



## (51) International Patent Classification:

C09K 11/06 (2006.01) H01L 51/50 (2006.01)

## (21) International Application Number:

PCT/US2018/039309

## (22) International Filing Date:

25 June 2018 (25.06.2018)

## (25) Filing Language:

English

## (26) Publication Language:

English

## (30) Priority Data:

62/523,948	23 June 2017 (23.06.2017)	US
62/523,957	23 June 2017 (23.06.2017)	US
62/523,954	23 June 2017 (23.06.2017)	US
62/531,401	12 July 2017 (12.07.2017)	US
62/653,880	06 April 2018 (06.04.2018)	US

(71) Applicant: **KYULUX INC.** [JP/JP]; Suite 227 FiaS Bldg. 2, 4-1 Kyudaishin-machi, Nishi-ku, Fukuoka 819-0388 (JP).

## (72) Inventors; and

(71) Applicants: **CHENG, Shuo-Hsien** [—/JP]; 4-1 Kyudaishin-machi, Fukuoka, 819-0388 (JP). **YANG, Yu, Seok** [KR/JP]; 4-1 Kyudaishin-machi, Fukuoka, 819-0388 (JP). **NOTSUKA, Naoto** [JP/JP]; 4-1 Kyudaishin-machi, Fukuoka, 819-0388 (JP). **SUZUKI, Yoshitake** [JP/JP]; 4-1 Kyudaishin-machi, Fukuoka, 819-0388 (JP). **ENDO, Ayataka** [JP/JP]; 4-1 Kyudaishin-machi, Fukuoka, 819-0388 (JP). **NASU, Keiro** [JP/JP]; 4-1 Kyudaishin-machi, Fukuoka, 819-0388 (JP). **KUEN, Tsang, Ping** [—/JP]; 4-1 Kyudaishin-machi, Fukuoka, 819-0388 (JP).

(72) Inventors: **AGUILERA-IPARRAGUIRRE, Jorge**; 35 Brown Avenue, #2, Roslindale, MA 02131 (US). **GOMEZ-BOMBARELLI, Rafael**; 2 Peabody Terrace, #412, Cambridge, MA 02138 (US). **HIRZEL, Timothy, D.**; 49 Ocean Street, Quincy, MA 02171 (US).

(74) Agent: **BLOUNT, Jennifer, V.**; Seaport West, Foley Hoag LLP, 155 Seaport Boulevard, Boston, MA 02210-2600 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

## Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) Title: COMPOSITION OF MATTER FOR USE IN ORGANIC LIGHT-EMITTING DIODES

(57) Abstract: The present disclosure relates in part to compounds capable of emitting delayed fluorescence and uses of these compounds in organic light-emitting diodes.

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**COMPOSITION OF MATTER FOR USE IN ORGANIC  
LIGHT-EMITTING DIODES**

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**RELATED APPLICATIONS**

This application claims the benefit of priority to United States Provisional Patent Application serial number 62/523,948, filed June 23, 2017; United States Provisional Patent Application serial number 62/523,954, filed June 23, 2017; United States Provisional Patent Application serial number 62/523,957, filed June 23, 2017; United States Provisional Patent Application serial number 62/531,401, filed July 12, 2017; and United States Provisional Patent Application serial number 62/653,880, filed April 6, 2018.

**BACKGROUND**

An organic light-emitting diode (OLED) is a light-emitting diode (LED) in which a film of organic compounds is placed between two conductors, which film emits light in response to excitation, such as an electric current. OLEDs are useful in displays, such as television screens, computer monitors, mobile phones, and tablets. A problem inherent in OLED displays is the limited lifetime of the organic compounds. OLEDs that emit blue light, in particular, degrade at a significantly increased rate as compared to green or red OLEDs.

OLED materials rely on the radiative decay of molecular excited states (excitons) generated by recombination of electrons and holes in a host transport material. The nature of excitation results in interactions between electrons and holes that split the excited states into bright singlets (with a total spin of 0) and dark triplets (with a total spin of 1). Since the recombination of electrons and holes affords a statistical mixture of four spin states (one singlet and three triplet sublevels), conventional OLEDs have a maximum theoretical efficiency of 25%.

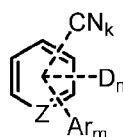
To date, OLED material design has focused on harvesting the remaining energy from the normally dark triplets. Recent work to create efficient phosphors, which emit light from the normally dark triplet state, have resulted in green and red OLEDs. Other colors, such as blue, however, require higher energy excited states, which accelerate the degradation process of the OLED.

The fundamental limiting factor to the triplet-singlet transition rate is a value of the parameter  $|H_{\text{fi}}/\Delta|^2$ , where  $H_{\text{fi}}$  is the coupling energy due to hyperfine or spin-orbit interactions, and  $\Delta$  is the energetic splitting between singlet and triplet states. Traditional phosphorescent OLEDs rely on the mixing of singlet and triplet states due to spin-orbital (SO) interaction, increasing  $H_{\text{fi}}$ , and affording a lowest emissive state shared between a heavy metal atom and an organic ligand. This results in energy harvesting from all higher singlet and triplet states, followed by phosphorescence (relatively short-lived emission from the excited triplet). The shortened triplet lifetime reduces triplet exciton annihilation by charges and other excitons. Recent work by others suggests that the limit to the performance of phosphorescent materials has been reached.

### SUMMARY

The present disclosure relates to novel materials for OLEDs. These OLEDs can reach higher excitation states without rapid degradation. It has now been discovered that thermally activated delayed fluorescence (TADF), which relies on minimization of  $\Delta$  as opposed to maximization of  $H_{\text{fi}}$ , can transfer population between singlet levels and triplet sublevels in a relevant timescale, such as, for example, 1-100  $\mu\text{s}$ . The compounds described herein are capable of luminescing at higher energy excitation states than compounds previously described.

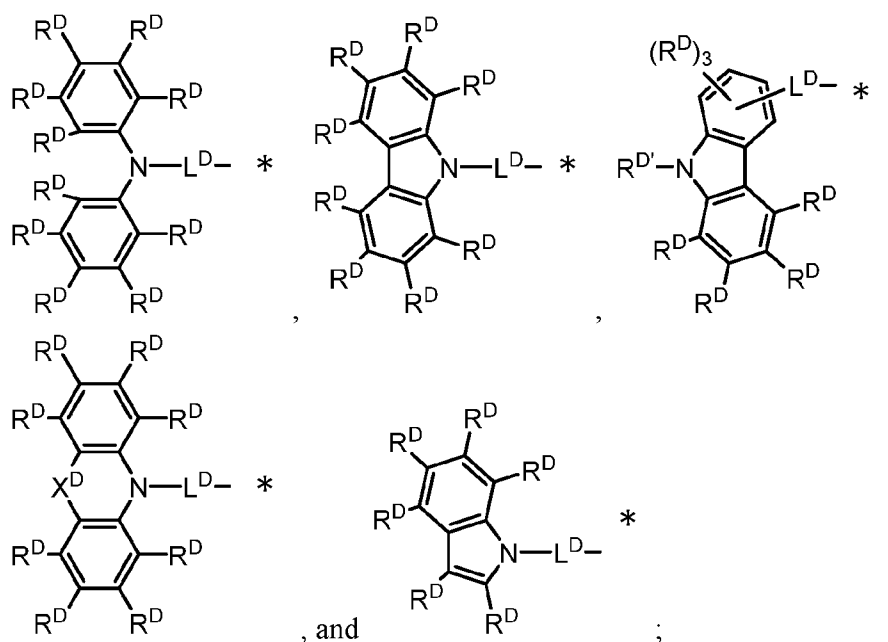
In one aspect, the present disclosure provides compounds of Formula (I):



(I)

wherein

$\text{D}$  is independently selected from



$X^D$  is independently selected from O, S,  $NR^{D'}$ ,  $C(O)$ , substituted or unsubstituted methylene, substituted or unsubstituted ethylene, substituted or unsubstituted vinylene, substituted or unsubstituted *o*-arylene, and substituted or unsubstituted *o*-heteroarylene; wherein each instance of methylene, ethylene, vinylene, *o*-arylene or *o*-heteroarylene can be substituted with one or more substituents independently selected from deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl;

two or more instances of  $X^D$  taken together can form a ring system;

$R^D$  is independently selected from hydrogen, deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted alkoxy, substituted or unsubstituted amino, substituted or unsubstituted aryl, substituted or unsubstituted aryloxy, substituted or unsubstituted heteroaryl, substituted or unsubstituted heteroaryloxy, and silyl;

two or more instances of  $R^D$  taken together can form a ring system;

$R^{D'}$  is independently selected from hydrogen, deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted amino, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl;

two or more instances of  $R^{D'}$  and  $R^D$  taken together can form a ring system;

$L^D$  is independently selected from single bond, substituted or unsubstituted arylene, and substituted or unsubstituted heteroarylene; wherein each instance of arylene and heteroarylene can be substituted with one or more substituents independently

selected from deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl; two or more of these substituents taken together can form a ring system;

Ar is independently selected from substituted or unsubstituted aryl and  
 5 substituted or unsubstituted heteroaryl, wherein the substituted or unsubstituted heteroaryl does not contain a nitrogen atom; and wherein each instance of aryl, and heteroaryl can be substituted with one or more substituents independently selected from deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl; two or more of these substituents taken together  
 10 can form a ring system;

Z is N or CR;

R is H, CN, D or Ar;

k is 1 to 3;

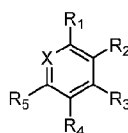
m is 0 to 4;

15 n is 1 to 5;

(k + m + n) is less than or equal to 5; and

each “\*” represents a point of attachment to Formula (I).

In one aspect, the present disclosure provides compounds of Formula (II):



20

(II)

wherein

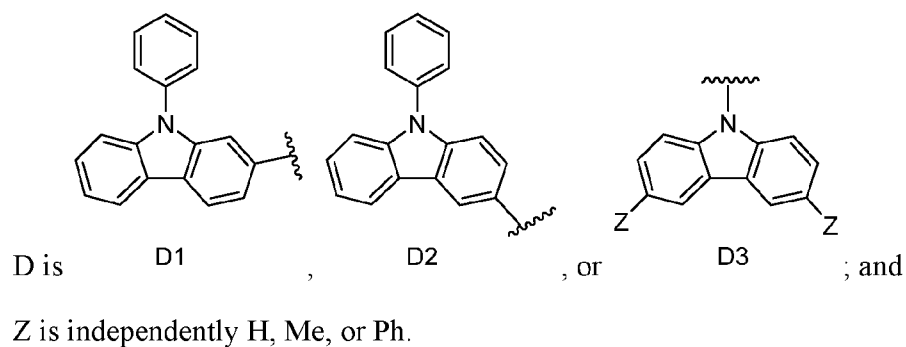
X is N or CR<sub>6</sub>;

R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, and R<sub>6</sub> are independently selected from the group consisting of A, D, H, and Ph;

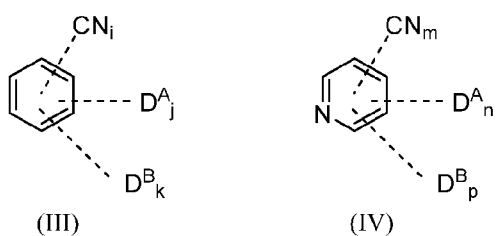
25 at least one of R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, and R<sub>6</sub> is A;

at least one of R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, and R<sub>6</sub> is D;

A is CN;



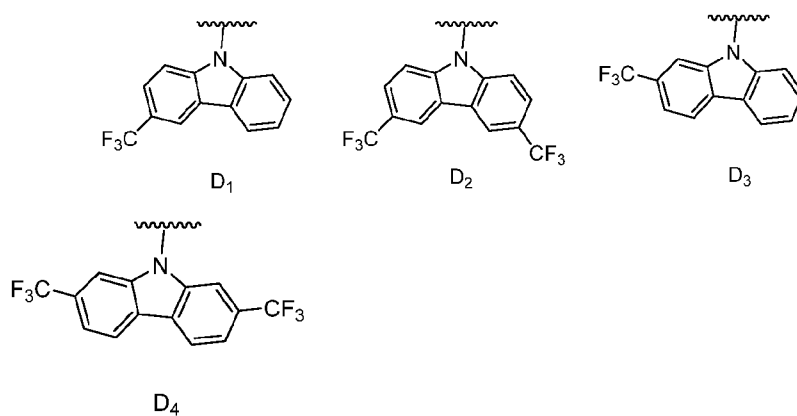
In one aspect, the present disclosure provides compounds of Formula (III) or Formula (IV):



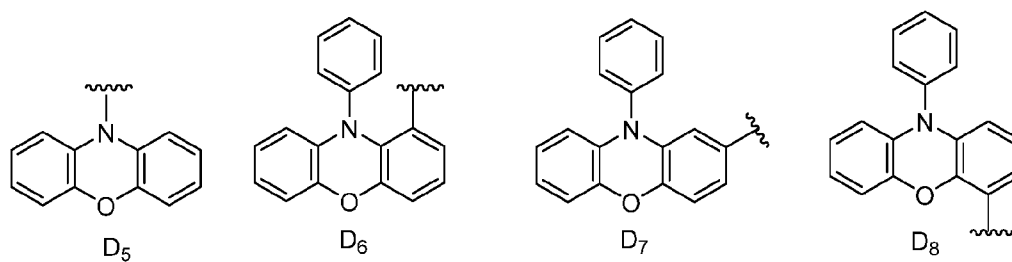
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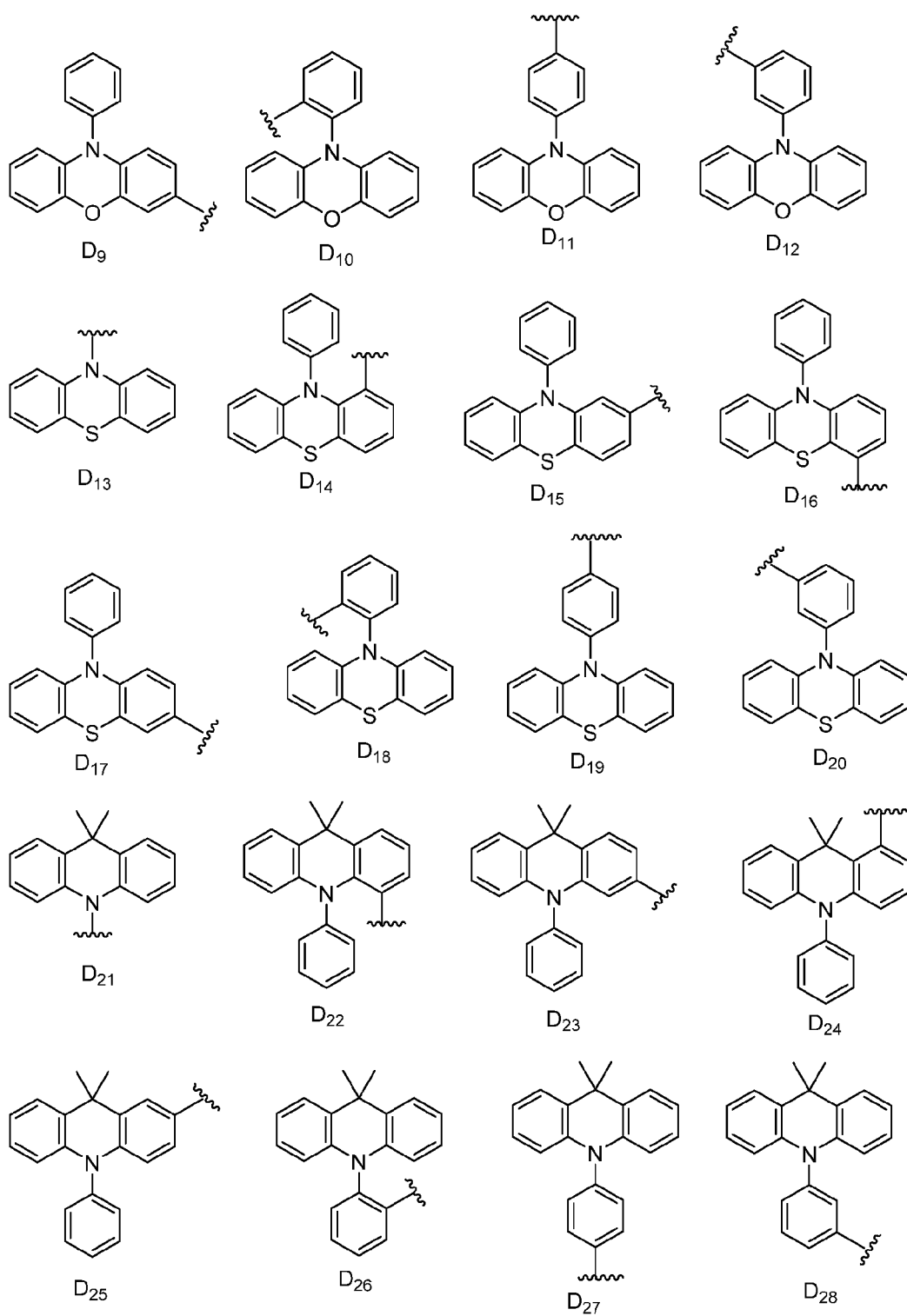
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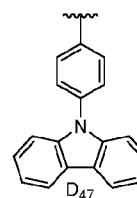
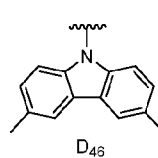
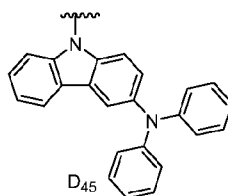
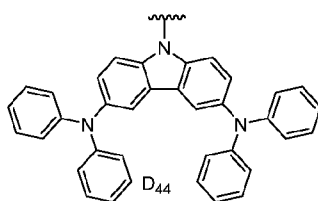
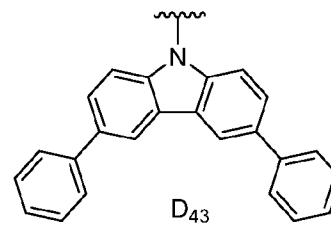
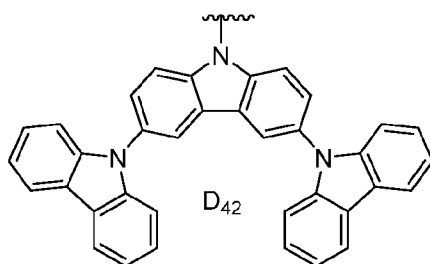
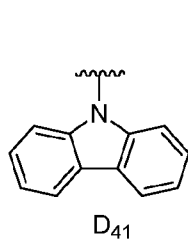
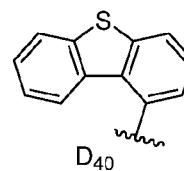
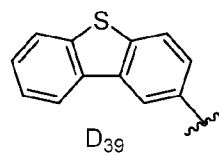
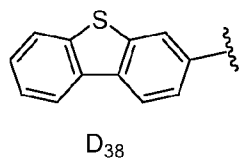
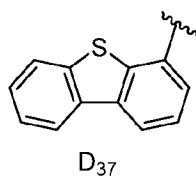
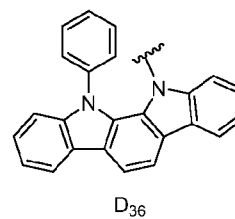
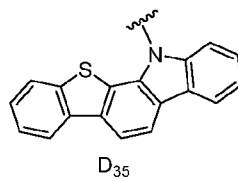
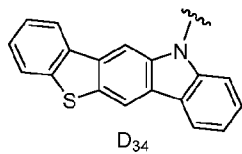
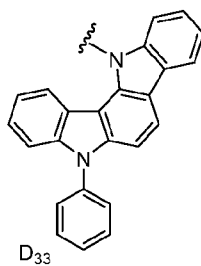
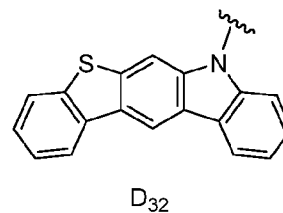
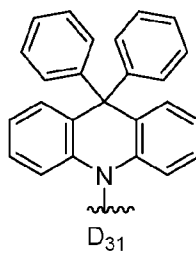
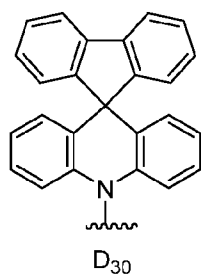
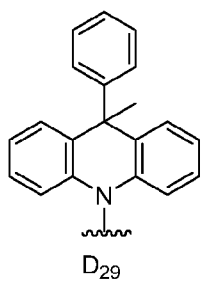
$D^A$  and  $D^B$  are independently selected from



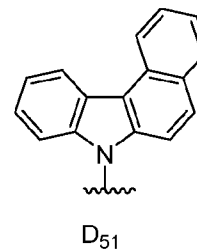
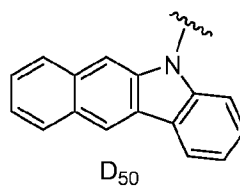
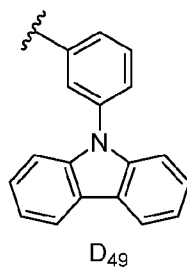
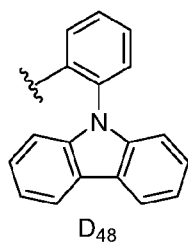
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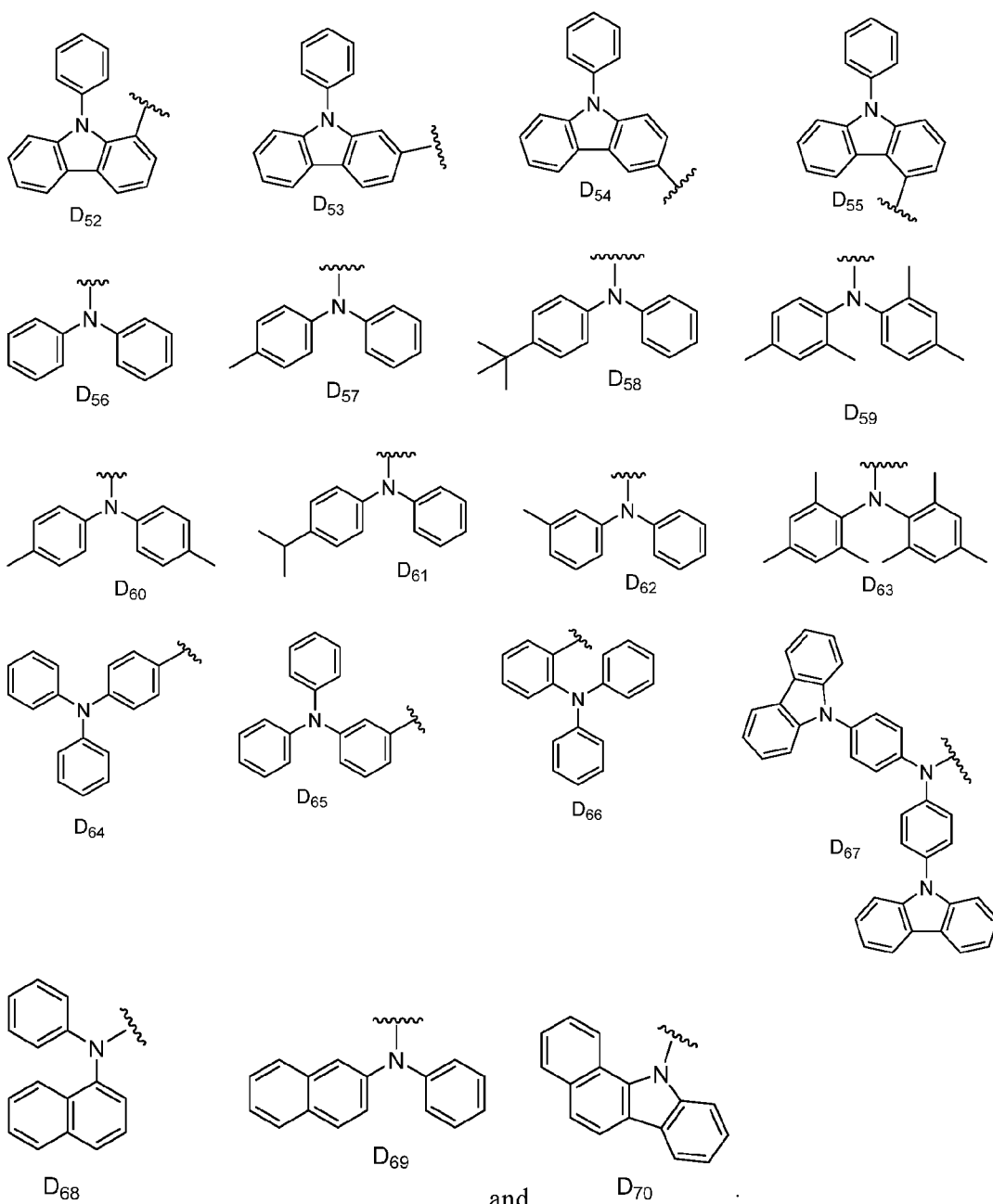




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i is 1, 2, or 3;

j is 1, 2, 3, 4, or 5;

k is 0, 1, 2, 3, or 4;

i + j + k is less than or equal to 6;

10

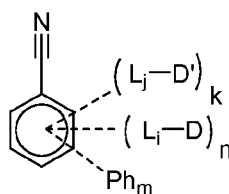
m is 1, 2, or 3;

n is 1, 2, 3, or 4;

p is 0, 1, 2, or 3; and

m + n + p is less than or equal to 5.

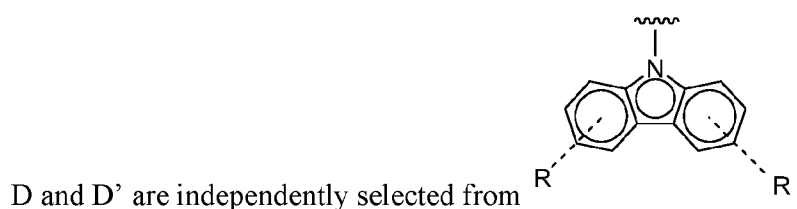
In one aspect, the present disclosure provides compounds of Formula (V)



(V)

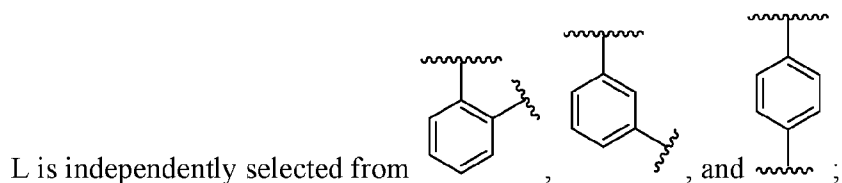
wherein

5           Ph is phenyl;



D and D' are independently selected from

R is independently selected from aryl, alkyl, and heteroaryl;



L is independently selected from

n, and m are each independently an integer greater than 0;

10           k is 0, 1, or 2, or 3;

n + m + k = 5; and

i and j are independently 0 or 1.

15           In another aspect, the present disclosure provides use of the compounds in a device. In some embodiments, provided herein is an organic light-emitting diode (OLED) comprising an anode, a cathode, and at least one organic layer comprising a light-emitting layer between the anode and the cathode, wherein the light-emitting layer comprises:

a host material;

20           a compound of Formula (I), (II), (III), (IV), or (V);

wherein the compound of formula (I), (II), (III), (IV), or (V) is a light-emitting material.

In some embodiments, a compound of Formula (I), (II), (III), (IV), or (V) is used in a screen or a display.

5 In yet another aspect, the present disclosure relates to a method of manufacturing an OLED display, the method comprising:

forming a barrier layer on a base substrate of a mother panel;

forming a plurality of display units in units of cell panels on the barrier layer;

forming an encapsulation layer on each of the display units of the cell panels; and

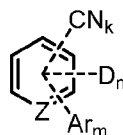
10 applying an organic film to an interface portion between the cell panels.

### BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a schematic wherein 1 denotes a substrate, 2 denotes an anode, 3 denotes a hole injection layer, 4 denotes a hole transporting layer, 5 denotes a light-emitting layer, 6 denotes an electron transporting layer, and 7 denotes a cathode.

### DETAILED DESCRIPTION

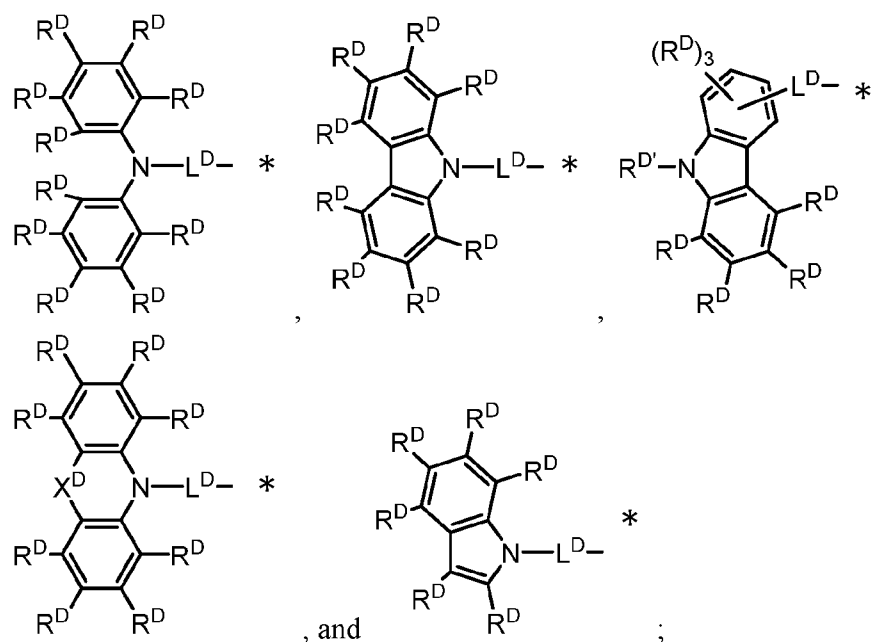
In one aspect, the present disclosure provides compounds of Formula (I):



(I)

wherein

D is independently selected from



$X^D$  is independently selected from O, S,  $NR^{D'}$ ,  $C(O)$ , substituted or unsubstituted methylene, substituted or unsubstituted ethylene, substituted or unsubstituted vinylene, substituted or unsubstituted *o*-arylene, and substituted or unsubstituted *o*-heteroarylene; wherein each instance of methylene, ethylene, vinylene, *o*-arylene or *o*-heteroarylene can be substituted with one or more substituents independently selected from deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl;

two or more instances of  $X^D$  taken together can form a ring system;

$R^D$  is independently selected from hydrogen, deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted alkoxy, substituted or unsubstituted amino, substituted or unsubstituted aryl, substituted or unsubstituted aryloxy, substituted or unsubstituted heteroaryl, substituted or unsubstituted heteroaryloxy, and silyl;

two or more instances of  $R^D$  taken together can form a ring system;

$R^{D'}$  is independently selected from hydrogen, deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted amino, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl;

two or more instances of  $R^{D'}$  and  $R^D$  taken together can form a ring system;

$L^D$  is independently selected from single bond, substituted or unsubstituted arylene, and substituted or unsubstituted heteroarylene; wherein each instance of arylene and heteroarylene can be substituted with one or more substituents independently selected from deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl; two or more of these substituents taken together can form a ring system;

Ar is independently selected from substituted or unsubstituted aryl and substituted or unsubstituted heteroaryl, wherein the substituted or unsubstituted heteroaryl does not contain a nitrogen atom; and wherein each instance of aryl, and heteroaryl can be substituted with one or more substituents independently selected from deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl; two or more of these substituents taken together can form a ring system;

Z is N or CR;

R is H, CN, D or Ar;

k is 1 to 3;

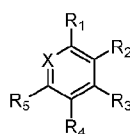
m is 0 to 4;

n is 1 to 5;

(k + m + n) is less than or equal to 5; and

each “\*” represents a point of attachment to Formula (I).

In one aspect, the present disclosure provides compounds of Formula (II):



(II)

wherein

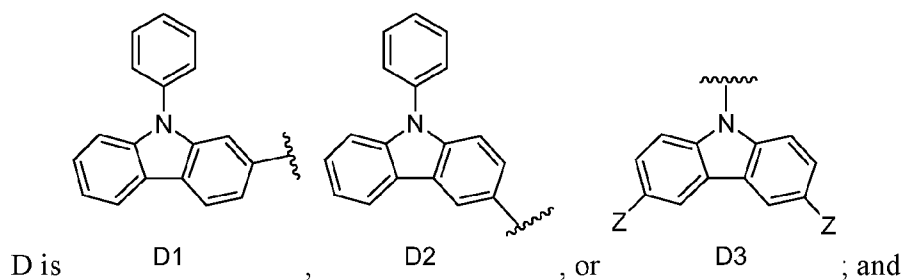
X is N or CR<sub>6</sub>;

R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, and R<sub>6</sub> are independently selected from the group consisting of A, D, H, and Ph;

at least one of  $R_1$ ,  $R_2$ ,  $R_3$ ,  $R_4$ ,  $R_5$ , and  $R_6$  is A;

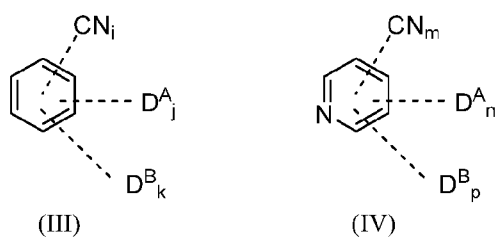
at least one of  $R_1$ ,  $R_2$ ,  $R_3$ ,  $R_4$ ,  $R_5$ , and  $R_6$  is D;

A is CN;



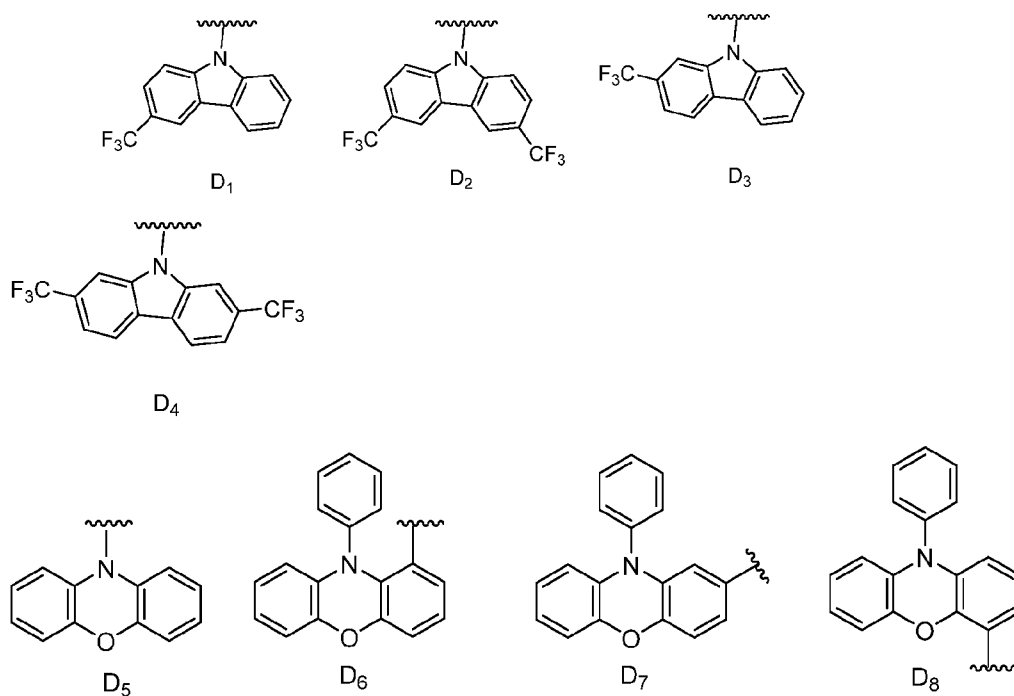
5 Z is independently H, Me, or Ph.

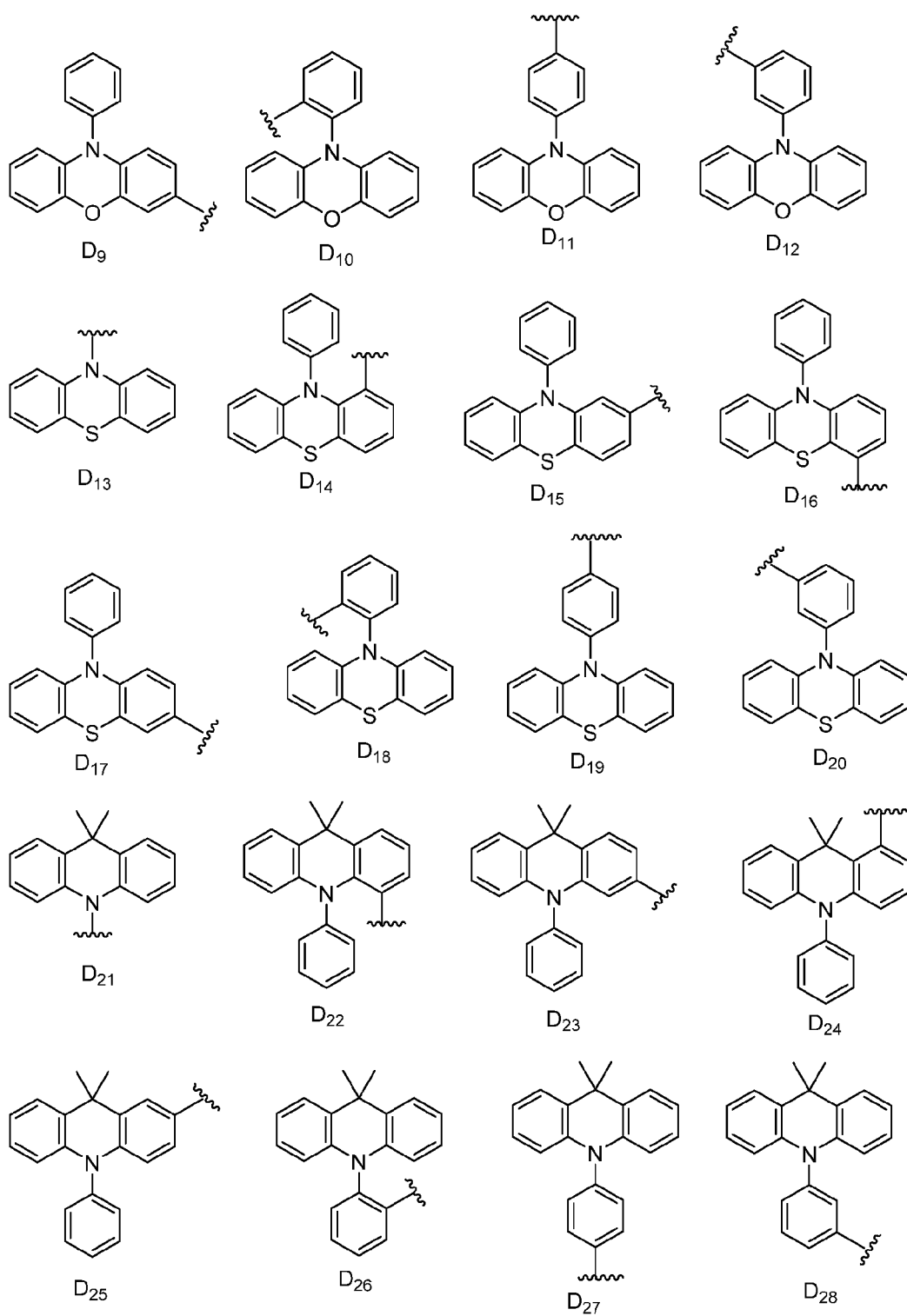
In one aspect, the present disclosure provides compounds of Formula (III) or Formula (IV):

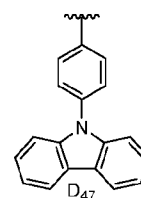
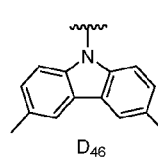
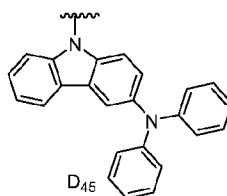
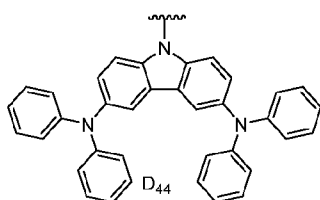
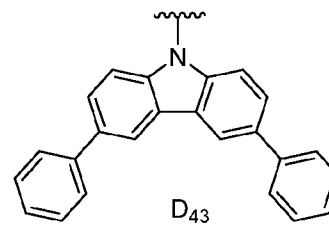
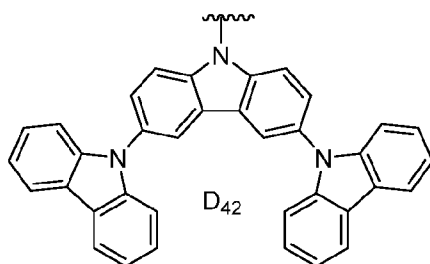
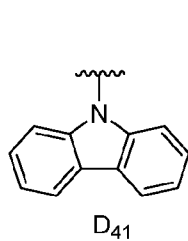
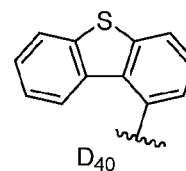
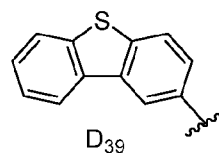
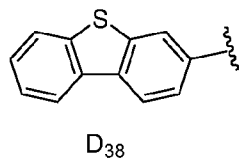
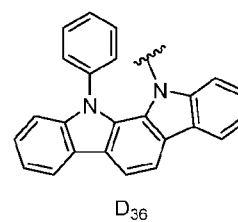
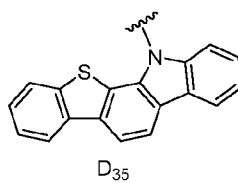
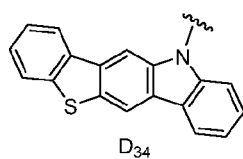
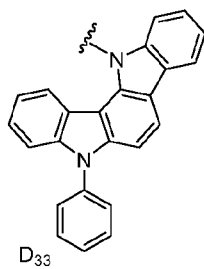
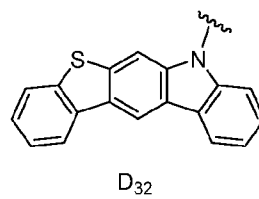
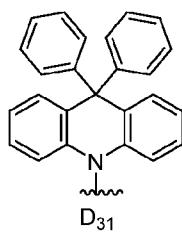
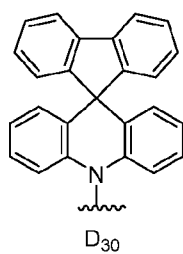
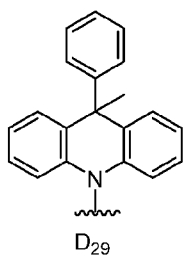


10 wherein

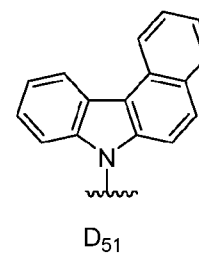
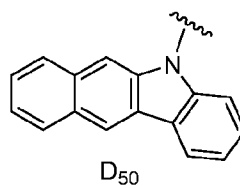
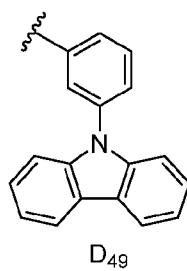
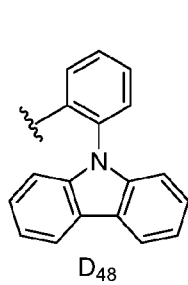
$D^A$  and  $D^B$  are independently selected from



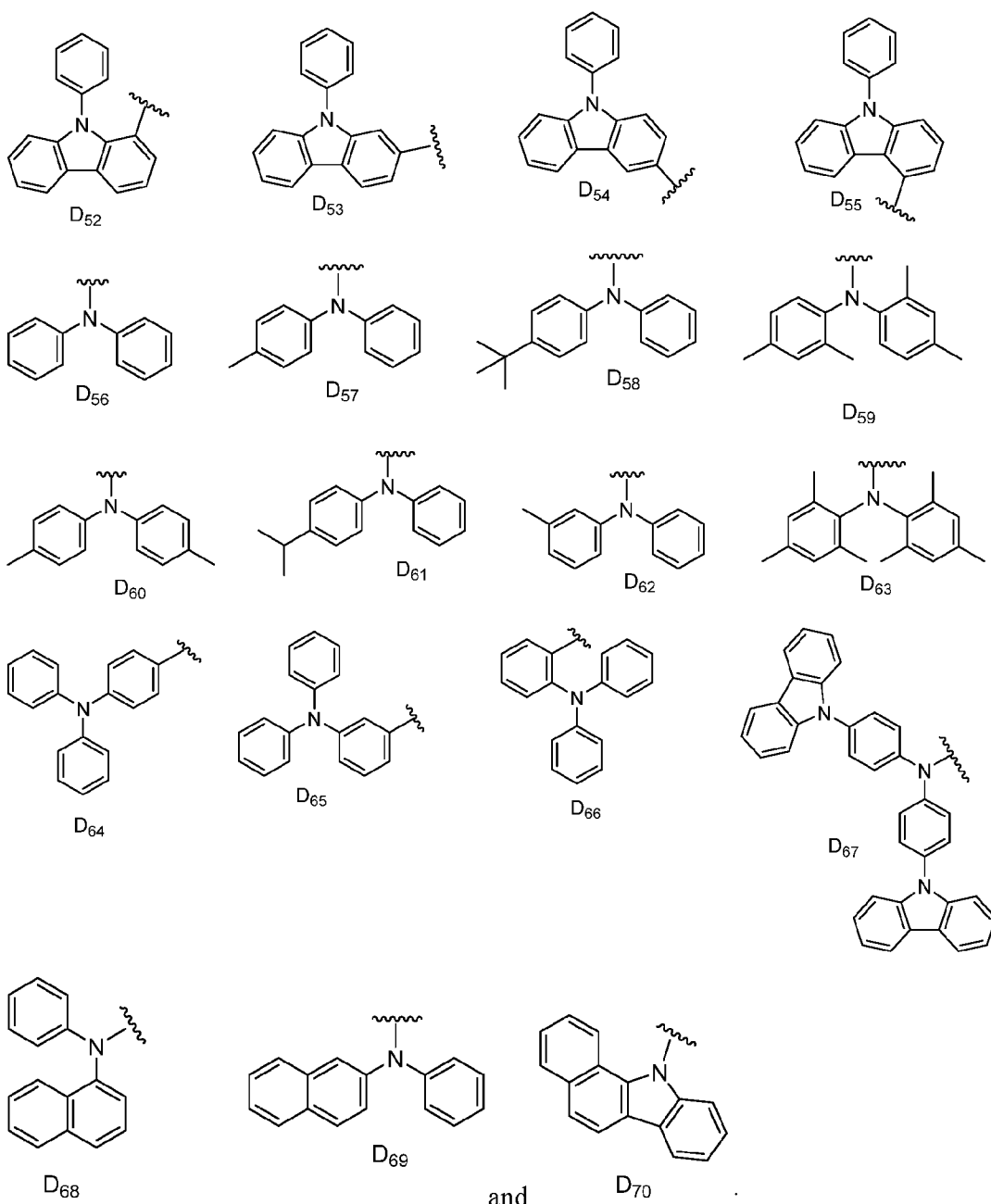




5







5

and

;

i is 1, 2, or 3;

j is 1, 2, 3, 4, or 5;

k is 0, 1, 2, 3, or 4;

i + j + k is less than or equal to 6;

10

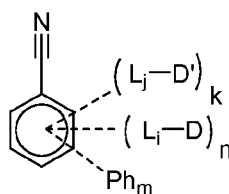
m is 1, 2, or 3;

n is 1, 2, 3, or 4;

p is 0, 1, 2, or 3; and

m + n + p is less than or equal to 5.

