069] In one embodiment, one of R₂ to R₅ in Formula 1 may be a group represented by Formula 2.

[0070] In one or more embodiments, one of R₂ to R₅ in Formula 1 may be a group represented by Formula 2, and groups other than the one of R₂ to R₅ which is the group represented by Formula 2 among R₁ to R₆ may be hydrogen.

[0071] In one or more embodiments, in Formula 1,

[0072] 1) R₂ may be a group represented by Formula 2 and R₁ and R₃ to R₆ may be hydrogen,

[0073] 2) R₃ may be a group represented by Formula 2 and R₁, R₂ and R₄ to R₆ may be hydrogen,

[0074] 3) R₄ may be a group represented by Formula 2 and R₁ to R₃, R₅ and R₆ may be hydrogen,

[0075] 4) R₅ may be a group represented by Formula 2 and R₁ to R₄ and R₆ may be hydrogen,

[0076] 5) R₄ may be a group represented by Formula 2, R₅ may be a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a phenyl group, a biphenyl group, or —Si(Q₃)(Q₄)(Q₅) and R₁, R₂, R₃ and R₆ may be hydrogen,

[0077] 6) R₅ may be a group represented by Formula 2, R₃ may be a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a phenyl group, a biphenyl group, or —Si(Q₃)(Q₄)(Q₅) and R₁, R₂, R₄ and R₆ may be hydrogen,

[0078] 7) R₂ may be a group represented by Formula 2, R₅ may be a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a phenyl group, a biphenyl group, or —Si(Q₃)(Q₄)(Q₅) and R₁, R₃, R₄ and R₆ may be hydrogen,

[0079] 8) R₄ may be a group represented by Formula 2, R₆ may be a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a phenyl group, a biphenyl group, or —Si(Q₃)(Q₄)(Q₅) and R₁, R₂, R₃ and R₅ may be hydrogen,

[0080] 9) R₃ may be a group represented by Formula 2, R₅ may be a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a phenyl group, a biphenyl group, or —Si(Q₃)(Q₄)(Q₅) and R₁, R₂, R₄ and R₆ may be hydrogen, or

[0081] 10) R₂ may be a group represented by Formula 2, R₄ and R₅ may each independently be a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a phenyl group, a biphenyl group, or —Si(Q₃)(Q₄)(Q₅) and R₁, R₃ and R₆ may be hydrogen.

[0082] In one or more embodiments, at least one of R₇ to R₉ in Formula 1 may not be hydrogen.

[0083] In one or more embodiments, at least one of R₇ to R₉ in Formula 1 may each independently be, a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, or a substituted or unsubstituted C₆-C₆₀ aryl group.

[0084] In one or more embodiments, at least one of R₇ to R₉ in Formula 1 may each independently be, a substituted or unsubstituted C₂-C₆₀ alkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, or a substituted or unsubstituted C₆-C₆₀ aryl group.

[0085] In one or more embodiments, in Formula 1,

[0086] 1) R₇ and R₉ may not hydrogen and R₈ and R₁₉ may be hydrogen,

[0087] 2) R₇ and R₈ may not hydrogen and R₉ and R₁₉ may be hydrogen,

[0088] 3) R₇ to R₉ may not hydrogen and R₁₉ may be hydrogen, or

[0089] 4) R₇ may not hydrogen and R₈, R₉ and R₁₉ may be hydrogen.

[0090] In one or more embodiments, R₁₉ in Formula 1 may be hydrogen.

[0091] In one or more embodiments, R₇ and R₉ in Formula 1 may not be hydrogen, and R₇ and R₉ may be identical to each other.

[0092] In one or more embodiments, R₇ and R₉ in Formula 1 may not be hydrogen, and R₇ and R₉ may be different from each other.

[0093] In one or more embodiments, R₇ and R₉ in Formula 1 may not be hydrogen, R₇ and R₉ may be different from each other, and the number of carbon atoms included in R₇ may be greater than that of carbon atoms included in R₉.

[0094] In one or more embodiments, R₁₃ in Formula 2 may be hydrogen or deuterium.

[0095] In one or more embodiments, R₁₃ in Formula 2 may be a C₁-C₂₀ alkyl group, a deuterium-containing C₁-C₂₀ alkyl group, a C₃-C₁₀ cycloalkyl group, or a deuterium-containing C₃-C₁₀ cycloalkyl group.

[0096] In one or more embodiments, R₁₄ and R₁₅ in Formula 2 may be different from each other.

[0097] In one or more embodiments, in Formula 2,

[0098] R₁₃ may be hydrogen, deuterium, —CH₃, —CDH₂, —CD₂H, or —CD₃,

[0099] R₁₄ and R₁₅ may each independently be:

[0100] a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neopentyl, an iso-pentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl 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 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, bicyclo[1.1.1]pentyl, bicyclo[2.1.1]hexyl, bicyclo[2.2.1]heptyl, or a bicyclo[2.2.2]octyl group; or

[0101] a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neopentyl, an iso-pentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl 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 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, bicyclo[1.1.1]pentyl, bicyclo[2.1.1]hexyl, bicyclo[2.2.1]heptyl, or a bicyclo[2.2.2]octyl group, each substituted with a deuterium.

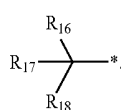
[0102] In one or more embodiments, in Formula 2, R_{14} and R_{15} may each independently be $-\text{CH}_3$, $-\text{CD}_3$, $-\text{CD}_2\text{H}$, $-\text{CDH}_2$, $-\text{CF}_3$, $-\text{CF}_2\text{H}$, $-\text{CFH}_2$, groups represented by Formulae 9-1 to 9-33, groups represented by Formulae 9-1 to 9-33 in which a hydrogen is substituted with deuterium, groups represented by Formulae 10-1 to 10-10, or groups represented by Formulae 10-1 to 10-10 in which a hydrogen is substituted with deuterium, but embodiments of the present disclosure are not limited thereto.

[0103] In one or more embodiments, a case where R_{13} to R_{15} in Formula 2 are identical to each other may be excluded.

[0104] In one or more embodiments, R_{13} to R_{15} in Formula 2 may be different from each other.

[0105] In one or more embodiments, a case where each of R_{13} to R_{15} in Formula 2 is a methyl group may be excluded. That is, R_{13} , R_{14} and R_{15} in Formula 2 may not be a methyl group, simultaneously.

[0106] At least one of R_{10} and R_{12} in Formula 1 may be a group represented by Formula 3:



Formula 3

[0107] R_{16} to R_{18} in Formula 3 may each independently be:

[0108] hydrogen, deuterium, a C_1 - C_{20} alkyl group, a C_3 - C_{10} cycloalkyl group, a C_6 - C_{60} aryl group, or a C_1 - C_{60} heteroaryl group; or

[0109] a C_1 - C_{20} alkyl group, a C_3 - C_{10} cycloalkyl group, a C_6 - C_{60} aryl group, or a C_1 - C_{60} heteroaryl group, each substituted with deuterium, a C_1 - C_{20} alkyl group, or a combination thereof, and

[0110] * indicates a binding site to a neighboring atom.

[0111] In an exemplary embodiment, R_{16} to R_{18} in Formula 3 may each independently be hydrogen or deuterium.

[0112] In one embodiment, one or more of R_{16} to R_{18} in Formula 3 may not be hydrogen or deuterium. That is, Formula 3 may include 0-2 benzylic protons.

[0113] In one embodiment, two or more of R_{16} to R_{18} in Formula 3 may not be hydrogen or deuterium. That is, Formula 3 may include 0-1 benzylic protons.

[0114] In one embodiment, R_{16} to R_{18} in Formula 3 may not be hydrogen or deuterium.

[0115] In one embodiment, in Formula 3,

[0116] R_{16} to R_{18} may each independently be hydrogen or deuterium,

[0117] R_{16} to R_{18} may each independently be a methyl group or a deuterium-containing methyl group,

[0118] R_{16} and R_{17} may each independently be hydrogen or deuterium, and R_{18} may be a methyl group or a deuterium-containing methyl group,

[0119] R_{16} and R_{17} may each independently be hydrogen or deuterium, and R_{18} may be a C_2 - C_{20} alkyl group or a deuterium-containing C_2 - C_{20} alkyl group,

[0120] R_{16} may be hydrogen or deuterium, and R_{17} and R_{18} may each independently be a methyl group or a deuterium-containing methyl group,

[0121] R_{16} may be hydrogen or deuterium, and R_{17} and R_{18} may each independently be a C_2 - C_{20} alkyl group or a deuterium-containing C_2 - C_{20} alkyl group,

[0122] R_{16} may be a methyl group or a deuterium-containing methyl group, and R_{17} and R_{18} may each independently be a C_2 - C_{20} alkyl group or a deuterium-containing C_2 - C_{20} alkyl group, or

[0123] R_{16} and R_{17} may each independently be a methyl group or a deuterium-containing methyl group, and R_{18} may be a C_2 - C_{20} alkyl group or a deuterium-containing C_2 - C_{20} alkyl group.

[0124] Examples of “the C_2 - C_{20} alkyl group or the deuterium-containing C_2 - C_{20} alkyl group” may include:

[0125] an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neopentyl, an iso-pentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl 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, or a tert-decyl group; or

[0126] an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neopentyl, an iso-pentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl 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, or a tert-decyl group, each substituted with a deuterium,

[0127] but embodiments of the present disclosure are not limited thereto.

[0128] In one or more embodiments, R_{10} and R_{12} in Formula 1 may be identical to each other.

[0129] In one or more embodiments, R_{10} and R_{12} in Formula 1 may be different from each other.

[0130] In an exemplary embodiment, in Formula 1, R_{10} may be an ethyl group, and R_{12} may be a methyl group, an n-propyl group, or an isopropyl group, but embodiments of the present disclosure are not limited thereto.

[0131] In one or more embodiments, at least one of R_{10} , R_{12} and R_{14} in Formulae 1 and 2 may each independently be a C_3 - C_{10} cycloalkyl group, a deuterium-containing C_3 - C_{10} cycloalkyl group, or a combination thereof.

[0132] Two or more of R_1 to R_9 and R_{19} in Formula 1 may optionally be linked to form a C_5 - C_{30} carbocyclic group unsubstituted or substituted with R_{1a} , a C_2 - C_{30} heterocyclic group unsubstituted or substituted with R_{1a} , or a combination thereof.

[0133] In an exemplary embodiment, two or more of R_1 to R_9 and R_{19} in Formula 1 may optionally be linked to form a cyclopentadiene group, a cyclohexane group, a cyclohep-

tane group, an adamantane group, a bicycle-heptane group, a bicycle-octane group, a benzene group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a naphthalene group, an anthracene group, a tetracene group, a phenanthrene group, a dihydronaphthalene group, a phenalene group, a benzofuran group, a benzothiophene group, a benzoselenophene group, an indole group, an indene group, a benzosilole group, an azabenzofuran group, an azabenzothiophene group, an azabenzoselenophene group, an azaindole group, an azaindene group, or an azabenzosilole group, each unsubstituted or substituted with R_{1a} , but embodiments of the present disclosure are not limited thereto.

[0134] R_{1a} may be the same as defined in connection with R_7 .

[0135] In one or more embodiments, the organometallic compound represented by Formula 1 may satisfy at least one of Condition 1 to Condition 6:

[0136] Condition 1. At least one of R_1 to R_3 , R_5 and R_6 in Formula 1 may not be hydrogen.

[0137] Condition 2. At least one of R_7 to R_9 in Formula 1 may each independently be a group having two or more carbons.

[0138] Condition 3. At least one of R_7 to R_9 in Formula 1 may each independently be a substituted or unsubstituted C_2 - C_{60} alkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, or a combination thereof.

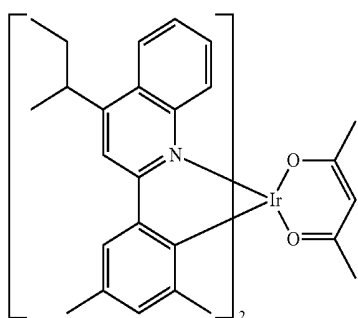
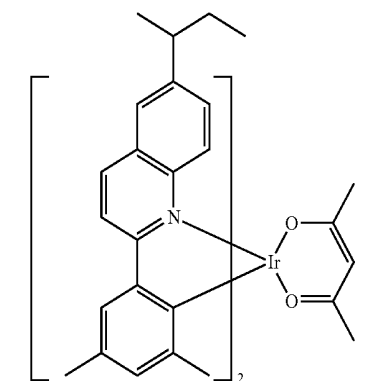
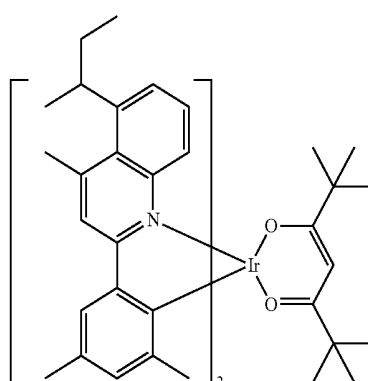
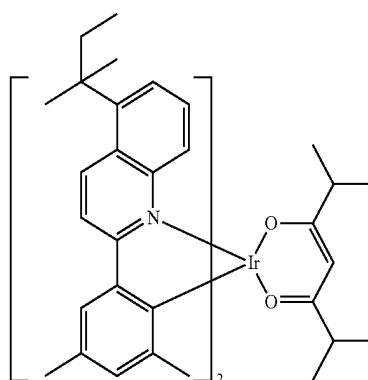
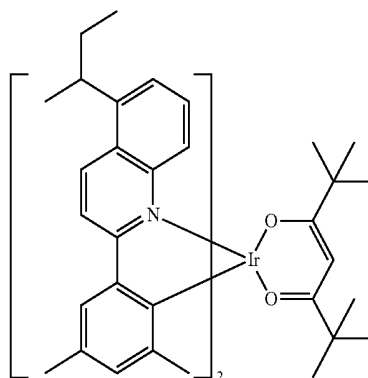
[0139] Condition 4. At least one of R_{10} and R_{12} in Formula 1 may each independently be a group represented by Formula 3 and R_{16} to R_{18} in Formula 3 may not be hydrogen.

[0140] Condition 5. At least one of R_{10} and R_{12} in Formula 1 may each independently be a group represented by Formula 3 and at least one of R_{16} to R_{18} in Formula 3 may each independently be a C_2 - C_{20} alkyl group, a C_3 - C_{10} cycloalkyl group, a C_6 - C_{60} aryl group, or a combination thereof; a C_2 - C_{20} alkyl group, a C_3 - C_{10} cycloalkyl group, a C_6 - C_{60} aryl group, or a combination thereof, each substituted with deuterium, a C_1 - C_{20} alkyl group, or a combination thereof.

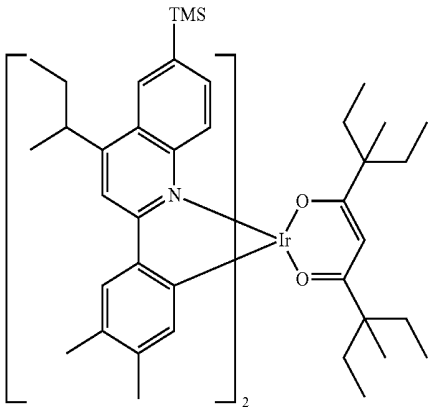
[0141] Condition 6. At least one of R_{10} and R_{12} in Formula 1 may each independently be a substituted or unsubstituted C_3 - C_{10} cycloalkyl group.

[0142] In one or more embodiments, the organometallic compound may be one of Compounds 1 to 20, but embodiments of the present disclosure are not limited thereto:

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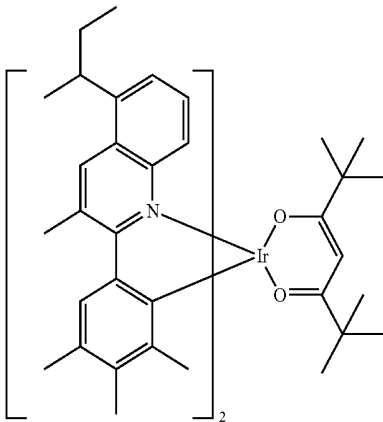


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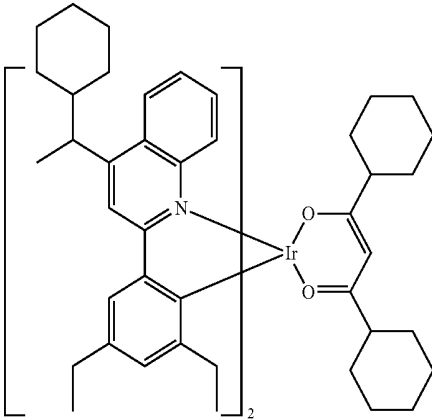


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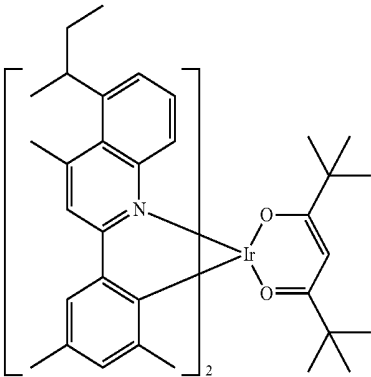
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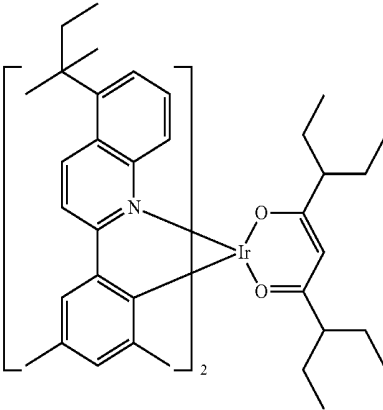
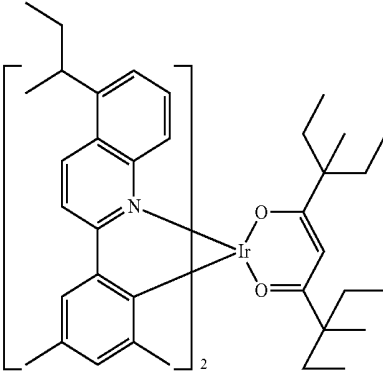
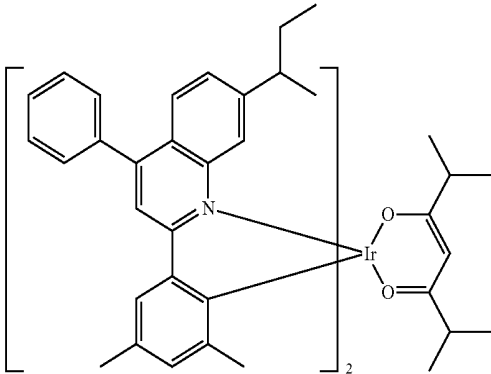
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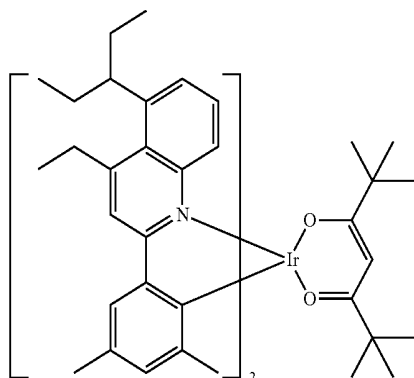
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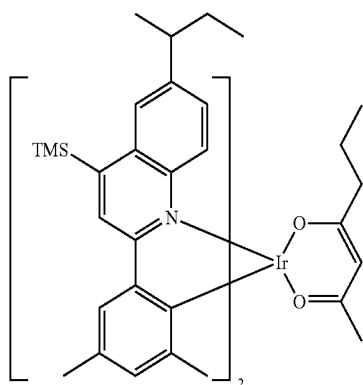
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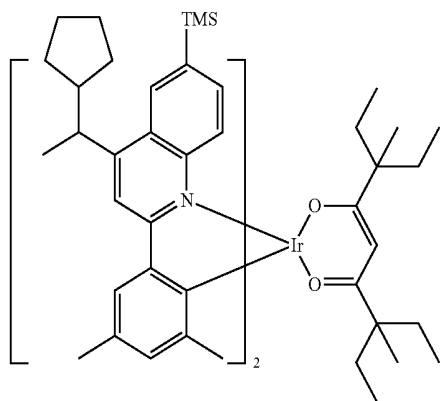
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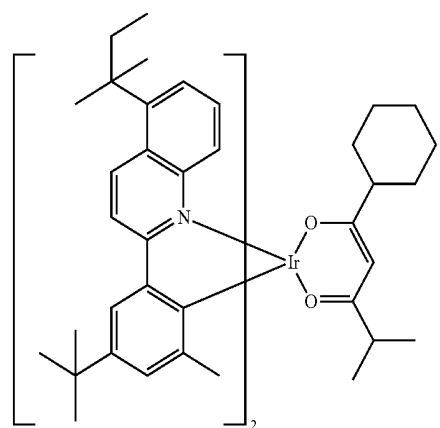
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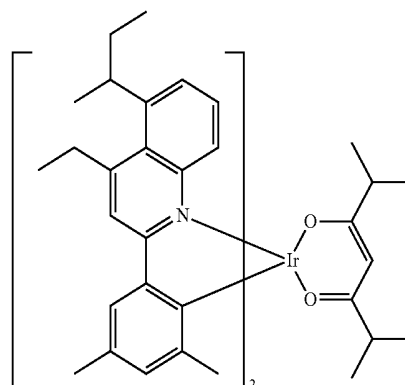


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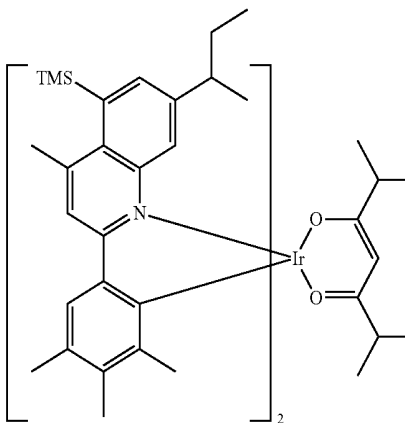


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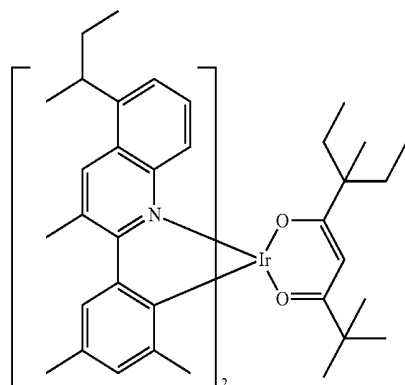
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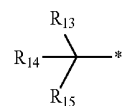


20

[0143] In Compounds 1 to 20, TMS is a tri(methyl)silyl group.

