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(12) **United States Patent**
Baek et al.(10) **Patent No.:** US 12,391,871 B2
(45) **Date of Patent:** Aug. 19, 2025(54) **LIGHT-EMITTING DEVICE INCLUDING CONDENSED CYCLIC COMPOUND AND ELECTRONIC APPARATUS INCLUDING THE LIGHT-EMITTING DEVICE**(71) Applicant: **Samsung Display Co., Ltd.**, Yongin-si (KR)(72) Inventors: **Jangyeol Baek**, Yongin-si (KR); **Seran Kim**, Yongin-si (KR); **Sunyoung Pak**, Yongin-si (KR); **Hankyu Pak**, Yongin-si (KR); **Munki Sim**, Yongin-si (KR); **Chanseok Oh**, Yongin-si (KR); **Hyoyoung Lee**, Yongin-si (KR)(73) Assignee: **Samsung Display Co., Ltd.**, Yongin-si (KR)

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(52) **U.S. Cl.**
CPC **C09K 11/06** (2013.01); **C07F 5/027** (2013.01); **H10K 85/322** (2023.02);
(Continued)(58) **Field of Classification Search**None
See application file for complete search history.(56) **References Cited**

U.S. PATENT DOCUMENTS

11,512,101 B2 11/2022 Dueck
11,637,249 B2 4/2023 Hatakeyama et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CN 110872316 A 3/2020
KR 10-2016-0119683 A 10/2016
(Continued)

OTHER PUBLICATIONS

Hatakeyama, Takuji et al., "Ultrapure Blue Thermally Activated Delayed Fluorescence Molecules: Efficient HOMO-LUMO Separation by the Multiple Resonance Effect", Advanced Materials, 2016, vol. 28 (2777-2781).

(Continued)

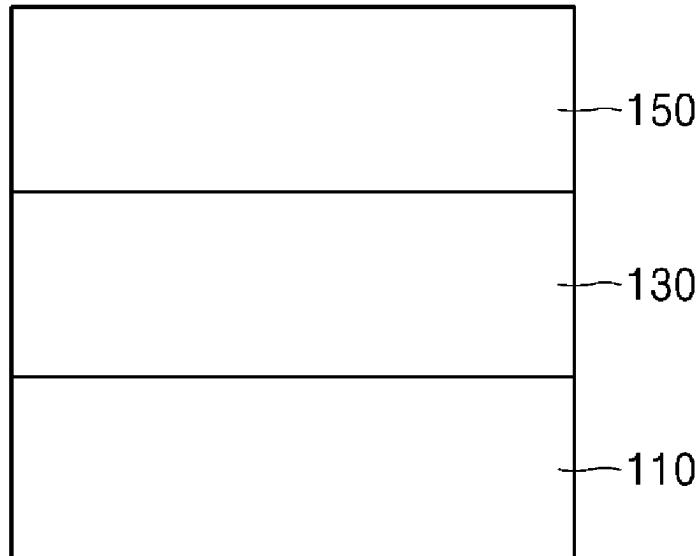
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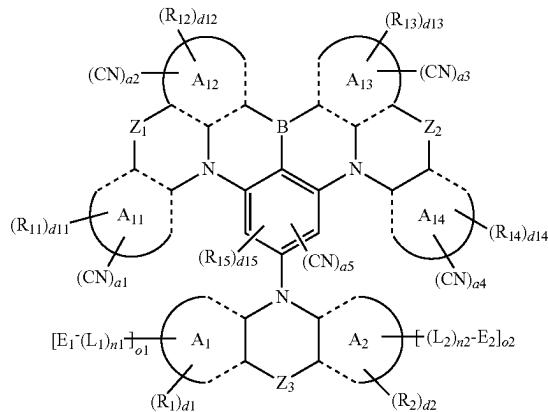
(57) **ABSTRACT**

A light-emitting device including a condensed cyclic compound represented by Formula 1, wherein the condensed

(Continued)

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cyclic compound of Formula 1 may be used in the emission layer of the light-emitting device:



where the detailed description of Formula 1 is the same as described in the present specification.

20 Claims, 3 Drawing Sheets

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H10K 2101/10 (2023.02)

(56)

References Cited

U.S. PATENT DOCUMENTS

12,286,450 B2	4/2025	Kim et al.
2019/0058124 A1	2/2019	Hatakeyama et al.
2019/0115538 A1	4/2019	Lim et al.
2019/0181350 A1	6/2019	Hatakeyama et al.
2019/0375768 A1	12/2019	Kim et al.
2020/0052212 A1	2/2020	Tasaki et al.
2020/0098991 A1	3/2020	Kim et al.
2020/0144513 A1	5/2020	Hatakeyama et al.
2020/0190115 A1	6/2020	Hatakeyama et al.
2020/0235303 A1	7/2020	Kim et al.
2021/0403489 A1 *	12/2021	Kim C07F 7/0812

FOREIGN PATENT DOCUMENTS

KR 10-2018-0108604 A	10/2018	
KR 10-2019-0042791 A	4/2019	
KR 10-2019-0069295 A	6/2019	
KR 10-2019-0127527 A	11/2019	
KR 10-2019-0132645 A	11/2019	
KR 10-2019-0141052 A	12/2019	
KR 10-2020-0019272 A	2/2020	
KR 10-2020-0034899 A	4/2020	
KR 10-2020-0041832 A	4/2020	
KR 10-2020-0073993 A	6/2020	
KR 10-2020-0091544 A	7/2020	
WO WO 2018/212169 A1	11/2018	

OTHER PUBLICATIONS

Pershin, Anton et al., "Highly emissive excitons with reduced exchange energy in thermally activated delayed fluorescent molecules", *Nature Communications*, 2019, vol. 10:597 (5 pages). Accessible on the Internet at <https://doi.org/10.1038/s41467-019-08495-5>. Partial English Translation of the relevant part of CN 110872316 A (Pub Date: Mar. 10, 2020) (12 pages). Korean Notice of Allowance issued Jun. 25, 2025, in corresponding KR Patent Application No. 10-2020-0101393 (3 pages).

* cited by examiner

FIG. 1

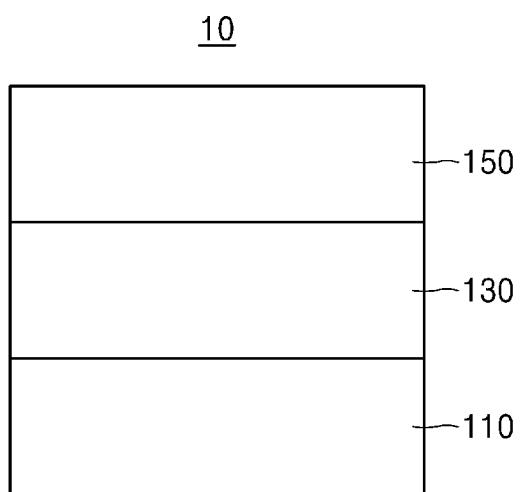


FIG. 2

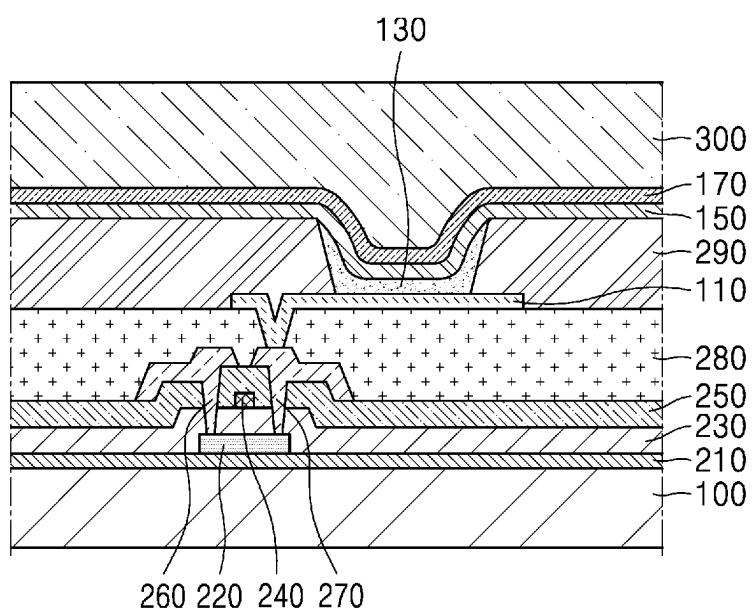
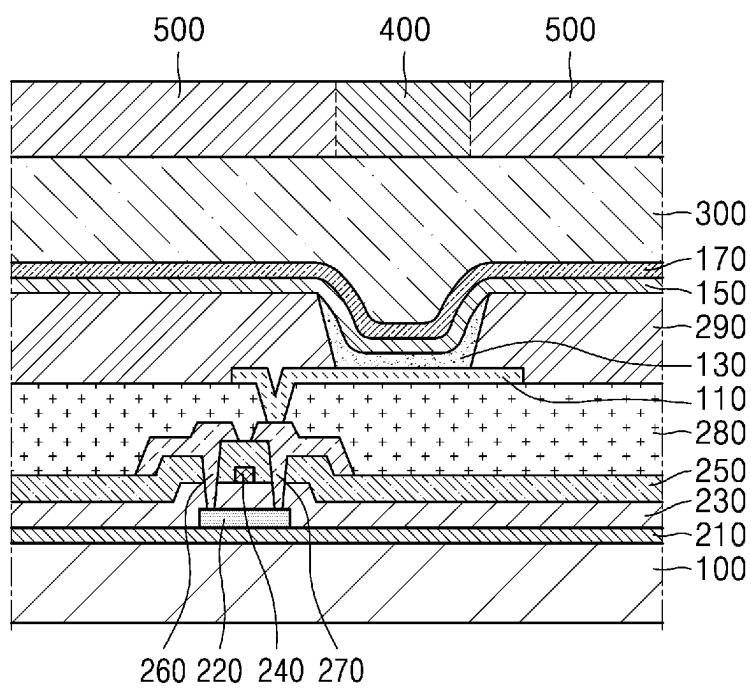


FIG. 3



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**LIGHT-EMITTING DEVICE INCLUDING
CONDENSED CYCLIC COMPOUND AND
ELECTRONIC APPARATUS INCLUDING
THE LIGHT-EMITTING DEVICE**

**CROSS-REFERENCE TO RELATED
APPLICATION**

This application claims priority to and the benefit of Korean Patent Application No. 10-2020-0101393, filed on Aug. 12, 2020, in the Korean Intellectual Property Office, the entire content of which is hereby incorporated by reference.

BACKGROUND

1. Field

One or more aspects of embodiments of the present disclosure relate to a light-emitting device including a condensed cyclic compound and an electronic apparatus including the light-emitting device.

2. Description of Related Art

Organic light-emitting devices from among light-emitting devices are self-emission devices that, as compared with related devices, have wide viewing angles, high contrast ratios, short response times, and excellent characteristics in terms of luminance, driving voltage, and/or response speed, and produce full-color images.

The organic light-emitting devices may include a first electrode located on a substrate, and a hole transport region, an emission layer, an electron transport region, and a second electrode sequentially stacked on the first electrode. Holes provided from the first electrode may move toward the emission layer through the hole transport region, and electrons provided from the second electrode may move toward the emission layer through the electron transport region. Carriers, such as the holes and the electrons, recombine in the emission layer to produce excitons. These excitons transition from an excited state to a ground state to thereby generate light.

SUMMARY

One or more embodiments of the present disclosure are directed towards a light-emitting device including a condensed cyclic compound and an electronic apparatus including the light-emitting device.

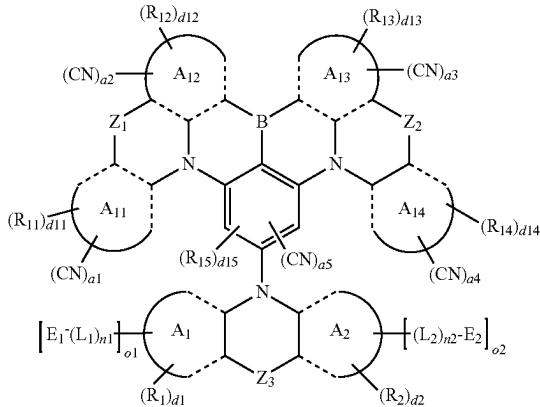
Additional embodiments will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments of the disclosure.

According to one or more embodiments, provided is a light-emitting device including a first electrode, a second electrode facing the first electrode, and an interlayer between the first electrode and the second electrode and including an emission layer, wherein the interlayer further includes a hole transport region between the first electrode and the emission layer, the hole transport region includes a compound represented by Formula 201, a compound represented by Formula 202, or a combination thereof, and the emission layer includes at least one condensed cyclic compound represented by Formula 1:

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Formula 1



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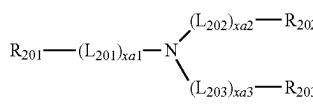
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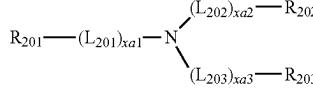
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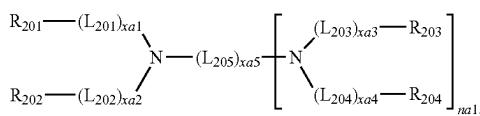
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Formula 201



Formula 202



In Formula 1,
a1 to a4 are each independently an integer from 0 to 20,
a5 is an integer from 0 to 2,
the sum of a1, a2, a3, a4, and a5 is an integer of 1 or more,
 R_1 , R_2 , and R_{11} to R_{15} are each independently hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a $\text{C}_1\text{-C}_{60}$ alkyl group unsubstituted or substituted with at least one R_{10a} , a $\text{C}_2\text{-C}_{60}$ alkenyl group unsubstituted or substituted with at least one R_{10a} , a $\text{C}_2\text{-C}_{60}$ alkynyl group unsubstituted or substituted with at least one R_{10a} , a $\text{C}_1\text{-C}_{60}$ alkoxy group unsubstituted or substituted with at least one R_{10a} , a $\text{C}_3\text{-C}_{60}$ carbocyclic group unsubstituted or substituted with at least one R_{10a} , a $\text{C}_1\text{-C}_{60}$ heterocyclic group unsubstituted or substituted with at least one R_{10a} , a $\text{C}_6\text{-C}_{60}$ aryloxy group unsubstituted or substituted with at least one R_{10a} , a $\text{C}_6\text{-C}_{60}$ arylthio group unsubstituted or substituted with at least one R_{10a} , —Si(Q_1) (Q_2) (Q_3) , —N(Q_1) (Q_2) , —B(Q_1) (Q_2) , —C(=O) (Q_1) , —S(=O) $_2(\text{Q}_1)$, or —P(=O) (Q_1) (Q_2) , d1, d2, and d11 to d14 are each independently an integer from 1 to 20, d15 is an integer from 0 to 2, the sum of a5 and d15 is 2,

two or more groups of R_1 , R_2 , and R_{11} to R_{15} are optionally linked to each other to form a $\text{C}_5\text{-C}_{30}$ carbocyclic group unsubstituted or substituted with at least one R_{10a} or a $\text{C}_2\text{-C}_{30}$ heterocyclic group unsubstituted or substituted with at least one R_{10a} ,

Z_1 to Z_3 are each independently a single bond or a non-bond,

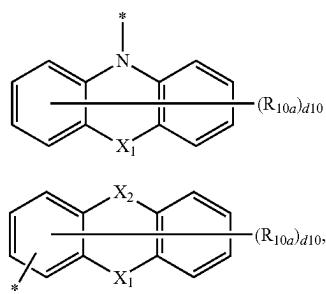
L_1 and L_2 are each independently a single bond, a benzene group, a naphthalene group, an anthracene group, an pyrrole group, a carbazole group, a dibenzofuran group, or a dibenzothiophene group, each unsubstituted or substituted with at least one R_{10a} , and

E_1 and E_2 are each independently selected from a $\text{C}_1\text{-C}_{60}$ alkyl group unsubstituted or substituted with at least one R_{10a} ,

a C_5 - C_{30} carbocyclic group and a C_2 - C_{30} heterocyclic group, each unsubstituted or substituted with at least one R_{10a} ,

$N(Q_4)(Q_5)$, and

a group represented by Formula A-1 and a group represented by Formula A-2,



in Formulae A-1 and A-2,

X_1 is a non-bond, a single bond, O, S, Se, $C(R_{a1})(R_{1b})$, $Si(R_{1a})(R_{1b})$, or $N(R_{1a})$,

X_2 is O, S, Se, $C(R_{2a})(R_{2b})$, $Si(R_{2a})(R_{2b})$, or $N(R_{2a})$, R_{1a} , R_{1b} , R_{2a} , and R_{2b} are each independently the same as described in connection with R_{11} ,

d10 is an integer from 0 to 8,

* indicates a binding site to a neighboring atom, in Formula 1, n1 and n2 are each independently an integer from 1 to 5, and

o1 and o2 are each independently an integer from 0 to 3, and

in Formulae 201 and 202,

L_{201} to L_{204} are each independently a C_3 - C_{60} carbocyclic group unsubstituted or substituted with at least one R_{10a} or a C_1 - C_{60} heterocyclic group unsubstituted or substituted with at least one R_{10a} ,

L_{205} is *—O—*, *—S—*, *—N(Q_{201})—*, a C_1 - C_{20} alkylene group unsubstituted or substituted with at least one R_{10a} , a C_2 - C_{20} alkenylene group unsubstituted or substituted with at least one R_{10a} , a C_3 - C_{60} carbocyclic group unsubstituted or substituted with at least one R_{10a} , or a C_1 - C_{60} heterocyclic group unsubstituted or substituted with at least one R_{10a} ,

x_{a1} to x_{a4} are each independently an integer from 0 to 5, x_{a5} is an integer from 1 to 10,

R_{201} to R_{204} and Q_{201} are each independently a C_3 - C_{60} carbocyclic group unsubstituted or substituted with at least one R_{10a} or a C_1 - C_{60} heterocyclic group unsubstituted or substituted with at least one R_{10a} ,

R_{201} and R_{202} are optionally linked to each other via a single bond, a C_1 - C_5 alkylene group unsubstituted or substituted with at least one R_{10a} , or a C_2 - C_5 alkenylene group unsubstituted or substituted with at least one R_{10a} , to form a C_8 - C_{60} polycyclic group unsubstituted or substituted with at least one R_{10a} ,

R_{203} and R_{204} are optionally linked to each other via a single bond, a C_1 - C_5 alkylene group unsubstituted or substituted with at least one R_{10a} , or a C_2 - C_5 alkenylene group unsubstituted or substituted with at least one R_{10a} , to form a C_8 - C_{60} poly cyclic group unsubstituted or substituted with at least one R_{10a} ,

n_{a1} is an integer from 1 to 4, and

R_{10a} is deuterium (—D), —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, or a nitro group;

a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, or a C_1 - C_{60} alkoxy group, each unsubstituted or substituted with deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_3 - C_{60} carbocyclic group, a C_1 - C_{60} heterocyclic group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, —Si(Q_{11})(Q_{12})(Q_{13}), —N(Q_{11})(Q_{12}), —B(Q_{11})(Q_{12}), —C(=O)(Q_{11}), —S(=O)₂(Q_{11}), —P(=O)(Q_{11})(Q_{12}), or any combination thereof,

a C_3 - C_{60} carbocyclic group, a C_1 - C_{60} heterocyclic group, a C_6 - C_{60} aryloxy group, or a C_6 - C_{60} arylthio group, each unsubstituted or substituted with deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, 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_{60} carbocyclic group, a C_1 - C_{60} heterocyclic group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, —Si(Q_{21})(Q_{22})(Q_{23}), —N(Q_{21})(Q_{22}), —B(Q_{21})(Q_{22}), —C(=O)(Q_{21}), —S(=O)₂(Q_{21}), —P(=O)(Q_{21})(Q_{22}), or any combination thereof, or —Si(Q_{31})(Q_{32})(Q_{33}), —N(Q_{31})(Q_{32}), —B(Q_{31})(Q_{32}), —C(=O)(Q_{31}), —S(=O)₂(Q_{31}), or —P(=O)(Q_{31})(Q_{32}),

wherein Q_1 to Q_3 , Q_{11} to Q_{13} , Q_{21} to Q_{23} , and Q_{31} to Q_{33} are each independently: hydrogen; deuterium; —F, —Cl; —Br; —I; a hydroxyl group; a cyano group; a nitro group; 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; or a C_3 - C_{60} carbocyclic group or a C_1 - C_{60} heterocyclic group, each unsubstituted or substituted with deuterium, —F, a cyano group, a C_1 - C_{60} alkyl group, a C_1 - C_{60} alkoxy group, a phenyl group, a biphenyl group, or any combination thereof.

According to one or more embodiments, provided is a light-emitting device including: a first electrode; a second electrode facing the first electrode; and an interlayer between the first electrode and the second electrode and including an emission layer,

wherein the light-emitting device further includes a capping layer outside the second electrode and having a refractive index of 1.6 or more, and the emission layer includes at least one condensed cyclic compound represented by Formula 1.

According to one or more embodiments, provided is an electronic apparatus including the light-emitting device, wherein the electronic apparatus further includes a thin-film transistor, the thin-film transistor includes a source electrode and a drain electrode, and the first electrode of the light-emitting device is electrically connected to the source electrode or the drain electrode.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects, features, and advantages of certain embodiments of the disclosure will be more apparent from the following description taken in conjunction with the accompanying drawings, in which

FIGS. 1-3 are each a schematic cross-sectional view of a structure of a light-emitting device according to one or more embodiments.

DETAILED DESCRIPTION

Reference will now be made in more 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 embodiment

ments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the embodiments are merely described below, by referring to the figures, to explain aspects of the present disclosure. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. Throughout the disclosure, the expression "at least one of a, b or c" indicates only a, only b, only c, both a and b, both a and c, both b and c, all of a, b, and c, or variations thereof. Also, throughout the disclosure, the expression "at least one selected from a, b and c" indicates only a, only b, only c, both a and b, both a and c, both b and c, all of a, b, and c, or variations thereof. Further, the use of "may" when describing embodiments of the present disclosure refers to "one or more embodiments of the present disclosure."

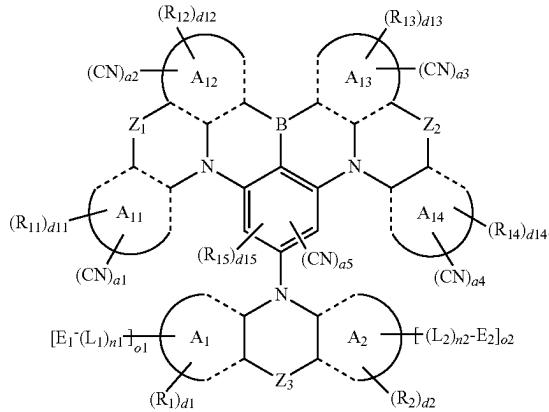
As used herein, the terms "use," "using," and "used" may be considered synonymous with the terms "utilize," "utilizing," and "utilized," respectively.

In addition, the terms "substantially," "about," and similar terms are used as terms of approximation and not as terms of degree, and are intended to account for the inherent deviations in measured or calculated values that would be recognized by those of ordinary skill in the art.

Also, any numerical range recited herein is intended to include all sub-ranges of the same numerical precision subsumed within the recited range. For example, a range of "1.0 to 10.0" is intended to include all subranges between (and including) the recited minimum value of 1.0 and the recited maximum value of 10.0, that is, having a minimum value equal to or greater than 1.0 and a maximum value equal to or less than 10.0, such as, for example, 2.4 to 7.6. Any maximum numerical limitation recited herein is intended to include all lower numerical limitations subsumed therein and any minimum numerical limitation recited in this specification is intended to include all higher numerical limitations subsumed therein. Accordingly, Applicant reserves the right to amend this specification, including the claims, to expressly recite any sub-range subsumed within the ranges expressly recited herein.

A condensed cyclic compound according to the present disclosure may be represented by Formula 1:

Formula 1



In Formula 1,

a1 to a4 may each independently be an integer from 0 to

20,

a5 may be an integer from 0 to 2, and

the sum of a1, a2, a3, a4, and a5 may be an integer of 1 or more.

In one or more embodiments, at least one of a1 to a4 may be greater than or equal to 1.

In one or more embodiments, a5 may be 1 or 2.

In one or more embodiments, at least one of a1 to a5 may not be 0;

a1 may not be 0, and at least one of a2 to a5 may not be 0;

a2 may not be 0, and at least one of a1, a3, a4, or a5 may not be 0;

a3 may not be 0, and at least one of a1, a2, a4, or a5 may not be 0;

a4 may not be 0, and at least one of a1 to a3 or a5 may not be 0;

a5 may not be 0, and at least one of a1 to a4 may not be 0;

a5 and a1 may not be 0, and at least one of a2 to a4 may not be 0;

a5 and a2 may not be 0, and at least one of a1, a3, or a4 may not be 0;

a5 and a3 may not be 0, and at least one of a1, a2, or a4 may not be 0; or

a5 and a4 may not be 0, and at least one of a1, a2, or a3 may not be 0.

In one or more embodiments, the sum of a1, a2, a3, a4, and a5 may be greater than or equal to 2.

ring A₁, ring A₃, and ring A₁₁ to ring A₁₄ may each independently be a C₅-C₃₀ carbocyclic group or a C₂-C₃₀ heterocyclic group.

In one or more embodiments, ring A₁, ring A₂, and ring A₁₁ to ring A₁₄ may each independently be a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a cyclopentadiene group, a 1,2,3,4-tetrahydronaphthalene group, a thiophene group, a furan group, an indole group, a benzoborole group, a benzophosphole group, an indene group, a benzosilole group, a benzogermole group, a benzothiophene group, a benzosenophene group, a benzofuran group, a carbazole group, a dibenzoborole group, a dibenzophosphole group, a fluorene group, a benzosilole group, a benzogermole group, a dibenzothiophene group, a dibenzosenophene group, a dibenzofuran group, a dibenzothiophene 5-oxide group, a 9H-fluorene-9-one group, a dibenzothiophene 5,5-dioxide group, an azaindole group, an azabenzoborole group, an azabenzenophosphole group, an azaindene group, an azabenzenolole group, an azabenzogermole group, an azabenzothiophene group, an azabenzenophene group, an azabenzfuran group, an azacarbazole group, an azadibenzoborole group, an azadibenzophosphole group, an azafluorene group, an azadibenzosilole group, an azadibenzogermole group, an azadibenzothiophene group, an azadibenzosenophene group, an azadibenzofuran group, an azadibenzothiophene 5-oxide group, an aza-9H-fluorene-9-one group, an azadibenzothiophene 5,5-dioxide group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a phenanthroline group, a pyrrole group, a pyrazole group, an imidazole group, a triazole group, an oxazole group, an isoxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazole group, a benzopyrazole group, a benzimidazole group, a benzoxazole group, a benzothiazole group, a benzoxadiazole group, a benzothiadiazole group, a 5,6,7,8-tetrahydroisoquinoline group, or a 5,6,7,8-tetrahydroquinoline group.

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In one or more embodiments, ring A₁, ring A₂, and ring A₁₁ to ring A₁₄ may each independently be a benzene group, a naphthalene group, a benzothiophene group, a carbazole group, a fluorene group, a dibenzosilole group, a dibenzothiophene group, a dibenzofuran group, a dibenzothiophene 5-oxide group, a 9H-fluorene-9-one group, or a dibenzothiophene 5,5-dioxide group.

In one or more embodiments, ring A₁ and ring A₂ may be identical to each other.

In one or more embodiments, ring A₁ and ring A₂ may not be identical to each other.

In one or more embodiments, ring A₁₁ and ring A₁₄ may be identical to each other.

In one or more embodiments, ring A₁ may be a benzene group, and ring A₂ may be a benzene group;

ring A₁ may be a carbazole group, and ring A₂ may be a benzene group;

ring A₁ may be a dibenzothiophene group, and ring A₂ may be a benzene group;

ring A₁ may be a dibenzofuran group, and ring A₂ may be a benzene group;

ring A₁ may be a dibenzosilole group, and ring A₂ may be a benzene group;

ring A₁ may be a carbazole group, and ring A₂ may be a carbazole group;

ring A₁ may be a dibenzothiophene group, and ring A₂ may be a dibenzothiophene group;

ring A₁ may be a dibenzofuran group, and ring A₂ may be a dibenzofuran group; or

ring A₁ may be a dibenzosilole group, and ring A₂ may be a dibenzosilole group.

R₁, R₂, and R₁₁ to R₁₅ may each independently be hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₁-C₆₀ alkyl group unsubstituted or substituted with at least one R_{10a}, a C₂-C₆₀ alkenyl group unsubstituted or substituted with at least one R_{10a}, a C₂-C₆₀ alkynyl group unsubstituted or substituted with at least one R_{10a}, a C₁-C₆₀ alkoxy group unsubstituted or substituted with at least one R_{10a}, a C₃-C₆₀ carbocyclic group unsubstituted or substituted with at least one R_{10a}, a C₁-C₆₀ heterocyclic group unsubstituted or substituted with at least one R_{10a}, a C₆-C₆₀ aryloxy group unsubstituted or substituted with at least one R_{10a}, a C₆-C₆₀ arylthio group unsubstituted or substituted with at least one R_{10a}, —Si(Q₁)(Q₂)(Q₃), —N(Q₁)(Q₂), —B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)₂(Q₁), or —P(=O)(Q₁)(Q₂).

R_{10a} may be:

deuterium (—D), —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, or a nitro group;

a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, or a C₁-C₆₀ alkoxy group, each unsubstituted or substituted with deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₃-C₆₀ carbocyclic group, a C₁-C₆₀ heterocyclic group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, —Si(Q₁₁)(Q₁₂)(Q₁₃), —N(Q₁₁)(Q₁₂), —B(Q₁₁)(Q₁₂), —C(=O)(Q₁₁), —S(=O)₂(Q₁₁), —P(=O)(Q₁₁)(Q₁₂), or any combination thereof;

a C₃-C₆₀ carbocyclic group, a C₁-C₆₀ heterocyclic group, a C₆-C₆₀ aryloxy group, or a C₆-C₆₀ arylthio group, each unsubstituted or substituted with deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₁-C₆₀ alkoxy group, a C₃-C₆₀ carbocyclic group, a C₁-C₆₀ heterocyclic group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, —Si(Q₂₁)(Q₂₂)(Q₂₃), —N(Q₂₁)(Q₂₂), —B(Q₂₁)(Q₂₂),

—C(=O)(Q₂₁), —S(=O)₂(Q₂₁), —P(=O)(Q₂₁)(Q₂₂), or any combination thereof; or

—Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂),

—C(=O)(Q₃₁), —S(=O)₂(Q₃₁), or —P(=O)(Q₃₁)(Q₃₂).

Q₁ to Q₃, Q₁₁ to Q₁₃, Q₂₁ to Q₂₃, and Q₃₁ to Q₃₃ may each independently be: hydrogen; deuterium; —F; —Cl; —Br; —I; a hydroxyl group; a cyano group; a nitro group; a C₁-C₆₀ alkyl group; a C₂-C₆₀ alkenyl group; a C₂-C₆₀ alkynyl group; a C₁-C₆₀ alkoxy group; or a C₃-C₆₀ carbocyclic group or a C₁-C₆₀ heterocyclic group, each unsubstituted or substituted with deuterium, —F, a cyano group, a C₁-C₆₀ alkyl group, a C₁-C₆₀ alkoxy group, a phenyl group, a biphenyl group, or any combination thereof.

In one or more embodiments, R₁, R₂, and R₁₁ to R₁₅ may each independently be selected from:

hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazine group, a hydrazone group, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group;

a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazine group, a hydrazone group, a C₁-C₁₀ alkyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a C₁-C₁₀ alkylphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azafluorenyl group, and an azadibenzosilolyl group, each unsubstituted or substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂,

a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazine group, a hydrazone group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group,

a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a C₁-C₁₀ alkylphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysene 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 isoaxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —P(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂); and —Si(Q₁)(Q₂)(Q₃), —N(Q₁)(Q₂), —B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)₂(Q₁), and —P(=O)(Q₁)(Q₂), wherein Q₁ to Q₃ and Q₃₁ to Q₃₃ may each independently be selected from: —CH₃, —CD₃, —CD₂H, —CDH₂, —CH₂CH₃, —CH₂CD₃, —CH₂CD₂H, —CH₂CDH₂, —CHDCH₃, —CHDCD₂H, —CHDCDH₂, —CHDCD₃, —CD₂CD₃, —CD₂CD₂H, and —CD₂CDH₂; and an n-propyl group, an iso-propyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyridazinyl group, a pyrazinyl group, and a triazinyl group, each unsubstituted or substituted with at least one selected from deuterium, a C₁-C₁₀ alkyl group, a phenyl group, a biphenyl group, a pyridinyl group, a pyrimidinyl group, a pyridazinyl group, a pyrazinyl group, and a triazinyl group.

In one or more embodiments, R₁, R₂, and R₁₁ to R₁₅ may each independently be selected from:

hydrogen, deuterium, a C₁-C₂₀ alkyl group, and C₁-C₂₀ alkoxy group; a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group, each substituted with at least one selected from deuterium, —CD₃, —CD₂H, —CDH₂, a C₁-C₁₀ alkyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, and a naphthyl group; a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a C₁-C₁₀ alkylphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysene 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 isoaxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —P(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂); and —Si(Q₁)(Q₂)(Q₃), —N(Q₁)(Q₂), and —B(Q₁)(Q₂), wherein Q₁ to Q₃ and Q₃₁ to Q₃₃ may each independently be selected from:

a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysene group, a pyrrolyl group, a thiophenyl group, a furanyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group, each unsubstituted or substituted with at least one selected from deuterium, —CD₃, —CD₂H, —CDH₂, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a C₁-C₁₀ alkylphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysene 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 isoaxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —P(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂); and —Si(Q₁)(Q₂)(Q₃), —N(Q₁)(Q₂), and —B(Q₁)(Q₂), wherein Q₁ to Q₃ and Q₃₁ to Q₃₃ may each independently be selected from:

—CH₃, —CD₃, —CD₂H, —CDH₂, —CH₂CH₃, —CH₂CD₃, —CH₂CD₂H, —CH₂CDH₂, —CHDCH₃, —CHDCD₂H, —CHDCDH₂, —CHDCD₃, —CD₂CD₃, —CD₂CD₂H, and —CD₂CDH₂; and an n-propyl group, an iso-propyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each unsubstituted or substituted with at least one selected from deuterium, a C₁-C₁₀ alkyl group, a phenyl group, and a biphenyl group.

d1, d2, and d11 to d14 may each independently be an integer from 1 to 20, and d15 may be an integer from 0 to 2.

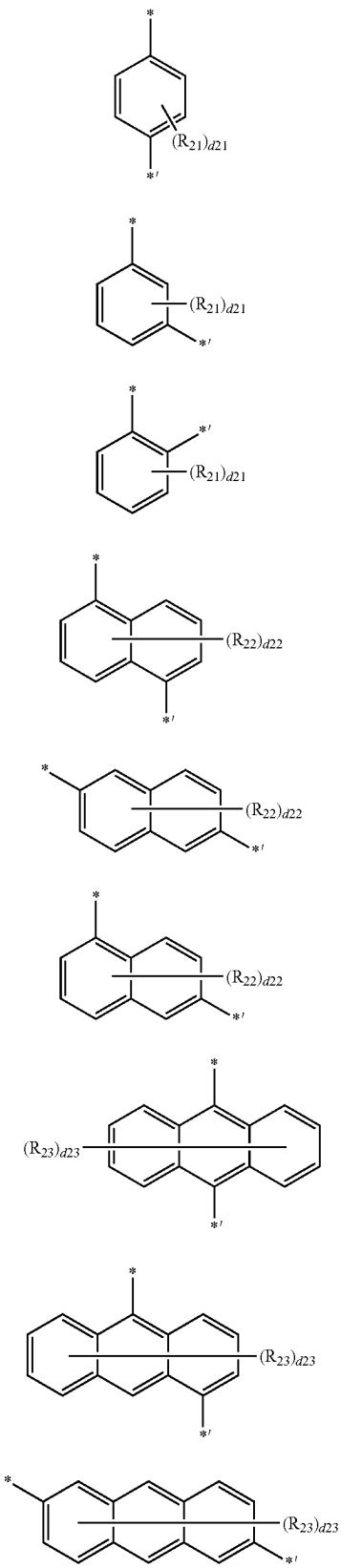
The sum of a5 and d15 may be 2.

two or more groups selected from R₁, R₂, and R₁₁ to R₁₅ may optionally be linked to each other to form a C₅-C₃₀ carbocyclic group unsubstituted or substituted with at least one R_{10a} or a C₂-C₃₀ heterocyclic group unsubstituted or substituted with at least one R_{10a}. Z₁ to Z₃ may each independently be a single bond or a non-bond.

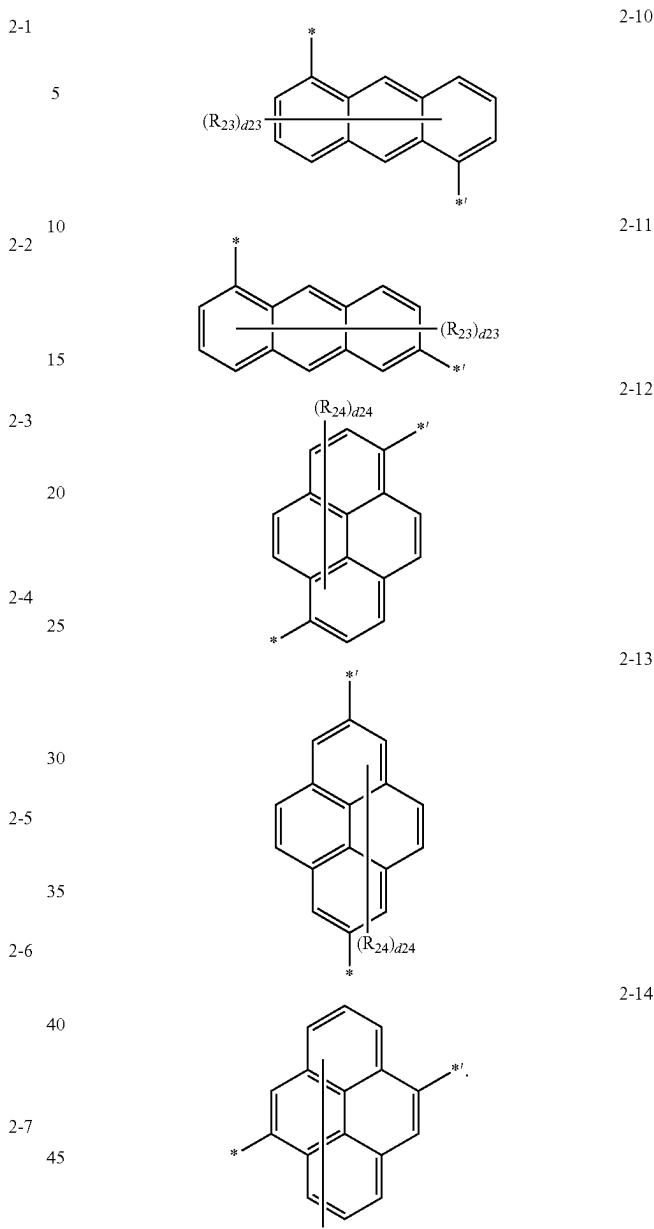
In one or more embodiments, Z₁ may be a non-bond, and Z₂ may be a non-bond; Z₁ may be a non-bond, and Z₂ may be a single bond; Z₁ may be a single bond, and Z₂ may be a non-bond; or Z₁ may be a single bond, and Z₂ may be a single bond.

In one or more embodiments, Z₃ may be a single bond. L₁ and L₂ may each independently be a single bond, or a benzene group, a naphthalene group, an anthracene group, an pyrrole group, a carbazole group, a dibenzofuran group, or a dibenzothiophene group, each unsubstituted or substituted with at least one R_{10a}.

In one or more embodiments, L₁ and L₂ may each independently be a single bond or may be represented by one of Formulae 2-1 to 2-14:

11**12**

-continued



2-8 In Formulae 2-1 to 2-14, R₂₁ to R₂₄ are each independently the same as described in connection with R₁ in the present specification,

2-9 50 d21 may be an integer from 1 to 4,

d22 may be an integer from 1 or 6,

d23 may be an integer from 1 to 8,

d24 may be an integer from 1 to 8, and

* and *' may each indicate a binding site to a neighboring atom.

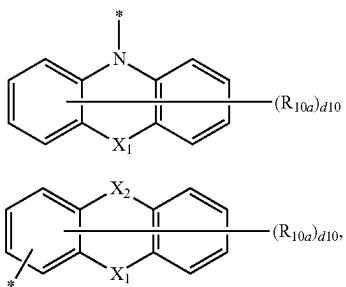
E₁ and E₂ may each independently be selected from: C₁-C₆₀ alkyl group unsubstituted or substituted with at least one R_{10a};

a C₅-C₃₀ carbocyclic group and a C₂-C₃₀ heterocyclic group, each unsubstituted or substituted with at least one R_{10a};

N(Q₄)(Q₅); and

a group represented by Formula A-1 and a group represented by Formula A-2;

13



in Formulae A-1 and A-2,

X₁ may be a non-bond, a single bond, O, S, Se, C(R_{1a})_{d1},(R_{1b}), Si(R_{1a})(R_{1b}), or N(R_{1a}),X₂ may be O, S, Se, C(R_{2a})(R_{2b}), Si(R_{2a})(R_{2b}), or N(R_{2a}),R_{1a}, R_{1b}, R_{a2}, and R_{b2} are each independently the same as described in connection with R₁₁ in the present specification,R_{10a} is the same as described in the present specification,

d10 may be an integer from 0 to 8, and

* may indicate a binding site to a neighboring atom.

In one or more embodiments, E₁ and E₂ may each independently be selected from: a C₁-C₁₀ alkyl group unsubstituted or substituted with at least one R_{10a};

a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a cyclopentadiene group, a 1,2,3,4-tetrahydronaphthalene group, a thiophene group, a furan group, an indole group, a benzo-borole group, a benzophosphole group, an indene group, a benzosilole group, a benzogermole group, a benzothiophene group, a benzosenophene group, a benzofuran group, a carbazole group, a dibenzoborole group, a dibenzophosphole group, a fluorene group, a dibenzosilole group, a dibenzogermole group, a dibenzothiophene group, a dibenzosenophene group, a dibenzofuran group, a dibenzothiophene 5-oxide group, a 9H-a fluorene-9-one group, a dibenzothiophene 5,5-dioxide group, an azaindole group, an azabenzoborole group, an azabenzophosphole group, an azaindene group, an azabenzoisole group, an azabenzogermole group, an azabenzothiophene group, an azabenzenophene group, an azacarbazole group, an azadibenzoborole group, an azadibenzophosphole group, an azafluorene group, an azadibenzosilole group, an azadibenzogermole group, an azadibenzothiophene group, an azadibenzosenophene group, an azadibenzofuran group, an azadibenzothiophene 5-oxide group, an az-9H-fluoren-9-one group, an azadibenzothiophene 5,5-dioxide group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a phenanthroline group, a pyrrole group, a pyrazole group, an imidazole group, a triazole group, an oxazole group, an isoxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazole group, a benzopyrazole group, a benzimidazole group, a benzoxazole group, a benzothiazole group, a benzoxadiazole group, a benzothiadiazole group, a 5,6,7,8-tetrahydroisoquinoline group, and a 5,6,7,8-tetrahydroquinoline group, each unsubstituted or substituted with at least one R_{10a};

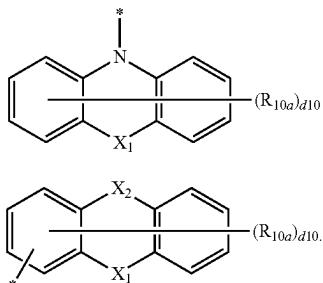
A-1

5

A-2

10

14

N(Q_a)(Q₅); and
a group represented by Formula A-1 and a group represented by Formula A-2;

A-1

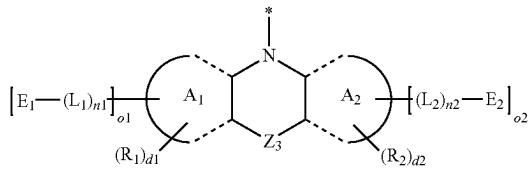
A-2

Formulae A-1 and A-2 are the same as described in the present specification, and

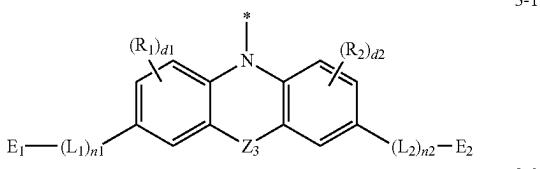
* may indicate a binding site to a neighboring atom.

In one or more embodiments, in Formula 1, *-(L₁)_{n1}-E₁ and *-(L₂)_{n2}-E₂ may be identical to each other.

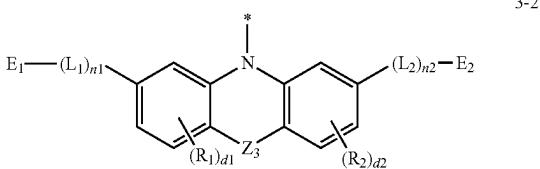
In one or more embodiments, a moiety represented by



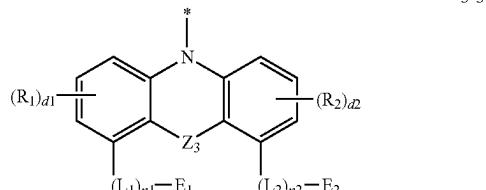
in Formula 1 may be represented by one of Formulae 3-1 to 3-18:



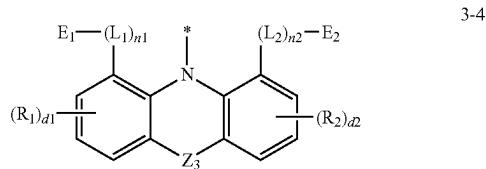
3-1



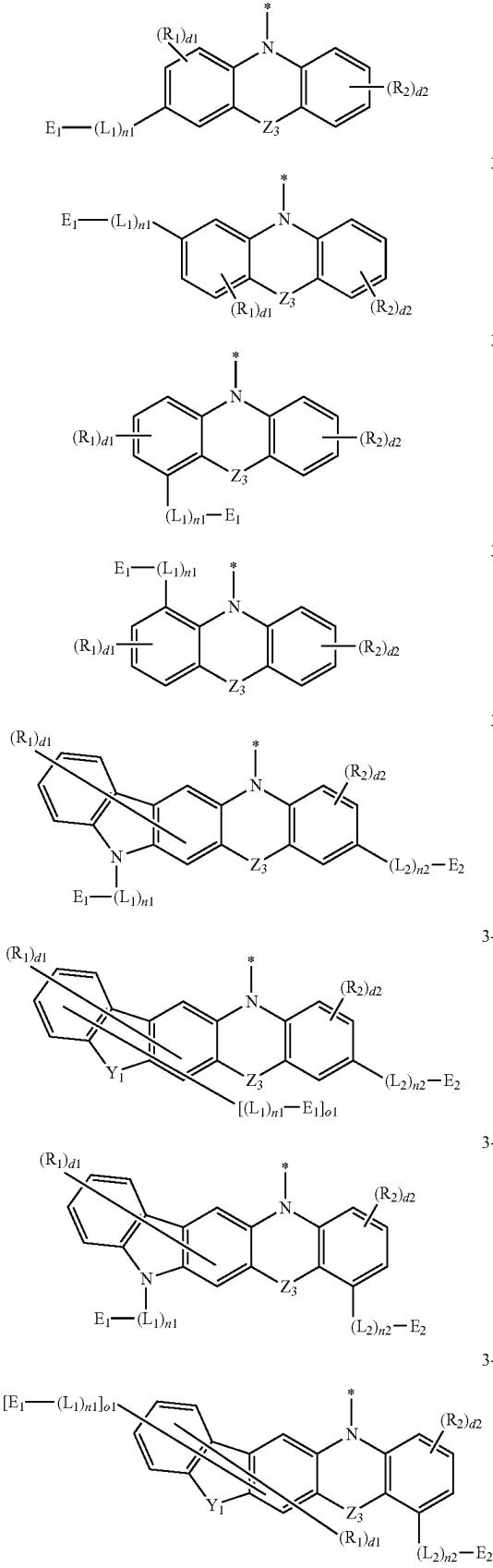
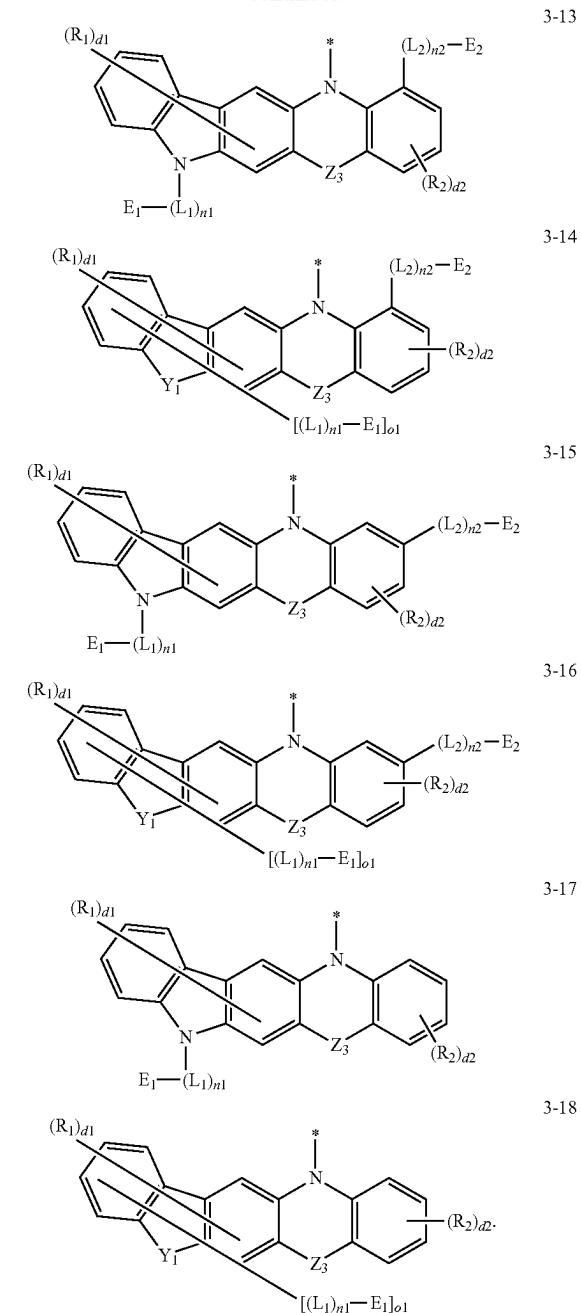
3-2



3-3

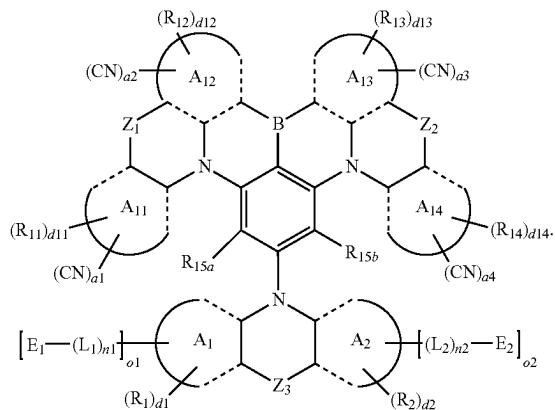
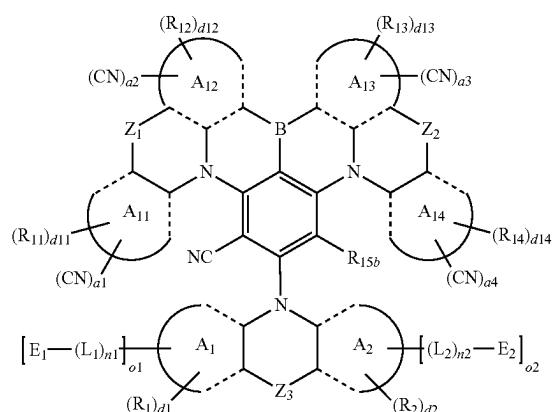
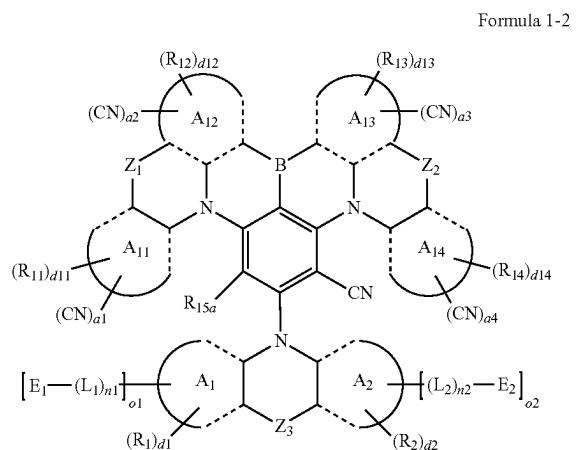
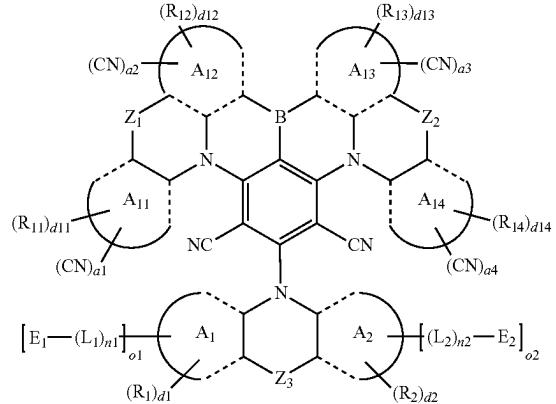


3-4

15
-continued**16**
-continued

In Formulae 3-1 to 3-18, Z_3 , L_1 , L_2 , n_1 , n_2 , E_1 , E_2 , o_1 , R_1 , R_2 , d_1 , and d_2 are the same as described in the present specification, Y_1 may be O, S, Se, C(R_{3a})(R_{3b}), Si(R_{3a})(R_{3b}), or N(R_{3a}), R_{3a} and R_{3b} are each independently the same as described in connection with R_{1a} in the present specification, and * may indicate a binding site to a neighboring atom. n_1 and n_2 may each independently be an integer from 1 to 5. In one or more embodiments, n_1 and n_2 may be 1. o_1 and o_2 may each independently be an integer from 0 to 3. In one or more embodiments, o_1 may be 1, and o_2 may be 0; o_1 may be 0, and o_2 may be 1; or o_1 may be 1, and o_2 may be 1.

In one or more embodiments, the condensed cyclic compound represented by Formula 1 may be represented by one of Formulae 1-1 to 1-4.

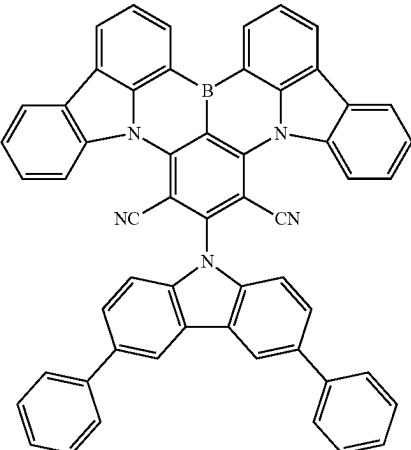
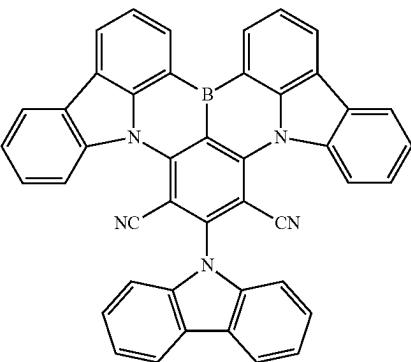


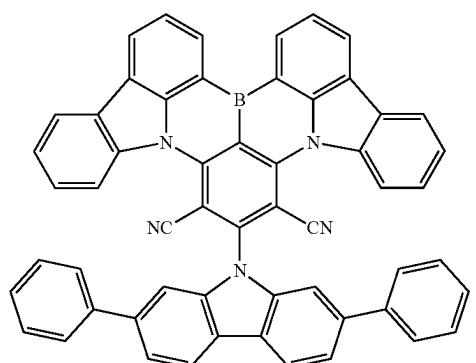
20 In Formulae 1-1 to 1-4, ring A₁, ring A₂, ring A₁₁ to ring A₁₄, R₁, R₂, R₁₁ to R₁₄, d₁, d₂, d₁₁ to d₁₄, Z₁ to Z₃, L₁, L₂, E₁, E₂, n₁, n₂, o₁, and o₂ are the same as described in the present specification,

25 R_{15a} and R_{15b} are each independently the same as described in connection with R₁₅ in the present specification, but the cyano group is excluded,

a₁ to a₄ may be an integer from 0 to 20, and in Formula 1-4, the sum of a₁, a₂, a₃, and a₄ may be an integer of 1 or more.