In one aspect, the present disclosure provides compounds of Formula (V)

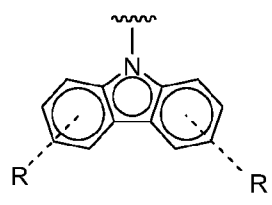


(V)

wherein

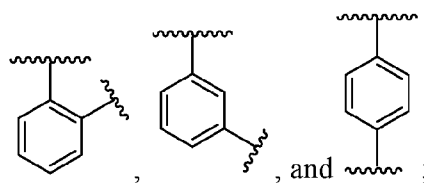
5        Ph is phenyl;

D and D' are independently selected from



R is independently selected from aryl, alkyl, and heteroaryl;

L is independently selected from



n, and m are each independently an integer greater than 0;

10        k is 0, 1, or 2, or 3;

n + m + k = 5; and

i and j are independently 0 or 1.

The examples are provided by way of explanation of the disclosure, and not by way of limitation of the disclosure. In fact, it will be apparent to those skilled in the art that various modification and variations can be made in the present disclosure without departing from the scope or spirit of the disclosure. For instance, features illustrated or described as part of one embodiment can be used on another embodiment to yield a still further embodiment. Thus it is intended that the present disclosure cover such modifications and variations as come within the scope of the appended claims and their equivalents. Other objects, features, and aspects of the present disclosure are disclosed in, or can be derived from, the following detailed description. It is to be understood by

15

20

one of ordinary skill in the art that the present discussion is a description of exemplary embodiments only, and is not to be construed as limiting the broader aspects of the present disclosure.

### *Definitions*

5 Unless otherwise defined herein, scientific and technical terms used in this application shall have the meanings that are commonly understood by those of ordinary skill in the art. Generally, nomenclature used in connection with, and techniques of, chemistry described herein, are those well-known and commonly used in the art.

The term “acyl” is art-recognized and refers to a group represented by the general  
10 formula hydrocarbylC(O)-, preferably alkylC(O)-.

The term “acylamino” is art-recognized and refers to an amino group substituted with an acyl group and may be represented, for example, by the formula hydrocarbylC(O)NH-.

The term “acyloxy” is art-recognized and refers to a group represented by the  
15 general formula hydrocarbylC(O)O-, preferably alkylC(O)O-.

The term “alkoxy” refers to an alkyl group, having an oxygen attached thereto. Representative alkoxy groups include methoxy, trifluoromethoxy, ethoxy, propoxy, tert-butoxy and the like.

The term “alkoxyalkyl” refers to an alkyl group substituted with an alkoxy group  
20 and may be represented by the general formula alkyl-O-alkyl.

The term “alkenyl”, as used herein, refers to an aliphatic group comprising at least one double bond and is intended to include both “unsubstituted alkenyls” and “substituted alkenyls”, the latter of which refers to alkenyl moieties having substituents replacing a hydrogen on one or more carbons of the alkenyl group. Typically, a straight  
25 chained or branched alkenyl group has from 1 to about 20 carbon atoms, preferably from 1 to about 10 unless otherwise defined. Such substituents may occur on one or more carbons that are included or not included in one or more double bonds. Moreover, such substituents include all those contemplated for alkyl groups, as discussed below, except where stability is prohibitive. For example, substitution of alkenyl groups by one or more  
30 alkyl, carbocyclyl, aryl, heterocyclyl, or heteroaryl groups is contemplated.

An “alkyl” group or “alkane” is a straight chained or branched non-aromatic hydrocarbon which is completely saturated. Typically, a straight chained or branched

alkyl group has from 1 to about 20 carbon atoms, preferably from 1 to about 10 unless otherwise defined. In some embodiments, the alkyl group has from 1 to 8 carbon atoms, from 1 to 6 carbon atoms, from 1 to 4 carbon atoms, or from 1 to 3 carbon atoms.

5 Examples of straight chained and branched alkyl groups include methyl, ethyl, n-propyl, iso-propyl, n-butyl, sec-butyl, tert-butyl, pentyl, hexyl, pentyl and octyl.

Moreover, the term “alkyl” as used throughout the specification, examples, and claims is intended to include both “unsubstituted alkyls” and “substituted alkyls”, the latter of which refers to alkyl moieties having substituents replacing a hydrogen on one or more substitutable carbons of the hydrocarbon backbone. Such substituents, if not  
10 otherwise specified, can include, for example, a halogen (e.g., fluoro), a hydroxyl, a carbonyl (such as a carboxyl, an alkoxy carbonyl, a formyl, or an acyl), a thiocarbonyl (such as a thioester, a thioacetate, or a thioformate), an alkoxy, a phosphoryl, a phosphate, a phosphonate, a phosphinate, an amino, an amido, an amidine, an imine, a cyano, a nitro, an azido, a sulfhydryl, an alkylthio, a sulfate, a sulfonate, a sulfamoyl, a  
15 sulfonamido, a sulfonyl, a heterocyclyl, an aralkyl, or an aromatic or heteroaromatic moiety. In preferred embodiments, the substituents on substituted alkyls are selected from C<sub>1-6</sub> alkyl, C<sub>3-6</sub> cycloalkyl, halogen, carbonyl, cyano, or hydroxyl. In more preferred embodiments, the substituents on substituted alkyls are selected from fluoro, carbonyl, cyano, or hydroxyl. It will be understood by those skilled in the art that the moieties  
20 substituted on the hydrocarbon chain can themselves be substituted, if appropriate. For instance, the substituents of a substituted alkyl may include substituted and unsubstituted forms of amino, azido, imino, amido, phosphoryl (including phosphonate and phosphinate), sulfonyl (including sulfate, sulfonamido, sulfamoyl and sulfonate), and silyl groups, as well as ethers, alkylthios, carbonyls (including ketones, aldehydes,  
25 carboxylates, and esters), -CF<sub>3</sub>, -CN and the like. Exemplary substituted alkyls are described below. Cycloalkyls can be further substituted with alkyls, alkenyls, alkoxy, alkylthios, aminoalkyls, carbonyl-substituted alkyls, -CF<sub>3</sub>, -CN, and the like.

The term “C<sub>x-y</sub>” when used in conjunction with a chemical moiety, such as, acyl, acyloxy, alkyl, alkenyl, alkynyl, or alkoxy is meant to include groups that contain from x  
30 to y carbons in the chain. For example, the term “C<sub>x-y</sub> alkyl” refers to substituted or unsubstituted saturated hydrocarbon groups, including straight-chain alkyl and branched-chain alkyl groups that contain from x to y carbons in the chain, including haloalkyl groups. Preferred haloalkyl groups include trifluoromethyl, difluoromethyl, 2,2,2-trifluoroethyl, and pentafluoroethyl. C<sub>0</sub> alkyl indicates a hydrogen where the group is in a

terminal position, a bond if internal. The terms “C<sub>2-y</sub> alkenyl” and “C<sub>2-y</sub> alkynyl” refer to substituted or unsubstituted unsaturated aliphatic groups analogous in length and possible substitution to the alkyls described above, but that contain at least one double or triple bond respectively.

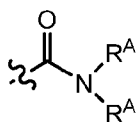
5           The term “alkylamino”, as used herein, refers to an amino group substituted with at least one alkyl group.

          The term “alkylthio”, as used herein, refers to a thiol group substituted with an alkyl group and may be represented by the general formula alkylS-

10           The term “arylthio”, as used herein, refers to a thiol group substituted with an alkyl group and may be represented by the general formula arylS-

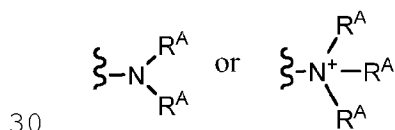
          The term “alkynyl”, as used herein, refers to an aliphatic group comprising at least one triple bond and is intended to include both “unsubstituted alkynyls” and “substituted alkynyls”, the latter of which refers to alkynyl moieties having substituents replacing a hydrogen on one or more carbons of the alkynyl group. Typically, a straight  
15           chained or branched alkynyl group has from 1 to about 20 carbon atoms, preferably from 1 to about 10 unless otherwise defined. Such substituents may occur on one or more carbons that are included or not included in one or more triple bonds. Moreover, such substituents include all those contemplated for alkyl groups, as discussed above, except where stability is prohibitive. For example, substitution of alkynyl groups by one or more  
20           alkyl, carbocyclyl, aryl, heterocyclyl, or heteroaryl groups is contemplated.

          The term “amide”, as used herein, refers to a group



25           wherein each R<sup>A</sup> independently represent a hydrogen or hydrocarbyl group, or two R<sup>A</sup> are taken together with the N atom to which they are attached complete a heterocycle having from 4 to 8 atoms in the ring structure.

          The terms “amine” and “amino” are art-recognized and refer to both unsubstituted and substituted amines and salts thereof, e.g., a moiety that can be represented by



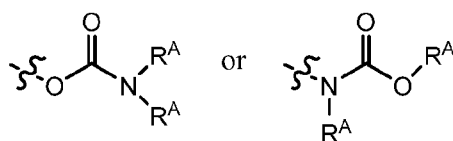
wherein each  $R^A$  independently represents a hydrogen or a hydrocarbyl group, or two  $R^A$  are taken together with the N atom to which they are attached complete a heterocycle having from 4 to 8 atoms in the ring structure.

The term “aminoalkyl”, as used herein, refers to an alkyl group substituted with an amino group.

The term “aralkyl”, as used herein, refers to an alkyl group substituted with an aryl group.

The term “aryl” as used herein include substituted or unsubstituted single-ring aromatic groups in which each atom of the ring is carbon. Preferably the ring is a 6- or 20-membered ring, more preferably a 6-membered ring. The term “aryl” also includes polycyclic ring systems having two or more cyclic rings in which two or more carbons are common to two adjoining rings wherein at least one of the rings is aromatic, e.g., the other cyclic rings can be cycloalkyls, cycloalkenyls, cycloalkynyls, aryls, heteroaryls, and/or heterocyclyls. Aryl groups include benzene, naphthalene, phenanthrene, phenol, aniline, and the like.

The term “carbamate” is art-recognized and refers to a group



wherein each  $R^A$  independently represent hydrogen or a hydrocarbyl group, such as an alkyl group, or both  $R^A$  taken together with the intervening atom(s) complete a heterocycle having from 4 to 8 atoms in the ring structure.

The terms “carbocycle”, and “carbocyclic”, as used herein, refers to a saturated or unsaturated ring in which each atom of the ring is carbon. Preferably, a carbocyclic group has from 3 to 20 carbon atoms. The term carbocycle includes both aromatic carbocycles and non-aromatic carbocycles. Non-aromatic carbocycles include both cycloalkane rings, in which all carbon atoms are saturated, and cycloalkene rings, which contain at least one double bond. “Carbocycle” includes 5-7 membered monocyclic and 8-12 membered bicyclic rings. Each ring of a bicyclic carbocycle may be selected from saturated, unsaturated and aromatic rings. Carbocycle includes bicyclic molecules in which one, two or three or more atoms are shared between the two rings. The term “fused carbocycle” refers to a bicyclic carbocycle in which each of the rings shares two adjacent atoms with the other ring. Each ring of a fused carbocycle may be selected from saturated, unsaturated and aromatic rings. In an exemplary embodiment, an aromatic

ring, e.g., phenyl (Ph), may be fused to a saturated or unsaturated ring, e.g., cyclohexane, cyclopentane, or cyclohexene. Any combination of saturated, unsaturated and aromatic bicyclic rings, as valence permits, is included in the definition of carbocyclic. Exemplary “carbocycles” include cyclopentane, cyclohexane, bicyclo[2.2.1]heptane, 1,5-  
5 cyclooctadiene, 1,2,3,4-tetrahydronaphthalene, bicyclo[4.2.0]oct-3-ene, naphthalene and adamantane. Exemplary fused carbocycles include decalin, naphthalene, 1,2,3,4-tetrahydronaphthalene, bicyclo[4.2.0]octane, 4,5,6,7-tetrahydro-1H-indene and bicyclo[4.1.0]hept-3-ene. “Carbocycles” may be substituted at any one or more positions capable of bearing a hydrogen atom.

10 A “cycloalkyl” group is a cyclic hydrocarbon which is completely saturated. “Cycloalkyl” includes monocyclic and bicyclic rings. Preferably, a cycloalkyl group has from 3 to 20 carbon atoms. Typically, a monocyclic cycloalkyl group has from 3 to about 10 carbon atoms, more typically 3 to 8 carbon atoms unless otherwise defined. The second ring of a bicyclic cycloalkyl may be selected from saturated, unsaturated and  
15 aromatic rings. Cycloalkyl includes bicyclic molecules in which one, two or three or more atoms are shared between the two rings. The term “fused cycloalkyl” refers to a bicyclic cycloalkyl in which each of the rings shares two adjacent atoms with the other ring. The second ring of a fused bicyclic cycloalkyl may be selected from saturated, unsaturated and aromatic rings. A “cycloalkenyl” group is a cyclic hydrocarbon  
20 comprising one or more double bonds.

The term “carbocyclalkyl”, as used herein, refers to an alkyl group substituted with a carbocycle group.

The term “carbonate”, as used herein, refers to a group  $-\text{OCO}_2\text{-R}^{\text{A}}$ , wherein  $\text{R}^{\text{A}}$  represents a hydrocarbyl group.

25 The term “carboxy”, as used herein, refers to a group represented by the formula  $-\text{CO}_2\text{H}$ .

The term “ester”, as used herein, refers to a group  $-\text{C}(\text{O})\text{OR}^{\text{A}}$  wherein  $\text{R}^{\text{A}}$  represents a hydrocarbyl group.

The term “ether”, as used herein, refers to a hydrocarbyl group linked through an  
30 oxygen to another hydrocarbyl group. Accordingly, an ether substituent of a hydrocarbyl group may be hydrocarbyl-O-. Ethers may be either symmetrical or unsymmetrical. Examples of ethers include, but are not limited to, heterocycle-O-heterocycle and aryl-O-

heterocycle. Ethers include “alkoxyalkyl” groups, which may be represented by the general formula alkyl-O-alkyl.

The terms “halo” and “halogen” as used herein means halogen and includes chloro, fluoro, bromo, and iodo.

5       The terms “hetaralkyl” and “heteroaralkyl”, as used herein, refers to an alkyl group substituted with a hetaryl group.

The term “heteroalkyl”, as used herein, refers to a saturated or unsaturated chain of carbon atoms and at least one heteroatom, wherein no two heteroatoms are adjacent.

10       The terms “heteroaryl” and “hetaryl” include substituted or unsubstituted aromatic single ring structures, preferably 5- to 20-membered rings, more preferably 5- to 6-membered rings, whose ring structures include at least one heteroatom, preferably one to four heteroatoms, more preferably one or two heteroatoms. The terms “heteroaryl” and “hetaryl” also include polycyclic ring systems having two or more cyclic rings in which two or more carbons are common to two adjoining rings wherein at least one of the rings is heteroaromatic, e.g., the other cyclic rings can be cycloalkyls, cycloalkenyls, cycloalkynyls, aryls, heteroaryls, and/or heterocyclyls. Heteroaryl groups include, for example, pyrrole, furan, thiophene, imidazole, oxazole, thiazole, pyrazole, pyridine, pyrazine, pyridazine, pyrimidine, and carbazole, and the like.

15       The term “heteroatom” as used herein means an atom of any element other than carbon or hydrogen. Preferred heteroatoms are nitrogen, oxygen, and sulfur.

20       The terms “heterocyclyl”, “heterocycle”, and “heterocyclic” refer to substituted or unsubstituted non-aromatic ring structures, preferably 3- to 20-membered rings, more preferably 3- to 7-membered rings, whose ring structures include at least one heteroatom, preferably one to four heteroatoms, more preferably one or two heteroatoms. The terms “heterocyclyl” and “heterocyclic” also include polycyclic ring systems having two or more cyclic rings in which two or more carbons are common to two adjoining rings wherein at least one of the rings is heterocyclic, e.g., the other cyclic rings can be cycloalkyls, cycloalkenyls, cycloalkynyls, aryls, heteroaryls, and/or heterocyclyls. Heterocyclyl groups include, for example, piperidine, piperazine, pyrrolidine, morpholine, lactones, lactams, and the like.

25       The term “heterocyclylalkyl”, as used herein, refers to an alkyl group substituted with a heterocycle group.

The term “hydrocarbyl”, as used herein, refers to a group that is bonded through a carbon atom, wherein that carbon atom does not have a =O or =S substituent.



Hydrocarbyls may optionally include heteroatoms. Hydrocarbyl groups include, but are not limited to, alkyl, alkenyl, alkynyl, alkoxyalkyl, aminoalkyl, aralkyl, aryl, aralkyl, carbocyclyl, cycloalkyl, carbocyclylalkyl, heteroaralkyl, heteroaryl groups bonded through a carbon atom, heterocyclyl groups bonded through a carbon atom,

5 heterocyclylakyl, or hydroxyalkyl. Thus, groups like methyl, ethoxyethyl, 2-pyridyl, and trifluoromethyl are hydrocarbyl groups, but substituents such as acetyl (which has a =O substituent on the linking carbon) and ethoxy (which is linked through oxygen, not carbon) are not.

10 The term “hydroxyalkyl”, as used herein, refers to an alkyl group substituted with a hydroxy group.

The term “lower” when used in conjunction with a chemical moiety, such as, acyl, acyloxy, alkyl, alkenyl, alkynyl, or alkoxy is meant to include groups where there are six or fewer non-hydrogen atoms in the substituent. A “lower alkyl”, for example, refers to an alkyl group that contains six or fewer carbon atoms. In some embodiments, the alkyl group has from 1 to 6 carbon atoms, from 1 to 4 carbon atoms, or from 1 to 3 carbon atoms. In certain embodiments, acyl, acyloxy, alkyl, alkenyl, alkynyl, or alkoxy substituents defined herein are respectively lower acyl, lower acyloxy, lower alkyl, lower alkenyl, lower alkynyl, or lower alkoxy, whether they appear alone or in combination with other substituents, such as in the recitations hydroxyalkyl and aralkyl (in which case, for example, the atoms within the aryl group are not counted when counting the carbon atoms in the alkyl substituent).

20 The terms “polycyclyl”, “polycycle”, and “polycyclic” refer to two or more rings (e.g., cycloalkyls, cycloalkenyls, cycloalkynyls, aryls, heteroaryls, and/or heterocyclyls) in which two or more atoms are common to two adjoining rings, e.g., the rings are “fused rings”. Each of the rings of the polycycle can be substituted or unsubstituted. In certain embodiments, each ring of the polycycle contains from 3 to 10 atoms in the ring, preferably from 5 to 7.

25 In the phrase “poly(*meta*-phenylene oxides)”, the term “phenylene” refers inclusively to 6-membered aryl or 6-membered heteroaryl moieties. Exemplary poly(*meta*-phenylene oxides) are described in the first through twentieth aspects of the present disclosure.

The term “silyl” refers to a silicon moiety with three hydrocarbyl moieties attached thereto.

The term “substituted” refers to moieties having substituents replacing a hydrogen on one or more carbons of the backbone. It will be understood that “substitution” or “substituted with” includes the implicit proviso that such substitution is in accordance with permitted valence of the substituted atom and the substituent, and that the substitution results in a stable compound, e.g., which does not spontaneously undergo transformation such as by rearrangement, cyclization, elimination, etc. Moieties that may be substituted can include any appropriate substituents described herein, for example, acyl, acylamino, acyloxy, alkoxy, alkoxyalkyl, alkenyl, alkyl, alkylamino, alkylthio, arylthio, alkynyl, amide, amino, aminoalkyl, aralkyl, carbamate, carbocyclyl, cycloalkyl, carbocyclylalkyl, carbonate, ester, ether, heteroaralkyl, heterocyclyl, heterocyclylalkyl, hydrocarbyl, silyl, sulfone, or thioether. As used herein, the term “substituted” is contemplated to include all permissible substituents of organic compounds. In a broad aspect, the permissible substituents include acyclic and cyclic, branched and unbranched, carbocyclic and heterocyclic, aromatic and non-aromatic substituents of organic compounds. The permissible substituents can be one or more and the same or different for appropriate organic compounds. For purposes of this invention, the heteroatoms such as nitrogen may have hydrogen substituents and/or any permissible substituents of organic compounds described herein which satisfy the valences of the heteroatoms. Substituents can include any substituents described herein, for example, a halogen, a hydroxyl, a carbonyl (such as a carboxyl, an alkoxy carbonyl, a formyl, or an acyl), a thiocarbonyl (such as a thioester, a thioacetate, or a thioformate), an alkoxy, a phosphoryl, a phosphate, a phosphonate, a phosphinate, an amino, an amido, an amidine, an imine, a cyano, a nitro, an azido, a sulfhydryl, an alkylthio, a sulfate, a sulfonate, a sulfamoyl, a sulfonamido, a sulfonyl, a heterocyclyl, an aralkyl, or an aromatic or heteroaromatic moiety. In preferred embodiments, the substituents on substituted alkyls are selected from C<sub>1-6</sub> alkyl, C<sub>3-6</sub> cycloalkyl, halogen, carbonyl, cyano, or hydroxyl. In more preferred embodiments, the substituents on substituted alkyls are selected from fluoro, carbonyl, cyano, or hydroxyl. It will be understood by those skilled in the art that substituents can themselves be substituted, if appropriate. Unless specifically stated as “unsubstituted,” references to chemical moieties herein are understood to include substituted variants. For example, reference to an “aryl” group or moiety implicitly includes both substituted and unsubstituted variants.

The term “sulfonate” is art-recognized and refers to the group SO<sub>3</sub>H, or a pharmaceutically acceptable salt thereof.

The term "sulfone" is art-recognized and refers to the group  $-S(O)_2-R^A$ , wherein  $R^A$  represents a hydrocarbonyl.

The term "thioether", as used herein, is equivalent to an ether, wherein the oxygen is replaced with a sulfur.

5       The term "symmetrical molecule," as used herein, refers to molecules that are group symmetric or synthetic symmetric. The term "group symmetric," as used herein, refers to molecules that have symmetry according to the group theory of molecular symmetry. The term "synthetic symmetric," as used herein, refers to molecules that are selected such that no regioselective synthetic strategy is required.

10       The term "donor," as used herein, refers to a molecular fragment that can be used in organic light-emitting diodes and is likely to donate electrons from its highest occupied molecular orbital to an acceptor upon excitation. In an example embodiment, donors have an ionization potential greater than or equal to -6.5 eV.

15       The term "acceptor," as used herein, refers to a molecular fragment that can be used in organic light-emitting diodes and is likely to accept electrons into its lowest unoccupied molecular orbital from a donor that has been subject to excitation. In an example embodiment, acceptors have an electron affinity less than or equal to -0.5 eV.

20       The term "bridge," as used herein, refers to a molecular fragment that can be included in a molecule which is covalently linked between acceptor and donor moieties. The bridge can, for example, be further conjugated to the acceptor moiety, the donor moiety, or both. Without being bound to any particular theory, it is believed that the bridge moiety can sterically restrict the acceptor and donor moieties into a specific configuration, thereby preventing the overlap between the conjugated  $\pi$  system of donor and acceptor moieties. Examples of suitable bridge moieties include phenyl, ethenyl, and  
25       ethynyl.

      The term "multivalent," as used herein, refers to a molecular fragment that is connected to at least two other molecular fragments. For example, a bridge moiety, is multivalent.

      "~~link~~" as used herein, refers to a point of attachment between two atoms.

30       "Hole transport layer (HTL)" and like terms mean a layer made from a material which transports holes. High hole mobility is recommended. The HTL is used to help block passage of electrons transported by the emitting layer. Low electron affinity is typically required to block electrons. The HTL should desirably have larger triplets to block exciton migrations from an adjacent emissive layer (EML). Examples of HTL

compounds include, but are not limited to, di(p-tolyl)aminophenyl]cyclohexane (TAPC), N,N-diphenyl-N,N-bis(3-methylphenyl)-1,1-biphenyl-4,4-diamine (TPD), and N,N'-diphenyl-N,N'-bis(1-naphthyl)-(1,1'-biphenyl)-4,4'-diamine (NPB,  $\alpha$ -NPD).

"Emitting layer" and like terms mean a layer which consists of host and dopant.

5 The host material could be bipolar or unipolar, and may be used alone or by combination of two or more host materials. The opto-electrical properties of the host material may differ to which type of dopant (Phosphorescent or Fluorescent) is used. For Fluorescent dopants, the assisting host materials should have good spectral overlap between adsorption of the dopant and emission of the host to induce good Förster transfer to  
10 dopants. For Phosphorescent dopants, the assisting host materials should have high triplet energy to confine triplets of the dopant.

"Dopant" and like terms, refer to an electron acceptor or a donator that increases the conductivity of an organic layer of an organic electronic device, when added to the organic layer as an additive. Organic semiconductors may likewise be influenced, with  
15 regard to their electrical conductivity, by doping. Such organic semiconducting matrix materials may be made up either of compounds with electron-donor properties or of compounds with electron-acceptor properties.

In the compounds of this invention any atom not specifically designated as a particular isotope is meant to represent any stable isotope of that atom. Unless otherwise  
20 stated, when a position is designated specifically as "H" or "hydrogen", the position is understood to have hydrogen at its natural abundance isotopic composition. Also unless otherwise stated, when a position is designated specifically as "D" or "deuterium", the position is understood to have deuterium at an abundance that is at least 3340 times greater than the natural abundance of deuterium, which is 0.015% (i.e., at least 50.1%  
25 incorporation of deuterium).

The term "isotopic enrichment factor" as used herein means the ratio between the isotopic abundance and the natural abundance of a specified isotope.

In various embodiments, compounds of this invention have an isotopic enrichment factor for each designated deuterium atom of at least 3500 (52.5% deuterium  
30 incorporation at each designated deuterium atom), at least 4000 (60% deuterium incorporation), at least 4500 (67.5% deuterium incorporation), at least 5000 (75% deuterium), at least 5500 (82.5% deuterium incorporation), at least 6000 (90% deuterium incorporation), at least 6333.3 (95% deuterium incorporation), at least 6466.7 (97%

deuterium incorporation), at least 6600 (99% deuterium incorporation), or at least 6633.3 (99.5% deuterium incorporation).

The term “isotopologue” refers to a species that differs from a specific compound of this invention only in the isotopic composition thereof.

5       The term “compound,” when referring to a compound of this invention, refers to a collection of molecules having an identical chemical structure, except that there may be isotopic variation among the constituent atoms of the molecules. Thus, it will be clear to those of skill in the art that a compound represented by a particular chemical structure containing indicated deuterium atoms, will also contain lesser amounts of isotopologues  
10       having hydrogen atoms at one or more of the designated deuterium positions in that structure. The relative amount of such isotopologues in a compound of this invention will depend upon a number of factors including the isotopic purity of deuterated reagents used to make the compound and the efficiency of incorporation of deuterium in the various synthesis steps used to prepare the compound. However, as set forth above the  
15       relative amount of such isotopologues *in toto* will be less than 49.9% of the compound. In other embodiments, the relative amount of such isotopologues *in toto* will be less than 47.5%, less than 40%, less than 32.5%, less than 25%, less than 17.5%, less than 10%, less than 5%, less than 3%, less than 1%, or less than 0.5% of the compound.

“D” and “d” both refer to deuterium.

20       “Substituted with deuterium” refers to the replacement of one or more hydrogen atoms with a corresponding number of deuterium atoms.

### *Principles of OLED*

OLEDs are typically composed of a layer of organic materials or compounds between two electrodes, an anode and a cathode. The organic molecules are electrically  
25       conductive as a result of delocalization of  $\pi$  electronics caused by conjugation over part or all of the molecule. When voltage is applied, electrons from the highest occupied molecular orbital (HOMO) present at the anode flow into the lowest unoccupied molecular orbital (LUMO) of the organic molecules present at the cathode. Removal of electrons from the HOMO is also referred to as inserting electron holes into the HOMO.  
30       Electrostatic forces bring the electrons and the holes towards each other until they recombine and form an exciton (which is the bound state of the electron and the hole). As the excited state decays and the energy levels of the electrons relax, radiation having

a frequency in the visible spectrum is emitted. The frequency of this radiation depends on the band gap of the material, which is the difference in energy between the HOMO and the LUMO.

As electrons and holes are fermions with half integer spin, an exciton may either  
5 be in a singlet state or a triplet state depending on how the spins of the electron and hole have been combined. Statistically, three triplet excitons will be formed for each singlet exciton. Decay from triplet states is spin forbidden, which results in increases in the timescale of the transition and limits the internal efficiency of fluorescent devices. Phosphorescent organic light-emitting diodes make use of spin-orbit interactions to  
10 facilitate intersystem crossing between singlet and triplet states, thus obtaining emission from both singlet and triplet states and improving the internal efficiency.

One prototypical phosphorescent material is iridium tris(2-phenylpyridine) ( $\text{Ir(ppy)}_3$ ) in which the excited state is a charge transfer from the Ir atom to the organic ligand. Such approaches have reduced the triplet lifetime to about several  $\mu\text{s}$ , several  
15 orders of magnitude slower than the radiative lifetimes of fully-allowed transitions such as fluorescence. Ir-based phosphors have proven to be acceptable for many display applications, but losses due to large triplet densities still prevent the application of OLEDs to solid-state lighting at higher brightness.

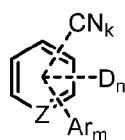
Thermally activated delayed fluorescence (TADF) seeks to minimize energetic  
20 splitting between singlet and triplet states ( $\Delta$ ,  $\Delta E_{\text{ST}}$ ). The reduction in exchange splitting from typical values of 0.4-0.7 eV to a gap of the order of the thermal energy (proportional to  $k_B T$ , where  $k_B$  represents the Boltzmann constant, and  $T$  represents temperature) means that thermal agitation can transfer population between singlet levels and triplet sublevels in a relevant timescale even if the coupling between states is small.

TADF molecules consist of donor and acceptor moieties connected directly by a  
25 covalent bond or via a conjugated linker (or "bridge"). A "donor" moiety is likely to transfer electrons from its HOMO upon excitation to the "acceptor" moiety. An "acceptor" moiety is likely to accept the electrons from the "donor" moiety into its LUMO. The donor-acceptor nature of TADF molecules results in low-lying excited  
30 states with charge-transfer character that exhibit very low  $\Delta$ . Since thermal molecular motions can randomly vary the optical properties of donor-acceptor systems, a rigid three-dimensional arrangement of donor and acceptor moieties can be used to limit the non-radiative decay of the charge-transfer state by internal conversion during the lifetime of the excitation.

It is beneficial, therefore, to decrease energetic splitting between singlet and triplet states ( $\Delta$ ), and to create a system with increased reversed intersystem crossing (RISC) capable of exploiting triplet excitons. Such a system, it is believed, will result in decreased emission lifetimes. Systems with these features will be capable of emitting  
 5 blue light without being subject to the rapid degradation prevalent in blue OLEDs known today.

### Compounds of the Disclosure

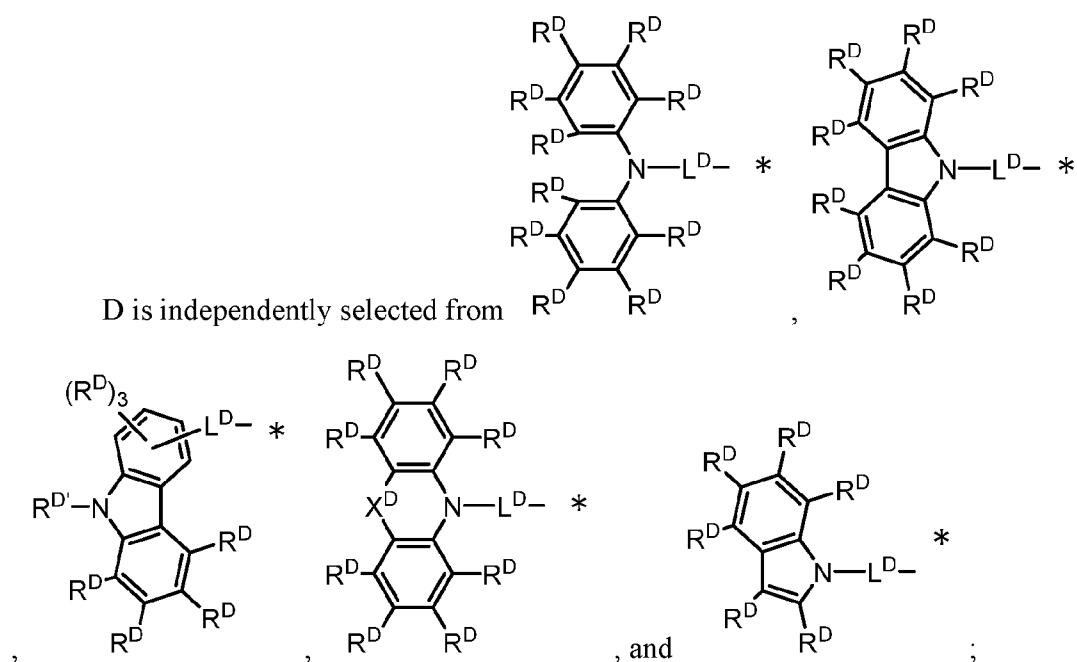
In some embodiments, the compounds have a structure of Formula (I):



10

(I)

wherein



$X^D$  is independently selected from O, S,  $NR^{D'}$ ,  $C(O)$ , substituted or unsubstituted  
 15 methylene, substituted or unsubstituted ethylene, substituted or unsubstituted vinylene, substituted or unsubstituted *o*-arylene, and substituted or unsubstituted *o*-heteroarylene; wherein each instance of methylene, ethylene, vinylene, *o*-arylene or *o*-heteroarylene can

be substituted with one or more substituents independently selected from deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl;

two or more instances of  $X^D$  taken together can form a ring system;

- 5  $R^D$  is independently selected from hydrogen, deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted alkoxy, substituted or unsubstituted amino, substituted or unsubstituted aryl, substituted or unsubstituted aryloxy, substituted or unsubstituted heteroaryl, substituted or unsubstituted heteroaryloxy, and silyl;

two or more instances of  $R^D$  taken together can form a ring system;

- 10  $R^{D'}$  is independently selected from hydrogen, deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted amino, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl;

two or more instances of  $R^{D'}$  and  $R^D$  taken together can form a ring system;

- 15  $L^D$  is independently selected from single bond, substituted or unsubstituted arylene, and substituted or unsubstituted heteroarylene; wherein each instance of arylene and heteroarylene can be substituted with one or more substituents independently selected from deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl; two or more of these substituents taken together can form a ring system;

- 20 Ar is independently selected from substituted or unsubstituted aryl and substituted or unsubstituted heteroaryl, wherein the substituted or unsubstituted heteroaryl does not contain a nitrogen atom; and wherein each instance of aryl, and heteroaryl can be substituted with one or more substituents independently selected from deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted aryl, and  
25 substituted or unsubstituted heteroaryl; two or more of these substituents taken together can form a ring system;

Z is N or CR;

R is H, CN, D or Ar;



k is 1 to 3;

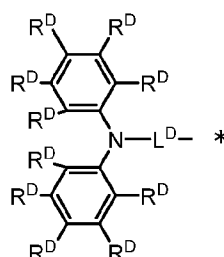
m is 0 to 4;

n is 1 to 5;

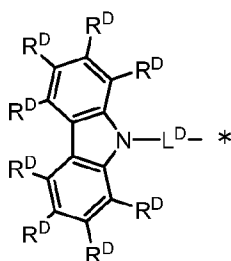
(k + m + n) is less than or equal to 5; and

5 each “\*” represents a point of attachment to Formula (I).

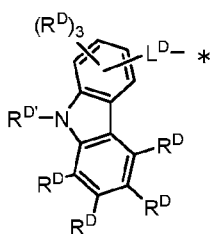
In some embodiments, alkyl is C1-C20-alkyl. In some embodiments, alkyl is C1-C12 alkyl. In some embodiments, aryl is C6-C40 aryl. In some embodiments, aryl is C6-C25 aryl. In some embodiments, heteroaryl is C2-C40 heteroaryl. In some embodiments, heteroaryl is C2-C25 heteroaryl. In some embodiments, alkoxy is C1-C20 alkoxy. In some embodiments, alkoxy is C1-C12 alkoxy. In some embodiments, aryloxy is C6-C40 aryloxy. In some embodiments, aryloxy is C6-C25 aryloxy. In some embodiments, heteroaryloxy is C3-C40 heteroaryloxy. In some embodiments, heteroaryloxy is C3-C25 heteroaryloxy.



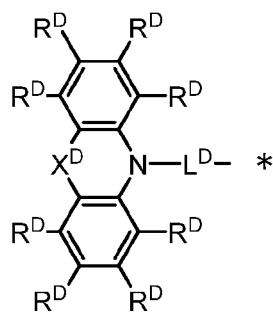
In some embodiments, wherein D is



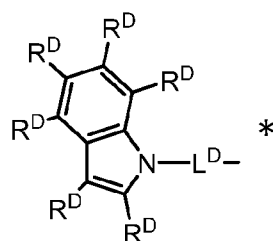
15 In some embodiments, D is



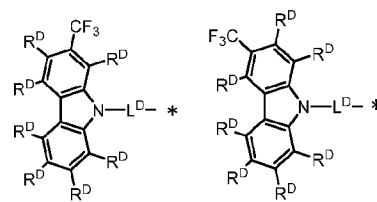
In some embodiments, D is



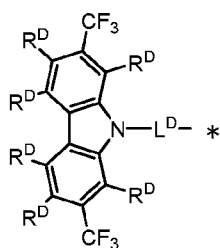
In some embodiments, D is



In some embodiments, D is

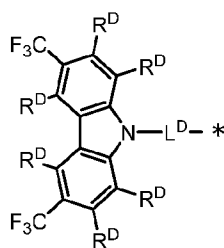


In some embodiments, D is selected from



5

, and



10

In some embodiments,  $X^D$  is O. In some embodiments,  $X^D$  is S. In some embodiments,  $X^D$  is  $NR^{D'}$ . In some embodiments,  $X^D$  is  $C(O)$ . In some embodiments,  $X^D$  is substituted or unsubstituted methylene. In some embodiments,  $X^D$  is substituted or unsubstituted ethylene. In some embodiments,  $X^D$  is substituted or unsubstituted vinylene. In some embodiments,  $X^D$  is substituted or unsubstituted *o*-arylene. In some embodiments,  $X^D$  is and substituted or unsubstituted *o*-heteroarylene. In some embodiments, methylene, ethylene, vinylene, *o*-arylene and *o*-heteroarylene can be substituted with deuterium, substituted or unsubstituted alkyl, substituted or

unsubstituted aryl, and substituted or unsubstituted heteroaryl. In some embodiments, two or more instances of  $X^D$  taken together can form a ring system.