[0144] Formula 1 has the structure as described herein, wherein at least one of R_1 to R_6 is each independently a group represented by Formula 2:

Formula 2



[0145] The number of carbon atoms included in Formula 2 may be 4 or more, R_{13} may be hydrogen, deuterium, a C_1 - C_{20} alkyl group, a deuterium-containing C_1 - C_{20} alkyl

group, a C₃-C₁₀ cycloalkyl group, or a deuterium-containing C₃-C₁₀ cycloalkyl group, R₁₄ and R₁₅ may each independently be a C₁-C₂₀ alkyl group, a deuterium-containing C₁-C₂₀ alkyl group, a C₃-C₁₀ cycloalkyl group, or a deuterium-containing C₃-C₁₀ cycloalkyl group, and * indicates a binding site to a neighboring atom.

[0146] That is, the group represented by Formula 2 may be an alkyl group having 0-1 benzylic protons or a derivative thereof.

[0147] While not wishing to be bound to a specific theory, since the benzylic proton has high chemical reactivity, as compared with protons other than the benzylic protons, the benzylic proton may cause a side reaction due to the generation of intermediates in various forms. However, since at least one of R₁ to R₆ in Formula 1 can each independently be a group represented by Formula 2 which is an alkyl group having 0-1 benzylic protons or a derivative thereof, the organometallic compound represented by Formula 1 has a stable chemical structure in which the generation of side reactions before and after synthesis is minimized. In addition, interaction between the organometallic compound molecules may be minimized during the driving of an electronic device (for example, an organic light-emitting device) including the organometallic compound represented by a Formula 1. Therefore, the electronic device, for example, the organic light-emitting device, which includes an organometallic compound represented by Formula 1, may have improved driving voltage, improved current density, improved external quantum luminescence efficiency, improved roll off ratio, and improved lifespan.

[0148] Furthermore, R₁₃, R₁₄ and R₁₅ in Formula 2 are not a methyl group, simultaneously. That is, a group represented by Formula 2 is not a tert-butyl (t-butyl) group. While not wishing to be bound to a specific theory, a t-butyl group may be cleaved from a quinoline ring of Formula 1 to form a t-butyl radical (or, t-butyl cation), which causes a decrease in lifespan of the electronic device, for example, the organic light-emitting device. However, when a group represented by Formula 2 is not a tert-butyl (t-butyl) group, the lifespan of the electronic device, for example, the organic light-emitting device, which includes an organometallic compound represented by Formula 1, may not be substantially decreased.

[0149] Synthesis methods of the organometallic compounds represented by Formula 1 may be understood by one of ordinary skill in the art by referring to Synthesis Examples provided below.

[0150] The organometallic compound represented by Formula 1 is suitable for use in an organic layer of an organic light-emitting device, for example, for use as a dopant in an emission layer of the organic layer. Thus, another aspect provides an organic light-emitting device that includes: a first electrode; a second electrode; and an organic layer that is disposed between the first electrode and the second electrode and includes an emission layer, wherein the organic layer includes the organometallic compound represented by Formula 1.

[0151] The organic light-emitting device may have, due to the inclusion of an organic layer including the organometallic compound represented by Formula 1, improved driving voltage, improved current density, improved external quantum luminescence efficiency, improved roll off ratio, and improved lifespan.

[0152] The organometallic compound of Formula 1 may be used between a pair of electrodes of an organic light-emitting device. In an exemplary embodiment, the organometallic compound represented by Formula 1 may be included in the emission layer. In this regard, the organometallic compound may act as a dopant, and the emission layer may further include a host (that is, in the emission layer, an amount of the organometallic compound represented by Formula 1 is smaller than an amount of the host).

[0153] In one embodiment, the emission layer may emit red light.

[0154] The expression “(an organic layer) includes organometallic compounds” as used herein may include a case in which “(an organic layer) includes identical organometallic compounds represented by Formula 1” and a case in which “(an organic layer) includes two or more different organometallic compounds represented by Formula 1.”

[0155] In an exemplary embodiment, the organic layer may include, as the organometallic compound, only Compound 1. In this regard, Compound 1 may exist in an emission layer of the organic light-emitting device. In one or more embodiments, the organic layer may include, as the organometallic compound, Compound 1, and Compound 2. In this regard, Compound 1 and Compound 2 may be present in the same layer (for example, Compound 1 and Compound 2 all may be present in an emission layer).

[0156] 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; or 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.

[0157] In one embodiment, in the organic light-emitting device, the first electrode is an anode, and the second electrode is a cathode, and the organic layer further includes a hole transport region between the first electrode and the emission layer and an electron transport region between the emission layer and the second electrode, and the hole transport region includes a hole injection layer, a hole transport layer, an electron blocking layer, a buffer layer, or any combination thereof, and the electron transport region includes a hole blocking layer, an electron transport layer, an electron injection layer, or any combination thereof.

[0158] The term “organic layer” as used herein refers to a single layer and/or a plurality of layers between the first electrode and the second electrode of the organic light-emitting device. The “organic layer” may include, in addition to an organic compound, an organometallic complex including metal.

[0159] FIG. 1s a schematic view of an organic light-emitting device **10** according to an embodiment. Hereinafter, the structure of an organic light-emitting device according to an embodiment and a method of manufacturing an organic light-emitting device according to an embodiment will be described in connection with the FIGURE. The organic light-emitting device **10** includes a first electrode **11**, an organic layer **15**, and a second electrode **19**, which are sequentially stacked.

[0160] A substrate may be additionally disposed under the first electrode 11 or above the second electrode 19. For use as the substrate, any substrate that is commonly used in organic light-emitting devices may be used, and the substrate may be a glass substrate or a transparent plastic substrate, each having excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water resistance.

[0161] The first electrode 11 may be formed by depositing or sputtering a material for forming the first electrode 11 on the substrate. The first electrode 11 may be an anode. The material for forming the first electrode 11 may be a material 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 forming the first electrode may be, for example, indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), and zinc oxide (ZnO). In one or more embodiments, magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), or magnesium-silver (Mg—Ag) may be used as the material for forming the first electrode.

[0162] The first electrode 11 may have a single-layered structure or a multi-layered structure including two or more layers. In an exemplary embodiment, the first electrode 11 may have a three-layered structure of ITO/Ag/ITO, but the structure of the first electrode 110 is not limited thereto.

[0163] The organic layer 15 is disposed on the first electrode 11.

[0164] The organic layer 15 may include a hole transport region, an emission layer, and an electron transport region.

[0165] The hole transport region may be disposed between the first electrode 11 and the emission layer.

[0166] 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.

[0167] The hole transport region may include only either a hole injection layer or a hole transport layer. In one or more embodiments, the hole transport region may have a hole injection layer/hole transport layer structure or a hole injection layer/hole transport layer/electron blocking layer structure, which are sequentially stacked in this stated order from the first electrode 11.

[0168] A hole injection layer may be formed on the first electrode 11 by using one or more suitable methods such as vacuum deposition, spin coating, casting, or Langmuir-Blodgett (LB) deposition.

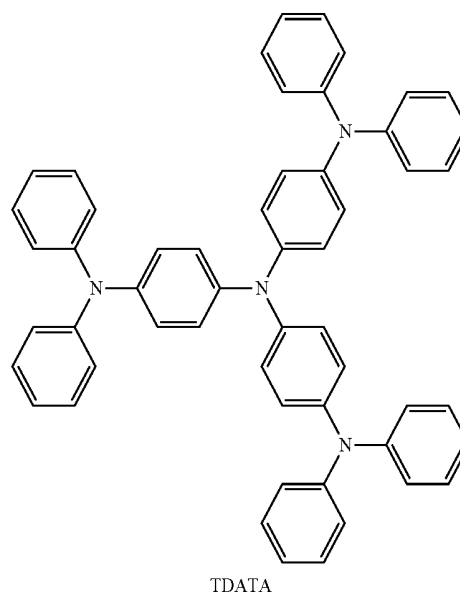
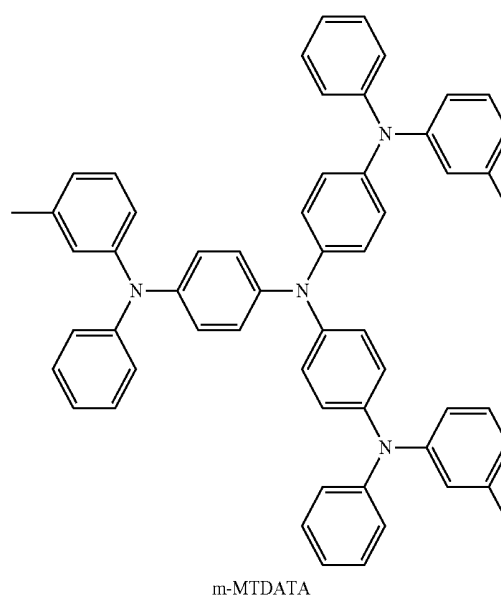
[0169] When a hole injection layer is formed by vacuum deposition, the deposition conditions may vary according to a compound that is used to form the hole injection layer, and the structure and thermal characteristics of the hole injection layer. In an exemplary embodiment, the deposition conditions may include a deposition temperature of about 100°C . to about 500°C ., a vacuum pressure of about 10^{-8} torr to about 10^{-3} torr, and a deposition rate of about 0.01 (angstroms per second) Å/sec to about 100 Å/sec. However, the deposition conditions are not limited thereto.

[0170] When the hole injection layer is formed using spin coating, coating conditions may vary according to the material used to form the hole injection layer, and the structure and thermal properties of the hole injection layer. In an exemplary embodiment, a coating speed may be from about 2,000 rpm to about 5,000 rpm, and a temperature at which

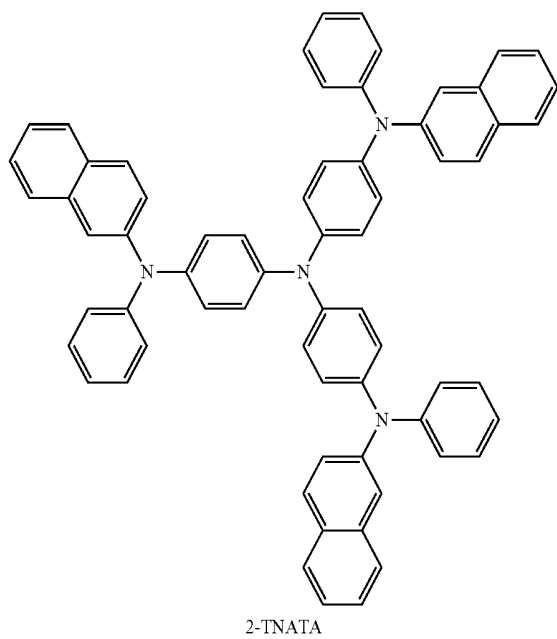
a heat treatment is performed to remove a solvent after coating may be from about 80°C . to about 200°C . However, the coating conditions are not limited thereto.

[0171] Conditions for forming a hole transport layer and an electron blocking layer may be understood by referring to conditions for forming the hole injection layer.

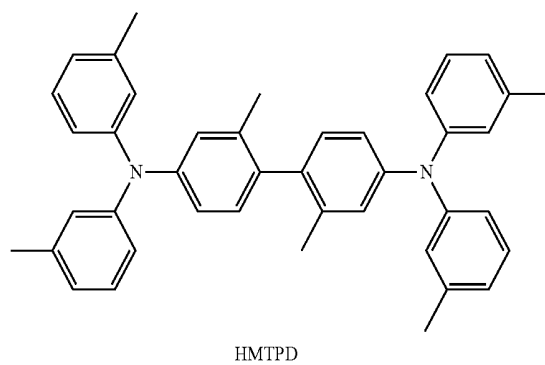
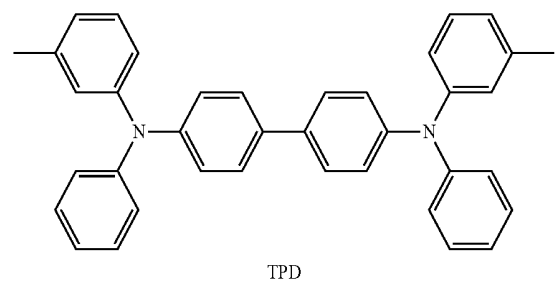
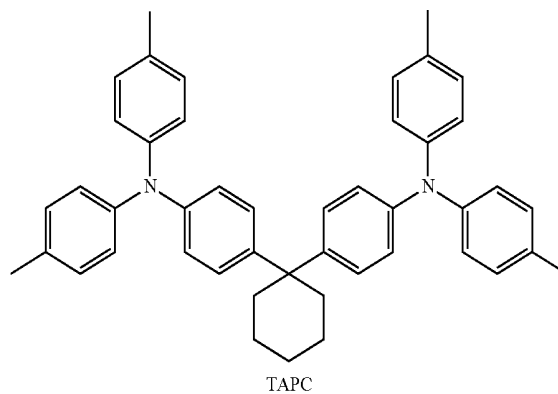
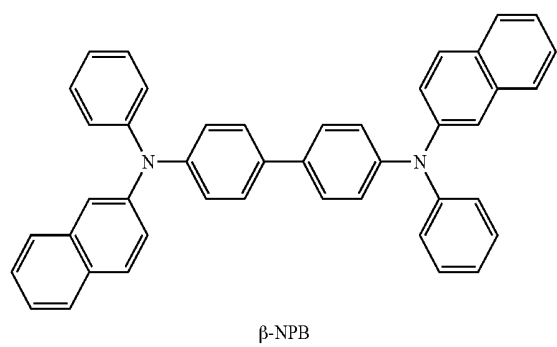
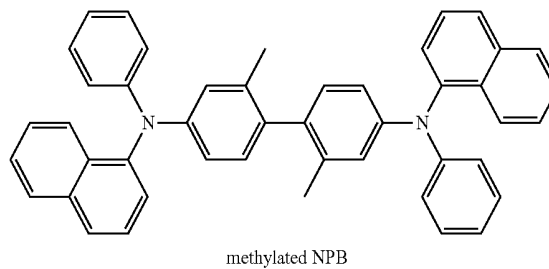
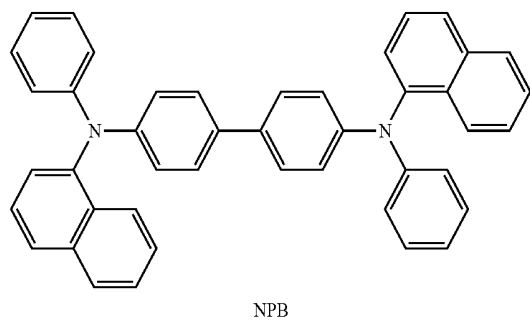
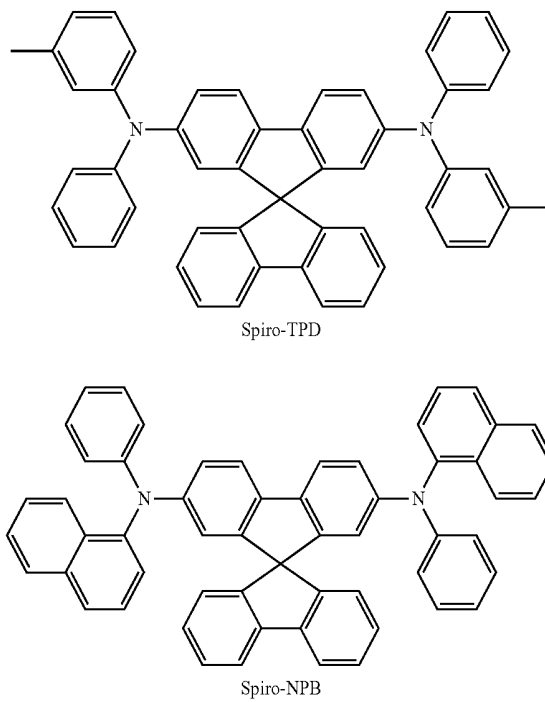
[0172] The hole transport region may include m-MT-DATA, TDATA, 2-TNATA, NPB, β -NPB, TPD, Spiro-TPD, Spiro-NPB, methylated-NPB, TAPC, HMTPD, 4,4',4"-tris (N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (PANI/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonic acid (PANI/CSA), polyaniline/poly(4-styrenesulfonate) (PANI/PSS), a compound represented by Formula 201 below, a compound represented by Formula 202 below, or a combination thereof:



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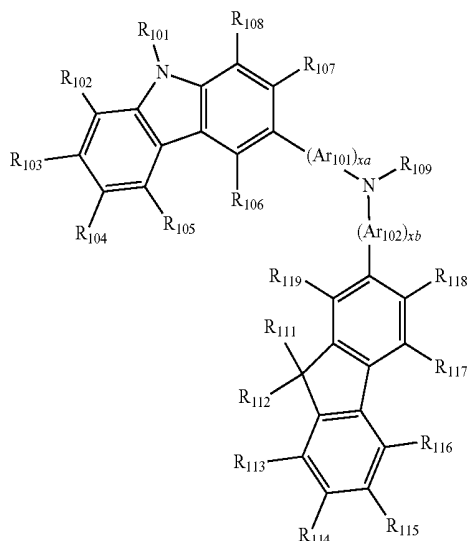


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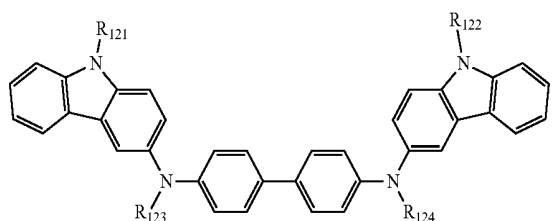


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Formula 201



Formula 202



[0173] Ar_{101} and Ar_{102} in Formula 201 may each independently be:

[0174] 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, or a pentacenylene group; or a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an acenaphthylene group, a fluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, or a pentacenylene group, each substituted with deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, a C_1 - C_{60} alkoxy group, a C_3 - C_{10} cycloalkyl

group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, or a combination thereof.

