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Lee et al.

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

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(65) **Prior Publication Data**

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(63) Continuation of application No. 17/101,379, filed on Nov. 23, 2020, which is a continuation of application (Continued)

(30) **Foreign Application Priority Data**

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

(51) **Int. Cl.**
H01L 51/00 (2006.01)
C07D 405/14 (2006.01)

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(52) **U.S. Cl.**
CPC **C07D 405/14** (2013.01); **C07D 491/048** (2013.01); **C09K 11/06** (2013.01);
(Continued)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,846,560 B2	12/2010	Nakano et al.
8,080,658 B2	12/2011	Iwakura et al.

(Continued)

FOREIGN PATENT DOCUMENTS

JP 2009155300 A	7/2009
JP 2010215759 A	9/2010

(Continued)

OTHER PUBLICATIONS

English Abstract of KR 20190024926.

(Continued)

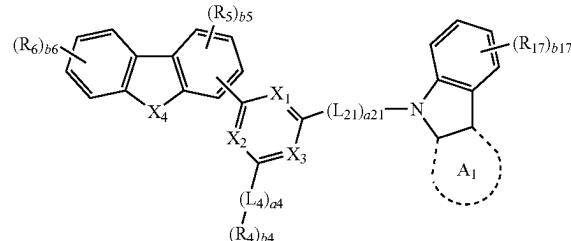
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(57) **ABSTRACT**

A condensed-cyclic compound represented by Formula 1A:

Formula 1A



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

6 Claims, 1 Drawing Sheet

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Related U.S. Application Data

No. 16/177,914, filed on Nov. 1, 2018, now Pat. No. 10,985,329, which is a continuation-in-part of application No. 14/573,422, filed on Dec. 17, 2014, now Pat. No. 10,158,085.

(51) Int. Cl.

C07D 491/048 (2006.01)
C09K 11/06 (2006.01)
H10K 85/60 (2023.01)
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H10K 50/17 (2023.01)
H10K 50/18 (2023.01)
H10K 85/30 (2023.01)
H10K 101/10 (2023.01)

(52) U.S. Cl.

CPC **H10K 85/654** (2023.02); **H10K 85/657** (2023.02); **H10K 85/6572** (2023.02); **H10K 85/6574** (2023.02); **C09K 2211/1018** (2013.01); **H10K 50/11** (2023.02); **H10K 50/15** (2023.02); **H10K 50/16** (2023.02); **H10K 50/17** (2023.02); **H10K 50/171** (2023.02); **H10K 50/18** (2023.02); **H10K 85/324** (2023.02); **H10K 85/342** (2023.02); **H10K 2101/10** (2023.02)

(56)**References Cited****U.S. PATENT DOCUMENTS**

9,847,501 B2	12/2017	Mizutani et al.
2006/0063031 A1 *	3/2006	Brown H01L 51/5016 313/506
2010/0032658 A1	2/2010	Lee et al.
2012/0086329 A1	4/2012	Dyatkin
2013/0062597 A1	3/2013	Yoshida et al.
2013/0077362 A1	5/2013	Mizutani
2014/0077179 A1	3/2014	Shin et al.
2014/0312338 A1	10/2014	Mizutani et al.
2015/0025239 A1	1/2015	Ahn et al.
2015/0228909 A1	8/2015	Kim et al.
2017/0012333 A1	1/2017	Kwon et al.

FOREIGN PATENT DOCUMENTS

JP	2010267847 A	11/2010
JP	2013026529 A	2/2013
JP	5317470 B2	7/2013
JP	5444594 B2	1/2014
KR	1020080080306 A	9/2008
KR	1020100007780 A	1/2010
KR	1020100031736 A	3/2010
KR	1020100032888 A	3/2010
KR	1020120052879 A	5/2012
KR	1020120116282 A	10/2012
KR	20130094903 A	8/2013
KR	1020130094903 A	8/2013
KR	20140046541 A	4/2014
KR	20190024926 A	3/2019
KR	102155600 B1	9/2020
WO	2010004877 A1	1/2010
WO	2012015017 A1	2/2012
WO	2012033062 A1	3/2012
WO	2012133644 A1	10/2012
WO	2012137958 A1	10/2012
WO	WO-2013/077362 A1 *	5/2013
WO	2013122402 A1	8/2013
WO	2013165192 A1	11/2013

OTHER PUBLICATIONS

Notice of Allowance issued in KR Patent Application No. 10-2020-0126376, dated Sep. 28, 2021, 2 pp.

Korean Office Action dated Dec. 12, 2019 issued in corresponding Korean Patent Application No. 10-2019-0020496, 136 pages.

Korean Office Action issued by the Korean Patent Office on Nov. 21, 2018, in the examination of the Korean Patent Application No. 10-2013-0157532.

Machine English Translation of Ito et al. (JP 2013-026529 A).

Office Action dated Dec. 17, 2019 in corresponding Korean Patent Application No. 10-2013-0157532.

Office Action issued by the Korean Patent Office on Apr. 18, 2019 in the examination of the Korean Patent Application No. 10-2013-0157532, with English Translation.

Office Action issued by the Korean Patent Office on Nov. 21, 2018, in the examination of the Korean Patent Application No. 1020130157532.

* cited by examiner

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

**CROSS-REFERENCE TO RELATED
APPLICATIONS**

This is a continuation application of U.S. patent application Ser. No. 17/101,379, which is a continuation application filed on Nov. 23, 2020, which claims priority to U.S. patent application Ser. No. 16/177,914, which is a continuation-in-part filed on Nov. 1, 2018, which claims priority to U.S. patent application Ser. No. 14/573,422, filed on Dec. 17, 2014, which claims priority to Korean Patent Application No. 10-2013-0157532, filed on Dec. 17, 2013, and all the benefits accruing therefrom under 35 U.S.C. § 119, the contents of which are incorporated herein in their entireties by reference.

BACKGROUND

1. Field

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

2. Description of the Related Art

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

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

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

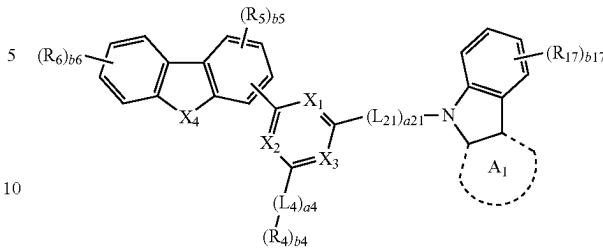
SUMMARY

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

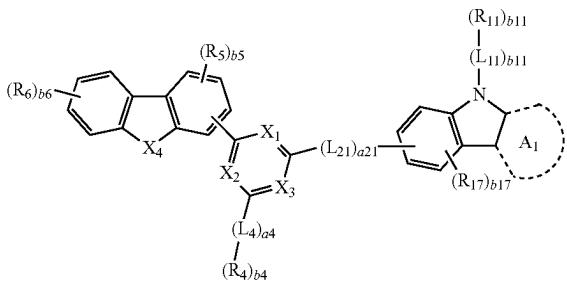
Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments.

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

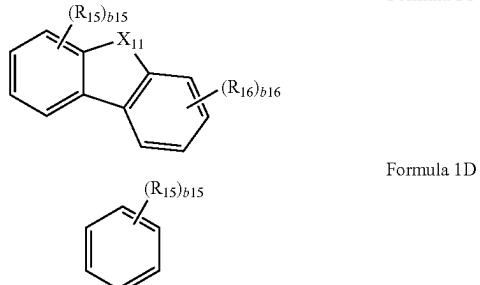
Formula 1A



Formula 1B



Formula 1C



Formula 1D

In the Formulae above, ring A₁ in Formulae 1A and 1B is represented by Formula 1C or 1 D;

X₁ is N or C-[L₁)_{a1}-(R₁)_{b1}], X₂ is N or C-[L₂)_{a2}-(R₂)_{b2}], X₃ is N or C-[L₃)_{a3}-(R₃)_{b3}], and at least one of X₁ to X₃ is N; X₄ is O or S;

X₁₁ is selected from N-[L₁₂)_{a12}-(R₁₂)_{b12}], S, O, S(=O),

S(=O)₂, C(=O), C(R₁₃)(R₁₄), Si(R₁₃)(R₁₄), P(R₁₃),

P(=O)(R₁₃), and C=N(R₁₂);

L₁ to L₄, L₁₁, L₁₂ and L₂₁ may be each independently selected from a substituted or unsubstituted C₃-C₁₀ cycloalkylene group, a substituted or unsubstituted C₂-C₁₀ heterocycloalkylene group, a substituted or unsubstituted C₃-C₁₀ cycloalkenylene group, a substituted or unsubstituted C₂-C₁₀ heterocycloalkenylene group, a substituted or unsubstituted C₆-C₆₀ arylene group, a substituted or unsubstituted C₂-C₆₀ heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic hetero-condensed polycyclic group;

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

R₁ to R₃, R₅, R₆, and R₁₁ to R₁₇ may be each independently selected from a hydrogen, a deuterium, —F (a fluoro group), —Cl (a chloro group), —Br (a bromo group), —I (an iodo group), a hydroxyl group, a cyano

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

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

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

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

a deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a $C_1\text{-}C_{60}$ alkyl group, a $C_2\text{-}C_{60}$ alkenyl group, a $C_2\text{-}C_{60}$ alkynyl group, and a $C_1\text{-}C_{60}$ alkoxy group; a $C_1\text{-}C_{60}$ alkyl group, a $C_2\text{-}C_{60}$ alkenyl group, a $C_2\text{-}C_{60}$ alkynyl group, and a $C_1\text{-}C_{60}$ alkoxy group, each substituted with at least one of a deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro

group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a $C_3\text{-}C_{10}$ cycloalkyl group, a $C_2\text{-}C_{10}$ heterocycloalkyl group, a $C_3\text{-}C_{10}$ cycloalkenyl group, a $C_2\text{-}C_{10}$ heterocycloalkenyl group, a $C_6\text{-}C_{60}$ aryl group, a $C_6\text{-}C_{60}$ aryloxy group, a $C_6\text{-}C_{60}$ arylthio group, a $C_2\text{-}C_{60}$ heteroaryl group, a mono-
valent non-aromatic condensed polycyclic group, a mono-
valent non-aromatic hetero-condensed polycyclic group, $-\text{N}(Q_{11})(Q_{12})$, $-\text{Si}(Q_{13})(Q_{14})(Q_{15})$ and $-\text{B}(Q_{16})(Q_{17})$;

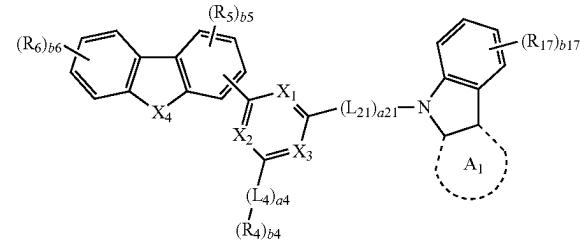
a $C_3\text{-}C_{10}$ cycloalkyl group, a $C_2\text{-}C_{10}$ heterocycloalkyl group, a $C_3\text{-}C_{10}$ cycloalkenyl group, a $C_2\text{-}C_{10}$ heterocycloalkenyl group, a $C_6\text{-}C_{60}$ aryl group, a $C_6\text{-}C_{60}$ aryloxy group, a $C_6\text{-}C_{60}$ arylthio group, a $C_2\text{-}C_{60}$ heteroaryl group, a mono-
valent non-aromatic condensed polycyclic group, and a mono-
valent non-aromatic hetero-condensed polycyclic group;

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

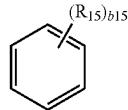
$-\text{N}(Q_{31})(Q_{32})$, $-\text{Si}(Q_{33})(Q_{34})(Q_{35})$ and $-\text{B}(Q_{36})(Q_{37})$; wherein Q_1 to Q_7 , Q_{11} to Q_{17} , Q_{21} to Q_{27} , and Q_{31} to Q_{37} may be each independently selected from a hydrogen, a $C_1\text{-}C_{60}$ alkyl group, a $C_2\text{-}C_{60}$ alkenyl group, a $C_2\text{-}C_{60}$ alkynyl group, a $C_1\text{-}C_{60}$ alkoxy group, a $C_3\text{-}C_{10}$ cycloalkyl group, a $C_2\text{-}C_{10}$ heterocycloalkyl group, a $C_3\text{-}C_{10}$ cycloalkenyl group, a $C_2\text{-}C_{10}$ heterocycloalkenyl group, a $C_6\text{-}C_{60}$ aryl group, a $C_6\text{-}C_{60}$ aryloxy group, a $C_6\text{-}C_{60}$ arylthio group, a $C_2\text{-}C_{60}$ heteroaryl group, a mono-
valent non-aromatic condensed polycyclic group, and a mono-
valent non-aromatic hetero-condensed polycyclic group.

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

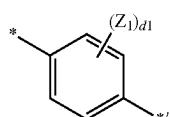
Formula 1A



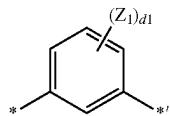
wherein in Formula 1A,
ring A₁ is represented by Formula 1 D;



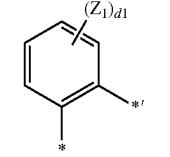
X₁ to X₃ is N;
X₄ is O or S;
L₄ and L₂₁ are each independently selected from groups
represented by Formulae 2-1, 2-2 and 2-34;



Formula 2-1



Formula 2-2



Formula 2-34

wherein in Formulae 2-1, 2-2 and 2-34, Z₁ is selected
from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a
hydroxyl group, a cyano group, a nitro group, an amino
group, an amidino group, a hydrazine group, a hydra-
zone group, a carboxylic acid or a salt thereof, a
sulfonic acid or a salt thereof, a phosphoric acid or a
salt thereof, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy
group and a phenyl group and d1 is selected from
integers of 1 to 4;
a4 is selected from integers 0 to 3 and a21 is 0, 1, 2 or 3;
R₅, R₆, R₁₅ and R₁₇ are each independently selected from
a hydrogen, a deuterium, —F, —Cl, —Br, —I, a
hydroxyl group, a cyano group, a nitro group, an amino
group, an amidino group, a hydrazine group, a hydra-
zone group, a carboxylic acid or a salt thereof, a
sulfonic acid or a salt thereof, a phosphoric acid or a
salt thereof, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy
group;

R₄ is selected from:

a phenyl group; and
a phenyl group, substituted with at least one of a deute-
rium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano
group, a nitro group, an amino group, an amidino
group, a hydrazine group, a hydrazone group, a car-
boxylic acid or a salt thereof, a sulfonic acid or a salt
thereof, a phosphoric acid or a salt thereof, a C₁-C₂₀
alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group,
and a biphenyl group; and

b4 to b6, b15 and b17 are each independently selected
from integers of 1 to 3.

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

a first electrode;
a second electrode; and
an organic layer disposed between the first electrode and
the second electrode,
wherein the organic layer includes an emission layer and
at least one condensed-cyclic compound described
above.

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

BRIEF DESCRIPTION OF THE DRAWING

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

20 the FIG. is a schematic view showing an organic light-
emitting device according to an embodiment.

DETAILED DESCRIPTION

25 Reference will now be made in detail to embodiments,
examples of which are illustrated in the accompanying
drawings, wherein like reference numerals refer to the like
elements throughout. In this regard, the present embodi-
ments may have different forms and should not be construed
30 as being limited to the descriptions set forth herein. Accord-
ingly, the embodiments are merely described below, by
referring to the figures, to explain aspects of the present
description. As used herein, the term "and/or" includes any
35 and all combinations of one or more of the associated listed
items. Expressions such as "at least one of," when preceding
a list of elements, modify the entire list of elements and do
not modify the individual elements of the list.

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

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

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

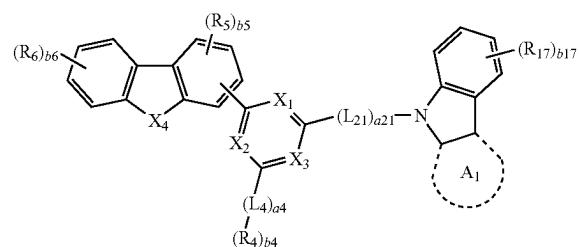
The term "or" means "and/or." It will be further under-
stood that the terms "comprises" and/or "comprising," or
"includes" and/or "including" when used in this specifica-
tion, specify the presence of stated features, regions, inte-
gers, steps, operations, elements, and/or components, but do
60 not preclude the presence or addition of one or more other
features, regions, integers, steps, operations, elements, com-
ponents, and/or groups thereof.

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

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

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

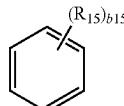
Formula 1A



35

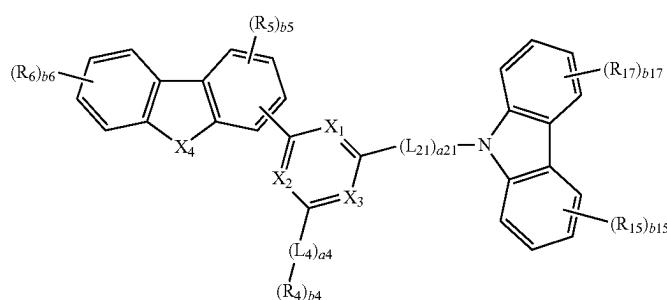
40

Formula 1D



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

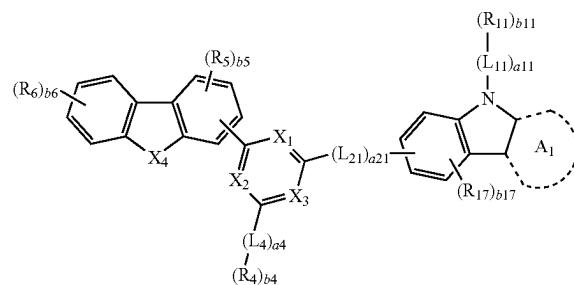
Formula 1A-1



8

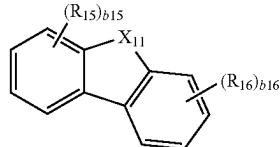
-continued

Formula 1B



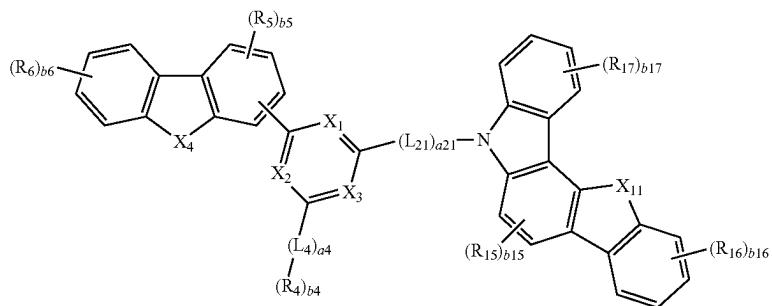
ring A_1 in Formula 1A and 1B may be represented by Formula 1C or 1 D.

Formula 1C



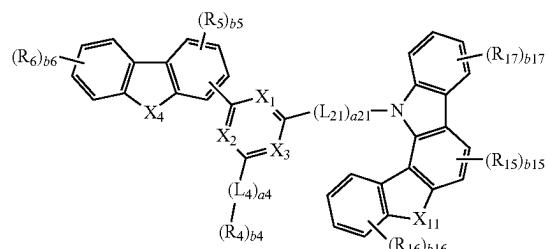
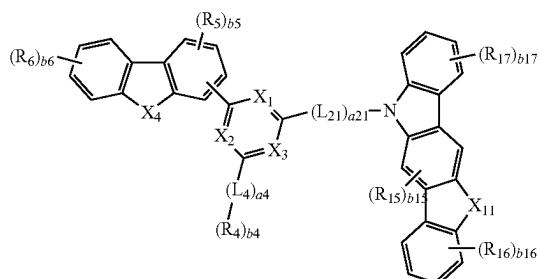
-continued

Formula 1A-2

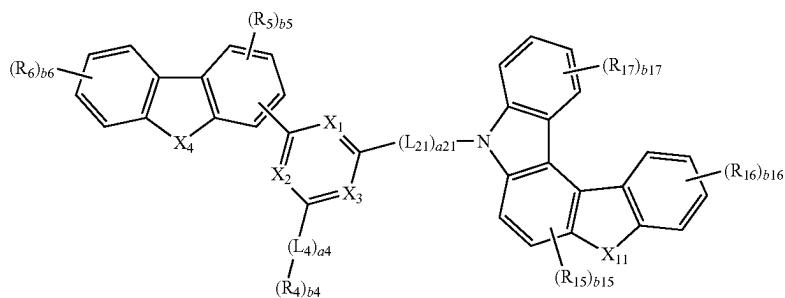


Formula 1A-3

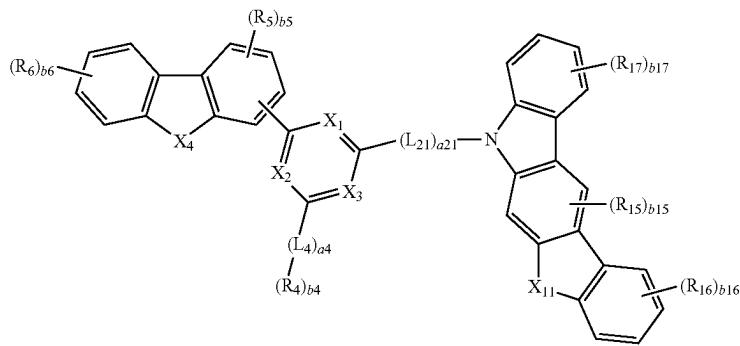
Formula 1A-4



Formula 1A-5

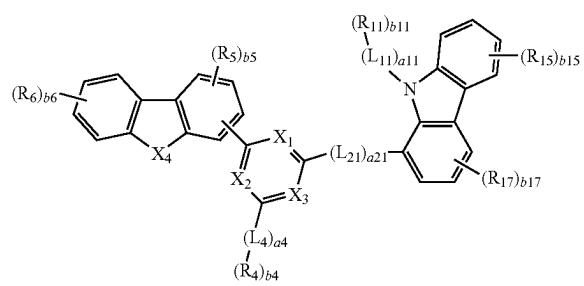
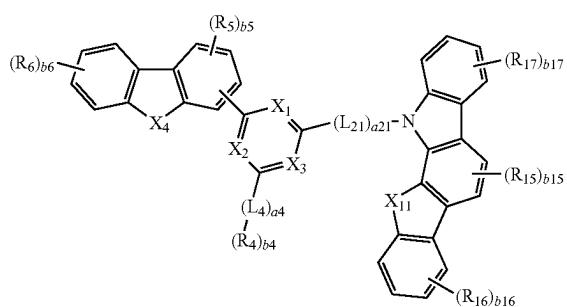


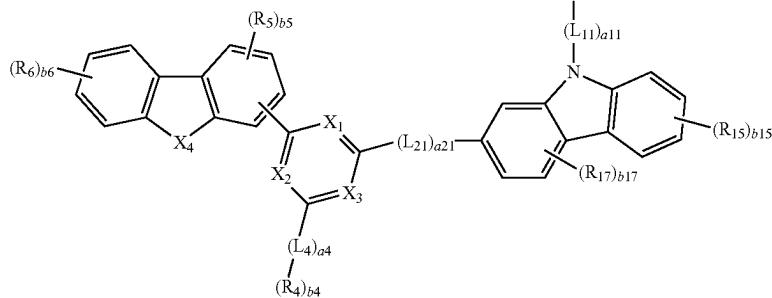
Formula 1A-6



Formula 1A-7

Formula 1B-1

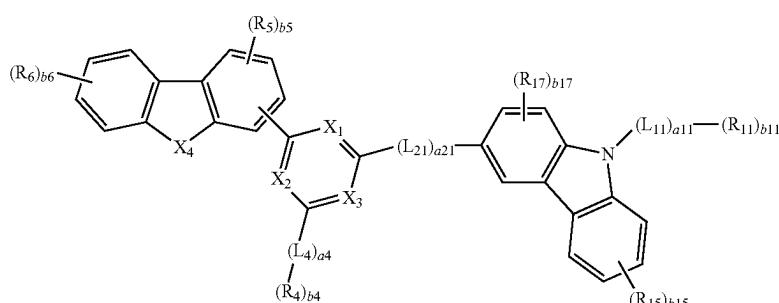


11

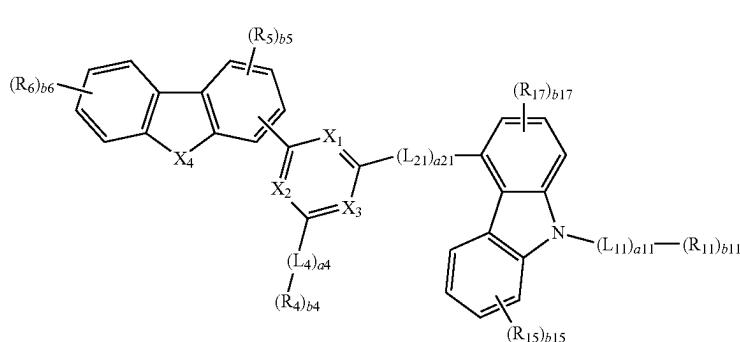
-continued

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Formula 1B-2



Formula 1B-3



Formula 1B-4

Descriptions of Formulae 1A-1 to 1A-7 and 1B-1 to 1B-4,

X₁ to X₄, L₁ to L₄, L₁₁, L₁₂, L₂₁, a1 to a4, a11, a12, a21,

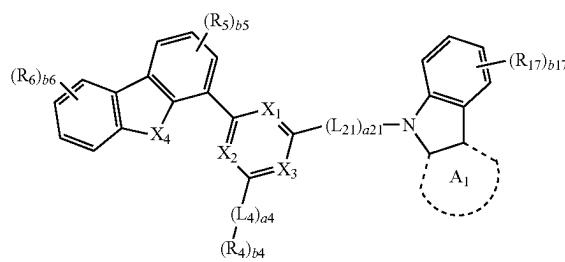
R₁ to R₆, R₁₁ to R₁₇, b1 to b6, and b11 to b17 are given 55 below.

According to an embodiment, the condensed-cyclic compound may be represented by Formula 1A-1, 1A-2, 1A-3, 1B-1, 1B-2, 1B-3, or 1B-4, but it is not limited thereto. 60

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

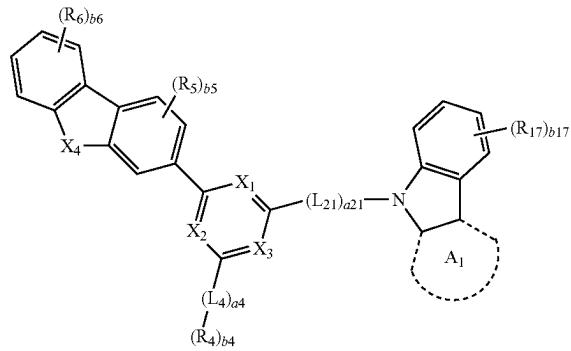
Formulae 1A and 1B may be represented by any one of 65 Formulae 1A(1) to 1A(4) and 1B(1) to 1B(4), but they are not limited thereto:

Formula 1A(1)

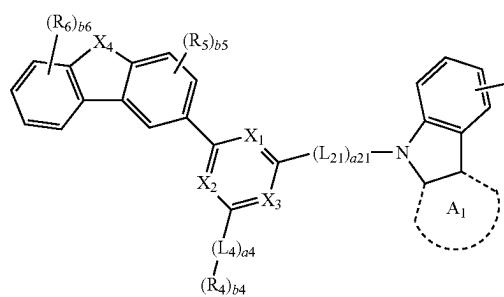


13

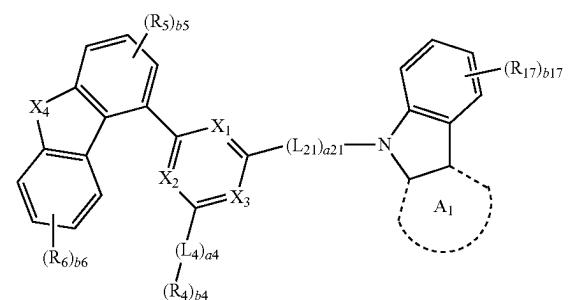
-continued



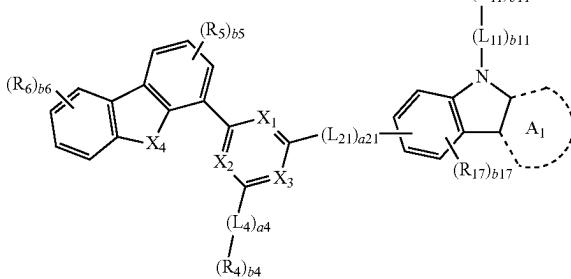
Formula 1A(2)



Formula 1A(3)



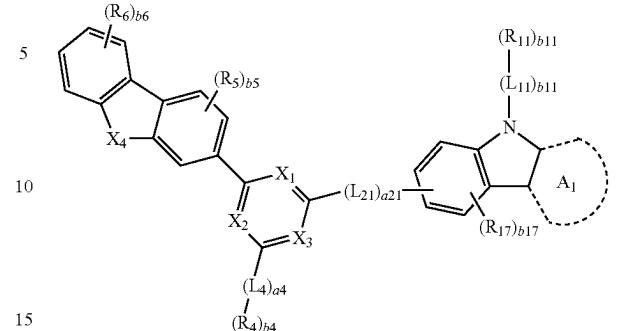
Formula 1A(4)



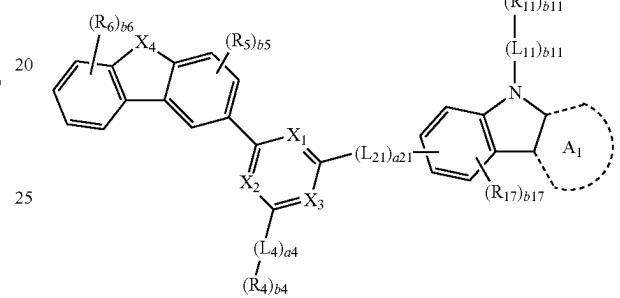
Formula 1B(1)

14

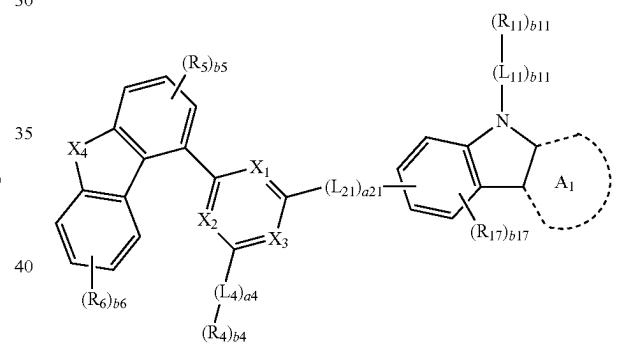
-continued



Formula 1B(2)



Formula 1B(3)



Formula 1B(4)

45 In Formulae 1A(1) to 1A(4) and 1B(1) to 1B(4), descriptions of ring A1, X₁ to X₄, X₁₁, L₁ to L₄, 11, L₁₂, L₂₁, a1 to a4, a11, a12, a21, R₁ to R₆, R₁₁ to R₁₇, b1 to b6, and b11 to b17 are given below.

In Formula 1C, X₁₁ is selected from N-[L₁₂)_{a12}-
50 (R₁₂)_{b12}], S, O, S(=O), S(=O)₂, C(=O), C(R₁₃)(R₁₄), Si(R₁₃)(R₁₄), P(R₁₃), P(=O)(R₁₃), and C=N(R₁₂). For example, in Formula 1C, X₁₁ may be selected from N-[L₁₂)_{a12}-
(R₁₂)_{b12}], S, O, and C(R₁₃)(R₁₄), but it is not limited thereto. Descriptions of L₁₂, a12, R₁₂ to R₁₄, and b12
55 may be understood by referring to the description below.

In Formula 1A and 1B, X₁ is N or C-[L₁)_{a1}-(R₁)_{b1}], X₂ is N or C-[L₂)_{a2}-(R₂)_{b2}], X₃ is N or C-[L₃)_{a3}-(R₃)_{b3}], and at least one of X₁ to X₃ is N.

For example, in Formulae 1A and 1B, X₁ to X₃ may be N; X₁ may be C-[L₁)_{a1}-(R₁)_{b1}], X₂ and X₃ may be N; X₁ may be N, X₂ may be C-[L₂)_{a2}-(R₂)_{b2}], and X₃ may be N; X₁ and X₂ may be N, and X₃ may be C-[L₃)_{a3}-(R₃)_{b3}]; X₁ may be C-[L₁)_{a1}-(R₁)_{b1}], X₂ may be N, and X₃ may be C-[L₃)_{a3}-(R₃)_{b3}]; X₁ may be C-[L₁)_{a1}-(R₁)_{b1}], X₂ may be C-[L₂)_{a2}-(R₂)_{b2}], and X₃ may be N; or

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

According to an embodiment,

X_1 may be C-[$(L_1)_{a1}$ - $(R_1)_{b1}$], X_2 and X_3 may be N; or X_1 and X_2 may be N, and X_3 may be C-[$(L_3)_{a3}$ - $(R_3)_{b3}$], 5 but they are not limited thereto.

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

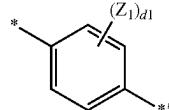
In Formulae 1A, 1B, and 1C, L_1 to L_4 , L_{11} , L_{12} , and L_{21} may be each independently selected from a substituted or 10 unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_2 - C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkenylene group, a substituted or unsubstituted C_2 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6 - C_{60} arylene group, 15 a substituted or unsubstituted C_2 - C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic hetero-condensed polycyclic group.

For example, in Formulae 1A, 1B, and 1C, L_1 to L_4 , 11, 20 L_{12} , and L_{21} may be each independently selected from:

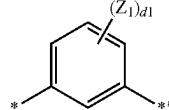
a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an ace-naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a phenalenylene group, a phenanthrenylene group, 25 an anthracenylene group, a fluoranthrenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a peryenylene group, a pentaphenylene group, a hexacenylene group, a pyrrolylene group, an imidazolylene group, a pyrazolylene group, 30 a pyridinylene group, a pyrimidinylene group, a pyridazinylene group, an isoindolylene group, an indolylene group, an indazolylene group, a purinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, 35 a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a cinnolinylene group, a carbazolylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzoxazolylene group, 40 a benzothiophenylene group, a thiazolylene group, an isothiazolylene group, a benzothiazolylene group, an isoxazolylene group, an oxazolylene group, a triazolylene group, a tetrazolylene group, an oxadiazolylene group, a triazinylene group, a dibenzofuranylene group, 45 a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, an imidazopyrimidinylene group, and an imidazopyridinylene group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a C_6 - C_{20} aryl group, a C_2 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic hetero-condensed cyclic group, and —Si(Q_{33})(Q_{34})(Q_{35}), Q_{33} to Q_{35} may be each independently selected from a hydrogen, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group, but they are not limited thereto.

For example, in Formulae 1A, 1B, and 1C, L_1 to L_4 , L_{11} , 40 L_{12} , and L_{21} may be each independently selected from Formulae 2-1 to 2-34:

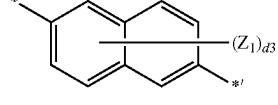
Formula 2-1



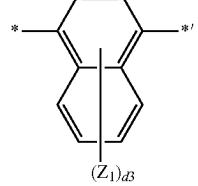
Formula 2-2



Formula 2-3



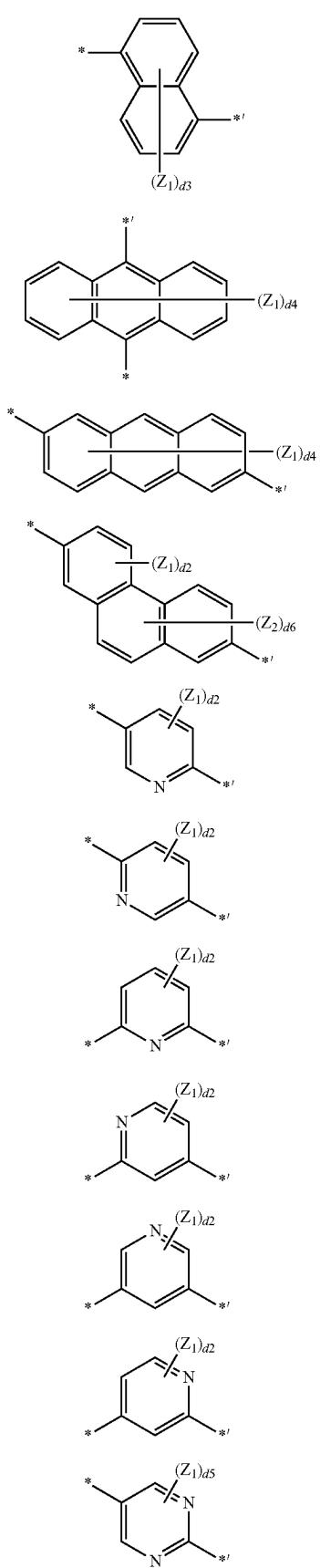
Formula 2-4



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zolylene group, a purinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a cinnolinylene group, a carbazolylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzoxazolylene group, a benzothiophenylene group, a thiazolylene group, an isothiazolylene group, a benzothiazolylene group, an isoxazolylene group, an oxazolylene group, a triazolylene group, a tetrazolylene group, an oxadiazolylene group, a triazinylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, an imidazopyrimidinylene group, and an imidazopyridinylene group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a C_6 - C_{20} aryl group, a C_2 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic hetero-condensed cyclic group, and —Si(Q_{33})(Q_{34})(Q_{35}), Q_{33} to Q_{35} may be each independently selected from a hydrogen, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group, but they are not limited thereto.

For example, in Formulae 1A, 1B, and 1C, L_1 to L_4 , L_{11} , 40 L_{12} , and L_{21} may be each independently selected from Formulae 2-1 to 2-34:

17
-continued

Formula 2-5

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Formula 2-6 10

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Formula 2-7

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Formula 2-8

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Formula 2-9 30

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Formula 2-10 40

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Formula 2-12

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Formula 2-13

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Formula 2-14

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Formula 2-15

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-continued

Formula 2-16

Formula 2-17

Formula 2-18

Formula 2-19

Formula 2-20

Formula 2-21

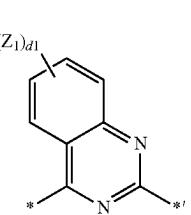
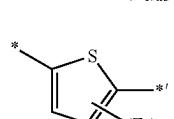
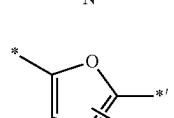
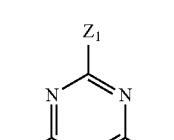
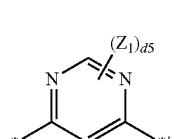
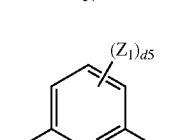
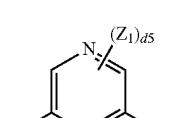
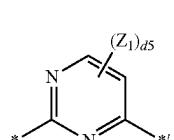
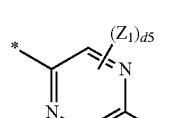
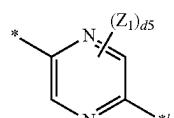
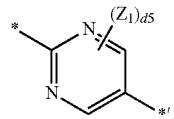
Formula 2-22

Formula 2-23

Formula 2-24

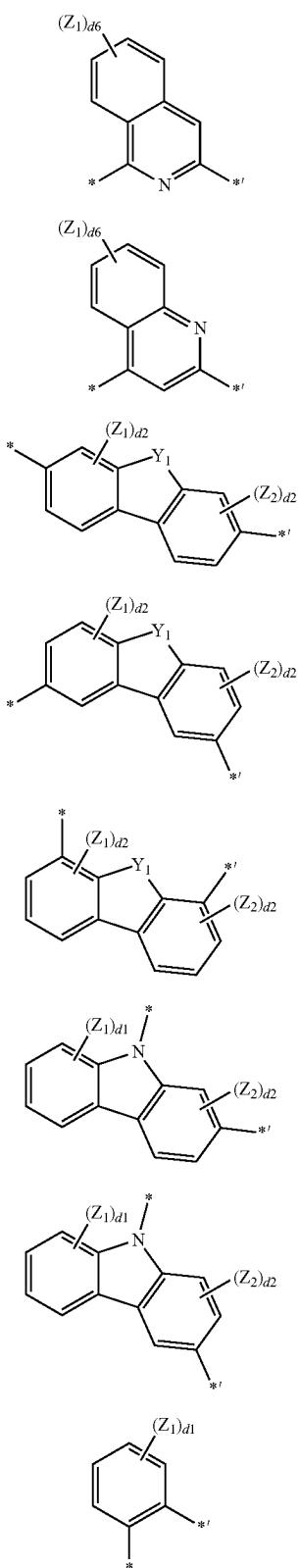
Formula 2-25

Formula 2-26



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-continued



In Formula 2-1 to 2-34,

Y₁ may be selected from O, S, S(=O), S(=O)₂, C(Z₃)_{d1}, N(Z₅), or Si(Z₆)(Z₇);**20**

Z₁ to Z₇ may be each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenlyl group, a chrysanyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, a isoquinolinyl group, a quinazolinyl group, a biphenyl group, and —Si(Q₃₃)(Q₃₄)(Q₃₅); wherein Q₃₃ to Q₃₅ may be each independently selected from a hydrogen, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenlyl group, a chrysanyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, a biphenyl group, and a quinoxaliny group; d₁ is selected from integers of 1 to 4, d₂ is selected from integers of 1 to 3, d₃ is selected from integers of 1 to 6, d₄ is selected from integers of 1 to 8, d₅ is 1 or 2, d₆ is selected from integers of 1 to 5, and each of * and *' indicates a bonding site to neighboring atoms.

For example, in Formulae 2-1 to 2-34, *' indicates a bonding site to neighboring atoms of L₁ to L₄, L₁₁, L₁₂, and L₂₁ or bonding site to each of R₁ to R₄, R₁₁, R₁₂, and R₂₁.

According to an embodiment, in Formulae 1A and 1B, L₁ to L₄, L₁₁, L₁₂, and L₂₁ may be each independently selected from Formulae 2-1 to 2-5, 2-9 to 2-23, and 2-34, but they are not limited thereto.

According to another embodiment, in Formulae 1A and 1B, L₁ to L₄, L₁₁, L₁₂, and L₂₁ may be each independently selected from:

- 45 a phenylene group and a naphthylene group; and a phenylene group and a naphthylene group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenlyl group, a chrysanyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, a biphenyl group, and —Si(Q₃₃)(Q₃₄)(Q₃₅) (wherein Q₃₃ to Q₃₅ may be each independently selected from a hydrogen, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenlyl group, a chrysanyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarba-

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zolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxaliny group, but they are not limited thereto.

In Formula 1A, a_1 represents the number of groups L_i , which may be 0, 1, 2, or 3, for example, 0, 1, or 2, or may be 0 or 1. When a_1 is 0, $-(L_i)_{a_1}$ is a single bond. When a_1 is 2 or greater, two or more groups L_i may be the same or different. Descriptions of a_2 to a_4 , a_{11} , a_{12} , and a_{21} may be understood by referring to the description of a_1 and structures of Formulae 1A and 1B.

According to an embodiment, in Formulae above, a_1 to a_4 , a_{11} , a_{12} , and a_{21} may be each independently, 0, 1, or 2.

According to another embodiment, in Formulae above, a_{21} may be 1, but it is not limited thereto.

In Formulae 1A, 1B, 1C, and 1D, R_1 to R_3 , R_5 , R_6 , and R_{11} to R_{17} may be each independently selected from a hydrogen, a deuterium, —F (a fluoro group), —Cl (a chloro group), —Br (a bromo group), —I (an iodo group), a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a substituted or unsubstituted C_1 - C_{20} alkyl group, a substituted or unsubstituted C_2 - C_{60} alkenyl group, a substituted or unsubstituted C_1 - C_{60} alkynyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_2 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_2 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_2 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic hetero-condensed polycyclic group, —N(Q_1)(Q_2), —Si(Q_3)(Q_4)(Q_5), and —B(Q_6)(Q_7). Here, descriptions of Q_1 to Q_7 are as described below.

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

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

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

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

nyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, —Si(Q₃₃)(Q₃₄)(Q₃₅), a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and a biphenyl group; and

—Si(Q₃)(Q₄)(Q₅) (provided that, R₁₃ and R₁₄ are not —Si(Q₃)(Q₄)(Q₅)),

wherein Q₃ to Q₅ and Q₃₃ to Q₃₅ may be each independently selected from a hydrogen, C₁-C₂₀ alkyl group, C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group, but they are not limited thereto.

According to another embodiment, in Formulae 1A, 1B, 1C, and 1D, R₁ to R₃, R₅, R₆, and R₁₃ to R₁₇ may be each independently selected from:

a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a

salt thereof, a phosphoric acid or a salt thereof, a 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 of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, and a phosphoric acid or a salt thereof; a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group; a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, —Si(Q₃₃)(Q₃₄)(Q₃₅), a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group; and

—Si(Q₃)(Q₄)(Q₅), provided that R₁₃ and R₁₄ are not —Si(Q₃)(Q₄)(Q₅),

wherein Q₃ to Q₅ and Q₃₃ to Q₃₅ may be each independently selected from a hydrogen, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group.

Meanwhile, in Formulae 1A and 1B, R₄, R₁₁, and R₁₂ may be each independently selected from:

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

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

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a 25 phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and

³⁵ each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group,

⁴⁰ a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, and a phosphoric acid or a salt thereof;

⁴⁵ each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, —Si(Q₃₃)(Q₃₄)(Q₃₅), a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, a 50 azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a 55 perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and

⁶⁰ each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, —Si(Q₃₃)(Q₃₄)(Q₃₅), a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, a 65 azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl

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

Q₃₃ to Q₃₅ may be each independently selected from a hydrogen, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group.

According to another embodiment, in Formulae 1A, 1B, 1C, and 1D,

R₁ to R₃, R₅, R₆, and R₁₃ to R₁₇ may be each independently selected from:

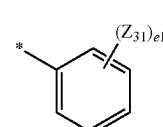
a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group;

a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, and a phosphoric acid or a salt thereof;

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

—Si(Q₃)(Q₄)(Q₅) (provided that, R₁₃ and R₁₄ are not —Si(Q₃)(Q₄)(Q₅)),

wherein, R₄, R₁₁, and R₁₂ may be each independently selected from Formulae 4-1 to 4-31 (for example, Formulae 4-1 to 4-3 and 4-6 to 4-13), but they are not limited thereto.

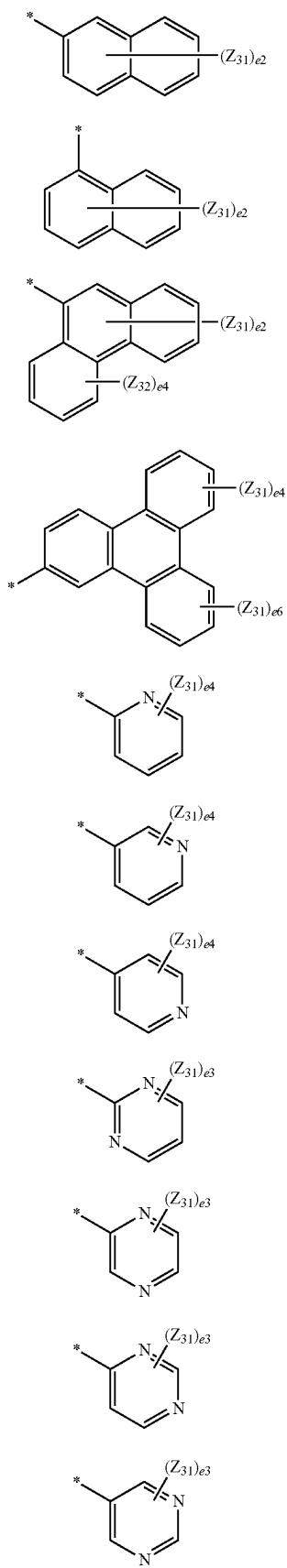


Formula 4-1

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Formula 4-2

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Formula 4-3

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Formula 4-4

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Formula 4-5 20

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Formula 4-6 30

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Formula 4-7 35

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Formula 4-8 45

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Formula 4-10 55

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Formula 4-11

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Formula 4-12

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Formula 4-13

Formula 4-14

Formula 4-15

Formula 4-16

Formula 4-17

Formula 4-18

Formula 4-19

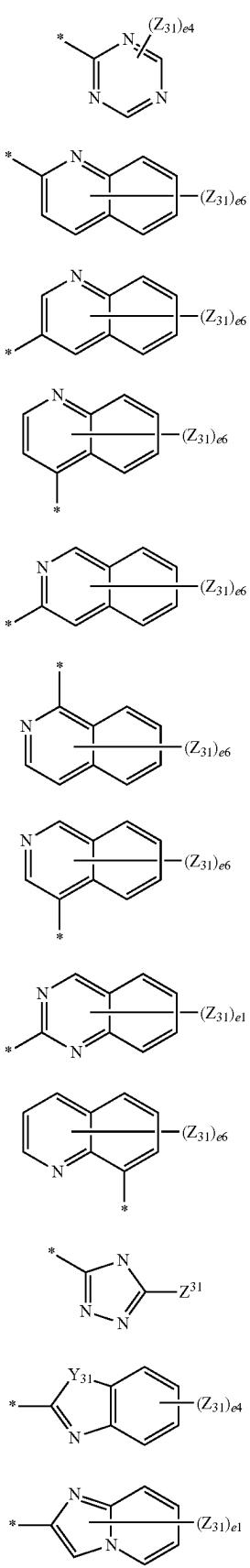
Formula 4-20

Formula 4-21

Formula 4-22

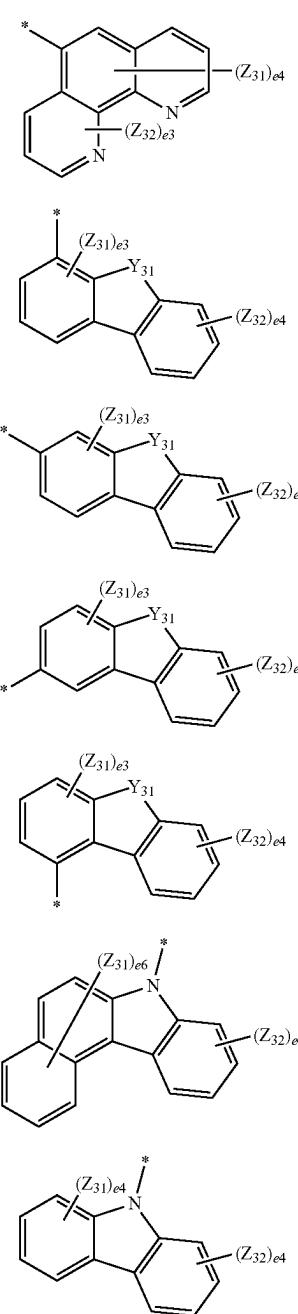
Formula 4-23

Formula 4-24



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Formula 4-25

5 Q_3 to Q_5 and Q_{33} to Q_{35} may be each independently selected from a hydrogen, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysene group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, a quinoxalinyl group, a biphenyl group, and —Si(Q_{33})(Q_{34})(Q_{35})

10 group; e_1 to Q_5 and Q_{33} to Q_{35} may be each independently selected from a hydrogen, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysene group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, and a quinoxalinyl group;

15 e_1 may be selected from integers of 1 to 5,
 e_2 is selected from integers of 1 to 7,
 e_3 is selected from integers of 1 to 3,
 e_4 is selected from integers of 1 to 4,
 e_5 is 1 or 2,

20 e_6 is selected from integers of 1 to 6, and
* indicates a bonding site to a neighboring atom.

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

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

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

35 —Si(Q_3)(Q_4)(Q_5) (provided that, R_{13} and R_{14} are not —Si(Q_3)(Q_4)(Q_5) and Q_3 to 05 are each independently selected from a hydrogen, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, and a naphthyl group);
40 R_4 , R_{11} , and R_{12} are each independently selected from:
a phenyl group and a naphthyl group; and
a phenyl group and a naphthyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, and a naphthyl group; but, they are not limited thereto.

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

50 In Formulae 1A and 1B, b_1 represents the number of groups R_1 and may be selected from integers of 1 to 3. For example, b_1 may be 1 or 2. In greater detail, b_1 may be 1.

In Formulae 4-1 to 4-31,

Y_{31} may be O, S, C(Z_{33})(Z_{34}), N(Z_{35}) or Si(Z_{36})(Z_{37});
55 Z_{31} to Z_{37} may be each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysene group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a

60 dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, a quinoxalinyl group, a biphenyl group, and —Si(Q_{33})(Q_{34})(Q_{35}))

65 group; e_1 to Q_5 and Q_{33} to Q_{35} may be each independently selected from a hydrogen, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a chrysene group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzofuranyl group, a

65 dibenzothiophenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinazolinyl group, a quinoxalinyl group, a biphenyl group, and —Si(Q_{33})(Q_{34})(Q_{35}))

31

When b1 is 2 or greater, two or more of groups R₁ may be the same or different. Descriptions of b2 to b6 and b11 to b17 may be understood by referring to the description of b1 and structures of Formulae 1A, 1B, 1C, and 1 D.

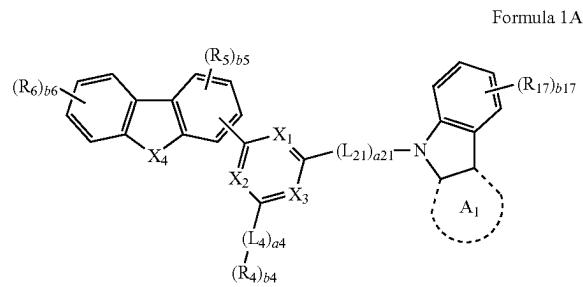
According to an embodiment, at least one substituent of the substituted C₃-C₁₀ cycloalkylene group, substituted C₂-C₁₀ heterocycloalkylene group, substituted C₃-C₁₀ cycloalkenylene group, substituted C₂-C₁₀ heterocycloalkenylene group, substituted C₆-C₆₀ arylene group, substituted C₂-C₆₀ heteroarylene group, substituted divalent non-aromatic condensed polycyclic group, substituted divalent non-aromatic hetero-condensed polycyclic group, substituted C₁-C₆₀ alkyl group, substituted C₂-C₆₀ alkenyl group, substituted C₂-C₆₀ alkynyl group, substituted C₁-C₆₀ alkoxy group, substituted C₃-C₁₀ cycloalkyl group, substituted C₂-C₁₀ heterocycloalkyl group, substituted C₃-C₁₀ cycloalkenyl group, substituted C₂-C₁₀ heterocycloalkenyl group, substituted C₆-C₆₀ aryl group, substituted C₆-C₆₀ aryloxy group, substituted C₆-C₆₀ arylthio group, substituted C₂-C₆₀ heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic hetero-condensed polycyclic group may be selected from:

- a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;
- a C₁-C₆₀ alkyl group, C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₃-C₁₀ cycloalkyl group, a C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₂-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic hetero-condensed polycyclic group, —N(Q₁₁)(Q₁₂), —Si(Q₁₃)(Q₁₄)(Q₁₅) and —B(Q₁₆) (Q₁₇);
- a C₃-C₁₀ cycloalkyl group, a C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₂-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic hetero-condensed polycyclic group;
- a C₃-C₁₀ cycloalkyl group, a C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₂-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic hetero-condensed polycyclic group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

32

a C₃-C₁₀ cycloalkyl group, a C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₂-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic hetero-condensed polycyclic group, —N(Q₂₁)(Q₂₂), —Si(Q₂₃)(Q₂₄)(Q₂₅), and —B(Q₂₆)(Q₂₇); and —N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₅) and —B(Q₃₆)(Q₃₇); wherein Q₁ to Q₇, Q₁₁ to Q₁₇, Q₂₁ to Q₂₇ and Q₃₁ to Q₃₇ may be each independently selected from a hydrogen, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₂-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic hetero-condensed polycyclic group.

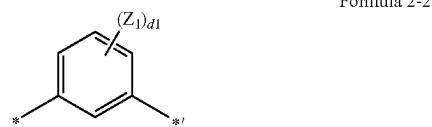
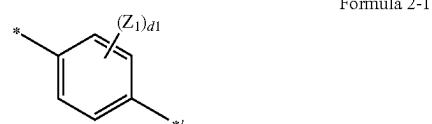
According to one or more embodiments, provided is a condensed-cyclic compound represented by Formula 1A:



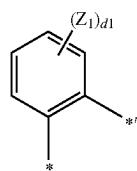
wherein in Formula 1A,
ring A₁ is represented by Formula 1 D;



X₁ to X₃ is N;
X₄ is O or S;
L₄ and L₂₁ are each independently selected from groups represented by Formulae 2-1, 2-2 and 2-34;



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Formula 2-34

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wherein in Formulae 2-1, 2-2 and 2-34, Z_1 is selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group and a phenyl group and $d1$ is selected from integers of 1 to 4;

15

a4 is selected from integers 0 to 3 and a21 is 0, 1, 2 or 3 (or a21 may be 1 or 2);

R_5 , R_6 , R_{15} and R_{17} are each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

20

R_4 is selected from:

a phenyl group; and

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

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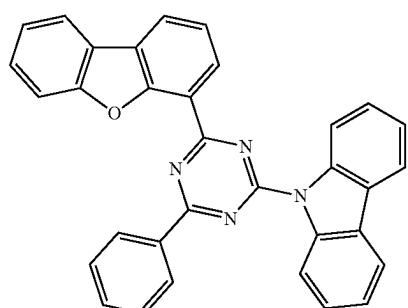
b4 to b6, b15 and b17 are each independently selected from integers of 1 to 3.

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For example, a condensed-cyclic compound represented by Formula 1A described above may be represented by one of Formulae 1A(1) to 1A(4) described herein.

The condensed-cyclic compound may be any one of Compounds 1 to 825, but it is not limited thereto:

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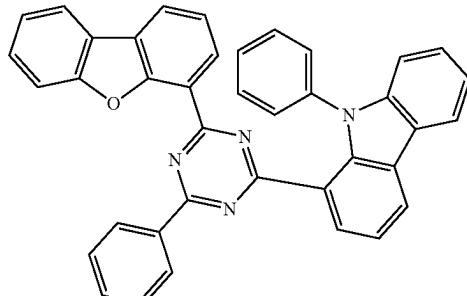
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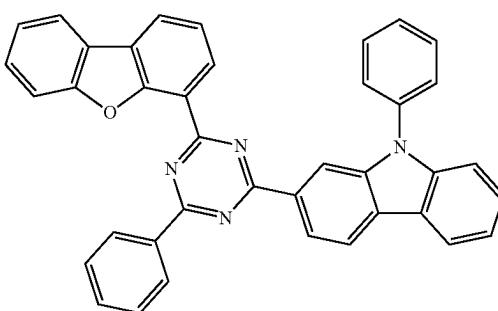
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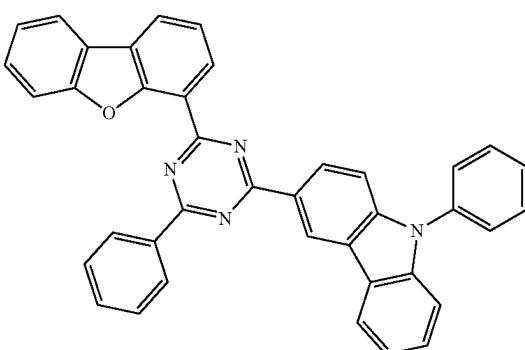
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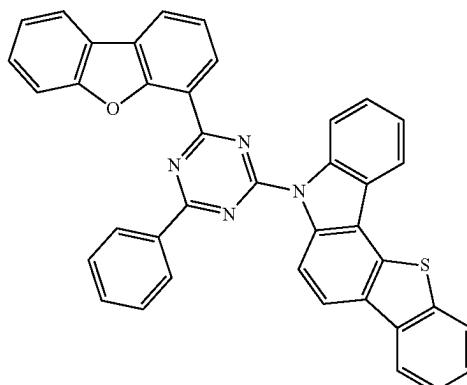
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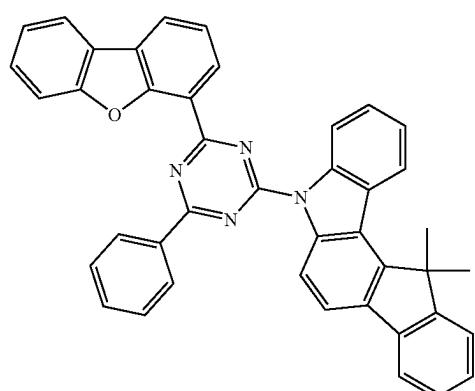


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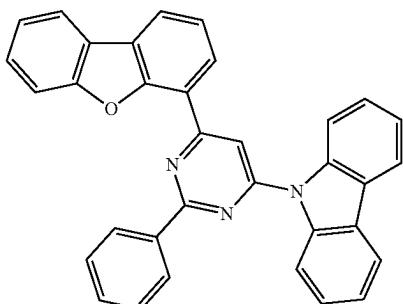
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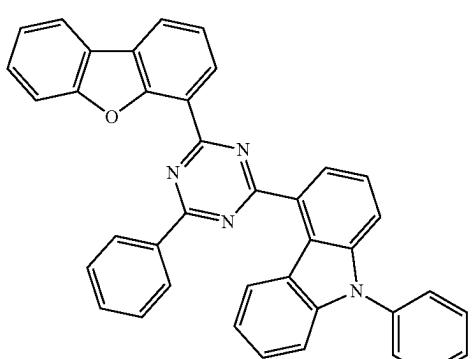
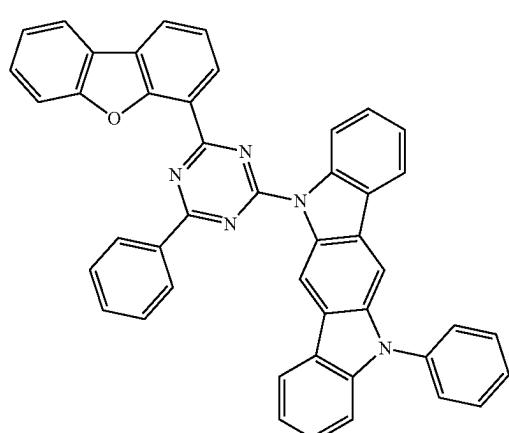
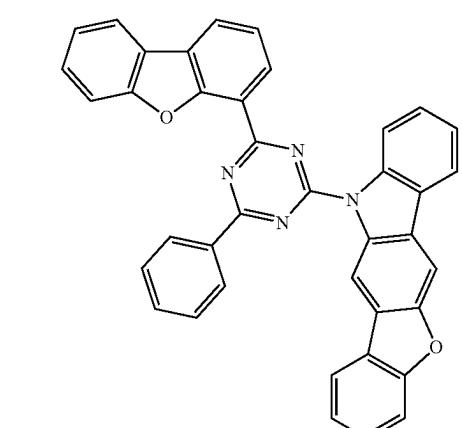
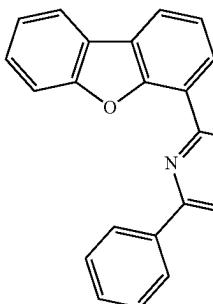
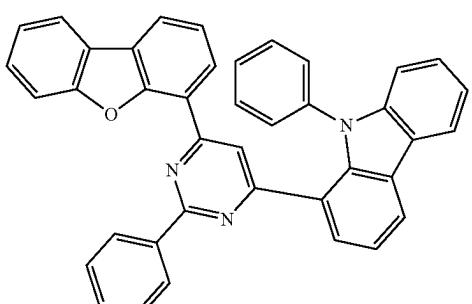


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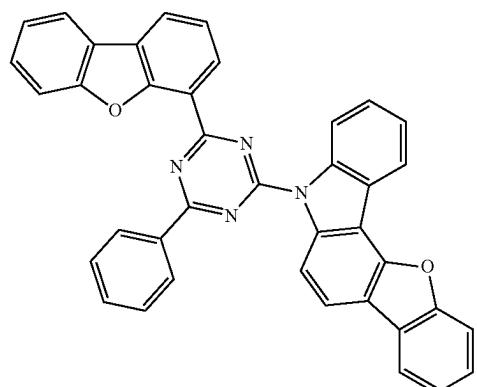
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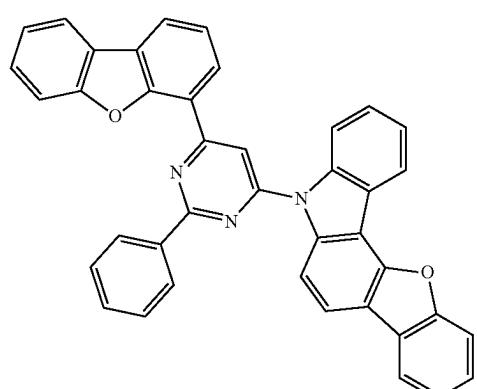


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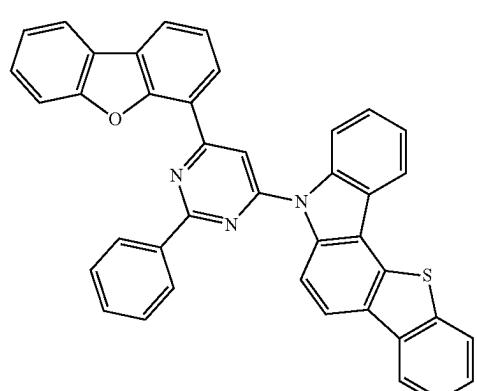
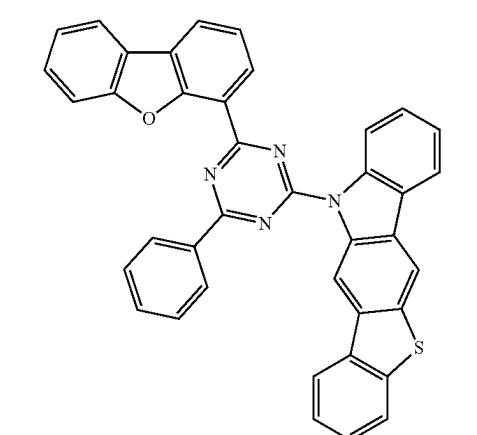
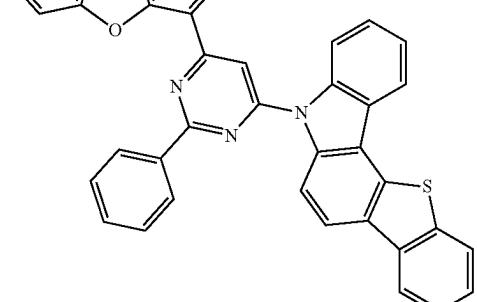
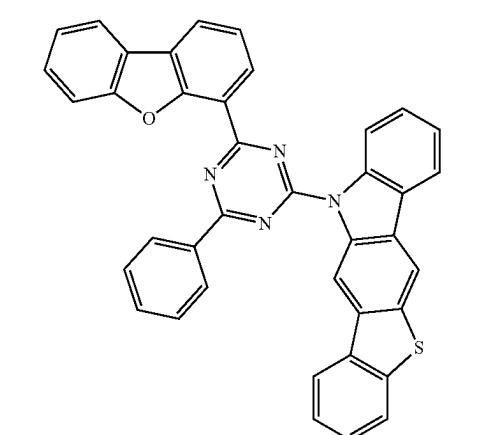
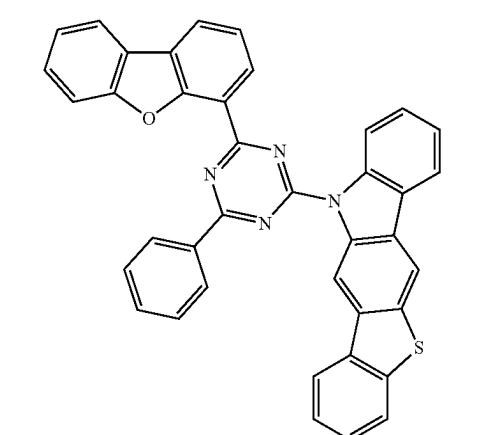
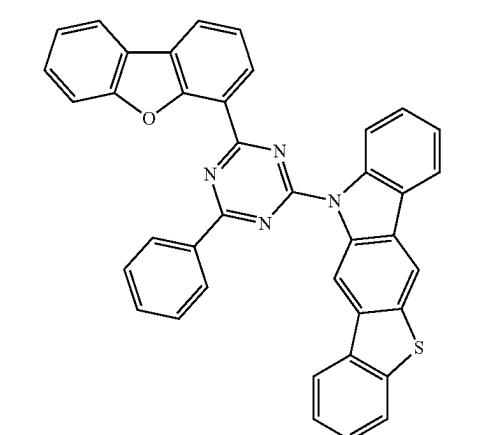
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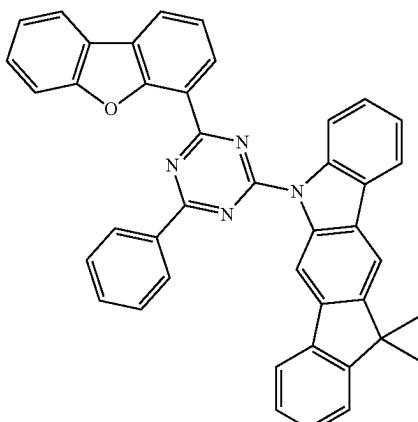
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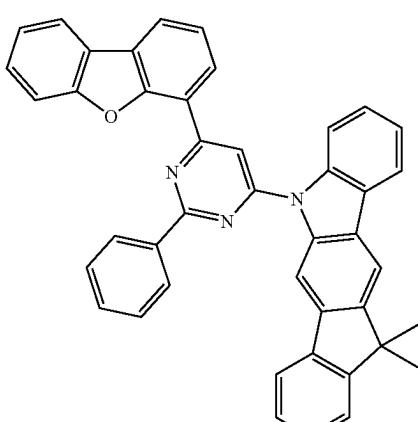
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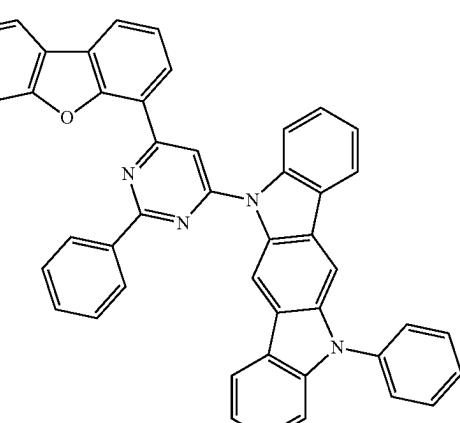
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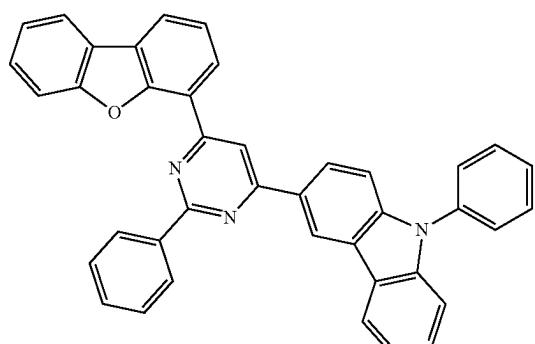
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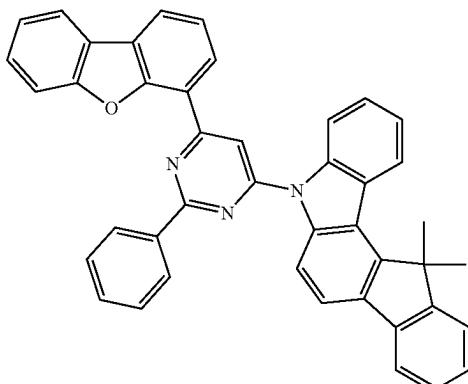
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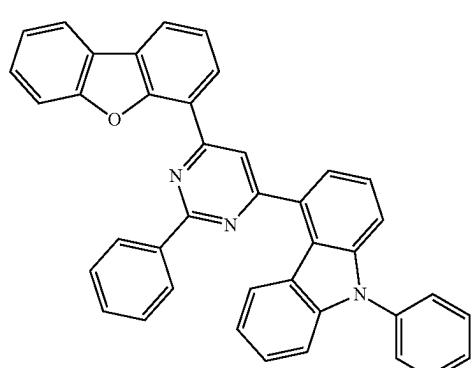
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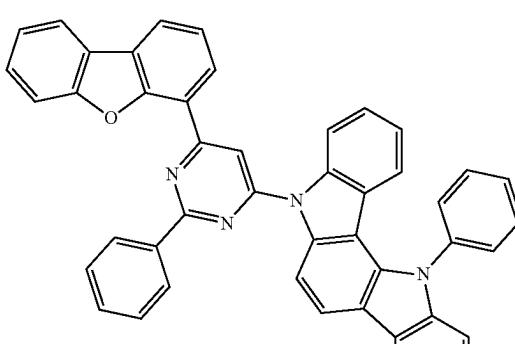
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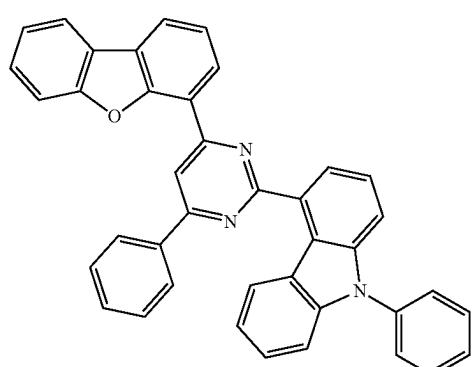
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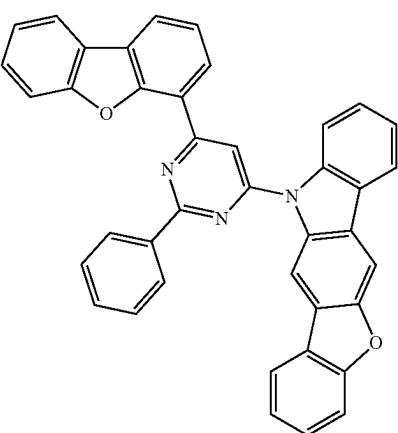
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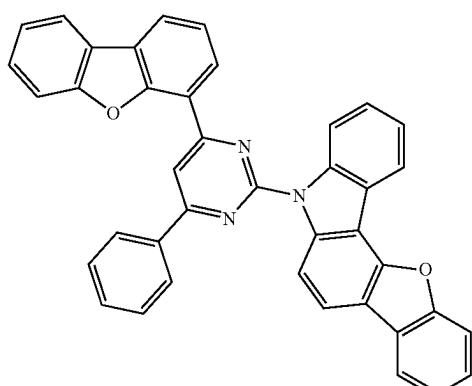
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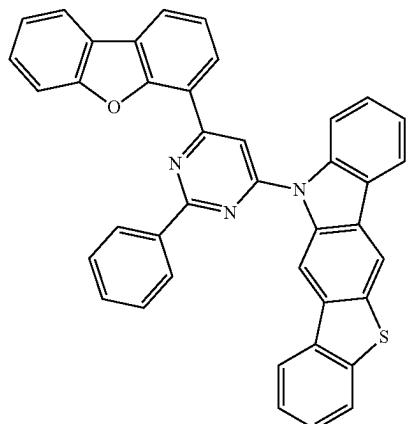
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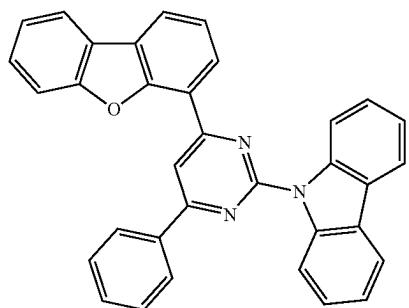
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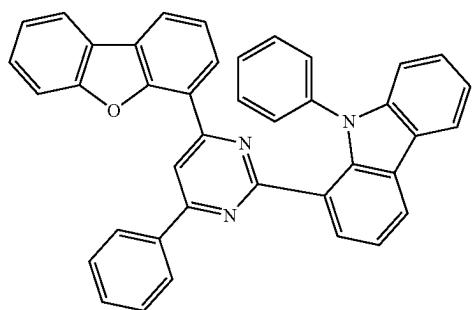
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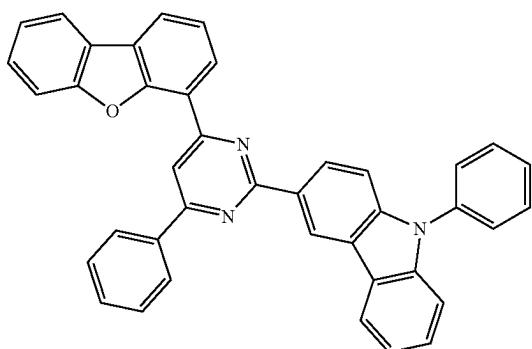
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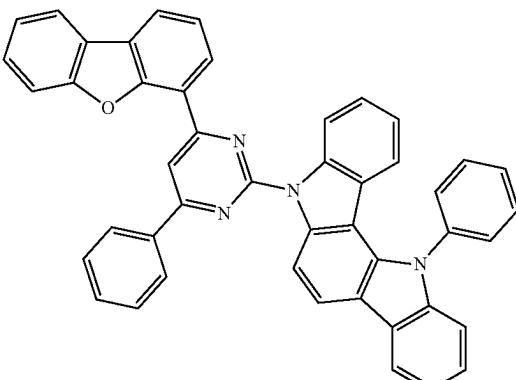
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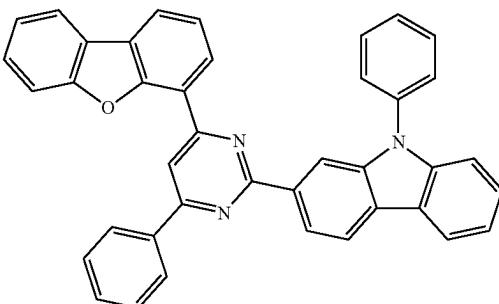
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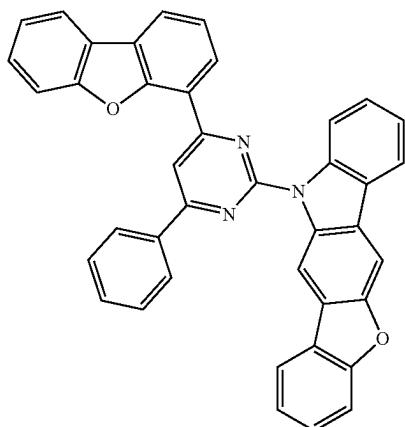
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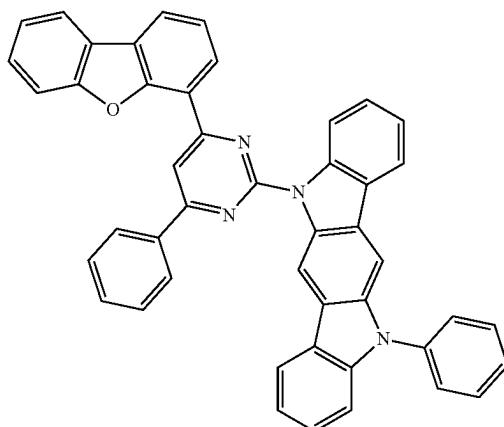
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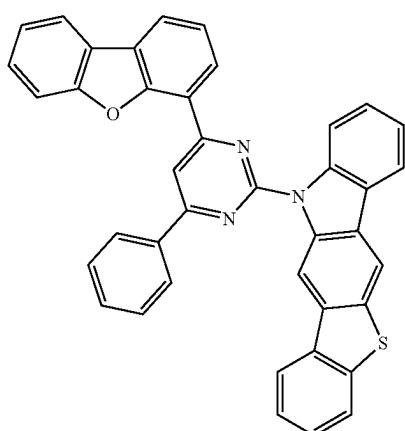
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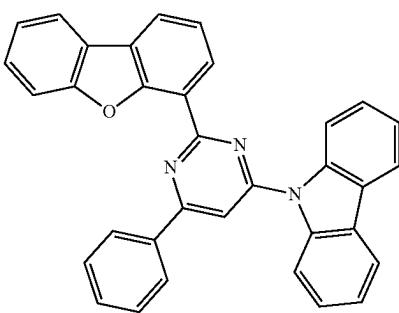
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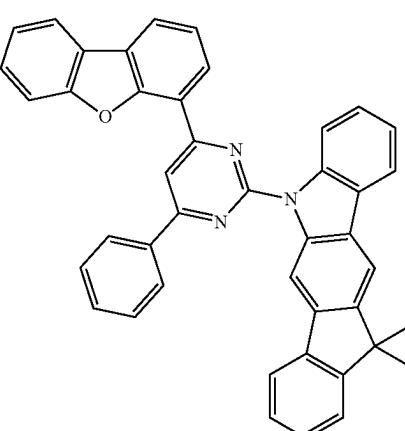
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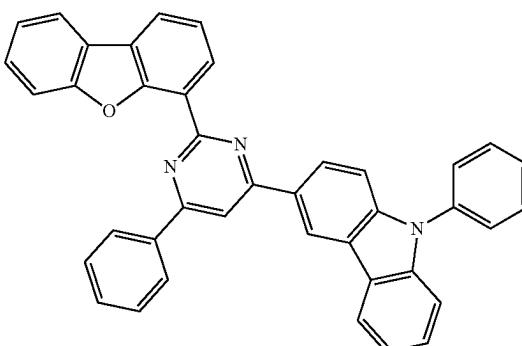
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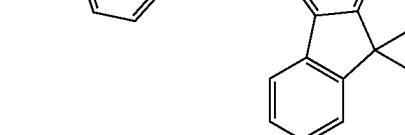
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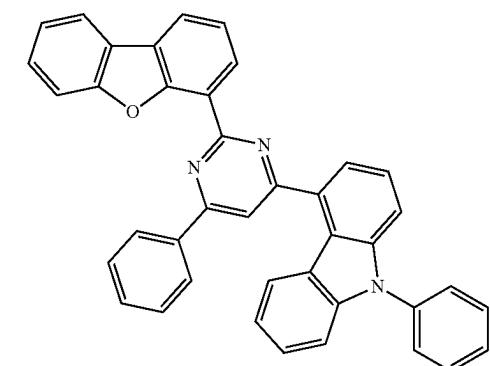
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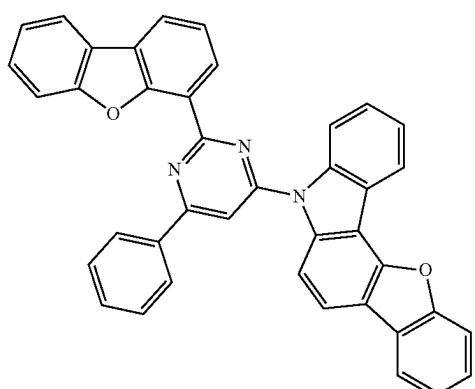
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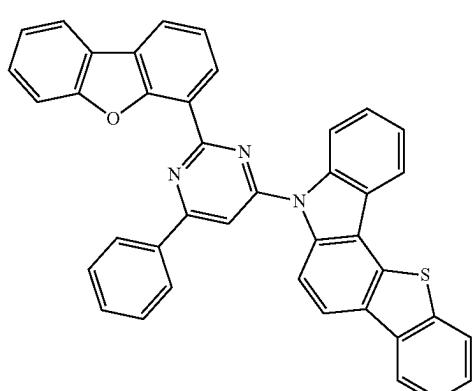
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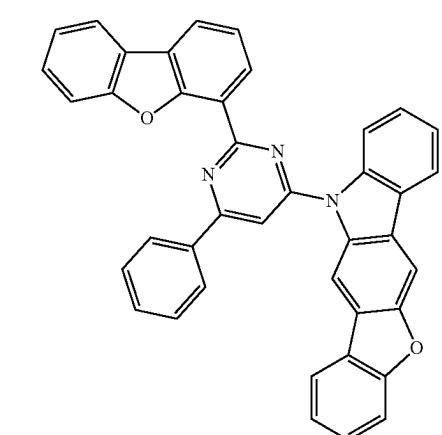
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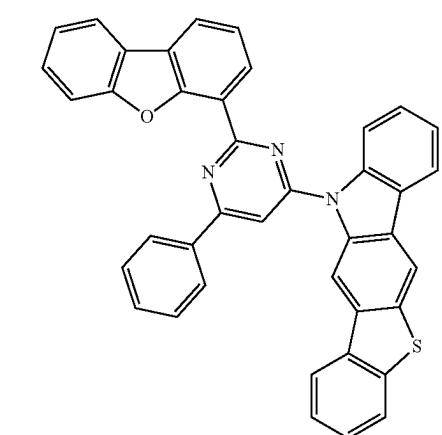
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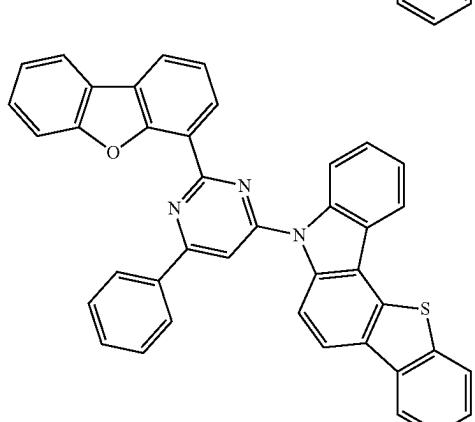
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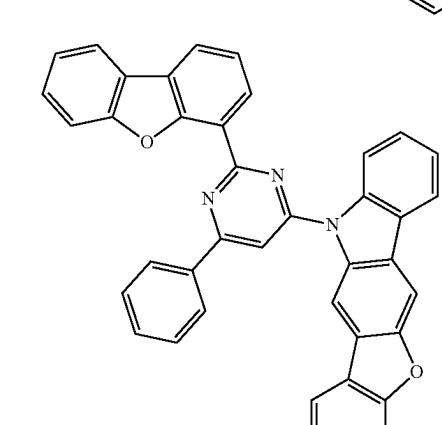
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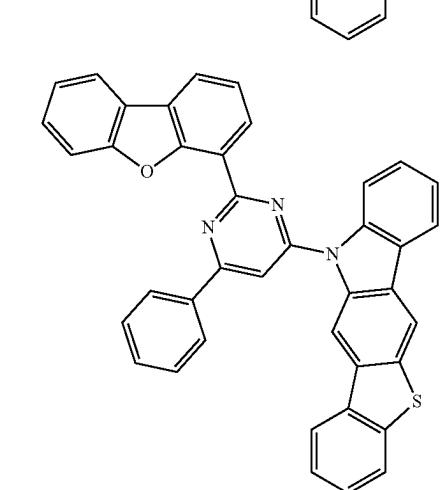
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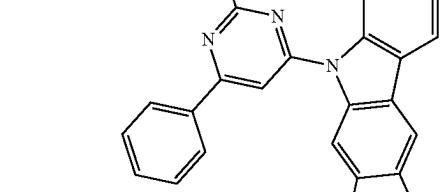
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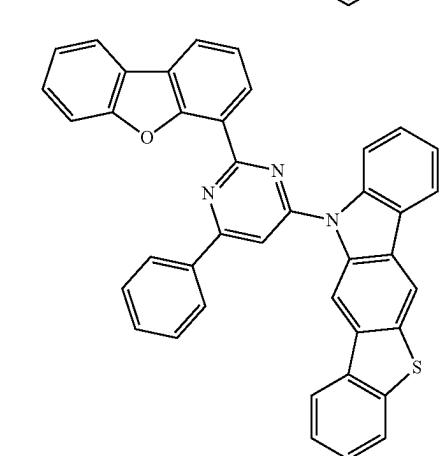
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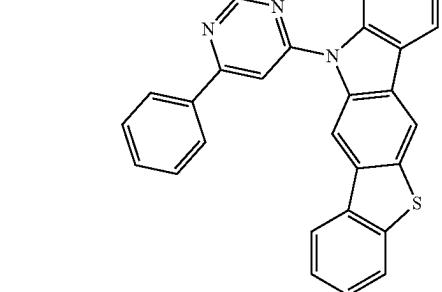
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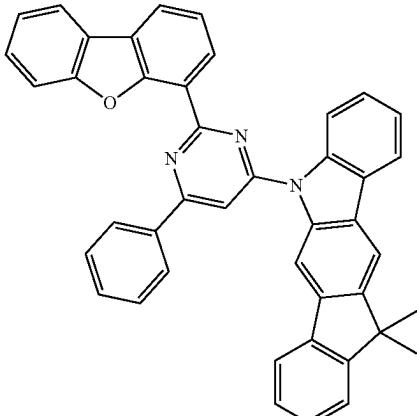
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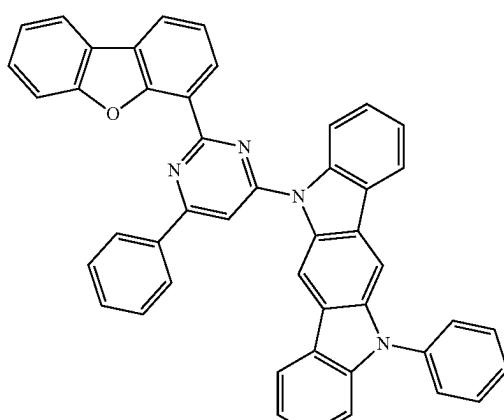
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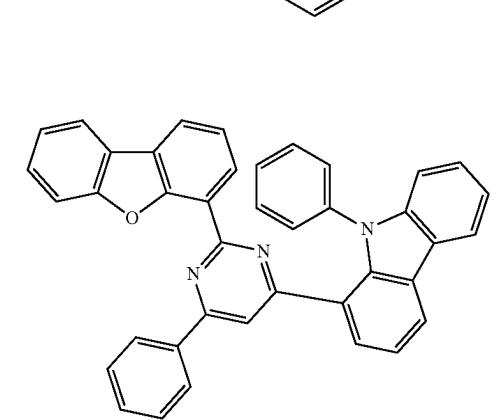
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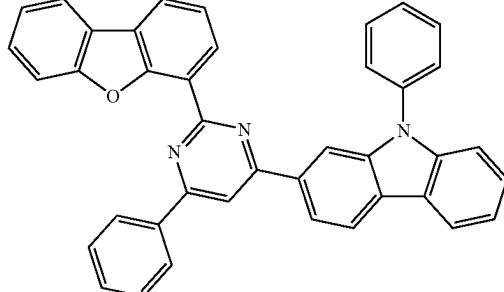
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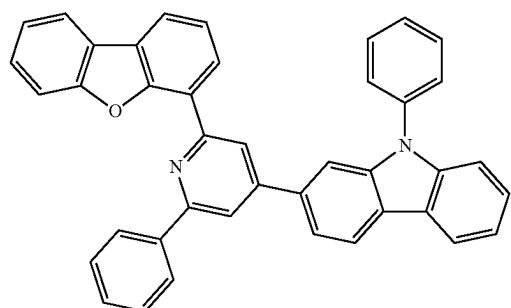
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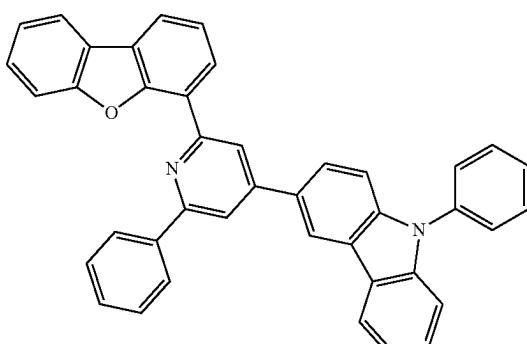
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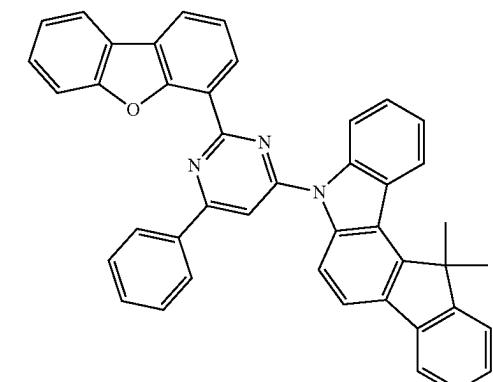
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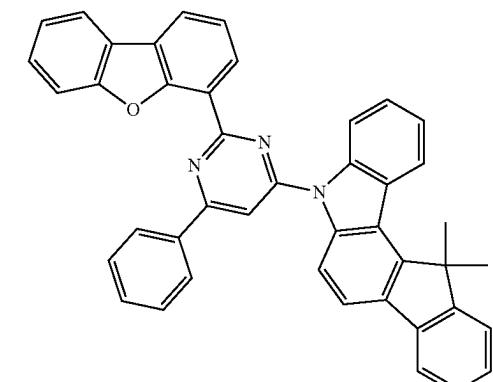
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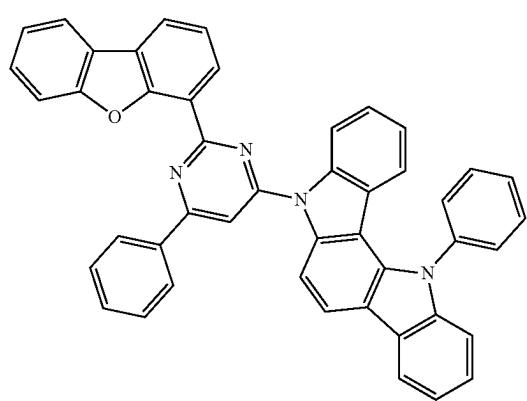
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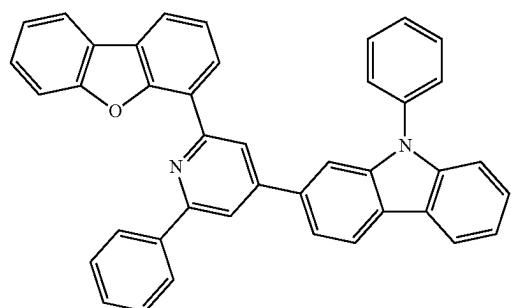
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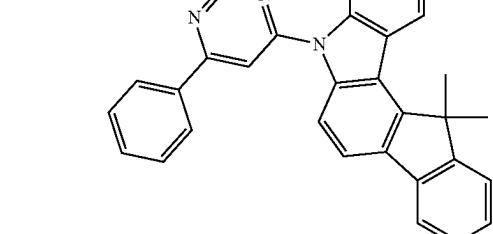
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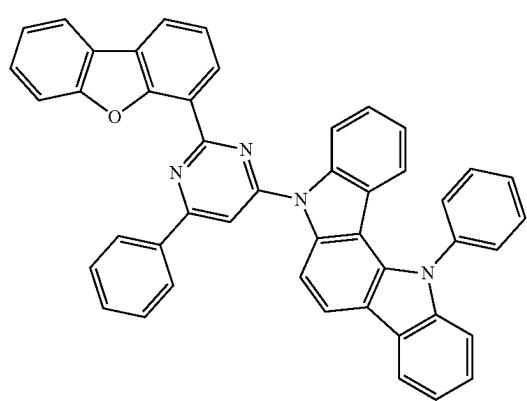
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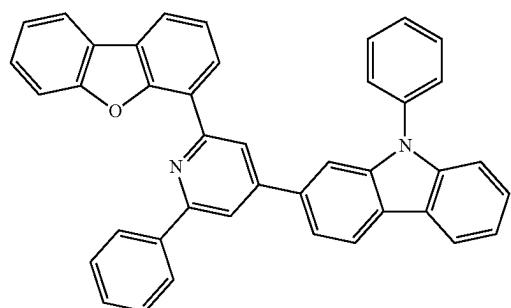
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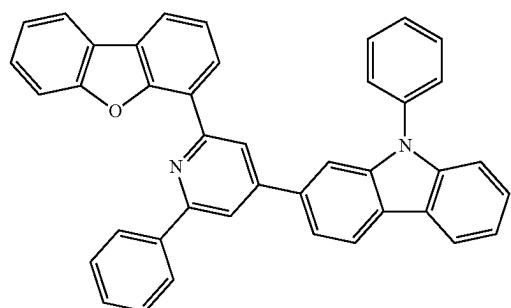
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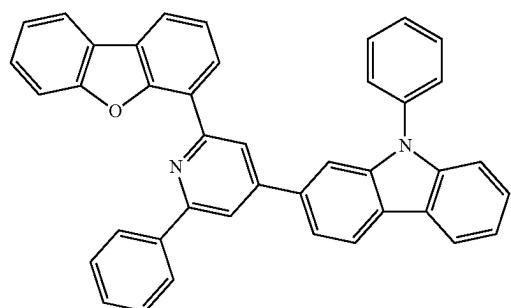
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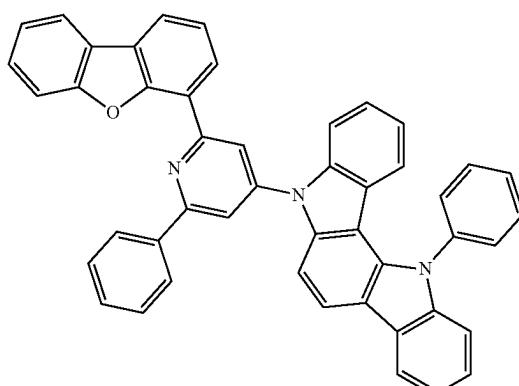
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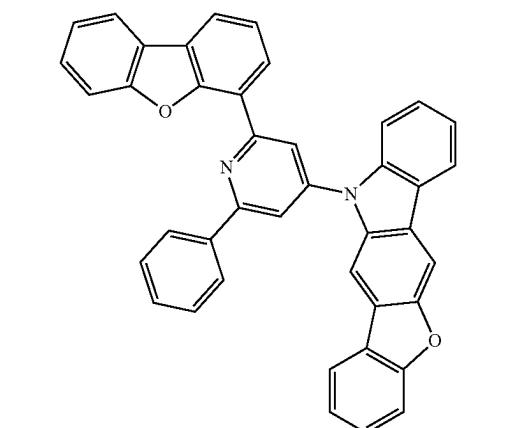
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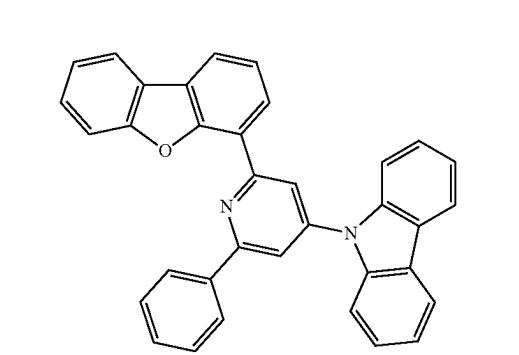
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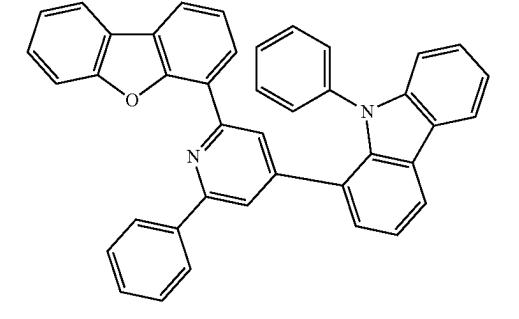
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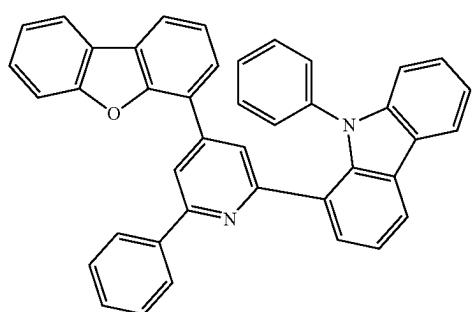