In some embodiments,  $R^D$  is hydrogen. In some embodiments,  $R^D$  is deuterium. In some embodiments,  $R^D$  is substituted or unsubstituted alkyl. In some embodiments,  $R^D$  is substituted or unsubstituted alkoxy. In some embodiments,  $R^D$  is substituted or unsubstituted amino. In some embodiments,  $R^D$  is substituted or unsubstituted aryl. In some embodiments,  $R^D$  is substituted or unsubstituted aryloxy. In some embodiments,  $R^D$  is substituted or unsubstituted heteroaryl. In some embodiments,  $R^D$  is substituted or unsubstituted heteroaryloxy. In some embodiments,  $R^D$  is silyl. In some embodiments, two or more instances of  $R^D$  taken together can form a ring system.

In some embodiments,  $R^{D'}$  is hydrogen. In some embodiments,  $R^{D'}$  is deuterium. In some embodiments,  $R^{D'}$  is substituted or unsubstituted alkyl. In some embodiments,  $R^{D'}$  is substituted or unsubstituted amino. In some embodiments,  $R^{D'}$  is substituted or unsubstituted aryl. In some embodiments,  $R^{D'}$  is substituted or unsubstituted heteroaryl. In some embodiments, two or more instances of  $R^{D'}$  and  $R^D$  taken together can form a ring system.

In some embodiments,  $L^D$  is a single bond. In some embodiments,  $L^D$  is substituted or unsubstituted arylene. In some embodiments,  $L^D$  is substituted or unsubstituted heteroarylene.

In some embodiments, when  $L^D$  is substituted each substituent is independently selected from deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl; two or more of these substituents taken together can form a ring system.

In some embodiments, Ar is substituted or unsubstituted aryl. In some embodiments, Ar is substituted or unsubstituted heteroaryl. In some embodiments, the substituted or unsubstituted heteroaryl group does not contain any nitrogen atoms; each substituent is independently selected from deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl; two or more of these substituents taken together can form a ring system;

In some embodiments, Z is a N. In some embodiments, Z is CR.

In some embodiments, R is H. In some embodiments, R is CN. In some embodiments, R is D. In some embodiments, R is Ar.

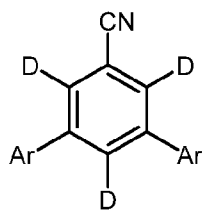
In some embodiments, k is 1. In some embodiments, k is 2. In some embodiments, k is 3.

5 In some embodiments, m is 0. In some embodiments, m is 1. In some embodiments, m is 2. In some embodiments, m is 3. In some embodiments, m is 4.

In some embodiments, n is 1. In some embodiments, n is 2. In some embodiments, n is 3. In some embodiments, n is 4. In some embodiments, n is 5.

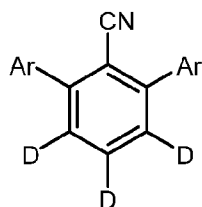
In some embodiments,  $(k + m + n)$  is 5, and m is equal to or greater than 2.

10 In some embodiments, the compound of Formula (I) is represented by Formula (Ia):



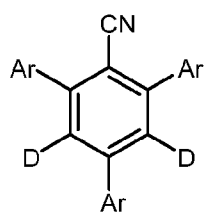
(Ia).

15 In some embodiments, the compound of Formula (I) is represented by Formula (Ib):

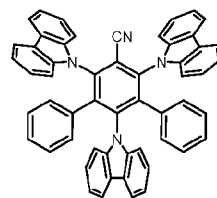


(Ib).

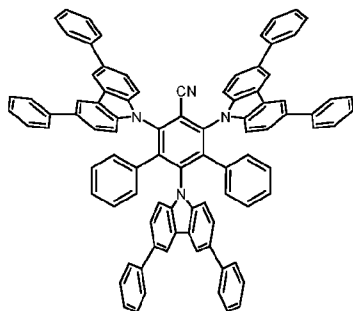
In some embodiments, the compound of Formula (I) is represented by Formula (Ic):



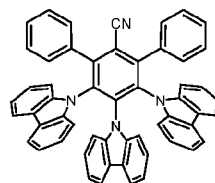
(Ic).



In some embodiments, the compound is selected from , and

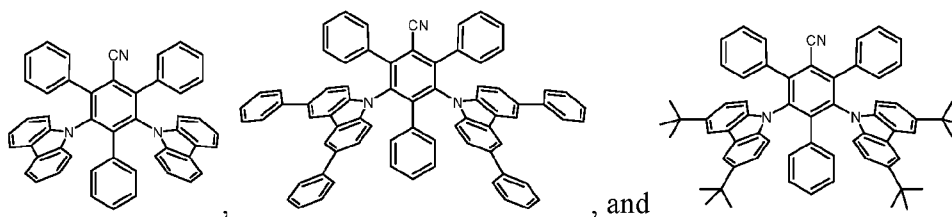


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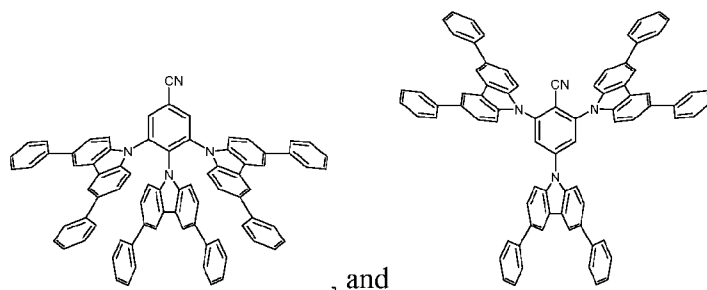


In some embodiments, the compound is

In some embodiments, the compound is selected from



In some embodiments, the compound is selected from



In some embodiments, the compound is selected from:

2,6-bis(3,6-diphenyl-9H-carbazol-9-yl)-3,5-bis(9-phenyl-9H-carbazol-2-yl)-[1,1'-biphenyl]-4-carbonitrile;

5        4,5-di(9H-carbazol-9-yl)-3,6-bis(9-phenyl-9H-carbazol-3-yl)phthalonitrile;

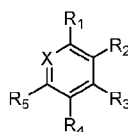
3,3'-(3',6'-bis(4,6-diphenyl-1,3,5-triazin-2-yl)-[1,1':2',1''-terphenyl]-4',5'-diyl)bis(9-phenyl-9H-carbazole);

2,5-di(9H-carbazol-9-yl)-4,6-bis(9-phenyl-9H-carbazol-3-yl)isophthalonitrile;

and

10        2',6'-bis(9-phenyl-9H-carbazol-2-yl)-[1,1':3',1''-terphenyl]-4',5'-dicarbonitrile.

In some embodiments, the compounds have a structure of Formula (II):



(II)

wherein

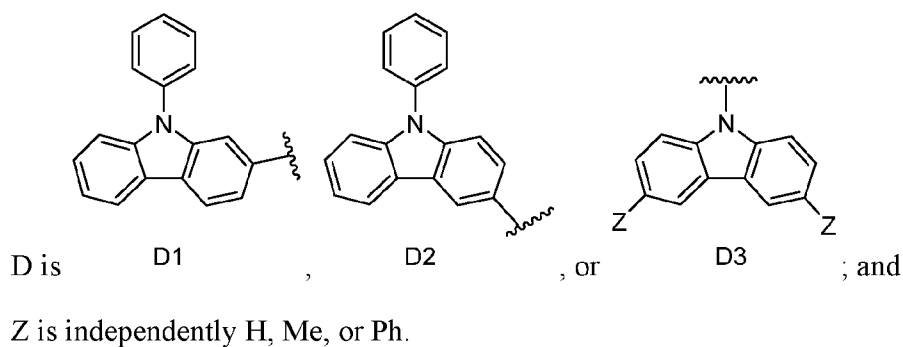
15        X is N or CR<sub>6</sub>;

R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, and R<sub>6</sub> are independently selected from the group consisting of A, D, H, and Ph;

at least one of R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, and R<sub>6</sub> is A;

at least one of R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, and R<sub>6</sub> is D;

20        A is CN;



In some embodiments, X is N. In some embodiments, X is CR<sub>6</sub>.

In some embodiments, R<sub>1</sub> is A. In some embodiments, R<sub>1</sub> is D. In some  
5 embodiments, R<sub>1</sub> is H. In some embodiments, R<sub>1</sub> is Ph.

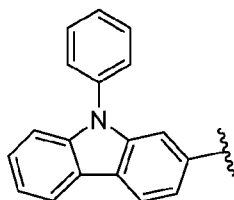
In some embodiments, R<sub>2</sub> is A. In some embodiments, R<sub>2</sub> is D. In some  
embodiments, R<sub>2</sub> is H. In some embodiments, R<sub>2</sub> is Ph.


In some embodiments, R<sub>3</sub> is A. In some embodiments, R<sub>3</sub> is D. In some  
embodiments, R<sub>3</sub> is H. In some embodiments, R<sub>3</sub> is Ph.

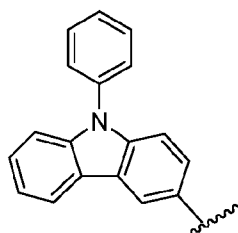
10 In some embodiments, R<sub>4</sub> is A. In some embodiments, R<sub>4</sub> is D. In some  
embodiments, R<sub>4</sub> is H. In some embodiments, R<sub>4</sub> is Ph.

In some embodiments, R<sub>5</sub> is A. In some embodiments, R<sub>5</sub> is D. In some  
embodiments, R<sub>5</sub> is H. In some embodiments, R<sub>5</sub> is Ph.

15 In some embodiments, R<sub>6</sub> is A. In some embodiments, R<sub>6</sub> is D. In some  
embodiments, R<sub>6</sub> is H. In some embodiments, R<sub>6</sub> is Ph.

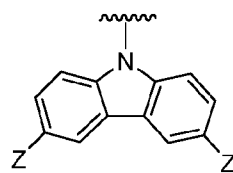


In some embodiments, D is  D1. In some embodiments, D is



D2

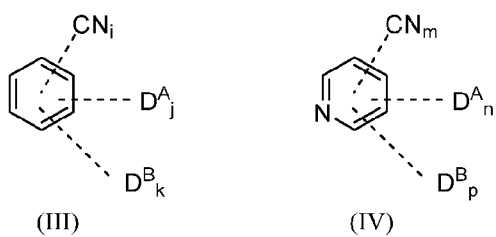
. In some embodiments, D is



D3

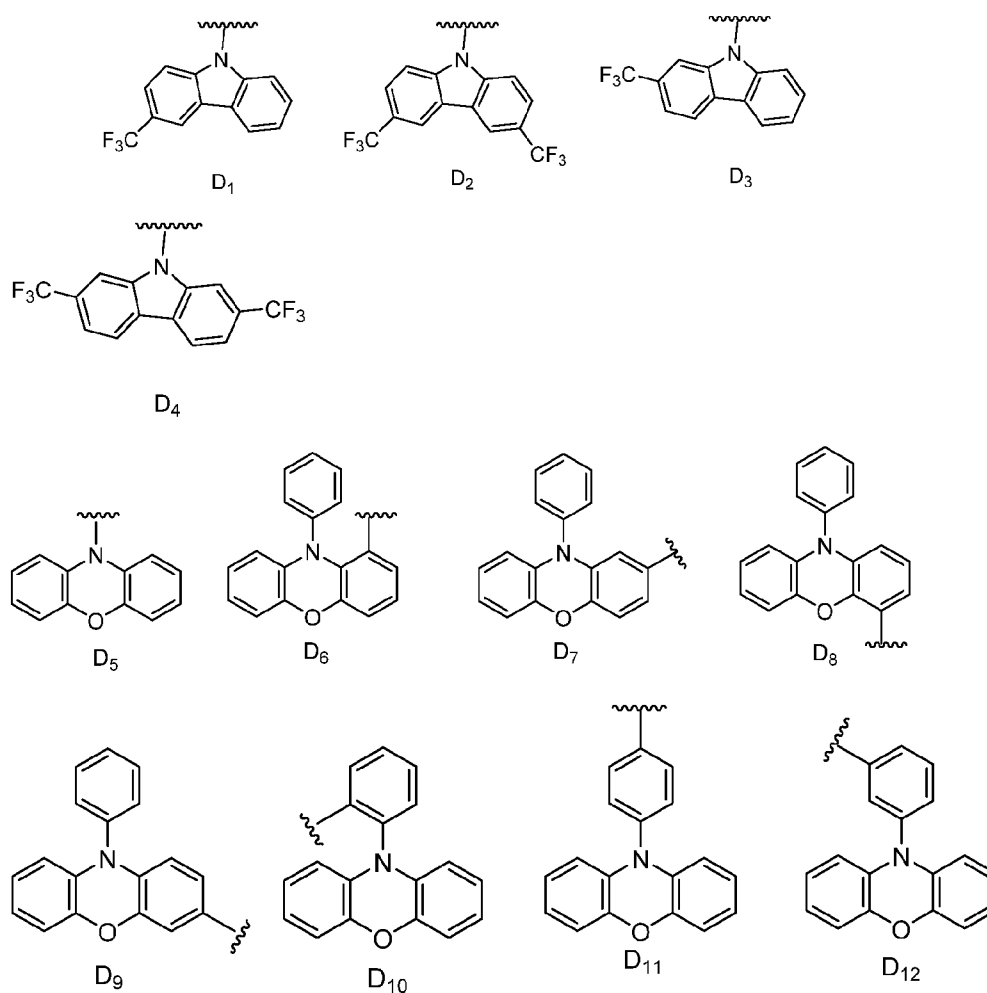
In some embodiments, Z is H. In some embodiments, Z is Me. In some  
embodiments, Z is Ph.

In some embodiments, the compounds have a structure of Formula (III) or Formula (IV):



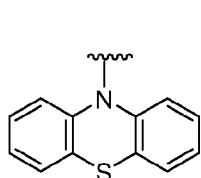
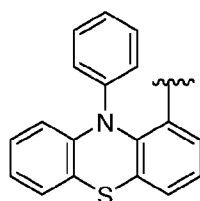
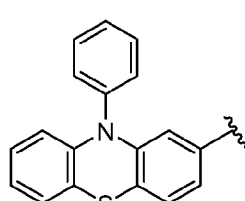
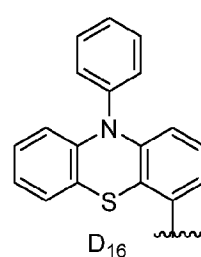
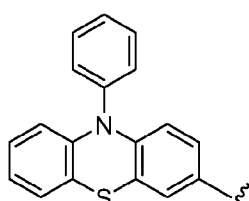
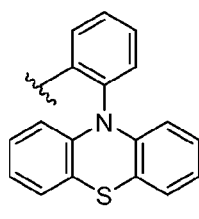
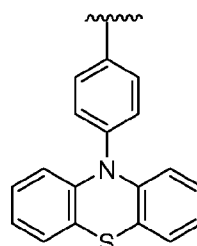
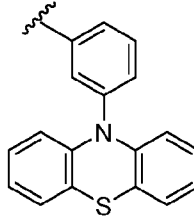
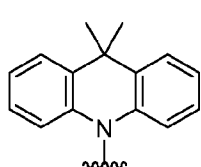
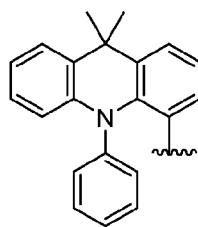
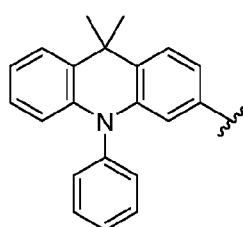
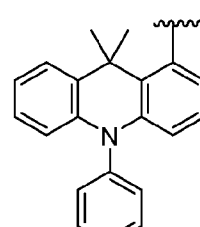
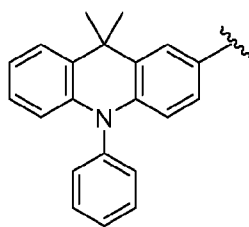
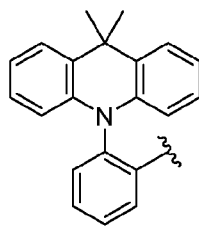
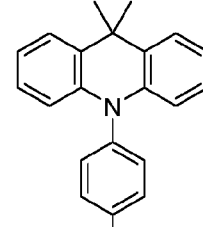
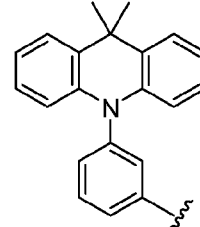
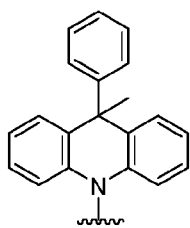
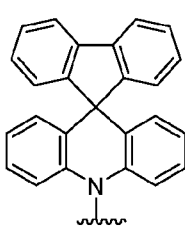
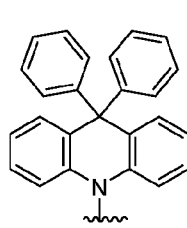
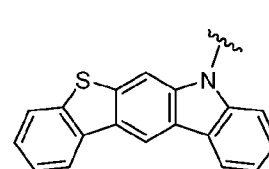
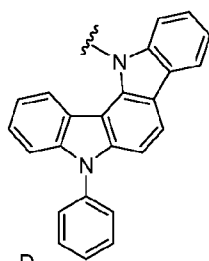
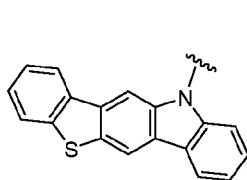
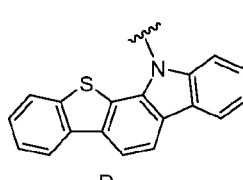
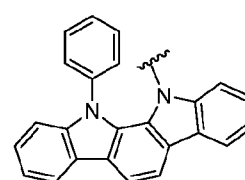
5 wherein

$D^A$  and  $D^B$  are independently selected from

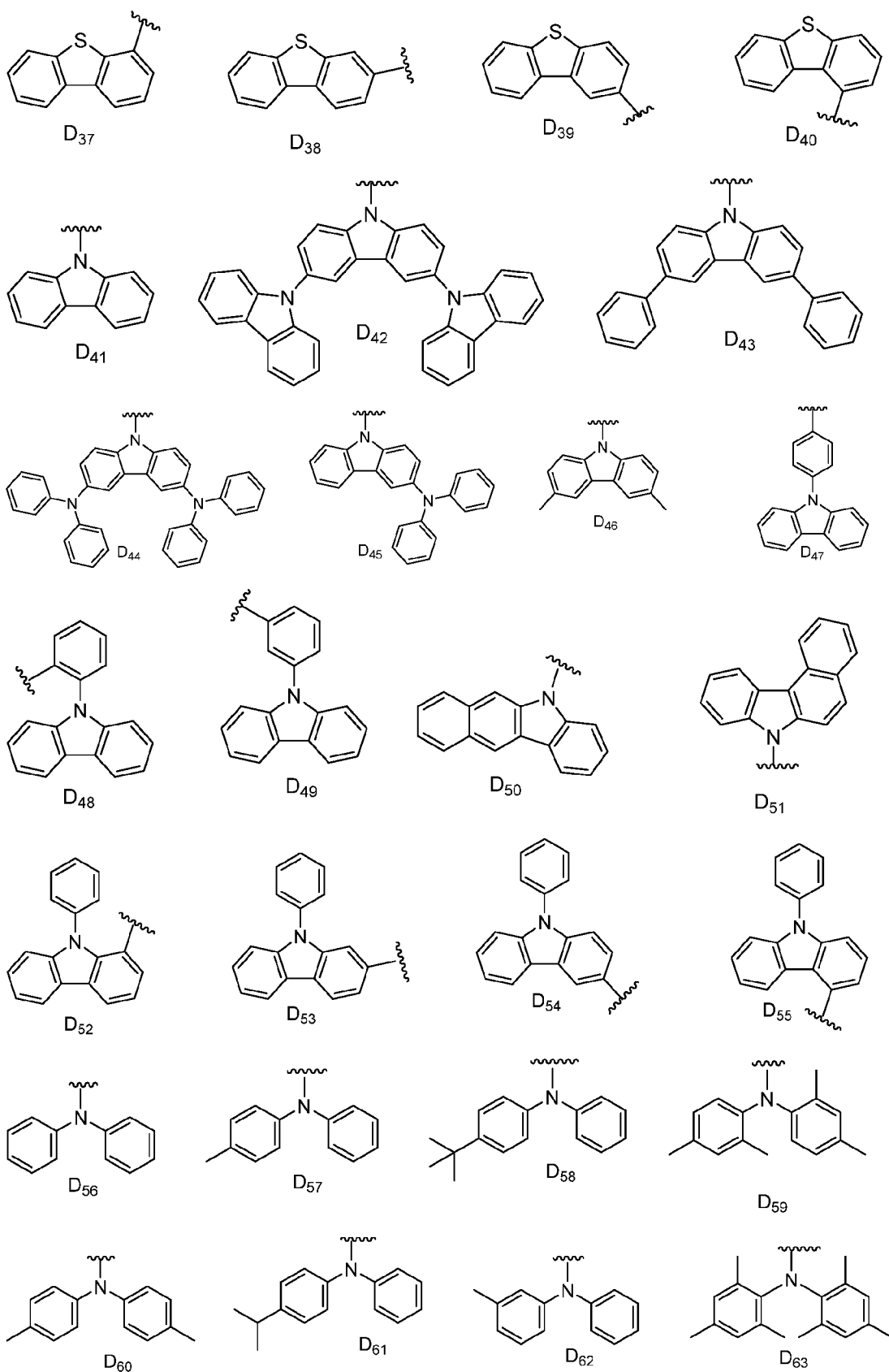


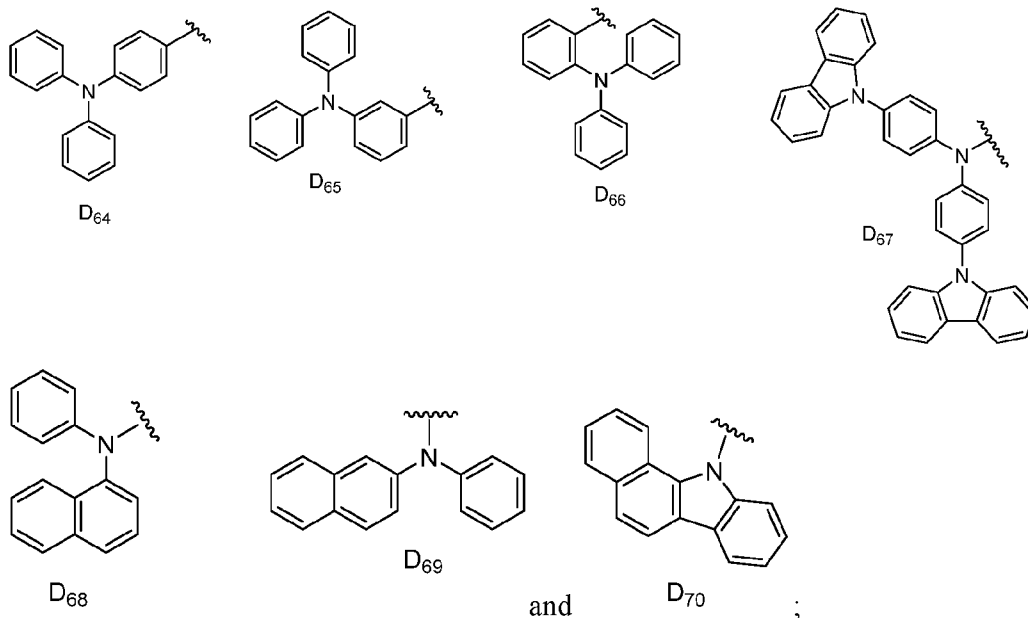
10



D<sub>13</sub>D<sub>14</sub>D<sub>15</sub>D<sub>16</sub>D<sub>17</sub>D<sub>18</sub>D<sub>19</sub>D<sub>20</sub>D<sub>21</sub>D<sub>22</sub>D<sub>23</sub>D<sub>24</sub>D<sub>25</sub>D<sub>26</sub>D<sub>27</sub>D<sub>28</sub>D<sub>29</sub>D<sub>30</sub>D<sub>31</sub>D<sub>32</sub>D<sub>33</sub>D<sub>34</sub>D<sub>35</sub>D<sub>36</sub>

5





i is 1, 2, or 3;

j is 1, 2, 3, 4, or 5;

5 k is 0, 1, 2, 3, or 4;

i + j + k is less than or equal to 6;

m is 1, 2, or 3;

n is 1, 2, 3, or 4;

p is 0, 1, 2, or 3; and

10 m + n + p is less than or equal to 5.

In some embodiments, D<sup>A</sup> is D1. In some embodiments, D<sup>A</sup> is D2. In some  
embodiments, D<sup>A</sup> is D3. In some embodiments, D<sup>A</sup> is D4. In some embodiments, D<sup>A</sup> is  
D5. In some embodiments, D<sup>A</sup> is D6. In some embodiments, D<sup>A</sup> is D7. In some  
embodiments, D<sup>A</sup> is D8. In some embodiments, D<sup>A</sup> is D9. In some embodiments, D<sup>A</sup> is  
15 D10. In some embodiments, D<sup>A</sup> is D11. In some embodiments, D<sup>A</sup> is D12. In some  
embodiments, D<sup>A</sup> is D13. In some embodiments, D<sup>A</sup> is D14. In some embodiments, D<sup>A</sup>  
is D15. In some embodiments, D<sup>A</sup> is D16. In some embodiments, D<sup>A</sup> is D17. In some  
embodiments, D<sup>A</sup> is D18. In some embodiments, D<sup>A</sup> is and D19. In some embodiments,  
D<sup>A</sup> is D20. In some embodiments, D<sup>A</sup> is D21. In some embodiments, D<sup>A</sup> is D22. In some  
20 embodiments, D<sup>A</sup> is D23. In some embodiments, D<sup>A</sup> is D24. In some embodiments, D<sup>A</sup>  
is D25. In some embodiments, D<sup>A</sup> is D26. In some embodiments, D<sup>A</sup> is D27. In some  
embodiments, D<sup>A</sup> is D28. In some embodiments, D<sup>A</sup> is D29. In some embodiments, D<sup>A</sup>  
is D30. In some embodiments, D<sup>A</sup> is D31. In some embodiments, D<sup>A</sup> is D32. In some

embodiments, D<sup>A</sup> is D33. In some embodiments, D<sup>A</sup> is D34. In some embodiments, D<sup>A</sup> is D35. In some embodiments, D<sup>A</sup> is D36. In some embodiments, D<sup>A</sup> is D37. In some embodiments, D<sup>A</sup> is D38. In some embodiments, D<sup>A</sup> is and D39. In some embodiments, D<sup>A</sup> is D40. In some embodiments, D<sup>A</sup> is D41. In some embodiments, D<sup>A</sup> is D42. In some  
 5 embodiments, D<sup>A</sup> is D43. In some embodiments, D<sup>A</sup> is D44. In some embodiments, D<sup>A</sup> is D45. In some embodiments, D<sup>A</sup> is D46. In some embodiments, D<sup>A</sup> is D47. In some embodiments, D<sup>A</sup> is D48. In some embodiments, D<sup>A</sup> is D49. In some embodiments, D<sup>A</sup> is D50. In some embodiments, D<sup>A</sup> is D51. In some embodiments, D<sup>A</sup> is D52. In some embodiments, D<sup>A</sup> is D53. In some embodiments, D<sup>A</sup> is D54. In some embodiments, D<sup>A</sup>  
 10 is D55. In some embodiments, D<sup>A</sup> is D56. In some embodiments, D<sup>A</sup> is D57. In some embodiments, D<sup>A</sup> is D58. In some embodiments, D<sup>A</sup> is and D59. In some embodiments, D<sup>A</sup> is D60. In some embodiments, D<sup>A</sup> is D61. In some embodiments, D<sup>A</sup> is D62. In some embodiments, D<sup>A</sup> is D63. In some embodiments, D<sup>A</sup> is D64. In some embodiments, D<sup>A</sup> is D65. In some embodiments, D<sup>A</sup> is D66. In some embodiments, D<sup>A</sup> is D67. In some  
 15 embodiments, D<sup>A</sup> is D68. In some embodiments, D<sup>A</sup> is D69. In some embodiments, D<sup>A</sup> is D70.

In some embodiments, D<sup>A</sup> is selected from D1, D2, D3, D4, D5, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, and D19. In some embodiments, D<sup>A</sup> is selected from D20, D21, D22, D23, D24, D25, D26, D27, D28, D29, D30, D31, D32,  
 20 D33, D34, D35, D36, D37, D38, and D39. In some embodiments, D<sup>A</sup> is selected from D40, D41, D42, D43, D44, D45, D46, D47, D48, D49, D50, D51, D52, D53, D54, D55, D56, D57, D58, and D59. In some embodiments, D<sup>A</sup> is selected from D60, D61, D62, D63, D64, D65, D66, D67, D68, D69, and D70.

In some embodiments, D<sup>B</sup> is D1. In some embodiments, D<sup>B</sup> is D2. In some  
 25 embodiments, D<sup>B</sup> is D3. In some embodiments, D<sup>B</sup> is D4. In some embodiments, D<sup>B</sup> is D5. In some embodiments, D<sup>B</sup> is D6. In some embodiments, D<sup>B</sup> is D7. In some embodiments, D<sup>B</sup> is D8. In some embodiments, D<sup>B</sup> is D9. In some embodiments, D<sup>B</sup> is D10. In some embodiments, D<sup>B</sup> is D11. In some embodiments, D<sup>B</sup> is D12. In some embodiments, D<sup>A</sup> is D13. In some embodiments, D<sup>A</sup> is D14. In some embodiments, D<sup>B</sup>  
 30 is D15. In some embodiments, D<sup>B</sup> is D16. In some embodiments, D<sup>B</sup> is D17. In some embodiments, D<sup>B</sup> is D18. In some embodiments, D<sup>B</sup> is and D19. In some embodiments, D<sup>B</sup> is D20. In some embodiments, D<sup>B</sup> is D21. In some embodiments, D<sup>B</sup> is D22. In some embodiments, D<sup>B</sup> is D23. In some embodiments, D<sup>B</sup> is D24. In some embodiments, D<sup>B</sup> is

D25. In some embodiments,  $D^B$  is D26. In some embodiments,  $D^B$  is D27. In some  
embodiments,  $D^B$  is D28. In some embodiments,  $D^B$  is D29. In some embodiments,  $D^A$  is  
D30. In some embodiments,  $D^B$  is D31. In some embodiments,  $D^B$  is D32. In some  
embodiments,  $D^B$  is D33. In some embodiments,  $D^B$  is D34. In some embodiments,  $D^B$  is  
5 D35. In some embodiments,  $D^B$  is D36. In some embodiments,  $D^B$  is D37. In some  
embodiments,  $D^B$  is D38. In some embodiments,  $D^B$  is and D39. In some embodiments,  
 $D^B$  is D40. In some embodiments,  $D^B$  is D41. In some embodiments,  $D^B$  is D42. In some  
embodiments,  $D^B$  is D43. In some embodiments,  $D^B$  is D44. In some embodiments,  $D^B$  is  
D45. In some embodiments,  $D^B$  is D46. In some embodiments,  $D^B$  is D47. In some  
10 embodiments,  $D^B$  is D48. In some embodiments,  $D^B$  is D49. In some embodiments,  $D^B$  is  
D50. In some embodiments,  $D^B$  is D51. In some embodiments,  $D^B$  is D52. In some  
embodiments,  $D^B$  is D53. In some embodiments,  $D^B$  is D54. In some embodiments,  $D^B$  is  
D55. In some embodiments,  $D^B$  is D56. In some embodiments,  $D^B$  is D57. In some  
embodiments,  $D^B$  is D58. In some embodiments,  $D^B$  is and D59. In some embodiments,  
15  $D^B$  is D60. In some embodiments,  $D^B$  is D61. In some embodiments,  $D^B$  is D62. In some  
embodiments,  $D^B$  is D63. In some embodiments,  $D^B$  is D64. In some embodiments,  $D^B$  is  
D65. In some embodiments,  $D^B$  is D66. In some embodiments,  $D^B$  is D67. In some  
embodiments,  $D^B$  is D68. In some embodiments,  $D^B$  is D69. In some embodiments,  $D^B$  is  
D70.

20 In some embodiments,  $D^B$  is selected from D1, D2, D3, D4, D5, D6, D7, D8, D9,  
D10, D11, D12, D13, D14, D15, D16, D17, D18, and D19. In some embodiments,  $D^B$  is  
selected from D20, D21, D22, D23, D24, D25, D26, D27, D28, D29, D30, D31, D32,  
D33, D34, D35, D36, D37, D38, and D39. In some embodiments,  $D^B$  is selected from  
D40, D41, D42, D43, D44, D45, D46, D47, D48, D49, D50, D51, D52, D53, D54, D55,  
25 D56, D57, D58, and D59. In some embodiments,  $D^B$  is selected from D60, D61, D62,  
D63, D64, D65, D66, D67, D68, D69, and D70.

In some embodiments, X is CH. In some embodiments, X is N.

In some embodiments, i is 1. In some embodiments, i is 2. In some embodiments,  
i is 3.

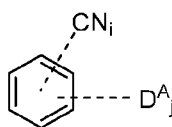
30 In some embodiments, j is 1. In some embodiments, j is 2. In some embodiments,  
j is 3. In some embodiments, j is 4. In some embodiments, j is 5.

In some embodiments, k is 0. In some embodiments, k is 1. In some embodiments, k is 2. In some embodiments, k is 3. In some embodiments, k is 4.

In some embodiments, k is 0, i is 1, and j is 4. In some embodiments, k is 0, i is 1, and j is 5. In some embodiments, k is 0, i is 2, and j is 3. In some embodiments, k is 0, i is 1, and j is 5.

In some embodiments, k is 1, i is 1, and j is 3. In some embodiments, k is 1, i is 1, and j is 4. In some embodiments, k is 1, i is 1, and j is 3. In some embodiments, k is 1, i is 1, and j is 4.

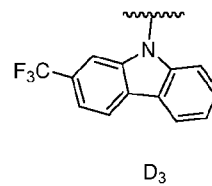
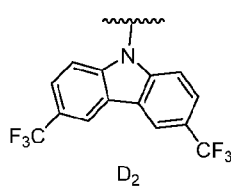
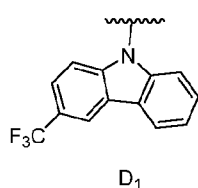
In some embodiments, the compounds of Formula (III) have the Formula (IIIa):



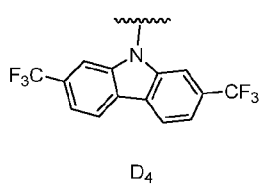
(IIIa)

wherein

$D^A$  is independently selected from



and



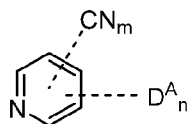
;

i is 1, 2, or 3;

j is 1, 2, 3, 4, or 5; and

i + j is less than or equal to 6.

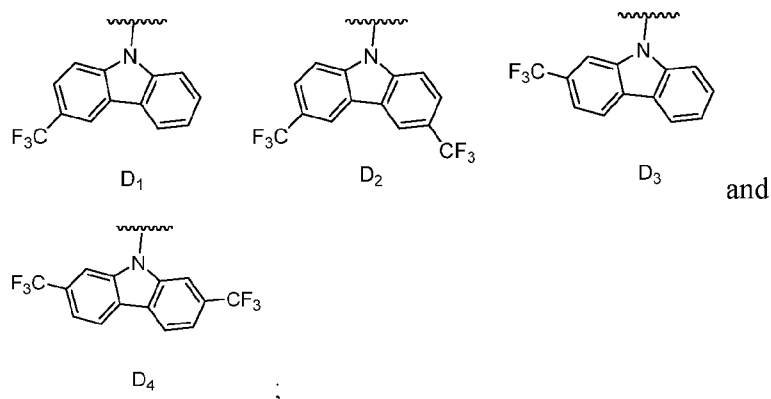
In some embodiments, the compounds of Formula (IV) have the Formula (IVa)



(IVa)

wherein

$D^A$  is independently selected from



m is 1, 2, or 3;

n is 1, 2, 3, or 4;

5                      m + n is less than or equal to 5.