[0175] In Formula 201, x_a and x_b may each independently be an integer from 0 to 5, or may be 0, 1, or 2. In an exemplary embodiment, x_a may be 1 and x_b may be 0, but x_a and x_b are not limited thereto.

[0176] R_{101} to R_{108} , R_{111} to R_{119} , and R_{121} to R_{124} in Formulae 201 and 202 may each independently be:

[0177] 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 C_1 - C_{10} alkyl group (for example, a methyl group, an ethyl group, a propyl group, a butyl group, a pentyl group, a hexyl group, and so on), or a C_1 - C_{10} alkoxy group (for example, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, and so on);

[0178] a C_1 - C_{10} alkyl group or a C_1 - C_{10} alkoxy group, each substituted with 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, or a combination thereof;

[0179] a phenyl group, a naphthyl group, an anthracenyl group, a fluorenyl group, or a pyrenyl group; or

[0180] a phenyl group, a naphthyl group, an anthracenyl group, a fluorenyl group, or a pyrenyl group, each substituted with 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_{100} alkyl group, a C_1 - C_{10} alkoxy group, or a combination thereof, but embodiments of the present disclosure are not limited thereto.

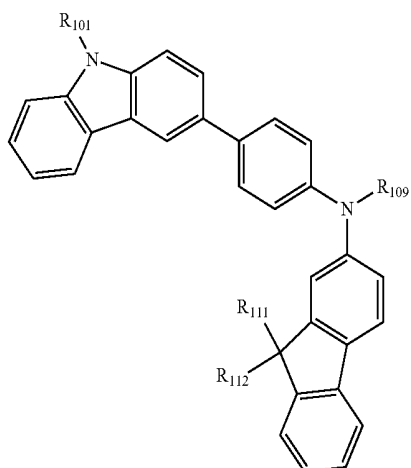
[0181] R_{109} in Formula 201 may be:

[0182] a phenyl group, a naphthyl group, an anthracenyl group, or a pyridinyl group; or

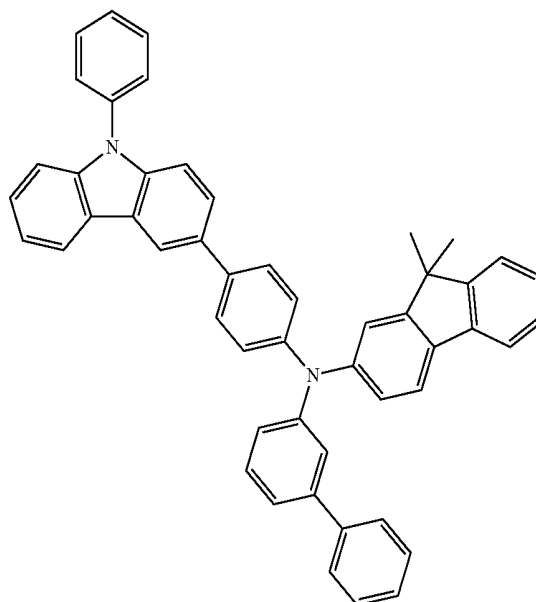
[0183] a phenyl group, a naphthyl group, an anthracenyl group, or a pyridinyl group, each substituted with deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyridinyl group, or a combination thereof.

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HT2

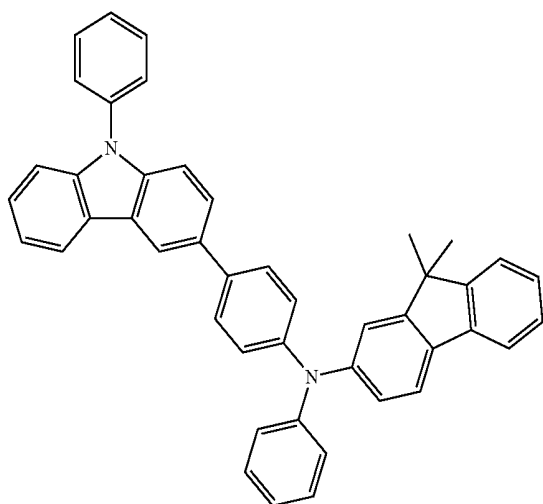


Formula 201A

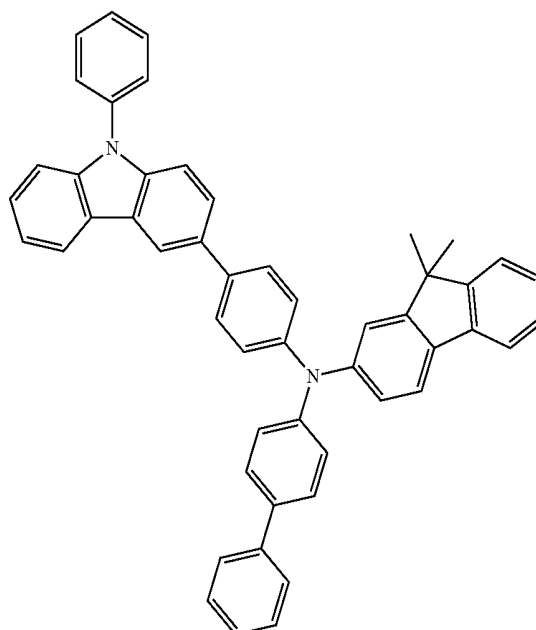


[0185] In an exemplary embodiment, the compound represented by Formula 201, and the compound represented by Formula 202 may include compounds HT1 to HT20 illustrated below, but are not limited thereto.

HT3



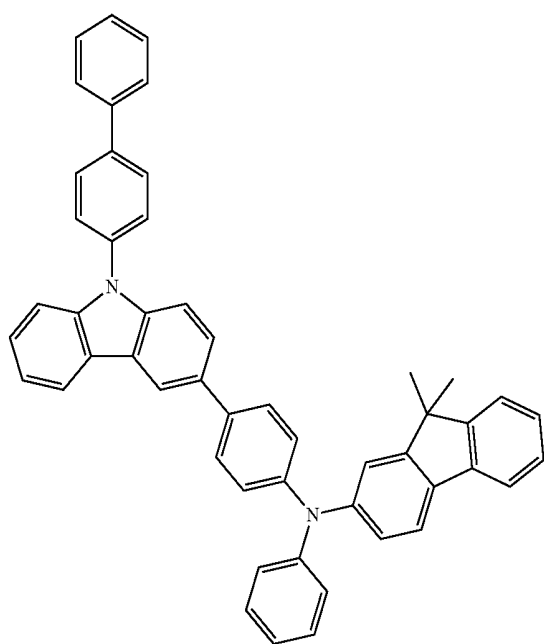
HT1



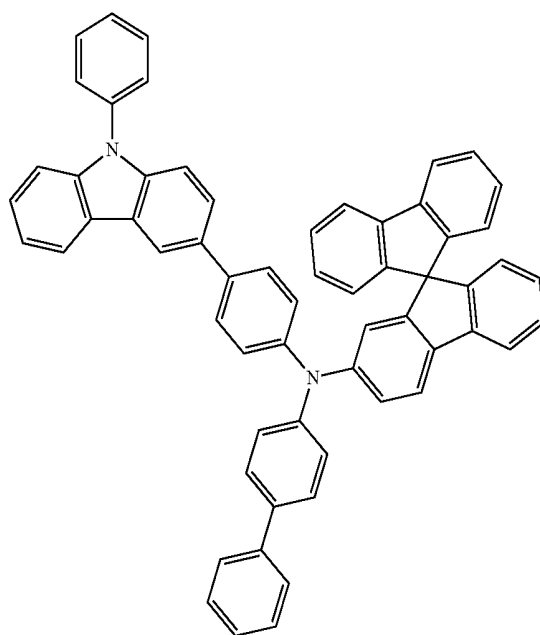
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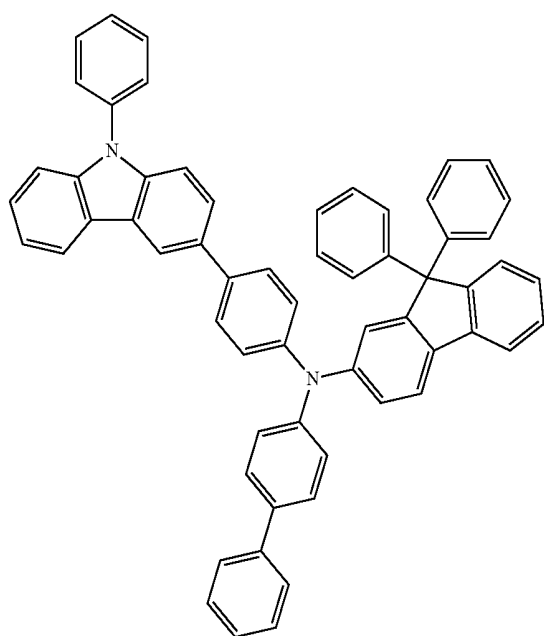
HT4



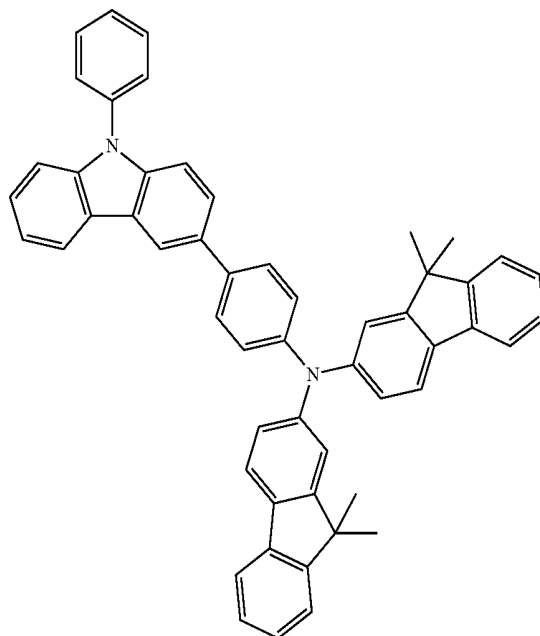
HT6



HT5

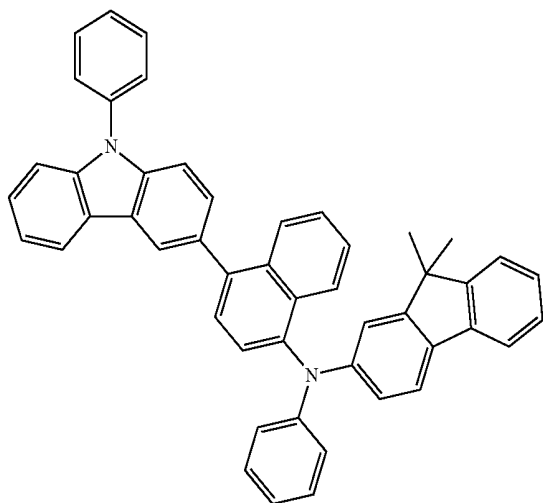


HT7

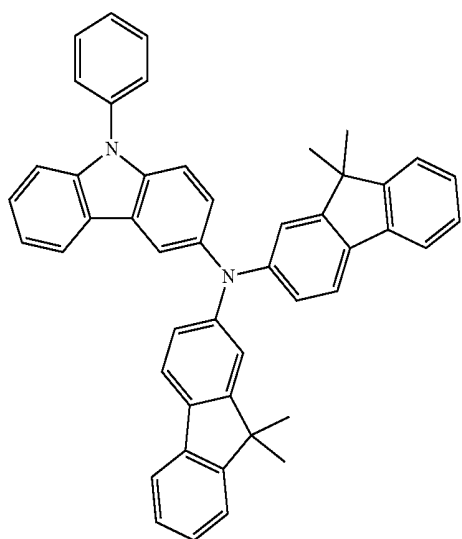


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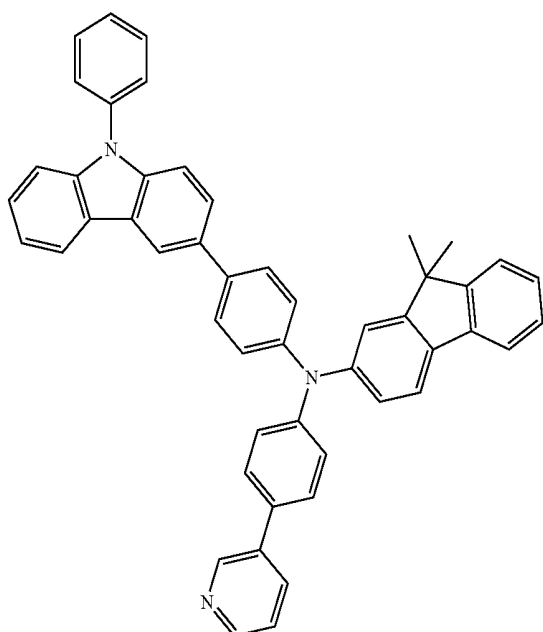
HT8



HT9

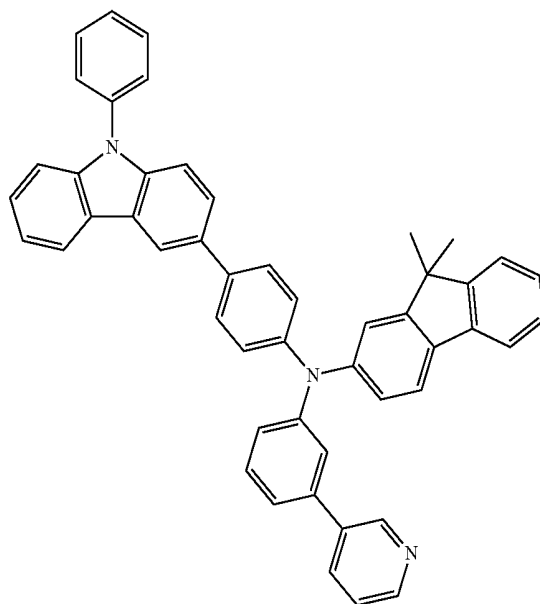


HT10

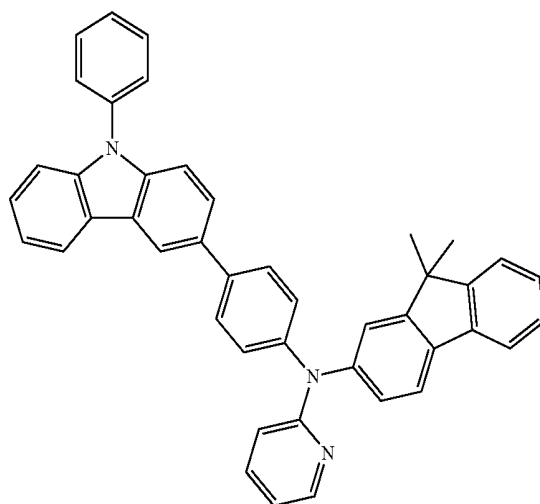


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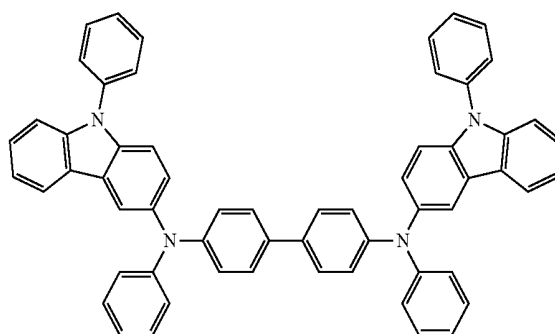
HT11



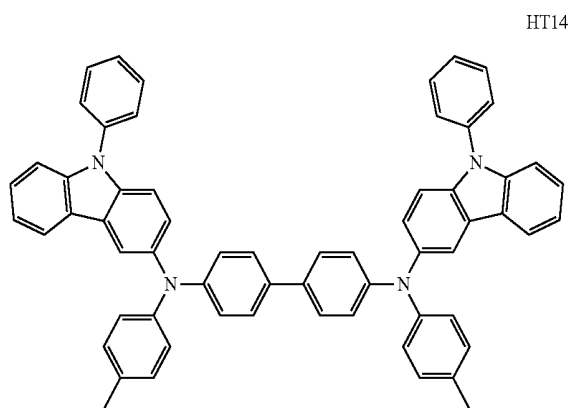
HT12



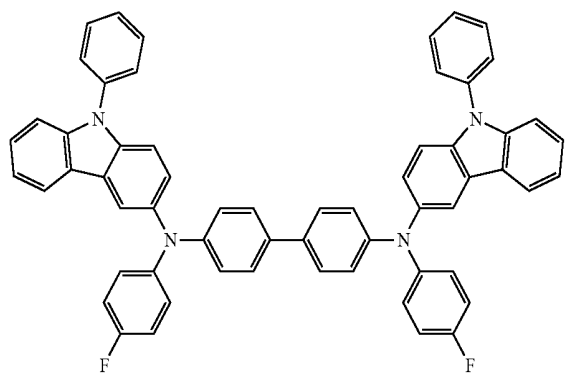
HT13



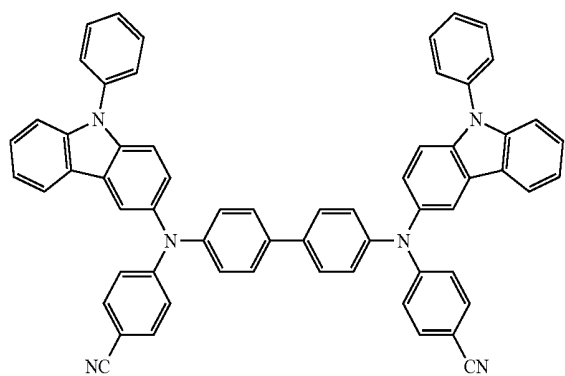
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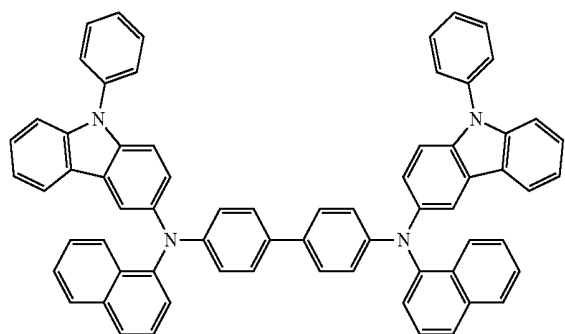
HT15



HT16

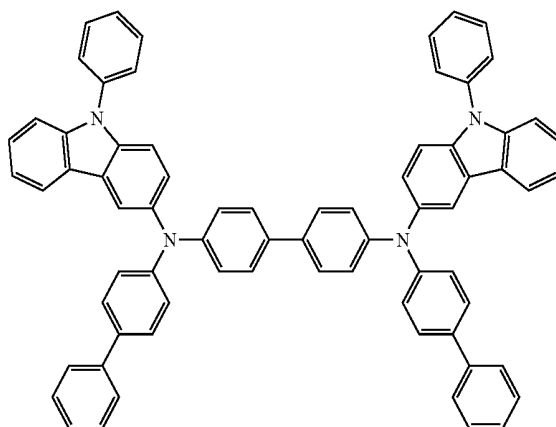


HT17

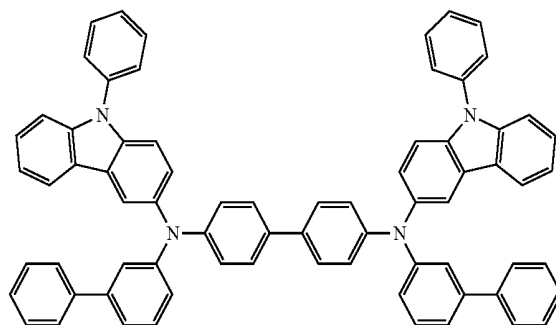


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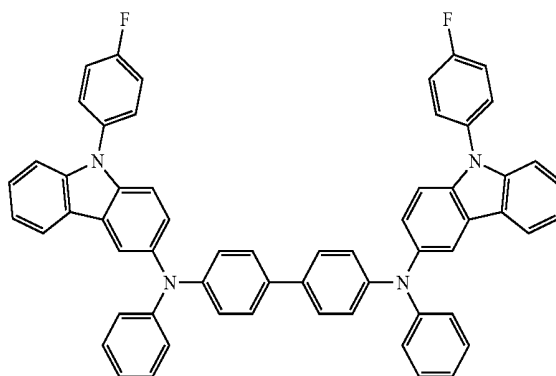
HT18



HT19



HT20

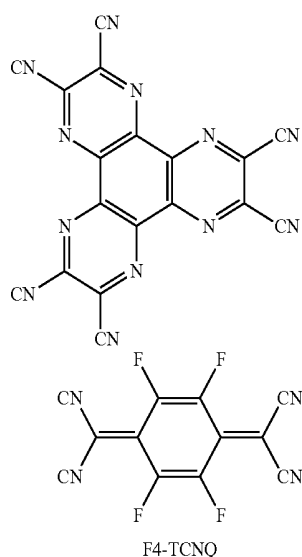


[0186] A thickness of the hole transport region may be in a range of about 100 angstroms (Å) to about 10,000 Å, for example, about 100 Å to about 1,000 Å. When the hole transport region includes at least one of a hole injection layer and a hole transport layer, the thickness of the hole injection layer may be in a range of about 100 Å to about 10,000 Å, and for example, about 100 Å to about 1,000 Å, and the thickness of the hole transport layer may be in a range of about 50 Å to about 2,000 Å, and for example, about 100 Å to about 1,500 Å. When the thicknesses of the hole transport region, the hole injection layer, and the hole transport layer are within these ranges, satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.