30 In one or more embodiments, the condensed cyclic compound may be at least one selected from Compounds 1 to 72, but is not limited thereto:



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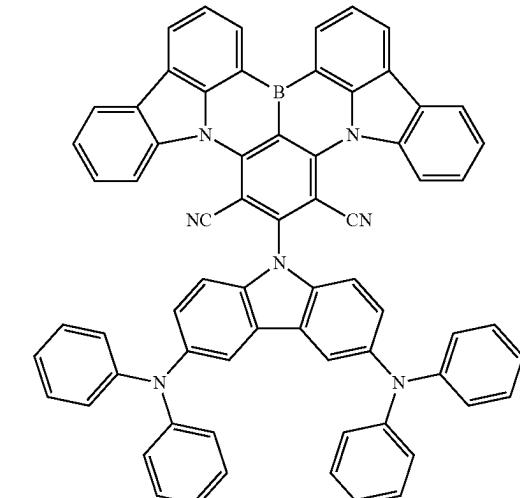
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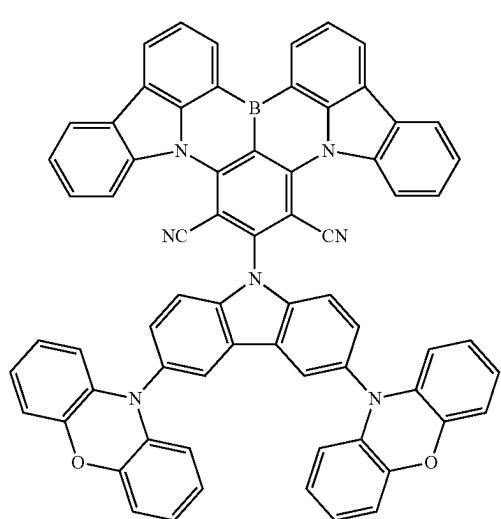
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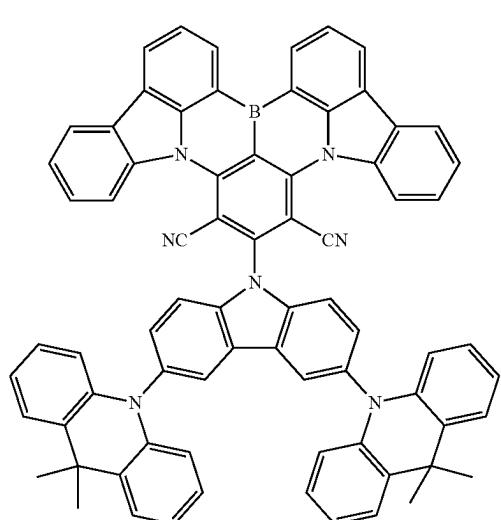


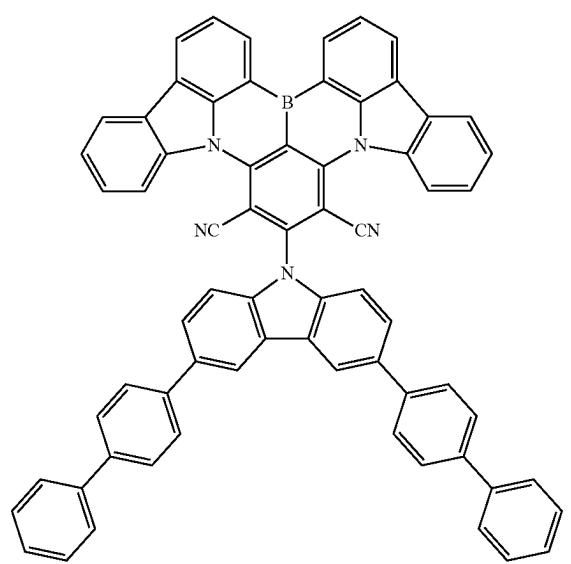
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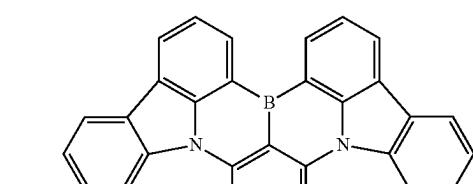
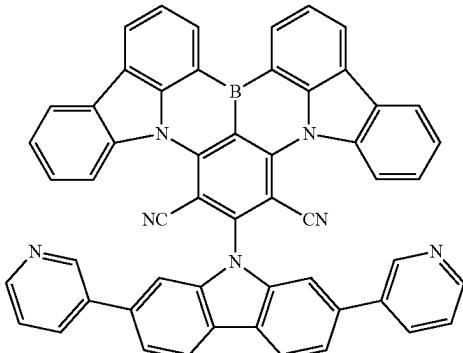
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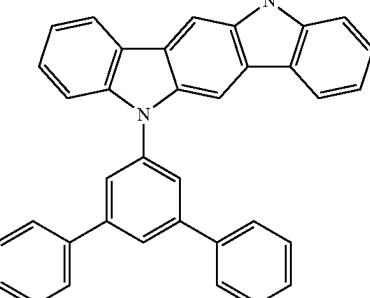
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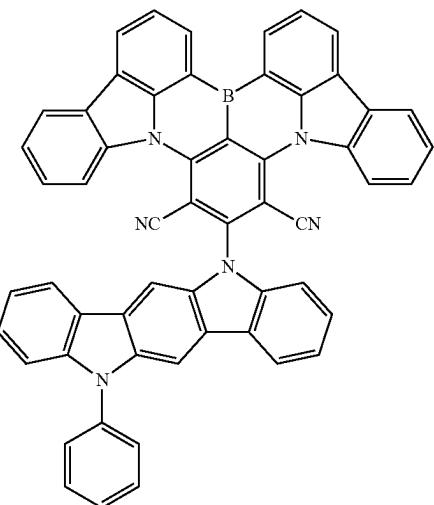
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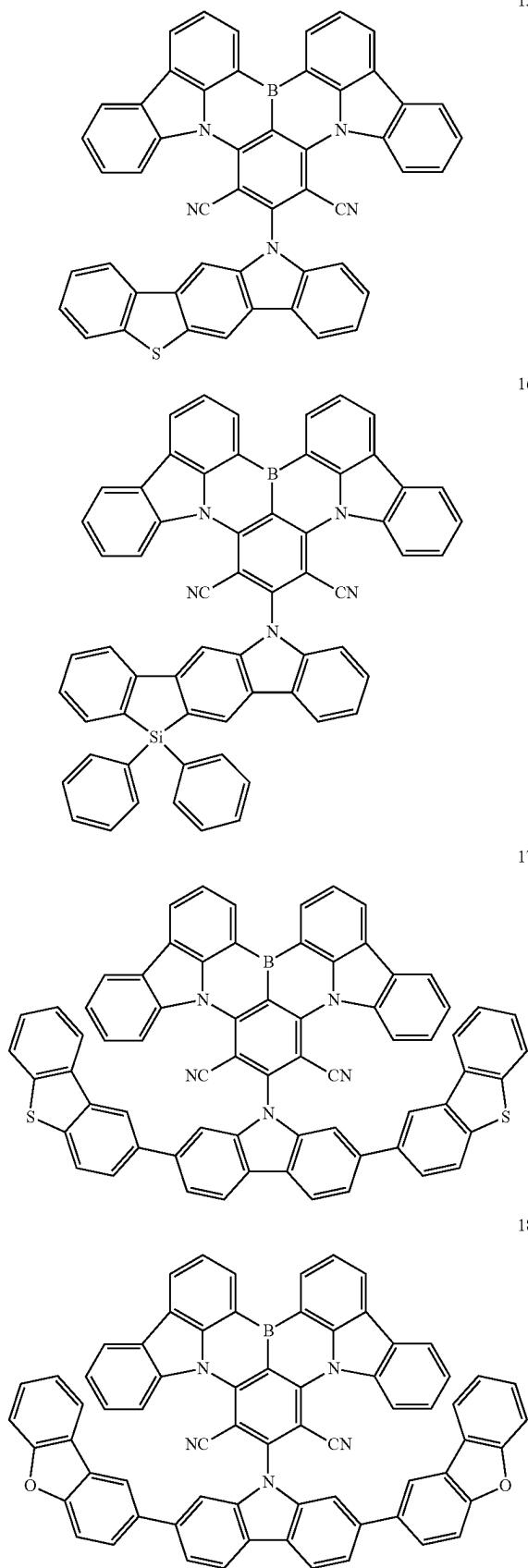


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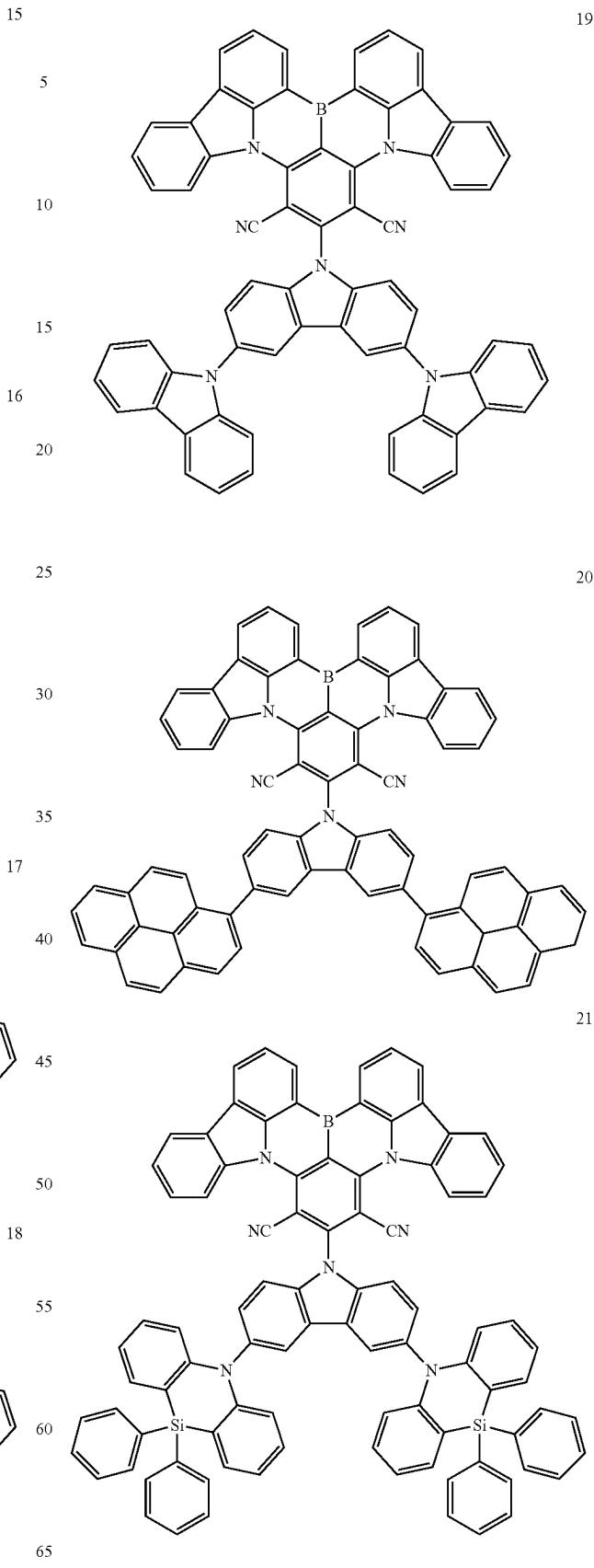


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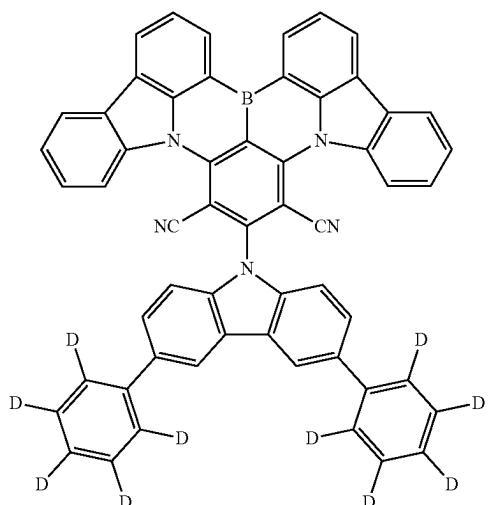
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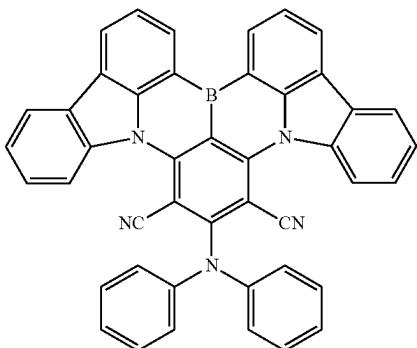
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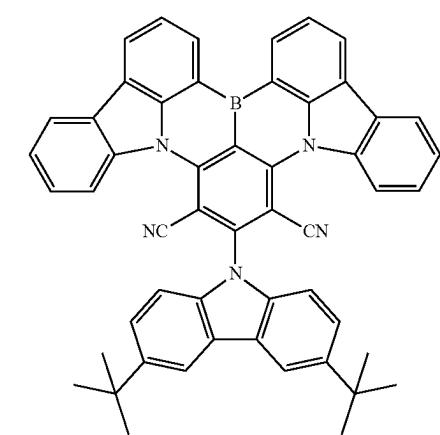
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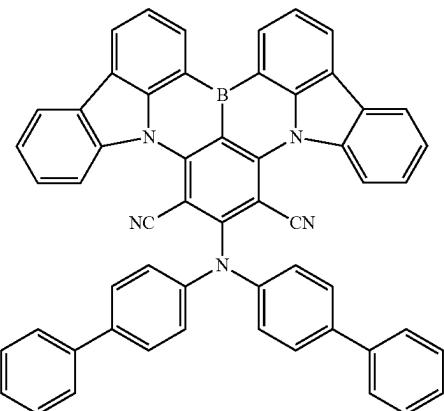


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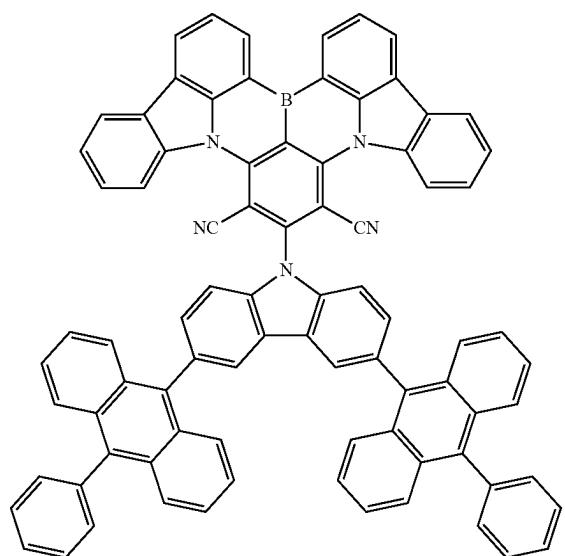
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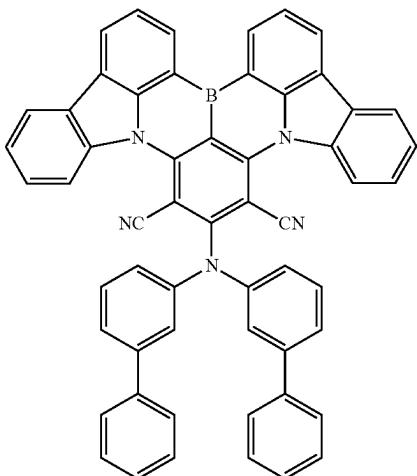
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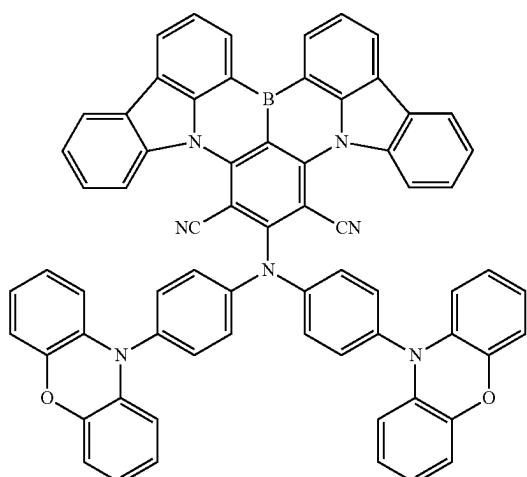
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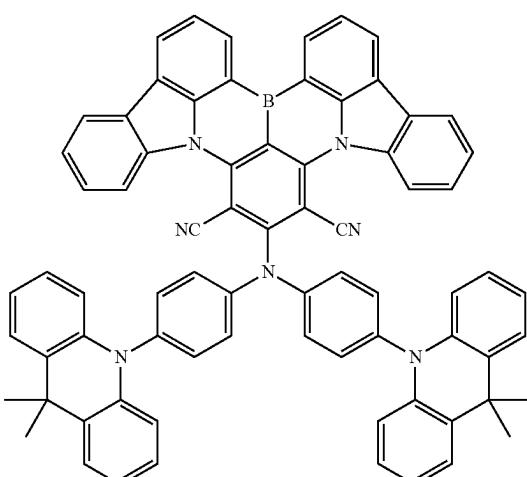
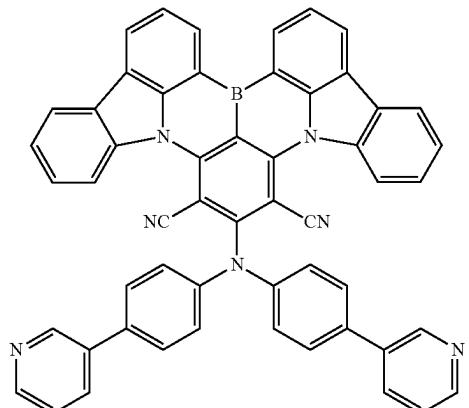
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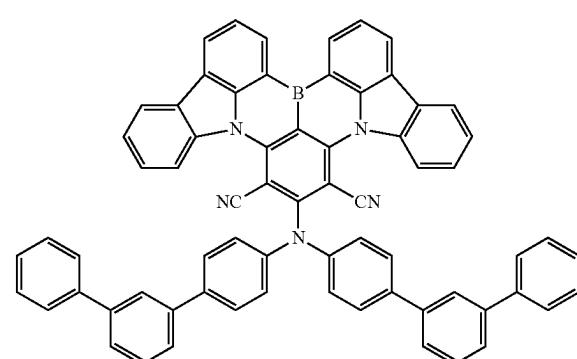


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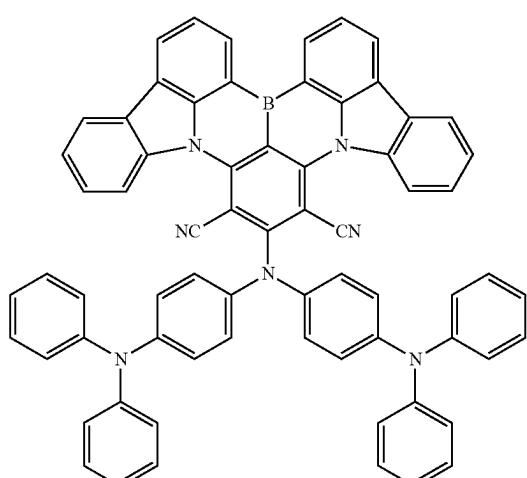
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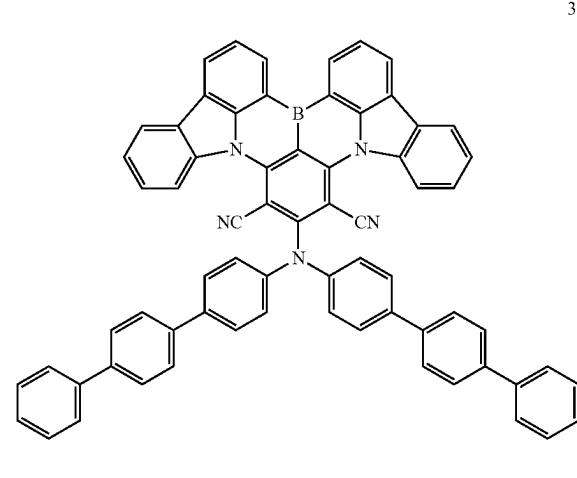
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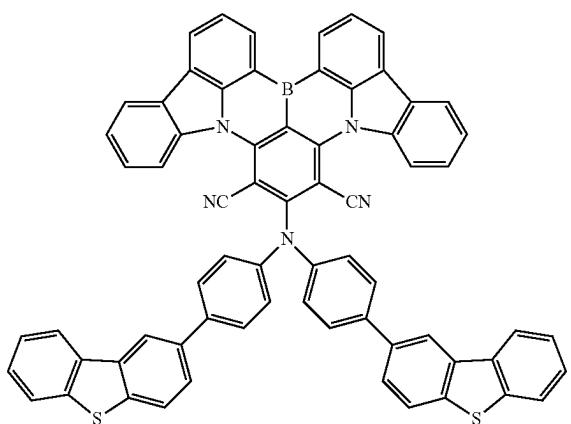
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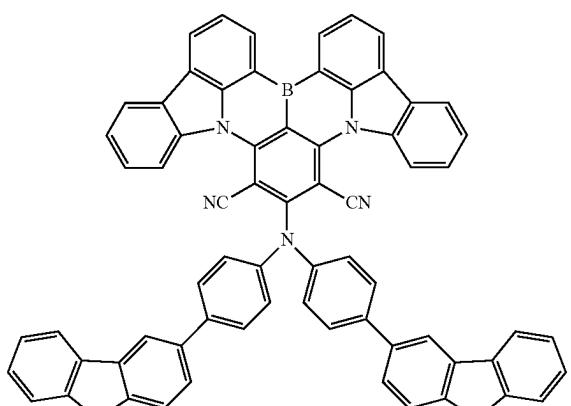
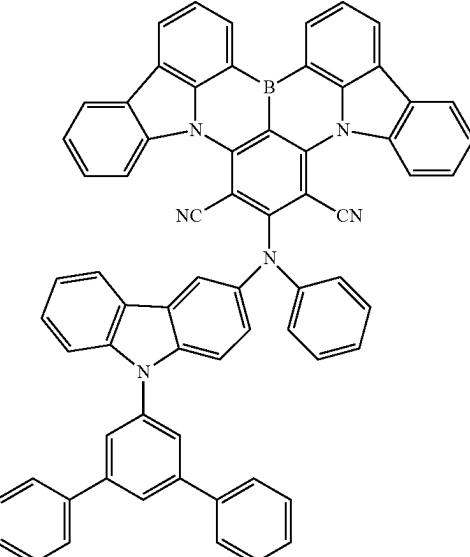
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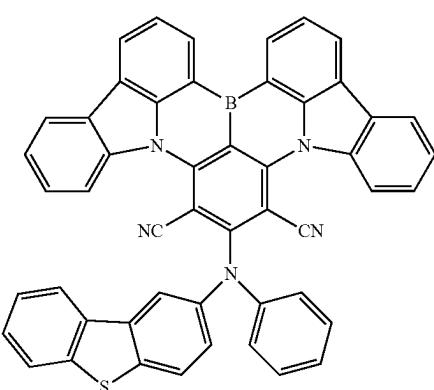
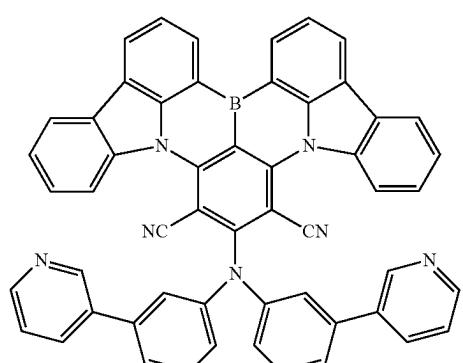
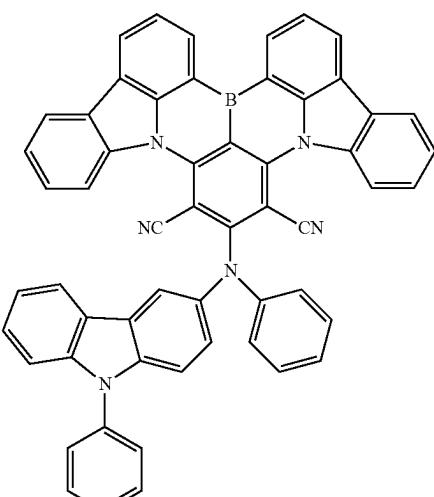
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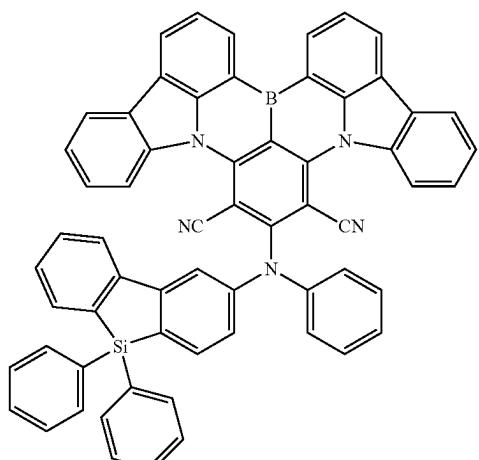
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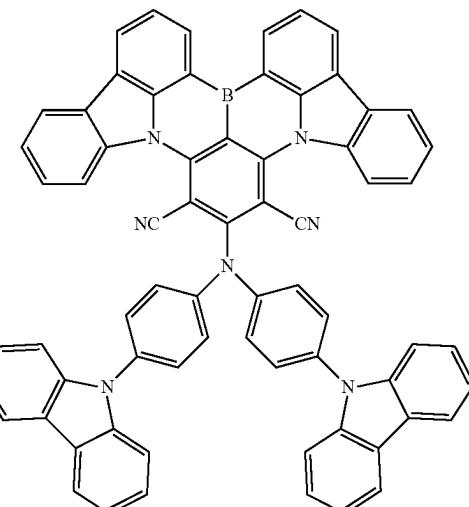


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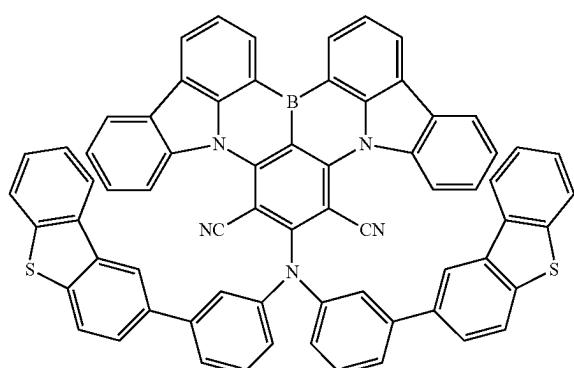


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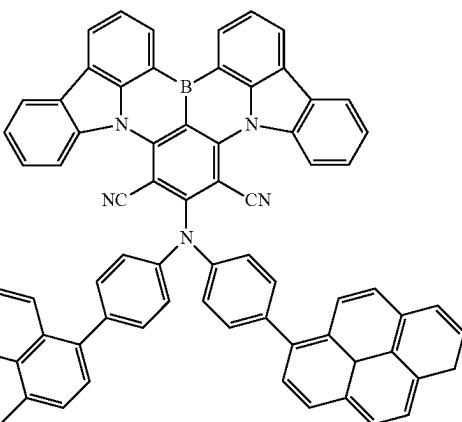
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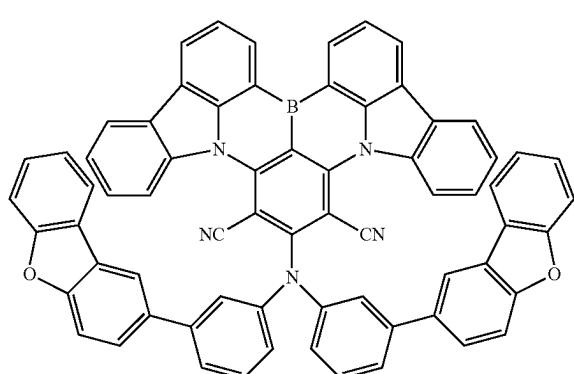


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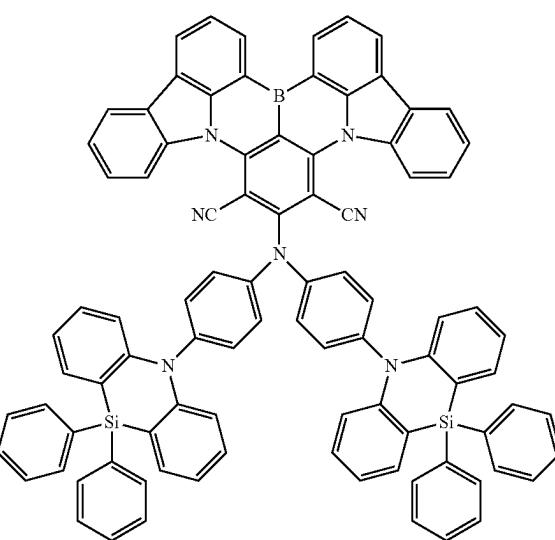


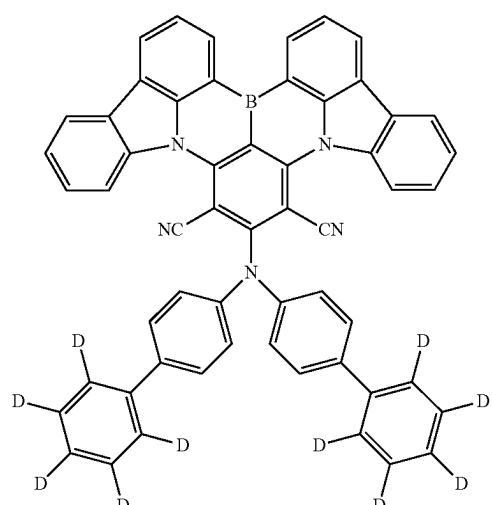
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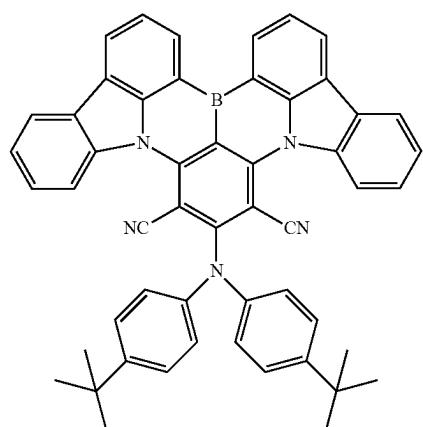
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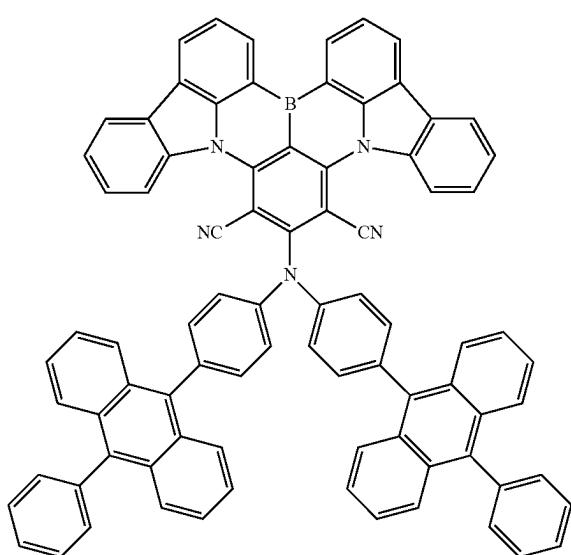
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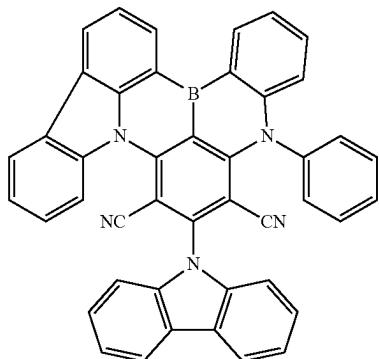


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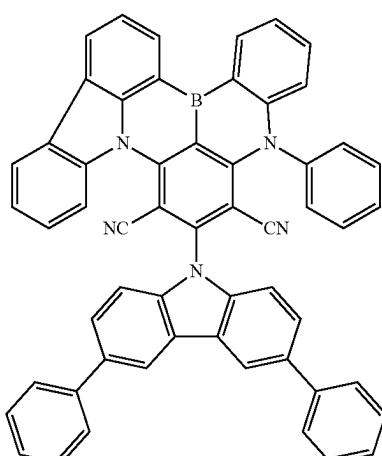
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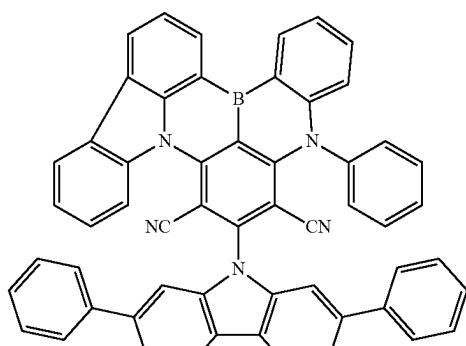
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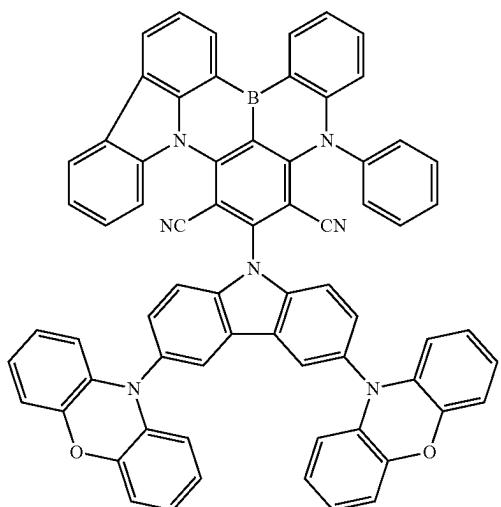
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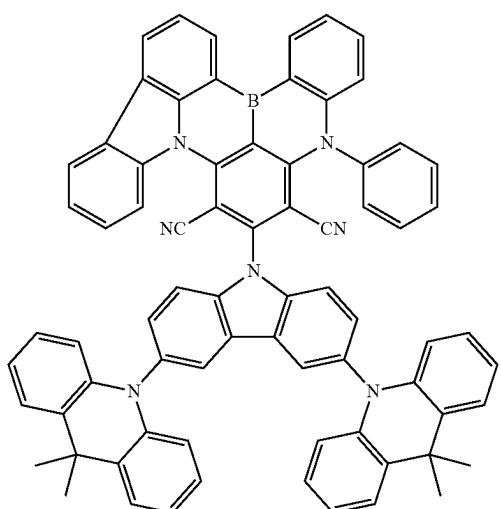
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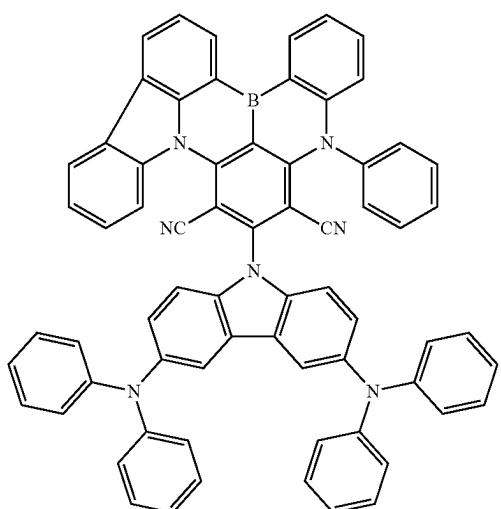
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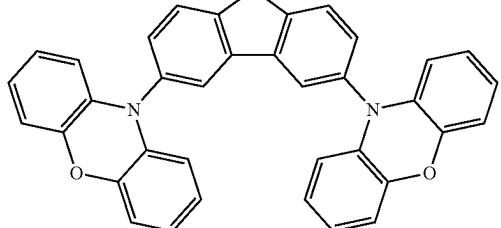
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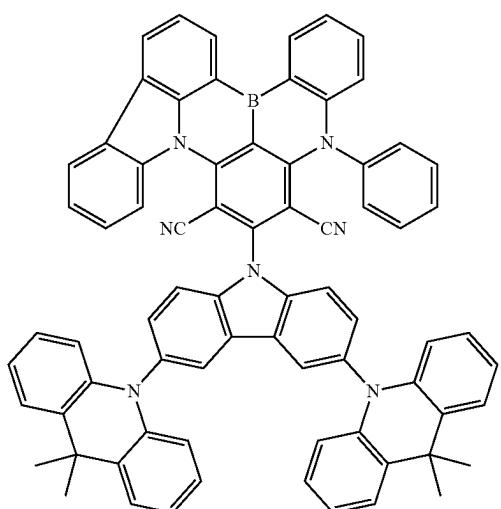
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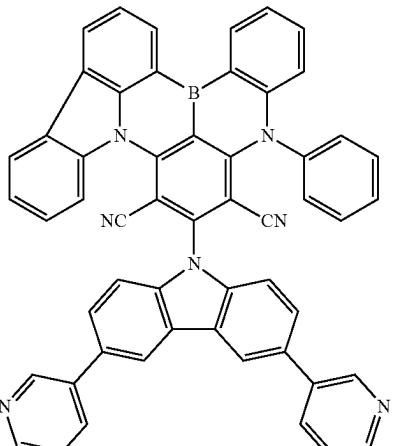
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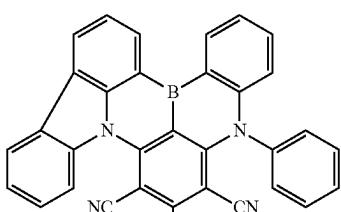
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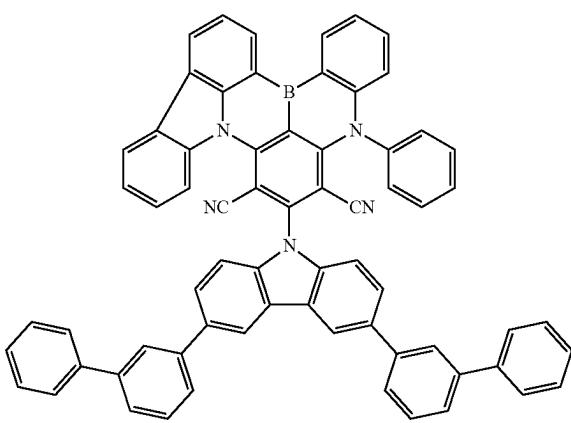
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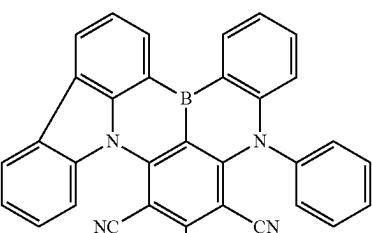
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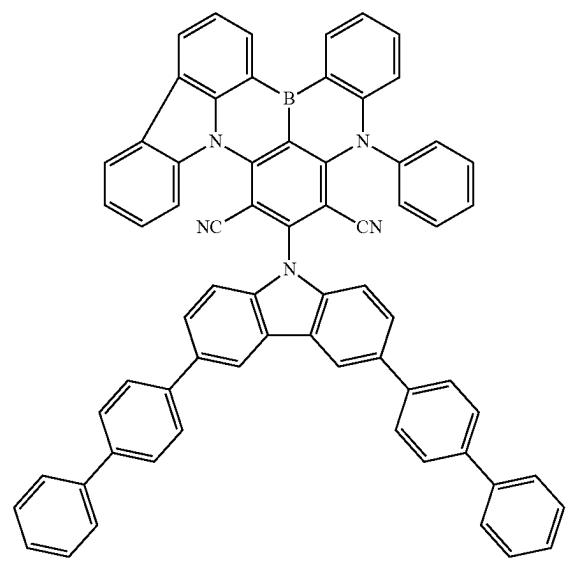
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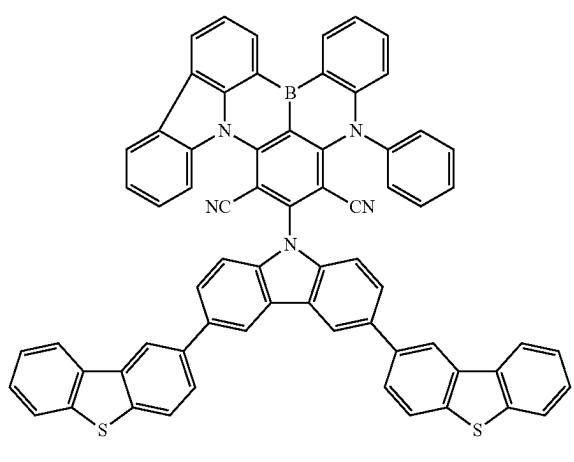


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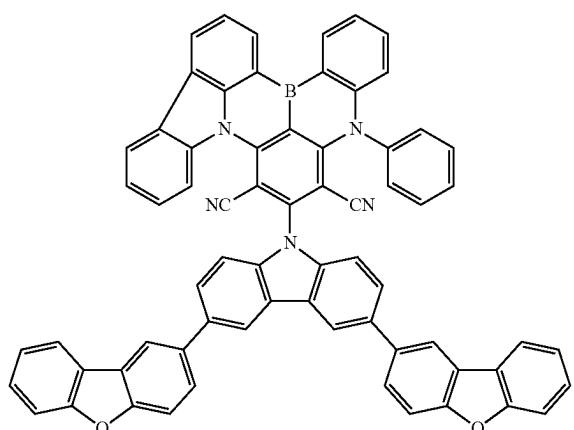
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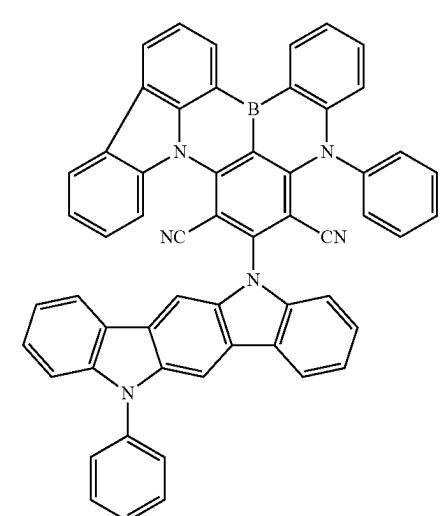
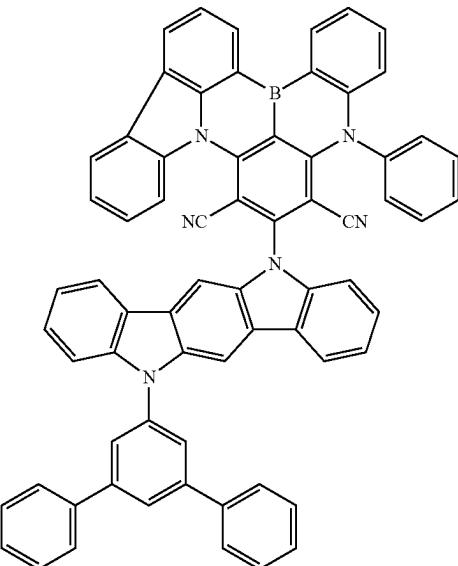
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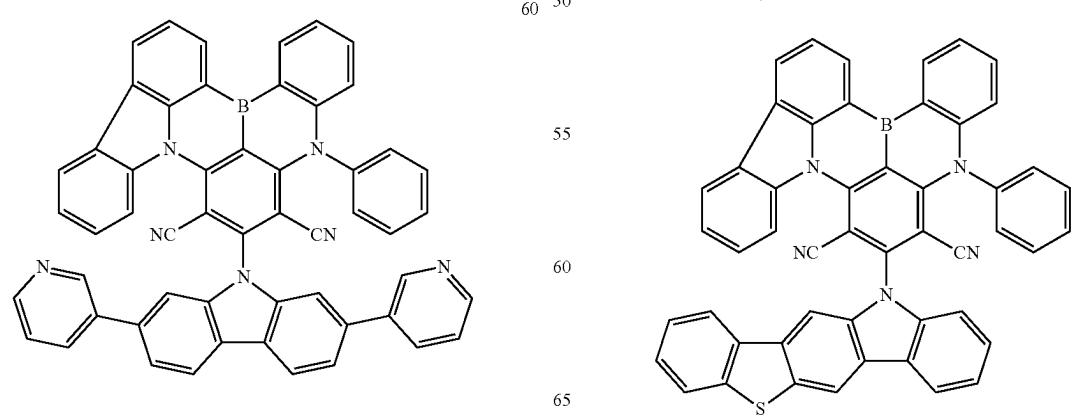
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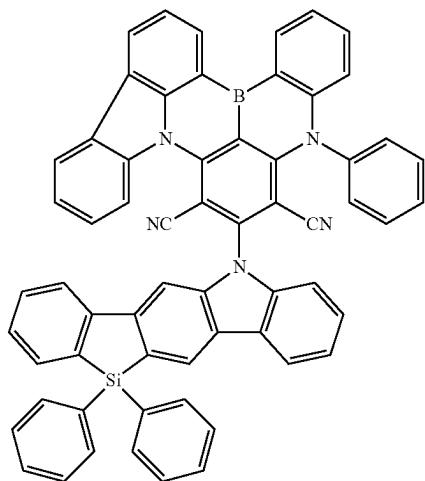
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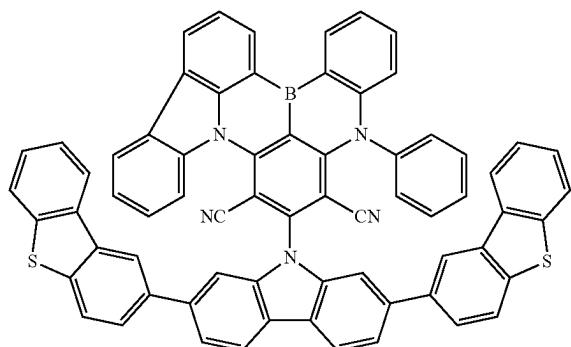


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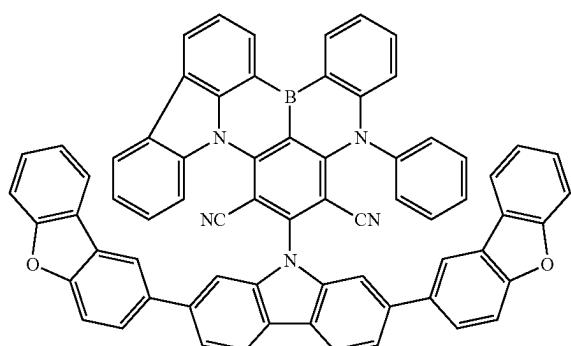
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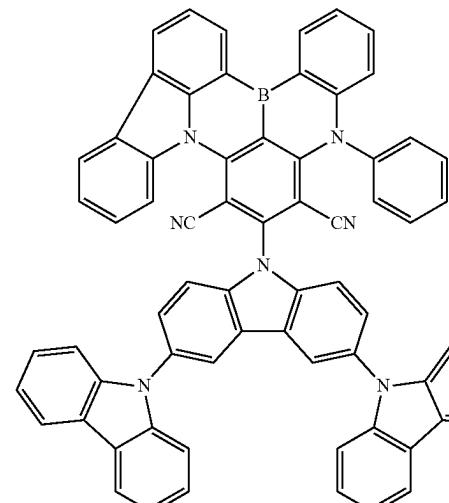
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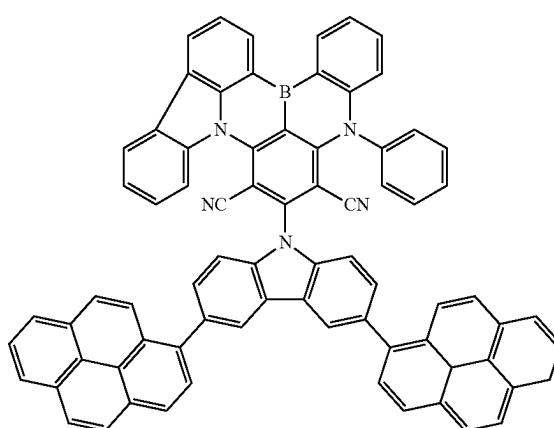
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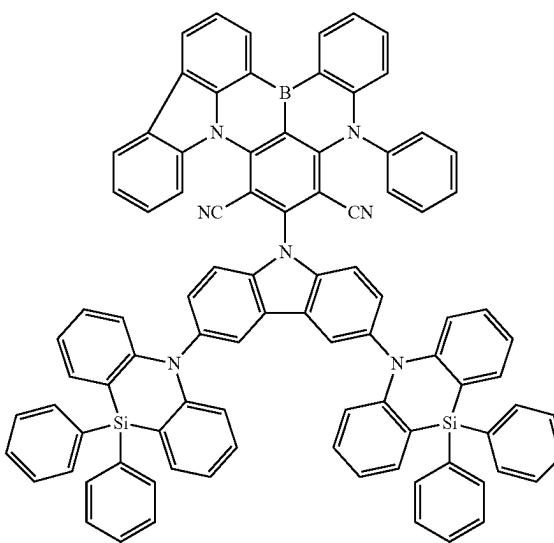
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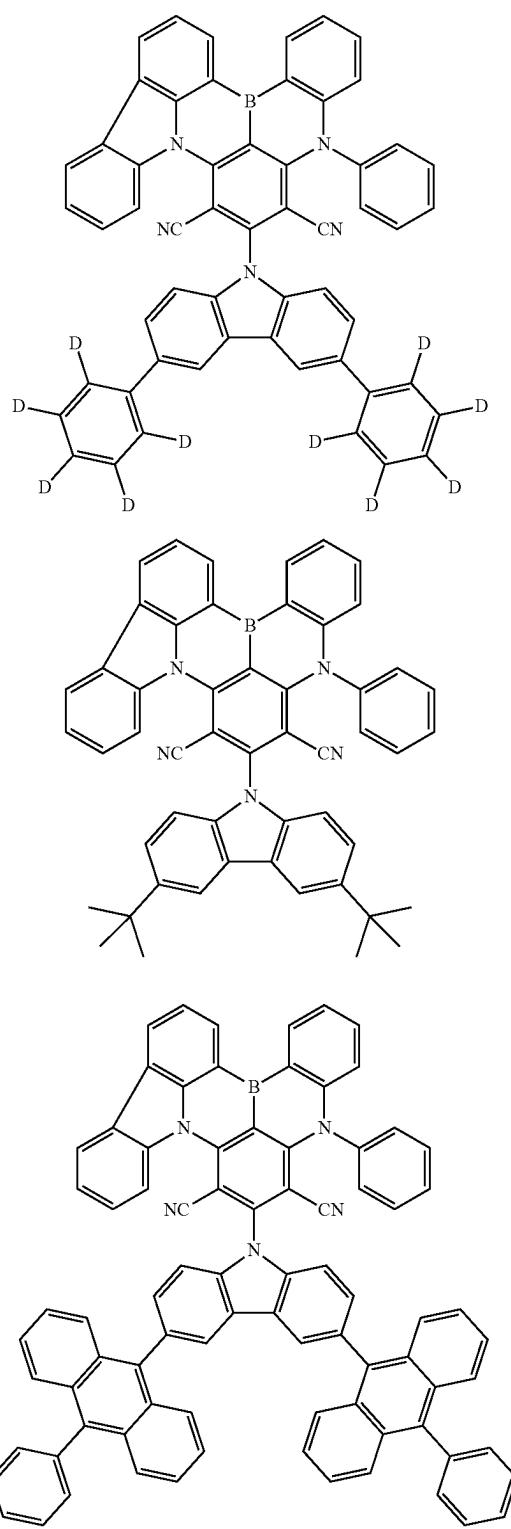
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The condensed cyclic compound represented by Formula 1 may have a broad plate-like (e.g., planar) structure including two nitrogen atoms and one boron atom, and a core structure in which at least one cyano group is substituted.

Formula 1 has the broad plate-like (e.g., planar) structure including two nitrogen atoms and one boron atom, and thus,

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70 due to the broad plate-like (e.g., planar) structure having a condensed ring, the multiple resonance is further activated such that delocalization of an electron in a molecule is expanded, and polarizability is increased such that the f value is further increased. Accordingly, the condensed cyclic compound represented by Formula 1 may be used as a light-emitting material for high-efficiency delayed fluorescence. Also, the backbone has a substituent condensed to a heterocycle. Accordingly, compared to a substituent that is not condensed, the number of C—N bonds that freely rotate is reduced, and thus, in view of a bond dissociation energy (BDE), a molecule may become more rigid, and due to the enriched electron, the chemical instability, which is caused by characteristics of a boron atom that lacks an electron, may be compensated.

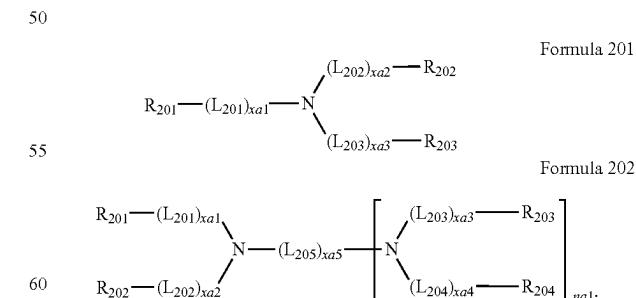
71 Also, because more than one electron withdrawing group is substituted at the core, the multiple resonance may be facilitated, and because the core has a hybrid-type structure 20 with a twist donor-acceptor type character, the larger f value may be obtained. Moreover, the twist donor-acceptor type character may improve the reverse intersystem crossing through small ΔE_{ST} due to highest occupied molecular orbital-lowest unoccupied molecular orbital (HOMO-LUMO) separation.

72 Therefore, an electronic device, e.g., an organic light-emitting device, using the condensed cyclic compound represented by Formula 1 may have a low driving voltage, high maximum quantum efficiency, high efficiency, and a long lifespan.

35 Synthesis methods of the condensed cyclic compound represented by Formula 1 may be recognizable by one of ordinary skill in the art by referring to Examples provided below.

30 At least one condensed cyclic compound represented by Formula 1 may be used in a light-emitting device (for example, an organic light-emitting device).

72 In one or more embodiments, provided is a light-emitting device including: a first electrode; a second electrode facing 40 the first electrode; and an interlayer located between the first electrode and the second electrode and including an emission layer, wherein the interlayer further includes a hole transport region between the first electrode and the emission layer, and the hole transport region includes a compound 45 represented by Formula 201, a compound represented by Formula 202, or any combination thereof, and the emission layer includes at least one condensed cyclic compound represented by Formula 1.



In Formulae 201 and 202, L₂₀₁ to L₂₀₄ may each independently be a C₃-C₆₀ carbocyclic group unsubstituted or substituted with at least one R_{10a} or a C₁-C₆₀ heterocyclic group unsubstituted or substituted with at least one R_{10a},

L_{205} may be $*-\text{O}-*$, $*-\text{S}-*$, $*-\text{N}(\text{Q}_{201})-*$, a $\text{C}_1\text{-C}_{20}$ alkylene group unsubstituted or substituted with at least one R_{10a} , a $\text{C}_2\text{-C}_{20}$ alkenylene group unsubstituted or substituted with at least one R_{10a} , a $\text{C}_3\text{-C}_{60}$ carbocyclic group unsubstituted or substituted with at least one R_{10a} , or a $\text{C}_1\text{-C}_{60}$ heterocyclic group unsubstituted or substituted with at least one R_{10a} , $\text{x}a1$ to $\text{x}a4$ may each independently be an integer from 0 to 5, $\text{x}a5$ may be an integer from 1 to 10, R_{201} to R_{204} and Q_{201} may each independently be a $\text{C}_3\text{-C}_{60}$ carbocyclic group unsubstituted or substituted with at least one R_{10a} or a $\text{C}_1\text{-C}_{60}$ heterocyclic group unsubstituted or substituted with at least one R_{10a} , R_{201} and R_{202} may optionally be linked to each other via a single bond, a $\text{C}_1\text{-C}_5$ alkylene group unsubstituted or substituted with at least one R_{10a} , or a $\text{C}_2\text{-C}_5$ alkenylene group unsubstituted or substituted with at least one R_{10a} , to form a $\text{C}_8\text{-C}_{60}$ polycyclic group unsubstituted or substituted with at least one R_{10a} , R_{203} and R_{204} may optionally be linked to each other via a single bond, a $\text{C}_1\text{-C}_5$ alkylene group unsubstituted or substituted with at least one R_{10a} , or a $\text{C}_2\text{-C}_5$ alkenylene group unsubstituted or substituted with at least one R_{10a} , to form a $\text{C}_8\text{-C}_{60}$ polycyclic group unsubstituted or substituted with at least one R_{10a} , and $\text{n}a1$ may be an integer from 1 to 4.

In one or more embodiments, the first electrode of the light-emitting device may be an anode, the second electrode of the light-emitting device may be a cathode, the interlayer may further include an electron transport region between the emission layer and the second electrode, the hole transport region may include a hole injection layer, a hole transport layer, an emission auxiliary layer, an electron blocking layer, or any combination thereof, and the electron transport region may include a hole blocking layer, an electron transport layer, an electron injection layer, or any combination thereof.

In one or more embodiments, the emission layer in the interlayer of the light-emitting device may include a dopant and a host, and the condensed cyclic compound may be included in the dopant. That is, the condensed cyclic compound may act as a dopant.

The emission layer may emit red light, green light, blue light, and/or white light. In one or more embodiments, the emission layer may emit blue light or blue-green light. The blue light or blue-green light may have, for example, a maximum luminescence wavelength in the range of about 400 nm to about 500 nm.

The condensed cyclic compound included in the emission layer acts as a delayed fluorescence dopant, so that delayed fluorescence may be emitted from the emission layer.

In one or more embodiments, the light-emitting device may further include:

- a first capping layer, located outside the first electrode;
- a second capping layer, located outside the second electrode; or
- the first capping layer and the second capping layer.

According to one or more embodiments, provided is a light-emitting device including: a first electrode; a second electrode facing the first electrode; and an interlayer located between the first electrode and the second electrode and including an emission layer,

wherein the light-emitting device further includes a capping layer, which is located outside the second electrode and has a refractive index of 1.6 or more, and the emission layer includes at least one condensed cyclic compound represented by Formula 1.

In one or more embodiments, an encapsulation portion may be disposed on the capping layer. The encapsulation portion may be disposed on a light-emitting device to protect the light-emitting device from moisture and/or oxygen.

In one or more embodiments, the encapsulation portion may include: an inorganic film including silicon nitride (SiNx), silicon oxide (SiOx), indium tin oxide, indium zinc oxide, or any combination thereof;

an organic film including polyethyleneterephthalate, polyethylenenaphthalate, polycarbonate, polyimide, polyethylenesulfonate, polyoxymethylene, polyarylate, hexamethyldisiloxane, an acrylic resin (for example, polymethylmethacrylate, polyacrylic acid, etc.), an epoxy-based resin (for example, an aliphatic glycidyl ether (AGE), etc.), or any combination thereof; or a combination of the inorganic film and the organic film.

The expression “(an interlayer) includes a condensed cyclic compound” used herein may include a case in which “(an interlayer) includes identical condensed cyclic compounds represented by Formula 1” and a case in which “(an interlayer) includes two or more different condensed cyclic compounds represented by Formula 1.”

In one or more embodiments, the interlayer may include, as the condensed cyclic compound, only Compound 1. In this regard, Compound 1 may exist (e.g., be included in) in the emission layer of the light-emitting device. In one or more embodiments, the interlayer may include, as the condensed cyclic compound, Compound 1 and Compound 2. In this regard, Compound 1 and Compound 2 may exist (e.g., be included in) in an identical layer (for example, Compound 1 and Compound 2 may both exist in an emission layer), or different layers (for example, Compound 1 may exist in an emission layer and Compound 2 may exist in an electron transport region).

The term “interlayer” as used herein refers to a single layer and/or all of a plurality of layers located between the first electrode and the second electrode of the light-emitting device.

According to one or more embodiments, provided is an electronic apparatus including the light-emitting device. The electronic apparatus may further include a thin-film transistor.

In one or more embodiments, the electronic apparatus may further include a thin-film transistor including a source electrode and a drain electrode, and the first electrode of the light-emitting device may be electrically connected to the source electrode or the drain electrode.

In one or more embodiments, the electronic apparatus may further include a color filter, a color conversion layer, a touch screen layer, a polarizing layer, or any combination thereof. For example, the electronic apparatus may be a flat panel display apparatus, but embodiments of the present disclosure are not limited thereto.

More detailed description of the electronic apparatus is the same as described in the present specification.

Description of FIG. 1

FIG. 1 is a schematic cross-sectional view of a light-emitting device 10 according to one or more embodiments. The light-emitting device 10 includes a first electrode 110, an interlayer 130, and a second electrode 150.

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Hereinafter, a structure of the light-emitting device **10** according to one or more embodiments and a method of manufacturing the light-emitting device **10** will be described in connection with FIG. 1.

First Electrode **110**

In FIG. 1, a substrate may be additionally located under the first electrode **110** or above the second electrode **150**. The substrate may be a glass substrate or a plastic substrate. The substrate may be a flexible substrate. In one or more embodiments, the substrate may include plastics with excellent heat resistance and durability, such as polyimide, polyethylene terephthalate (PET), polycarbonate, polyethylene naphthalate, polyarylate (PAR), polyetherimide, or any combination thereof.

The first electrode **110** may be formed by, for example, 15 depositing or sputtering a material for forming the first electrode **110** on the substrate. When the first electrode **110** is an anode, a high work function material that can easily inject holes may be used as a material for forming the first electrode **110**.

The first electrode **110** may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. When the first electrode **110** is a transmissive electrode, a material for forming the first electrode **110** may include indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO₂), zinc oxide (ZnO), or any combination thereof. In one or more embodiments, when the first electrode **110** is a semi-transmissive electrode or a reflective electrode, magnesium (Mg), silver (Ag), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), or any combination thereof may be used as a material for forming the first electrode **110**.

The first electrode **110** may have a single-layered structure including (e.g., consisting of) a single layer or a multi-layered structure including a plurality of layers. In one or more embodiments, the first electrode **110** may have a three-layered structure of ITO/Ag/ITO.

Interlayer **130**

The interlayer **130** is located on the first electrode **110**. The interlayer **130** includes an emission layer.

The interlayer **130** may further include a hole transport region located between the first electrode **110** and the emission layer, and an electron transport region located between the emission layer and the second electrode **150**.

The interlayer **130** may further include metal-containing compounds such as organometallic compounds, inorganic materials such as quantum dots, and/or the like, in addition to various suitable organic materials.

In one or more embodiments, the interlayer **130** may include, i) two or more emitting units sequentially stacked between the first electrode **110** and the second electrode **150** and ii) a charge generation layer between the two emitting units. When the interlayer **130** includes the emitting units and the charge generation layer, the light-emitting device **10** may be a tandem light-emitting device.

Hole Transport Region in Interlayer **130**

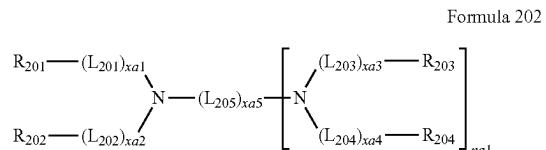
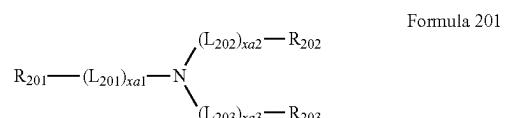
The hole transport region may have: i) a single-layered structure including (e.g., consisting of) a single layer including (e.g., consisting of) a single material, ii) a single-layered structure including (e.g., consisting of) a single layer including a plurality of different materials, or iii) a multi-layered structure including a plurality of layers including different materials.

The hole transport region may include a hole injection layer (HIL), a hole transport layer (HTL), an emission auxiliary layer, an electron blocking layer (EBL), or any combination thereof.

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For example, the hole transport region may have a multi-layered structure including a hole injection layer/hole transport layer structure, a hole injection layer/hole transport layer/emission auxiliary layer structure, a hole injection layer/emission auxiliary layer structure, a hole transport layer/emission auxiliary layer structure, or a hole injection layer/hole transport layer/electron blocking layer structure, wherein, in each structure, layers are stacked sequentially from the first electrode **110**.

The hole transport region may include a compound represented by Formula 201, a compound represented by Formula 202, or any combination thereof:



In Formulae 201 and 202,

L_{201} to L_{204} may each independently be a C₃-C₆₀ carbocyclic group unsubstituted or substituted with at least one R_{10a} or a C₁-C₆₀ heterocyclic group unsubstituted or substituted with at least one R_{10a} ,

L_{205} may be *—O—*, *—S—*, *—N(Q₂₀₁)—*, a C₁-C₂₀ alkylene group unsubstituted or substituted with at least one R_{10a} , a C₂-C₂₀ alkenylene group unsubstituted or substituted with at least one R_{10a} , a C₃-C₆₀ carbocyclic group unsubstituted or substituted with at least one R_{10a} , or a C₁-C₆₀ heterocyclic group unsubstituted or substituted with at least one R_{10a} ,

$xa1$ to $xa4$ may each independently be an integer from 0 to 5,

$xa5$ may be an integer from 1 to 10,

R_{201} to R_{204} and Q_{201} may each independently be a C₃-C₆₀ carbocyclic group unsubstituted or substituted with at least one R_{10a} or a C₁-C₆₀ heterocyclic group unsubstituted or substituted with at least one R_{10a} ,

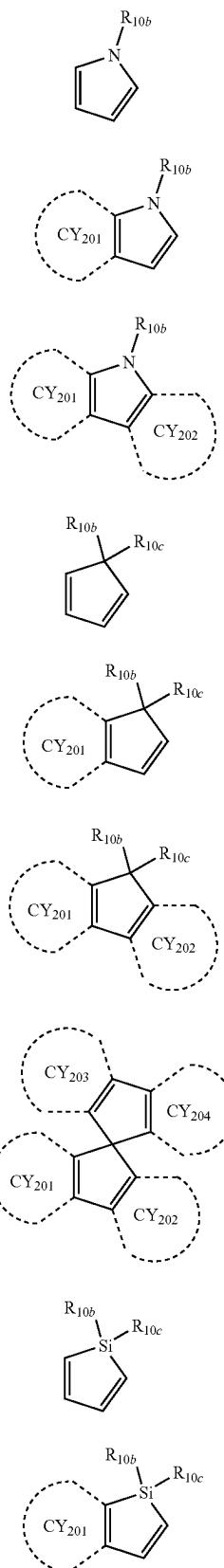
R_{201} and R_{202} may optionally be linked to each other via a single bond, a C₁-C₅ alkylene group unsubstituted or substituted with at least one R_{10a} , or a C₂-C₅ alkenylene group unsubstituted or substituted with at least one R_{10a} , to form a C₈-C₆₀ polycyclic group unsubstituted or substituted with at least one R_{10a} (for example, a carbazole group and/or the like) (for example, refer to the following Compound HT16),

R_{203} and R_{204} may optionally be linked to each other via a single bond, a C₁-C₅ alkylene group unsubstituted or substituted with at least one R_{10a} , or a C₂-C₅ alkenylene group unsubstituted or substituted with at least one R_{10a} , to form a C₈-C₆₀ poly cyclic group unsubstituted or substituted with at least one R_{10a} , and

$na1$ may be an integer from 1 to 4.