In some embodiments the compound of Formula (III) or Formula (IV) is selected from:

2-(11H-benzo[a]carbazol-11-yl)-4,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)benzene-1,3,5-tricarbonitrile

10                      2-(12H-benzo[4,5]thieno[2,3-a]carbazol-12-yl)-3,5,6-tris(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2-(2-(diphenylamino)phenyl)-3,5,6-tris(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

15                      2-(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-4,6-bis(3-(diphenylamino)-9H-carbazol-9-yl)isophthalonitrile

2-(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-3,5,6-tris(10-phenyl-10H-phenoxazin-2-yl)isonicotinonitrile

2-(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-4,6-bis(3,6-dimethyl-9H-carbazol-9-yl)isophthalonitrile

20                      2-(5H-benzo[b]carbazol-5-yl)-3,5,6-tris(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2-(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-4,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)benzene-1,3,5-tricarbonitrile

25                      2-(9-phenyl-9H-carbazol-1-yl)-3,5,6-tris(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

- 2-(9,9-dimethylacridin-10(9H)-yl)-3,5,6-tris(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 2-(9H-carbazol-9-yl)-3,5,6-tris(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 5 2-(9H-carbazol-9-yl)-3,5,6-tris(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 2-(9H-carbazol-9-yl)-4,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile
- 2-(naphthalen-2-yl(phenyl)amino)-4,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile
- 10 2,2''-bis(diphenylamino)-2',5'-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-4',6'-dicarbonitrile
- 2,2''-bis(diphenylamino)-6'-(2-(diphenylamino)phenyl)-3',5'-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':2',1''-terphenyl]-4'-carbonitrile
- 15 2,2''-di(9H-carbazol-9-yl)-2',6'-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-4',5'-dicarbonitrile
- 2,3-bis(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-5,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile
- 2,3-bis(12-phenylindolo[2,3-a]carbazol-11(12H)-yl)-5,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 20 2,3-bis(12-phenylindolo[2,3-a]carbazol-11(12H)-yl)-5,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile
- 2,3-bis(12H-benzo[4,5]thieno[2,3-a]carbazol-12-yl)-5,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile
- 25 2,3-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-5,6-bis(10-phenyl-10H-phenothiazin-3-yl)terephthalonitrile
- 2,3-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile
- 2,3-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-5,6-bis(10-phenyl-10H-phenothiazin-3-yl)terephthalonitrile



2,3-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-5,6-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-4-yl)isonicotinonitrile

2,3-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-5,6-bis(dibenzo[b,d]thiophen-1-yl)terephthalonitrile

5 2,3-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-5,6-bis(dibenzo[b,d]thiophen-3-yl)terephthalonitrile

2,3-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-5,6-di(9H-carbazol-9-yl)terephthalonitrile

2,3-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile

10 2,3-bis(3,6-dimethyl-9H-carbazol-9-yl)-5,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,3-bis(5H-benzo[b]carbazol-5-yl)-5,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

15 2,3-bis(5H-benzo[b]carbazol-5-yl)-5,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,3-bis(5H-benzo[b]carbazol-5-yl)-5,6-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,3-bis(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-5,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

20 2,3-bis(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-5,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,3-bis(7H-benzo[c]carbazol-7-yl)-5,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

25 2,3-bis(9-phenyl-9H-carbazol-1-yl)-5,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,3-bis(9-phenyl-9H-carbazol-1-yl)-5,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile

2,3-bis(9-phenyl-9H-carbazol-1-yl)-5,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile

2,3-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-4-yl)-5,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile

2,3-bis(dibenzo[b,d]thiophen-2-yl)-5,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile

5 2,3-di(9H-carbazol-9-yl)-5,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile

2,3-di(9H-carbazol-9-yl)-5,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile

2,3,4,6-tetrakis(3-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

10 2,3,4,6-tetrakis(7H-benzo[c]carbazol-7-yl)-5-(2-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

2,3,5-tri(9H-carbazol-9-yl)-6-(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

15 2,3,5-tris(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-6-(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,3,5-tris(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-6-(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,3,5-tris(12H-benzo[4,5]thieno[2,3-a]carbazol-12-yl)-6-(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

20 2,3,5-tris(2-(diphenylamino)phenyl)-6-(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,3,5-tris(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-6-(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-4-yl)isonicotinonitrile

25 2,3,5-tris(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-6-(10H-phenothiazin-10-yl)isonicotinonitrile

2,3,5-tris(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-6-(dibenzo[b,d]thiophen-1-yl)isonicotinonitrile

2,3,5-tris(5H-benzo[b]carbazol-5-yl)-6-(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

- 2,3,5-tris(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-6-(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 2,3,5-tris(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-6-(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 5        2,3,5-tris(7H-benzo[c]carbazol-7-yl)-6-(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 2,4-bis(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-5,6-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile
- 2,4-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-6-(9H-carbazol-9-yl)benzene-1,3,5-tricarbonitrile
- 10       1,3,5-tricarbonitrile
- 2,4-bis(5H-benzo[b]carbazol-5-yl)-5,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile
- 2,4-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-1-yl)-5,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile
- 15       2,4-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-1-yl)-5,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile
- 2,4-di(9H-carbazol-9-yl)-6-(3-(trifluoromethyl)-9H-carbazol-9-yl)benzene-1,3,5-tricarbonitrile
- 2,4,6-tri(9H-carbazol-9-yl)-3,5-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile
- 20       2,4,6-tri(9H-carbazol-9-yl)-3,5-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile
- 2,5-bis(10-phenyl-10H-phenothiazin-3-yl)-3,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile
- 25       2,5-bis(10-phenyl-10H-phenoxazin-2-yl)-3,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 2,5-bis(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-3,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile

- 2,5-bis(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-3,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 2,5-bis(12-phenylindolo[2,3-a]carbazol-11(12H)-yl)-3,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 5 2,5-bis(12-phenylindolo[2,3-a]carbazol-11(12H)-yl)-3,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 2,5-bis(12H-benzo[4,5]thieno[2,3-a]carbazol-12-yl)-3,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile
- 10 2,5-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-3,6-bis(10-phenyl-10H-phenothiazin-3-yl)terephthalonitrile
- 2,5-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-3,6-bis(2-(diphenylamino)phenyl)isonicotinonitrile
- 2,5-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-4,6-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-2-yl)isophthalonitrile
- 15 2,5-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-4,6-di(9H-carbazol-9-yl)isophthalonitrile
- 2,5-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-3,6-bis(3,6-dimethyl-9H-carbazol-9-yl)terephthalonitrile
- 2,5-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-3,6-bis(9-phenyl-9H-carbazol-4-yl)isonicotinonitrile
- 20 2,5-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-3,6-di(9H-carbazol-9-yl)isonicotinonitrile
- 2,5-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-4,6-bis(10-phenyl-10H-phenoxazin-3-yl)isophthalonitrile
- 25 2,5-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-4,6-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-2-yl)isophthalonitrile
- 2,5-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-4,6-di(9H-carbazol-9-yl)isophthalonitrile

2,5-bis(3,6-dimethyl-9H-carbazol-9-yl)-3,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,5-bis(4-(9H-carbazol-9-yl)phenyl)-3,6-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

5 2,5-bis(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-3,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,5-bis(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-3,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

10 2,5-bis(9-methyl-9-phenylacridin-10(9H)-yl)-3,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,5-bis(9-phenyl-9H-carbazol-1-yl)-3,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile

2,5-bis(9-phenyl-9H-carbazol-1-yl)-3,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile

15 2,5-bis(9-phenyl-9H-carbazol-4-yl)-3,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,5-bis(dibenzo[b,d]thiophen-3-yl)-3,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile

20 2,5-bis(dibenzo[b,d]thiophen-4-yl)-3,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile

2,5-bis(dibenzo[b,d]thiophen-4-yl)-4,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

2,5-di(9H-carbazol-9-yl)-3,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

25 2,5-di(9H-carbazol-9-yl)-3,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)terephthalonitrile

2,5-di(9H-carbazol-9-yl)-4,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

2,6-bis(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-3,5-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,6-bis(11H-benzo[a]carbazol-11-yl)-3,5-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

5        2,6-bis(12-phenylindolo[2,3-a]carbazol-11(12H)-yl)-3,5-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

2,6-bis(2-(diphenylamino)phenyl)-3,5-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

10       2,6-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-3-(3,6-dimethyl-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

2,6-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-3,5-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-2-yl)isonicotinonitrile

2,6-bis(3-(diphenylamino)-9H-carbazol-9-yl)-3,5-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

15       2,6-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-3-(3,6-dimethyl-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

2,6-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-3,5-di(9H-carbazol-9-yl)benzonitrile

20       2,6-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-3,5-di(9H-carbazol-9-yl)isonicotinonitrile

2,6-bis(3,6-dimethyl-9H-carbazol-9-yl)-3,5-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

2,6-bis(4-(9H-carbazol-9-yl)phenyl)-3,5-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

25       2,6-bis(4-(9H-carbazol-9-yl)phenyl)-3,5-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,6-bis(5H-benzo[b]carbazol-5-yl)-3,5-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

2,6-bis(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-3,5-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

2,6-bis(7H-benzo[c]carbazol-7-yl)-3,5-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

5 2,6-bis(9-phenyl-9H-carbazol-4-yl)-3,5-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,6-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-1-yl)-3,5-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

10 2,6-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-4-yl)-3,5-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,6-bis(dibenzo[b,d]thiophen-1-yl)-3,4,5-tris(2-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

2,6-bis(dibenzo[b,d]thiophen-3-yl)-3,4,5-tris(2-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

15 2'-(11H-benzo[a]carbazol-11-yl)-4',6'-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile

2'-(3-(diphenylamino)-9H-carbazol-9-yl)-4',6'-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile

20 2'-(3,6-bis(diphenylamino)-9H-carbazol-9-yl)-4',6'-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile

2'-(3,6-diphenyl-9H-carbazol-9-yl)-4',6'-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile

2'-(9H-carbazol-9-yl)-3,5-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1'-biphenyl]-2,6-dicarbonitrile

25 2'-(dibenzo[b,d]thiophen-1-yl)-4',6'-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile

2',5'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-2,2''-bis(diphenylamino)-[1,1':3',1''-terphenyl]-4',6'-dicarbonitrile

3-(10H-phenoxazin-10-yl)-2,4,5,6-tetrakis(3-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

3-(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-2,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

5 3-(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-2,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

3-(12H-benzo[4,5]thieno[2,3-a]carbazol-12-yl)-2,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

10 3-(3,6-diphenyl-9H-carbazol-9-yl)-2,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

3-(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-2,6-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

3-(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-2,6-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

15 3-(9'H-[9,3':6',9"-tercarbazol]-9'-yl)-2,6-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

3-(9H-carbazol-9-yl)-2,4,5,6-tetrakis(3-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

20 3-(bis(4-(9H-carbazol-9-yl)phenyl)amino)-2,6-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

3,4-bis(10-phenyl-10H-phenoxazin-2-yl)-5,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)phthalonitrile

3,4-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-5,6-di(9H-carbazol-9-yl)phthalonitrile

25 3,4-bis(3,6-diphenyl-9H-carbazol-9-yl)-5,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)phthalonitrile

3,4-bis(3,6-diphenyl-9H-carbazol-9-yl)-5,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)phthalonitrile



- 3,4-bis(dibenzo[b,d]thiophen-4-yl)-5,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)phthalonitrile
- 3,4-bis(dibenzo[b,d]thiophen-4-yl)-5,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)phthalonitrile
- 5 3,5-bis(10-phenyl-10H-phenoxazin-1-yl)-2,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 3,5-bis(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-2,6-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile
- 10 3,5-bis(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-2,6-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 3,5-bis(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-2,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 3,5-bis(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-2,6-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile
- 15 3,5-bis(12H-benzo[4,5]thieno[2,3-a]carbazol-12-yl)-2,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 3,5-bis(12H-benzo[4,5]thieno[2,3-a]carbazol-12-yl)-2,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile
- 20 3,5-bis(12H-benzo[4,5]thieno[2,3-a]carbazol-12-yl)-4,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)phthalonitrile
- 3,5-bis(2-(10H-phenoxazin-10-yl)phenyl)-2,6-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 3,5-bis(2-(9,9-dimethylacridin-10(9H)-yl)phenyl)-2,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 25 3,5-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-2,6-bis(3,6-dimethyl-9H-carbazol-9-yl)benzonitrile
- 3,5-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-4,6-bis(9-phenyl-9H-carbazol-3-yl)phthalonitrile
- 3,5-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

3,5-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-2,4,6-tri(9H-carbazol-9-yl)benzonitrile

3,5-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-2,6-di(9H-carbazol-9-yl)benzonitrile

5 3,5-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-2'-(9H-carbazol-9-yl)-[1,1'-biphenyl]-2,6-dicarbonitrile

3,5-bis(3,6-dimethyl-9H-carbazol-9-yl)-2,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

10 3,5-bis(3,6-diphenyl-9H-carbazol-9-yl)-2,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

3,5-bis(3,6-diphenyl-9H-carbazol-9-yl)-2,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

3,5-bis(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-2,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

15 3,5-bis(7H-benzo[c]carbazol-7-yl)-2,6-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

3,5-bis(7H-benzo[c]carbazol-7-yl)-2,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

20 3,5-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-4-yl)-2,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

3',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-2,2''-bis(diphenylamino)-[1,1':4',1''-terphenyl]-2',5'-dicarbonitrile

3',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-4,4''-bis(diphenylamino)-[1,1':4',1''-terphenyl]-2',5'-dicarbonitrile

25 3',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-4,4''-di(9H-carbazol-9-yl)-[1,1':4',1''-terphenyl]-2',5'-dicarbonitrile

4,4''-bis(diphenylamino)-2',6'-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-4',5'-dicarbonitrile

- 4,4''-bis(diphenylamino)-2',6'-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-  
[1,1':3',1''-terphenyl]-4',5'-dicarbonitrile
- 4,4''-bis(diphenylamino)-4',5'-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-  
[1,1':2',1''-terphenyl]-3',6'-dicarbonitrile
- 5        4,4''-bis(diphenylamino)-4',6'-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-  
[1,1':2',1''-terphenyl]-3',5'-dicarbonitrile
- 4,4''-bis(diphenylamino)-5',6'-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-  
[1,1':2',1''-terphenyl]-3',4'-dicarbonitrile
- 4,4''-di(9H-carbazol-9-yl)-2',5'-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-  
10       [1,1':3',1''-terphenyl]-4',6'-dicarbonitrile
- 4,4''-di(9H-carbazol-9-yl)-4',6'-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-  
[1,1':2',1''-terphenyl]-3',5'-dicarbonitrile
- 4,5-bis(10-phenyl-10H-phenoxazin-3-yl)-2,6-bis(2-(trifluoromethyl)-9H-  
carbazol-9-yl)isophthalonitrile
- 15       4,5-bis(10-phenyl-10H-phenoxazin-3-yl)-3,6-bis(2-(trifluoromethyl)-9H-  
carbazol-9-yl)phthalonitrile
- 4,5-bis(10-phenyl-10H-phenoxazin-3-yl)-3,6-bis(3-(trifluoromethyl)-9H-  
carbazol-9-yl)phthalonitrile
- 4,5-bis(3,6-dimethyl-9H-carbazol-9-yl)-2,6-bis(3-(trifluoromethyl)-9H-carbazol-  
20       9-yl)isophthalonitrile
- 4,5-bis(3,6-diphenyl-9H-carbazol-9-yl)-2,6-bis(3-(trifluoromethyl)-9H-carbazol-  
9-yl)isophthalonitrile
- 4,5-bis(5H-benzo[b]carbazol-5-yl)-2,6-bis(3,6-bis(trifluoromethyl)-9H-carbazol-  
9-yl)isophthalonitrile
- 25       4,5-bis(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-2,6-bis(2,7-  
bis(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile
- 4,5-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-2-yl)-3,6-bis(2-  
(trifluoromethyl)-9H-carbazol-9-yl)phthalonitrile

4,5-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-4-yl)-3,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)phthalonitrile

4,5-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-4-yl)-3,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)phthalonitrile

5 4,5-di(9H-carbazol-9-yl)-2,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

4,6-bis(10-phenyl-10H-phenoxazin-2-yl)-2,5-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

10 4,6-bis(11H-benzo[a]carbazol-11-yl)-2-(2-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

4,6-bis(12-phenylindolo[2,3-a]carbazol-11(12H)-yl)-2-(3-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

4,6-bis(12H-benzo[4,5]thieno[2,3-a]carbazol-12-yl)-2-(2-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

15 4,6-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-2,5-di(9H-carbazol-9-yl)isophthalonitrile

4,6-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-2-(10-phenyl-10H-phenothiazin-1-yl)isophthalonitrile

20 4,6-bis(3,6-diphenyl-9H-carbazol-9-yl)-2,5-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

4,6-bis(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-2-(2-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

4,6-bis(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-2-(3-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

25 4,6-bis(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-2,5-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

4,6-bis(9-phenyl-9H-carbazol-1-yl)-2,5-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

4,6-bis(9-phenyl-9H-carbazol-1-yl)-2,5-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

4,6-bis(dibenzo[b,d]thiophen-3-yl)-2,5-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

5 4,6-bis(dibenzo[b,d]thiophen-4-yl)-2,5-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

4',6'-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-2'-(3-(diphenylamino)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile

10 4',6'-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-5'-(10H-phenoxazin-10-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-5'-(2-(diphenylamino)phenyl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-2'-(9,9-diphenylacridin-10(9H)-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile

15 4',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-4,4''-bis(diphenylamino)-[1,1':2',1''-terphenyl]-3',5'-dicarbonitrile

4',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-4,4''-di(9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

20 4',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-5'-(10H-phenothiazin-10-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-5'-(10H-phenoxazin-10-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-5'-(9,9-dimethylacridin-10(9H)-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

25 5'-(10H-spiro[acridine-9,9'-fluoren]-10-yl)-4',6'-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-4',6'-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-4',6'-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(12-phenylindolo[2,3-a]carbazol-11(12H)-yl)-4',6'-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5 5'-(12-phenylindolo[2,3-a]carbazol-11(12H)-yl)-4',6'-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(12H-benzo[4,5]thieno[2,3-a]carbazol-12-yl)-4',6'-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

10 5'-(12H-benzo[4,5]thieno[2,3-a]carbazol-12-yl)-4',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(2-(diphenylamino)phenyl)-4',6'-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(3-(diphenylamino)-9H-carbazol-9-yl)-4',6'-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

15 5'-(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-4',6'-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-3-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(3,6-dimethyl-9H-carbazol-9-yl)-4',6'-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

20 5'-(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-4',6'-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-4',6'-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-4',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

25 5'-(9-methyl-9-phenylacridin-10(9H)-yl)-4',6'-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(9,9-dimethylacridin-10(9H)-yl)-4',6'-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

- 5'-(9,9-diphenylacridin-10(9H)-yl)-4',6'-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile
- 5'-(9'H-[9,3':6',9''-tercarbazol]-9'-yl)-4',6'-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile
- 5 6'-(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-2''-(diphenylamino)-4'-(2-(diphenylamino)phenyl)-5'-phenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile
- 2,6-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-3,5-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-4-yl)isonicotinonitrile
- 2,5-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-3,6-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-4-yl)isonicotinonitrile
- 10 4,5-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-2,6-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-1-yl)isophthalonitrile
- 2,5-bis(9-methyl-9-phenylacridin-10(9H)-yl)-3,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 15 3,4-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-5,6-bis(3,6-dimethyl-9H-carbazol-9-yl)phthalonitrile
- 3,5-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-2,6-bis(3,6-dimethyl-9H-carbazol-9-yl)isonicotinonitrile
- 4,4''-di(9H-carbazol-9-yl)-4',5',6'-tris(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile
- 20 2,5-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-3,6-bis(dibenzo[b,d]thiophen-4-yl)isonicotinonitrile
- 4,6-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-2,5-bis(dibenzo[b,d]thiophen-4-yl)isophthalonitrile
- 25 3,5-bis(2-(9H-carbazol-9-yl)phenyl)-2,6-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 5'-(12H-benzo[4,5]thieno[2,3-a]carbazol-12-yl)-4',6'-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(11H-benzo[a]carbazol-11-yl)-4',6'-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-5'-(10H-spiro[acridine-9,9'-fluoren]-10-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5 4',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-5'-(3,6-diphenyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-5'-(3-(diphenylamino)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

10 5'-(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-4',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-5'-(9,9-diphenylacridin-10(9H)-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(3,6-diphenyl-9H-carbazol-9-yl)-4',6'-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

15 5'-(9'H-[9,3':6',9''-tercarbazol]-9'-yl)-4',6'-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(3,6-bis(diphenylamino)-9H-carbazol-9-yl)-4',6'-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

20 4',6'-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-2,2''-di(10H-phenoxazin-10-yl)-5'-phenyl-[1,1':3',1''-terphenyl]-2'-carbonitrile

2,3,5-tris(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-6-(dibenzo[b,d]thiophen-1-yl)isonicotinonitrile

2'-(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-4',6'-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile

25 2-(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-3,5,6-tris(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile

2,6-bis(12H-benzo[4,5]thieno[2,3-a]carbazol-12-yl)-3,5-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile



- 2,4-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-5,6-di(9H-carbazol-9-yl)isophthalonitrile
- 4,6-bis(7H-benzo[c]carbazol-7-yl)-2,5-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile
- 5 2'-(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-4',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile
- 4',6'-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-2'-(12-phenylindolo[2,3-a]carbazol-11(12H)-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile
- 10 2-(5H-benzo[b]carbazol-5-yl)-3,5,6-tris(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 3,5-bis(dibenzo[b,d]thiophen-4-yl)-2,4,6-tris(3-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile
- 2,4-bis(12-phenylindolo[2,3-a]carbazol-11(12H)-yl)-5,6-bis(3-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile
- 15 2,3,5-tris(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-6-(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 2,6-bis(3,6-diphenyl-9H-carbazol-9-yl)-3,5-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isonicotinonitrile
- 3-(9H-carbazol-9-yl)-2,4,5,6-tetrakis(2-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile
- 20 4,6-bis(11H-benzo[a]carbazol-11-yl)-2,5-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile
- 2,3-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-5,6-di(9H-carbazol-9-yl)terephthalonitrile
- 25 4,6-bis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-2,5-di(9H-carbazol-9-yl)isophthalonitrile
- 4,5-bis(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-3,6-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)phthalonitrile

4,5-di(10H-spiro[acridine-9,9'-fluoren]-10-yl)-3,6-bis(2-(trifluoromethyl)-9H-carbazol-9-yl)phthalonitrile

3-(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-2,6-bis(12-phenylindolo[2,3-a]carbazol-11(12H)-yl)-[1,1'-biphenyl]-4-carbonitrile

5        2,4,6-tris(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)-3,5-bis(3,6-diphenyl-9H-carbazol-9-yl)benzonitrile

2,4,5,6-tetrakis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

2,4,5,6-tetrakis(3-(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

3,5-bis(3,6-diphenyl-9H-carbazol-9-yl)-2,4,6-tris(3-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

2,3,5,6-tetrakis(2-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

2,3,5,6-tetrakis(3,6-bis(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

2,3,5,6-tetrakis(3-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile

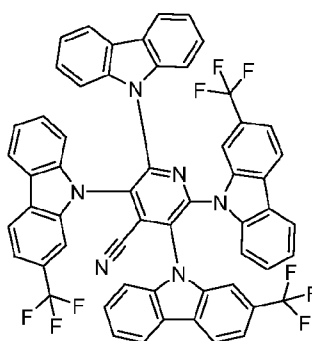
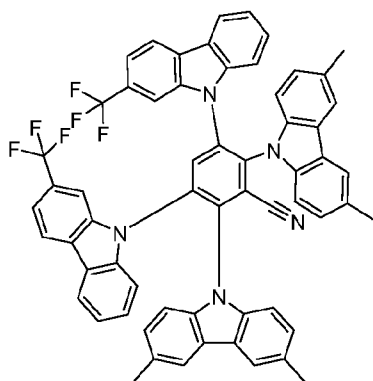
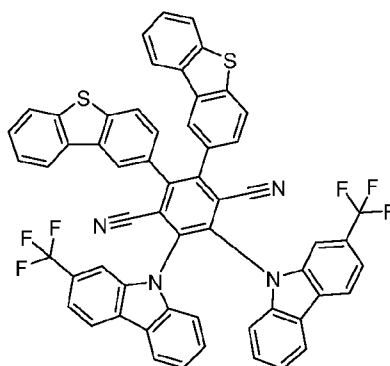
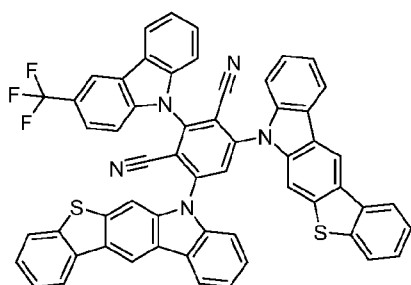
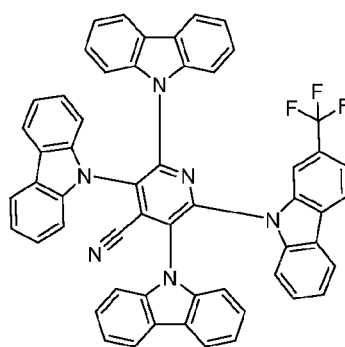
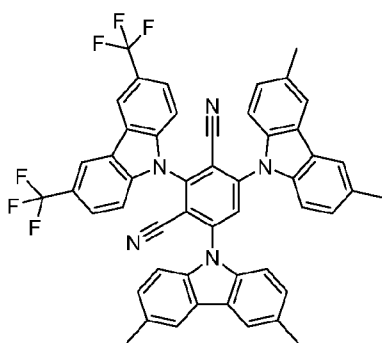
2,4,5,6-tetrakis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)isophthalonitrile

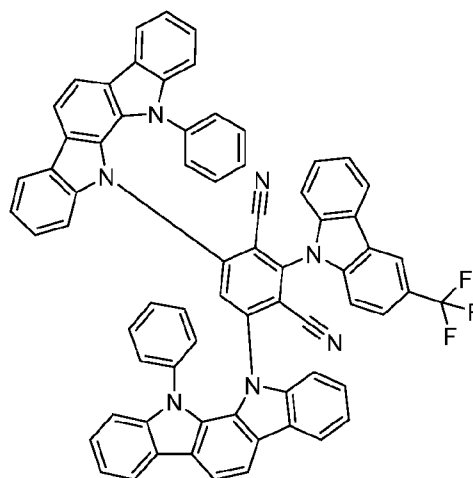
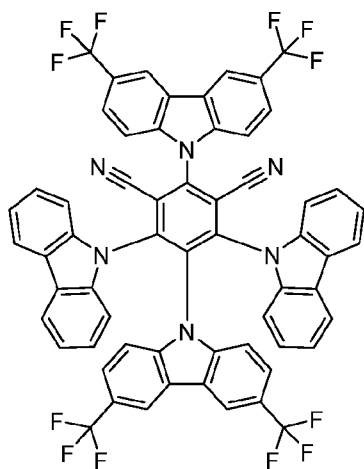
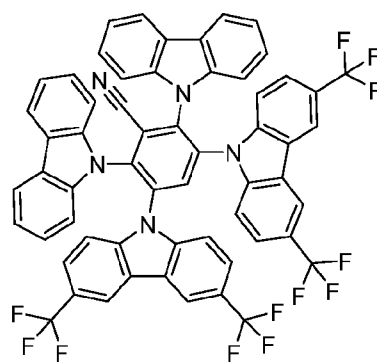
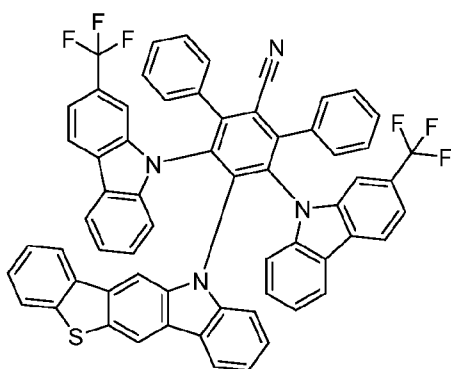
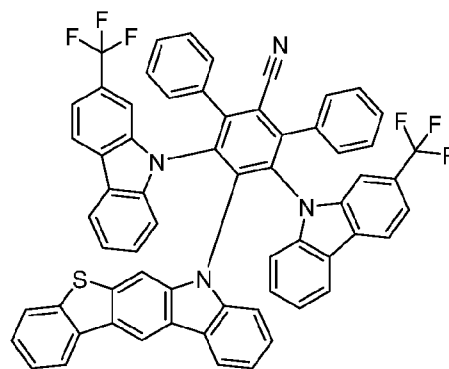
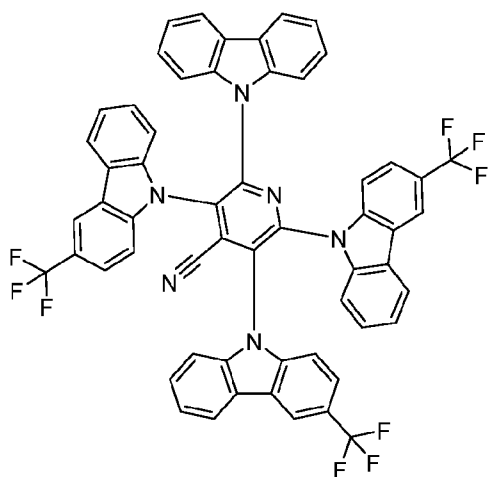
15        2,4,6-tris(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-3,5-bis(3,6-diphenyl-9H-carbazol-9-yl)benzonitrile

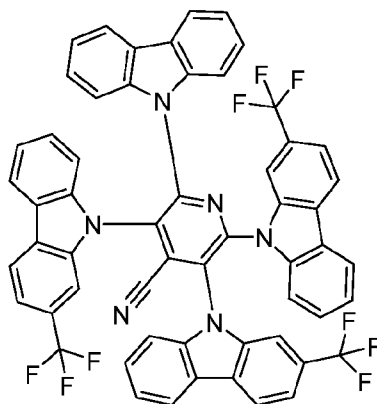
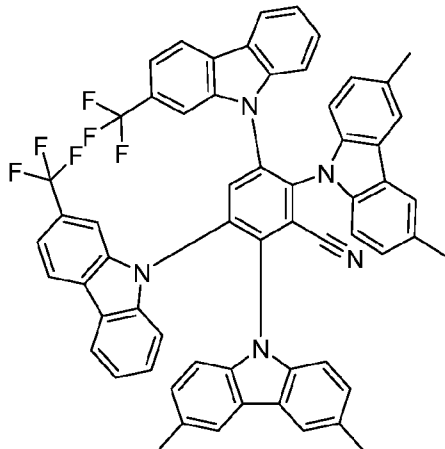
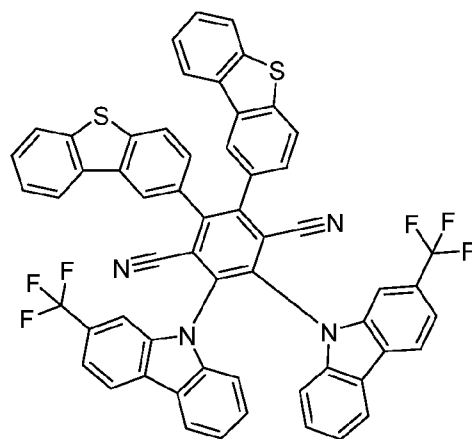
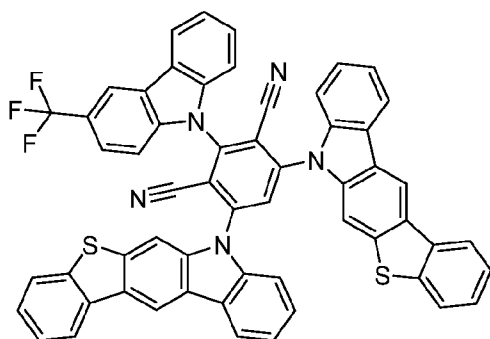
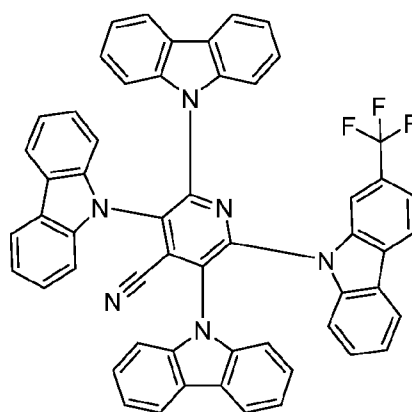
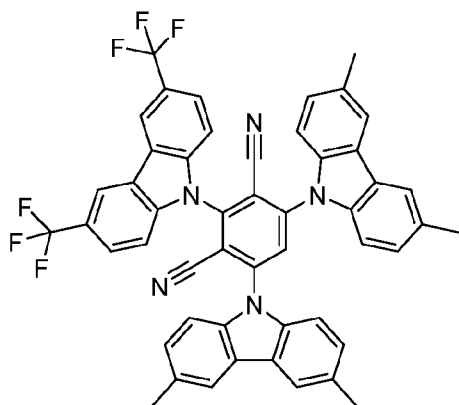
3,5-bis(3,6-diphenyl-9H-carbazol-9-yl)-2,4,6-tris(2-(trifluoromethyl)-9H-carbazol-9-yl)benzonitrile, and

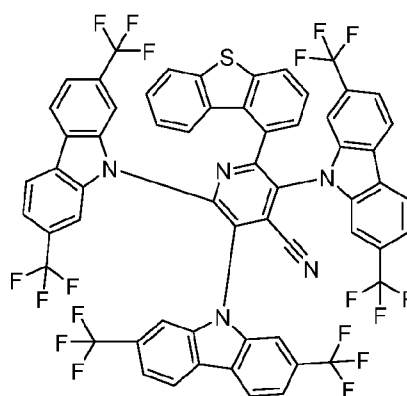
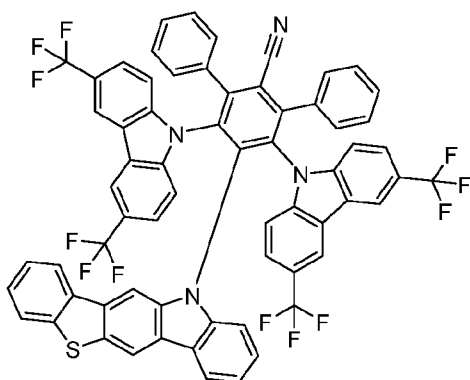
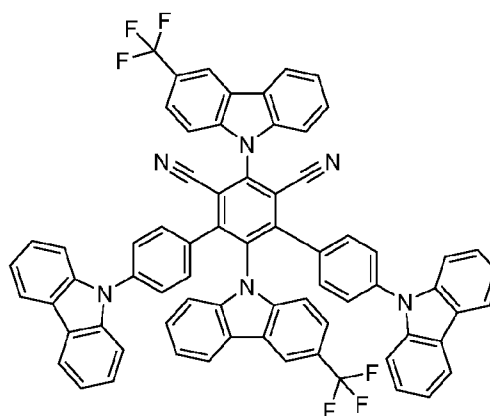
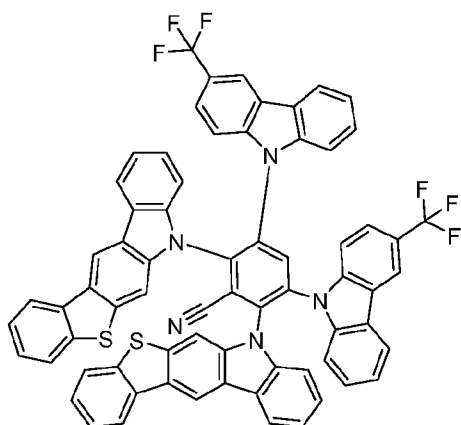
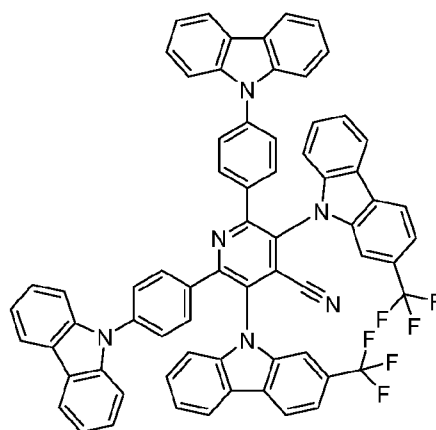
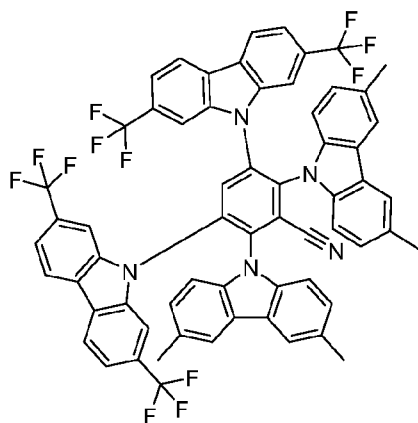
3,5-bis(2,7-bis(trifluoromethyl)-9H-carbazol-9-yl)-2,4,6-tri(9H-carbazol-9-yl)benzonitrile.

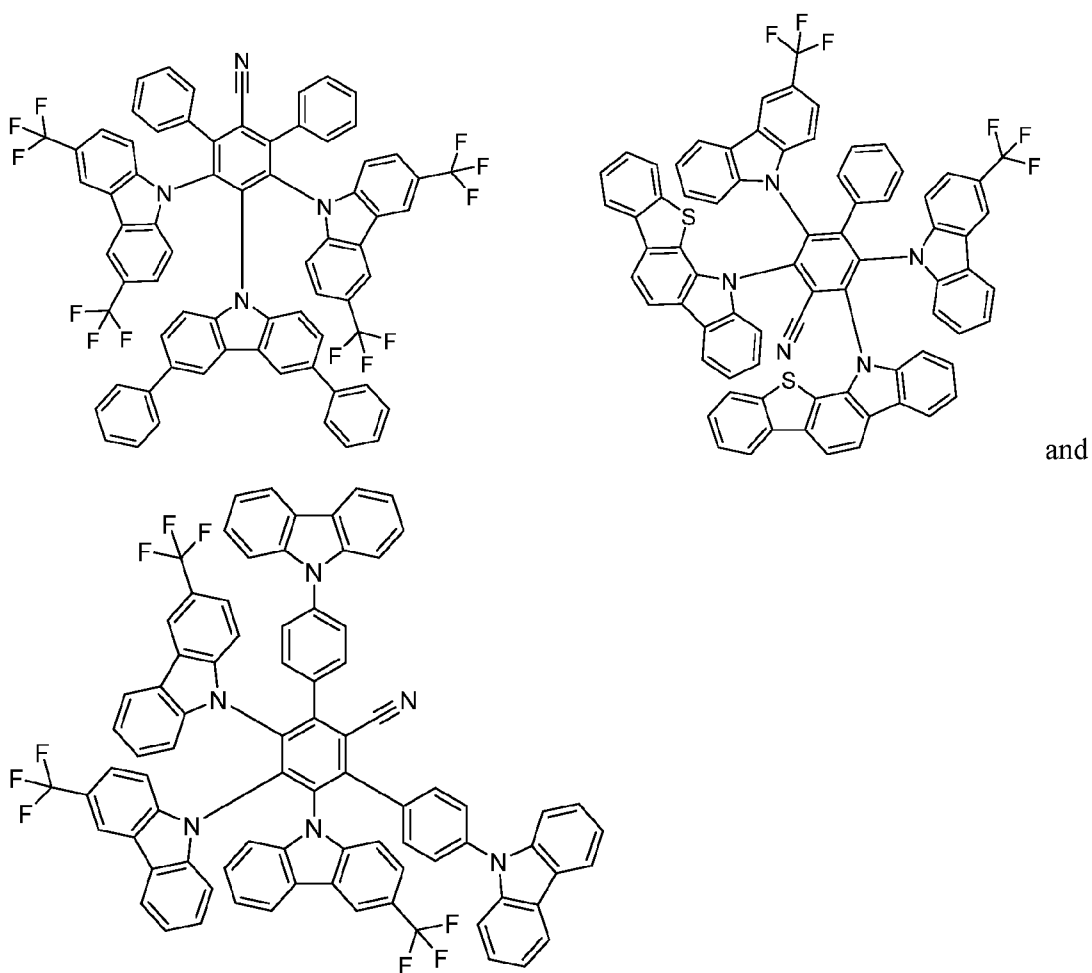
In some embodiments, compounds of Formula (III) or Formula (IV) are selected from:



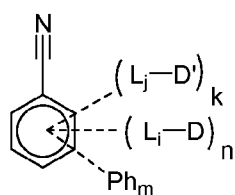








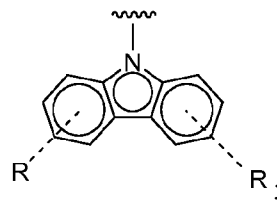
5 In some embodiments, the compounds have a structure of Formula (V)



(V)

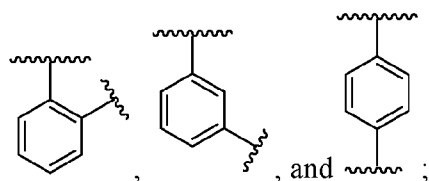
wherein

Ph is phenyl;



D and D' are independently selected from

R is independently selected from aryl, alkyl, and heteroaryl;



L is independently selected from

n, and m are each independently an integer greater than 0;

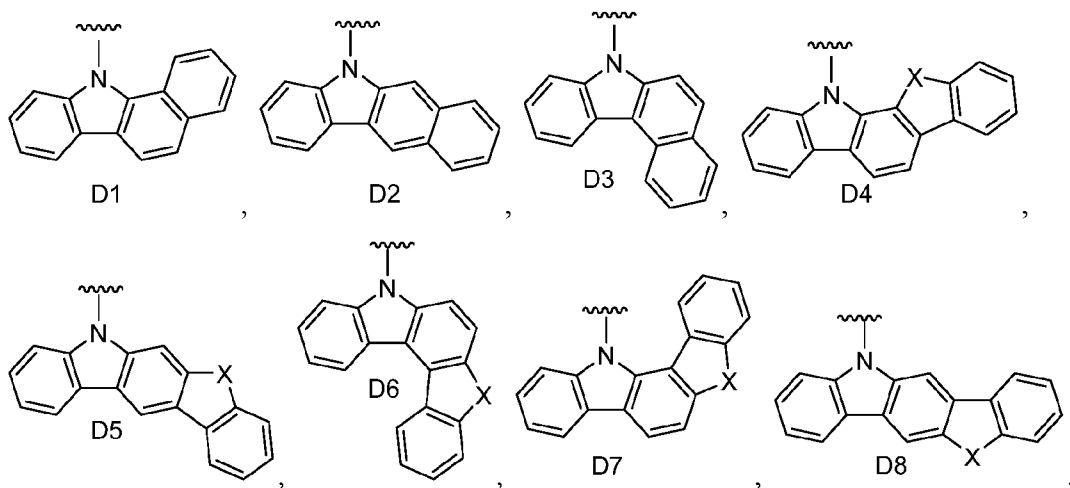
5 k is 0, 1, or 2, or 3;

n + m + k = 5; and

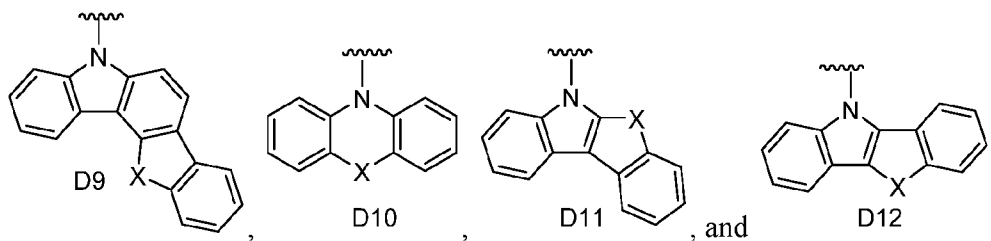
i and j are independently 0 or 1.

In some embodiments, R is aryl. In some embodiments, R is phenyl. In some  
embodiments, R is alkyl. In some embodiments, R is methyl. In some embodiments, R is  
10 heteroaryl.

In some embodiments at least one instance of D is selected from





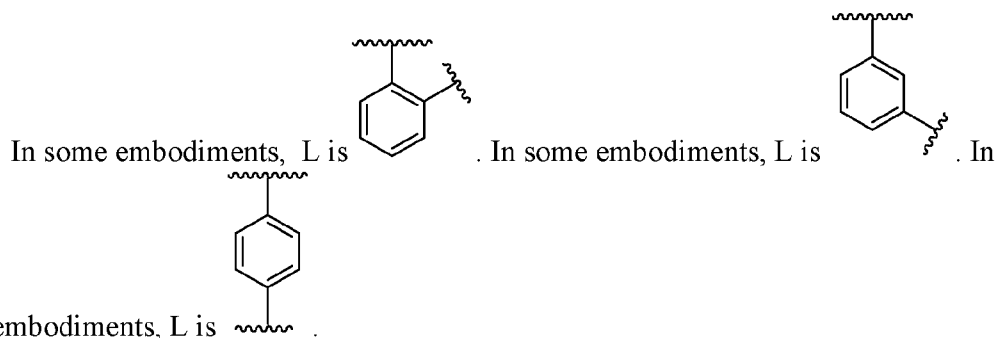


wherein X is selected from O, S, N-Ph, C(CH<sub>3</sub>)<sub>2</sub>, C(CH<sub>3</sub>)Ph, and C(Ph)<sub>2</sub>.

In some embodiments, at least one instance of D is selected from D1-D4. In some  
embodiments, at least one instance of D is selected from D5-D8. In some embodiments,  
5 at least one instance of D is selected from D9-D12.

In some embodiments, at least one instance of D' is selected from D1-D4. In  
some embodiments, at least one instance of D' is selected from D5-D8. In some  
embodiments, at least one instance of D' is selected from D9-D12.

In some embodiments, X is O. In some embodiments, X is S. In some  
10 embodiments, X is C(CH<sub>3</sub>)<sub>2</sub>. In some embodiments, X is C(CH<sub>3</sub>)Ph. In some  
embodiments, X is C(Ph)<sub>2</sub>.



In some embodiments, n is 1, m is 1 and k is 3. In some embodiments, n is 1, m is  
15 2 and k is 2. In some embodiments, n is 3, m is 1 and k is 1. In some embodiments, n is  
2, m is 2 and k is 1. In some embodiments, n is 2, m is 1 and k is 2. In some  
embodiments, n is 1, m is 3 and k is 1.

In some embodiments, i is 0. In some embodiments, j is 0. In some embodiments,  
i is 1. In some embodiments, j is 1.