[0187] The hole transport region may further include, in addition to these materials, a charge-generation material for the improvement of conductive properties. The charge-

generation material may be homogeneously or non-homogeneously dispersed in the hole transport region.

[0188] The charge-generation material may be, for example, a p-dopant. The p-dopant may be a quinone derivative, a metal oxide, or a cyano group-containing compound, but embodiments of the present disclosure are not limited thereto. Non-limiting examples of the p-dopant are 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; or a cyano group-containing compound, such as Compound HT-D1 below, but are not limited thereto.



[0189] The hole transport region may include a buffer layer.

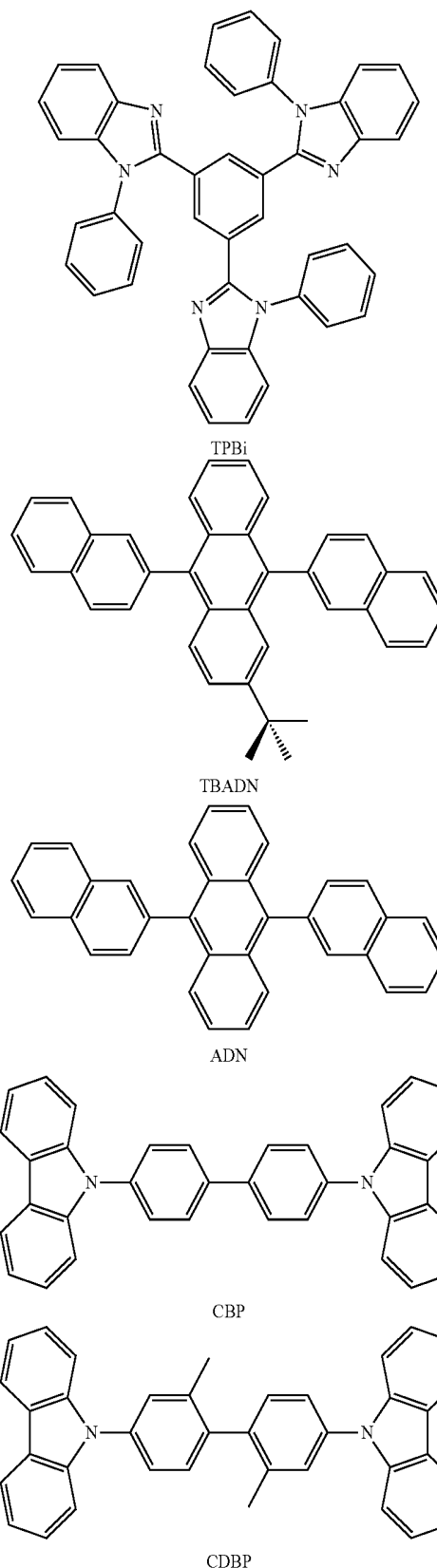
[0190] Also, the buffer layer may compensate for an optical resonance distance according to a wavelength of light emitted from the emission layer, and thus, efficiency of a formed organic light-emitting device may be improved.

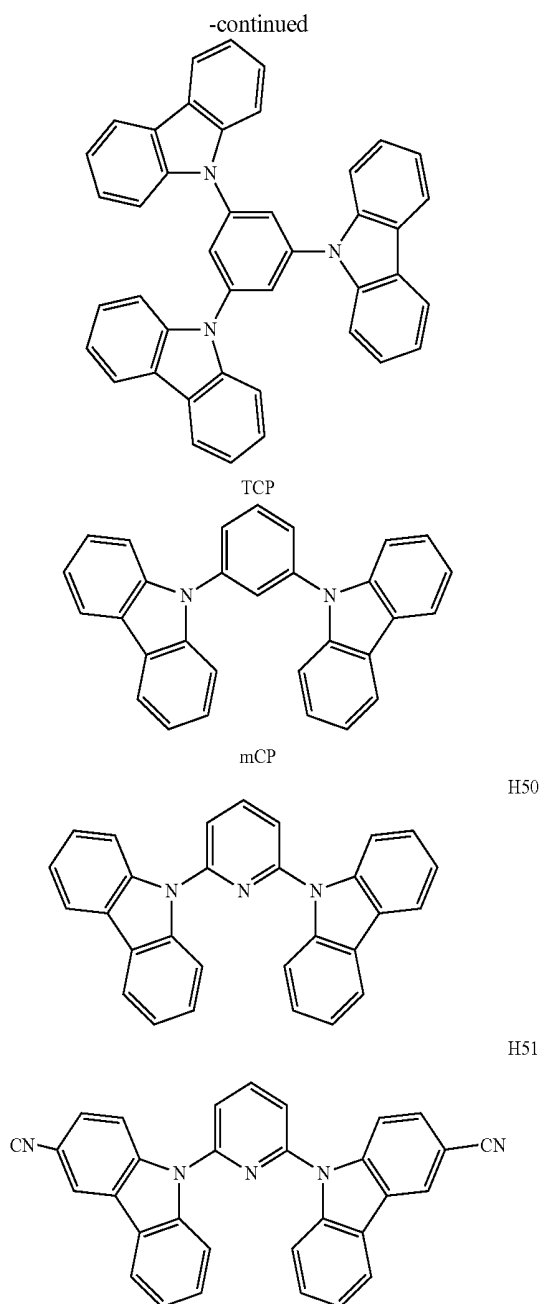
[0191] Then, an emission layer may be formed on the hole transport region by vacuum deposition, spin coating, casting, LB deposition, or the like. When the emission layer is formed by vacuum deposition or spin coating, the deposition or coating conditions may be similar to those applied in forming the hole injection layer although the deposition or coating conditions may vary according to a compound that is used to form the emission layer.

[0192] When the hole transport region includes an electron blocking layer, a material for the electron blocking layer may be materials for the hole transport region described above and/or materials for a host to be explained later. However, the material for the electron blocking layer is not limited thereto. In an exemplary embodiment, when the hole transport region includes an electron blocking layer, a material for the electron blocking layer may be mCP, which will be explained later.

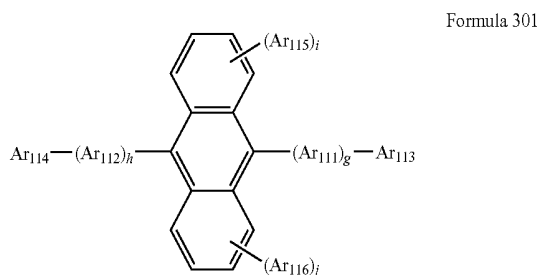
[0193] The emission layer may include a host and a dopant, and the dopant may include the organometallic compound represented by Formula 1.

[0194] The host may include TPBi, TBADN, ADN (also referred to as "DNA"), CBP, CDBP, TCP, mCP, Compound H50, Compound H51, or a combination thereof:





[0195] In one or more embodiments, the host may further include a compound represented by Formula 301:



[0196] Ar₁₁₁ and Ar₁₁₂ in Formula 301 may each independently be:

[0197] a phenylene group, a naphthylene group, a phenanthrenylene group, or a pyrenylene group; or

[0198] a phenylene group, a naphthylene group, a phenanthrenylene group, or a pyrenylene group, each substituted with a phenyl group, a naphthyl group, an anthracenyl group, or a combination thereof.

[0199] Ar₁₁₃ to Ar₁₁₆ in Formula 301 may each independently be:

[0200] a C₁-C₁₀ alkyl group, a phenyl group, a naphthyl group, a phenanthrenyl group, or a pyrenyl group; or

[0201] a phenyl group, a naphthyl group, a phenanthrenyl group, or a pyrenyl group, each substituted with a phenyl group, a naphthyl group, an anthracenyl group, or a combination thereof.

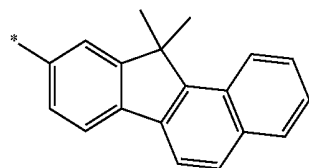
[0202] In Formula 301, g, h, i, and j may each independently be an integer from 0 to 4, and may be, for example, 0, 1, or 2.

[0203] Ar₁₁₃ to Ar₁₁₆ in Formula 301 may each independently be:

[0204] a C₁-C₁₀ alkyl group, substituted with a phenyl group, a naphthyl group, an anthracenyl group, or a combination thereof;

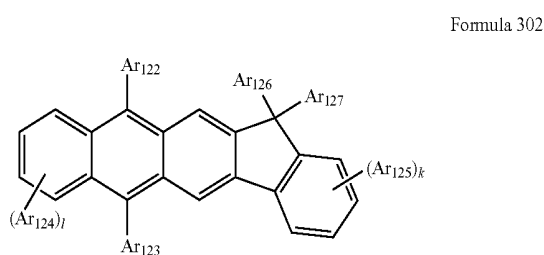
[0205] a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl, a phenanthrenyl group, or a fluorenyl group;

[0206] a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, or a fluorenyl group, each substituted with 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 phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, or a combination thereof; or



but embodiments of the present disclosure are not limited thereto.

[0207] In one or more embodiments, the host may include a compound represented by Formula 302 below:



[0208] Ar_{122} to Ar_{125} in Formula 302 may be the same as described in connection with Ar_{113} in Formula 301.

[0209] Ar_{126} and Ar_{127} in Formula 302 may each independently be a C_1 - C_{10} alkyl group (for example, a methyl group, an ethyl group, or a propyl group).

[0210] In Formula 302, k and l may each independently be an integer from 0 to 4. In an exemplary embodiment, k and l may be 0, 1, or 2.

[0211] 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. In one or more embodiments, due to a stacked structure including a red emission layer, a green emission layer, and/or a blue emission layer, the emission layer may emit white light.

[0212] When the emission layer includes a host and a dopant, an amount of the dopant may be in a range of about 0.01 parts by weight to about 15 parts by weight based on 100 parts by weight of the host, but embodiments of the present disclosure are not limited thereto.

[0213] 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. 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.

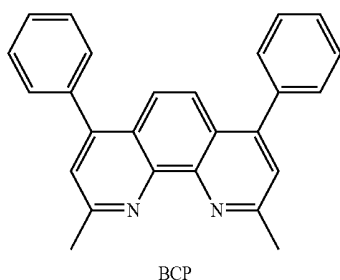
[0214] Then, an electron transport region may be disposed on the emission layer.

[0215] The electron transport region may include a hole blocking layer, an electron transport layer, an electron injection layer, or any combination thereof.

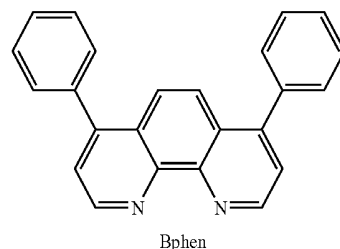
[0216] In an exemplary embodiment, the electron transport region may have a hole blocking layer/electron transport layer/electron injection layer structure or an electron transport layer/electron injection layer structure, but the structure of the electron transport region is not limited thereto. The electron transport layer may have a single-layered structure or a multi-layered structure including two or more different materials.

[0217] Conditions for forming the hole blocking layer, the electron transport layer, and the electron injection layer which constitute the electron transport region may be understood by referring to the conditions for forming the hole injection layer.

[0218] When the electron transport region includes a hole blocking layer, the hole blocking layer may include, for example, BCP, Bphen, BAlq, or a combination thereof, but embodiments of the present disclosure are not limited thereto:

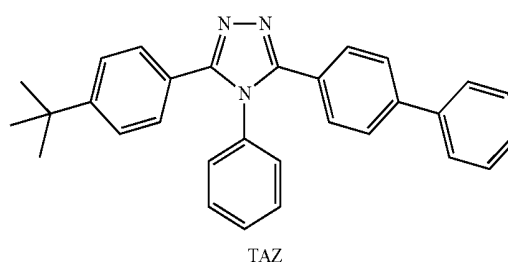
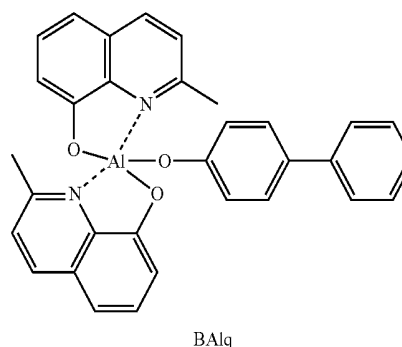
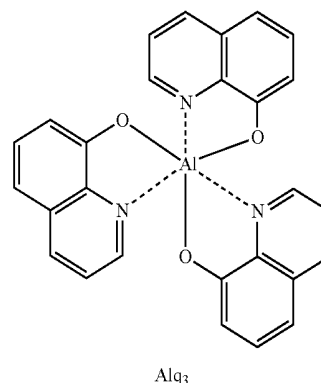


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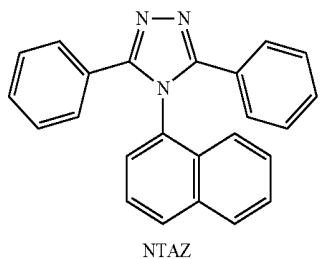


[0219] A thickness of the hole blocking layer may be in a range of about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. When the thickness of the hole blocking layer is within these ranges, the hole blocking layer may have improved hole blocking ability without a substantial increase in driving voltage.

[0220] The electron transport layer may include BCP, Bphen, Alq₃, BAlq, TAZ, NTAZ, or a combination thereof:



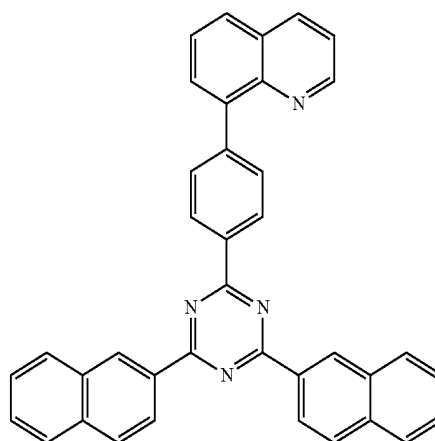
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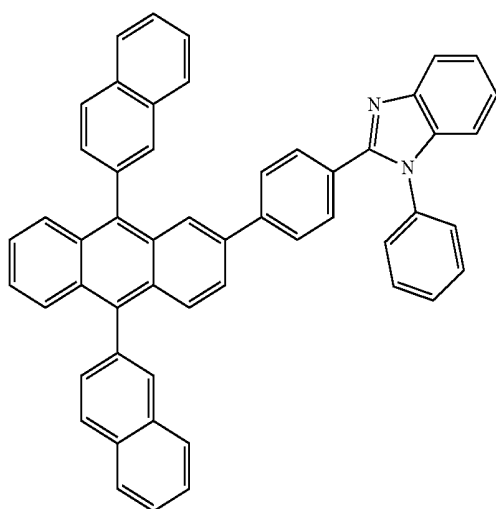
[0221] In one or more embodiments, the electron transport layer may include at least one ET1 to ET25, but are not limited thereto:

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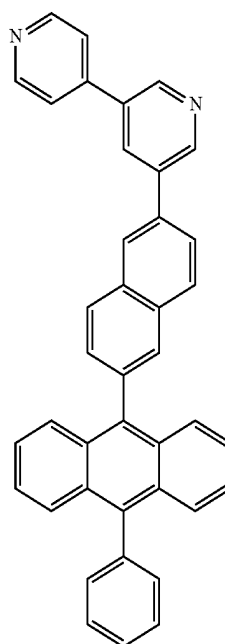
ET3