In one or more embodiments, Formulae 201 and 202 may each include at least one of groups represented by Formulae CY201 to CY217:

47



48

-continued

CY210

CY211

CY212

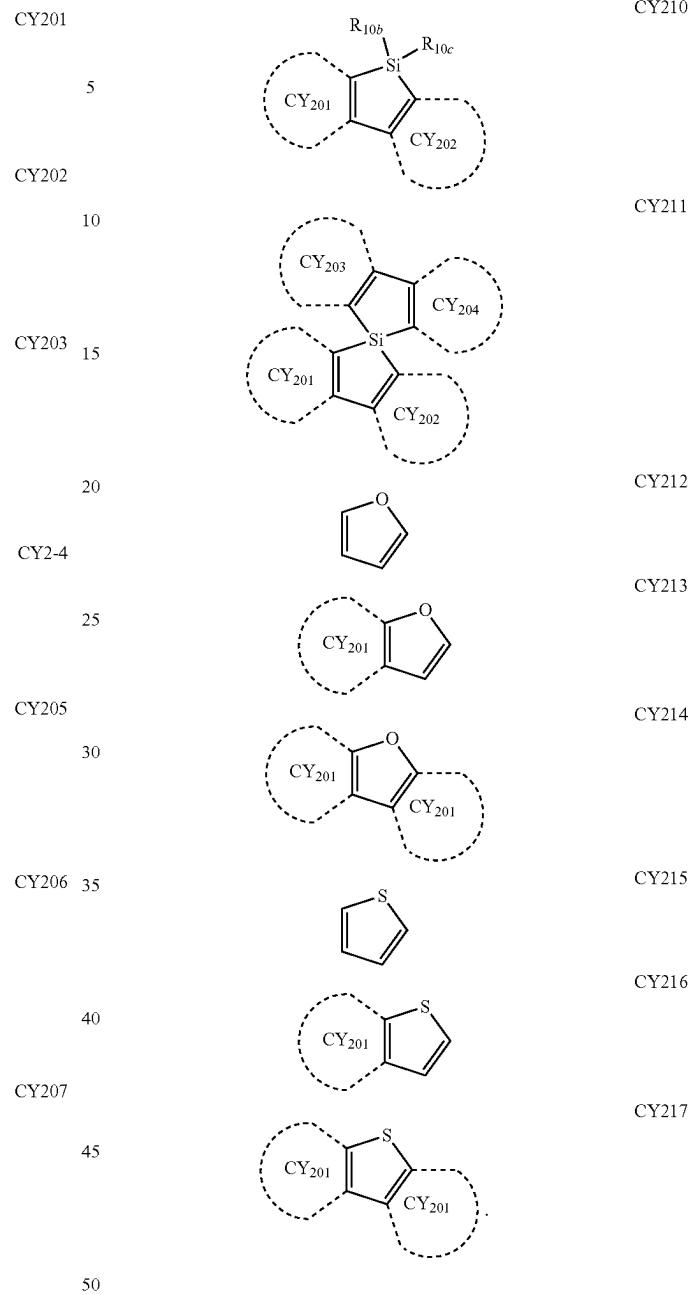
CY213

CY214

CY215

CY216

CY217



Regarding Formulae CY201 to CY217, R_{10b} and R_{10c} are the same as described in connection with R_{10a}, ring CY201 to ring CY204 may each independently be a C₃-C₂₀ carbocyclic group or a C₁-C₂₀ heterocyclic group, and at least one hydrogen in Formula CY201 to CY217 may be unsubstituted or substituted with at least one R_{10a} described herein.

In one or more embodiments, ring CY201 to ring CY204 in Formulae CY201 to CY217 may each independently be a benzene group, a naphthalene group, a phenanthrene group, or an anthracene group.

In one or more embodiments, Formulae 201 and 202 may each include at least one of groups represented by Formulae CY201 to CY203.

In one or more embodiments, Formula 201 may include at least one of groups represented by Formulae CY201 to CY203 and at least one of groups represented by Formulae CY204 to CY217.

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In one or more embodiments, in Formula 201, xa1 is 1, R₂₀₁ is a group represented by one of Formulae CY201 to CY203, xa2 is 0, and R₂₀₂ is a group represented by one of Formulae CY204 to CY207.

In one or more embodiments, each of Formulae 201 and 202 may not include a group represented by one of Formulae CY201 to CY203.

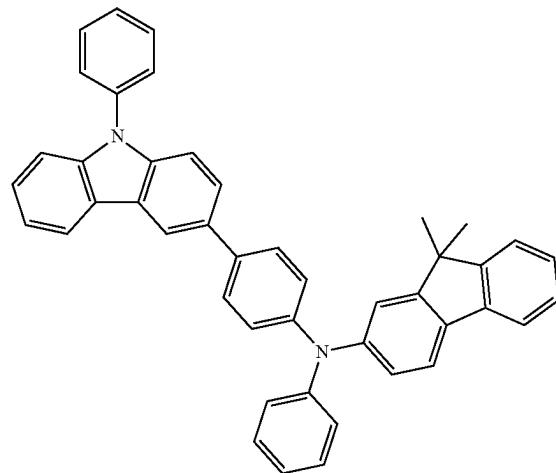
In one or more embodiments, each of Formulae 201 and 202 may not include a group represented by one of Formulae CY201 to CY203 and may include at least one of groups represented by Formulae CY204 to CY217.

In one or more embodiments, each of Formulae 201 and 202 may not include a group represented by one of Formulae CY201 to CY217.

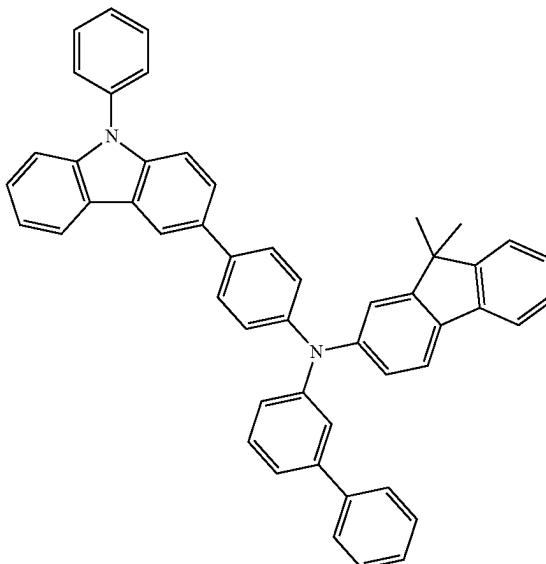
50

In one or more embodiments, the hole transport region may include one of Compounds HT1 to HT44, m-MT-DATA, TDATA, 2-TNATA, NPB(NPD), 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), or any combination thereof:

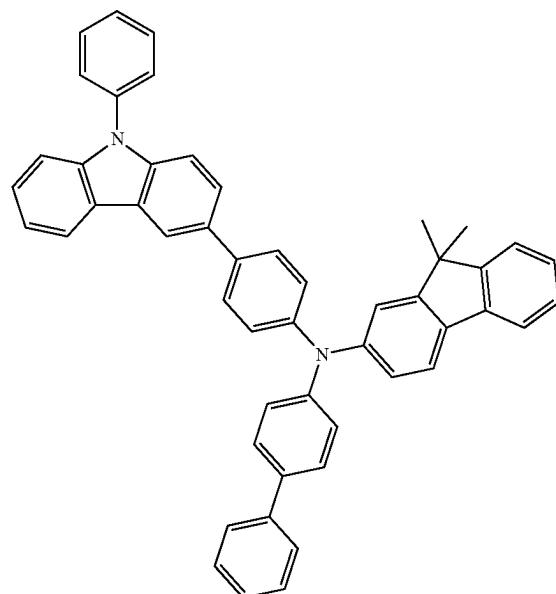
HT1



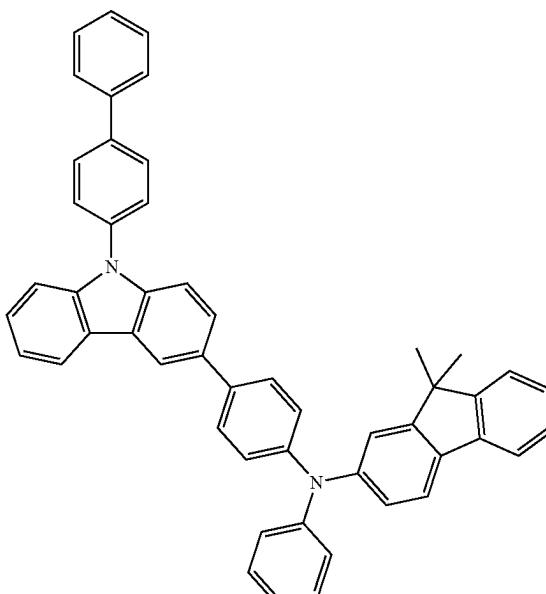
HT2



HT3



HT4

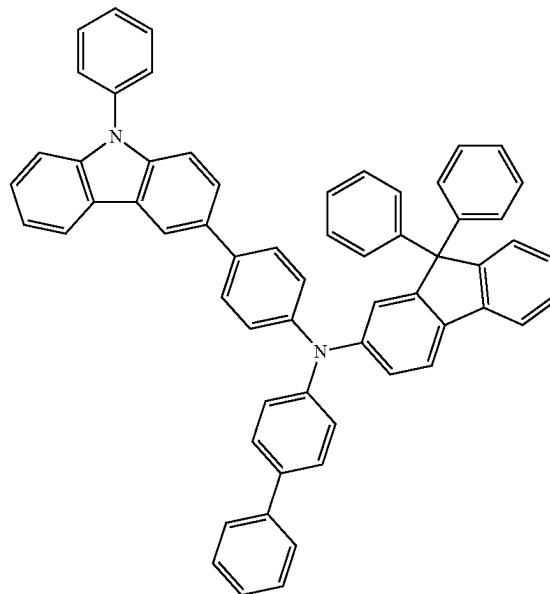
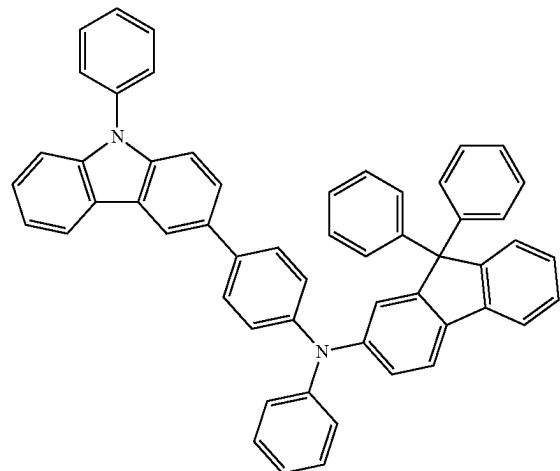


51**52**

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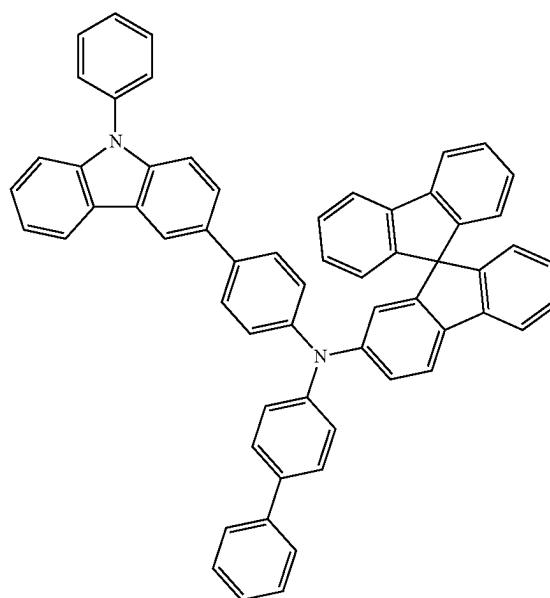
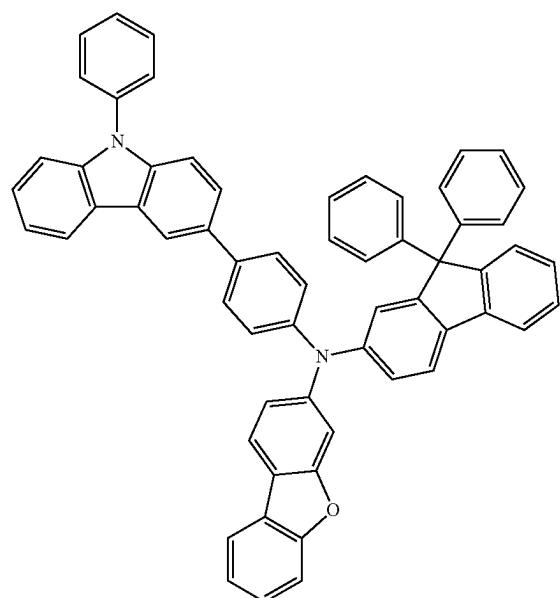
HT5

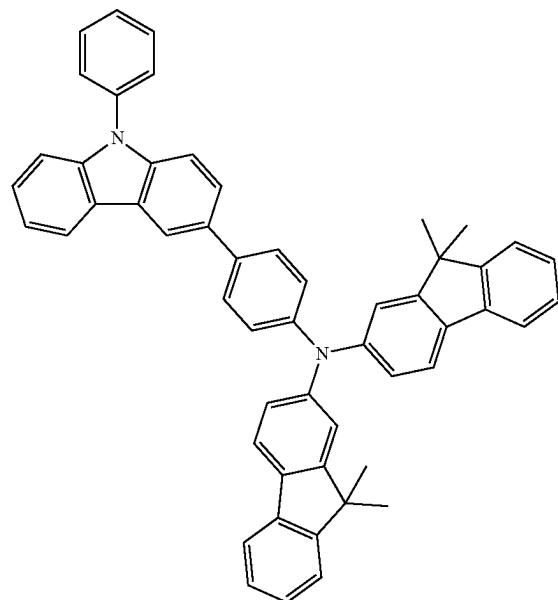
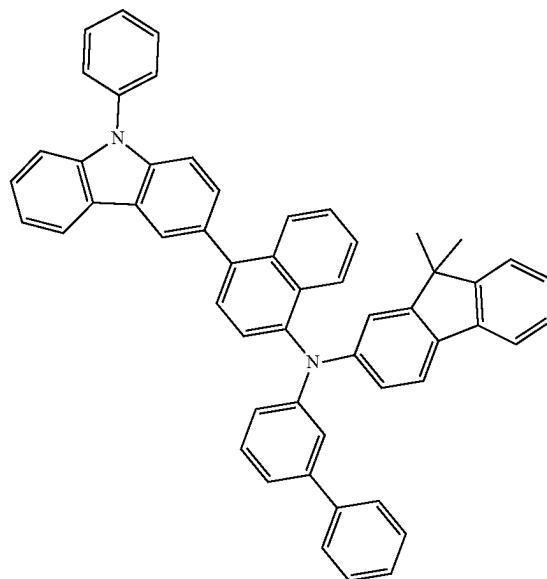
HT6



HT7

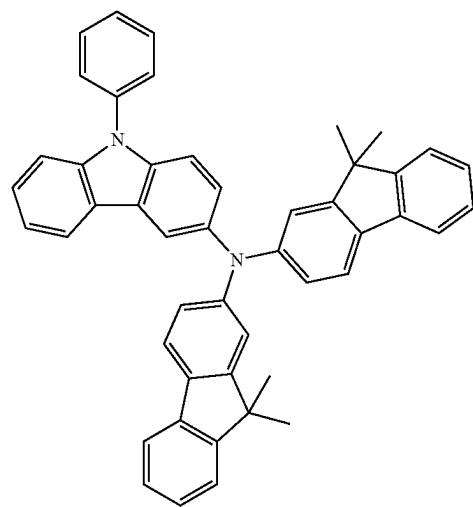
HT8



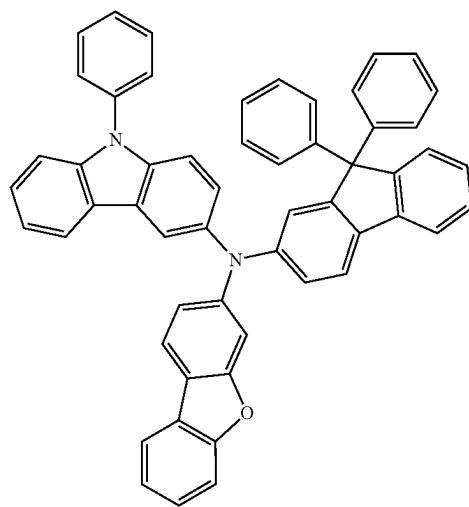
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HT9

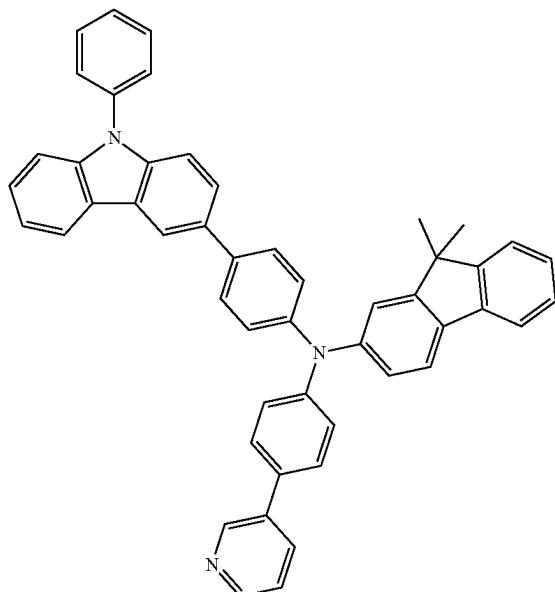
HT10

HT11

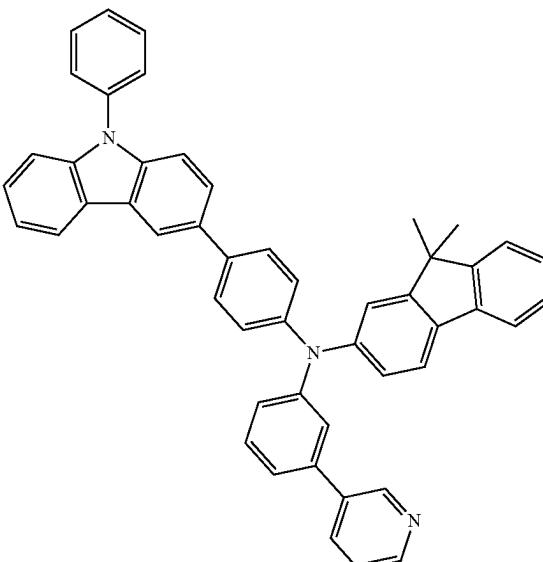


HT12

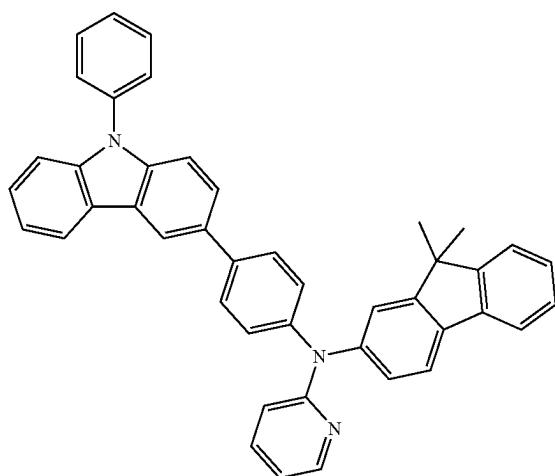


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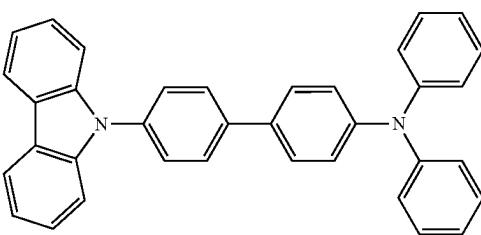
HT15

56-continued
HT13

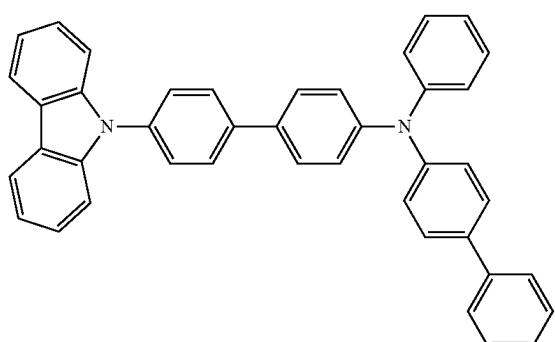
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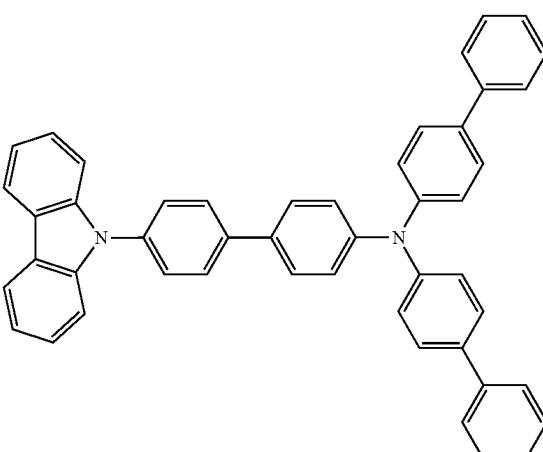
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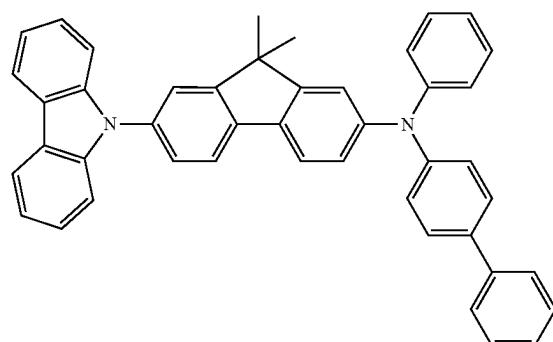
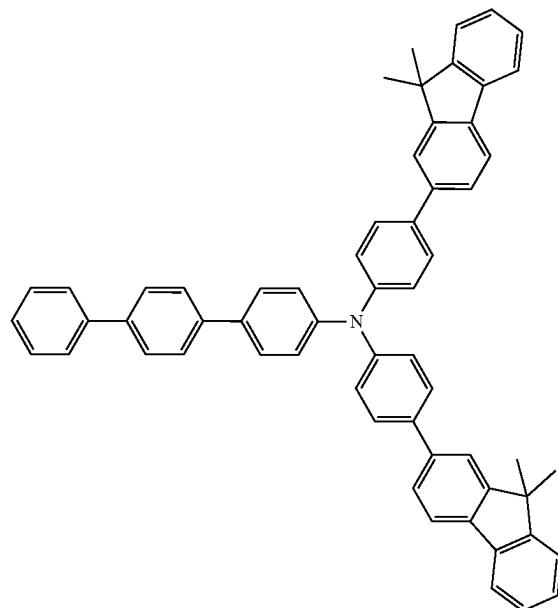
HT16



HT17

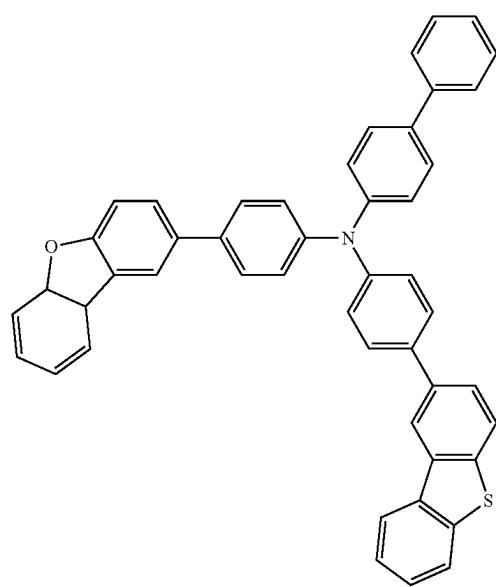


HT18

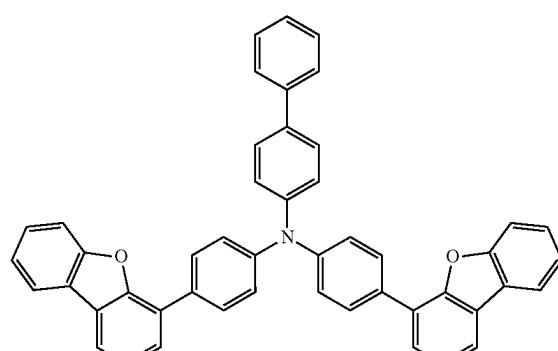
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HT19

HT20

HT21



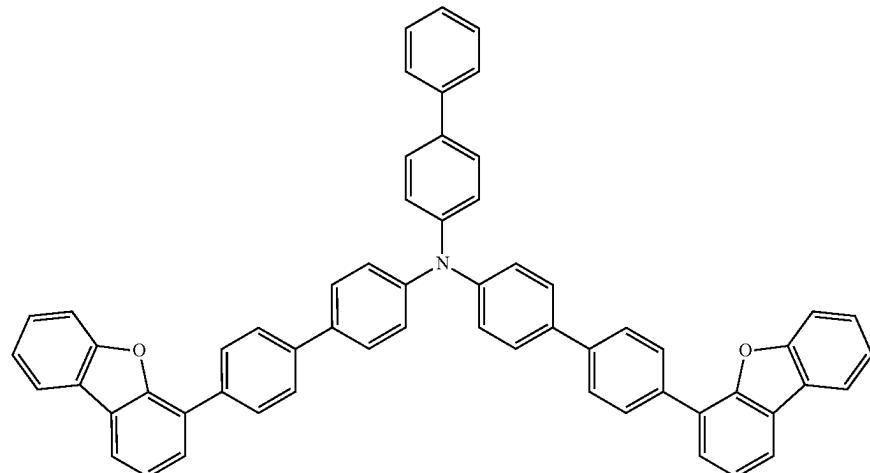
HT22



59**60**

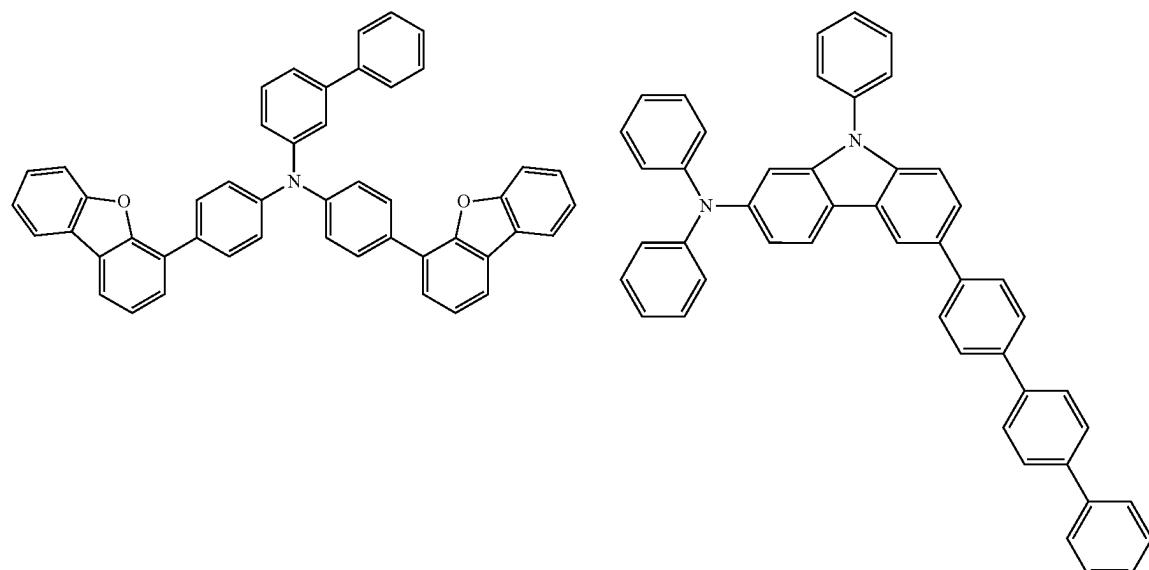
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HT23



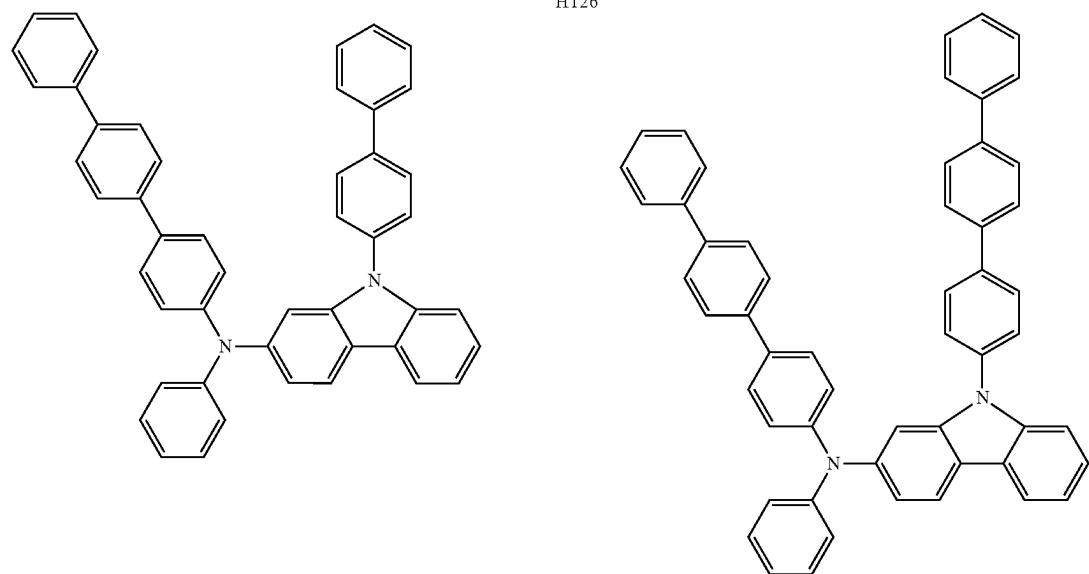
HT24

HT25



HT26

HT27

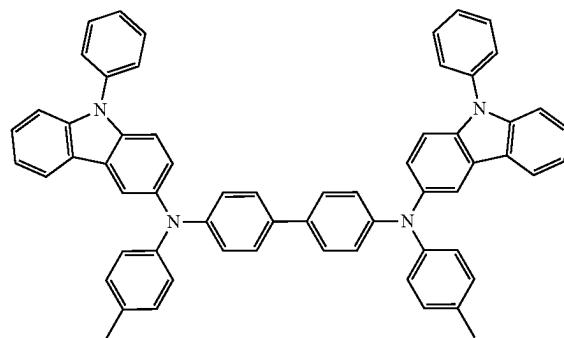
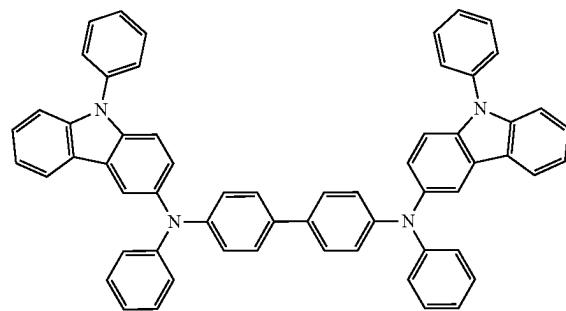


61**62**

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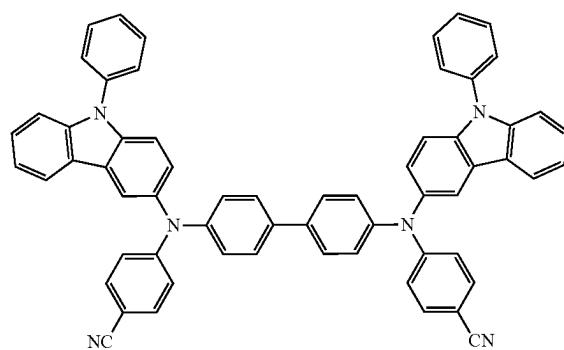
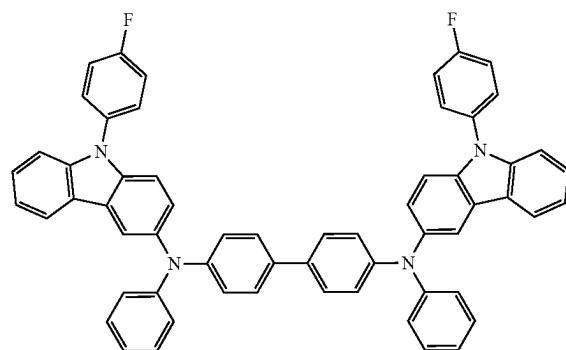
HT28

HT29



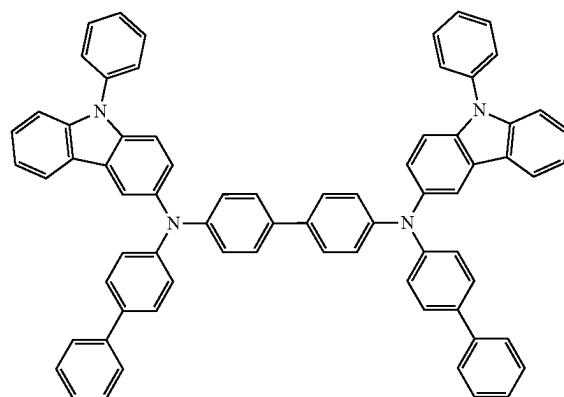
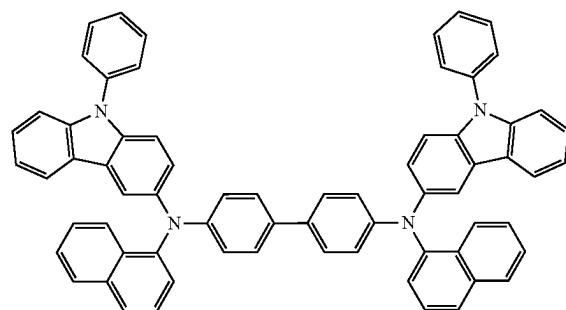
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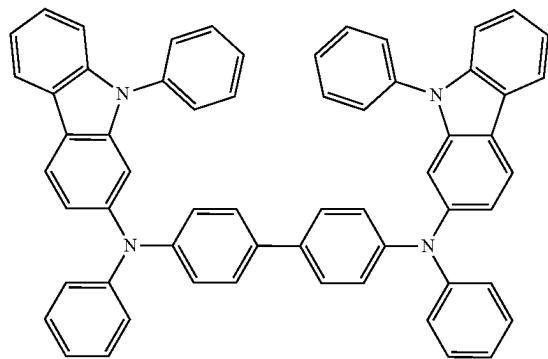
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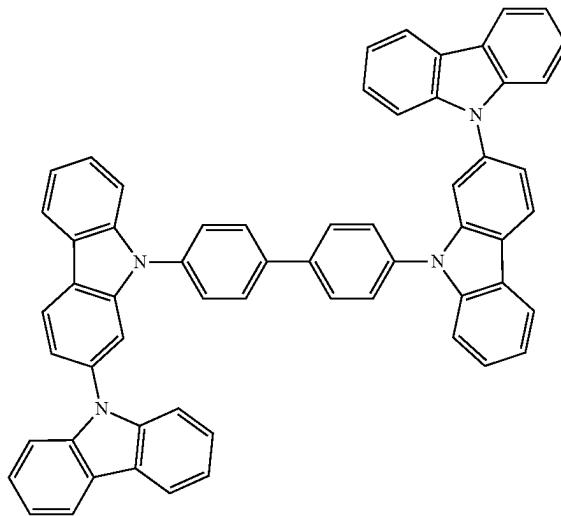
HT32

HT33



63**64**

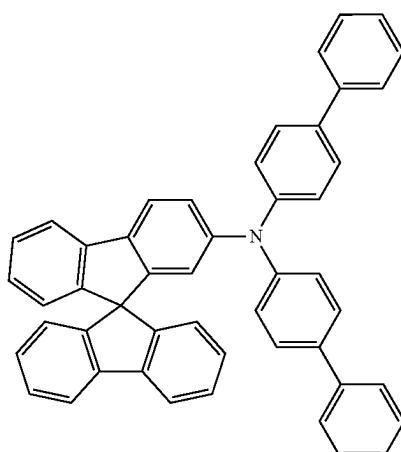
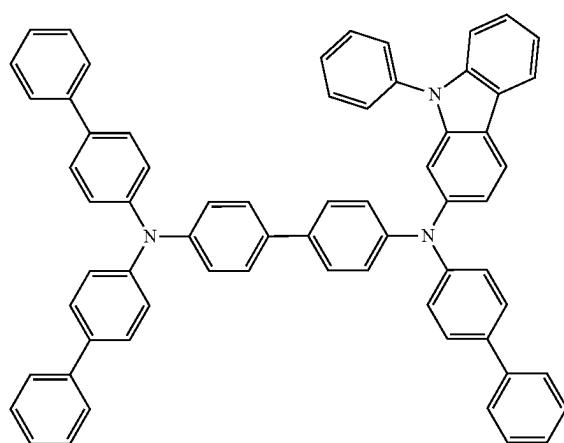
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HT34



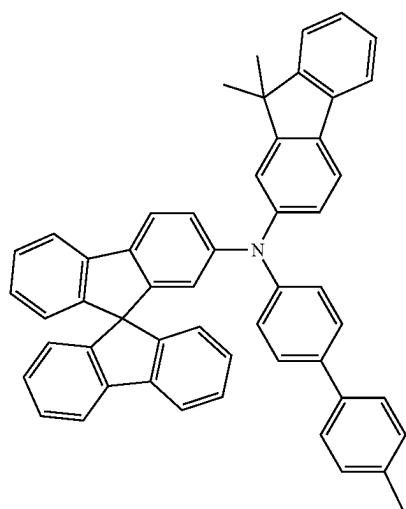
HT35

HT36

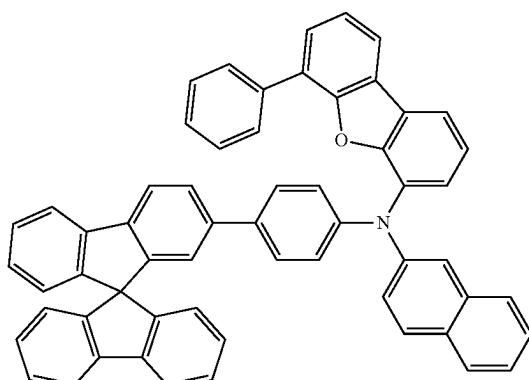
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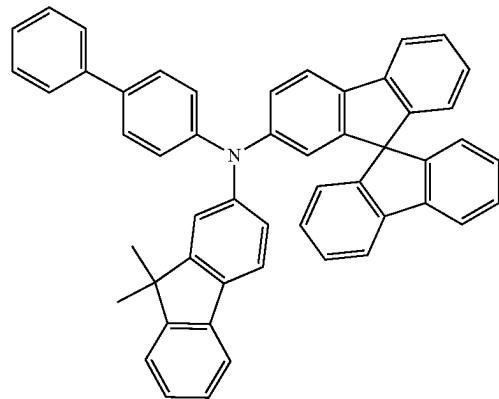
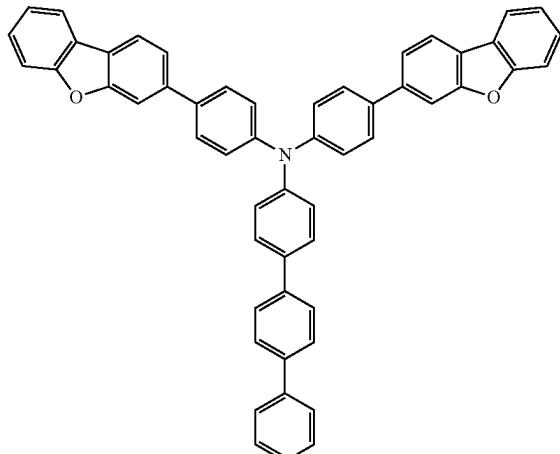


HT39



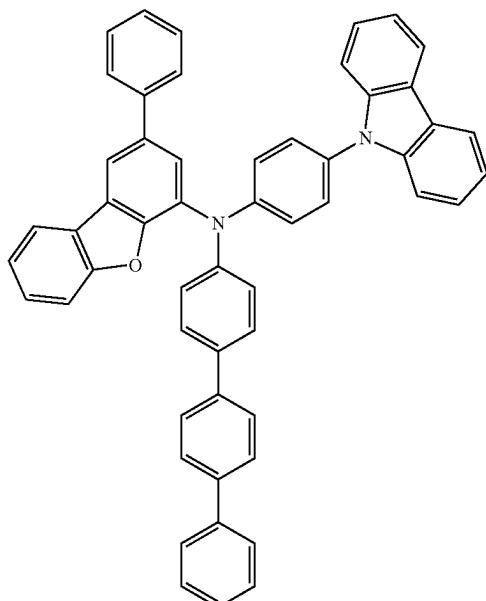
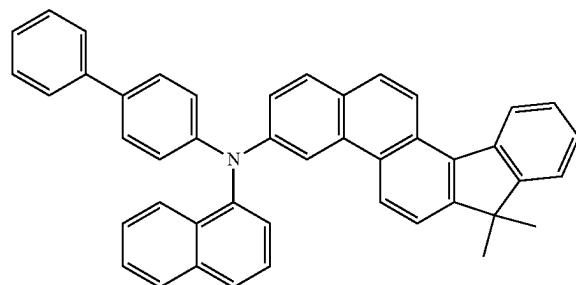
HT38



65**66**-continued
HT40

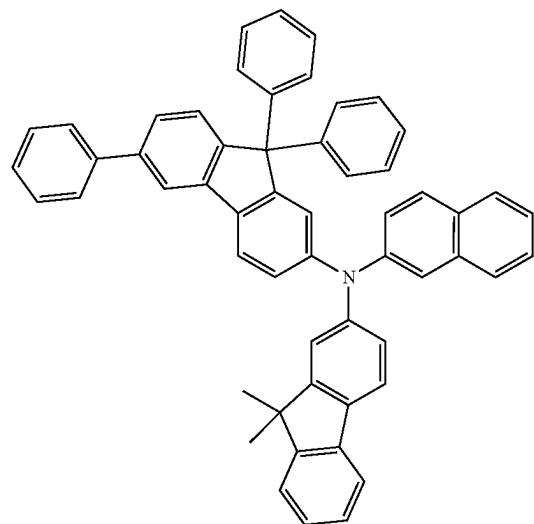
HT41

HT42

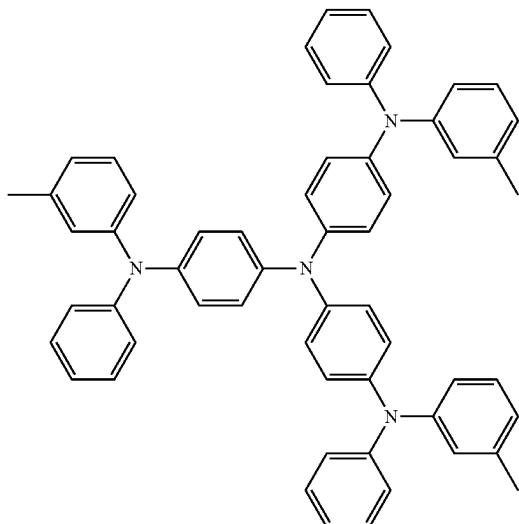


HT43

HT44



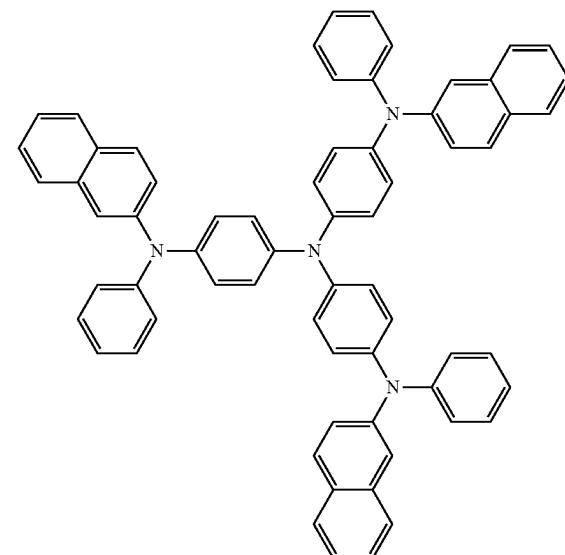
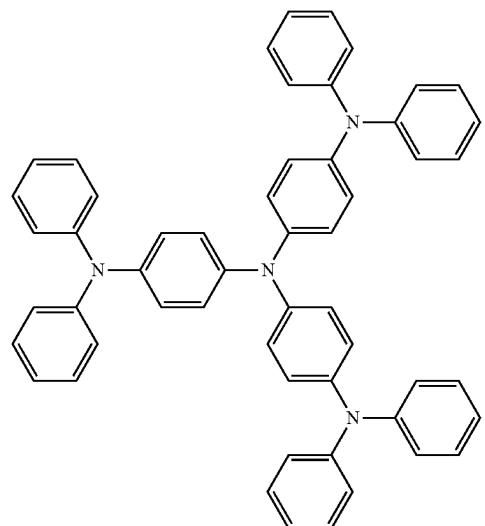
m-MTDATA



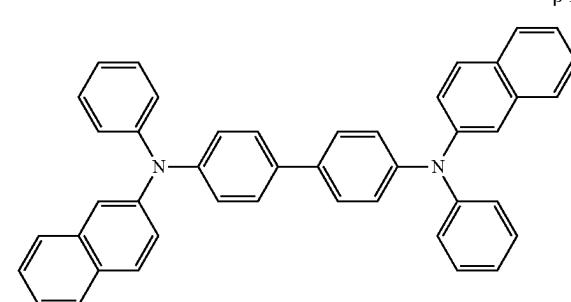
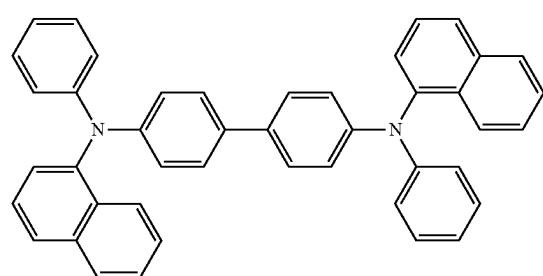
67**68**

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TDATA

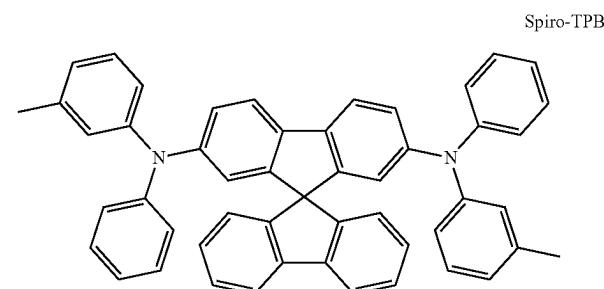
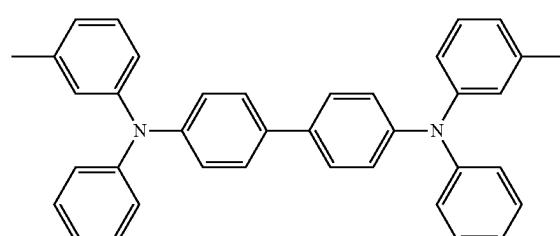
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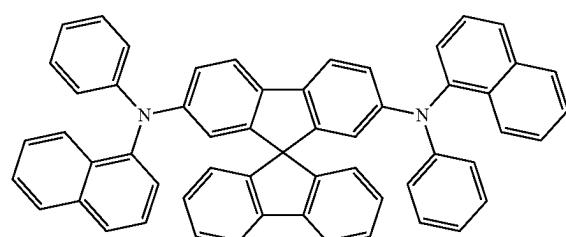
NPB



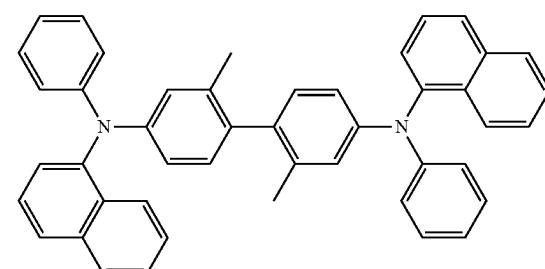
TPD



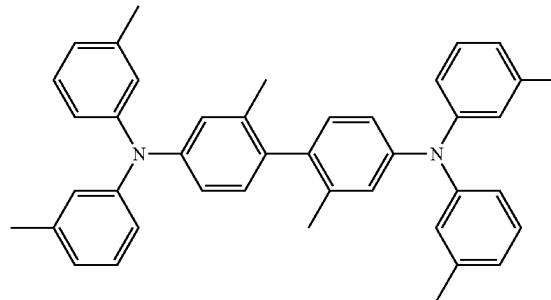
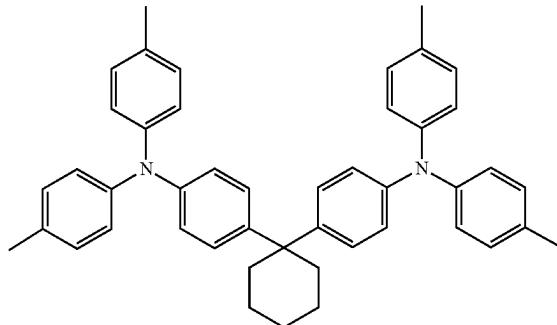
Spiro-NPB



methylated-NPB



-continued
TAPC



A thickness of the hole transport region may be in a range of about 50 Å to about 10,000 Å, for example, about 100 Å to about 4,000 Å. When the hole transport region includes a hole injection layer, a hole transport layer, or any combination thereof, a thickness of the hole injection layer may be in a range of about 100 Å to about 9,000 Å, for example, about 100 Å to about 1,000 Å, and a thickness of the hole transport layer may be in a range of about 50 Å to about 2,000 Å, for example, about 100 Å to about 1,500 Å. When the thicknesses of the hole transport region, the hole injection layer, and the hole transport layer are within these ranges, satisfactory (or suitable) hole transporting characteristics may be obtained without a substantial increase in driving voltage.

The emission auxiliary layer may increase light-emission efficiency by compensating for an optical resonance distance according to the wavelength of light emitted by an emission layer, and the electron blocking layer may block or reduce the flow of electrons from an electron transport region. The emission auxiliary layer and the electron blocking layer may include any of the materials as described above.

p-dopant

The hole transport region may further include, in addition to the materials described above, a charge-generation material for improvement of conductive properties. The charge-generation material may be uniformly or non-uniformly dispersed in the hole transport region (for example, in the form of a single layer of a charge-generating material).

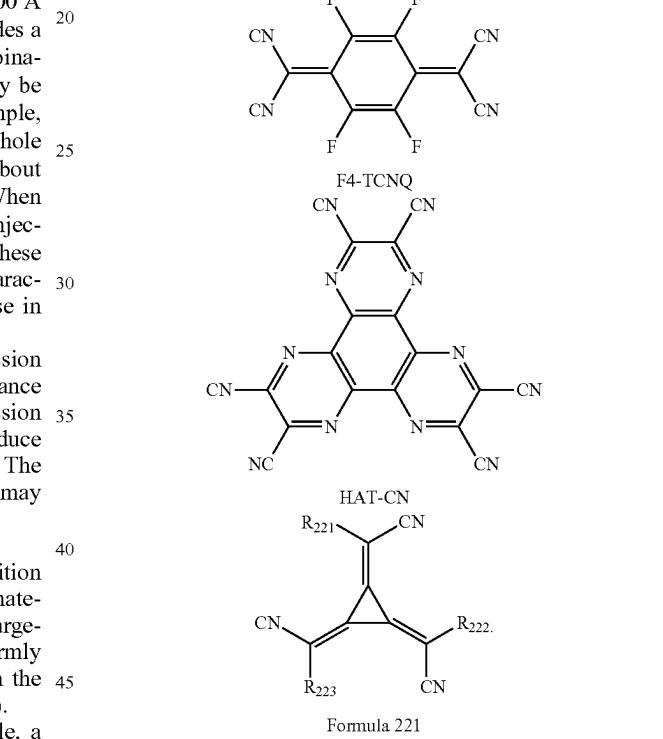
The charge-generation material may be, for example, a p-dopant.

In one or more embodiments, a LUMO energy level of the p-dopant may be -3.5 eV or less.

In one or more embodiments, the p-dopant may include a quinone derivative, a cyano group-containing compound, a compound containing element EL1 and/or element EL2, or any combination thereof.

Examples of the quinone derivative may include TCNQ and F4-TCNQ.

Examples of the cyano group-containing compound may include HAT-CN and a compound represented by Formula 221 below.



In Formula 221,

R_{221} to R_{223} may each independently be a C_3 - C_{60} carbocyclic group unsubstituted or substituted with at least one R_{10a} or a C_1 - C_{60} heterocyclic group unsubstituted or substituted with at least one R_{10a} , and

at least one of R_{221} to R_{223} may each independently be a C_3 - C_{60} carbocyclic group or a C_1 - C_{60} heterocyclic group, each substituted with: a cyano group; —F; —Cl; —Br; —I; a C_1 - C_{20} alkyl group substituted with a cyano group, —F, —Cl, —Br, —I, or any combination thereof; or any combination thereof.

Regarding the compound containing element EL1 and/or element EL2, element EL1 may be metal, metalloid, or a combination thereof, and element EL2 may be a non-metal, metalloid, or a combination thereof.

Examples of the metal may include: an alkali metal (for example, lithium (Li), sodium (Na), potassium (K), rubidium (Rb), cesium (Cs), and/or the like); an alkaline

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earth metal (for example, beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba), and/or the like); a transition metal (for example, titanium (Ti), zirconium (Zr), hafnium (Hf), vanadium (V), niobium (Nb), tantalum (Ta), chromium (Cr), molybdenum (Mo), tungsten (W), manganese (Mn), technetium (Tc), rhenium (Re), iron (Fe), ruthenium (Ru), osmium (Os), cobalt (Co), rhodium (Rh), iridium (Ir), nickel (Ni), palladium (Pd), platinum (Pt), copper (Cu), silver (Ag), gold (Au), and/or the like); a post-transition metal (for example, zinc (Zn), indium (In), tin (Sn), and/or the like); and a lanthanide metal (for example, lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), ruthenium (Lu), and/or the like).

Examples of the metalloid may include silicon (Si), antimony (Sb), and tellurium (Te).

Examples of the non-metal may include oxygen (O) and halogen (for example, F, Cl, Br, I, etc.).

In one or more embodiments, examples of the compound containing element EL1 and/or element EL2 may include metal oxide, metal halide (for example, metal fluoride, metal chloride, metal bromide, and/or metal iodide), metalloid halide (for example, metalloid fluoride, metalloid chloride, metalloid bromide, and/or metalloid iodide), metal telluride, or any combination thereof.

Examples of the metal oxide may include tungsten oxide (for example, WO, W₂O₃, WO₂, WO₃, and/or W₂O₅), vanadium oxide (for example, VO, V₂O₃, VO₂, and/or V₂O₅), molybdenum oxide (MoO, Mo₂O₃, MoO₂, MoO₃, and/or Mo₂O₅), and rhenium oxide (for example, ReO₃).

Examples of the metal halide may include alkali metal halide, alkaline earth metal halide, transition metal halide, post-transition metal halide, and lanthanide metal halide.

Examples of the alkali metal halide may include LiF, NaF, KF, RbF, CsF,

LiCl, NaCl, KCl, RbCl, CsCl, LiBr, NaBr, KBr, RbBr, CsBr, LiI, NaI, KI, RbI, and CsI.

Examples of the alkaline earth metal halide may include BeF₂, MgF₂, CaF₂, SrF₂, BaF₂, BeCl₂, MgCl₂, CaCl₂, SrCl₂, BaCl₂, BeBr₂, MgBr₂, CaBr₂, SrBr₂, BaBr₂, BeI₂, MgI₂, CaI₂, SrI₂, and BaI₂.

Examples of the transition metal halide may include titanium halide (for example, TiF₄, TiCl₄, TiBr₄, and/or TiI₄), zirconium halide (for example, ZrF₄, ZrCl₄, ZrBr₄, and/or ZrI₄), hafnium halide (for example, HfF₄, HfCl₄, HfBr₄, and/or HfI₄), vanadium halide (for example, VF₃, VCl₃, VBr₃, and/or VI₃), niobium halide (for example, NbF₃, NbCl₃, NbBr₃, and/or NbI₃), tantalum halide (for example, TaF₃, TaCl₃, TaBr₃, and/or TaI₃), chromium halide (for example, CrF₃, CrCl₃, CrBr₃, and/or CrI₃), molybdenum halide (for example, MoF₃, MoCl₃, MoBr₃, and/or MoI₃), tungsten halide (for example, WF₃, WCl₃, WBr₃, and/or WI₃), manganese halide (for example, MnF₂, MnCl₂, MnBr₂, and/or MnI₂), technetium halide (for example, TcF₂, TcCl₂, TcBr₂, and/or TcI₂), rhenium halide (for example, ReF₂, ReCl₂, ReBr₂, and/or ReI₂), iron halide (for example, FeF₂, FeCl₂, FeBr₂, and/or FeI₂), ruthenium halide (for example, RuF₂, RuCl₂, RuBr₂, and/or RuI₂), osmium halide (for example, OsF₂, OsCl₂, OsBr₂, and/or OsI₂), cobalt

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halide (for example, CoF₂, CoCl₂, CoBr₂, and/or CoI₂), rhodium halide (for example, RhF₂, RhCl₂, RhBr₂, and/or RhI₂), iridium halide (for example, IrF₂, IrCl₂, IrBr₂, and/or IrI₂), nickel halide (for example, NiF₂, NiCl₂, NiBr₂, and/or NiI₂), palladium halide (for example, PdF₂, PdCl₂, PdBr₂, and/or PdI₂), platinum halide (for example, PtF₂, PtCl₂, PtBr₂, and/or PtI₂), copper halide (for example, CuF, CuCl, CuBr, and/or CuI), silver halide (for example, AgF, AgCl, AgBr, and/or AgI), and gold halide (for example, AuF, AuCl, AuBr, and/or AuI).

Examples of the post-transition metal halide may include zinc halide (for example, ZnF₂, ZnCl₂, ZnBr₂, and/or ZnI₂), indium halide (for example, InI₃), and tin halide (for example, SnI₂).

Examples of the lanthanide metal halide may include YbF, YbF₂, YbF₃, SmF₃, YbCl, YbCl₂, YbCl₃, SmCl₃, YbBr, YbBr₂, YbBr₃, SmBr₃, YbI, YbI₂, YbI₃, and SmI₃.

Examples of the metalloid halide may include antimony halide (for example, SbCl₅).

Examples of the metal telluride may include alkali metal telluride (for example, Li₂Te, Na₂Te, K₂Te, Rb₂Te, and/or Cs₂Te), alkaline earth metal telluride (for example, BeTe, MgTe, CaTe, SrTe, and/or BaTe), transition metal telluride (for example, TiTe₂, ZrTe₂, HfTe₂, V₂Te₃, Nb₂Te₃, Ta₂Te₃, Cr₂Te₃, Mo₂Te₃, W₂Te₃, MnTe, TcTe, ReTe, FeTe, RuTe, OsTe, CoTe, RhTe, IrTe, NiTe, PdTe, PtTe, Cu₂Te, CuTe, Ag₂Te, AgTe, and/or Au₂Te), post-transition metal telluride (for example, ZnTe), and lanthanide metal telluride (for example, LaTe, CeTe, PrTe, NdTe, PmTe, EuTe, GdTe, TbTe, DyTe, HoTe, ErTe, TmTe, YbTe, and/or LuTe).

Emission Layer in Interlayer 130

When the light-emitting device 10 is a full-color light-emitting device, the emission layer may be patterned into a red emission layer, a green emission layer, and/or a blue emission layer, according to a sub-pixel. In one or more embodiments, the emission layer may have a stacked structure of two or more layers of a red emission layer, a green emission layer, and a blue emission layer, in which the two or more layers contact each other or are separated from each other to emit white light. In one or more embodiments, the emission layer may include two or more materials of a red light-emitting material, a green light-emitting material, and a blue light-emitting material, in which the two or more materials are mixed with each other in a single layer to emit white light.

The emission layer may include a host and a dopant. The dopant may include a phosphorescent dopant, a fluorescent dopant, or any combination thereof.

The dopant may include the condensed cyclic compound represented by Formula 1.