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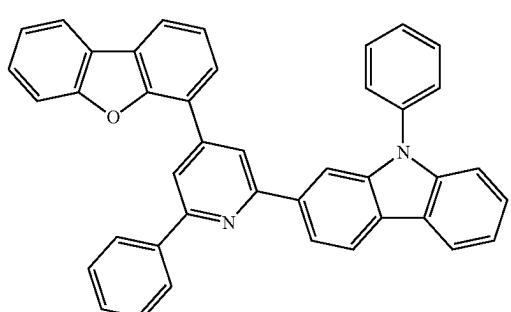


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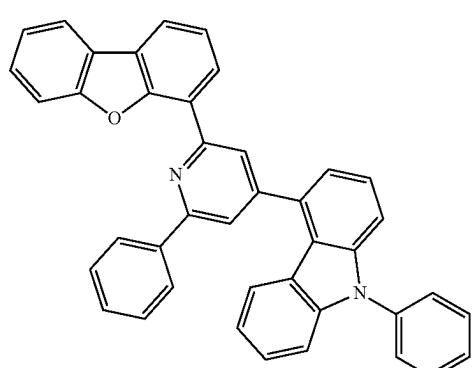


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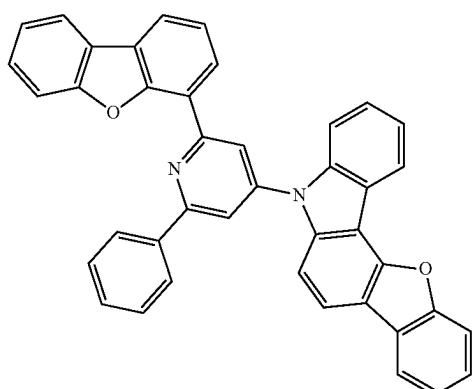
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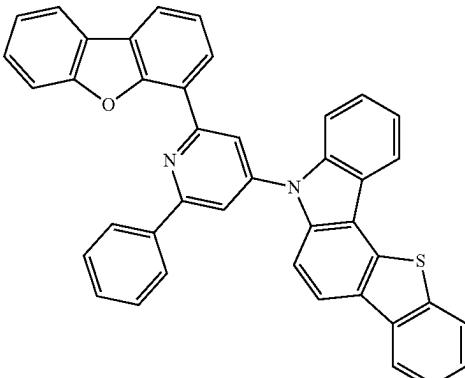


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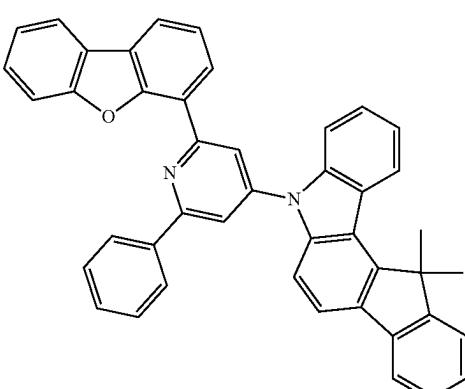


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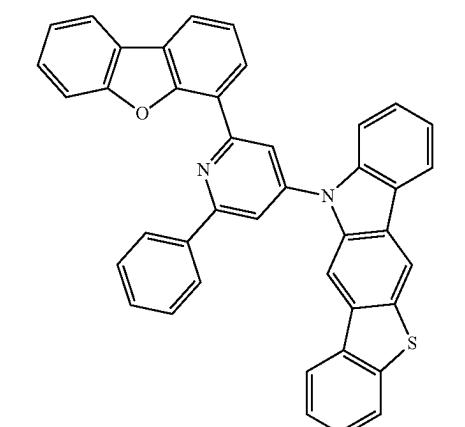
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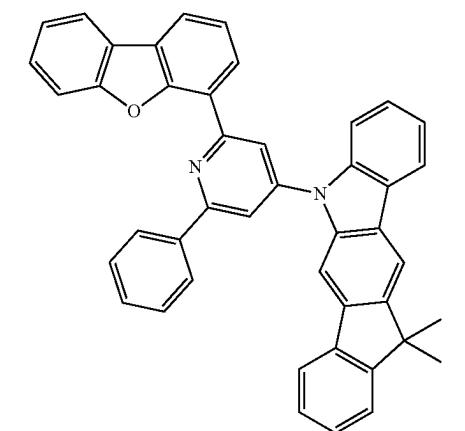
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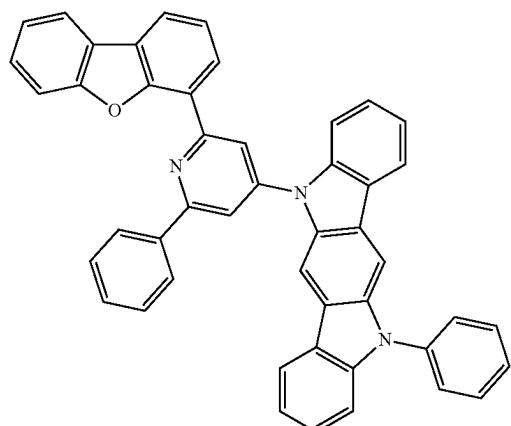
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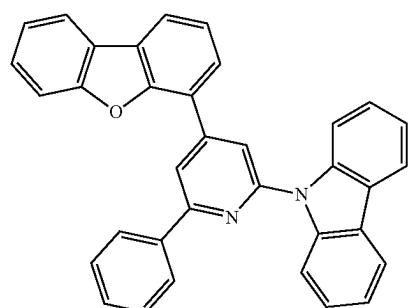
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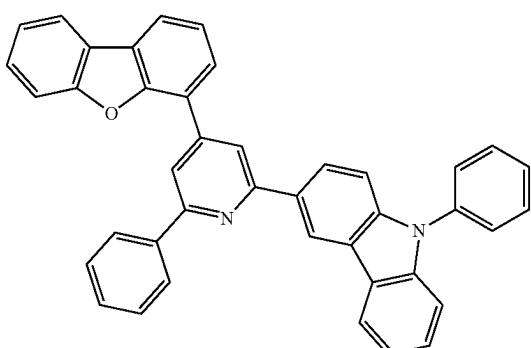
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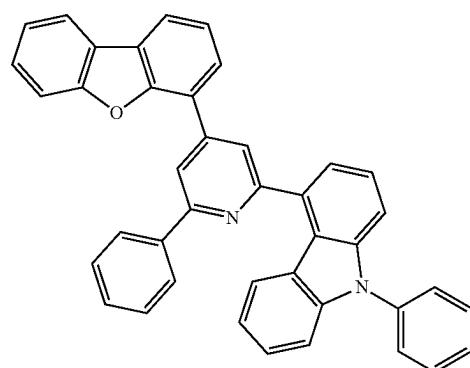
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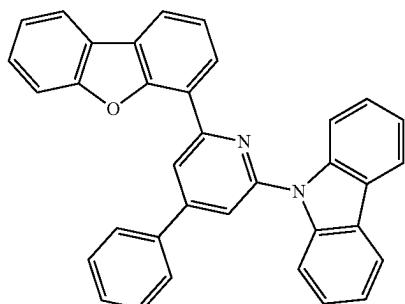
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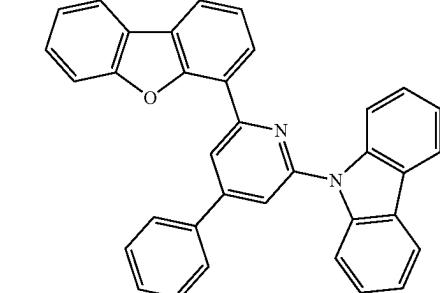
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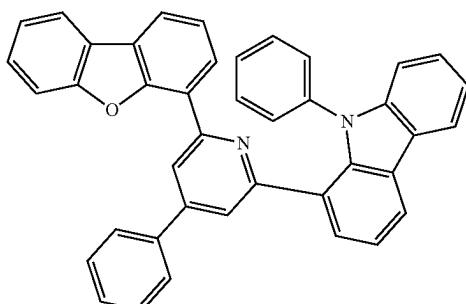
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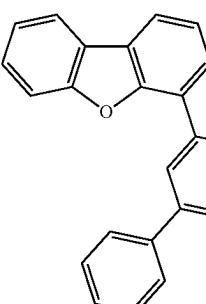
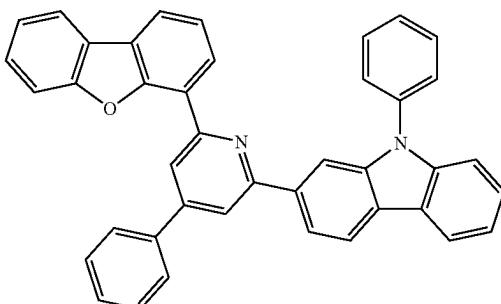
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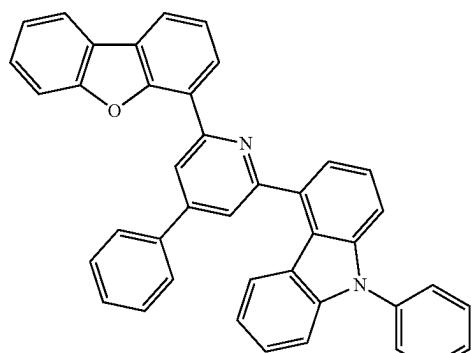
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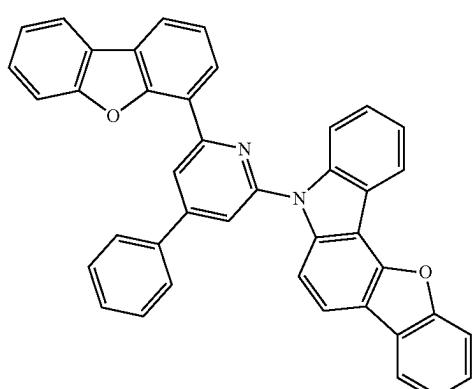


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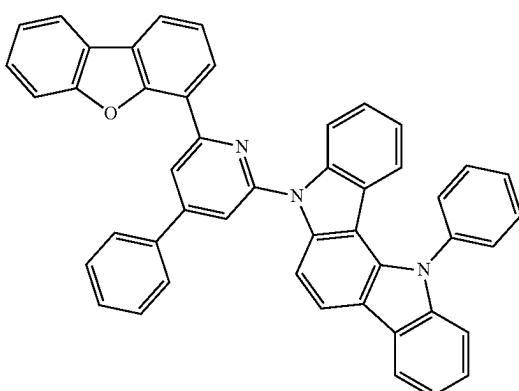


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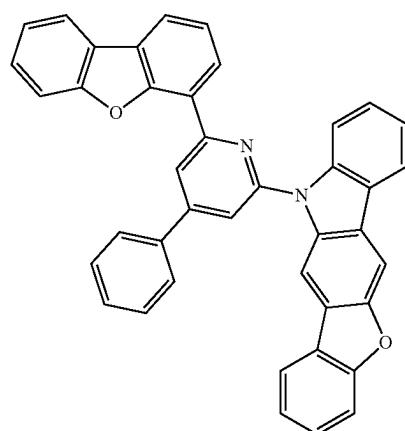


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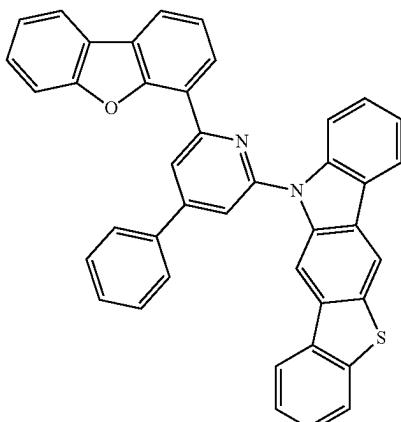
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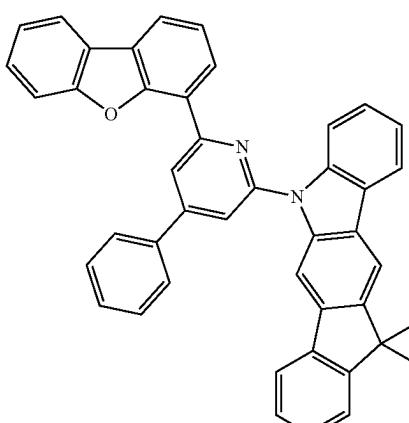
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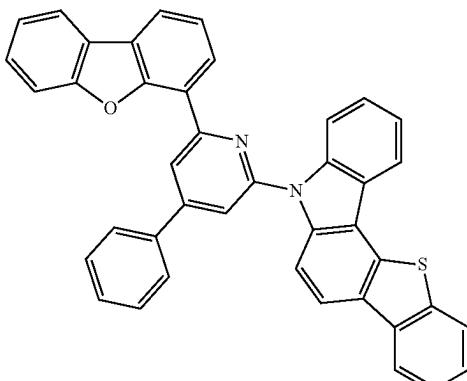
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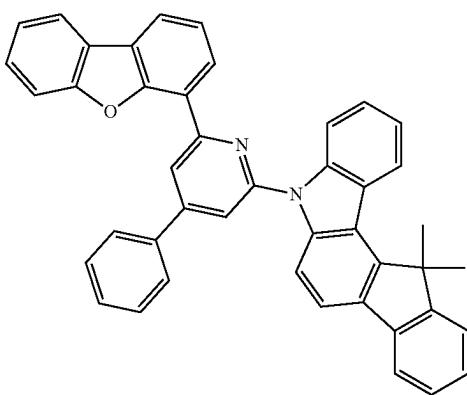
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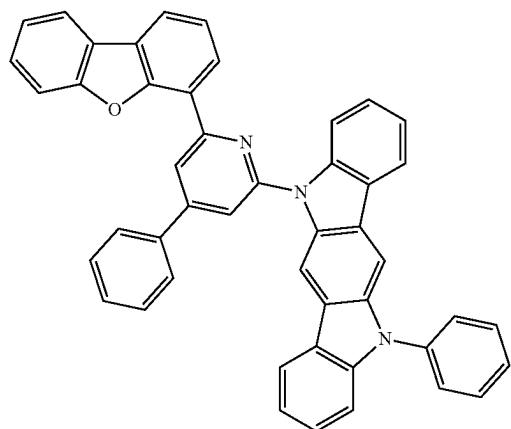
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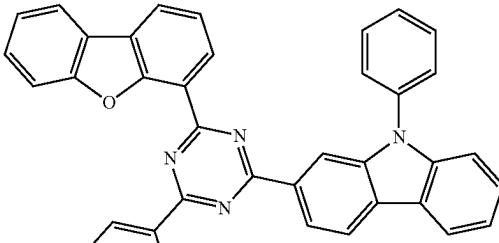
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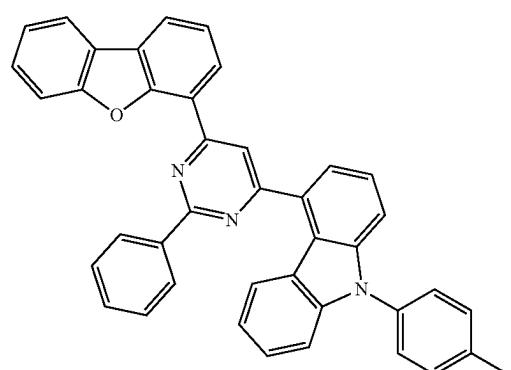
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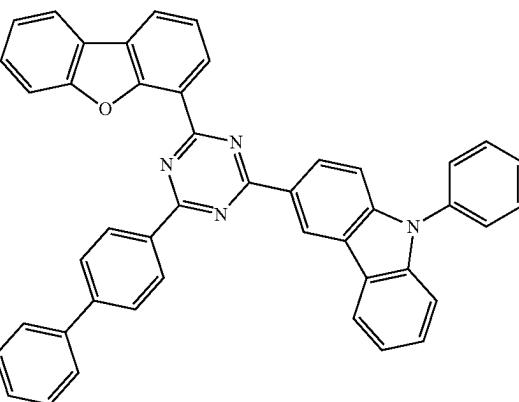
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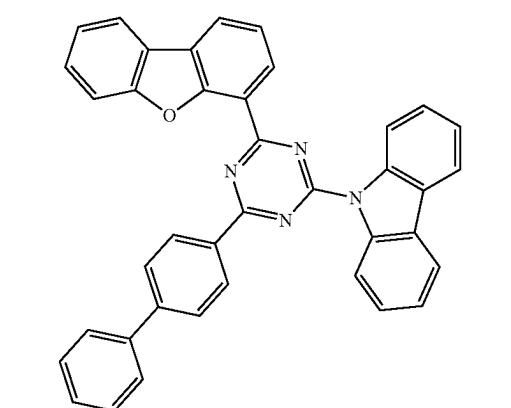
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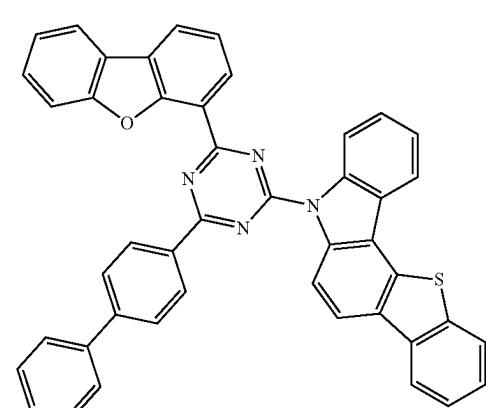
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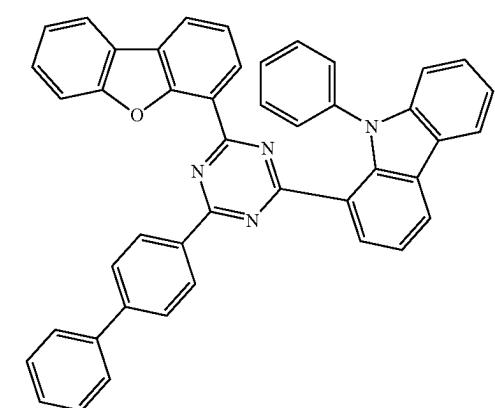
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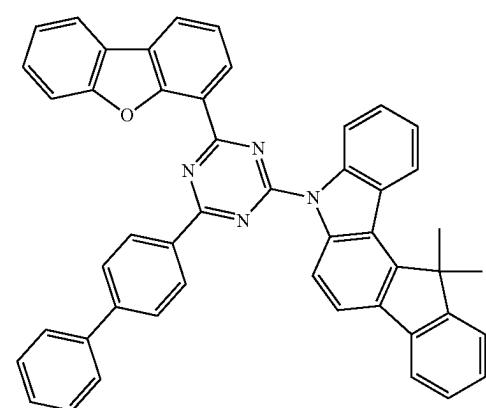
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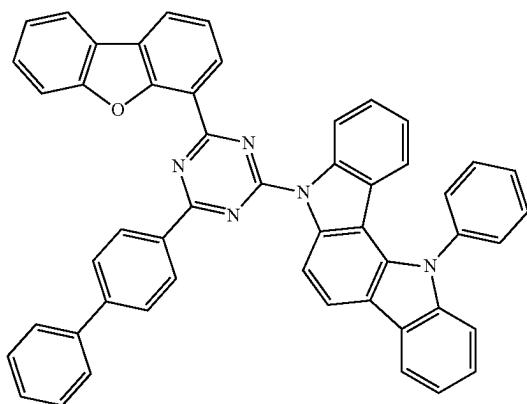
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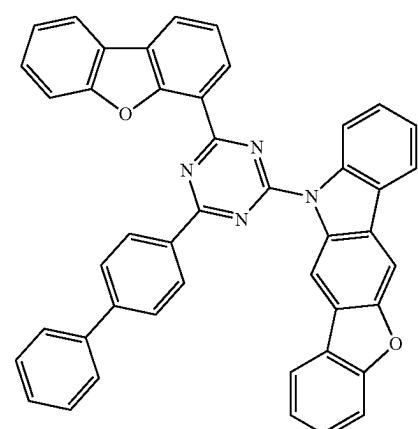
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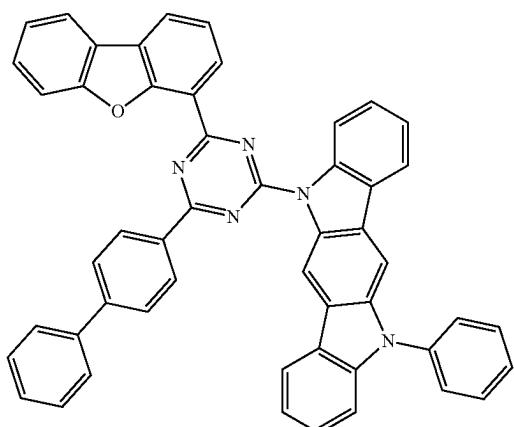
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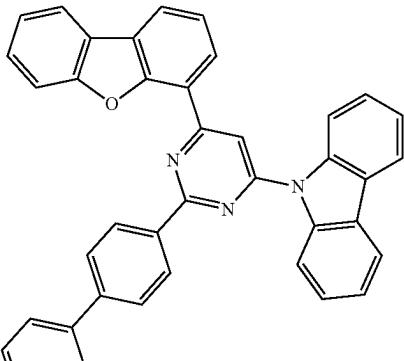
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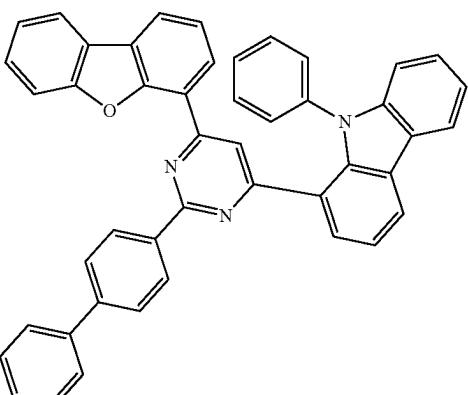
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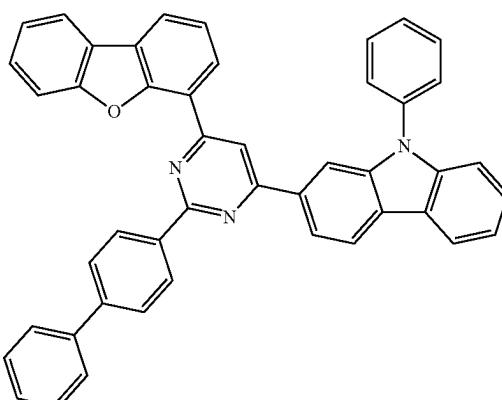
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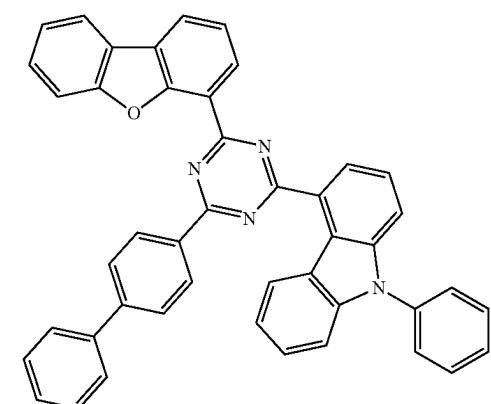
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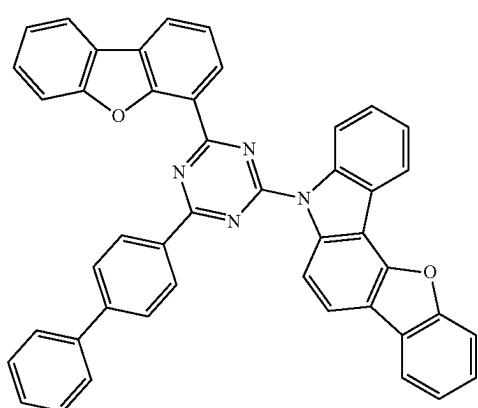
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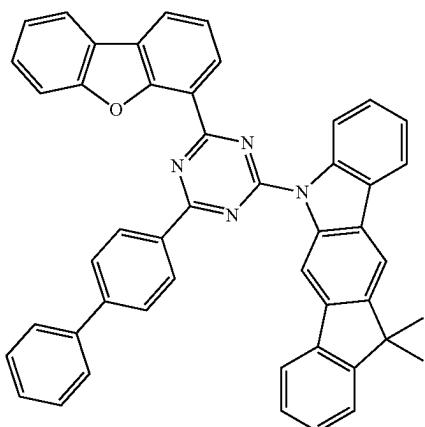
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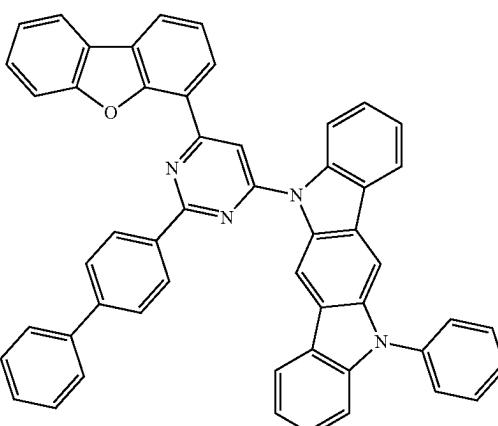


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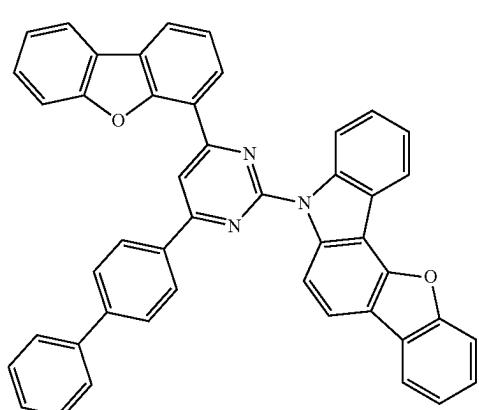
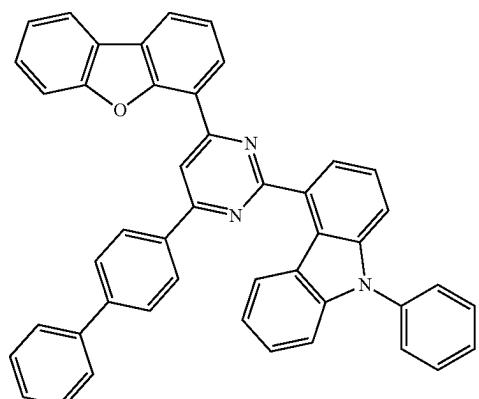
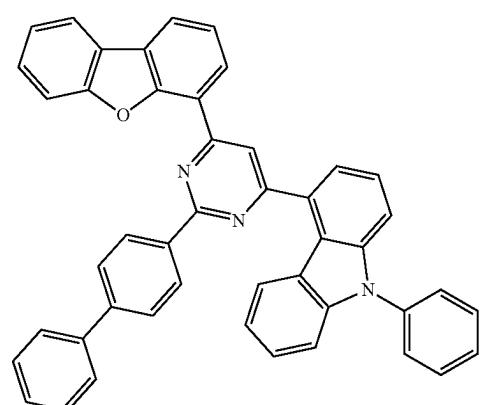
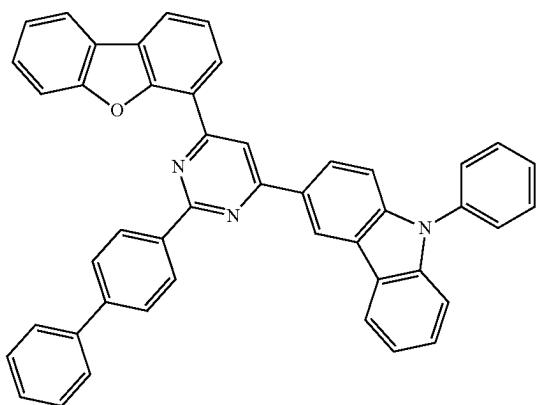
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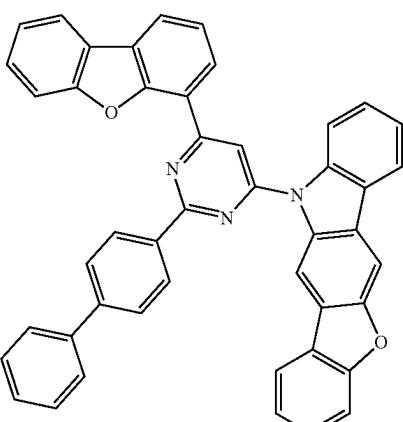
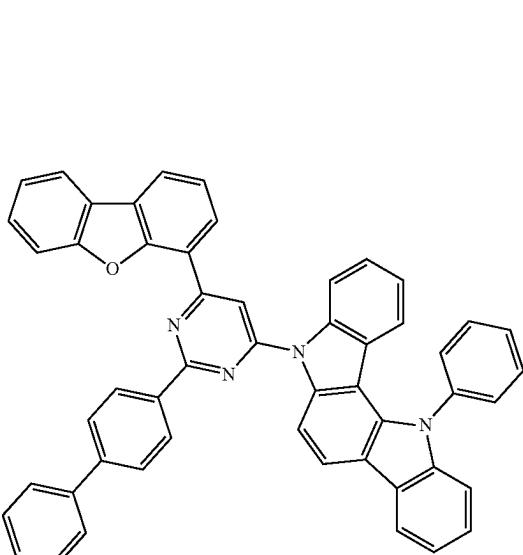
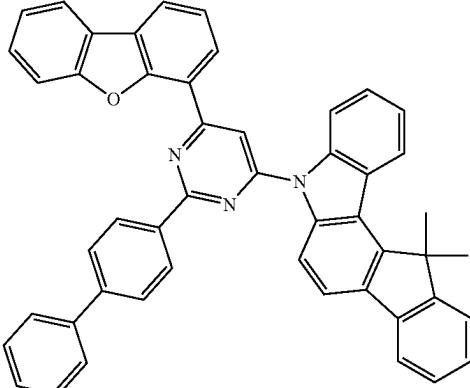
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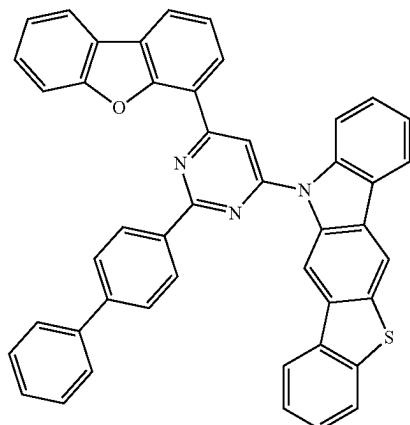
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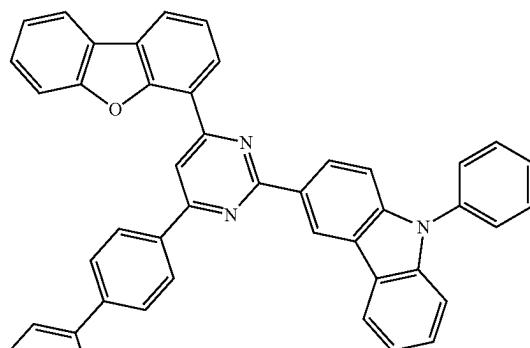
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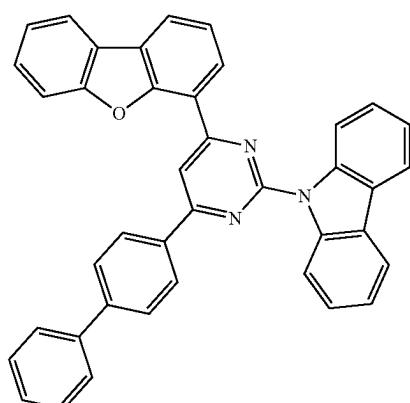
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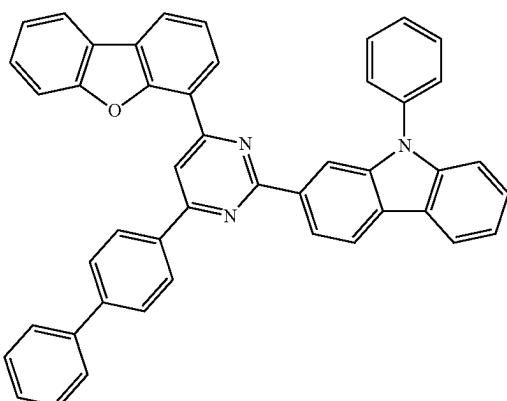
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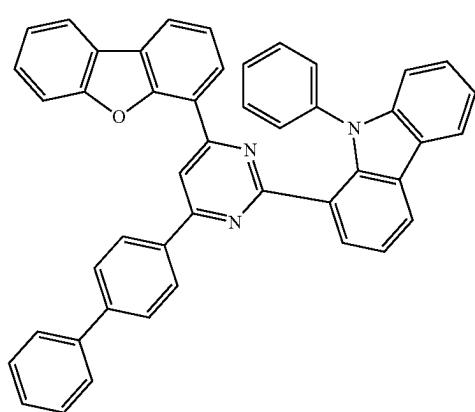
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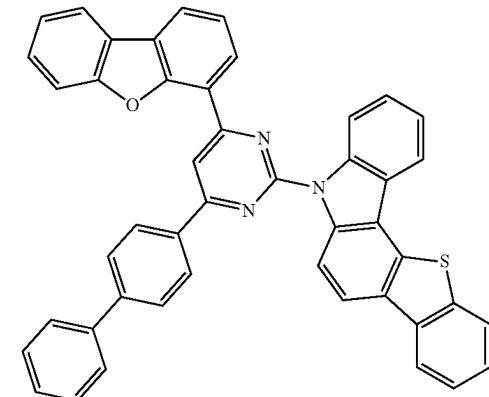
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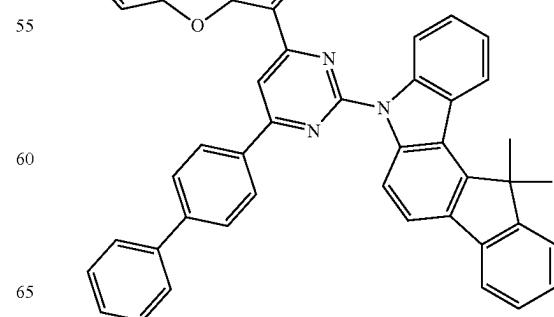
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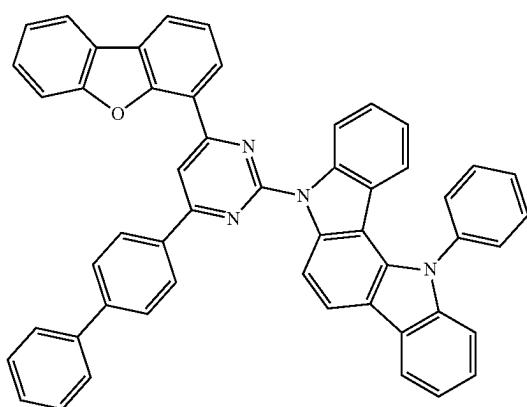
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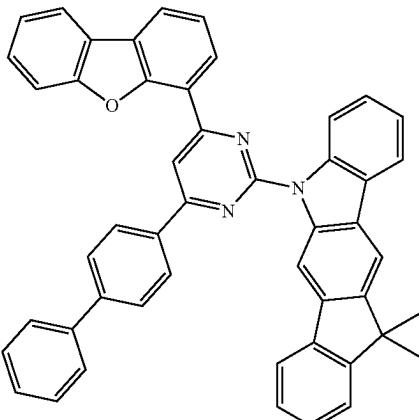
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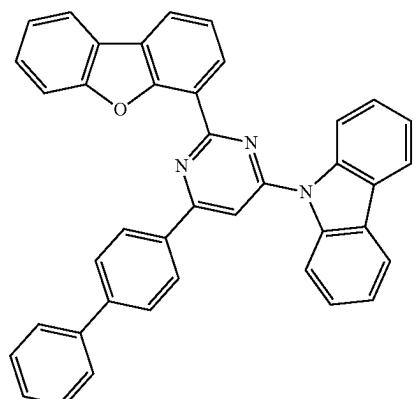
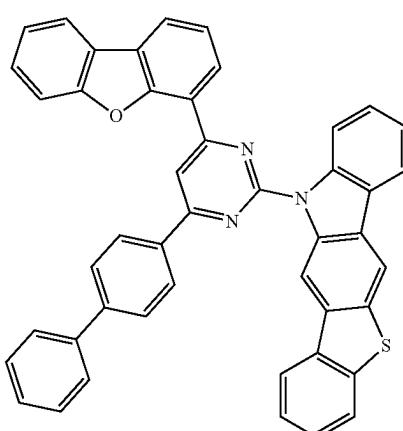
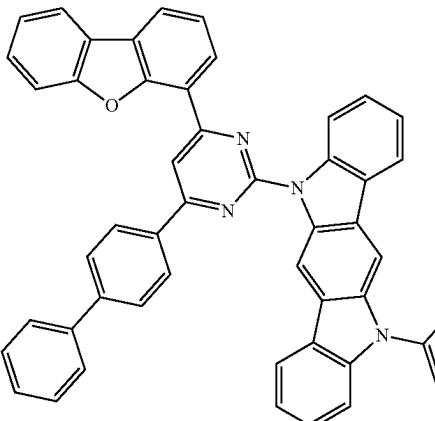
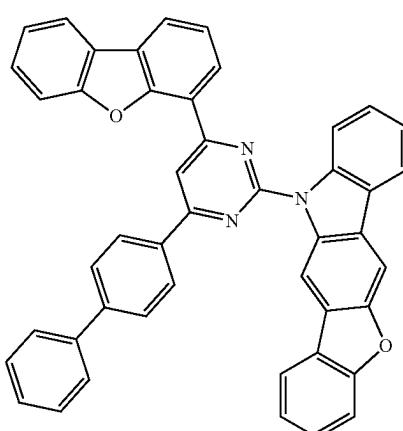
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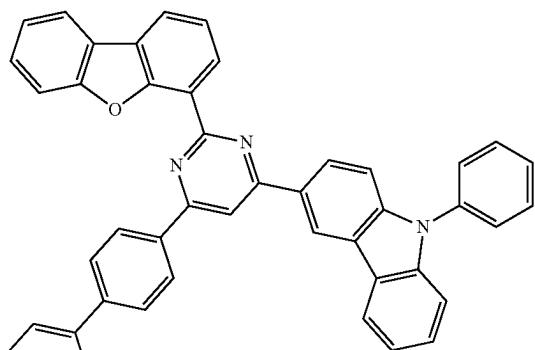


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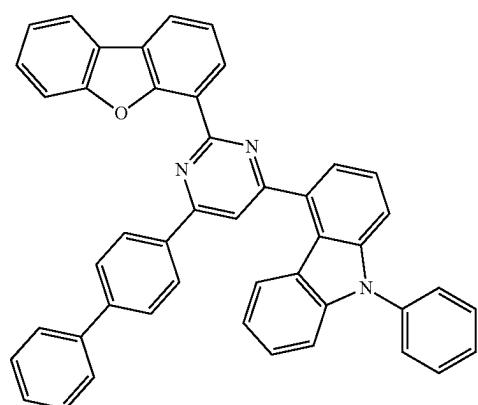
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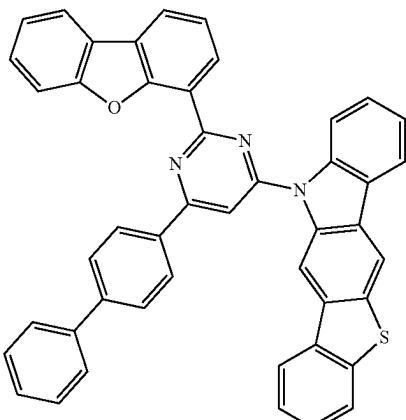
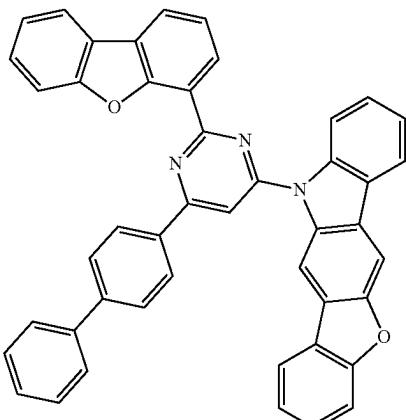
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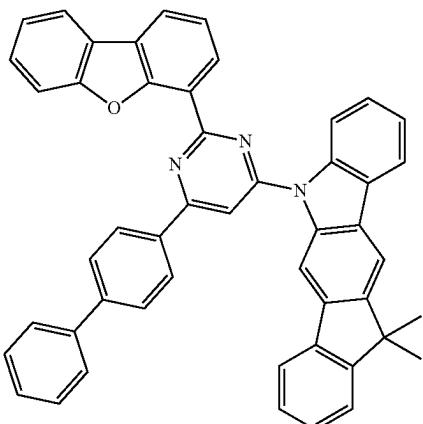
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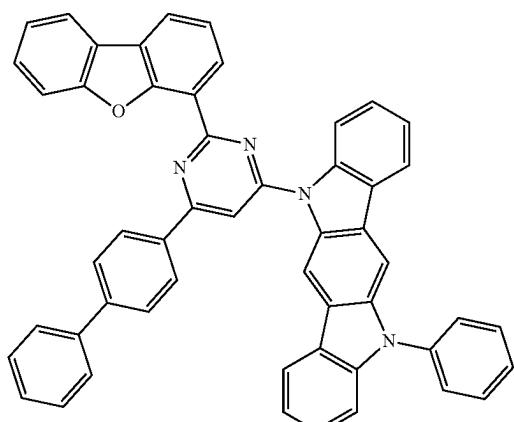
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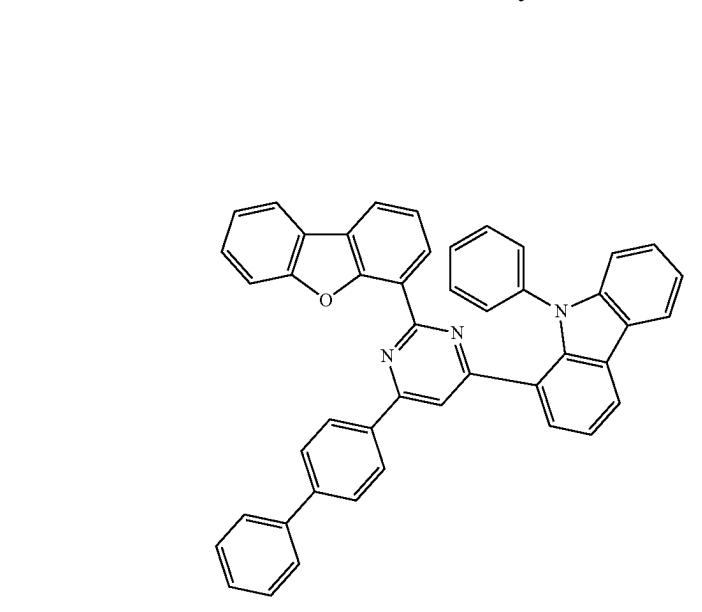


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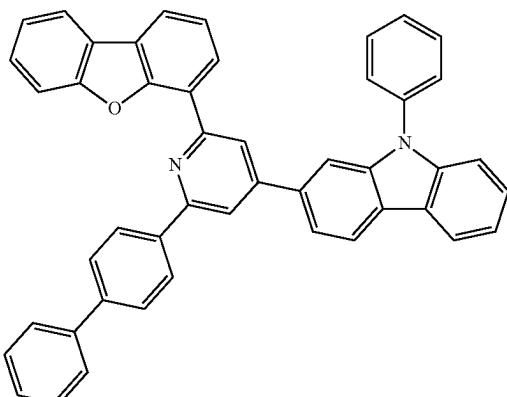
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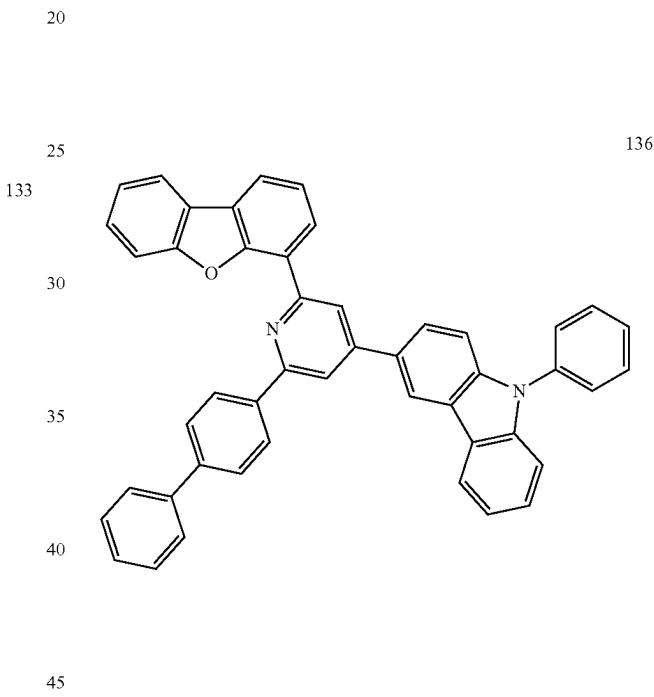
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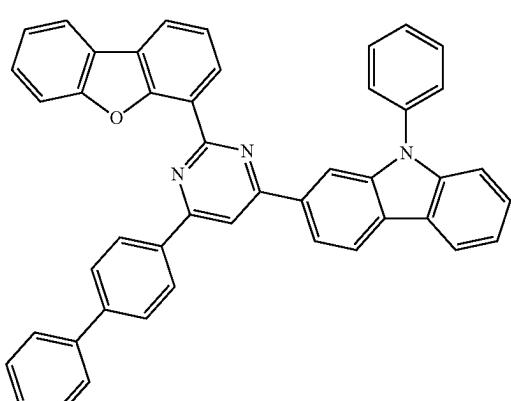
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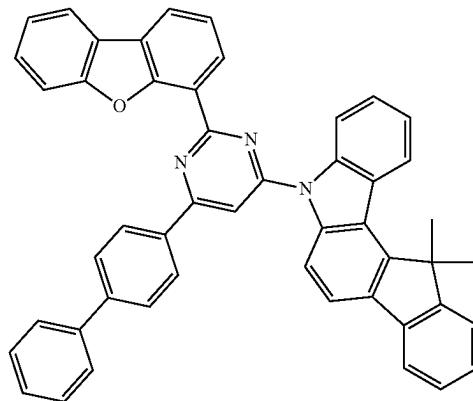
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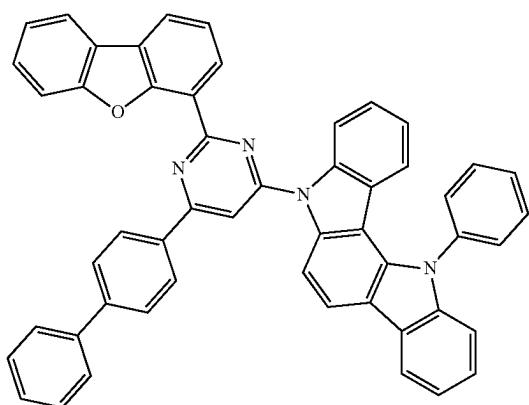
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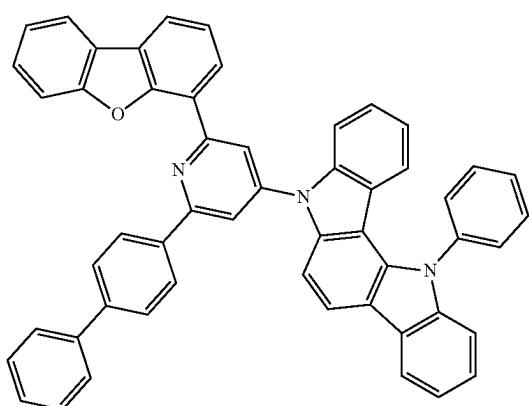


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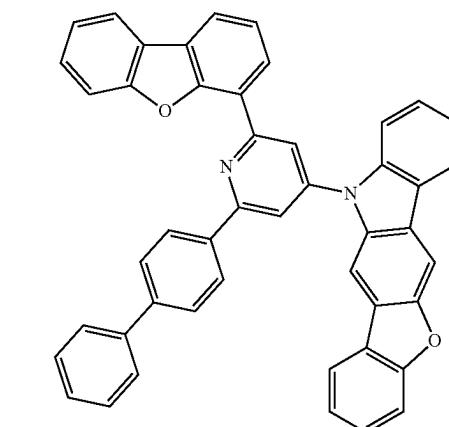
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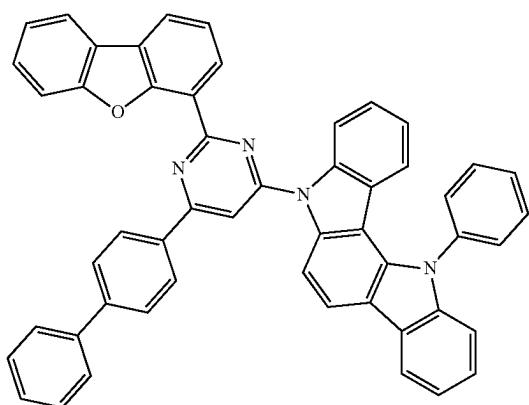
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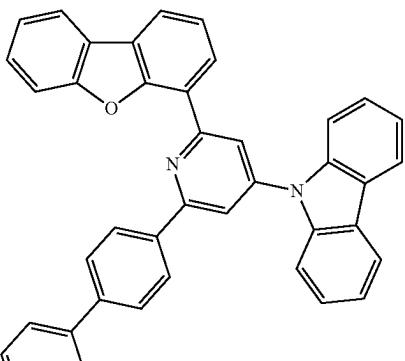
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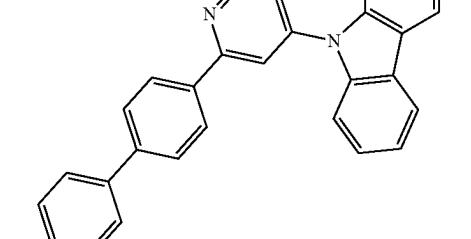


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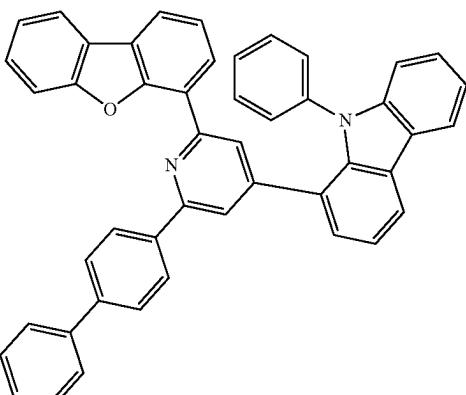


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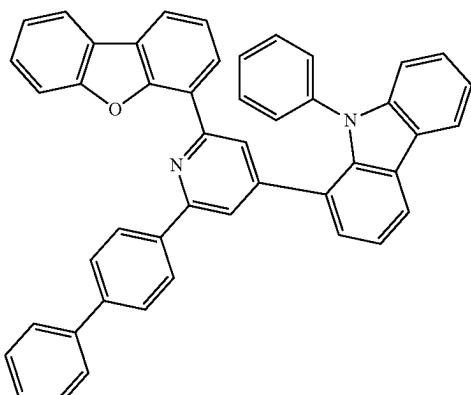
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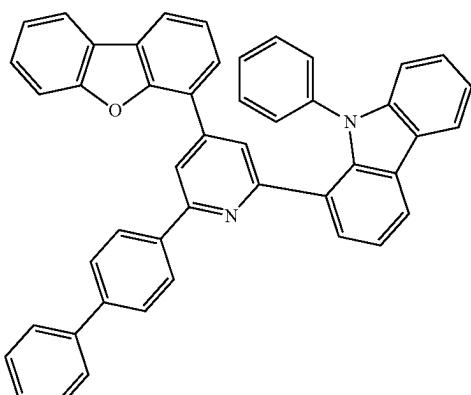
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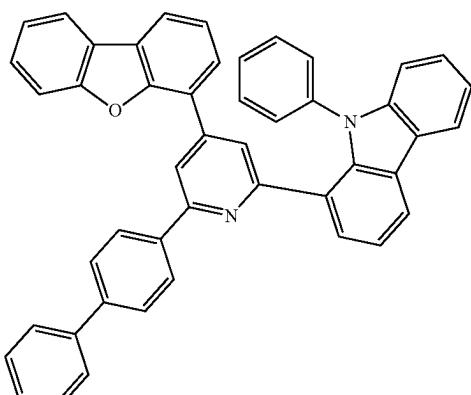


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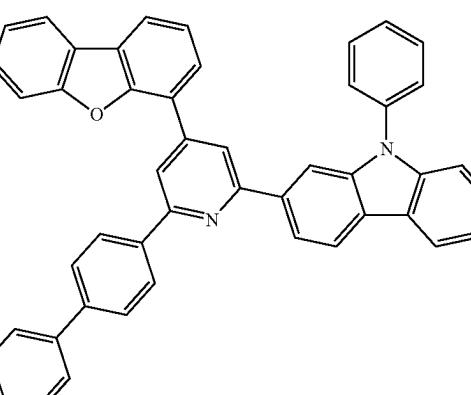


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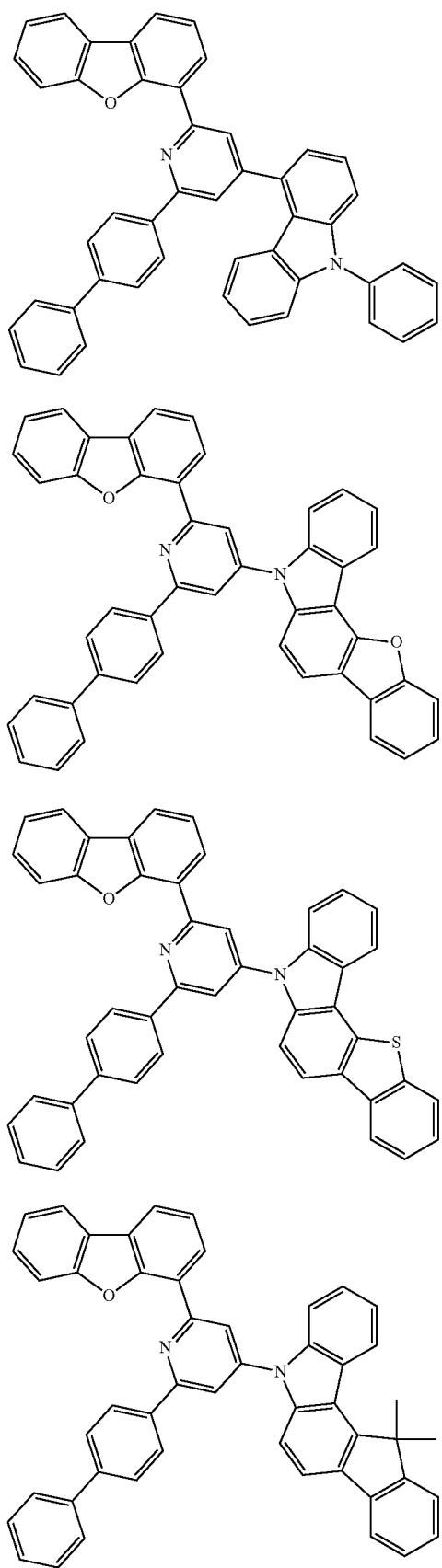
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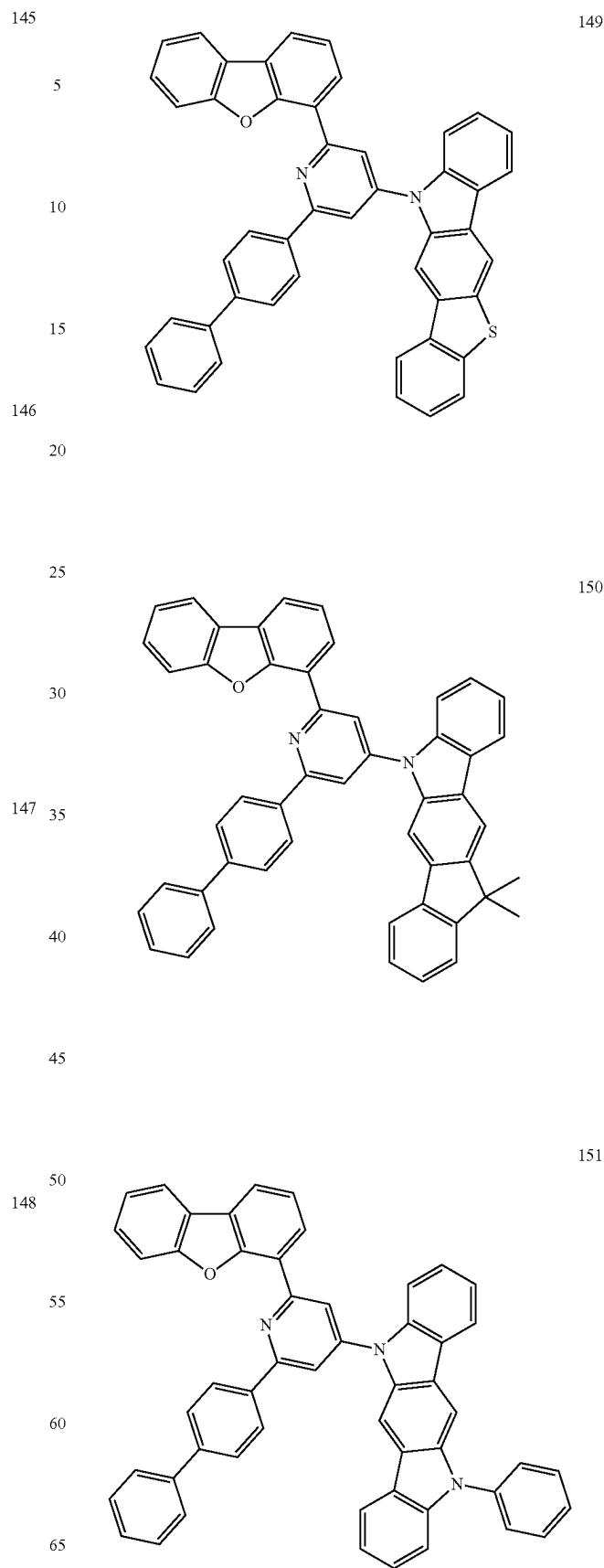
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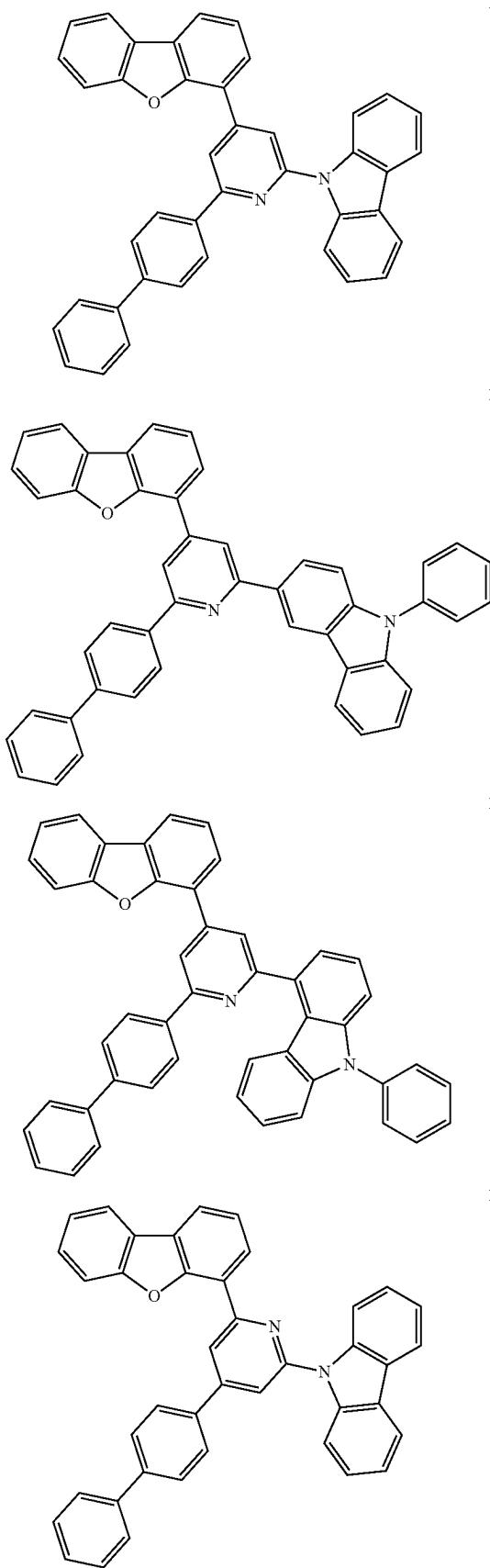
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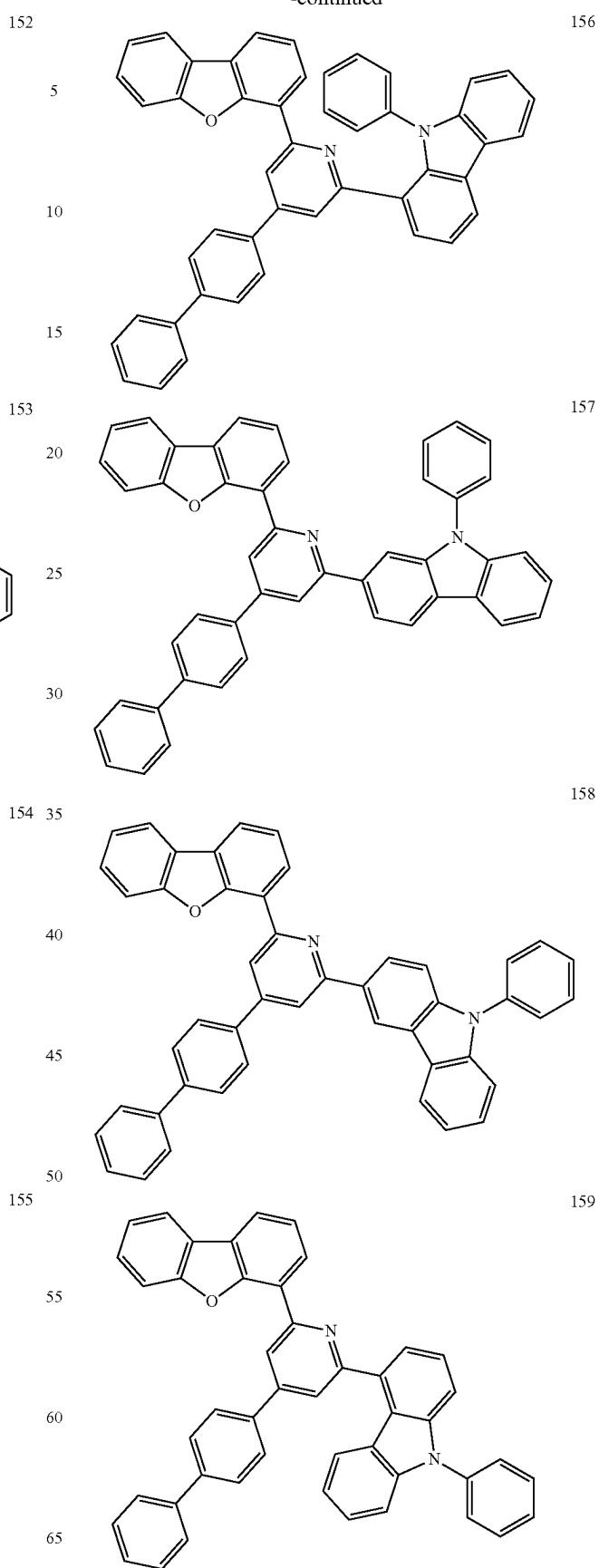
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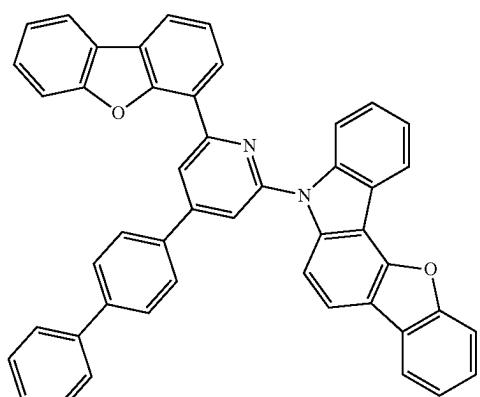
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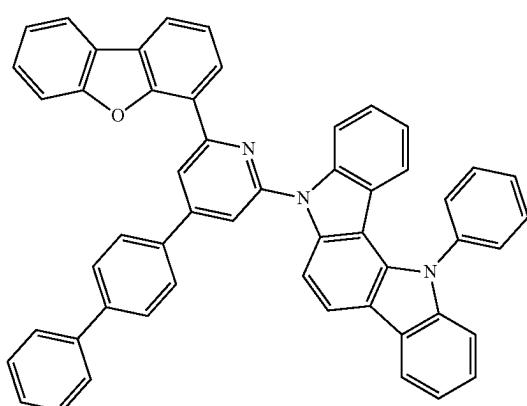
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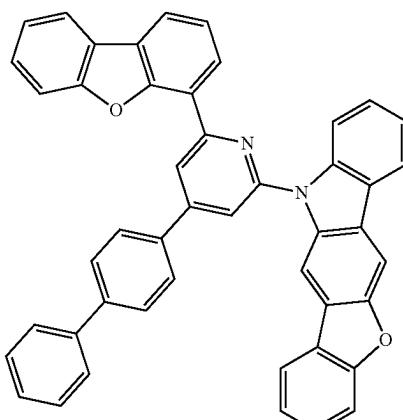
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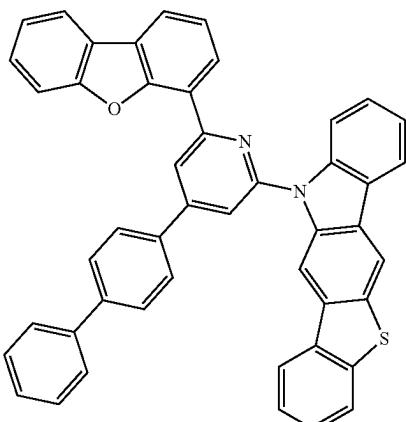
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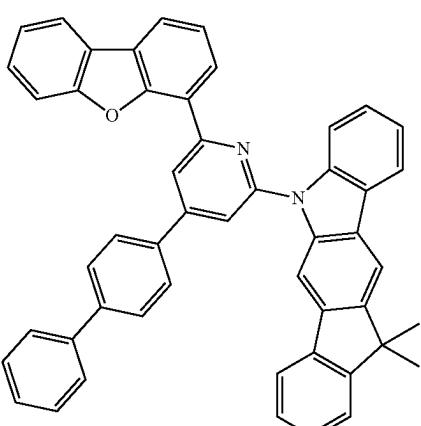
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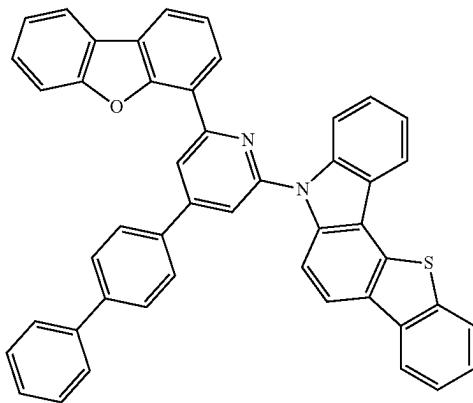
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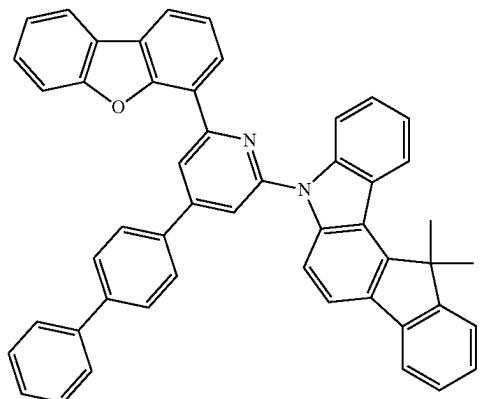
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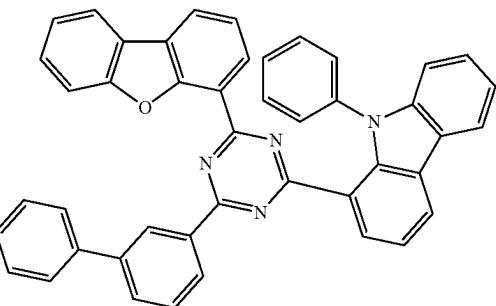
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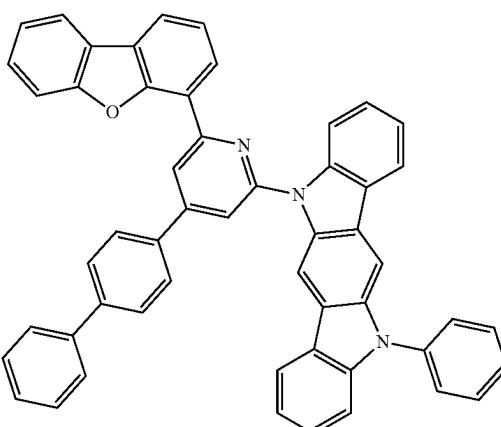
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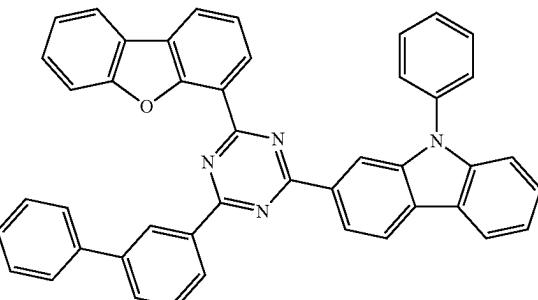
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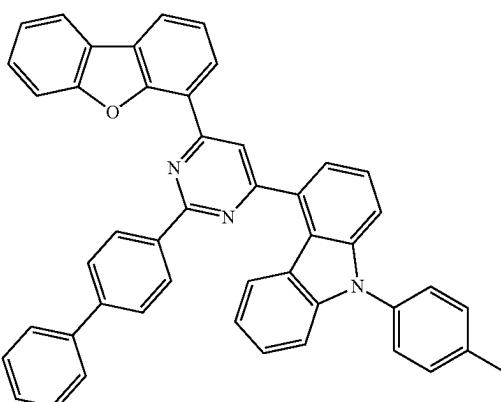
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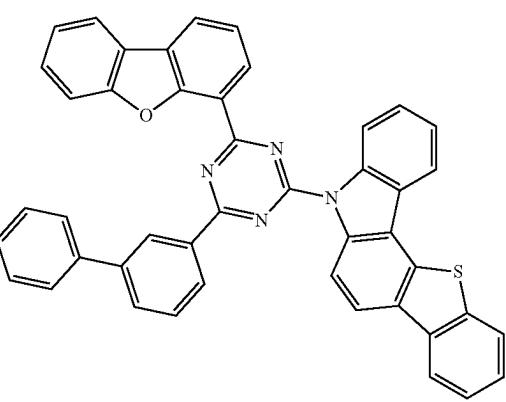
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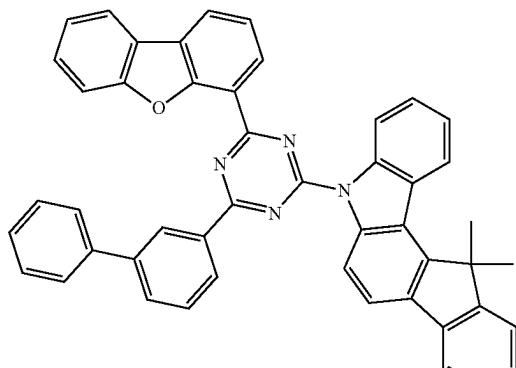
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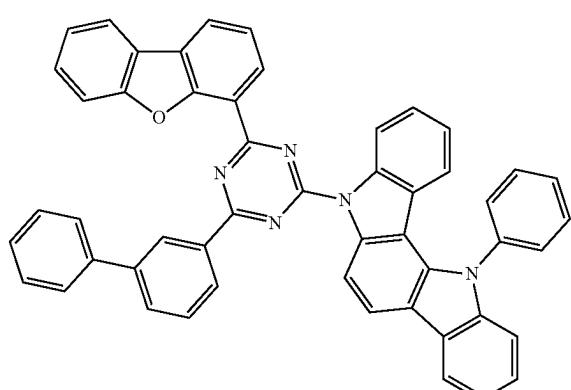


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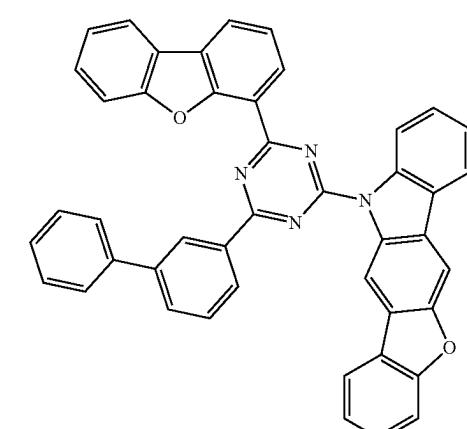


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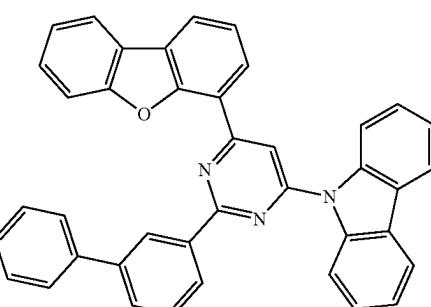
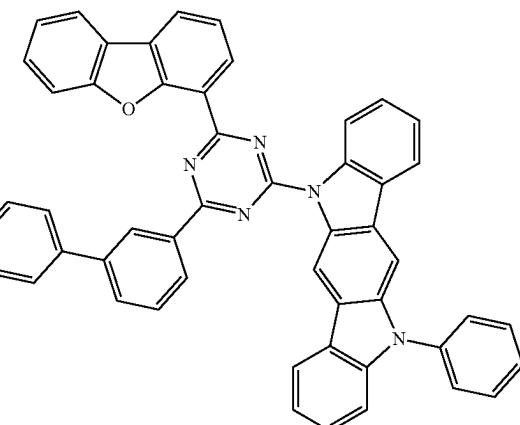
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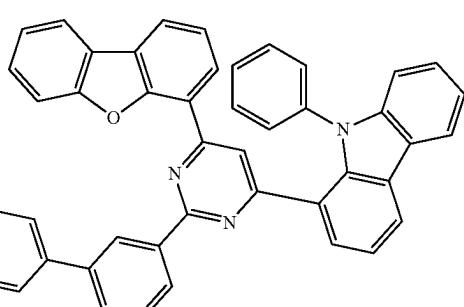
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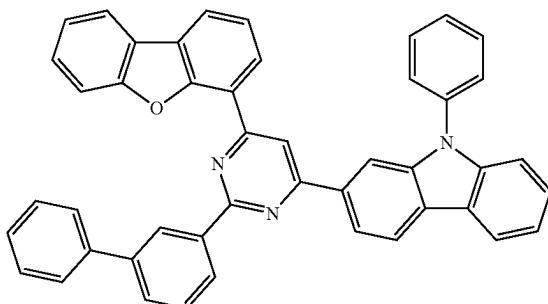
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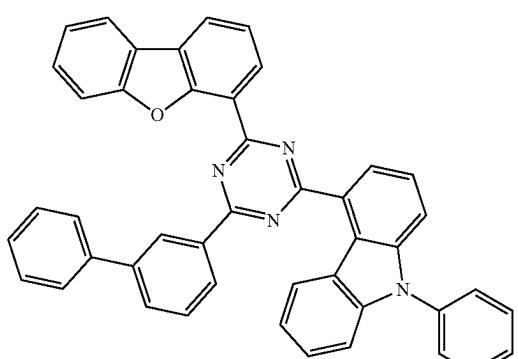
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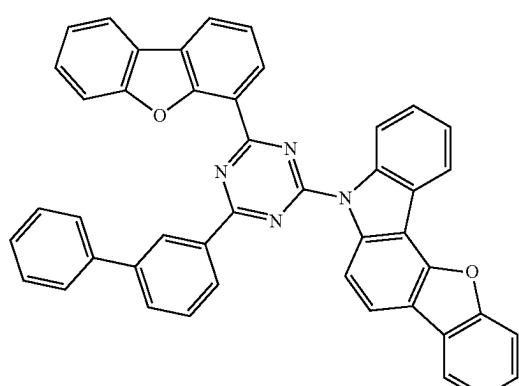
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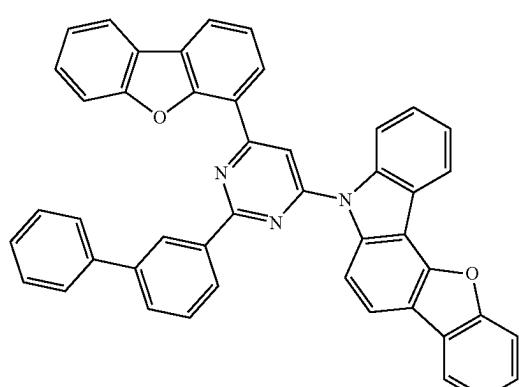
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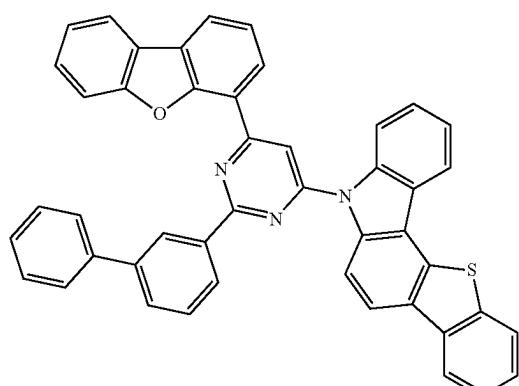
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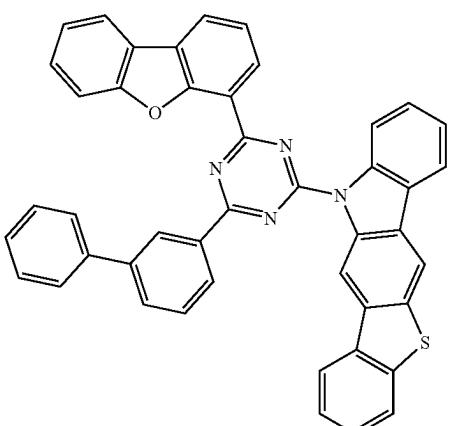
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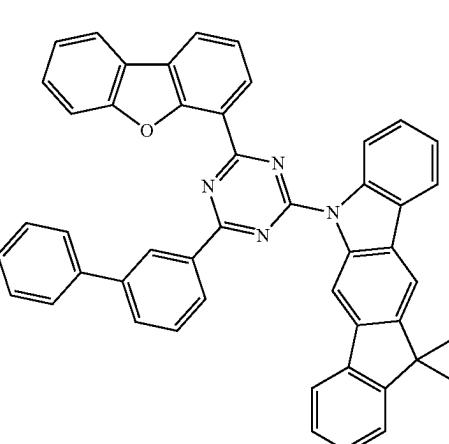
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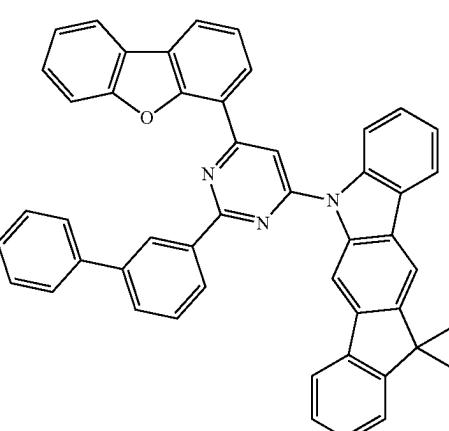
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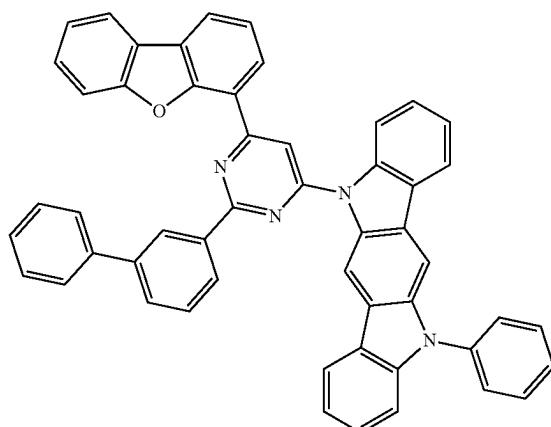


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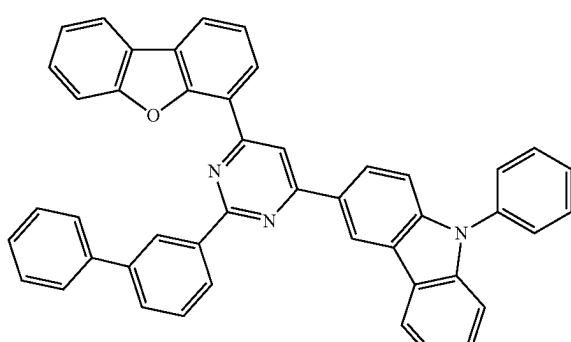
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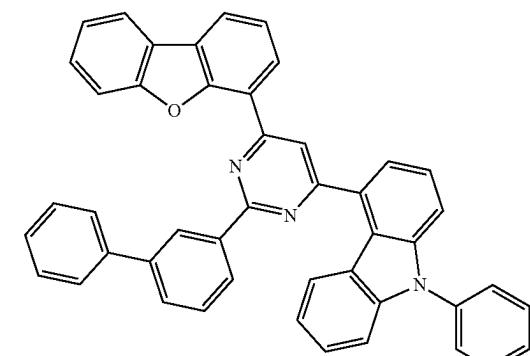
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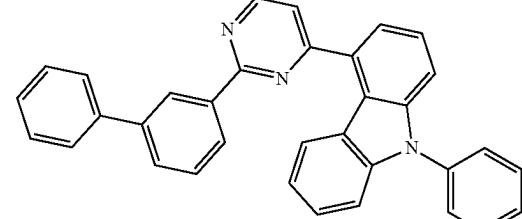


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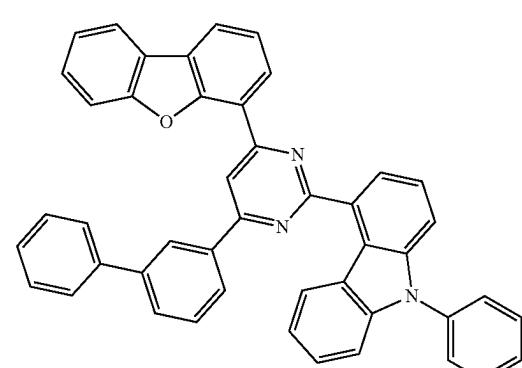


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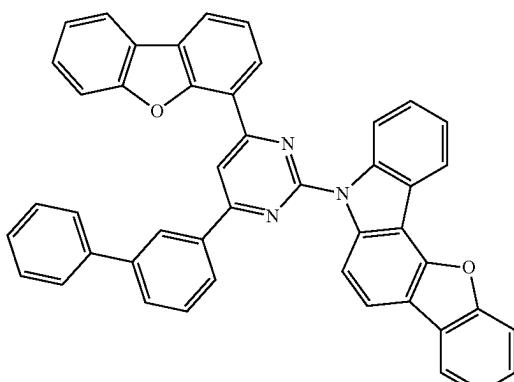
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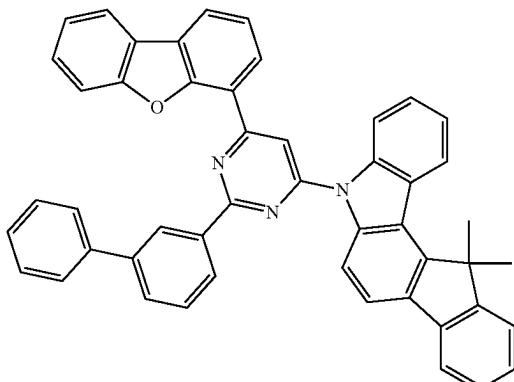