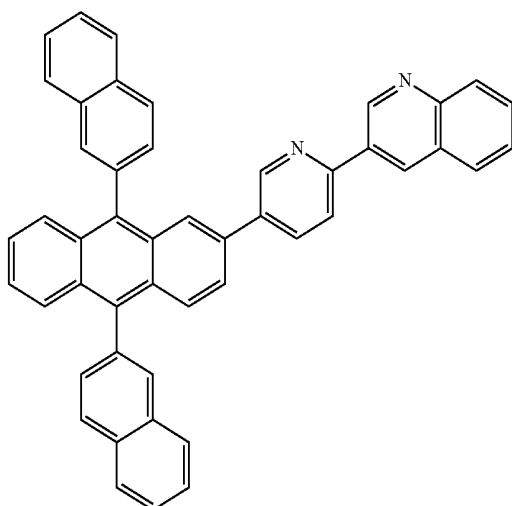
ET1



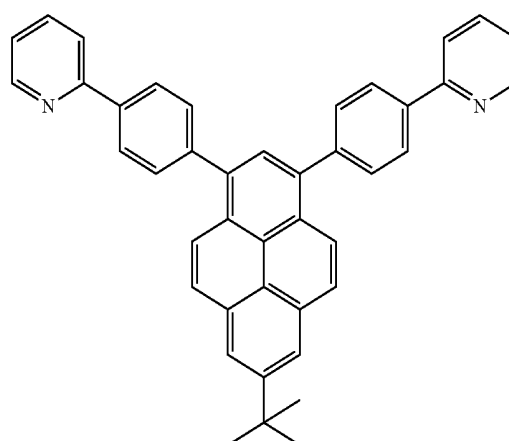
ET4



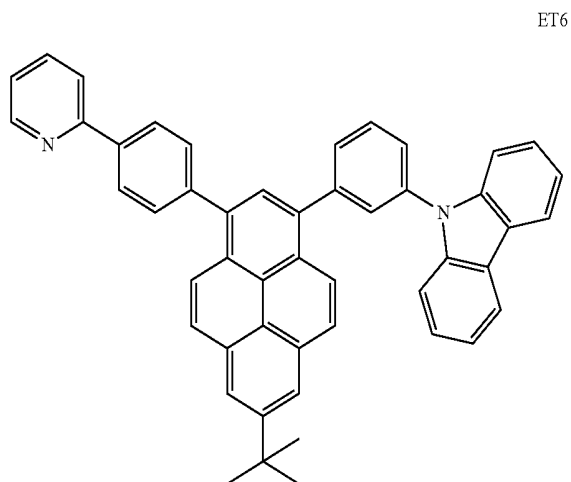
ET2



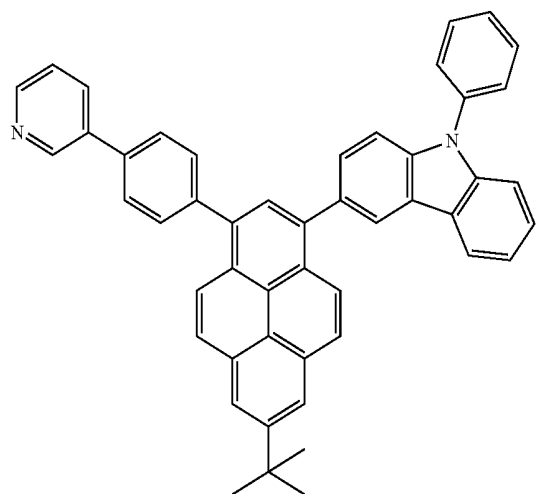
ET5



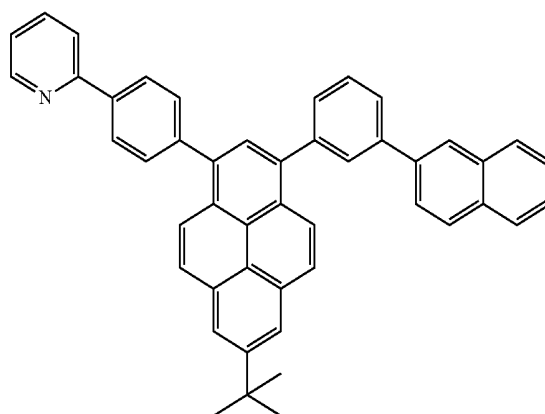
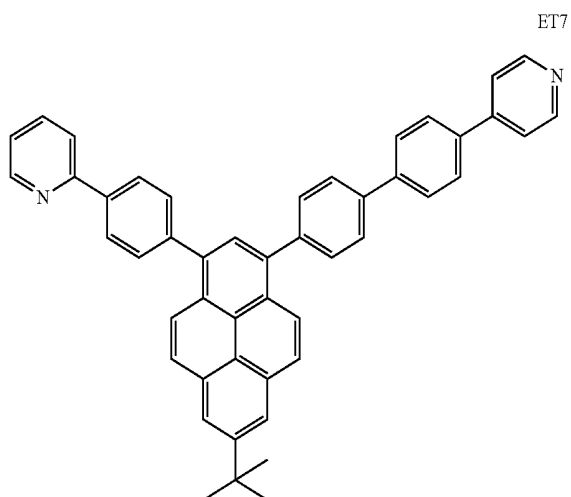
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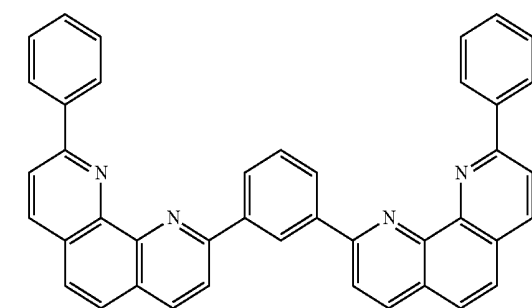
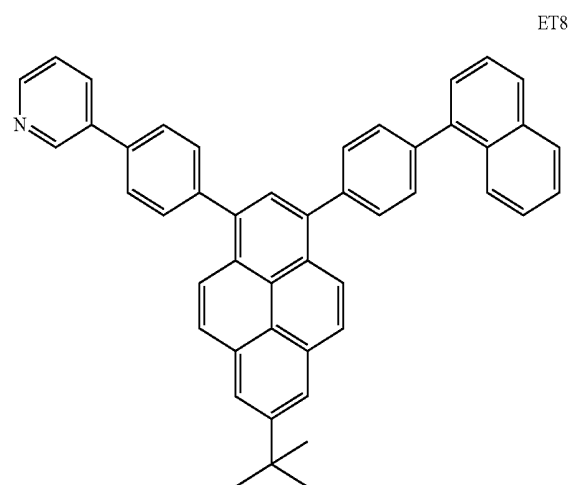
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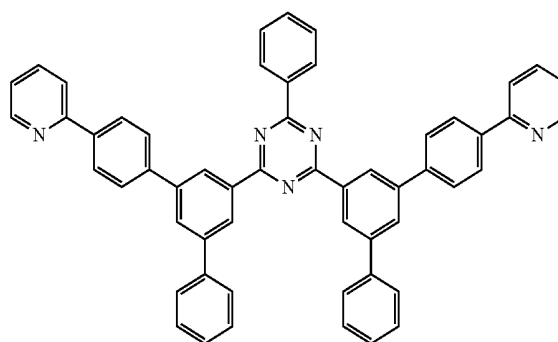
ET10



ET11

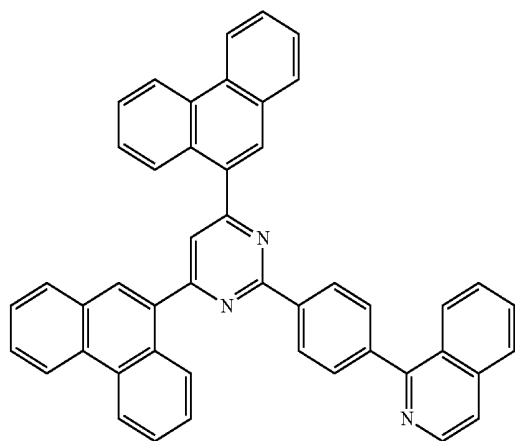


ET12



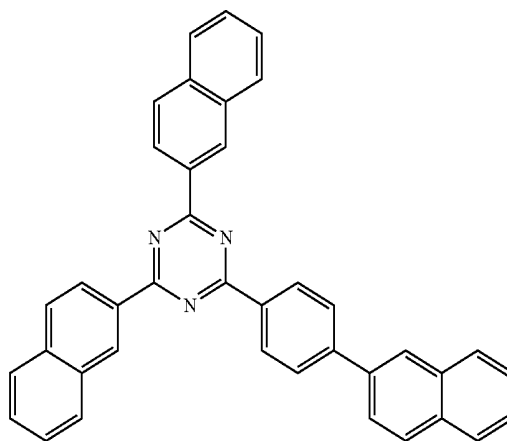
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ET13

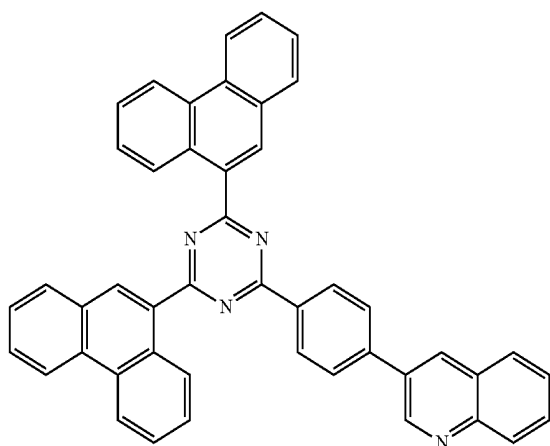


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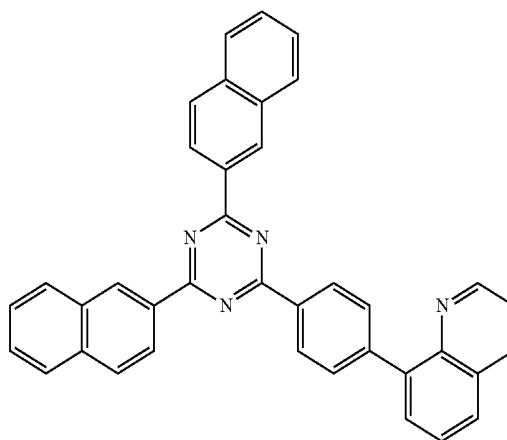
ET16



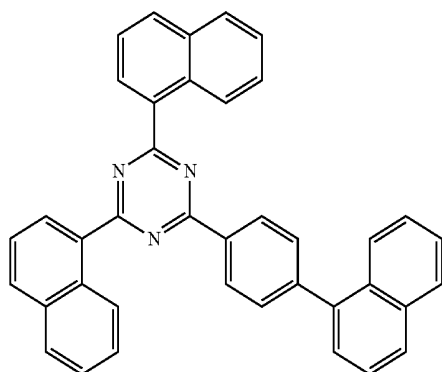
ET14



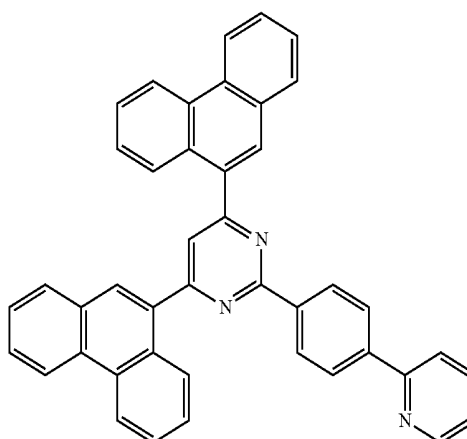
ET17



ET15

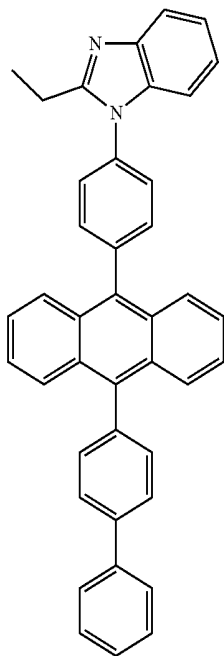


ET18

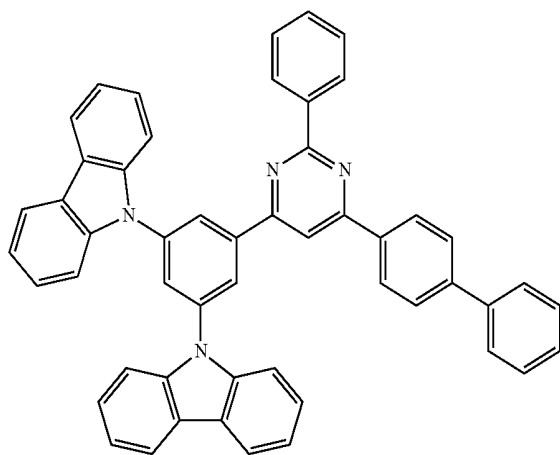


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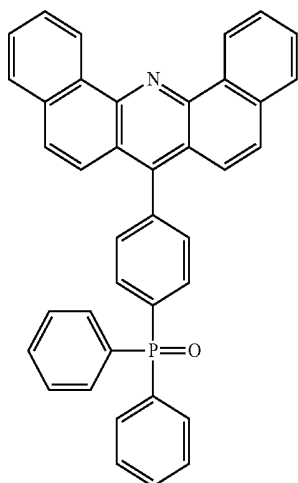
ET19



ET20

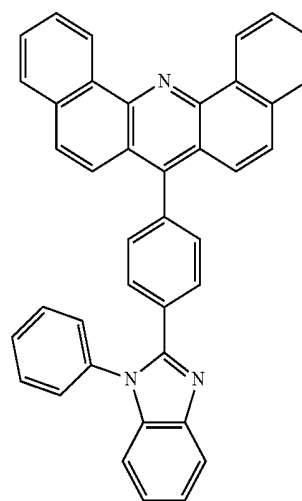


ET21

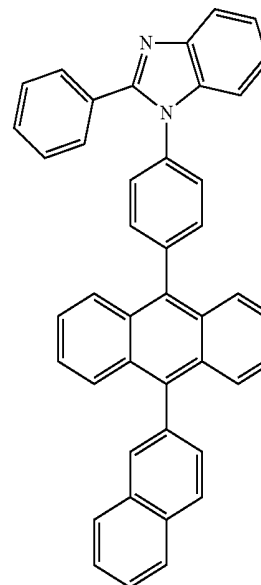


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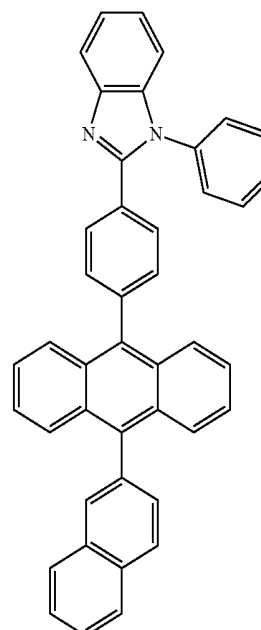
ET22



ET23

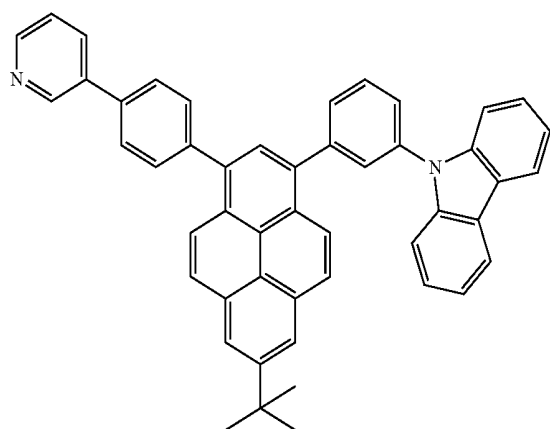


ET24



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ET25

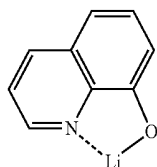


[0222] A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, for example, about 150 Å to about 500 Å. When the thickness of the electron transport layer is within the range described above, the electron transport layer may have satisfactory electron transport characteristics without a substantial increase in driving voltage.

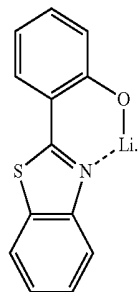
[0223] Also, the electron transport layer may further include, in addition to the materials described above, a metal-containing material.

[0224] The metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (LiQ) or ET-D2:

ET-D1



ET-D2



[0225] The electron transport region may include an electron injection layer that promotes flow of electrons from the second electrode 19 therein.

[0226] The electron injection layer may include LiF, NaCl, CsF, Li₂O, BaO, or a combination thereof.

[0227] 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. When the thickness of the electron injection layer is within the range described above, the

electron injection layer may have satisfactory electron injection characteristics without a substantial increase in driving voltage.

[0228] The second electrode 19 is disposed on the organic layer 15. The second electrode 19 may be a cathode. A material for forming the second electrode 19 may be a metal, an alloy, an electrically conductive compound, or a combination thereof, which have a relatively low work function. In an exemplary embodiment, lithium (Li), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), or magnesium-silver (Mg—Ag) may be used as a material for forming the second electrode 19. In one or more embodiments, to manufacture a top-emission type light-emitting device, a transmissive electrode formed using ITO or IZO may be used as the second electrode 19.

[0229] Hereinbefore, the organic light-emitting device has been described with reference to the FIGURE, but embodiments of the present disclosure are not limited thereto.

[0230] Another aspect of the present disclosure provides a diagnostic composition including an organometallic compound represented by Formula 1.

[0231] The organometallic compound represented by Formula 1 provides high luminescent efficiency. Accordingly, a diagnostic composition including the organometallic compound may have high diagnostic efficiency.

[0232] The diagnostic composition may be used in various applications including a diagnosis kit, a diagnosis reagent, a biosensor, and a biomarker.

[0233] The term “C₁-C₆₀ alkyl group” as used herein refers to a linear or branched saturated aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms, and non-limiting examples thereof include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an isoamyl group, and a hexyl group. The term “C₁-C₆₀ alkylene group” as used herein refers to a divalent group having the same structure as the C₁-C₆₀ alkyl group.

[0234] The term “C₁-C₆₀ alkoxy group” as used herein refers to a monovalent group represented by —OA₁₀₁ (wherein A₁₀₁ is the C₁-C₆₀ alkyl group), and non-limiting examples thereof include a methoxy group, an ethoxy group, and an isopropoxy group.

[0235] The term “C₂-C₆₀ alkenyl group” as used herein refers to a hydrocarbon group formed by substituting at least one carbon-carbon double bond for a carbon-carbon single bond anywhere in the chain of the C₂-C₆₀ alkyl group, and examples thereof include an ethenyl group, a propenyl group, and a butenyl group. The term “C₂-C₆₀ alkenylene group” as used herein refers to a divalent group having the same structure as the C₂-C₆₀ alkenyl group.

[0236] The term “C₂-C₆₀ alkynyl group” as used herein refers to a hydrocarbon group formed by substituting at least one carbon-carbon triple bond for a carbon-carbon single bond anywhere in the chain of the C₂-C₆₀ alkyl group, and examples thereof include an ethynyl group, and a propynyl group. The term “C₂-C₆₀ alkynylene group” as used herein refers to a divalent group having the same structure as the C₂-C₆₀ alkynyl group.

[0237] The term “C₃-C₁₀ cycloalkyl group” as used herein refers to a monovalent saturated hydrocarbon monocyclic or multi-cyclic group having 3 to 10 carbon atoms, and non-limiting examples thereof include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group,

and a cycloheptyl group. The term “C₃-C₁₀ cycloalkylene group” as used herein refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkyl group.

[0238] The term “C₁-C₁₀ heterocycloalkyl group” as used herein refers to a monovalent saturated monocyclic group having at least one heteroatom selected from N, O, P, Si and S as a ring-forming atom and 1 to 10 carbon atoms, and non-limiting examples thereof include a tetrahydrofuran group, and a tetrahydrothiophenyl group. The term “C₁-C₁₀ heterocycloalkylene group” as used herein refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkyl group.

[0239] The term “C₃-C₁₀ cycloalkenyl group” as used herein refers to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one carbon-carbon double bond in the ring thereof and no aromaticity, and non-limiting examples thereof include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term “C₃-C₁₀ cycloalkenylene group” as used herein refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkenyl group.

[0240] The term “C₁-C₁₀ heterocycloalkenyl group” as used herein refers to a monovalent monocyclic group that has at least one heteroatom selected from N, O, P, Si, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one double bond in its ring. Examples of the C₁-C₁₀ heterocycloalkenyl group are a 2,3-dihydrofuran group, and a 2,3-dihydrothiophenyl group. The term “C₁-C₁₀ heterocycloalkenylene group” as used herein refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkenyl group.

[0241] The term “C₆-C₆₀ aryl group” as used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and the term “C₆-C₆₀ arylene group” as used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Non-limiting examples of the C₆-C₆₀ aryl group include 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.

[0242] The term “C₁-C₆₀ heteroaryl group” as used herein refers to a monovalent group having a heteroaromatic system that has at least one heteroatom selected from N, O, P, Si, and S as a ring-forming atom, and 1 to 60 carbon atoms. The term “C₁-C₆₀ heteroarylene group” as used herein refers to a divalent group having a heteroaromatic system that has at least one heteroatom selected from N, O, P, Si, and S as a ring-forming atom, and 1 to 60 carbon atoms. Non-limiting examples of the C₁-C₆₀ heteroaryl group include 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.

[0243] The term “C₆-C₆₀ aryloxy group” as used herein indicates —OA₁₀₂ (wherein A₁₀₂ is the C₆-C₆₀ aryl group), and a C₆-C₆₀ arylthio group used herein indicates —SA₁₀₃ (wherein A₁₀₃ is the C₆-C₆₀ aryl group).

[0244] The term “monovalent non-aromatic condensed polycyclic group” as used herein refers to a monovalent group (for example, having 8 to 60 carbon atoms) having two or more rings condensed to each other, only carbon

atoms as ring-forming atoms, and no aromaticity in its entire molecular structure. Examples of the monovalent non-aromatic condensed polycyclic group include a fluorenyl group. The term “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.

[0245] The term “monovalent non-aromatic condensed heteropolycyclic group” as used herein refers to a monovalent group (for example, having 2 to 60 carbon atoms) having two or more rings condensed to each other, a heteroatom selected from N, O, P, Si, and S, other than carbon atoms, as a ring-forming atom, and no aromaticity in its entire molecular structure. Non-limiting examples of the monovalent non-aromatic condensed heteropolycyclic group include a carbazolyl group. The term “divalent non-aromatic condensed heteropolycyclic group” as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

[0246] The term “C₅-C₃₀ carbocyclic group” as used herein refers to a saturated or unsaturated cyclic group having, as a ring-forming atom, 5 to 30 carbon atoms only. The C₅-C₃₀ carbocyclic group may be a monocyclic group or a polycyclic group.