An amount of the dopant in the emission layer may be from about 0.01 to about 15 parts by weight based on 100 parts by weight of the host.

In one or more embodiments, the emission layer may include a quantum dot.

In one or more embodiments, the emission layer may include a delayed fluorescent material. The delayed fluorescent material may act as a host or a dopant in the emission layer.

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

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about 600 Å. When the thickness of the emission layer is within this range, excellent (or improved) light-emission characteristics may be obtained without a substantial increase in driving voltage.

Host

The host may include a compound represented by Formula 301 below:



In Formula 301,

Ar_{301} and L_{301} may each independently be a C_3 - C_{60} carbocyclic group unsubstituted or substituted with at least one R_{10a} or a C_1 - C_{60} heterocyclic group unsubstituted or substituted with at least one R_{10a} ,

$xb1$ may be 1, 2, or 3,

$xb1$ may be an integer from 0 to 5,

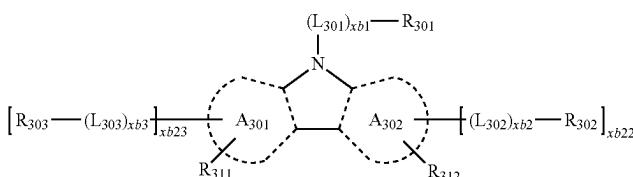
R_{301} may be hydrogen, deuterium, —F, —Cl, —Br, —I, hydroxyl group, a cyano group, a nitro group, a C_1 - C_{60} alkyl group unsubstituted or substituted with at least one R_{10a} , a C_2 - C_{60} alkenyl group unsubstituted or substituted with at least one R_{10a} , a C_2 - C_{60} alkynyl group unsubstituted or substituted with at least one R_{10a} , a C_1 - C_{60} alkoxy group unsubstituted or substituted with at least one R_{10a} , a C_3 - C_{60} carbocyclic group unsubstituted or substituted with at least one R_{10a} , a C_1 - C_{60} heterocyclic group unsubstituted or substituted with at least one R_{10a} , —Si(Q_{301})(Q_{302})(Q_{303}), —N(Q_{301})(Q_{302}), —B(Q_{301})(Q_{302}), —C(=O)(Q_{301}), —S(=O)₂(Q_{301}), or —P(=O)(Q_{301})(Q_{302}),

$xb21$ may be an integer from 1 to 5, and

Q_{301} to Q_{303} are the same as described in connection with Q_1 .

In one or more embodiments, when $xb1$ in Formula 301 is 2 or more, two or more of Ar_{301} (*s*) may be linked to each other via a single bond.

In one or more embodiments, the host may include a compound represented by Formula 301-1, a compound represented by Formula 301-2, or any combination thereof:



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In Formulae 301-1 and 301-2,

ring A_{301} to ring A_{304} may each independently be a C_3 - C_{60} carbocyclic group unsubstituted or substituted with at least one R_{10a} or a C_1 - C_{60} heterocyclic group unsubstituted or substituted with at least one R_{10a} ,

X_{301} may be O, S, N-[$(\text{L}_{304})_{xb4}-\text{R}_{304}$], C(R_{304})(R_{305}), or Si(R_{304})(R_{305}),

$xb22$ and $xb23$ may each independently be 0, 1, or 2,

L_{301} , $xb1$, and R_{301} are the same as described in the present specification,

L_{302} to L_{304} are each independently the same as described in connection with L_{301} ,

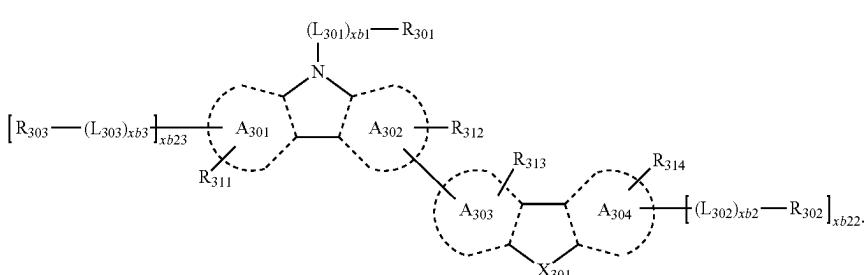
$xb2$ to $xb4$ are each independently the same as described in connection with $xb1$, and

R_{302} to R_{305} and R_{311} to R_{314} are each independently the same as described in connection with R_{301} .

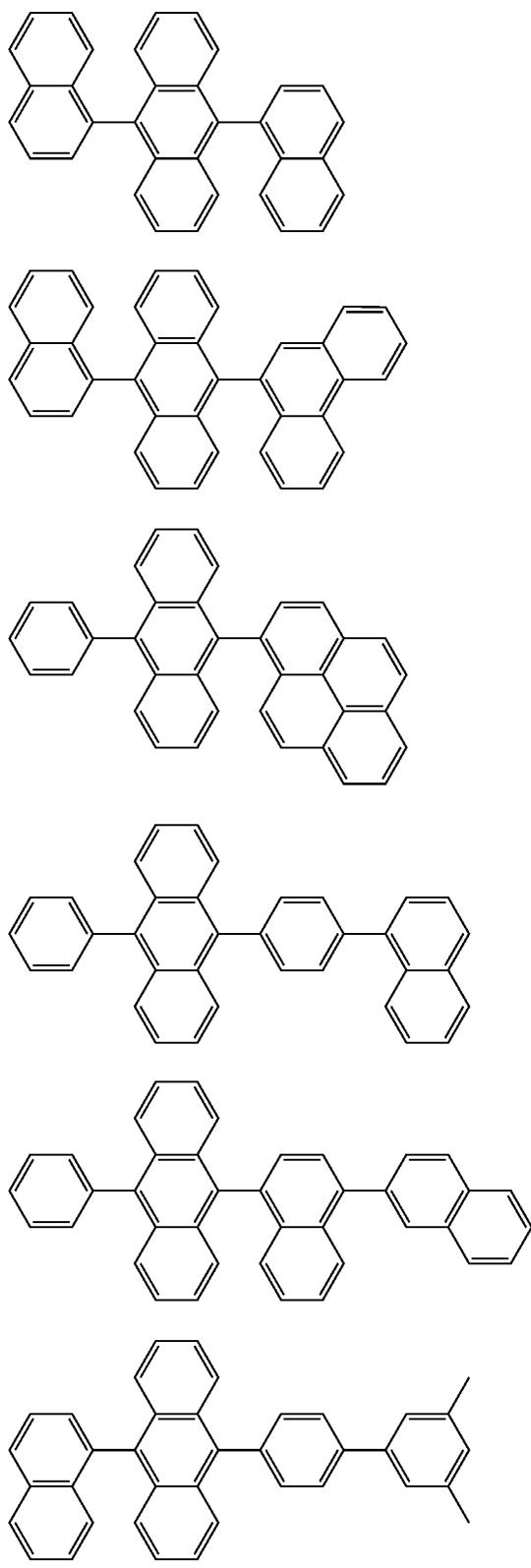
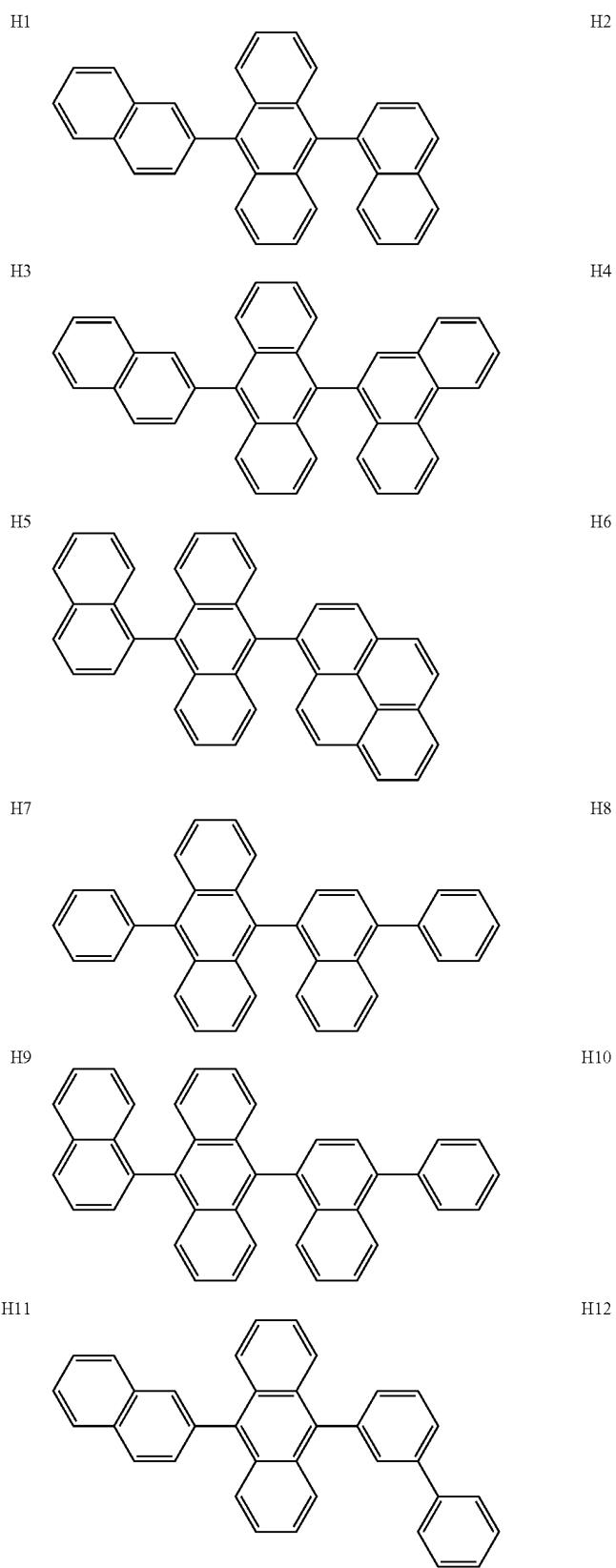
In one or more embodiments, the host may include an alkaline earth metal complex. In one or more embodiments, the host may be a Be complex (for example, Compound H55), a Mg complex, a Zn complex, or any combination thereof.

In one or more embodiments, the host may include one of Compounds H1 to H124, 9,10-di(2-naphthyl) anthracene (ADN), 2-methyl-9,10-bis(naphthalen-2-yl)anthracene (MADN), 9,10-di-(2-naphthyl)-2-t-butyl-anthracene (TBADN), 4,4'-bis(N-carbazolyl)-1,1'-biphenyl (CBP), 1,3-di-9-carbazolylbenzene (mCP), 1,3,5-tri (carbazol-9-yl)benzene (TCP), or any combination thereof, but embodiments of the present disclosure are not limited thereto:

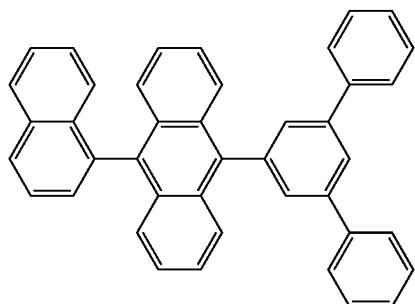
Formula 301-1



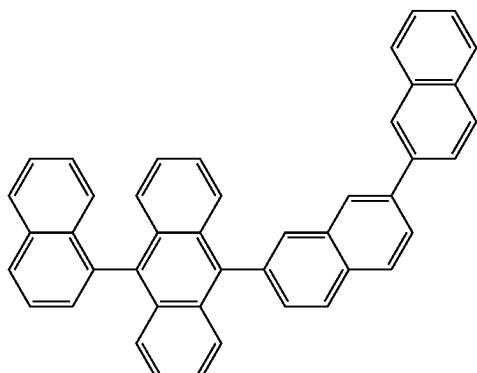
Formula 301-2

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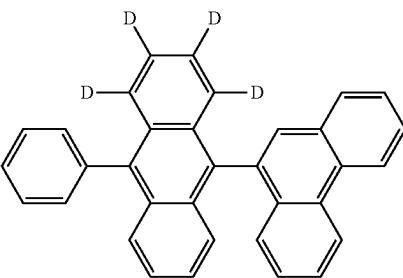
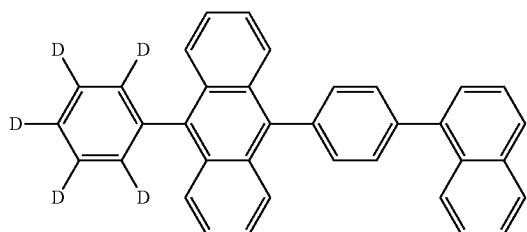


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H13

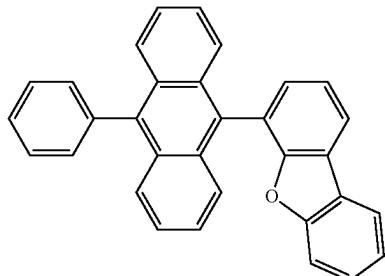
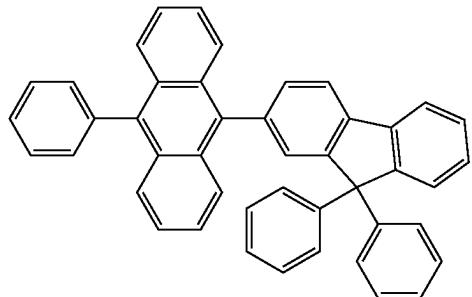
H14

H15



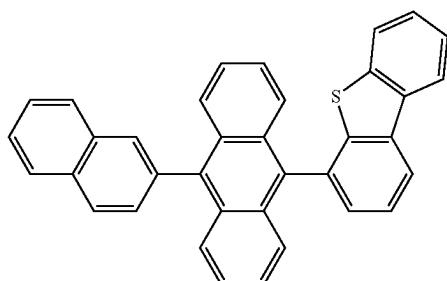
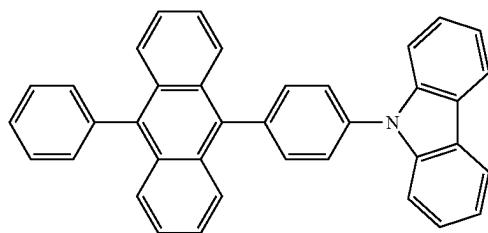
H16

H17



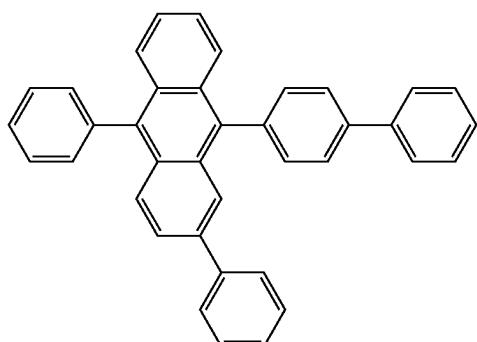
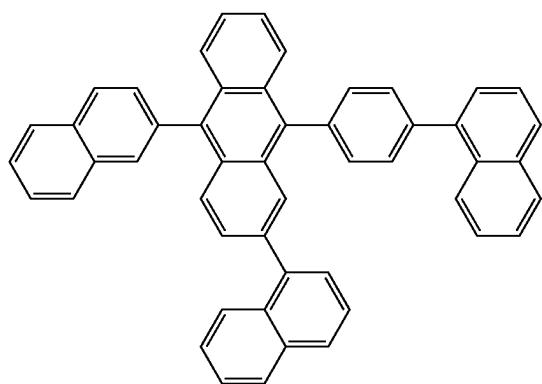
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H19



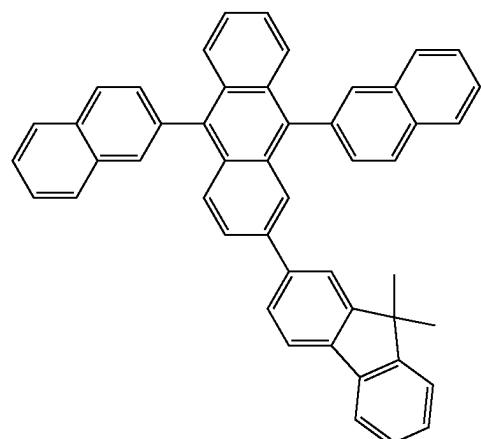
H20

H21



H22

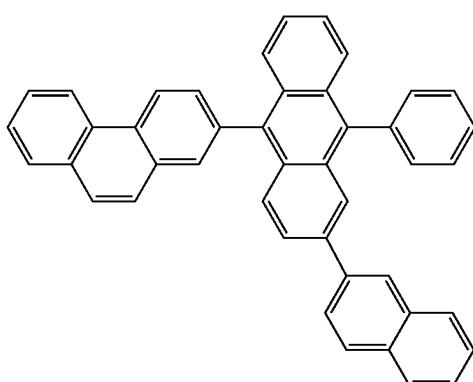
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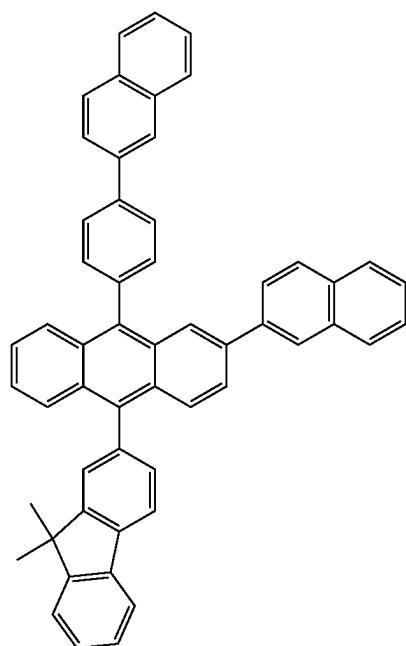
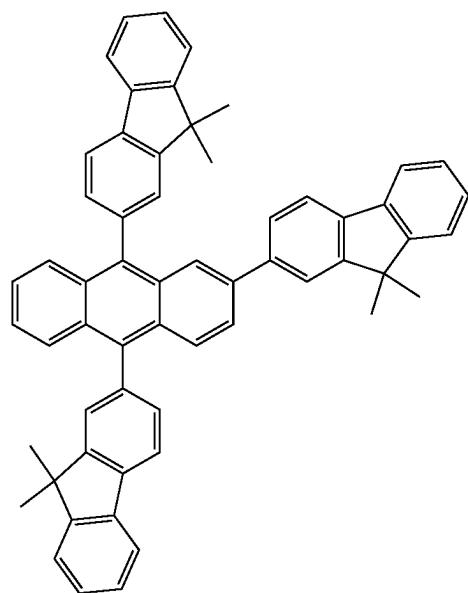
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H23

H24



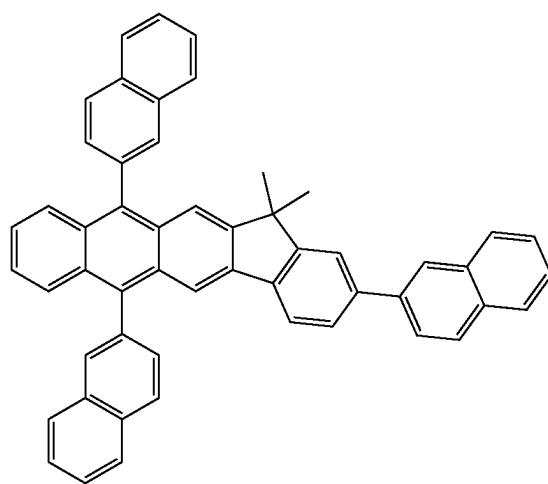
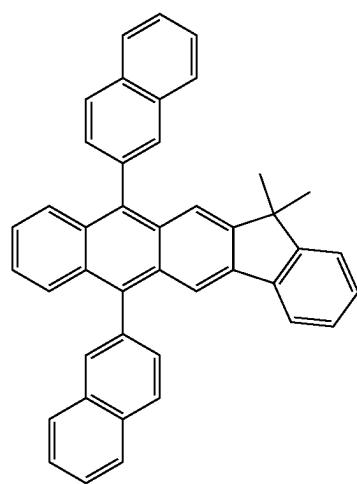
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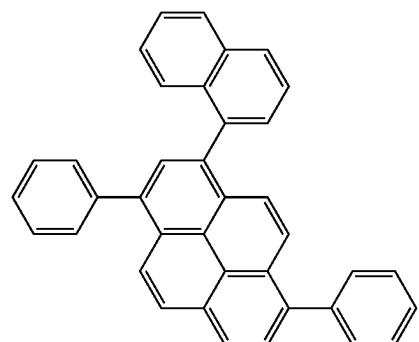
H26



H27

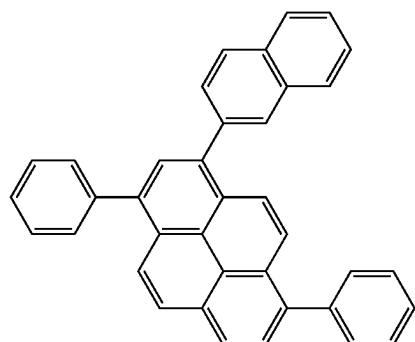
H28



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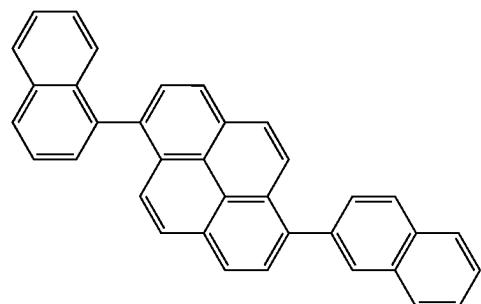
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H29

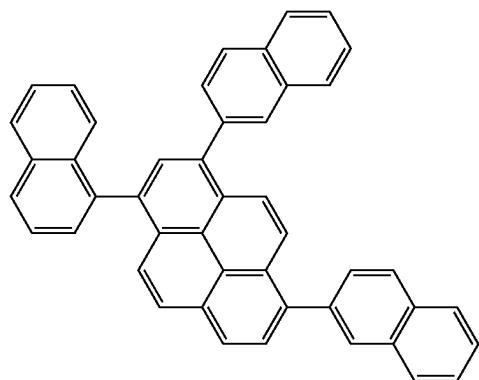


H30

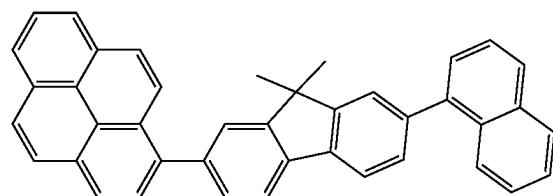
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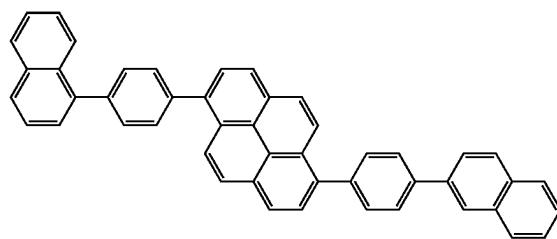
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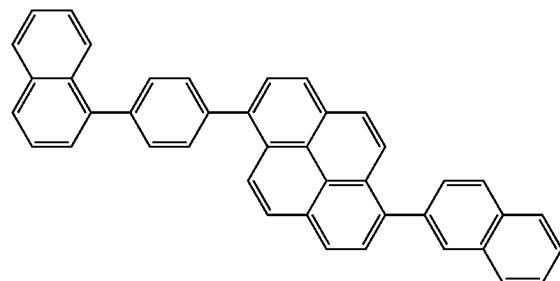
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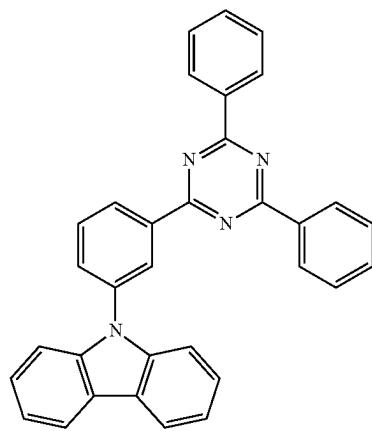
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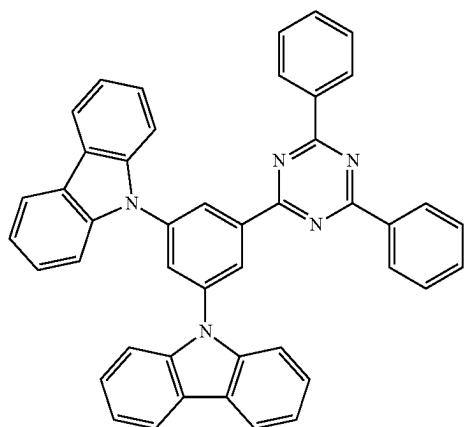


H35



H36

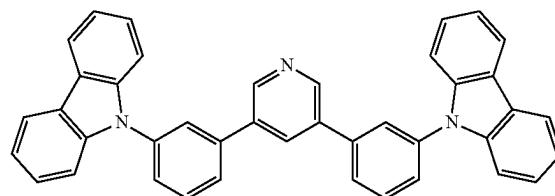


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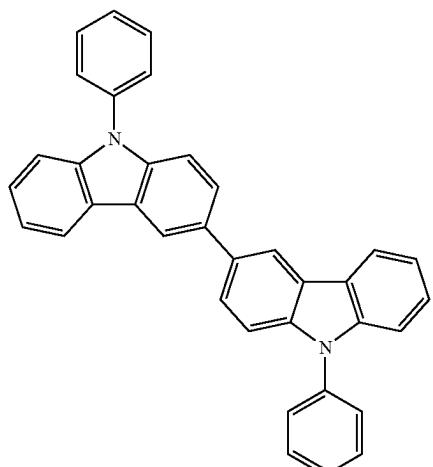
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H37

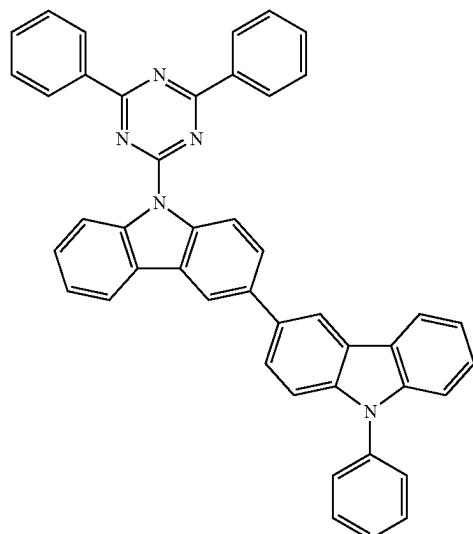
H38



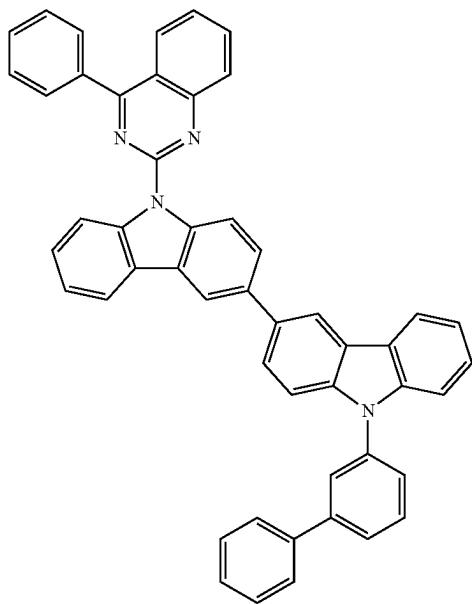
H39



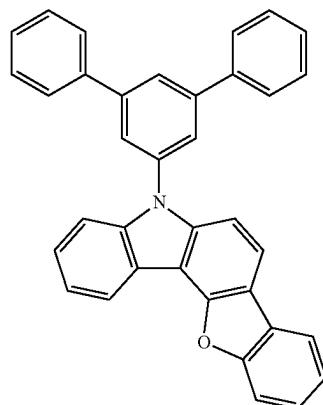
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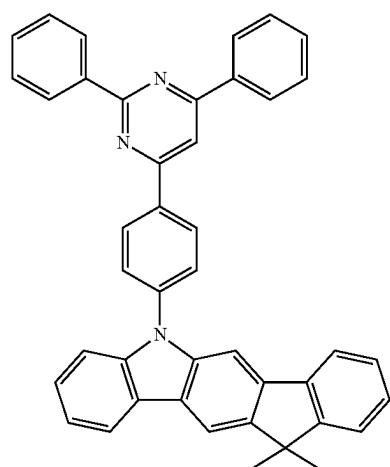
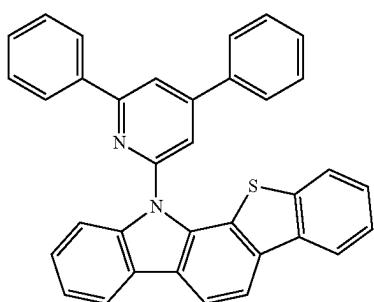


H41



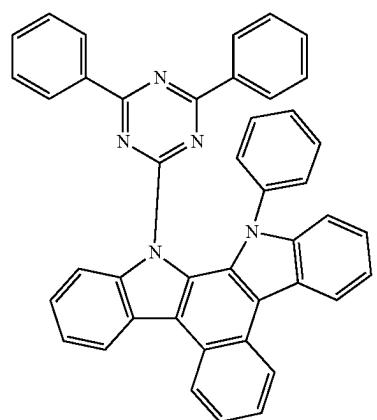
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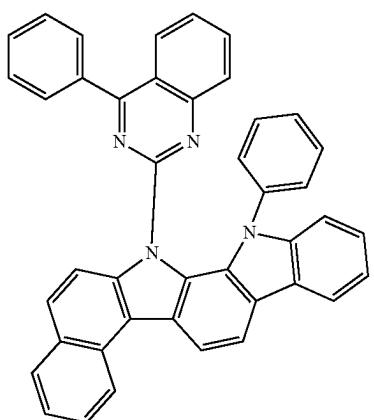
85**86**-continued
H43

H44

H45

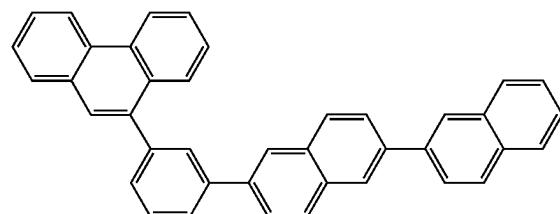


H46

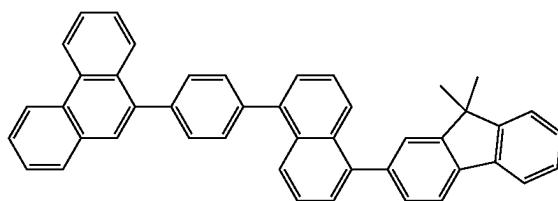


H47

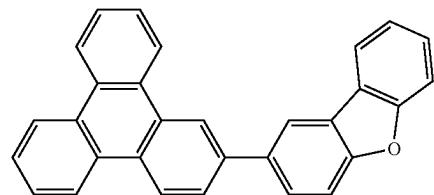
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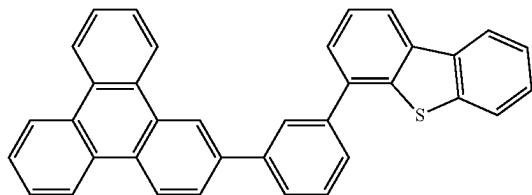
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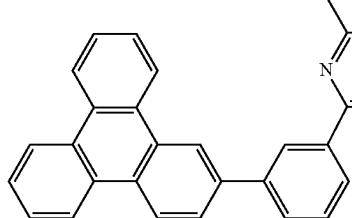
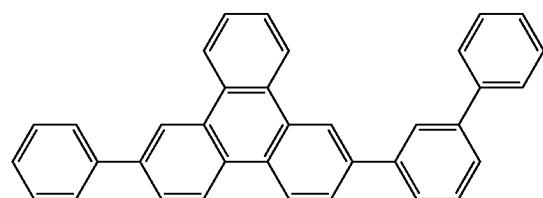
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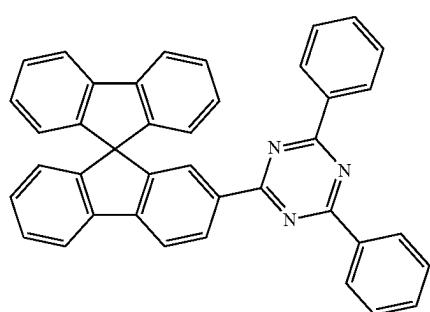


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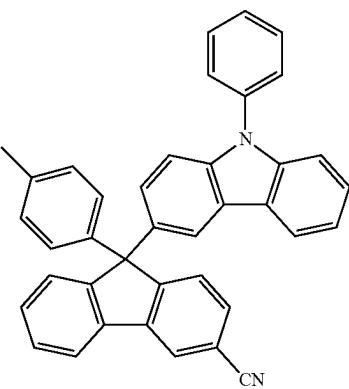
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87**88**

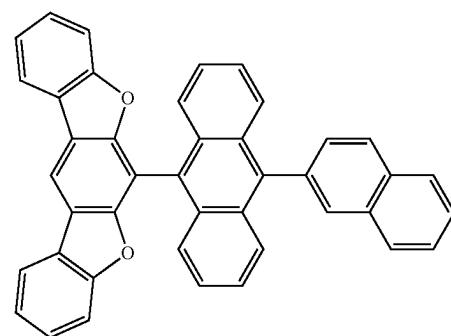
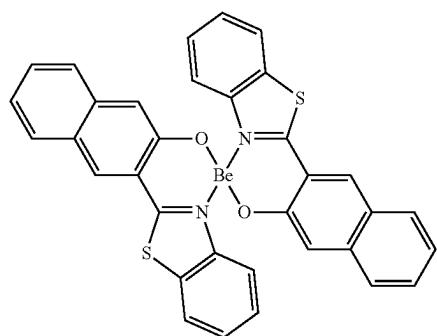
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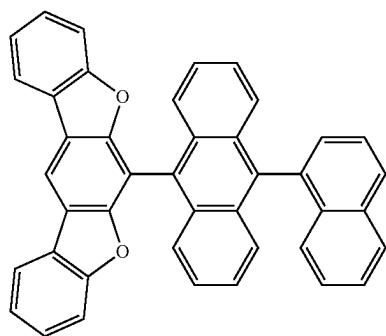


H54

H55

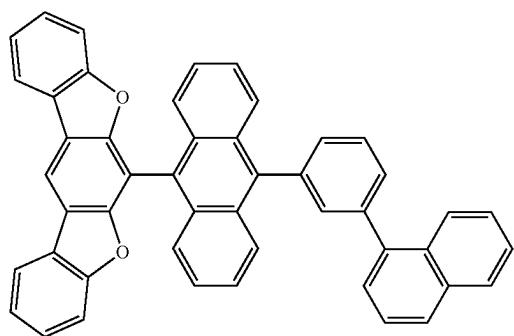
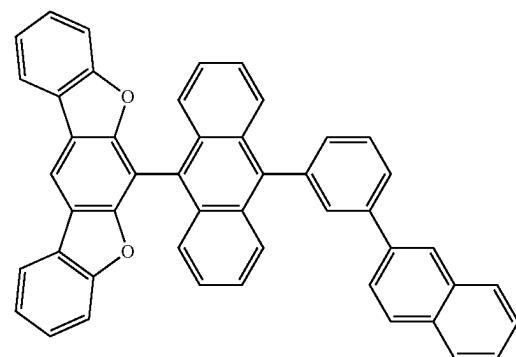


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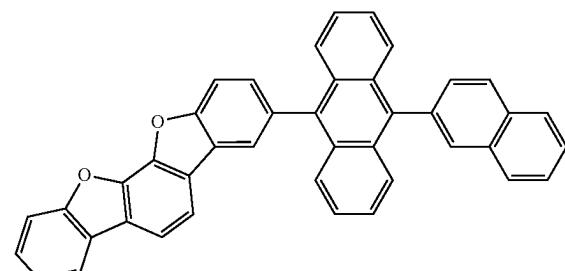
H57

H58



H59

H60

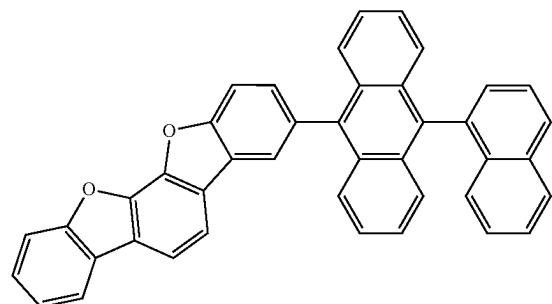


89**90**

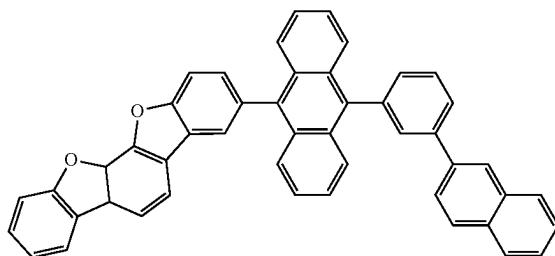
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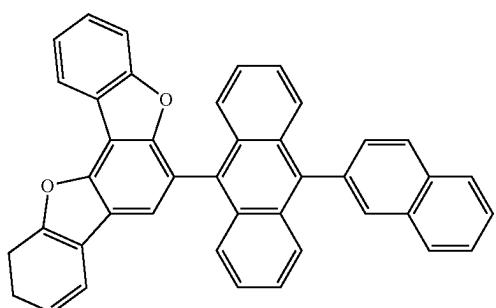
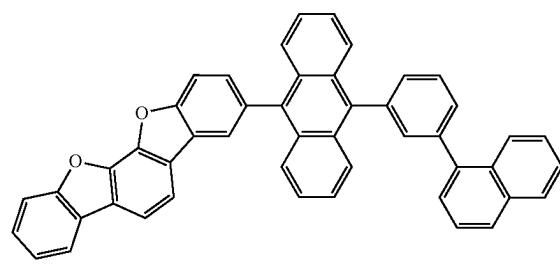
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H63

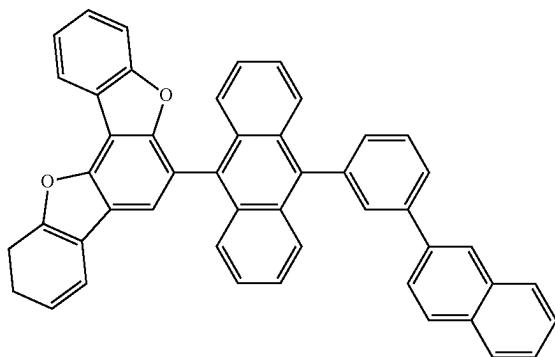
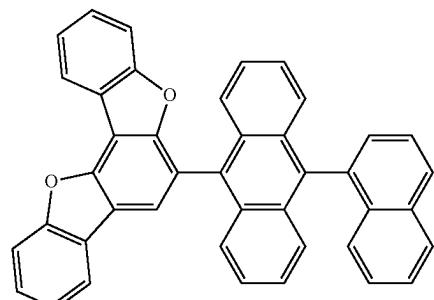


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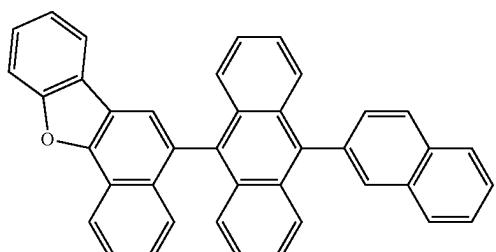
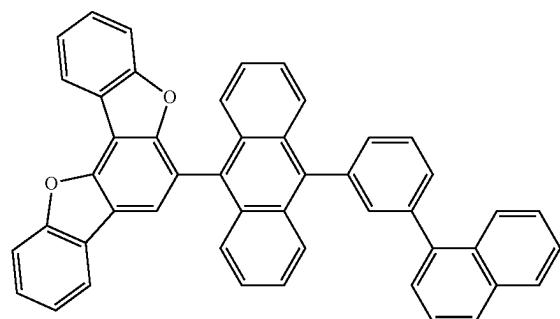
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H65

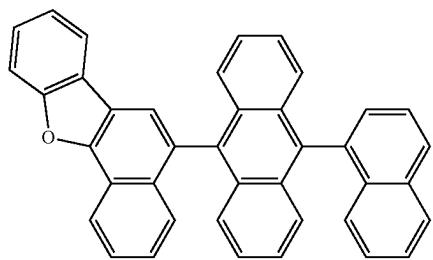
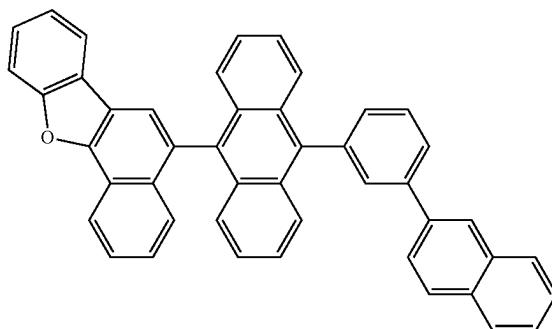


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H67

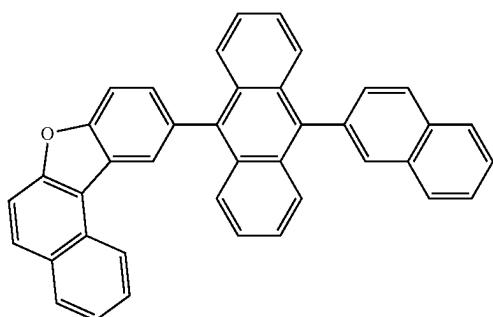
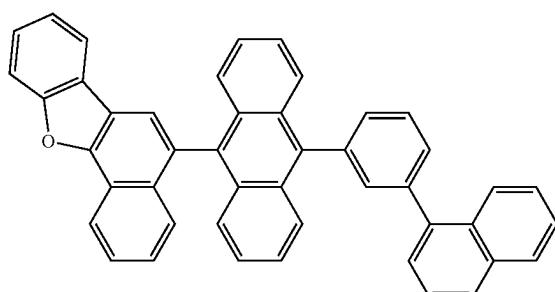


H68

91**92**-continued
H69

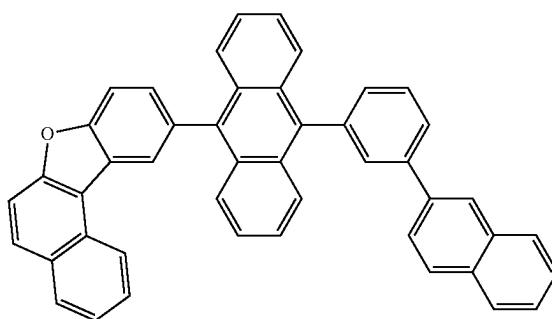
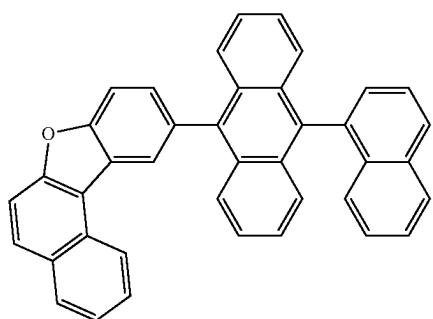
H70

H71



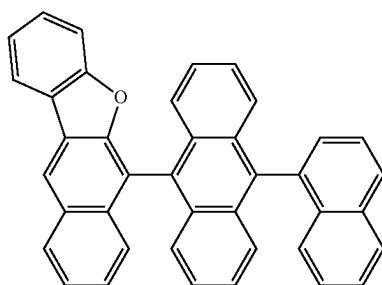
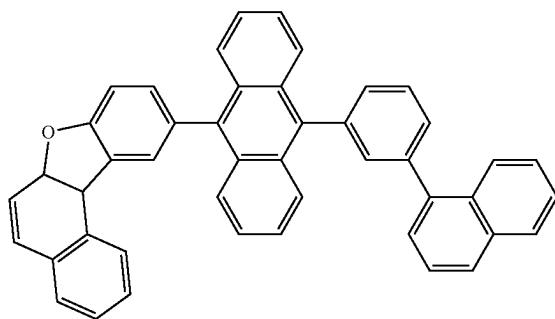
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H73

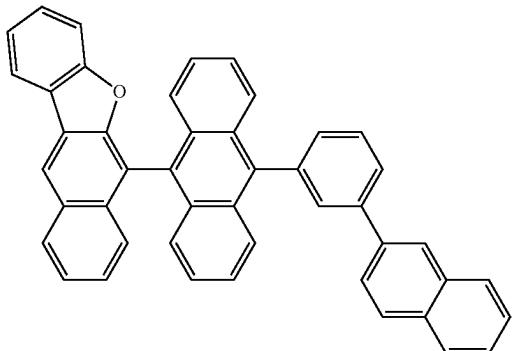


H74

H75



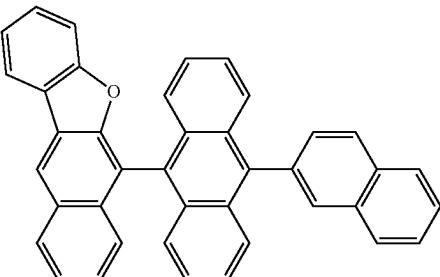
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93

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94

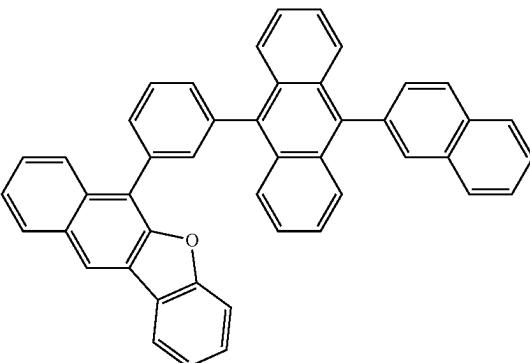
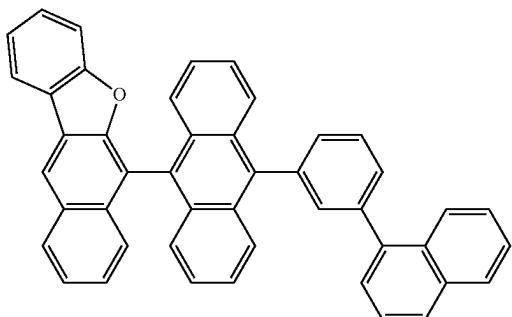
H77



H78

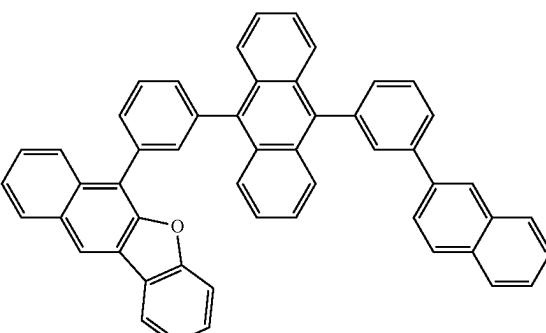
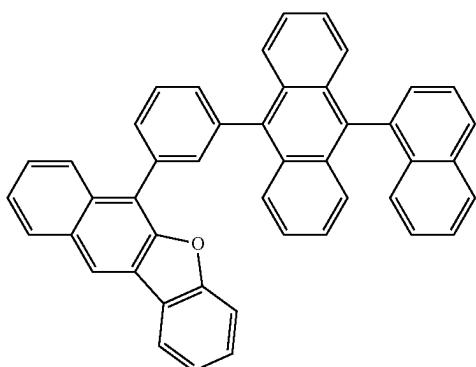
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H100



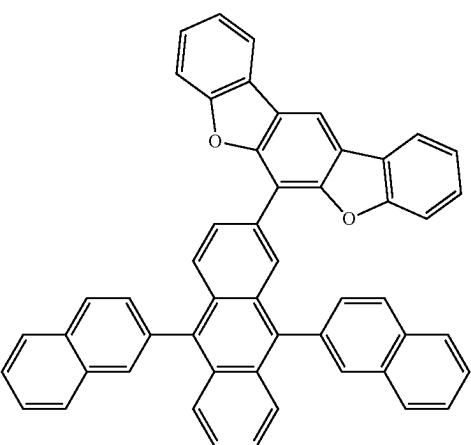
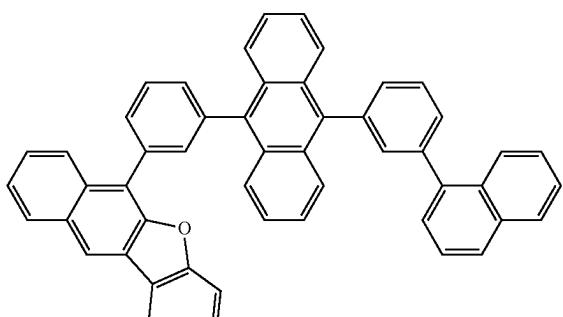
H101

H102



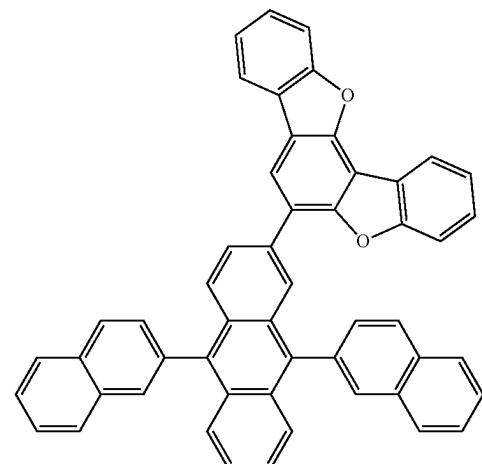
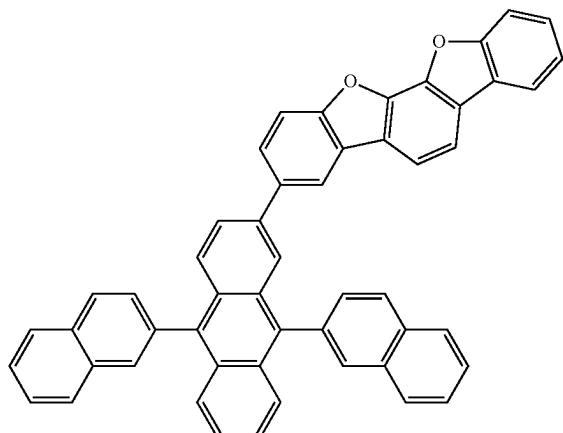
H103

H104

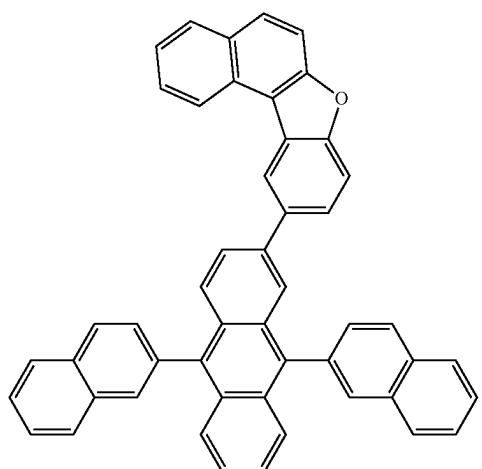


95**96**-continued
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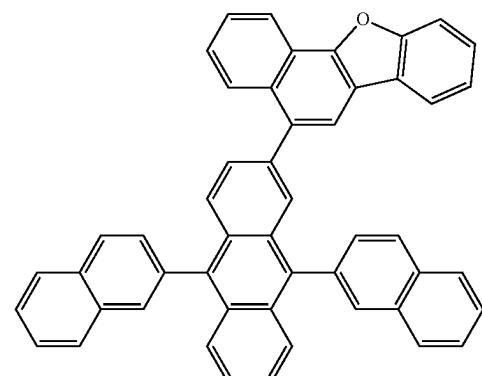
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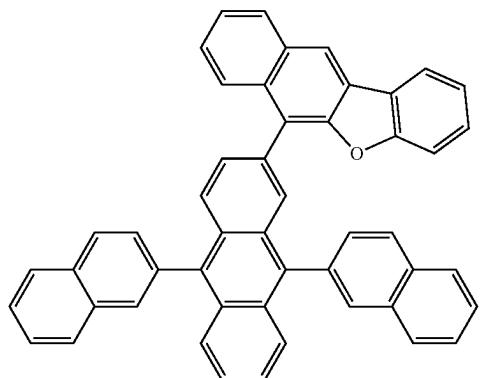
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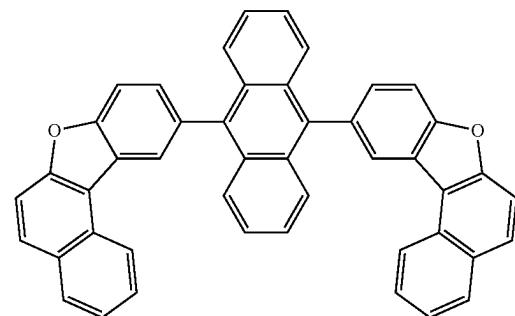
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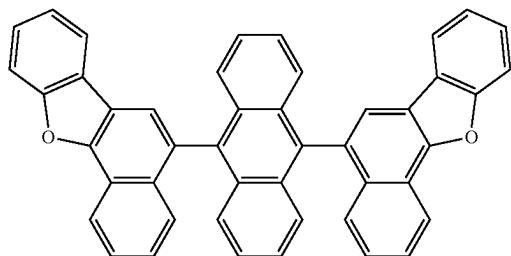
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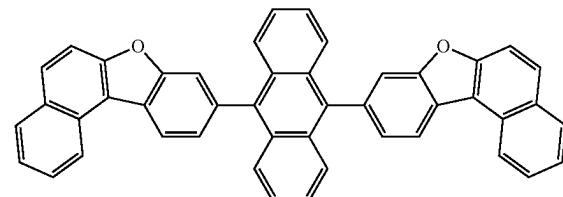
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H111



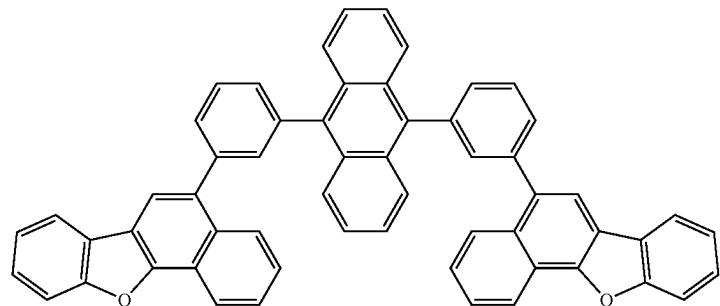
H112



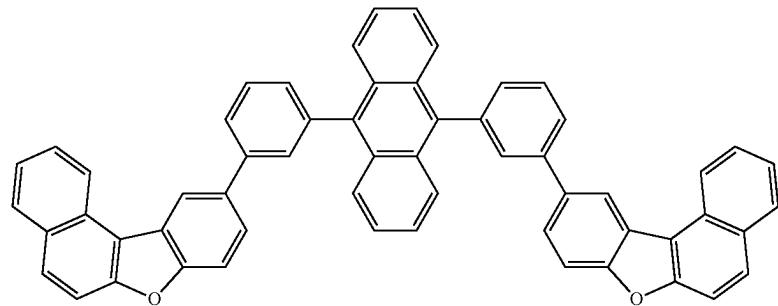
97**98**

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H113

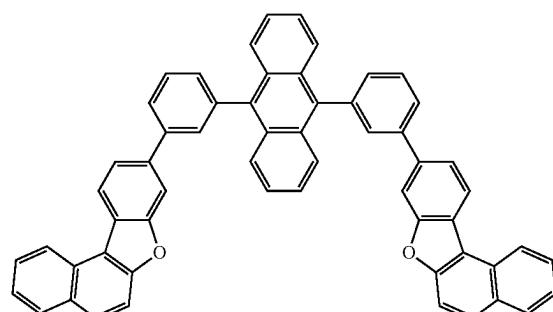


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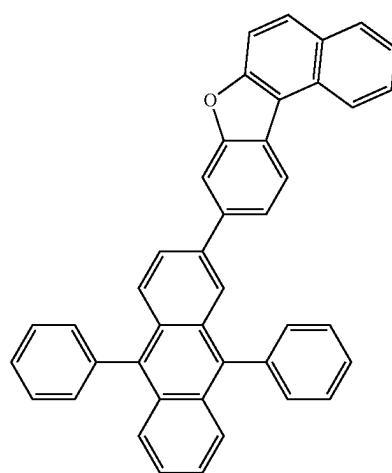


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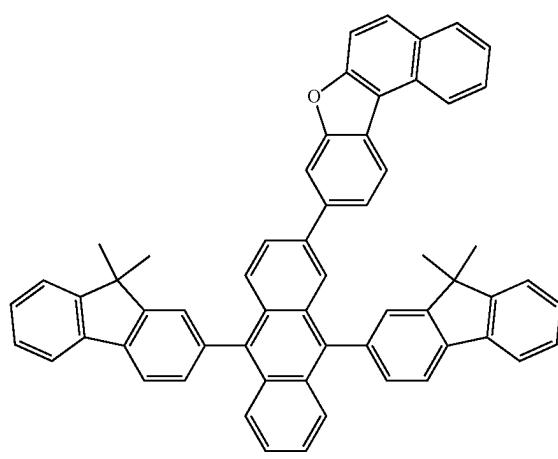
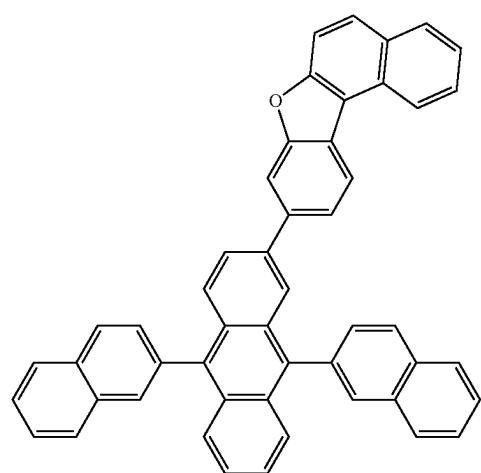
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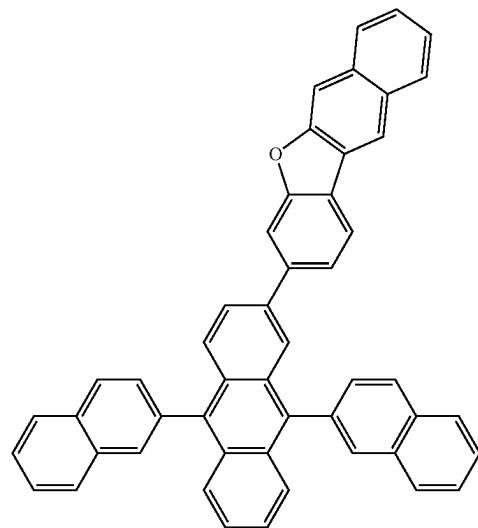
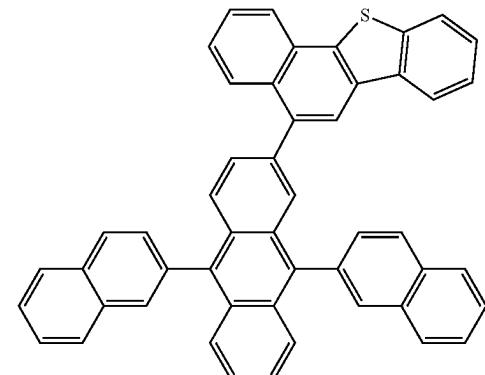


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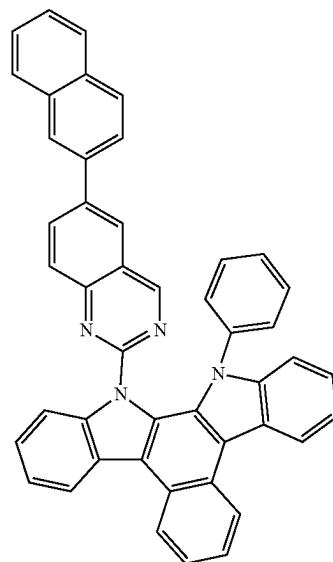


H118

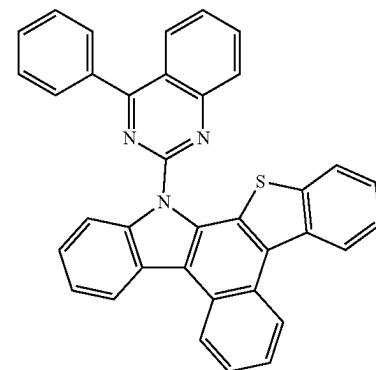


99**100**-continued
H119

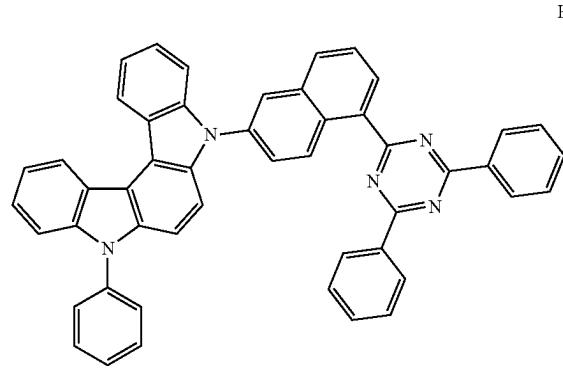
H120



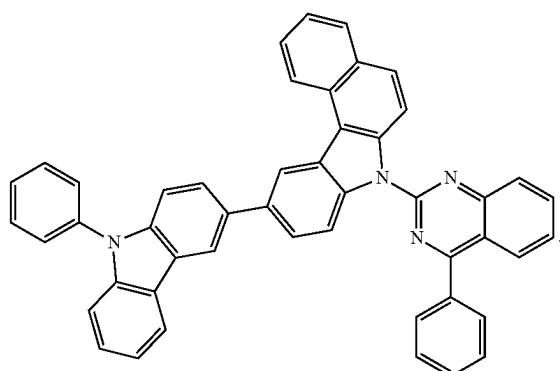
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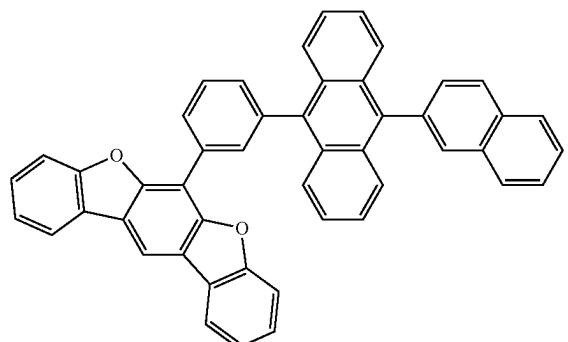
H122