20 In some embodiments, m is 4.

In some embodiments the compound of Formula (V) is selected from

4',6'-di(9H-carbazol-9-yl)-5'-(5-phenylindolo[3,2-a]carbazol-12(5H)-yl)-  
[1,1':3',1''-terphenyl]-2'-carbonitrile

2,3,5,6-tetra(9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

5 2,3,5,6-tetrakis(3,6-di-tert-butyl-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

2,3,5,6-tetrakis(3,6-dimethyl-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

2,3,5,6-tetrakis(5H-pyrido[3,2-b]indol-5-yl)-[1,1':3',1''-terphenyl]-4-carbonitrile

2,3,5,6-tetrakis(9H-pyrido[3,4-b]indol-9-yl)-[1,1':3',1''-terphenyl]-4-carbonitrile

10 2,4,5,6-tetrakis(10,11-dihydro-5H-dibenzo[b,f]azepin-5-yl)-[1,1'-biphenyl]-3-  
carbonitrile

2,6-bis(3-([1,1'-biphenyl]-4-yl)-6-phenyl-9H-carbazol-9-yl)-3,5-di(9H-carbazol-  
9-yl)-[1,1'-biphenyl]-4-carbonitrile

2,6-bis(3,6-dimethyl-9H-carbazol-9-yl)-3,5-bis(9-methyl-9-phenylacridin-  
10(9H)-yl)-[1,1'-biphenyl]-4-carbonitrile

15 2,6-bis(3,6-dimethyl-9H-carbazol-9-yl)-3,5-di(10H-phenothiazin-10-yl)-[1,1'-  
biphenyl]-4-carbonitrile

2,6-bis(3,6-diphenyl-9H-carbazol-9-yl)-3,5-bis(9-phenyl-9H-carbazol-2-yl)-[1,1'-  
biphenyl]-4-carbonitrile

20 2,6-bis(3,6-diphenyl-9H-carbazol-9-yl)-3,5-di(10H-phenoxazin-10-yl)-[1,1'-  
biphenyl]-4-carbonitrile

2,6-bis(dibenzo[b,d]thiophen-3-yl)-3,5-bis(3,6-dimethyl-9H-carbazol-9-yl)-[1,1'-  
biphenyl]-4-carbonitrile

2,6-di(9H-carbazol-9-yl)-3,5-bis(3,6-di-tert-butyl-9H-carbazol-9-yl)-[1,1'-  
biphenyl]-4-carbonitrile

25 2,6-di(9H-carbazol-9-yl)-3,5-bis(3,6-dimethyl-9H-carbazol-9-yl)-[1,1'-biphenyl]-  
4-carbonitrile

2,6-di(9H-carbazol-9-yl)-3,5-bis(9-phenyl-9H-carbazol-1-yl)-[1,1'-biphenyl]-4-  
carbonitrile

- 2'-(3,6-bis(diphenylamino)-9H-carbazol-9-yl)-4',6'-bis(dibenzo[b,d]thiophen-4-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile
- 2'-(3,6-bis(diphenylamino)-9H-carbazol-9-yl)-4',6'-bis(naphthalen-1-yl(phenyl)amino)-[1,1':3',1''-terphenyl]-5'-carbonitrile
- 5 2'-(3,6-di-tert-butyl-9H-carbazol-9-yl)-4',6'-bis(3,6-dimethyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile
- 2'-(3,6-dimethyl-9H-carbazol-9-yl)-4',6'-bis(3,6-diphenyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile
- 10 2'-(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-1-yl)-4',6'-bis(3,6-diphenyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile
- 2'-(9H-carbazol-9-yl)-4',6'-bis(3-(diphenylamino)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile
- 2'-(9H-carbazol-9-yl)-4',6'-bis(3,6-dimethyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile
- 15 2',4',6'-tri(9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile
- 2',4',6'-tris(10,11-dihydro-5H-dibenzo[b,f]azepin-5-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile
- 2',4',6'-tris(3,6-dimethyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile
- 2',4',6'-tris(9H-tribenzo[b,d,f]azepin-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile
- 20 3-(diphenylamino)-3',5'-bis(3-(diphenylamino)-9H-carbazol-9-yl)-6'-phenyl-[1,1':2',1''-terphenyl]-4'-carbonitrile
- 3,5-bis(11H-benzo[a]carbazol-11-yl)-2,6-di(9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile
- 3,5-bis(3,6-dimethyl-9H-carbazol-9-yl)-2,6-bis(9-methyl-9-phenylacridin-10(9H)-yl)-[1,1'-biphenyl]-4-carbonitrile
- 25 3,5-bis(3,6-dimethyl-9H-carbazol-9-yl)-2,6-di(10H-phenoxazin-10-yl)-[1,1'-biphenyl]-4-carbonitrile
- 3,5-di(9H-carbazol-9-yl)-2,6-bis(3,6-dimethyl-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

3',5'-bis(3,6-dimethyl-9H-carbazol-9-yl)-6'-phenyl-[1,1':2',1''-terphenyl]-4'-carbonitrile

3',5'-bis(3,6-diphenyl-9H-carbazol-9-yl)-4''-(diphenylamino)-6'-(4-(diphenylamino)phenyl)-[1,1':2',1''-terphenyl]-4'-carbonitrile

5 3',5'-bis(3,6-diphenyl-9H-carbazol-9-yl)-6'-phenyl-[1,1':2',1''-terphenyl]-4'-carbonitrile

3',5'-di(9H-carbazol-9-yl)-6'-phenyl-[1,1':2',1''-terphenyl]-4'-carbonitrile

4-(3-(diphenylamino)-9H-carbazol-9-yl)-2,3,5,6-tetra(pyridin-3-yl)benzonitrile

4-(3-(diphenylamino)-9H-carbazol-9-yl)-2,3,5,6-tetra(pyridin-4-yl)benzonitrile

10 4-(4,6-diphenylpyrimidin-2-yl)-2,3,5,6-tetrakis(9H-pyrido[3,4-b]indol-9-yl)benzonitrile

4',5'-diphenyl-6'-(12-phenylindolo[3,2-a]carbazol-5(12H)-yl)-[1,1':2',1''-terphenyl]-3'-carbonitrile

15 4',5'-diphenyl-6'-(3-(phenylamino)-9H-carbazol-9-yl)-[1,1':2',1''-terphenyl]-3'-carbonitrile

4',5'-diphenyl-6'-(3,3'',6,6''-tetraphenyl-9'H-[9,3':6',9''-tercarbazol]-9'-yl)-[1,1':2',1''-terphenyl]-3'-carbonitrile

4',5'-diphenyl-6'-(8-phenylindolo[2,3-c]carbazol-5(8H)-yl)-[1,1':2',1''-terphenyl]-3'-carbonitrile

20 4',5'-diphenyl-6'-(9'-phenyl-9H,9'H-[3,3'-bicarbazol]-9-yl)-[1,1':2',1''-terphenyl]-3'-carbonitrile

4',5',6'-tris(3,6-di-tert-butyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',5',6'-tris(3,6-diphenyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

25 4',6'-bis(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-2'-(9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile

4',6'-bis(11H-benzo[a]carbazol-11-yl)-5'-(9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-bis(3-(diphenylamino)-9H-carbazol-9-yl)-2'-(10H-phenothiazin-10-yl)-  
[1,1':3',1''-terphenyl]-5'-carbonitrile

4',6'-bis(3-(diphenylamino)-9H-carbazol-9-yl)-2'-(naphthalen-1-  
yl(phenyl)amino)-[1,1':3',1''-terphenyl]-5'-carbonitrile

5 4',6'-bis(3,6-di-tert-butyl-9H-carbazol-9-yl)-2'-(3,6-dimethyl-9H-carbazol-9-yl)-  
[1,1':3',1''-terphenyl]-5'-carbonitrile

4',6'-bis(3,6-di-tert-butyl-9H-carbazol-9-yl)-2'-(3,6-diphenyl-9H-carbazol-9-yl)-  
[1,1':3',1''-terphenyl]-5'-carbonitrile

10 4',6'-bis(3,6-di-tert-butyl-9H-carbazol-9-yl)-2'-(diphenylamino)-[1,1':3',1''-  
terphenyl]-5'-carbonitrile

4',6'-bis(3,6-di-tert-butyl-9H-carbazol-9-yl)-5'-(3,6-dimethyl-9H-carbazol-9-yl)-  
[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-bis(3,6-di-tert-butyl-9H-carbazol-9-yl)-5'-(3,6-diphenyl-9H-carbazol-9-yl)-  
[1,1':3',1''-terphenyl]-2'-carbonitrile

15 4',6'-bis(3,6-dimethyl-9H-carbazol-9-yl)-2'-(10H-spiro[acridine-9,9'-fluoren]-10-  
yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile

4',6'-bis(3,6-dimethyl-9H-carbazol-9-yl)-2'-(3,6-diphenyl-9H-carbazol-9-yl)-  
[1,1':3',1''-terphenyl]-5'-carbonitrile

20 4',6'-bis(3,6-dimethyl-9H-carbazol-9-yl)-2'-(diphenylamino)-[1,1':3',1''-  
terphenyl]-5'-carbonitrile

4',6'-bis(3,6-dimethyl-9H-carbazol-9-yl)-5'-(3-(diphenylamino)-9H-carbazol-9-  
yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-bis(3,6-dimethyl-9H-carbazol-9-yl)-5'-(3,6-diphenyl-9H-carbazol-9-yl)-  
[1,1':3',1''-terphenyl]-2'-carbonitrile

25 4',6'-bis(3,6-dimethyl-9H-carbazol-9-yl)-5'-(4,6-diphenylpyrimidin-2-yl)-  
[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-bis(3,6-dimethyl-9H-carbazol-9-yl)-5'-phenyl-[1,1':3',1''-terphenyl]-2'-  
carbonitrile

4',6'-bis(3,6-diphenyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-bis(3,6-diphenyl-9H-carbazol-9-yl)-2'-(diphenylamino)-[1,1':3',1''-terphenyl]-5'-carbonitrile

4',6'-bis(3,6-diphenyl-9H-carbazol-9-yl)-5'-phenyl-[1,1':3',1''-terphenyl]-2'-carbonitrile

5 4',6'-bis(5-phenylindolo[3,2-a]carbazol-12(5H)-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-bis(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-5'-(9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

10 4',6'-di(9H-carbazol-9-yl)-2'-(3,6-di-tert-butyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile

4',6'-di(9H-carbazol-9-yl)-2'-(3,6-dimethyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile

4',6'-di(9H-carbazol-9-yl)-2'-(3,6-diphenyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile

15 4',6'-di(9H-carbazol-9-yl)-5'-(10-phenyl-10H-phenoxazin-4-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-di(9H-carbazol-9-yl)-5'-(10H-phenoxazin-10-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

20 4',6'-di(9H-carbazol-9-yl)-5'-(3-(9,9-dimethylacridin-10(9H)-yl)phenyl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-di(9H-carbazol-9-yl)-5'-(3-(diphenylamino)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-di(9H-carbazol-9-yl)-5'-(3,6-diphenyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

25 4',6'-di(9H-carbazol-9-yl)-5'-(9-phenylacridin-10(9H)-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-di(9H-carbazol-9-yl)-5'-(9,9-dimethylacridin-10(9H)-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

4',6'-di(9H-carbazol-9-yl)-5'-(9,9-diphenylacridin-10(9H)-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-4',6'-di(9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5 5'-(2-(10H-phenoxazin-10-yl)phenyl)-4',6'-di(9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(3-(10H-phenothiazin-10-yl)phenyl)-4',6'-di(9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

10 5'-(3-(acridin-10(9H)-yl)phenyl)-4',6'-di(9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(3,6-bis(diphenylamino)-9H-carbazol-9-yl)-4',6'-di(9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(3,6-di-tert-butyl-9H-carbazol-9-yl)-4',6'-bis(3,6-diphenyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

15 5'-(7H-benzo[4,5]thieno[2,3-b]carbazol-7-yl)-4',6'-di(9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(9H-carbazol-9-yl)-4',6'-bis(10-phenyl-10H-phenothiazin-4-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

20 5'-(9H-carbazol-9-yl)-4',6'-bis(3,6-dimethyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(9H-carbazol-9-yl)-4',6'-bis(9-methyl-9-phenylacridin-10(9H)-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(9H-carbazol-9-yl)-4',6'-bis(9-phenylacridin-10(9H)-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

25 5'-(9H-carbazol-9-yl)-4',6'-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-3-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

5'-(9H-carbazol-9-yl)-4',6'-di(10H-phenoxazin-10-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

6'-(1'-methyl-9H-[3,9'-bicarbazol]-9-yl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

6'-(3-(1H-indol-1-yl)-9H-carbazol-9-yl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

5 6'-(3-(2-(diphenylamino)phenyl)-9H-carbazol-9-yl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

6'-(3-(4-aminophenyl)-9H-carbazol-9-yl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

10 6'-(3-(bis(4-(tert-butyl)phenyl)amino)-9H-carbazol-9-yl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

6'-(3-(di-p-tolylamino)-9H-carbazol-9-yl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

6'-(3-(diphenylamino)-9H-carbazol-9-yl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

15 6'-(3-amino-9H-carbazol-9-yl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

6'-(3,6-bis(2-(diphenylamino)phenyl)-9H-carbazol-9-yl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

6'-(3,6-bis(9H-pyrido[3,4-b]indol-9-yl)-9H-carbazol-9-yl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

20 6'-(3,6-bis(di-p-tolylamino)-9H-carbazol-9-yl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

6'-(3,6-bis(diphenylamino)-9H-carbazol-9-yl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

25 6'-(3,6-di-tert-butyl-9H-carbazol-9-yl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

6'-(3,6-di(1H-pyrrol-1-yl)-9H-carbazol-9-yl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

6'-(3,6-diphenyl-9H-carbazol-9-yl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile



- 6'-(3',6'-di-tert-butyl-9H-[3,9'-bicarbazol]-9-yl)-4',5'-diphenyl-[1,1':2,1''-terphenyl]-3'-carbonitrile
- 6'-(5H-benzofuro[3,2-c]carbazol-5-yl)-4',5'-diphenyl-[1,1':2,1''-terphenyl]-3'-carbonitrile
- 5 6'-(9H-[3,9'-bicarbazol]-9-yl)-4',5'-diphenyl-[1,1':2,1''-terphenyl]-3'-carbonitrile
- 6'-(9H-[3,9':3',9''-tercarbazol]-9-yl)-4',5'-diphenyl-[1,1':2,1''-terphenyl]-3'-carbonitrile
- 4',6'-di(9H-carbazol-9-yl)-5'-(10H-spiro[acridine-9,9'-fluoren]-10-yl)-[1,1':3,1''-terphenyl]-2'-carbonitrile
- 10 3,5-di(9H-carbazol-9-yl)-2,6-bis(3,6-diphenyl-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile
- 2'-(9,9-dimethylacridin-10(9H)-yl)-4',6'-bis(3-(diphenylamino)-9H-carbazol-9-yl)-[1,1':3,1''-terphenyl]-5'-carbonitrile
- 2',4',6'-tris(3,6-di-tert-butyl-9H-carbazol-9-yl)-[1,1':3,1''-terphenyl]-5'-carbonitrile
- 15 2,6-di(9H-carbazol-9-yl)-3,5-bis(3,6-diphenyl-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile
- 5'-(9'H-[9,3':6',9''-tercarbazol]-9'-yl)-4',6'-bis(3,6-dimethyl-9H-carbazol-9-yl)-[1,1':3,1''-terphenyl]-2'-carbonitrile
- 20 2,6-bis(9,9-dimethyl-10-phenyl-9,10-dihydroacridin-3-yl)-3,5-bis(3,6-dimethyl-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile
- 6'-(3,6-di(1H-indol-1-yl)-9H-carbazol-9-yl)-4',5'-diphenyl-[1,1':2,1''-terphenyl]-3'-carbonitrile
- 5'-(3,6-bis(diphenylamino)-9H-carbazol-9-yl)-4',6'-bis(3,6-dimethyl-9H-carbazol-9-yl)-[1,1':3,1''-terphenyl]-2'-carbonitrile
- 25 5'-(3,6-dimethyl-9H-carbazol-9-yl)-4',6'-bis(3,6-diphenyl-9H-carbazol-9-yl)-[1,1':3,1''-terphenyl]-2'-carbonitrile
- 4',6'-bis(3,6-di-tert-butyl-9H-carbazol-9-yl)-5'-phenyl-[1,1':3,1''-terphenyl]-2'-carbonitrile

- 2',4',6'-tris(3,6-diphenyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile
- 2,6-bis(3-([1,1'-biphenyl]-3-yl)-6-phenyl-9H-carbazol-9-yl)-3,5-di(9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile
- 6'-(9,9''-diphenyl-9H,9'H,9''H-[3,3':6',3''-tercarbazol]-9'-yl)-4',5'-diphenyl-
- 5 [1,1':2',1''-terphenyl]-3'-carbonitrile
- 6'-(3,6-bis(diphenylamino)-9H-carbazol-9-yl)-4''-(diphenylamino)-4'-(4-(diphenylamino)phenyl)-5'-phenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile
- 4',5',6'-tris(3-(diphenylamino)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile
- 10 4',6'-di(9H-carbazol-9-yl)-2,2''-di(10H-phenothiazin-10-yl)-5'-phenyl-[1,1':3',1''-terphenyl]-2'-carbonitrile
- 4',6'-di(9H-carbazol-9-yl)-3,3''-bis(9,9-dimethylacridin-10(9H)-yl)-5'-phenyl-[1,1':3',1''-terphenyl]-2'-carbonitrile
- 2,6-bis(3,6-di-tert-butyl-9H-carbazol-9-yl)-3,5-bis(3,6-dimethyl-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile
- 15 yl)-[1,1'-biphenyl]-4-carbonitrile
- 3,4,5-tri(9H-carbazol-9-yl)-2,6-bis(3,6-diphenyl-9H-carbazol-9-yl)benzonitrile
- 3,5-di(9H-carbazol-9-yl)-2,6-bis(3,6-di-tert-butyl-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile
- 6'-(3,6-bis(5H-pyrido[3,2-b]indol-5-yl)-9H-carbazol-9-yl)-4',5'-diphenyl-
- 20 [1,1':2',1''-terphenyl]-3'-carbonitrile
- 4',5'-diphenyl-6'-(3,3'',6,6''-tetra-tert-butyl-9'H-[9,3':6',9''-tercarbazol]-9'-yl)-[1,1':2',1''-terphenyl]-3'-carbonitrile
- 2'-(9H-carbazol-9-yl)-4',6'-bis(5-phenylindolo[3,2-a]carbazol-12(5H)-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile
- 6'-(2-(9H-[3,9'-bicarbazol]-9-yl)phenyl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile
- 25 carbonitrile
- 5'-(4-(10H-phenoxazin-10-yl)phenyl)-6'-(9H-carbazol-9-yl)-4-(10H-phenoxazin-10-yl)-4'-phenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

5'-(9H-carbazol-9-yl)-4',6'-bis(3-(diphenylamino)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

3,5-bis(3,6-dimethyl-9H-carbazol-9-yl)-2,6-bis(3,6-diphenyl-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

5 2,6-bis(3-(diphenylamino)-9H-carbazol-9-yl)-3,5-bis(phenyl(p-tolyl)amino)-[1,1'-biphenyl]-4-carbonitrile

4'-(2-(9H-carbazol-9-yl)phenyl)-2''-(9H-carbazol-9-yl)-6'-(3,6-diphenyl-9H-carbazol-9-yl)-5'-phenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

10 3,5-di(9H-carbazol-9-yl)-2,6-bis(3-(diphenylamino)-9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

4''-(9,9-dimethylacridin-10(9H)-yl)-4'-(4-(9,9-dimethylacridin-10(9H)-yl)phenyl)-6'-(3-(diphenylamino)-9H-carbazol-9-yl)-5'-phenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

15 3',5'-bis(3,6-di-tert-butyl-9H-carbazol-9-yl)-4''-(diphenylamino)-6'-(4-(diphenylamino)phenyl)-[1,1':2',1''-terphenyl]-4'-carbonitrile

2,6-bis(3-([1,1'-biphenyl]-2-yl)-6-phenyl-9H-carbazol-9-yl)-3,5-di(9H-carbazol-9-yl)-[1,1'-biphenyl]-4-carbonitrile

5'-(3,6-dimethyl-9H-carbazol-9-yl)-4',6'-bis(3-(diphenylamino)-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

20 6'-(9H-carbazol-9-yl)-3''-(9,9-dimethylacridin-10(9H)-yl)-4'-(3-(9,9-dimethylacridin-10(9H)-yl)phenyl)-5'-phenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

3',5'-bis(3,6-dimethyl-9H-carbazol-9-yl)-4''-(diphenylamino)-6'-(4-(diphenylamino)phenyl)-[1,1':2',1''-terphenyl]-4'-carbonitrile

25 2'-(3,6-di-tert-butyl-9H-carbazol-9-yl)-4',6'-bis(3,6-diphenyl-9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile

5'-(9H-[9,3':6',9''-tercarbazol]-9-yl)-4',6'-di(9H-carbazol-9-yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

3',5'-di(9H-carbazol-9-yl)-4''-(diphenylamino)-6'-(4-(diphenylamino)phenyl)-[1,1':2',1''-terphenyl]-4'-carbonitrile

3,5-di(9H-carbazol-9-yl)-2,6-bis(3,6-di([1,1'-biphenyl]-4-yl)-9H-carbazol-9-yl)-  
[1,1'-biphenyl]-4-carbonitrile

6'-(3,6-bis(bis(4-(tert-butyl)phenyl)amino)-9H-carbazol-9-yl)-4',5'-diphenyl-  
[1,1':2',1''-terphenyl]-3'-carbonitrile

5        2,6-bis(3,6-dimethyl-9H-carbazol-9-yl)-3,5-bis(3,6-diphenyl-9H-carbazol-9-yl)-  
[1,1'-biphenyl]-4-carbonitrile

6'-(1,1''-dimethyl-9'H-[9,3':6',9''-tercarbazol]-9'-yl)-4',5'-diphenyl-[1,1':2',1''-  
terphenyl]-3'-carbonitrile

10       2'-(9H-carbazol-9-yl)-4',6'-bis(3,6-di-tert-butyl-9H-carbazol-9-yl)-[1,1':3',1''-  
terphenyl]-5'-carbonitrile

6'-(9'H-[9,3':6',9''-tercarbazol]-9'-yl)-4',5'-diphenyl-[1,1':2',1''-terphenyl]-3'-  
carbonitrile

4',6'-di(9H-carbazol-9-yl)-2'-(12-phenylindolo[2,3-a]carbazol-11(12H)-yl)-  
[1,1':3',1''-terphenyl]-5'-carbonitrile

15       5'-(9H-carbazol-9-yl)-4',6'-bis(3,6-di-tert-butyl-9H-carbazol-9-yl)-[1,1':3',1''-  
terphenyl]-2'-carbonitrile

6'-(9''H-[9,3':9',3'':6'',9''':3''',9''''-quinquecarbazol]-9''-yl)-4',5'-diphenyl-[1,1':2',1''-  
terphenyl]-3'-carbonitrile

20       4',6'-bis(3,6-diphenyl-9H-carbazol-9-yl)-5'-(3-(diphenylamino)-9H-carbazol-9-  
yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile

3,5-bis(3,6-di-tert-butyl-9H-carbazol-9-yl)-2,6-bis(3,6-dimethyl-9H-carbazol-9-  
yl)-[1,1'-biphenyl]-4-carbonitrile

3,5-bis(3,6-dimethyl-9H-carbazol-9-yl)-2,6-bis(3-(diphenylamino)-9H-carbazol-  
9-yl)-[1,1'-biphenyl]-4-carbonitrile

25       2'-(3,6-diphenyl-9H-carbazol-9-yl)-4',6'-bis(9,9-diphenylacridin-10(9H)-yl)-  
[1,1':3',1''-terphenyl]-5'-carbonitrile

2'-(9H-carbazol-9-yl)-4',6'-bis(3,6-diphenyl-9H-carbazol-9-yl)-[1,1':3',1''-  
terphenyl]-5'-carbonitrile

3,5-di(9H-carbazol-9-yl)-2,6-bis(3,6-di([1,1'-biphenyl]-2-yl)-9H-carbazol-9-yl)-  
[1,1'-biphenyl]-4-carbonitrile

3,5-bis(3-(diphenylamino)-9H-carbazol-9-yl)-2,6-bis(phenyl(m-tolyl)amino)-  
[1,1'-biphenyl]-4-carbonitrile

5 3,5'-bis(3,6-di-tert-butyl-9H-carbazol-9-yl)-6'-phenyl-[1,1':2',1''-terphenyl]-4'-  
carbonitrile

5'-(3-(10H-phenothiazin-10-yl)phenyl)-6'-(9H-carbazol-9-yl)-3-(10H-  
phenothiazin-10-yl)-4'-phenyl-[1,1':2',1''-terphenyl]-3'-carbonitrile

10 3,5-di(9H-carbazol-9-yl)-2,6-bis(9,9-diphenylacridin-10(9H)-yl)-[1,1'-biphenyl]-  
4-carbonitrile

3,5-di(9H-carbazol-9-yl)-2,6-bis(3,6-di([1,1'-biphenyl]-3-yl)-9H-carbazol-9-yl)-  
[1,1'-biphenyl]-4-carbonitrile

4',6'-di(9H-carbazol-9-yl)-5'-(12-phenylindolo[2,3-a]carbazol-11(12H)-yl)-  
[1,1':3',1''-terphenyl]-2'-carbonitrile

15 5'-(9H-carbazol-9-yl)-4',6'-bis(5-phenylindolo[3,2-a]carbazol-12(5H)-yl)-  
[1,1':3',1''-terphenyl]-2'-carbonitrile

2,3,5,6-tetra(9H-carbazol-9-yl)-4-(9-phenyl-9H-carbazol-3-yl)benzonitrile

2,3,4,6-tetra(9H-carbazol-9-yl)-5-(3,6-diphenyl-9H-carbazol-9-yl)benzonitrile

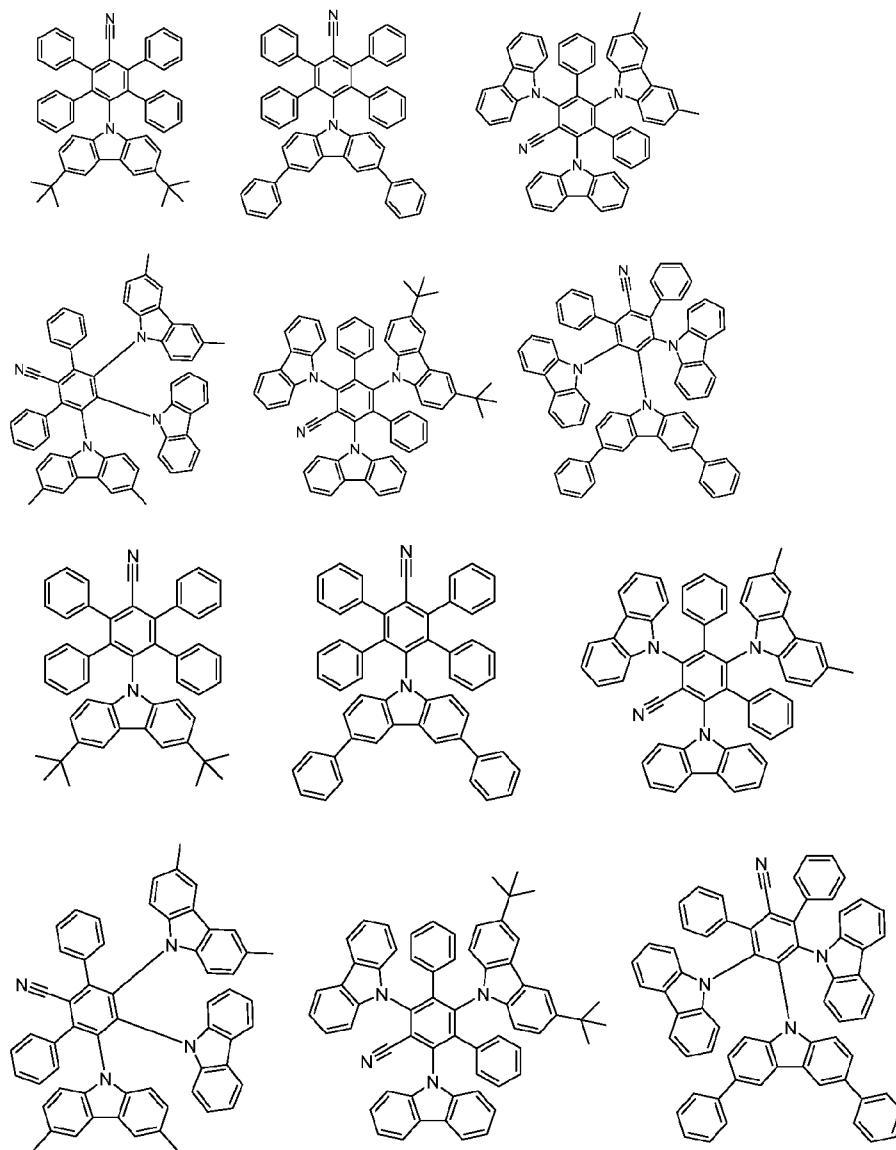
2,4,6-tri(9H-carbazol-9-yl)-3,5-bis(3,6-diphenyl-9H-carbazol-9-yl)benzonitrile

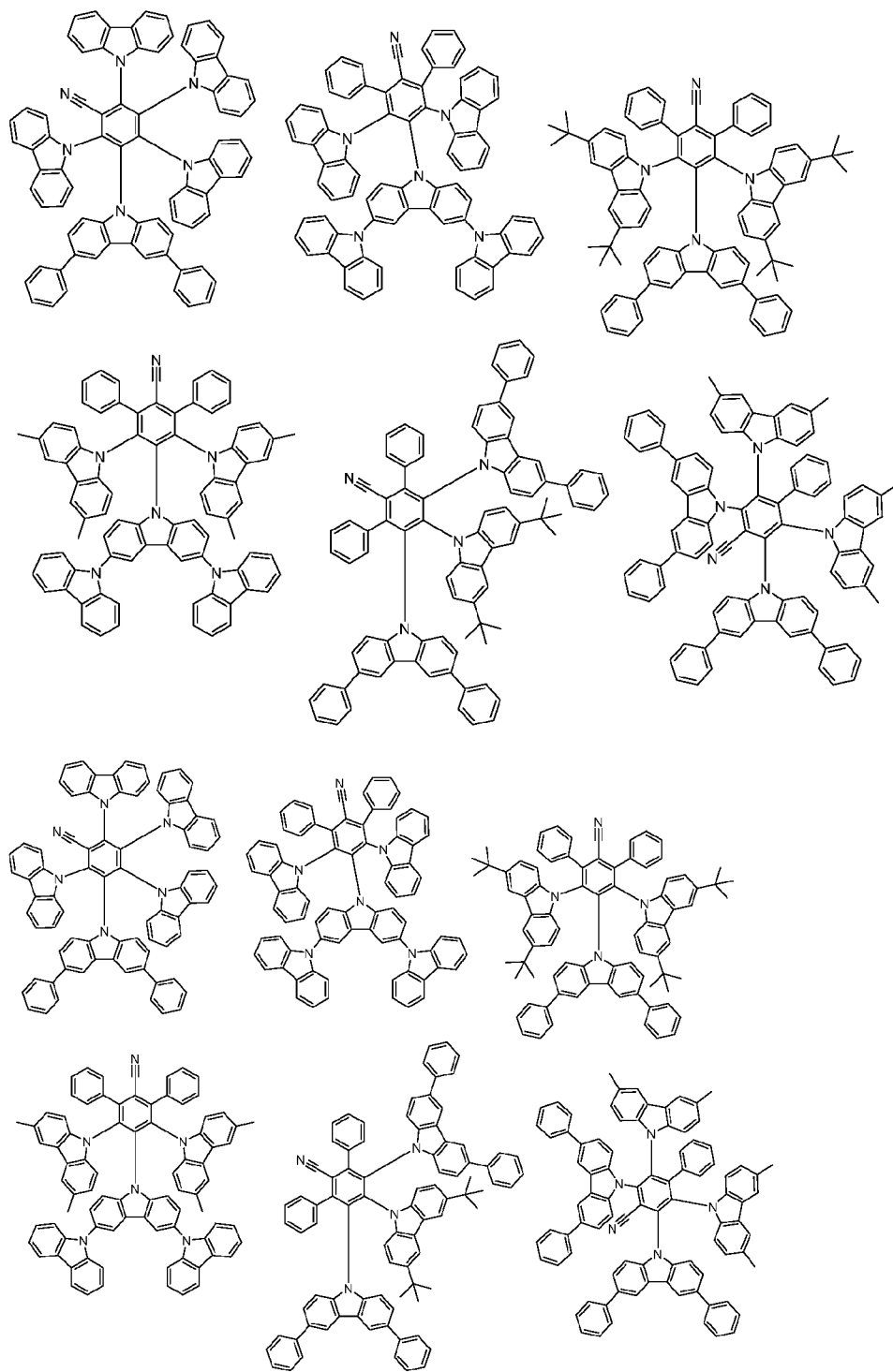
20 5'-(9H-carbazol-9-yl)-4',6'-bis(3,6-diphenyl-9H-carbazol-9-yl)-[1,1':3',1''-  
terphenyl]-2'-carbonitrile

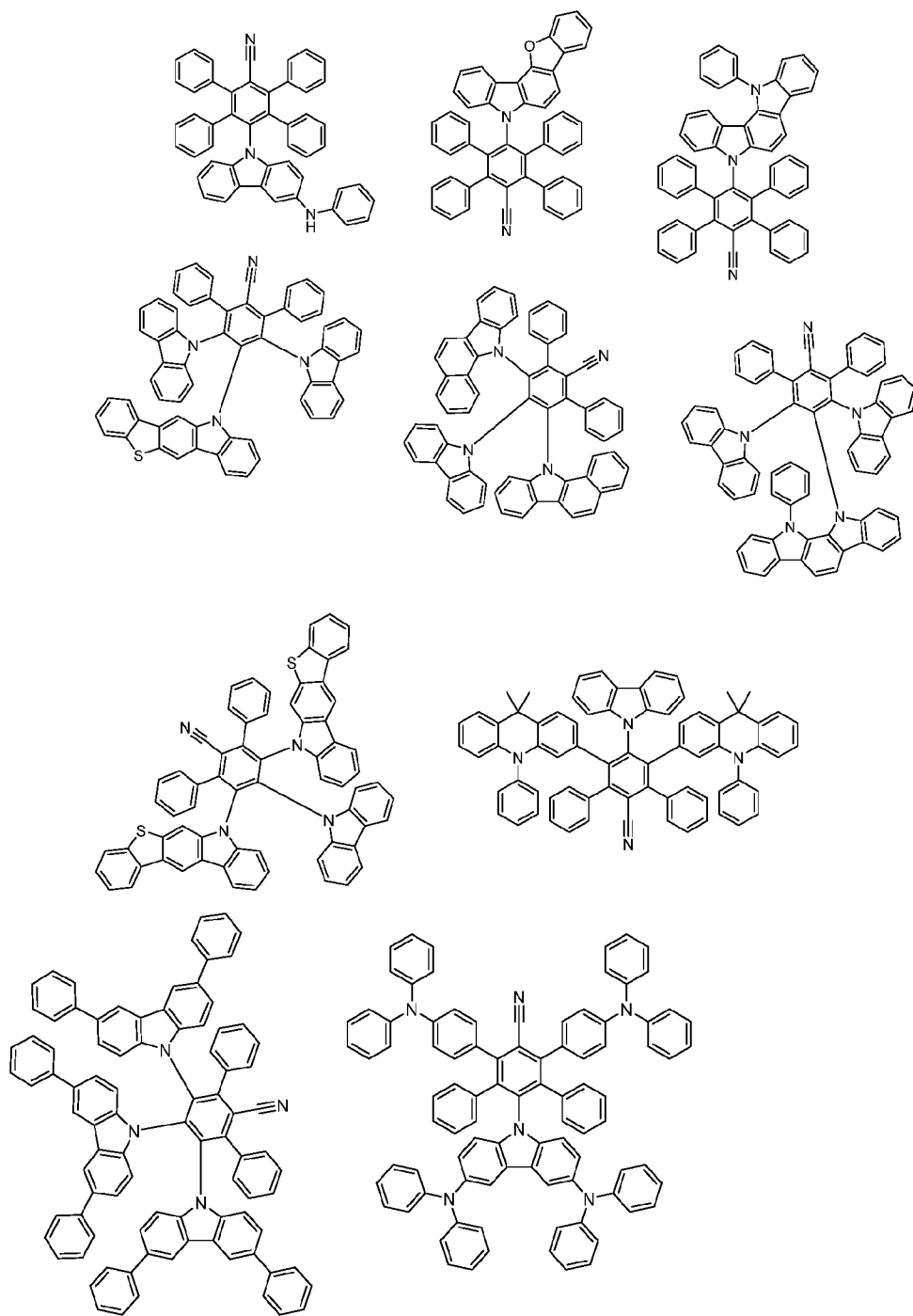
4',6'-bis(11H-benzo[4,5]thieno[3,2-b]carbazol-11-yl)-2'-(3,6-diphenyl-9H-  
carbazol-9-yl)-[1,1':3',1''-terphenyl]-5'-carbonitrile, and

25 5'-(3,6-diphenyl-9H-carbazol-9-yl)-4',6'-bis(3-(diphenylamino)-9H-carbazol-9-  
yl)-[1,1':3',1''-terphenyl]-2'-carbonitrile.

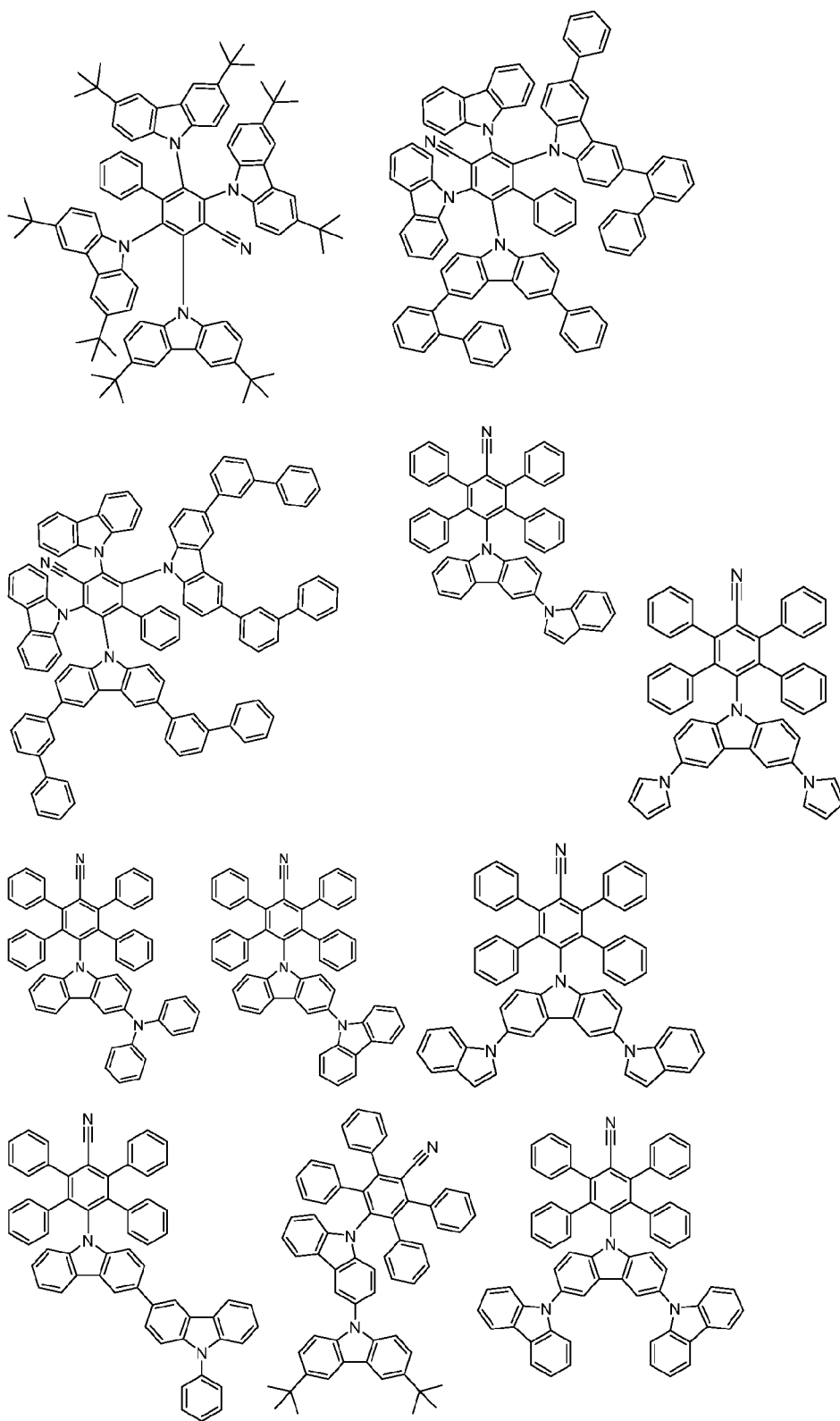
In some embodiments, the compound of Formula (V) is selected from

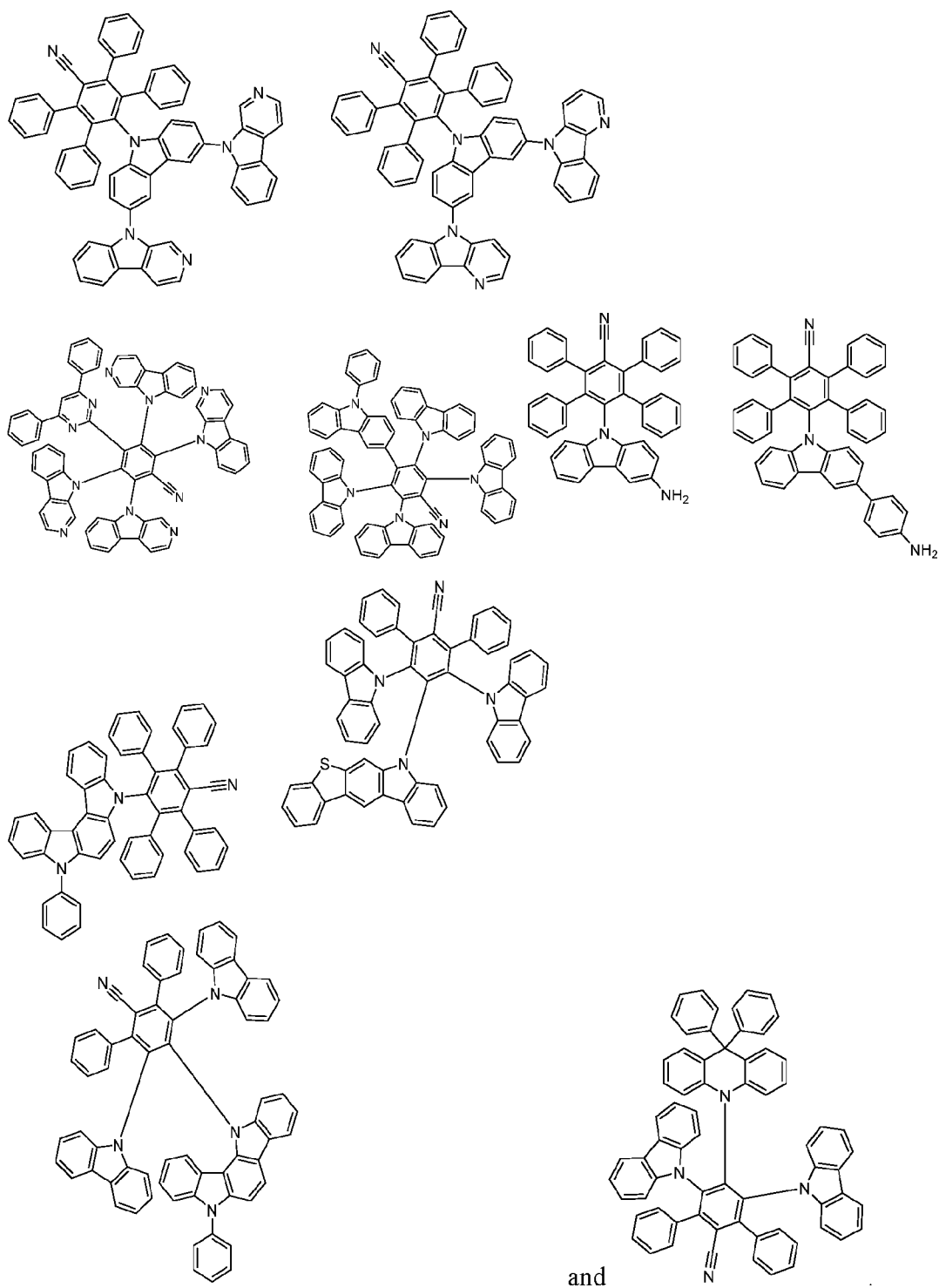




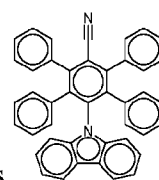


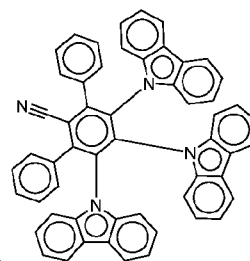






In some embodiments, the compound of formula (V) is





In some embodiments, the compound of formula (V) is

In some embodiments, compounds of formula (I), (II), (III), (IV), or (V) are substituted with deuterium.