[0247] The term “C₂-C₃₀ heterocyclic group” as used herein refers to a saturated or unsaturated cyclic group having, as a ring-forming atom, at least one heteroatom selected from N, O, Si, P, and S other than 2 to 30 carbon atoms. The C₂-C₃₀ heterocyclic group may be a monocyclic group or a polycyclic group.

[0248] A substituent of the substituted C₅-C₃₀ carbocyclic group, the substituted C₂-C₃₀ heterocyclic group, the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, the substituted monovalent non-aromatic condensed heteropolycyclic group, or a combination thereof may be:

[0249] 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-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, or a C₁-C₆₀ alkoxy group;

[0250] a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, or a C₁-C₆₀ alkoxy group, each substituted with 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 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, —N(Q₁₁)(Q₁₂), —Si(Q₁₃)(Q₁₄)(Q₁₅), —Ge(Q₁₃)(Q₁₄)(Q₁₅), —B(Q₁₆)(Q₁₇), —P(=O)(Q₁₈)(Q₁₉), —P(Q₁₈)(Q₁₉), or a combination thereof;

[0251] 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, or a monovalent non-aromatic condensed heteropolycyclic group;

[0252] 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, or a monovalent non-aromatic condensed heteropolycyclic group, each substituted with 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-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, —N(Q₂₁)(Q₂₂), —Si(Q₂₃)(Q₂₄)(Q₂₅), —Ge(Q₂₃)(Q₂₄)(Q₂₅), —B(Q₂₆)(Q₂₇), —P(=O)(Q₂₈)(Q₂₉), —P(Q₂₈)(Q₂₉), or a combination thereof;

[0253] —N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₅), —Ge(Q₃₃)(Q₃₄)(Q₃₅), —B(Q₃₆)(Q₃₇), —P(=O)(Q₃₈)(Q₃₉), or —P(Q₃₈)(Q₃₉); or

[0254] any combination thereof.

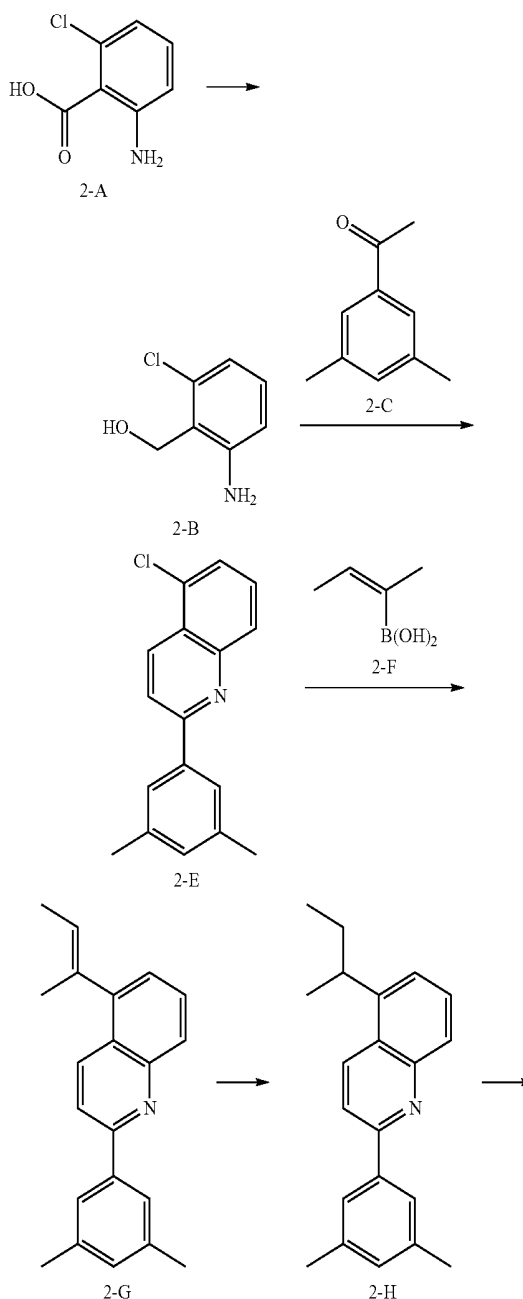
[0255] The Q₁ to Q₉, Q₁₁ to Q₁₉, Q₂₁ to Q₂₉, and Q₃₁ to Q₃₉ may each independently be hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-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 aryl group substituted with at least one of a C₁-C₆₀ alkyl group and 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, or a monovalent non-aromatic condensed heteropolycyclic group.

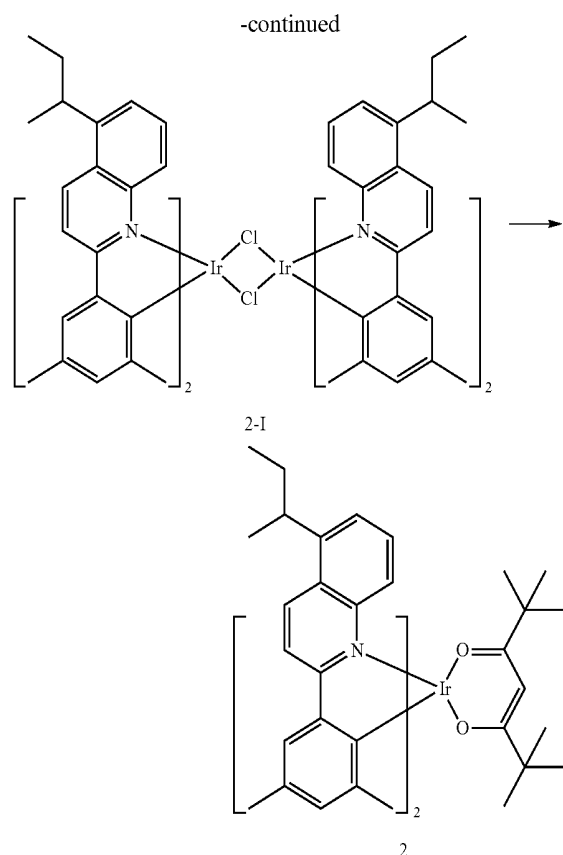
[0256] Hereinafter, a compound and an organic light-emitting device according to embodiments are described in detail with reference to Synthesis Example and Examples. However, the organic light-emitting device is not limited thereto. The wording “B was used instead of A” as used in describing Synthesis Examples means that an amount of A used was identical to an amount of B used, in terms of a molar equivalent.

EXAMPLES

Synthesis Example 1 (Compound 2)

[0257]





Synthesis of Intermediate 2-B

[0258] (17.48 mmol) of a starting material 2-A was mixed with 72 mL of tetrahydrofuran (THF), and the mixture was cooled to a temperature of 0° C. 29 mL of 1M LiAlH₄ in THF solution was added dropwise thereto. Then, the mixture was heated to room temperature and refluxed overnight. 1 mL of water was added to a reactant obtained therefrom, 2 mL of 50% NaOH (aq) was added thereto, and ethyl acetate (EA) was added thereto to extract an organic layer therefrom. The extracted organic layer was dried, and column chromatography was performed thereon to obtain 3.0 g (yield of 82%) of Intermediate 2-B.

Synthesis of Intermediate 2-E

[0259] 3 g (19.04 mmol) of Intermediate 2-B, 4.23 g (28.55 mmol) of starting material 2-C, 0.18 g (0.190 mmol) of RuCl₂(PPh₃)₃, and 1.92 g (34.26 mmol) of KOH were mixed with 53 mL of toluene and refluxed overnight at a temperature of 120° C. The result obtained therefrom was cooled to room temperature and washed with water. Then, column chromatography was performed thereon to obtain 4.4 g (yield of 48%) of Intermediate 2-E. The obtained compound was identified by LC-MS analysis.

[0260] LC-MS $m/z=268.14$ (M+H)+.

Synthesis of Intermediate 2-G

[0261] 4.4 g (16.43 mmol) of Intermediate 2-E, 1.81 g (18.08 mmol) of starting material 2-F, 0.37 g (1.64 mmol) of Pd(OAc)₂, 6.81 g (49.30 mmol) of K₂CO₃, and 2.70 g (3.29 mmol) of S-phos were mixed with 154 mL of dioxane and

38 mL of H₂O and refluxed overnight at a temperature of 90° C. The result obtained therefrom was cooled to room temperature and washed with water and methylene chloride. Then, column chromatography was performed thereon to obtain 3.8 g (yield of 80%) of Intermediate 2-G. The obtained compound was identified by LC-MS analysis. LC-MS: $m/z=288.28$ (M+H)+.

Synthesis of Intermediate 2-H

[0262] 1.8 g (6.26 mmol) of Intermediate 2-G was mixed with methanol, and 0.36 g of Pd on carbon was added thereto. A hydrogen gas was bubbled into a reactant obtained therefrom for 6 hours or more. After the reaction was completed, MeOH was removed therefrom, and the reaction product was washed with H₂O and methylene chloride. Then, column chromatography was performed thereon to obtain 0.8 g (yield of 44%) of Intermediate 2-H. The obtained compound was identified by LC-MS analysis.

[0263] LC-MS: $m/z=290.20$ (M+H)+.

Synthesis of Intermediate 2-I

[0264] 0.40 g (1.13 mmol) of IrCl₃·4H₂O, 14 mL of 2-ethoxyethanol, and 4.5 mL of H₂O were added to 0.74 g (2.55 mmol) of Intermediate 2-H and refluxed overnight at a temperature of 120° C. A result obtained therefrom was cooled to room temperature, filtered, washed with methanol, and then dried to obtain 0.65 g of Intermediate 2-I.

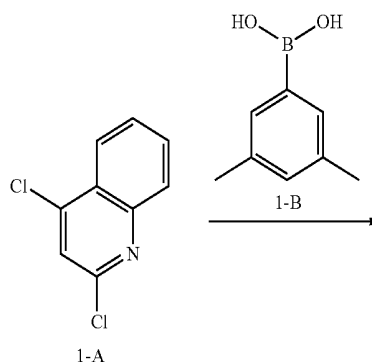
Synthesis of Compound 2

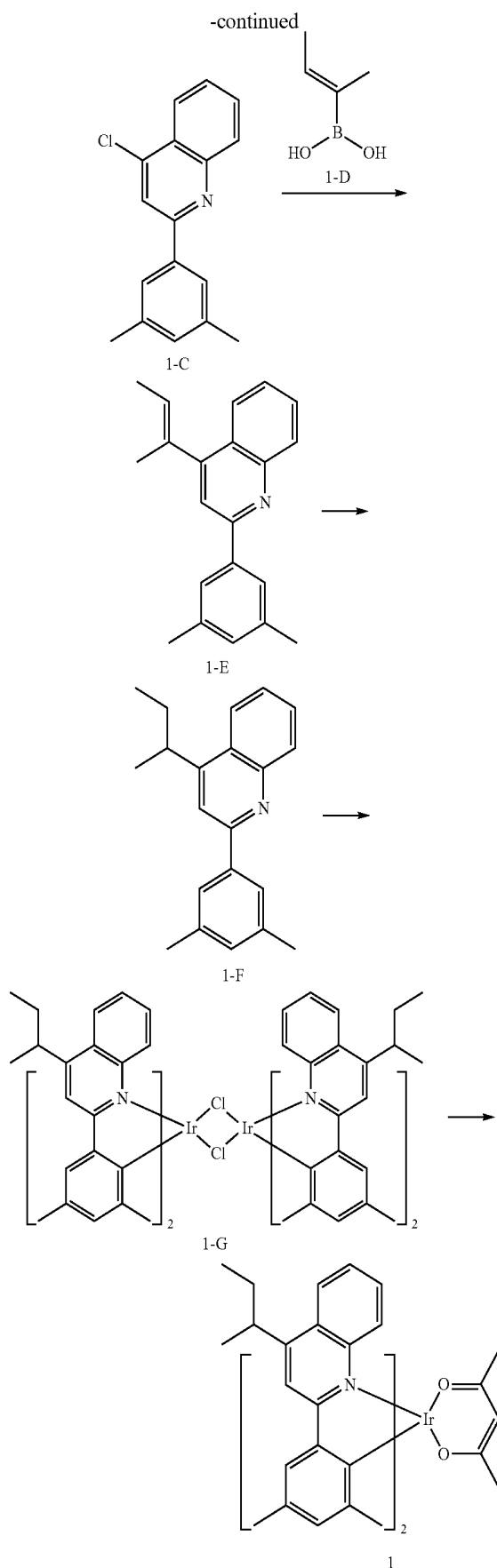
[0265] 0.65 g (0.40 mmol) of Intermediate 2-I, 0.74 g (4.04 mmol) of 2,2,6,6-tetramethylheptane-3,5-dione, and 0.56 g (4.04 mmol) of K₂CO₃ were mixed with 22 mL of 2-ethoxyethanol and stirred overnight at room temperature. A result obtained therefrom was washed with ethyl acetate and H₂O. Then, column chromatography was performed thereon to obtain 0.43 g (yield of 57%) of Compound 2. The obtained compound was identified by LC-MS analysis.

[0266] LC-MS/ $m/z=953.27$ (M+H)+.

Synthesis Example 2 (Compound 1)

[0267]





Synthesis of Intermediate 1-C

[0268] 3.70 g (18.67 mmol) of a starting material 1-A, 2.94 g (19.61 mmol) of a starting material 1-B, 1.08 g (0.93 mmol) of $\text{Pd}(\text{PPh}_3)_4$, and 6.45 g (46.68 mmol) of K_2CO_3 were mixed with 60 mL of THF and 30 mL of H_2O and refluxed overnight at a temperature of 90°C . A result obtained therefrom was cooled to room temperature and washed with water and methylene chloride. Then, column chromatography was performed thereon to obtain 4.00 g (yield of 80%) of Intermediate 1-C. The obtained compound was identified by LC-MS analysis.

[0269] LC-MS $m/z=268.12$ (M+H)+.

Synthesis of Intermediate 1-E

[0270] 4.00 g (14.96 mmol) of Intermediate 1-C, 1.79 g (18.95 mmol) of starting material 1-D, 0.17 g (0.75 mmol) of $\text{Pd}(\text{OAc})_2$, 5.17 g (37.40 mmol) of K_2CO_3 , and 0.61 g (1.50 mmol) of S-phos were mixed with 50 mL of THF and 25 mL of H_2O and refluxed overnight at a temperature of 90°C . A result obtained therefrom was cooled to room temperature and washed with water and methylene chloride. Then, column chromatography was performed thereon to obtain 2.20 g (yield of 51%) of Intermediate 1-E. The obtained compound was identified by LC-MS analysis.

[0271] LC-MS $m/z=288.22$ (M+H)+

Synthesis of Intermediate 1-F

[0272] 2.20 g (7.60 mmol) of Intermediate 1-E was mixed with methanol, and 0.24 g of Pd on carbon was added thereto. A hydrogen gas was bubbled into a reactant obtained therefrom for 6 hours or more. After the reaction was completed, MeOH was removed therefrom, and the reaction product was washed with H_2O and methylene chloride.

[0273] Then, column chromatography was performed thereon to obtain 1.55 g (yield of 70%) of Intermediate 1-F. The obtained compound was identified by LC-MS analysis.

[0274] LC-MS $m/z=290.22$ (M+H)+.

Synthesis of Intermediate 1-G

[0275] 0.96 g (2.73 mmol) of $\text{IrCl}_3 \cdot 4\text{H}_2\text{O}$, 10 mL of 2-ethoxyethanol, and 3.5 mL of H_2O were added to 1.58 g (5.47 mmol) of Intermediate 1-F and refluxed overnight at a temperature of 120°C . A result obtained therefrom was cooled to room temperature, filtered, washed with methanol, and then dried to obtain 1.35 g of Intermediate 1-G.

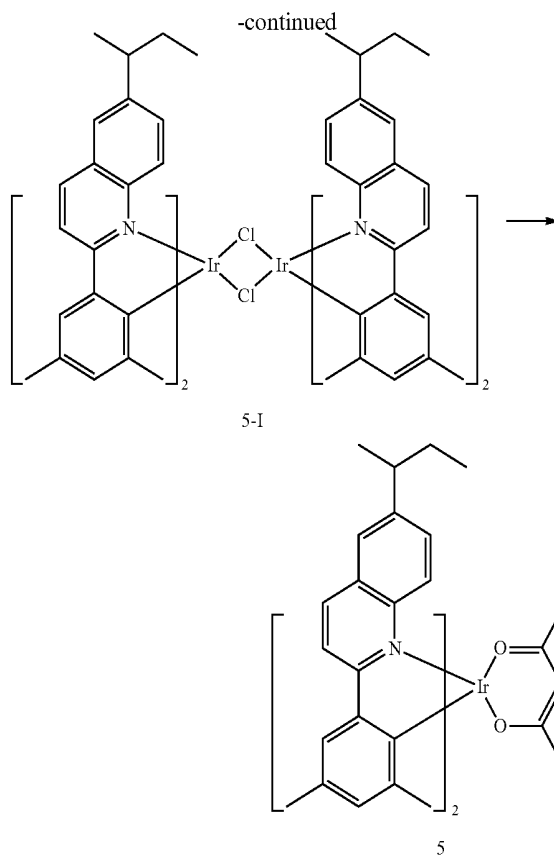
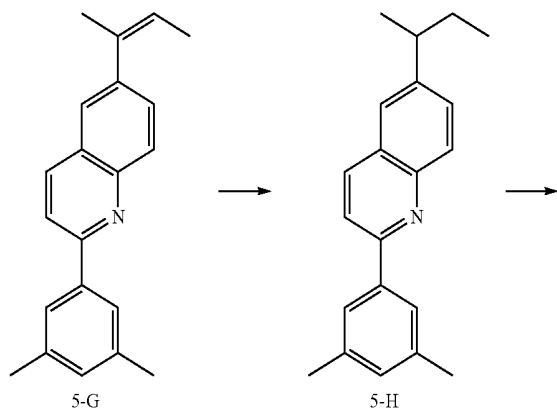
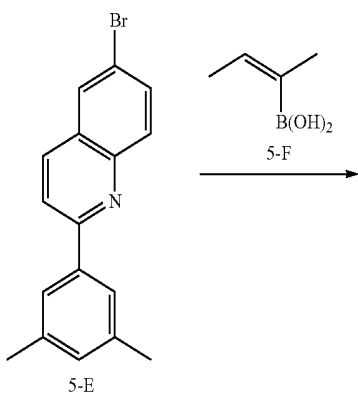
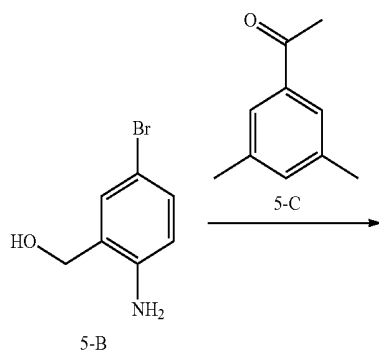
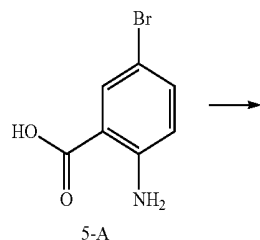
Synthesis of Compound 1

[0276] 1.35 g (0.86 mmol) of Intermediate 1-G, 0.89 g (8.64 mmol) of pentane-2,4-dione, and 0.91 g (8.64 mmol) of Na_2CO_3 were mixed with 17 mL of 2-ethoxyethanol and refluxed overnight. A result obtained therefrom was washed with ethyl acetate and H_2O . Then, column chromatography was performed thereon to obtain 0.50 g (yield of 33%) of Compound 1. The obtained compound was identified by LC-MS analysis.

[0277] LC-MS $m/z=869.36$ (M+H)+.

Synthesis Example 3 (Compound 5)

[0278]



Synthesis of Intermediate 5-B

[0279] 3.33 g (yield of 89%) of Intermediate 5-B was obtained in the same manner as in Synthesis of Intermediate 2-B in Synthesis Example 1, except that 4.00 g (18.52 mmol) of a starting material 5-A was used instead of the starting material 2-A.