H123



H124

101

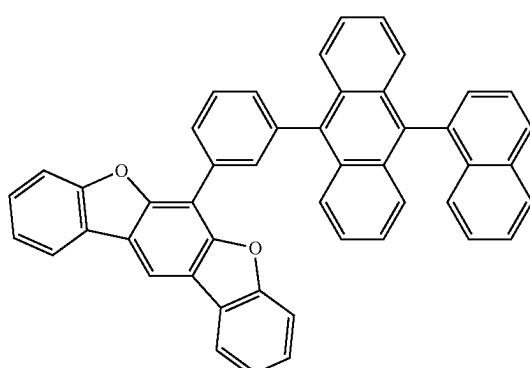
H80

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H81

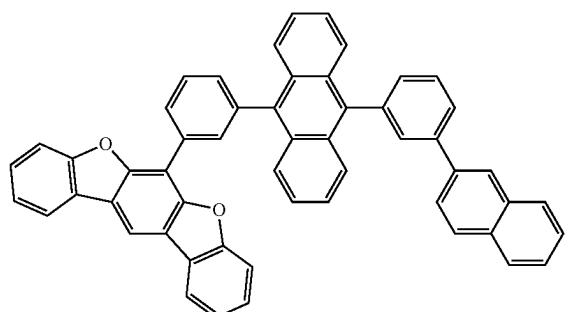


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H85



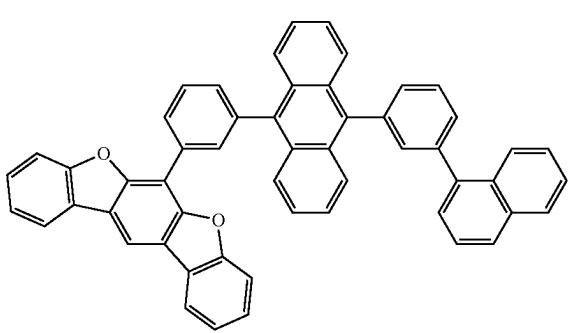
H82

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H87



H83

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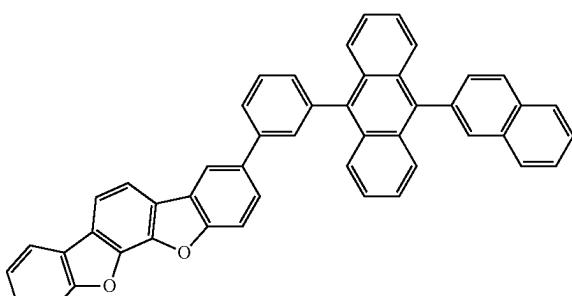
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102

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H84



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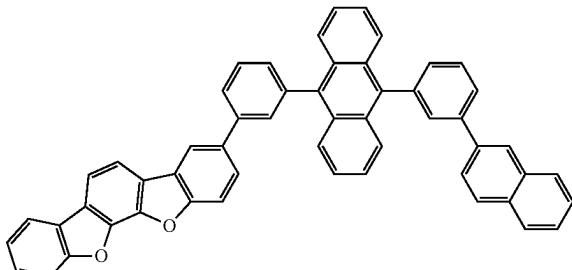
H81

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H86



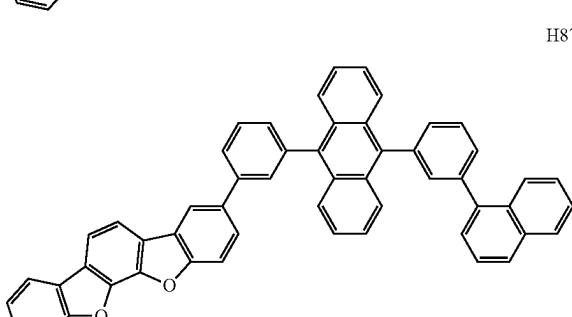
H82

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H87



H83

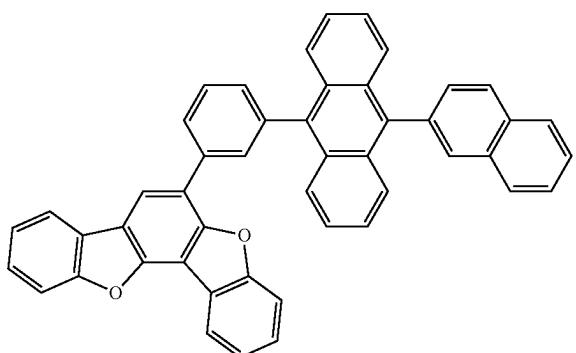
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103

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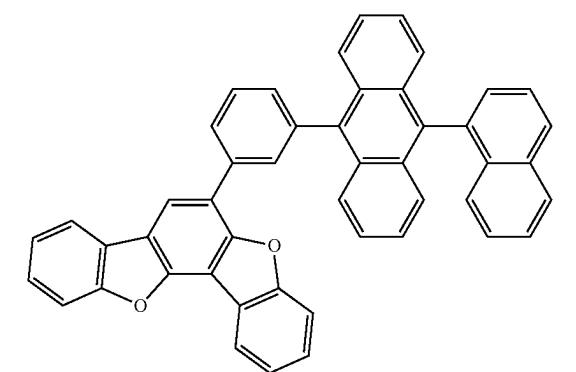
H88

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H89

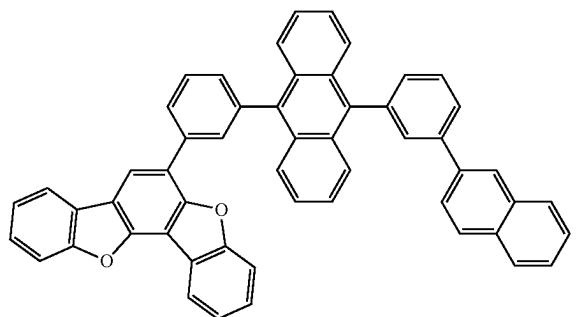


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H90



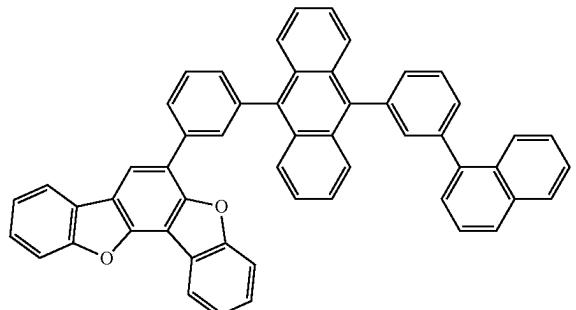
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H91

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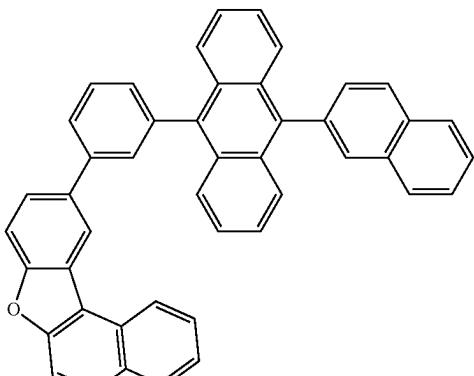
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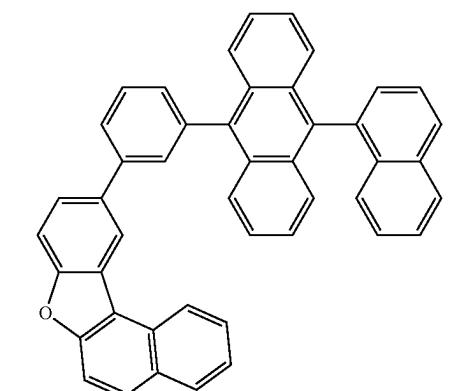
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104

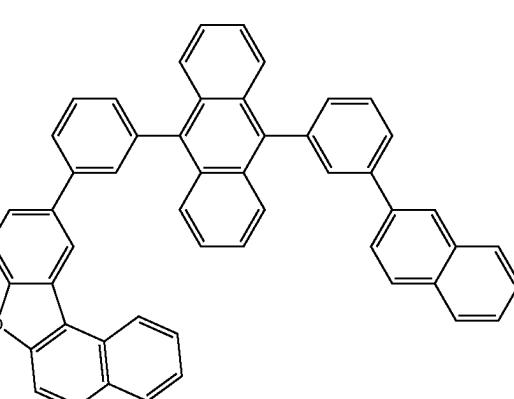
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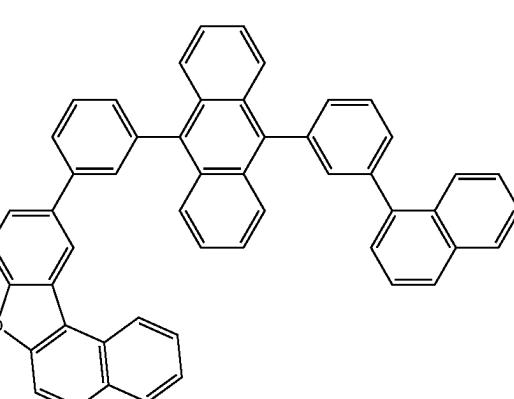
H92



H93



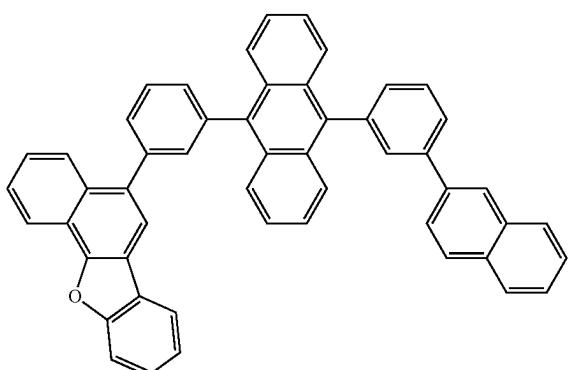
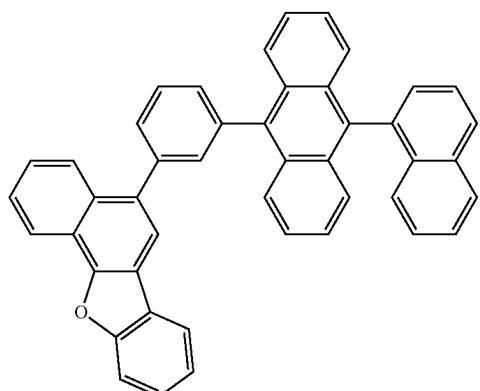
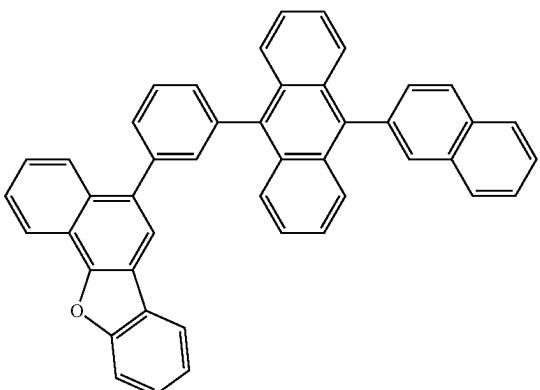
H94



H95

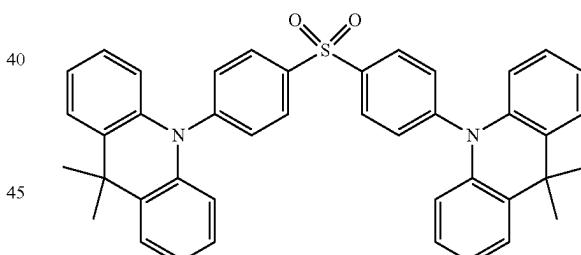
105

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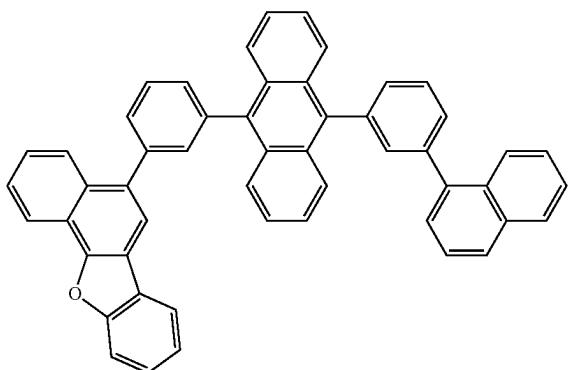


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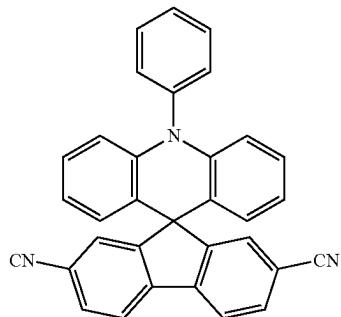
The delayed fluorescent material may include at least one of Compounds DF1 to DF9:



H99 50

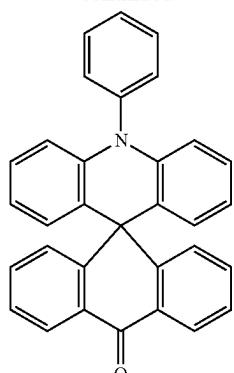


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107

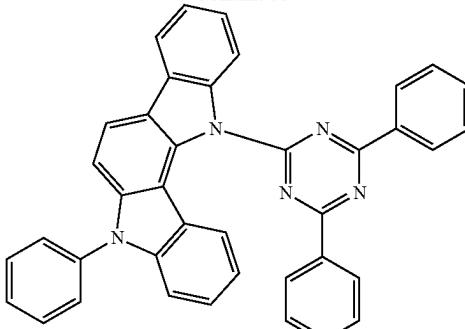
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DF3(ACRSA)

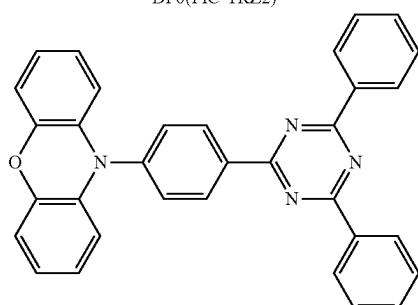
108

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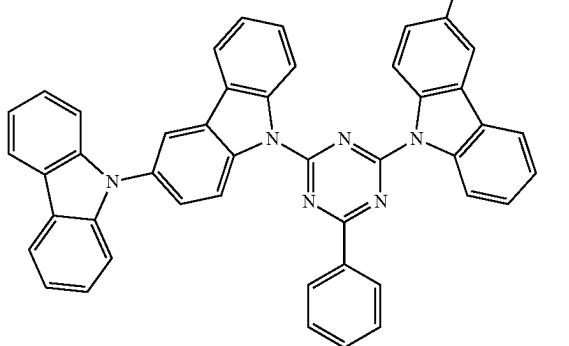
DF6(PIC-TRZ2)

20



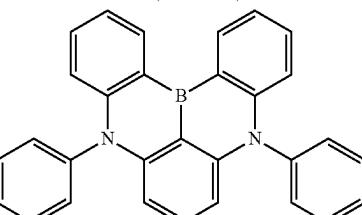
DF7(PXZ-TRZ)

30



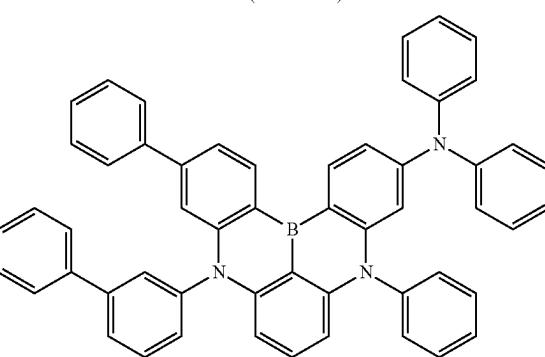
DF4(CC2TA)

35



DF8(DABNA-1)

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DF9(DABNA-2)

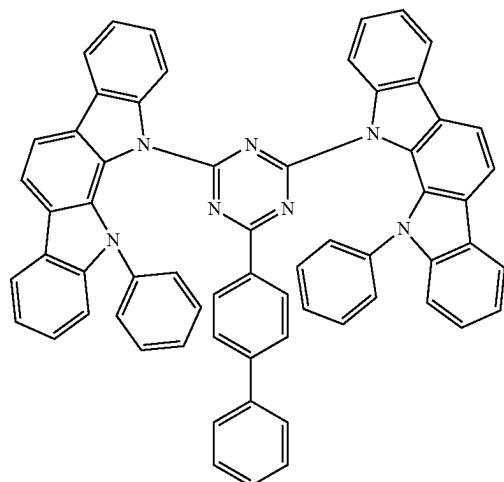
55 Quantum Dot

The emission layer may include a quantum dot.

The quantum dot as used herein refers to a crystal of a semiconductor compound, and may include any suitable material that is capable of emitting light of various emission wavelengths depending on a size of the crystal.

A diameter of the quantum dot may be, for example, in a range of about 1 nm to about 10 nm.

The quantum dot may be synthesized by a wet chemical process, an organometallic chemical vapor deposition process, a molecular beam epitaxy process, or a process that is similar to these processes.



DF5(PIC-TRZ)

109

The wet chemical process refers to a method in which a solvent and a precursor material are mixed, and then, a quantum dot particle crystal is grown. When the crystal grows, the organic solvent acts as a dispersant naturally coordinated on the surface of the quantum dot crystal and controls the growth of the crystal. Accordingly, by using a process that is easily performed at low costs compared to a vapor deposition process, such as a metal organic chemical vapor deposition (MOCVD) process and/or a molecular beam epitaxy (MBE) process, the growth of quantum dot particles may be controlled.

The quantum dot may include Groups III-VI semiconductor compound, Groups II-VI semiconductor compound, Groups III-V semiconductor compound, Group I-III-VI semiconductor compound, Groups IV-VI semiconductor compound, Group IV element or compound, or any combination thereof.

Examples of the Groups III-VI semiconductor compound may include: a binary compound, such as In_2S_3 ; a ternary compound, such as $AgInS$, $AgInS_2$, $CuInS$, and/or $CuInS_2$; and any combinations thereof.

Examples of the Groups II-VI semiconductor compound may include: a binary compound, such as $CdSe$, $CdTe$, ZnS , $ZnSe$, $ZnTe$, ZnO , $HgSe$, $HgTe$, $MgSe$, and/or MgS ; a ternary compound, such as $CdSeS$, $CdSeTe$, $CdSTe$, $ZnSeS$, $ZnSeTe$, $ZnSTe$, $HgSeS$, $HgSeTe$, $HgSTe$, $CdZnS$, $CdZnSe$, $CdZnTe$, $CdHgS$, $CdHgSe$, $CdHgTe$, $HgZnS$, $HgZnSe$, $HgZnTe$, $MgZnSe$, and/or $MgZnS$; a quaternary compound, such as $CdZnSeS$, $CdZnSeTe$, $CdZnSTe$, $CdHgSeS$, $CdHgSeTe$, $CdHgSTe$, $HgZnSeS$, $HgZnSeTe$, and/or $HgZnSTe$; and any combinations thereof.

Examples of the Groups III-V semiconductor compound may include: a binary compound, such as GaN , GaP , $GaAs$, $GaSb$, AlN , AlP , $AlAs$, $AlSb$, InN , InP , $InAs$, and/or $InSb$; a ternary compound, such as $GaNP$, $GaNAs$, $GaNSb$, $GaPAS$, $GaPSb$, $AlNP$, $AlNAs$, $AlNSb$, $AlPAS$, $AlPSb$, $InGaP$, $InNP$, $InAlP$, $InNAs$, $InNSb$, $InPAs$, $InPSb$, and/or $GaAlNP$; a quaternary compound, such as $GaAlNAs$, $GaAlNSb$, $GaAlPAs$, $GaAlPSb$, $GaInNP$, $GaInNAs$, $GaInNSb$, $GaInPAs$, $GaInPSb$, $InAlNP$, $InAlNAs$, $InAlNSb$, $InAlPAs$, and/or $InAlPSb$; and any combinations thereof. The Groups III-V semiconductor compound may further include a Group II element. Examples of the Groups III-V semiconductor compound further including a Group II element may include $InZnP$, $InGaZnP$, and $InAlZnP$.

Examples of the Groups III-VI semiconductor compound may include: a binary compound, such as GaS , $GaSe$, $GaZnSe_3$, $GaTe$, InS , $InSe$, In_2Se_3 , and/or $InTe$; a ternary compound, such as $InGaS_3$, and/or $InGaSe_3$; and any combinations thereof.

Examples of the Group I-III-VI semiconductor compound may include: a ternary compound, such as $AgInS$, $AgInS_2$, $CuInS$, $CuInS_2$, $CuGaO_2$, $AgGaO_2$, and/or $AgAlO_2$; and any combinations thereof.

Examples of the Group IV-VI semiconductor compound may include: a binary compound, such as SnS , $SnSe$, $SnTe$, PbS , $PbSe$, and/or $PbTe$; a ternary compound, such as $SnSeS$, $SnSeTe$, $SnSTe$, $PbSeS$, $PbSeTe$, $PbSTe$, $SnPbS$, $SnPbSe$, and/or $SnPbTe$; a quaternary compound, such as $SnPbSSe$, $SnPbSeTe$, and/or $SnPbSTe$; and any combinations thereof.

In one or more embodiments, the Group IV element or compound may include: a single element compound, such as Si and/or Ge ; a binary compound, such as SiC and/or $SiGe$; or any combination thereof.

Each element included in the multi-element compound, such as the binary compound, ternary compound, and/or

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quaternary compound, may be present in a particle at a uniform concentration or a non-uniform concentration.

For example, the quantum dot may have a single structure having a uniform concentration of each element included in the corresponding quantum dot or a dual structure of a core-shell. In one or more embodiments, the material included in the core may be different from the material included in the shell.

The shell of the quantum dot may function as a protective layer for maintaining semiconductor characteristics by preventing or reducing chemical degeneration of the core, and/or may function as a charging layer for imparting electrophoretic characteristics to the quantum dot. The shell may be a single layer or a multilayer. An interface between the core and the shell may have a concentration gradient in which the concentration of elements existing in the shell decreases toward the center.

Examples of the shell of the quantum dot are a metal oxide, a non-metal oxide, a semiconductor compound, and any combinations thereof. Examples of the oxide of metal oxide and non-metal may include: a binary compound, such as SiO_2 , Al_2O_3 , TiO_2 , ZnO , MnO , Mn_2O_3 , Mn_{304} , CuO , FeO , Fe_2O_3 , Fe_3O_4 , CoO , Co_3O_4 , and/or NiO ; a ternary compound, such as $MgAl_2O_4$, $CoFe_2O_4$, $NiFe_2O_4$, and/or $CoMn_2O_4$; and any combinations thereof. Examples of the semiconductor compound may include, as described herein, Groups III-VI semiconductor compound, Groups II-VI semiconductor compound, Groups III-V semiconductor compound, Groups I-III-VI semiconductor compound, Groups IV-VI semiconductor compound, and any combinations thereof. In one or more embodiments, the semiconductor compound may include CdS , $CdSe$, $CdTe$, ZnS , $ZnSe$, $ZnTe$, $ZnSeS$, $ZnTeS$, $GaAs$, GaP , $GaSb$, HgS , $HgSe$, $HgTe$, $InAs$, InP , $InGaP$, $InSb$, $AlAs$, AlP , $AlSb$, or any combination thereof.

A full width at half maximum (FWHM) of an emission wavelength spectrum of the quantum dot may be about 45 nm or less, for example, about 40 nm or less, for example, about 30 nm or less. When the FWHM of the emission wavelength spectrum of the quantum dot is within this range, color purity or color reproduction may be improved. In addition, light emitted through such quantum dots is irradiated in omnidirection. Accordingly, a wide viewing angle may be increased.

In addition, the quantum dot may be, for example, a spherical, pyramidal, multi-arm, and/or cubic nanoparticle, a nanotube, a nanowire, a nanofiber, and/or a nanoplate particle.

By adjusting the size of the quantum dot, the energy band gap may also be adjusted, thereby obtaining light of various wavelengths in a quantum dot emission layer. Therefore, by using quantum dots of different sizes, a light-emitting device that emits light of various wavelengths may be implemented. For example, the size of the quantum dot may be selected to emit red, green and/or blue light. In addition, the size of the quantum dot may be adjusted such that light of various colors are combined to emit white light.

60 Electron Transport Region in Interlayer 130

The electron transport region may have: i) a single-layered structure including (e.g., consisting of) a single layer including (e.g., consisting of) a single material, ii) a single-layered structure including (e.g., consisting of) a single layer including a plurality of different materials, or iii) a multi-layered structure including a plurality of layers including different materials.

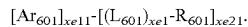
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The electron transport region may include a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, an electron injection layer, or any combination thereof.

In one or more embodiments, the electron transport region may have an electron transport layer/electron injection layer structure, a hole blocking layer/electron transport layer/electron injection layer structure, an electron control layer/electron transport layer/electron injection layer structure, or a buffer layer/electron transport layer/electron injection layer structure, wherein, for each structure, constituting layers are sequentially stacked from an emission layer.

The electron transport region (for example, the buffer layer, the hole blocking layer, the electron control layer, and/or the electron transport layer in the electron transport region) may include a metal-free compound including at least one π -electron-deficient nitrogen-containing C₁-C₆₀ cyclic group.

In one or more embodiments, the electron transport region may include a compound represented by Formula 601 below:



Formula 601

In Formula 601,

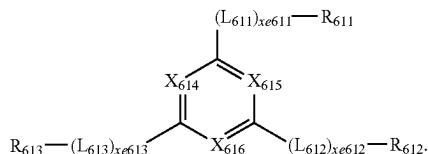
Ar_{601} and L_{601} may each independently be a C₃-C₆₀ carbocyclic group unsubstituted or substituted with at least one R_{10a} or a C₁-C₆₀ heterocyclic group unsubstituted or substituted with at least one R_{10a}, xe11 may be 1, 2, or 3, xe1 may be 0, 1, 2, 3, 4, or 5, R₆₀₁ may be a C₃-C₆₀ carbocyclic group unsubstituted or substituted with at least one R_{10a}, a C₁-C₆₀ heterocyclic group unsubstituted or substituted with at least one R_{10a}, —Si(Q₆₀₁)(Q₆₀₂)(Q₆₀₃), —C(=O)(Q₆₀₁), —S(=O)₂(Q₆₀₁), or —P(=O)(Q₆₀₁)(Q₆₀₂), Q₆₀₁ to Q₆₀₃ are the same as described in connection with Q₁, xe21 may be 1, 2, 3, 4, or 5, and at least one of Ar₆₀₁, L₆₀₁, or R₆₀₁ may each independently be a π -electron-deficient nitrogen-containing C₁-C₆₀ cyclic group unsubstituted or substituted with at least one R_{10a}.

In one or more embodiments, when xe11 in Formula 601 is 2 or more, two or more of Ar₆₀₁ (s) may be linked to each other via a single bond.

In one or more embodiments, Ar₆₀₁ in Formula 601 may be a substituted or unsubstituted anthracene group.

In one or more embodiments, the electron transport region may include a compound represented by Formula 601-1:

Formula 601-1



In Formula 601-1,

X₆₁₄ may be N or C(R₆₁₄), X₆₁₅ may be N or C(R₆₁₅), X₆₁₆ may be N or C(R₆₁₆), and at least one of X₆₁₄ to X₆₁₆ may be N, L₆₁₁ to L₆₁₃ may be understood by referring to the description presented in connection with L₆₀₁, xe611 to xe613 may be understood by referring to the description presented in connection with xe1,

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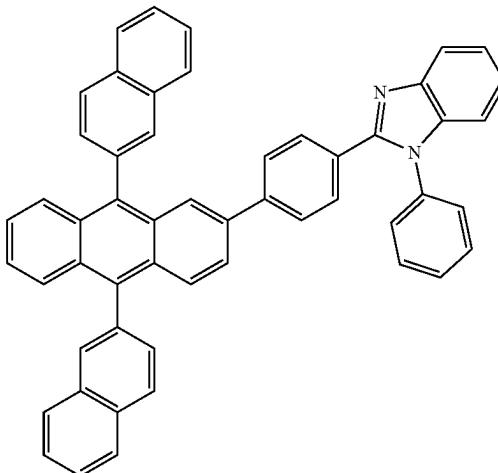
R₆₁₁ to R₆₁₃ may be understood by referring to the description presented in connection with R₆₀₁, and

R₆₁₄ to R₆₁₆ may each independently be hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a C₃-C₆₀ carbocyclic group unsubstituted or substituted with at least one R_{10a}, or a C₁-C₆₀ heterocyclic group unsubstituted or substituted with at least one R_{10a}.

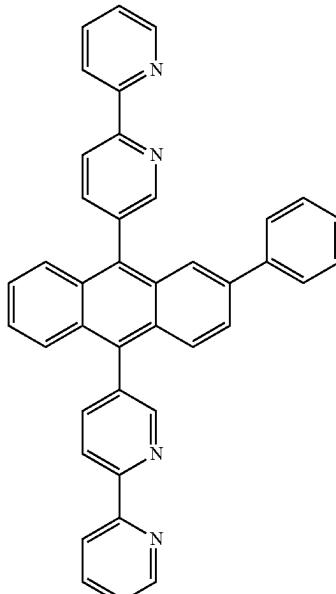
In one or more embodiments, xe1 and xe611 to xe613 in Formula 601 and 601-1 may each independently be 0, 1, or 2.

The electron transport region may include one of Compounds ET1 to ET45, 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 4,7-diphenyl-1,10-phenanthroline (Bphen), Alq₃, BAq, TAZ, NTAZ, or any combination thereof:

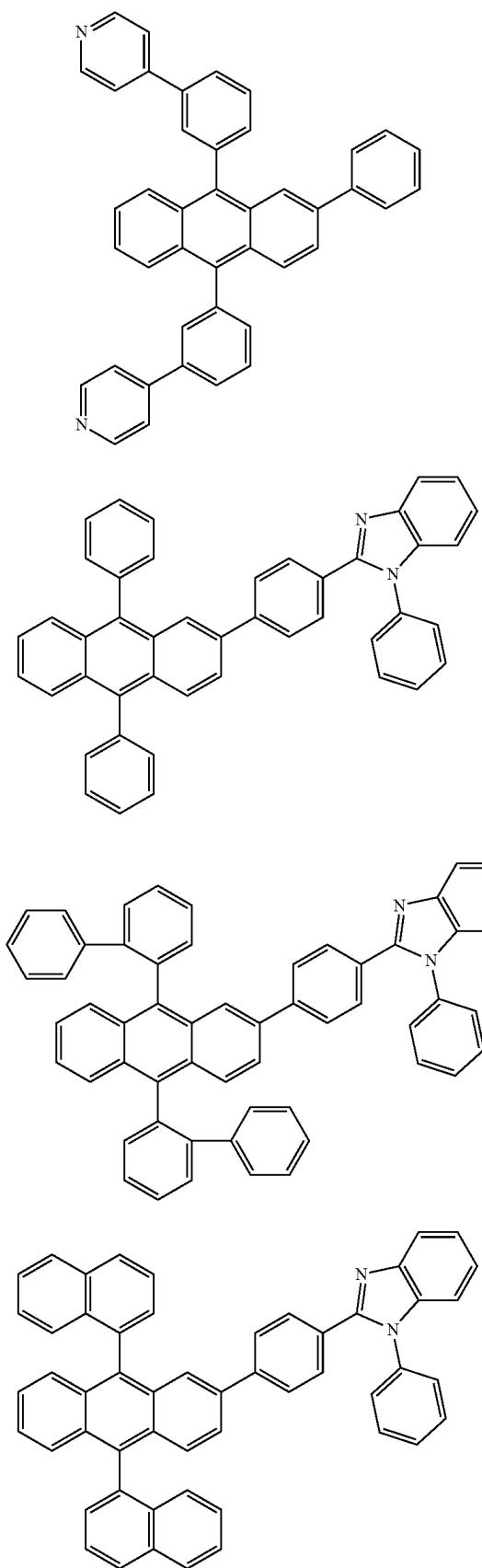
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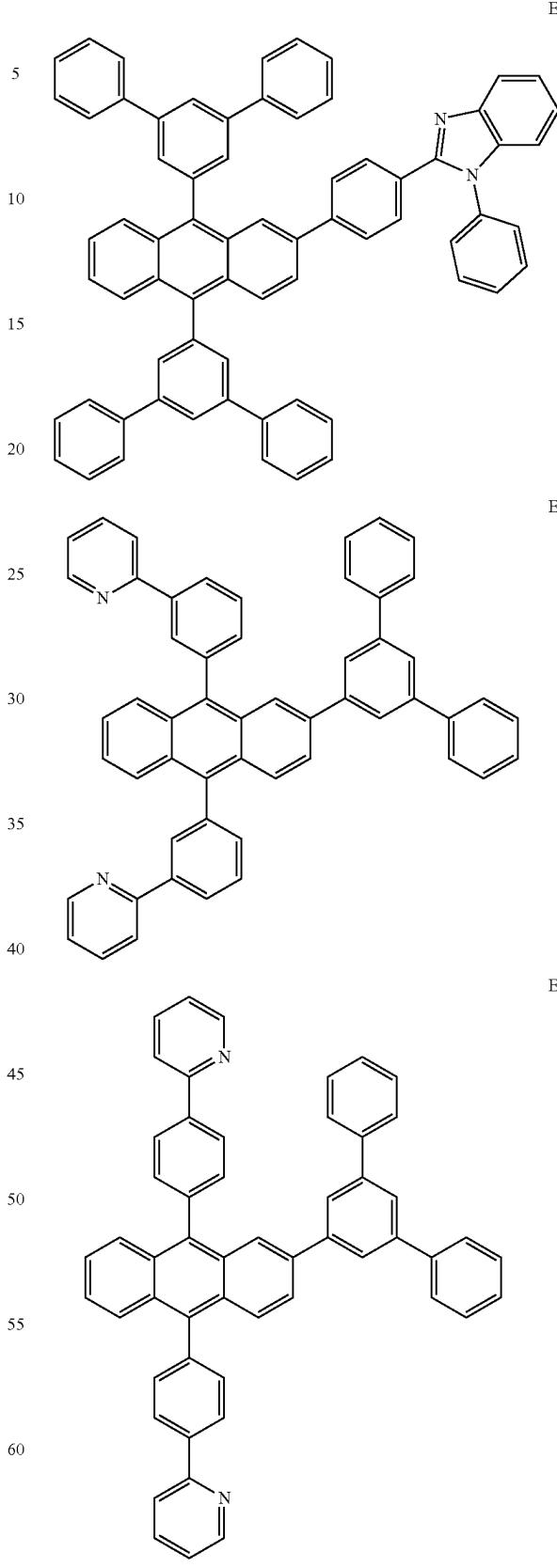


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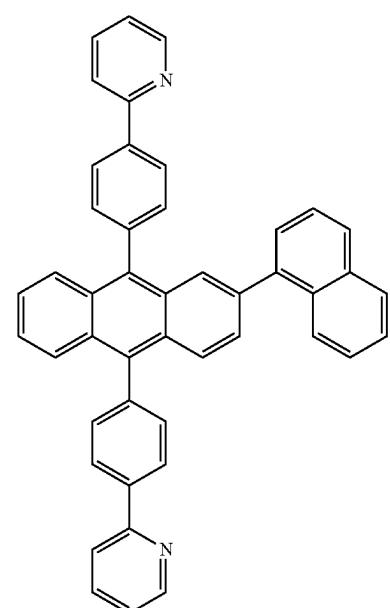
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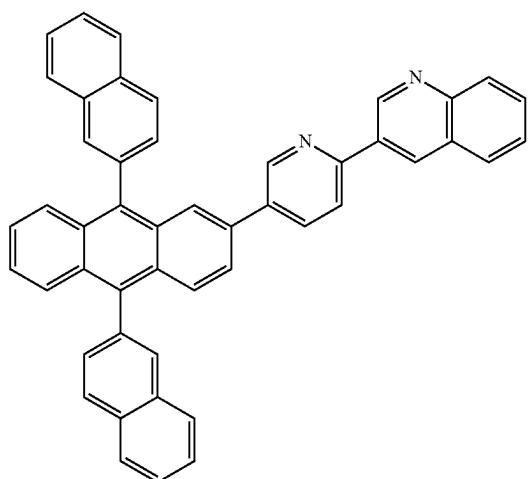
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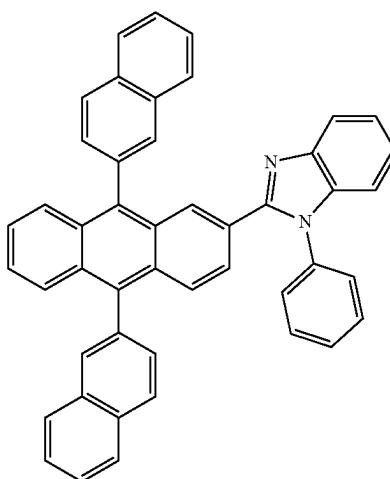
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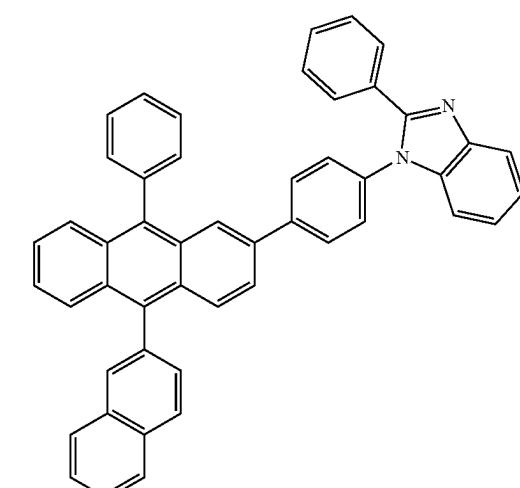


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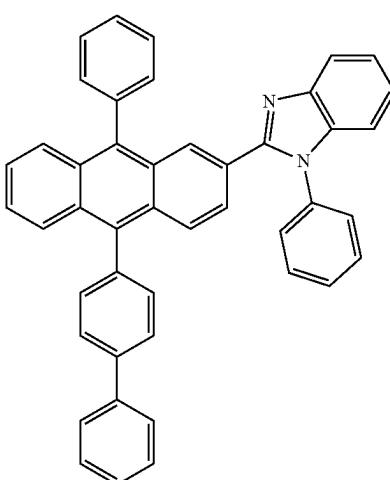
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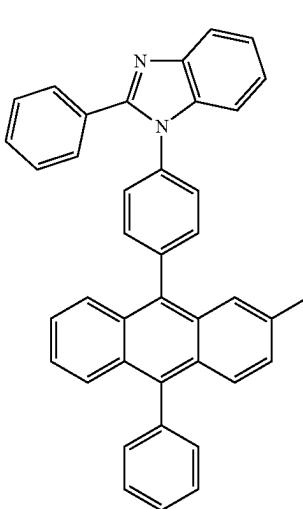
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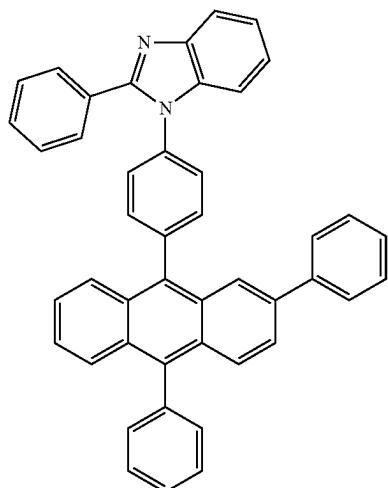
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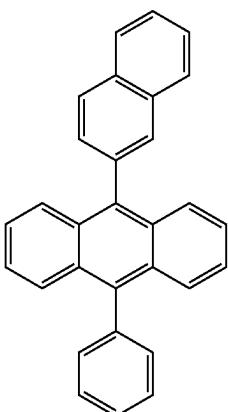
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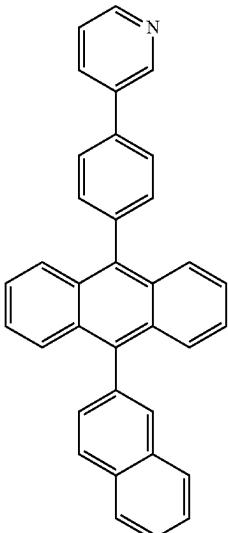
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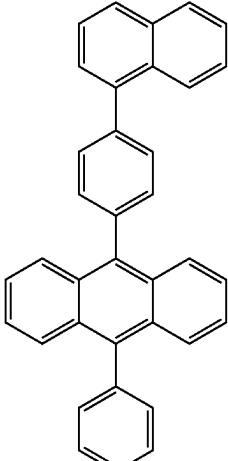


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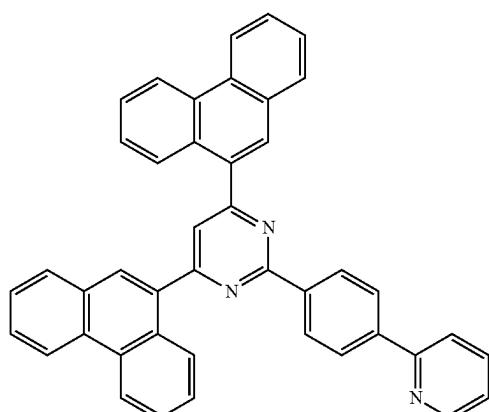


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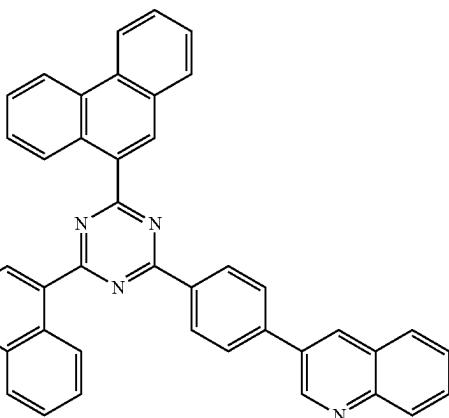
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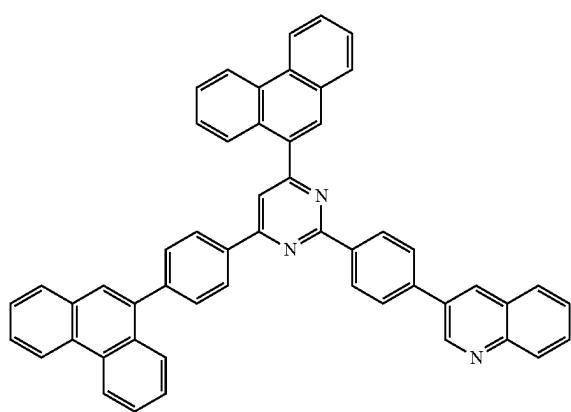
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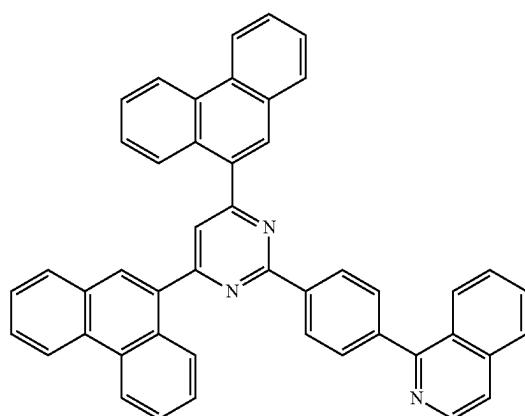
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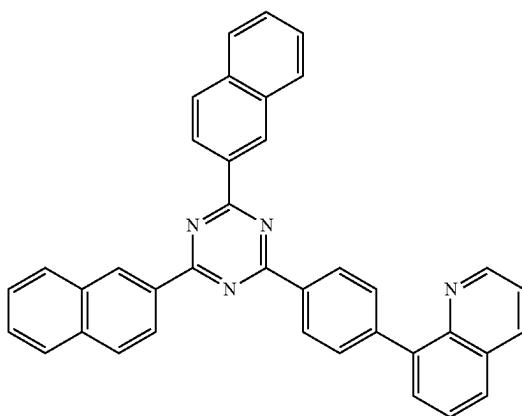


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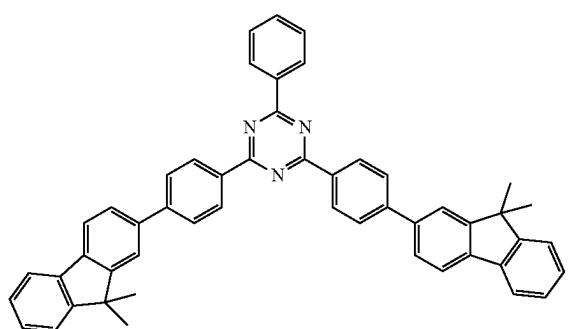
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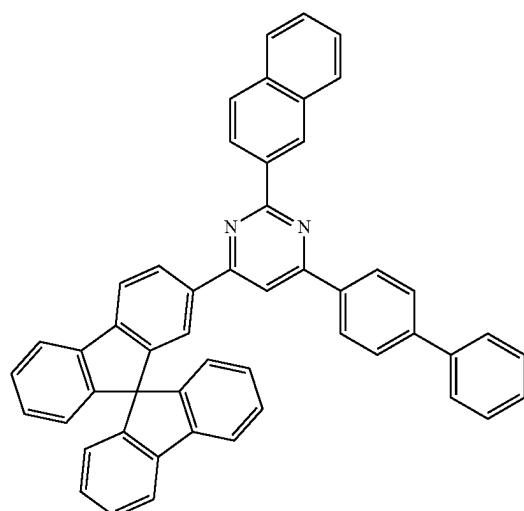


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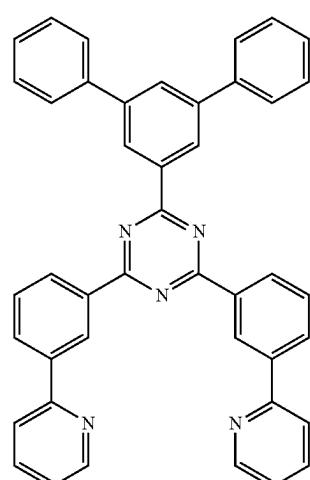
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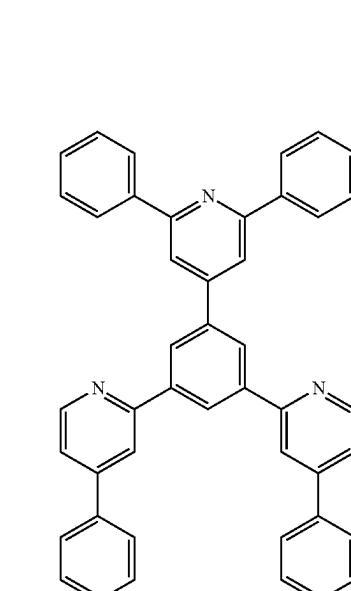
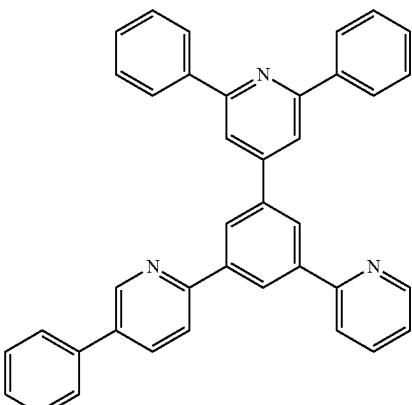
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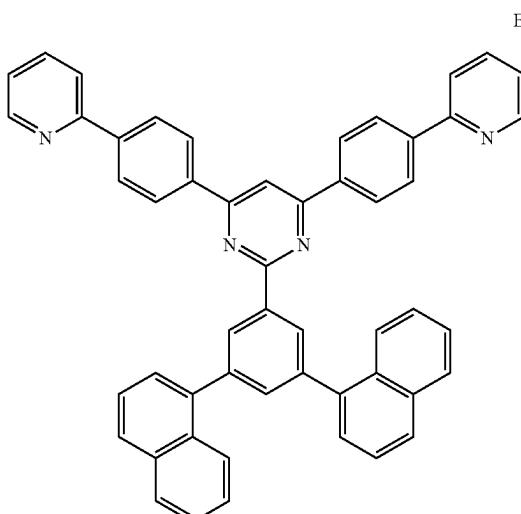
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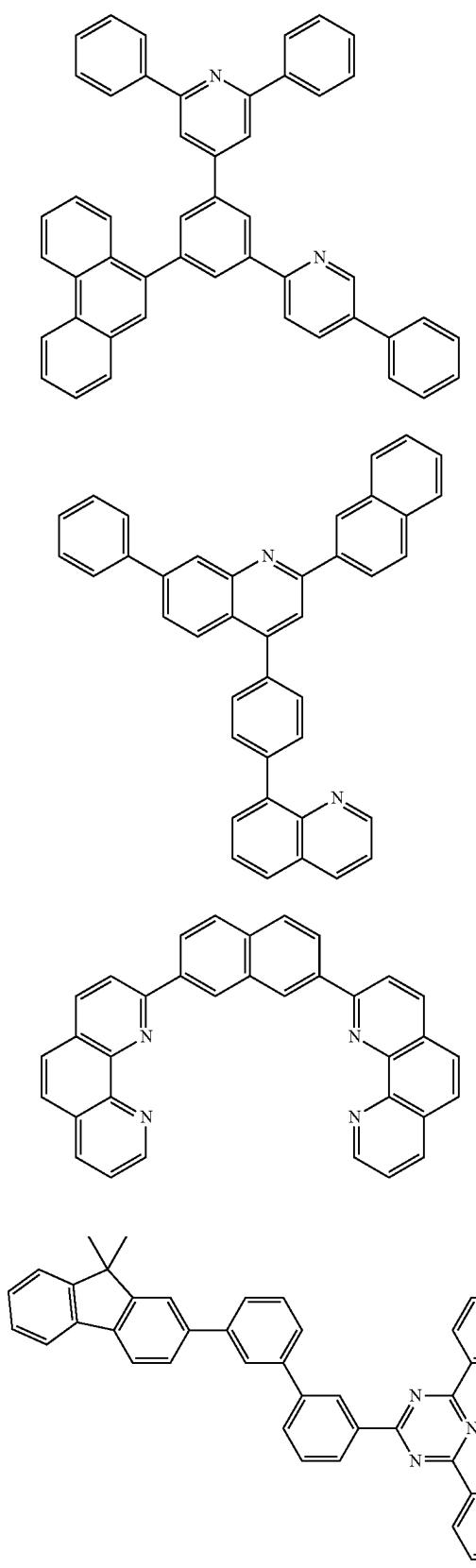


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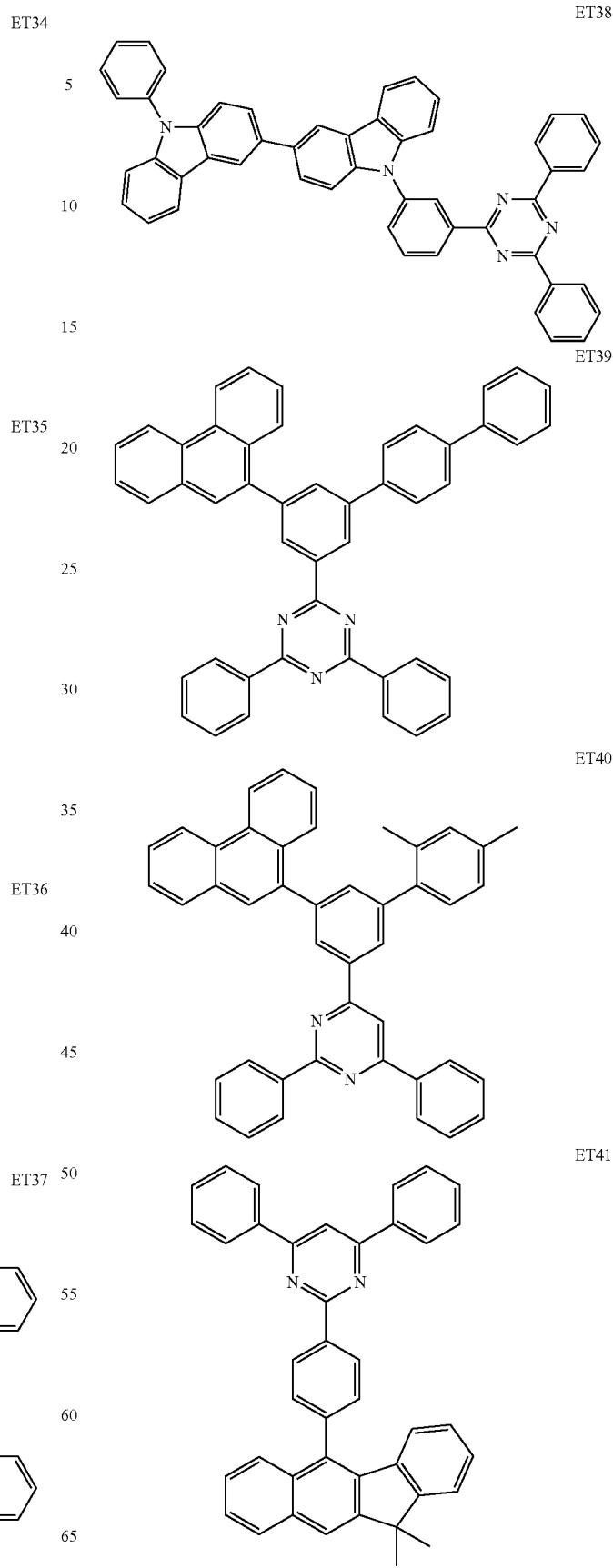


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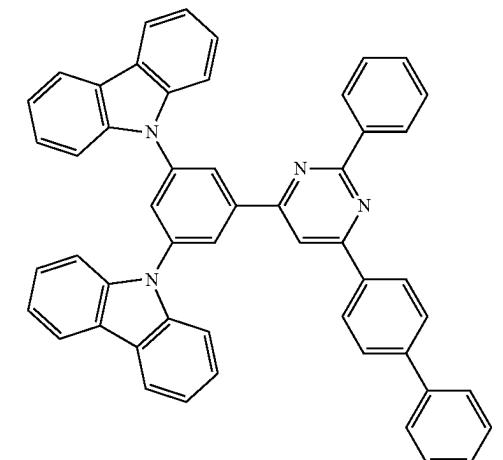


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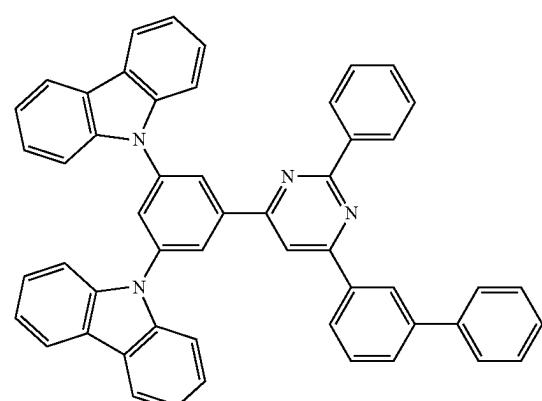
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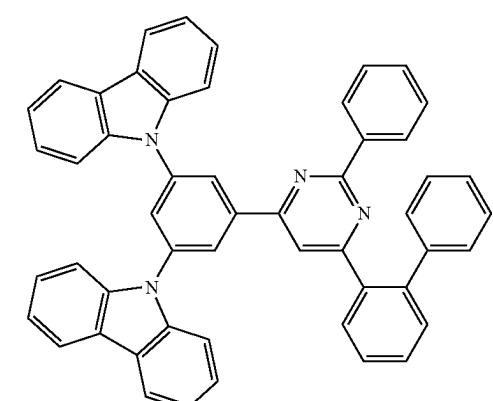
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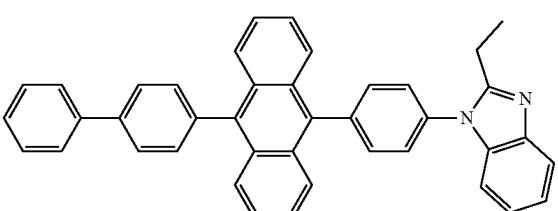
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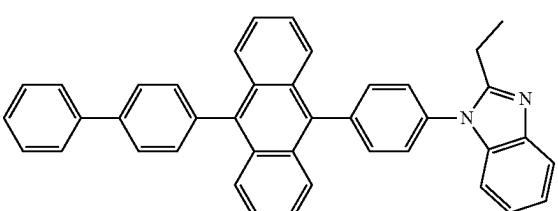
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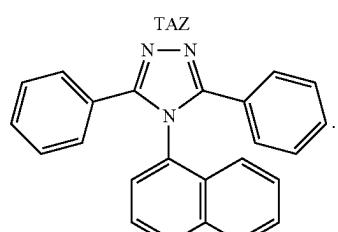
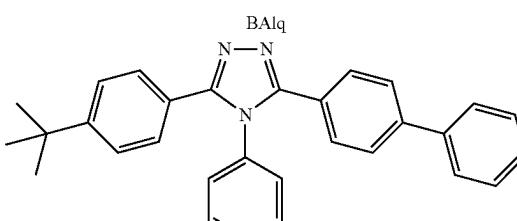
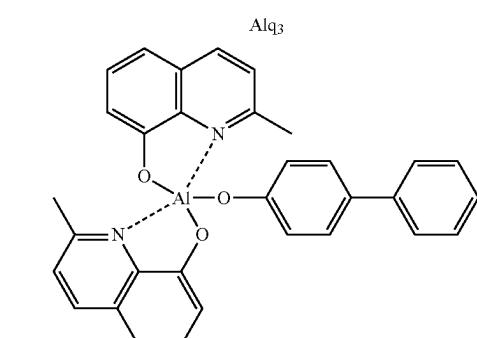
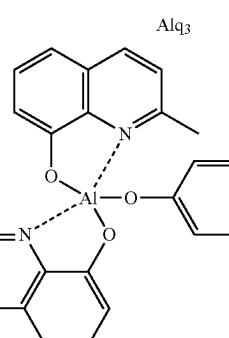
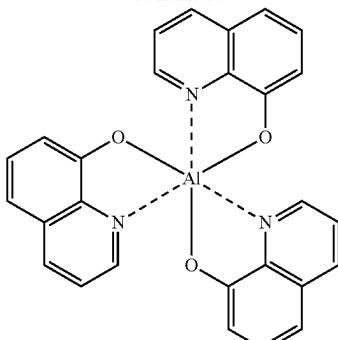
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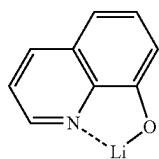
A thickness of the electron transport region may be from about 160 Å to about 5,000 Å, for example, about 100 Å to about 4,000 Å. When the electron transport region includes a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, or any combination thereof, a thickness of the buffer layer, the hole blocking layer, or the electron control layer may each independently be in a range from about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å, and the thickness of the electron transport layer may be in a range from about 100 Å to about 1,000 Å, for example, about 150 Å to about 500 Å. When the thickness of the buffer layer, the hole blocking layer, the electron control layer, the electron transport layer, and/or the electron transport layer are within these ranges, satisfactory (or suitable) hole transporting characteristics may be obtained without a substantial increase in driving voltage.

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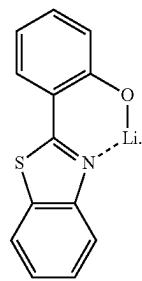
The electron transport region (for example, the electron transport layer in the electron transport region) may further include, in addition to the materials described above, a metal-containing material.

The metal-containing material may include an alkali metal complex, an alkaline earth-metal complex, or any combination thereof. A metal ion of the alkali metal complex may be a Li ion, a Na ion, a K ion, a Rb ion, and/or a Cs ion, and a metal ion of the alkaline earth-metal complex may be a Be ion, a Mg ion, a Ca ion, a Sr ion, and/or a Ba ion. A ligand coordinated with the metal ion of the alkali metal complex or the alkaline earth-metal complex may each independently be a hydroxy quinoline, a hydroxy isoquinoline, a hydroxy benzoquinoline, a hydroxy acridine, a hydroxy phenanthridine, a hydroxy phenyloxazole, a hydroxy phenylthiazole, a hydroxy diphenyloxadiazole, a hydroxy diphenylthiadiazole, a hydroxy phenylpyridine, a hydroxy phenylbenzimidazole, a hydroxy phenylbenzothiazole, a bipyridine, a phenanthroline, a cyclopentadiene, or any combination thereof.

In one or more embodiments, the metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (LiQ) and/or Compound ET-D2:



ET-D1



ET-D2

The electron transport region may include an electron injection layer that facilitates the injection of electrons from the second electrode 150. The electron injection layer may directly contact (e.g., physically contact) the second electrode 150.