5 In some embodiments, compounds of formula (I), (II), (III), (IV), or (V) are light-emitting materials.

In some embodiments, compounds of formula (I), (II), (III), (IV), or (V) are compound capable of emitting delayed fluorescence.

10 In some embodiments of the present disclosure, when excited via thermal or electronic means, the compounds of formula (I), (II), (III), (IV), or (V) can produce light in the blue, green, yellow, orange, or red region of the visible spectrum (e.g., about 420 nm to about 500 nm, about 500 nm to about 600 nm, or about 600 nm to about 700 nm).

15 In some embodiments of the present disclosure, when excited via thermal or electronic means, the compounds of formula (I), (II), (III), (IV), or (V) can produce light in the red or orange region of the visible spectrum (e.g., about 620 nm to about 780 nm; about 650 nm).

20 In some embodiments of the present disclosure, when excited via thermal or electronic means, the compounds of formula (I), (II), (III), (IV), or (V) can produce light in the orange or yellow region of the visible spectrum (e.g., about 570 nm to about 620 nm; about 590 nm; about 570 nm).

In some embodiments of the present disclosure, when excited via thermal or electronic means, the compounds of formula (I), (II), (III), (IV), or (V) can produce light in the green region of the visible spectrum (e.g., about 490 nm to about 575 nm; about 510 nm).

25 In some embodiments of the present disclosure, when excited via thermal or electronic means, the compounds of formula (I), (II), (III), (IV), or (V) can produce light

in the blue region of the visible spectrum (e.g., about 400 nm to about 490 nm; about 475 nm).

Electronic properties of a library of small chemical molecules can be computed using known ab initio quantum mechanical computations. For example, using a time-dependent density functional theory using, as a basis set, the set of functions known as 6-31G\* and a Becke, 3-parameter, Lee- Yang-Parr hybrid functional to solve Hartree-Fock equations (TD-DFT/B3LYP/6-31G\*), molecular fragments (moieties) can be screened which have HOMOs above a specific threshold and LUMOs below a specific threshold, and wherein the calculated triplet state of the moieties is above 2.75 eV.

Therefore, for example, a donor moiety ("D") can be selected because it has a HOMO energy (e.g., an ionization potential) of greater than or equal to -6.5 eV. An acceptor moiety ("A") can be selected because it has, for example, a LUMO energy (e.g., an electron affinity) of less than or equal to -0.5 eV. The bridge moiety ("B") can be a rigid conjugated system which can, for example, sterically restrict the acceptor and donor moieties into a specific configuration, thereby preventing the overlap between the conjugated  $\pi$  system of donor and acceptor moieties.

In some embodiments, the compound library is filtered using one or more of the following properties:

1. emission near a certain wavelength;
2. calculated triplet state above a certain energy level;
3.  $\Delta$ EST value below a certain value;
4. quantum yield above a certain value;
5. HOMO level; and
6. LUMO level.

In some embodiments, the difference between the lowest singlet excited state and the lowest triplet excited state at 77K ( $\Delta$ EST) is less than about 0.5 eV, less than about 0.4 eV, less than about 0.3 eV, less than about 0.2 eV, or less than about 0.1 eV. In some embodiments, the  $\Delta$ EST value is less than about 0.09 eV, less than about 0.08 eV, less than about 0.07 eV, less than about 0.06 eV, less than about 0.05 eV, less than about 0.04 eV, less than about 0.03 eV, less than about 0.02 eV, or less than about 0.01 eV.

In some embodiments, a compound of formula (I), (II), (III), (IV), or (V) exhibits an external quantum yield of greater than 25%, such as about 30%, about 35%, about 40%, about 45%, about 50%, about 55%, about 60%, about 65%, about 70%, about 75%, about 80%, about 85%, about 90%, about 95%, or greater.

*Compositions with the Disclosed Compounds*

In some embodiments, a compound of formula (I), (II), (III), (IV), or (V) is combined with, dispersed within, covalently bonded to, coated with, formed on, or otherwise associated with, one or more materials (e.g., small molecules, polymers, metals, metal complexes, etc.) to form a film or layer in solid state. For example, the compound of formula (I), (II), (III), (IV), or (V) may be combined with an electroactive material to form a film. In some cases, the compound of formula (I), (II), (III), (IV), or (V) may be combined with a hole-transport polymer. In some cases, the compound of formula (I), (II), (III), (IV), or (V) may be combined with an electron-transport polymer. In some cases, the compound of formula (I), (II), (III), (IV), or (V) may be combined with a hole-transport polymer and an electron-transport polymer. In some cases, the compound of formula (I), (II), (III), (IV), or (V) may be combined with a copolymer comprising both hole-transport portions and electron-transport portions. In such embodiments, electrons and/or holes formed within the solid film or layer may interact with the compound of formula (I), (II), (III), (IV), or (V).

*Exemplary Uses of the Disclosed Compounds*

In some embodiments, a compound of formula (I), (II), (III), (IV), or (V) is combined with, dispersed within, covalently bonded to, coated with, formed on, or otherwise associated with, one or more materials (e.g., small molecules, polymers, metals, metal complexes, etc.) to form a film or layer in solid state. For example, the compound of formula (I), (II), (III), (IV), or (V) may be combined with an electroactive material to form a film. In some cases, the compound of formula (I), (II), (III), (IV), or (V) may be combined with a hole-transport polymer. In some cases, the compound of formula (I), (II), (III), (IV), or (V) may be combined with an electron-transport polymer. In some cases, the compound of formula (I), (II), (III), (IV), or (V) may be combined with a hole-transport polymer and an electron-transport polymer. In some cases, the compound of formula (I), (II), (III), (IV), or (V) may be combined with a copolymer comprising both hole-transport portions and electron-transport portions. In such embodiments, electrons and/or holes formed within the solid film or layer may interact with the compound of formula (I), (II), (III), (IV), or (V).

*Exemplary Uses of the Disclosed Compounds*Organic Light-Emitting Diodes

One aspect of the invention relates to use of the compound of formula (I), (II), (III), (IV), or (V) of the invention as a light-emitting material of an organic light-emitting device. In some embodiments, the compound represented by the formula (I), (II), (III), (IV), or (V) of the invention may be effectively used as a light-emitting material in a light-emitting layer of an organic light-emitting device. In some embodiments, the compound of formula (I), (II), (III), (IV), or (V) comprises a delayed fluorescent material emitting delayed fluorescent light (delayed fluorescence emitter). In some embodiments, the invention provides a delayed fluorescence emitter having the structure of formula (I), (II), (III), (IV), or (V). In some embodiments, the invention relates to the use of the compound of formula (I), (II), (III), (IV), or (V) as the delayed fluorescence emitter. In some embodiments, the invention relates to a method for emitting delayed fluorescent light from the compound of formula (I), (II), (III), (IV), or (V). In some embodiments, an organic light-emitting device comprising the compound as a light-emitting material, emits delayed fluorescent light, and has a high light emission efficiency.

In some embodiments, a light-emitting layer comprises a compound of formula (I), wherein the compound of formula (I), (II), (III), (IV), or (V) is oriented parallel to the substrate. In some embodiments, the substrate is a film forming surface. In some embodiments, the orientation of the compound of formula (I), (II), (III), (IV), or (V) with respect to the film forming surface influences or determines the propagation directions of the light emitted by the compound to be aligned. In some embodiments, the alignment of the propagation directions of the light emitted by the compound of formula (I), (II), (III), (IV), or (V) enhances the light extraction efficiency from the light-emitting layer.

One aspect of the invention relates to an organic light-emitting device. In some embodiments, the organic light-emitting device comprises a light-emitting layer. In some embodiments, the light-emitting layer comprises a compound of formula (I), (II), (III), (IV), or (V) as a light-emitting material. In some embodiments, the organic light-emitting device is an organic photoluminescent device (organic PL device). In some embodiments, the organic light-emitting device is an organic electroluminescent device (organic EL device). In some embodiments, the compound of formula (I), (II), (III), (IV), or (V) assists the light emission of another light-emitting material comprised in the light-emitting layer, i.e., as a so-called assistant dopant. In some embodiments, the

compound of formula (I), (II), (III), (IV), or (V) comprised in the light-emitting layer is in its the lowest excited singlet energy level, which is comprised between the lowest excited singlet energy level of the host material comprised in the light-emitting layer and the lowest excited singlet energy level of the another light-emitting material comprised in the light-emitting layer.

In some embodiments, the organic photoluminescent device comprises at least one light-emitting layer. In some embodiments, the organic electroluminescent device comprises at least an anode, a cathode, and an organic layer between the anode and the cathode. In some embodiments, the organic layer comprises at least a light-emitting layer. In some embodiments, the organic layer comprises only a light-emitting layer. In some embodiments, the organic layer, comprises one or more organic layers in addition to the light-emitting layer. Examples of the organic layer include a hole transporting layer, a hole injection layer, an electron barrier layer, a hole barrier layer, an electron injection layer, an electron transporting layer and an exciton barrier layer. In some embodiments, the hole transporting layer may be a hole injection and transporting layer having a hole injection function, and the electron transporting layer may be an electron injection and transporting layer having an electron injection function. An example of an organic electroluminescent device is shown in Fig. 1.

## *Substrate*

In some embodiments, the organic electroluminescent device of the invention is supported by a substrate, wherein the substrate is not particularly limited and may be any of those that have been commonly used in an organic electroluminescent device, for example those formed of glass, transparent plastics, quartz and silicon.

## *Anode*

In some embodiments, the anode of the organic electroluminescent device is made of a metal, an alloy, an electroconductive compound, or a combination thereof. In some embodiments, the metal, alloy, or electroconductive compound has a large work function (4 eV or more). In some embodiments, the metal is Au. In some embodiments, the electroconductive transparent material is selected from CuI, indium tin oxide (ITO), SnO<sub>2</sub>, and ZnO. In some embodiments, an amorphous material capable of forming a transparent electroconductive film, such as IDIXO (In<sub>2</sub>O<sub>3</sub>-ZnO), is be used. In some

embodiments, the anode is a thin film. In some embodiments the thin film is made by vapor deposition or sputtering. In some embodiments, the film is patterned by a photolithography method. In some embodiments, where the pattern may not require high accuracy (for example, approximately 100  $\mu\text{m}$  or more), the pattern may be formed with  
5 a mask having a desired shape on vapor deposition or sputtering of the electrode material. In some embodiments, when a material can be applied as a coating, such as an organic electroconductive compound, a wet film forming method, such as a printing method and a coating method is used. In some embodiments, when the emitted light goes through the anode, the anode has a transmittance of more than 10%, and the anode  
10 has a sheet resistance of several hundred Ohm per square or less. In some embodiments, the thickness of the anode is from 10 to 1,000 nm. In some embodiments, the thickness of the anode is from 10 to 200 nm. In some embodiments, the thickness of the anode varies depending on the material used.

#### 15 *Cathode*

In some embodiments, the cathode is made of an electrode material a metal having a small work function (4 eV or less) (referred to as an electron injection metal), an alloy, an electroconductive compound, or a combination thereof. In some embodiments, the electrode material is selected from sodium, a sodium-potassium alloy,  
20 magnesium, lithium, a magnesium-copper mixture, a magnesium-silver mixture, a magnesium-aluminum mixture, a magnesium-indium mixture, an aluminum-aluminum oxide ( $\text{Al}_2\text{O}_3$ ) mixture, indium, a lithium-aluminum mixture, and a rare earth metal. In some embodiments, a mixture of an electron injection metal and a second metal that is a stable metal having a larger work function than the electron injection metal is used. In  
25 some embodiments, the mixture is selected from a magnesium-silver mixture, a magnesium-aluminum mixture, a magnesium-indium mixture, an aluminum-aluminum oxide ( $\text{Al}_2\text{O}_3$ ) mixture, a lithium-aluminum mixture, and aluminium. In some embodiments, the mixture increases the electron injection property and the durability against oxidation. In some embodiments, the cathode is produced by forming the  
30 electrode material into a thin film by vapor deposition or sputtering. In some embodiments, the cathode has a sheet resistance of several hundred Ohm per square or less. In some embodiments, the thickness of the cathode ranges from 10 nm to 5  $\mu\text{m}$ . In some embodiments, the thickness of the cathode ranges from 50 to 200 nm. In some



embodiments, for transmitting the emitted light, any one of the anode and the cathode of the organic electroluminescent device is transparent or translucent. In some embodiments, the transparent or translucent electroluminescent devices enhances the light emission luminance.

5           In some embodiments, the cathode is formed with an electroconductive transparent material, as described for the anode, to form a transparent or translucent cathode. In some embodiments, a device comprises an anode and a cathode, both being transparent or translucent.

#### *Light-emitting Layer*

10           In some embodiments, the light-emitting layer is a layer, in which holes and electrons, injected respectively from the anode and the cathode, are recombined to form excitons. In some embodiments the layer emits light.

          In some embodiments, a light-emitting material is solely used as the light-emitting layer. In some embodiments, the light-emitting layer contains a light-emitting material, and a host material. In some embodiments, the light-emitting material is one or  
15           more compounds of formula (I), (II), (III), (IV), or (V). In some embodiments, for the organic electroluminescent device and the organic photoluminescent device to exhibit a high light emission efficiency, the singlet excitons and the triplet excitons generated in the light-emitting material are confined in the light-emitting material. In some  
20           embodiments, a host material is used in addition to the light-emitting material in the light-emitting layer. In some embodiments, the host material is an organic compound. In some embodiments, the organic compounds has excited singlet energy and excited triplet energy, at least one of which is higher than those of the light-emitting material of the invention. In some embodiments, the singlet excitons and the triplet excitons  
25           generated in the light-emitting material of the invention are confined in the molecules of the light-emitting material of the invention. In some embodiments, the singlet and triplet excitons are sufficient confined to elicit the light emission efficiency. In some embodiments, the singlet excitons and the triplet excitons are not confined sufficiently, though a high light emission efficiency is still obtained, and thus a host material capable  
30           of achieving a high light emission efficiency can be used in the invention without any particular limitation. In some embodiments, the light emission occurs in the light-emitting material of the light-emitting layer in the devices of the invention. In some

embodiments, the emitted light contains both fluorescent light and delayed fluorescent light. In some embodiments, the emitted light comprises emitted light from the host material. In some embodiments, the emitted light consists of emitted light from the host material. In some embodiments, the emitted light light comprises emitted light from a compound of formula (I), (II), (III), (IV), or (V), and emitted light from the host material. In some embodiments, a TADF molecule and a host material are used. In some embodiments, the TADF will be assistant dopant.

In some embodiments, when a host material is used, the amount of the compound of the invention as the light-emitting material contained in the light-emitting layer is 0.1% by weight or more. In some embodiments, when a host material is used, the amount of the compound of the invention as the light-emitting material contained in the light-emitting layer is 1% by weight or more. In some embodiments, when a host material is used, the amount of the compound of the invention as the light-emitting material contained in the light-emitting layer is 50% by weight or less. In some embodiments, when a host material is used, the amount of the compound of the invention as the light-emitting material contained in the light-emitting layer is 20% by weight or less. In some embodiments, when a host material is used, the amount of the compound of the invention as the light-emitting material contained in the light-emitting layer is 10% by weight or less.

In some embodiments, the host material in the light-emitting layer is an organic compound comprising a hole transporting function and an electron transporting function. In some embodiments, the host material in the light-emitting layer is an organic compound that prevents the emitted light from being increased in wavelength. In some embodiments, the host material in the light-emitting layer is an organic compound with a high glass transition temperature.

### *Injection Layer*

An injection layer is a layer between the electrode and the organic layer. In some embodiments, the injection layer decreases the driving voltage and enhances the light emission luminance. In some embodiments the injection layer includes a hole injection layer and an electron injection layer. The injection layer can be positioned between the anode and the light-emitting layer or the hole transporting layer, and between the cathode and the light-emitting layer or the electron transporting layer. In some embodiments, an injection layer is present. In some embodiments, no injection layer is present.

*Barrier Layer*

A barrier layer is a layer capable of inhibiting charges (electrons or holes) and/or excitons present in the light-emitting layer from being diffused outside the light-emitting layer. In some embodiments, the electron barrier layer is between the light-emitting layer and the hole transporting layer, and inhibits electrons from passing through the light-emitting layer toward the hole transporting layer. In some embodiments, the hole barrier layer is between the light-emitting layer and the electron transporting layer, and inhibits holes from passing through the light-emitting layer toward the electron transporting layer. In some embodiments, the barrier layer inhibits excitons from being diffused outside the light-emitting layer. In some embodiments, the electron barrier layer and the hole barrier layer are exciton barrier layers. As used herein, the term "electron barrier layer" or "exciton barrier layer" includes a layer that has the functions of both electron barrier layer and of an exciton barrier layer.

*Hole Barrier Layer*

A hole barrier layer acts as an electron transporting layer. In some embodiments, the hole barrier layer inhibits holes from reaching the electron transporting layer while transporting electrons. In some embodiments, the hole barrier layer enhances the recombination probability of electrons and holes in the light-emitting layer. The material for the hole barrier layer may be the same materials as the ones described for the electron transporting layer.

*Electron Barrier Layer*

As electron barrier layer transports holes. In some embodiments, the electron barrier layer inhibits electrons from reaching the hole transporting layer while transporting holes. In some embodiments, the electron barrier layer enhances the recombination probability of electrons and holes in the light-emitting layer.

*Exciton Barrier Layer*

An exciton barrier layer inhibits excitons generated through recombination of holes and electrons in the light-emitting layer from being diffused to the charge transporting layer. In some embodiments, the exciton barrier layer enables effective confinement of excitons in the light-emitting layer. In some embodiments, the light emission efficiency of the device is enhanced. In some embodiments, the exciton barrier

layer is adjacent to the light-emitting layer on any of the side of the anode and the side of the cathode, and on both the sides. In some embodiments, where the exciton barrier layer is on the side of the anode, the layer can be between the hole transporting layer and the light-emitting layer and adjacent to the light-emitting layer. In some embodiments, where the exciton barrier layer is on the side of the cathode, the layer can be between the light-emitting layer and the cathode and adjacent to the light-emitting layer. In some embodiments, a hole injection layer, an electron barrier layer, or a similar layer is between the anode and the exciton barrier layer that is adjacent to the light-emitting layer on the side of the anode. In some embodiments, a hole injection layer, an electron barrier layer, a hole barrier layer, or a similar layer is between the cathode and the exciton barrier layer that is adjacent to the light-emitting layer on the side of the cathode. In some embodiments, the exciton barrier layer comprises excited singlet energy and excited triplet energy, at least one of which is higher than the excited singlet energy and the excited triplet energy of the light-emitting material, respectively.

#### *Hole Transporting Layer*

The hole transporting layer comprises a hole transporting material. In some embodiments, the hole transporting layer is a single layer. In some embodiments, the hole transporting layer comprises a plurality of layers.

In some embodiments, the hole transporting material has one of injection or transporting property of holes and barrier property of electrons. In some embodiments, the hole transporting material is an organic material. In some embodiments, the hole transporting material is an inorganic material. Examples of known hole transporting materials that may be used herein include but are not limited to a triazole derivative, an oxadiazole derivative, an imidazole derivative, a carbazole derivative, an indolocarbazole derivative, a polyarylalkane derivative, a pyrazoline derivative, a pyrazolone derivative, a phenylenediamine derivative, an arylamine derivative, an amino-substituted chalcone derivative, an oxazole derivative, a styrylanthracene derivative, a fluorenone derivative, a hydrazone derivative, a stilbene derivative, a silazane derivative, an aniline copolymer and an electroconductive polymer oligomer, particularly a thiophene oligomer, or a combination thereof. In some embodiments, the hole transporting material is selected from a porphyrin compound, an aromatic tertiary amine compound, and a styrylamine compound. In some embodiments, the hole transporting material is an aromatic tertiary amine compound.

*Electron Transporting Layer*

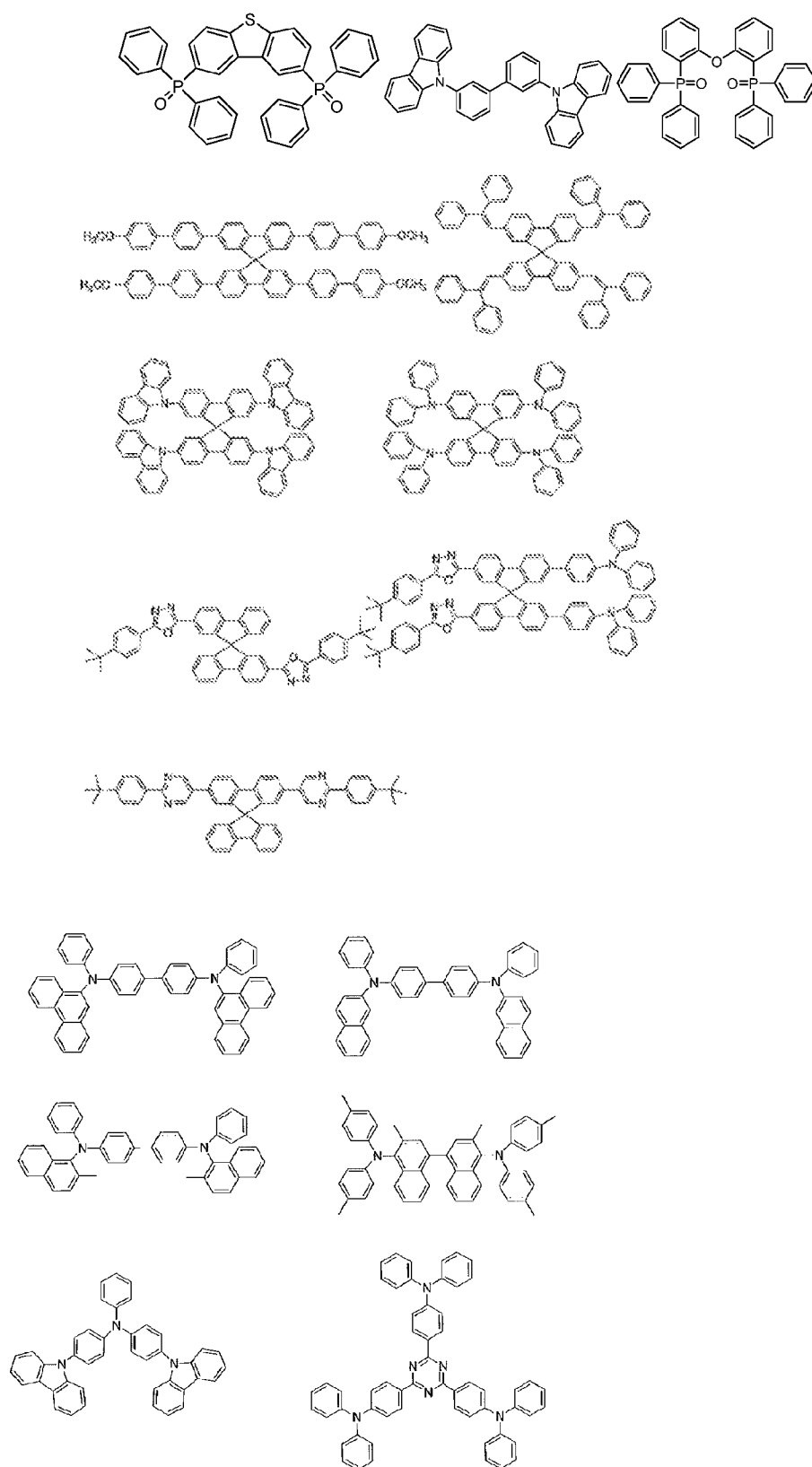
The electron transporting layer comprises an electron transporting material. In some embodiments, the electron transporting layer is a single layer. In some embodiments, the electron transporting layer comprises a plurality of layer.

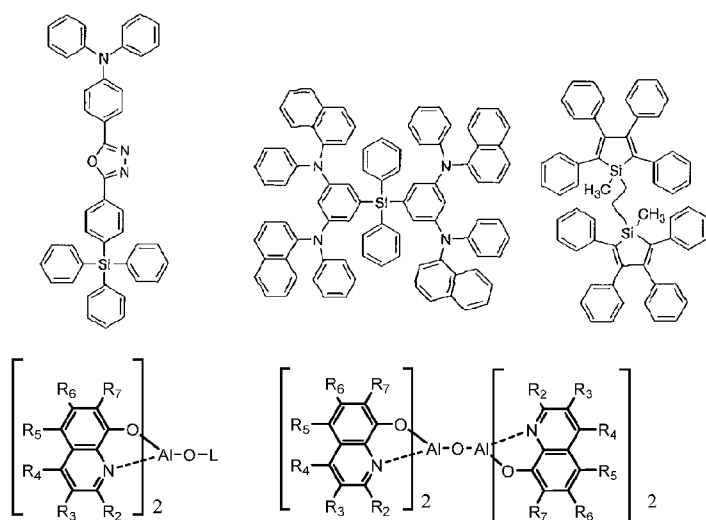
5 In some embodiments, the electron transporting material needs only to have a function of transporting electrons, which are injected from the cathode, to the light-emitting layer. In some embodiments, the electron transporting material also function as a hole barrier material. Examples of the electron transporting layer that may be used herein include but are not limited to a nitro-substituted fluorene derivative, a  
10 diphenylquinone derivative, a thiopyran dioxide derivative, carbodiimide, a fluorenylidene methane derivative, anthraquinodimethane, an anthrone derivatives, an oxadiazole derivative, an azole derivative, an azine derivative, or a combination thereof, or a polymer thereof. In some embodiments, the electron transporting material is a thiadiazole derivative, or a quinoxaline derivative. In some embodiments, the electron  
15 transporting material is a polymer material.

In some embodiments, a compound of formula (I), (II), (III), (IV), or (V) is comprised in the light-emitting layer of a device of the invention. In some embodiments, a compound of formula (I), (II), (III), (IV), or (V) is comprised in the light-emitting layer and at least one other layers. In some embodiments, the compounds of formula (I), (II),  
20 (III), (IV), or (V) are independently selected for each layers. In some embodiments, the compounds of formula (I), (II), (III), (IV), or (V) are the same. In some embodiments, the compounds of formula (I), (II), (III), (IV), or (V) are different. For example, the compound represented by the formula (I), (II), (III), (IV), or (V) may be used in the injection layer, the barrier layer, the hole barrier layer, the electron barrier layer, the  
25 exciton barrier layer, the hole transporting layer, the electron transporting layer and the like described above. The film forming method of the layers are not particularly limited, and the layers may be produced by any of a dry process and a wet process.

Specific examples of materials that can be used in the organic electroluminescent device are shown below, but the materials that may be used in the invention are not  
30 construed as being limited to the example compounds. In some embodiments, a material having a particular function can also have another function.

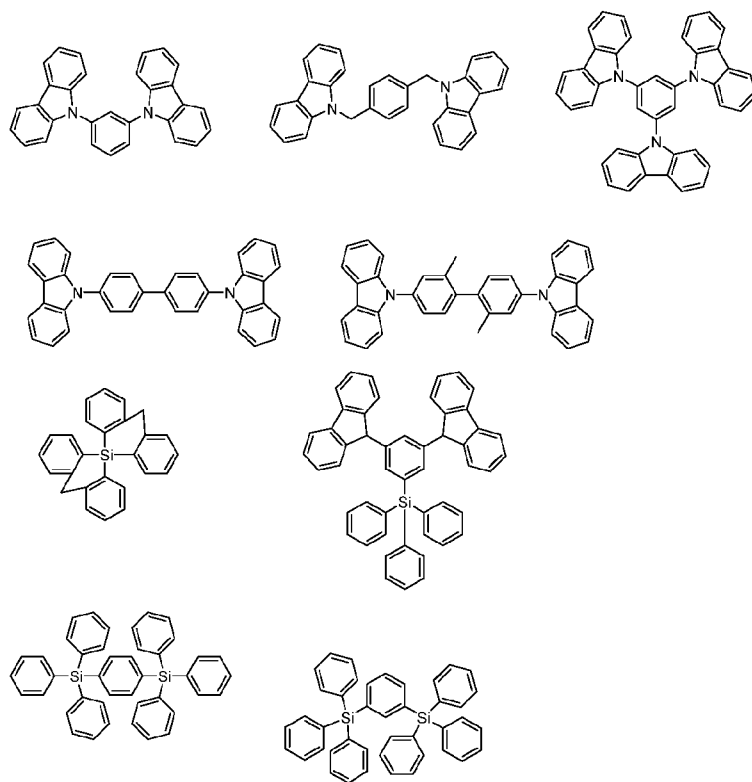
In some embodiments, the host material is selected from the group consisting of:

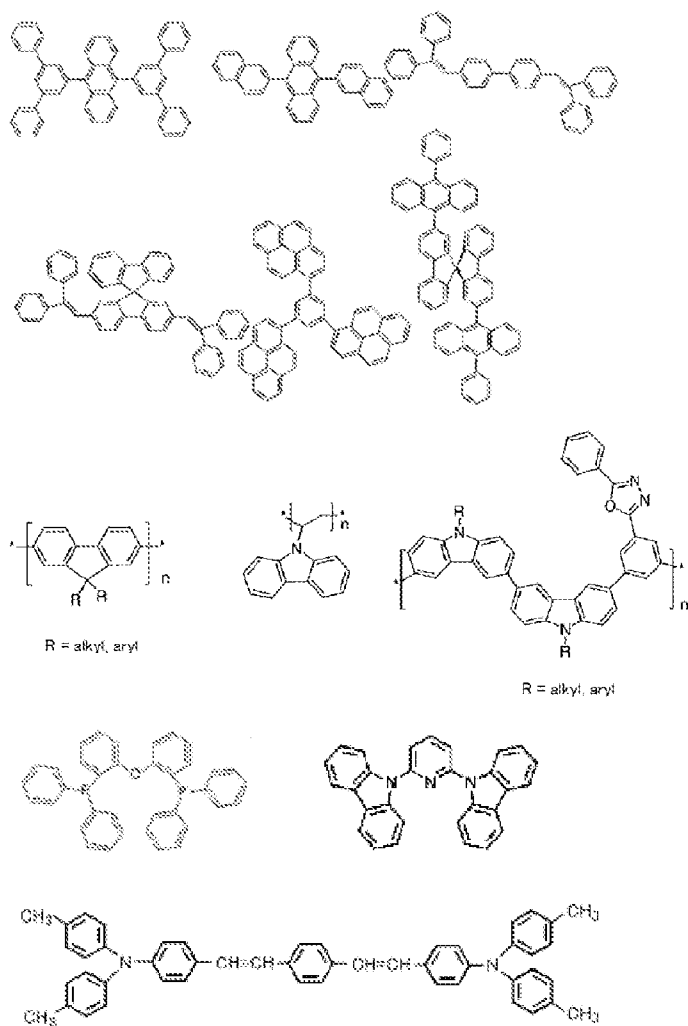




$R_2-R_7$  = H or substituent

L = Ligand





## 5 Devices

In some embodiments, the compounds of the disclosure are incorporated into a device. For example, the device includes, but is not limited to an OLED bulb, an OLED lamp, a television screen, a computer monitor, a mobile phone, and a tablet.

In some embodiments, an electronic device comprises an OLED comprising an anode, a cathode, and at least one organic layer comprising a light-emitting layer between the anode and the cathode, wherein the light-emitting layer comprises a host material; and a compound of Formula (I), (II), (III), (IV), or (V).

In some embodiments, the light-emitting layer of the OLED further comprises a  
15 fluorescent material wherein the compound of formula (I), (II), (III), (IV), or (V)  
converts triplets to singlets for the fluorescent emitter.



In some embodiments, compositions described herein may be incorporated into various light-sensitive or light-activated devices, such as a OLEDs or photovoltaic devices. In some embodiments, the composition may be useful in facilitating charge transfer or energy transfer within a device and/or as a hole-transport material. The device  
5 may be, for example, an organic light-emitting diode (OLED), an organic integrated circuit (O-IC), an organic field-effect transistor (O-FET), an organic thin-film transistor (O-TFT), an organic light-emitting transistor (O-LET), an organic solar cell (O-SC), an organic optical detector, an organic photoreceptor, an organic field-quench device (O-FQD), a light-emitting electrochemical cell (LEC) or an organic laser diode (O-laser).

#### 10 Bulbs or Lamps

In some embodiments, an electronic device comprises an OLED comprising an anode, a cathode, and at least one organic layer comprising a light-emitting layer between the anode and the cathode, wherein the light-emitting layer comprises

a host material;

15 a compound of formula (I), (II), (III), (IV), or (V);

wherein the compound of formula (I), (II), (III), (IV), or (V) is a light-emitting material; and

an OLED driver circuit.

In some embodiments, a device comprises OLEDs that differ in color. In some  
20 embodiments, a device comprises an array comprising a combination of OLEDs. In some embodiments, the combination of OLEDs is a combination of three colors (e.g., RGB). In some embodiments, the combination of OLEDs is a combination of colors that are not red, green, or blue (for example, orange and yellow green). In some embodiments, the combination of OLEDs is a combination of two, four, or more colors.

25 In some embodiments, a device is an OLED light comprising:

a circuit board having a first side with a mounting surface and an opposing second side, and defining at least one aperture;

at least one OLED on the mounting surface, the at least one OLED configured to emanate light, comprising:

30 an anode, a cathode, and at least one organic layer comprising a light-emitting layer between the anode and the cathode, wherein the light-emitting layer comprises

a host material;

a compound of formula (I), (II), (III), (IV), or (V);

wherein the compound of formula (I), (II), (III), (IV), or (V) is a light-emitting material;

5 a housing for the circuit board; and

at least one connector arranged at an end of the housing, the housing and the connector defining a package adapted for installation in a light fixture.

In some embodiments, the OLED light comprises a plurality of OLEDs mounted on a circuit board such that light emanates in a plurality of directions. In some  
10 embodiments, a portion of the light emanated in a first direction is deflected to emanate in a second direction. In some embodiments, a reflector is used to deflect the light emanated in a first direction.

#### Displays or Screens

15 In some embodiments, the compounds of formula (I), (II), (III), (IV), or (V) can be used in a screen or a display. In some embodiments, the compounds of formula (I), (II), (III), (IV), or (V) are deposited onto a substrate using a process including, but not limited to, vacuum evaporation, deposition, vapor deposition, or chemical vapor  
20 deposition (CVD). In some embodiments, the substrate is a photoplate structure useful in a two-sided etch provides a unique aspect ratio pixel. The screen (which may also be referred to as a mask) is used in a process in the manufacturing of OLED displays. The corresponding artwork pattern design facilitates a very steep and narrow tie-bar between the pixels in the vertical direction and a large, sweeping bevel opening in the horizontal direction. This allows the close patterning of pixels needed for high definition displays  
25 while optimizing the chemical deposition onto a TFT backplane.

The internal patterning of the pixel allows the construction of a 3-dimensional pixel opening with varying aspect ratios in the horizontal and vertical directions. Additionally, the use of imaged “stripes” or halftone circles within the pixel area inhibits etching in specific areas until these specific patterns are undercut and fall off the  
30 substrate. At that point the entire pixel area is subjected to a similar etch rate but the depths are varying depending on the halftone pattern. Varying the size and spacing of the halftone pattern allows etching to be inhibited at different rates within the pixel allowing for a localized deeper etch needed to create steep vertical bevels.

A preferred material for the deposition mask is invar. Invar is a metal alloy that is cold rolled into long thin sheet in a steel mill. Invar cannot be electrodeposited onto a rotating mandrel as the nickel mask. A preferred and more cost feasible method for forming the open areas in the mask used for deposition is through a wet chemical etching.

In some embodiments, a screen or display pattern is a pixel matrix on a substrate. In some embodiments, a screen or display pattern is fabricated using lithography (e.g., photolithography and e-beam lithography). In some embodiments, a screen or display pattern is fabricated using a wet chemical etch. In further embodiments, a screen or display pattern is fabricated using plasma etching.

#### *Methods of Manufacturing Devices Using the Disclosed Compounds*

An OLED display is generally manufactured by forming a large mother panel and then cutting the mother panel in units of cell panels. In general, each of the cell panels on the mother panel is formed by forming a thin film transistor (TFT) including an active layer and a source/drain electrode on a base substrate, applying a planarization film to the TFT, and sequentially forming a pixel electrode, a light-emitting layer, a counter electrode, and an encapsulation layer, and then is cut from the mother panel.

An OLED display is generally manufactured by forming a large mother panel and then cutting the mother panel in units of cell panels. In general, each of the cell panels on the mother panel is formed by forming a thin film transistor (TFT) including an active layer and a source/drain electrode on a base substrate, applying a planarization film to the TFT, and sequentially forming a pixel electrode, a light-emitting layer, a counter electrode, and an encapsulation layer, and then is cut from the mother panel.

In another aspect, provided herein is a method of manufacturing an organic light-emitting diode (OLED) display, the method comprising:

- forming a barrier layer on a base substrate of a mother panel;
- forming a plurality of display units in units of cell panels on the barrier layer;
- forming an encapsulation layer on each of the display units of the cell panels;
- applying an organic film to an interface portion between the cell panels.

In some embodiments, the barrier layer is an inorganic film formed of, for example, SiN<sub>x</sub>, and an edge portion of the barrier layer is covered with an organic

film formed of polyimide or acryl. In some embodiments, the organic film helps the mother panel to be softly cut in units of the cell panel.

In some embodiments, the thin film transistor (TFT) layer includes a light-emitting layer, a gate electrode, and a source/drain electrode. Each of the plurality of display units may include a thin film transistor (TFT) layer, a planarization film formed on the TFT layer, and a light-emitting unit formed on the planarization film, wherein the organic film applied to the interface portion is formed of a same material as a material of the planarization film and is formed at a same time as the planarization film is formed. In some embodiments, a light-emitting unit is connected to the TFT layer with a passivation layer and a planarization film therebetween and an encapsulation layer that covers and protects the light-emitting unit. In some embodiments of the method of manufacturing, the organic film contacts neither the display units nor the encapsulation layer.

Each of the organic film and the planarization film may include any one of polyimide and acryl. In some embodiments, the barrier layer may be an inorganic film. In some embodiments, the base substrate may be formed of polyimide. The method may further include, before the forming of the barrier layer on one surface of the base substrate formed of polyimide, attaching a carrier substrate formed of a glass material to another surface of the base substrate, and before the cutting along the interface portion, separating the carrier substrate from the base substrate. In some embodiments, the OLED display is a flexible display.

In some embodiments, the passivation layer is an organic film disposed on the TFT layer to cover the TFT layer. In some embodiments, the planarization film is an organic film formed on the passivation layer. In some embodiments, the planarization film is formed of polyimide or acryl, like the organic film formed on the edge portion of the barrier layer. In some embodiments, the planarization film and the organic film are simultaneously formed when the OLED display is manufactured. In some embodiments, the organic film may be formed on the edge portion of the barrier layer such that a portion of the organic film directly contacts the base substrate and a remaining portion of the organic film contacts the barrier layer while surrounding the edge portion of the barrier layer.

In some embodiments, the light-emitting layer includes a pixel electrode, a counter electrode, and an organic light-emitting layer disposed between the pixel electrode and the counter electrode. In some embodiments, the pixel electrode is connected to the source/drain electrode of the TFT layer.

In some embodiments, when a voltage is applied to the pixel electrode through the TFT layer, an appropriate voltage is formed between the pixel electrode and the counter electrode, and thus the organic light-emitting layer emits light, thereby forming an image. Hereinafter, an image forming unit including the TFT layer and the light-emitting unit is referred to as a display unit.

In some embodiments, the encapsulation layer that covers the display unit and prevents penetration of external moisture may be formed to have a thin film encapsulation structure in which an organic film and an inorganic film are alternately stacked. In some embodiments, the encapsulation layer has a thin film encapsulation structure in which a plurality of thin films are stacked. In some embodiments, the organic film applied to the interface portion is spaced apart from each of the plurality of display units. In some embodiments, the organic film is formed such that a portion of the organic film directly contacts the base substrate and a remaining portion of the organic film contacts the barrier layer while surrounding an edge portion of the barrier layer.

In one embodiment, the OLED display is flexible and uses the soft base substrate formed of polyimide. In some embodiments, the base substrate is formed on a carrier substrate formed of a glass material, and then the carrier substrate is separated.

In some embodiments, the barrier layer is formed on a surface of the base substrate opposite to the carrier substrate. In one embodiment, the barrier layer is patterned according to a size of each of the cell panels. For example, while the base substrate is formed over the entire surface of a mother panel, the barrier layer is formed according to a size of each of the cell panels, and thus a groove is formed at an interface portion between the barrier layers of the cell panels. Each of the cell panels can be cut along the groove.

In some embodiments, the method of manufacture further comprises cutting along the interface portion, wherein a groove is formed in the barrier layer, wherein at least a portion of the organic film is formed in the groove, and wherein the groove does not penetrate into the base substrate. In some embodiments, the TFT layer of each of the cell panels is formed, and the passivation layer which is an inorganic film and the planarization film which is an organic film are disposed on the TFT layer to cover the TFT layer. At the same time as the planarization film formed of, for example, polyimide or acryl is formed, the groove at the interface portion is covered with the organic film formed of, for example, polyimide or acryl. This is to prevent cracks from occurring by allowing the organic film to absorb an impact generated when each of the cell

panels is cut along the groove at the interface portion. That is, if the entire barrier layer is entirely exposed without the organic film, an impact generated when each of the cell panels is cut along the groove at the interface portion is transferred to the barrier layer, thereby increasing the risk of cracks. However, in one embodiment, since the groove at  
5 the interface portion between the barrier layers is covered with the organic film and the organic film absorbs an impact that would otherwise be transferred to the barrier layer, each of the cell panels may be softly cut and cracks may be prevented from occurring in the barrier layer. In one embodiment, the organic film covering the groove at the interface portion and the planarization film are spaced apart from each other. For  
10 example, if the organic film and the planarization film are connected to each other as one layer, since external moisture may penetrate into the display unit through the planarization film and a portion where the organic film remains, the organic film and the planarization film are spaced apart from each other such that the organic film is spaced apart from the display unit.