Synthesis of Intermediate 5-E

[0280] 3.09 g (yield of 60%) of Intermediate 5-E was obtained in the same manner as in Synthesis of Intermediate 2-E in Synthesis Example 1, except that 3.33 g (16.48 mmol) of Intermediate 5-B was used instead of Intermediate 2-B, and 3.66 g (24.72 mmol) of starting material 5-C was used instead of starting material 2-C.

Synthesis of Intermediate 5-G

[0281] 2.26 g (yield of 82%) of Intermediate 5-G was obtained in the same manner as in Synthesis of Intermediate 2-G in Synthesis Example 1, except that 3.00 g (9.61 mmol) of Intermediate 5-E was used instead of Intermediate 2-E, and 1.06 g (10.57 mmol) of starting material 5-F was used instead of starting material 2-F. The obtained compound was identified by LC-MS analysis. LC-MS m/z =288.28 (M+H)⁺.

Synthesis of Intermediate 5-H

[0282] 1.22 g (yield of 55%) of Intermediate 5-H was obtained in the same manner as in Synthesis of Intermediate 2-H in Synthesis Example 1, except that 2.2 g (7.65 mmol) of Intermediate 5-G was used instead of Intermediate 2-G.

The obtained compound was identified by LC-MS analysis. LC-MS $m/z=290.20$ (M+H)+.

Synthesis of Intermediate 5-1

[0283] 1.00 g of Intermediate 5-1 was obtained in the same manner as in Synthesis of Intermediate 2-1, except that 1.22 g (4.22 mmol) of Intermediate 5-H was used instead of Intermediate 2-H.

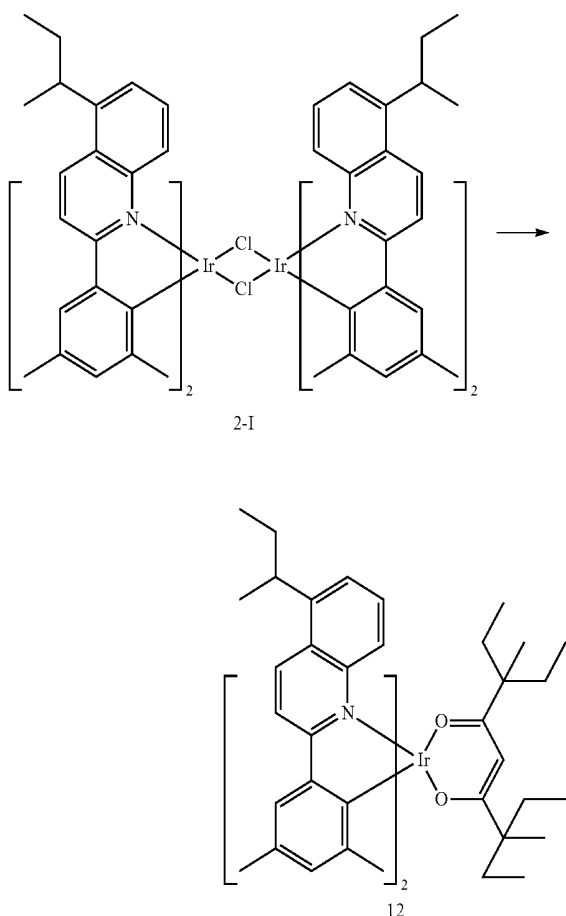
Synthesis of Compound 5

[0284] 0.72 g (yield of 55%) of Compound 5 was obtained in the same manner as in Synthesis of Compound 2 of Synthesis Example 1, except that 1.00 g (0.97 mmol) of Intermediate 5-1 was used instead of Intermediate 2-1, and pentane-2,4-dione was used instead of 2,2,6,6-tetramethylheptane-3,5-dione. The obtained compound was identified by LC-MS analysis.

[0285] LC-MS: $m/z=869.40$ (M+H)+.

Synthesis Example 4 (Compound 12)

[0286]



[0287] 1.10 g (yield of 65%) of Compound 12 was obtained in the same manner as in Synthesis of Compound

2 of Synthesis Example 1, except that 3,7-diethyl-3,7-dimethylnonane-4,6-dione was used instead of 2,2,6,6-tetramethylheptane-3,5-dione.

[0288] LC-MS: $m/z=1008.61$ (M+H)+.

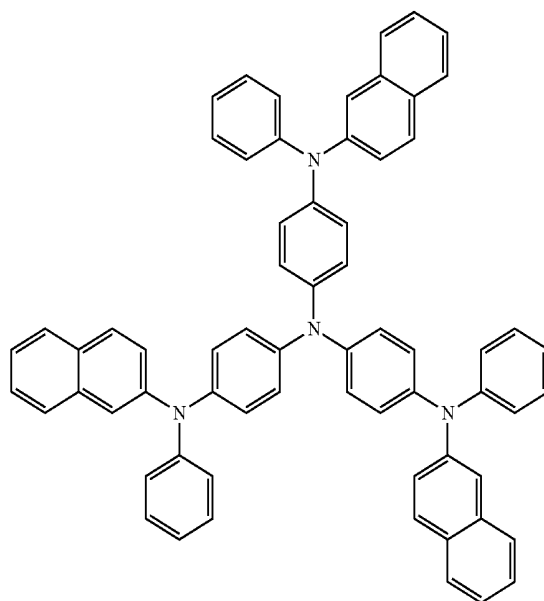
Example 1

[0289] As an anode, a glass substrate, on which ITO/Ag/ITO were deposited to thicknesses of 70 Å/1,000 Å/70 Å, was cut to a size of 50 mm×50 mm×0.5 mm, sonicated with isopropyl alcohol and pure water each for 5 minutes, and then cleansed by exposure to ultraviolet rays and ozone for 30 minutes. Then, the glass substrate was provided to a vacuum deposition apparatus.

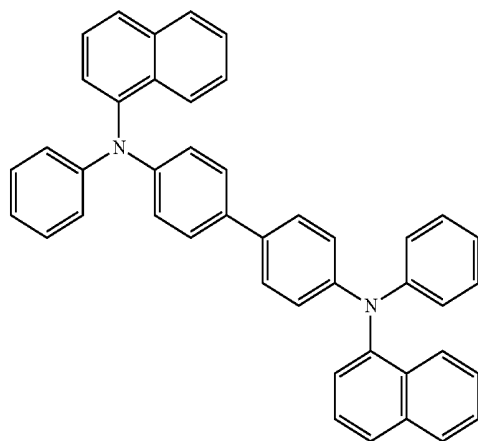
[0290] 2-TNATA was vacuum-deposited on the anode to form a hole injection layer having a thickness of 600 Å, and 4,4'-bis[N-(1-naphthyl)-N-phenylamino]biphenyl (NPB) was vacuum-deposited on the hole injection layer to form a hole transport layer having a thickness of 1,350 Å.

[0291] Then, CBP (host) and Compound 2 (dopant) were co-deposited on the hole transport layer at a weight ratio of 98:2 to form an emission layer having a thickness of 400 Å.

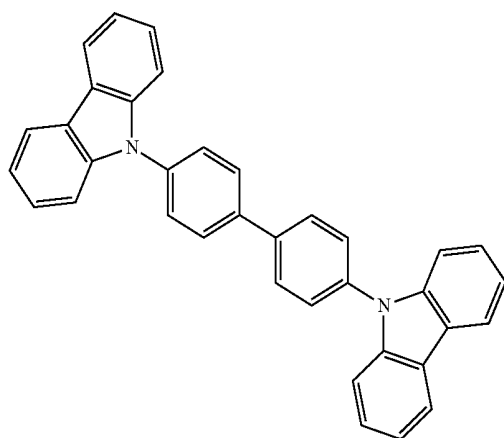
[0292] Then, BCP was vacuum-deposited on the emission layer to form a hole blocking layer having a thickness of 50 Å, Alq₃ was vacuum-deposited on the hole blocking layer to form an electron transport layer having a thickness of 350 Å, LiF was vacuum-deposited on the electron transport layer to form an electron injection layer having a thickness of 10 Å, and Mg and Ag were co-deposited on the electron injection layer at a weight ratio of 90:10 to form a cathode having a thickness of 120 Å, thereby completing the manufacture of an organic light-emitting device (which emits red light).



-continued

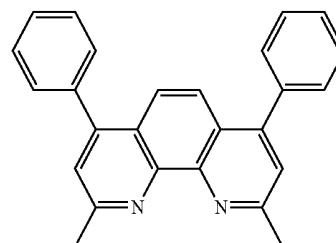


NPB



CBP

-continued



BCP

Examples 2 to 4 and Comparative Examples A to F

[0293] Organic light-emitting devices were manufactured in the same manner as in Example 1, except that Compounds shown in Table 1 were each used instead of Compound 2 as a dopant in forming an emission layer.

Evaluation Example 1: Evaluation of Characteristics of Organic Light-Emitting Devices

[0294] The driving voltage, current density, external quantum luminescent efficiency (EQE), roll-off ratio, full width at half maximum (FWHM) and peak wavelength of emission peaks in EL spectra, and lifespan (LT_{97}) of the organic light-emitting devices manufactured according to Examples 1 to 4 and Comparative Examples A to F are evaluated, and results thereof are shown in Table 1. A current-voltage meter (KEITHLEY 2400) and a luminance meter (MINOLTA Cs-1000 A) were used as the evaluation apparatuses, and the lifespan (LT_{97}) (at 3,500 nit) indicates the time that lapsed when luminance was 97% of initial luminance (100%). The roll-off ratio was calculated by Equation 20 below.

$$\text{Roll off ratio} = \{1 - (\text{Efficiency (at 3,500 nit)} / \text{Maximum luminescent efficiency})\} \times 100\% \quad \text{Equation 20}$$

TABLE 1

	Dopant in emission layer	Driving voltage (V)	Current density (mA/cm ²)	Max EQE (%)	Roll-Off ratio (%)	FWHM (nm)	peak wavelength (nm)	LT_{97} (hr)
Example 1	Compound 2	5.35	17.4	25.8	10	62.47	617	250
Example 2	Compound 1	5.02	17.3	26.8	11	58.64	608	226
Example 3	Compound 5	5.06	17.3	26.0	13	61.98	614	207
Example 4	Compound 12	5.10	16.7	27.8	10	62.75	619	280
Comparative Example A	Compound A	5.49	12.2	20.4	28	82.39	623	50
Comparative Example B	Compound B	9.82	670.2	13.7	89	23.6	652	1
Comparative Example C	Compound C	5.81	20.1	21.2	25	78.21	602	22
Comparative Example D	Compound D	5.65	19.4	21.8	17	68.17	615	80
Comparative Example E	Compound E	5.65	19.4	22.8	16	63.57	614	23

TABLE 1-continued

	Dopant in emission layer	Driving voltage (V)	Current density (mA/cm ²)	Max EQE (%)	Roll-Off ratio (%)	FWHM (nm)	peak wavelength (nm)	LT ₉₇ (hr)
Comparative Example F	Compound F	5.80	20.0	25.9	13	59.41	616	150

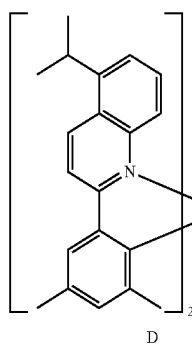
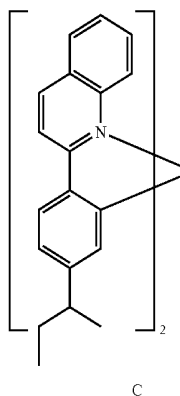
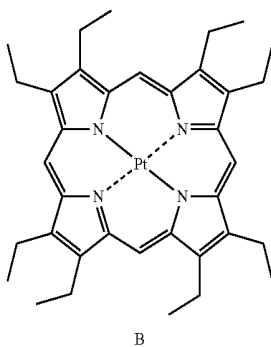
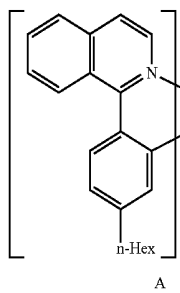
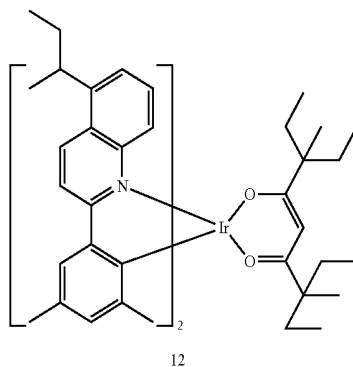
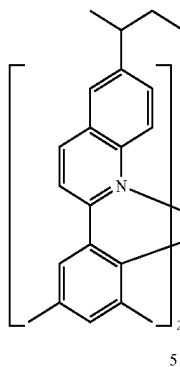
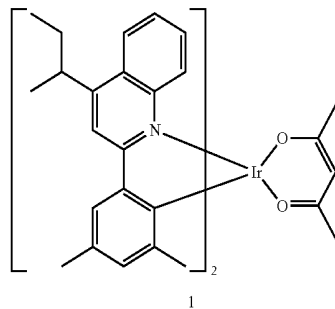
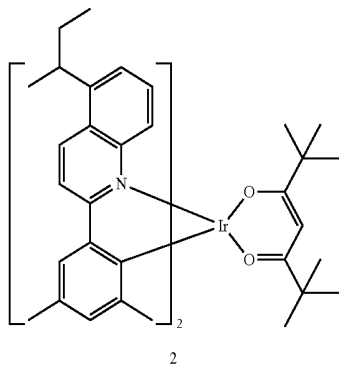
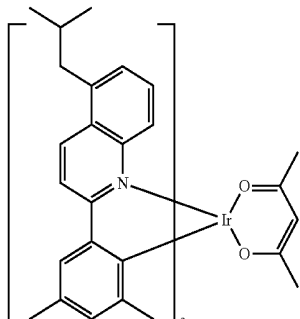
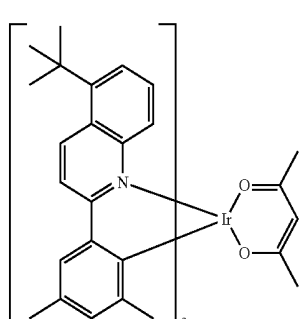


TABLE 1-continued

Dopant in emission layer	Driving voltage (V)	Current density (mA/cm ²)	Max EQE (%)	Roll-Off ratio (%)	FWHM (nm)	peak wavelength (nm)	LT ₉₇ (hr)
							
E							
							
F							

[0295] n-Hex in Compound A indicates an n-hexyl group.

[0296] Referring to Table 1, it was confirmed that the organic light-emitting devices of Examples 1 to 4 showed improved driving voltage, improved current density, improved external quantum luminescent efficiency, improved roll-off ratio, and improved lifespan characteristics compared to those of the organic light-emitting device of Comparative Examples A to F.

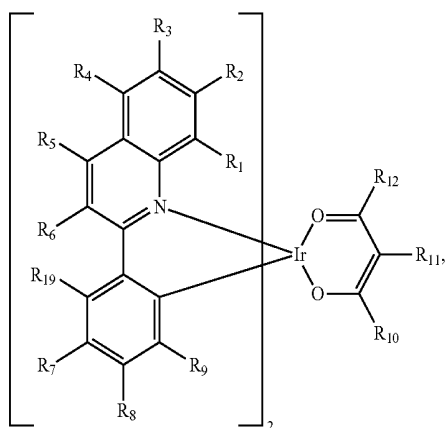
[0297] Since the organometallic compound has excellent electric characteristics and thermal stability, an organic light-emitting device including the organometallic compound may have excellent driving voltage, luminescent efficiency, quantum efficiency, roll-off ratio, and lifespan characteristics.

[0298] It should be understood that embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each embodiment should typically be considered as available for other similar features or aspects in other embodiments.

[0299] While one or more embodiments have been described with reference to the figures, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope as defined by the following claims.

What is claimed is:

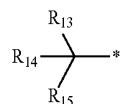
1. An organometallic compound represented by Formula 1:



Formula 1

wherein, in Formula 1, R₁ to R₁₂ and R₁₉ are each independently hydrogen, deuterium, —F, —Cl, —Br, —I, —SF₅, 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 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, —N(Q₁)(Q₂), —Si(Q₃)(Q₄)(Q₅), —Ge(Q₃)(Q₄)(Q₅), —B(Q₆)(Q₇), —P(=O)(Q₈)(Q₉), or —P(Q₈)(Q₉), and

at least one of R₁ to R₆ is each independently a group represented by Formula 2:



Formula 2

wherein the number of carbon atoms included in Formula 2 is 4 or more,

R₁₃ in Formula 2 is hydrogen, deuterium, a C₁-C₂₀ alkyl group, a deuterium-containing C₁-C₂₀ alkyl group, a C₃-C₁₀ cycloalkyl group, or a deuterium-containing C₃-C₁₀ cycloalkyl group,

R₁₄ and R₁₅ in Formula 2 are each independently a C₁-C₂₀ alkyl group, a deuterium-containing C₁-C₂₀ alkyl group, a C₃-C₁₀ cycloalkyl group, or a deuterium-containing C₃-C₁₀ cycloalkyl group,

provided that, R₁₃, R₁₄ and R₁₅ are not a methyl group, simultaneously,

* indicates a binding site to a neighboring atom,

two or more of R₁ to R₉ and R₁₉ in Formula 1 are optionally linked to form a C₅-C₃₀ carbocyclic group that is unsubstituted or substituted with R_{1a}, a C₂-C₃₀ heterocyclic group that is unsubstituted or substituted with R_{1a}, or a combination thereof

R_{1a} is the same as described in connection with R₇,

a substituent of the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, or the substituted monovalent non-aromatic condensed heteropolycyclic group is:

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-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, or a combination thereof;

a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, or a combination thereof each substituted with 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 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, —N(Q₁₁)(Q₁₂), —Si(Q₁₃)(Q₁₄)(Q₁₅), —Ge(Q₁₃)(Q₁₄)(Q₁₅), —B(Q₁₆)(Q₁₇), —P(=O)(Q₁₈)(Q₁₉), —P(Q₁₈)(Q₁₉), or a combination thereof;

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, or a combination thereof;

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 con-

densed heteropolycyclic group, or a combination thereof, each substituted with 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-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, —N(Q₂₁)(Q₂₂), —Si(Q₂₃)(Q₂₄)(Q₂₅), —Ge(Q₂₃)(Q₂₄)(Q₂₅), —B(Q₂₆)(Q₂₇), —P(=O)(Q₂₈)(Q₂₉), —P(Q₂₈)(Q₂₉), or a combination thereof;

—N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₅), —Ge(Q₃₃)(Q₃₄)(Q₃₅), —B(Q₃₆)(Q₃₇), —P(=O)(Q₃₈)(Q₃₉), or —P(Q₃₈)(Q₃₉); or

a combination thereof; and

Q₁ to Q₉, Q₁₁ to Q₁₉, Q₂₁ to Q₂₉, and Q₃₁ to Q₃₉ are each independently 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-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 aryl group substituted with at least one of a C₁-C₆₀ alkyl group and 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, or a monovalent non-aromatic condensed heteropolycyclic group.