The electron injection layer may have: i) a single-layered structure including (e.g., consisting of) a single layer including (e.g., consisting of) a single material, ii) a single-layered structure including (e.g., consisting of) a single layer including a plurality of different materials, or iii) a multi-layered structure including a plurality of layers including different materials.

The electron injection layer may include an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal-containing compound, an alkaline earth metal-containing compound, a rare earth metal-containing compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combination thereof.

The alkali metal may include Li, Na, K, Rb, Cs, or any combination thereof. The alkaline earth metal may include

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Mg, Ca, Sr, Ba, or any combination thereof. The rare earth metal may include Sc, Y, Ce, Tb, Yb, Gd, or any combination thereof.

The alkali metal-containing compound, the alkaline earth metal-containing compound, and the rare earth metal-containing compound may each independently be selected from oxides and halides (for example, fluorides, chlorides, bromides, and/or iodides) of the alkali metal, the alkaline earth metal, and the rare earth metal, telluride, or any combination thereof.

The alkali metal-containing compound may be alkali metal oxides, such as Li_2O , Cs_2O , and/or K_2O ; and alkali metal halides, such as LiF , NaF , CsF , KF , LiI , NaI , CsI , and/or KI ; or any combination thereof. The alkaline earth metal-containing compound may include an alkaline earth metal compound, such as BaO , SrO , CaO , $\text{Ba}_x\text{Sr}_{1-x}\text{O}$ (x is a real number that satisfies the condition of $0 < x < 1$), and/or $\text{Ba}_x\text{Ca}_{1-x}\text{O}$ (x is a real number that satisfies the condition of $0 < x < 1$). The rare earth metal-containing compound may include YbF_3 , ScF_3 , SC_2O_3 , Y_2O_3 , Ce_2O_3 , GdF_3 , TbF_3 , YbI_3 , ScI_3 , TbI_3 , or any combination thereof. In one or more embodiments, the rare earth metal-containing compound may include lanthanide metal telluride. Examples of the lanthanide metal telluride may include LaTe , CeTe , PrTe , NdTe , PmTe , SmTe , EuTe , GdTe , TbTe , DyTe , HoTe , ErTe , TmTe , YbTe , LuTe , La_2Te_3 , Ce_2Te_3 , Pr_2Te_3 , Nd_2Te_3 , Pm_2Te_3 , Sm_2Te_3 , Eu_2Te_3 , Gd_2Te_3 , Tb_2Te_3 , Dy_2Te_3 , Ho_2Te_3 , Er_2Te_3 , Tm_2Te_3 , Yb_2Te_3 , and LuZnTe_3 .

The alkali metal complex, the alkaline earth-metal complex, and the rare earth metal complex may each independently include i) one of ions of the alkali metal, the alkaline earth metal, and the rare earth metal, respectively, and ii) as a ligand linked to the metal ion, for example, a hydroxy quinoline, a hydroxy isoquinoline, a hydroxy benzoquinoline, a hydroxy acridine, a hydroxy phenanthridine, a hydroxy phenyloxazole, a hydroxy phenylthiazole, a hydroxy diphenyloxadiazole, a hydroxy diphenylthiadiazole, a hydroxy phenylpyridine, a hydroxy phenylbenzimidazole, a hydroxy phenylbenzothiazole, a bipyridine, a phenanthroline, a cyclopentadiene, or any combination thereof.

The electron injection layer may include (e.g., consist of) an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal-containing compound, an alkaline earth metal-containing compound, a rare earth metal-containing compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combination thereof, or may further include an organic material (for example, a compound represented by Formula 601).

In one or more embodiments, the electron injection layer may include (e.g., consist of) i) an alkali metal-containing compound (for example, an alkali metal halide), or ii) a) an alkali metal-containing compound (for example, an alkali metal halide); and b) alkali metal, alkaline earth metal, rare earth metal, or any combination thereof. In one or more embodiments, the electron injection layer may be a KI:Yb co-deposited layer or a RbI:Yb co-deposited layer.

When the electron injection layer further includes an organic material, the alkali metal, the alkaline earth metal, the rare earth metal, the alkali metal-containing compound, the alkaline earth metal-containing compound, the rare earth metal-containing compound, the alkali metal complex, the alkaline earth-metal complex, the rare earth metal complex, or any combination thereof may be homogeneously or non-homogeneously dispersed in a matrix including the organic material.

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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 (or suitable) electron injection characteristics without a substantial increase in driving voltage.

Second Electrode 150

The second electrode 150 may be located on the interlayer 130 having the structure according to embodiments of the present disclosure. The second electrode 150 may be a cathode, which is an electron injection electrode, and as a material for forming the second electrode 150, a metal, an alloy, an electrically conductive compound, or any combination thereof, each having a low work function, may be used.

The second electrode 150 may include at least one selected from lithium (Li), silver (Ag), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), ytterbium (Yb), silver-ytterbium (Ag—Yb), ITO, IZO, or any combination thereof. The second electrode 150 may be a transmissive electrode, a semi-transmissive electrode, or a reflective electrode.

The second electrode 150 may have a single-layered structure or a multi-layered structure including two or more layers.

Capping Layer

A first capping layer may be located outside the first electrode 110, and/or a second capping layer may be located outside the second electrode 150. For example, the light-emitting device 10 may have a structure in which the first capping layer, the first electrode 110, the interlayer 130, and the second electrode 150 are sequentially stacked in this stated order, a structure in which the first electrode 110, the interlayer 130, the second electrode 150, and the second capping layer are sequentially stacked in this stated order, or a structure in which the first capping layer, the first electrode 110, the interlayer 130, the second electrode 150, and the second capping layer are sequentially stacked in this stated order.

Light generated in an emission layer of the interlayer 130 of the light-emitting device 10 may be directed or extracted toward the outside through the first electrode 110, which is a semi-transmissive electrode or a transmissive electrode, and the first capping layer, and light generated in an emission layer of the interlayer 130 of the light-emitting device 10 may be directed or extracted toward the outside through the second electrode 150, which is a semi-transmissive electrode or a transmissive electrode, and the second capping layer.

The first capping layer and the second capping layer may increase external luminescence efficiency according to the principle of constructive interference. Accordingly, the light extraction efficiency of the organic light-emitting device 10 is increased, so that the luminescence efficiency of the organic light-emitting device 10 may be improved.

Each of the first capping layer and the second capping layer may include a material having a refractive index of 1.6 or more (at 589 nm).

The first capping layer and the second capping layer may each independently be an organic capping layer including an organic material, an inorganic capping layer including an inorganic material, or a composite capping layer including an organic material and an inorganic material.

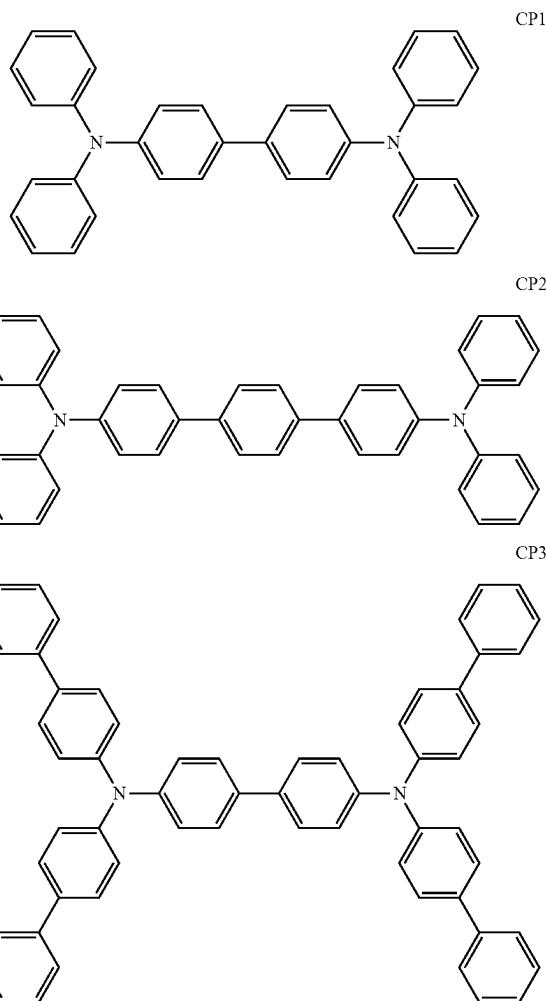
At least one of the first capping layer or the second capping layer may each independently include a carbocyclic

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compound, a heterocyclic compound, an amine group-containing compound, a porphyrin derivative, a phthalocyanine derivative, a naphthalocyanine derivative, an alkali metal complex, an alkaline earth-metal complex, or any combination thereof. The carbocyclic compound, the heterocyclic compound, and the amine group-containing compound may each independently be optionally substituted with a substituent containing O, N, S, Se, Si, F, Cl, Br, I, or any combination thereof. In one or more embodiments, at least one of the first capping layer or the second capping layer may each independently include an amine group-containing compound.

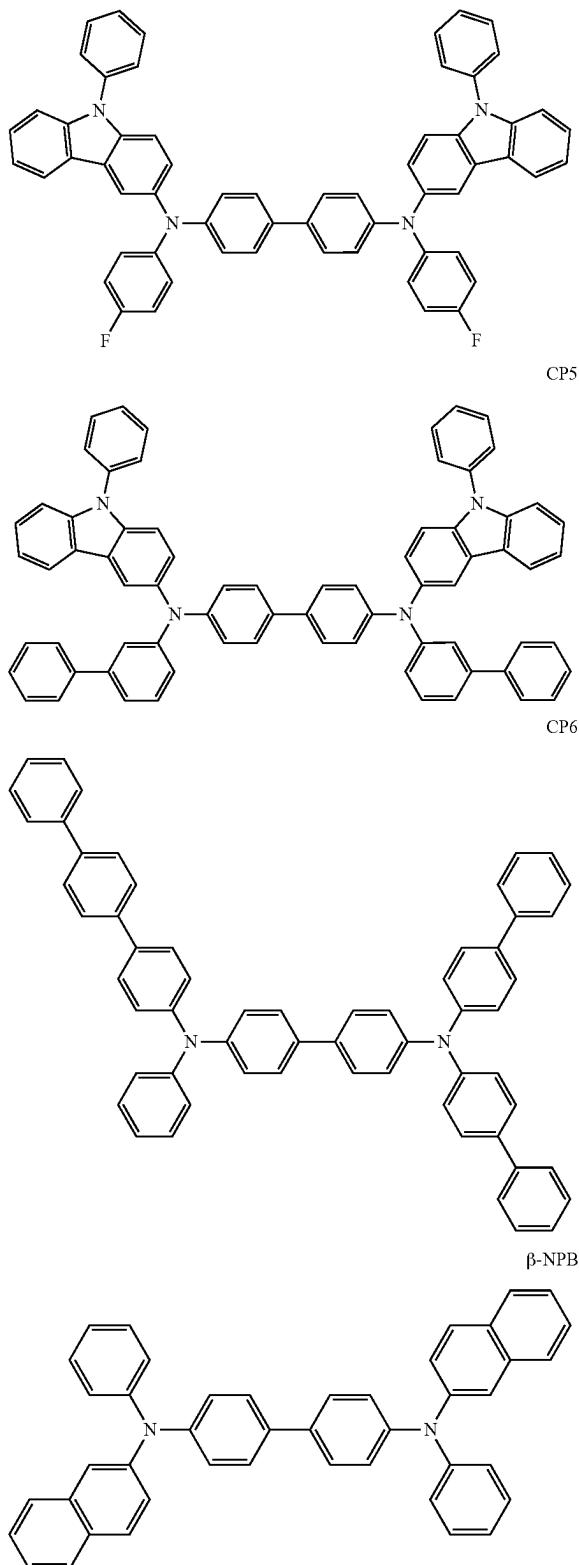
In one or more embodiments, at least one of the first capping layer or second capping layer may each independently include a compound represented by Formula 201, a compound represented by Formula 202, or any combination thereof.

In one or more embodiments, at least one of the first capping layer or the second capping layer may each independently include one of Compounds HT28 to HT33, one of Compounds CP1 to CP6, β-NPB, or any combination thereof:



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-continued



Electronic Apparatus

The light-emitting device may be included in various suitable electronic apparatuses. In one or more embodiments,

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ments, the electronic apparatus including the light-emitting device may be a light-emitting apparatus, an authentication apparatus, and/or the like.

The electronic apparatus (for example, light-emitting apparatus) may further include, in addition to the light-emitting device, i) a color filter, ii) a color conversion layer, or iii) a color filter and a color conversion layer. The color filter and/or the color conversion layer may be located in at least one traveling direction of light emitted from the light-emitting device. In one or more embodiments, light emitted from the light-emitting device may be blue light or white light. The light-emitting device may be the same as described above. In one or more embodiments, the color conversion layer may include a quantum dot. The quantum dot may be, for example, a quantum dot as described herein.

The electronic apparatus may include a first substrate. The first substrate includes a plurality of subpixel areas, the color filter includes a plurality of color filter areas corresponding to the plurality of subpixel areas, respectively, and the color conversion layer may include a plurality of color conversion areas corresponding to the subpixel areas, respectively.

A pixel-defining film may be between the plurality of subpixel areas to define each of the subpixel areas.

The color filter may further include a plurality of color filter areas and a light-blocking pattern between the plurality of color filter areas, and the color conversion layer may further include a plurality of color conversion areas and a light-blocking pattern between the plurality of color conversion areas.

The plurality of color filter areas (or the plurality of color conversion areas) may include a first area to emit first color light, a second area to emit second color light, and/or a third area to emit third color light, and the first color light, the second color light, and/or the third color light may have different maximum emission wavelengths from one another. In one or more embodiments, the first color light may be red light, the second color light may be green light, and the third color light may be blue light. In one or more embodiments, the plurality of color filter areas (or the plurality of color conversion areas) may include a quantum dot. For example, the first area may include a red quantum dot, the second area may include a green quantum dot, and the third area may not include a quantum dot. The quantum dot is the same as described in the present specification. Each of the first area, the second area and/or the third area may further include a scatterer.

In one or more embodiments, the light-emitting device may emit first light, the first area may absorb the first light to emit first first-color light, the second area may absorb the first light to emit second first-color light, and the third area may absorb the first light to emit third first-color light. In this regard, the first first-color light, the second first-color light, and the third first-color light may have different maximum emission wavelengths from one another. For example, the first light may be blue light, the first first-color light may be red light, the second first-color light may be green light, and the third first-color light may be blue light.

The electronic apparatus may further include a thin-film transistor, in addition to the light-emitting device as described above. The thin-film transistor may include a source electrode, a drain electrode, and an activation layer, wherein any one of the source electrode and the drain electrode may be electrically connected to any one of the first electrode and the second electrode of the light-emitting device.

The thin-film transistor may further include a gate electrode, a gate insulating film, and/or the like.

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The activation layer may include crystalline silicon, amorphous silicon, organic semiconductor, oxide semiconductor, and/or the like.

The electronic apparatus may further include a sealing portion for sealing the light-emitting device. The sealing portion may be between the color filter and/or the color conversion layer and the light-emitting device. The sealing portion allows light from the light-emitting device to be extracted to the outside, while simultaneously (or concurrently) preventing (or reducing) ambient air and/or moisture from penetrating into the light-emitting device. The sealing portion may be a sealing substrate including a transparent glass substrate and/or a plastic substrate. The sealing portion may be a thin film encapsulation layer including at least one layer of an organic layer and/or an inorganic layer. When the sealing portion is a thin film encapsulation layer, the electronic apparatus may be flexible.

On the sealing portion, in addition to the color filter and/or the color conversion layer, various functional layers may be further located according to the use of the electronic apparatus. The functional layers may include a touch screen layer, a polarizing layer, and/or the like. The touch screen layer may be a pressure-sensitive touch screen layer, a capacitive touch screen layer, and/or an infrared touch screen layer. The authentication apparatus may be, for example, a biometric authentication apparatus for authenticating an individual by using biometric information of a biometric body (for example, a fingertip, a pupil, and/or the like).

The authentication apparatus may further include, in addition to the light-emitting device, a biometric information collector.

The electronic apparatus may be applied to various suitable displays, light sources, lighting, personal computers (for example, a mobile personal computer), mobile phones, digital cameras, electronic organizers, electronic dictionaries, electronic game machines, medical instruments (for example, electronic thermometers, sphygmomanometers, blood glucose meters, pulse measurement devices, pulse wave measurement devices, electrocardiogram displays, ultrasonic diagnostic devices, and/or endoscope displays), fish finders, various measuring instruments, meters (for example, meters for a vehicle, an aircraft, and/or a vessel), projectors, and/or the like.

Description of FIGS. 2 and 3

FIG. 2 is a cross-sectional view of a light-emitting apparatus according to one or more embodiments.

The light-emitting apparatus of FIG. 2 includes a substrate 100, a thin-film transistor (TFT), a light-emitting device, and an encapsulation portion 300 that seals the light-emitting device.

The substrate 100 may be a flexible substrate, a glass substrate, and/or a metal substrate. A buffer layer 210 may be located on the substrate 100. The buffer layer 210 prevents or reduces the penetration of impurities through the substrate 100, and may provide a flat surface on the substrate 100.

A TFT may be located on the buffer layer 210. The TFT may include an activation layer 220, a gate electrode 240, a source electrode 260, and a drain electrode 270.

The activation layer 220 may include an inorganic semiconductor such as silicon and/or polysilicon, an organic semiconductor, and/or an oxide semiconductor, and may include a source region, a drain region, and a channel region.

A gate insulating film 230 for insulating the activation layer 220 from the gate electrode 240 may be located on the

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activation layer 220, and the gate electrode 240 may be located on the gate insulating film 230.

An interlayer insulating film 250 may be located on the gate electrode 240. The interlayer insulating film 250 is located between the gate electrode 240 and the source electrode 260 to insulate the gate electrode 240 from the source electrode 260, and between the gate electrode 240 and the drain electrode 270 to insulate the gate electrode 240 from the drain electrode 270.

10 The source electrode 260 and the drain electrode 270 may be located on the interlayer insulating film 250. The interlayer insulating film 250 and the gate insulating film 230 may be formed to expose the source region and the drain region of the activation layer 220, and the source electrode 260 and the drain electrode 270 may be located to be in contact with the exposed portions of the source region and the drain region of the activation layer 220.

15 The TFT may be electrically connected to a light-emitting device to drive the light-emitting device, and is covered by a passivation layer 280. The passivation layer 280 may include an inorganic insulating film, an organic insulating film, or a combination thereof. A light-emitting device is provided on the passivation layer 280. The light-emitting device includes the first electrode 110, the interlayer 130, and the second electrode 150.

20 The first electrode 110 may be located on the passivation layer 280. The passivation layer 280 does not completely cover the drain electrode 270 and may expose a certain region of the drain electrode 270, and the first electrode 110 may be connected to the exposed region of the drain electrode 270.

25 The pixel defining layer 290 including an insulating material may be located on the first electrode 110. The pixel defining layer 290 may expose a certain region of the first electrode 110, and the interlayer 130 may be formed in the exposed region of the first electrode 110. The pixel defining layer 290 may be a polyimide or polyacryl-based organic film. In one or more embodiments, at least some layers of the interlayer 130 may extend beyond the upper portion of the pixel defining layer 290 and may thus be located in the form of a common layer.

30 The second electrode 150 may be located on the interlayer 130, and a capping layer 170 may be additionally formed on the second electrode 150. The capping layer 170 may be formed to cover the second electrode 150.

35 The encapsulation portion 300 may be located on the capping layer 170. The encapsulation portion 300 may be located on a light-emitting device and protects the light-emitting device from moisture or oxygen. The encapsulation portion 300 may include: an inorganic film including silicon nitride (SiNx), silicon oxide (SiOx), indium tin oxide, indium zinc oxide, or a combination thereof; an organic film including polyethylene terephthalate, polyethylene naphthalate, polycarbonate, polyimide, polyethylene sulfonate, 40 polyoxymethylene, polyarylate, hexamethyldisiloxane, an acrylic resin (for example, polymethyl methacrylate and/or polyacrylic acid), an epoxy-based resin (for example, aliphatic glycidyl ether (AGE), or a combination thereof; or a combination of an inorganic film and an organic film.

45 FIG. 3 is a cross-sectional view showing a light-emitting apparatus according to one or more embodiments of the present disclosure.

50 The light-emitting apparatus of FIG. 3 is the same as the light-emitting apparatus of FIG. 2, except that a light-blocking pattern 500 and a functional region 400 are additionally located on the encapsulation portion 300. The functional region 400 may be i) a color filter area, ii) a color

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conversion area, or iii) a combination of the color filter area and the color conversion area. In one or more embodiments, the light-emitting device included in the light-emitting apparatus of FIG. 3 may be a tandem light-emitting device.

Preparation Method

Layers constituting the hole transport region, the emission layer, and layers constituting the electron transport region may each independently be formed in a certain region by using one or more suitable methods selected from vacuum deposition, spin coating, casting, Langmuir-Blodgett (LB) deposition, ink-jet printing, laser-printing, and laser-induced thermal imaging.

When layers constituting the hole transport region, the emission layer, and layers constituting the electron transport region are formed by vacuum deposition, the deposition may be performed at a deposition temperature of about 100° C. to about 500° C., a vacuum degree of about 10⁻⁸ torr to about 10⁻³ torr, and a deposition speed of about 0.01 Å/sec to about 100 Å/sec, by taking into account a material to be included in a layer to be formed and the structure of a layer to be formed.

DEFINITION OF TERMS

The term “C₃-C₆₀ carbocyclic group” as used herein refers to a cyclic group that consists of carbon only as ring-forming atoms, and has three to sixty ring-forming carbon atoms, and the term “C₁-C₆₀ heterocyclic group” as used herein refers to a cyclic group that has one to sixty ring-forming carbon atoms and further includes, in addition to carbon atoms, a ring-forming heteroatom. The C₃-C₆₀ carbocyclic group and the C₁-C₆₀ heterocyclic group may each be a monocyclic group that consists of one ring or a polycyclic group in which two or more rings are condensed with each other. In one or more embodiments, the number of ring-forming atoms of the C₁-C₆₀ heterocyclic group may be from 3 to 61.

The term “cyclic group” as used herein includes the C₃-C₆₀ carbocyclic group and the C₁-C₆₀ heterocyclic group.

The term “TT electron-rich C₃-C₆₀ cyclic group” as used herein refers to a cyclic group that has three to sixty carbon atoms and does not include *—N—* as a ring-forming moiety, and the term “IT-electron-deficient nitrogen-containing C₁-C₆₀ cyclic group” as used herein refers to a heterocyclic group that has one to sixty carbon atoms and includes *—N—* as a ring-forming moiety.

For example,

the C₃-C₆₀ carbocyclic group may be i) a group T1 or ii) a condensed cyclic group in which two or more groups T1 are condensed with each other (for example, the C₃-C₆₀ carbocyclic group may include a cyclopentadiene group, an adamantane group, a norbornane group, a benzene group, a pentalene group, a naphthalene group, an azulene group, an indacene group, acenaphthylene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a perylene group, a pentaphene group, a heptalene group, a naphthacene group, a picene group, a hexacene group, a pentacene group, a rubicene group, a coronene group, an ovalene group, an indene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, an indeno-phenanthrene group, and/or an indenoanthracene group),

the C₁-C₆₀ heterocyclic group may be i) a group T2, ii) a condensed cyclic group in which two or more groups T2 are condensed with each other, or iii) a condensed cyclic group in which at least one group T2 and at least

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one group T1 are condensed with each other (for example, the C₁-C₆₀ heterocyclic group may include a pyrrole group, a thiophene group, a furan group, an indole group, a benzoindole group, a naphthoindole group, an isoindole group, a benzoisoindole group, a naphthoisindole group, a benzosilole group, a benzothiophene group, a benzofuran group, a carbazole group, a dibenzosilole group, a dibenzothiophene group, a dibenzofuran group, an indenocarbazole group, an indolocarbazole group, a benzofurocarbazole group, a benzothienocarbazole group, a benzosilolocarbazole group, a benzoindolocarbazole group, a benzocarbazole group, a benzonaphthofuran group, a benzophenothiophene group, a benzonaphthosilole group, a benzofurodibenzofuran group, a benzothieno dibenzothiophene group, a pyrazole group, an imidazole group, a triazole group, an oxazole group, an isoxazole group, an oxadiazole group, a thiazole group, an isothiazole group, a thiadiazole group, a benzopyrazole group, a benzimidazole group, a benzoxazole group, a benzoisoxazole group, a benzothiazole group, a benzoisothiazole group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a benzoquinoline group, a quinazoline group, a benzoquinazoline group, a phenanthroline group, a cinnoline group, a phthalazine group, a naphthyridine group, an imidazopyridine group, an imidazopyrimidine group, an imidazotriazine group, an imidazopyrazine group, an imidazopyridazine group, an azacarbazole group, an azafluorene group, an azadibenzosilole group, an azadibenzothiophene group, and/or an azadibenzofuran group).

the π electron-rich C₃-C₆₀ cyclic group may be i) a group T1, ii) a condensed cyclic group in which two or more groups T1 are condensed with each other, iii) a group T3, iv) a condensed cyclic group in which two or more groups T3 are condensed with each other, or v) a condensed cyclic group in which at least one group T3 and at least one group T1 are condensed with each other (for example, the IT electron-rich C₃-C₆₀ cyclic group may include a C₃-C₆₀ carbocyclic group, a pyrrole group, a thiophene group, a furan group, an indole group, a benzoindole group, a naphthoindole group, an isoindole group, a benzoisoindole group, a naphthoisindole group, a benzosilole group, a benzothiophene group, a benzofuran group, a carbazole group, a dibenzosilole group, a dibenzothiophene group, a dibenzofuran group, an indenocarbazole group, an indolocarbazole group, a benzofurocarbazole group, a benzothienocarbazole group, a benzosilolocarbazole group, a benzoindolocarbazole group, a benzocarbazole group, a benzonaphthofuran group, a benzophenothiophene group, a benzonaphthosilole group, a benzofurodibenzofuran group, a benzothieno dibenzothiophene group, and/or a benzothienodibenzothiophene group),

the π-electron-deficient nitrogen-containing C₁-C₆₀ cyclic group may be i) a group T4, ii) a condensed cyclic group in which two or more groups T4 are condensed with each other, iii) a condensed cyclic group in which at least one group T4 and at least one group T1 are condensed with each other, iv) a condensed cyclic group in which at least one group T4 and at least one group T3 are condensed with each other, or v) a

condensed cyclic group in which at least one group T4, at least one group T1, and at least one group T3 are condensed with each other (for example, the π -electron-deficient nitrogen-containing $C_1\text{-}C_{60}$ cyclic group may include a pyrazole group, an imidazole group, a triazole group, an oxazole group, an isoxazole group, an oxadiazole group, a thiazole group, an isothiazole group, a thiadiazole group, a benzopyrazole group, a benzimidazole group, a benzoazazole group, a benzoisoxazole group, a benzothiazole group, a benzoisothiazole group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a benzoisoquinoline group, a quinoxaline group, a benzoquinazoline group, a phenanthroline group, a cinnoline group, a phthalazine group, a naphthyridine group, an imidazopyridine group, an imidazopyrimidine group, an imidazotriazine group, an imidazopyrazine group, an imidazopyridazine group, an azacarbazole group, an azaflorene group, an azadibenzosilole group, an azadibenzothiophene group, and/or an azadibenzofuran group), the group T1 may be a cyclopropane group, a cyclobutane group, a cyclopentane group, a cyclohexane group, a cycloheptane group, a cyclooctane group, a cyclobutene group, a cyclopentene group, a cyclohexene group, a cyclohexadiene group, a cycloheptene group, an adamantine group, a norbornane group (or, a bicyclo[2.2.1]heptane group), a norbornene group, a bicyclo[1.1.1]pentane group, a bicyclo[2.1.1]hexane group, a bicyclo[2.2.2]octane group, and/or a benzene group, the group T2 may be a furan group, a thiophene group, a 1H-pyrrole group, a silole group, a borole group, a 2H-pyrrole group, a 3H-pyrrole group, an imidazole group, a pyrazole group, a triazole group, a tetrazole group, an oxazole group, an isoxazole group, an oxadiazole group, a thiazole group, an isothiazole group, a thiadiazole group, an azasilole group, an azaborole group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, and/or a tetrazine group, the group T3 may be a furan group, a thiophene group, a 1H-pyrrole group, a silole group, and/or a borole group, and the group T4 may be a 2H-pyrrole group, a 3H-pyrrole group, an imidazole group, a pyrazole group, a triazole group, a tetrazole group, an oxazole group, an isoxazole group, an oxadiazole group, a thiazole group, an isothiazole group, a thiadiazole group, an azasilole group, an azaborole group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, and/or a tetrazine group.

The terms “the cyclic group,” “the $C_3\text{-}C_{60}$ carbocyclic group,” “the $C_1\text{-}C_{60}$ heterocyclic group,” “the TT electron-rich $C_3\text{-}C_{60}$ cyclic group,” or “the π -electron-deficient nitrogen-containing $C_1\text{-}C_{60}$ cyclic group” as used herein refer to a group that is condensed with a cyclic group, a monovalent group, a polyvalent group (for example, a divalent group, a trivalent group, a tetravalent group, and/or the like), according to a structure of a formula described with corresponding terms. In one or more embodiments, “a benzene group” may be a benzo group, a phenyl group, a phenylene group, and/or the like, which may be easily understood by one of ordinary skill in the art according to the structure of a formula including the “benzene group.”

In one or more embodiments, examples of the monovalent $C_3\text{-}C_{60}$ carbocyclic group and the monovalent $C_1\text{-}C_{60}$ heterocyclic group may include a $C_3\text{-}C_{10}$ cycloalkyl group, a $C_1\text{-}C_{10}$ heterocycloalkyl group, a $C_3\text{-}C_{10}$ cycloalkenyl group, a $C_1\text{-}C_{10}$ heterocycloalkenyl group, a $C_6\text{-}C_{60}$ aryl group, a $C_1\text{-}C_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, and examples of the divalent $C_3\text{-}C_{60}$ carbocyclic group and the monovalent $C_1\text{-}C_{60}$ heterocyclic group may include a $C_3\text{-}C_{10}$ cycloalkylene group, a $C_1\text{-}C_{10}$ heterocycloalkylene group, a $C_3\text{-}C_{10}$ cycloalkenylene group, a $C_1\text{-}C_{10}$ heterocycloalkenylene group, a $C_6\text{-}C_{60}$ arylene group, a $C_1\text{-}C_{60}$ heteroarylene group, a divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group.

The term “ $C_1\text{-}C_{60}$ alkyl group” as used herein refers to a linear or branched aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms, and non-limiting examples thereof include 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 isoheyl 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 isoocetyl 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, and a tert-decyl group. The term “ $C_1\text{-}C_{60}$ alkylene group” as used herein refers to a divalent group having the same structure as the $C_1\text{-}C_{60}$ alkyl group.

The term “ $C_2\text{-}C_{60}$ alkenyl group” as used herein refers to a monovalent hydrocarbon group having at least one carbon-carbon double bond in the middle and/or at the terminus of a $C_2\text{-}C_{60}$ alkyl group, and non-limiting examples thereof include an ethenyl group, a propenyl group, and a butenyl group. The term “ $C_2\text{-}C_{60}$ alkynyl group” as used herein refers to a divalent group having the same structure as the $C_2\text{-}C_{60}$ alkenyl group.

The term “ $C_2\text{-}C_{60}$ alkynyl group” as used herein refers to a monovalent hydrocarbon group having at least one carbon-carbon triple bond in the middle and/or at the terminus of a $C_2\text{-}C_{60}$ alkyl group, and non-limiting examples thereof include an ethynyl group and a propynyl group. The term “ $C_2\text{-}C_{60}$ alkynylene group” as used herein refers to a divalent group having the same structure as the $C_2\text{-}C_{60}$ alkynyl group.

The term “ $C_1\text{-}C_{60}$ alkoxy group” as used herein refers to a monovalent group represented by —OA₁₀₁ (wherein A₁₀₁ is the $C_1\text{-}C_{60}$ alkyl group), and non-limiting examples thereof include a methoxy group, an ethoxy group, and an isopropoxy group.

The term “ $C_3\text{-}C_{10}$ cycloalkyl group” as used herein refers to a monovalent saturated hydrocarbon 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, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group (or a bicyclo[2.2.1]heptyl group), a bicyclo[1.1.1]pentyl group, a bicyclo[2.1.1]hexyl group, and a bicyclo[2.2.2]octyl group. The term “ $C_3\text{-}C_{10}$ cycloalkylene group” as used herein refers to a divalent group having the same structure as the $C_3\text{-}C_{10}$ cycloalkyl group.

The term “ $C_1\text{-}C_{10}$ heterocycloalkyl group” as used herein refers to a monovalent cyclic group that includes, in addition

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to carbon atoms, at least one heteroatom as a ring-forming atom, and has 1 to 10 ring-forming carbon atoms, and non-limiting examples thereof include a 1,2,3,4-oxatriazolidinyl group, a tetrahydrofuranyl 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.

The term “C₃-C₁₀ cycloalkenyl group” as used herein refers to a monovalent cyclic 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.

The term “C₁-C₁₀ heterocycloalkenyl group” as used herein refers to a monovalent cyclic group that has, in addition to carbon atoms, at least one heteroatom as a ring-forming atom, and 1 to 10 ring-forming carbon atoms, and at least one carbon-carbon double bond in the cyclic structure thereof. Non-limiting examples of the C₁-C₁₀ heterocycloalkenyl group include a 4,5-dihydro-1,2,3,4-oxatriazolyl group, a 2,3-dihydrofuranyl group, and a 2,3-dihydrothiophenyl group. The term “C₁-C₁₀ heterocycloalkylene group” as used herein refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkenyl group.

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. Non-limiting examples of the C₆-C₆₀ aryl group include a phenyl group, a pentenyl group, a naphthyl group, an azulenyl group, an indacenyl group, an acenaphthyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysanyl group, a perylenyl group, a pentaphenyl group, a heptalenyl group, a naphthacenyl group, a picenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, and an ovalenyl group. The term “C₆-C₆₀ arylene group” as used herein refers to a divalent group having the same structure as the C₆-C₆₀ aryl group. When the C₆-C₆₀ aryl group and the C₆-C₆₀ arylene group each independently include two or more rings, the respective two or more rings may be fused to each other.

The term “C₁-C₆₀ heteroaryl group” as used herein refers to a monovalent group having a heterocyclic aromatic system that has, in addition to carbon atoms, at least one heteroatom as a ring-forming atom, and 1 to 60 ring-forming 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, a benzoquinolinyl group, an isoquinolinyl group, a benzoisoquinolinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a cinnolinyl group, a phenanthrolinyl group, a phthalazinyl group, and a naphthyridinyl group. The term “C₁-C₆₀ heteroarylene group” as used herein refers to a divalent group having the same structure as the C₁-C₆₀ heteroaryl group. When the C₁-C₆₀ heteroaryl group and the C₁-C₆₀ heteroarylene group each independently include two or more rings, the respective two or more rings may be condensed with each other.

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

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carbon atoms), and non-aromaticity in its entire molecular structure (e.g., the molecular structure as a whole is non-aromatic). Non-limiting examples of the monovalent non-aromatic condensed polycyclic group include an indenyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, an indenophenanthrenyl group, and an indenoanthracenyl 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.

The term “monovalent non-aromatic condensed heteropolycyclic group” as used herein refers to a monovalent group having two or more rings condensed to each other, at least one heteroatom other than carbon atoms (for example, 1 to 60 carbon atoms), as a ring-forming atom, and non-aromaticity in its entire molecular structure (e.g., the molecular structure as a whole is non-aromatic). Non-limiting examples of the monovalent non-aromatic condensed heteropolycyclic group include a pyrrolyl group, a thiophenyl group, a furanyl group, an indolyl group, a benzoindolyl group, a naphthoindolyl group, an isoindolyl group, a benzoisoindolyl group, a naphthoisooindolyl group, a benzisoliolyl group, a benzothiophenyl group, a benzofuranyl group, a carbazolyl group, a dibenzosilolyl group, a dibenzothiophenyl group, a dibenzofuranyl group, an azacarbazolyl group, an azafluorenyl group, an azadibenzosilolyl group, an azadibenzothiophenyl group, an azadibenzofuranyl group, a pyrazolyl group, an imidazolyl group, a triazolyl group, a tetrazolyl group, an oxazolyl group, an isoxazolyl group, a thiazolyl group, an isothiazolyl group, an oxadiazolyl group, a thiadiazolyl group, a benzopyrazolyl group, a benzimidazolyl group, a benzoxazolyl group, a benzothiazolyl group, a benzoxadiazolyl group, a benzothiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an imidazotriazinyl group, an imidazopyrazinyl group, an imidazopyridazinyl group, an indenocarbazolyl group, an indolocarbazolyl group, a benzofurocarbazolyl group, a benzothienocarbazolyl group, a benzosilolocarbazolyl group, a benzoindolocarbazolyl group, a benzocarbazolyl group, a benzonaphthofuranyl group, a benzonaphthosilolyl group, a benzofurodibenzofuranyl group, a benzothienodibenzothiophenyl 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.

The term “C₆-C₆₀ aryloxy group” as used herein refers to a monovalent group represented by —OA₁₀₂ (wherein A₁₀₂ is the C₆-C₆₀ aryl group), and the term “C₆-C₆₀ arylthio group” as used herein refers to a monovalent group represented by —SA₁₀₃ (wherein A₁₀₃ is the C₆-C₆₀ aryl group).

The term “R₁₀₂” as used herein refers to: deuterium (—D), —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, or a nitro group; a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, or a C₁-C₆₀ alkoxy group, each unsubstituted or substituted with deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₃-C₆₀ carbocyclic group, a C₁-C₆₀ heterocyclic group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, —Si(Q₁₁)(Q₁₂)(Q₁₃), —N(Q₁₁)(Q₁₂), —B(Q₁₁)(Q₁₂), —C(=O)(Q₁₁), —S(=O)₂(Q₁₁), —P(=O)(Q₁₁)(Q₁₂), or any combination thereof; a C₃-C₆₀ carbocyclic group, a C₁-C₆₀ heterocyclic group, a C₆-C₆₀ aryloxy group, or a C₆-C₆₀ arylthio group, each unsubstituted or substituted with deuterium, —F,

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—Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₆₀ carbocyclic group, a C₁-C₆₀ heterocyclic group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, —Si(Q₂₁)(Q₂₂)(Q₂₃), —N(Q₂₁)(Q₂₂), —B(Q₂₁)(Q₂₂), —C(=O)(Q₂₁), —S(=O)₂(Q₂₁), —P(=O)(Q₂₁) (Q₂₂), or any combination thereof; or —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), or —P(=O)(Q₃₁) (Q₃₂).

Q₁ to Q₃, Q₁₁ to Q₁₃, Q₂₁ to Q₂₃ and Q₃₁ to Q₃₃ used herein may each independently be: hydrogen; deuterium; —F; —Cl; —Br; —I; a hydroxyl group; a cyano group; a nitro group; a C₁-C₆₀ alkyl group; a C₂-C₆₀ alkenyl group; a C₂-C₆₀ alkynyl group; a C₁-C₆₀ alkoxy group; or a C₃-C₆₀ carbocyclic group or a C₁-C₆₀ heterocyclic group, each unsubstituted or substituted with deuterium, —F, a cyano group, a C₁-C₆₀ alkyl group, a C₁-C₆₀ alkoxy group, a phenyl group, a biphenyl group, or any combination thereof.

The term “heteroatom” as used herein refers to any atom other than a carbon atom. Examples of the heteroatom include O, S, N, P, Si, B, Ge, Se, and any combination thereof.

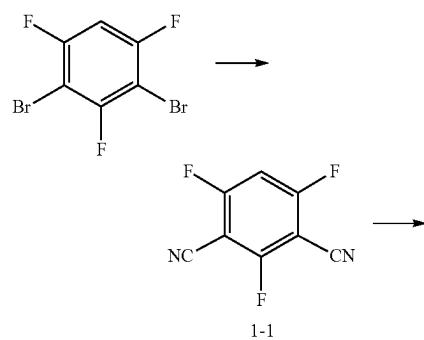
The term “Ph” as used herein refers to a phenyl group, the term “Me” as used herein refers to a methyl group, the term “Et” as used herein refers to an ethyl group, the term “ter-Bu” or “But” as used herein refers to a tert-butyl group, and the term “OMe” as used herein refers to a methoxy group.

The term “biphenyl group” as used herein refers to “a phenyl group substituted with a phenyl group.” For example, the “biphenyl group” may be a substituted phenyl group having a C₆-C₆₀ aryl group as a substituent.

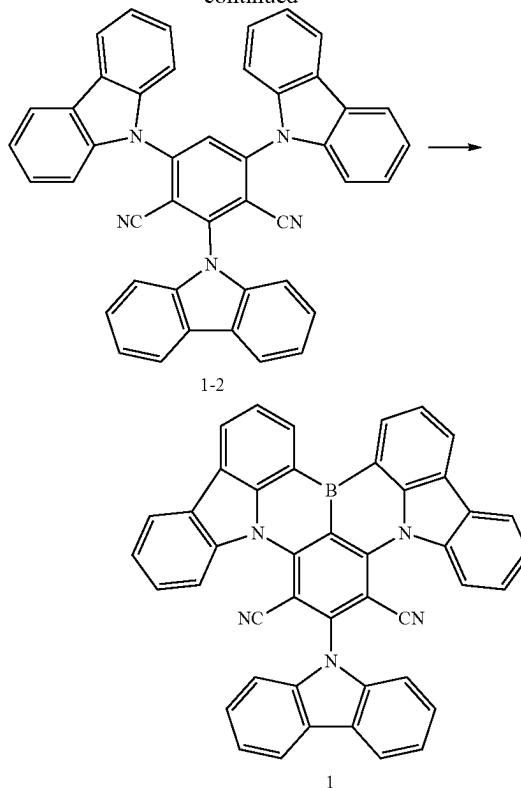
The term “terphenyl group” as used herein refers to “a phenyl group substituted with a biphenyl group”. For example, the “terphenyl group” may be a substituted phenyl group having, as a substituent, a C₆-C₆₀ aryl group substituted with a C₆-C₆₀ aryl group.

* and ** as used herein, unless defined otherwise, each refer to a binding site to a neighboring atom in a corresponding formula.

Hereinafter, a compound according to embodiments and a light-emitting device according to embodiments will be described in more detail with reference to Synthesis Examples and Examples. The wording “B was used instead of A” used in describing Synthesis Examples refers to an identical molar equivalent of B being used in place of A.

EXAMPLES**Synthesis Example 1: Synthesis of Compound 1****142**

-continued

**Synthesis of Intermediate 1-1**

2,4-dibromo-1,3,5-trifluorobenzene (1 eq), pyridine (10 mL), and copper (I) cyanide (2.5 eq) were dissolved in DMF, and then stirred while refluxing at 180° C. for 6 hours in the nitrogen atmosphere. After cooling, a byproduct was filtered by Celite filter. The resultant product was extracted using ether, water, and ammonium hydroxide aqueous solution and then washed by water three times, and an organic layer obtained by separation was dried through MgSO₄ under reduced pressure. Purification was performed by column chromatography using MC and hexane to thereby obtain Intermediate 1-1. (Yield: 35%)

Synthesis of Intermediate 1-2

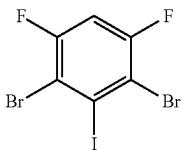
Intermediate 1-1 (1 eq), carbazole (3 eq), and K₃PO₄ were dissolved in DMF, and then stirred while refluxing at 160° C. for 12 hours. After cooling, the solvent was removed therefrom under reduced pressure, and the resultant product was washed three times using ethyl acetate and water, and an organic layer obtained by separation was dried using MgSO₄ under reduced pressure. Purification was performed by column chromatography using MC and hexane to thereby obtain Intermediate 1-2. (Yield: 55%)

Synthesis of Compound 1

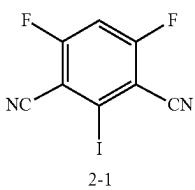
Intermediate 1-2 (1 eq) was dissolved in O-dichlorobenzene and cooled to 0° C. using an ice bath, and then BBr₃ (5 eq) was slowly added thereto in the nitrogen atmosphere. After the addition was completed, the temperature was raised to 180° C. and the resultant solution was stirred for 24 hours. After cooling, triethylamine was slowly added to a flask containing reactants to terminate the reaction, ethyl alcohol was added to the reactants, and then a precipitated solid was filtered, to thereby obtain a product. The obtained product was purified by a column chromatography using MC and hexane to thereby obtain Compound 1. (Yield: 5%)

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Synthesis Example 2: Synthesis of Compound 2

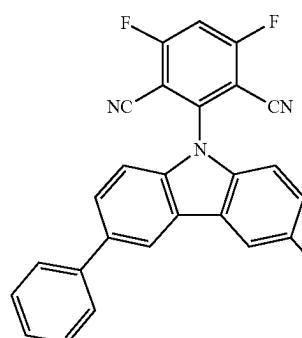


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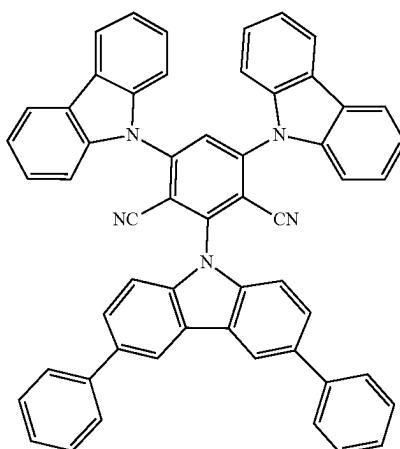
2-1

5



2-2

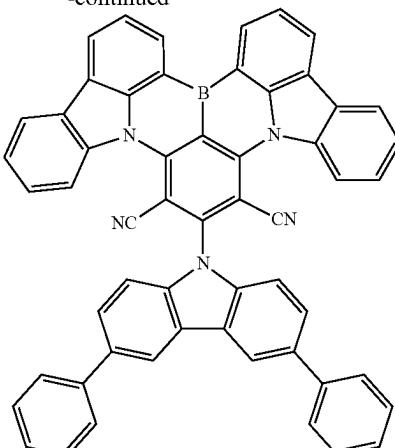
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2-3

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-continued



2

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Synthesis of Intermediate 2-1

2,4-dibromo-1,5-difluoro-3-iodobenzene (1 eq), pyridine (10 mL), and copper (I) cyanide (2.0 eq) were dissolved in DMF, and then stirred while refluxing at 180° C. for 6 hours in the nitrogen atmosphere. After cooling, a byproduct was filtered by Celite filter. The resultant product was extracted using ether, water, and ammonium hydroxide aqueous solution, and then washed using water three times, and an organic layer obtained by separation was dried using MgSO₄ under reduced pressure. Purification was performed by flash column chromatography using MC and hexane to thereby obtain Intermediate 2-1. (Yield: 20%)

Synthesis of Intermediate 2-2

Intermediate 2-1 (1 eq), 3,6-diphenyl-9H-carbazole (1.1 eq), Pd₂dba₃, P(tBu)₃ (50 wt % in xylene), NaOtBu were added in a reaction vessel, and then stirred while refluxing at 120° C. for 12 hours. After cooling, the solvent was removed therefrom under reduced pressure, and the resultant product was washed three times using ethyl acetate and water, and an organic layer obtained by separation was dried using MgSO₄ under reduced pressure. Purification was performed by column chromatography using MC and hexane to thereby obtain Intermediate 2-2. (Yield: 50%)

Synthesis of Intermediate 2-3

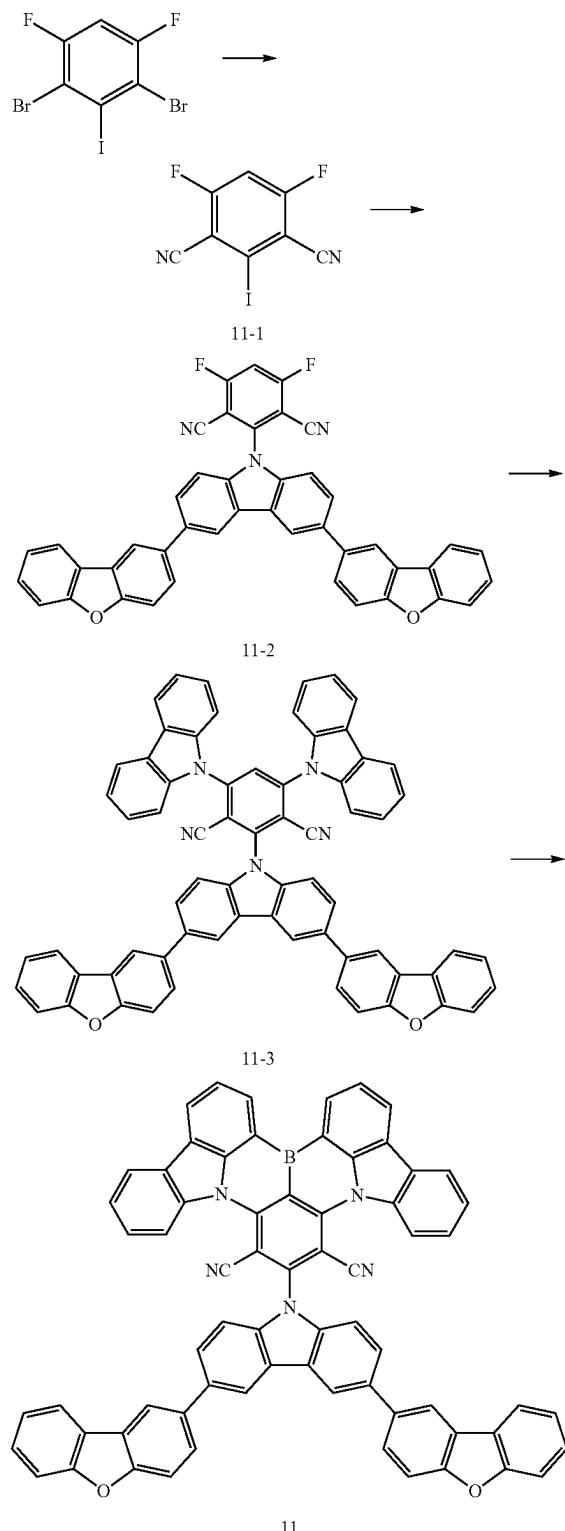
Intermediate 2-2 (1 eq), carbazole (2 eq), and K₃PO₄ were dissolved in DMF, and then stirred while refluxing at 160° C. for 12 hours. After cooling, the solvent was removed therefrom under reduced pressure, and the resultant product was washed three times using ethyl acetate and water, and an organic layer obtained by separation was dried using MgSO₄ under reduced pressure. Purification was performed by column chromatography using MC and hexane to thereby obtain Intermediate 2-3. (Yield: 60%)

Synthesis of Compound 2

Intermediate 2-3 (1 eq) was dissolved in O-dichlorobenzene and cooled to 0° C. using an ice bath, and then BBr₃ (5 eq) was slowly added thereto in the nitrogen atmosphere. After the addition was completed, the temperature was raised to 180° C. and the resultant solution was stirred for 24 hours. After cooling, triethylamine was slowly added to a flask containing reactants to terminate the reaction, ethyl alcohol was added to the reactants, and then a precipitated solid was filtered, to thereby obtain a product. The obtained product was purified by a column chromatography using MC and hexane to thereby obtain Compound 2. (Yield: 7%)

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Synthesis Example 3: Synthesis of Compound 11



Synthesis of Intermediate 11-1

Intermediate 11-1 was synthesized in substantially the same manner as used in the synthesis of Intermediate 2-1.

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Synthesis of Intermediate 11-2

Intermediate 11-2 was synthesized in substantially the same manner as the synthesis of Intermediate 2-2, except that 3,6-bis(dibenzo[b,d]furan-2-yl)-9H-carbazole was used instead of 3,6-diphenyl-9H-carbazole. (Yield: 55%)

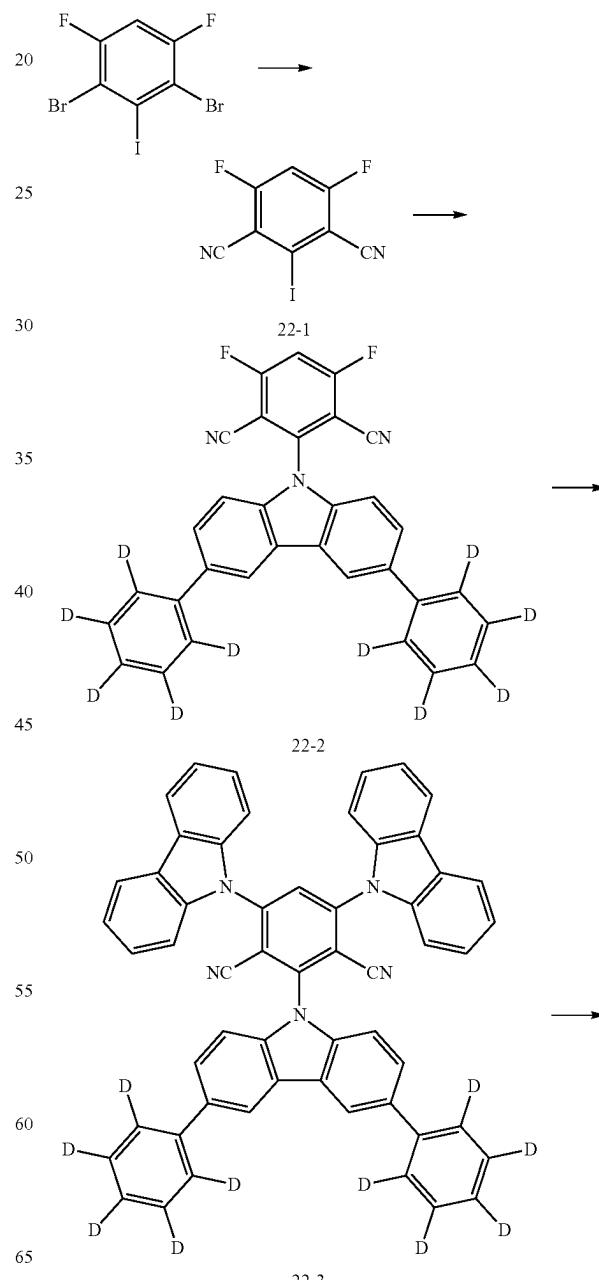
Synthesis of Intermediate 11-3

Intermediate 11-3 was synthesized in substantially the same manner as the synthesis of Intermediate 2-3, except that Intermediate 11-2 was used instead of Intermediate 2-2. (Yield: 60%)

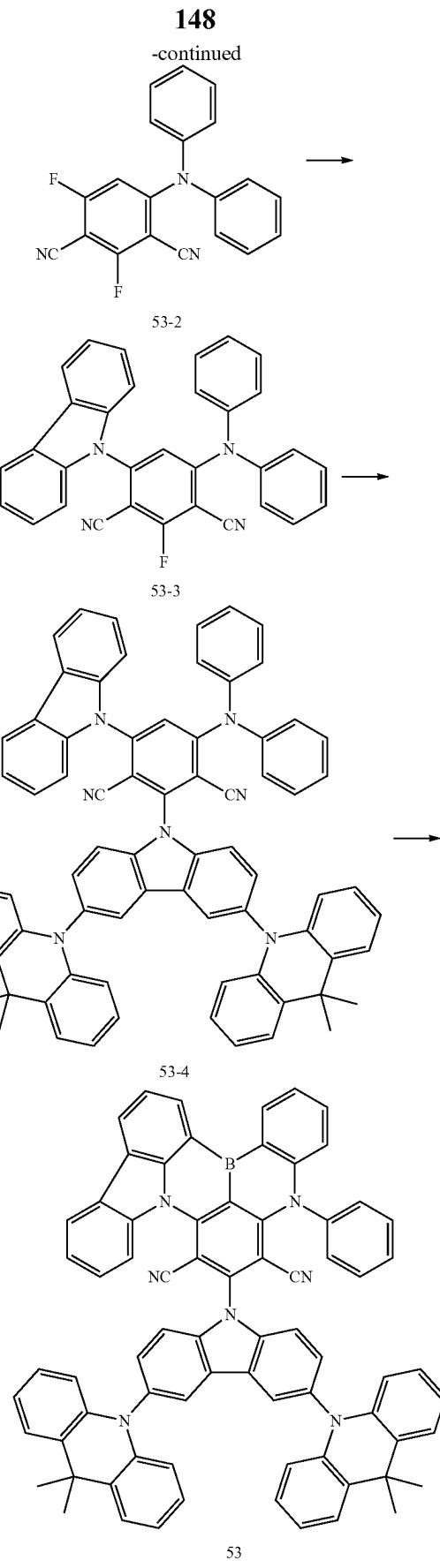
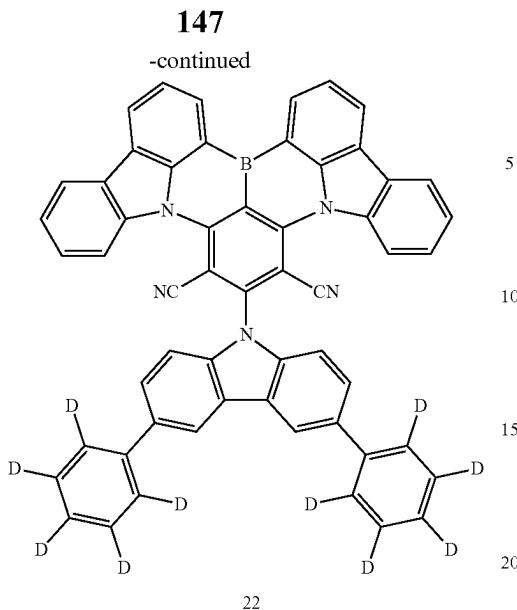
Synthesis of Compound 11

Compound 11 was synthesized in substantially the same manner as synthesis of Compound 2, except that Intermediate 11-3 was used instead of Intermediate 2-3. (Yield: 5%)

Synthesis Example 4: Synthesis of Compound 22



22-3



Synthesis of Intermediate 22-1

Intermediate 22-1 was synthesized in substantially the same manner as used in the synthesis of Intermediate 2-1.