15 In some embodiments, the display unit is formed by forming the light-emitting unit, and the encapsulation layer is disposed on the display unit to cover the display unit. As such, once the mother panel is completely manufactured, the carrier substrate that supports the base substrate is separated from the base substrate. In some embodiments, when a laser beam is emitted toward the carrier substrate, the carrier substrate is  
20 separated from the base substrate due to a difference in a thermal expansion coefficient between the carrier substrate and the base substrate.

In some embodiments, the mother panel is cut in units of the cell panels. In some embodiments, the mother panel is cut along an interface portion between the cell panels by using a cutter. In some embodiments, since the groove at the interface portion  
25 along which the mother panel is cut is covered with the organic film, the organic film absorbs an impact during the cutting. In some embodiments, cracks may be prevented from occurring in the barrier layer during the cutting.

In some embodiments, the methods reduce a defect rate of a product and stabilize its quality.

30 Another aspect is an OLED display including: a barrier layer that is formed on a base substrate; a display unit that is formed on the barrier layer; an encapsulation layer that is formed on the display unit; and an organic film that is applied to an edge portion of the barrier layer.

## EXAMPLES

An embodiment of the present disclosure provides the preparation of compounds of formula (I), (II), (III), (IV), or (V) according to the procedures of the following example(s), using appropriate materials. Those skilled in the art will understand that known variations of the conditions and processes of the following preparative procedures can be used to prepare these compounds. Moreover, by utilizing the procedures described in detail, one of ordinary skill in the art can prepare additional compounds of the present disclosure.

### General Information on Analytical Methods

The features of the invention will be described more specifically with reference to examples below. The materials, processes, procedures and the like shown below may be appropriately modified unless they deviate from the substance of the invention. Accordingly, the scope of the invention is not construed as being limited to the specific examples shown below. The characteristics of samples were evaluated by using NMR (Nuclear Magnetic Resonance 500 MHz, produced by Bruker), LC / MS (Liquid Chromatography Mass Spectrometry, produced by Waters), AC3 (produced by RIKEN KEIKI), High-performance UV/Vis/NIR Spectrophotometer (Lambda 950, produced by PerkinElmer, Co., Ltd.), Fluorescence Spectrophotometer (FluoroMax-4, produced by Horiba, Ltd.), Photonic multichannel analyzer (PMA-12 C10027-01, produced by Hamamatsu Photonics K.K.), Absolute PL Quantum Yield Measurement System (C11347, produced by Hamamatsu Photonics K.K.), Automatic Current voltage brightness measurement system (ETS-170, produced by System engineers co ltd), Life Time Measurement System (EAS-26C, produced by System engineers co ltd), and Streak Camera (Model C4334, produced by Hamamatsu Photonics K.K.).

### Example 1

The principle of the features may be described as follows for an organic electroluminescent device as an example.

In an organic electroluminescent device, carriers are injected from an anode and a cathode to a light-emitting material to form an excited state for the light-emitting material, with which light is emitted. In the case of a carrier injection type organic electroluminescent device, in general, excitons that are excited to the excited singlet state

are 25% of the total excitons generated, and the remaining 75% thereof are excited to the excited triplet state. Accordingly, the use of phosphorescence, which is light emission from the excited triplet state, provides a high energy utilization. However, the excited triplet state has a long lifetime and thus causes saturation of the excited state and

5 deactivation of energy through mutual action with the excitons in the excited triplet state, and therefore the quantum yield of phosphorescence may generally be often not high. A delayed fluorescent material emits fluorescent light through the mechanism that the energy of excitons transits to the excited triplet state through intersystem crossing or the like, and then transits to the excited singlet state through reverse intersystem crossing

10 due to triplet-triplet annihilation or absorption of thermal energy, thereby emitting fluorescent light. It is considered that among the materials, a thermal activation type delayed fluorescent material emitting light through absorption of thermal energy is particularly useful for an organic electroluminescent device. In the case where a delayed fluorescent material is used in an organic electroluminescent device, the excitons in the

15 excited singlet state normally emit fluorescent light. On the other hand, the excitons in the excited triplet state emit fluorescent light through intersystem crossing to the excited singlet state by absorbing the heat generated by the device. At this time, the light emitted through reverse intersystem crossing from the excited triplet state to the excited singlet state has the same wavelength as fluorescent light since it is light emission from

20 the excited singlet state, but has a longer lifetime (light emission lifetime) than the normal fluorescent light and phosphorescent light, and thus the light is observed as fluorescent light that is delayed from the normal fluorescent light and phosphorescent light. The light may be defined as delayed fluorescent light. The use of the thermal activation type exciton transition mechanism may raise the proportion of the compound

25 in the excited singlet state, which is generally formed in a proportion only of 25%, to 25% or more through the absorption of the thermal energy after the carrier injection. A compound that emits strong fluorescent light and delayed fluorescent light at a low temperature of lower than 100°C undergoes the intersystem crossing from the excited triplet state to the excited singlet state sufficiently with the heat of the device, thereby

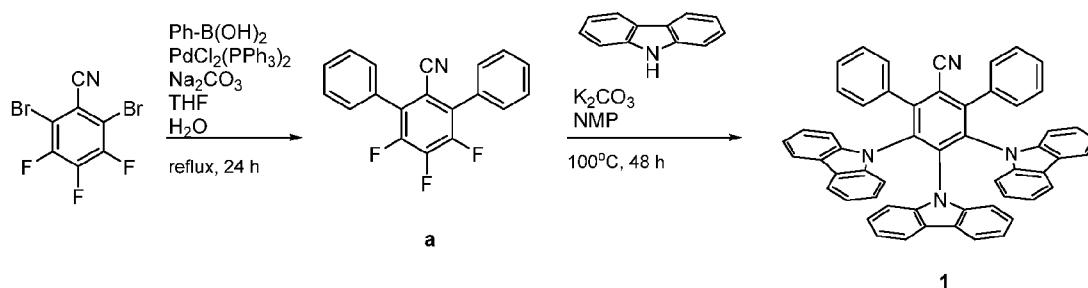
30 emitting delayed fluorescent light, and thus the use of the compound may drastically enhance the light emission efficiency.



## Example 2

The compounds of the invention can be synthesized by any method known to one of ordinary skills in the art. The compounds are synthesized from the commonly available starting material. The various moieties can be assembled via linear or branched synthetic routes.

### Compound 1



### Compound a

A mixture of 2,6-Dibromo-3,4,5-trifluorobenzonitrile (0.50 g, 1.58 mmol), Phenylboronic acid (0.46 g, 3.81 mmol),  $\text{PdCl}_2(\text{PPh}_3)_2$  (0.056 g, 0.079 mmol),  $\text{Na}_2\text{CO}_3$  (0.50 g, 4.76 mmol) in THF (20 mL) and  $\text{H}_2\text{O}$  (5 mL) was refluxed for 24h. The reaction mixture was quenched with  $\text{H}_2\text{O}$ , washed with brine and extracted with  $\text{CHCl}_3$ . The crude was purified by silica gel column chromatography (hexane: toluene=1:1) to afford compound **a** (0.426 g, 1.37 mmol) in 87% yield as white powder.

$^1\text{H-NMR}$  (500MHz,  $\text{CDCl}_3$ ,  $\delta$ ): 7.58-7.48 (m, 10H).

MS (ASAP): 308.2(M<sup>+</sup>). Calcd for  $\text{C}_{19}\text{H}_{10}\text{F}_3\text{N}$ : 309.1.

### Compound 1

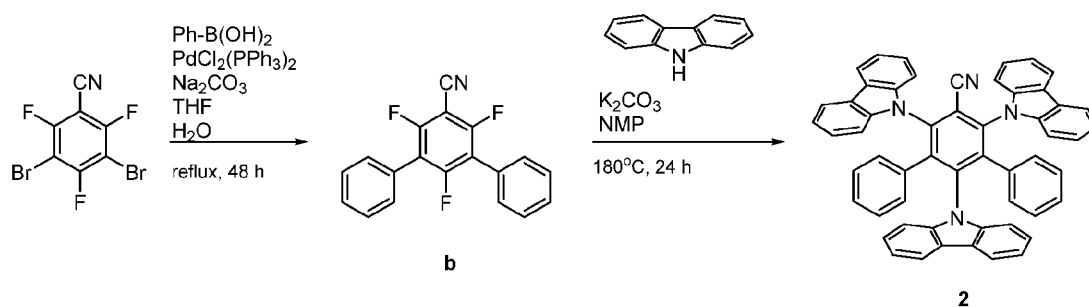
A mixture of  $\text{K}_2\text{CO}_3$  (1.07 g, 7.76 mmol) and 9H-Carbazole (0.86 g, 5.17 mmol) in NMP (10 mL) was stirred at r.t. for 1 h and then compound **a** (0.384 g, 1.29 mmol) was added. The mixture was stirred at 100°C for 48h. The reaction mixture was quenched with  $\text{H}_2\text{O}$ . The precipitated product was filtered, washed with MeOH, and purified by silica gel column chromatography ( $\text{CHCl}_3$ ) to give compound **1** (0.68 g, 0.90 mmol) in 70% yield as white powder.

$^1\text{H-NMR}$  (500MHz,  $\text{CDCl}_3$ ,  $\delta$ ): 7.52 (dd,  $J=7.5$ , 1.0Hz, 4H), 7.32-7.28 (m, 6H), 7.12 (d,  $J=7.5\text{Hz}$ , 4H), 7.08-7.00 (m, 8H), 6.92-6.87 (m, 8H), 6.71 (dt,  $J=7.5\text{Hz}$ , 2H), 6.58 (dt,  $J=7.5\text{Hz}$ , 2H).

MS (ASAP): 750.6(M $^+$ ). Calcd for  $\text{C}_{55}\text{H}_{34}\text{N}_4$ : 750.3.

5

### Compound 2



### Compound b

A mixture of 3,5-Dibromo-2,4,6-trifluorobenzonitrile (0.50 g, 1.58 mmol), Phenylboronic acid (0.46 g, 3.81 mmol),  $\text{PdCl}_2(\text{PPh}_3)_2$  (0.056 g, 0.079 mmol),  $\text{Na}_2\text{CO}_3$  (0.50 g, 4.76 mmol) in THF (20 mL) and  $\text{H}_2\text{O}$  (5 mL) was refluxed for 48h. The reaction mixture was quenched with  $\text{H}_2\text{O}$ , washed with brine and extracted with  $\text{CHCl}_3$ . The crude was purified by silica gel column chromatography (hexane: toluene=4:1) to afford compound **b** (0.329 g, 1.06 mmol) in 67% yield as white powder.

$^1\text{H-NMR}$  (500MHz,  $\text{CDCl}_3$ ,  $\delta$ ): 7.52-7.40 (m, 10H).

MS (ASAP): 309.2(M $^+$ ). Calcd for  $\text{C}_{19}\text{H}_{10}\text{F}_3\text{N}$ : 309.1.

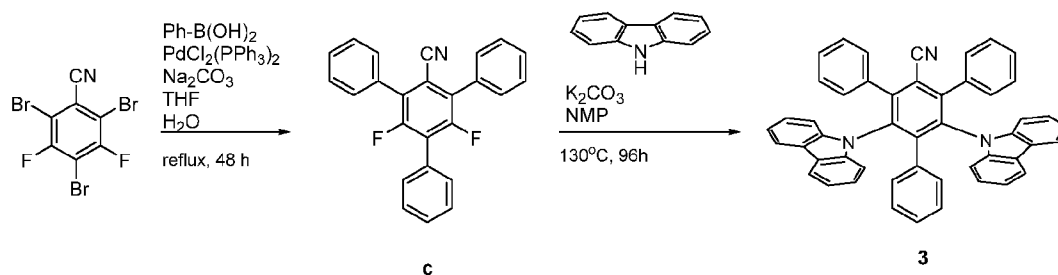
### Compound 2

A mixture of  $\text{K}_2\text{CO}_3$  (1.34 g, 9.69 mmol) and 9H-Carbazole (1.08 g, 6.46 mmol) in NMP (30 mL) was stirred at r.t. for 1 h and then compound **b** (0.5 g, 1.62 mmol) was added. The mixture was stirred at  $180^\circ\text{C}$  for 48h. The reaction mixture was quenched with  $\text{H}_2\text{O}$ . The precipitated product was filtered, washed with MeOH, and purified by silica gel column chromatography (hexane:  $\text{CHCl}_3$  = 1:1) to give compound 2 (0.98 g, 1.30 mmol) in 81% yield as white powder.

$^1\text{H-NMR}$  (500MHz,  $\text{CDCl}_3$ ,  $\delta$ ): 7.97 (d,  $J=7.5\text{Hz}$ , 4H), 7.77 (d,  $J=7.5\text{Hz}$ , 2H), 7.41 (dt,  $J=7.5\text{Hz}$ , 4H), 7.28-7.21 (m, 10H), 7.11-7.05 (m, 4H), 6.61 (dd,  $J=7.5\text{Hz}$ , 4H), 6.53 (t,  $J=7.5\text{Hz}$ , 2H), 6.40 (t,  $J=7.5\text{Hz}$ , 4H).

MS (ASAP): 750.3(M<sup>+</sup>). Calcd for C<sub>55</sub>H<sub>34</sub>N<sub>4</sub>: 750.2.

### Compound 3



### 5 Compound c

A mixture of 2,4,6-Tribromo-3,5-difluorobenzonitrile (5.00 g, 13.3 mmol), Phenylboronic acid (5.84 g, 47.9 mmol), PdCl<sub>2</sub>(PPh<sub>3</sub>)<sub>2</sub> (0.46 g, 0.66 mmol), Na<sub>2</sub>CO<sub>3</sub> (4.23 g, 39.9 mmol) in THF (100 mL) and H<sub>2</sub>O (25 mL) was refluxed for 48h. The reaction mixture was quenched with H<sub>2</sub>O, washed with brine and extracted with CHCl<sub>3</sub>.

10 The crude was purified by silica gel column chromatography (hexane: CHCl<sub>3</sub>=1:1) to afford compound c (3.92 g, 10.66 mmol) in 80% yield as white powder.

<sup>1</sup>H-NMR (500MHz, CDCl<sub>3</sub>, δ): 7.54-7.45 (m, 15H).

MS (ASAP): 367.2(M<sup>+</sup>). Calcd for C<sub>25</sub>H<sub>15</sub>F<sub>2</sub>N: 367.1.

### 15 Compound 3

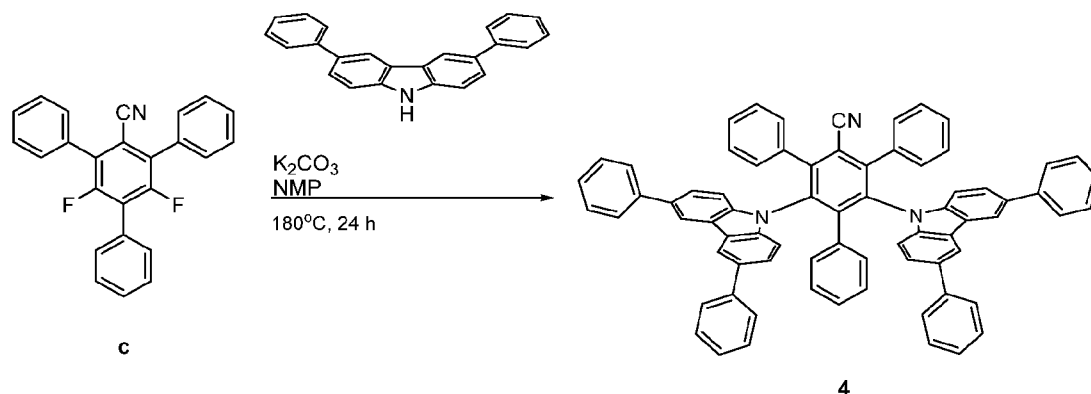
A mixture of K<sub>2</sub>CO<sub>3</sub> (0.90 g, 6.53 mmol) and 9H-Carbazole (0.72 g, 4.35 mmol) in NMP (30 mL) was stirred at r.t. for 1 h and then compound c (0.4 g, 1.08 mmol) was added. The mixture was stirred at 130°C for 96h. The reaction mixture was quenched

20 with H<sub>2</sub>O. The precipitated product was filtered, washed with MeOH, and purified by silica gel column chromatography (hexane: CHCl<sub>3</sub> = 1:1) to give compound 3 (0.52 g, 0.785 mmol) in 72% yield as white powder.

<sup>1</sup>H-NMR (500MHz, CDCl<sub>3</sub>, δ): 7.78 (d, J=7.5Hz, 4H), 7.30-7.20 (m, 8H), 7.12 (d, J=7.5Hz, 4H), 7.10-7.03 (m, 6H), 7.00 (t, J=7.5Hz, 4H), 6.55 (d, J=7.5Hz, 2H), 6.45 (t, J=7.5Hz, 1H), 6.31 (t, J=7.5Hz, 2H).

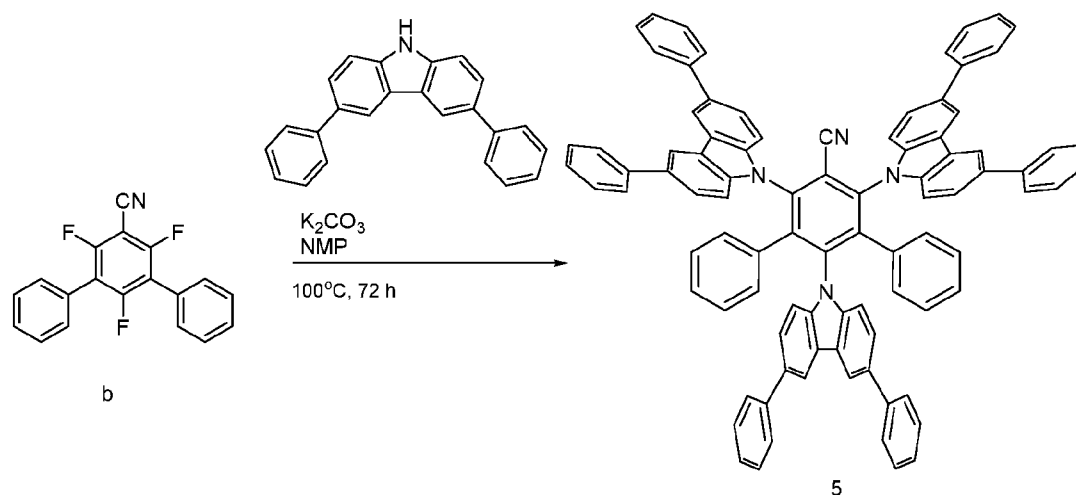
25 MS (ASAP): 661.3(M<sup>+</sup>). Calcd for C<sub>49</sub>H<sub>31</sub>N<sub>3</sub>: 661.2.

MS (ASAP): 661.3(M<sup>+</sup>). Calcd for C<sub>49</sub>H<sub>31</sub>N<sub>3</sub>: 661.2.

Compound 4**Compound 4**

A mixture of  $K_2CO_3$  (1.12 g, 8.16 mmol) and 3,6-Diphenylcarbazole (1.30 g, 4.08 mmol) in NMP (30 mL) was stirred at r.t. for 1 h and then compound c (0.5 g, 1.36 mmol) was added. The mixture was stirred at 180°C for 24h. The reaction mixture was quenched with  $H_2O$ . The precipitated product was filtered, washed with MeOH, and purified by silica gel column chromatography (hexane:  $CHCl_3$  = 1:1) to give compound 4 (1.24 g, 1.28 mmol) in 94% yield as white powder.

$^1H$ -NMR (500MHz,  $CDCl_3$ ,  $\delta$ ): 8.07 (d,  $J=1.5$ Hz, 4H), 7.64 (dd,  $J=7.5, 1.5$ Hz, 8H), 7.57 (dd,  $J=7.5, 1.5$ Hz, 4H), 7.44 (t,  $J=7.5$ Hz, 8H), 7.33-7.28 (m, 8H), 7.21 (d,  $J=7.5$ Hz, 4H), 7.10-7.04 (m, 6H), 6.68 (d,  $J=7.5$ Hz, 2H), 6.49 (t,  $J=7.5$ Hz, 1H), 6.41 (t,  $J=7.5$ Hz, 2H). MS (ASAP): 965.3(M<sup>+</sup>). Calcd for  $C_{73}H_{47}N_3$ : 965.4.

Compound 5

**Compound 5**

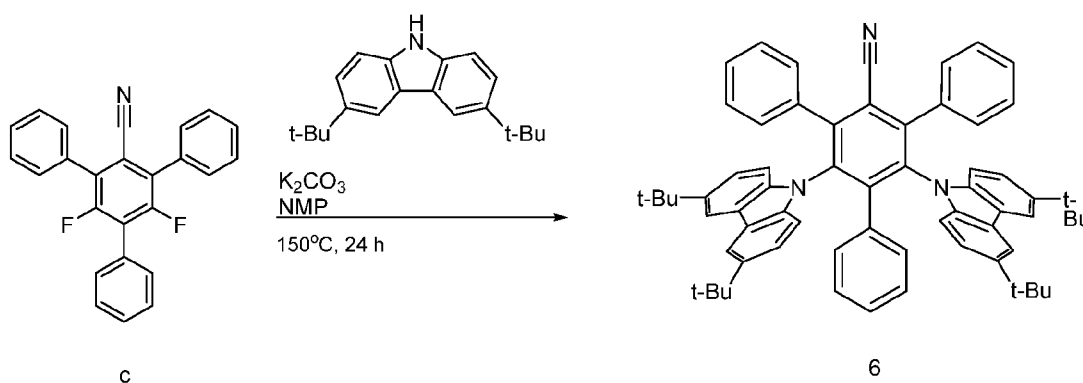
A mixture of  $K_2CO_3$  (1.28 g, 8.16 mmol) and 3,6-Diphenylcarbazole (1.30 g, 4.08 mmol) in NMP (30 mL) was stirred at r.t. for 1 h and then compound b (0.5 g, 1.62 mmol) was added. The mixture was stirred at 100°C for 72h. The reaction mixture was

5 quenched with  $H_2O$ . The precipitated product was filtered, washed with MeOH, and purified by silica gel column chromatography (hexane:  $CHCl_3$  = 1:1) to give compound 5 (0.66 g, 0.55 mmol) in 34% yield as white powder.

$^1H$ -NMR (500MHz,  $CDCl_3$ ,  $\delta$ ): 8.27 (d,  $J$ =1.5Hz, 4H), 8.02 (d,  $J$ =1.5Hz, 2H), 7.70-7.67 (m, 12H), 7.62 (dd,  $J$ =7.5, 1.5Hz, 4H), 7.56 (dd,  $J$ =7.5, 1.5Hz, 2H), 7.50-7.30 (m, 22H),

10 7.21 (d,  $J$ =7.5Hz, 2H), 6.77 (d,  $J$ =7.5Hz, 4H), 6.61 (t,  $J$ =7.5Hz, 2H), 6.53 (t,  $J$ =7.5Hz, 4H).

MS (ASAP): 1206.3. ( $M^+$ ). Calcd for  $C_{91}H_{58}N_4$ : 1206.5.

**Compound 6****Compound 6**

A mixture of  $K_2CO_3$  (1.28 g, 8.16 mmol) and 3,6-Di-tert-butylcarbazole (1.14 g, 4.08 mmol) in NMP (30 mL) was stirred at r.t. for 1 h and then compound c (0.5 g, 1.36 mmol) was added. The mixture was stirred at 150°C for 24h. The reaction mixture was

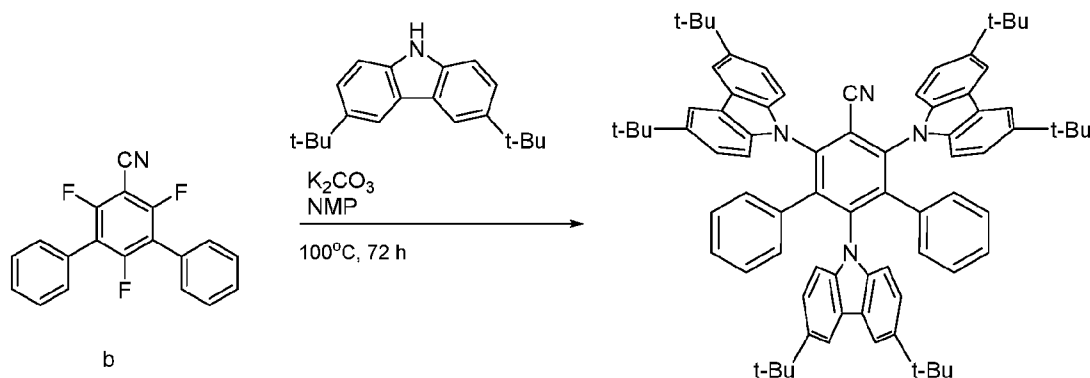
20 quenched with  $H_2O$ . The precipitated product was filtered, washed with MeOH, and purified by silica gel column chromatography (hexane:  $CHCl_3$  = 1:1) to give compound 6 (0.43 g, 0.485 mmol) in 35% yield as white powder.

$^1H$ -NMR (500MHz,  $CDCl_3$ ,  $\delta$ ): 7.74 (d,  $J$ =1.5Hz, 4H), 7.29 (dd,  $J$ =7.5, 1.5Hz, 4H), 7.22 (dd,  $J$ =7.5, 1.5Hz, 4H), 7.05-6.98 (m, 10H), 6.55 (d,  $J$ =7.5Hz, 2H), 6.41 (dd,  $J$ =7.5Hz, 1H), 6.28 (t,  $J$ =7.5Hz, 2H), 1.33 (s, 36H).

25

MS (ASAP): 885.6. (M<sup>+</sup>). Calcd for C<sub>65</sub>H<sub>63</sub>N<sub>3</sub>: 885.5.

### Compound 7



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7

### **Compound 7**

A mixture of K<sub>2</sub>CO<sub>3</sub> (1.34 g, 9.67 mmol) and 3,6-Di-tert-butylcarbazole (1.81 g, 6.46 mmol) in NMP (30 mL) was stirred at r.t. for 1 h and then compound **b** (0.5 g, 1.62 mmol) was added. The mixture was stirred at 100°C for 72h. The reaction mixture was

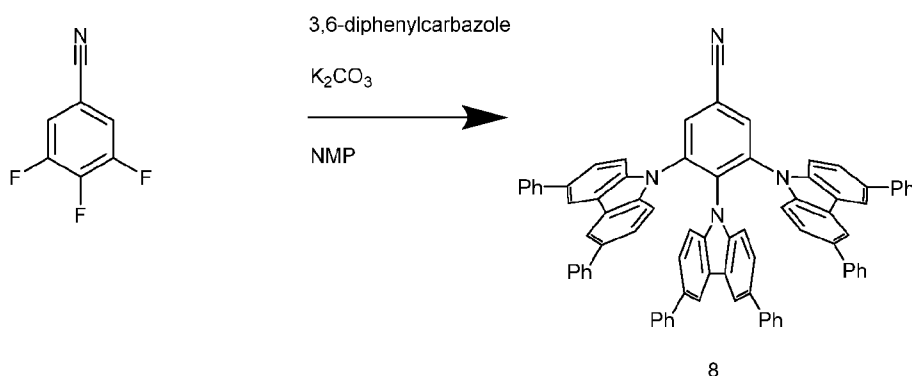
10 quenched with H<sub>2</sub>O. The precipitated product was filtered, washed with MeOH, and purified by silica gel column chromatography (hexane: CHCl<sub>3</sub> = 1:1) to give compound 7 (1.70 g, 1.56 mmol) in 96% yield as white powder.

<sup>1</sup>H-NMR (500MHz, CDCl<sub>3</sub>, δ): 8.95 (d, J=1.5Hz, 4H), 7.73 (d, J=1.5Hz, 2H), 7.42 (dd, J=7.5, 1.5Hz, 4H), 7.27 (dd, J=7.5, 1.5Hz, 2H), 7.13 (d, J=7.5Hz, 4H), 6.98 (d, J=7.5Hz, 2H), 6.62 (dd, J=7.5, 1.5Hz, 4H), 6.50 (t, J=7.5Hz, 2H), 6.40 (t, J=7.5Hz, 4H), 1.39 (s, 36H), 1.31 (s, 18H).

15

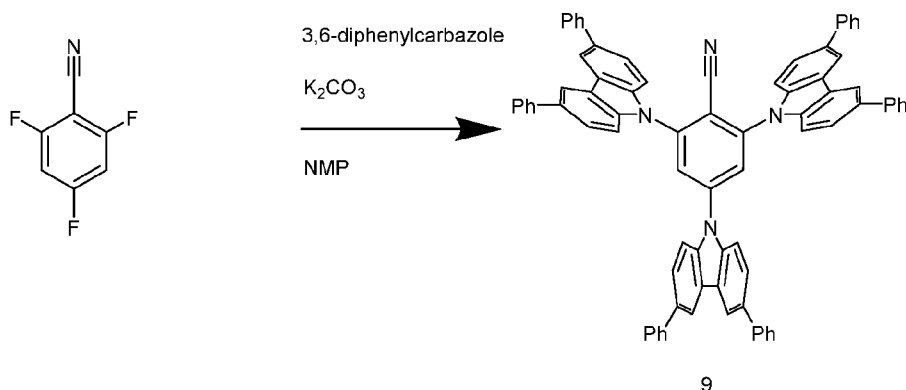
MS (ASAP): 1086.6. (M<sup>+</sup>). Calcd for C<sub>79</sub>H<sub>82</sub>N<sub>4</sub>: 1086.7.

### Compound 8

**Compound 8**

A mixture of 3,6-diphenyl-9H-carbazole (4.05g, 12.7mmol),  $K_2CO_3$  (2.83g, 15.9mmol), 3,4,5-trifluorobenzonitrile (0.50g, 3.18mmol) and 1-methyl-2-pyrrolidone (NMP, 30mL) was stirred for 24 hour at 100 °C. After cooling at room temperature, the reaction solution was quenched with water. The filtrated precipitate was purified by silica chromatography (toluene), recrystallized with dichloromethane/ethanol and then yielded pale yellow solid (1.09g, 1.03mmol, 32.5%).

$^1H$ -NMR (500MHz,  $CDCl_3$ ,  $\delta$ ): 8.33(s, 2H), 8.03(d,  $J=1.5$ Hz, 4H), 7.61 (d,  $J=8.2$ ,  $J=1.0$ Hz, 2H), 7.55(dd,  $J=7.5$ ,  $J=2.0$ Hz, 8H), 7.41-7.28(m, 28H), 7.00-6.96(m, 4H)  
 ASAP MS : 1053.8( $M^+$ ). Calcd for  $C_{79}H_{50}N_4$ : 1054.4

**Compound 9****Compound 9**

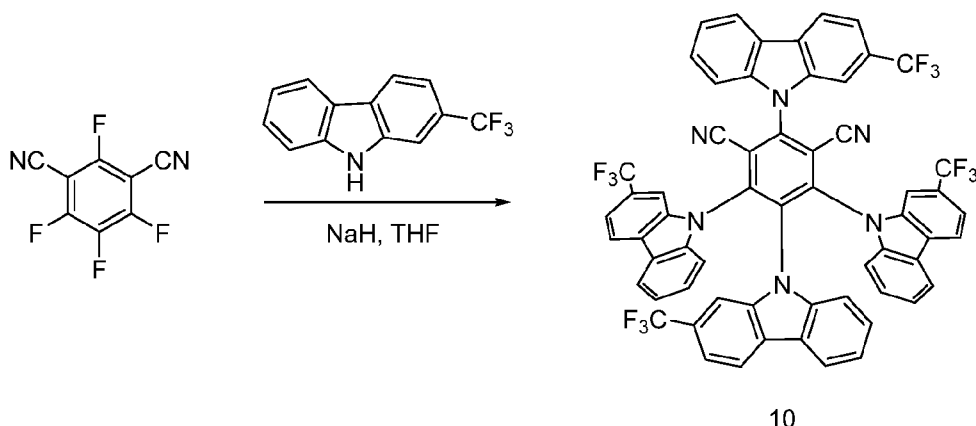
A mixture of 3,6-diphenyl-9H-carbazole (4.05g, 12.7mmol),  $K_2CO_3$  (2.83g, 15.9mmol), 2,4,6-trifluorobenzonitrile (0.50g, 3.18mmol) and 1-methyl-2-pyrrolidone (NMP, 30mL) was stirred for 24 hour at 100 °C. After cooling at room temperature, the reaction solution was quenched with water. The filtrated precipitate was purified by

silica chromatography (toluene), recrystallized with dichloromethane/ethanol and then yielded pale yellow solid (2.80g, 2.64mmol, 83.5%).

<sup>1</sup>H-NMR (500MHz, CDCl<sub>3</sub>, δ): 8.45(d, J=1.5Hz, 4H), 8.39(d, J=1.5Hz, 2H), 8.20 (s, 2H), 7.86(dd, J=7.5, J=2.0Hz, 4H), 7.80(d, J=8.5Hz, 2H), 7.77-6.68(m, 18H), 7.53-7.47(m, 12H), 7.40-7.36(m, 6H).

ASAP MS : 1054.6(M<sup>+</sup>). Calcd for C<sub>79</sub>H<sub>50</sub>N<sub>4</sub>: 1054.4.

### Compound 10



### Compound 10

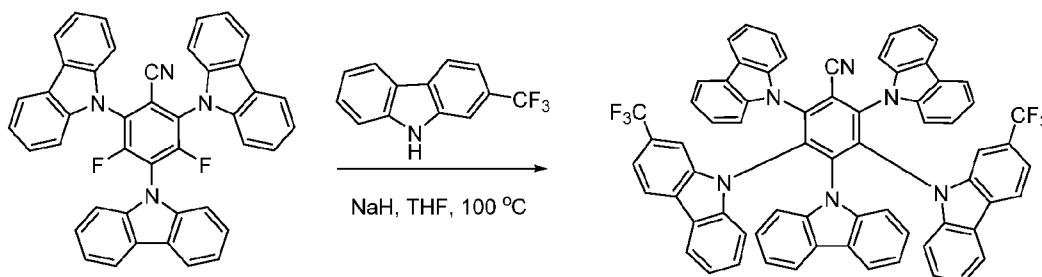
To a stirred solution of 2-(trifluoromethyl)-9H-carbazole (1g, 4.2 mmol) in dry tetrahydrofuran (20 mL), sodium hydride (60% in oil, 182 mg, 4.55 mmol) was added under a nitrogen atmosphere at room temperature. After stirring 1 h, 2,4,5,6-tetrafluoroisophthalonitrile (203 mg, 1.01 mmol) was added. The reaction mixture was heated at 50 °C for 18 h. The reaction was quenched with ethyl acetate and water, and the organic layer was separated and further washed with brine. The solvent was evaporated in vacuo, and the residue was purified by column chromatography using hexane/ethyl acetate as eluent to afford 5 rotamers of 4CzIPN-2CF<sub>3</sub> 0.626 mg in total (58.5% yield). The yellow solid rotamers were separately purified again by sublimation, whereas the LC examination revealed those rotamers thermally equilibrated during the sublimation and re-formed a rotamer mixture as observed.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>, δ): 8.35 (d, J = 8.0 Hz, 1H), 8.30 (d, J = 7.5 Hz, 1H), 8.08 (s, 1H), 7.78-7.85 (m, 6H), 7.70 (d, J = 8.5 Hz, 1H), 7.58 (t, J = 7.5 Hz, 1H), 7.52 (s, 2H), 7.47 (d, J = 6.5 Hz, 1H), 7.43-7.39 (m, 3H), 7.25-7.22 (m, 2H), 7.20-7.13 (m, 5H), 7.09



(s, 1H), 6.91 (t,  $J = 7.5$  Hz, 1H), 6.80 (d,  $J = 8.5$  Hz, 1H), 6.69 (t,  $J = 7.5$  Hz, 1H); APCI-MS  $m/z$ : 1060.6  $M^+$ .

### Compound 11



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11

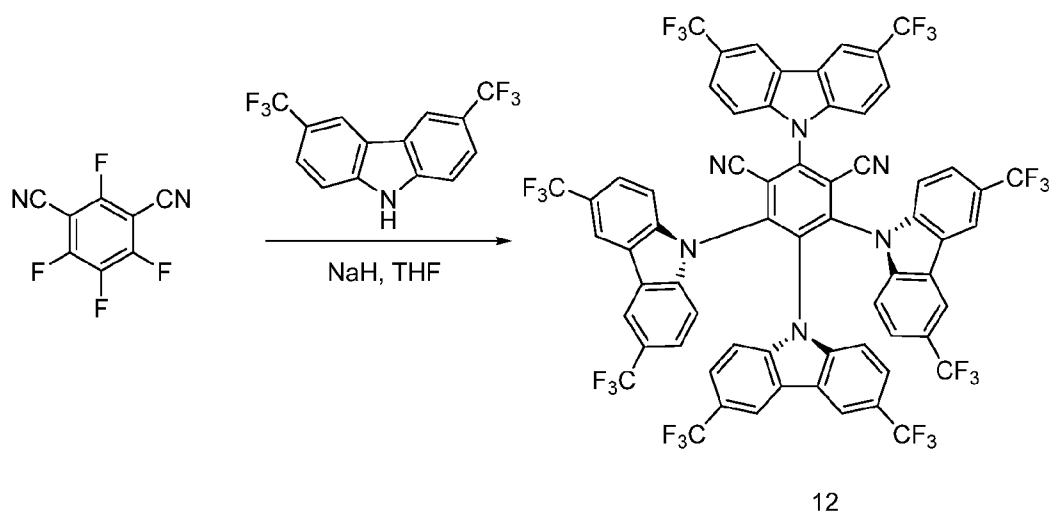
### Compound 11

A mixture of (trifluoromethyl)-9H-carbazole (0.93 g, 3.94 mmol), 2,4,6-tri(9H-carbazol-9-yl)-3,5-difluorobenzonitrile (1.00 g, 1.58 mmol), and potassium carbonate (2.18 g, 15.8 mmol) in 10 ml of *N*-Methyl-2-pyrrolidinone (NMP) was stirred at 100 °C under ambient atmosphere for 18 h. After cooled to room temperature, the reaction mixture was filtered through a Celite pad rinsing with chloroform. The resulting filtrate was evaporated *in vacuo*. The residue was purified by column chromatography on silica gel using hexane/chloroform as eluent to afford an orange solid 0.935 g in 55.7% yield.

$^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ ,  $\delta$ ): 7.75-7.72 (m, 4H), 7.42 (d,  $J = 8.0$  Hz, 2H), 7.38-7.36 (m, 3H), 7.33-7.24 (m, 6H), 7.17-6.98 (m, 15H), 6.86-6.82 (m, 2H), 6.76-6.70 (m, 3H), 6.66 (t,  $J = 8.0$  Hz, 1H), 6.56-6.54 (m, 2H); APCI-MS  $m/z$ : 1064.7  $M^+$ .

15

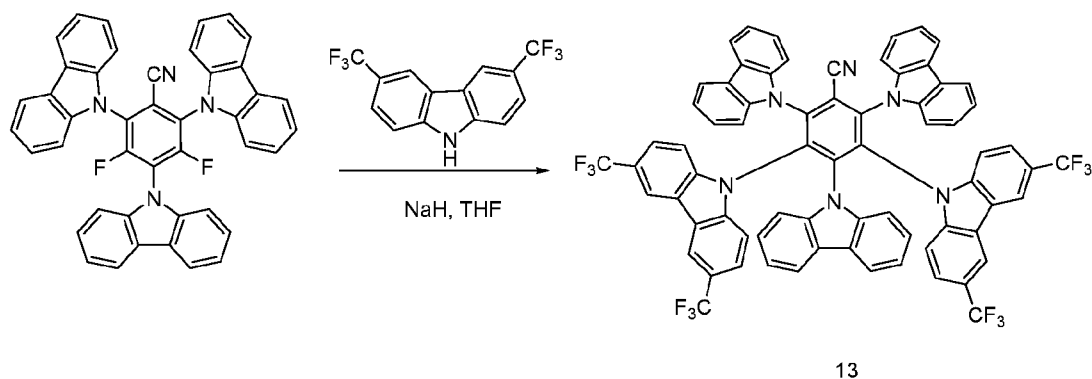
### Compound 12



### Compound 12

To a stirred solution of 3,6-bis(trifluoromethyl)-9H-carbazole (0.50 g, 1.65 mmol) in dry tetrahydrofuran (10 mL), sodium hydride (60% in oil, 79 mg, 1.98 mmol) was added under a nitrogen atmosphere at room temperature. After stirring 1 h, 2,4,5,6-tetrafluoroisophthalonitrile (66 mg, 0.33 mmol) was added. The reaction mixture was stirred at room temperature for 18 h. The reaction was quenched with ethyl acetate and water, and the organic layer was separated and further washed with brine. The solvent was evaporated in vacuo, and the residue was purified by column chromatography using hexane/ethyl acetate as eluent to afford a light yellow solid 0.626 mg in 58.5% yield.

### Compound 13



### Compound 13

To a stirred solution of 3,6-bis(trifluoromethyl)-9H-carbazole (0.29 g, 0.95 mmol) in dry tetrahydrofuran (10 mL), sodium hydride (60% in oil, 48 mg, 1.26 mmol)

was added under a nitrogen atmosphere at room temperature. After stirring 1 h, 2,4,5,6-tetrafluoroisophthalonitrile (200 mg, 0.32 mmol) was added. The reaction mixture was stirred at room temperature for 18 h. The reaction was quenched with ethyl acetate and water, and the organic layer was separated and further washed with brine. The solvent  
5 was evaporated in vacuo, and the residue was purified by column chromatography using hexane/chloroform as eluent to afford a greenish yellow solid 0.136 g in 36.0% yield.  
<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>, δ): 7.73 (d, *J* = 7.5 Hz, 4H), 7.65 (s, 4H), 7.35 (d, *J* = 7.5 Hz, 2H), 7.19 (d, *J* = 8.0 Hz, 4H), 7.15-7.10 (m, 8H), 7.07-7.03 (m, 6H), 6.89 (dd, *J* = 8.5, 1.5 Hz, 4H), 6.83 (t, *J* = 7.0 Hz, 2H), 6.63 (t, *J* = 8.5 Hz, 2H); APCI-MS *m/z*: 1200.5 M<sup>+</sup>.

10

### Example 3

#### *Preparation of neat films*

In this example, the compound 1 synthesised in Example 2 was vapor-deposited on a quartz substrate by a vacuum vapor deposition method under a condition of a  
15 vacuum degree of 10<sup>-3</sup> Pa or less, so as to form a thin film having a thickness of 70 nm.