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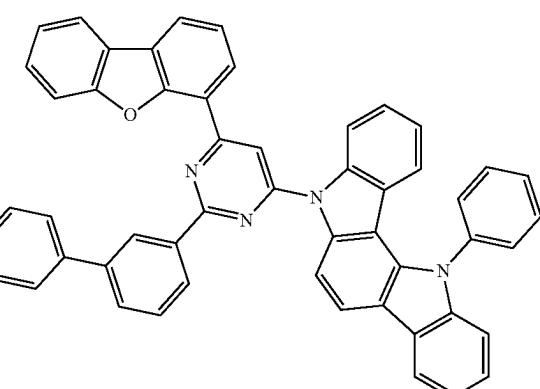
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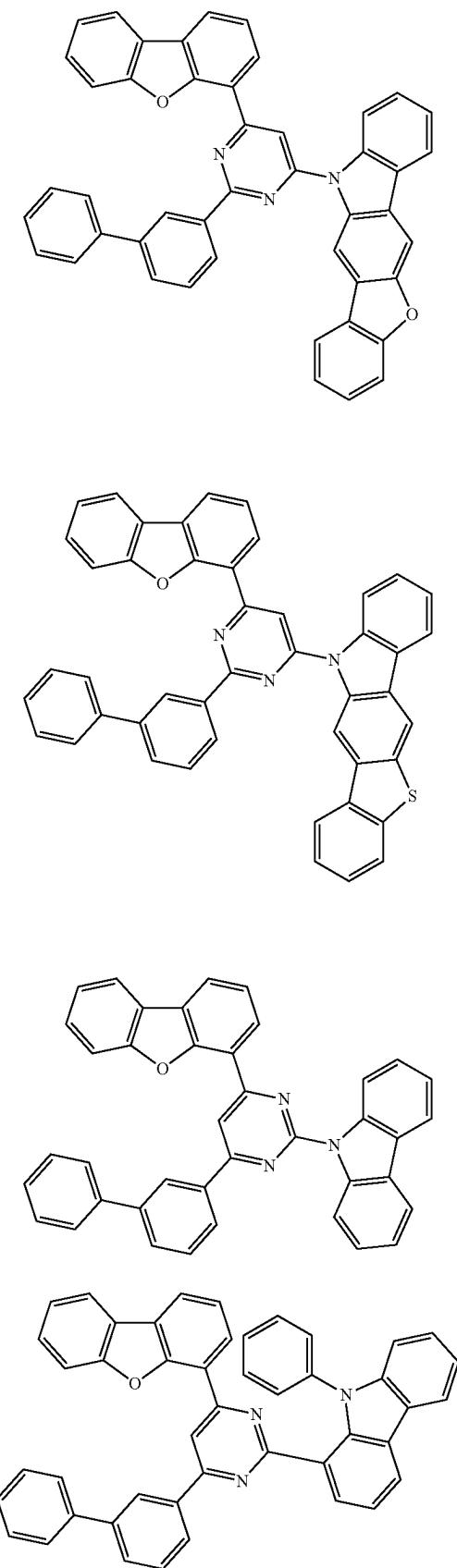
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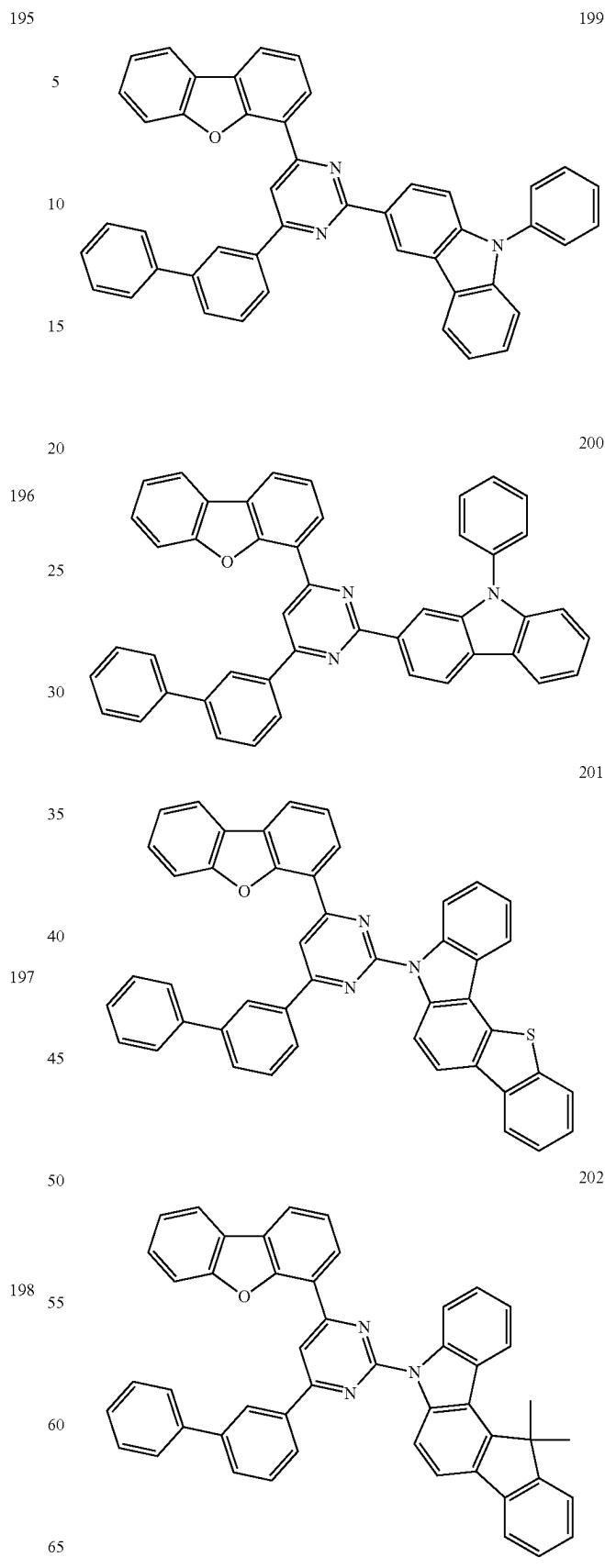


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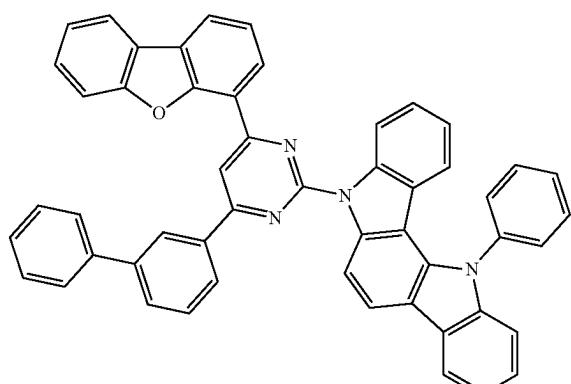
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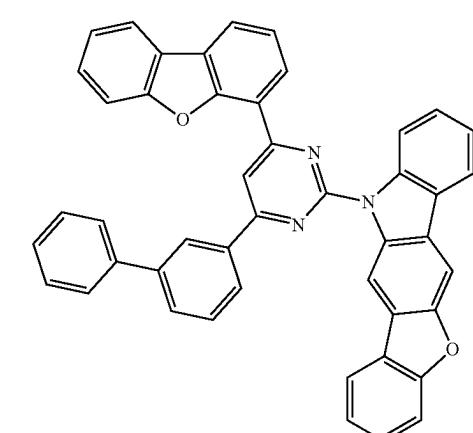
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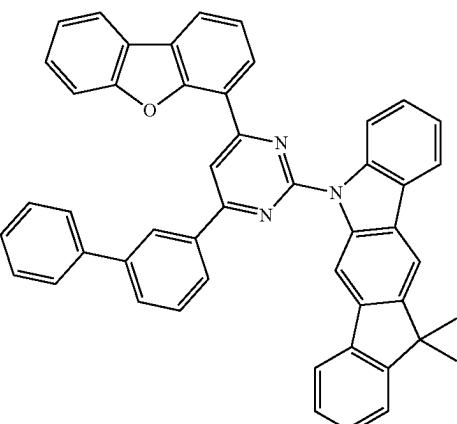
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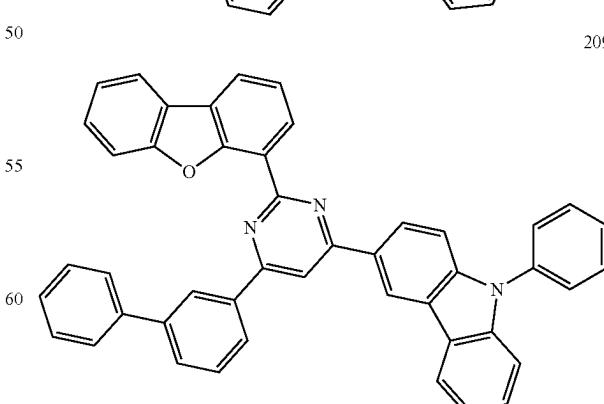
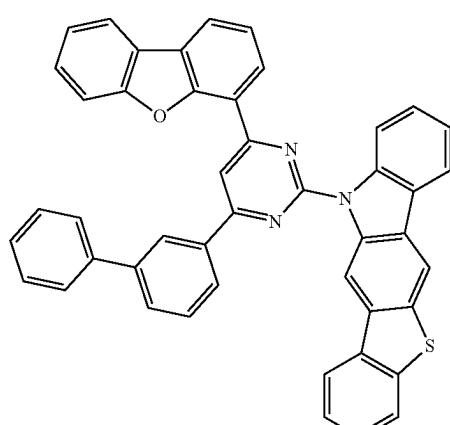
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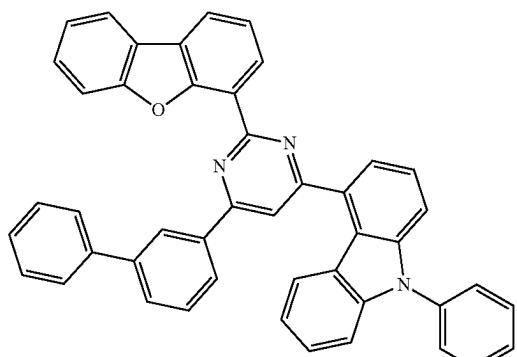
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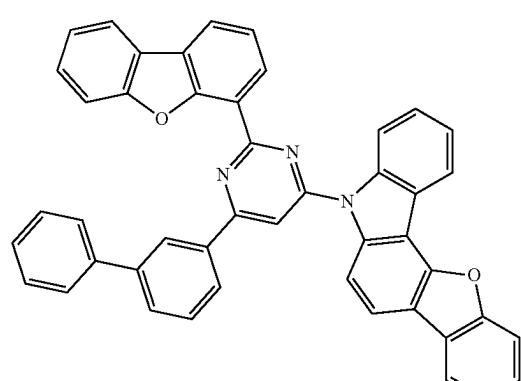
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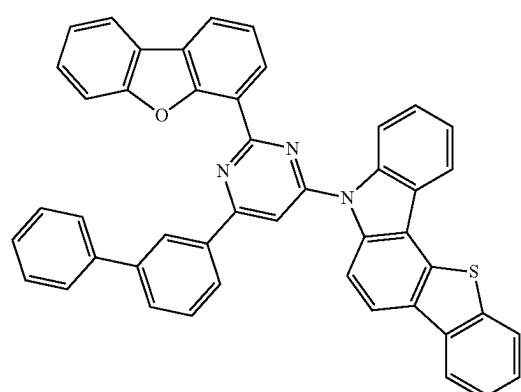
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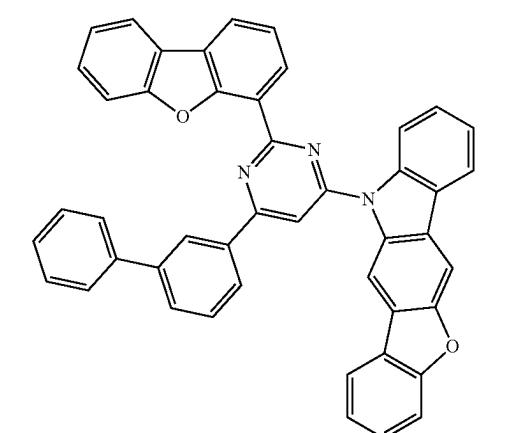
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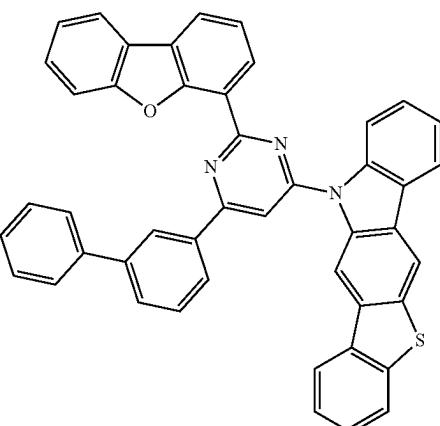
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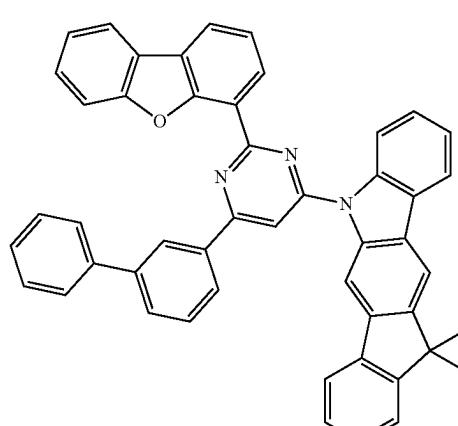
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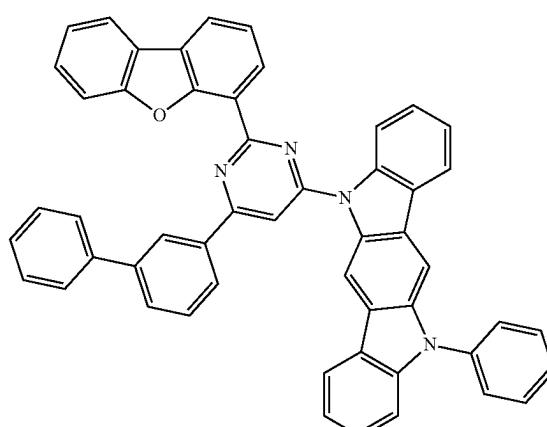
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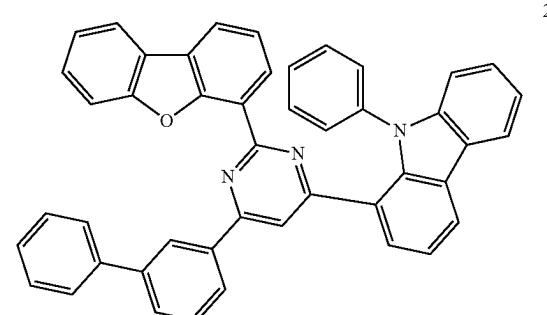
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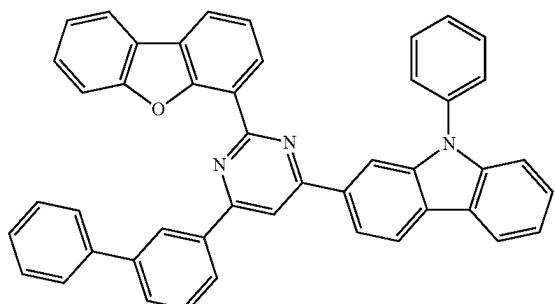


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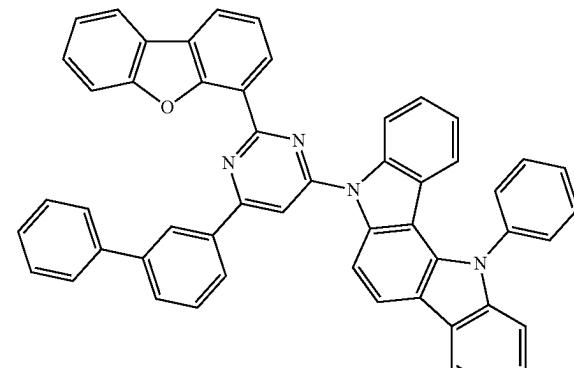
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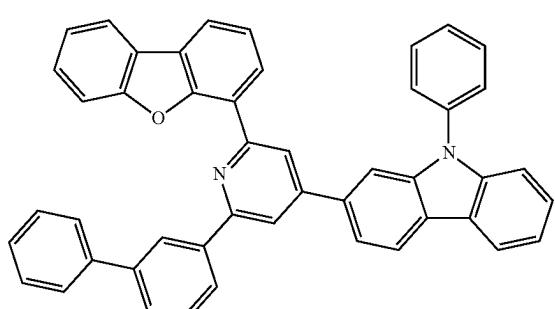
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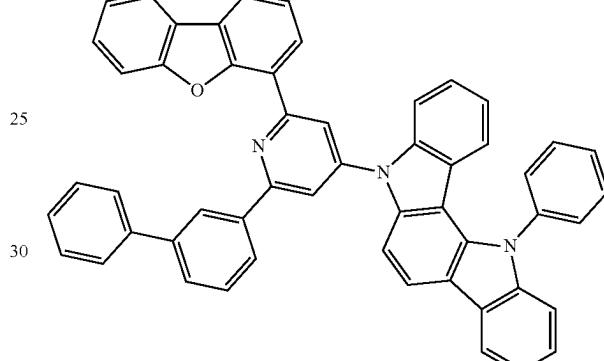
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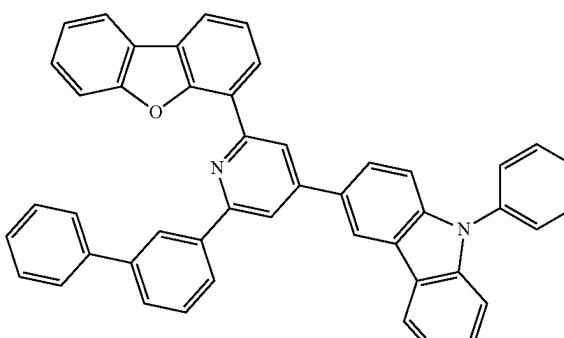


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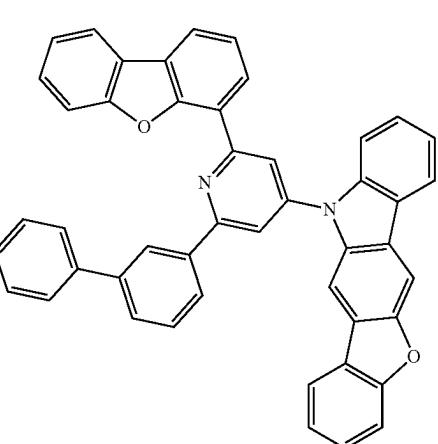


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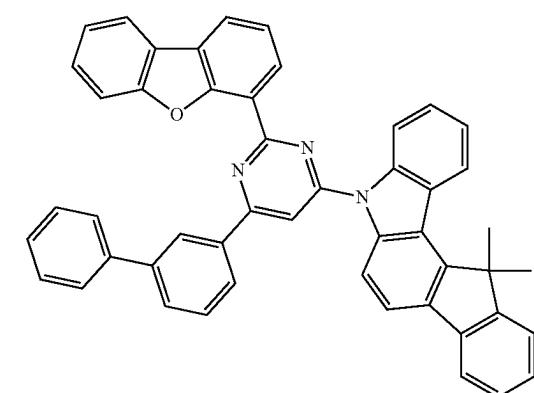


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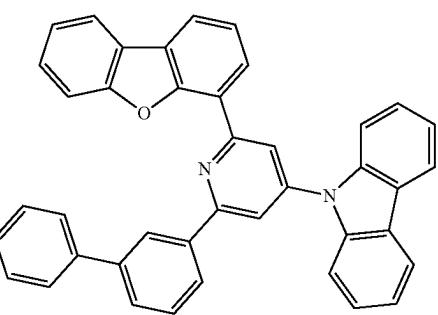


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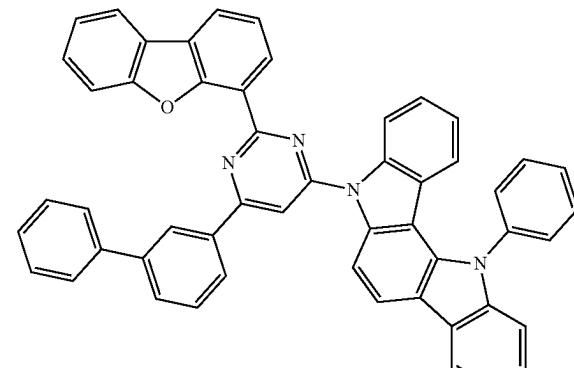
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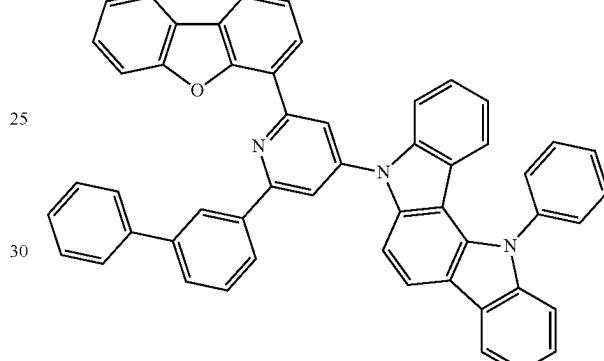
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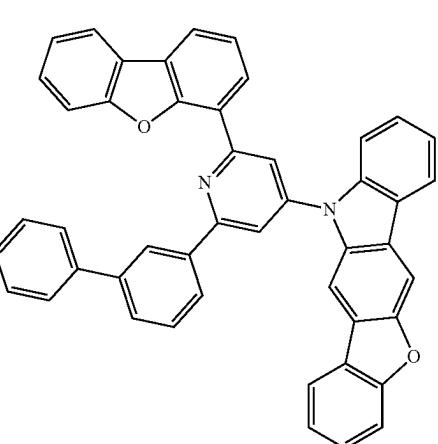


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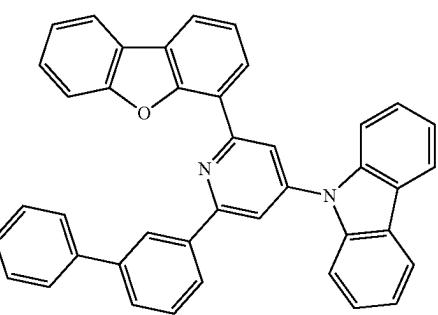
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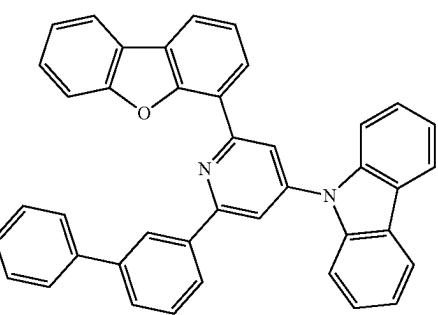
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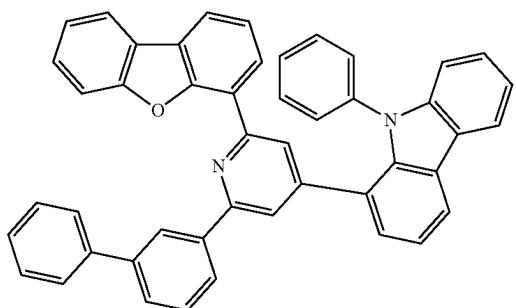
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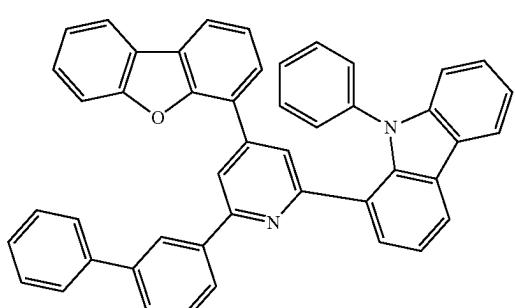
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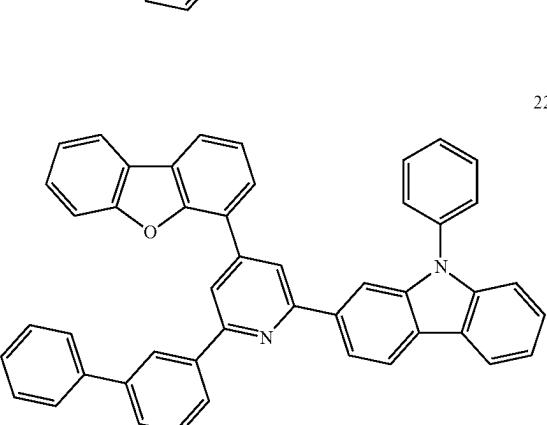


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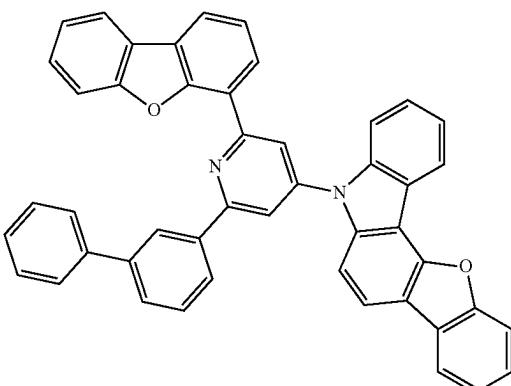
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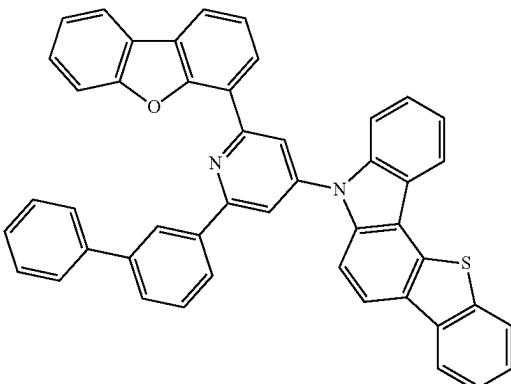
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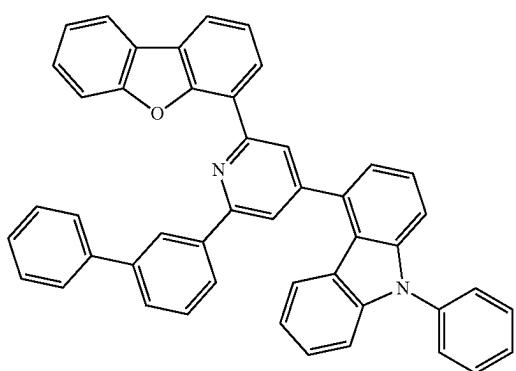


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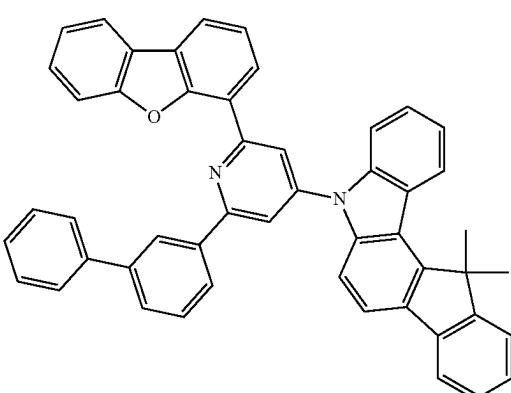


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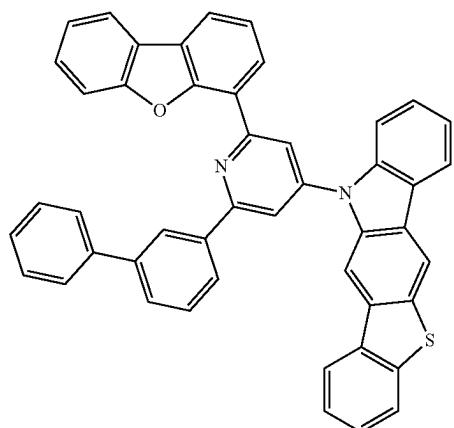
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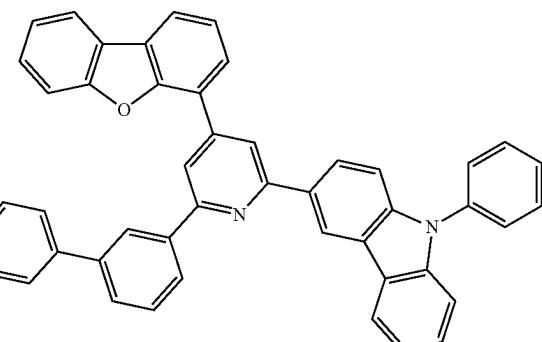
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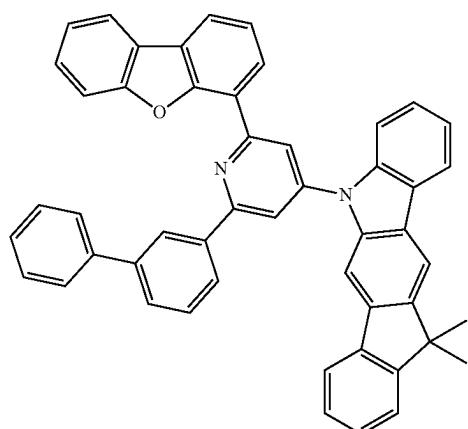
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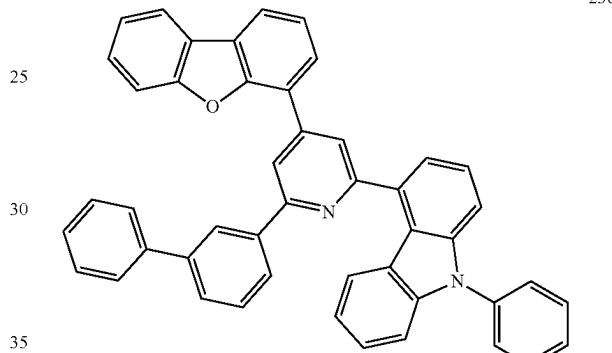
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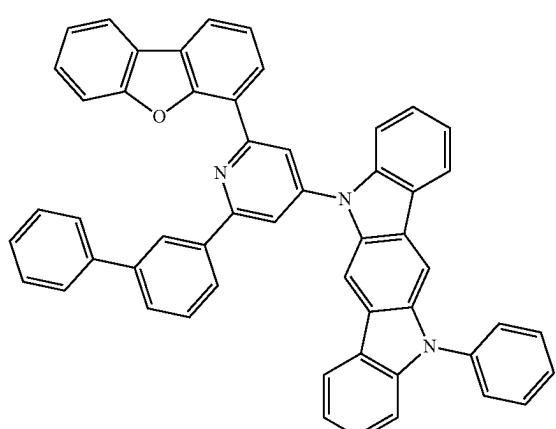
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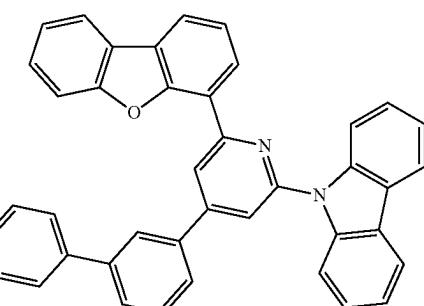


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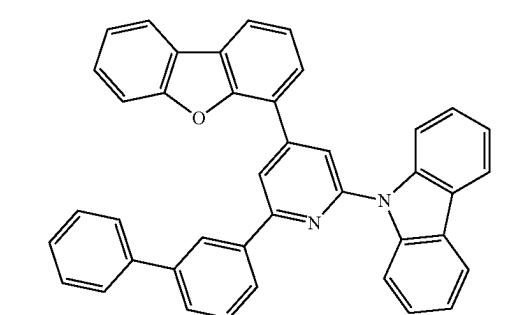


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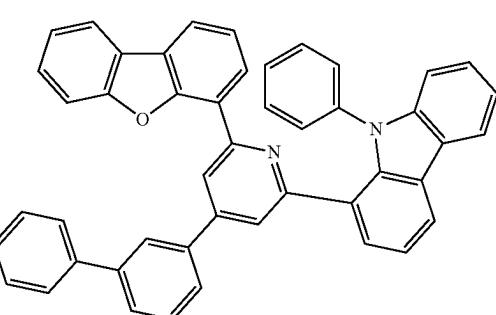


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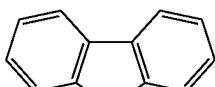
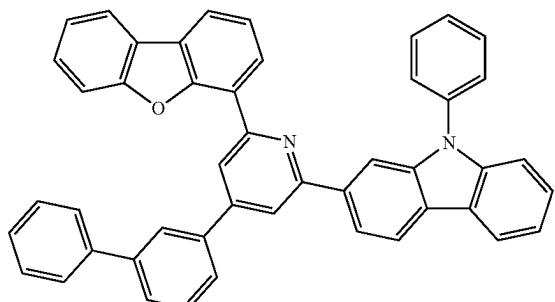


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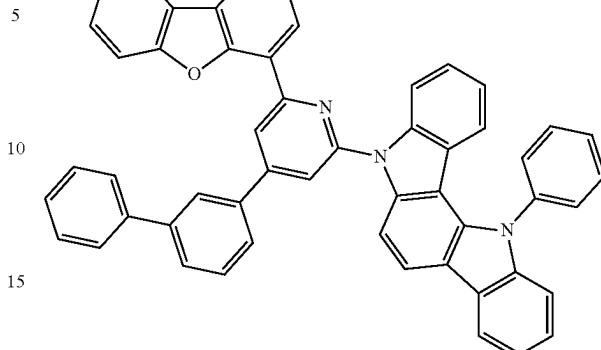
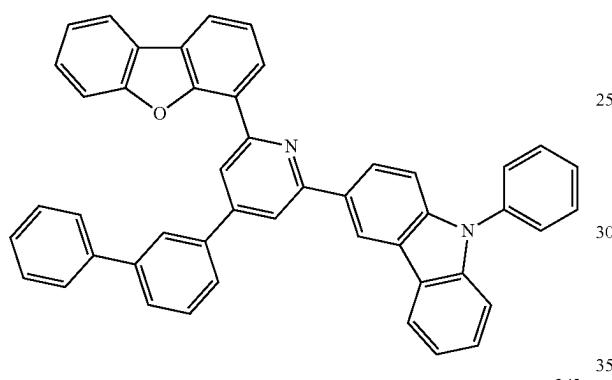
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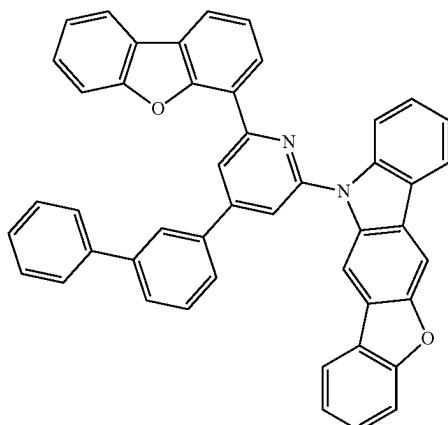
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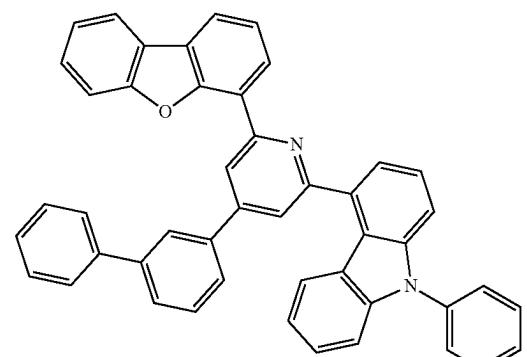
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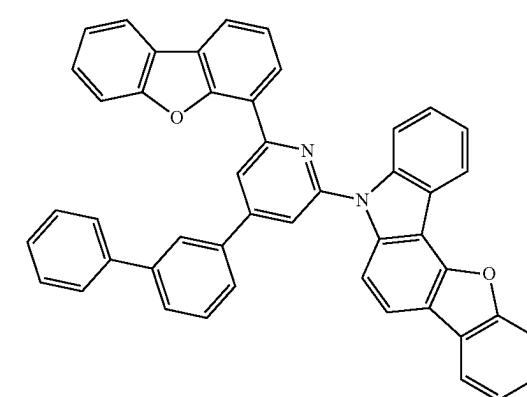


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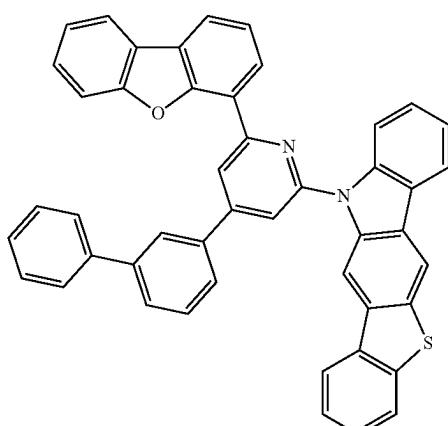
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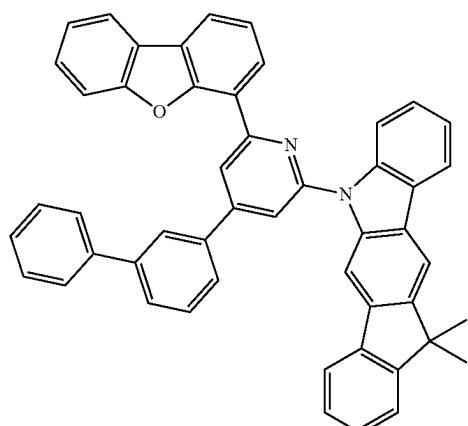
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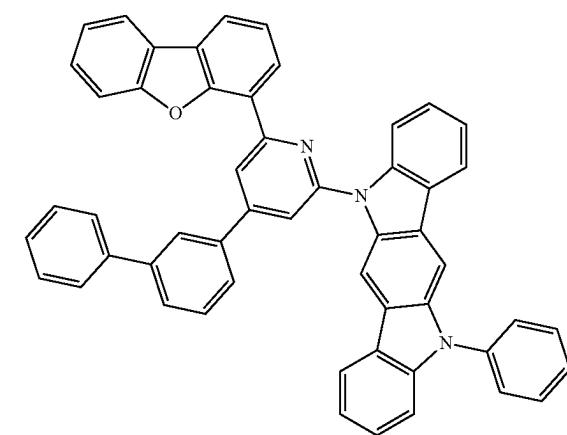
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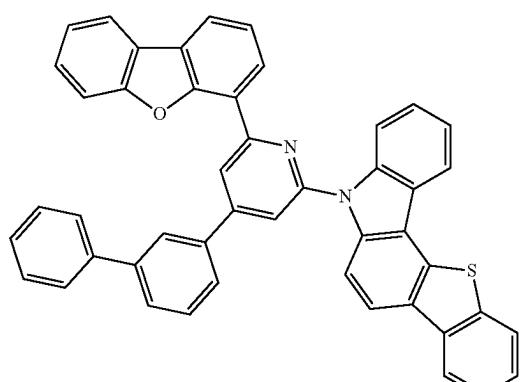
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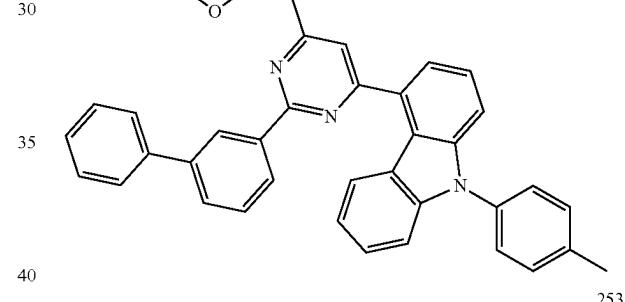
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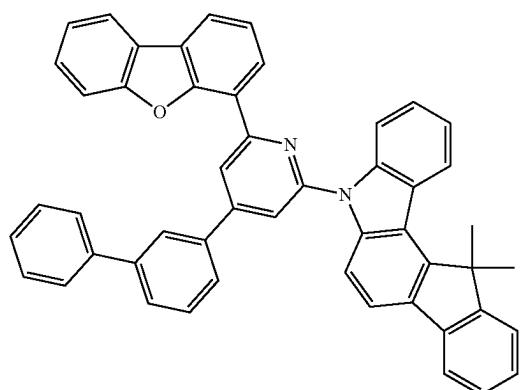
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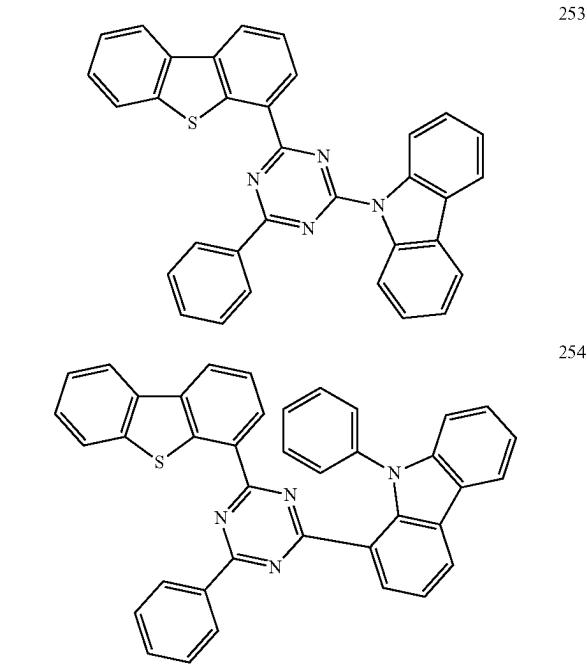
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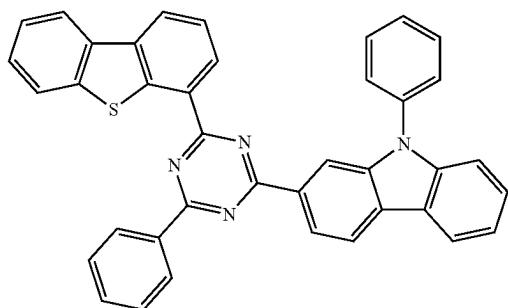
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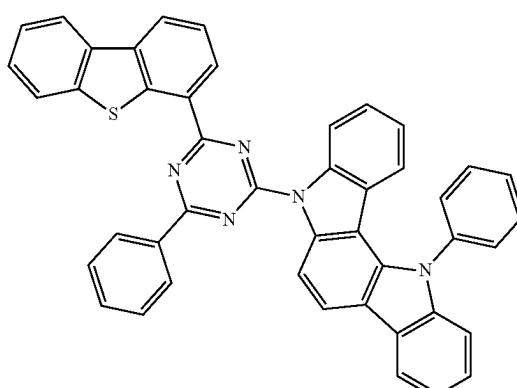
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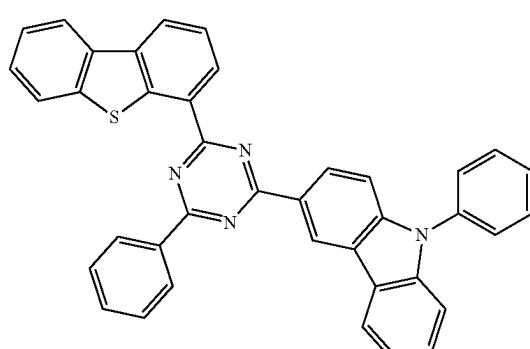
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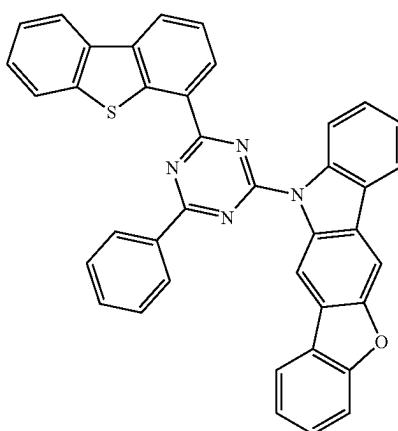
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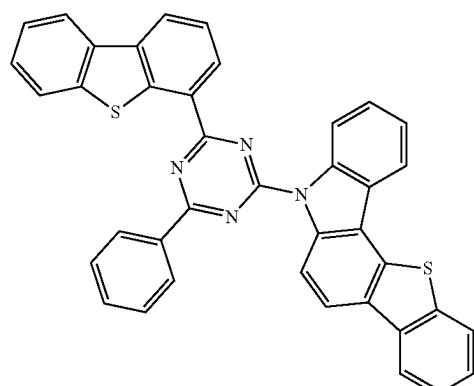
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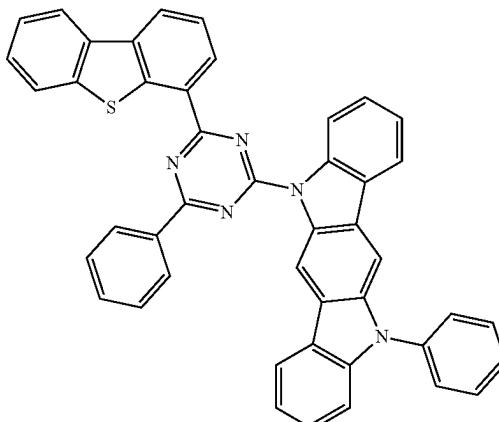
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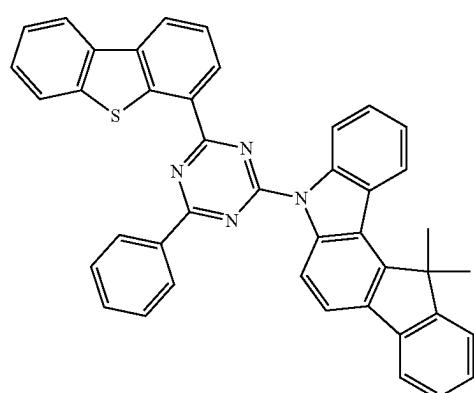
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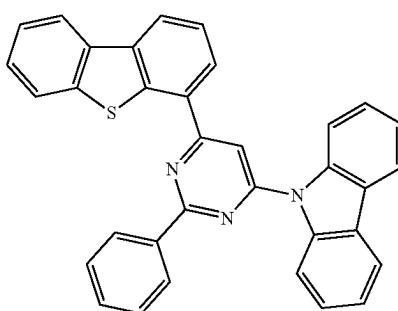
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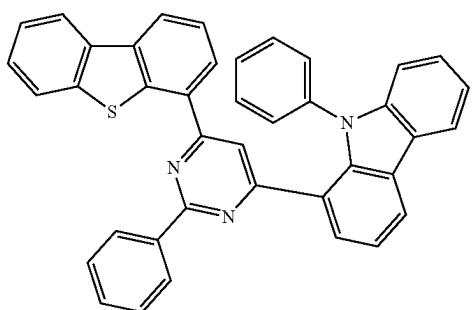


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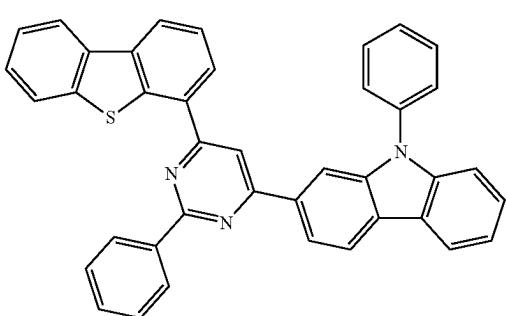
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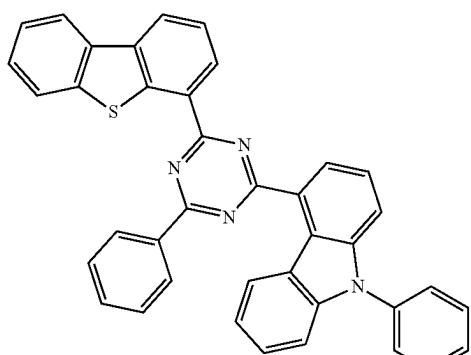
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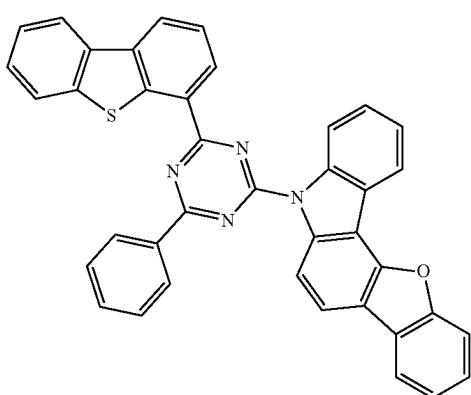
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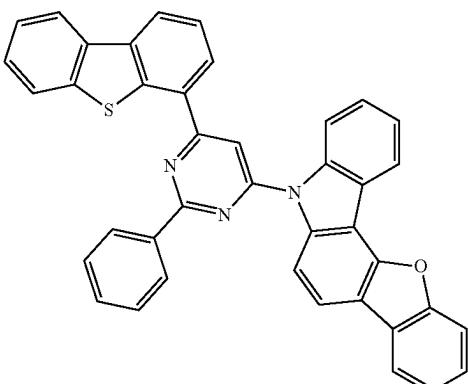
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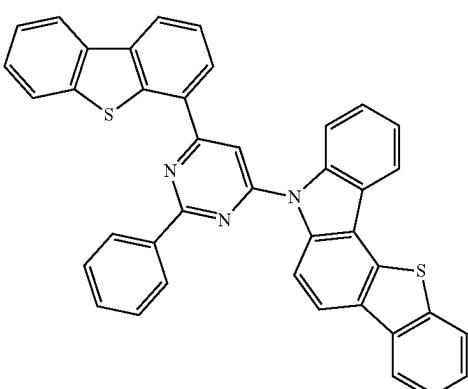
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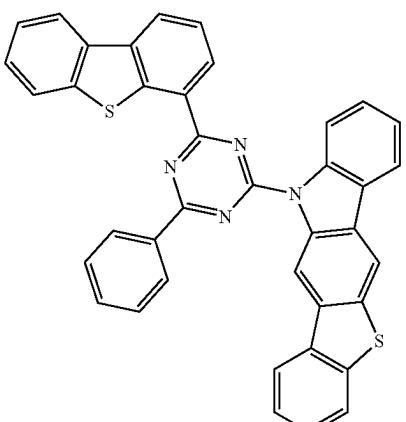
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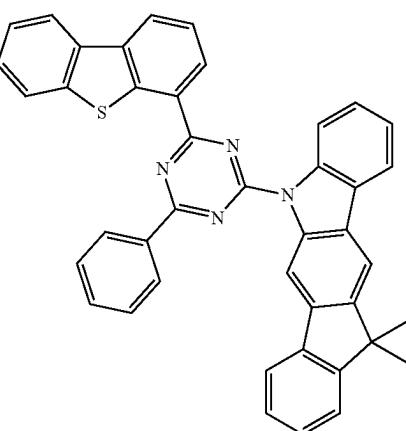
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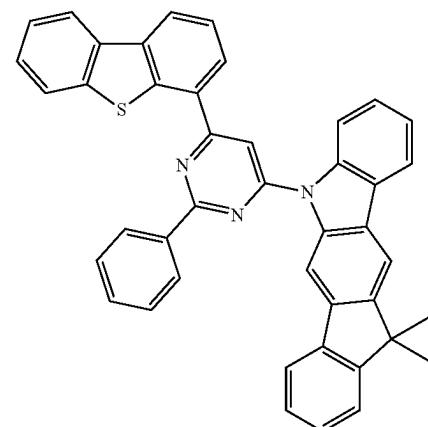
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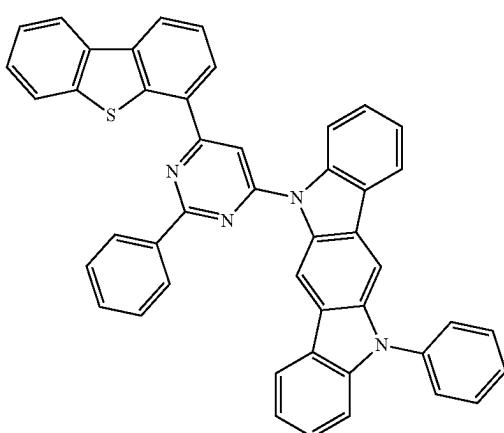
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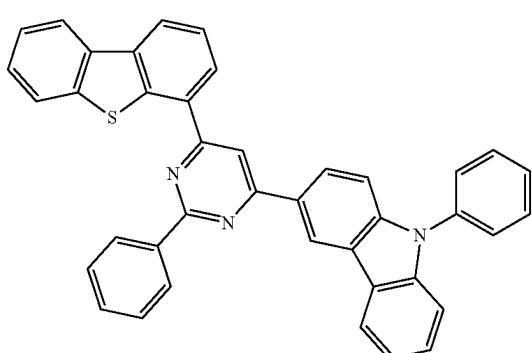
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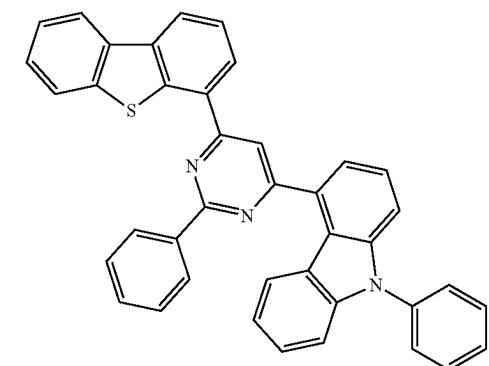
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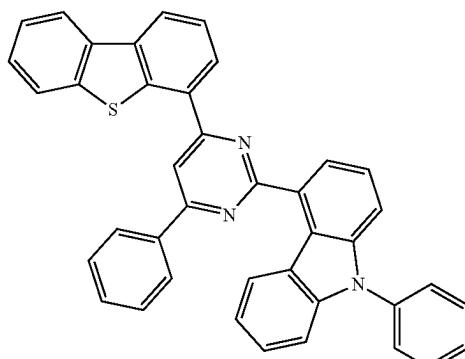
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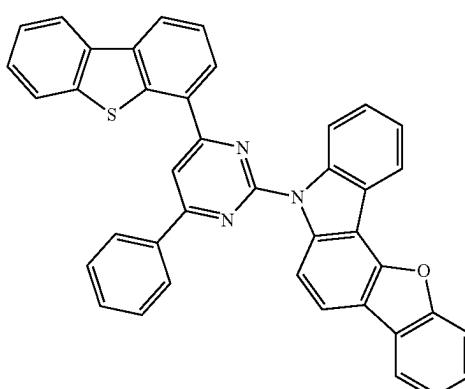
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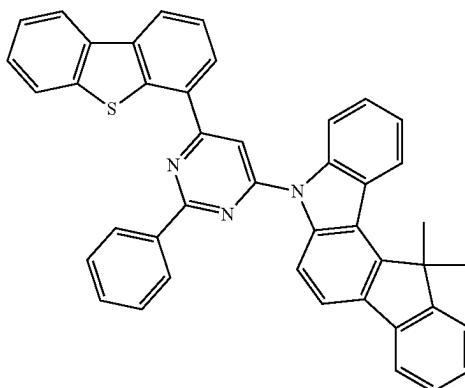
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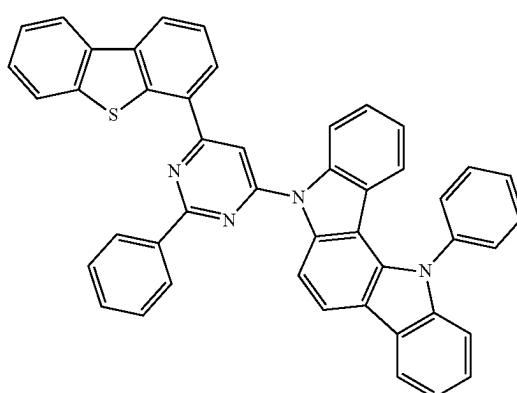
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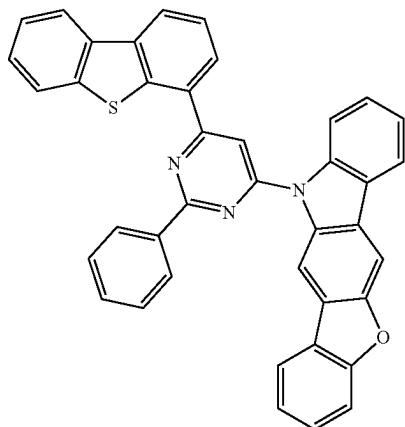
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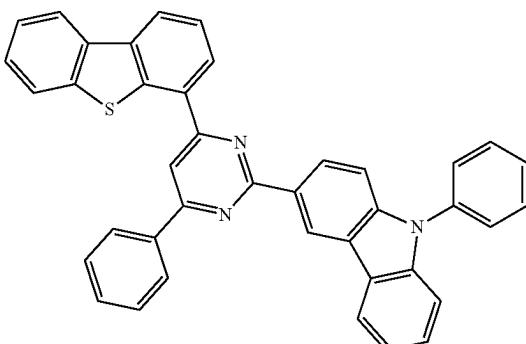
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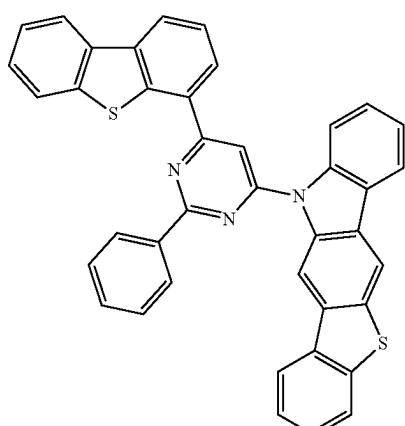
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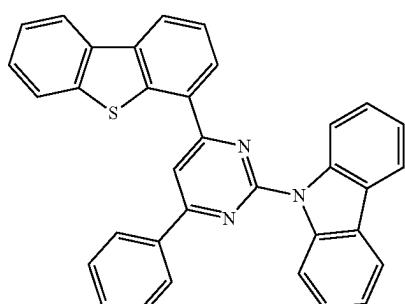
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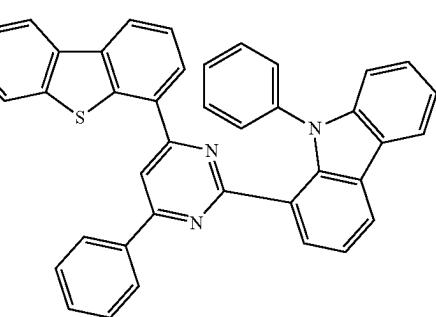
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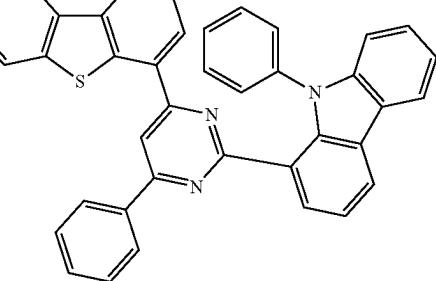
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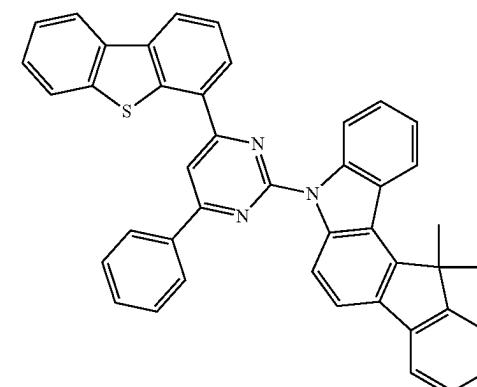
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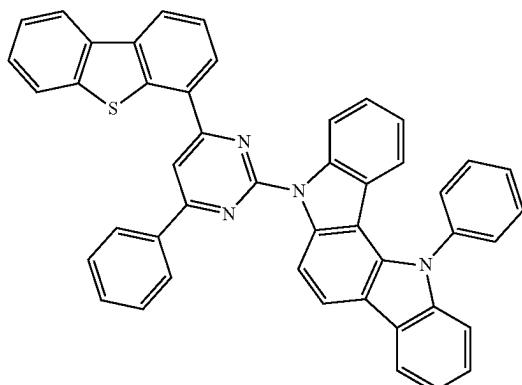
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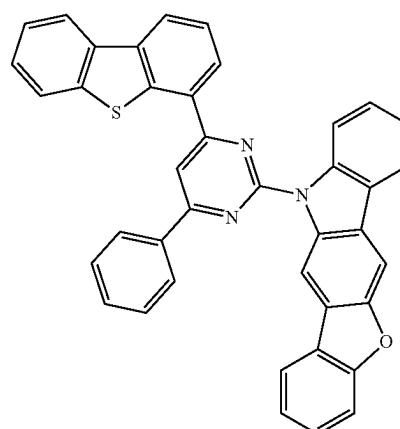
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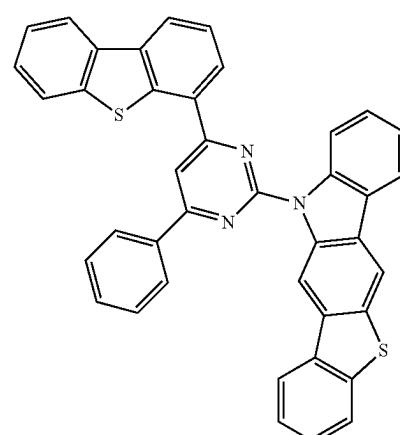
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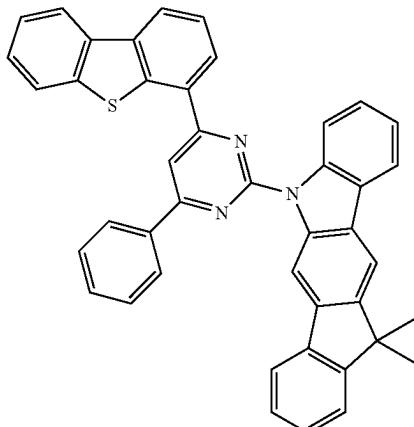
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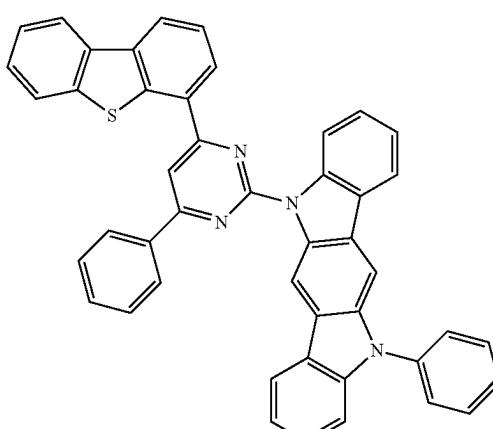
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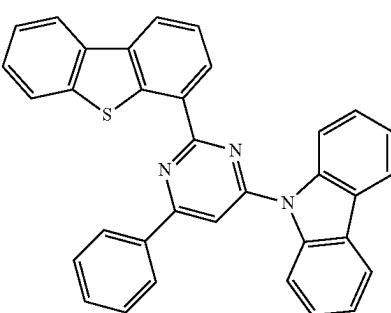
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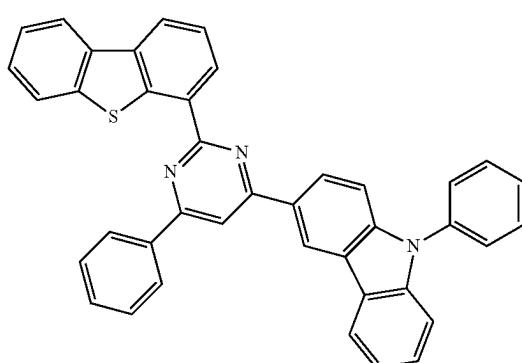
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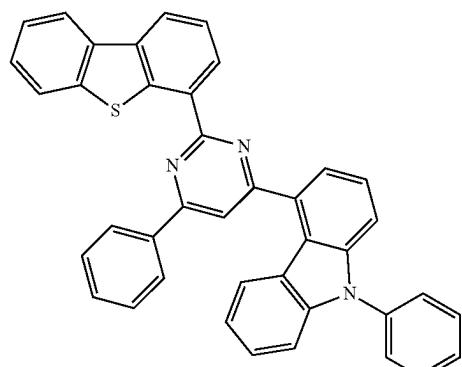


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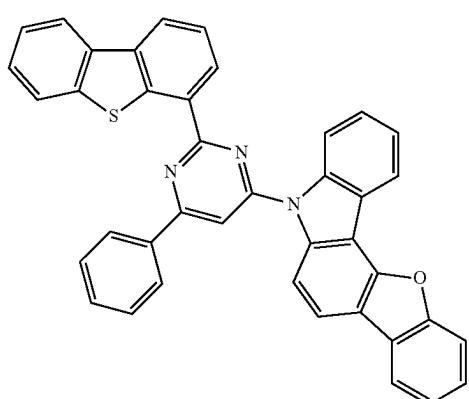
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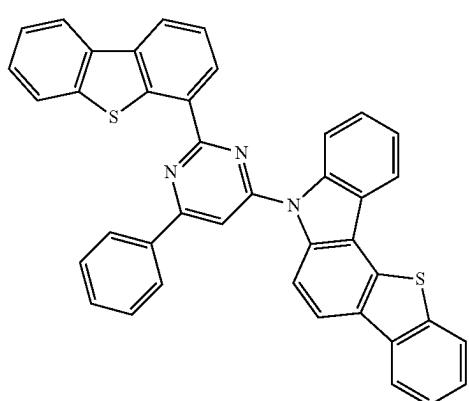
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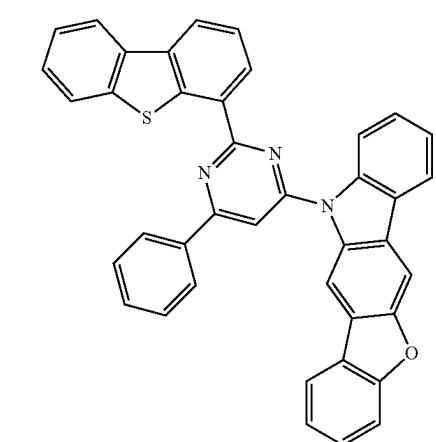
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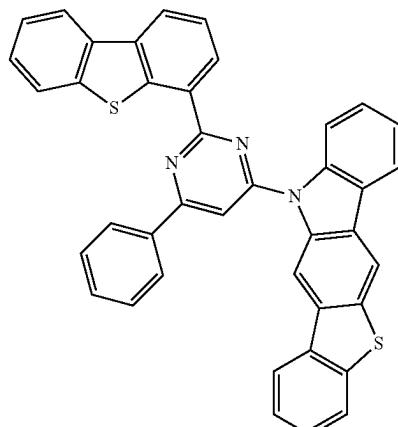
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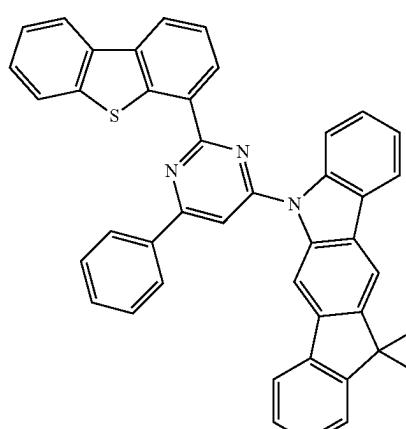
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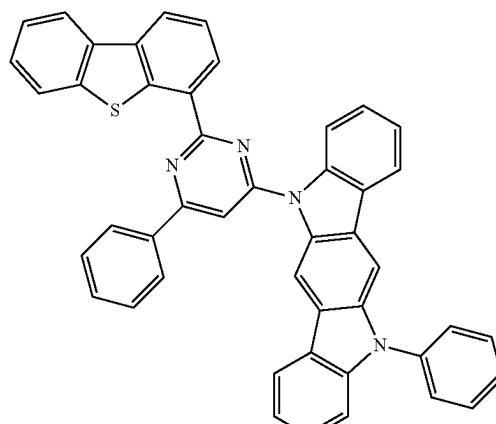
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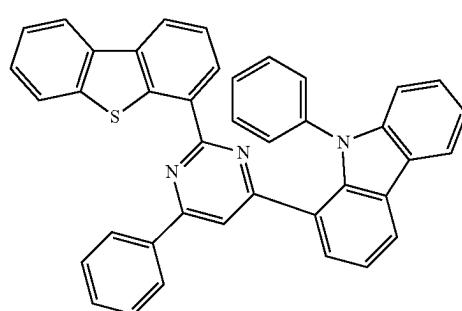
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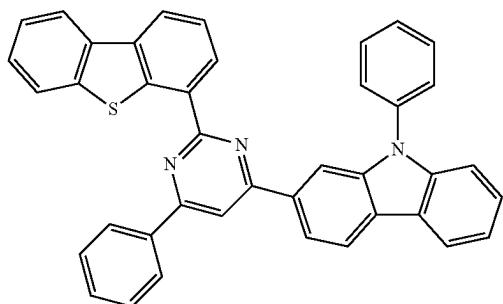
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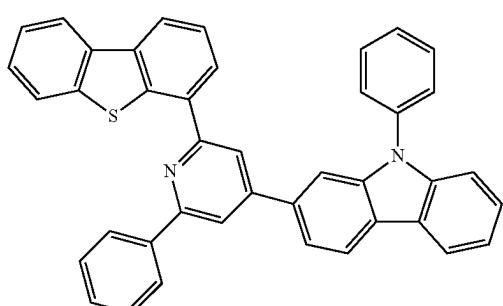
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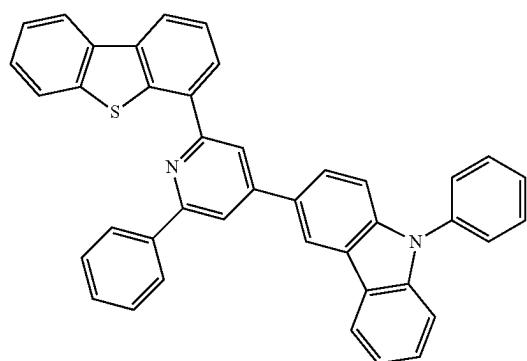
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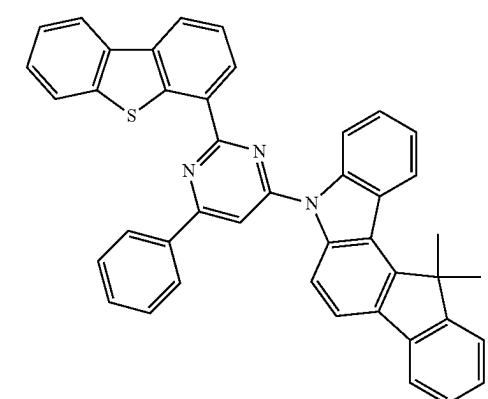
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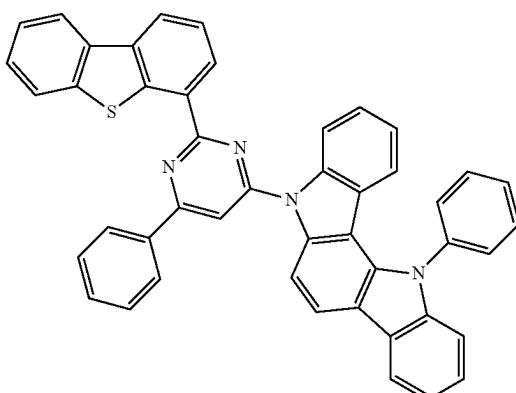
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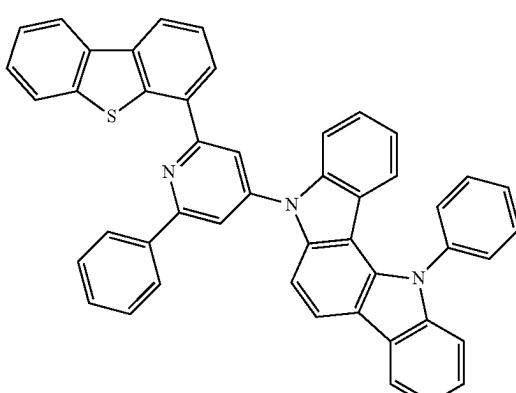
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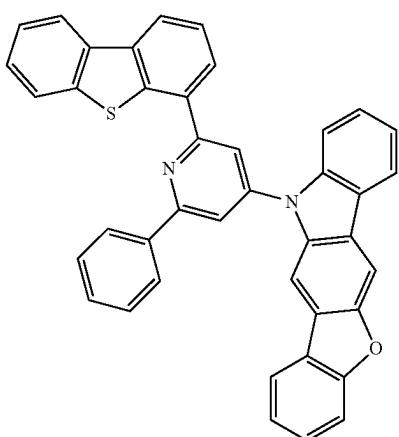
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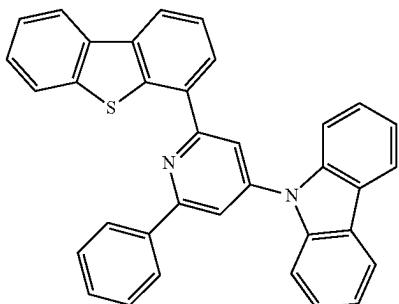
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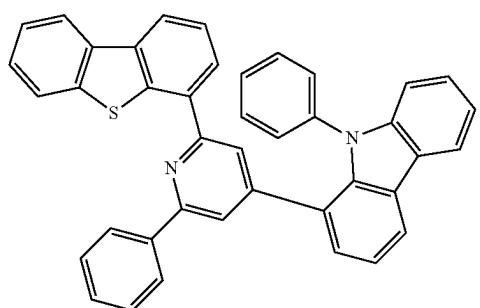
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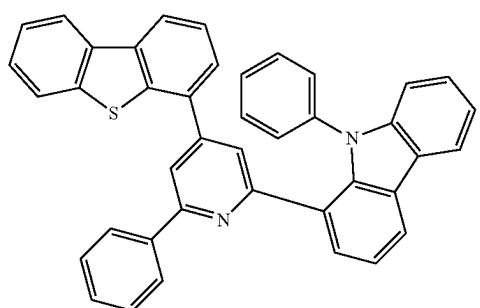
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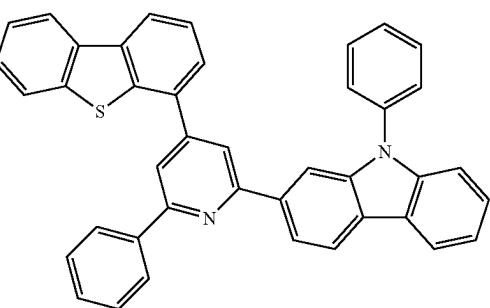
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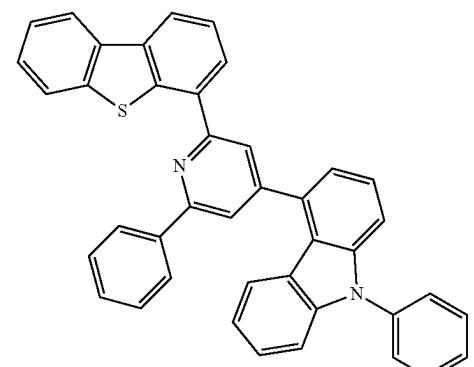
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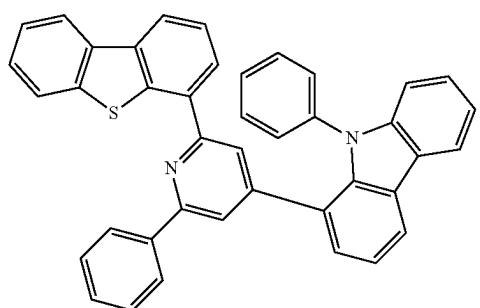
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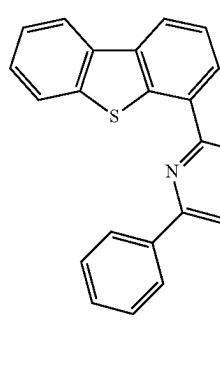
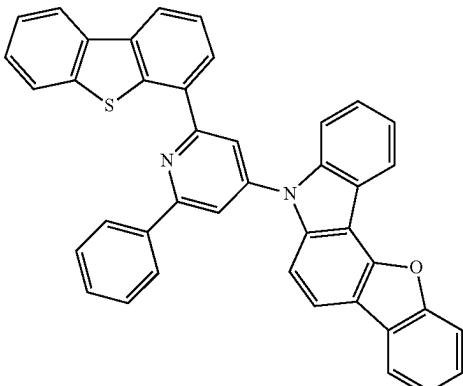


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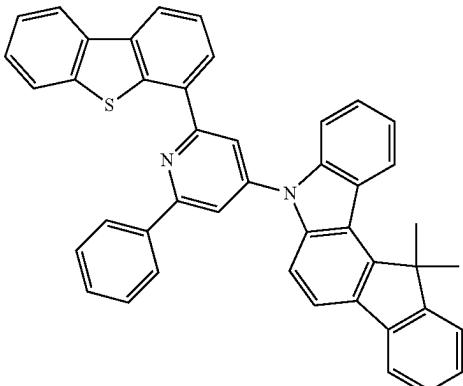
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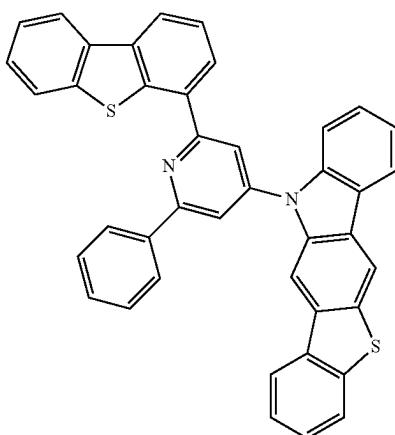
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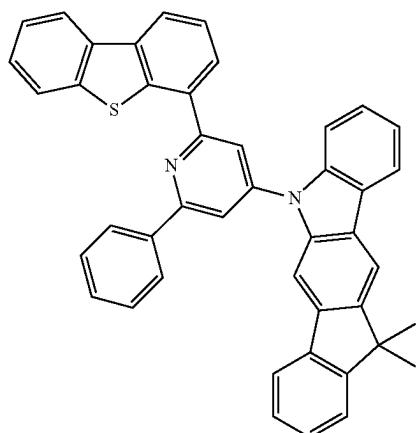
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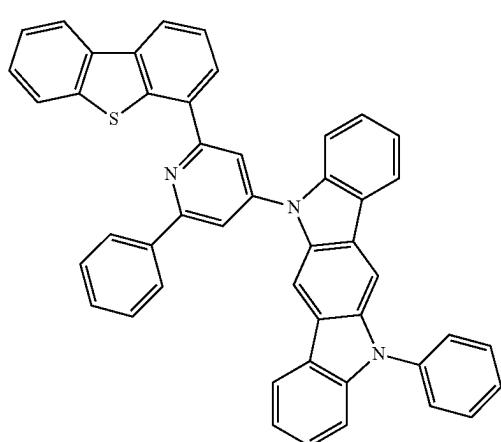
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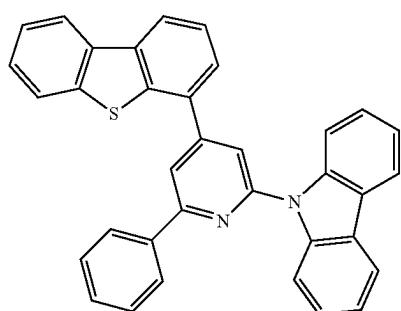
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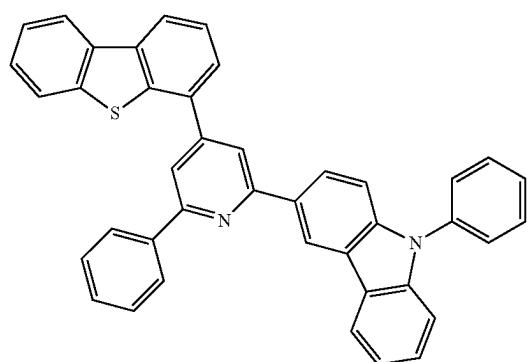
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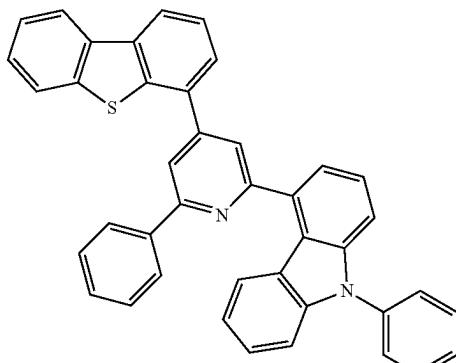
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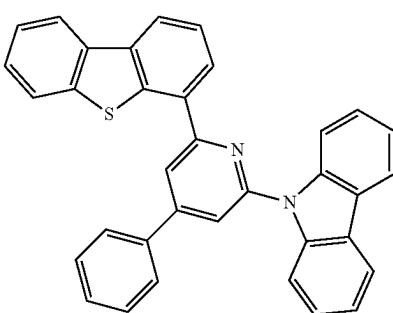
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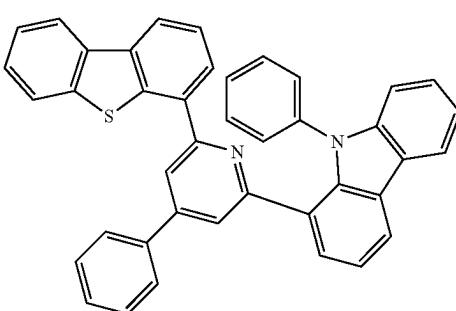
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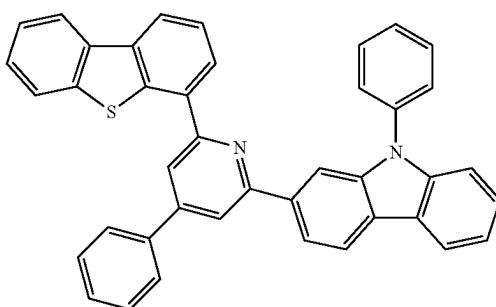
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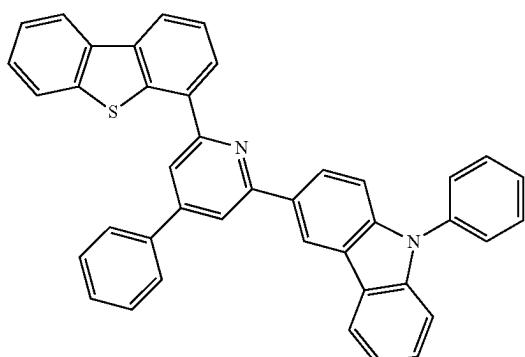


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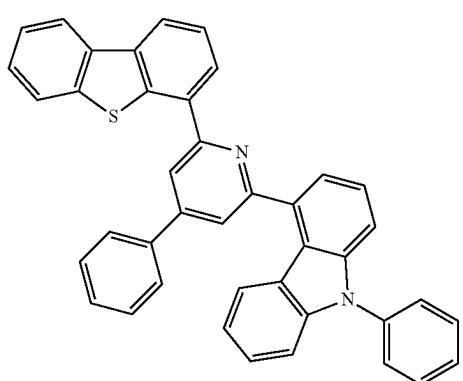


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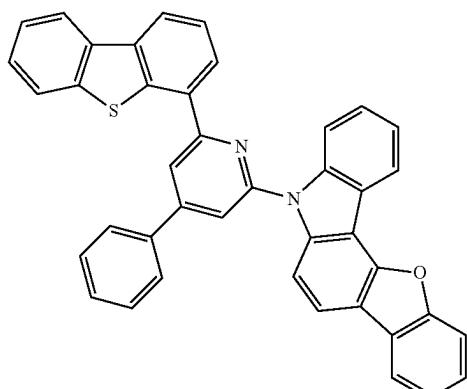


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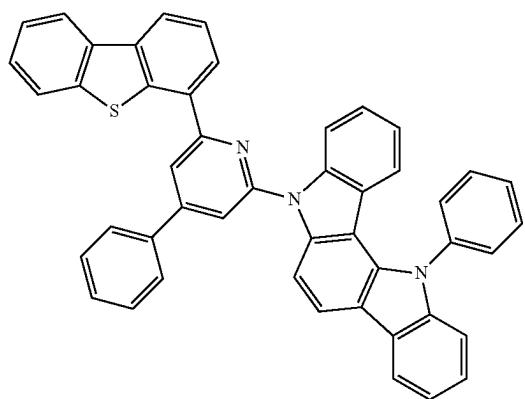
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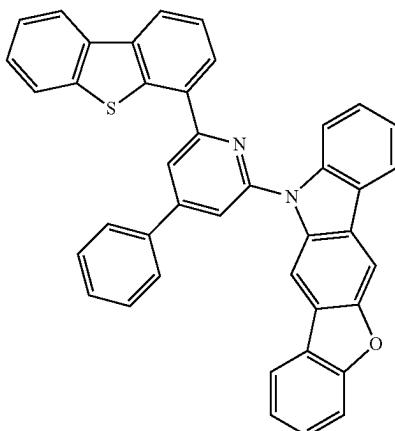
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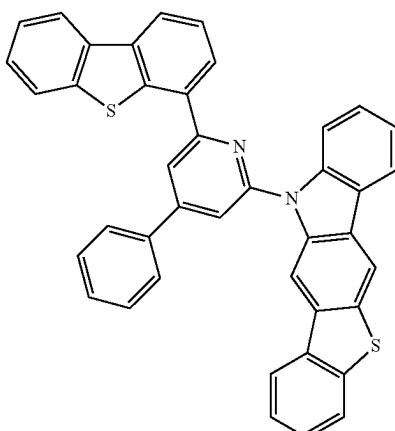
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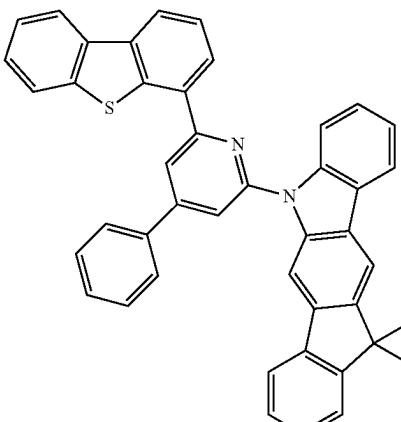
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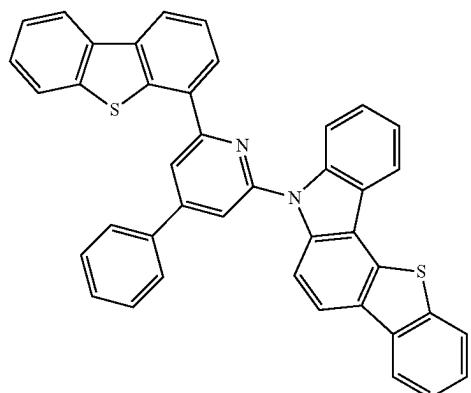


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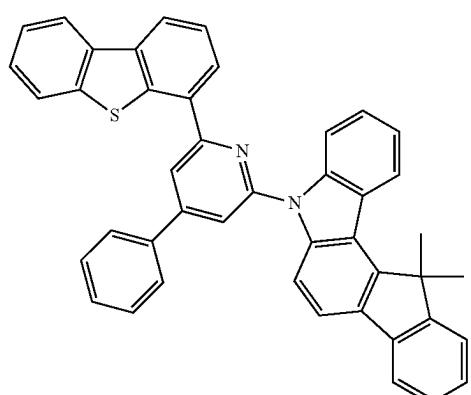


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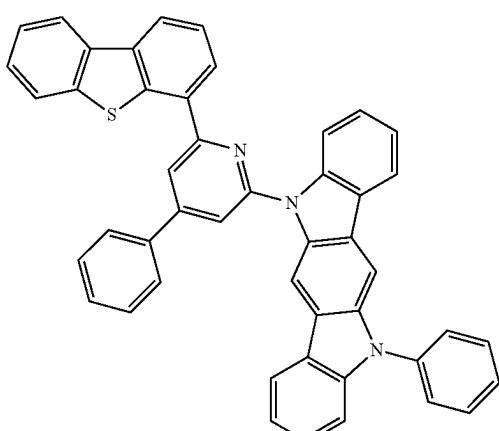
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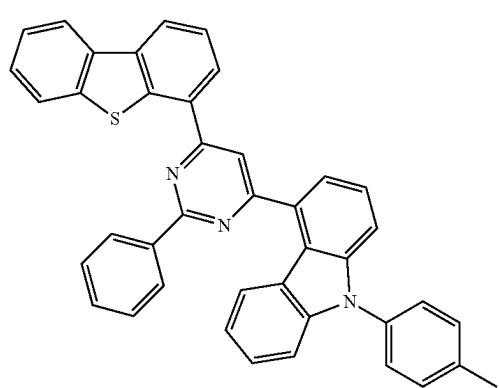
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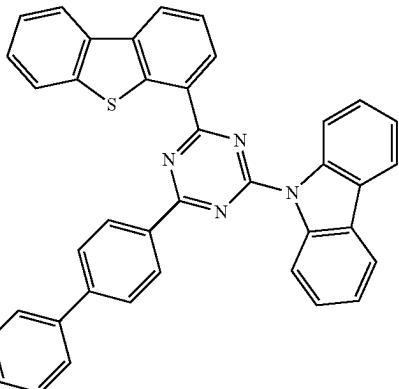
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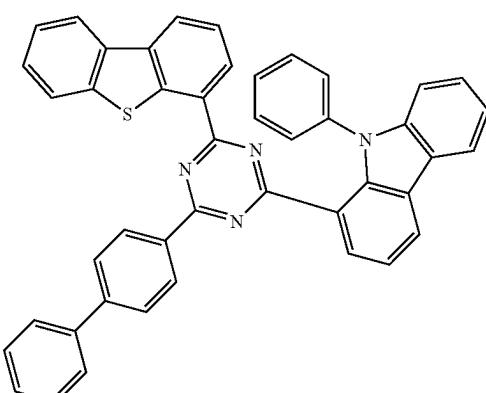
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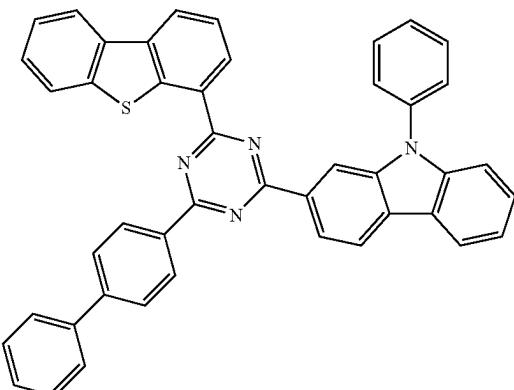
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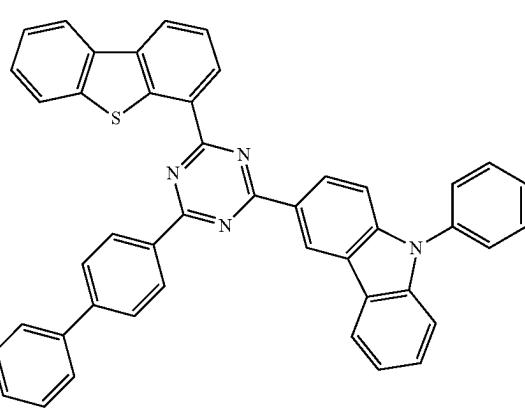
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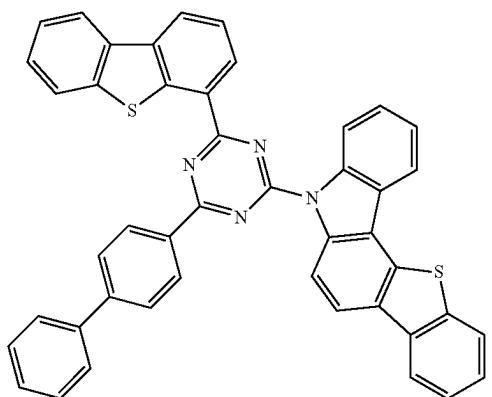