Synthesis of Intermediate 22-2

Intermediate 22-2 was synthesized in substantially the same manner as the synthesis of Intermediate 2-2, except that 3,6-bis(phenyl-d₅)-9H-carbazole was used instead of 3,6-diphenyl-9H-carbazole. (Yield: 55%)

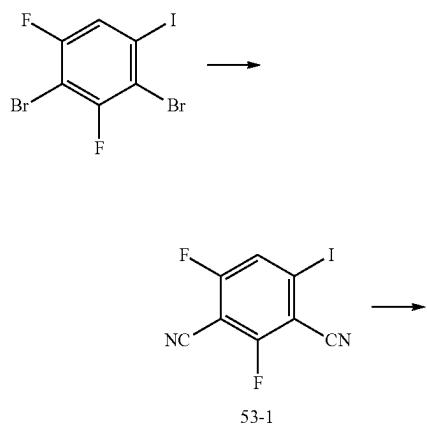
Synthesis of Intermediate 22-3

Intermediate 22-3 was synthesized in substantially the same manner as the synthesis of Intermediate 2-3, except that Intermediate 22-2 was used instead of Intermediate 2-2. (Yield: 60%)

Synthesis of Compound 22

Compound 22 was synthesized in substantially the same manner as the synthesis of Compound 2, except that Intermediate 22-3 was used instead of Intermediate 2-3. (Yield: 5%)

Synthesis Example 5: Synthesis of Compound 53



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Synthesis of Intermediate 53-1

Intermediate 53-1 was synthesized in substantially the same manner as the synthesis of Intermediate 1-1, except that 2,4-dibromo-1,3-difluoro-5-iodobenzene was used instead of 2,4-dibromo-1,3,5-trifluorobenzene. (Yield: 21%)

Synthesis of Intermediate 53-2

Intermediate 53-1 (1 eq), diphenylamine (1 eq), Pd₂dba₃ (0.05 eq), P(tBu)₃ (50 wt % in xylene) (0.1 eq), and NaOtBu (2 eq) were dissolved in toluene, and then stirred while refluxing at 120° C. for 12 hours. After cooling, the solvent was removed therefrom under reduced pressure, and the resultant product was washed three times using ethyl acetate and water, and an organic layer obtained by separation was dried using MgSO₄ under reduced pressure. Purification was performed by column chromatography using MC and hexane to thereby obtain Intermediate 53-2. (Yield: 60%)

Synthesis of Intermediate 53-3

Intermediate 53-3 was synthesized in substantially the same manner as the synthesis of Intermediate 1-2, except that Intermediate 53-2 was used instead of

Intermediate 1-1. (Yield: 20%)

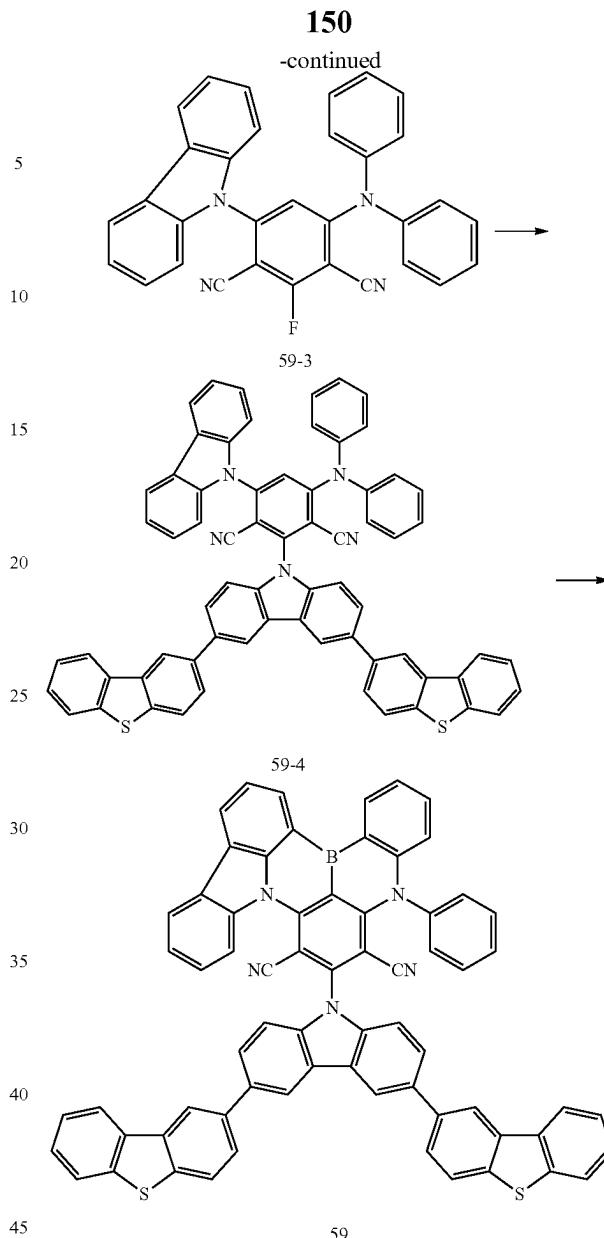
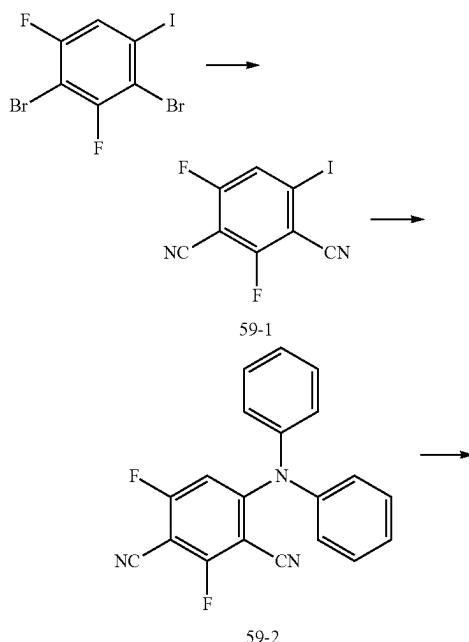
Synthesis of Intermediate 53-4

Intermediate 53-4 was synthesized in substantially the same manner as the synthesis of Intermediate 1-2, except that Intermediate 53-3 was used instead of Intermediate 1-1 and 3,6-bis(9,9-dimethylacridin-10 (9H)-yl)-9H-carbazole was used instead of carbazole. (Yield: 33%)

Synthesis of Compound 53

Compound 53 was synthesized in substantially the same manner as the synthesis of Compound 1, except that Intermediate 53-4 was used instead of Intermediate 1-2. (Yield: 5%)

Synthesis Example 6: Synthesis of Compound 59



Synthesis of Intermediate 59-1

Intermediate 59-1 was synthesized in substantially the same manner as used in the synthesis of Intermediate 53-1. (Yield: 21%)

Synthesis of Intermediate 59-2

Intermediate 59-2 was synthesized in substantially the same manner as used in the synthesis of Intermediate 53-2. (Yield: 60%)

Synthesis of Intermediate 59-3

Intermediate 59-3 was synthesized in substantially the same manner as used in the synthesis of Intermediate 53-3. (Yield: 20%)

Synthesis of Intermediate 59-4

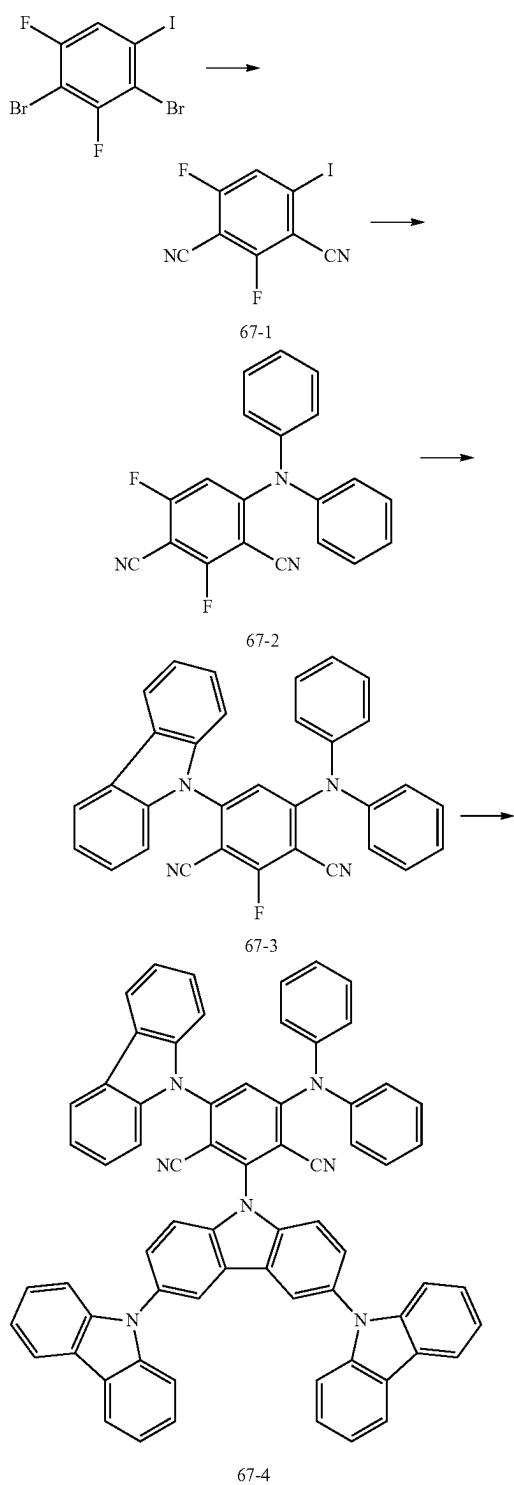
Intermediate 59-4 was synthesized in substantially the same manner as the synthesis of Intermediate 1-2, except that Intermediate 59-3 was used instead of Intermediate 1-1 and 3,6-bis(dibenzo[b,d]thiophen-2-yl)-9H-carbazole was used instead of carbazole. (Yield: 33%)

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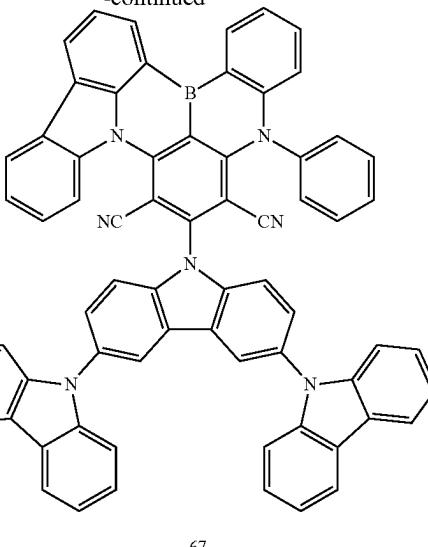
Synthesis of Compound 59

Compound 59 was synthesized in substantially the same manner as the synthesis of Compound 1, except that Intermediate 59-4 was used instead of Intermediate 1-2. (Yield: 5%)

Synthesis Example 7: Synthesis of Compound 67

**152**

-continued



Synthesis of Intermediate 67-1

Intermediate 67-1 was synthesized in substantially the same manner as used in the synthesis of Intermediate 53-1. (Yield: 21%)

Synthesis of Intermediate 67-2

Intermediate 67-2 was synthesized in substantially the same manner as used in the synthesis of Intermediate 53-2. (Yield: 60%)

Synthesis of Intermediate 67-3

Intermediate 67-3 was synthesized in substantially the same manner as used in the synthesis of Intermediate 53-3. (Yield: 20%)

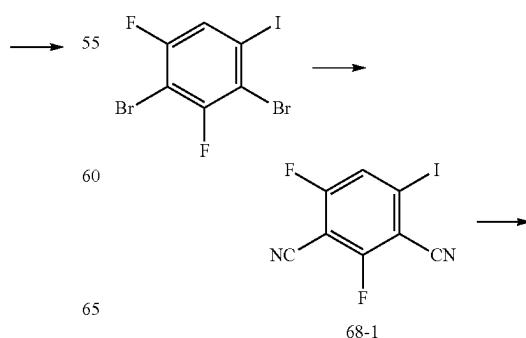
Synthesis of Intermediate 67-4

Intermediate 67-4 was synthesized in substantially the same manner as used to prepare Intermediate 1-2, except that Intermediate 67-3 was used instead of Intermediate 1-1 and 9H-9,3':6',9''-tercarbazole was used instead of carbazole. (Yield: 35%)

Synthesis of Compound 67

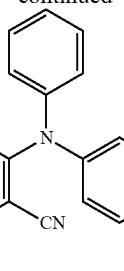
Compound 67 was synthesized in substantially the same manner as used to prepare Compound 1, except that Intermediate 67-4 was used instead of Intermediate 1-2. (Yield: 5%)

Synthesis Example 8: Synthesis of Compound 68

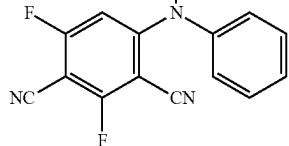


153

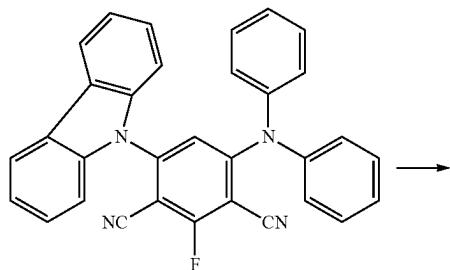
-continued



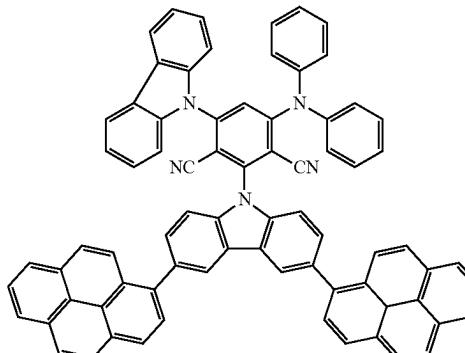
→



68-2



68-3



68-4

68

154

Synthesis of Intermediate 68-3

Intermediate 68-3 was synthesized in substantially the same manner as used in the synthesis of Intermediate 53-3. (Yield: 20%)

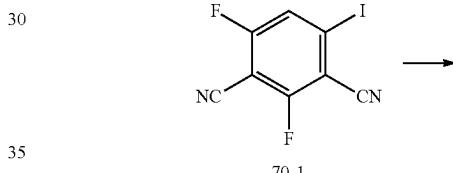
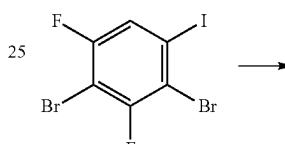
Synthesis of Intermediate 68-4

Intermediate 68-4 was synthesized in substantially the same manner as the synthesis of Intermediate 1-2, except that Intermediate 68-3 was used instead of Intermediate 1-1 and 3-(3a1,6-dihydropyren-1-yl)-6-(pyren-1-yl)-9H-carbazole was used instead of carbazole. (Yield: 32%)

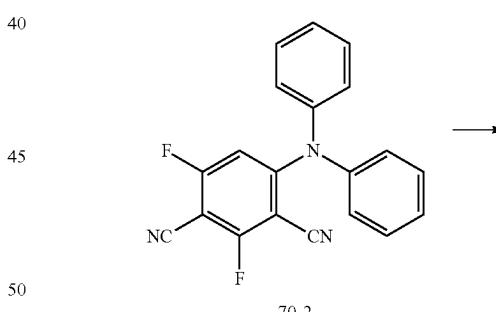
Synthesis of Compound 68

Compound 68 was synthesized in substantially the same manner as the synthesis of Compound 1, except that Intermediate 68-4 was used instead of Intermediate 1-2. (Yield: 5%)

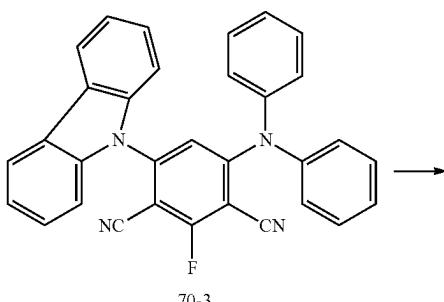
Synthesis Example 9: Synthesis of Compound 70



70-1



70-2



70-3

Synthesis of Intermediate 68-1

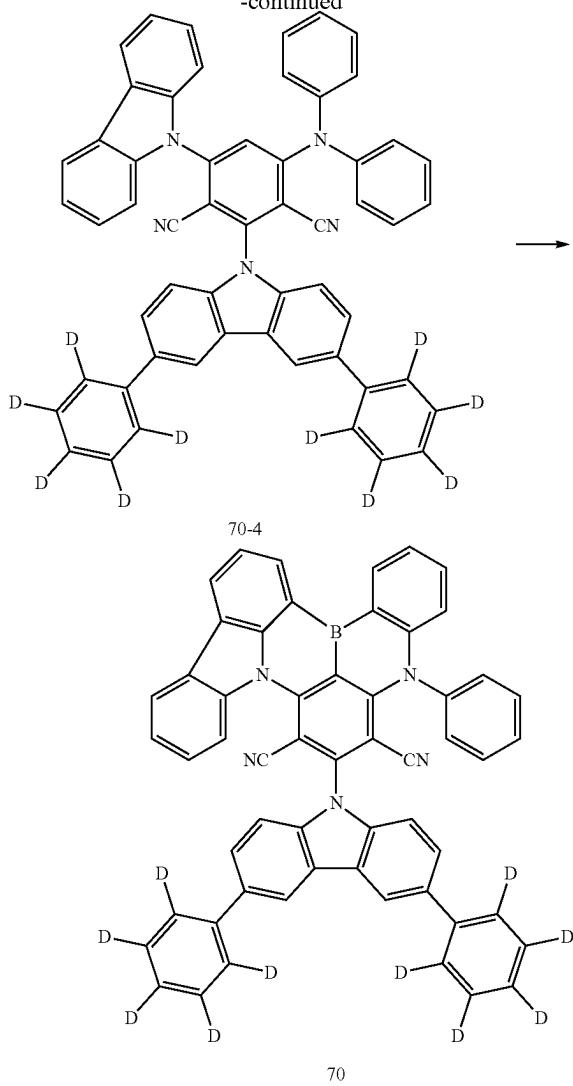
Intermediate 68-1 was synthesized in substantially the same manner as used in the synthesis of Intermediate 53-1. (Yield: 21%)

Synthesis of Intermediate 68-2

Intermediate 68-2 was synthesized in substantially the same manner as used in the synthesis of Intermediate 53-2. (Yield: 60%)

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-continued

**156**

Compounds other than the compounds shown in Table 1 may be easily recognized by those skilled in the art by referring to the above synthesis routes and source materials.

TABLE 1

Compound	¹ H NMR (CDCl ₃ , 400 MHz)	HR-EIMS	
		found	calc.
1	9.32 (d) 2H, 8.55 (d) 3H, 8.19 (d) 3H, 7.94 (d) 2H, 7.58 (d) 2H, 7.50 (t) 2H, 7.16-7.29 (m) 10H	632.18	631.20
2	9.29 (d) 2H, 8.55 (d) 2H, 8.13-8.20 (d) 3H, 7.99-7.89 (m) 4H, 7.77-7.75 (m) 5H, 7.49-7.20 (m) 14H	784.24	783.26
11	9.27 (d) 2H, 8.49 (d) 2H, 8.30 (d) 2H, 8.19-8.13 (d) 3H, 7.98-7.77 (m) 13H, 7.54-7.50 (m) 6H, 7.39-7.35 (m) 4H, 7.12-7.08 (d) 2H	964.26	963.28
22	9.33 (d) 2H, 8.54 (d) 2H, 8.20 (d) 2H, 8.01 (s) 2H, 7.94-7.90 (m) 6H, 7.54-7.50 (m) 8H, 7.35-6.95 (m) 22H, 6.89-6.77 (m) 6H	794.3	793.32
53	9.28 (d) 2H, 8.54 (d) 2H, 8.20 (d) 2H, 8.12-8.09 (d) 4H, 7.94-7.90 (m) 6H, 7.54-7.50 (m) 8H, 7.35-6.95 (m) 10H, 6.89-6.77 (m) 4H, 1.71 (s) 12H	1048.4	1047.42
59	9.27 (d) 2H, 8.53 (d) 2H, 8.32 (d) 2H, 8.25-8.21 (d) 4H, 7.88-7.81 (m) 8H, 7.61-7.50 (m) 8H, 7.30-7.20 (m) 8H, 7.05-6.91 (d) 2H	966.28	965.30
67	9.32 (d) 2H, 8.54 (d) 2H, 8.23-8.29 (d) 4H, 8.10-8.01 (m) 4H, 7.94-7.90 (m) 10H, 7.54-7.50 (m) 6H, 7.35-6.95 (m) 8H, 6.97-6.92 (m) 2H	964.31	963.33
68	9.29 (d) 2H, 8.54-8.51 (d) 2H, 8.11-8.07 (m) 4H, 7.97-7.94 (m) 6H, 7.88-7.82 (m) 12H, 7.33-7.17 (m) 10H, 7.02-6.94 (m) 4H, 6.77-6.75 (m) 2H	1036.33	1035.35
70	9.37 (d) 2H, 8.52-8.50 (d) 2H, 8.11-8.07 (d) 2H, 7.92-7.87 (m) 4H, 7.77-7.71 (m) 2H, 7.35-6.95 (m) 8H, 6.88-6.85 (d) 2H	796.32	795.34

Example 1

As an anode, a 15 Ωcm² (1,200 Å) ITO glass substrate available from Corning Inc. was cut to a size of 50 mm×50 mm×0.7 mm, sonicated by using isopropyl alcohol and pure water for 5 minutes each, and then cleaned by irradiation of ultraviolet rays and exposure of ozone thereto for 30 minutes. Then, the resultant glass substrate was loaded onto a vacuum deposition apparatus.

N,N'-di(1-naphthyl)-N,N'-diphenylbenzidine (NPD) was vacuum-deposited on the ITO anode formed on the glass substrate to form a hole injection layer having a thickness of 300 Å, and then, HT3 was vacuum-deposited on the hole injection layer to form a hole transport layer having a thickness of 200 Å.

CzSi was vacuum deposited on the hole transport layer to 55 form an emission auxiliary layer having a thickness of 100 Å.

mCP (host) and Compound 1 (dopant) were co-deposited at the weight ratio of 99:1 on the emission auxiliary layer to form an emission layer having a thickness of 200 Å.

Then, TSPO1 was deposited on the emission layer to form an electron transport layer having a thickness of 200 Å, and then, TPBI was deposited on the electron transport layer to form an electron transport layer having a thickness of 300 Å.

An alkali metal halide, LiF, was deposited on the electron 65 transport layer to form an electron injection layer having a thickness of 10 Å, and Al was vacuum deposited thereon to form a LiF/Al electrode having a thickness of 3,000 Å.

Synthesis of Intermediate 70-1

Intermediate 70-1 was synthesized in substantially the same manner as used in the synthesis of Intermediate 53-1. (Yield: 21%)

Synthesis of Intermediate 70-2

Intermediate 70-2 was synthesized in substantially the same manner as used in the synthesis of Intermediate 53-2. (Yield: 60%)

Synthesis of Intermediate 70-3

Intermediate 70-3 was synthesized in substantially the same manner as used in the synthesis of Intermediate 53-3. (Yield: 20%)

Synthesis of Intermediate 70-4

Intermediate 70-4 was synthesized in substantially the same manner as the synthesis of Intermediate 1-2, except that Intermediate 70-3 was used instead of Intermediate 1-1 and 3,6-bis(phenyl-d5)-9H-carbazole was used instead of carbazole. (Yield: 35%)

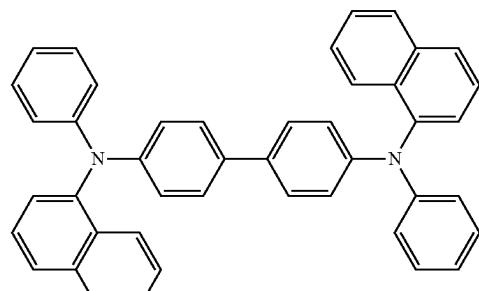
Synthesis of Compound 70

Compound 70 was synthesized in substantially manner as the synthesis of Compound 1, except that Intermediate 70-4 was used instead of Intermediate 1-2. (Yield: 5%)

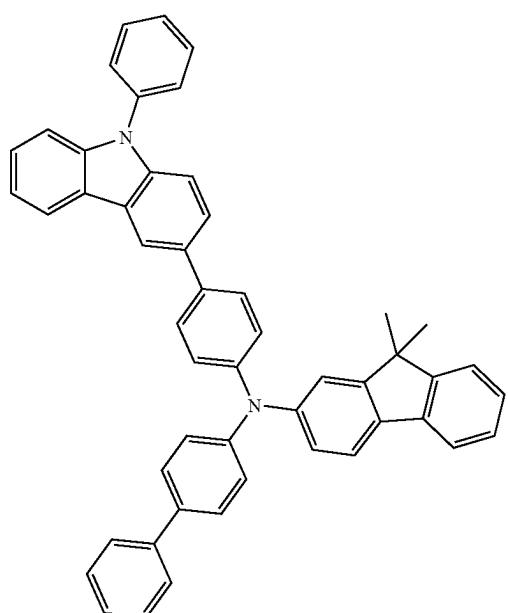
The synthesized compounds were identified by ¹H NMR and MS/FAB, and results are shown in Table 1 below.

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HT28 was vacuum deposited on the electrode to form a capping layer having a thickness of 700 Å, thereby completing manufacture of a light-emitting device.



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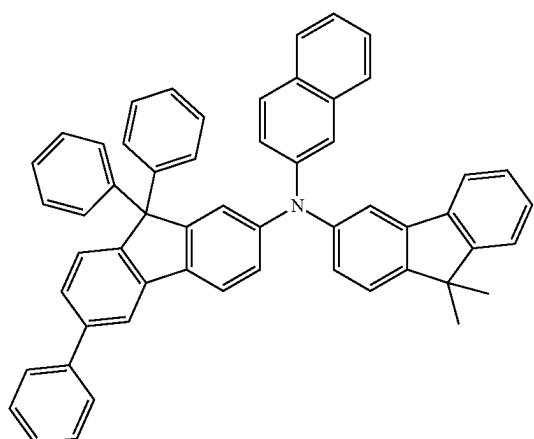
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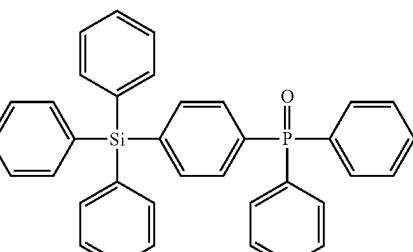
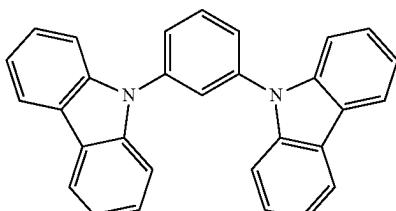
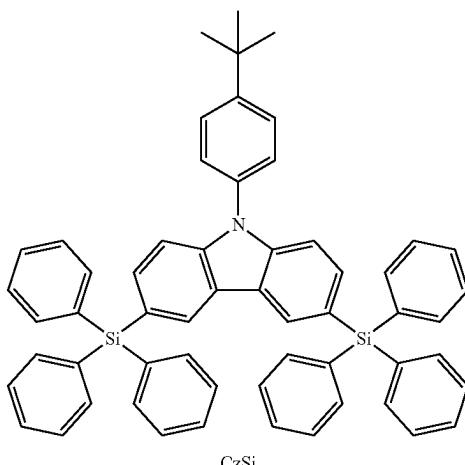
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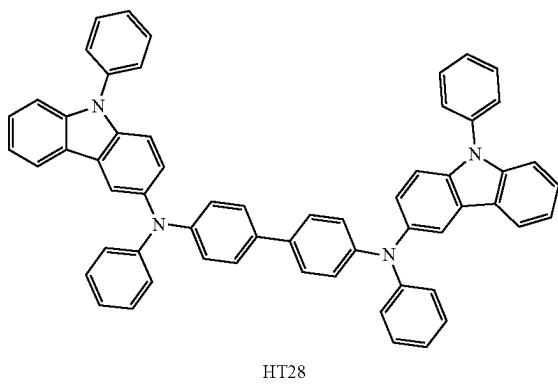
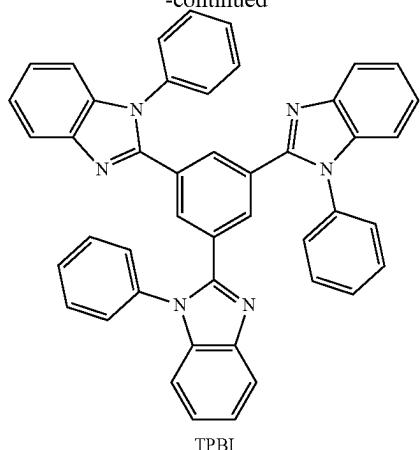
158

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-continued

**160**Examples 2 to 18 and Comparative Examples 1 to
4

Light-emitting devices were manufactured in substantially the same manner as used in Example 1, except that compounds described in Table 2 below were used instead of Compound 1 in forming a respective emission layer, and the compounds described in Table 2 below were used instead of HT3 in forming a respective hole transport layer.

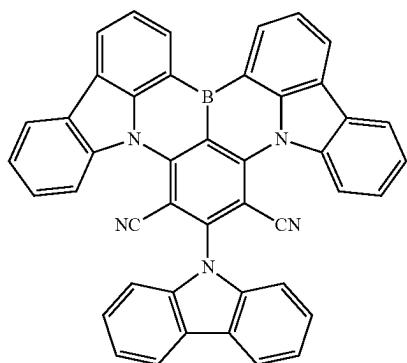
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Evaluation Example 1

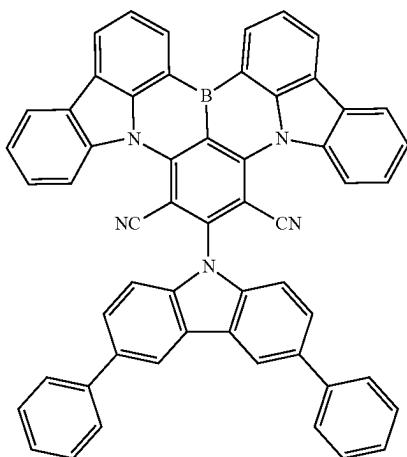
To evaluate characteristics of the light-emitting devices manufactured according to Examples 1 to 18 and Comparative Examples 1 to 4, the driving voltage at the current density of 10 mA/cm², luminescence efficiency, and maximum external quantum efficiency (EQE) thereof were measured. The driving voltage of the light-emitting devices was measured using a source meter (Keithley Instrument Inc., 2400 series), and the maximum external quantum efficiency was measured using the external quantum efficiency measurement apparatus C9920-2-12 of Hamamatsu Photonics Inc. In evaluating the maximum external quantum efficiency, the luminance/current density was measured using a luminance meter that was calibrated for wavelength sensitivity, and the maximum external quantum efficiency was converted by assuming an angular luminance distribution (Lambertian) which introduced a perfect reflecting diffuser. Table 2 below shows the evaluation results of the characteristics of the light-emitting devices.

TABLE 2

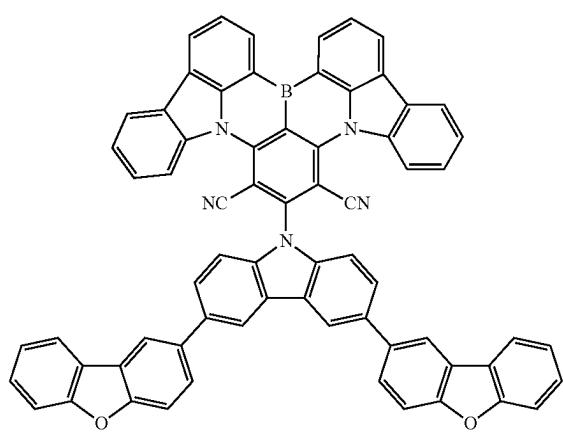
	Material for hole transport layer	Luminescent material	Driving voltage (V)	Efficiency (cd/A)	Maximum quantum efficiency (%)	Emission color
Example 1	HT3	Compound 1	4.3	21.2	20.9	Blue
Example 2	HT3	Compound 2	4.3	23.3	22.4	Blue
Example 3	HT3	Compound 11	4.2	22.9	22.3	Blue
Example 4	HT3	Compound 22	4.2	24.1	23.8	Blue
Example 5	HT3	Compound 53	4.4	23.8	22.6	Blue
Example 6	HT3	Compound 59	4.2	22.5	22.3	Blue
Example 7	HT3	Compound 67	4.2	21.5	20.3	Blue
Example 8	HT3	Compound 68	4.2	23.3	23.3	Blue
Example 9	HT3	Compound 70	4.2	20.9	20.5	Blue
Example 10	HT44	Compound 1	4.3	21.2	20.9	Blue
Example 11	HT44	Compound 2	4.3	23.3	22.4	Blue
Example 12	HT44	Compound 11	4.2	22.9	22.3	Blue
Example 13	HT44	Compound 22	4.2	24.1	23.8	Blue
Example 14	HT44	Compound 53	4.4	23.8	22.6	Blue
Example 15	HT44	Compound 59	4.2	22.5	22.3	Blue
Example 16	HT44	Compound 67	4.2	21.5	20.3	Blue
Example 17	HT44	Compound 68	4.2	23.3	23.3	Blue
Example 18	HT44	Compound 70	4.2	20.9	20.5	Blue
Comparative Example 1	HT3	DABNA-1	5.6	14.5	14.1	Blue
Comparative Example 2	HT3	DABNA-2	5.4	20.3	19.5	Blue
Comparative Example 3	HT3	Compound A	5.2	16.1	15.2	Blue
Comparative Example 4	HT3	Compound B	5.4	17.6	17.4	Blue

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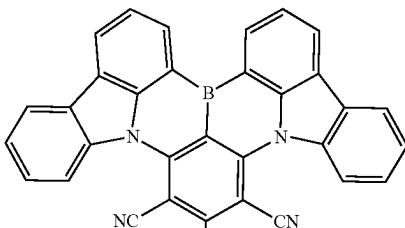


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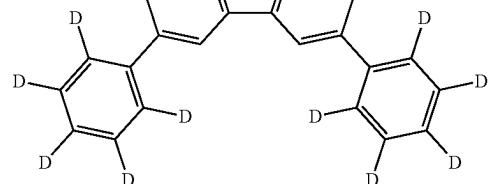
162

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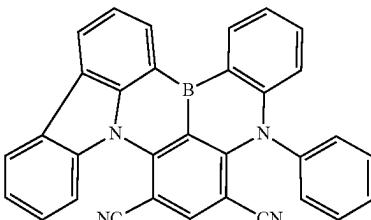
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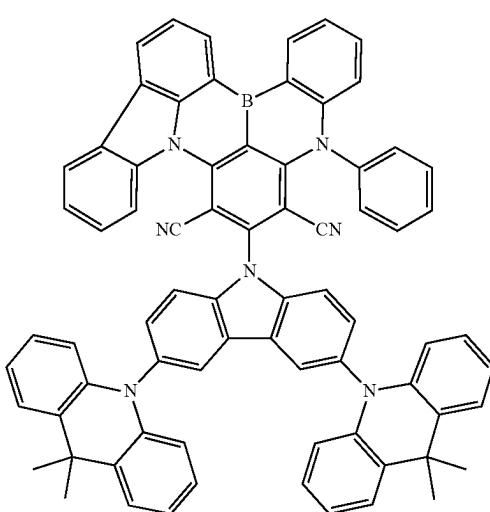
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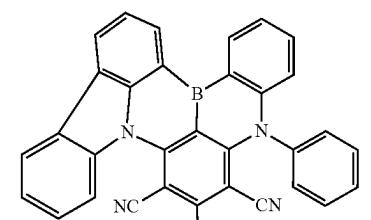
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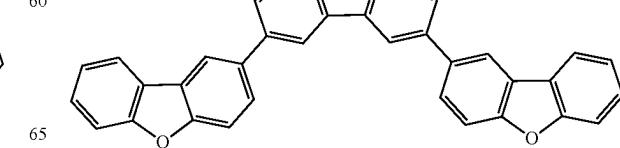
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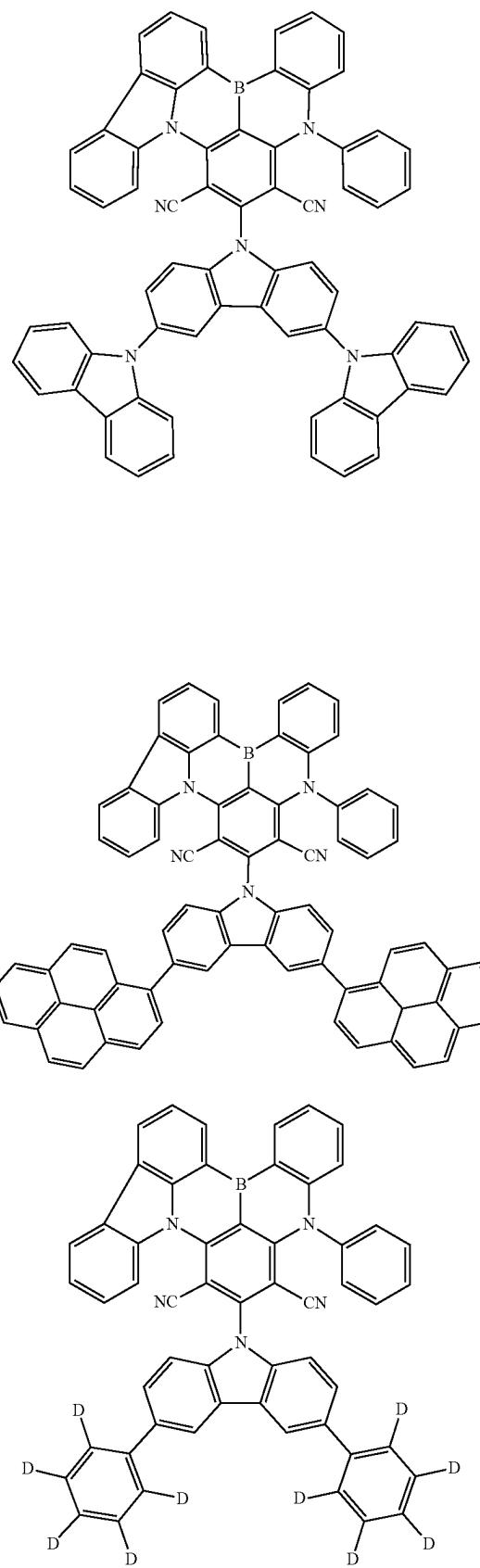
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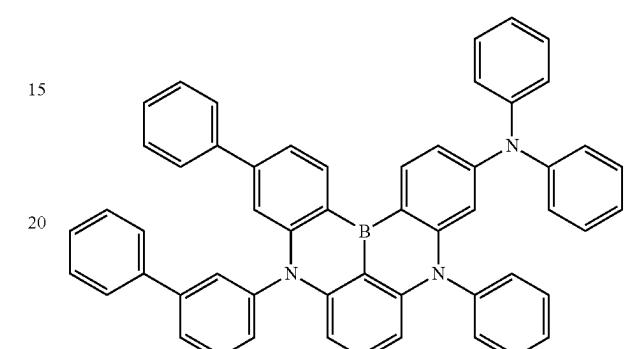
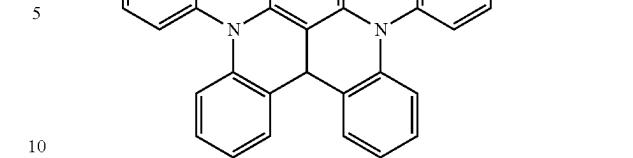
163

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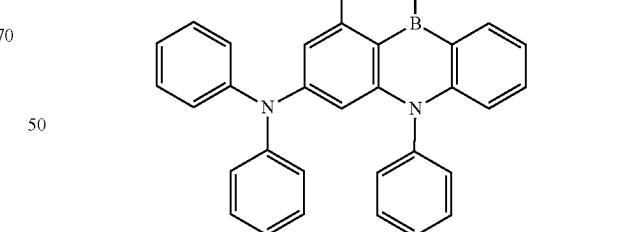
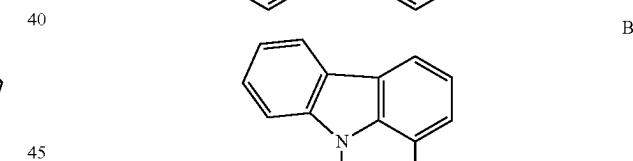
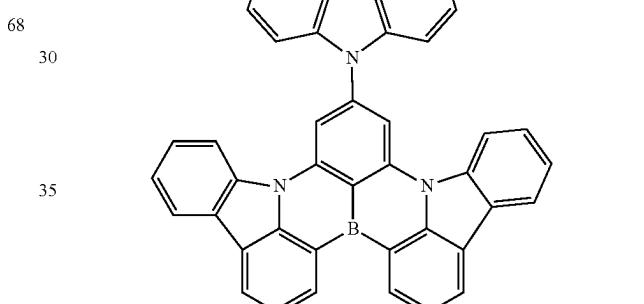
**164**

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DABNA-1



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From the results shown in Table 2, it may be confirmed that the light-emitting devices of Examples 1 to 18 have lower driving voltage, higher luminescence efficiency, and higher maximum quantum efficiency than the light-emitting devices of Comparative Examples 1 to 4.

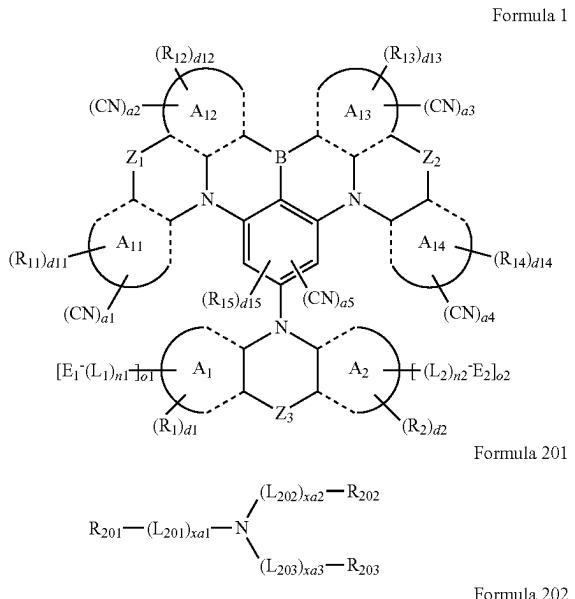
It should be understood that embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each embodiment should typically be considered as available for other similar features or aspects in other embodiments. While one or more embodiments have been described with reference to the figures, it will be

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understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present disclosure as defined by the following claims and their equivalents.

What is claimed is:

1. A light-emitting device comprising:
a first electrode;
a second electrode facing the first electrode; and
an interlayer between the first electrode and the second electrode, the interlayer comprising an emission layer, wherein the interlayer further comprises a hole transport region between the first electrode and the emission layer,
the hole transport region comprises a compound represented by Formula 201, a compound represented by Formula 202, or a combination thereof, and
the emission layer comprises at least one condensed cyclic compound represented by Formula 1:



wherein, in Formula 1,

a1 to a4 are each independently an integer from 0 to 20,
a5 is an integer from 0 to 2,
the sum of a1, a2, a3, a4, and a5 is an integer of 1 or more,
R₁, R₂, and R₁₁ to R₁₅ are each independently hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₁-C₆₀ alkyl group unsubstituted or substituted with at least one R_{10a}, a C₂-C₆₀ alkenyl group unsubstituted or substituted with at least one R_{10a}, a C₂-C₆₀ alkynyl group unsubstituted or substituted with at least one R_{10a}, a C₁-C₆₀ alkoxy group unsubstituted or substituted with at least one R_{10a}, a C₃-C₆₀ carbocyclic group unsubstituted or substituted with at least one R_{10a}, a C₁-C₆₀ heterocyclic group unsubstituted or substituted with at least one R_{10a}, a C₆-C₆₀ aryloxy group unsubstituted or substituted with at least one R_{10a}, a C₆-C₆₀ arylthio group

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unsubstituted or substituted with at least one R_{10a}, —Si(Q₁)(Q₂)(Q₃), —N(Q₁)(Q₂), —B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)₂(Q₁), or —P(=O)(Q₁)(Q₂), d1, d2, and d11 to d14 are each independently an integer from 1 to 20,

d15 is an integer from 0 to 2,
the sum of a5 and d15 is 2,
two or more groups of R₁, R₂, and R₁₁ to R₁₅ are optionally linked to each other to form a C₅-C₃₀ carbocyclic group unsubstituted or substituted with at least one R_{10a} or a C₂-C₃₀ heterocyclic group unsubstituted or substituted with at least one R_{10a},

Z₁ to Z₃ are each independently a single bond or a non-bond,

L₁ and L₂ are each independently a single bond, or a benzene group, a naphthalene group, an anthracene group, an pyrrole group, a carbazole group, a dibenzofuran group, or a dibenzothiophene group, each unsubstituted or substituted with at least one R_{10a}, and

E₁ and E₂ are each independently selected from:

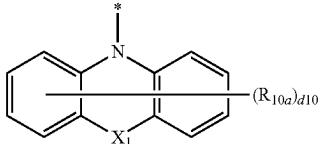
a C₁-C₆₀ alkyl group unsubstituted or substituted with at least one R_{10a};

a C₅-C₃₀ carbocyclic group and a C₂-C₃₀ heterocyclic group, each unsubstituted or substituted with at least one R_{10a};

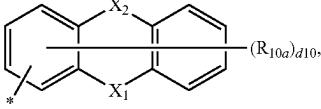
N(Q₄)(Q₅); and

a group represented by Formula A-1 and a group represented by Formula A-2:

A-1



A-2



wherein, in Formulae A-1 and A-2,
X₁ is a non-bond, a single bond, O, S, Se, C(R_{1a})(R_{1b}), Si(R_{1a})(R_{1b}), or N(R_{1a}),
X₂ is O, S, Se, C(R_{2a})(R_{2b}), Si(R_{2a})(R_{2b}), or N(R_{2a}),
R_{1a}, R_{1b}, R_{2a}, and R_{2b} are each independently the same as described in connection with R₁₁,

d10 is an integer from 0 to 8,

* indicates a binding site to a neighboring atom,

n1 and n2 are each independently an integer from 1 to 5, and

o1 and o2 are each independently an integer from 0 to 3, wherein, in Formulae 201 and 202,

L₂₀₁ to L₂₀₄ are each independently a C₅-C₆₀ carbocyclic group unsubstituted or substituted with at least one R_{10a} or a C₁-C₆₀ heterocyclic group unsubstituted or substituted with at least one R_{10a},

L₂₀₅ is *—O—*, *—S—*, *—N(Q₂₀₁)-*, a C₁-C₂₀ alkylene group unsubstituted or substituted with at least one R_{10a}, a C₂-C₂₀ alkenylene group unsubstituted or substituted with at least one R_{10a}, a C₃-C₆₀ carbocyclic group unsubstituted or substituted with at least one R_{10a}, or a C₁-C₆₀ heterocyclic group unsubstituted or substituted with at least one R_{10a},

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xa1 to xa4 are each independently an integer from 0 to 5, xa5 is an integer from 1 to 10, R₂₀₁ to R₂₀₄ and Q₂₀₁ are each independently a C₃-C₆₀ carbocyclic group unsubstituted or substituted with at least one R_{10a} or a C₁-C₆₀ heterocyclic group unsubstituted or substituted with at least one R_{10a}, R₂₀₁ and R₂₀₂ are optionally linked to each other via a single bond, a C₁-C₅ alkylene group unsubstituted or substituted with at least one R_{10a}, or a C₂-C₅ alkenylene group unsubstituted or substituted with at least one R_{10a}, to form a C₈-C₆₀ polycyclic group unsubstituted or substituted with at least one R_{10a}, R₂₀₃ and R₂₀₄ are optionally linked to each other via a single bond, a C₁-C₅ alkylene group unsubstituted or substituted with at least one R_{10a}, or a C₂-C₅ alkenylene group unsubstituted or substituted with at least one R_{10a}, to form a C₈-C₆₀ poly cyclic group unsubstituted or substituted with at least one R_{10a},

na1 is an integer from 1 to 4, and

R_{10a} is:

deuterium (—D), —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, or a nitro group; a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, or a C₁-C₆₀ alkoxy group, each unsubstituted or substituted with deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₃-C₆₀ carbocyclic group, a C₁-C₆₀ heterocyclic group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, —Si(Q₁₁)(Q₁₂)(Q₁₃), —N(Q₁₁)(Q₁₂), —B(Q₁₁)(Q₁₂), —C(=O)(Q₁₁), —S(=O)₂(Q₁₁), —P(=O)(Q₁₁)(Q₁₂), or any combination thereof; a C₃-C₆₀ carbocyclic group, a C₁-C₆₀ heterocyclic group, a C₆-C₆₀ aryloxy group, or a C₆-C₆₀ arylthio group, each unsubstituted or substituted with deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₆₀ carbocyclic group, a C₁-C₆₀ heterocyclic group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, —Si(Q₂₁)(Q₂₂)(Q₂₃), —N(Q₂₁)(Q₂₂), —B(Q₂₁)(Q₂₂), —C(=O)(Q₂₁), —S(=O)₂(Q₂₁), —P(=O)(Q₂₁)(Q₂₂), or any combination thereof; or —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), or —P(=O)(Q₃₁)(Q₃₂), and

wherein Q₁ to Q₃, Q₁₁ to Q₁₃, Q₂₁ to Q₂₃, and Q₃₁ to Q₃₃ are each independently: hydrogen; deuterium; —F; —Cl; —Br; —I; a hydroxyl group; a cyano group; a nitro group; a C₁-C₆₀ alkyl group; a C₂-C₆₀ alkenyl group; a C₂-C₆₀ alkynyl group; a C₁-C₆₀ alkoxy group; or a C₃-C₆₀ carbocyclic group or a C₁-C₆₀ heterocyclic group, each unsubstituted or substituted with deuterium, —F, a cyano group, a C₁-C₆₀ alkyl group, a C₁-C₆₀ alkoxy group, a phenyl group, a biphenyl group, or any combination thereof.

2. The light-emitting device of claim 1, wherein the first electrode is an anode,

the second electrode is a cathode,

the interlayer further comprises 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 emission auxiliary layer, an electron blocking layer, or any combination thereof, and

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

3. The light-emitting device of claim 1, wherein a5 is 1 or 5 2.

4. The light-emitting device of claim 1, wherein the sum of a1, a2, a3, a4, and a5 is greater than or equal to 2.

5. The light-emitting device of claim 1, wherein ring A₁, ring A₂, and ring A₁₁ to ring A₁₄ are each independently a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a cyclopentadiene group, a 1,2,3,4-tetrahydronaphthalene group, a thiophene group, a furan group, an indole group, a benzoborole group, a benzophosphole group, an indene group, a benzosilole group, a benzoger-mole group, a benzothiophene group, a benzoselenophene group, a benzofuran group, a carbazole group, a dibenzo-borole group, a dibenzophosphole group, a fluorene group, a dibenzosilole group, a dibenzogermole group, a dibenzo-thiophene group, a dibenzoselenophene group, a dibenzo-furan group, a dibenzothiophene 5-oxide group, a 9H-fluo-rene-9-one group, a dibenzothiophene 5,5-dioxide group, an azaindole group, an azabenzoborole group, an azabenzo-phosphole group, an azaindene group, an azabenzosilole group, an azabenzogermole group, an azabenzothiophene group, an azabenzoselenophene group, an azabenzofuran group, an azacarbazole group, an azadibenzoborole group, an azadibenzophosphole group, an azafluorene group, an azadibenzosilole group, an azadibenzogermole group, an azadibenzothiophene group, an azadibenzofuran group, an azadibenzothiophene 5,5-dioxide group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a phenanthroline group, a pyrrole group, a pyrazole group, an imidazole group, a triazole group, an oxazole group, an isoxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazole group, a benzopyrazole group, a benz-imidazole group, a benzoxazole group, a benzothiazole group, a benzoxadiazole group, a benzothiadiazole group, a 5,6,7,8-tetrahydroisoquinoline group, or a 5,6,7,8-tetrahyd-roquinoline group.

6. The light-emitting device of claim 1, wherein ring A₁, ring A₂, and ring A₁₁ to ring A₁₄ are each independently a benzene group, a naphthalene group, a benzothiophene group, a carbazole group, a fluorene group, a dibenzosilole group, a dibenzothiophene group, a dibenzofuran group, a dibenzothiophene 5-oxide group, a 9H-fluorene-9-one group, or a dibenzothiophene 5,5-dioxide group.

7. The light-emitting device of claim 1, wherein ring A₁ is a benzene group, and ring A₂ is a benzene group; ring A₁ is a carbazole group, and ring A₂ is a benzene group;

ring A₁ is a dibenzothiophene group, and ring A₂ is a benzene group;

ring A₁ is a dibenzofuran group, and ring A₂ is a benzene group;

ring A₁ is a dibenzosilole group, and ring A₂ is a benzene group;

ring A₁ is a carbazole group, and ring A₂ is a carbazole group;

ring A₁ is a dibenzothiophene group, and ring A₂ is a dibenzothiophene group;

ring A₁ is a dibenzofuran group, and ring A₂ is a diben-zofuran group; or

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ring A₁ is a dibenzosilole group, and ring A₂ is a dibenzosilole group.

8. The light-emitting device of claim 1, wherein R₁, R₂, and R₁₁ to R₁₅ are each independently selected from: hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazine group, a hydrazone group, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group; a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazine group, a hydrazone group, a C₁-C₁₀ alkyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group; a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a C₁-C₁₀ alkylphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —P(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂); and —Si(Q₁)(Q₂)(Q₃), —N(Q₁)(Q₂), —B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)₂(Q₁), and —P(=O)(Q₁)(Q₂), and

wherein Q₁ to Q₃ and Q₃₁ to Q₃₃ are each independently selected from: —CH₃, —CD₃, —CD₂H, —CDH₂, —CH₂CH₃, —CH₂CD₃, —CH₂CD₂H, —CH₂CDH₂, —CHDCH₃, —CHDCD₂H, —CHDCDH₂, —CHDCD₃, —CD₂CD₃, —CD₂CD₂H, and —CD₂CDH₂; and an n-propyl group, an iso-propyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrazinyl group, and a triazinyl group, each unsubstituted or substituted with at least one selected from deuterium, a C₁-C₁₀ alkyl group, a phenyl group, a biphenyl group, a pyridinyl group, a pyrimidinyl group, a pyridazinyl group, a pyrazinyl group, and a triazinyl group.

9. The light-emitting device of claim 1, wherein Z₁ is a non-bond, and Z₂ is a single bond; Z₁ is a non-bond, and Z₂ is a single bond; or Z₁ is a single bond, and Z₂ is a non-bond; or Z₁ is a single bond, and Z₂ is a single bond.

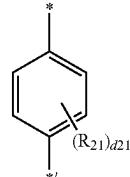
10. The light-emitting device of claim 1, wherein L₁ and L₂ are each independently: a single bond; or one of Formulae 2-1 to 2-14:

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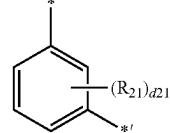
pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —P(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂); and

wherein Q₁ to Q₃ and Q₃₁ to Q₃₃ are each independently selected from: —CH₃, —CD₃, —CD₂H, —CDH₂, —CH₂CH₃, —CH₂CD₃, —CH₂CD₂H, —CH₂CDH₂, —CHDCH₃, —CHDCD₂H, —CHDCDH₂, —CHDCD₃, —CD₂CD₃, —CD₂CD₂H, and —CD₂CDH₂; and an n-propyl group, an iso-propyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrazinyl group, and a triazinyl group, each unsubstituted or substituted with at least one selected from deuterium, a C₁-C₁₀ alkyl group, a phenyl group, a biphenyl group, a pyridinyl group, a pyrimidinyl group, a pyridazinyl group, a pyrazinyl group, and a triazinyl group.

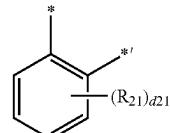
2-1



2-2

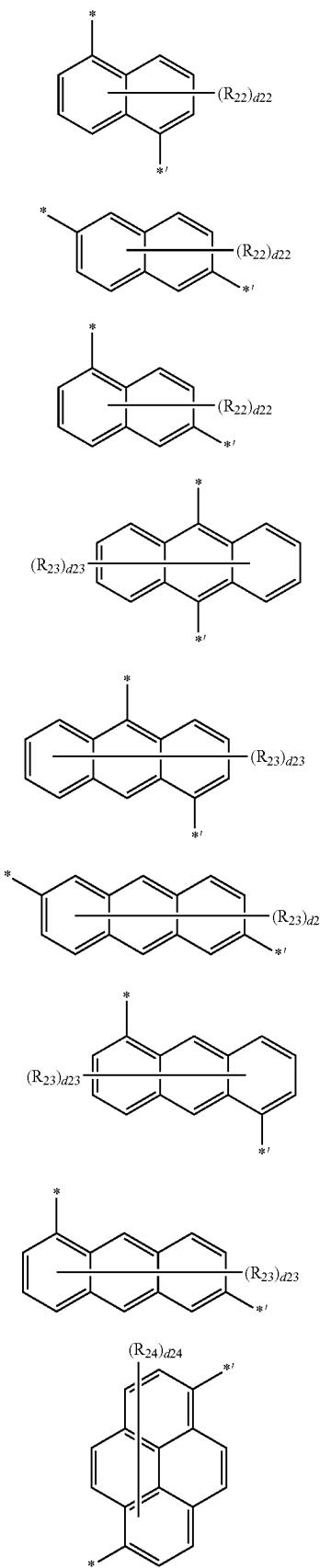


2-3



171

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**172**

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2-4

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2-5 10

2-6 15

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2-7

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2-8 30

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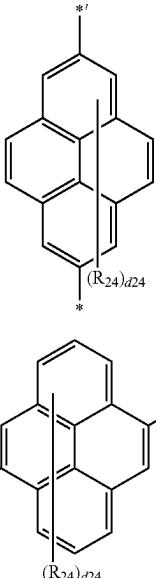
55

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2-13

2-14



wherein, in Formulae 2-1 to 2-14, R₂₁ to R₂₄ are each independently the same as described in connection with R₁ in Formula 1,

d21 is an integer from 1 to 4,

d22 is an integer from 1 or 6,

d23 is an integer from 1 to 8,

d24 is an integer from 1 to 8, and

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

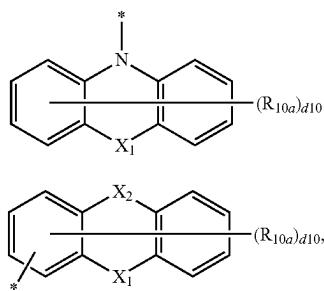
11. The light-emitting device of claim 1, wherein E₁ and E₂ are each independently selected from: a C₁-C₁₀ alkyl group unsubstituted or substituted with at least one R_{10a}; a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a cyclopentadiene group, a 1,2,3,4-tetrahydronaphthalene group, a thiophene group, a furan group, an indole group, a benzoborole group, a benzophosphole group, an indene group, a benzosilole group, a benzogermole group, a benzothiophene group, a benzoselenophene group, a benzofuran group, a carbazole group, a dibenzoborole group, a dibenzophosphole group, a fluorene group, a dibenzosilole group, a dibenzogermole group, a dibenzothiophene group, a dibenzoselenophene group, a dibenzofuran group, a dibenzothiophene 5-oxide group, a 9H-a fluorene-9-one group, a dibenzothiophene 5,5-dioxide group, an azaindole group, an azabenzoborole group, an azabenzophosphole group, an azaindene group, an azabenzosilole group, an azabenzogermole group, an azabenzothiophene group, an azabenzoselenophene group, an azabenzofuran group, an azacarbazole group, an azadibenzoborole group, an azadibenzophosphole group, an azafluorene group, an azadibenzosilole group, an azadibenzogermole group, an azadibenzothiophene group, an azadibenzoselenophene group, an azadibenzofuran group, an azadibenzothiophene 5-oxide group, an az-9H-fluoren-9-one group, an azadibenzothiophene 5,5-dioxide group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline

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group, a quinazoline group, a phenanthroline group, a pyrrole group, a pyrazole group, an imidazole group, a triazole group, an oxazole group, an isoxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazole group, a benzopyrazole group, a 5 benzimidazole group, a benzoxazole group, a benzo-thiazole group, a benzoxadiazole group, a benzothiadiazole group, a 5,6,7,8-tetrahydroisoquinoline group, and a 5,6,7,8-tetrahydroquinoline group, each unsubstituted or substituted with at least one R_{10a} ; 10

$N(Q_4)(Q_5)$; and

a group represented by Formula A-1 and a group represented by Formula A-2:

15
A-120
A-2

25

and

wherein, in Formulae A-1 and A-2,

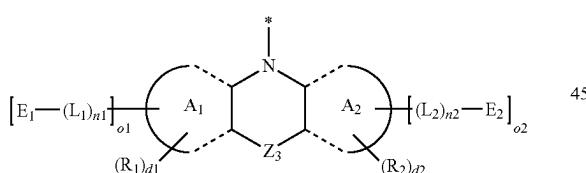
X_1 is a non-bond, a single bond, O, S, Se, $C(R_{1a})(R_{1b})$, $Si(R_{1a})(R_{1b})$, or $N(R_{1a})$,

X_2 is O, S, Se, $C(R_{2a})(R_{2b})$, $Si(R_{2a})(R_{2b})$, or $N(R_{2a})$,

R_{10a} , R_{1a} , R_{1b} , R_{2a} , R_{2b} , Q_4 , Q_5 , and $d10$ are the same as defined in Formula 1, and

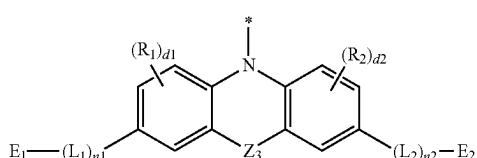
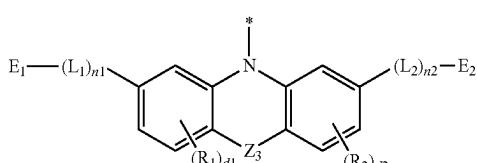
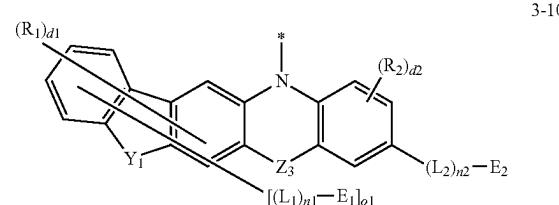
* indicates a binding site to a neighboring atom.