2. The organometallic compound of claim 1, wherein

R₁ to R₁₂ and R₁₉ are each independently:

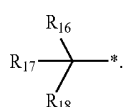
hydrogen, deuterium, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neopentyl group, an iso-pentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl 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, bicyclo[1.1.1]pentyl, bicyclo[2.1.1]hexyl, bicyclo[2.2.1]heptyl, a bicyclo[2.2.2]octyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a pyridinyl group, a

- pyrimidinyl group, a carbazolyl group, a fluorenyl group, a dibenzosilolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, or $-\text{Si}(\text{Q}_3)(\text{Q}_4)(\text{Q}_5)$;
- a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neopentyl group, an isopentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl 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, or a tert-decyl group, each substituted with deuterium;
- 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, bicyclo[1.1.1]pentyl, bicyclo[2.1.1]hexyl, bicyclo[2.2.1]heptyl, a bicyclo[2.2.2]octyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a carbazolyl group, a fluorenyl group, a dibenzosilolyl group, a dibenzofuranyl group, or a dibenzothiophenyl group, each substituted with deuterium, a $\text{C}_1\text{-C}_{100}$ alkyl group, or a combination thereof, and
- Q_3 to Q_5 are each independently:
- $-\text{CH}_3$, $-\text{CD}_3$, $-\text{CD}_2\text{H}$, $-\text{CDH}_2$, $-\text{CH}_2\text{CH}_3$, $-\text{CH}_2\text{CD}_3$, $-\text{CH}_2\text{CD}_2\text{H}$, $-\text{CH}_2\text{CDH}_2$, $-\text{CHDCD}_3$, $-\text{CHDCD}_2\text{H}$, $-\text{CHDCDH}_2$, $-\text{CHDCD}_3$, $-\text{CD}_2\text{CD}_3$, $-\text{CD}_2\text{CD}_2\text{H}$, or $-\text{CD}_2\text{CDH}_2$;
- an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, or a naphthyl group;
- an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with deuterium, a $\text{C}_1\text{-C}_{10}$ alkyl group, or a phenyl group.
3. The organometallic compound of claim 1, wherein one of R_2 to R_5 in Formula 1 is a group represented by Formula 2.
4. The organometallic compound of claim 1, wherein
- 1) R_2 is a group represented by Formula 2 and R_1 and R_3 to R_6 are hydrogen,
 - 2) R_3 is a group represented by Formula 2 and R_1 , R_2 and R_4 to R_6 are hydrogen,
 - 3) R_4 is a group represented by Formula 2 and R_1 to R_3 , R_5 and R_6 are hydrogen,
 - 4) R_5 is a group represented by Formula 2 and R_1 to R_4 and R_6 are hydrogen,
 - 5) R_4 is a group represented by Formula 2, R_5 is a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ alkyl group, a substituted or unsubstituted $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a phenyl group, a biphenyl group, or $-\text{Si}(\text{Q}_3)(\text{Q}_4)(\text{Q}_5)$ and R_1 , R_2 , R_3 and R_6 are hydrogen,
 - 6) R_5 is a group represented by Formula 2, R_3 is a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ alkyl group, a substituted or unsubstituted $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a phenyl group, a biphenyl group, or $-\text{Si}(\text{Q}_3)(\text{Q}_4)(\text{Q}_5)$ and R_1 , R_2 , R_4 and R_6 are hydrogen,
 - 7) R_2 is a group represented by Formula 2, R_5 is a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ alkyl group, a substituted or unsubstituted $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a phenyl group, a biphenyl group, or $-\text{Si}(\text{Q}_3)(\text{Q}_4)(\text{Q}_5)$ and R_1 , R_3 , R_4 and R_6 are hydrogen,
 - 8) R_4 is a group represented by Formula 2, R_6 is a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ alkyl group, a substituted or unsubstituted $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a phenyl group, a biphenyl group, or $-\text{Si}(\text{Q}_3)(\text{Q}_4)(\text{Q}_5)$ and R_1 , R_2 , R_3 and R_5 are hydrogen,
 - 9) R_3 is a group represented by Formula 2, R_5 is a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ alkyl group, a substituted or unsubstituted $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a phenyl group, a biphenyl group, or $-\text{Si}(\text{Q}_3)(\text{Q}_4)(\text{Q}_5)$ and R_1 , R_2 , R_4 and R_6 are hydrogen, or
 - 10) R_2 is a group represented by Formula 2, R_4 and R_5 are each independently a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ alkyl group, a substituted or unsubstituted $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a phenyl group, a biphenyl group, or $-\text{Si}(\text{Q}_3)(\text{Q}_4)(\text{Q}_5)$ and R_1 , R_3 and R_6 are hydrogen.
5. The organometallic compound of claim 1, wherein at least one of R_7 to R_9 is each independently a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ alkyl group, a substituted or unsubstituted $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a substituted or unsubstituted $\text{C}_6\text{-C}_{60}$ aryl group, or a combination thereof.
6. The organometallic compound of claim 1, wherein R_{13} in Formula 2 is hydrogen or deuterium.
7. The organometallic compound of claim 1, wherein R_{13} in Formula 2 is a $\text{C}_1\text{-C}_{20}$ alkyl group, a deuterium-containing $\text{C}_1\text{-C}_{20}$ alkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, or a deuterium-containing $\text{C}_3\text{-C}_{10}$ cycloalkyl group.
8. The organometallic compound of claim 1, wherein R_{14} and R_{15} in Formula 2 are different from each other.
9. The organometallic compound of claim 1, wherein, in Formula 2,
- R_{13} is hydrogen, deuterium, $-\text{CH}_3$, $-\text{CDH}_2$, $-\text{CD}_2\text{H}$, or $-\text{CD}_3$,
- R_{14} and R_{15} are each independently:
- a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neopentyl, an iso-pentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl 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 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, bicyclo[1.1.1]pentyl, bicyclo[2.1.1]hexyl, bicyclo[2.2.1]heptyl, or a bicyclo[2.2.2]octyl group; or

a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neopentyl, an iso-pentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl 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 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, bicyclo[1.1.1]pentyl, bicyclo[2.1.1]hexyl, bicyclo[2.2.1]heptyl, or a bicyclo[2.2.2]octyl group, each substituted with deuterium.

10. The organometallic compound of claim 1, wherein at least one of R_{10} and R_{12} in Formula 1 are each independently a group represented by Formula 3:



Formula 3

wherein, in Formula 3,

R_{16} to R_{18} are each independently:

hydrogen, deuterium, a C_1 - C_{20} alkyl group, a C_3 - C_{10} cycloalkyl group, a C_6 - C_{60} aryl group, or a C_1 - C_{60} heteroaryl group; or

a C_1 - C_{20} alkyl group, a C_3 - C_{10} cycloalkyl group, a C_6 - C_{60} aryl group, a C_1 - C_{60} heteroaryl group, each substituted with deuterium, a C_1 - C_{20} alkyl group, or a combination thereof, and

* indicates a binding site to a neighboring atom.

11. The organometallic compound of claim 1, wherein

R_{10} and R_{12} in Formula 1 are identical to each other.

12. The organometallic compound of claim 1, wherein

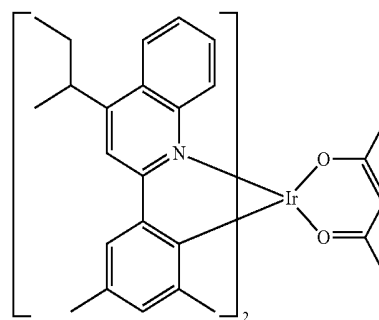
R_{10} and R_{12} in Formula 1 are different from each other.

13. The organometallic compound of claim 12, wherein,

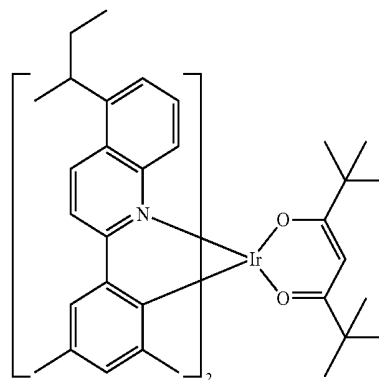
at least one of R_{10} , R_{12} , and R_{14} in Formulae 1 and 2 is each independently a C_3 - C_{10} cycloalkyl group, a deuterium-containing C_3 - C_{10} cycloalkyl group, or a combination thereof.

14. The organometallic compound of claim 1, wherein

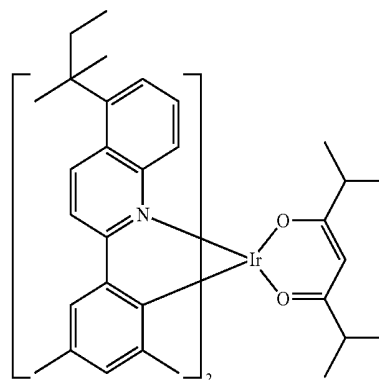
the organometallic compound is one of Compounds 1 to 20:



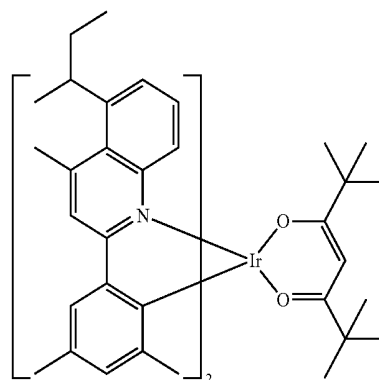
1



2

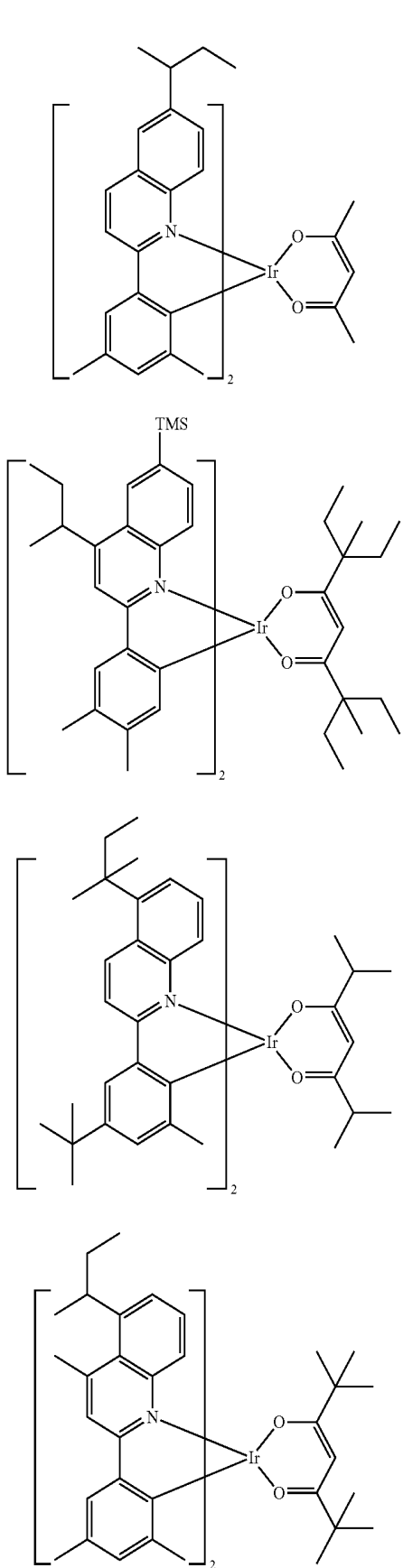


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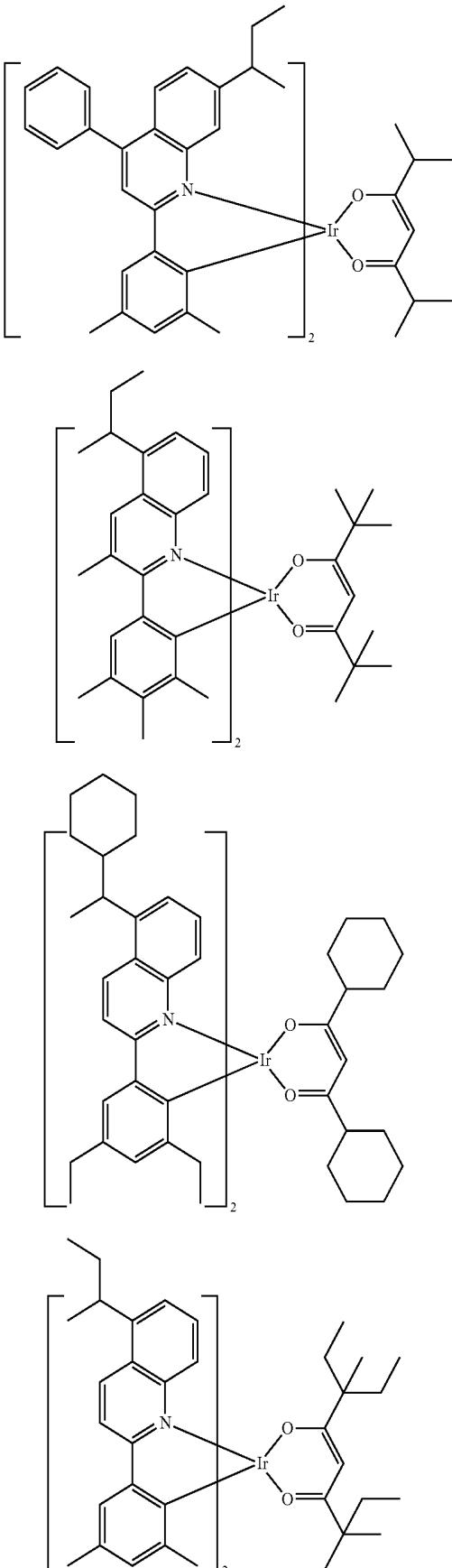


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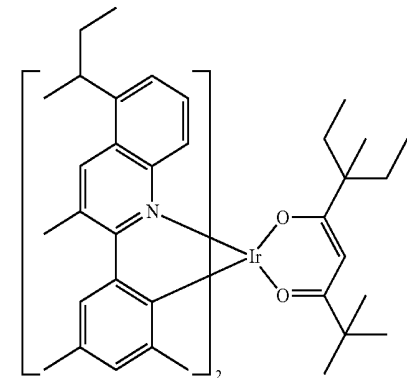
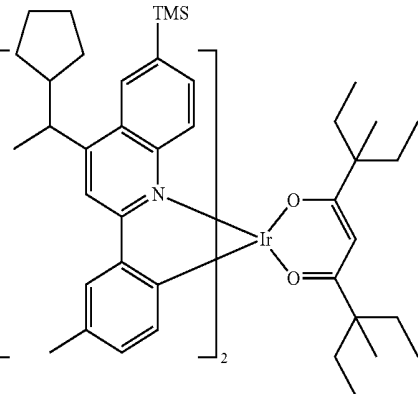
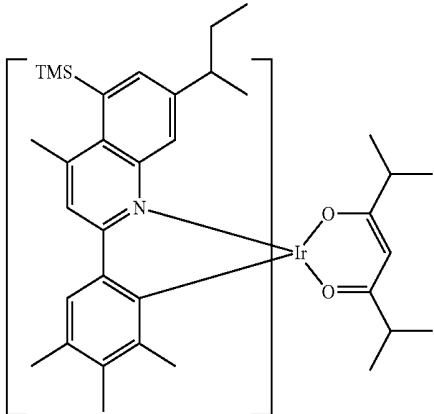
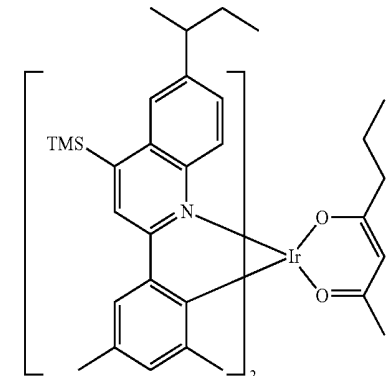
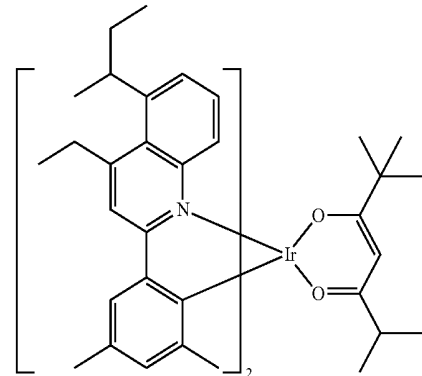
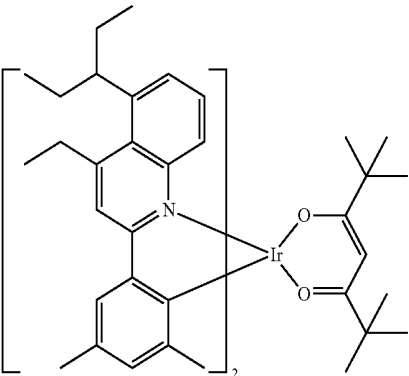
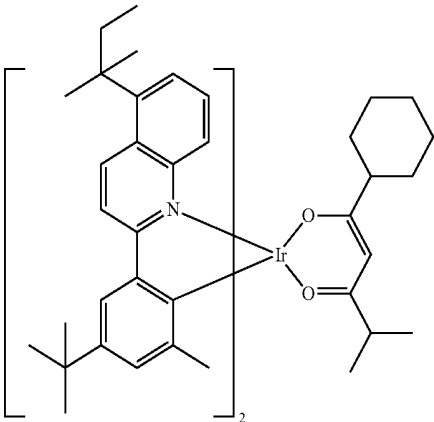
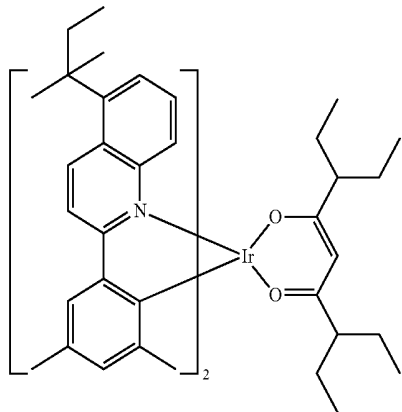


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15. An organic light-emitting device comprising:
a first electrode;
a second electrode; and
an organic layer between the first electrode and the second electrode and comprising an emission layer,
wherein the organic layer comprises the organometallic compound of claim 1.

16. The organic light-emitting device of claim 15, wherein the first electrode is an anode,
the second electrode is a cathode,
the organic layer further comprises a hole transport region between the first electrode and the emission layer and an electron transport region between the emission layer and the second electrode,

the hole transport region comprises a hole injection layer, a hole transport layer, an electron blocking layer, a buffer layer, or any combination thereof, and

the electron transport region comprises a hole blocking layer, an electron transport layer, an electron injection layer, or any combination thereof.

17. The organic light-emitting device of claim 15, wherein the emission layer comprises the organometallic compound.

18. The organic light-emitting device of claim 17, wherein the emission layer emits red light.

19. The organic light-emitting device of claim 17, wherein the emission layer further comprises a host, and an amount of the host in the emission layer is larger than an amount of the organometallic compound in the emission layer.

20. A diagnostic composition comprising the organometallic compound of claim 1.

* * * * *

专利名称(译)	有机金属化合物，包括该有机金属化合物的有机发光器件以及包括该有机金属化合物的诊断组合物		
公开(公告)号	US20190326526A1	公开(公告)日	2019-10-24
申请号	US16/391808	申请日	2019-04-23
[标]申请(专利权)人(译)	三星电子株式会社		
申请(专利权)人(译)	SAMSUNG ELECTRONICS CO. , LTD.		
当前申请(专利权)人(译)	SAMSUNG ELECTRONICS CO. , LTD.		
[标]发明人	KWAK YOONHYUN LEE SUNYOUNG LEE JUNGIN LEE JIYOUN JEON ARAM KOO HYUN ARATANI SUKEKAZU ISHIHARA SHINGO CHO YURI CHOI BYOUNGKI HONG SEOKHWAN		
发明人	KWAK, YOONHYUN LEE, SUNYOUNG LEE, JUNGIN LEE, JIYOUN JEON, ARAM KOO, HYUN ARATANI, SUKEKAZU ISHIHARA, SHINGO CHO, YURI CHOI, BYOUNGKI HONG, SEOKHWAN		
IPC分类号	H01L51/00 C07F15/00 C09K11/06		
CPC分类号	C09K11/06 H01L51/5016 H01L51/5088 H01L51/5092 H01L51/5096 H01L51/5072 C07F15/0033 C09K2211/185 H01L51/0085 H01L51/5056 C09K2211/1029 H01L51/0081		
优先权	1020180046990 2018-04-23 KR 1020190046949 2019-04-22 KR		
外部链接	Espacenet USPTO		

摘要(译)

由式1表示的有机金属化合物，包括该有机金属化合物的有机发光装置以及包括该有机金属化合物的诊断组合物。其中，在式1中，R 1 到R 12 和R 19 与规范中描述的相同。