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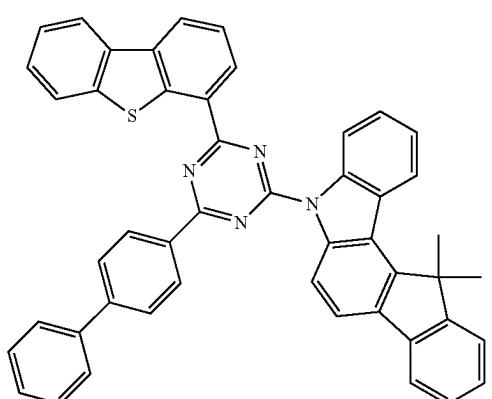
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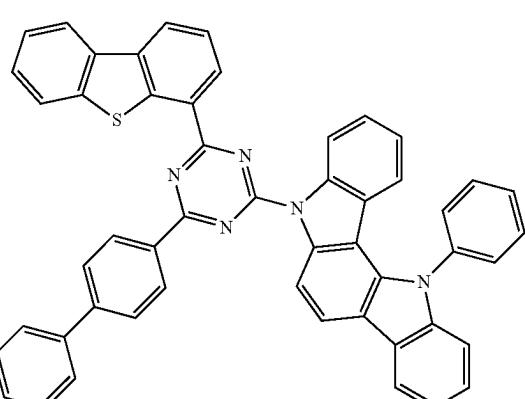
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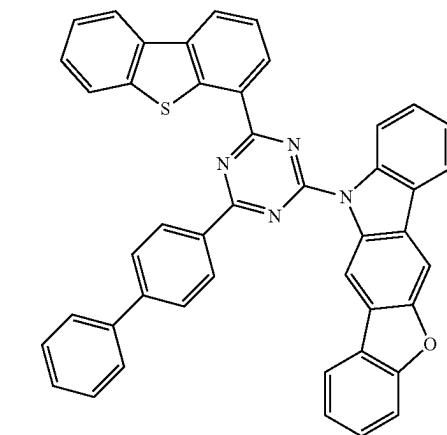
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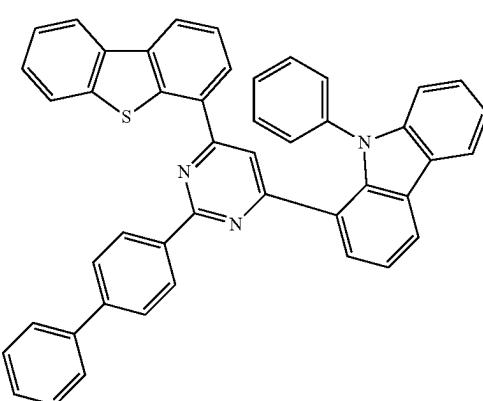
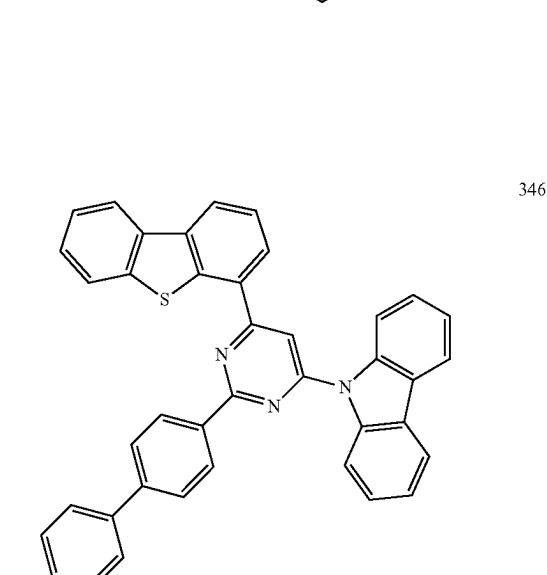
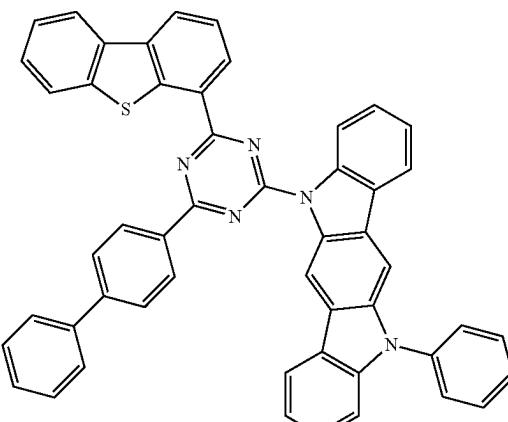
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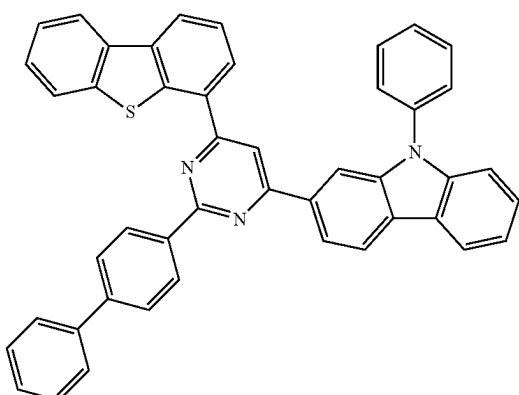
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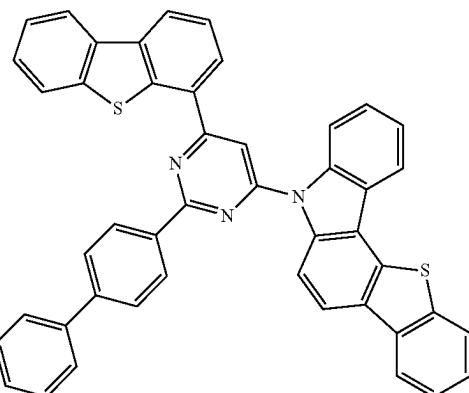
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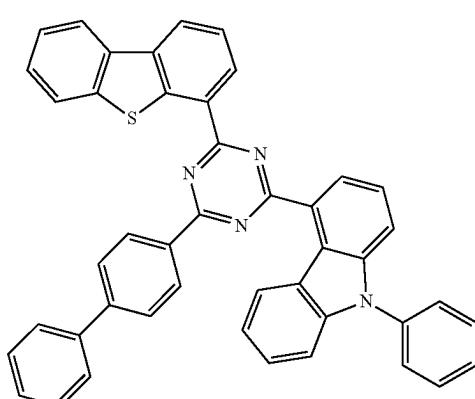
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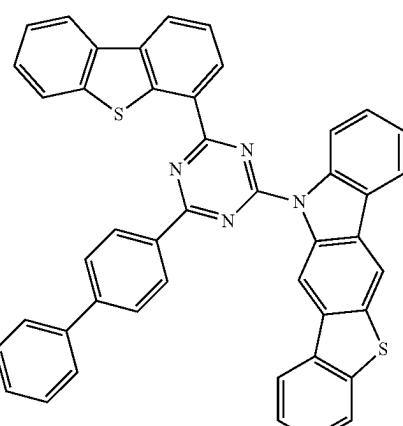
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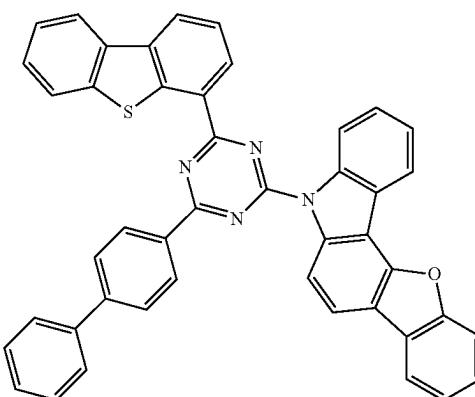


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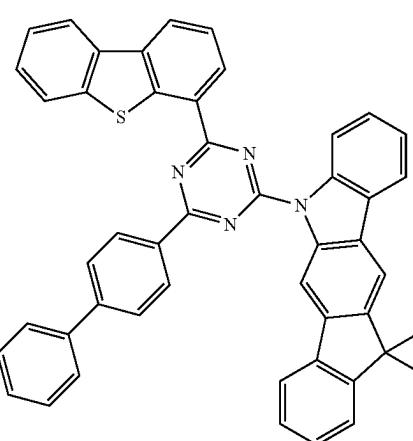


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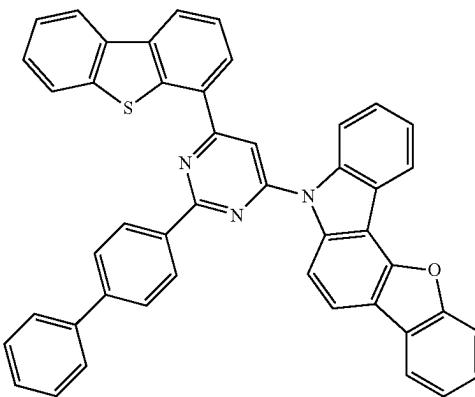
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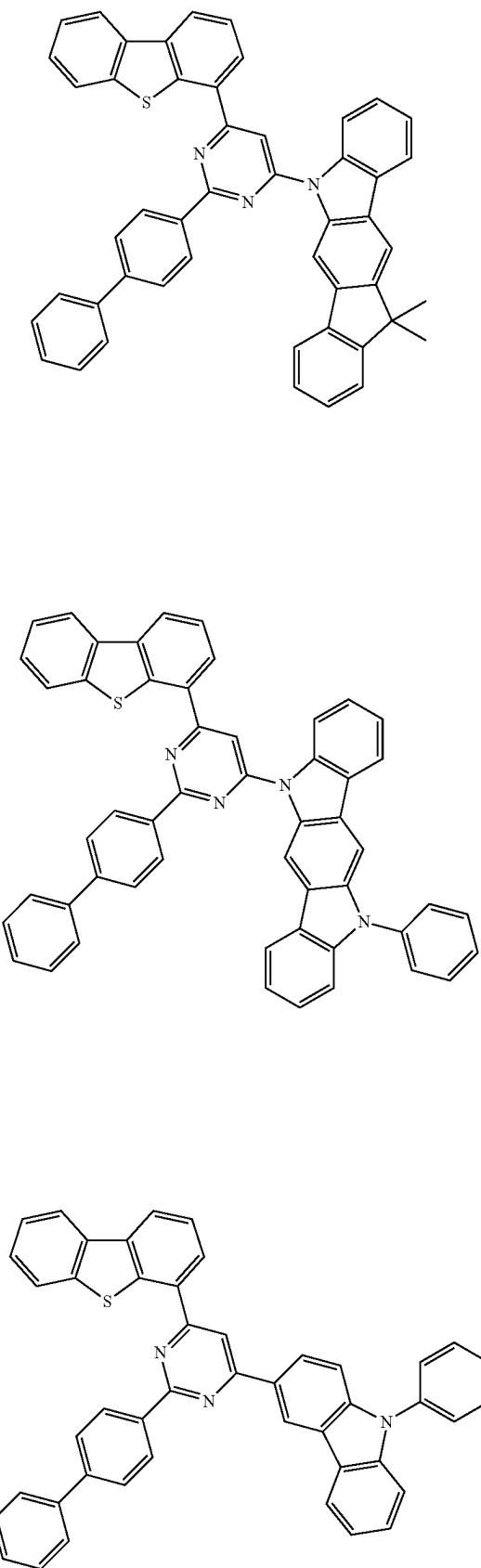


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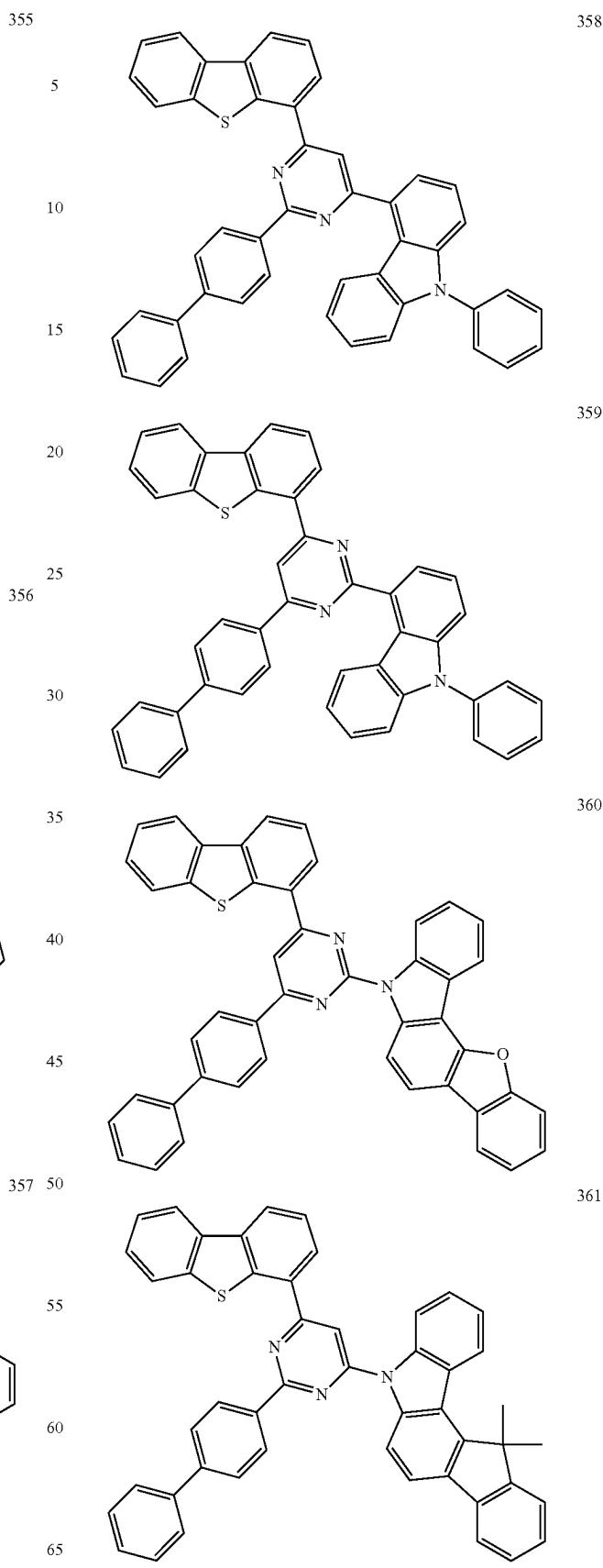
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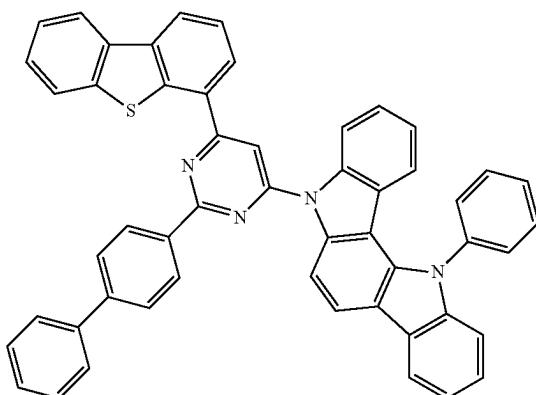
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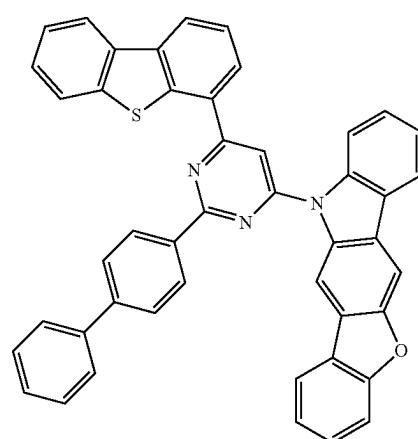


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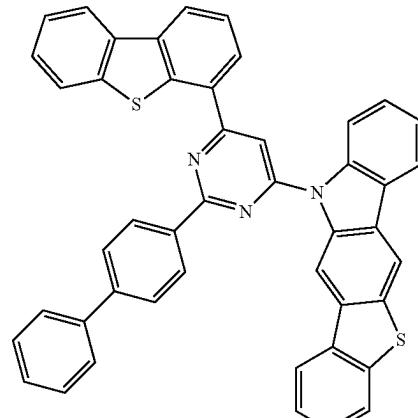
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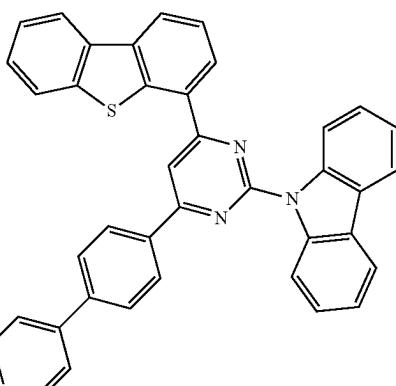
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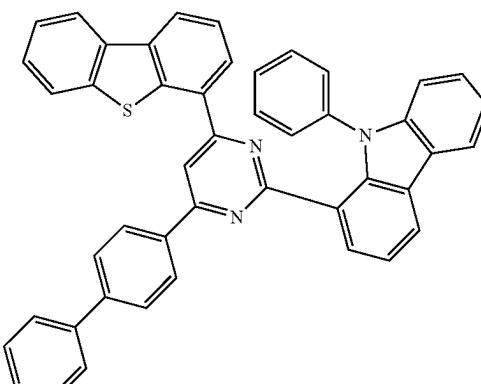
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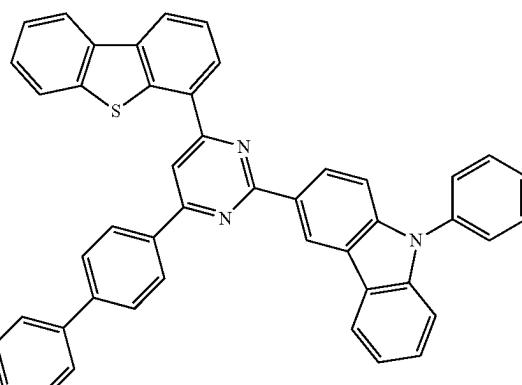
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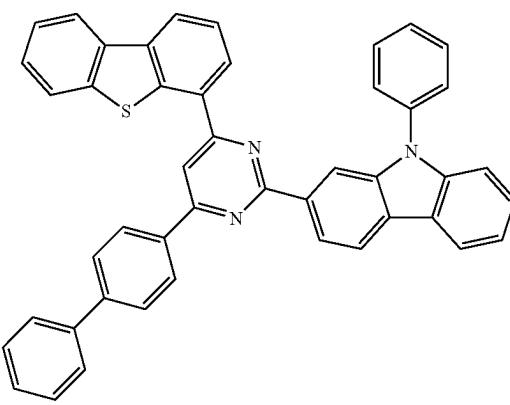
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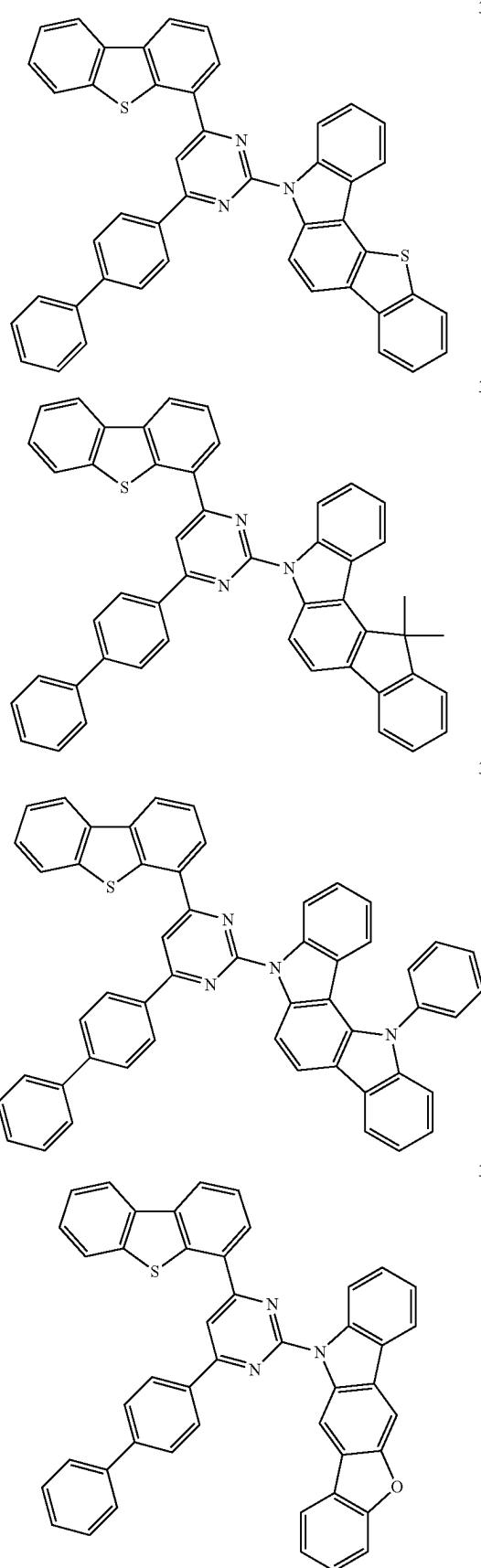


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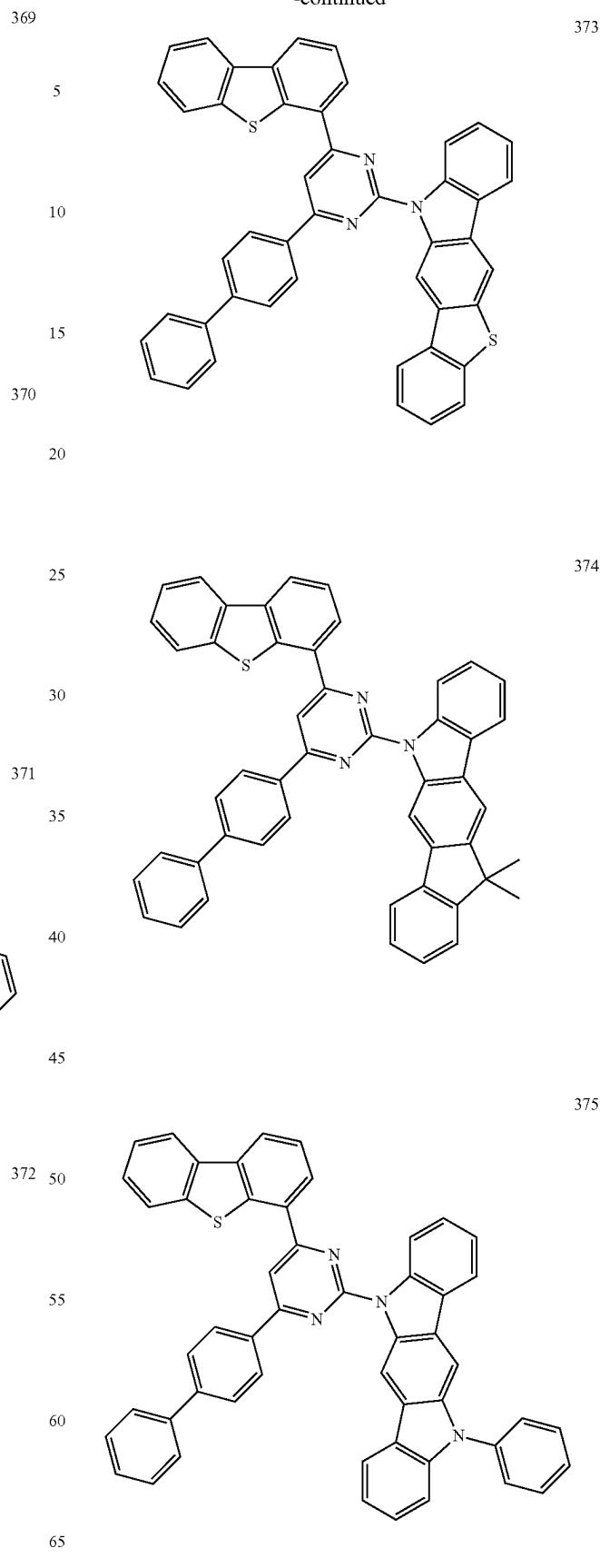


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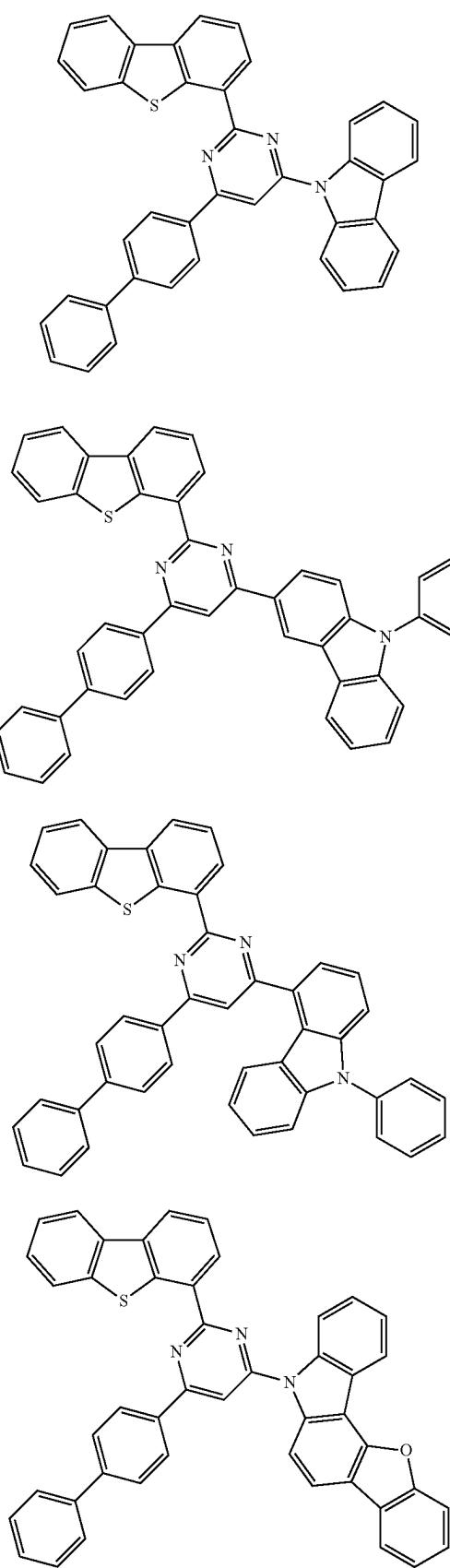


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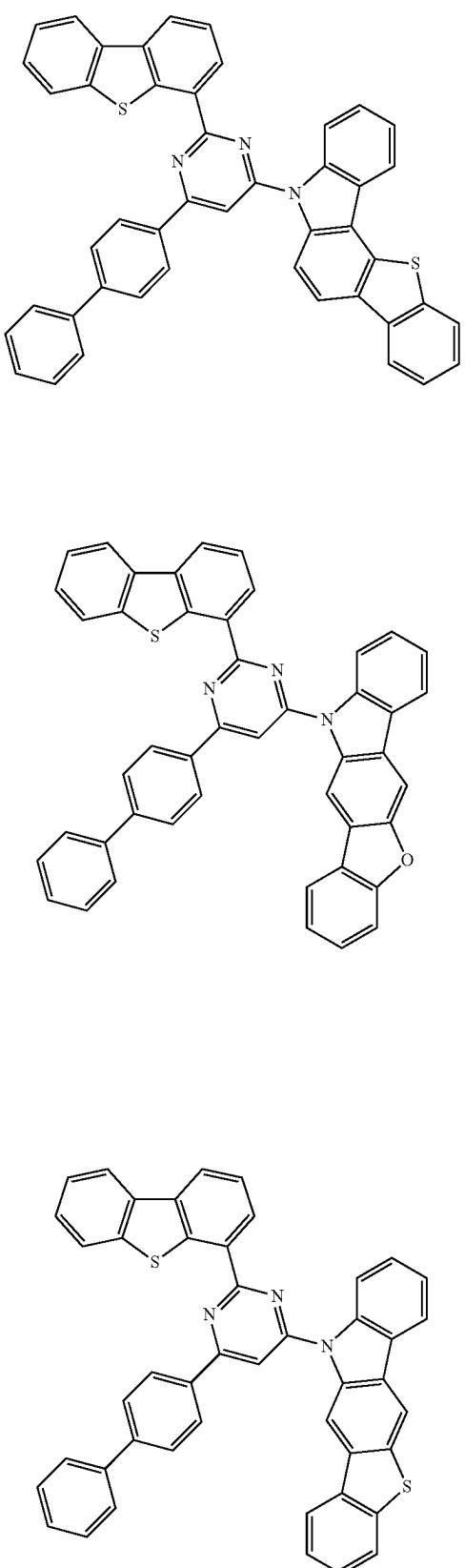


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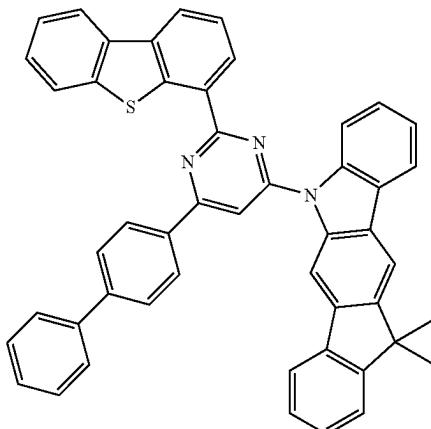
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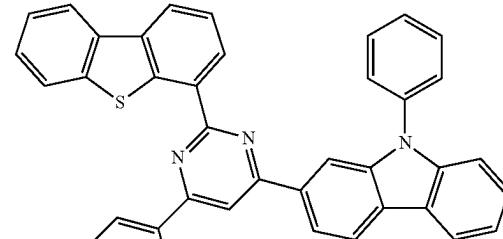
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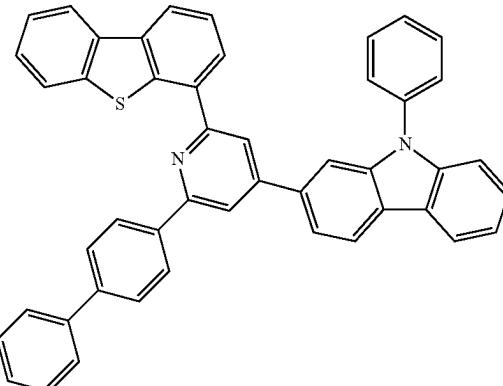
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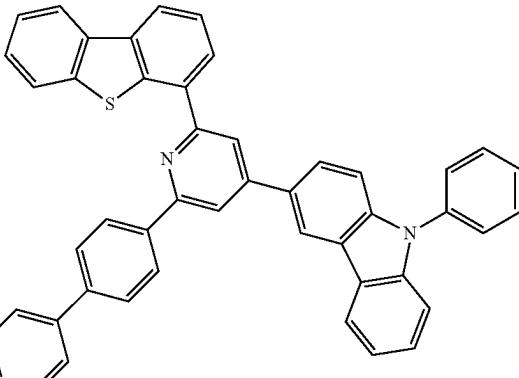
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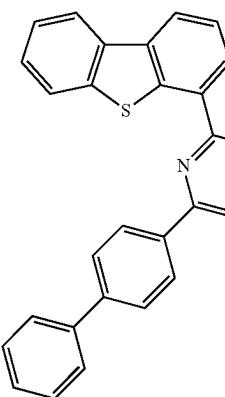
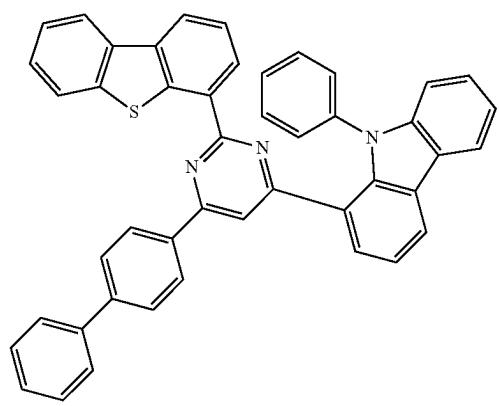
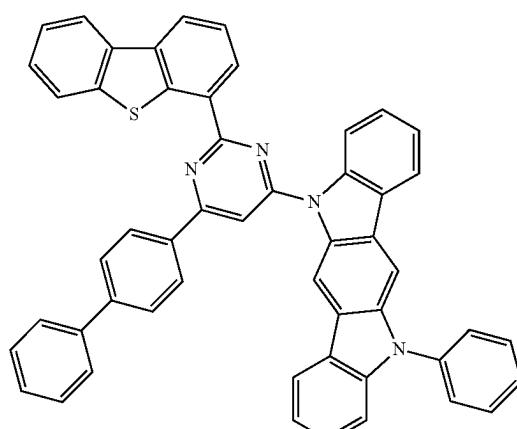
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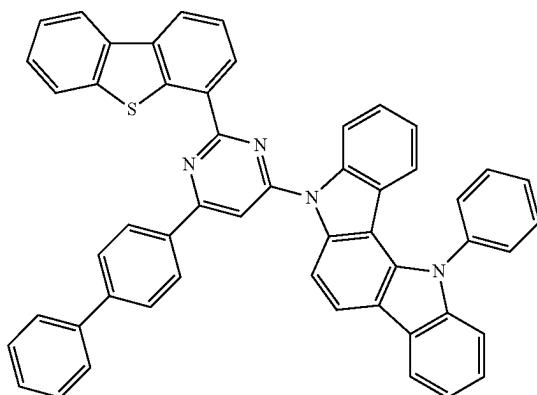


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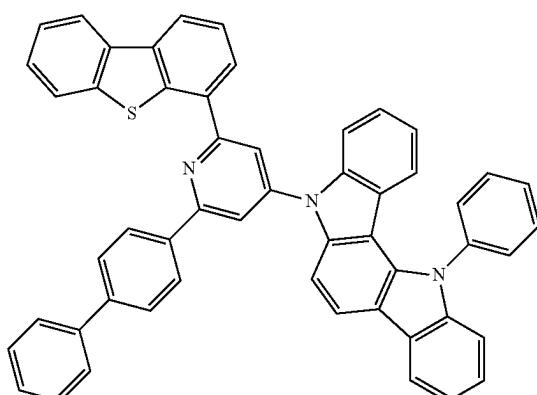


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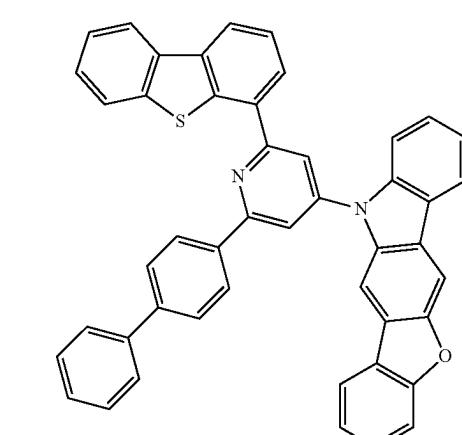
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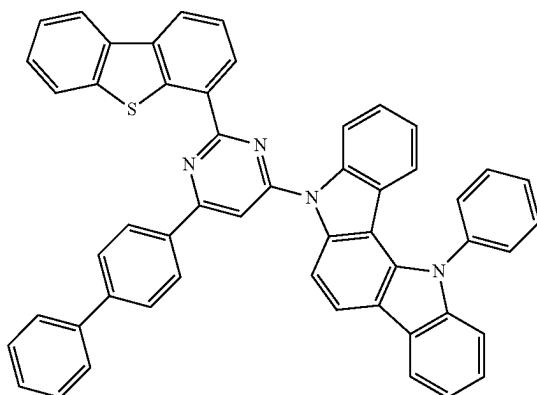
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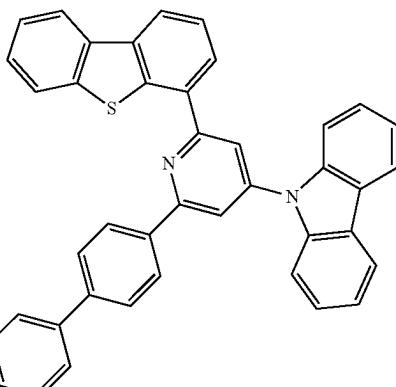
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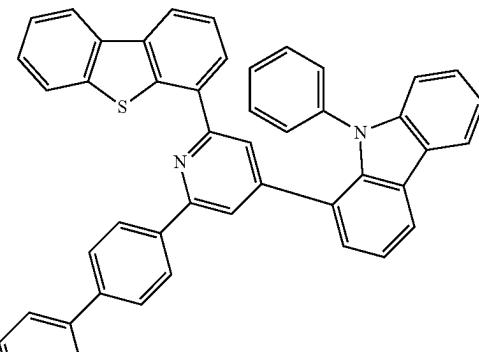
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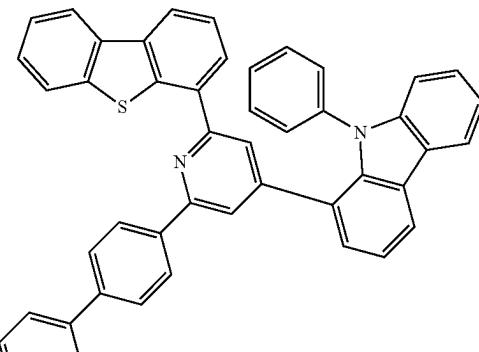
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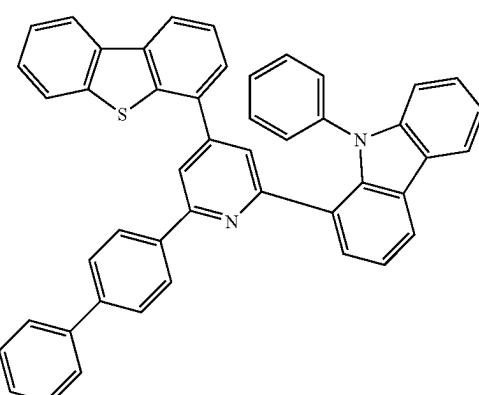
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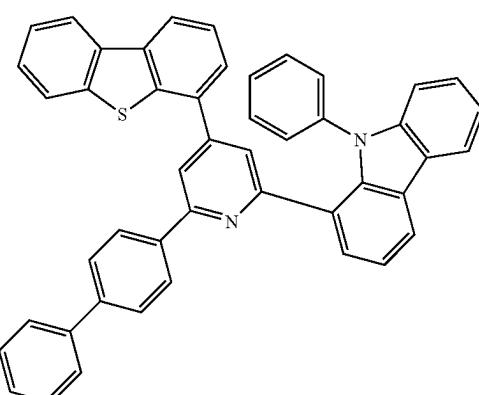
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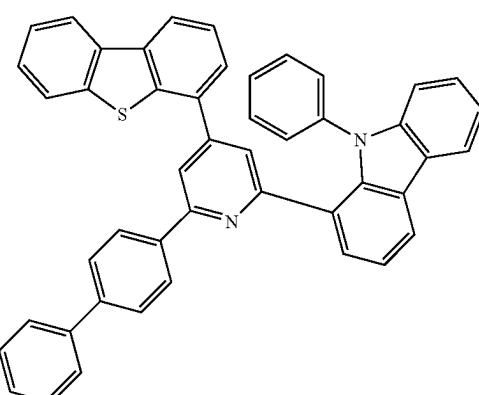
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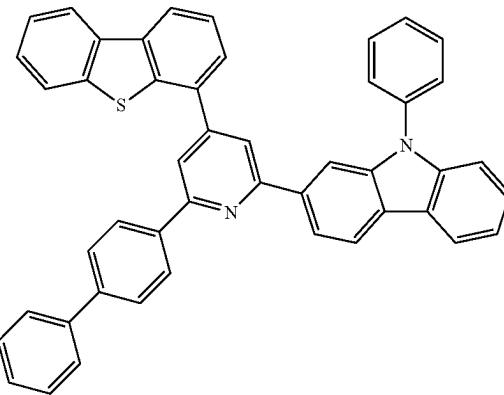
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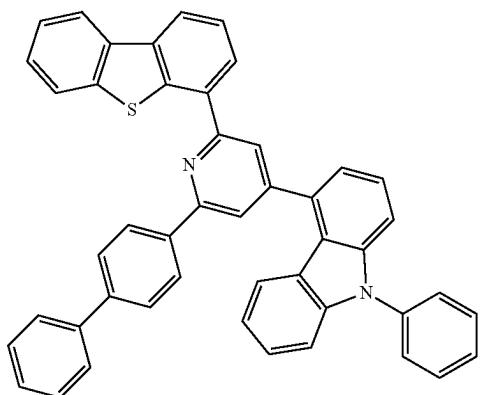
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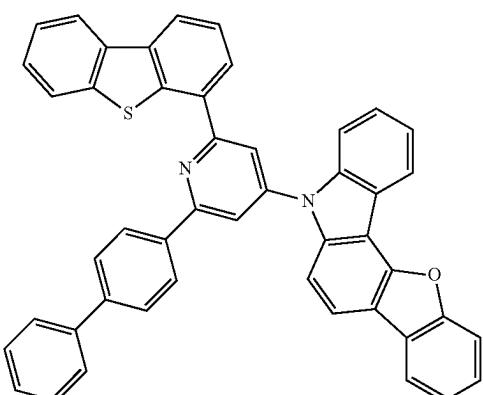
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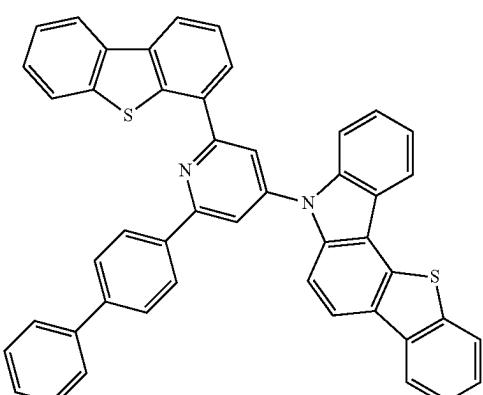
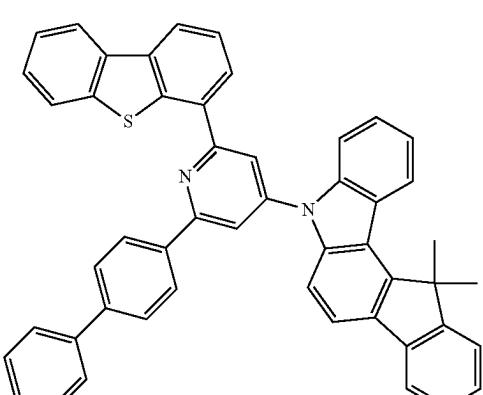
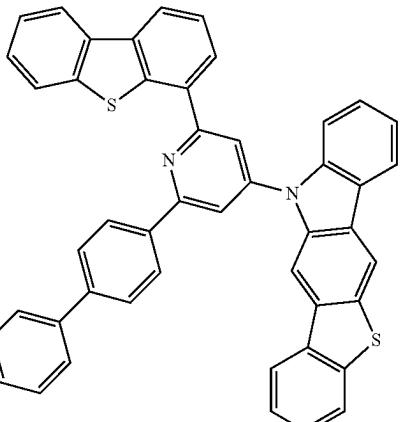
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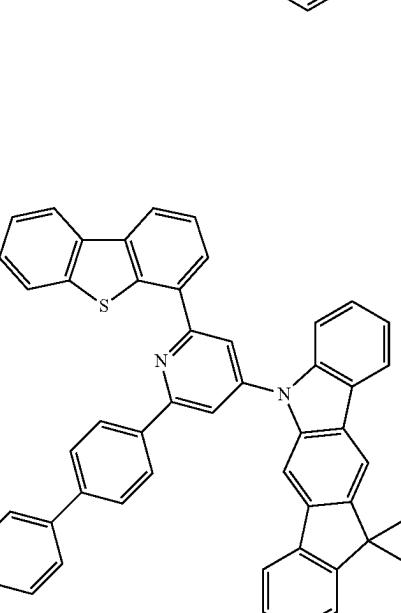
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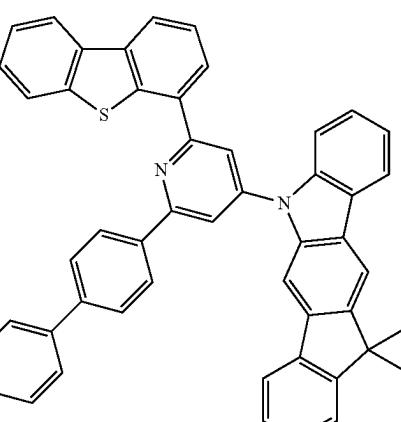
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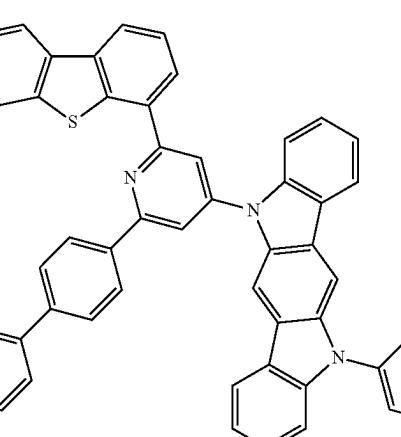
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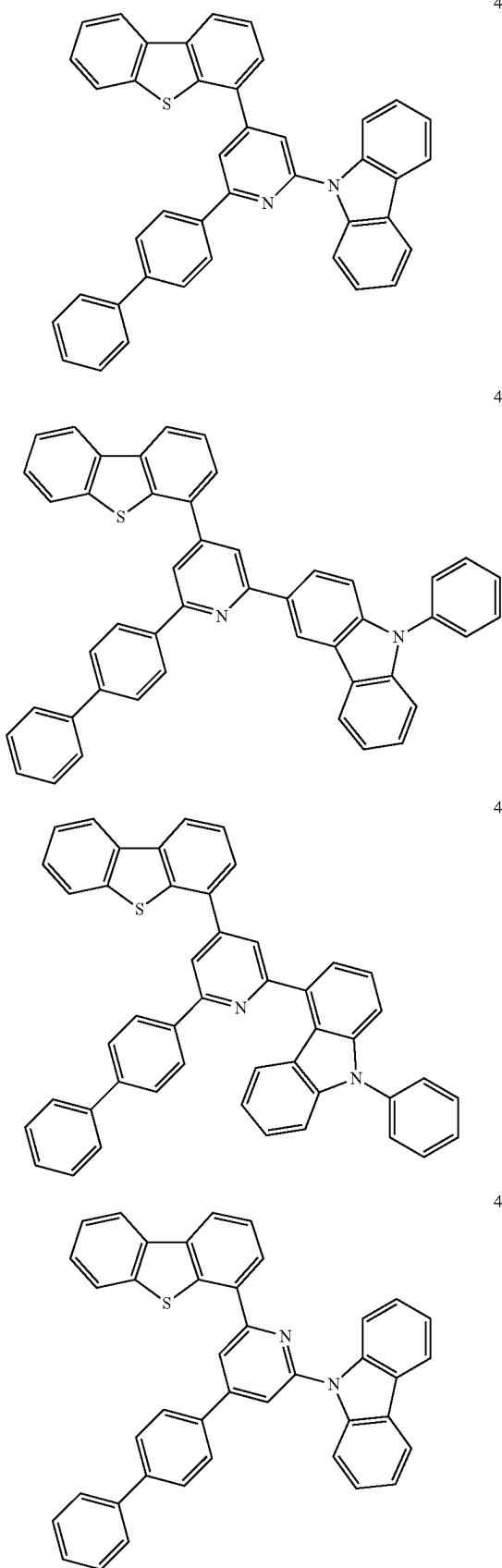
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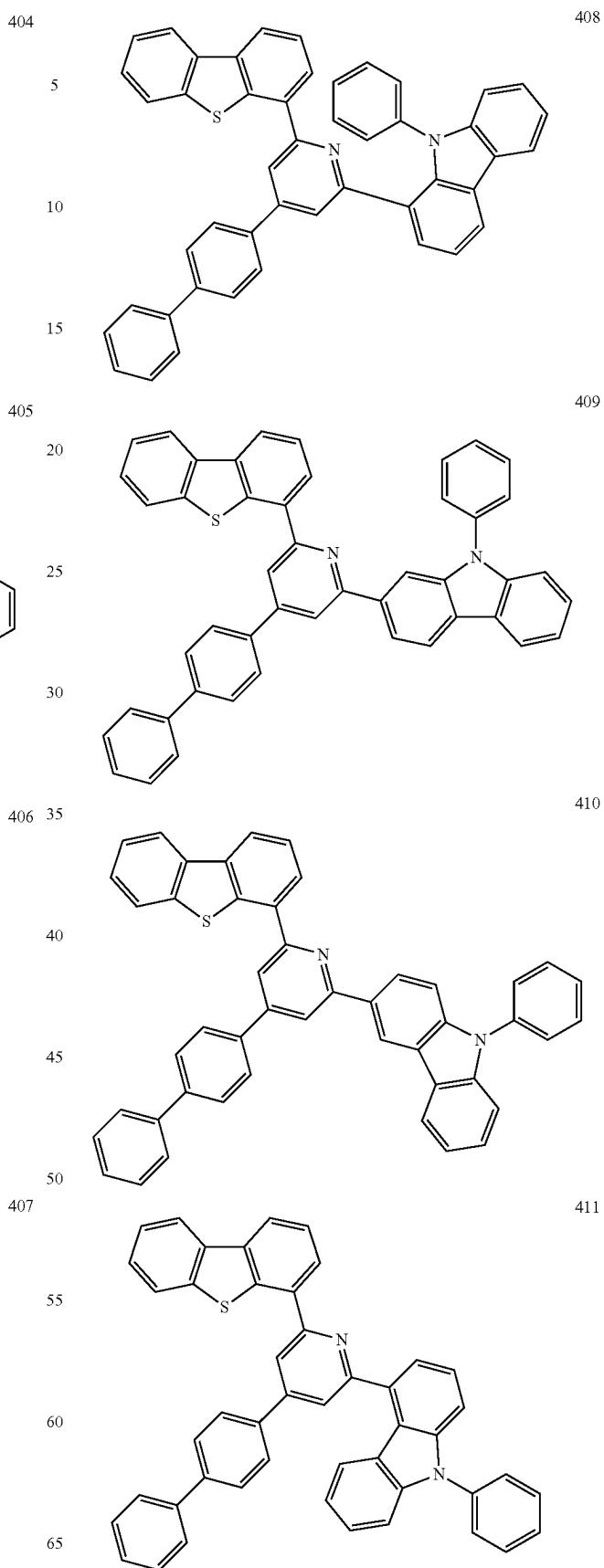
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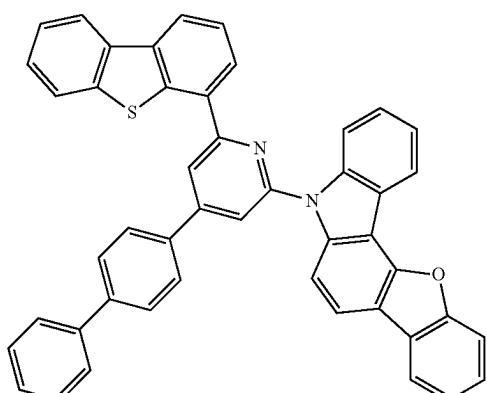
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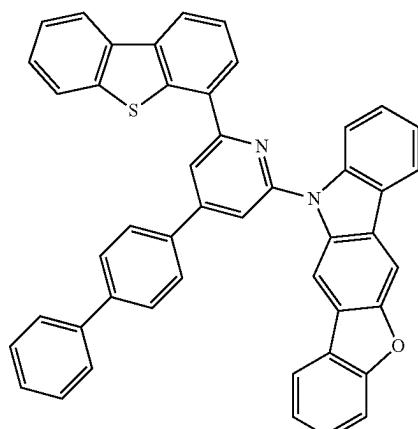
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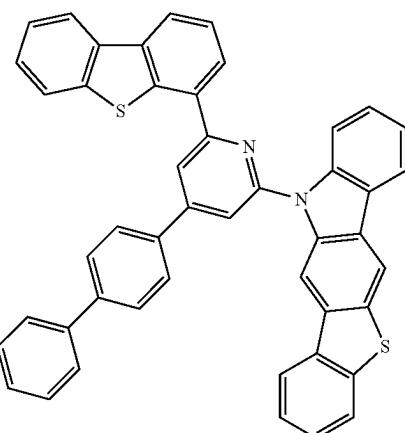
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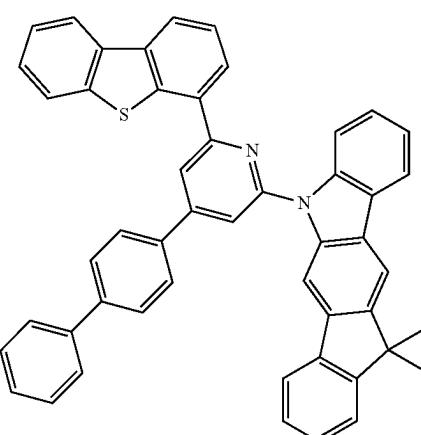
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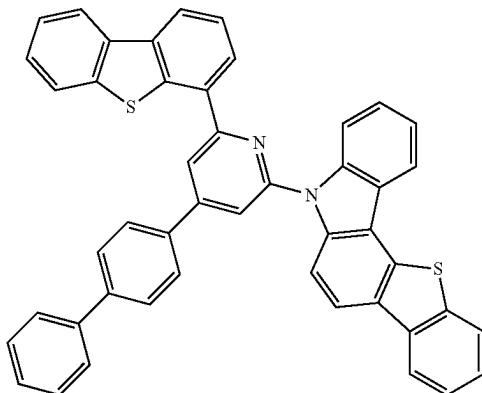
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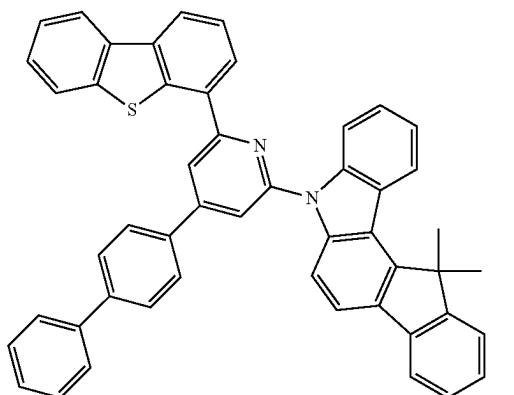
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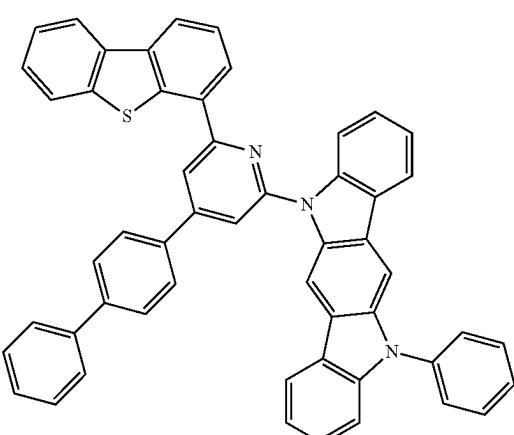
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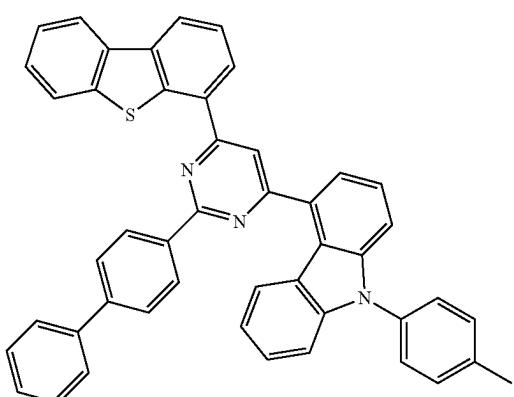
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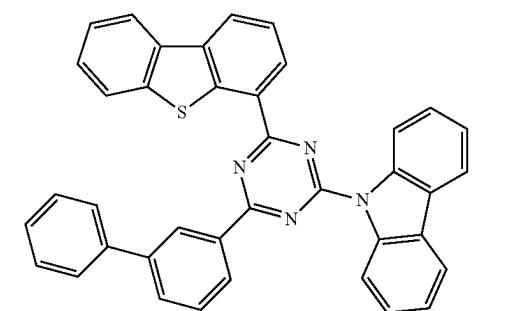
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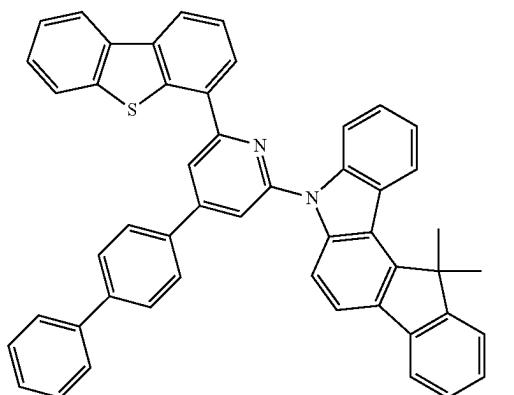
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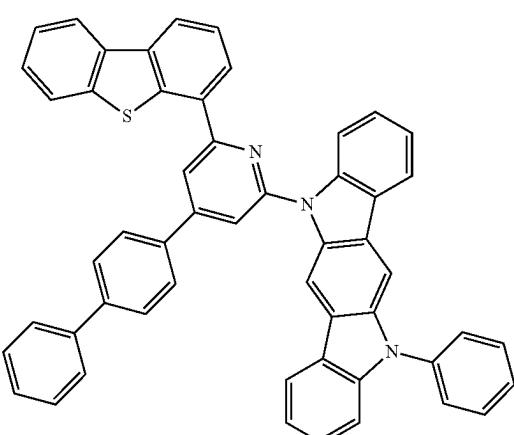
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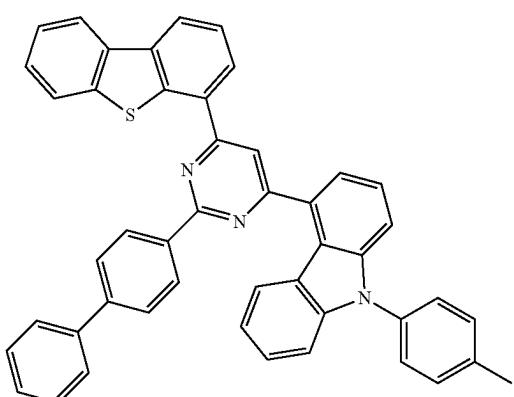
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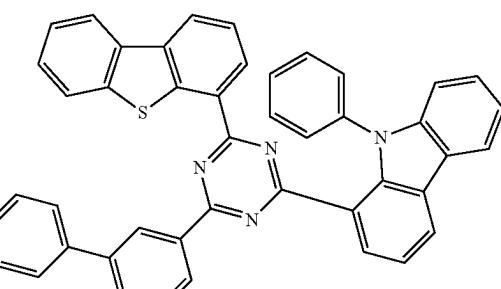
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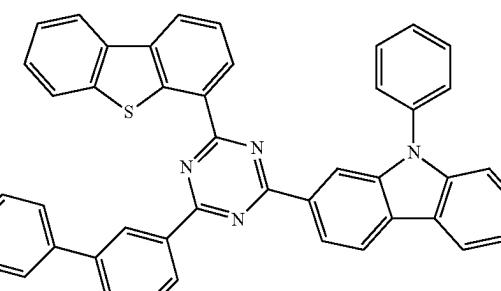
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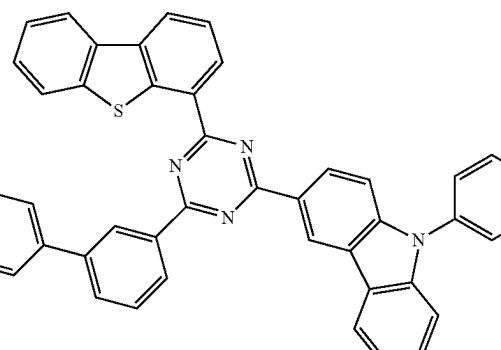
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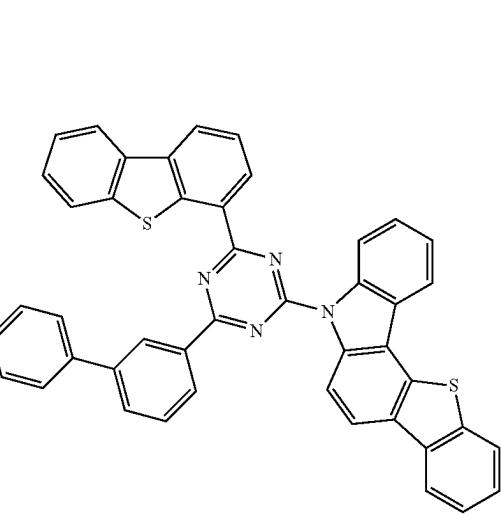
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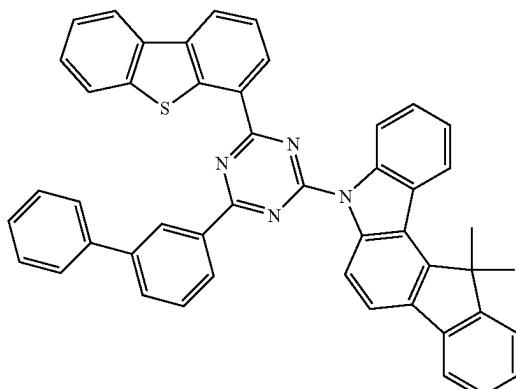


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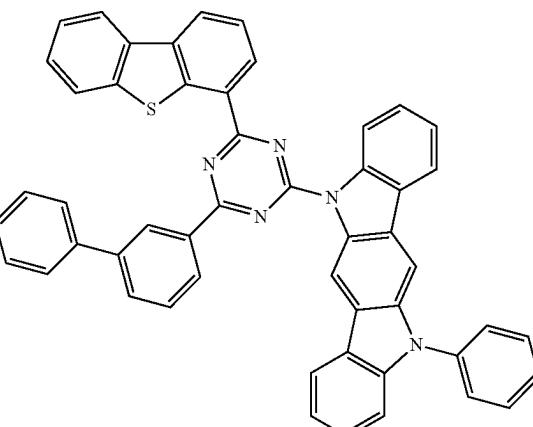
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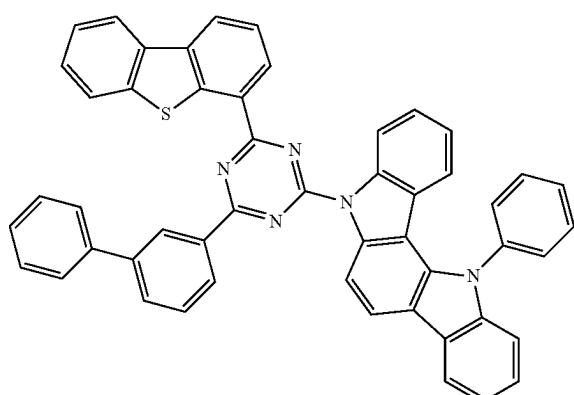
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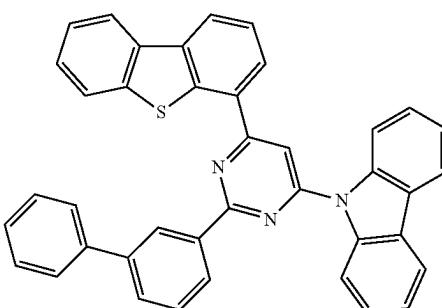


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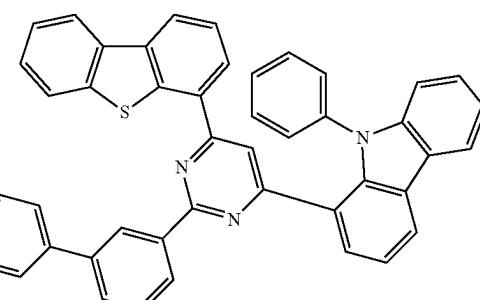


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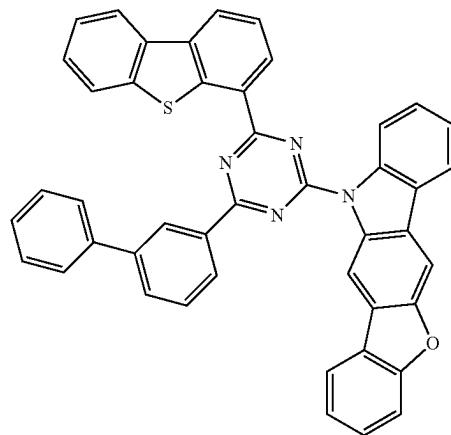
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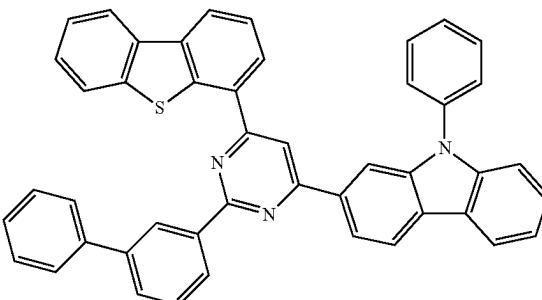
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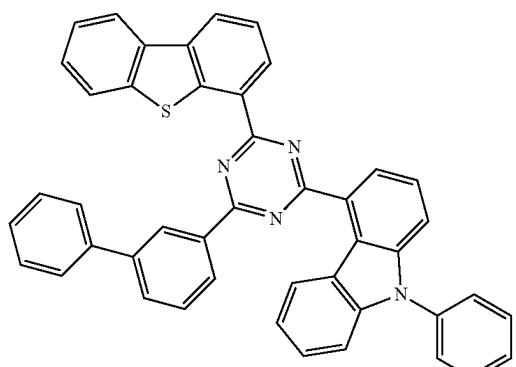


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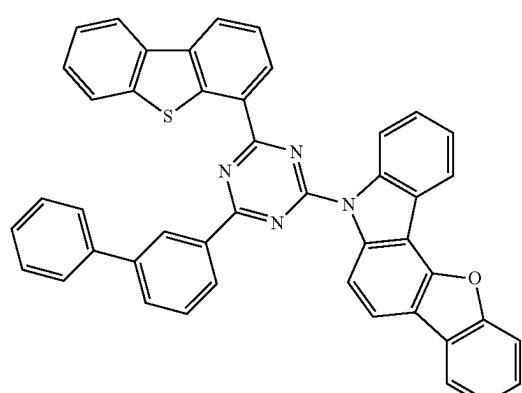


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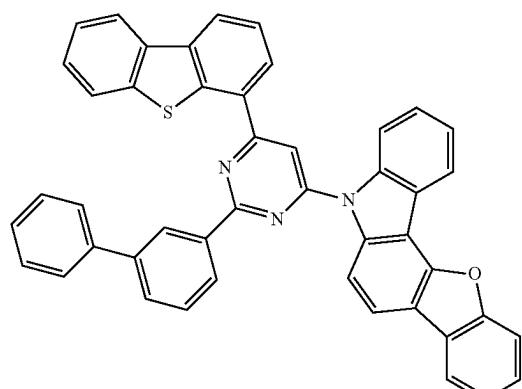


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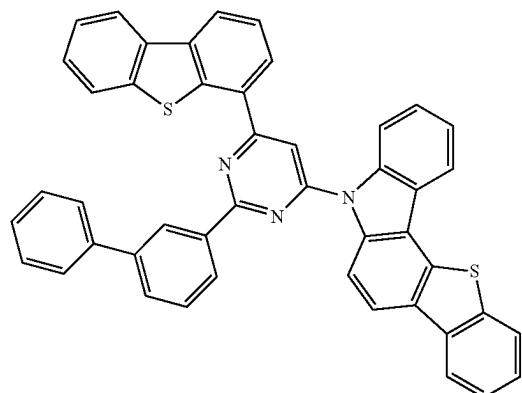
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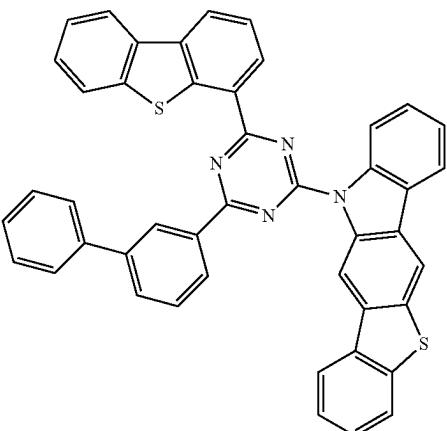
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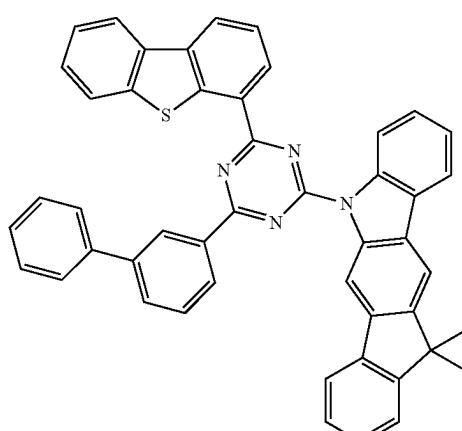
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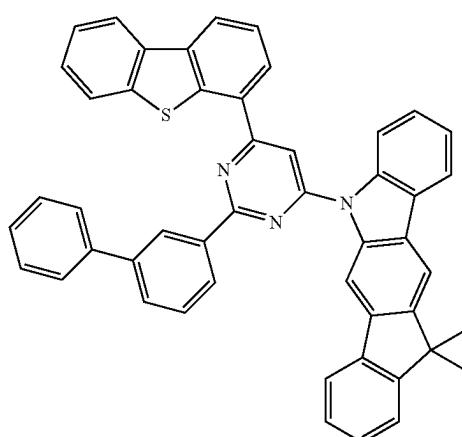
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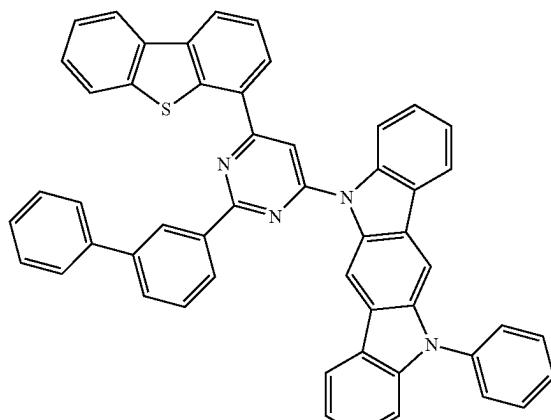
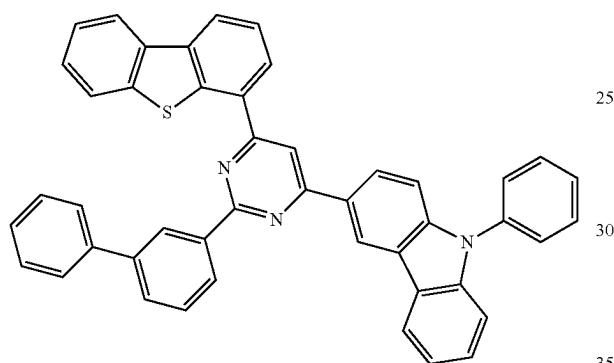


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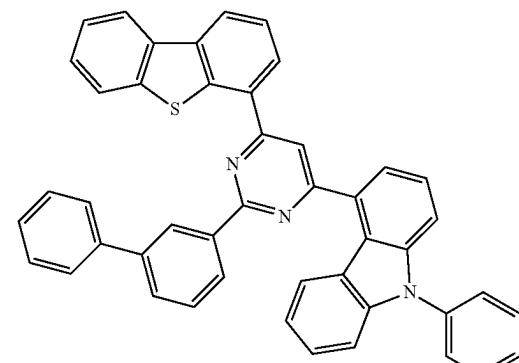
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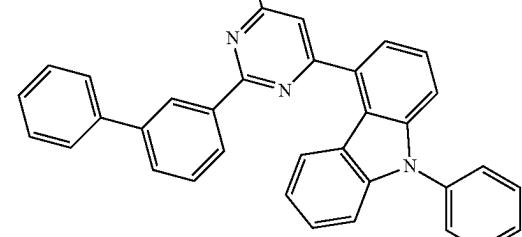
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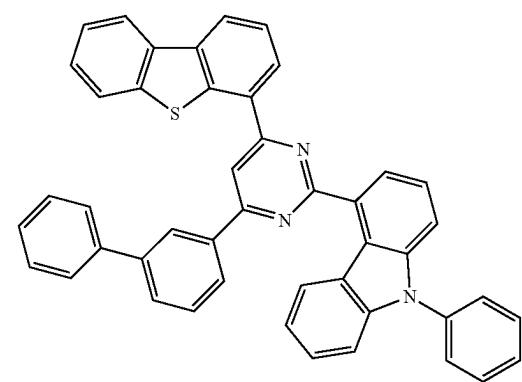
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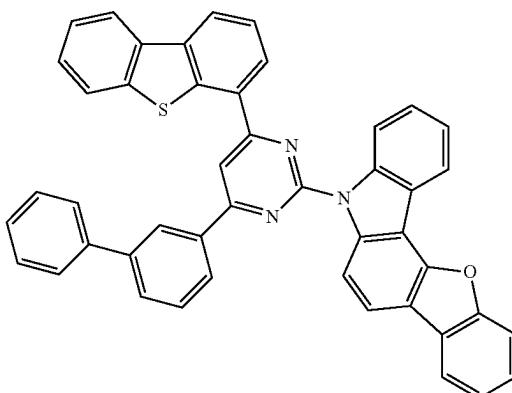


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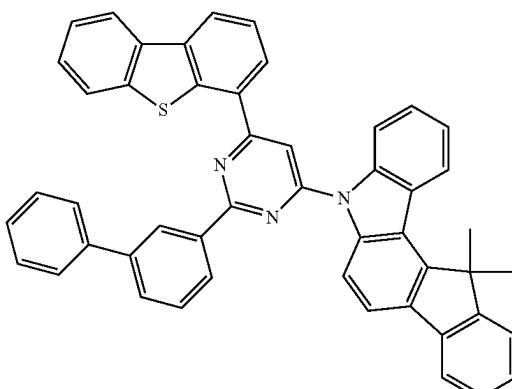
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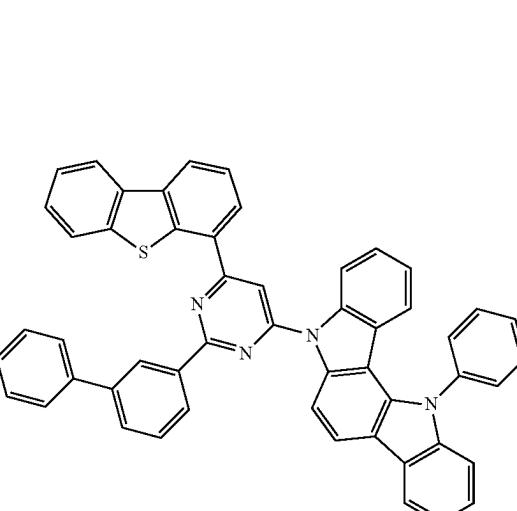
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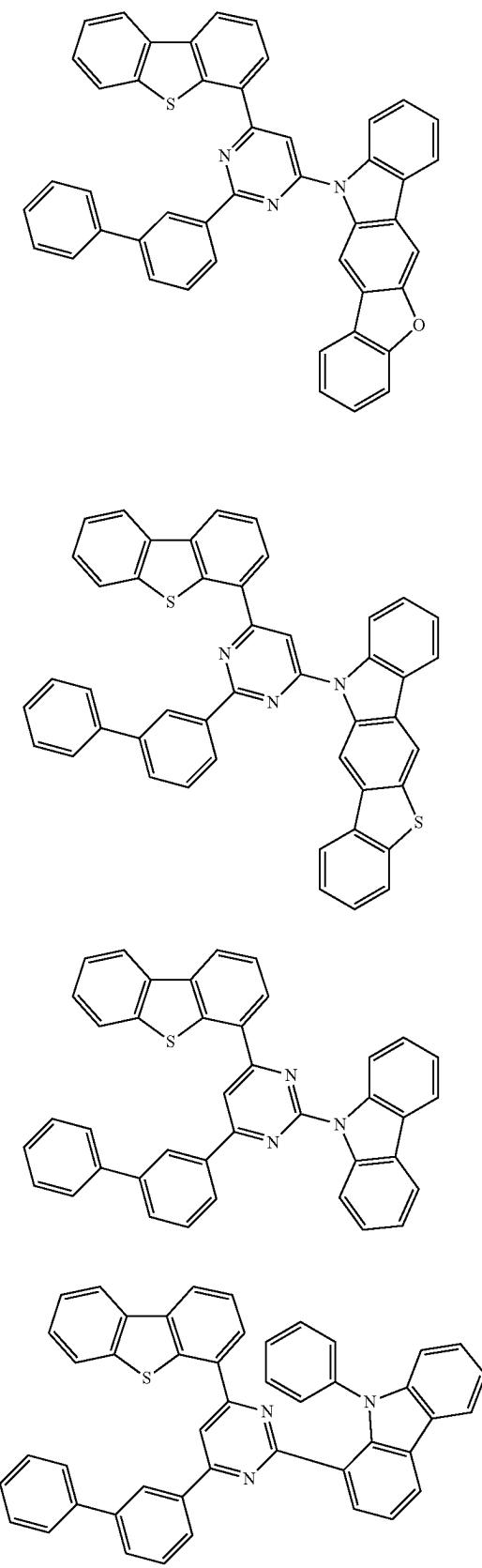
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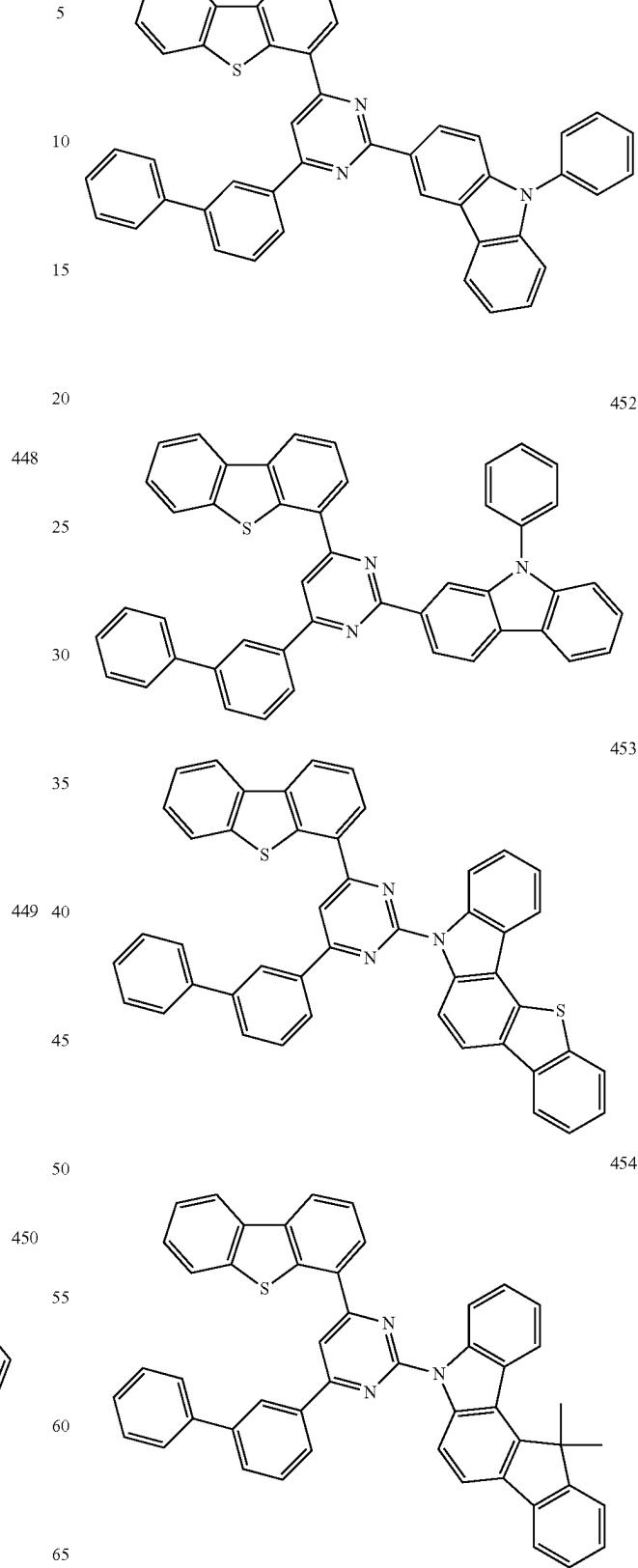
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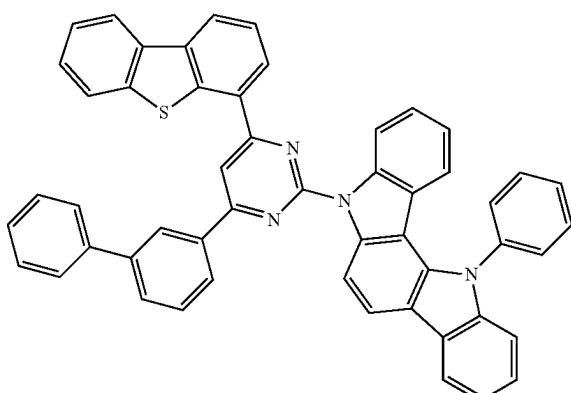
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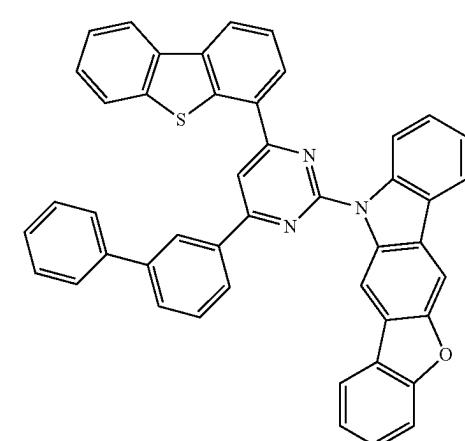


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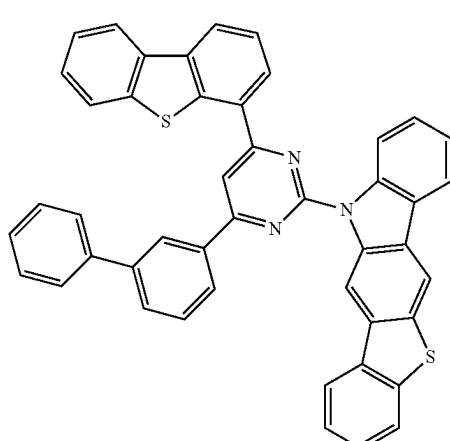
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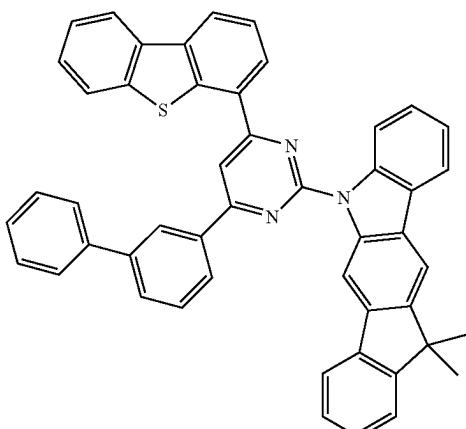
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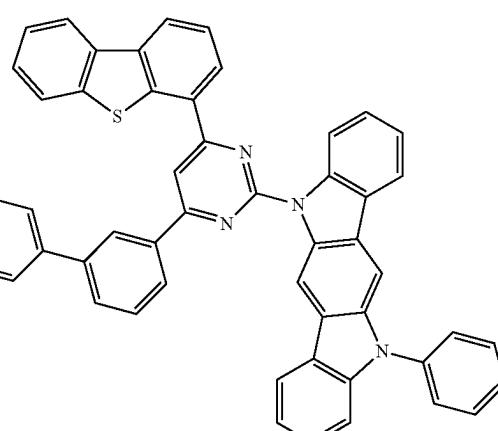
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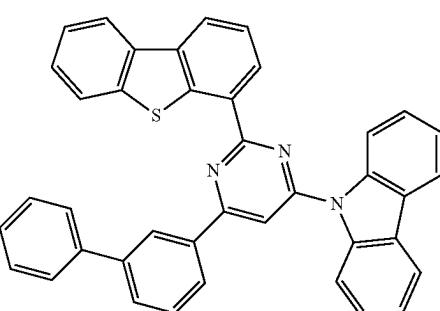
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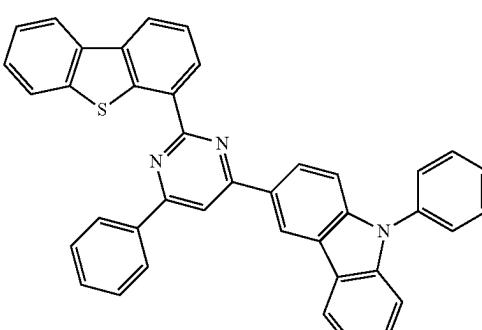
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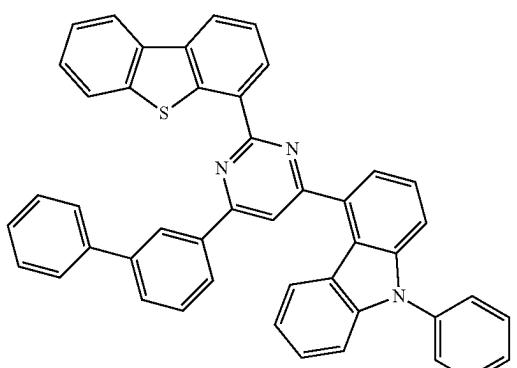


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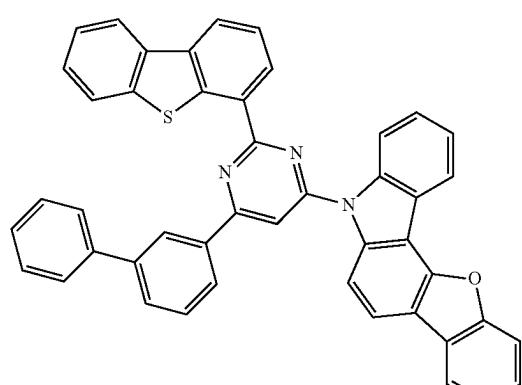
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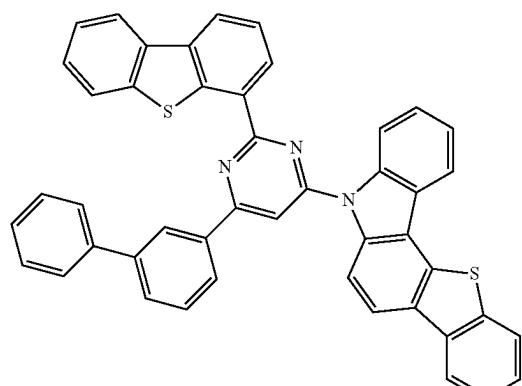
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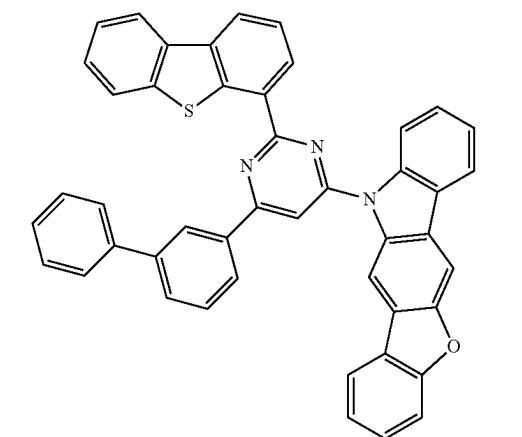
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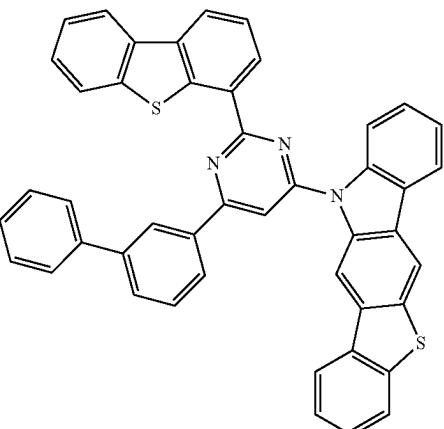
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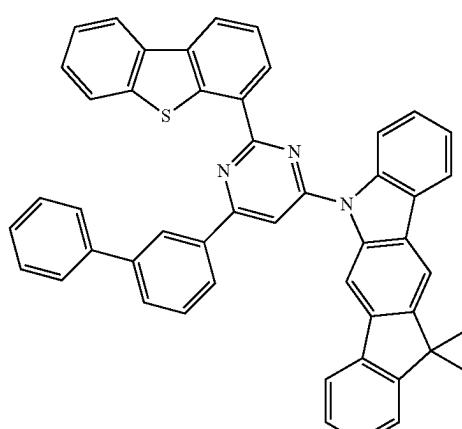
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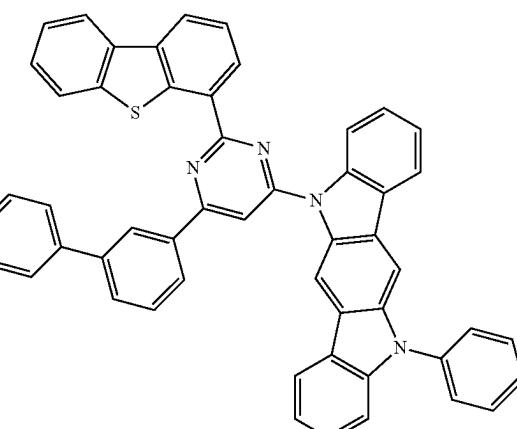
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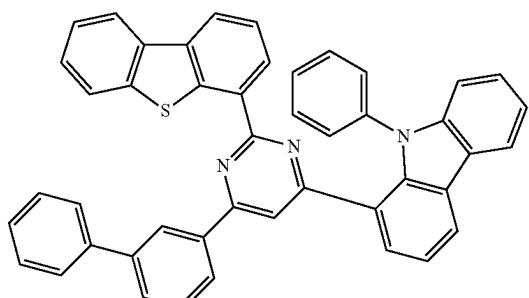


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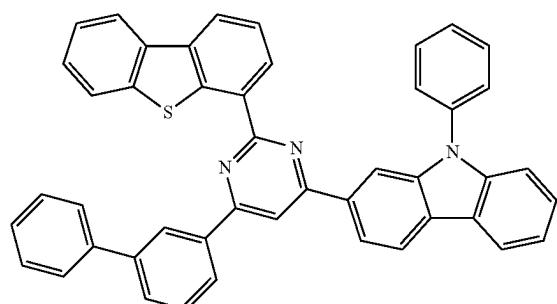
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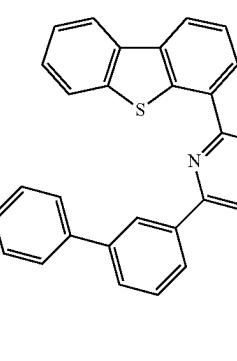
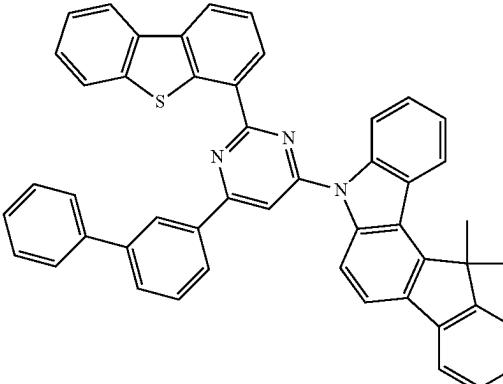
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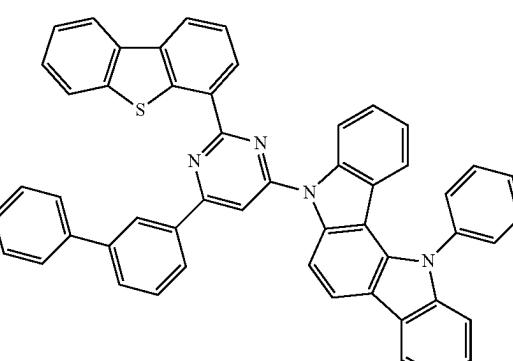
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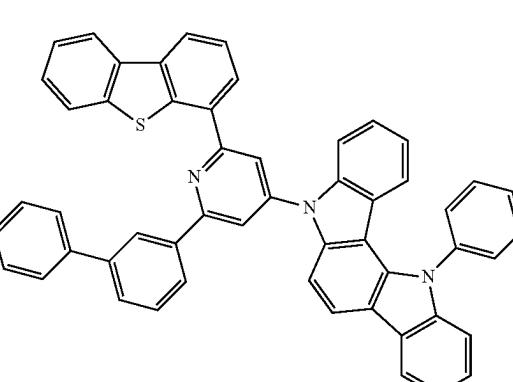
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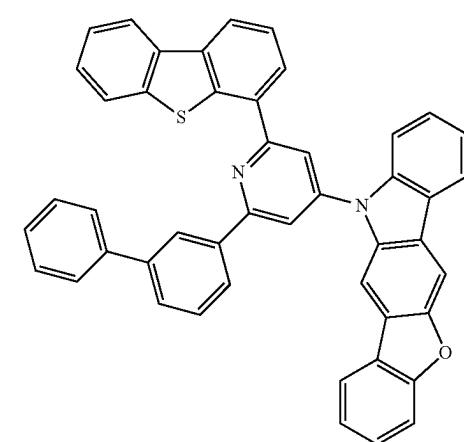
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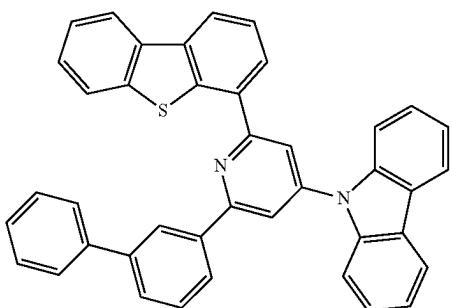
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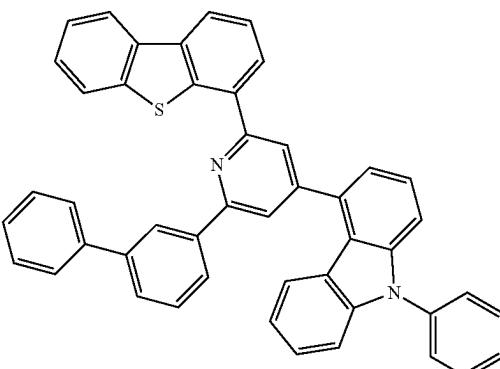