12. The light-emitting device of claim 1, wherein a moiety represented by

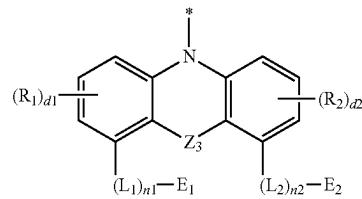
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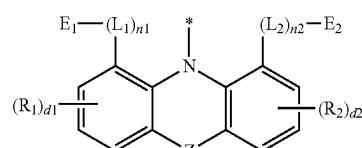
in Formula 1 is represented by one of Formulae 3-1 to 3-18:

50
3-1
553-2
60
65

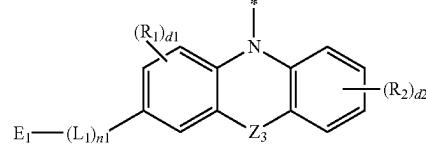
3-3

174
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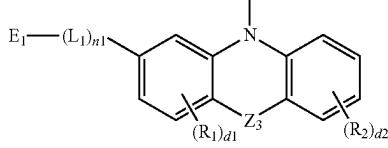
3-4



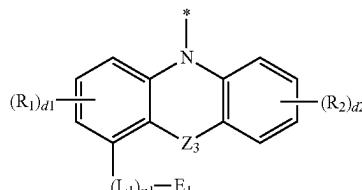
3-5



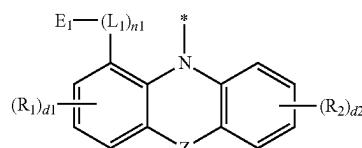
3-6



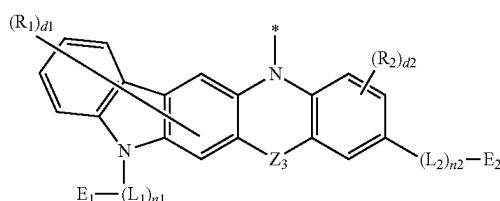
3-7



3-8

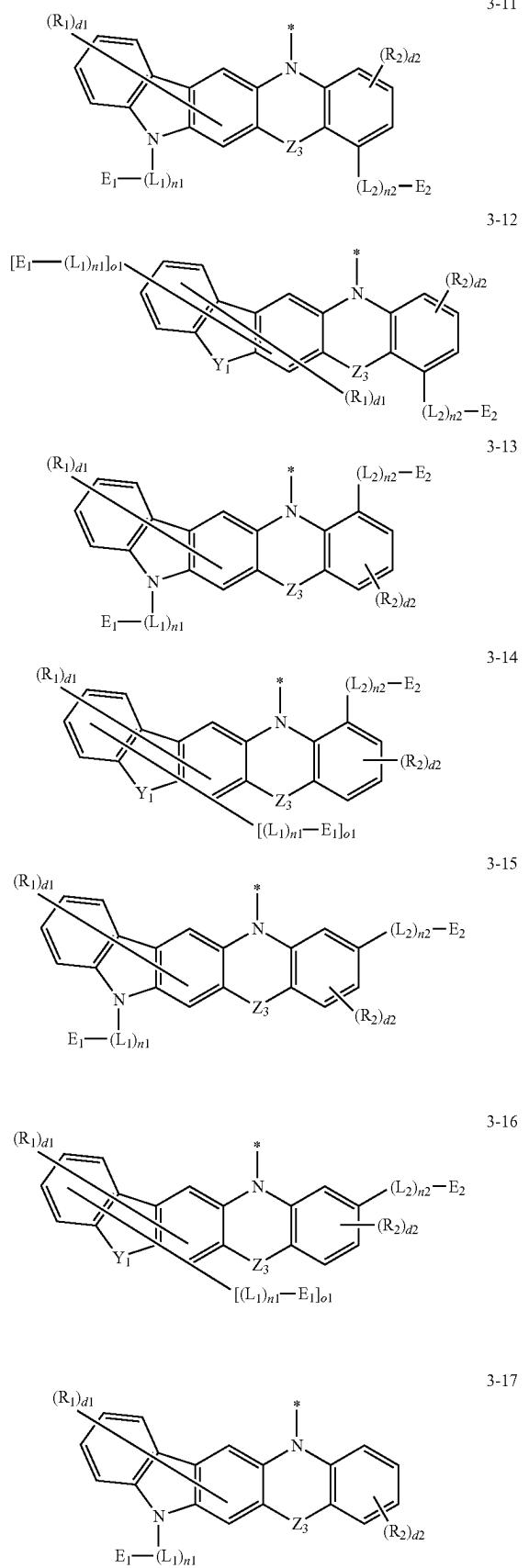


3-9

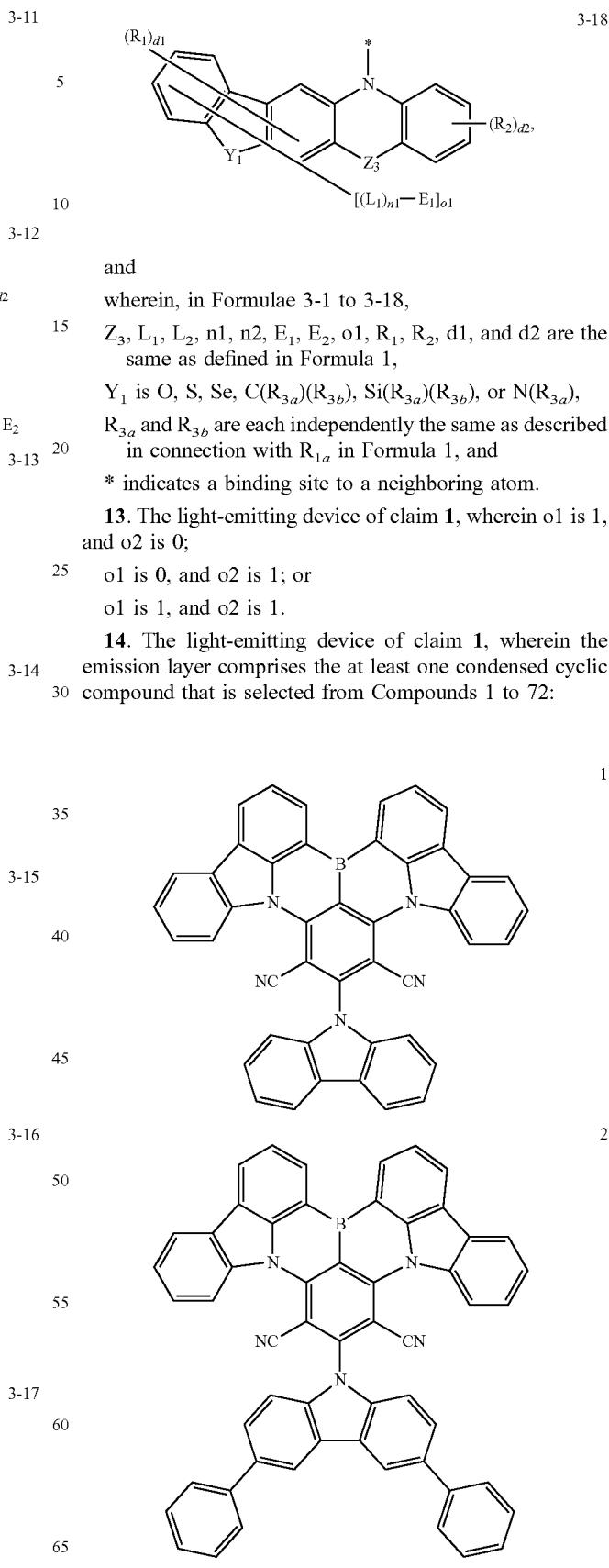


3-10

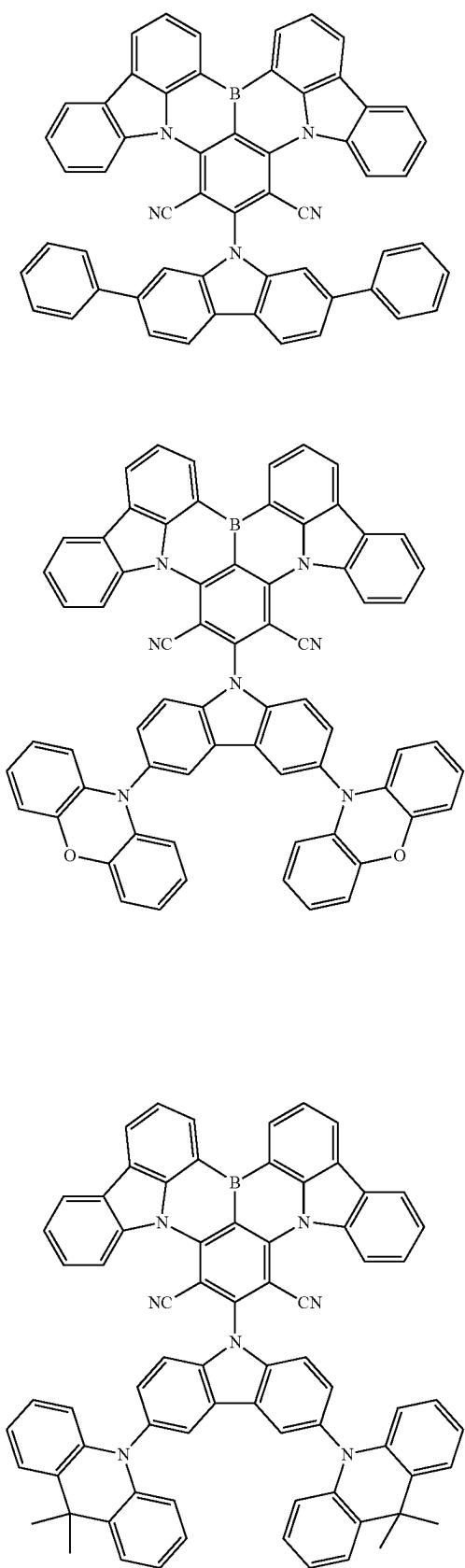
175
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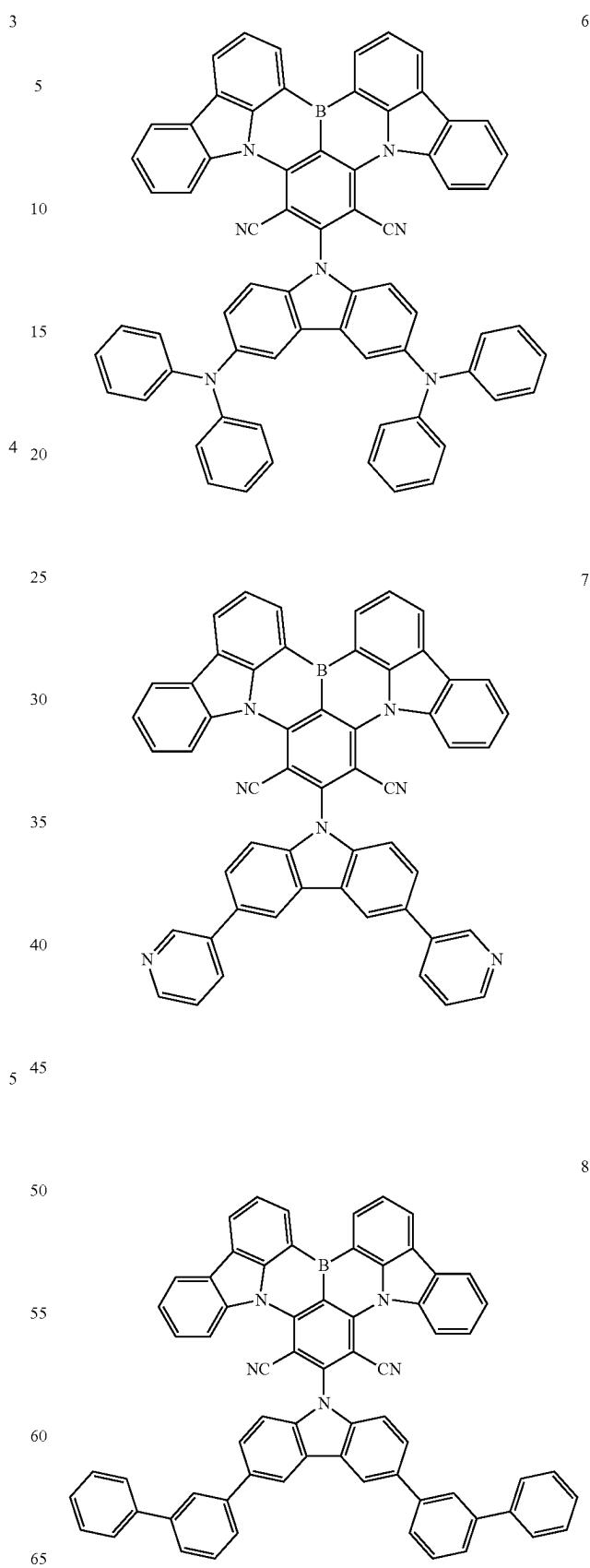
176
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177
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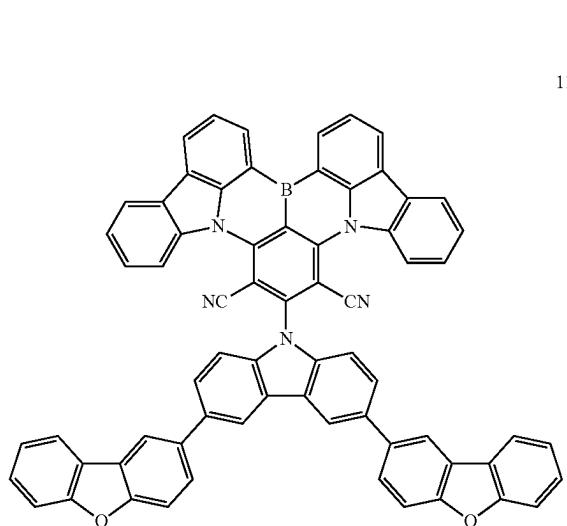
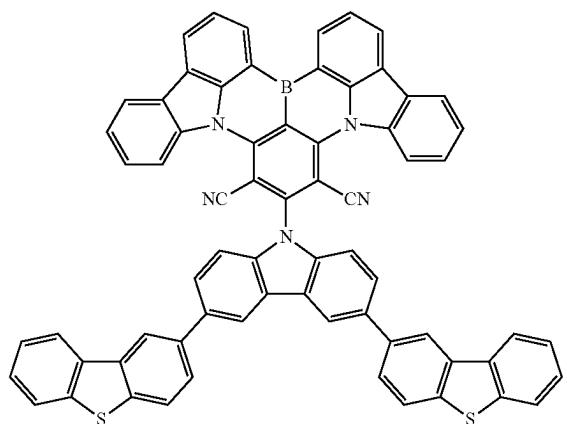
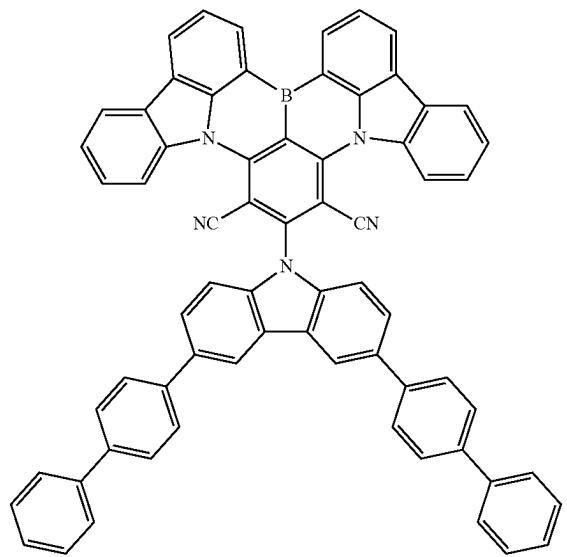


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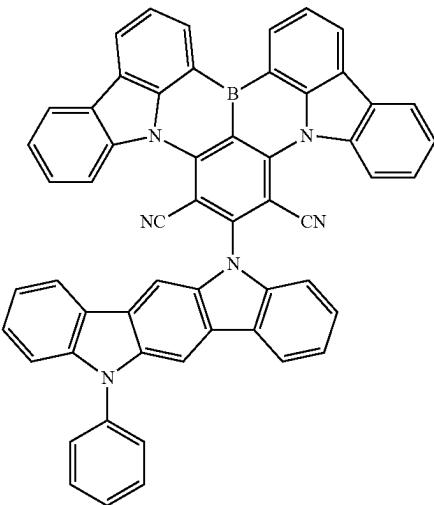
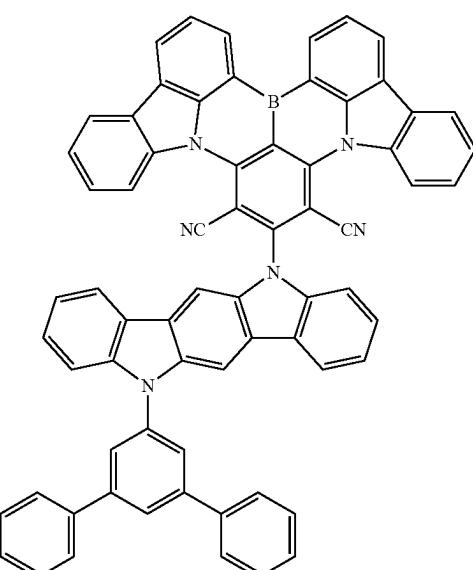
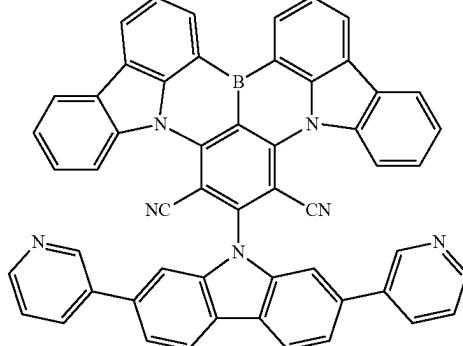


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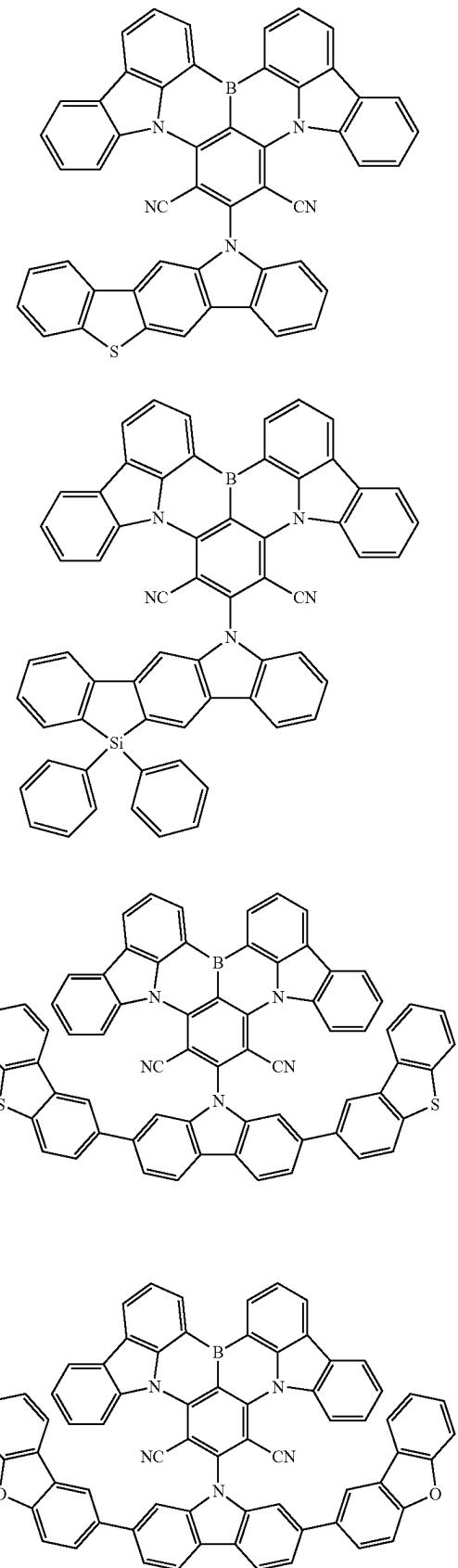
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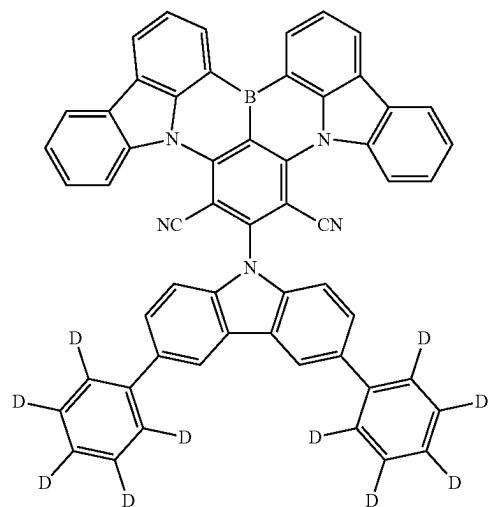
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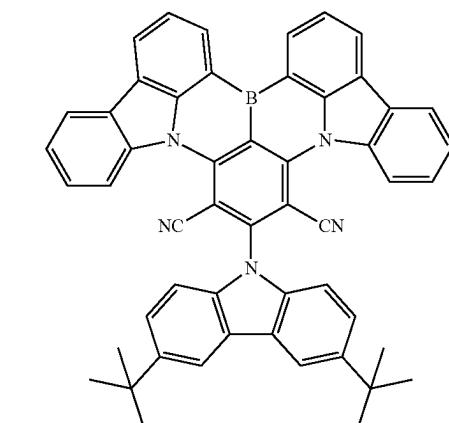
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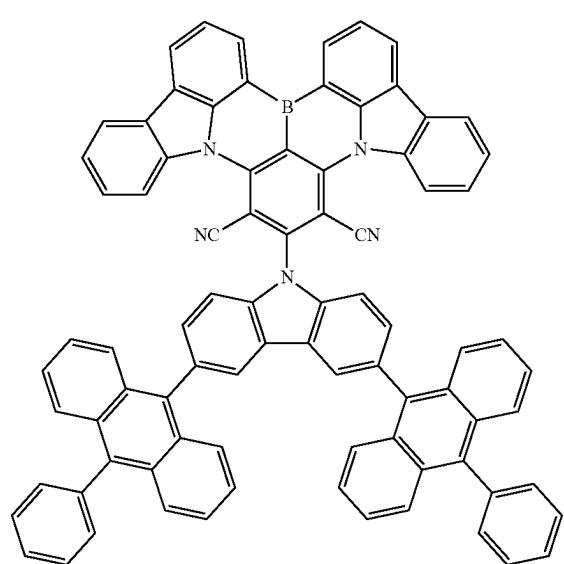


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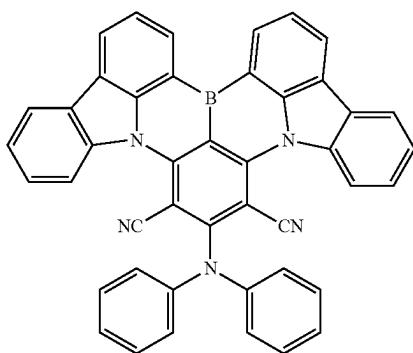
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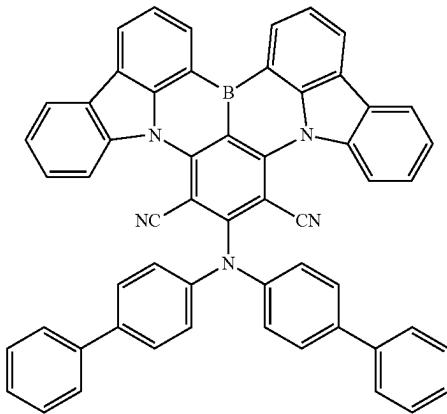
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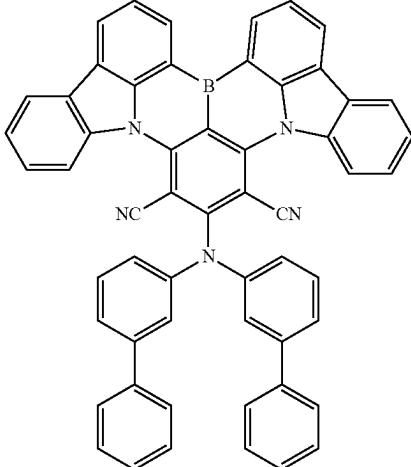


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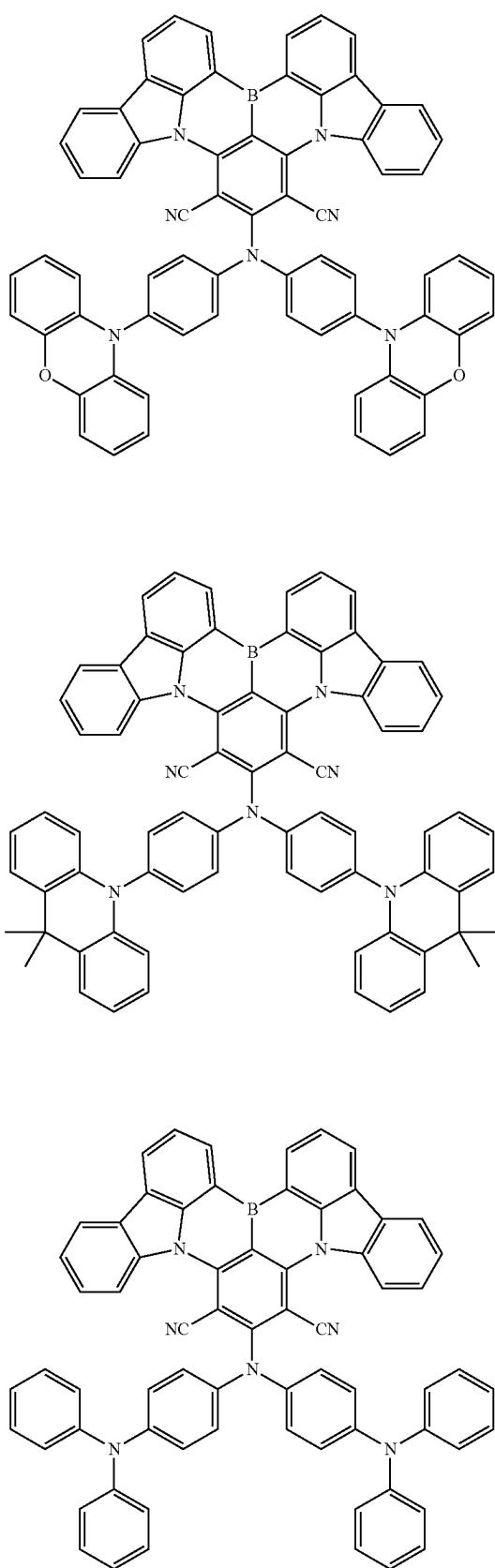


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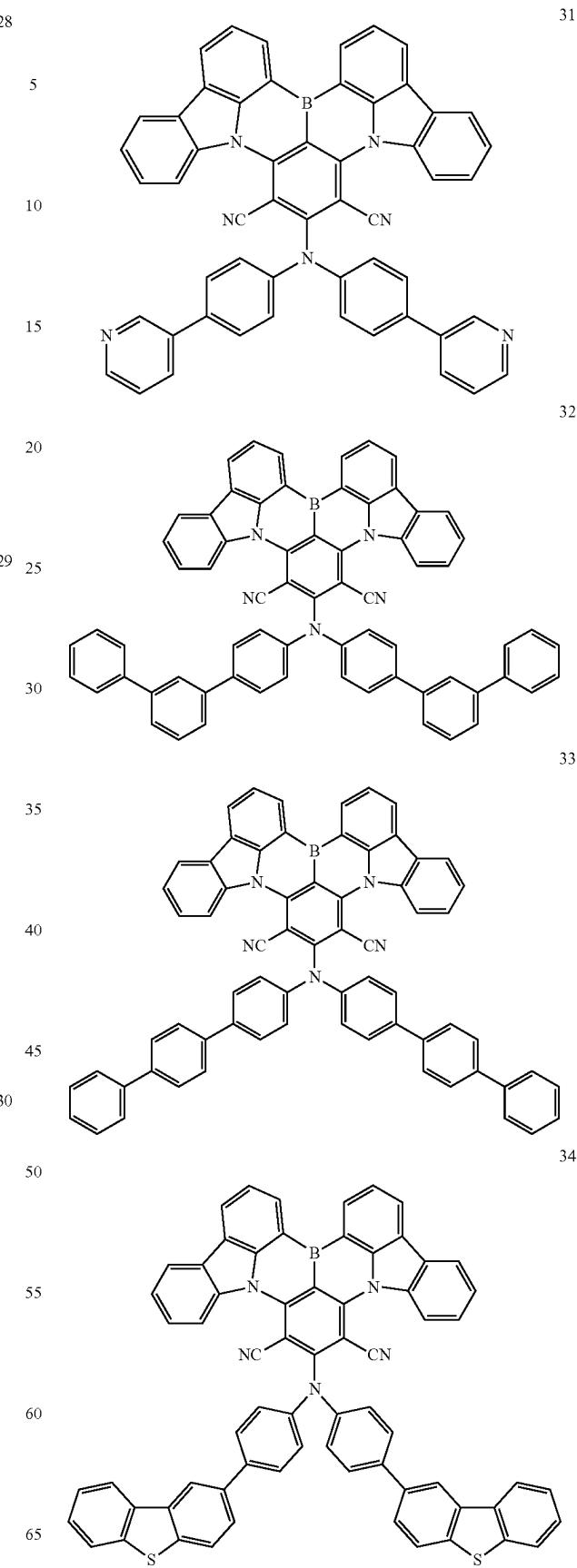


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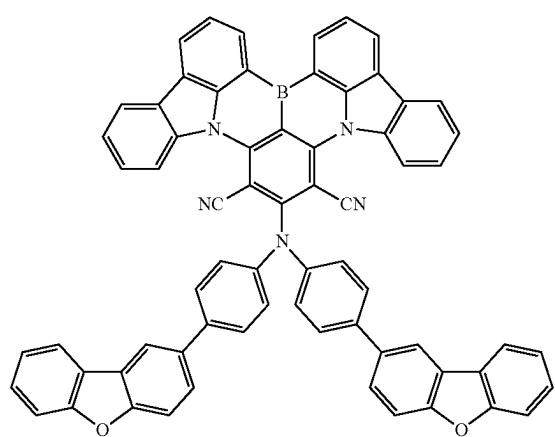
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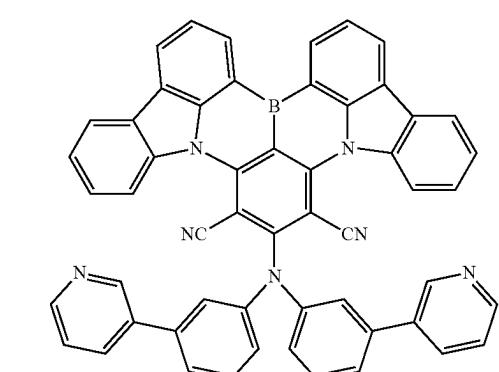
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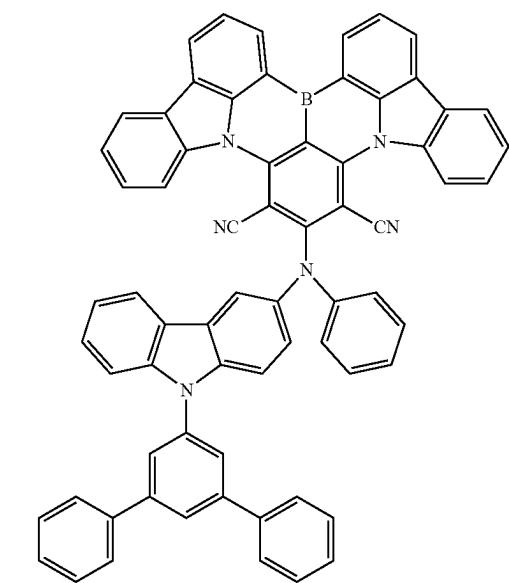
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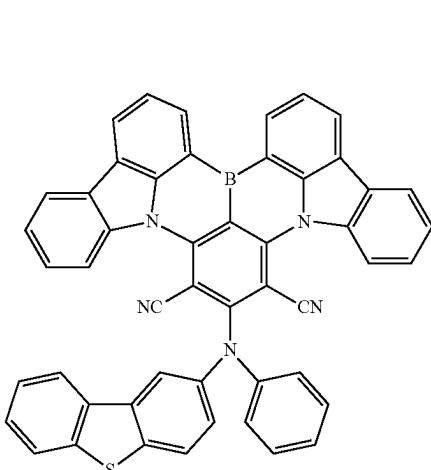
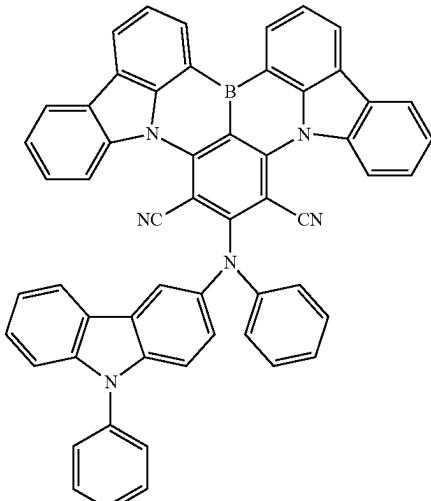
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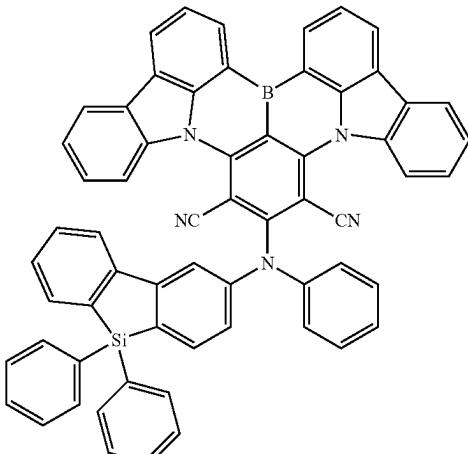
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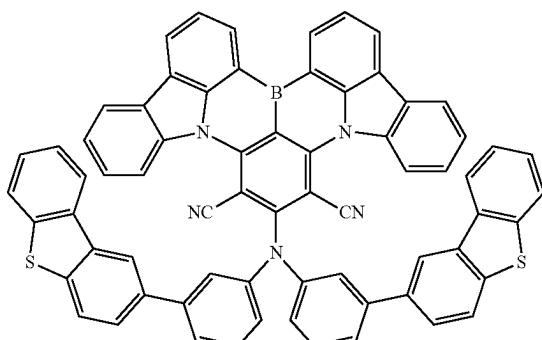
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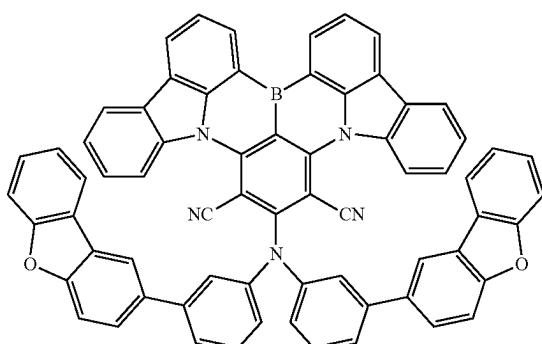


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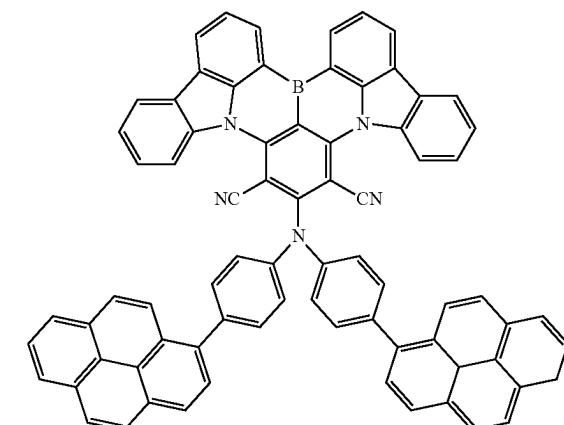
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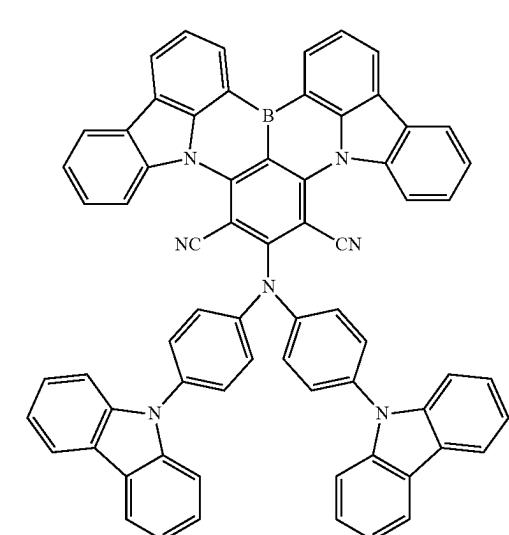
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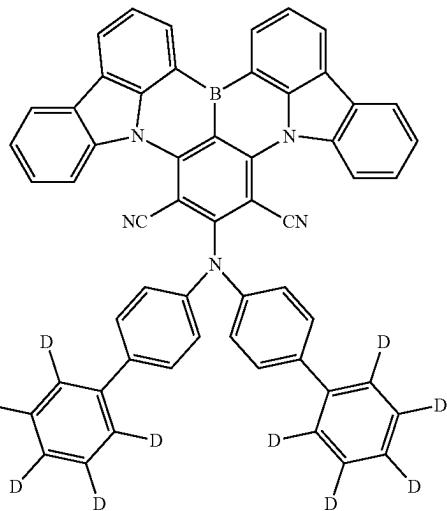
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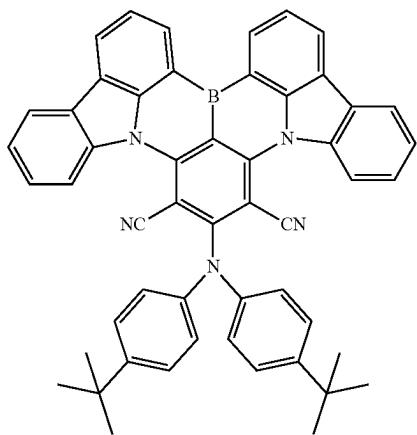
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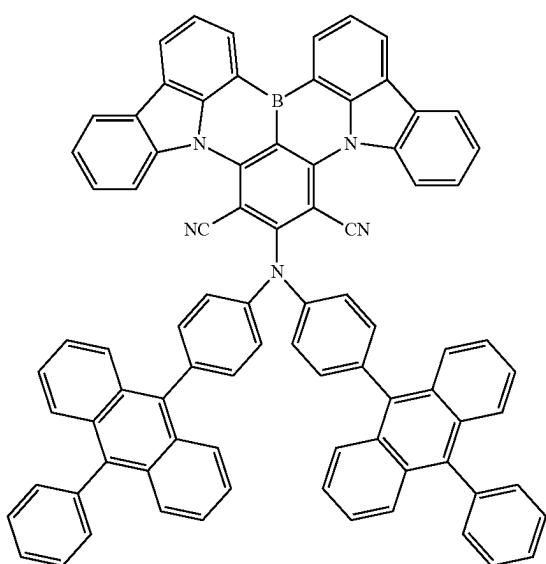
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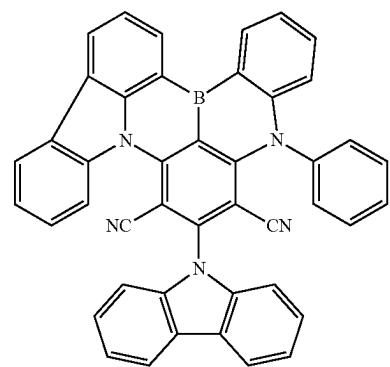
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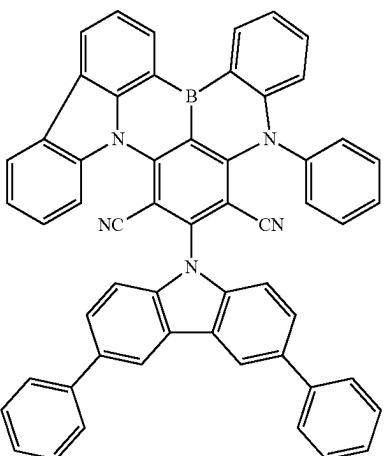
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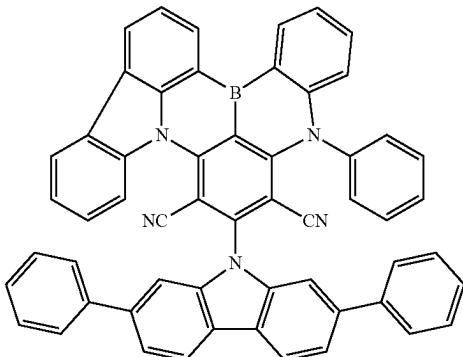
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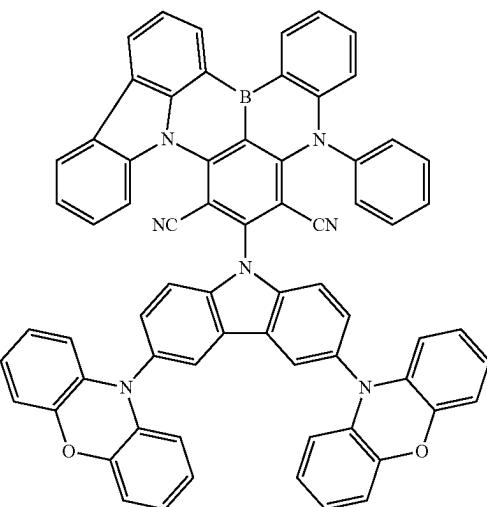
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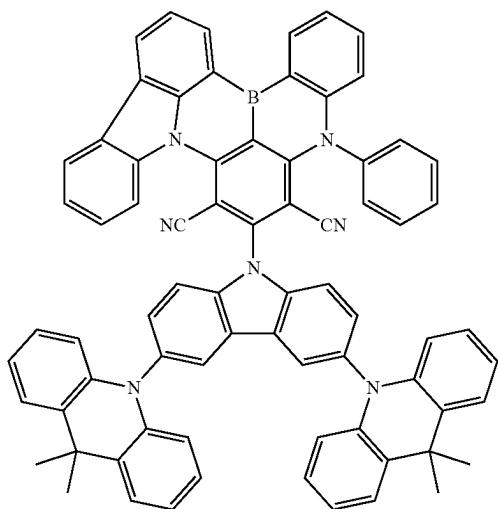


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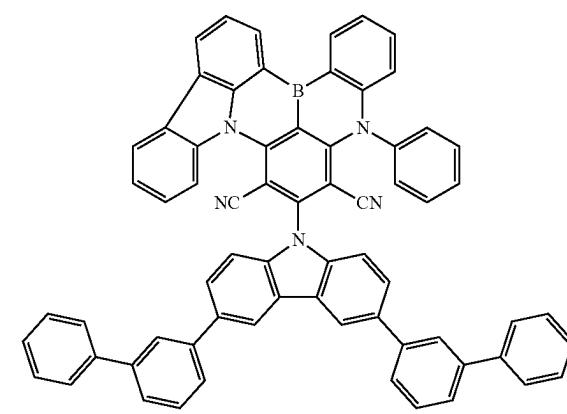
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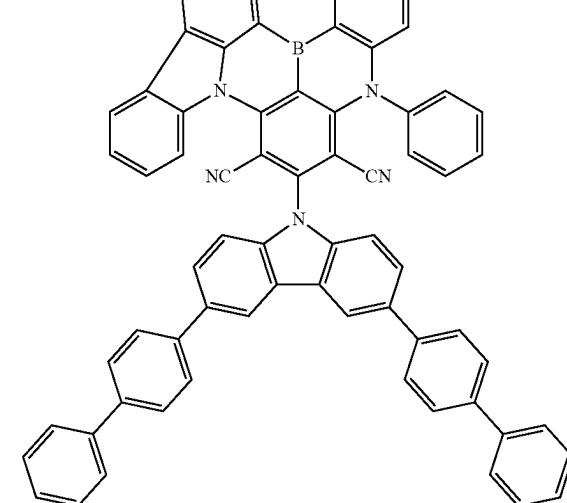
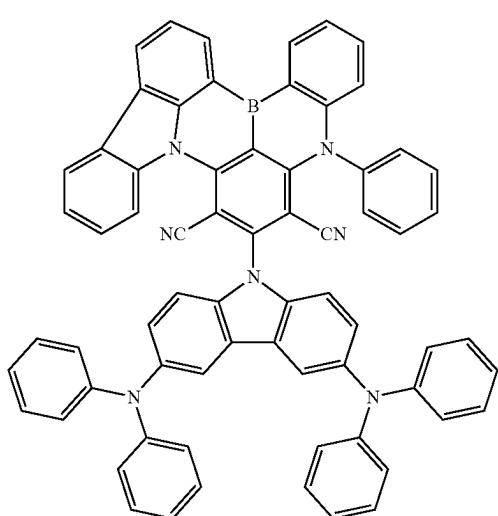
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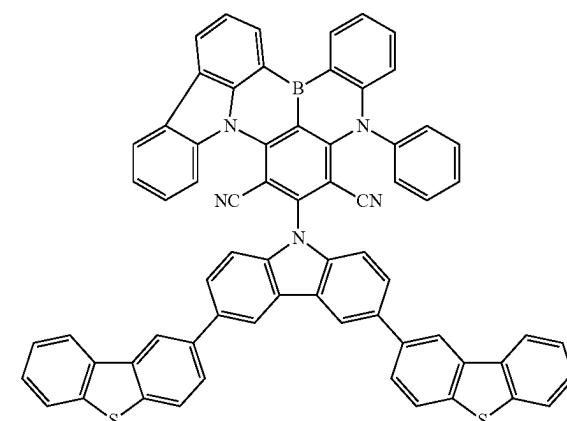
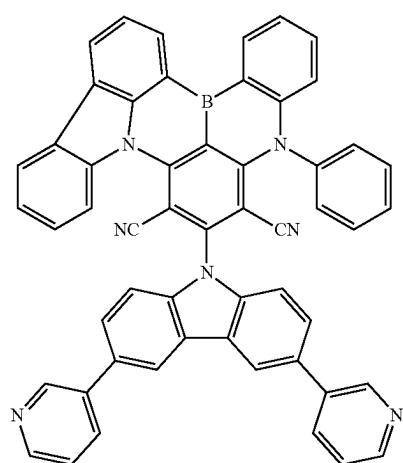
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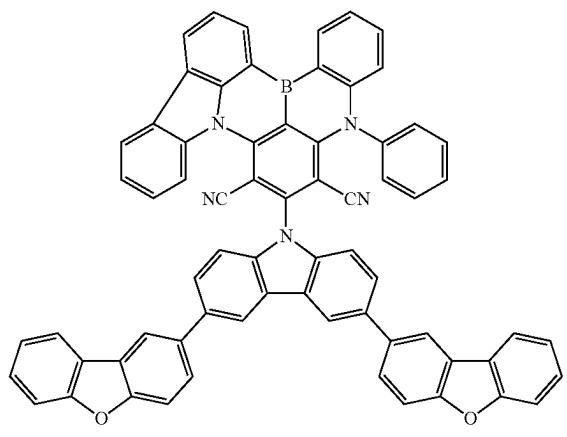
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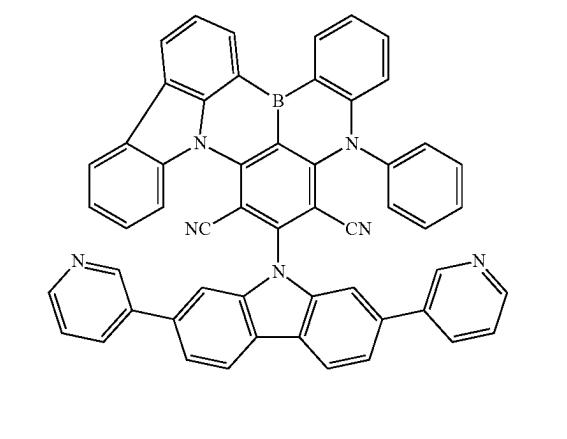
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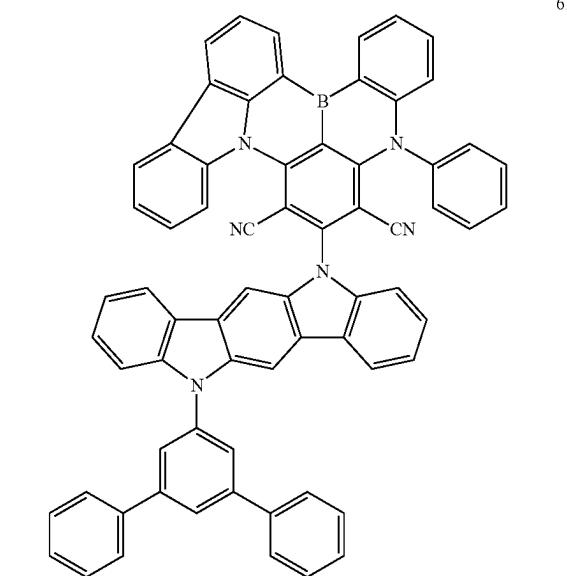
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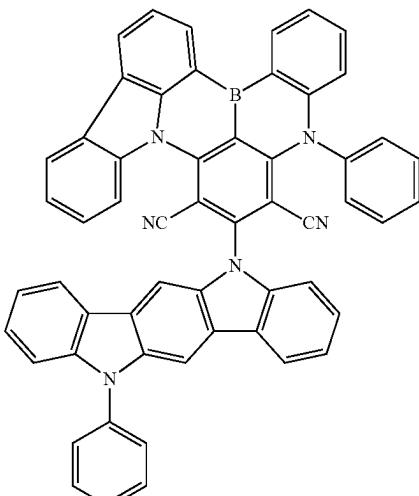


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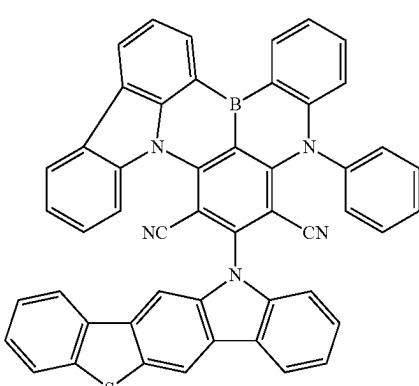
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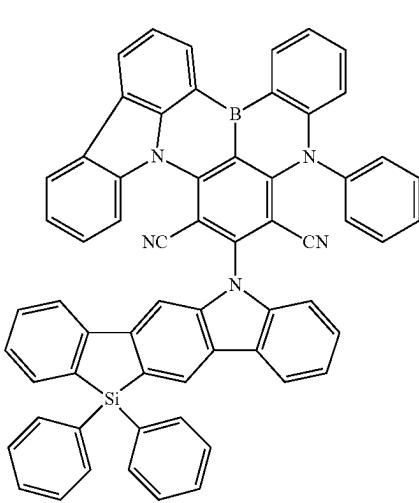
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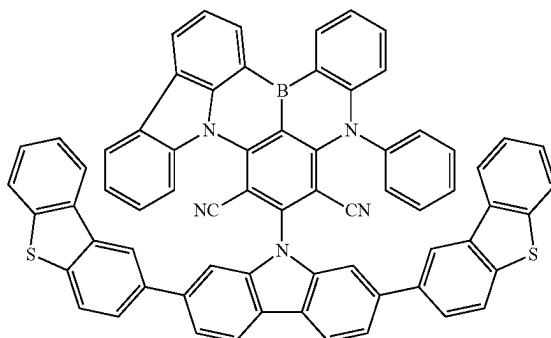


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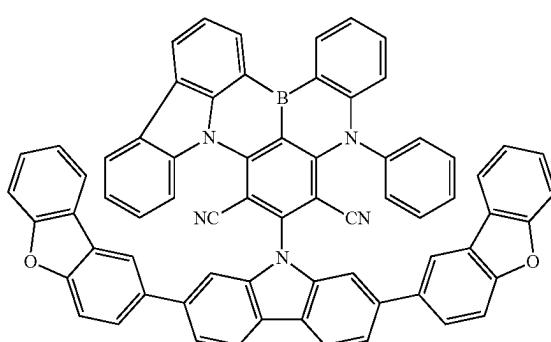


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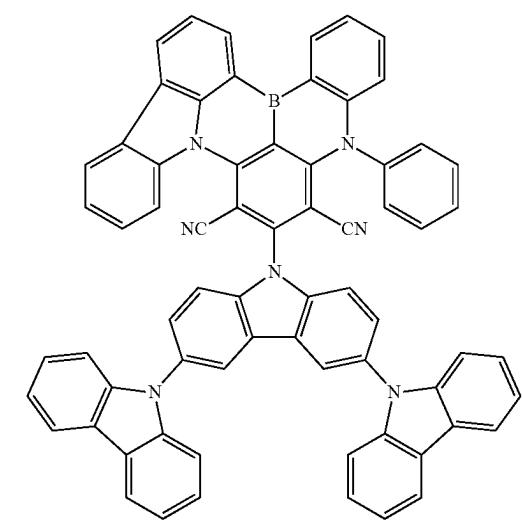
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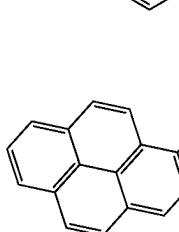
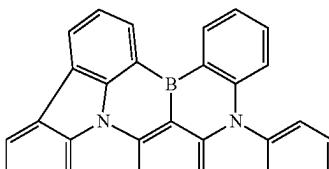
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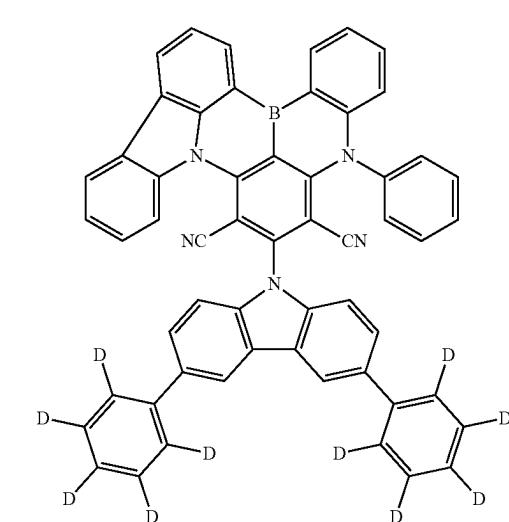
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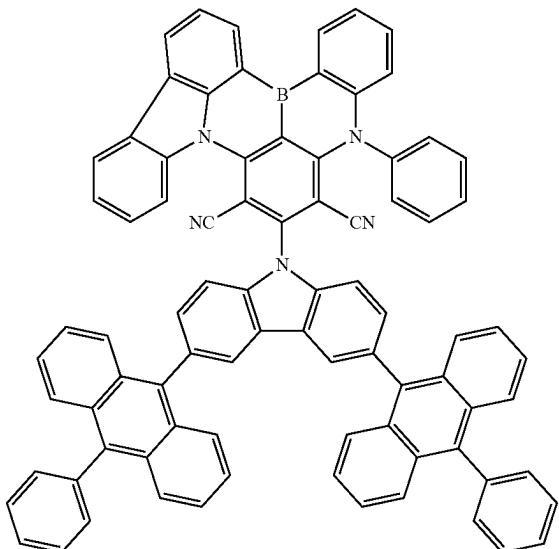
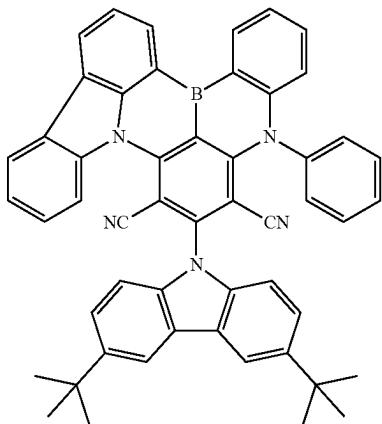
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15. The light-emitting device of claim 1, wherein the emission layer is to emit light having a maximum luminescence wavelength of about 400 nm to about 500 nm.

16. A light-emitting device comprising:

a first electrode;

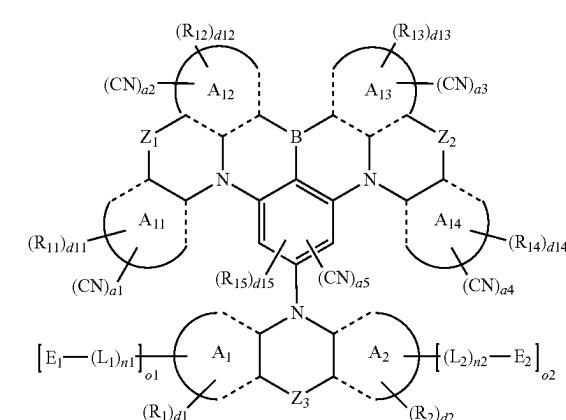
a second electrode facing the first electrode; and

an interlayer between the first electrode and the second electrode, the interlayer comprising an emission layer, wherein the light-emitting device further comprises a capping layer outside the second electrode and having a refractive index of 1.6 or more, and

the emission layer comprises at least one condensed cyclic compound represented by Formula 1:

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Formula 1



wherein, in Formula 1,

a1 to a4 are each independently an integer from 0 to 20,
a5 is an integer from 0 to 2,

the sum of a1, a2, a3, a4, and a5 is an integer of 1 or more,

R₁, R₂, and R₁₁ to R₁₅ are each independently hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₁-C₆₀ alkyl group unsubstituted or substituted with at least one R_{10a}, a C₂-C₆₀ alkenyl group unsubstituted or substituted with at least one R_{10a}, a C₂-C₆₀ alkynyl group unsubstituted or substituted with at least one R_{10a}, a C₁-C₆₀ alkoxy group unsubstituted or substituted with at least one R_{10a}, a C₃-C₆₀ carbocyclic group unsubstituted or substituted with at least one R_{10a}, a C₁-C₆₀ heterocyclic group unsubstituted or substituted with at least one R_{10a}, a C₆-C₆₀ aryloxy group unsubstituted or substituted with at least one R_{10a}, a C₆-C₆₀ arylthio group unsubstituted or substituted with at least one R_{10a}, —Si(Q₁)(Q₂)(Q₃), —N(Q₁)(Q₂), —B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)₂(Q₁), or —P(=O)(Q₁)(Q₂), d1, d2, and d11 to d14 are each independently an integer from 1 to 20,

d15 is an integer from 0 to 2,

the sum of a5 and d15 is 2,

two or more groups of R₁, R₂, and R₁₁ to R₁₅ are optionally linked to each other to form a C₅-C₃₀ carbocyclic group unsubstituted or substituted with at least one R_{10a} or a C₂-C₃₀ heterocyclic group unsubstituted or substituted with at least one R_{10a},

Z₁ to Z₃ are each independently a single bond or a non-bond,

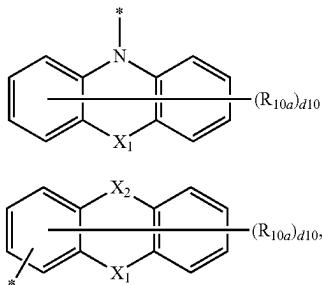
L₁ and L₂ are each independently a single bond, or a benzene group, a naphthalene group, an anthracene group, a pyrrole group, a carbazole group, a dibenzofuran group, or a dibenzothiophene group, each unsubstituted or substituted with at least one R_{10a}, and E₁ and E₂ are each independently selected from:

a C₁-C₆₀ alkyl group unsubstituted or substituted with at least one R_{10a};

a C₅-C₃₀ carbocyclic group and a C₂-C₃₀ heterocyclic group, each unsubstituted or substituted with at least one R_{10a};

N(Q₄)(Q₅); and

a group represented by Formula A-1 and a group represented by Formula A-2:

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wherein, in Formulae A-1 and A-2,
 X_1 is a non-bond, a single bond, O, S, Se, C(R_{1a})(R_{1b}),
 $\text{Si}(\mathbf{R}_{1a})(\mathbf{R}_{1b})$, or N(R_{1a}),
 X_2 is O, S, Se, C(R_{2a})(R_{2b}), $\text{Si}(\mathbf{R}_{2a})(\mathbf{R}_{2b})$, or N(R_{2a}), R_{1a} ,
 R_{1b} , R_{2a} , and R_{2b} are each independently the same as
described in connection with R_{11} ,
d10 is an integer from 0 to 8,
* indicates a binding site to a neighboring atom,
n1 and n2 are each independently an integer from 1 to 5,
and
o1 and o2 are each independently an integer from 0 to 3,
and
 R_{10a} is:
deuterium (—D), —F, —Cl, —Br, —I, a hydroxyl group,
a cyano group, or a nitro group;
a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60}
alkynyl group, or a C_1 - C_{60} alkoxy group, each unsub-
stituted or substituted with deuterium, —F, —Cl, —Br,
—I, a hydroxyl group, a cyano group, a nitro group, a
 C_3 - C_{60} carbocyclic group, a C_1 - C_{60} heterocyclic group,
a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, —Si
(35) (Q_{11})(Q_{12})(Q_{13}), —N(Q_{11})(Q_{12}), —B(Q_{11})(Q_{12}),
—C(=O)(Q_{11}), —S(=O)₂(Q_{11}), —P(=O)(Q_{11})
(Q_{12}), or any combination thereof;
a C_3 - C_{60} carbocyclic group, a C_1 - C_{60} heterocyclic group,
a C_6 - C_{60} aryloxy group, or a C_6 - C_{60} arylthio group,
each unsubstituted or substituted with deuterium, —F,
—Cl, —Br, —I, a hydroxyl group, a cyano group, a
nitro group, 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,

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a C_3 - C_{60} carbocyclic group, a C_1 - C_{60} heterocyclic group,
a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group,
—Si(Q_{21})(Q_{22})(Q_{23}), —N(Q_{21})(Q_{22}), —B(Q_{21})(Q_{22}),
—C(=O)(Q_{21}), —S(=O)₂(Q_{21}), —P(=O)(Q_{21})
(Q_{22}), or any combination thereof; or
—Si(Q_{31})(Q_{32})(Q_{33}), —N(Q_{31})(Q_{32}), —B(Q_{31})(Q_{32}),
—C(=O)(Q_{31}), —S(=O)₂(Q_{31}), or —P(=O)(Q_{31})
(Q_{32}), and
wherein Q_1 to Q_3 , Q_{11} to Q_{13} , Q_{21} to Q_{23} , and Q_{31} to Q_{33}
are each independently: hydrogen; deuterium; —F;
—Cl; —Br; —I; a hydroxyl group; a cyano group; a
nitro group; 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;
or a C_3 - C_{60} carbocyclic group or a C_1 - C_{60} heterocyclic
group, each unsubstituted or substituted with deute-
rium, —F, a cyano group, a C_1 - C_{60} alkyl group, a
 C_1 - C_{60} alkoxy group, a phenyl group, a biphenyl group,
or any combination thereof.

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17. The light-emitting device of claim 16, wherein an encapsulation portion is on the capping layer.

18. The light-emitting device of claim 17, wherein the encapsulation portion comprises:

an inorganic film comprising silicon nitride (SiNx), sili-
con oxide (SiOx), indium tin oxide, indiumzincoxide,
or any combination thereof;

an organic film comprising polyethylene terephthalate,
polyethylene naphthalate, polycarbonate, polyimide,
polyethylene sulfonate, polyoxymethylene, polyary-
late, hexamethyldisiloxane, an acryl-based resin, an
epoxy-based resin, or any combination thereof; or
a combination of the inorganic film and the organic film.

19. An electronic apparatus comprising:
the light-emitting device of claim 1; and
a thin-film transistor,
wherein the thin-film transistor comprises a source elec-
trode and a drain electrode, and
the first electrode of the light-emitting device is electri-
cally connected to the source electrode or the drain
electrode.

20. The electronic apparatus of claim 19, further com-
prising a color filter, a color conversion layer, a touch screen
layer, a polarizing layer, or any combination thereof.

* * * * *