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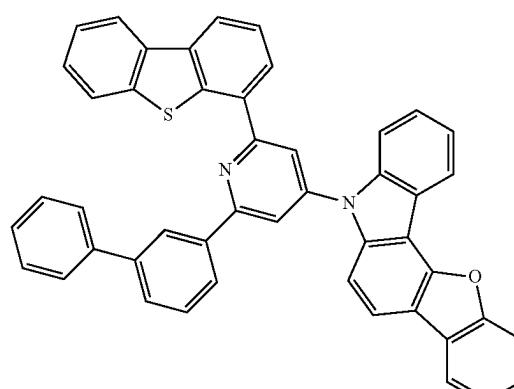


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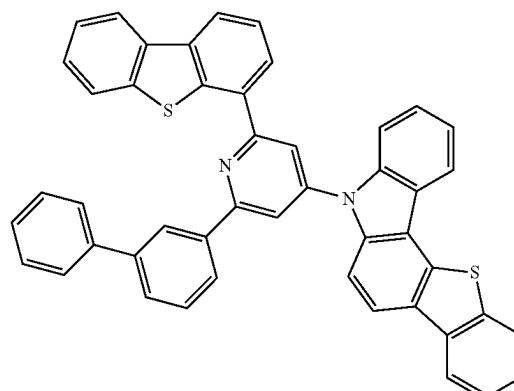


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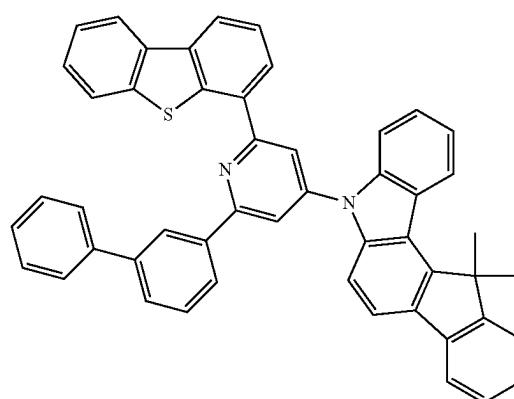
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480

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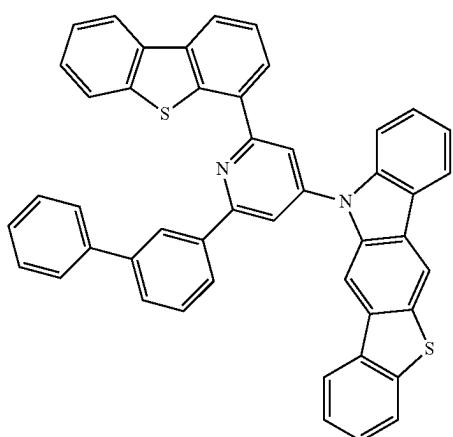
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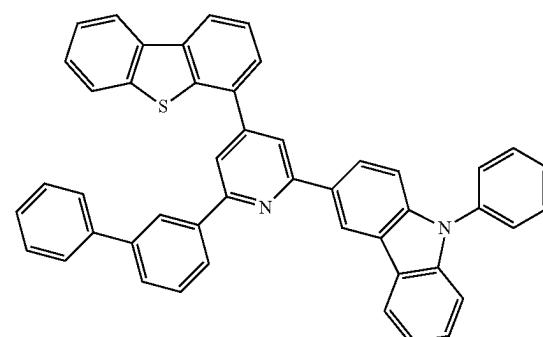
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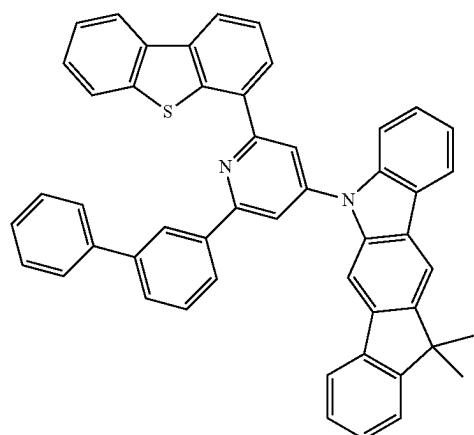
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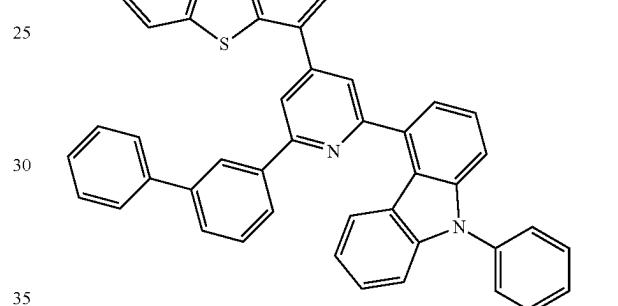
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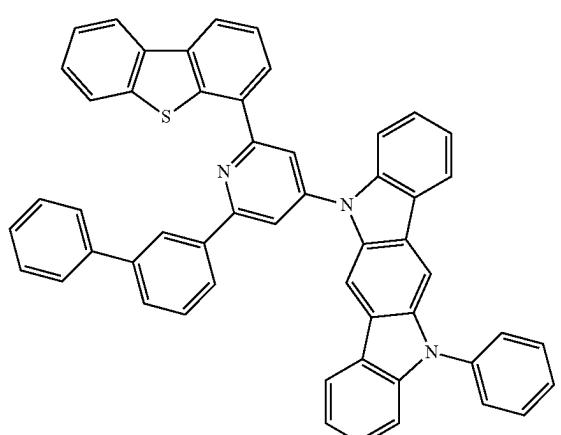
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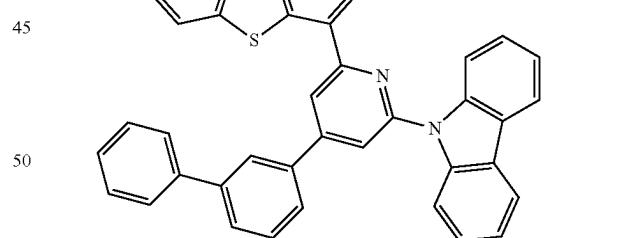
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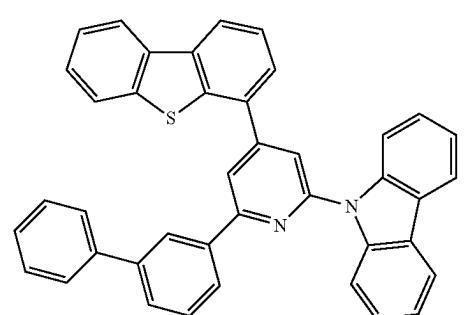
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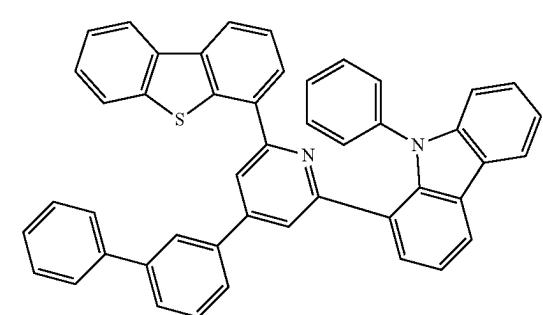
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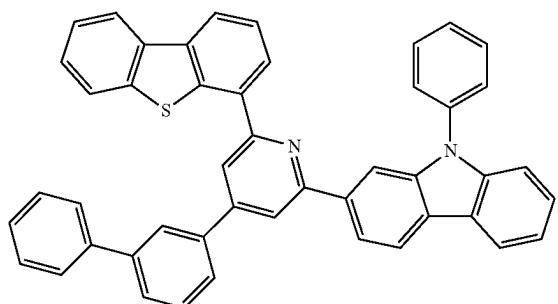


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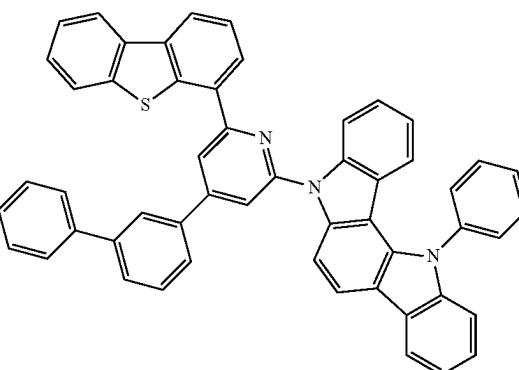
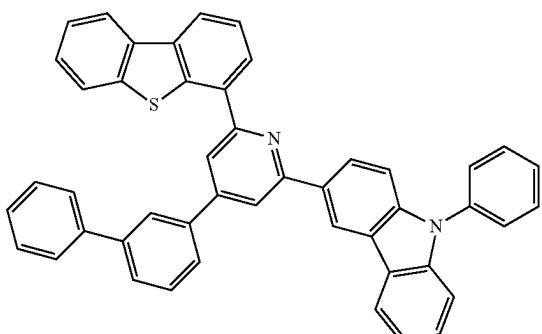
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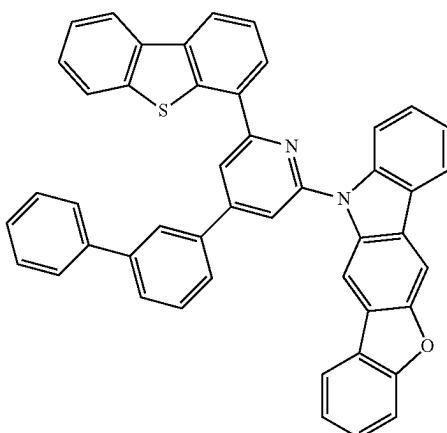
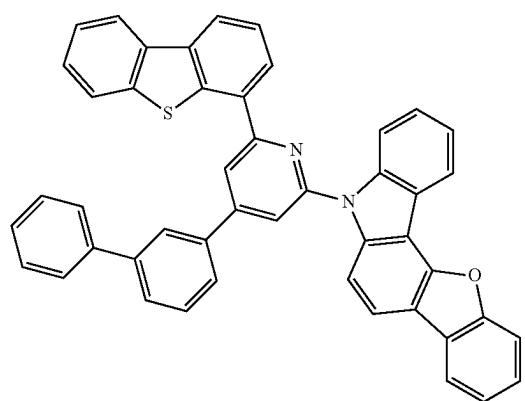
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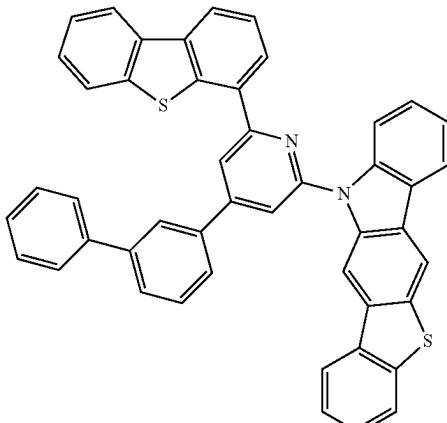
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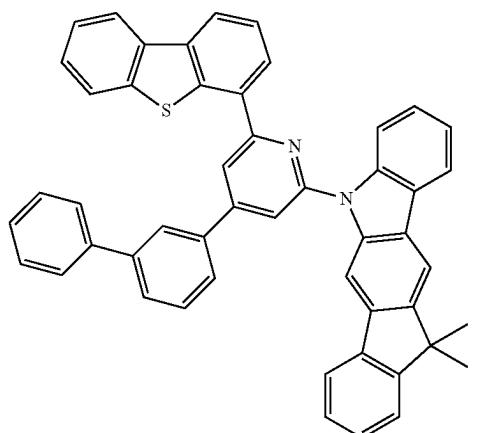
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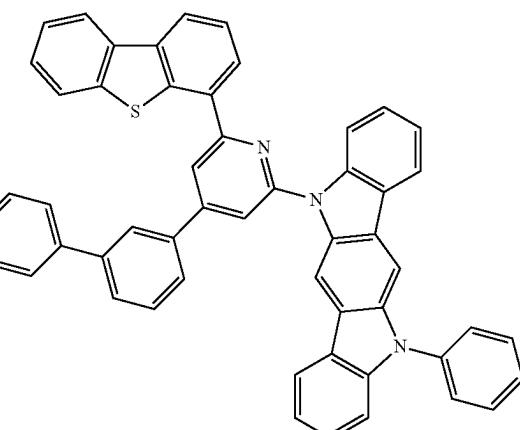
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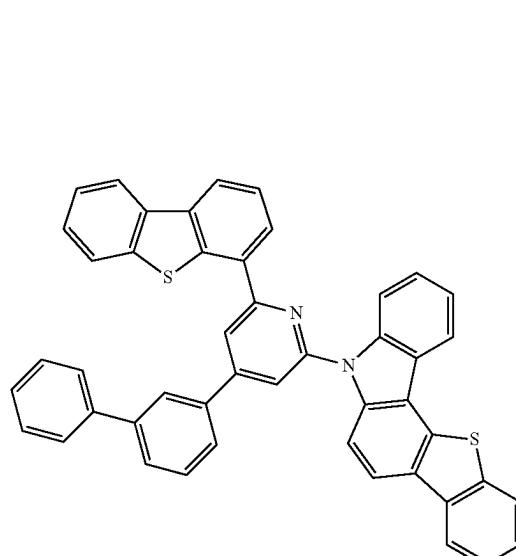
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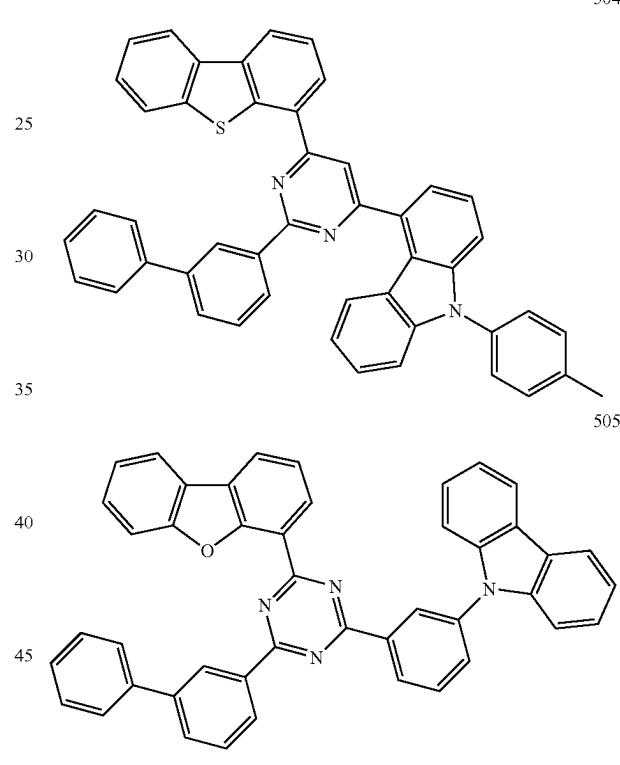
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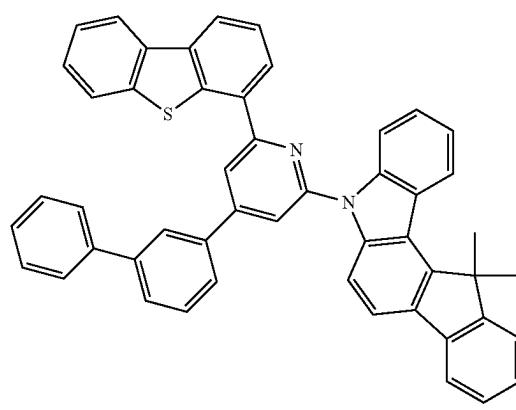
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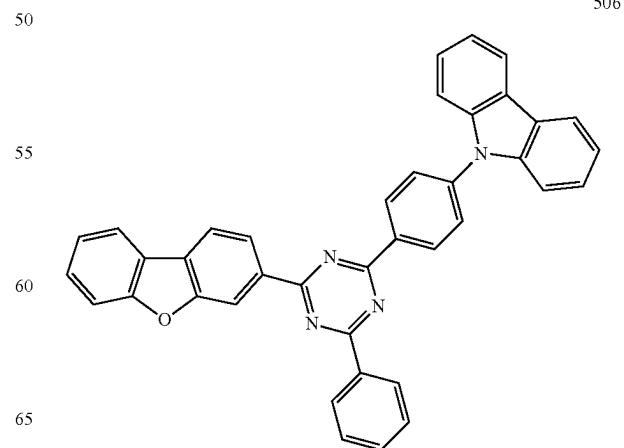
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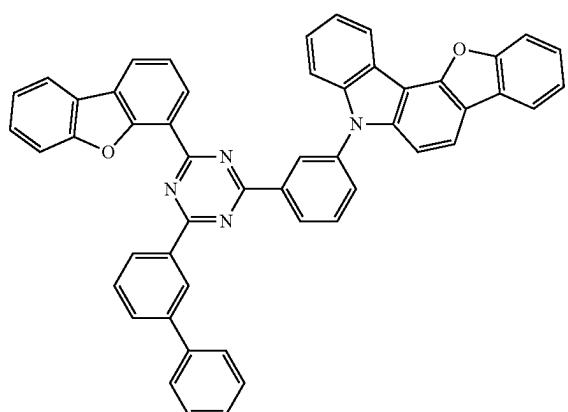
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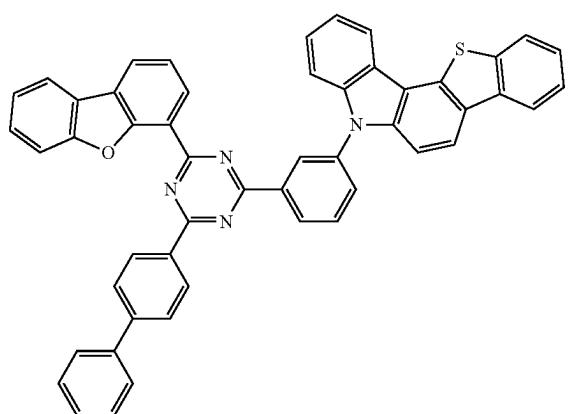


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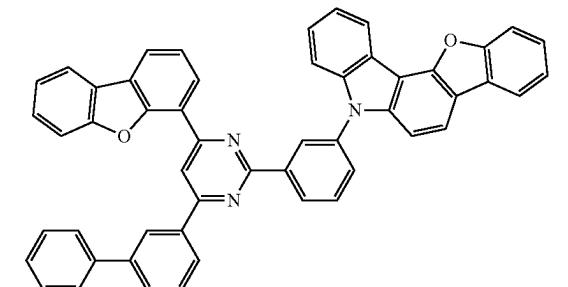
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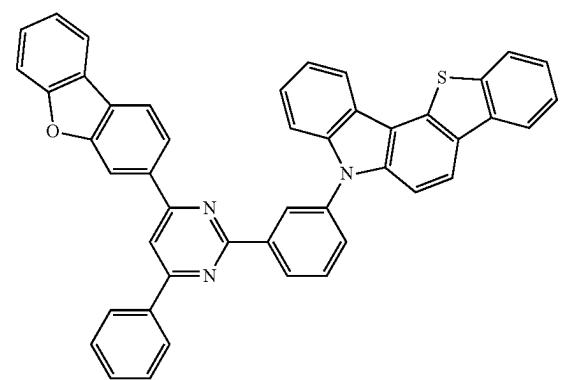
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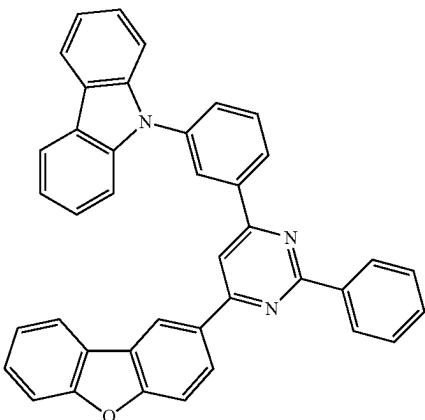


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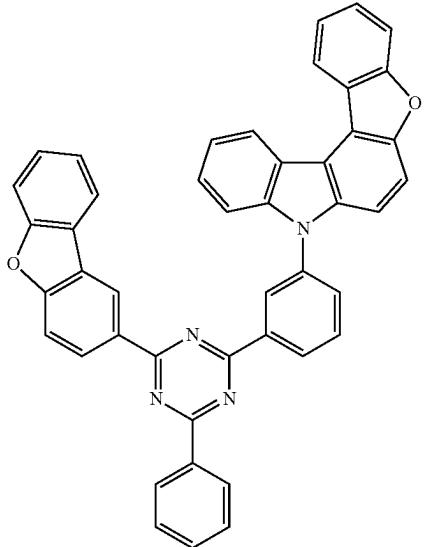
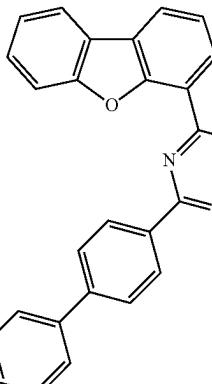
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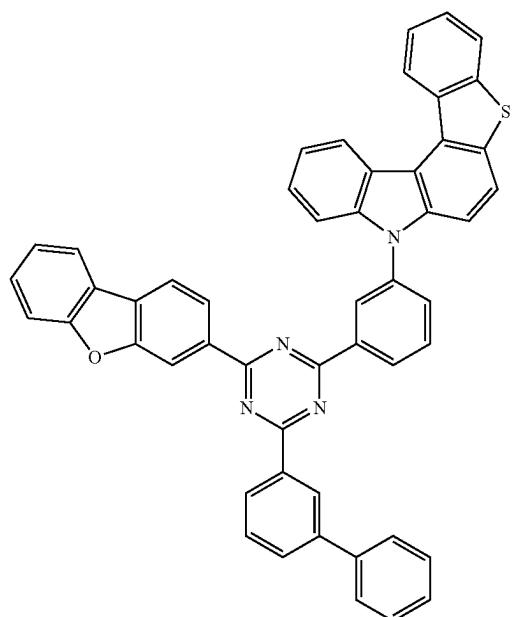
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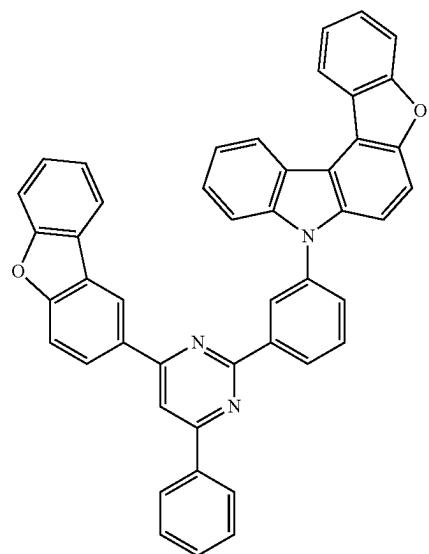
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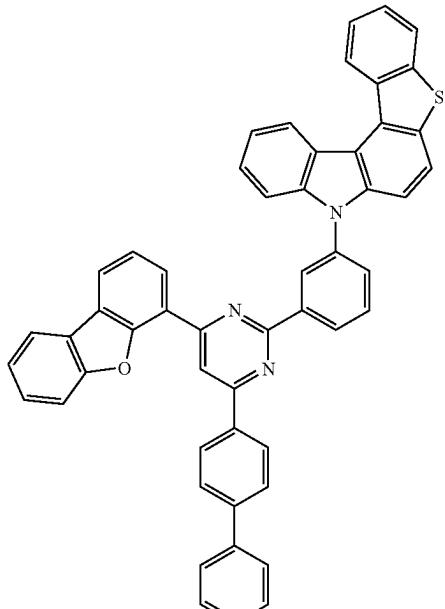
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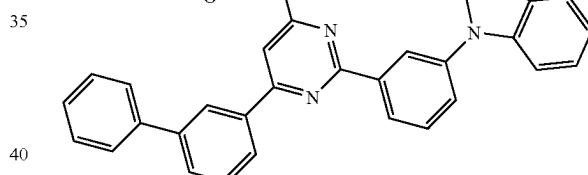
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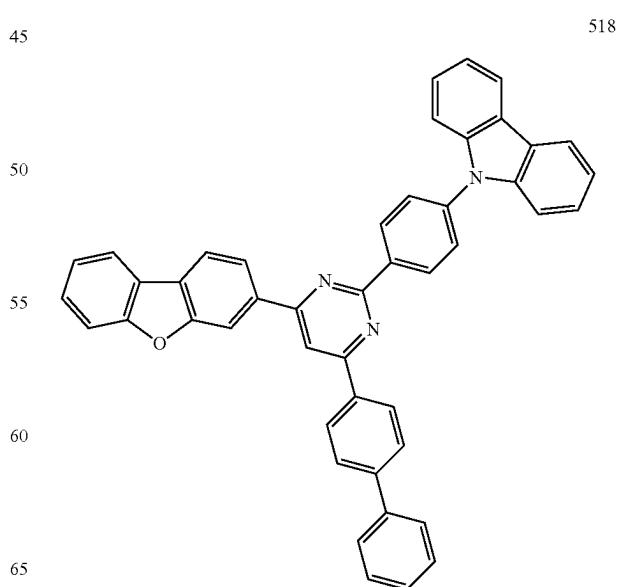
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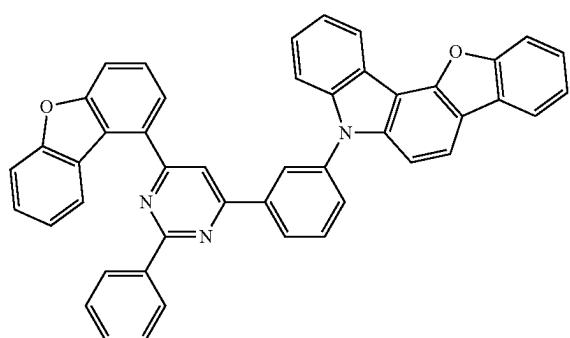
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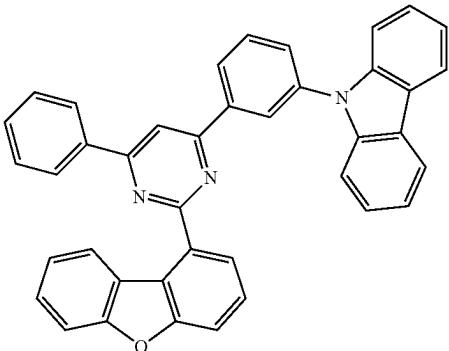
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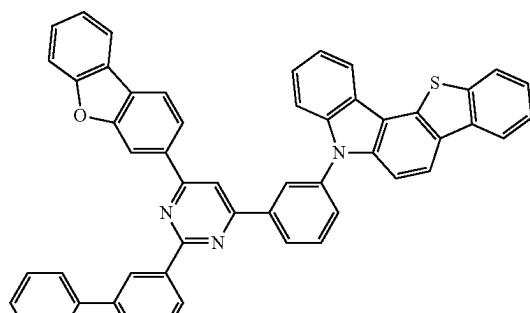
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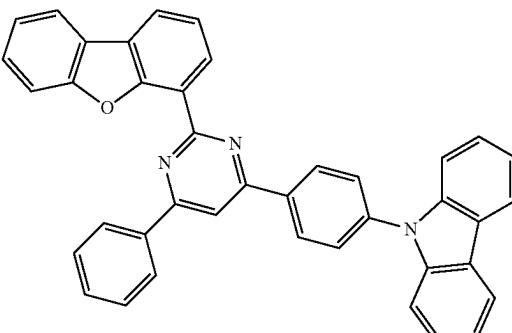


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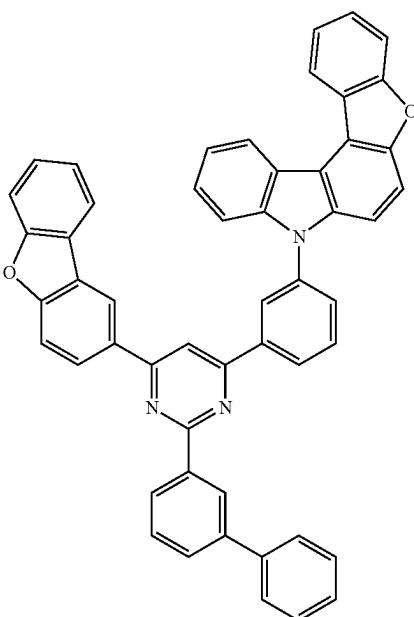
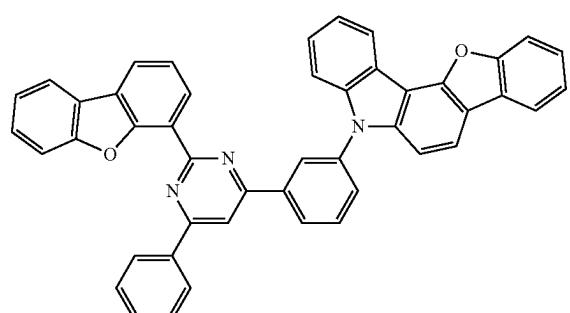
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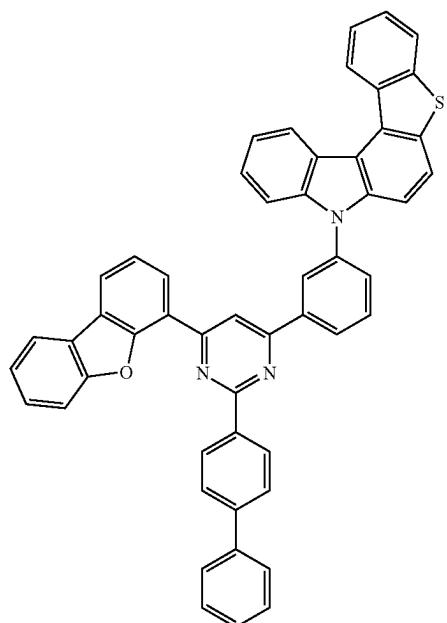
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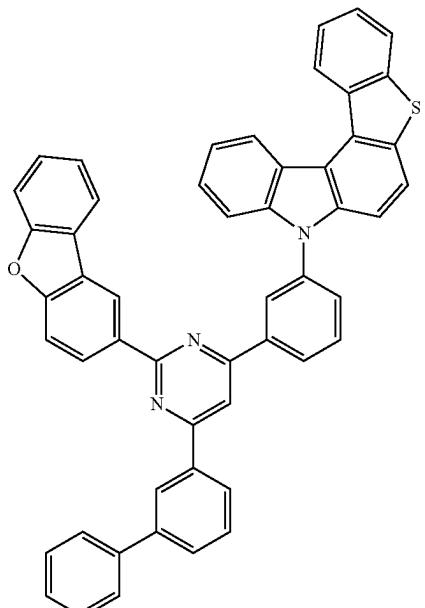
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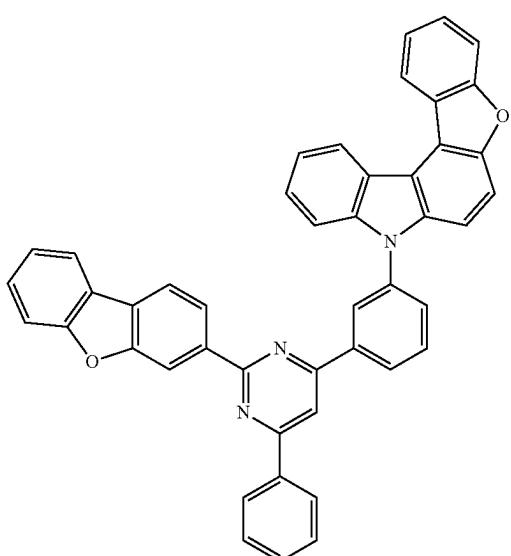
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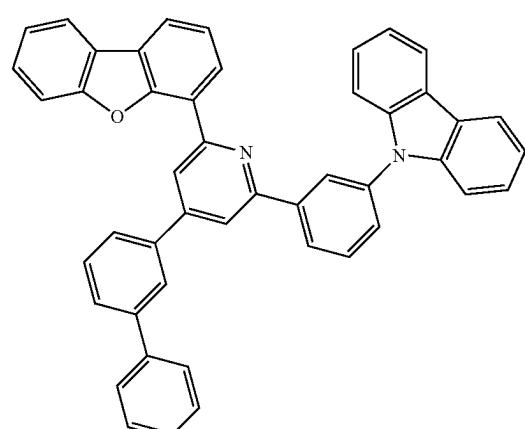
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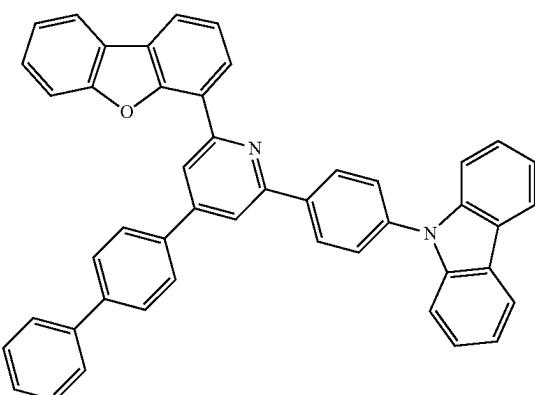
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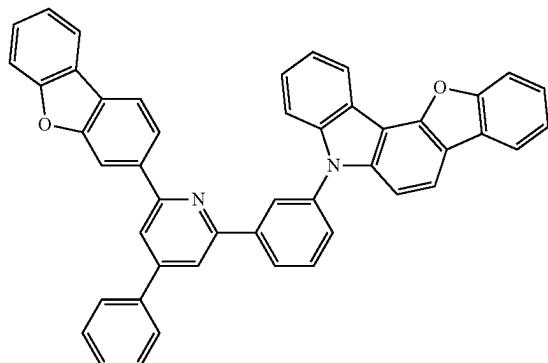
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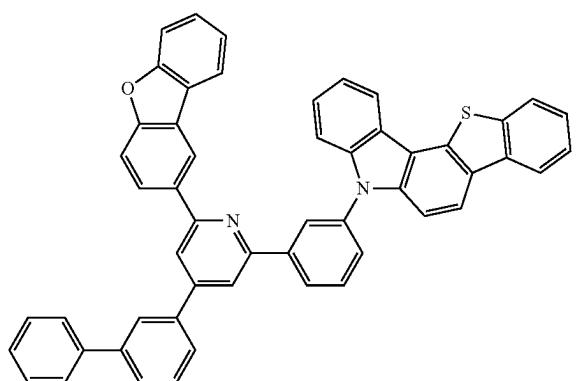


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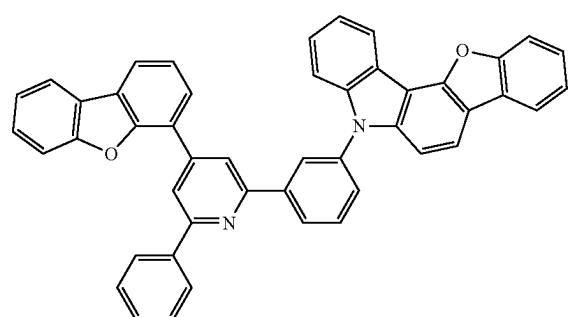


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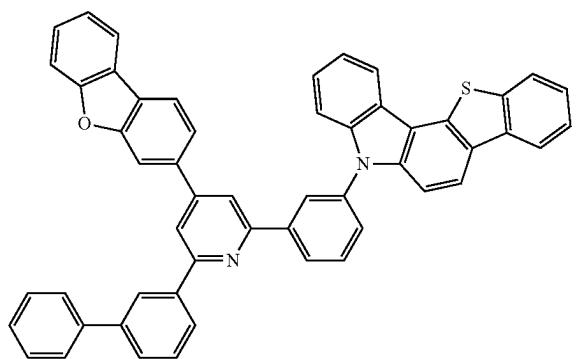
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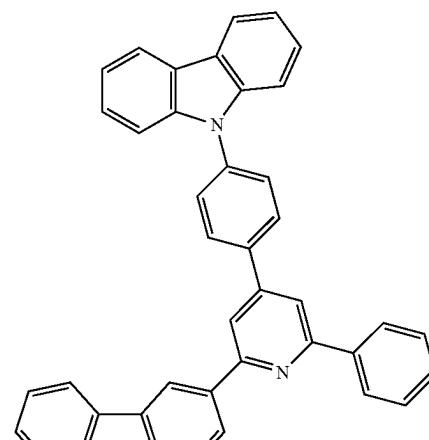
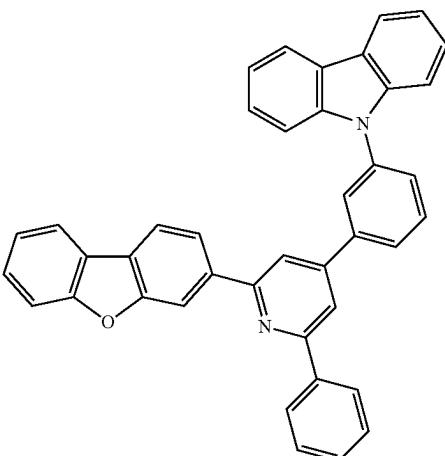
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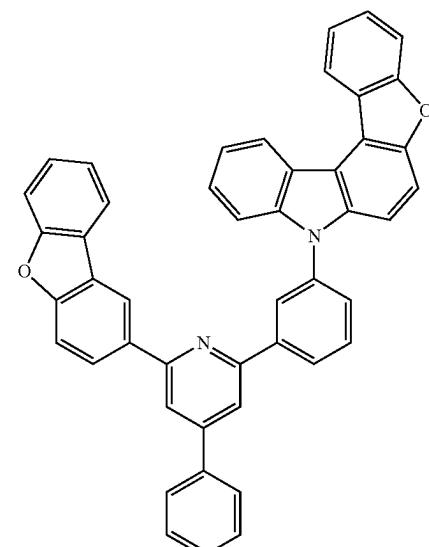
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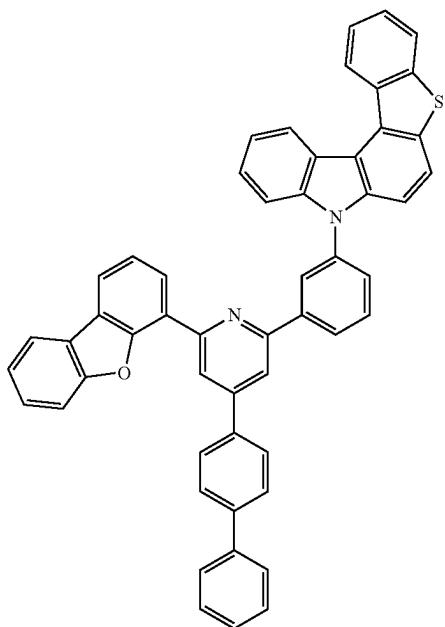
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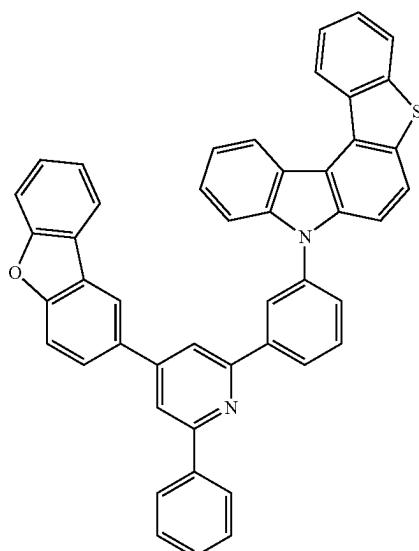
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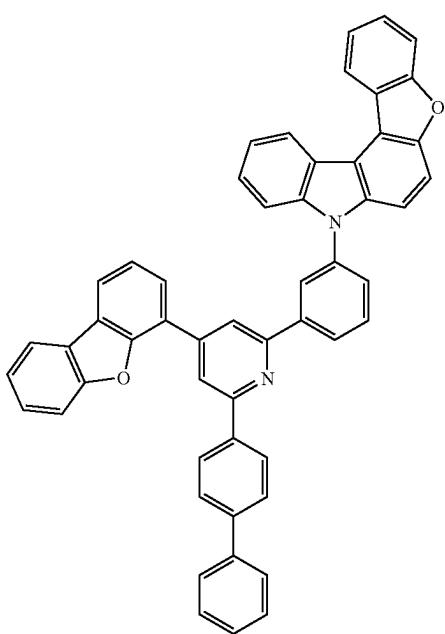
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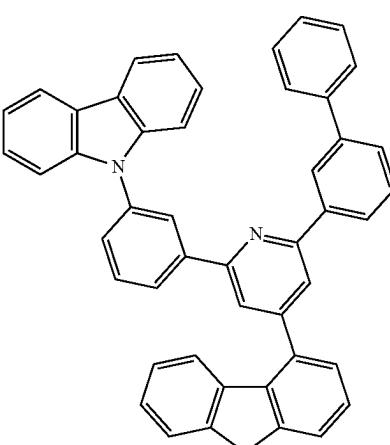
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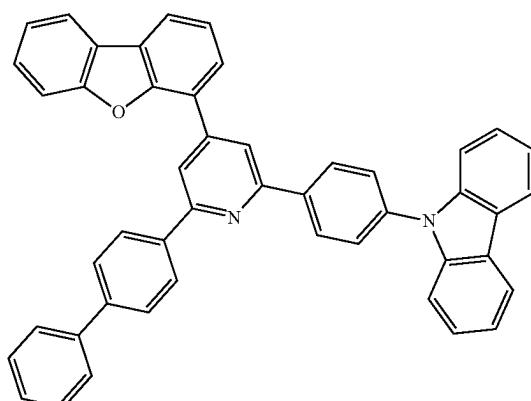
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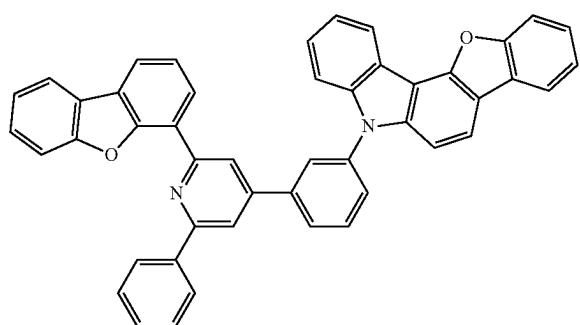
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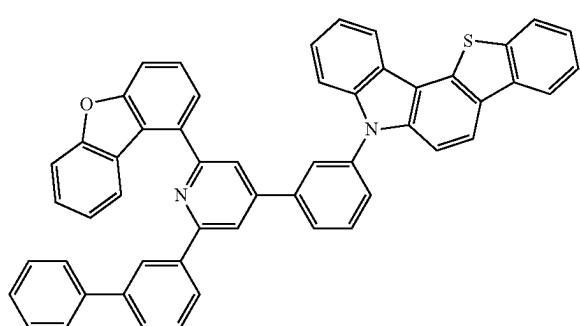
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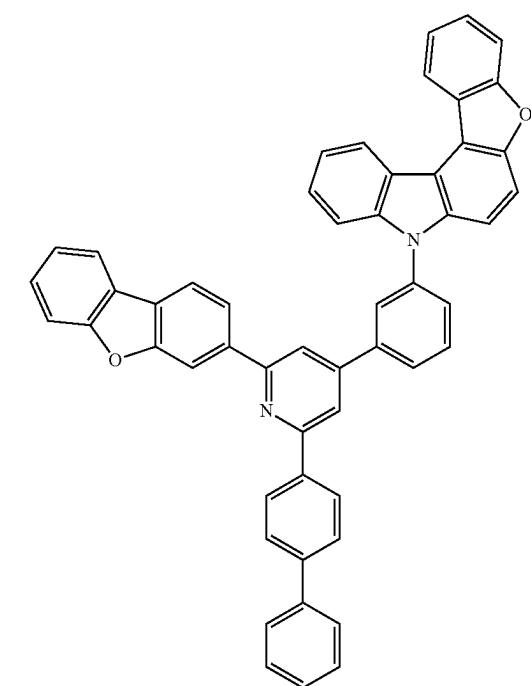


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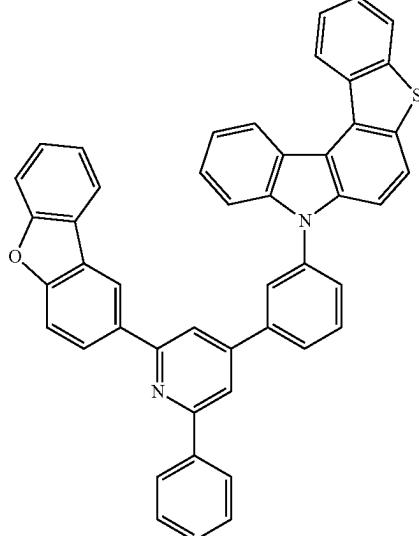
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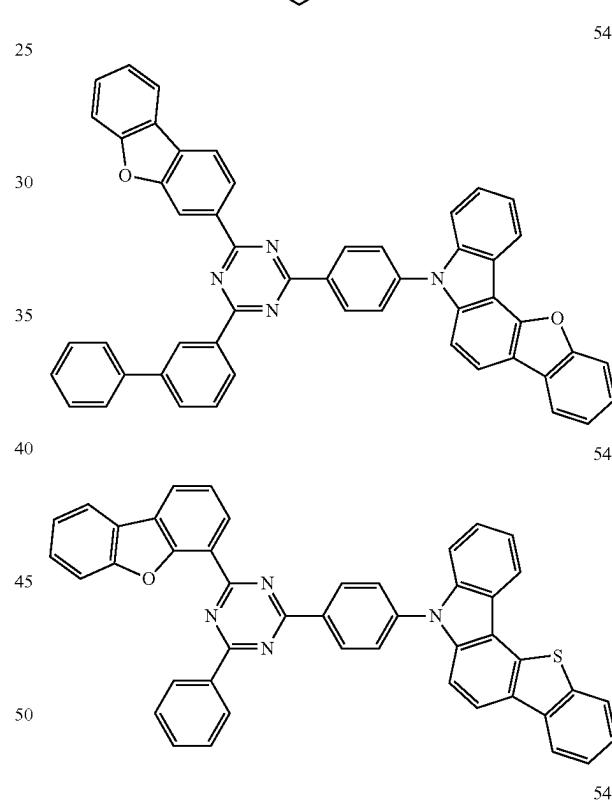
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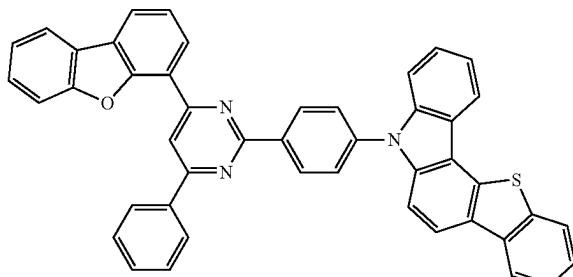
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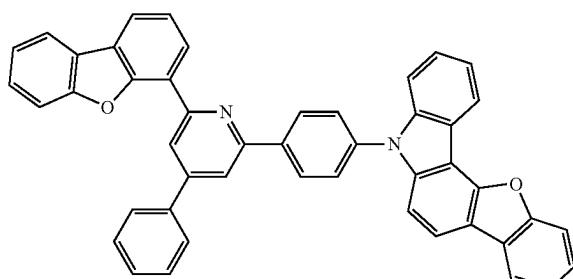
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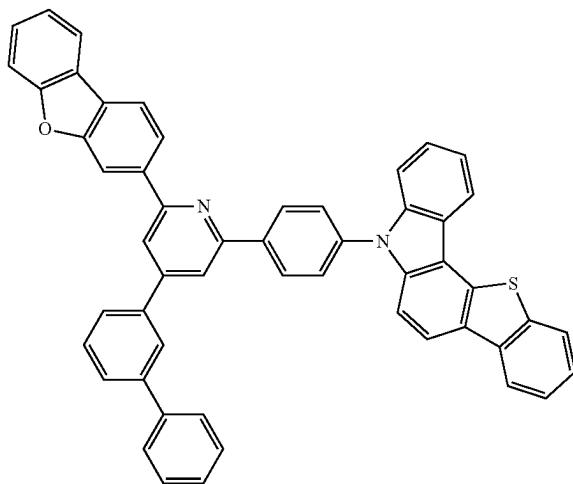
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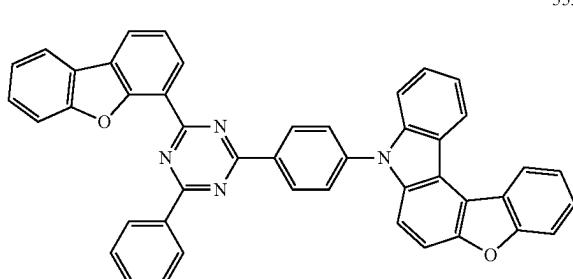
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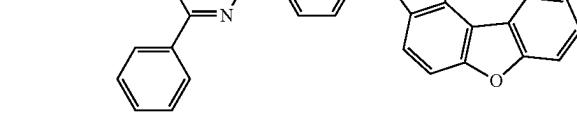
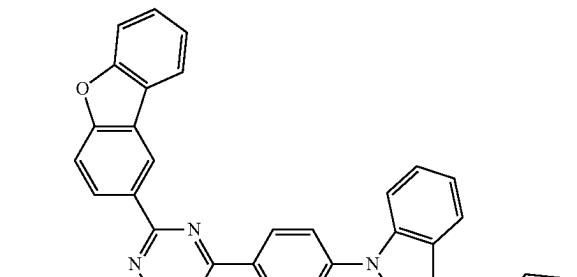
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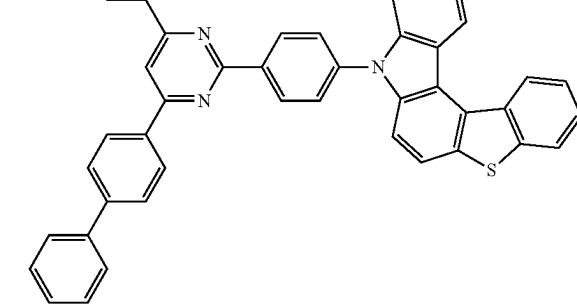
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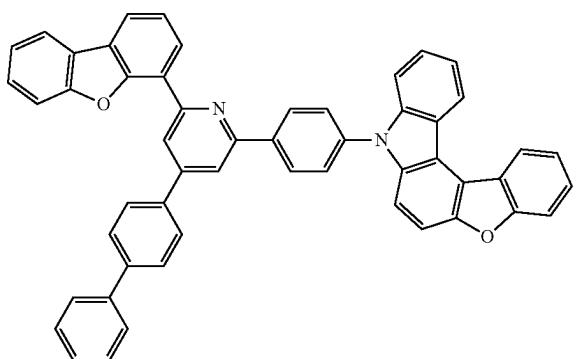
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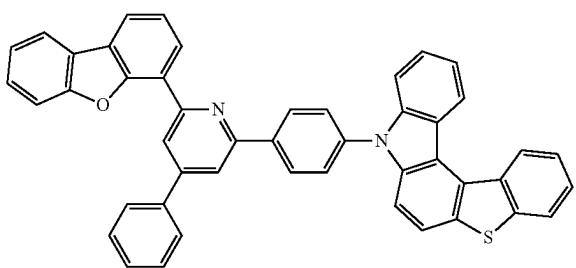


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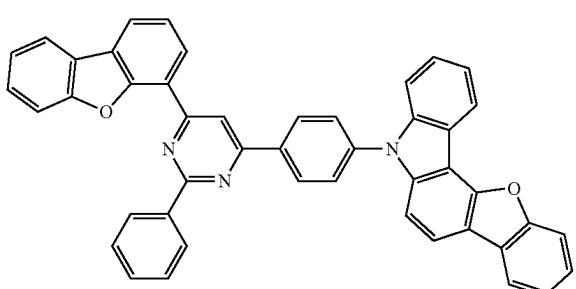


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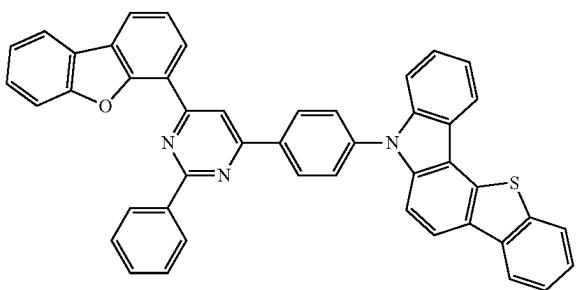


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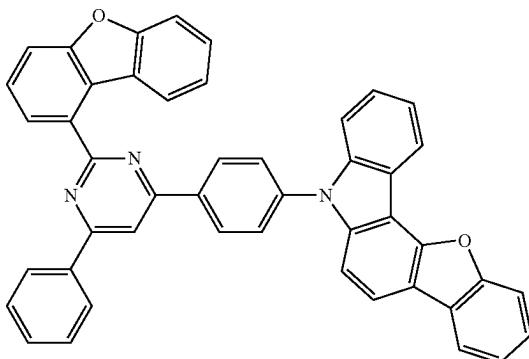
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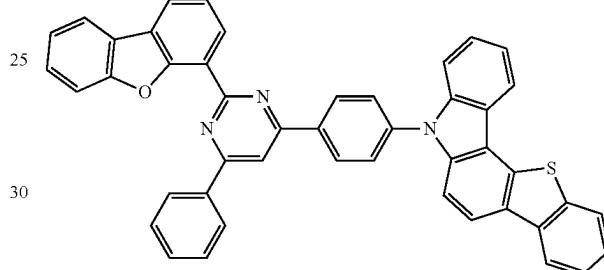


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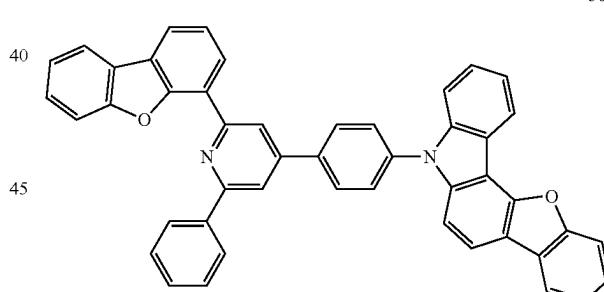


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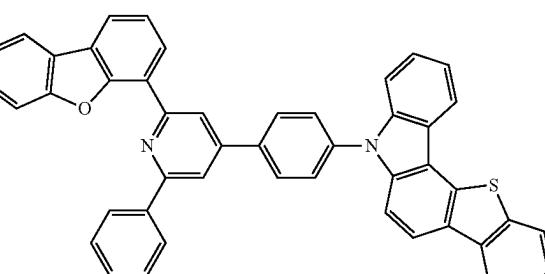
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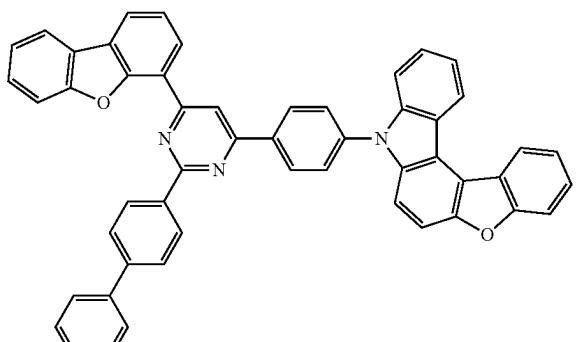
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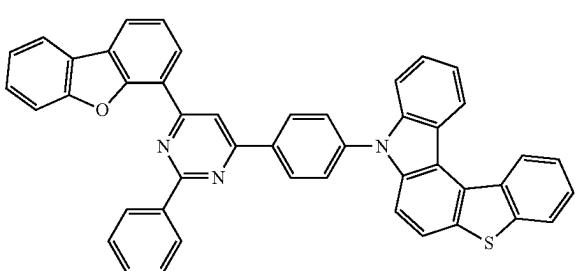


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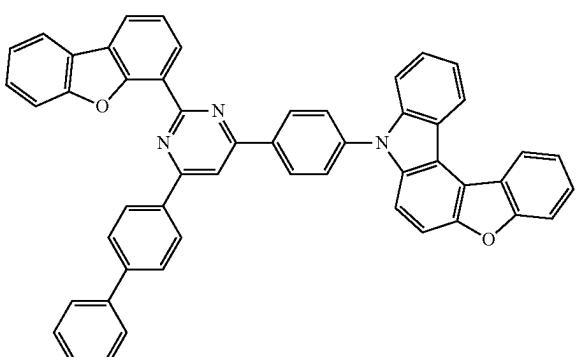


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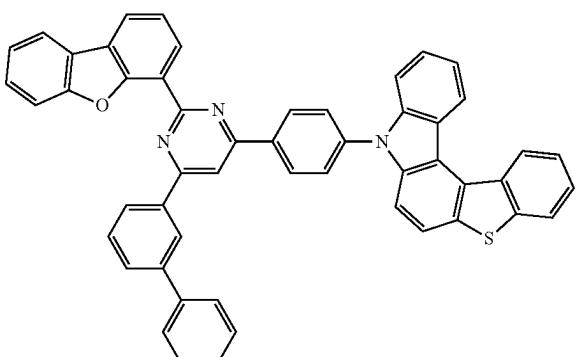


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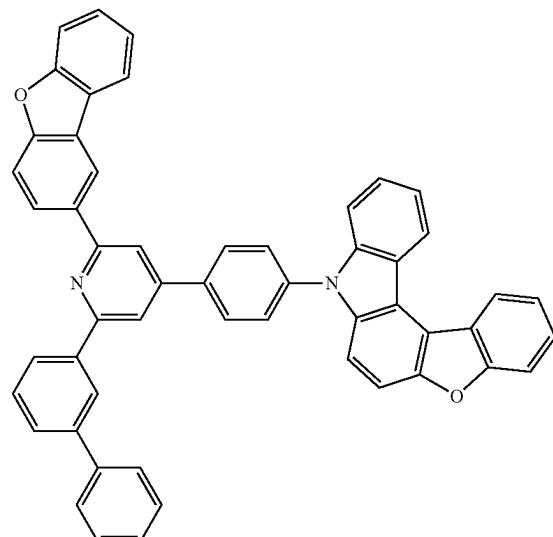
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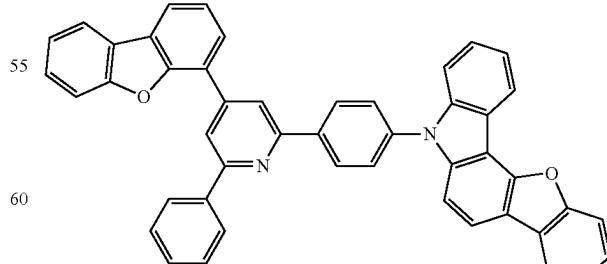
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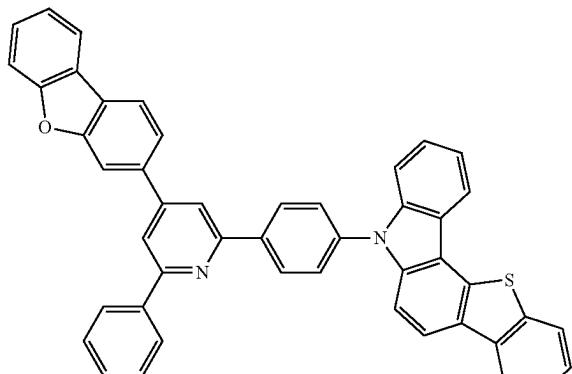
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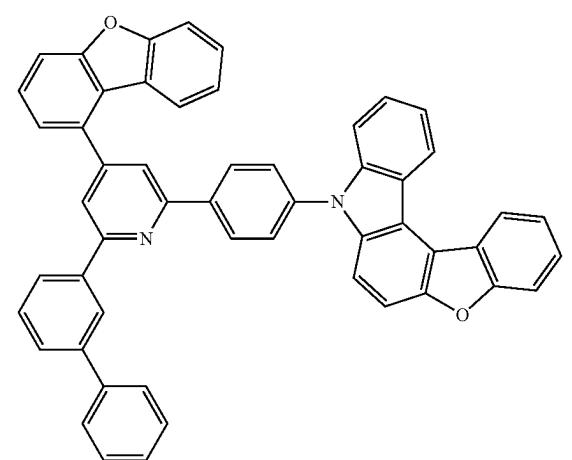
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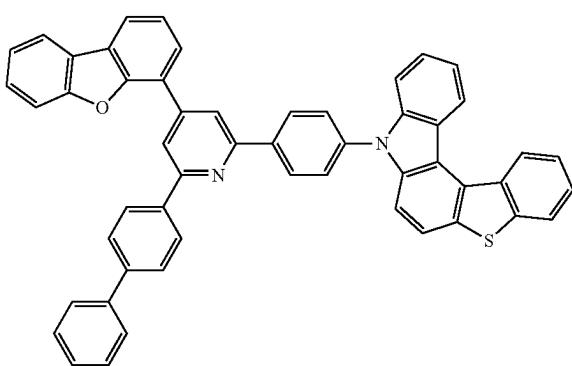
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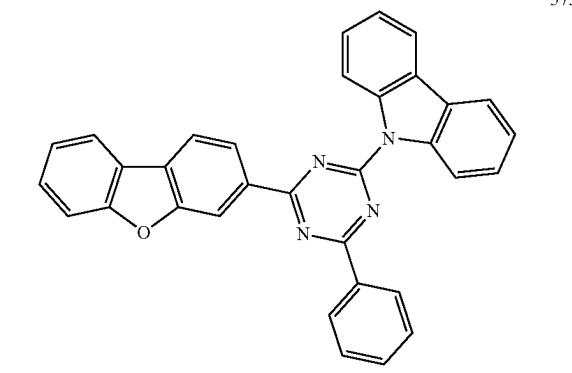
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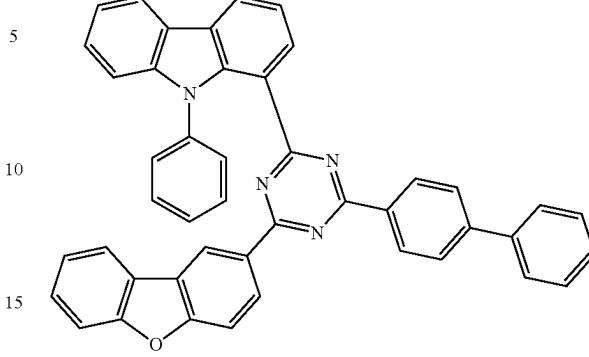
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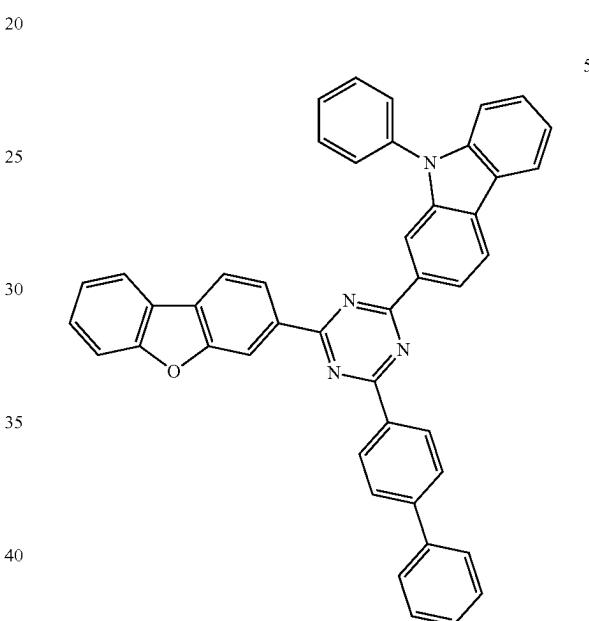
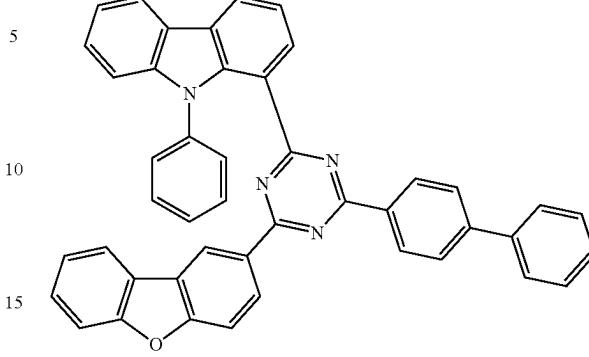
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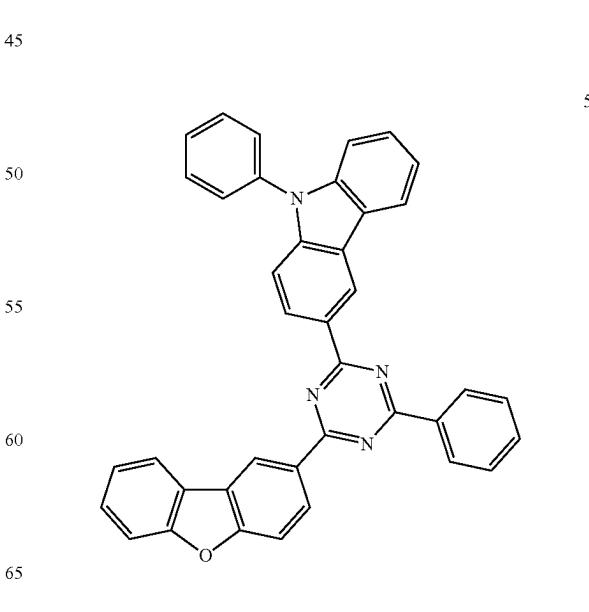
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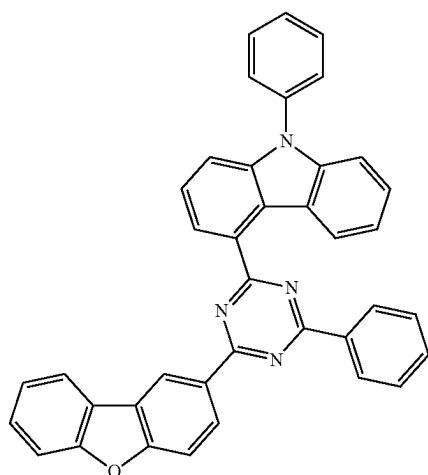
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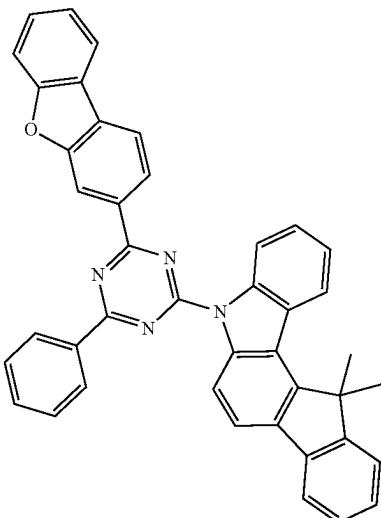
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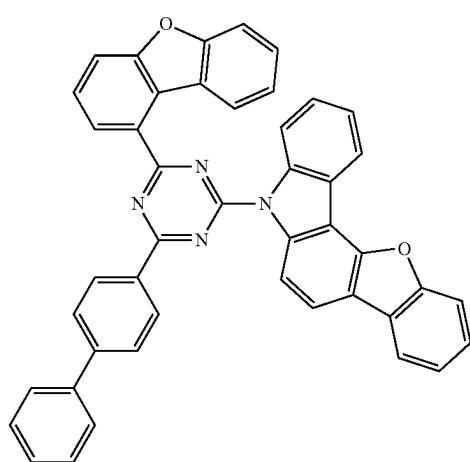
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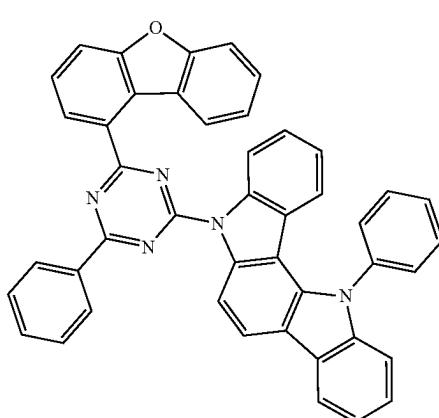
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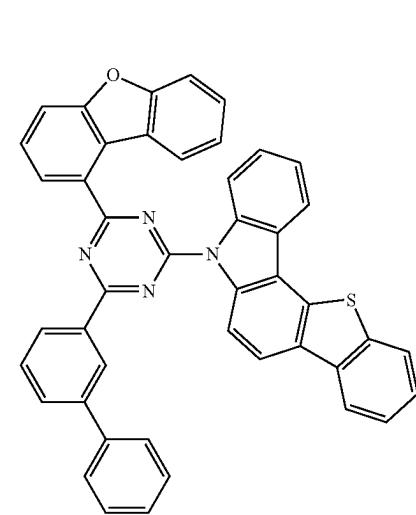
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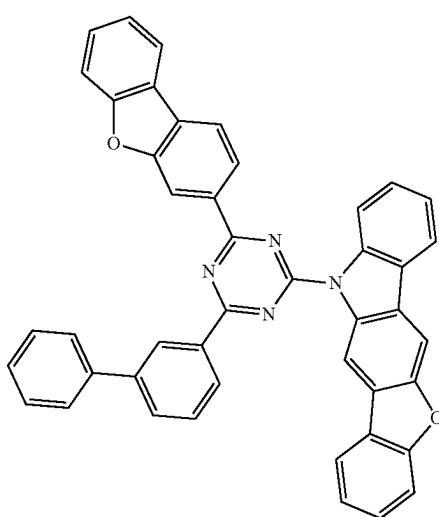
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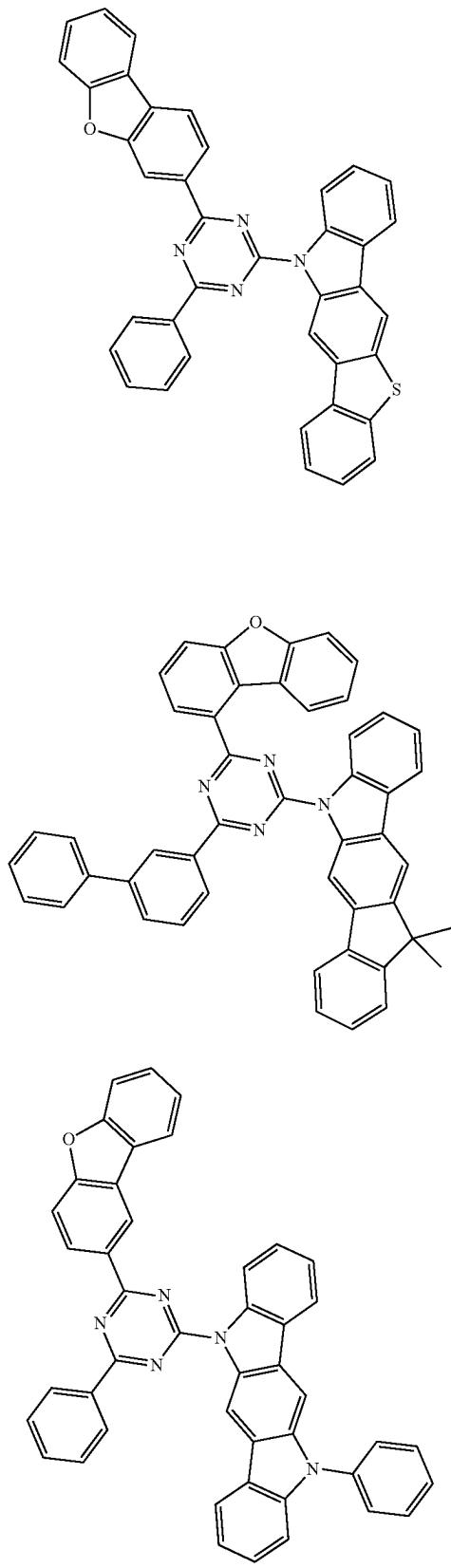
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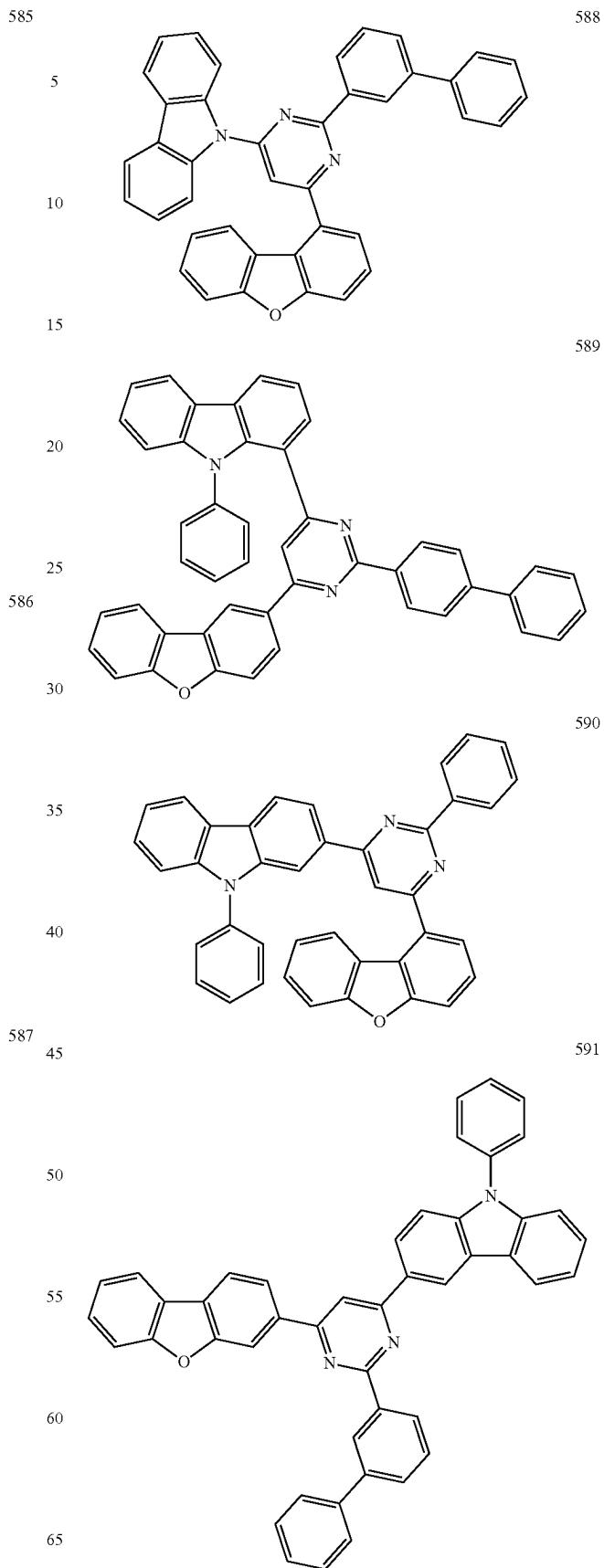
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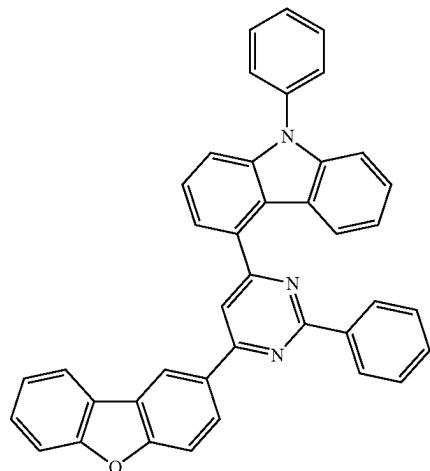
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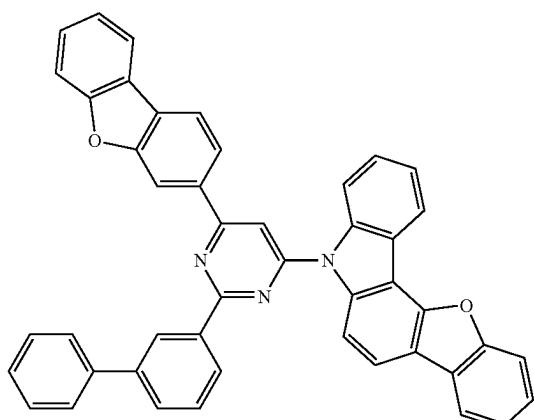


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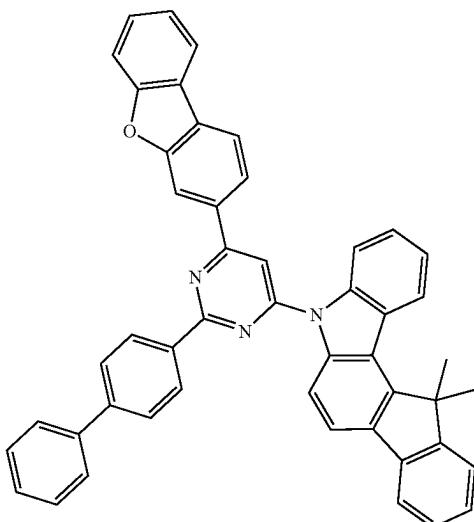
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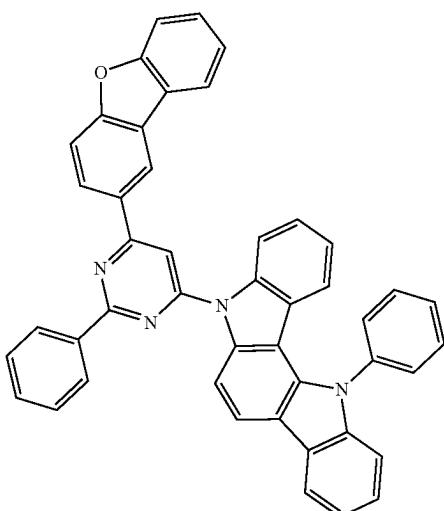
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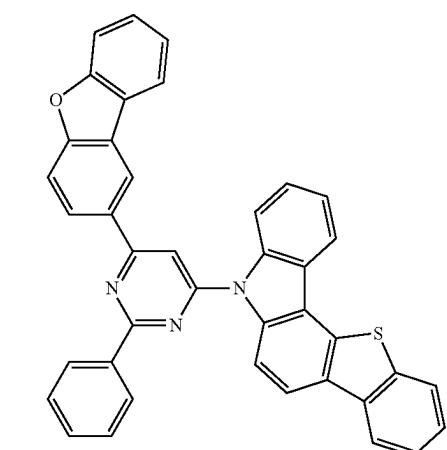
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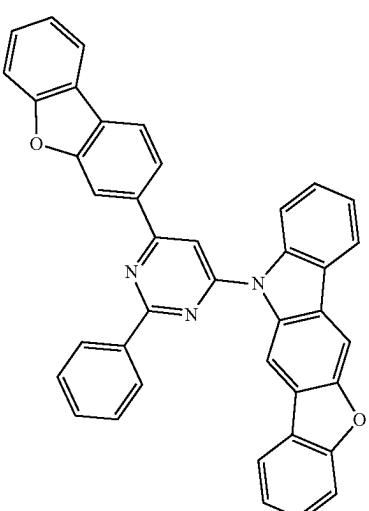
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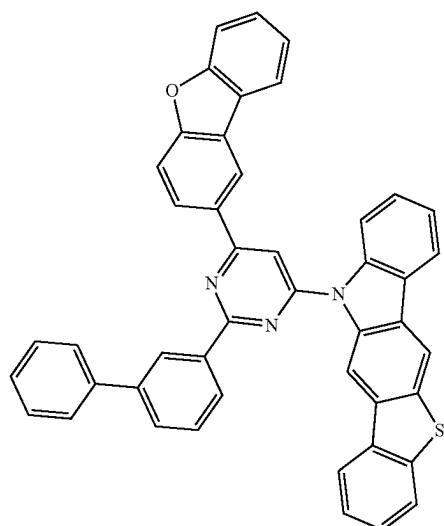


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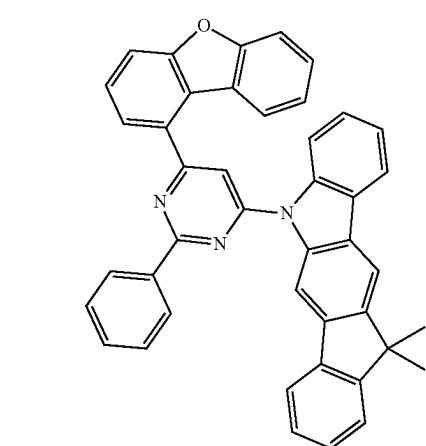
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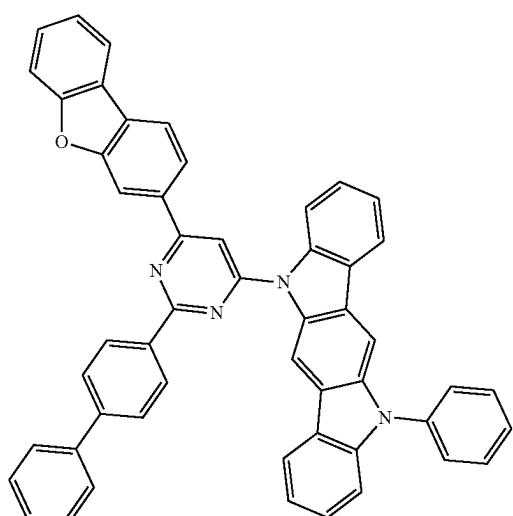
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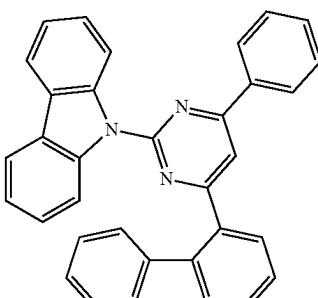
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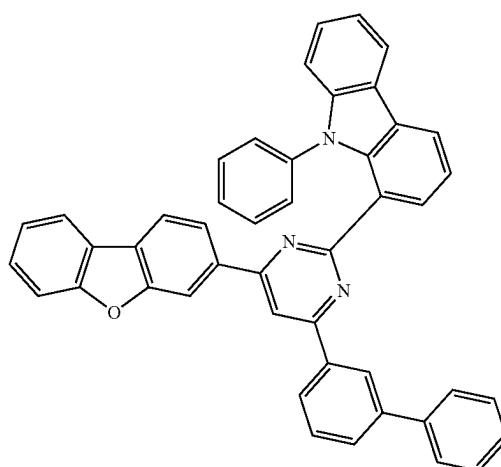
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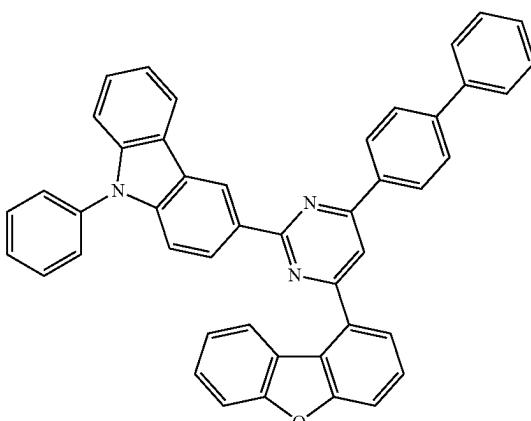
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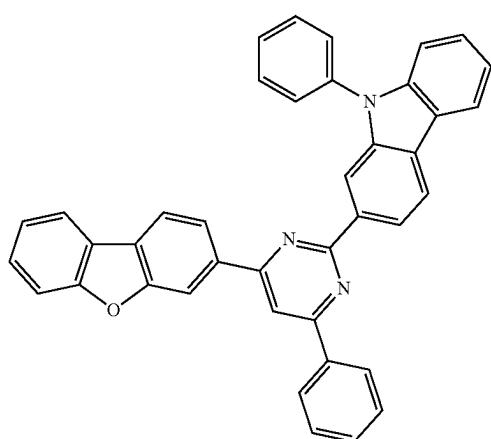
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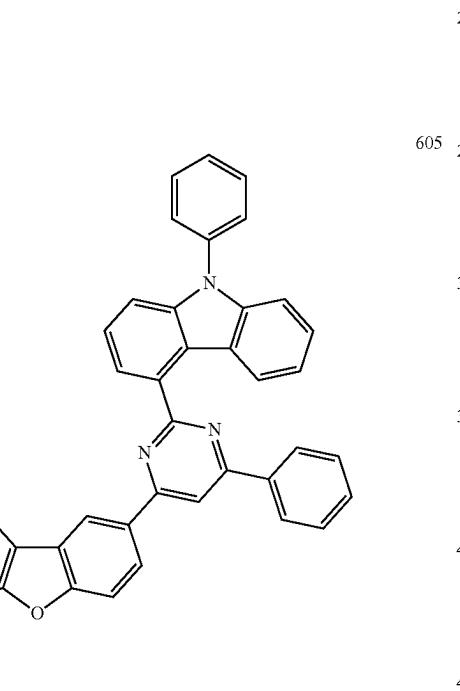


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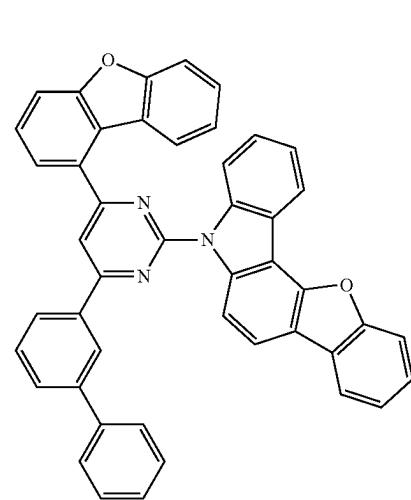
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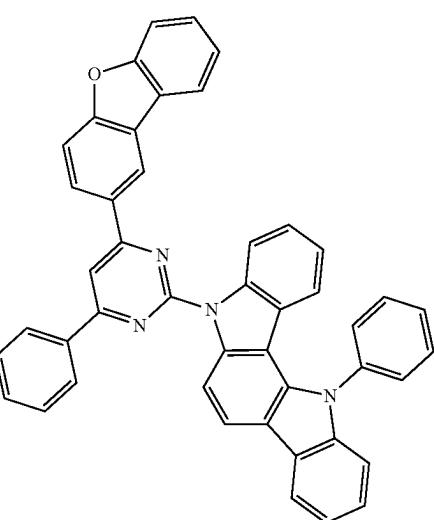
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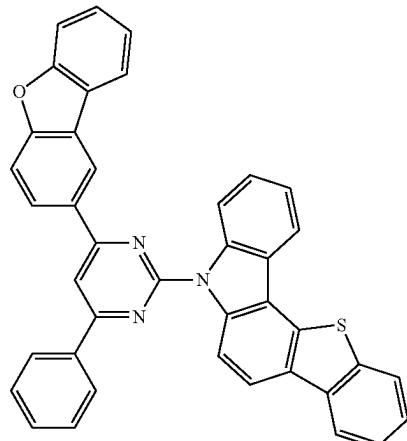
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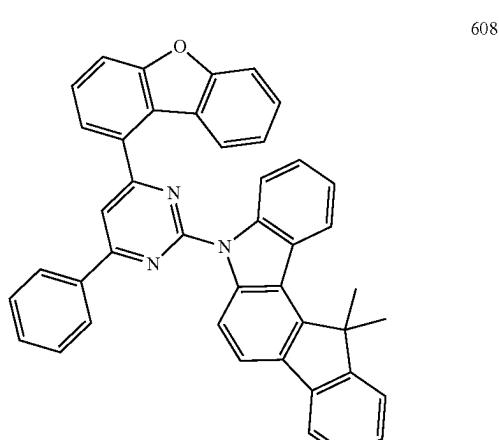
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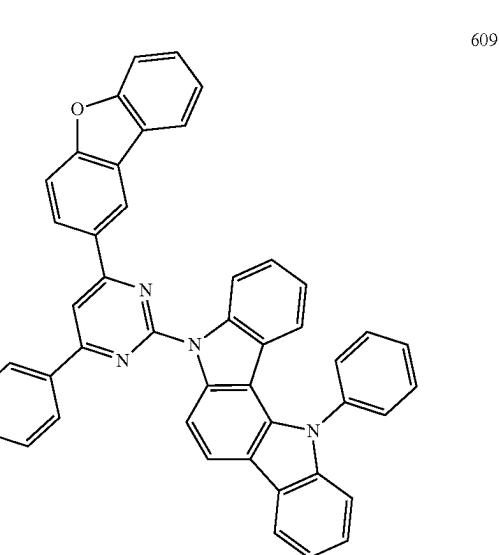
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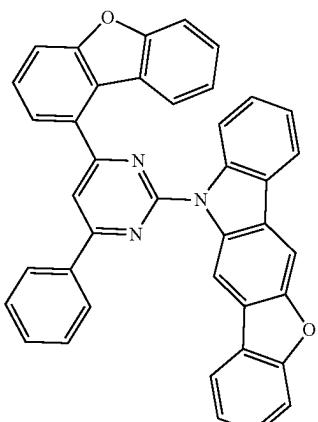


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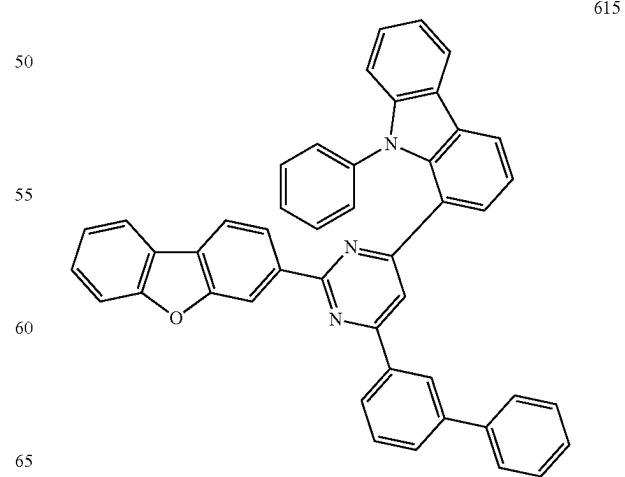
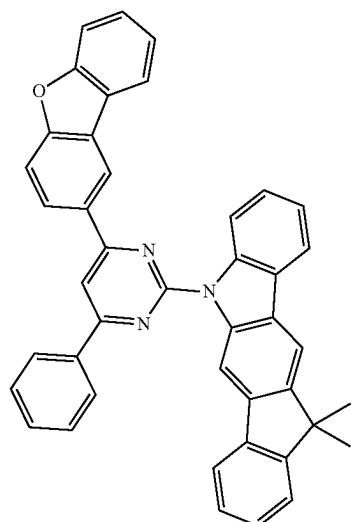
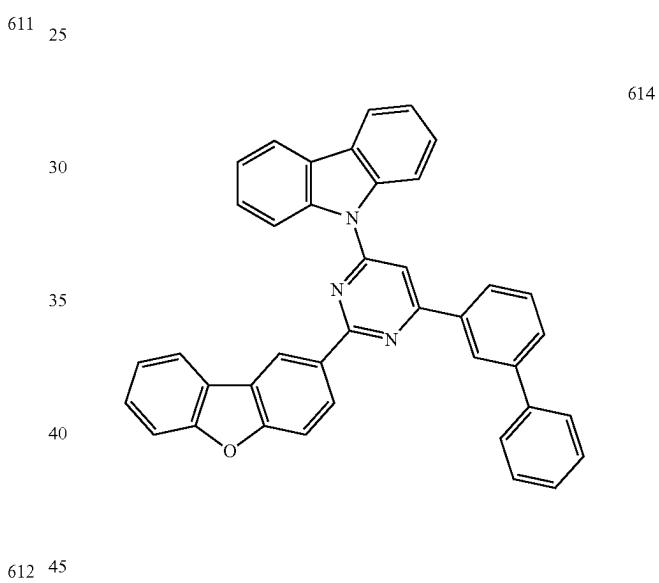
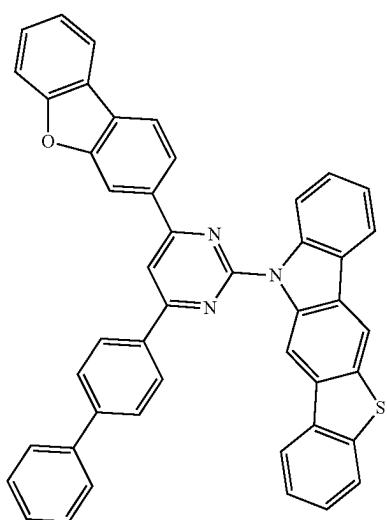
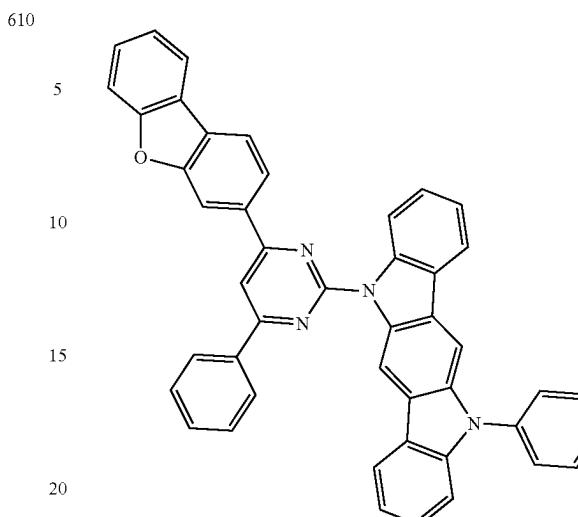


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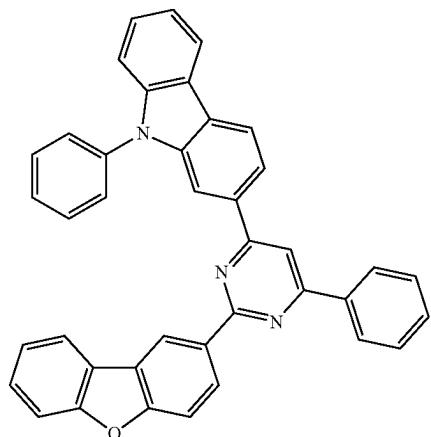


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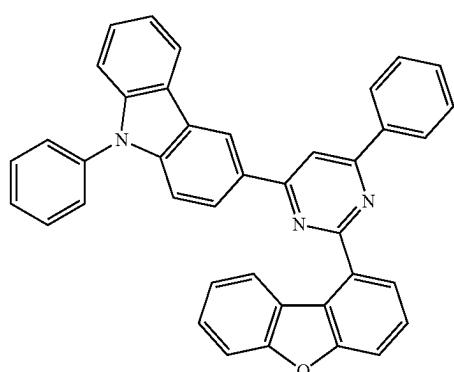


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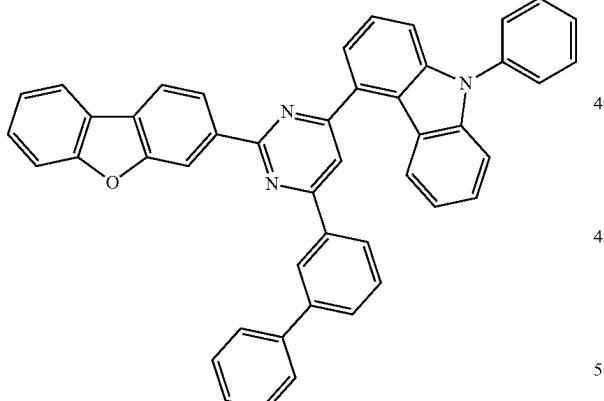
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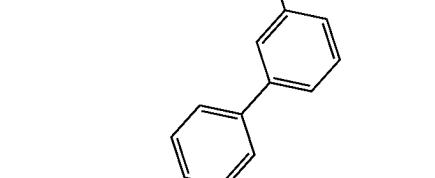
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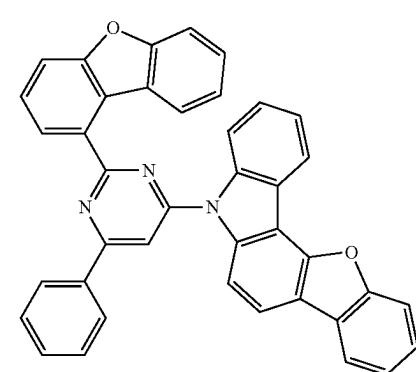
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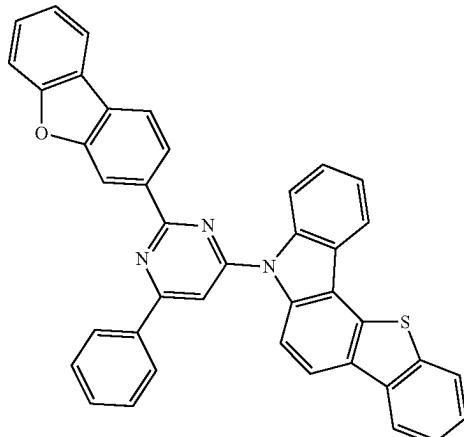
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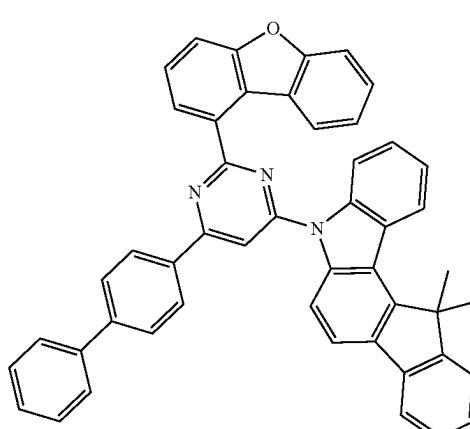
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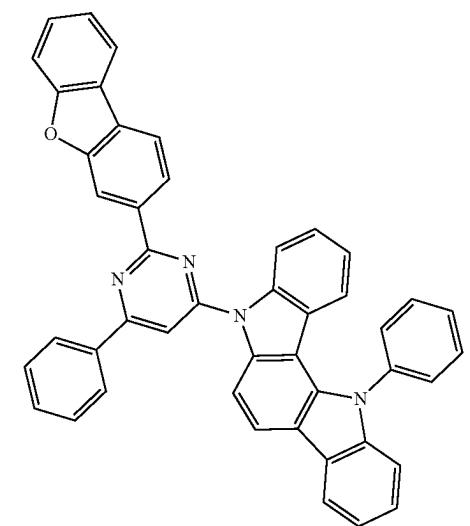
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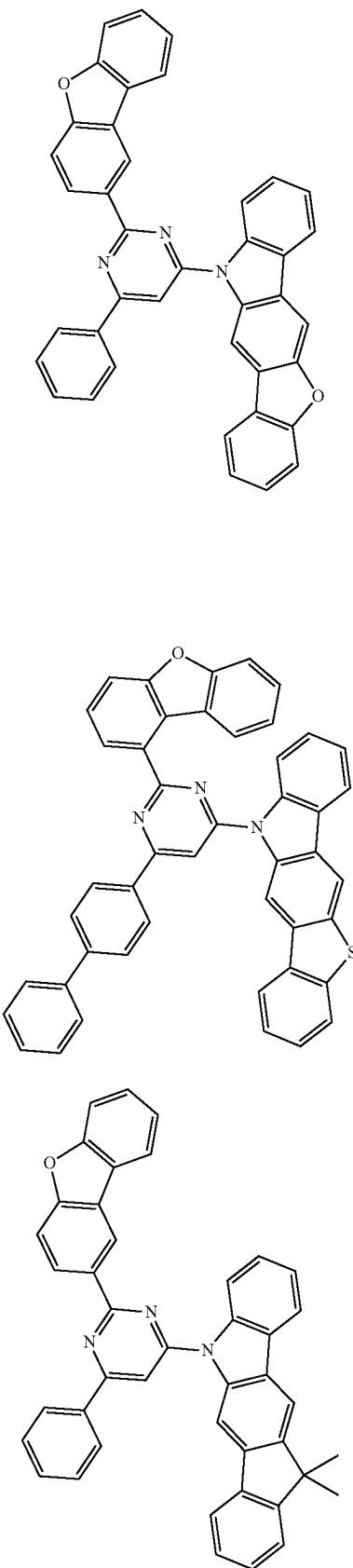
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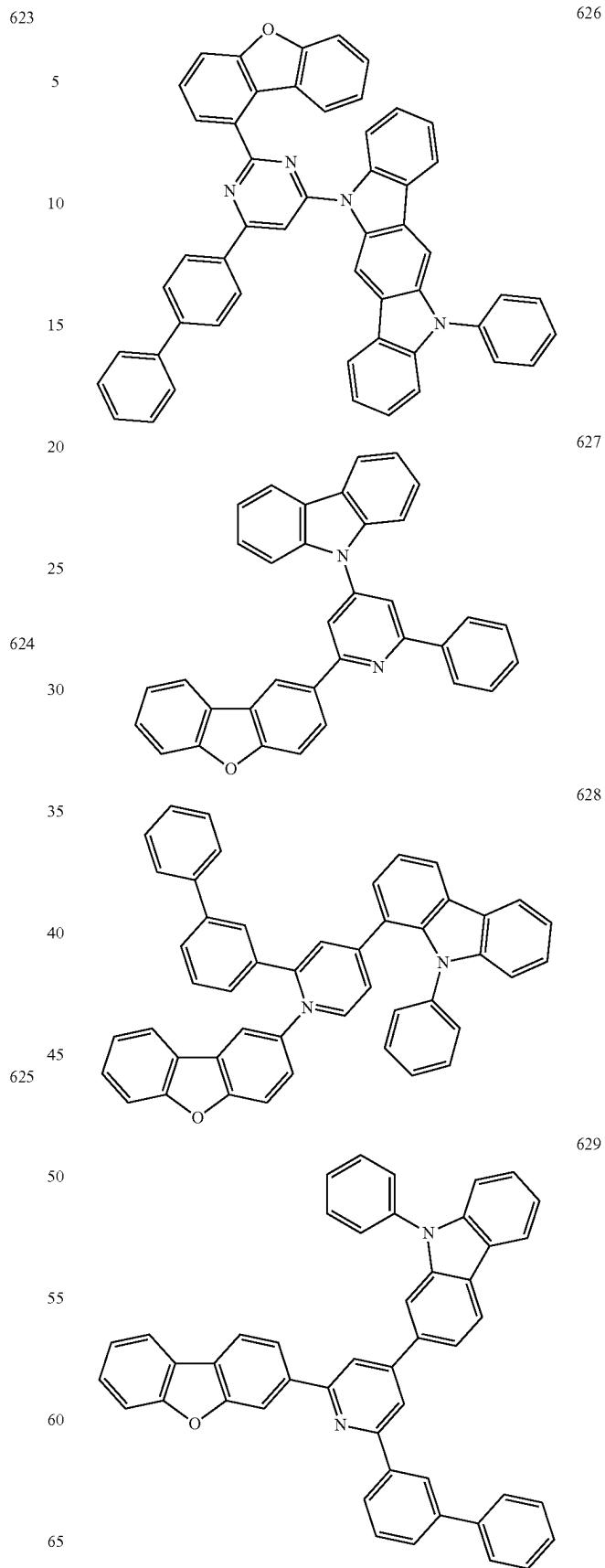
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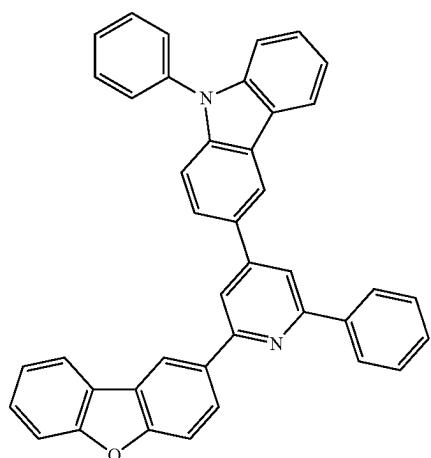
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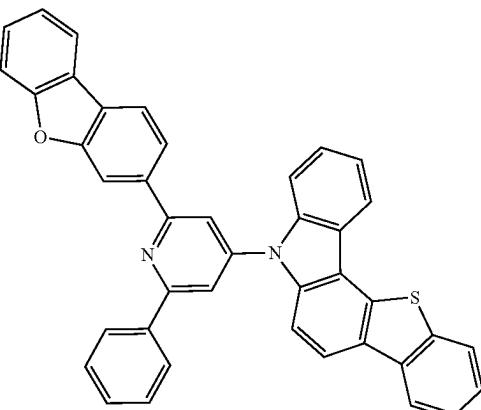


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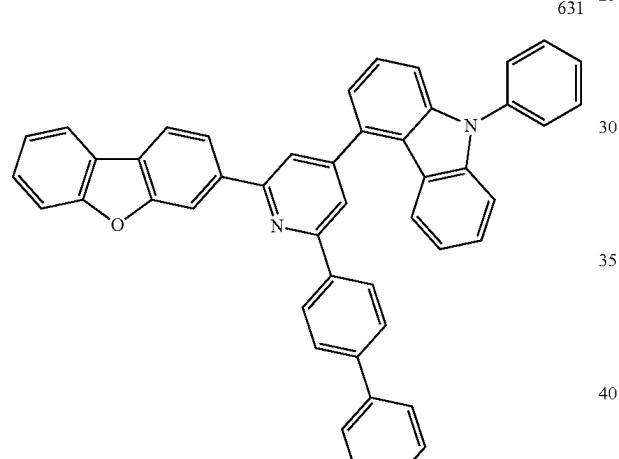
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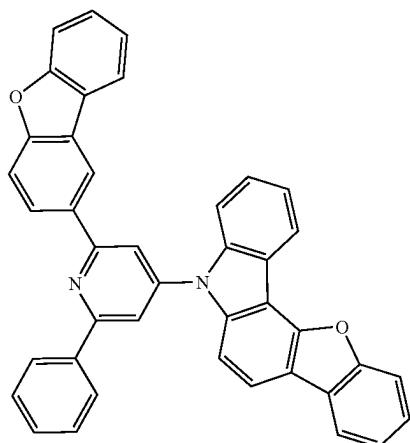
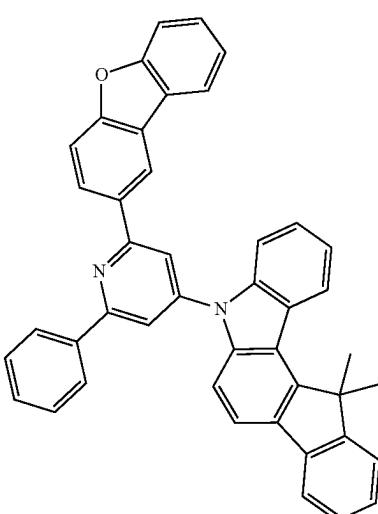
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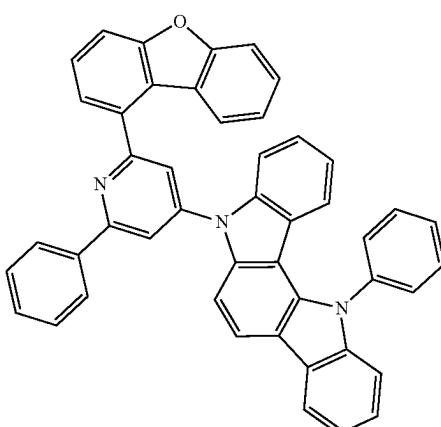
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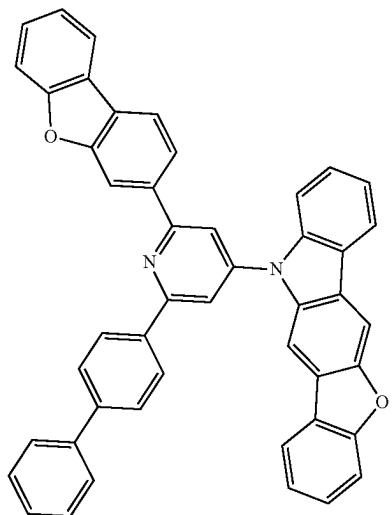
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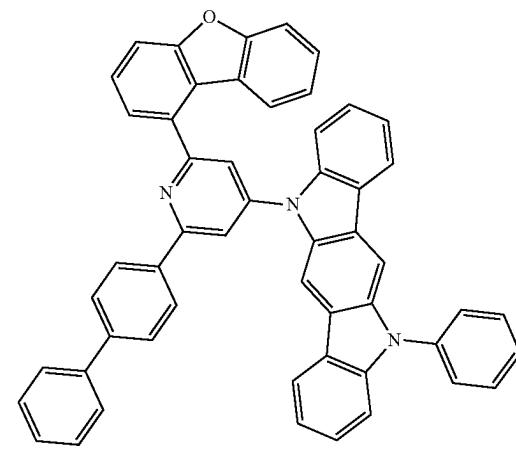
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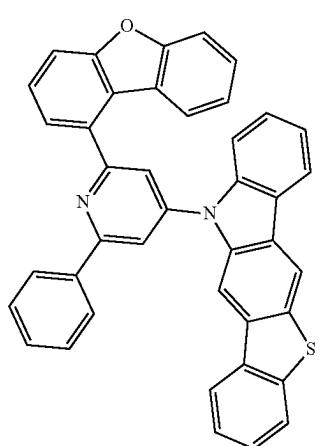
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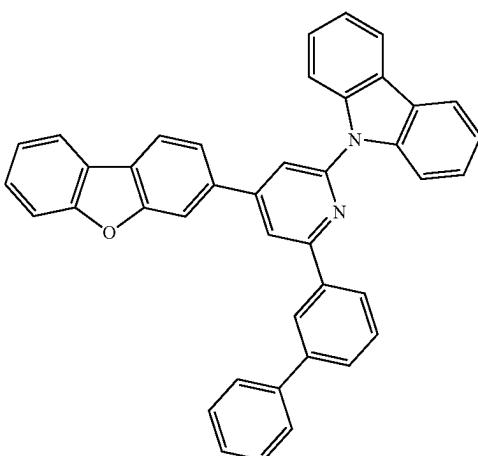
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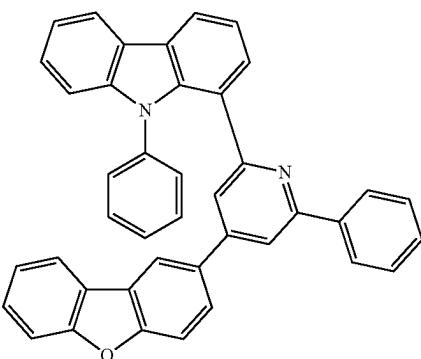
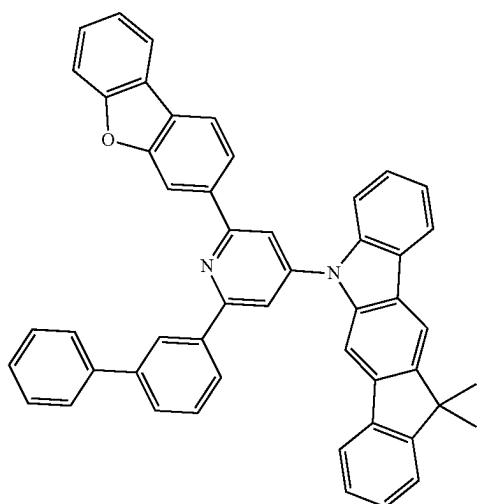
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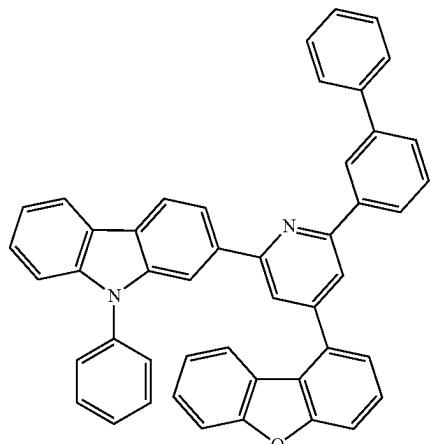
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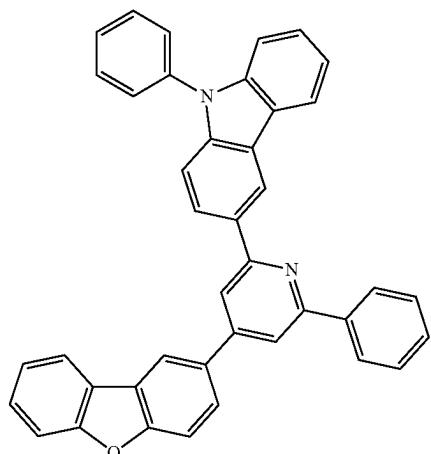


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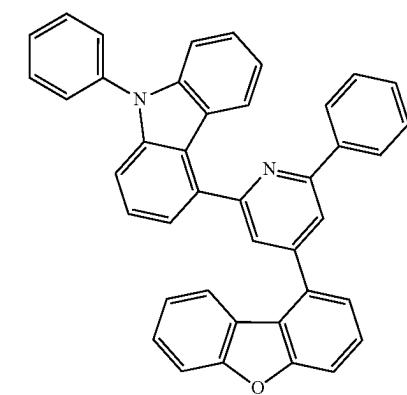
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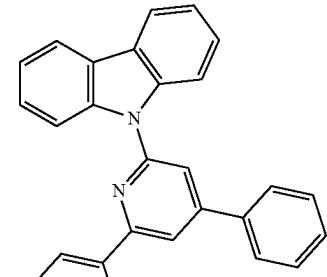
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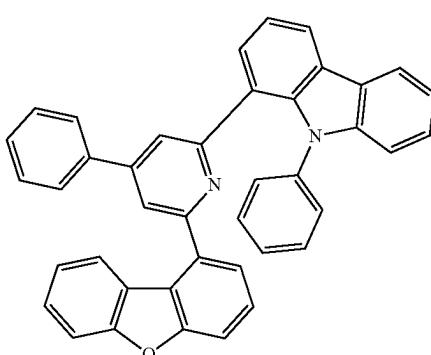


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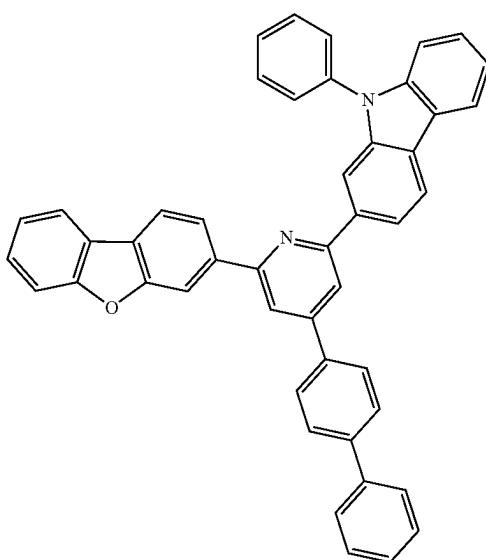
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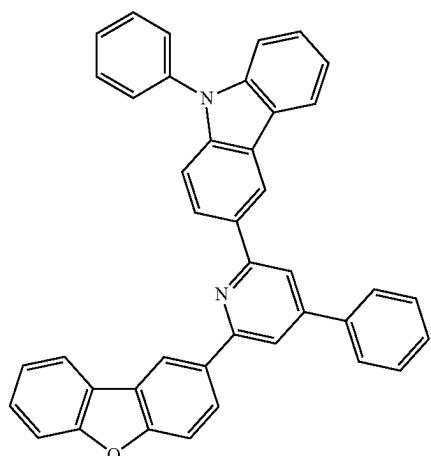
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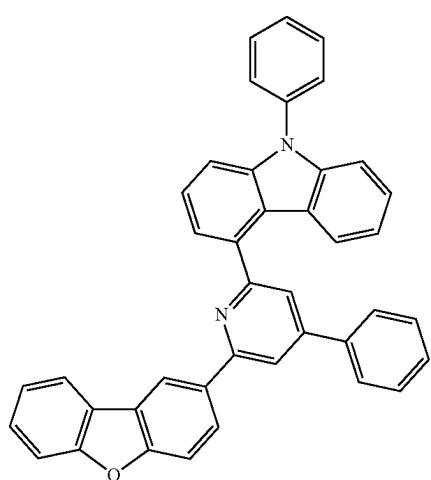
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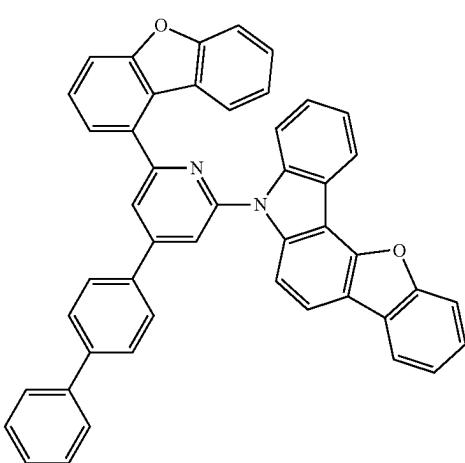
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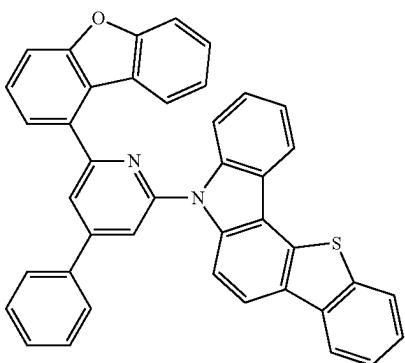
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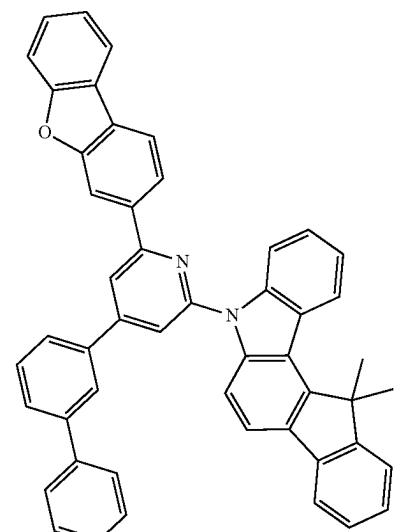
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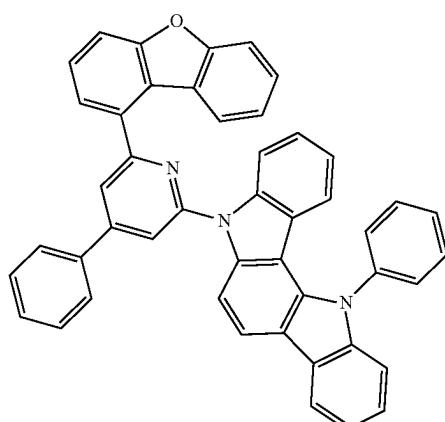
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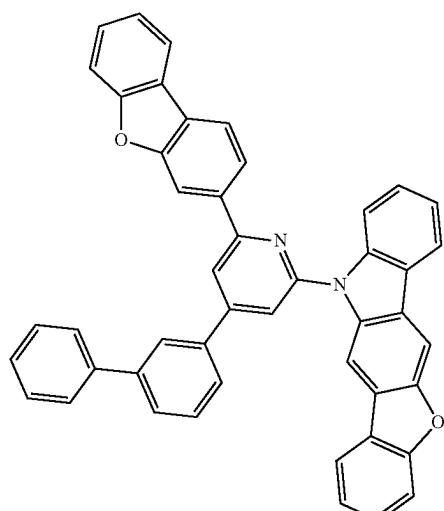


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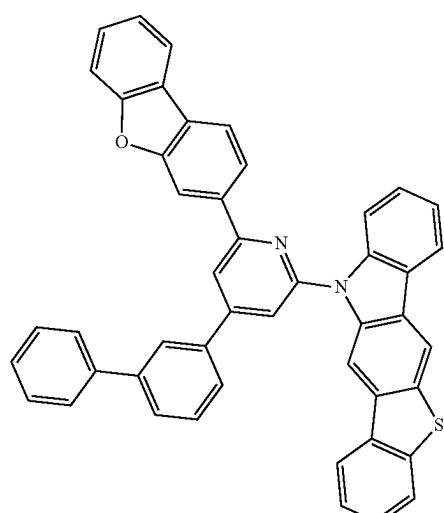


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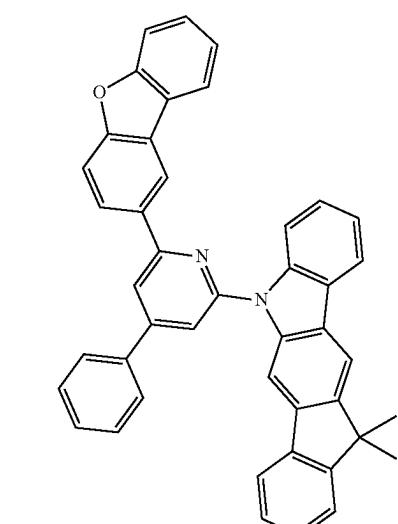
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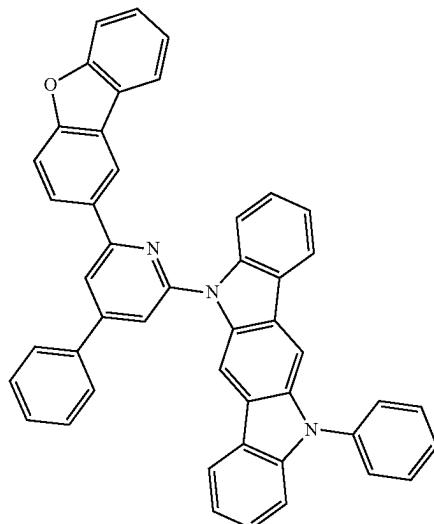
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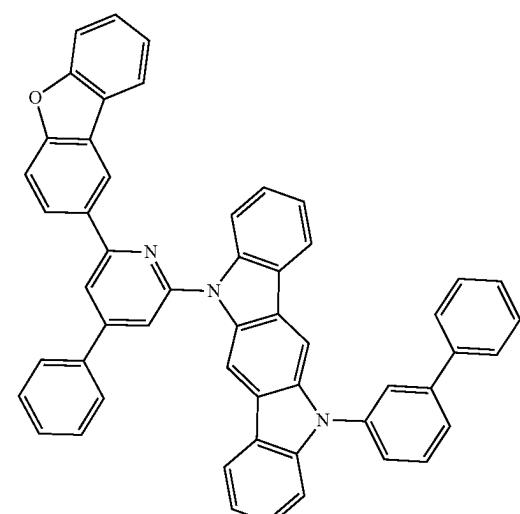
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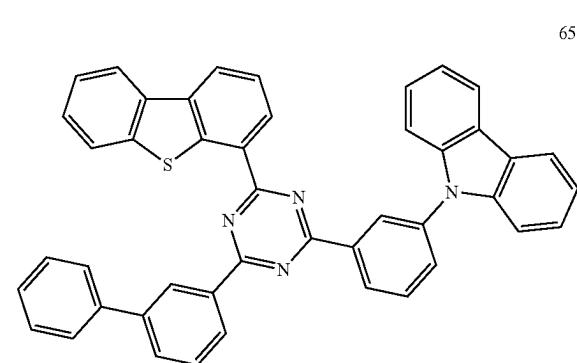
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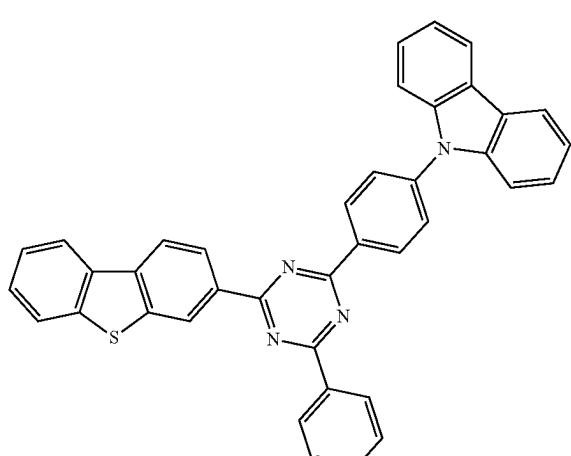


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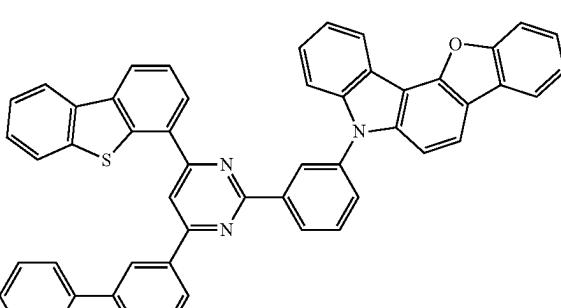
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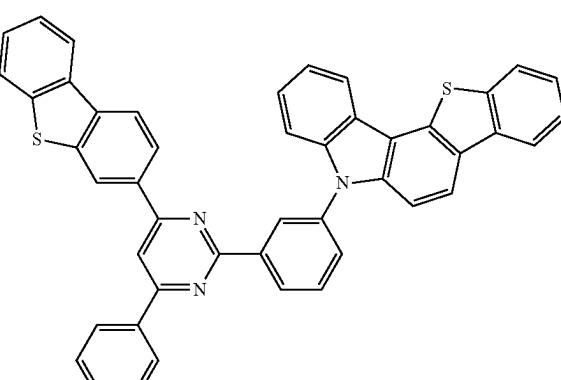
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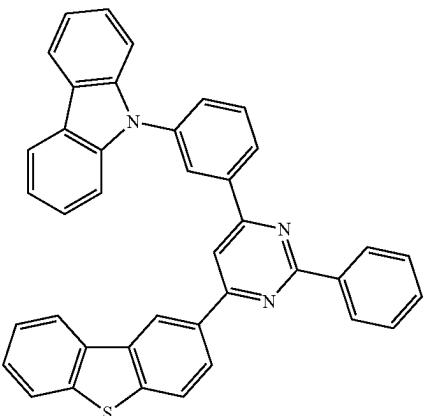


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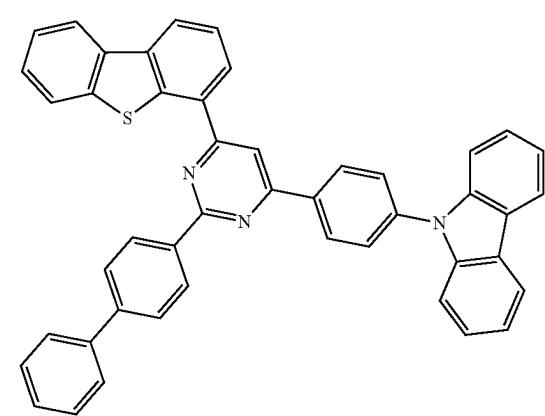
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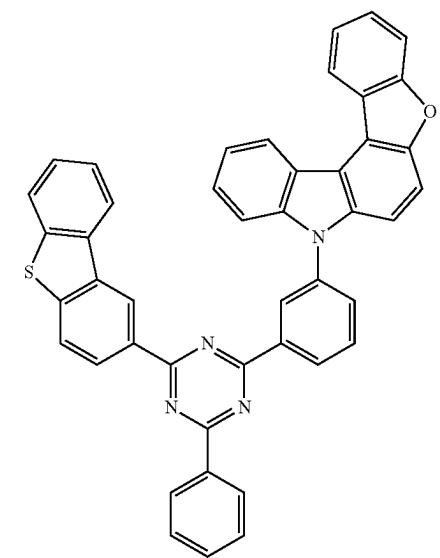


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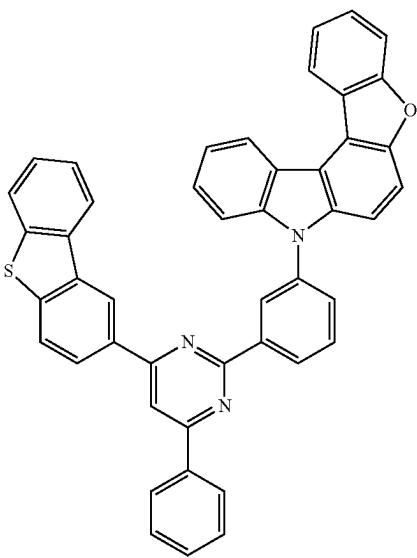
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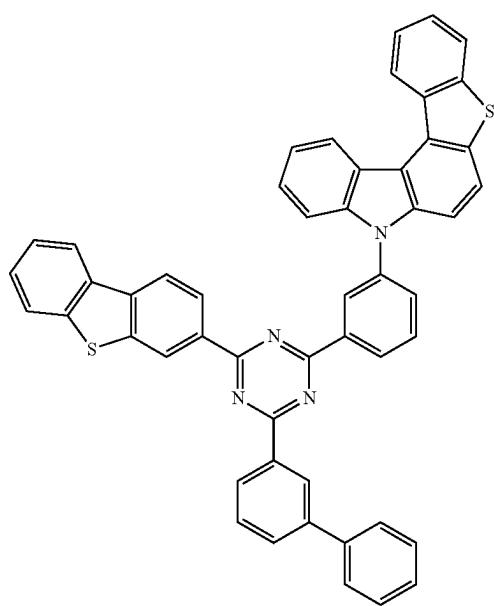
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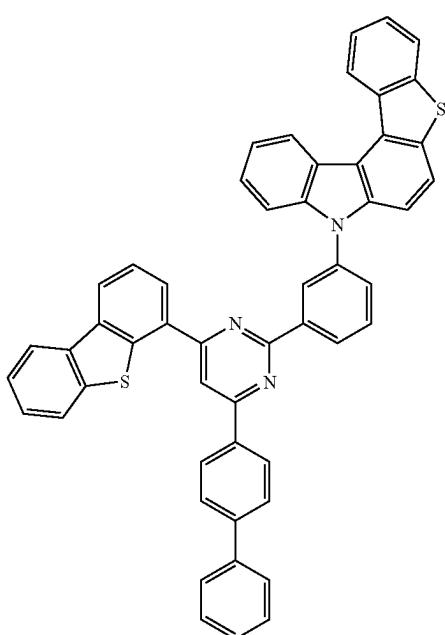
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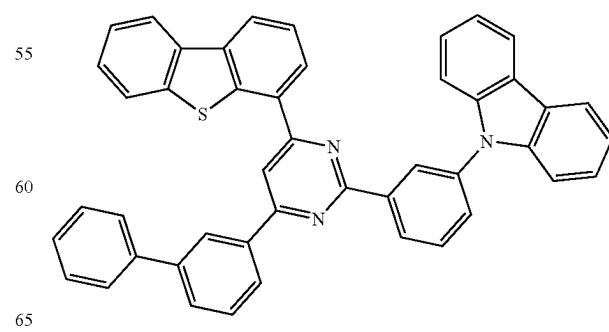
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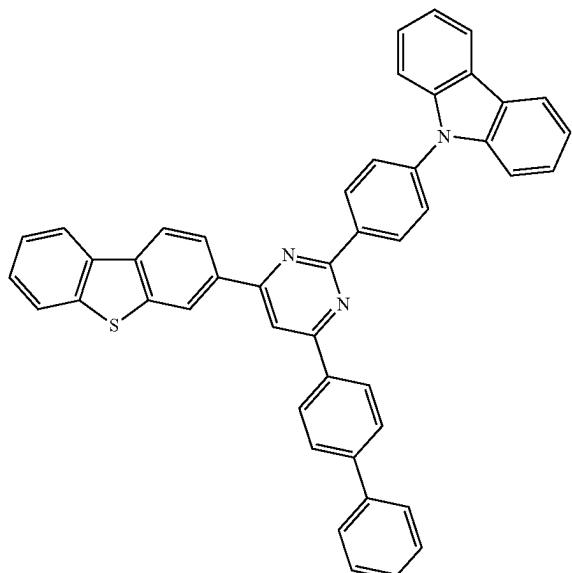


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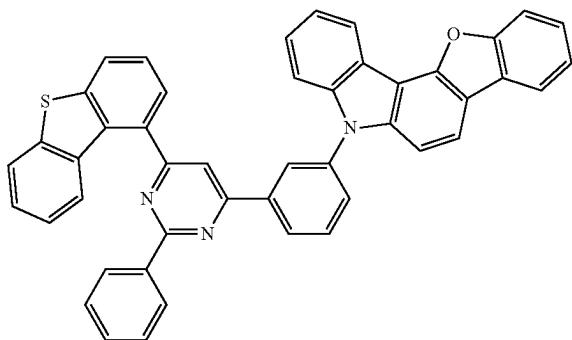
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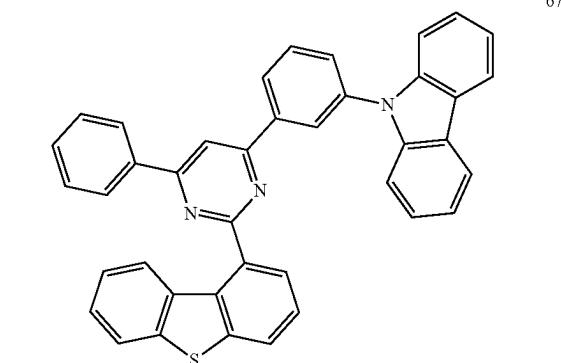
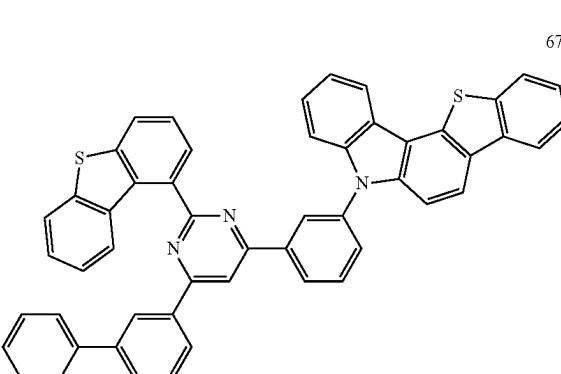
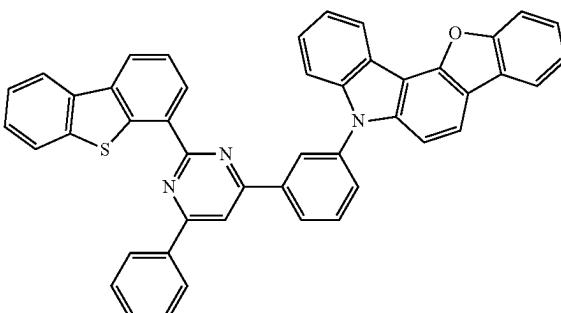
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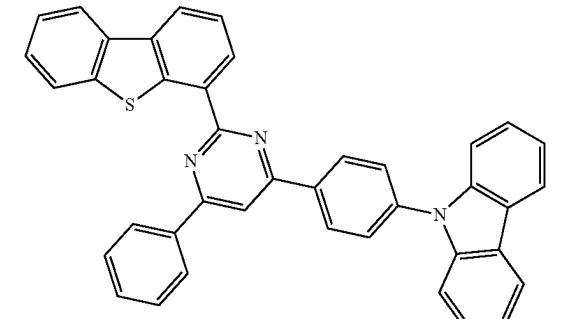
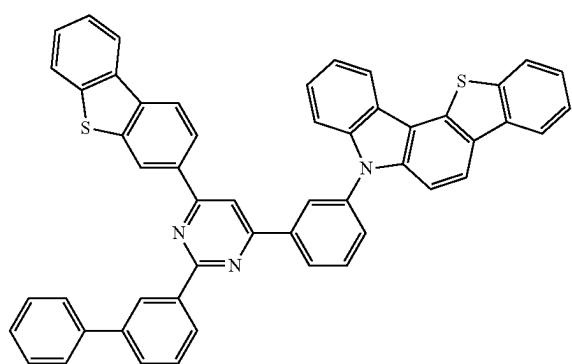
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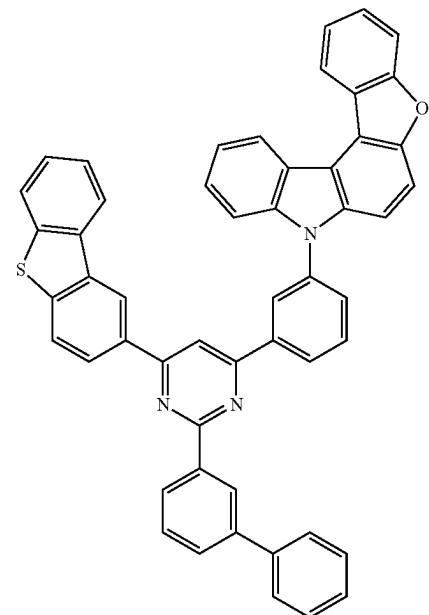
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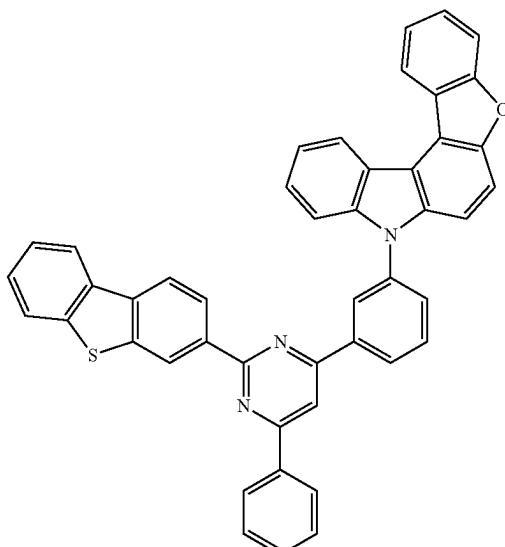
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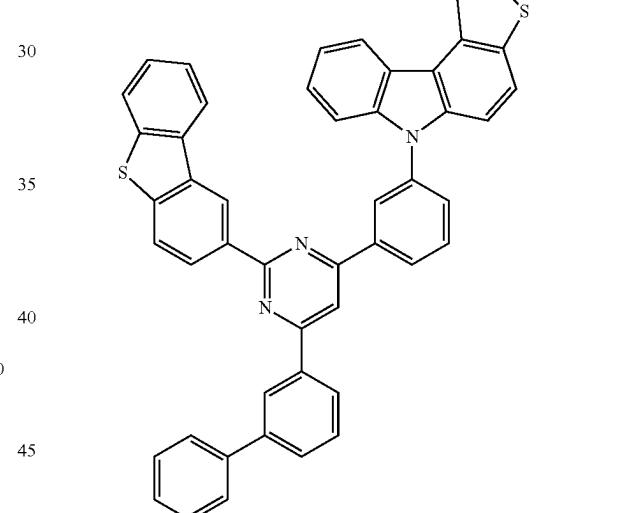
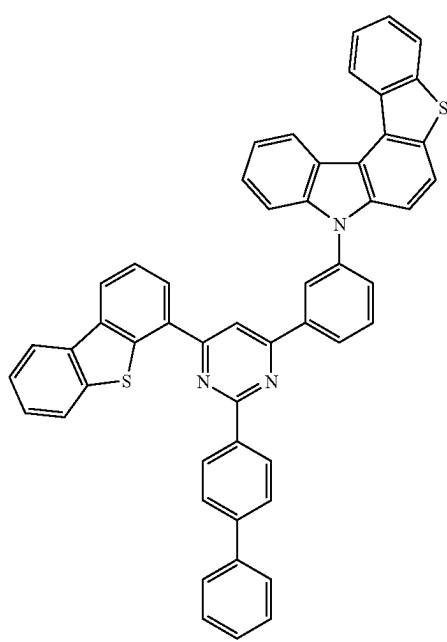
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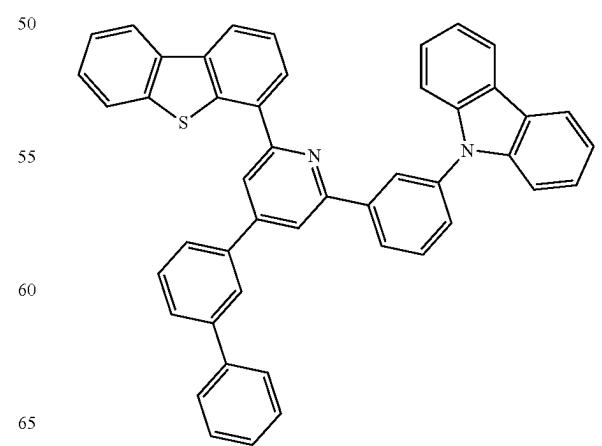
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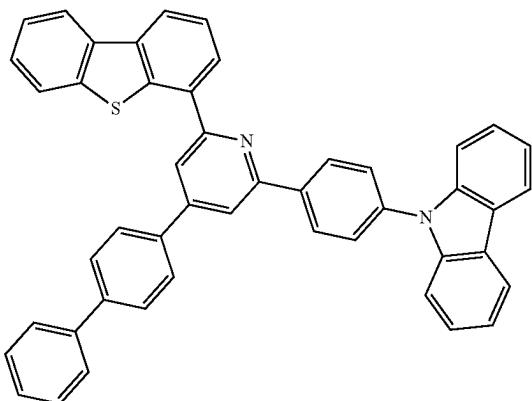


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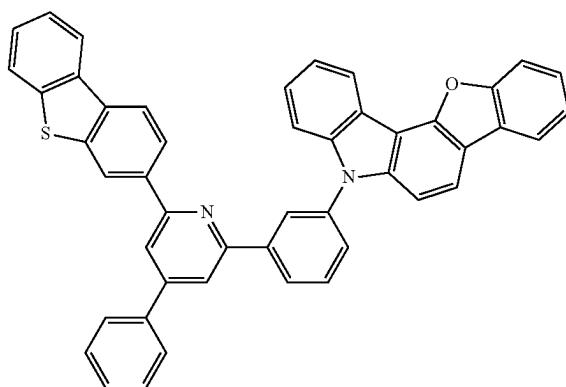


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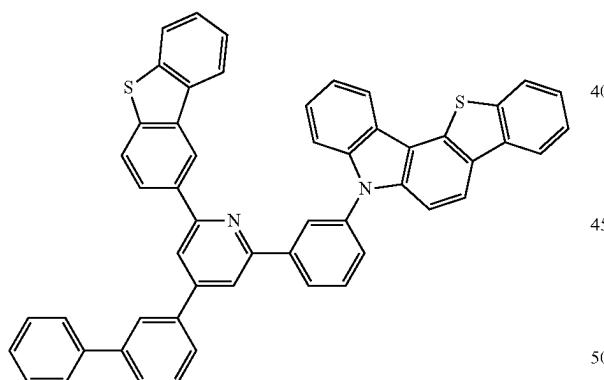
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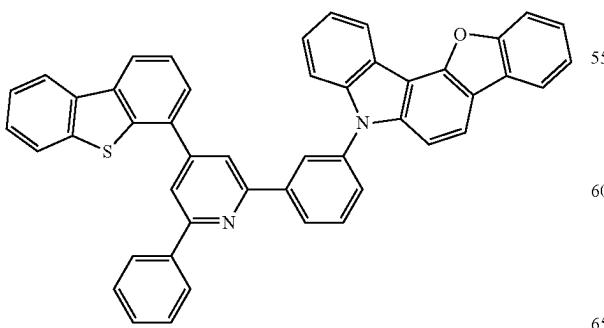


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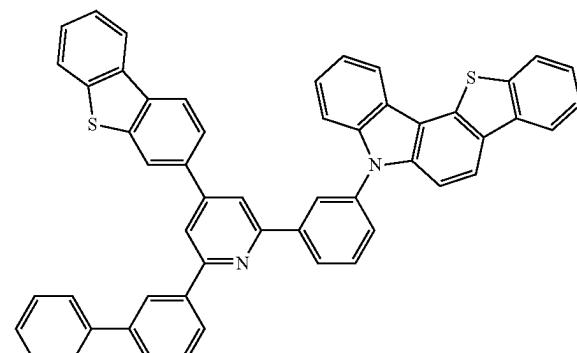
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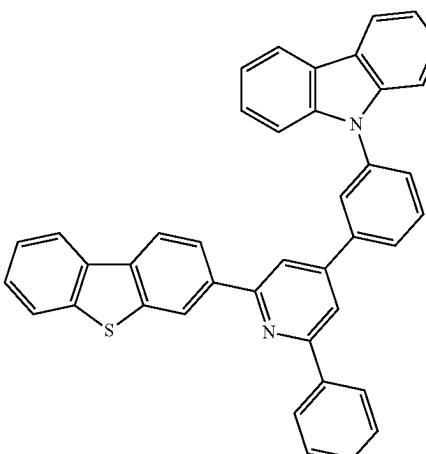


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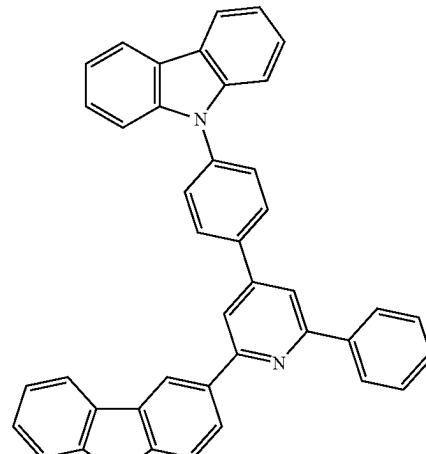
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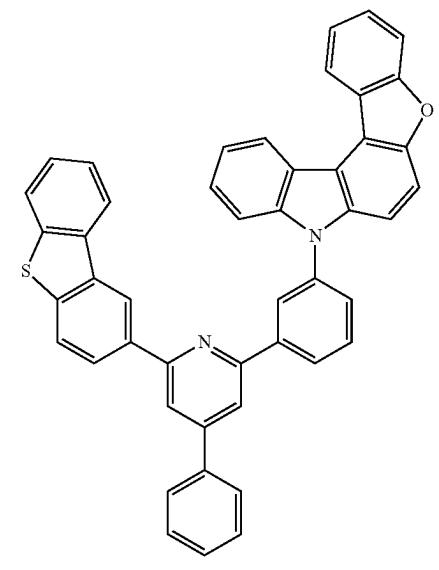


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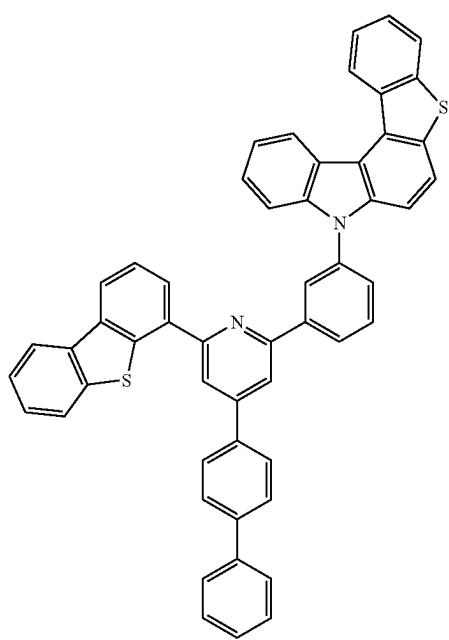
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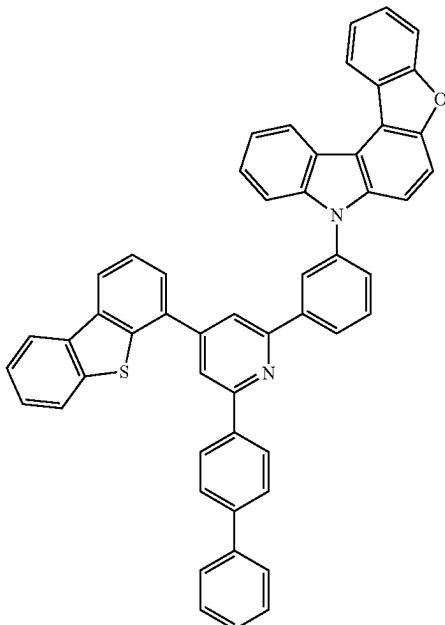
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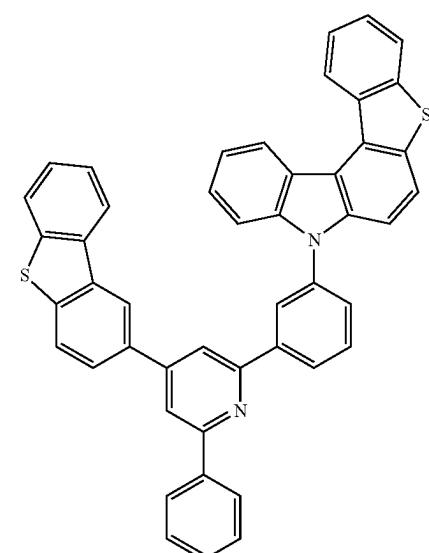
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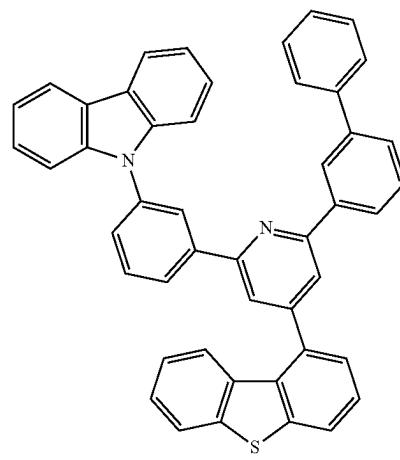
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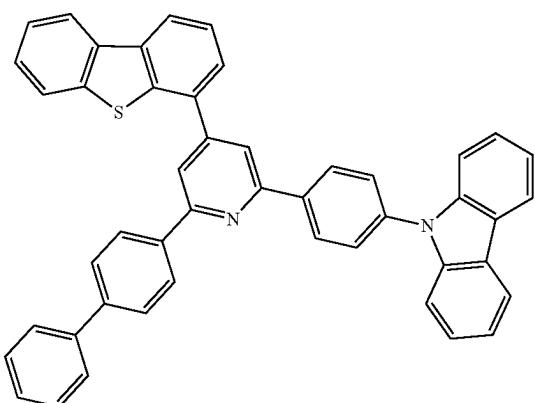


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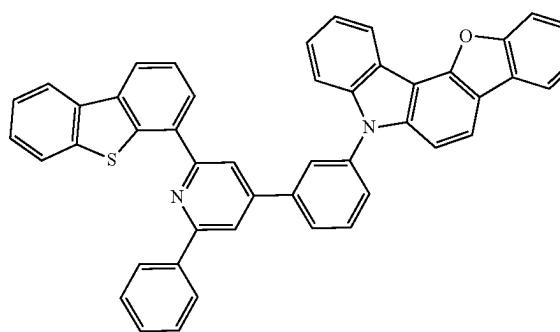
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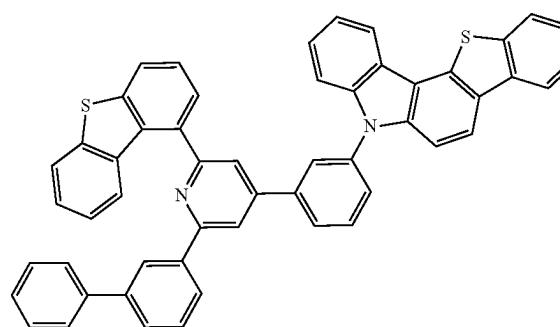
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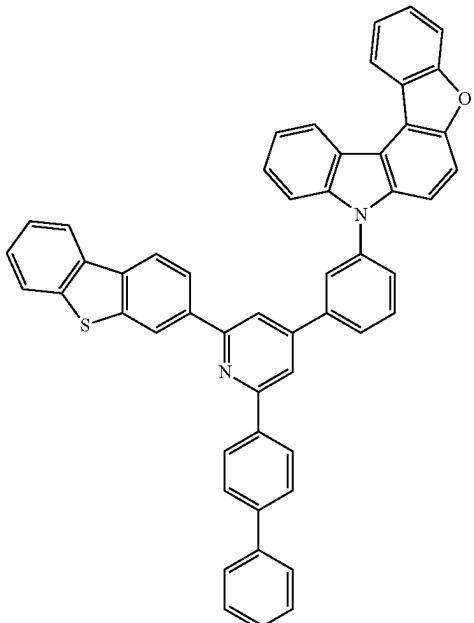
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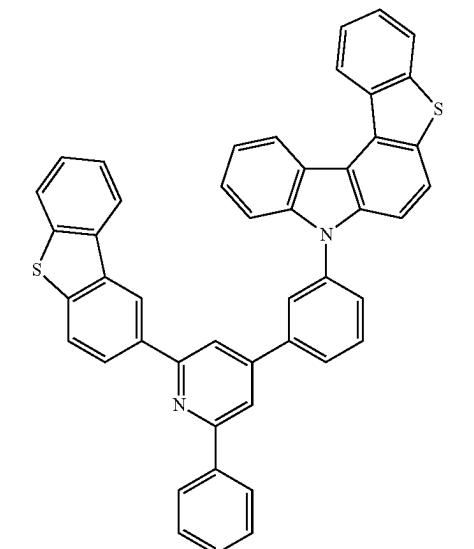
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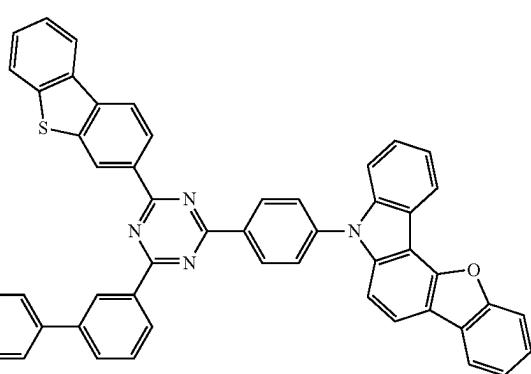
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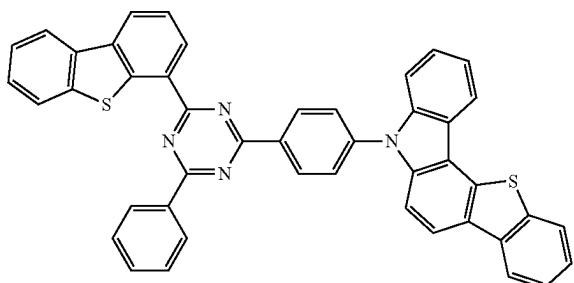
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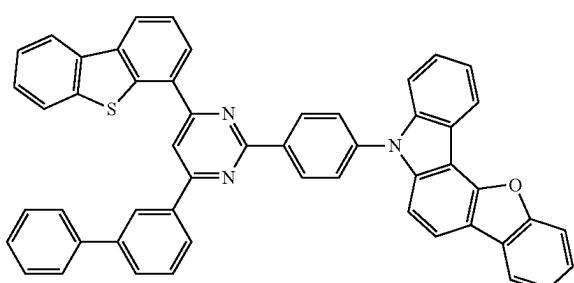
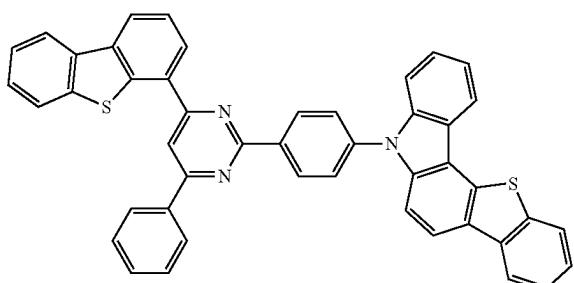
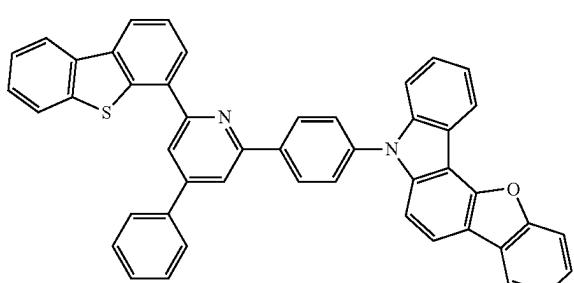


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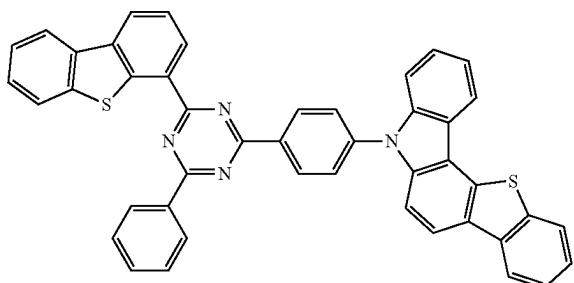
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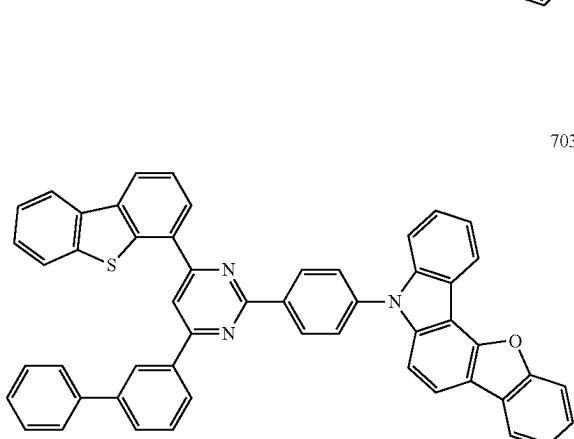
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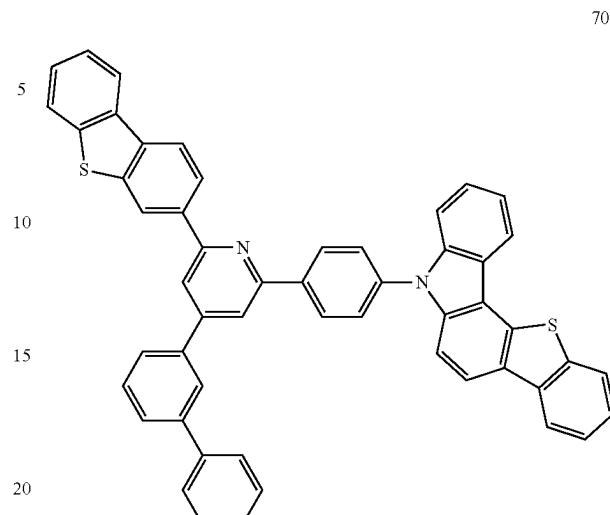
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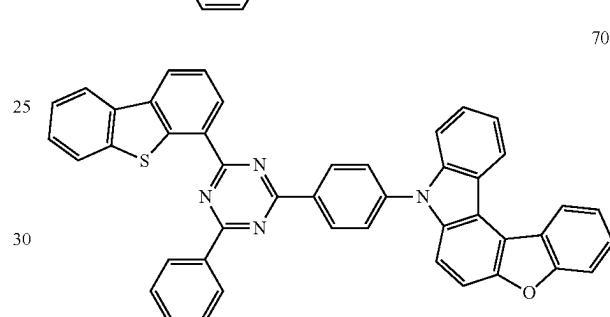
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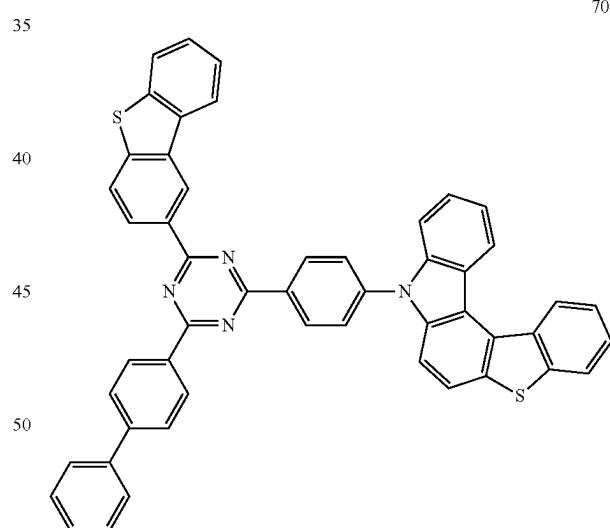
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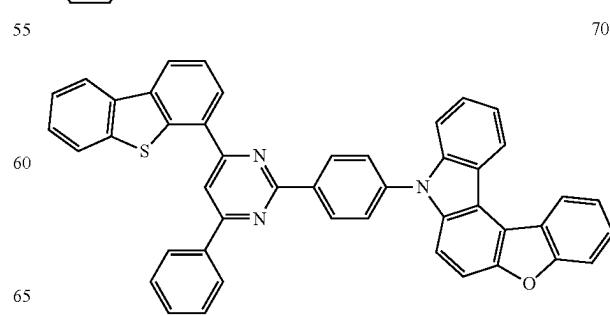
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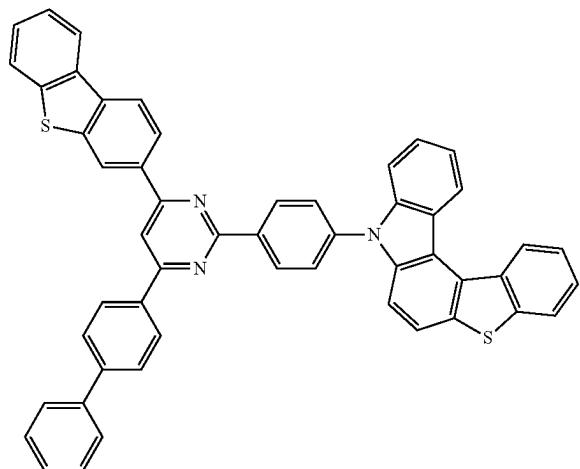
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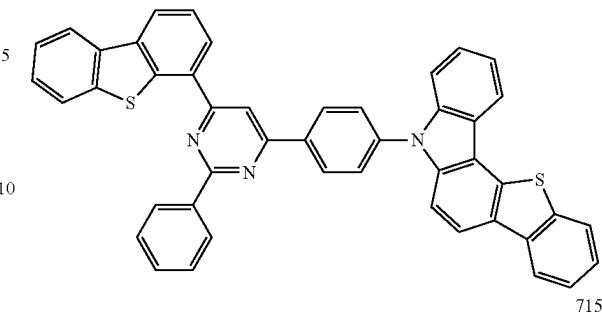
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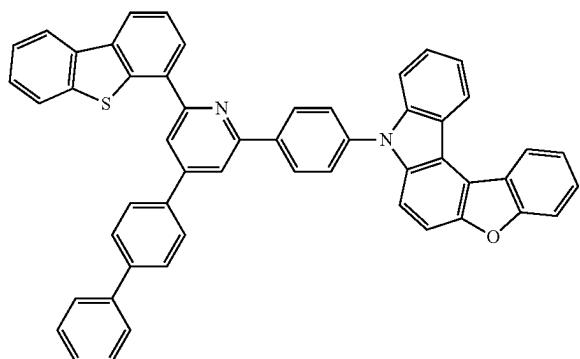
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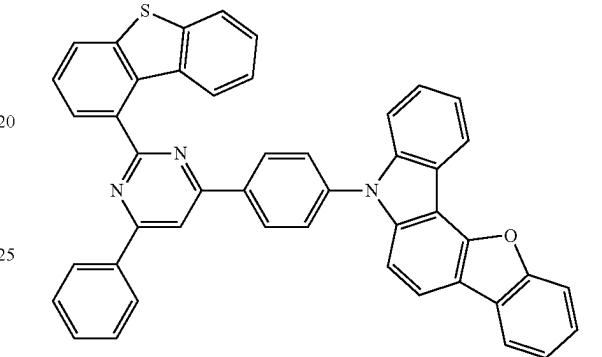
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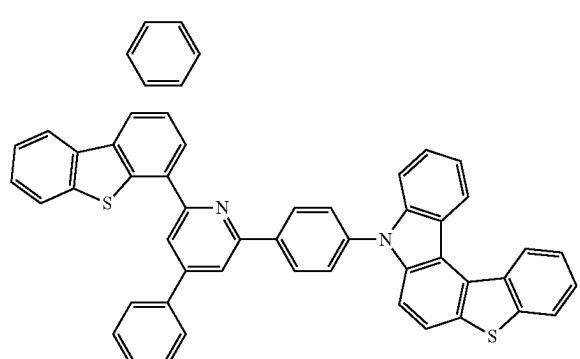
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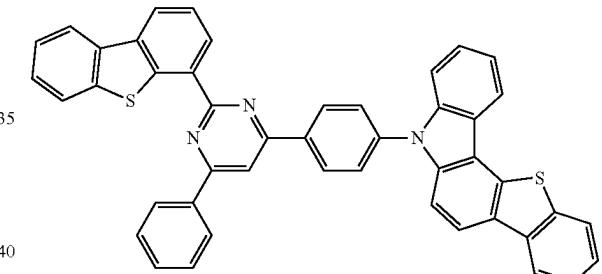
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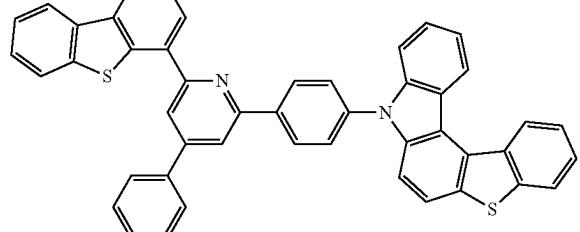
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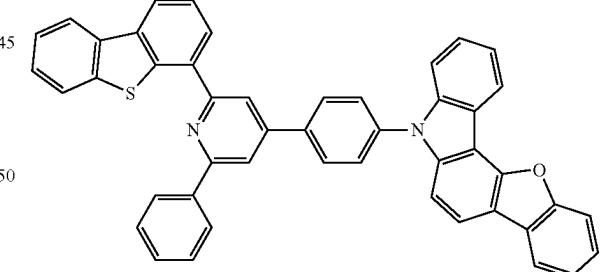
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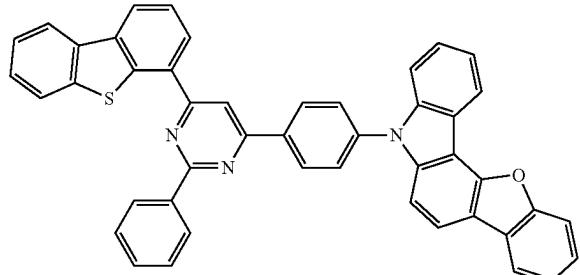
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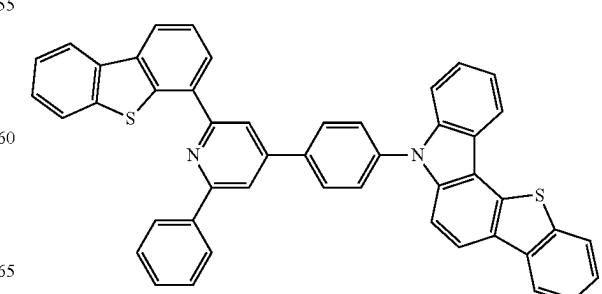
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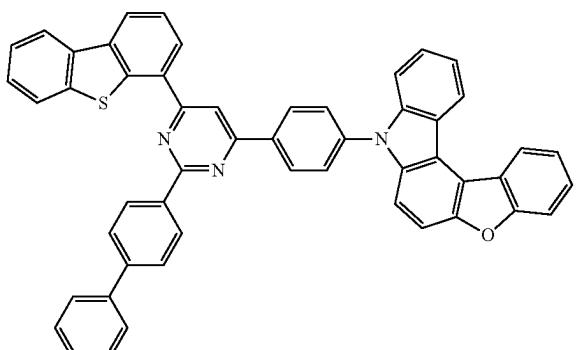


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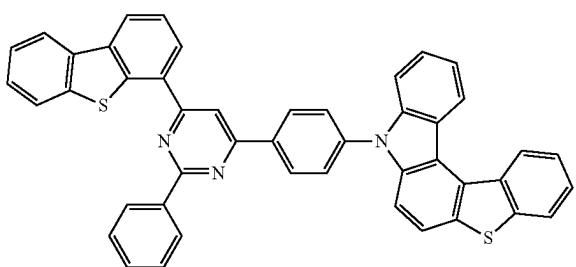
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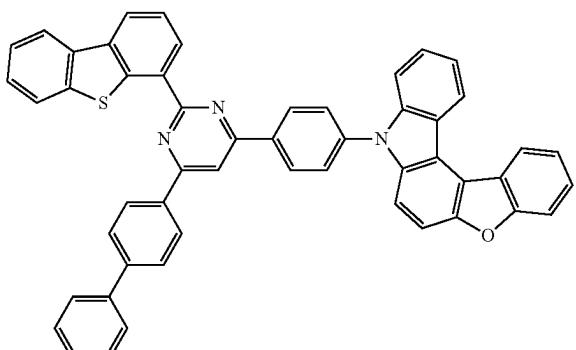


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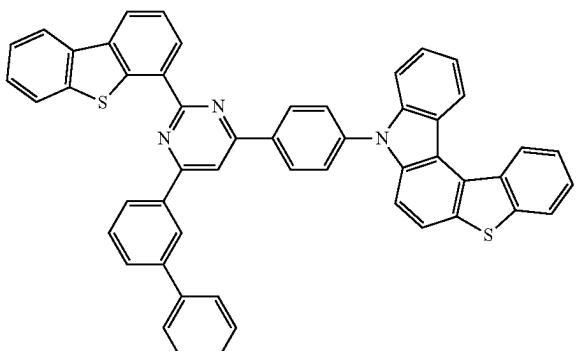
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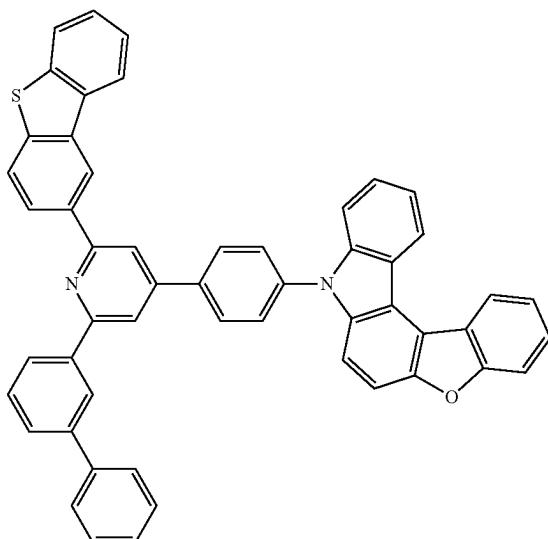
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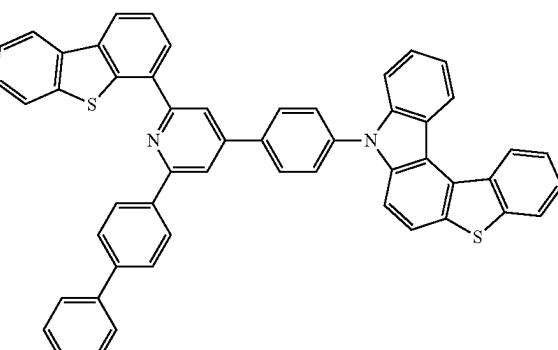
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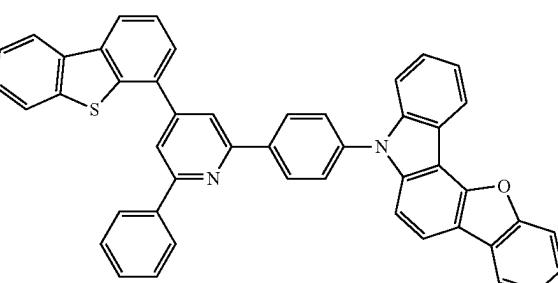


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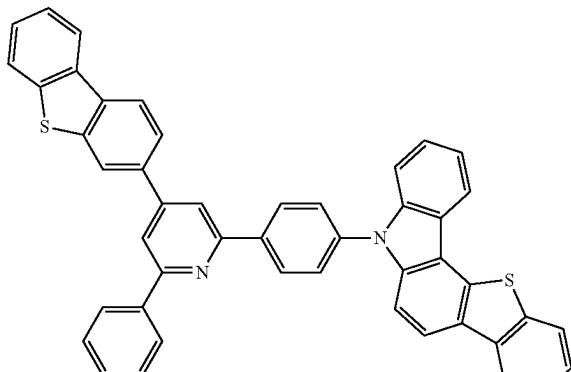
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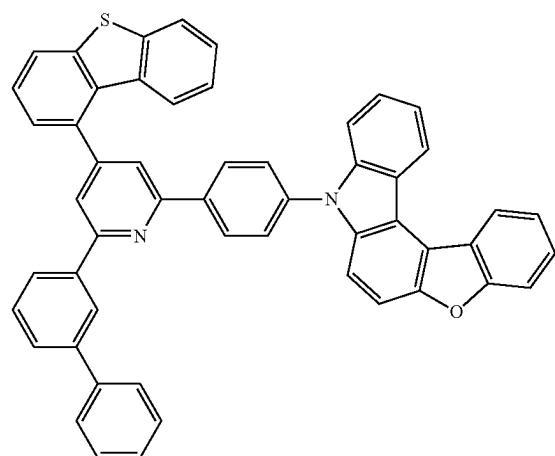
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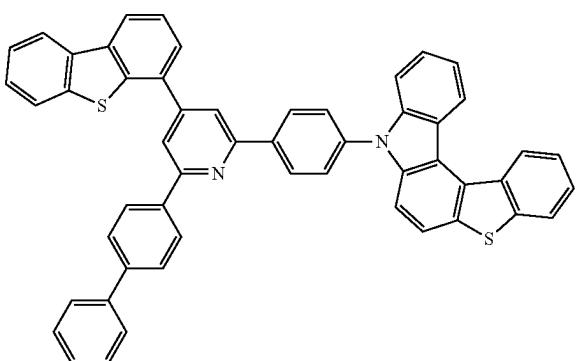
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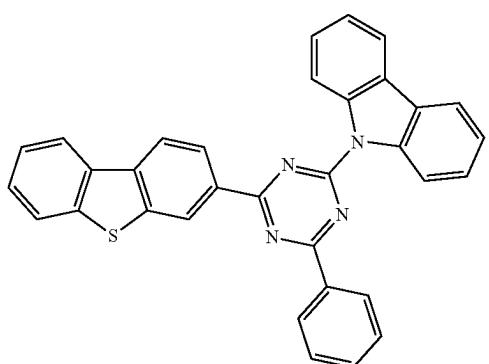
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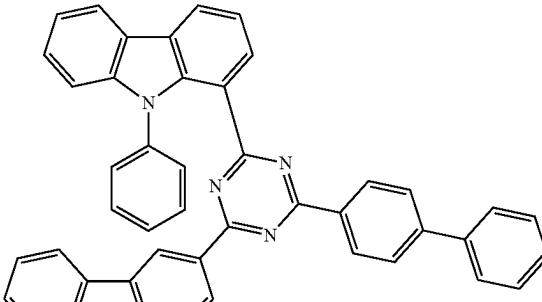
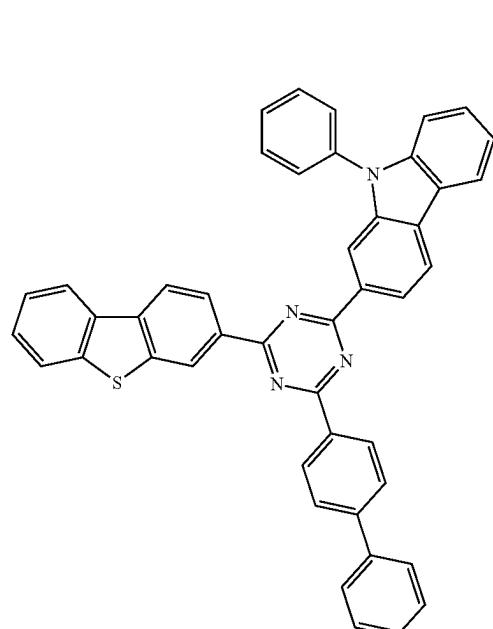
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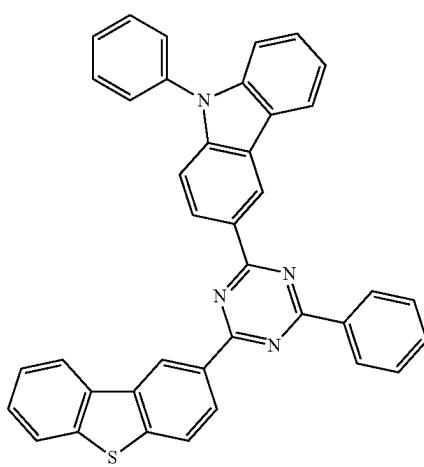
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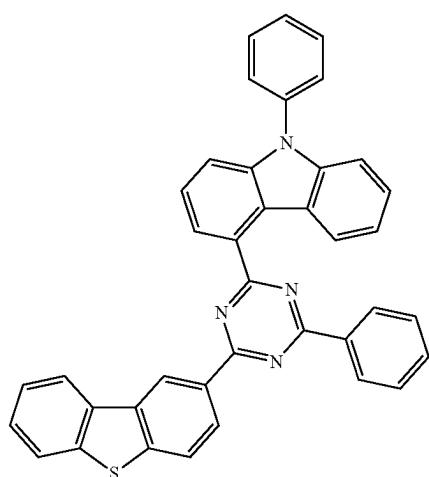
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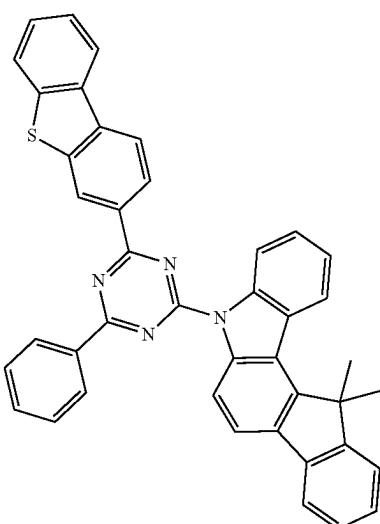
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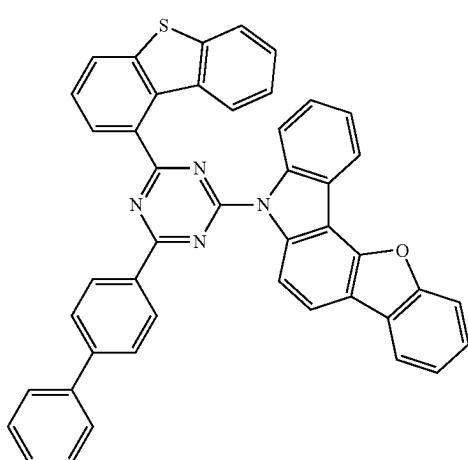
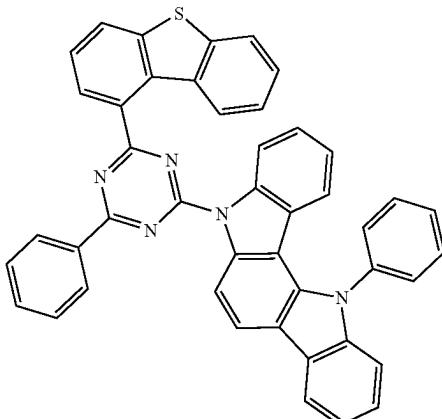
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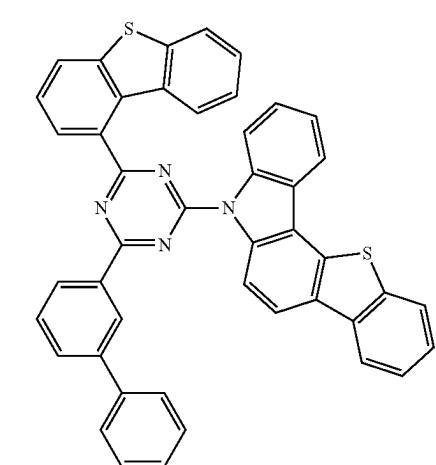
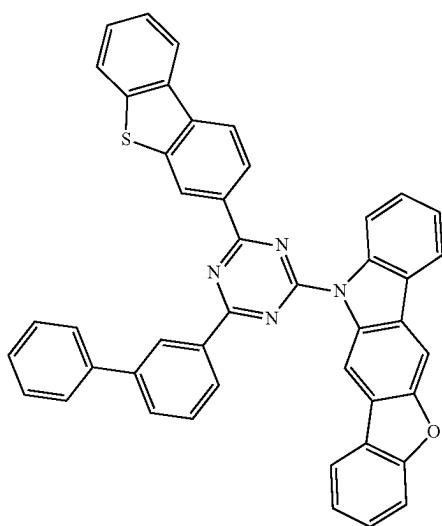
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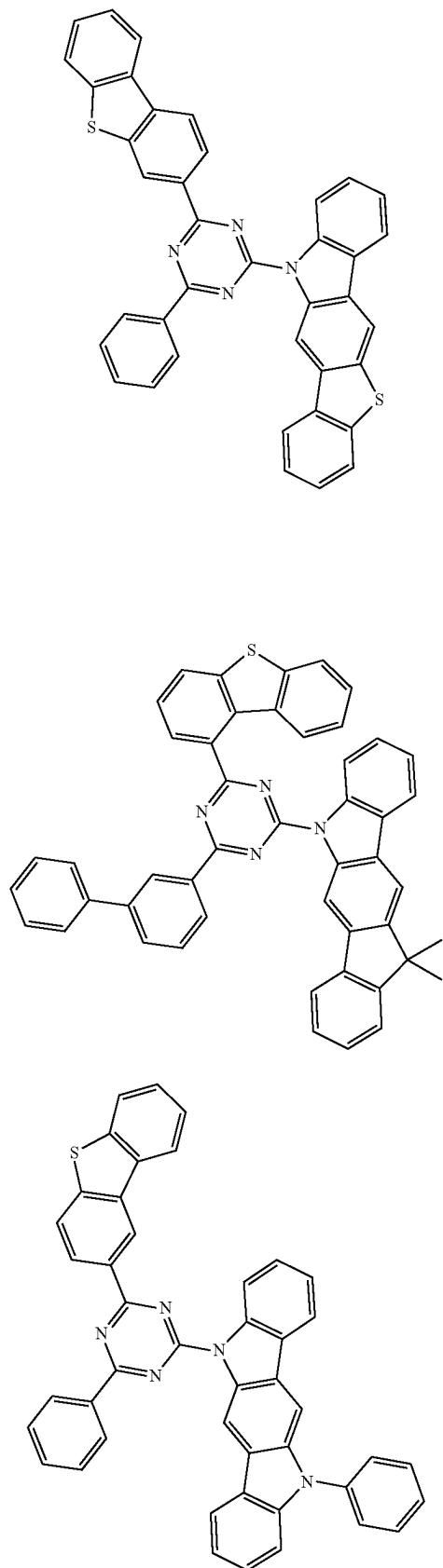
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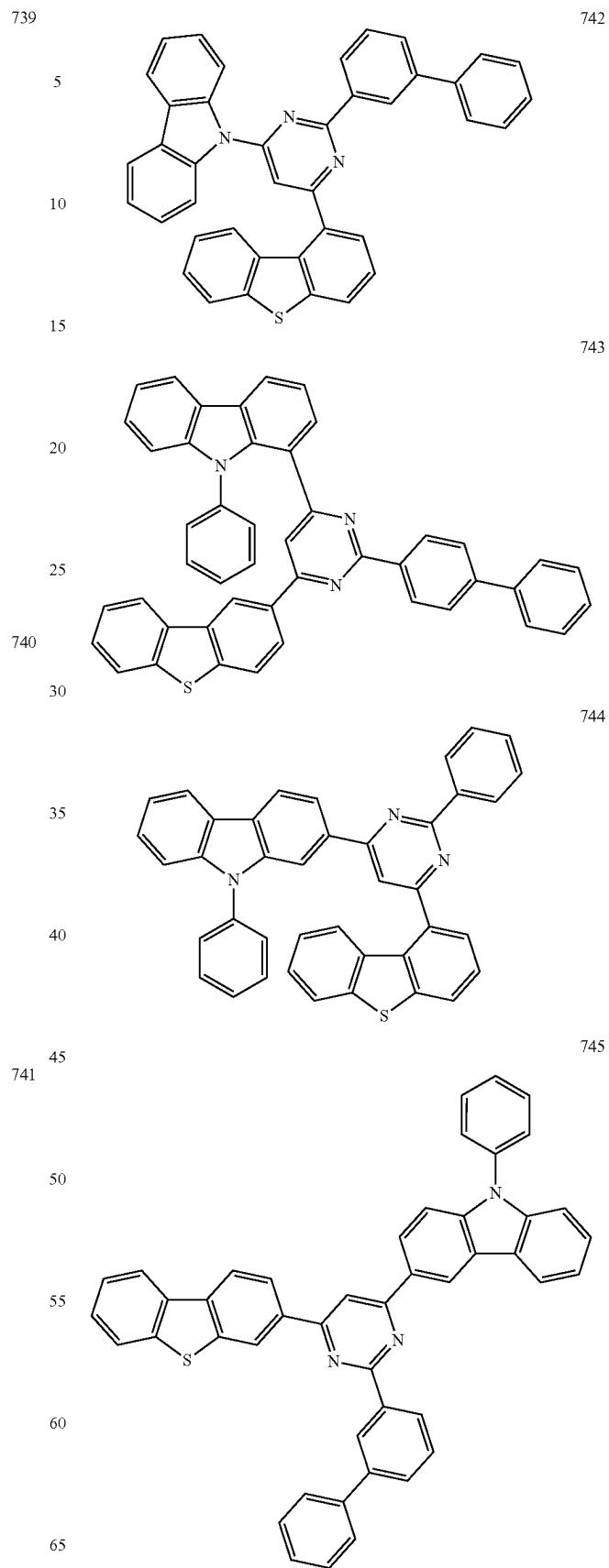
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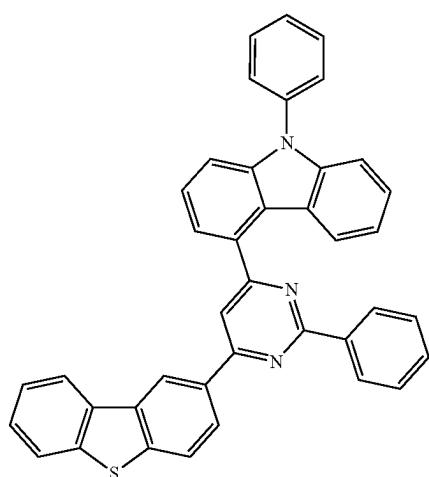
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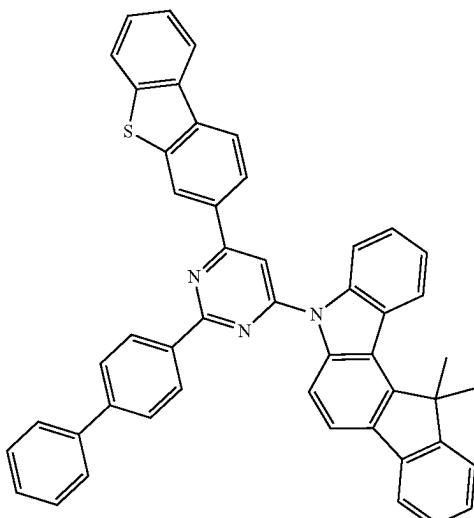
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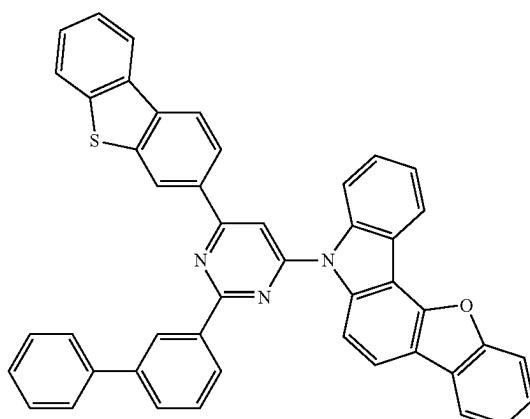
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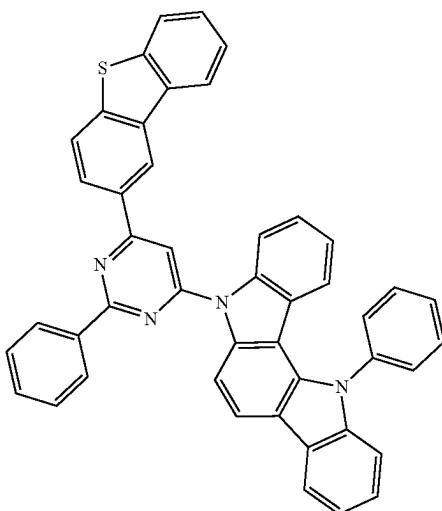
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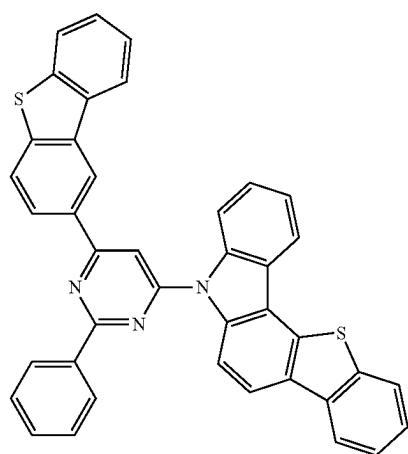
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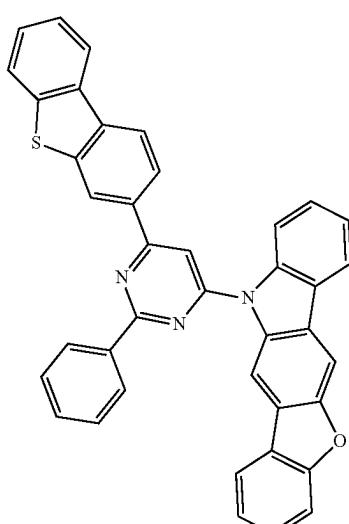
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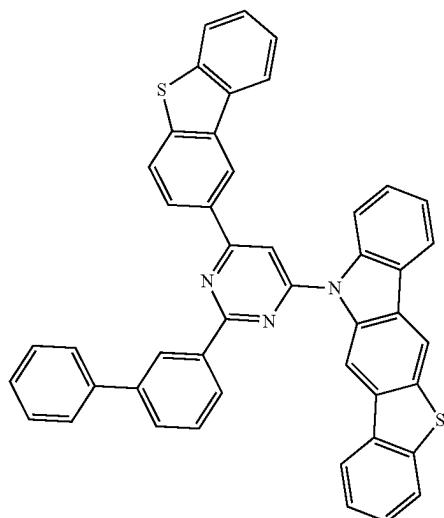
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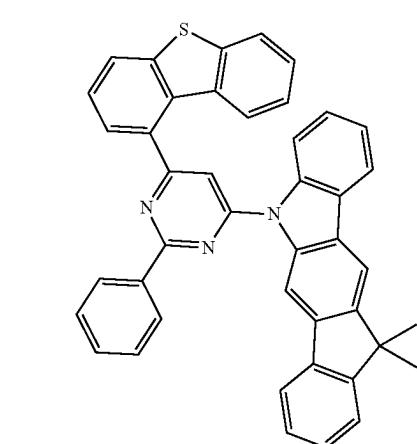
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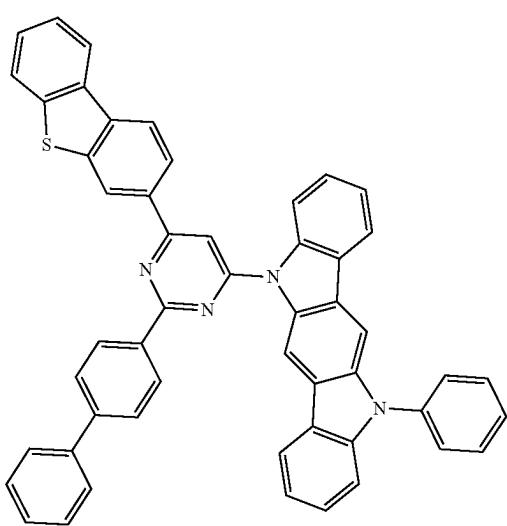
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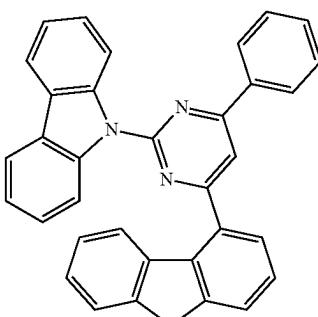
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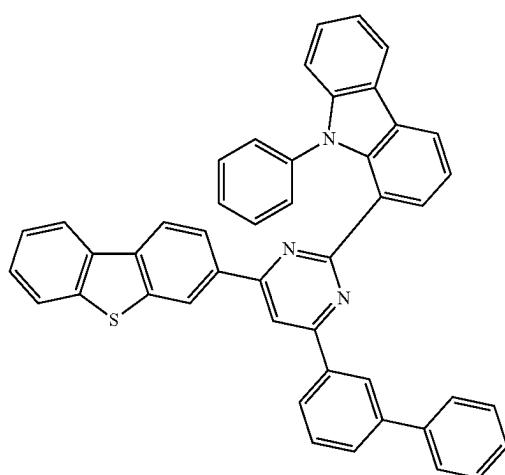
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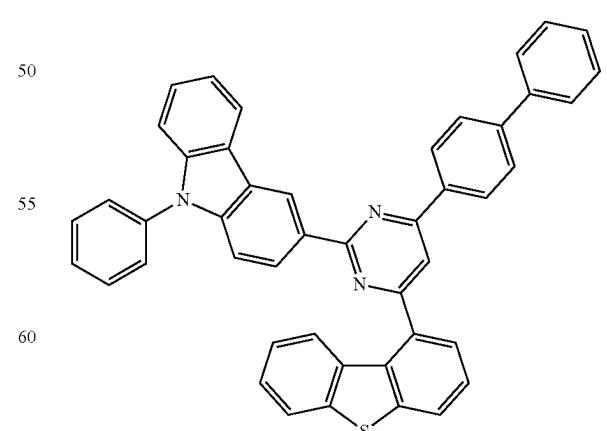
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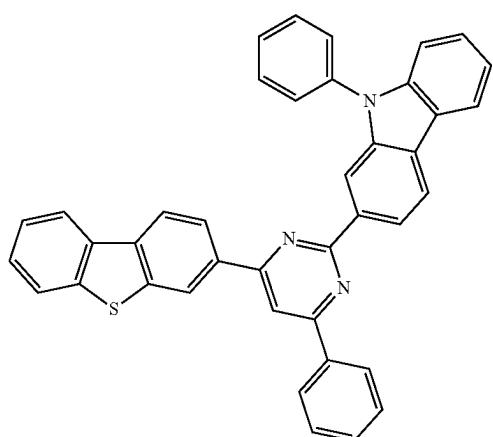
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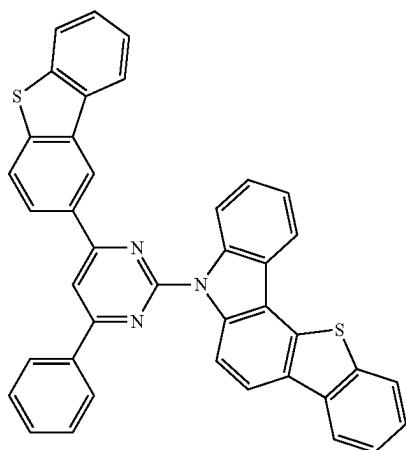
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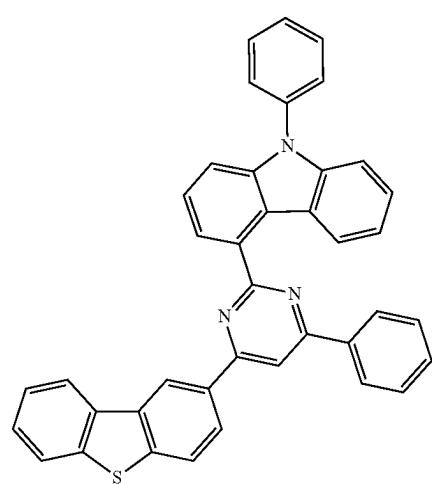


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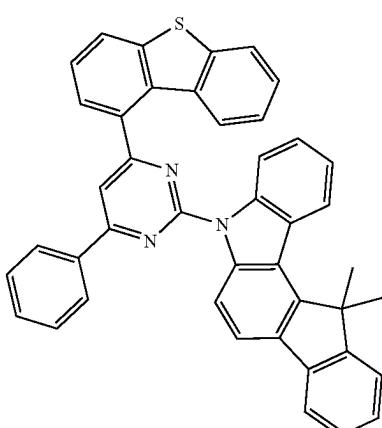
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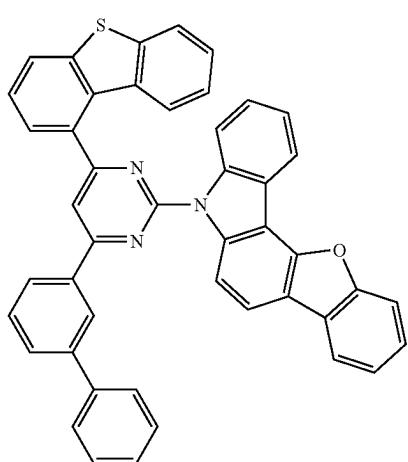
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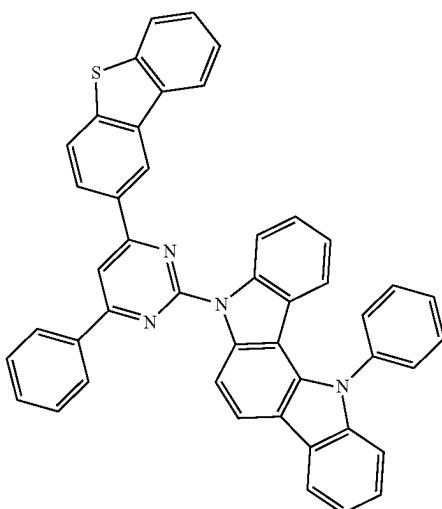
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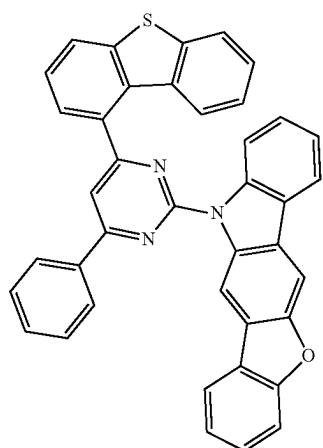


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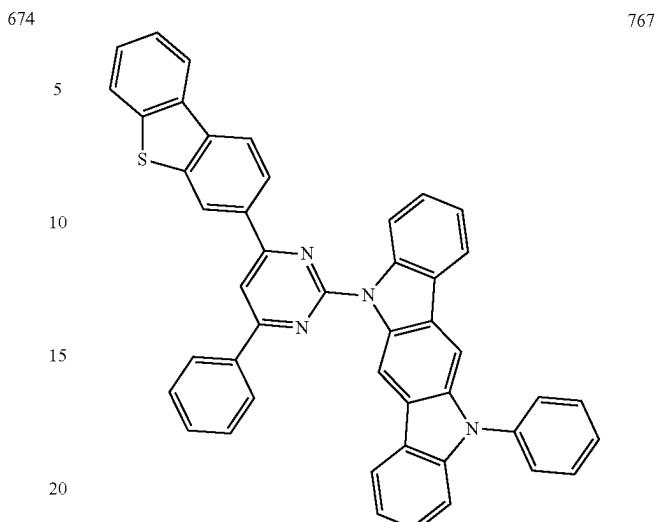
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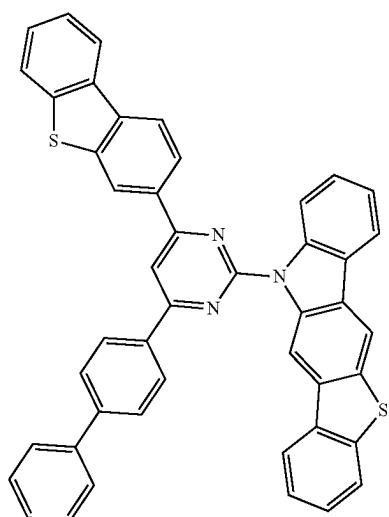
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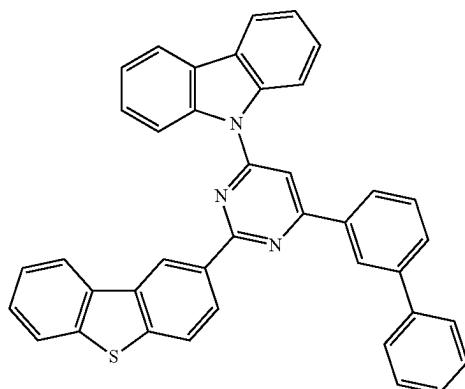


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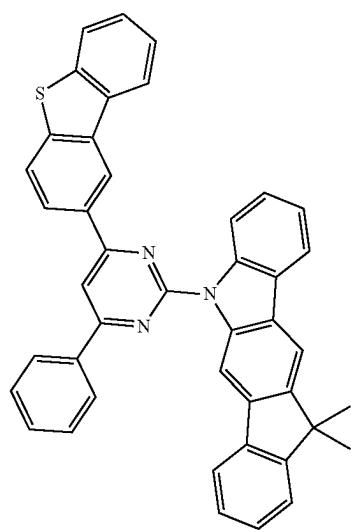
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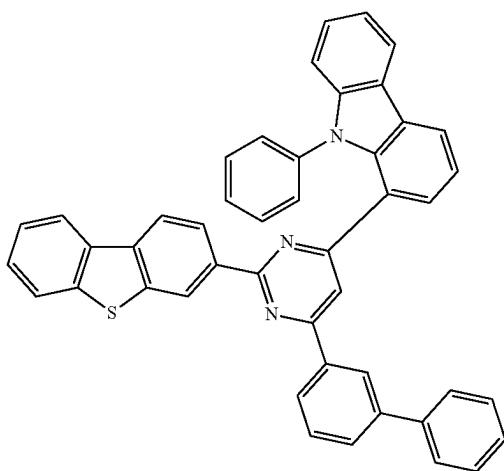


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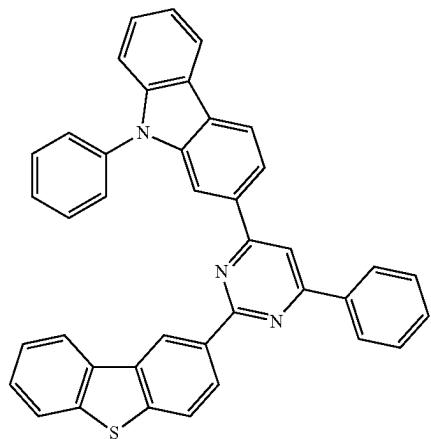
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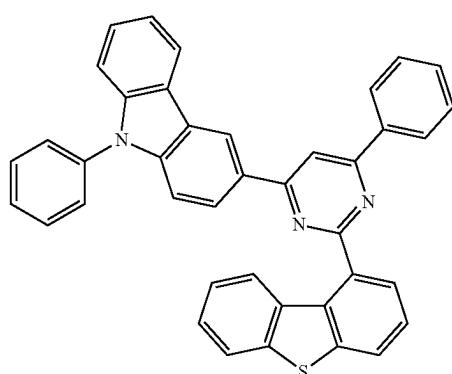


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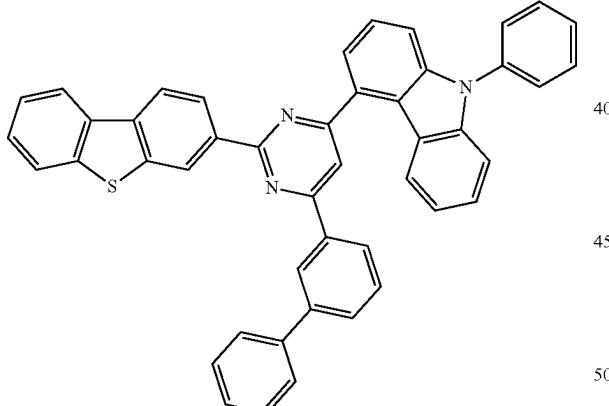
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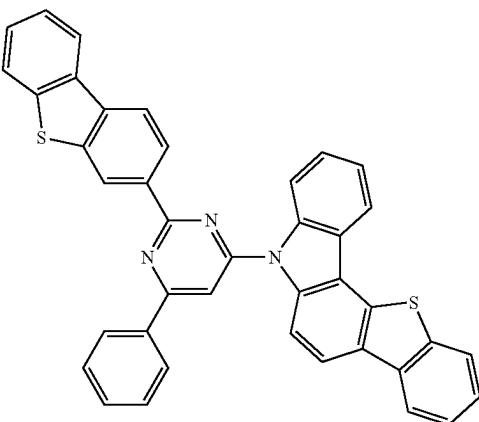
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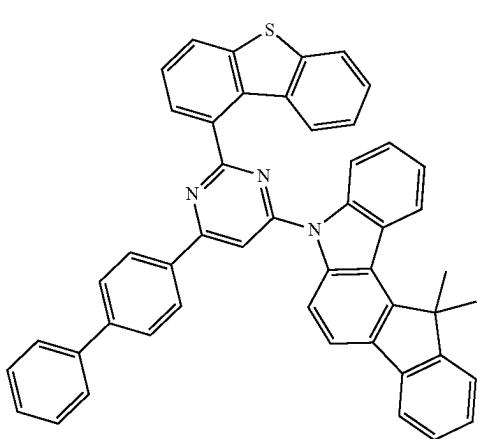
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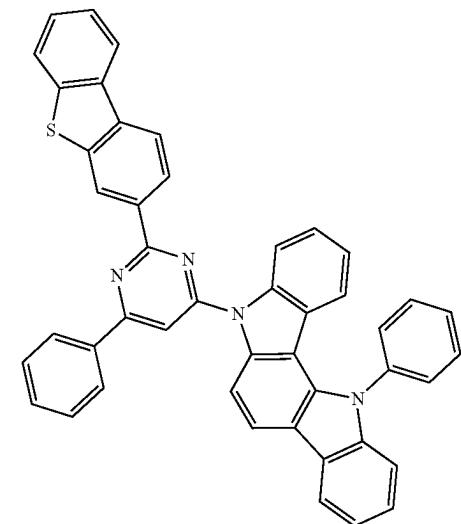
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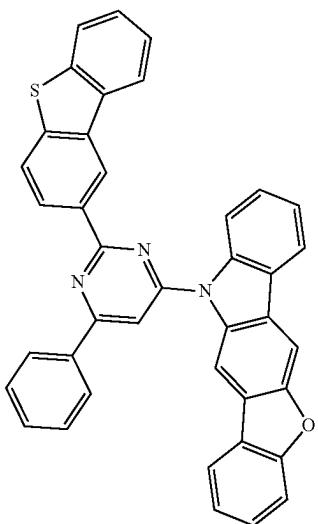
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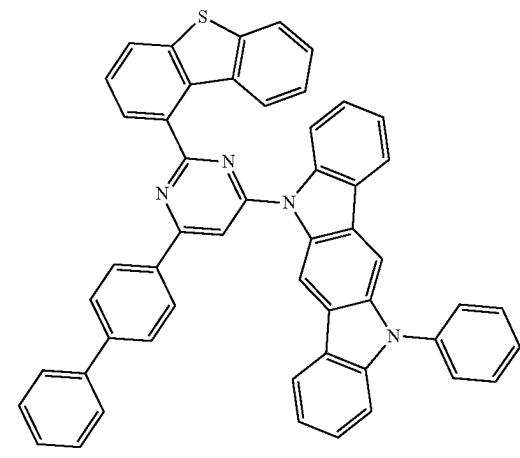
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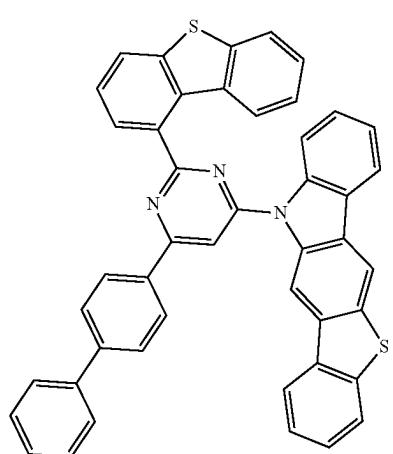
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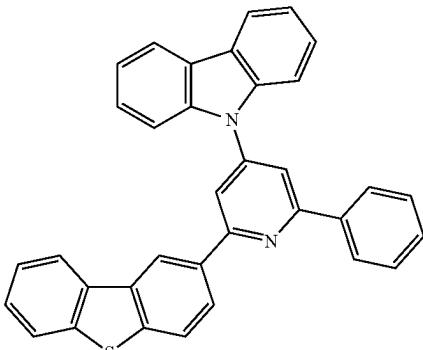


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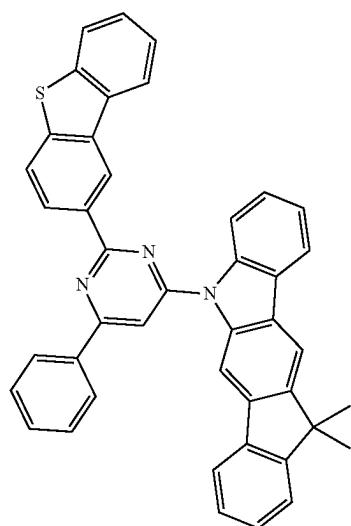


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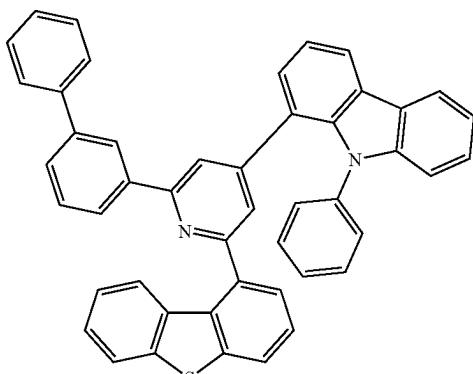
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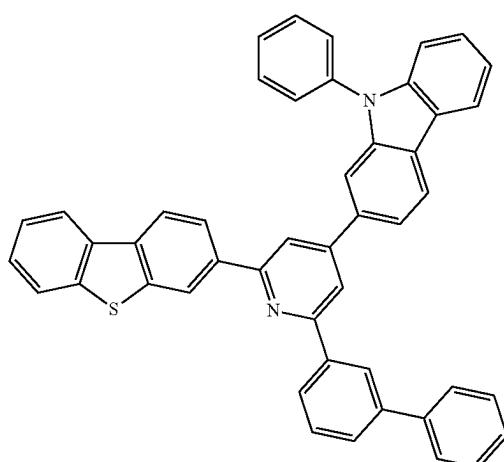
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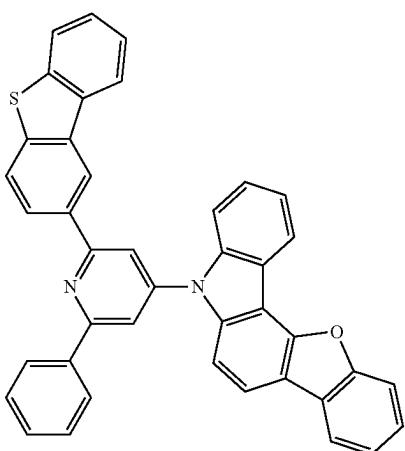
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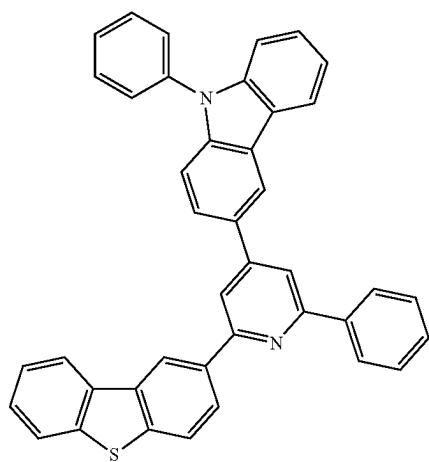
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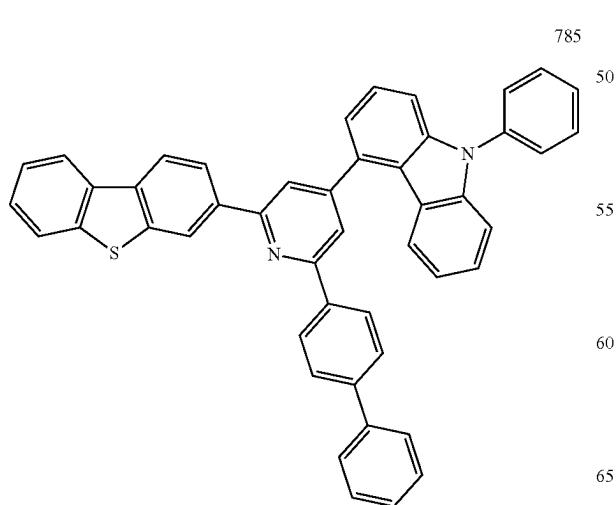
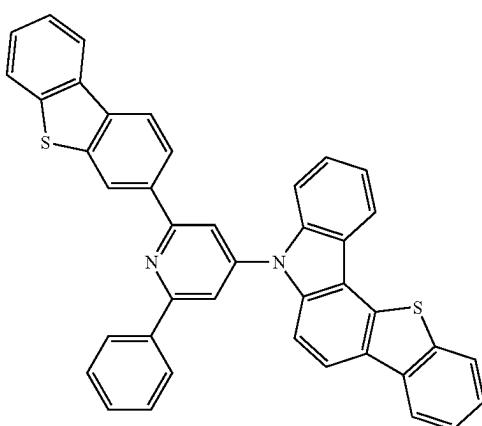
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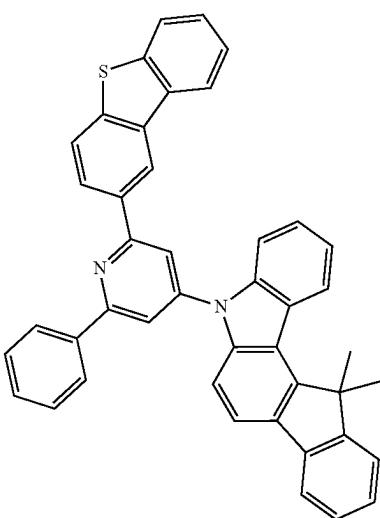
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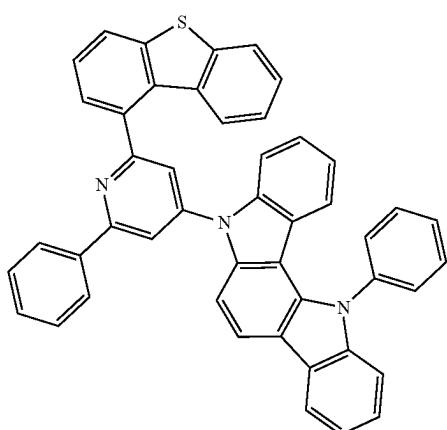
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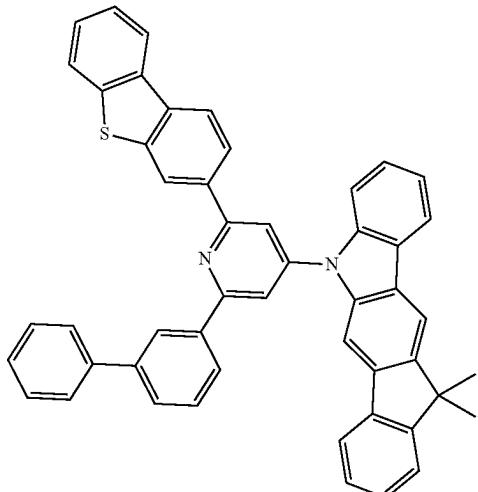
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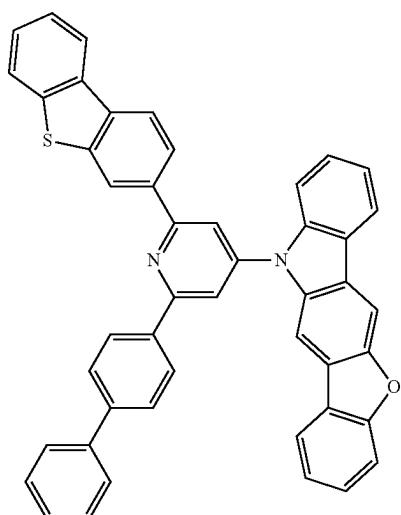
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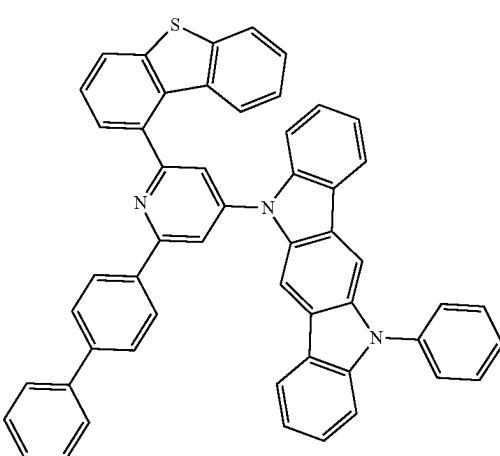
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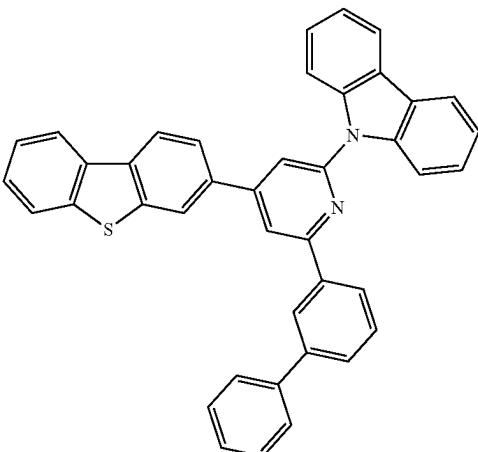
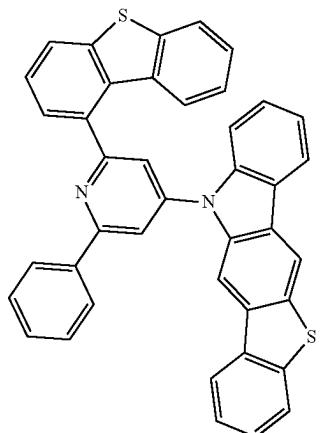
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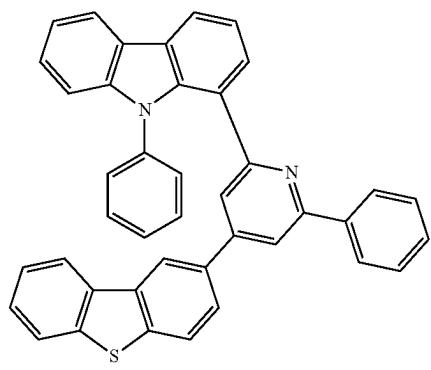
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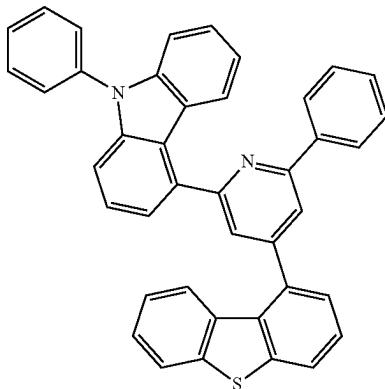
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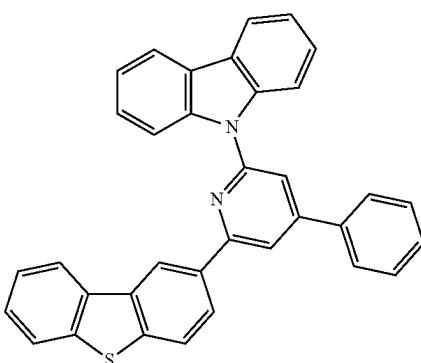
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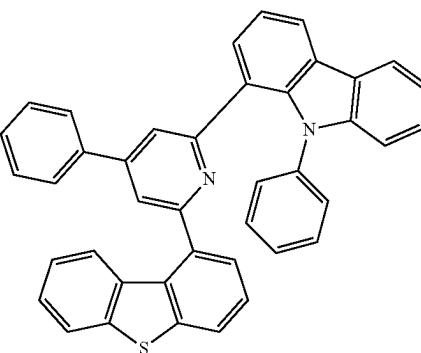
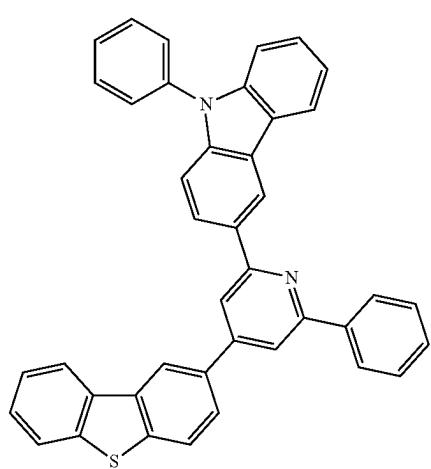
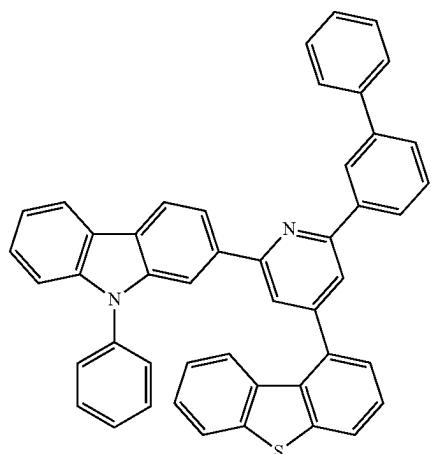
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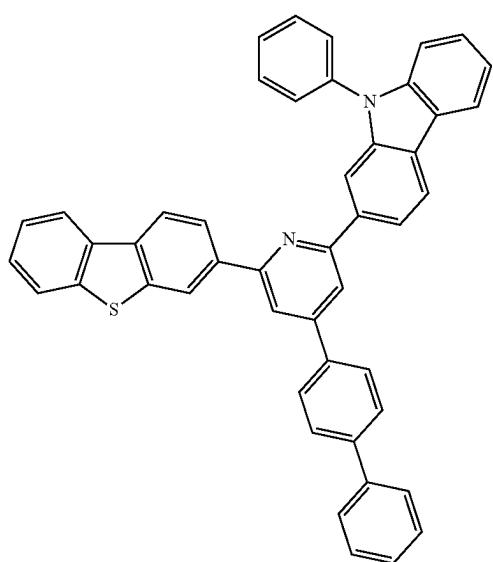
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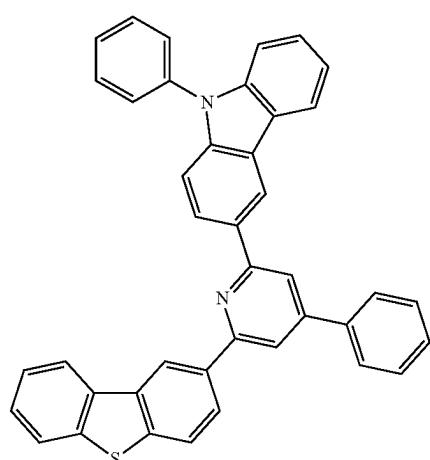
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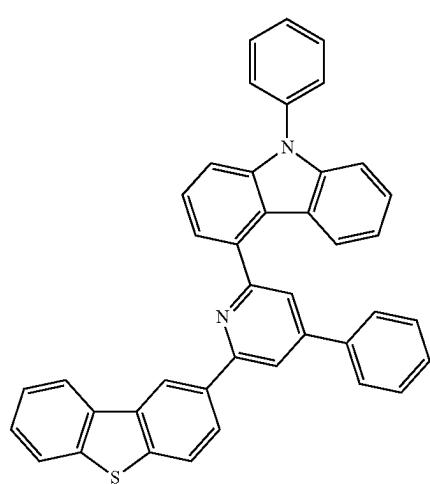
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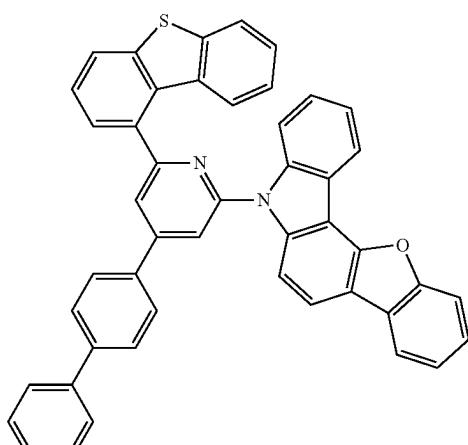
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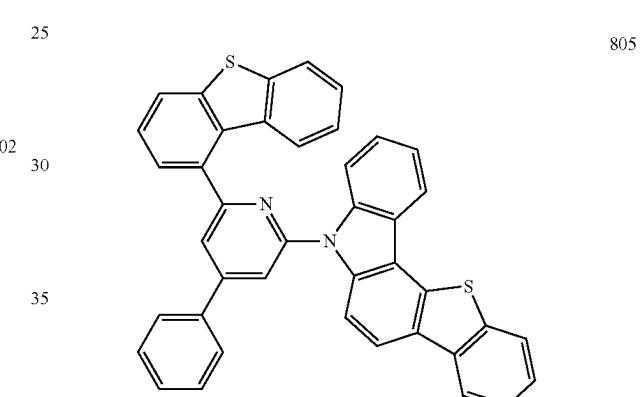
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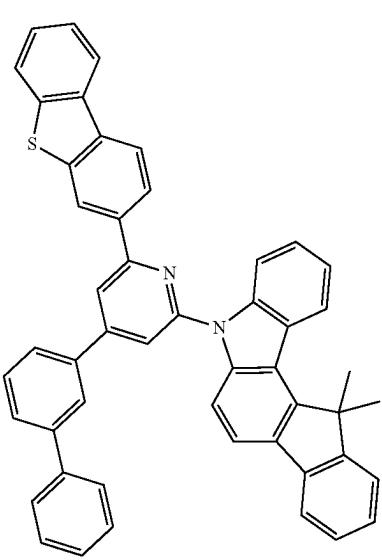
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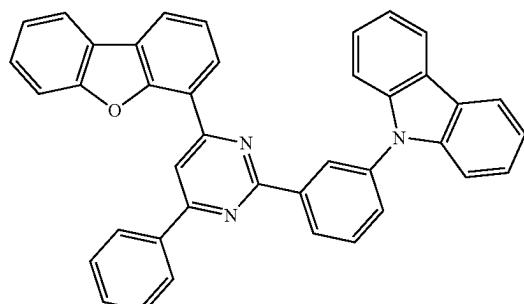


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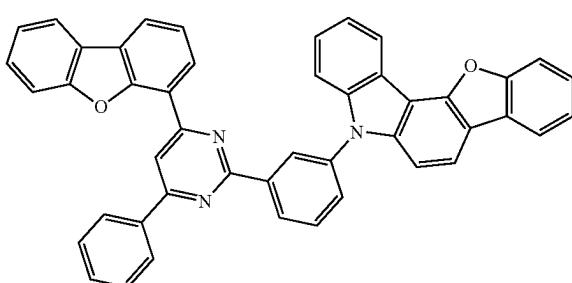
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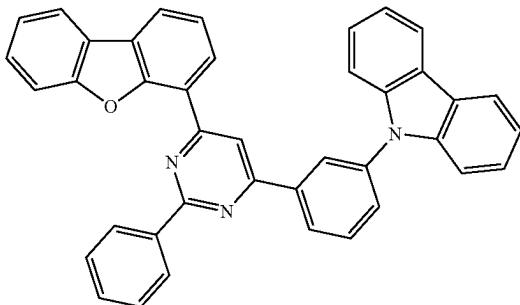
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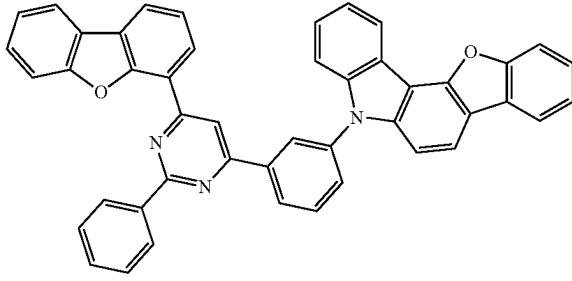
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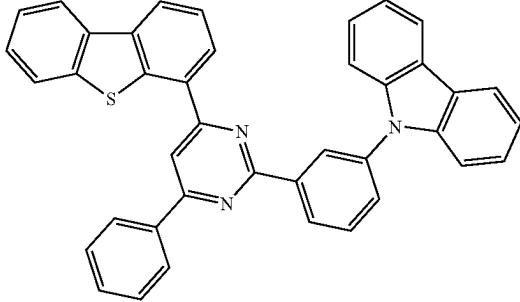
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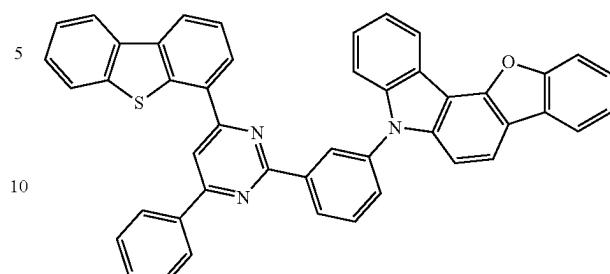
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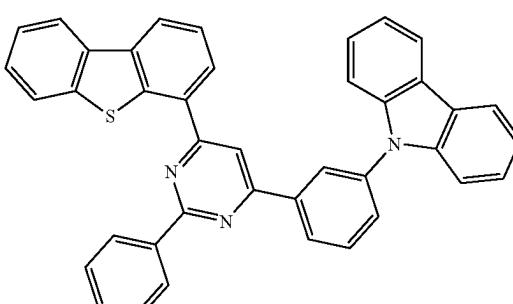
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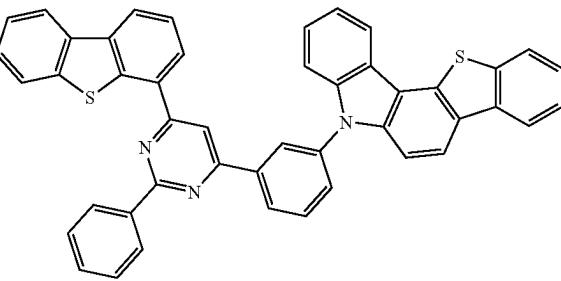
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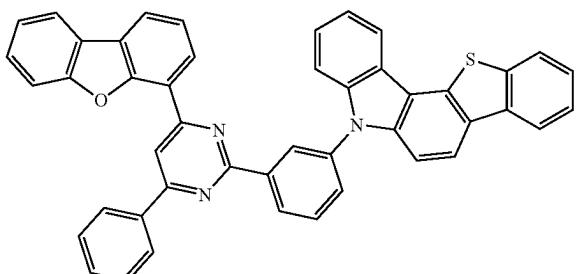
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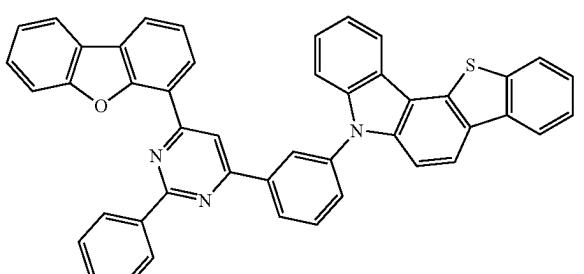
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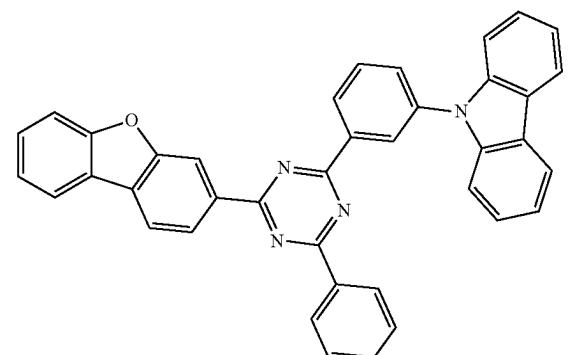
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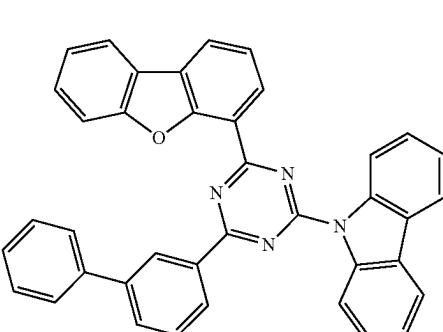
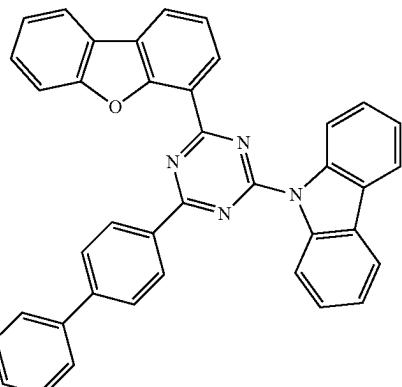
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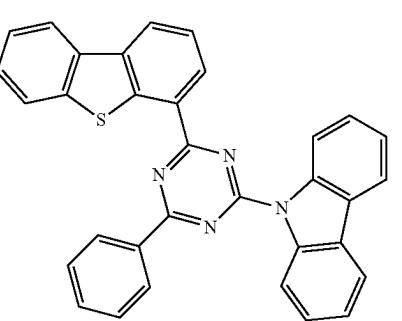
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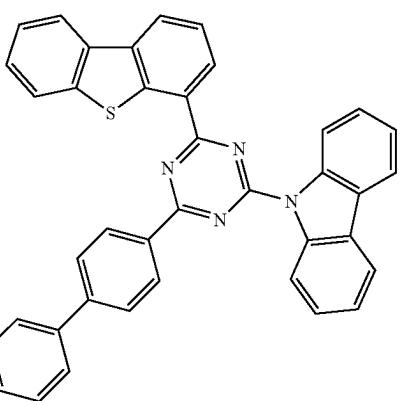
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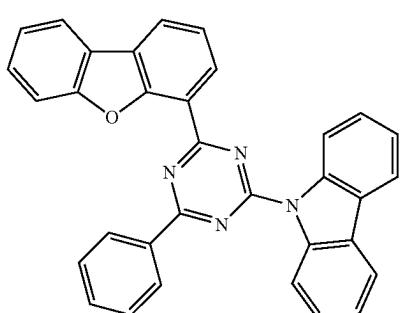
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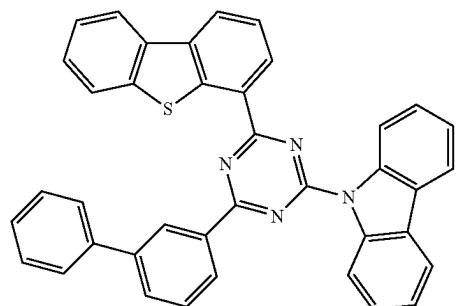
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Alternatively, the condensed-cyclic compound may be 50
any one of Compounds 1, 85, 169, 253, 337, 421, 505, 506,
575, 659, 660, 729 and 825, but it is not limited thereto:

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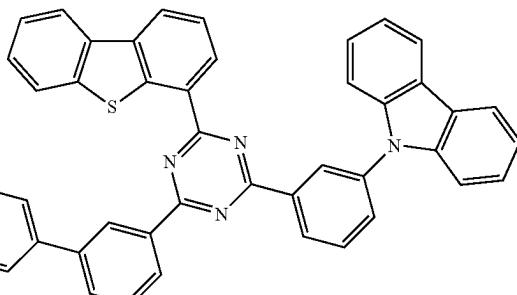
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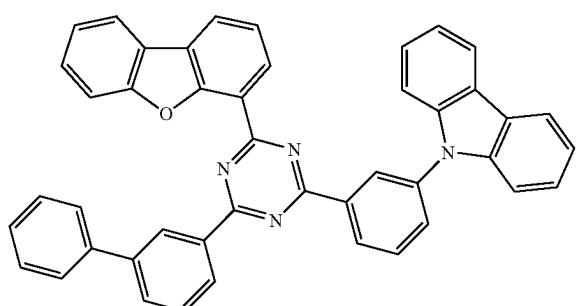
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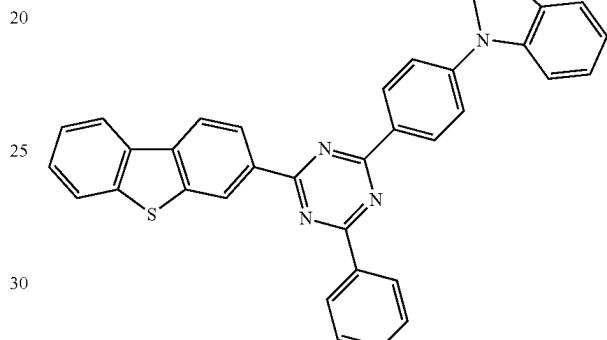
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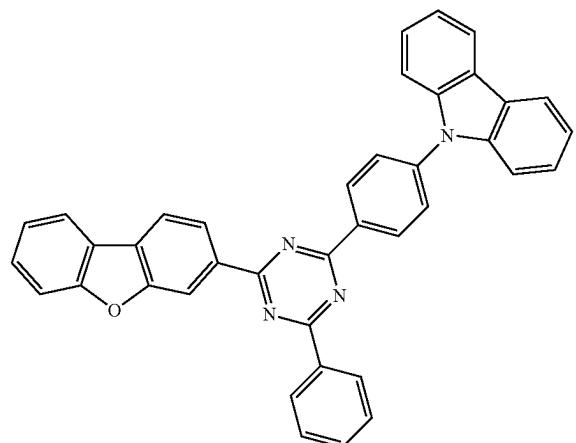


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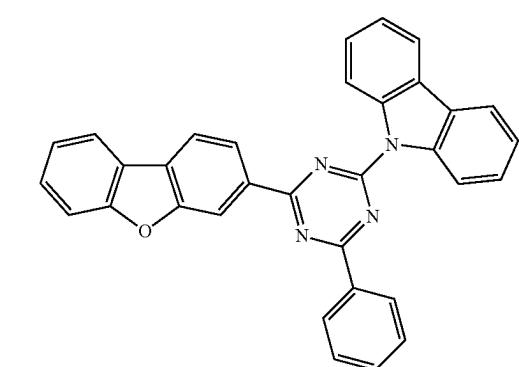
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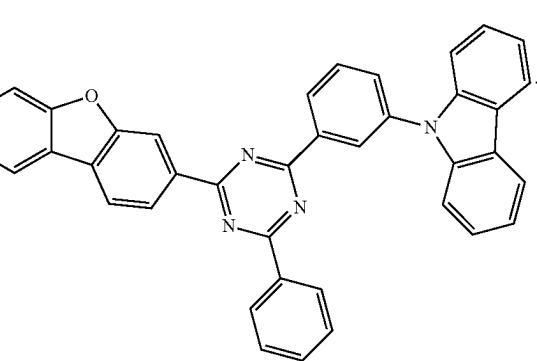
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In the condensed-cyclic compound represented by Formula 1A or 1B, R₄ is selected from a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₂-C₁₀ heterocycloalkyl group, a substituted or

unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₂-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₂-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic hetero-condensed polycyclic group.

In other words, in Formula 1A and 1B, R₄ necessarily includes a ring structure. As a result, the condensed-cyclic compound represented by Formula 1A or 1B is chemically and structurally stable and may actually have a spherical molecular structure. Accordingly, the condensed-cyclic compound represented by Formula 1A or 1B may have excellent thermal stability, which may increase deposition temperature. As a result, efficiency and lifespan of an organic light-emitting device including the condensed-cyclic compound may be improved to improve formability of the organic light-emitting device during the manufacturing process thereof.

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

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

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

10 electrode;

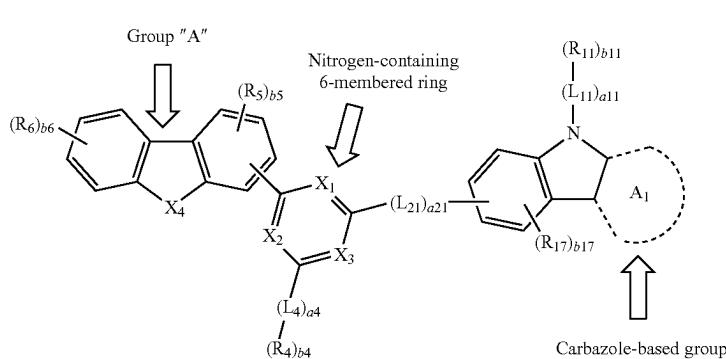
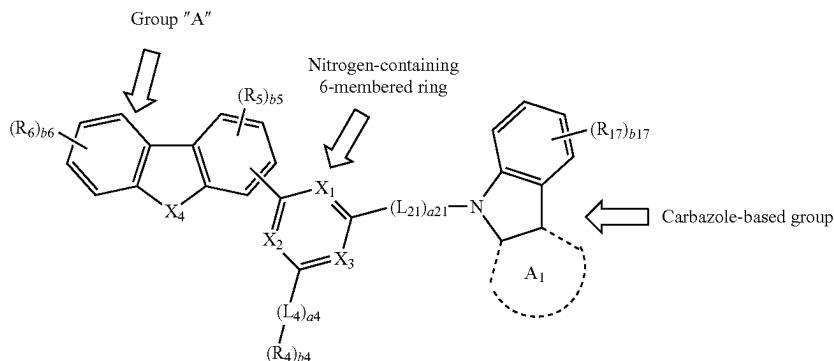
a second electrode; and
an organic layer disposed between the first electrode and
the second electrode,

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

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

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

Formula 1A'



the condensed-cyclic compound represented by Formula 1A or 1B may be included in the EML. In this regard, the EML further includes a dopant and the condensed-cyclic compound included in the EML may act as a host. The EML may be a green EML emitting green light and the dopant may be a phosphorescent dopant.

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

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

The organic layer includes

- i) a hole transport region that is disposed between the first electrode and the EML and includes at least one of an HIL, an HTL, a buffer layer, and an EBL, and
- ii) an electron transport region that is disposed between the EML and the second electrode and includes at least one layer selected from a HBL, an ETL, and an EIL.

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

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

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

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

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

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

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

The hole transport region may be disposed between the first electrode **11** and the EML.

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

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

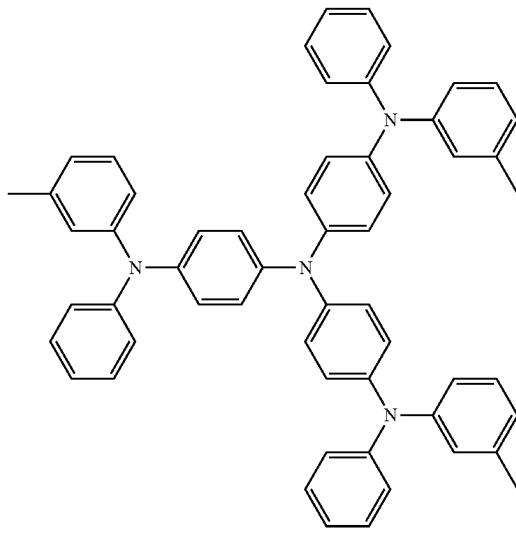
When the hole transport region includes an HIL, the HIL may be formed on the first electrode **11** by using various methods, such as vacuum deposition, spin coating, casting, a Langmuir-Blodgett (LB) method, or the like.

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

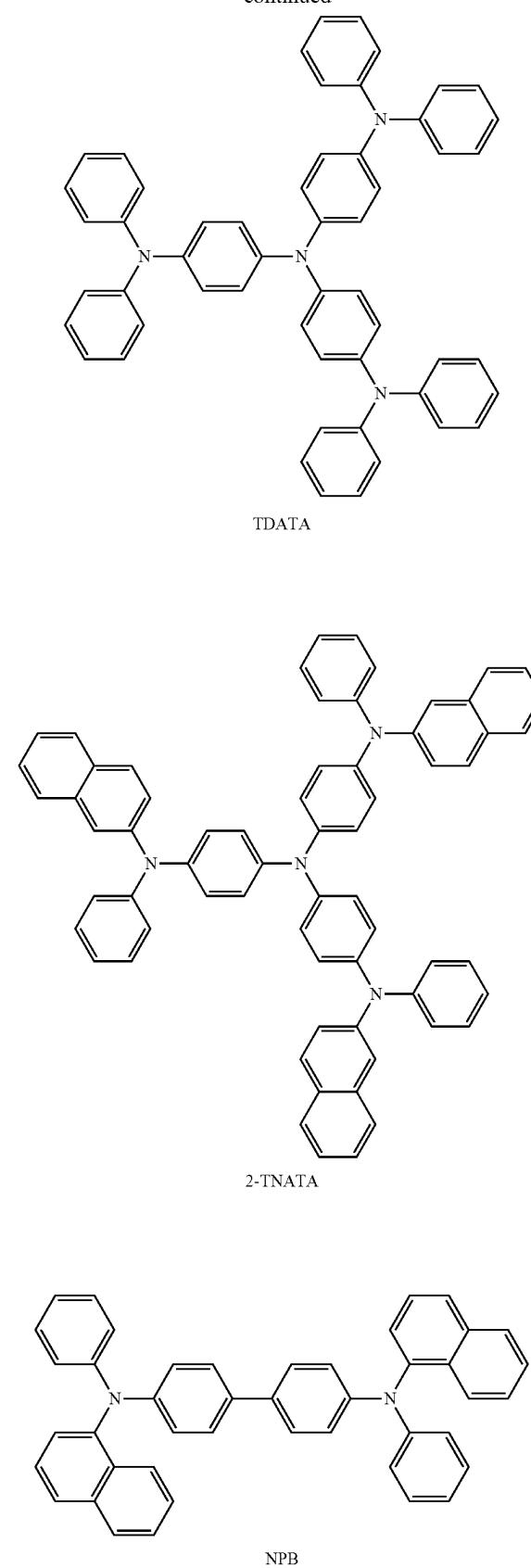
When an HIL is formed by spin coating, the spin coating may be performed at a coating rate of about 2,000 revolutions per minute (rpm) to about 5,000 rpm, and at a temperature of about 80° C. to 200° C. for removing a solvent after the spin coating, in consideration of a compound for an HIL to be deposited,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

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

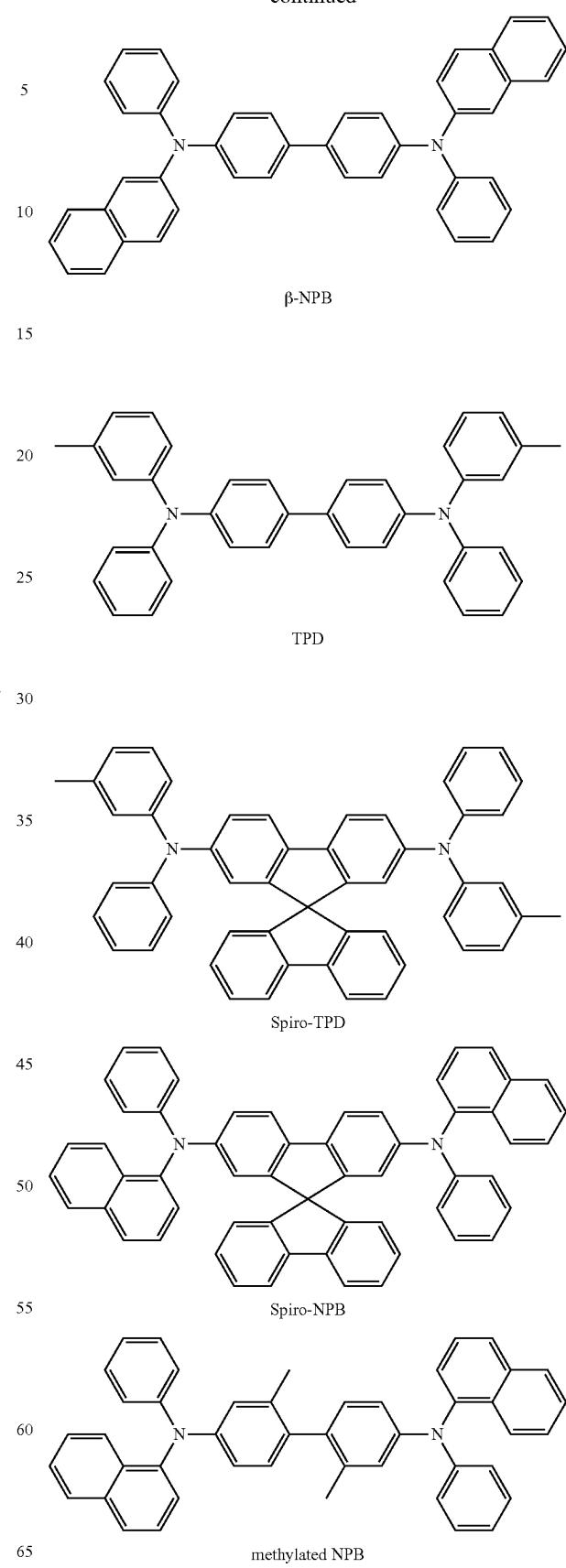
The hole transport region may include at least one compound selected from m-MTDATA, TDATA, 2-TNATA, NPB, β -NPB, TPD, Spiro-NPB, methylated NPB, TAPC, HMTPD, 4,4',4''-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (Pani/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonic acid (Pani/CSA), (polyaniline)/poly(4-styrene sulfonate) (PANI/PSS), a compound represented by Formula 201 below, and a compound represented by Formula 202 below:



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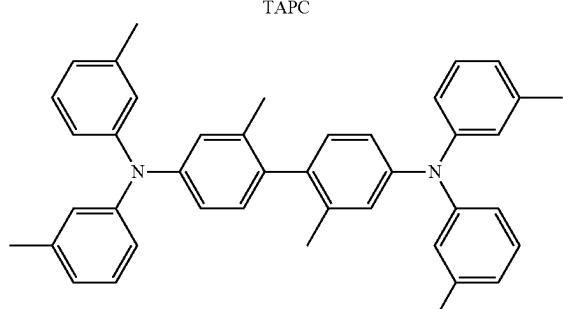
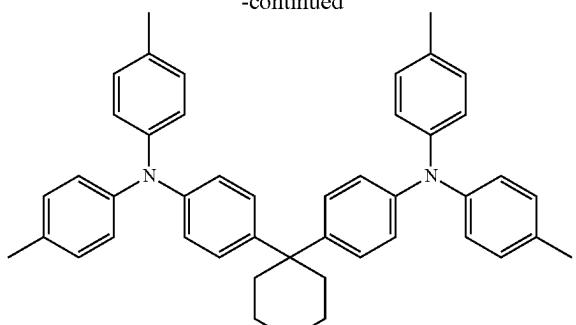


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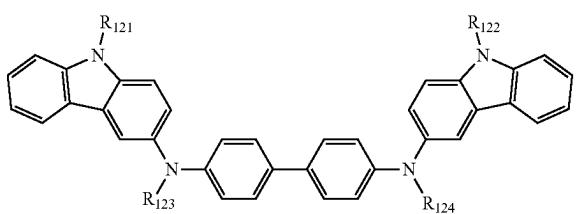
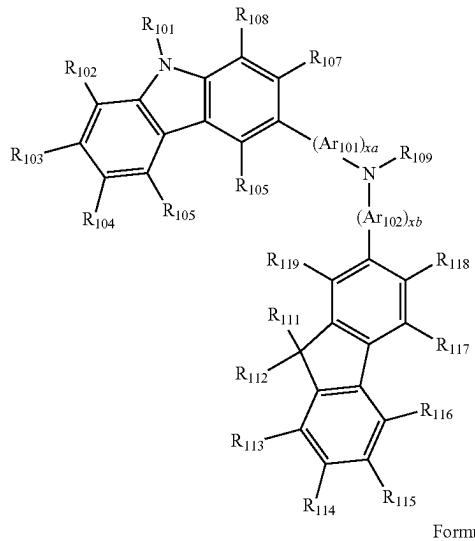


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Formula 201



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

a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an acenaphthylene group, a fluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthrenylene group, a triphenylenylene group, a pyrenylene

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group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, and a pentacenylene group; and

a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an acenaphthylene group, a fluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthrenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, and a pentacenylene group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, a $\text{C}_1\text{-C}_{60}$ alkoxy group, a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_2\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_2\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_2\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic hetero-condensed polycyclic group.

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

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

a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a $\text{C}_1\text{-C}_{10}$ alkyl group (for example, a methyl group, an ethyl group, a propyl group, a butyl group, a pentyl group, and a hexyl group) and a $\text{C}_1\text{-C}_{10}$ alkoxy group (for example, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, and a pentoxy group);

a $\text{C}_1\text{-C}_{10}$ alkyl group and a $\text{C}_1\text{-C}_{10}$ alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, and a phosphoric acid group or a salt thereof;

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

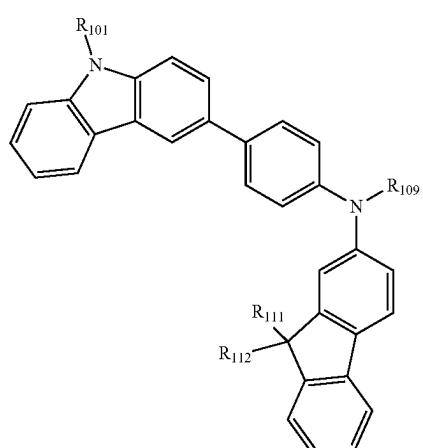
a phenyl group, a naphthyl group, an anthracenyl group, a fluorenyl group, and a pyrenyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a $\text{C}_1\text{-C}_{10}$ alkyl group, and a $\text{C}_1\text{-C}_{10}$ alkoxy group, but they are not limited thereto.

In Formula 201, R_{109} may be any one of a phenyl group, a naphthyl group, an anthracenyl group and a pyridinyl group; a phenyl group, a naphthyl group, an anthracenyl group, and a pyridinyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino

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group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group.

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



Formula 201A

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HT1

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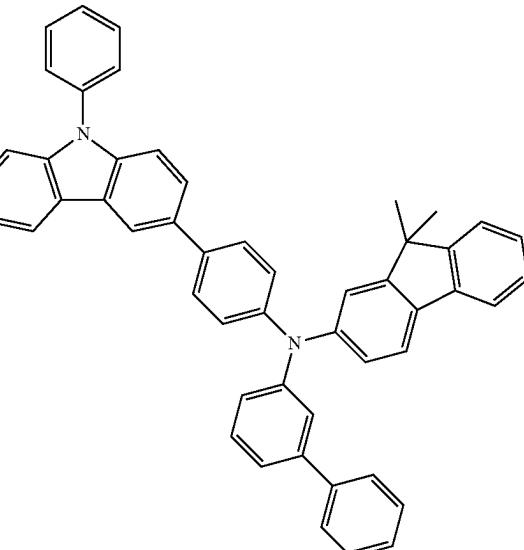
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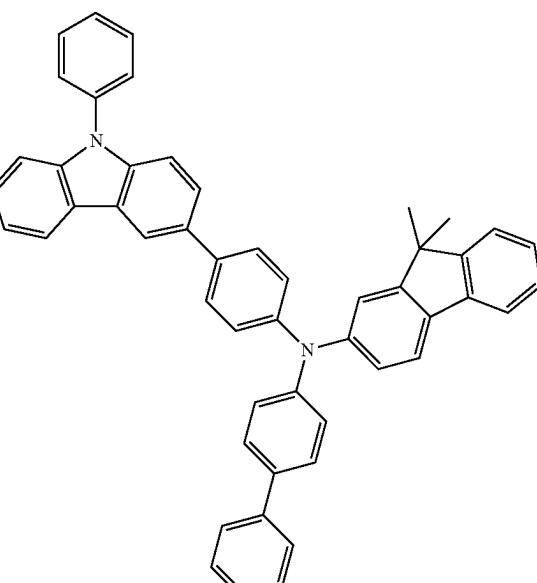
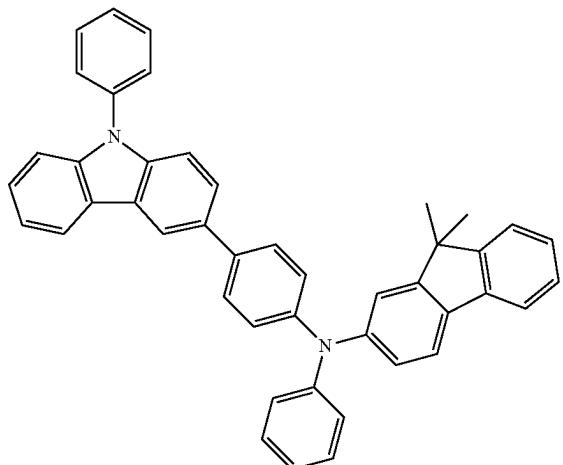
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HT2



In Formula 201A, detailed descriptions of R₁₀₁, R₁₁₁, R₁₁₂, and R₁₀₉ may be the same as described herein.

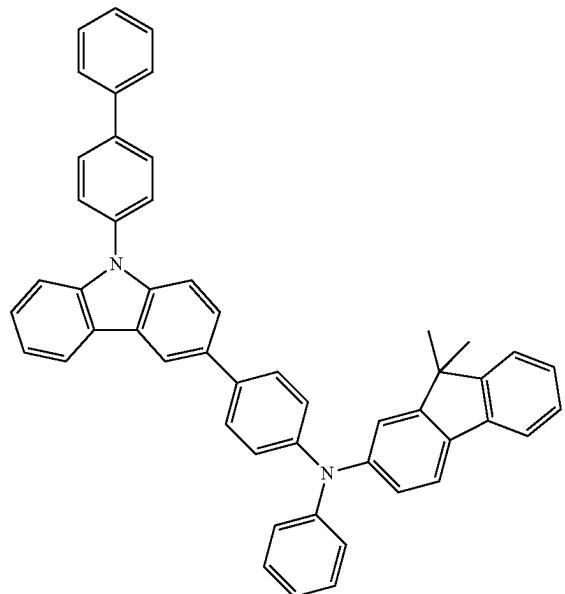
For example, the compound represented by Formula 201 and the compound represented by Formula 202 may include Compounds HT1 to HT20, but the compound is not limited thereto:



HT3

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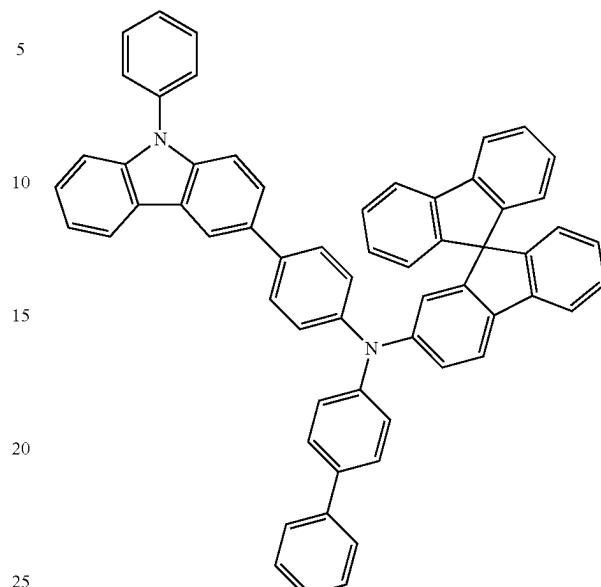
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HT4

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HT6

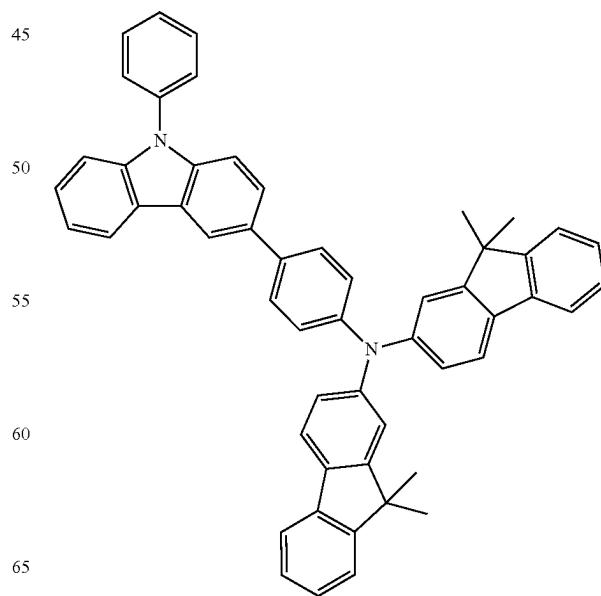
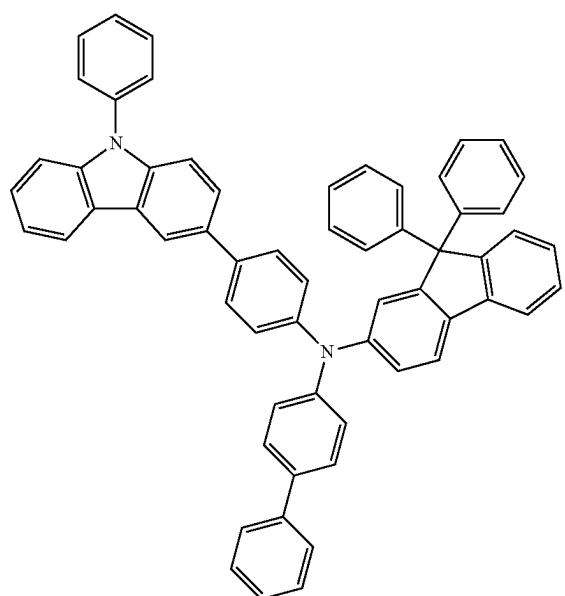
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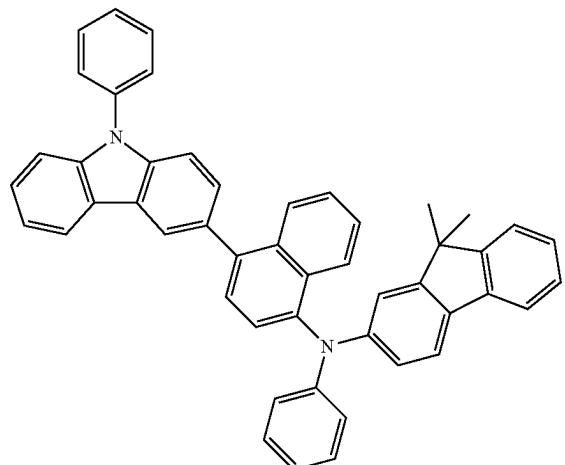
HT5

HT7

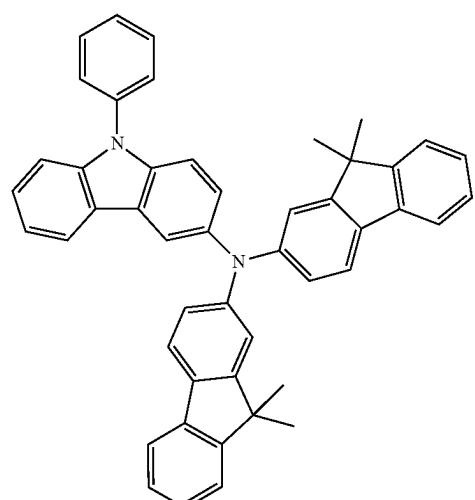


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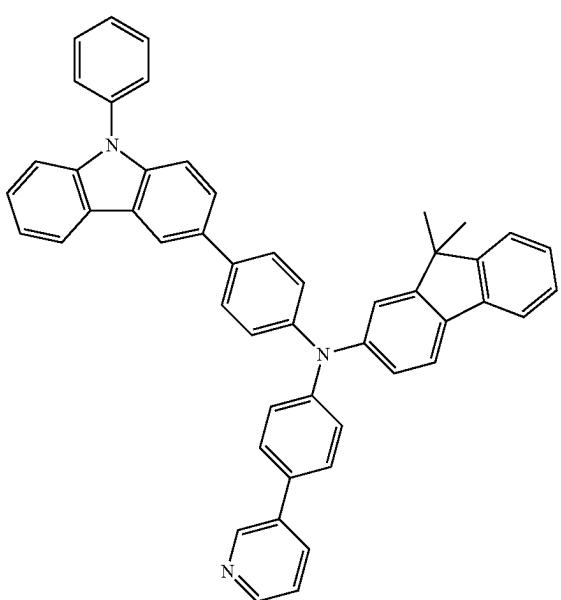
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HT8



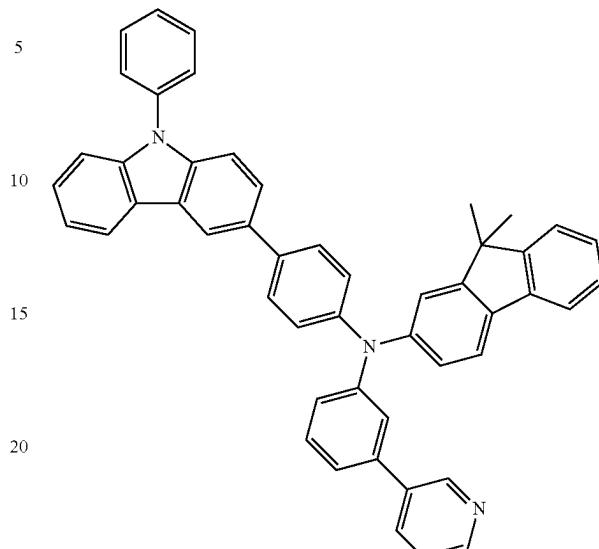
HT9



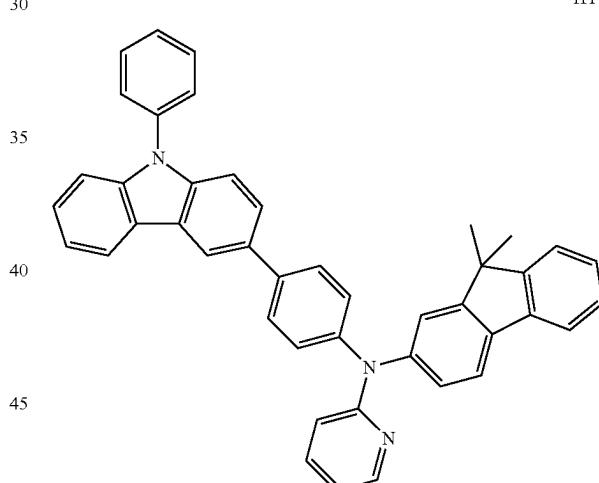
HT10

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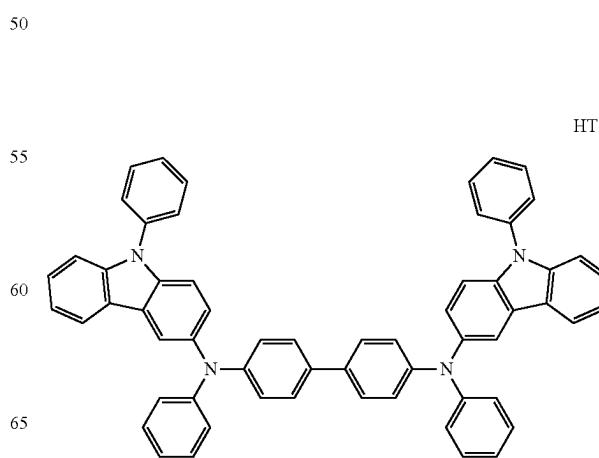
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HT11



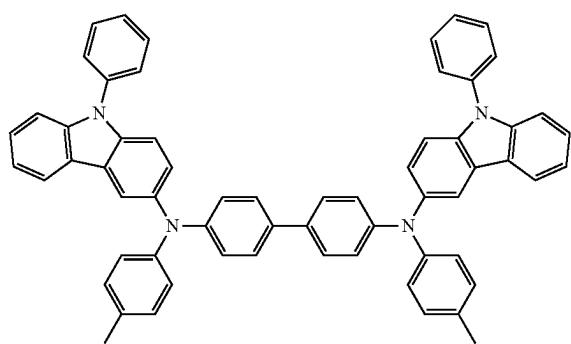
HT12



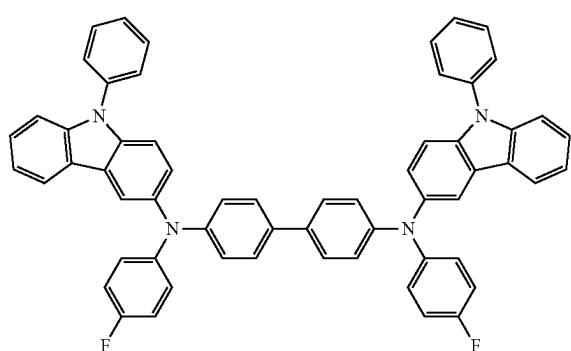
HT13

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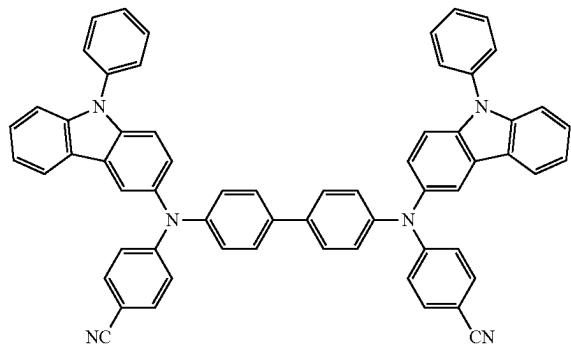
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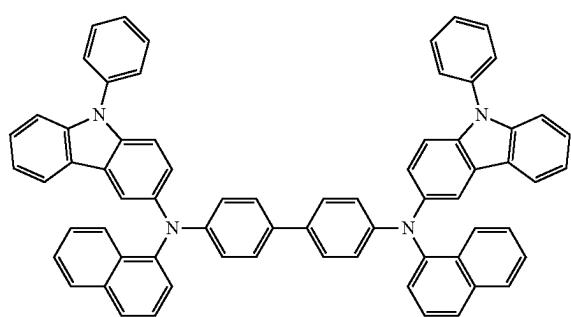
HT14



HT15



HT16

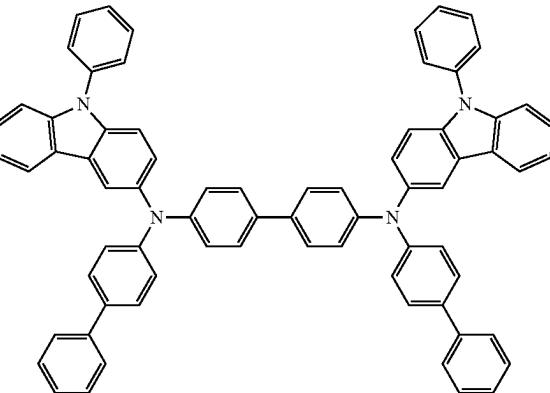


HT17

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HT18



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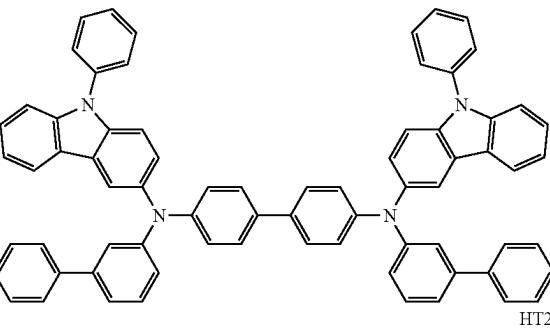
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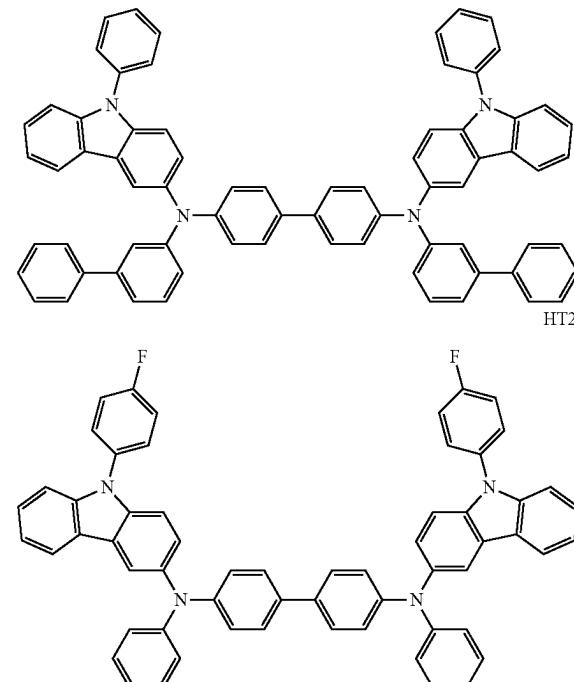
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HT20



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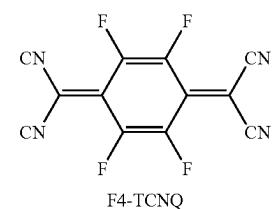
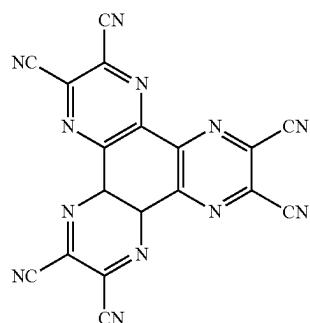
A thickness of the hole transport region may be in a range of about 100 Angstrom (\AA) to about 10,000 \AA , for example, about 100 \AA to about 1,000 \AA . When the hole transport region includes an HIL and a HTL, a thickness of the HIL may be in a range of about 100 \AA to about 10,000 \AA , for example,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

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

The charge-generating material may be, for example, a p-dopant. The p-dopant may be one of a quinone derivative,

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



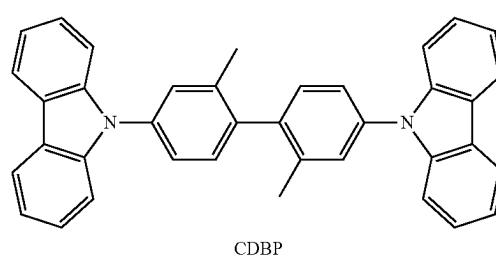
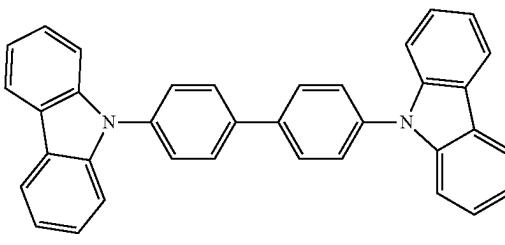
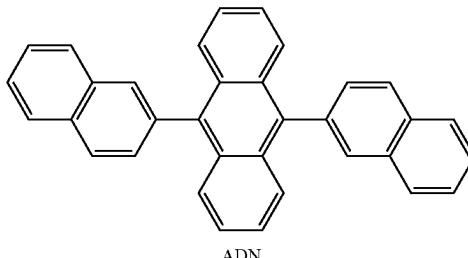
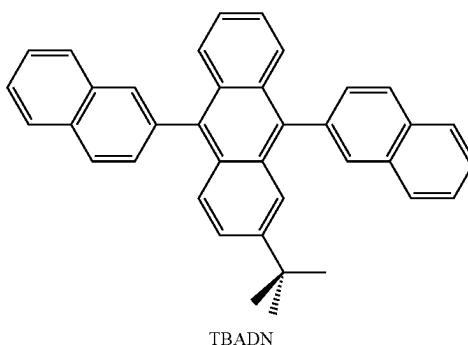
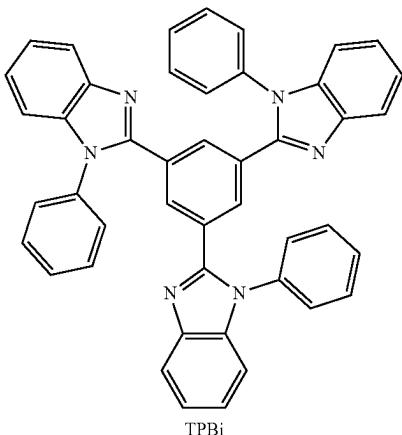
The hole transport region may further include a buffer layer.

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

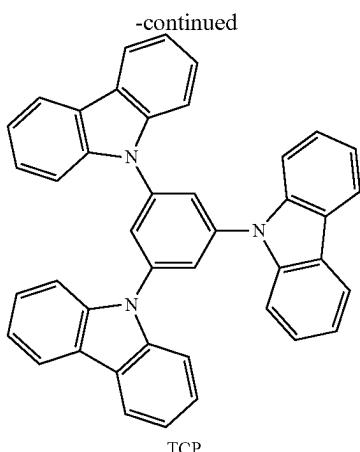
An EML may be formed on the hole transport region by using various methods, such as vacuum deposition, spin coating, casting, or an LB method. When the EML is formed by vacuum deposition or spin coating, deposition and coating conditions for the EML may be determined by referring to the deposition and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

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

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

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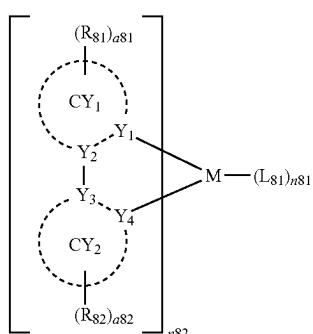


When the organic light-emitting device **10** is a full color organic light-emitting device, the EML may be patterned into a red EML, a green EML, and a blue EML. In some embodiments, the EML may have a stacked structure of a red EML, a green EML, and/or a blue EML to emit white light. The host in the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

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

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

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



In Formula 81,
M may be selected from Iridium (Ir), platinum (Pt),
osmium (Os), titanium (Ti), zirconium (Zr), hafnium
(Hf), europium (Eu), terbium (Tb), and thulium (Tm);
 Y_1 to Y_4 may be each independently carbon (C) or
nitrogen (N);
 Y_1 and Y_2 may be connected by a single bond or a double
bond, and Y_3 and Y_4 may be connected by a single bond
or a double bond;

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

R_{81} and R_{82} are each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, —SF₅, a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₂-C₆₀ alkenyl group, a substituted or unsubstituted C₂-C₆₀ alkynyl group, a substituted or unsubstituted C₁-C₆₀ alkoxy group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₂-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₂-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₂-C₆₀ heteroaryl group, a substituted or unsubstituted monoaromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic hetero-condensed polycyclic group, —N(Q₁)(Q₂), —Si(Q₃)(Q₄)(Q₅), and —B(Q₆)(Q₇);

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

n81 is selected from integers of 0 to 4;

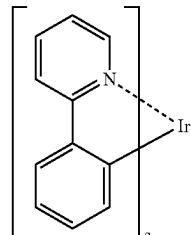
n82 is 1, 2, or 3; and

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

Descriptions of R₈₁ and R₈₂ may be the same as the description of R₅.

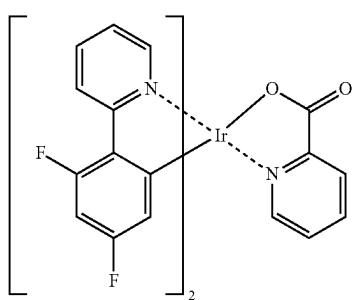
The phosphorescent dopant may include at least one of Compounds PD1 to PD74, but it is not limited thereto:

PD1



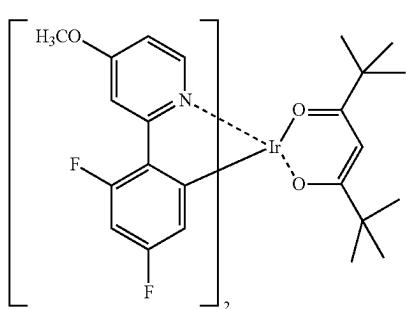
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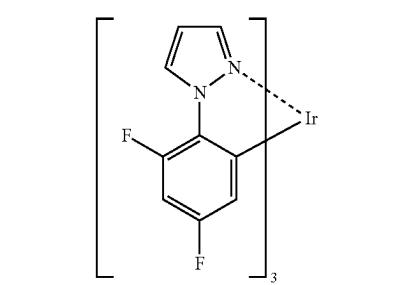
PD2

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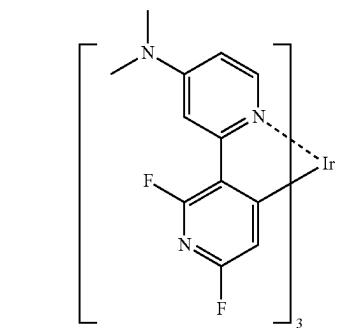
PD3

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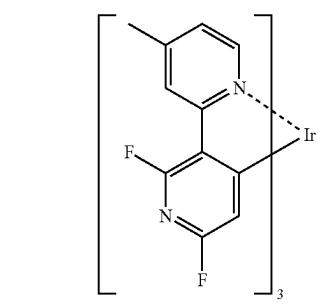
PD4

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PD6

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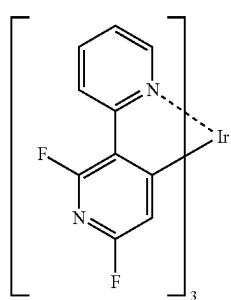


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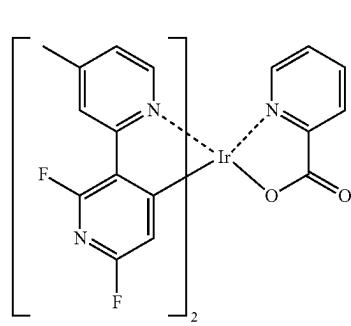
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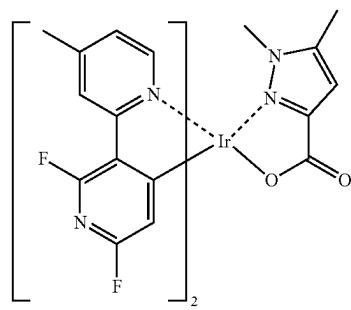
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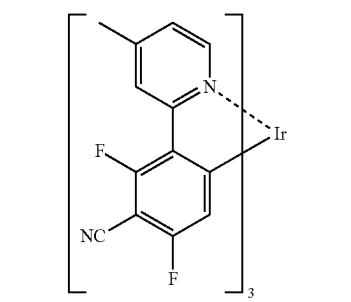
PD7



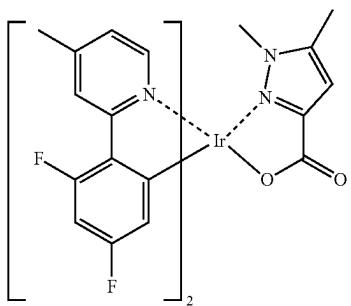
PD8



PD9



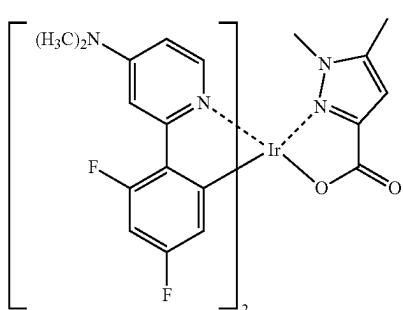
PD10



PD11

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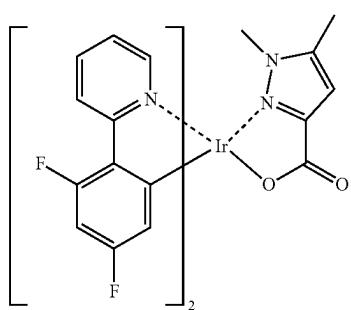


PD12

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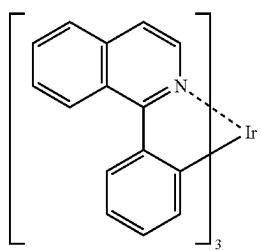


PD13

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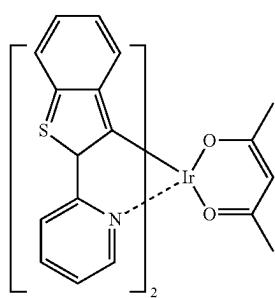


PD14

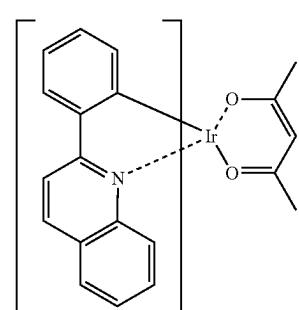
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PD15 - 45

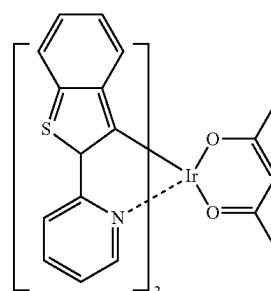
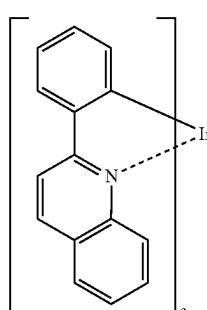


PD17

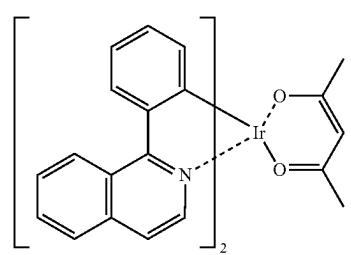
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PD18



PD19



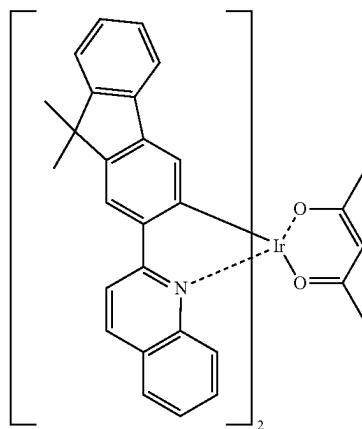
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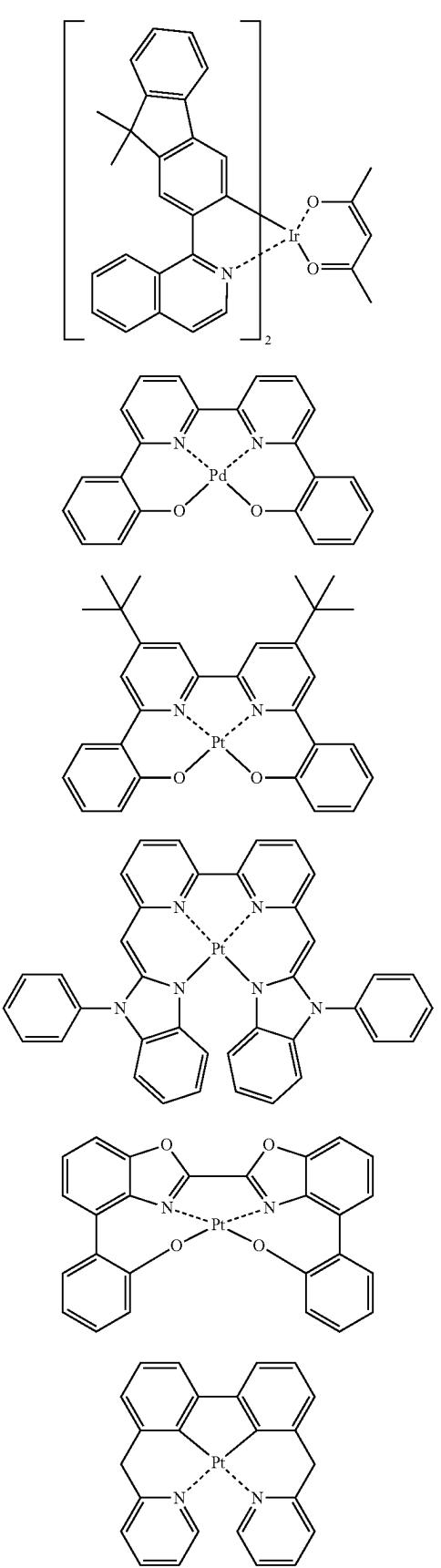
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PD20

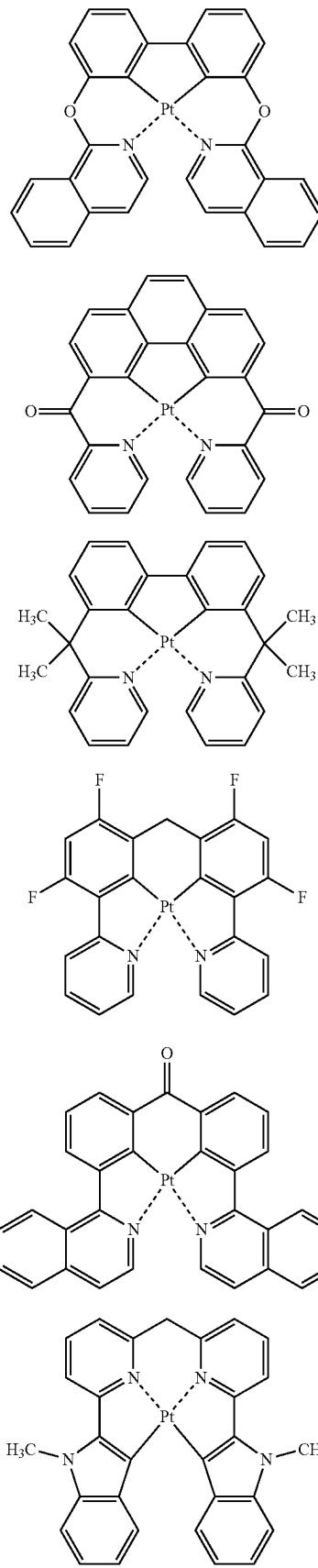
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**298**

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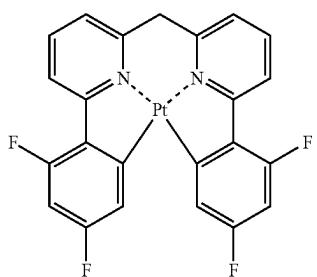
PD27



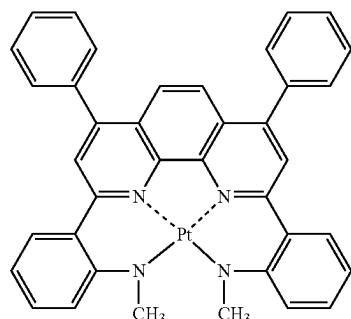
US 12,384,766 B2

299

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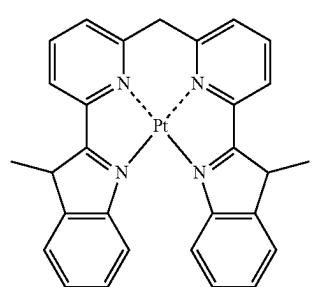
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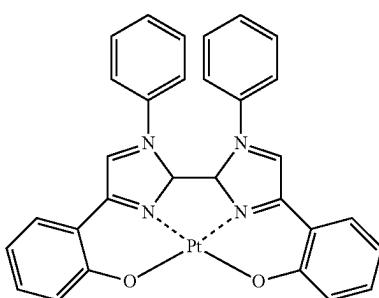
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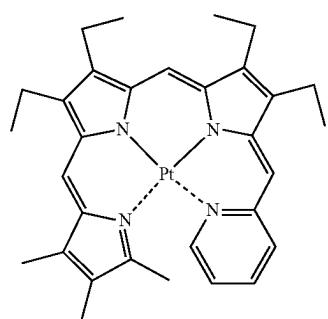
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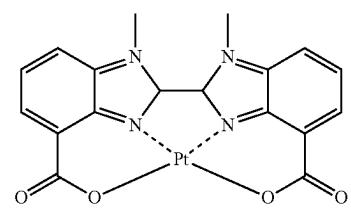
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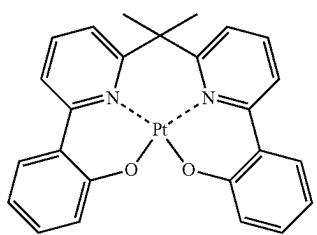
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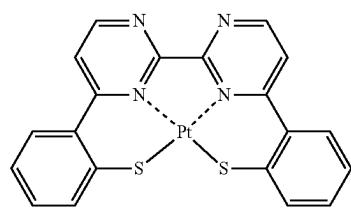
PD35 30



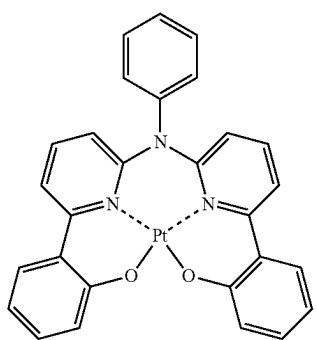
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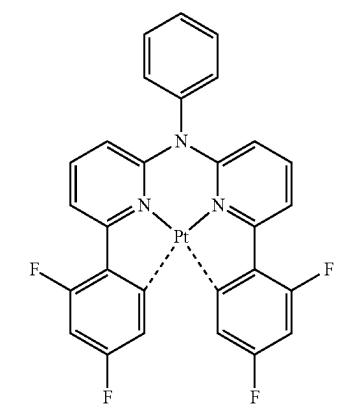
PD36



PD41



PD37

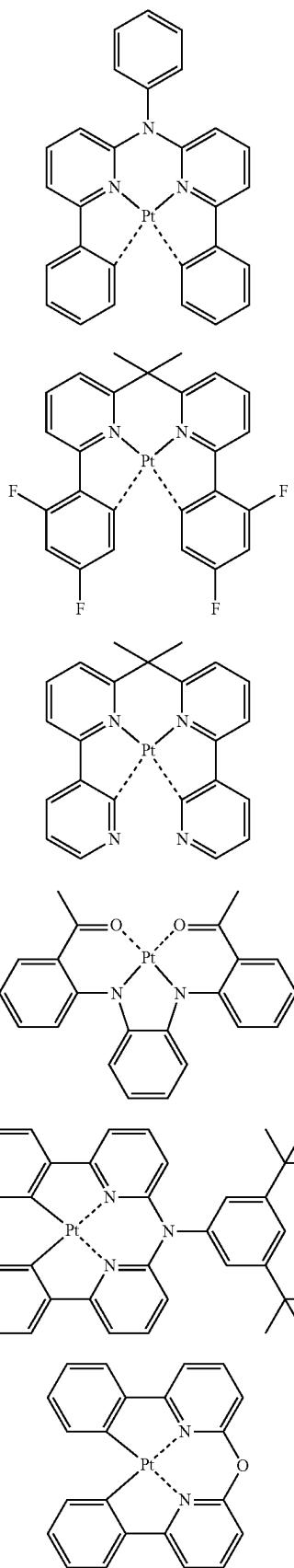


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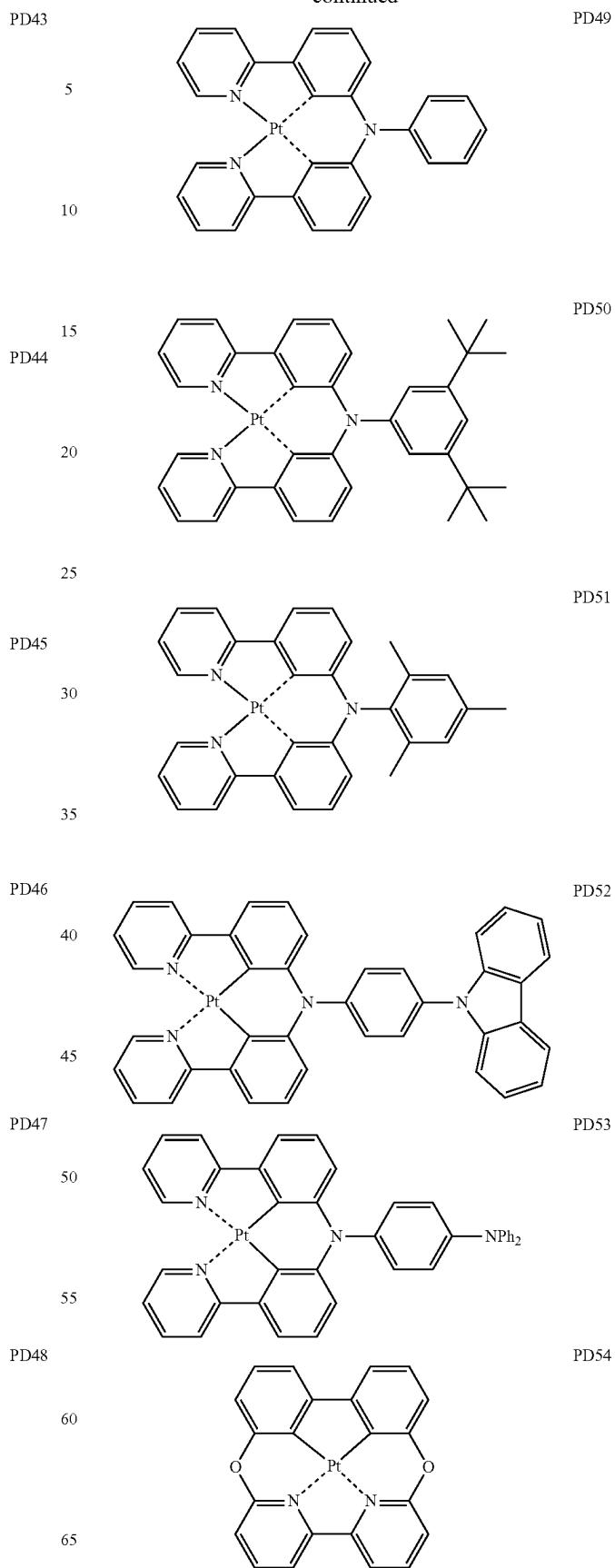
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301

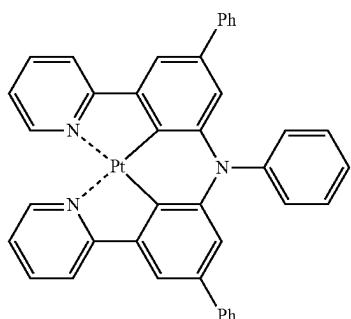
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**302**

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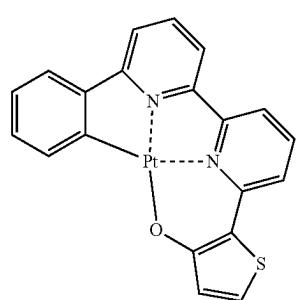


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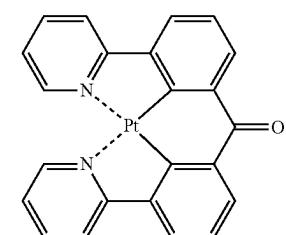
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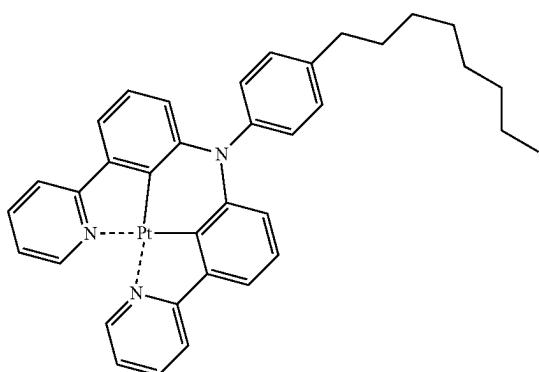
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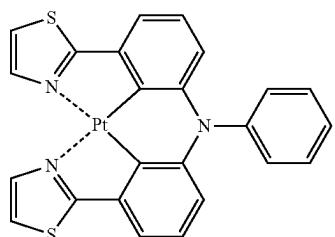
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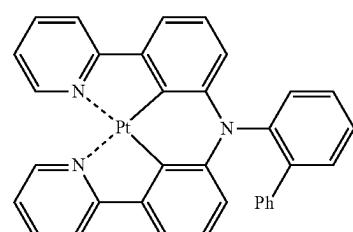
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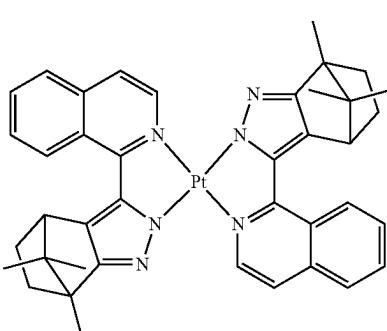
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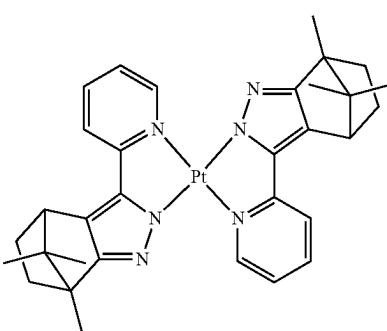


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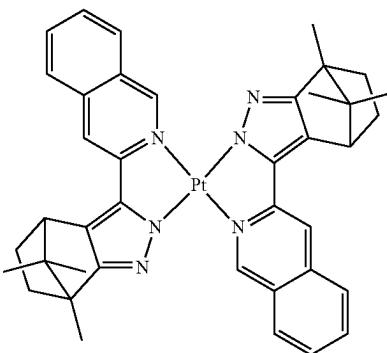
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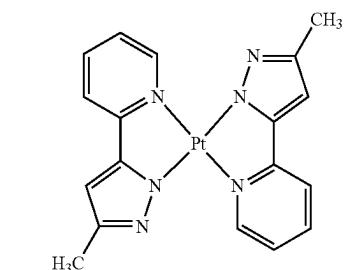
PD61



PD62



PD63



PD64

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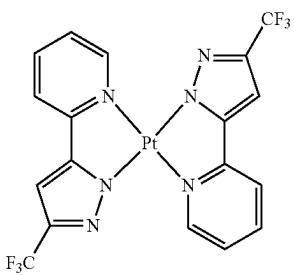
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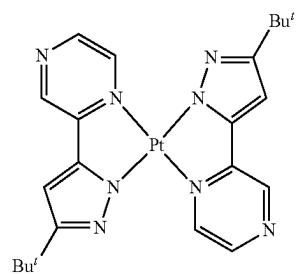
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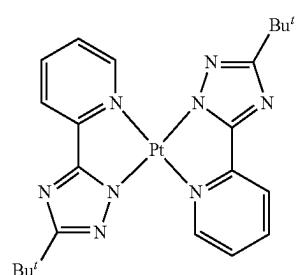
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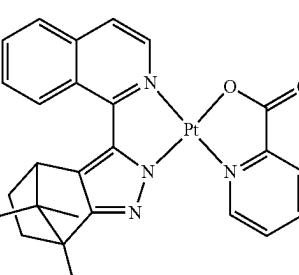
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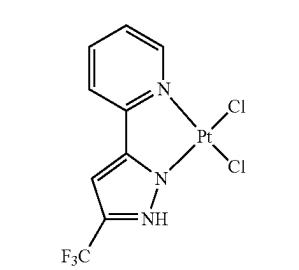
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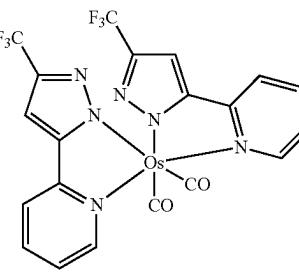
PD68 35

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PD69

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PD70

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PD71

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PD72

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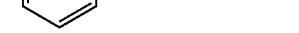
PD73

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PD74

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PD75

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PD76

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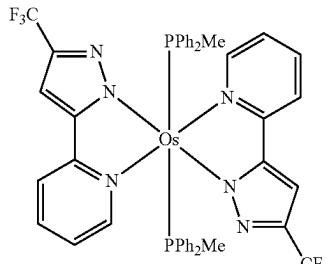
PD77

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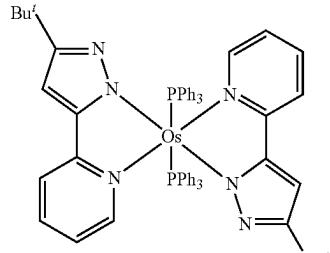
Alternatively, the phosphorescent dopant may include PtOEP or compound PhGD:

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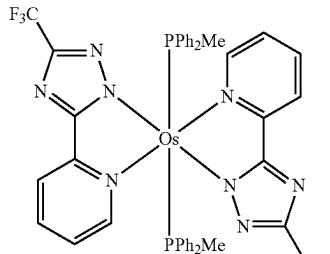
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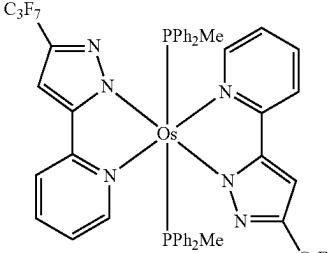
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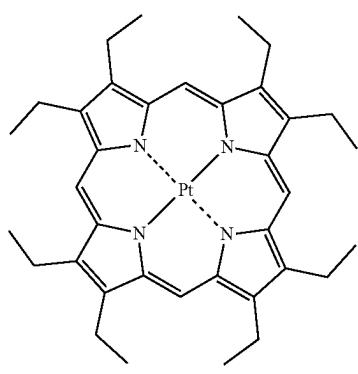
PD72



PD73



PD74

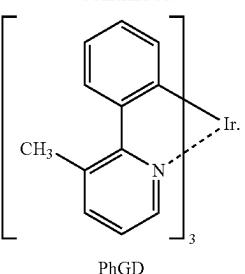
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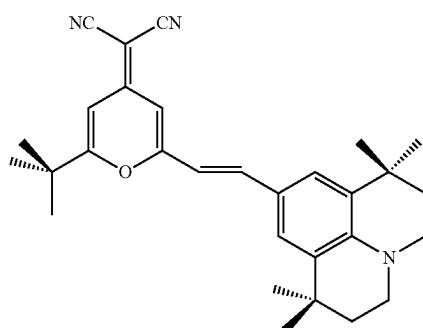
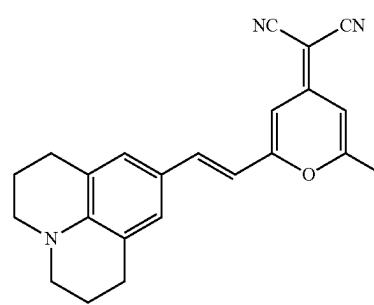
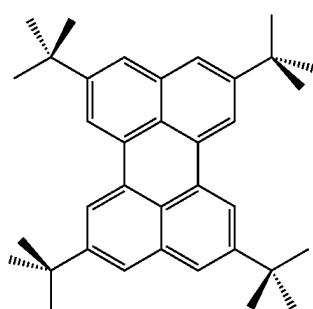
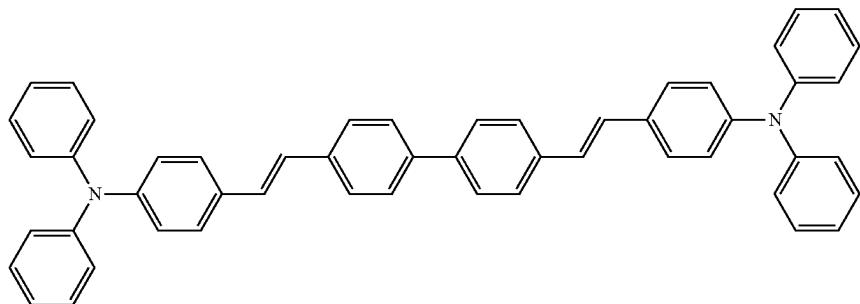
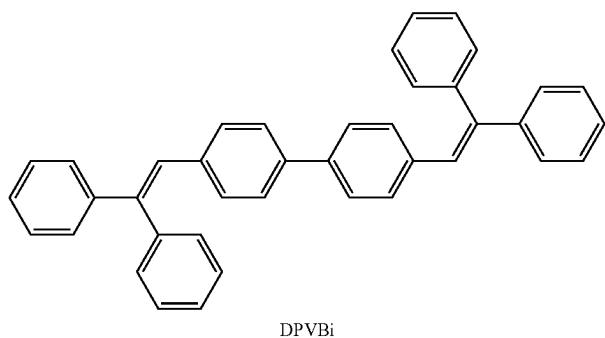
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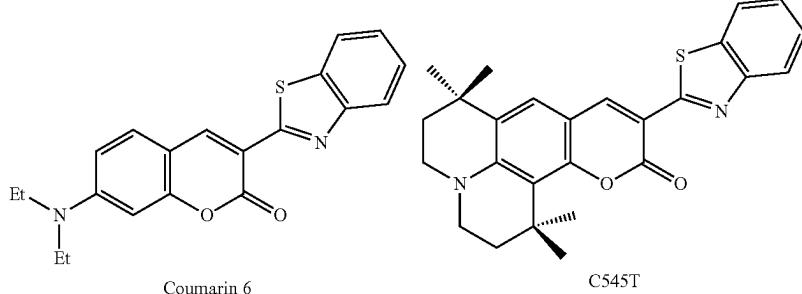
The fluorescent dopant may include at least one of DPVBi, DPAVBi, TBPe, DCM, DCJTB, Coumarin 6, and C545T.



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-continued



Coumarin 6

C545T

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

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

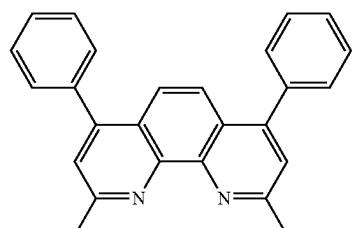
Then, an electron transport region may be disposed on the EML.

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

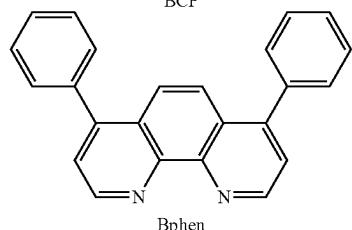
For example, the electron transport region may have an HBL/ETL/EIL structure or an ETL/EIL structure, wherein layers of each structure are sequentially stacked from the EML in the stated order, but is not limited thereto. The ETL may have a single layer or a multi-layer structure including two or more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

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

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



BCP

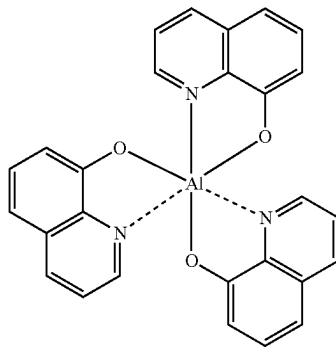
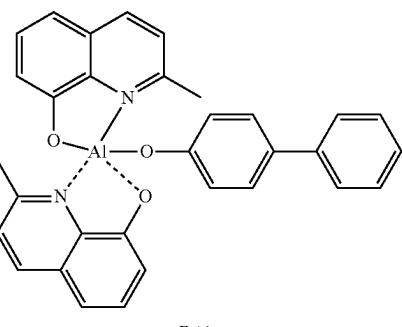


Bphen

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above, the HBL may have excellent hole blocking characteristics without a substantial increase in driving voltage.

The ETL may include at least one of BCP and Bphen, and may further include at least one of Alq₃, Balq, TAZ, and NTAZ.

Alq₃

BAHQ

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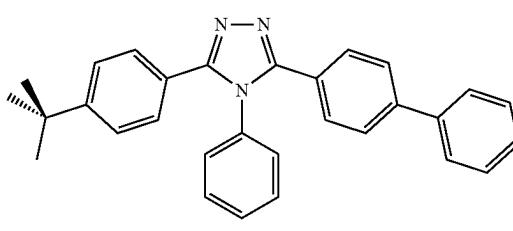
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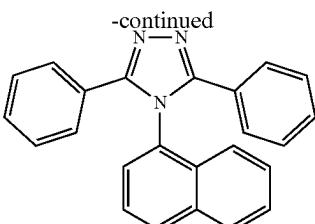


TAZ

A thickness of the HBL may be in a range of about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. When the thickness of the HBL is within the range described

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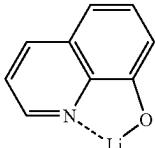
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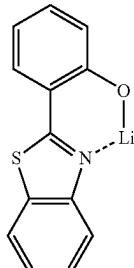
NTAZ

312

ET-D1

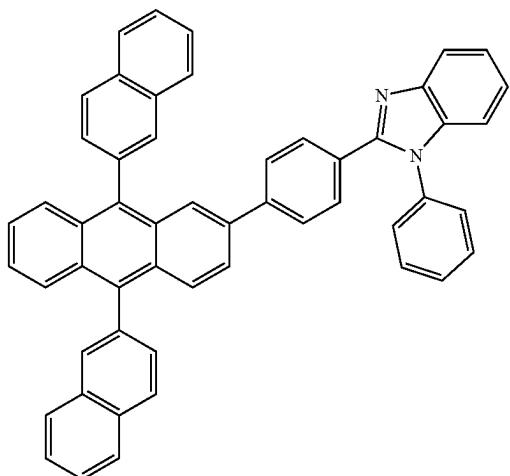


ET-D2

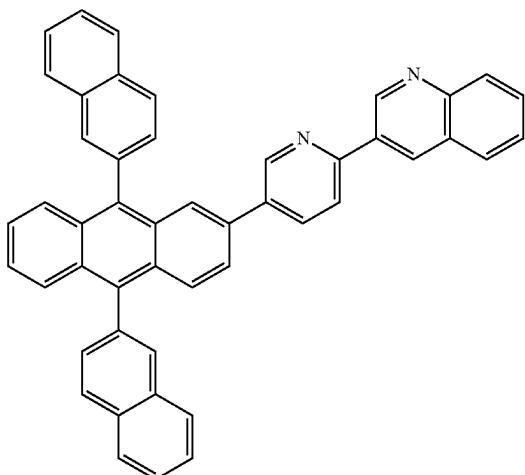


Alternatively, the ETL may include at least one of Compound ET1 and ET2, but it is not limited thereto.

ET1



ET2



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

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

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

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

The EIL may include at least one compound selected from LiF, NaCl, CsF, Li₂O, and BaO.

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

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

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

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

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

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

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A C₂-C₆₀ alkynyl group used herein refers to a hydrocarbon group formed by substituting at least one carbon triple bond in the middle or at the terminal of the C₂-C₆₀ alkyl group. Detailed examples thereof are an ethynyl group and a propynyl group. A C₂-C₆₀ alkynylene group used herein refers to a divalent group having the same structure as the C₂-C₆₀ alkynyl group.

A C₃-C₁₀ cycloalkyl group used herein refers to a monovalent hydrocarbon monocyclic group having 3 to 10 carbon atoms. Detailed examples thereof are a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. A C₃-C₁₀ cycloalkylene group used herein refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkyl group.

A C₃-C₁₀ heterocycloalkyl group used herein refers to a monovalent monocyclic group having at least one heteroatom selected from N, O, P, and S as a ring-forming atom and 3 to 10 carbon atoms. Detailed examples thereof are tetrahydrofuryl and tetrahydrothiophenyl. A C₃-C₁₀ heterocycloalkylene group used herein refers to a divalent group having the same structure as the C₃-C₁₀ heterocycloalkyl group.

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

A C₂-C₁₀ heterocycloalkenyl group used herein refers to a monovalent monocyclic group that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom, 2 to 10 carbon atoms, and at least one double bond in its ring. Detailed examples of the C₂-C₁₀ heterocycloalkenyl group are a 2,3-dihydrofuryl group and a 2,3-dihydrothiophenyl group. A C₂-C₁₀ heterocycloalkenylene group used herein refers to a divalent group having the same structure as the C₂-C₁₀ heterocycloalkenyl group.

A C₆-C₆₀ aryl group used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and a C₆-C₆₀ arylene group used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Detailed examples of the C₆-C₆₀ aryl group are a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C₆-C₆₀ aryl group and the C₆-C₆₀ arylene group each include two or more rings, the rings may be fused to each other.

A C₂-C₆₀ heteroaryl group used herein refers to a monovalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom, and 2 to 60 carbon atoms. A C₂-C₆₀ heteroarylene group used herein refers to a divalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom, and 2 to 60 carbon atoms. Detailed examples of the C₂-C₆₀ heteroaryl group are a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the C₂-C₆₀ heteroaryl group and the C₂-C₆₀ heteroarylene group each include two or more rings, the rings may be fused to each other.

A C₆-C₆₀ aryloxy group used herein indicates -OA₁₀₂ (wherein A₁₀₂ is the C₆-C₆₀ aryl) and a C₆-C₆₀ arylthio group used herein indicates -SA₁₀₃ (wherein A₁₀₃ is the C₆-C₆₀ aryl group).

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

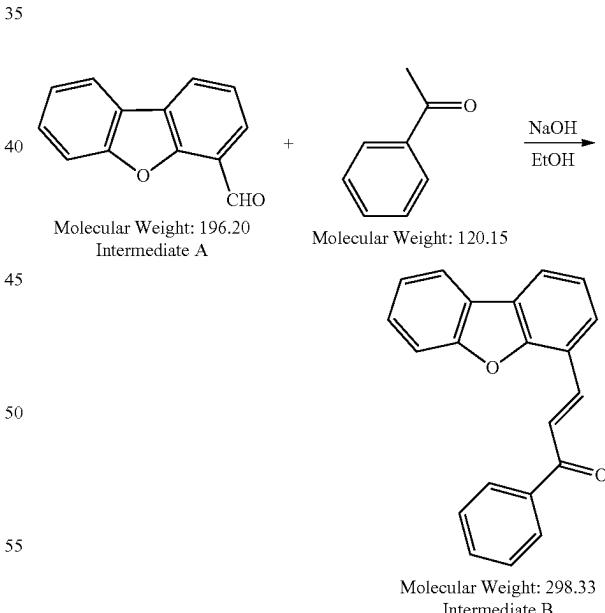
A monovalent non-aromatic condensed heteropolycyclic group (for example, having 2 to 60 carbon atoms) used herein refers to a monovalent group that has two or more rings condensed to each other, has a heteroatom selected from N, O, P, and S, other than carbon atoms, as a ring forming atom, wherein the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

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

EXAMPLE

Synthesis Example 1: Synthesis of Compound 813

Synthesis of Intermediate B

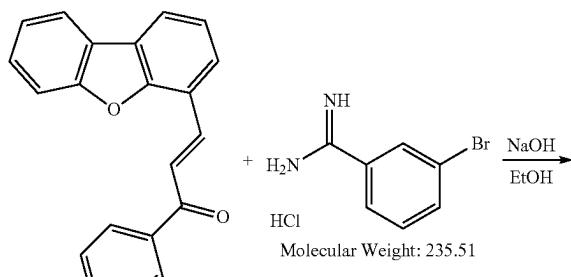


44.0 g (224.3 mmol) of Intermediate A, 126.9 g (224.3 mmol) of acetophenone, and 9.0 g (224.3 mmol) of sodium hydroxide were added in 670 mL of ethanol in a 1,000 mL round bottom flask and then stirred in nitrogen atmosphere for 2 hours at room temperature to prepare a mixture. Crystallized solids in the mixture were filtered to obtain Intermediate B (59.2. g and yield 88.0%). Element analysis results of Intermediate B are as follows.

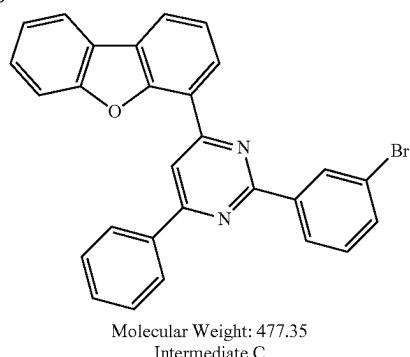
315

calcd. C₂₁H₄O₂; C, 84.54; H, 4.73; O, 10.73; found: C, 84.51; H, 4.75; O, 10.71;

Synthesis of Intermediate C



Intermediate B
Molecular Weight: 298.33

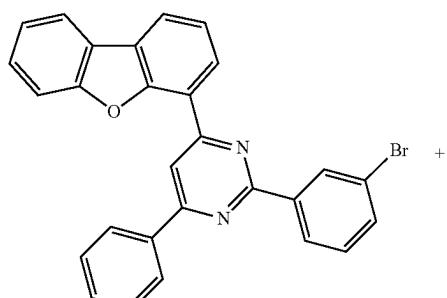


Molecular Weight: 477.35
Intermediate C

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

calcd. C₂₈H₁₇BrN₂O: C, 70.45; H, 3.59; Br, 16.74; N, 5.87; O, 3.35; found C, 70.43; H, 3.60; Br, 16.72; N, 5.85; O, 3.36;

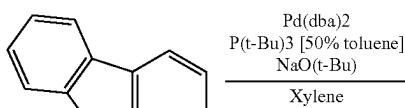
Synthesis of Compound 813



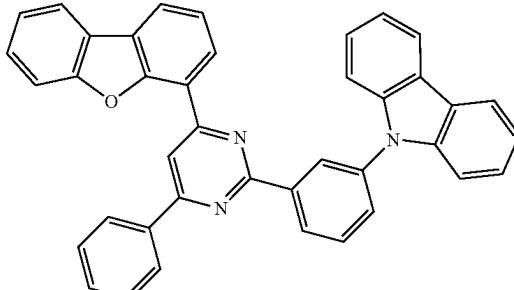
Molecular Weight: 477.35
Intermediate C

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-continued



Molecular Weight: 167.21



Molecular Weight: 563.65
Compound 813

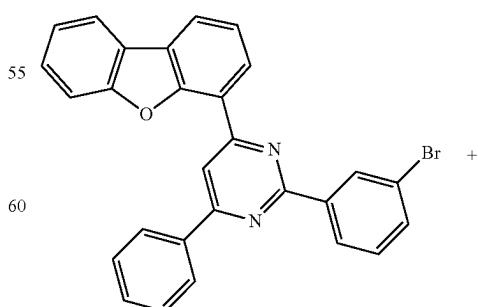
25 23.8 g (49.9 mmol) of Intermediate C, 7.0 g (41.6 mmol) of 9H-carbazole, 8.0 g (83.1 mmol) of sodium t-butoxide, 3.8 g (4.2 mmol) of Pd(dba)₂, and 4.2 mL (8.3 mmol) of tri-t-butyl phosphine (50% in toluene solution) were added to 166.2 mL of xylene in a 500 mL round bottom flask, and 30 heated in a nitrogen atmosphere for 15 hours to reflux the same to prepare a mixture. The mixture was added to 1,000 mL of methanol to filter crystallized solids, dissolved in monochlorobenzene to filter the same by using a silica gel/celite, a suitable amount of organic solvent was removed therefrom, and then the same was recrystallized with methanol to obtain Compound 813 (11.7 g and yield 50%). Element analysis results and NMR analysis results of Compound 813 are as follows.

40 calcd. C₄₀H₂₅N₃O: C, 85.24; H, 4.47; N, 7.46; O, 2.84; found C, 85.22; H, 4.46; N, 7.47; O, 2.83;

300 MHz (CDCl₃, ppm): δ 8.960 (m, 1H), 8.865 (m, 2H), 8.657 (dd, 1H), 8.359 (dd, 2H), 8.196 (d, 2H), 8.081 (dd, 1H), 7.999 (d, 1H), 7.816 (t, 1H), 7.659-7.727 (m, 2H), 45 7.381-7.601 (m, 10H), 7.316 (t, 2H)

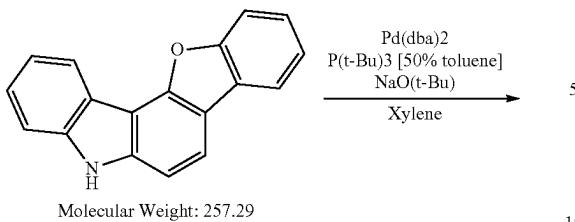
Synthesis Example 2: Synthesis of Compound 814

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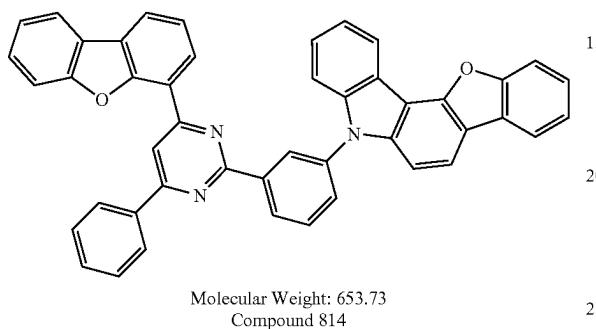


Molecular Weight: 477.35
Intermediate C

317
-continued



5



15

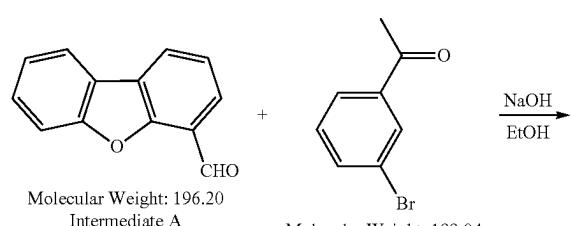
15.0 g (31.4 mmol) of Intermediate C, 9.7 g (37.7 mmol) of 5H-benzofuro[3,2-c]carbazole, 6.0 g (62.9 mmol) of sodium t-butoxide, 2.9 g (3.1 mmol) of Pd(dba)₂, and 3.1 mL (6.3 mmol) of tri-t-butyl phosphine (50% in toluene solution) were added to 125.7 mL of xylene in a 500 mL round bottom flask, and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

calcd. C₄₆H₂₇N₃O₂: C, 84.51; H, 4.16; N, 6.43; O, 4.89;
found C, 84.49; H, 4.17; N, 6.44; O, 4.87

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

Synthesis Example 3: Synthesis of Compound 815

Synthesis of Intermediate D



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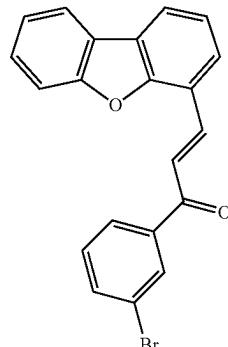
55

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318

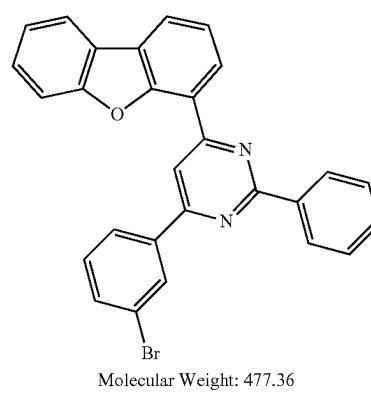
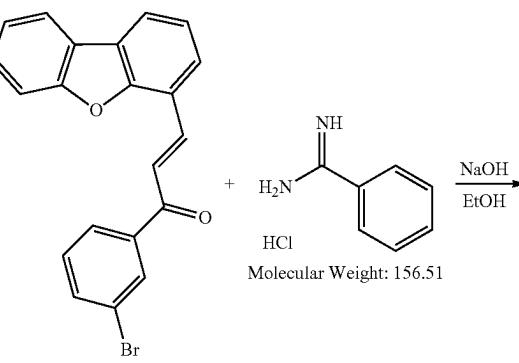
-continued



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

calcd. C₂₁H₁₃BrO₂; C, 66.86; H, 3.47; Br, 21.18; O, 8.48;
found C, 66.83; H, 3.45; Br, 21.17; O, 8.49;

Synthesis of Intermediate E



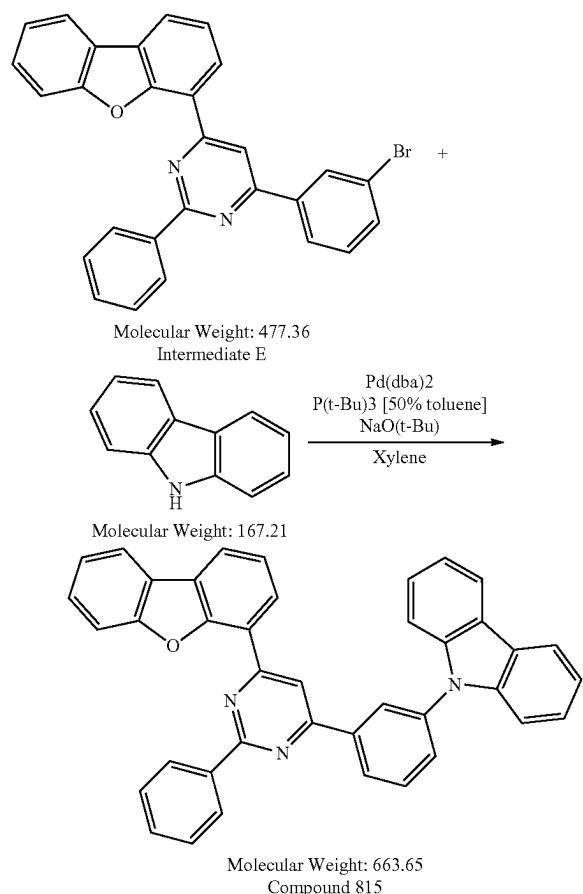
80.3 g (212.9 mmol) of Intermediate D, 40.0 g (255.4 mmol) of benzimidamide, and 17 g (425.7 mmol) of sodium

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

calcd. C₂₈H₁₇BrN₂O: C, 70.45; H, 3.59; Br, 16.74; N, 5.87; O, 3.35; found C, 70.44; H, 3.61; Br, 16.71; N, 5.84; O, 3.35;

Synthesis of Compound 815



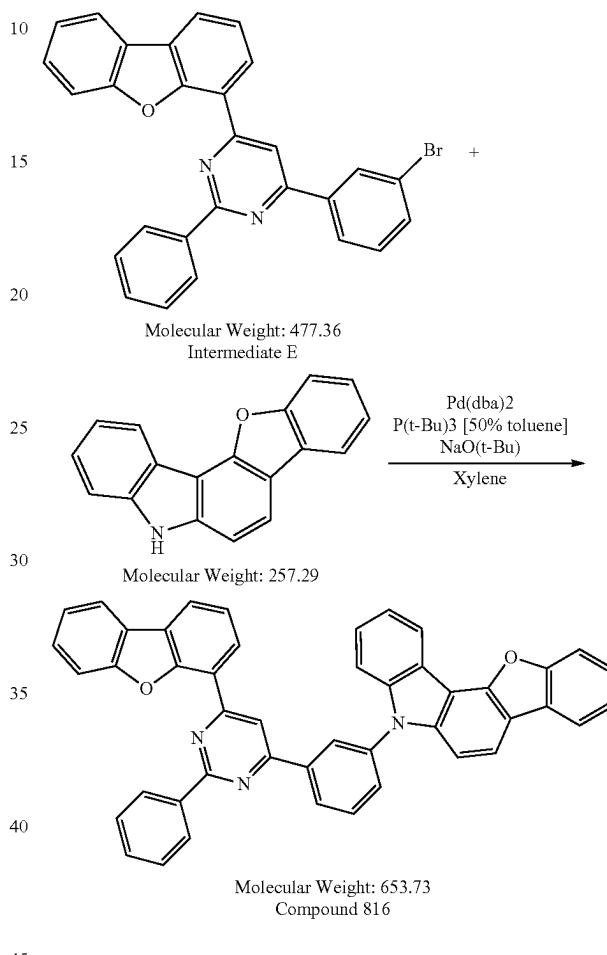
34.3 g (71.8 mmol) of Intermediate E, 10.0 g (60.0 mmol) of 9H-carbazole, 11.5 g (119.6 mmol) of sodium t-butoxide, 5.5 g (6.0 mmol) of Pd(dba)₂, and 2.9 mL (12.0 mmol) of tri-t-butyl phosphine (50% in toluene solution) were added to 239.2 mL of xylene in a 500 mL round bottom flask and then heated in a nitrogen atmosphere for 15 hours to reflux the same to prepare a mixture. The mixture was added to 1,000 mL of methanol to filter crystallized solids, which were dissolved in monochlorobenzene to be filtered by using a silica gel/celite, a suitable amount of organic solvent was removed therefrom and then recrystallized with methanol to obtain Compound 815 (22.2 g, yield 66%). Element analysis results and NMR analysis results of Compound 815 are as follows.

calcd. C₄₀H₂₅N₃O: C, 85.24; H, 4.47; N, 7.46; O, 2.84; found C, 85.21; H, 4.47; N, 7.48; O, 2.86;

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300 MHz (CDCl₃, ppm): δ 8.905 (s, 1H), 8.745 (m, 3H), 8.635 (t, 1H), 8.473 (tt, 1H), 8.208 (d, 2H), 8.120 (dd, 1H), 8.016 (d, 1H), 7.802-7.885 (m, 2H), 7.317-7.600 (m, 13H)

5 Synthesis Example 4: Synthesis of Compound 816



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

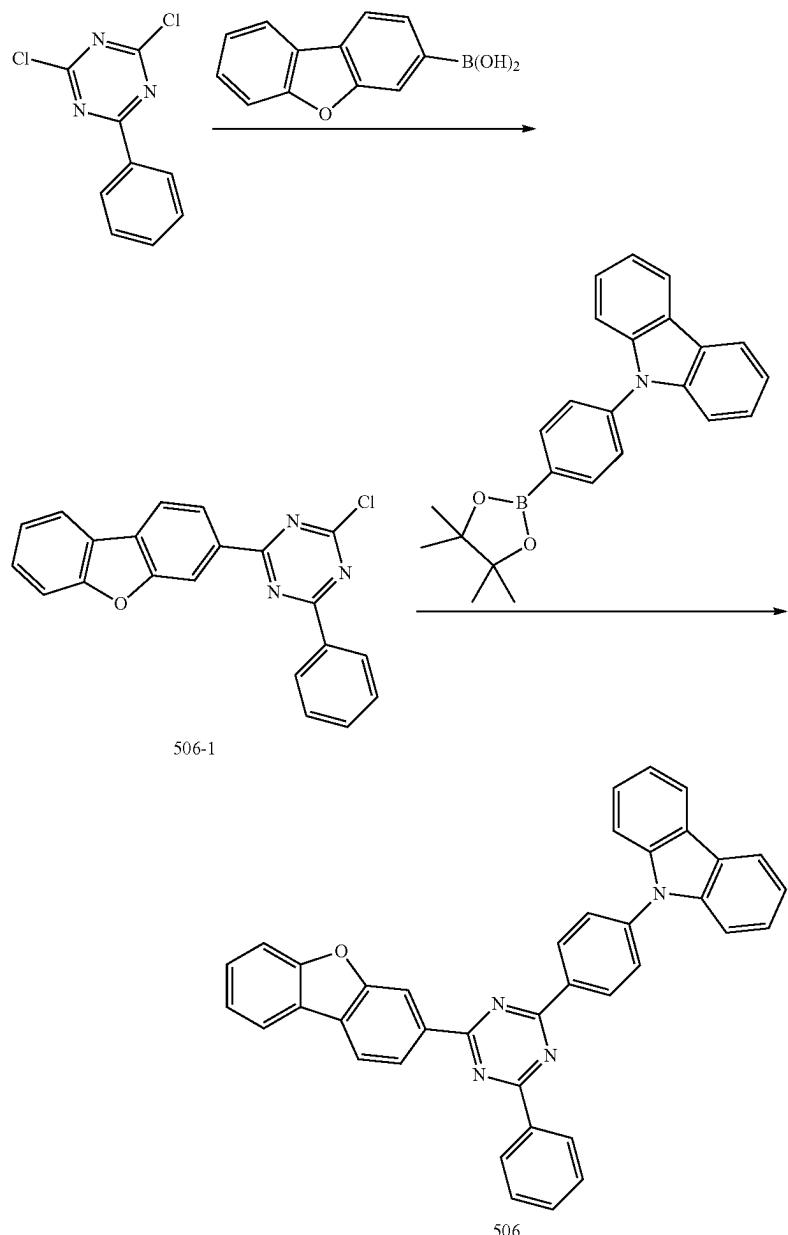
calcd. C₄₆H₂₇N₃O₂: C, 84.51; H, 4.16; N, 6.43; O, 4.89; found C, 84.53; H, 4.18; N, 6.42; O, 4.87

65 300 MHz (CDCl₃, ppm): δ 8.903 (s, 1H), 8.739 (d, 3H), 8.641 (t, 2H), 8.506 (d, 1H), 8.096 (d, 1H), 7.976 (m, 3H), 7.868 (m, 2H), 7.763 (d, 1H), 7.347-7.634 (m, 13H)

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Synthesis Example 5: Synthesis of Compound 506

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a) Synthesis of Intermediate 506-1

22.6 g (100 mmol) of 2,4-dichloro-6-phenyltriazine was added to 100 mL of tetrahydrofuran, 100 mL of toluene, and 100 mL of distilled water in a 500 mL round-bottom flask, and then, 0.9 equivalent weights of dibenzofuran-3-boronic acid, 0.03 equivalent weights of tetrakis(triphenylphosphine)palladium, and 2 equivalent weights of potassium carbonate were added thereto, followed by heating while refluxing in a nitrogen atmosphere. After 6 hours, the reaction solution was cooled, the water layer was removed, and the organic layer was dried under reduced pressure. The resulting solid was washed with water and hexane, and the solid was

recrystallized by using 200 ml of toluene to complete the preparation of Intermediate 506-1 at a yield of 60%.

55

b) Synthesis of Compound 506

8.01 g (22.4 mmol) of Intermediate 506-1 synthesized above was added to 80 mL of tetrahydrofuran and 40 mL of distilled water in a 500 mL round-bottom flask, and 1.0 equivalent weight of 9-(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-phenyl)-carbazole (CAS: 785051-54-9), 0.03 equivalent weights of tetrakis(triphenylphosphine)palladium, and 2 equivalent weights of potassium carbonate were added thereto, followed by heating while refluxing in a nitrogen atmosphere. After 18 hours, the reaction solution was cooled and the precipitated solid was filtered and washed with 500

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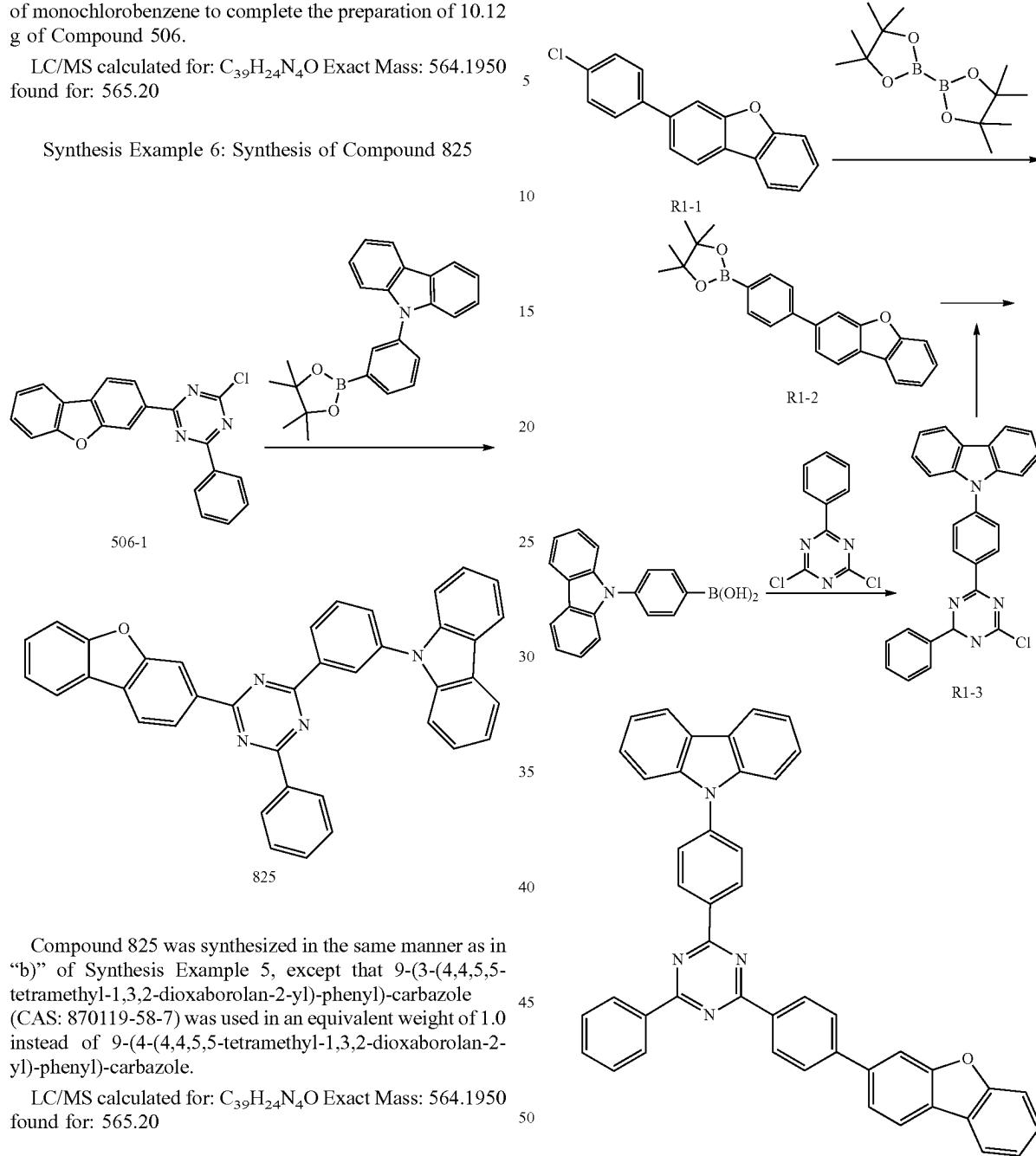
65

323

mL of water. The solid was recrystallized by using 500 mL of monochlorobenzene to complete the preparation of 10.12 g of Compound 506.

LC/MS calculated for: C₃₉H₂₄N₄O Exact Mass: 564.1950 found for: 565.20

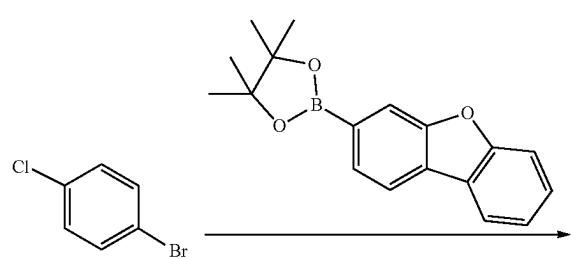
Synthesis Example 6: Synthesis of Compound 825



Compound 825 was synthesized in the same manner as in "b)" of Synthesis Example 5, except that 9-(3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-phenyl)-carbazole (CAS: 870119-58-7) was used in an equivalent weight of 1.0 instead of 9-(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-phenyl)-carbazole.

LC/MS calculated for: C₃₉H₂₄N₄O Exact Mass: 564.1950 found for: 565.20

Comparative Synthesis Example 1: Synthesis of Comparative Compound R1



a) Synthesis of Intermediate R1-1

Intermediate R1-1 was synthesized in the same manner as in "b)" of Synthesis Example 5, except that each of 3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-dibenzofuran and 1-bromo-4-chloro-benzene was used in an equivalent weight of 1 instead of Intermediate 506-i and 9-(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-phenyl)-carbazole.

b) Synthesis of Intermediate R₁-2

One equivalent weight of Intermediate R1-1 synthesized above was added to 150 mL of xylene in a 500 mL

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round-bottom flask, and 0.05 equivalent weights of dichlorodiphenylphosphinoferrocene palladium, 1.2 equivalent weights of bis(pina colato)diboron, and 2 equivalent weights of potassium acetate were added thereto, followed by heating while refluxing for 18 hours in a nitrogen atmosphere. After cooling the reaction solution, the resultant solution was washed with water through extraction, the organic layer was treated with activated carbon and filtered through silica gel, and the filtrate was concentrated. The concentrated solid was stirred with a small amount of hexane, and then the solid was filtered therefrom to complete the preparation of Intermediate R₁-2 at a yield of 75%.

c) Synthesis of Intermediate R1-3

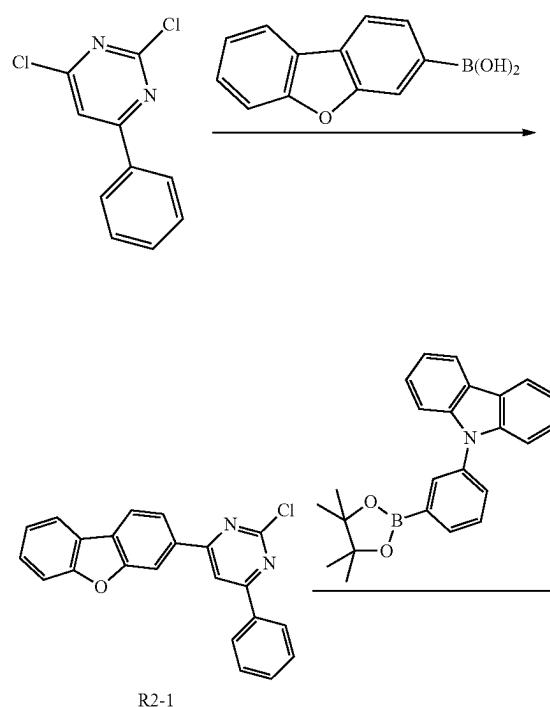
Intermediate R1-3 was synthesized in the same manner as in "a)" of Synthesis Example 5, except that 0.9 equivalent weights of [4-(9H-carbazol-9-yl)phenyl]boronic acid was used instead of dibenzofuran-3-boronic acid.

d) Synthesis of Comparative Compound R1

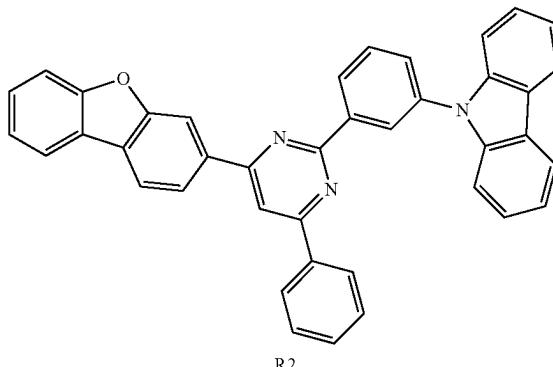
Comparative Compound R1 was synthesized in the same manner as in "a)" of Synthesis Example 5, except that Intermediate R1-2 and Intermediate R1-3 was used in an equivalent weight of 1 instead of 2,4-dichloro-6-phenyltriazine and dibenzofuran-3-boronic acid.

LC/MS calculated for: C₄₅H₂₈N₄O Exact Mass: 640.2263 found for: 641.23

Comparative Synthesis Example 2: Synthesis of Comparative Compound R2

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-continued



a) Synthesis of Intermediate R2-1

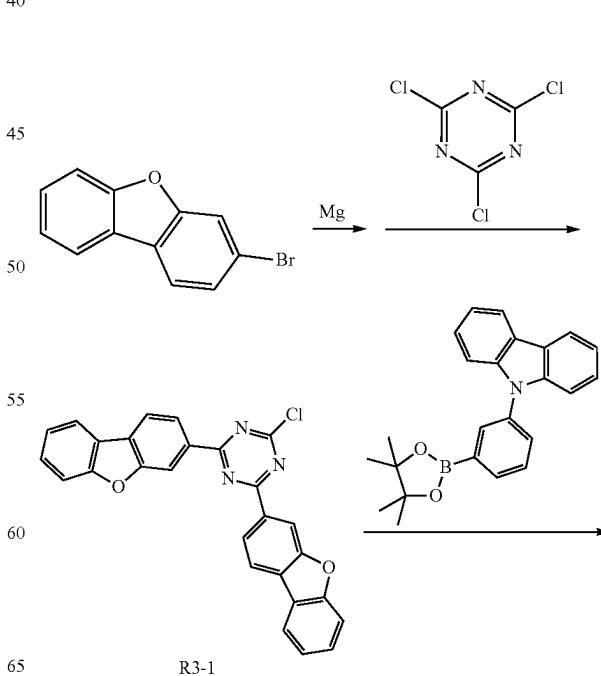
Intermediate R2-1 was synthesized in the same manner as in "a)" of Synthesis Example 5, except that 2,4-dichloro-6-phenylpyrimidine was used in an equivalent weight of 1 instead of 2,4-dichloro-6-phenyltriazine.

b) Synthesis of Comparative Compound R2

Comparative Compound R2 was synthesized in the same manner as in "b)" of Synthesis Example 5, except that each of Intermediate R2-1 synthesized above was used in an equivalent weight of 1.0 instead of Intermediate 506-1.

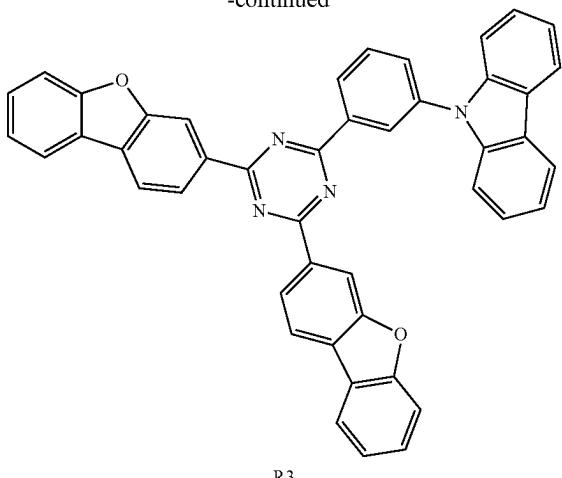
LC/MS calculated for: C₄₀H₂₅N₃O Exact Mass: 563.1998 found for: 564.23

Comparative Synthesis Example 3: Synthesis of Comparative Compound R3



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-continued



a) Synthesis of Intermediate R3-1

In a nitrogen atmosphere, 7.86 g (323 mmol) of magnesium and 1.64 g (6.46 mmol) of iodine were added to 0.1 L of tetrahydrofuran (THF) and stirred for 30 minutes, and then, 80 g (323 mmol) of 3-bromodibenzofuran dissolved in 0.3 L of THF was slowly added dropwise thereto at a temperature of 0° C. for 30 minutes. The resulting mixed solution was slowly added dropwise to 29.5 g (160 mmol) of cyanuric chloride dissolved in 0.5 L of THF at a temperature of 0° C. for 30 minutes. The reaction temperature was raised to room temperature, followed by 1 hour of stirring. Then, in the refluxing condition, the resultant solu-

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Evaluation Example 1: Evaluation of HOMO, LUMO, and Triplet (T1) Energy Levels of Compounds

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

TABLE 1

	Compound No.	HOMO (eV)	LUMO (eV)	T ₁ energy level (eV)
15	813	-5.236	-1.880	2.994
	815	-5.355	-1.802	3.096
	817	-5.252	-1.877	3.002
20	819	-5.435	-1.894	3.089
	814	-5.150	-1.894	2.9
	816	-5.344	-1.909	3.02
	820	-5.303	-1.925	2.959
	818	-5.139	-1.885	2.904
	821	-5.188	-1.893	2.945
	822	-5.350	-1.934	2.997
	823	-5.206	-1.897	2.951
30	824	-5.394	-1.913	3.063

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

TABLE 2

An evaluation method of a HOMO energy level	Each compound was diluted in CHCl ₃ at a concentration of 1×10^{-5} M to measure UV absorption spectrum by using a Shimadzu UV-350 Spectrometer at room temperature and then a HOMO energy level was calculated by using an optical band gap (Eg) from an edge of the absorption spectrum.
An evaluation method of a LUMO energy level	Cyclic voltammetry (CV) (electrolyte: 0.1M Bu ₄ NClO ₄ /solvent: CH ₂ Cl ₂ /electrode: a 3-electrode system (working electrode: GC, standard electrode: Ag/AgCl, and supply electrode: Pt)) was used to obtain a voltage (V)-current (A) graph for each compound and a LUMO energy level was calculated from a reduction onset of the graph.
An evaluation method of evT ₁ energy level	A mixture of toluene and each compound (1 mg of each compound was dissolved in 3 cc of toluene) was added to a quartz cell and liquid nitrogen (77K) was added thereto, a photoluminescence measurement device was used to measure photoluminescence spectrum, which was compared to a conventional room temperature photoluminescence spectrum to only analyze the peak observed only at low temperature and calculate a T ₁ energy level.

tion was additionally stirred for 12 hours. After cooling the reaction mixture, water was added slowly to terminate the reaction, and the organic solvent was concentrated under reduced pressure to obtain a solid. This was stirred with 200 mL of acetone and then filtered to complete the preparation of Intermediate R3-1 at a yield of 40%.

b) Synthesis of Comparative Compound R3

Comparative Compound R3 was synthesized in the same manner as in "b)" of Synthesis Example 5, except that each of Intermediate R3-1 synthesized above was used in an equivalent weight of 1.0 instead of Intermediate 506-1.

LC/MS calculated for: C₄₅H₂₆N₄O₂ Exact Mass: 654.2056 found for: 655.2089

TABLE 3

	Compound No.	HOMO (eV)	LUMO (eV)	T ₁ energy level (eV)
55	813	-5.432	-1.901	2.994
	815	-5.665	-1.972	3.096
60	814	-5.451	-1.998	2.9
	816	-5.643	-1.942	3.02

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

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Evaluation Example 2: Evaluation of Thermal Properties of Synthesized Compounds

compounds 813 to 816 were subjected to thermal analyses by using Thermo Gravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC) (N_2 atmosphere and temperature range for TGA: room temperature $\sim 800^\circ C.$ ($10^\circ C./min$), for DSC: from room temperature to $400^\circ C.$, Pan Type: for TGA: Pt Pan in a disposable Al Pan, for DSC: a disposable Al pan) and results obtained therefrom are shown in Table 4. From Table 4, it may be concluded that Compounds 813 to 816 have excellent thermal stabilities.

TABLE 4

Compound No.	T _e (° C.)	T _m (° C.)	T _g (° C.)
813	—	—	101.21
815	218.72	241.72	102.57
814	—	312.38	—
816	—	—	139.38

Example 1

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

m-MTDATA was vacuum deposited on the ITO glass substrate to form an HIL having a thickness of 600 \AA , and α -NPB was vacuum deposited at a rate of 1 \AA/sec on the HIL to form an EML having a thickness of 300 \AA . Thereafter, Ir(ppy)₃ (dopant) and Compound 813 (host) were co-deposited at a rate of 0.1 \AA/sec and 1 \AA/sec , respectively, on the HTL to form an EML having a thickness of 400 \AA . BAlq was vacuum deposited on the EML at a rate of 1 \AA/sec to form an HBL having a thickness of 50 \AA and then Alq₃ was vacuum deposited on the HBL to form an ETL having a thickness of 300 \AA . Then, LiF 10 \AA (EIL) and Al 2000 \AA (cathode) were sequentially vacuum deposited on the ETL to manufacture an organic light-emitting device.

Example 2

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

Example 3

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

Example 4

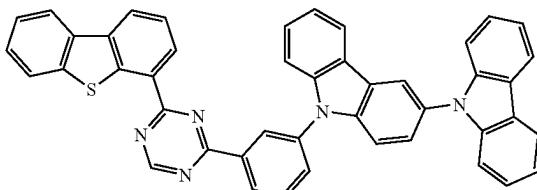
An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 816 was used as a host instead of Compound 813 when forming an EML.

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Comparative Example 1

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

Compound A



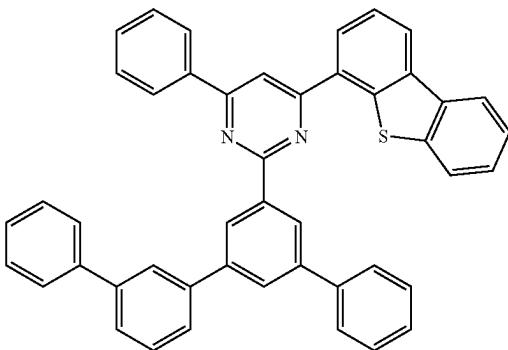
Example 1

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

Comparative Example 2

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

Compound B

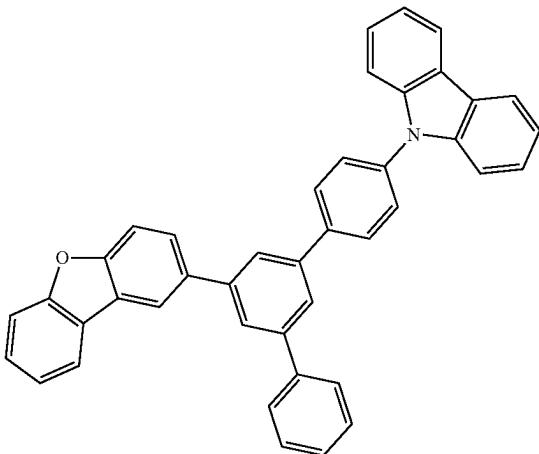


Comparative Example 3

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

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Compound C



Evaluation Example 2: Evaluation of Characteristics of Organic Light-Emitting Device

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

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

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

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

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

(3) Measurement of Emission Efficiency

Brightness, current density, and voltage measured from (1) and (2) were used to calculate current efficiency (candela per ampere (cd/A)) at the same current density (10 milliamperes per square centimeter (mA/cm²)).

TABLE 5

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

From Table 5, it may be concluded that the organic light-emitting devices of Examples 1 to 4 have lower driving

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voltage, high efficiency, and high brightness compared the organic light-emitting devices of Comparative Examples 1 to 3.

Examples 5 and 6

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 506 and 825, respectively, was used as a host instead of Compound 813 when forming an EML.

Comparative Examples R1 to R3

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound R1 to R₃, respectively, was used as a host instead of Compound 813 when forming an EML.

Evaluation Example 3

Driving voltage, luminous power efficiency and lifespan ($T_{90}@24K$) of each organic light-emitting device manufactured in Example 5 and Comparative Example R1 were measured. A detailed method of measurement is as described below and results obtained therefrom are shown as a relative value (%) in Table 6 below. The relative value of the driving voltage, the luminous power efficiency and the lifespan of the organic light-emitting device of Comparative Example R1 were regarded as "100%."

(1) Measurement of Current Density Change Depending on Voltage Change

Current values flowing in the unit device of the manufactured organic light emitting diodes were measured for, while increasing the voltage from 0 V to 10 V using a current-voltage meter (Keithley 2400), and the measured current values were divided by an area to provide the results.

(2) Measurement of Luminance Change Depending on Voltage Change

Luminance of the manufactured organic light emitting diodes was measured for luminance, while increasing the voltage from 0 V to 10 V using a luminance meter (Minolta Cs-1000 Å).

(3) Measurement of Luminous Power Efficiency

Luminous Power efficiency (Im/W) at the same current density (10 mA/cm²) was calculated by using the luminance, current density, and voltages (V) from the items (1) and (2).

(4) Measurement of Driving Voltage

Driving voltages (V) of each device were measured at 15 mA/cm² using a current-voltage meter (Keithley 2400).

(5) Measurement of Lifespan ($T_{90}@24K$)

T_{90} was measured an amount of time that lapsed when 100% of the initial luminance (2400 cd/m²) was decreased to 90% at 24K using a Polanonix life-span measurement system.

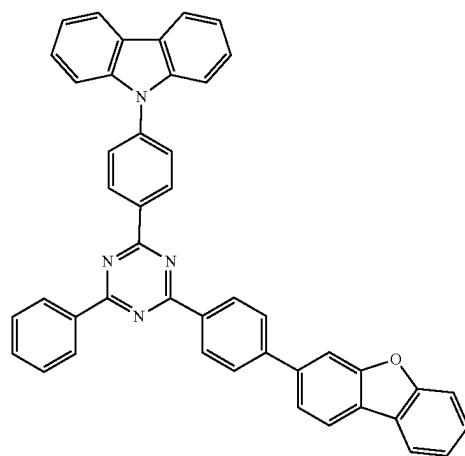
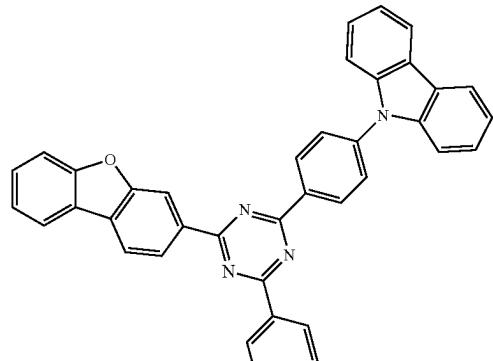
TABLE 6

	Host	Driving voltage (relative value)	Luminous Power Efficiency (relative value)	$T_{90}@24K$ (relative value)
Example 5	Compound 506	91%	137%	288%
Comparative Example R1	Comparative Compound R1	100%	100%	100%

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TABLE 6-continued

Host	Driving voltage (relative value)	Luminous Power Efficiency (relative value)	T ₉₀ @24K (relative value)
			5



From Table 6, it may be concluded that the organic light-emitting device of Example 5 has lower driving voltage, higher luminous power efficiency, and longer lifespan compared the organic light-emitting devices of Comparative Example R1.

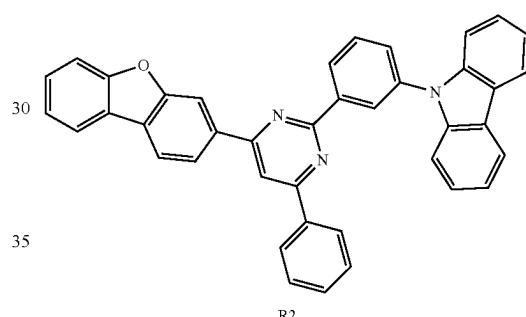
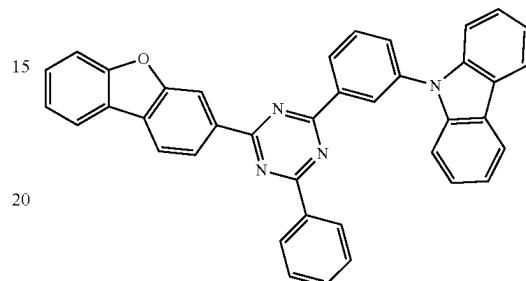
Evaluation Example 4

Driving voltage and lifespan (T₉₀@24K) of each organic light-emitting device manufactured in Example 6 and Comparative Example R2 were measured. A detailed method of measurement is as described in Evaluation Example 3 and results obtained therefrom are shown as a relative value (%) in Table 7 below. The relative value of the driving voltage and the lifespan of the organic light-emitting device of Comparative Example R2 were regarded as “100%.”

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TABLE 7

Host	Driving voltage (relative value)	T ₉₀ @24K (relative value)
Example 6	Compound 825	96%
Comparative	Comparative	100%
Example R2	Compound R2	100%



40 From Table 7, it may be concluded that the organic light-emitting device of Example 6 has lower driving voltage, and longer lifespan compared the organic light-emitting devices of Comparative Example R2.

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Evaluation Example 5

Driving voltage and lifespan (T₉₀@24K) of each organic light-emitting device manufactured in Example 6 and Comparative Example R3 were measured. A detailed method of measurement is as described in Evaluation Example 3 and results obtained therefrom are shown as a relative value (%) in Table 8 below. The relative value of the driving voltage and the lifespan of the organic light-emitting device of Comparative Example R3 were regarded as “100%.”

TABLE 8

Host	Driving voltage (relative value)	T ₉₀ @24K (relative value)
Example 6	Compound 825	105%
Comparative	Comparative	100%
Example R3	Compound R3	100%

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TABLE 8-continued

Host	Driving voltage (relative value)	T ₉₀ @24K (relative value)
	5	10
	15	20

From Table 8, it may be concluded that the organic light-emitting device of Example 6 has longer lifespan compared the organic light-emitting devices of Comparative Example R2.

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

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

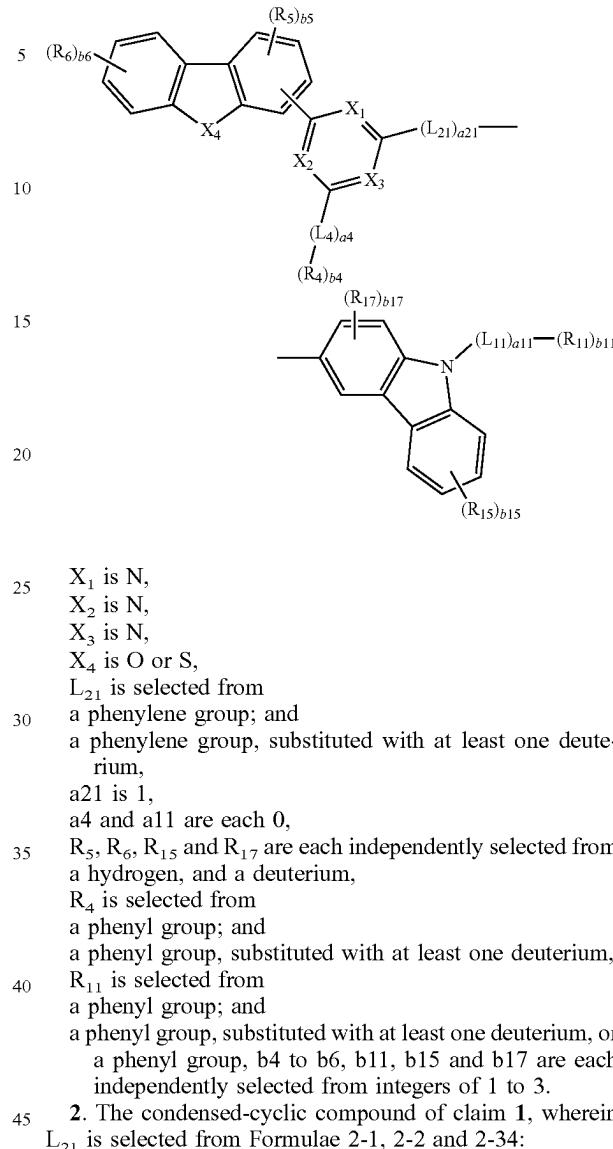
While one or more embodiments have been described with reference to the figures, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present disclosure as defined by the following claims.

What is claimed is:

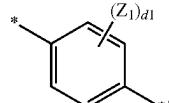
1. A condensed-cyclic compound represented by Formula 1B-3:

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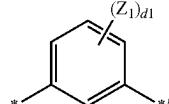
Formula IB-3



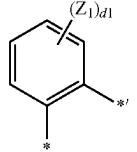
Formula 2-1



Formula 2-2



Formula 2-34



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wherein in Formulae 2-1, 2-2, and 2-34,
 Z_1 are each independently selected from a hydrogen, a
deuterium,
 d_1 is selected from integers of 1 to 4,
and
each of * and ** indicates a binding site to a neighboring atom.

3. An organic light-emitting device comprising
a first electrode;
a second electrode; and
an organic layer disposed between the first electrode and
the second electrode,

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

4. The organic light-emitting device of claim 3, wherein
the first electrode is an anode and
the second electrode is a cathode,
wherein the organic layer comprises

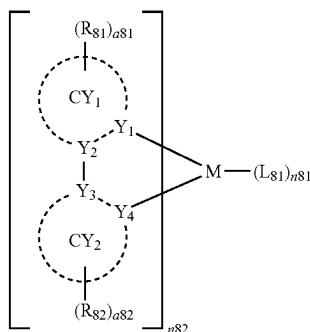
i) a hole transport region disposed between the first
electrode and the emission layer,
wherein the hole transport region comprises at least one of

a hole-injection layer, a hole-transporting layer, and an
electron-blocking layer; and

ii) an electron transport region disposed between the
emission layer and the second electrode,
wherein the electron transport region comprises at least
one layer selected from a hole-blocking layer, an elec-
tron-transporting layer, and an electron-injecting layer.

5. The organic light-emitting device of claim 3, wherein
the emission layer comprises the condensed-cyclic com-
pound.

6. The organic light-emitting device of claim 5, wherein
the emission layer further comprises an organometallic
compound represented by Formula 81:



Formula 81

wherein in Formula 81,
M is selected from Ir, Pt, Os, Ti, Zr, Hf, Eu, Tb, and Tm;
 Y_1 to Y_4 are each independently C or N;
 Y_1 and Y_2 are connected by a single bond or a double 55
bond and

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Y_3 and Y_4 are connected by a single bond or a double bond;
 CY_1 and CY_2 are each independently selected from a
benzene, a naphthalene, a fluorene, a spiro-fluorene, an
indene, a pyrrole, a thiopene, a furan, an imidazole, a
pyrazole, a thiazole, an isothiazole, an oxazole, an
isooxazole, a pyridine, a pyrazine, a pyrimidine, a
pyridazine, a quinoline, an isoquinoline, a benzoqui-
noline, a quinoxaline, a quinazoline, a carbazole, a
benzimidazole, a benzofuran, a benzothiopene, an
isobenzothiopene, a benzoxazole, an isobenzoxazole,
a triazole, a tetrazole, an oxadiazole, a triazine, a
dibenzofuran, and a dibenzothiopene, wherein CY_1 and
 CY_2 are optionally bound to each other by a single bond
or an organic linking group;

R_{81} and R_{82} are each independently selected from a
hydrogen, a deuterium, —F, —Cl, —Br, —I, a
hydroxyl group, a cyano group, a nitro group, an amino
group, an amidino group, a hydrazine group, a hydra-
zone group, a carboxylic acid or a salt thereof, a sulfonic
acid or a salt thereof, a phosphoric acid or a
salt thereof, —SF₅, a substituted or unsubstituted
C₁-C₆₀ alkyl group, a substituted or unsubstituted
C₂-C₆₀ alkenyl group, a substituted or unsubstituted
C₂-C₆₀ alkynyl group, a substituted or unsubstituted
C₁-C₆₀ alkoxy group, a substituted or unsubstituted
C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted
C₂-C₁₀ heterocycloalkyl group, a substituted or un-
substituted C₃-C₁₀ cycloalkenyl group, a substituted or
unsubstituted C₂-C₁₀ heterocycloalkenyl group, a sub-
stituted or unsubstituted C₆-C₆₀ aryl group, a sub-
stituted or unsubstituted C₆-C₆₀ aryloxy group, a sub-
stituted or unsubstituted C₆-C₆₀ arylthio group, a
substituted or unsubstituted C₂-C₆₀ heteroaryl group, a
substituted or unsubstituted monovalent non-aromatic
condensed polycyclic group, a substituted or unsubsti-
tuted monovalent non-aromatic hetero-condensed
polycyclic group, —N(Q₁)(Q₂), —Si(Q₃)(Q₄)(Q₅), and
—B(Q₆)(Q₇);

Q₁ to Q₇ are each independently selected from a hydro-
gen, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a
C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀
cycloalkyl group, a C₂-C₁₀ heterocycloalkyl group, a
C₃-C₁₀ cycloalkenyl group, a C₂-C₁₀ heterocycloalkenyl
group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy
group, a C₆-C₆₀ arylthio group, a C₂-C₆₀ heteroaryl
group, a monovalent non-aromatic condensed polycy-
clic group, and a monovalent non-aromatic hetero-
condensed polycyclic group,

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

n81 is selected from integers of 0 to 4;

n82 is 1, 2, or 3; and

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

* * * * *