#### *Preparation of doped films*

The compound 1 and host were also vapor-deposited from a separate vapor deposition source on a quartz substrate by vacuum vapor deposition method under a condition of a vacuum degree of 10<sup>-3</sup> Pa or less, so as to form a thin film having a  
20 thickness of 100 nm and a concentration of the compound 1 of 20% by weight.

#### *Evaluation of the optical properties*

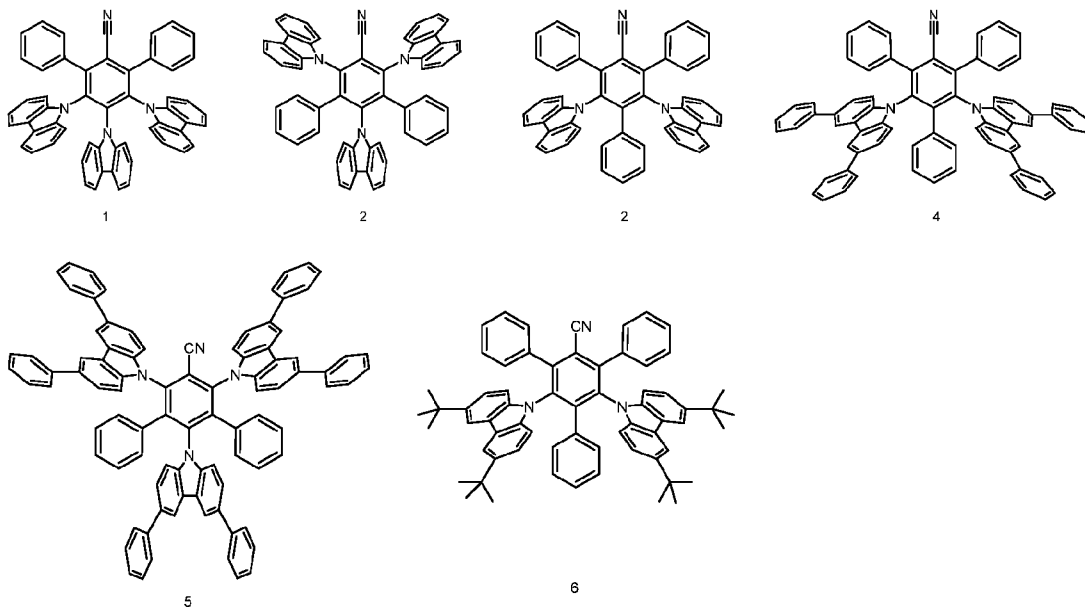
The samples were irradiated with light having a wavelength of 300 nm at 300 K, and thus the light emission spectrum was measured and designated as fluorescence. The  
25 spectrum at 77K was also measured and designated as phosphorescence. The lowest singlet energy (S1) and the lowest triplet energy (T1) was estimated from the onset of fluorescence and phosphorescence spectrum respectively. ΔEST was calculated from the energy gap between S1 and T1. PLQY was also measured by excitation light 300nm. The time resolved spectrum was obtained by excitation light 337nm with Streak Camera,  
30 and the component with a short light emission lifetime was designated as fluorescent light, whereas the component with a long light emission lifetime was designated as

delayed fluorescent light. The lifetimes of the fluorescent light component ( $\tau_{\text{prompt}}$ ) and the delayed fluorescent light component ( $\tau_{\text{delay}}$ ) were calculated from the decay curves.

*Preparation and measurement of OLEDs*

Thin films were laminated on a glass substrate having formed thereon an anode  
5 formed of indium tin oxide (ITO) having a thickness of 50 nm, by a vacuum vapor  
deposition method at a vacuum degree of  $1.0 \times 10^{-4}$  Pa or less. Firstly, HAT-CN was  
formed to a thickness of 60 nm on ITO, and thereon TrisPCz was formed to a thickness  
of 30 nm. mCBP was formed to a thickness of 5 nm, and thereon compound 1 and host  
10 were then vapor-co-deposited from separate vapor deposition sources to form a layer  
having a thickness of 30 nm, which was designated as a light-emitting layer. At this time,  
the concentration of compound 1 was 20% by weight. SF3-TRZ was then formed to a  
thickness of 5 nm, and thereon SF3-TRZ and Liq were vapor-co-deposited to a thickness  
of 30 nm. Liq was then vacuum vapor-deposited to a thickness of 2 nm, and then  
15 aluminum (Al) was vapor-deposited to a thickness of 100 nm to form a cathode, thereby  
producing organic electroluminescent devices and measured its photoelectrical  
properties.

The results of the same evaluation with compounds 2-6, 8-9 and 10-11  
synthesized in Examples 2, instead of the compound 1 is also measured.



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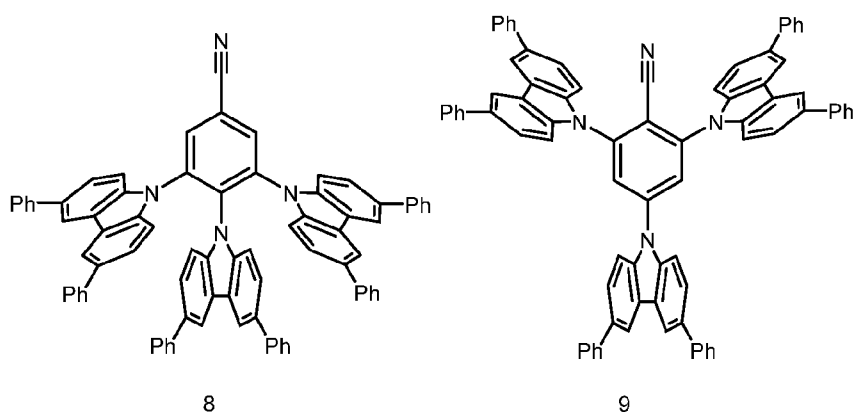
compound	neat film or dope film				$\Delta E_{\text{est}}$
	concentration		$\lambda_{\text{em}}$ (PL)	PLQY (in N2)	
1	100wt%	-	487nm	67.0%	0.20eV
2	100wt%	-	465nm	52.1%	0.17eV
3	100wt%	-	427nm	9.0%	0.38eV
4	100wt%	-	449nm	8.3%	0.37eV
5	100wt%	-	492nm	49.0%	0.15eV
6	100wt%	-	427nm	9.0%	0.34eV

compound	neat film or dope film			
	concentration	host	$\lambda_{\text{em}}$ (PL)	PLQY (in N2)
1	20wt%	DPEPO	487nm	75.0%
2	20wt%	DPEPO	448nm	79.0%
2	20wt%	PYD2Cz	457nm	50.0%
4	20wt%	DPEPO	468nm	47.7%
5	20wt%	DPEPO	477nm	77.0%
6	20wt%	DPEPO	443nm	61.8%

device property @1000 nit					
EML					
compound	concentration	host	$\lambda_{\text{em}}$ (EL)	EQE	structure
1	20wt%	PYD2Cz	475nm	5.6%	*3
1	20wt%	PYD2Cz	465nm	4.7%	*3'
1	30wt%	PYD2Cz	477nm	6.2%	*3
2	20wt%	PYD2Cz	464nm	4.4%	*3
2	30wt%	PYD2Cz	463nm	5.2%	*2
2	100%	-	479nm	8.2%	*3
2	30wt%	PYD2Cz/PPT (49:21)	467nm	5.6%	*3
2	30wt%	PYD2Cz	464nm	4.4%	*3'
6	30wt%	PYD2Cz	491nm	14.0%	*3'
6	30wt%	PYD2Cz	495nm	11.6%	*3'

\*3 device structure: ITO(100) /HATCN (10) /TrisPCz (25) /PYD2Cz (5)/ EML(30) /SF3-TRZ (10) /SF3-TRZ:Liq =70:30 (35) /LiQ (20 ) /Al (100)

\*3' device structure: ITO(100) /HATCN (10) /TrisPCz (25) /PYD2Cz (5)/ EML [host : comp. x: TBPe = 100-(concentration+0.5): concentration: 0.5 ](30) /SF3-TRZ (10) /SF3-TRZ:Liq =70:30 (35) /LiQ (20 ) /Al (100)

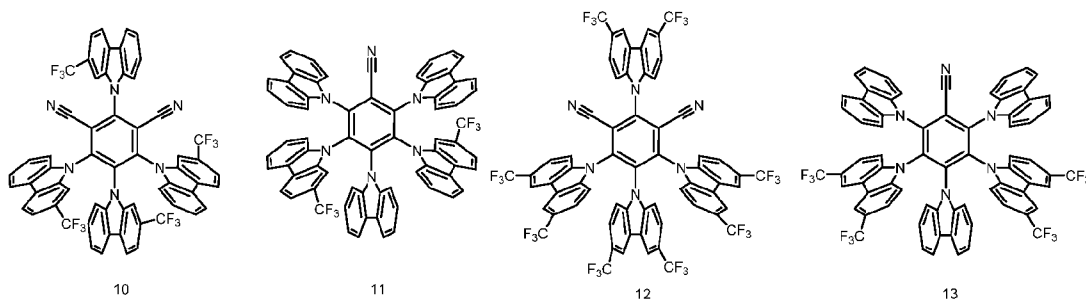


compound	doped film (20% compound X: host)			neat film			$\Delta$ Est
	host	$\lambda_{em}$ (PL)	PLQY (in N <sub>2</sub> )	$\lambda_{em}$ (PL)	PLQY (in N <sub>2</sub> )	$\tau_{delay}$	
8	DPEPO	481 nm	75%	466 nm	34%	16 $\mu$ s	0.20 eV

compound	neat film			$\Delta$ Est
	$\lambda_{em}$ (PL)	PLQY (in N <sub>2</sub> )	$\tau_{delay}$	
9	465 nm	23%	0.65 $\mu$ s	0.16 eV

device property*1 @500 nit				
EML				
compound	concentration	host	$\lambda_{em}$ (EL)	EQE
8	20wt%	DPEPO	485 nm	5.3%
9	20wt%	DPEPO	475 nm	5.0%

\*1 ITO(50)/HAT-CN(60)/TrisPCz(30)/mCBP(5)/EML(30)/SF3-TRZ(5)/SF3-TRZ:Liq=7:3(30)/Liq(2)/Al(100)

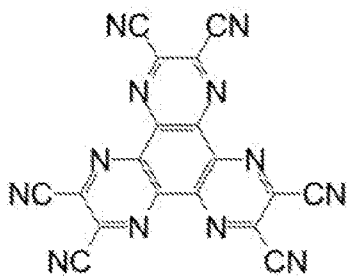


compound	neat film					$\Delta E_{\text{st}}$
	concentration		$\lambda_{\text{em}}$ (PL)	PLQY (in N <sub>2</sub> )		
10	100%	-	536nm	62.2%	-	0.082eV
11	100%	-	456nm	14.0%	-	0.136eV
13	100%	-	504.8	61.0%	-	0.160eV

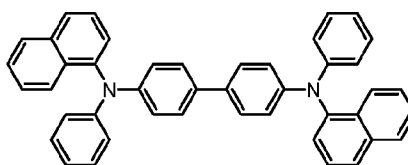
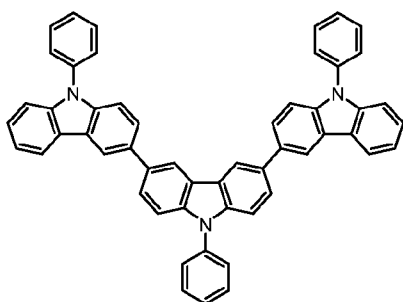
compound	doped film				Lifetime of delayed fluorescence
	concentration	host	$\lambda_{\text{em}}$ (PL)	PLQY (in N <sub>2</sub> )	$\tau_d$
10	20wt%	DPEPO	546nm	79.3%	5.35 $\mu$ s
11	20wt%	DPEPO	487nm	42.7%	18.7 $\mu$ s
13	20wt%	DPEPO	485nm	78.3%	

device property*2 @1000 nit				
EML				
compound	concentration	host	$\lambda_{\text{em}}$ (EL)	EQE
13	30wt%	PYD2Cz	501 nm	9.1%

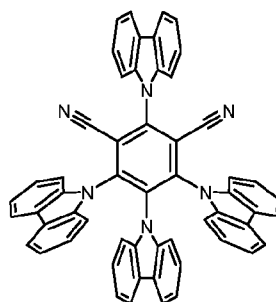
\*2 ITO(50)/HAT-CN(60)/TrisPCz(30)/PYD2Cz(5)/EML(30)/SF3-TRZ(5)/SF3-TRZ:Liq=7:3(30)/Liq(2)/Al(100)



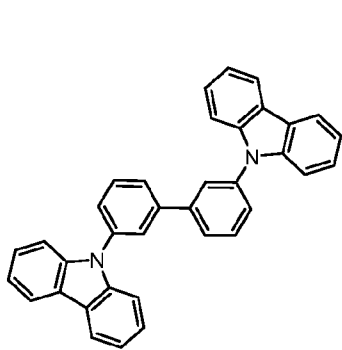
HAT-CN

 $\alpha$ -NPD

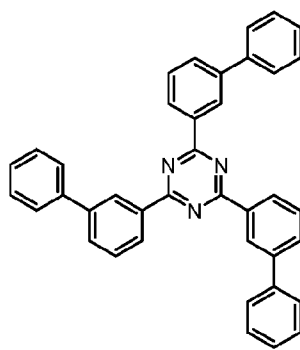
Tris-PCz



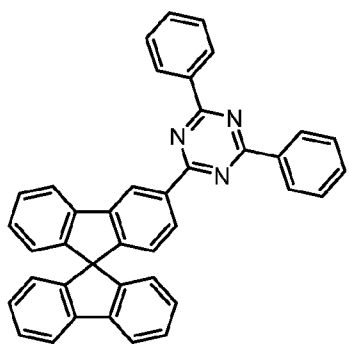
4CzIPN



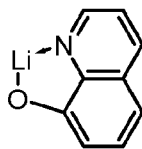
mCBP



T2T

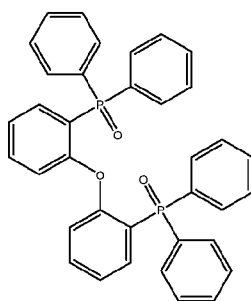


SF3-TRZ

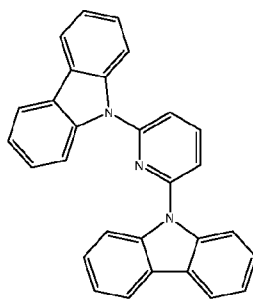


Liq

5



DPEPO



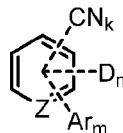
FYD2Cz

10



We claim:

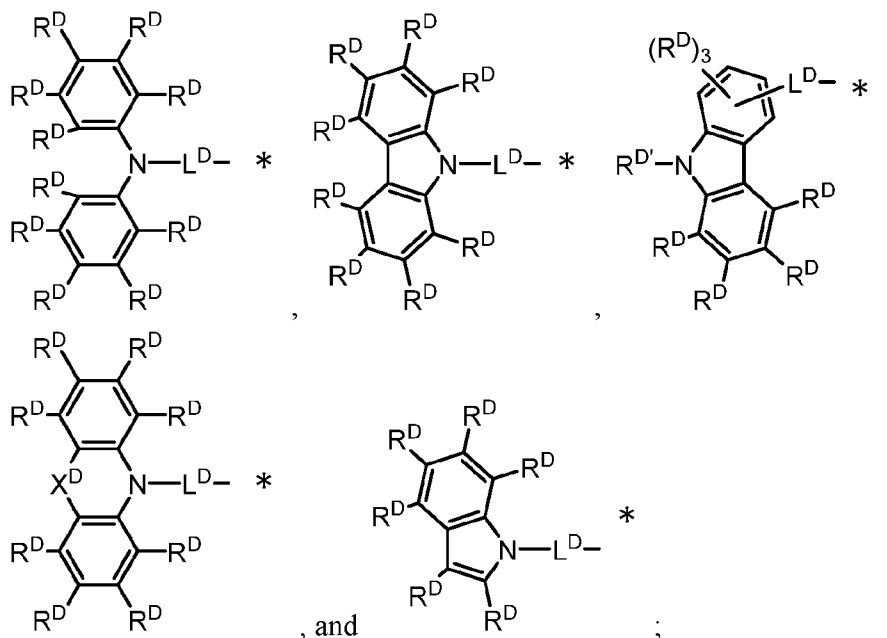
1. A compound of Formula (I):



(I)

wherein

D is independently selected from



- 10  $X^D$  is independently selected from O, S,  $NR^{D'}$ ,  $C(O)$ , substituted or unsubstituted methylene, substituted or unsubstituted ethylene, substituted or unsubstituted vinylene, substituted or unsubstituted *o*-arylene, and substituted or unsubstituted *o*-heteroarylene; wherein each instance of methylene, ethylene, vinylene, *o*-arylene or *o*-heteroarylene can be substituted with one or more substituents independently selected from deuterium,
- 15 substituted or unsubstituted alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl;

two or more instances of  $X^D$  taken together can form a ring system;

$R^D$  is independently selected from hydrogen, deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted alkoxy, substituted or unsubstituted

amino, substituted or unsubstituted aryl, substituted or unsubstituted aryloxy, substituted or unsubstituted heteroaryl, substituted or unsubstituted heteroaryloxy, and silyl;

two or more instances of  $R^D$  taken together can form a ring system;

$R^{D'}$  is independently selected from hydrogen, deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted amino, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl;

two or more instances of  $R^{D'}$  and  $R^D$  taken together can form a ring system;

$L^D$  is independently selected from single bond, substituted or unsubstituted arylene, and substituted or unsubstituted heteroarylene; wherein each instance of arylene and heteroarylene can be substituted with one or more substituents independently selected from deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl; two or more of these substituents taken together can form a ring system;

Ar is independently selected from substituted or unsubstituted aryl and substituted or unsubstituted heteroaryl, wherein the substituted or unsubstituted heteroaryl does not contain a nitrogen atom; and wherein each instance of aryl, and heteroaryl can be substituted with one or more substituents independently selected from deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl; two or more of these substituents taken together can form a ring system;

Z is N or CR;

R is H, CN, D or Ar;

k is 1 to 3;

m is 0 to 4;

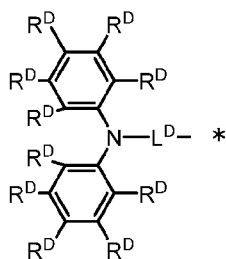
n is 1 to 5;

(k + m + n) is less than or equal to 5; and

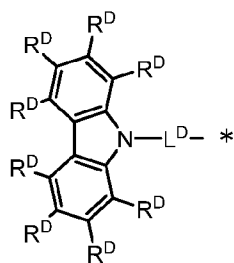
each “\*” represents a point of attachment to Formula (I).

2. The compound of claim 1, wherein alkyl is C1-C20-alkyl.

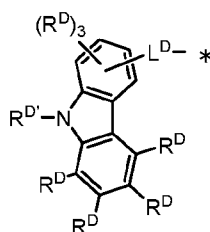
3. The compound of claim 1, wherein alkyl is C1-C12 alkyl.
4. The compound of any one of claims 1-3, wherein aryl is C6-C40 aryl.
5. The compound of any one of claims 1-3, wherein aryl is C6-C25 aryl.
6. The compound of any one of claims 1-5, wherein heteroaryl is C2-C40 heteroaryl.
7. The compound of any one of claims 1-5, wherein heteroaryl is C2-C25 heteroaryl.
8. The compound of any one of claims 1-7, wherein alkoxy is C1-C20 alkoxy.
9. The compound of any one of claims 1-7, wherein alkoxy is C1-C12 alkoxy.
10. The compound of any one of claims 1-9, wherein aryloxy is C6-C40 aryloxy.
11. The compound of any one of claims 1-9, wherein aryloxy is C6-C25 aryloxy.
12. The compound of any one of claims 1-11, wherein heteroaryloxy is C3-C40 heteroaryloxy.
13. The compound of any one of claims 1-11, wherein heteroaryloxy is C3-C25 heteroaryloxy.
14. The compound of claims 1-13, wherein D is



15. The compound of claim 1-13, wherein D is



16. The compound of claim 1-13, wherein D is



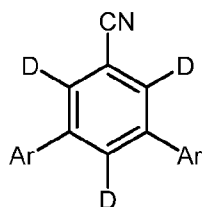
17. The compound of claims 1-16, wherein Z is CR.

5 18. The compound of claim 17, wherein k is 1.

19. The compound of claim 18, wherein  $(k + m + n)$  is 5, and m is greater than or equal to 2.

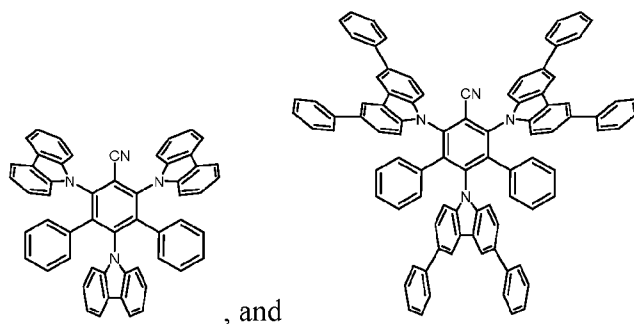
20. The compound of claim 19, wherein m is 2.

10 21. The compound of claim 20, wherein the compound of Formula (I) is represented by Formula (Ia):

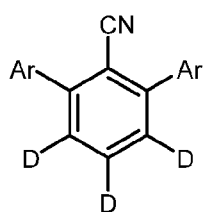


(Ia).

22. The compound of claim 1, wherein the compound is selected from



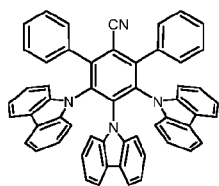
23. The compound of claim 20, wherein the compound of Formula (I) is represented by Formula (Ib):



(Ib).

5

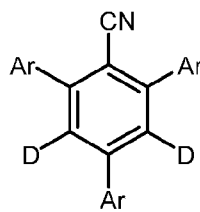
24. The compound of claim 1, wherein the compound is



25. The compound of claim 19, wherein m is 3.

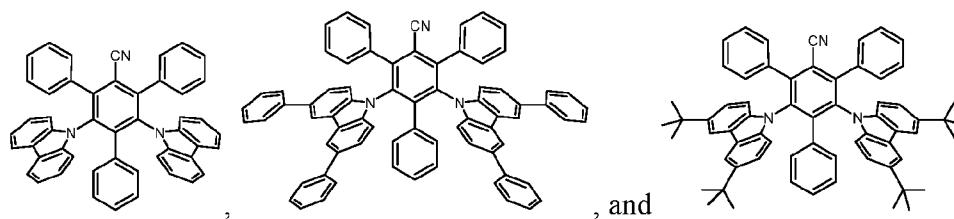
10

26. The compound of claim 25, wherein the compound of Formula (I) is represented by Formula (Ic):



(Ic).

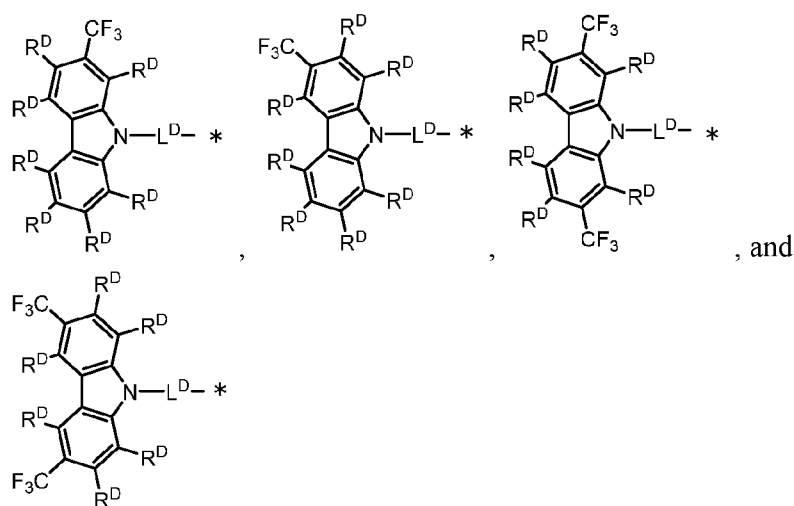
27. The compound of claim 1, wherein the compound is selected from



28. The compound of any one of claims 1-27, wherein Ar is substituted or unsubstituted aryl.

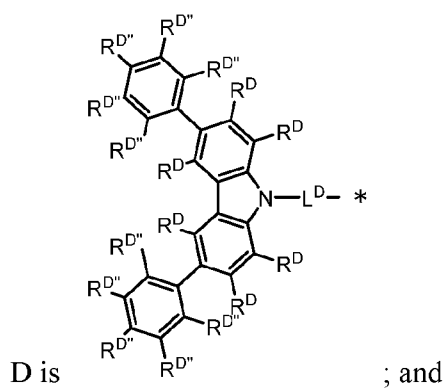
29. The compound of any one of claims 1-28, wherein  $L^D$  is single bond.

5 30. The compound of any one of claims 1-29, wherein at least one of D is selected from



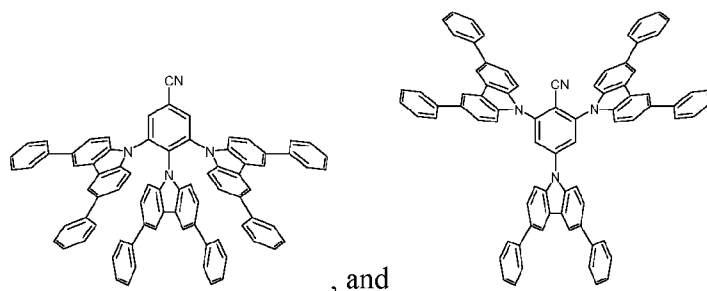
31. The compound of claim 18, wherein

10 n is 3;

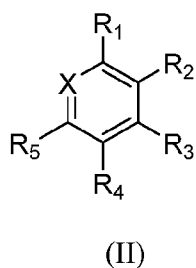


$R^{D''}$  is independently selected from hydrogen, deuterium, substituted or unsubstituted alkyl, substituted or unsubstituted alkoxy, substituted or unsubstituted amino, substituted or unsubstituted aryl, substituted or unsubstituted aryloxy, substituted or unsubstituted heteroaryl, substituted or unsubstituted heteroaryloxy, and silyl.

5 32. The compound of claim 31, wherein the compound is selected from



33. A compound of Formula (II):



10 Wherein

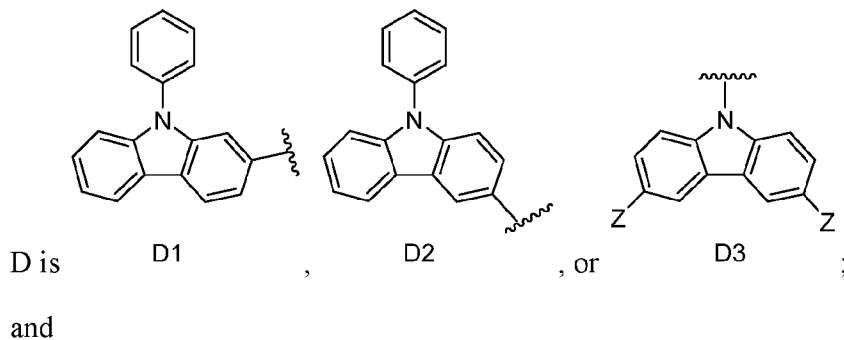
X is N or CR<sub>6</sub>;

R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, and R<sub>6</sub> are independently selected from the group consisting of A, D, H, and Ph;

at least one of R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, and R<sub>6</sub> is A;

15 at least one of R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, and R<sub>6</sub> is D;

A is CN;



Z is independently H, Me, or Ph.

34. The compound of claim 33, wherein X is CR<sub>6</sub>.
35. The compound of claim 33, wherein X is N.
36. The compound of any one of claims 33-35, wherein D is D1.
- 5 37. The compound of any one of claims 33-35, wherein D is D2.
38. The compound of any one of claims 33-35, wherein D is D3.
39. The compound of any one of claims 33-35, and 38, wherein Z is H.
40. The compound of any one of claims 33-35, and 38, wherein Z is Me.
41. The compound of any one of claims 33-35, and 38, wherein Z is Ph.
- 10 42. The compound of any one of claims 33-41, wherein only one instance of A is present.
43. The compound of any one of claims 33-41, wherein two instances of A are present.
44. The compound of any one of claims 33-41, wherein three instances of A are present.
- 15 45. The compound of any one of claims 33-41, wherein four instances of A are present.
46. The compound of any one of claims 33-44, wherein two instances of D are present.
- 20 47. The compound of any one of claims 33-43, wherein three instances of D are present.
48. The compound of any one of claims 33-42, wherein four instances of D are present.
49. The compound of any one of claims 33-41, wherein two instances of A are present; and two instances of D are present.
- 25 50. The compound of any one of claims 33-41, wherein one instance of A is present; and three instances of D are present.
51. The compound of any one of claims 33-41, wherein three instances of A are present; and two instances of D are present.
- 30 52. The compound of any one of claims 33-41, wherein two instances of A are present; and three instances of D are present.
53. The compound of any one of claims 33-41, wherein four instances of A are present; and two instances of D are present.



54. The compound of any one of claims 33-41, wherein at least one of  $R_1$ ,  $R_2$ ,  $R_3$ ,  $R_4$ ,  $R_5$ , and  $R_6$  is H.

55. The compound of any one of claims 33-41, wherein at least one of  $R_1$ ,  $R_2$ ,  $R_3$ ,  $R_4$ ,  $R_5$ , and  $R_6$  is Ph.

56. The compound of any one of claims 33-41, wherein at least one of  $R_1$ ,  $R_2$ ,  $R_3$ ,  $R_4$ ,  $R_5$ , and  $R_6$  is H; and at least one of  $R_1$ ,  $R_2$ ,  $R_3$ ,  $R_4$ ,  $R_5$ , and  $R_6$  is Ph.

57. The compound of claim 33, wherein the compound of Formula (I) is selected from the group consisting of:

2,6-bis(3,6-diphenyl-9H-carbazol-9-yl)-3,5-bis(9-phenyl-9H-carbazol-2-yl)-[1,1'-biphenyl]-4-carbonitrile;

4,5-di(9H-carbazol-9-yl)-3,6-bis(9-phenyl-9H-carbazol-3-yl)phthalonitrile;

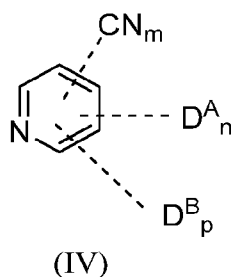
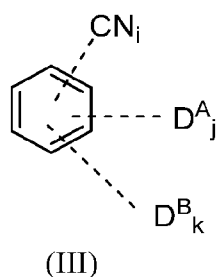
3,3'-(3',6'-bis(4,6-diphenyl-1,3,5-triazin-2-yl)-[1,1':2',1''-terphenyl]-4',5'-diyl)bis(9-phenyl-9H-carbazole);

2,5-di(9H-carbazol-9-yl)-4,6-bis(9-phenyl-9H-carbazol-3-yl)isophthalonitrile;

and

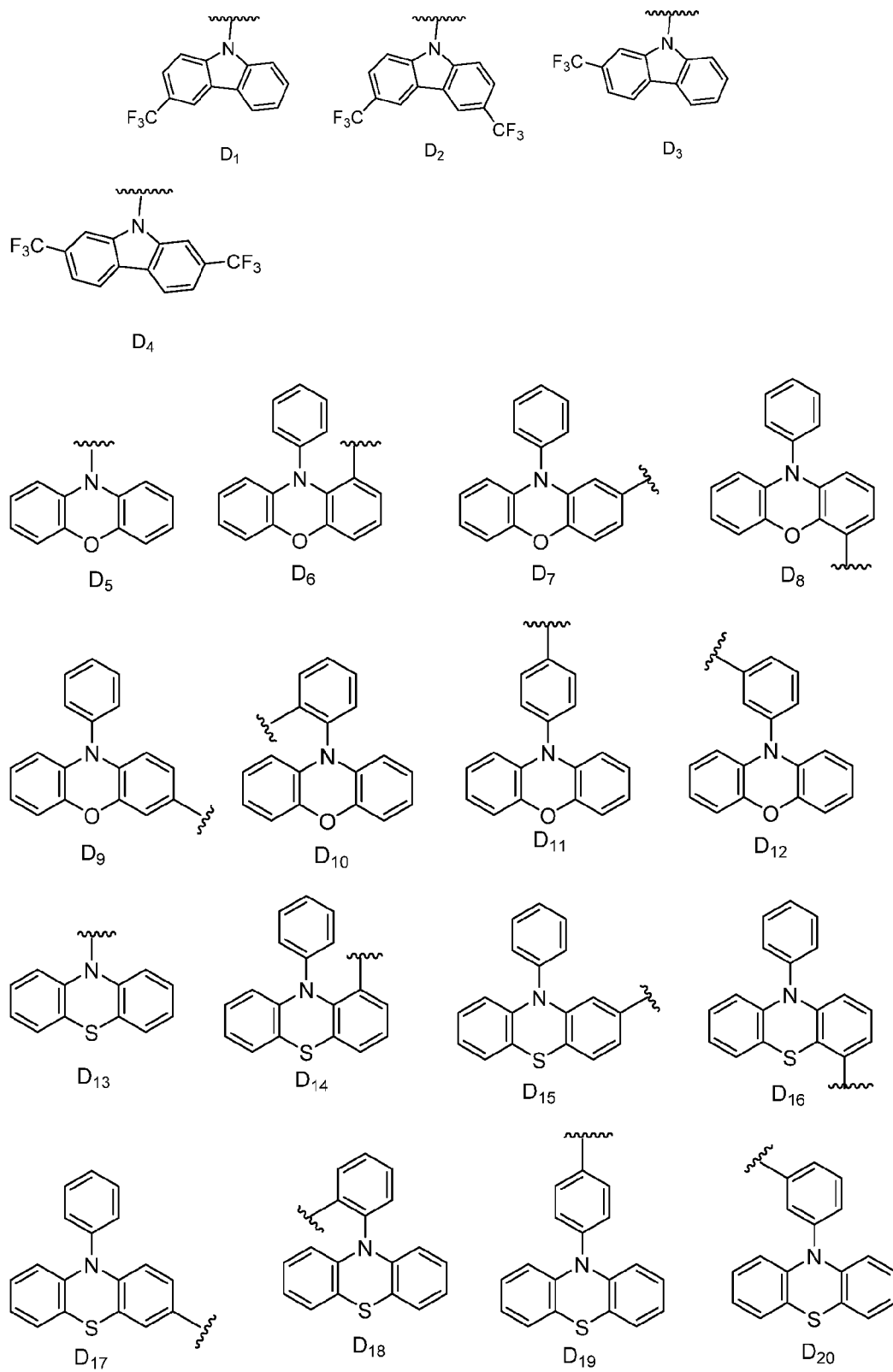
2',6'-bis(9-phenyl-9H-carbazol-2-yl)-[1,1':3',1''-terphenyl]-4',5'-dicarbonitrile.

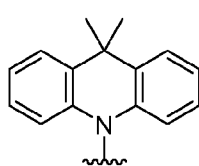
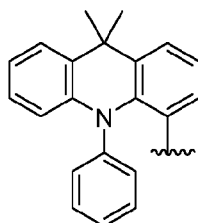
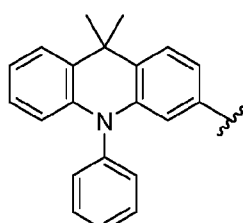
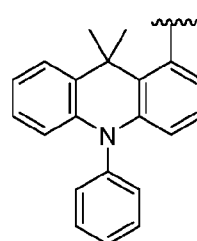
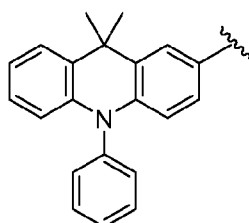
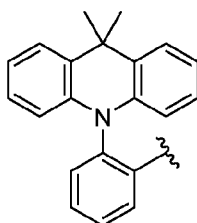
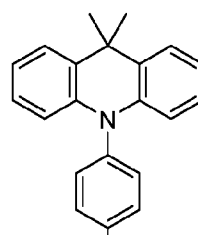
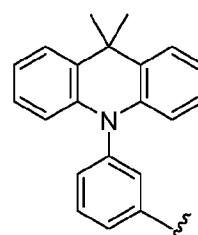
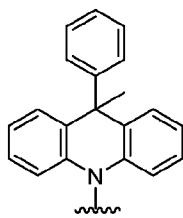
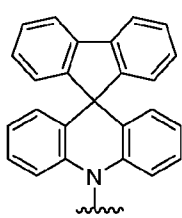
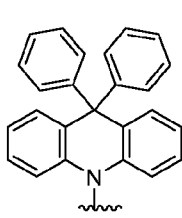
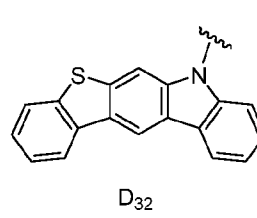
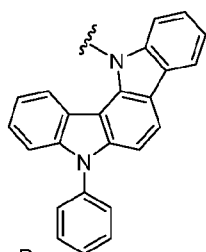
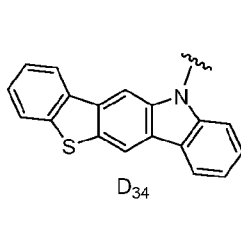
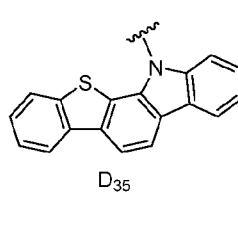
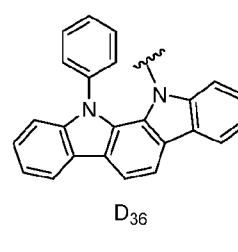
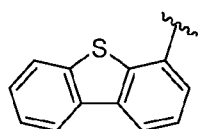
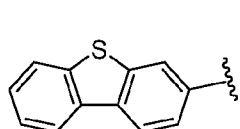
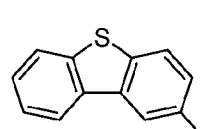
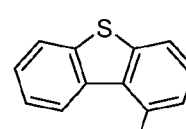
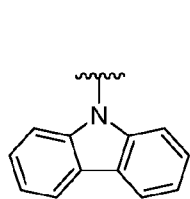
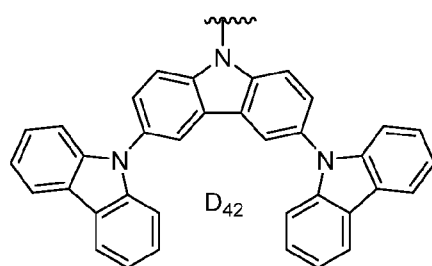
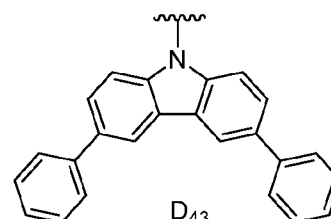
58. A compound of Formula (III) or Formula (IV):

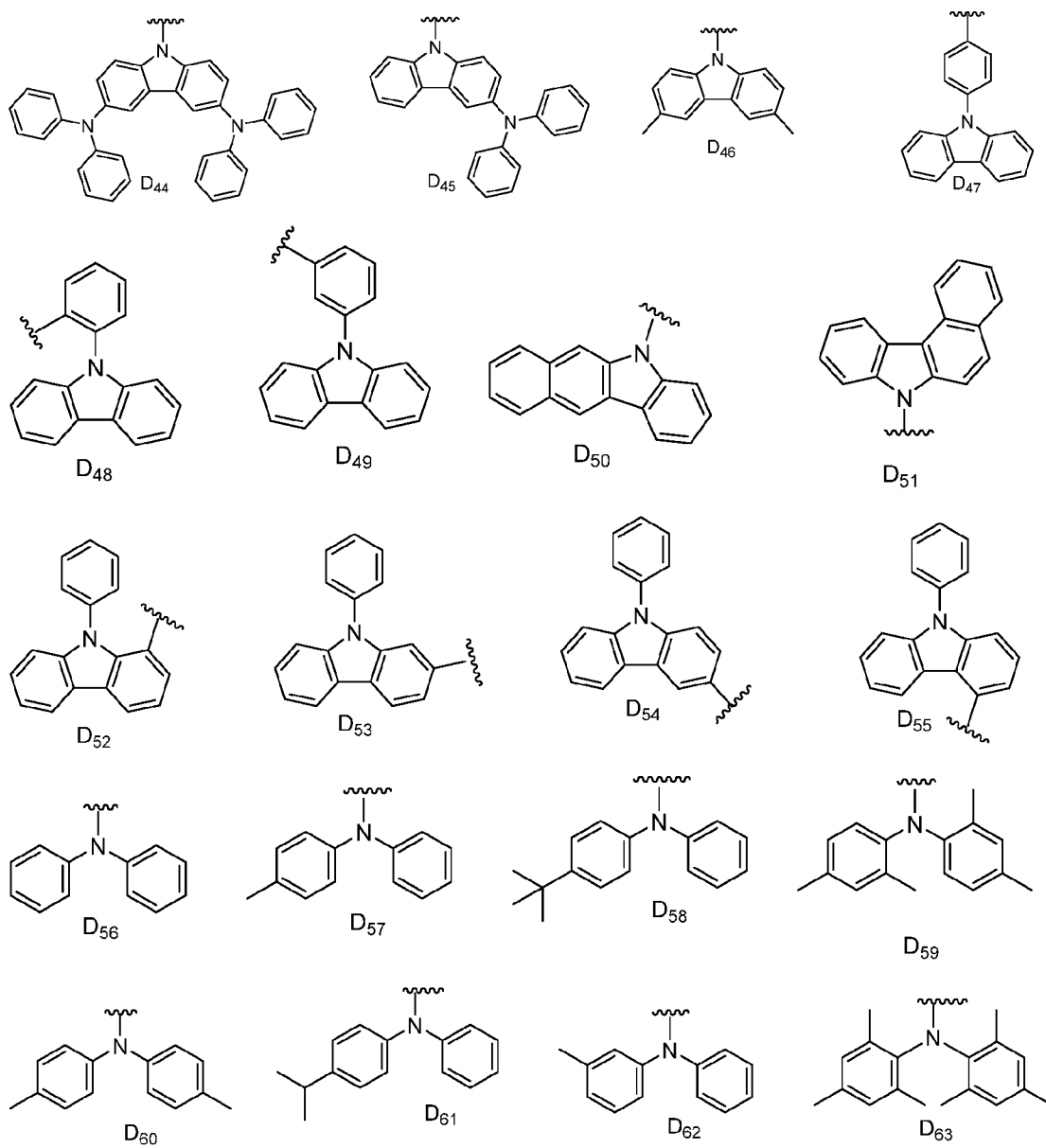


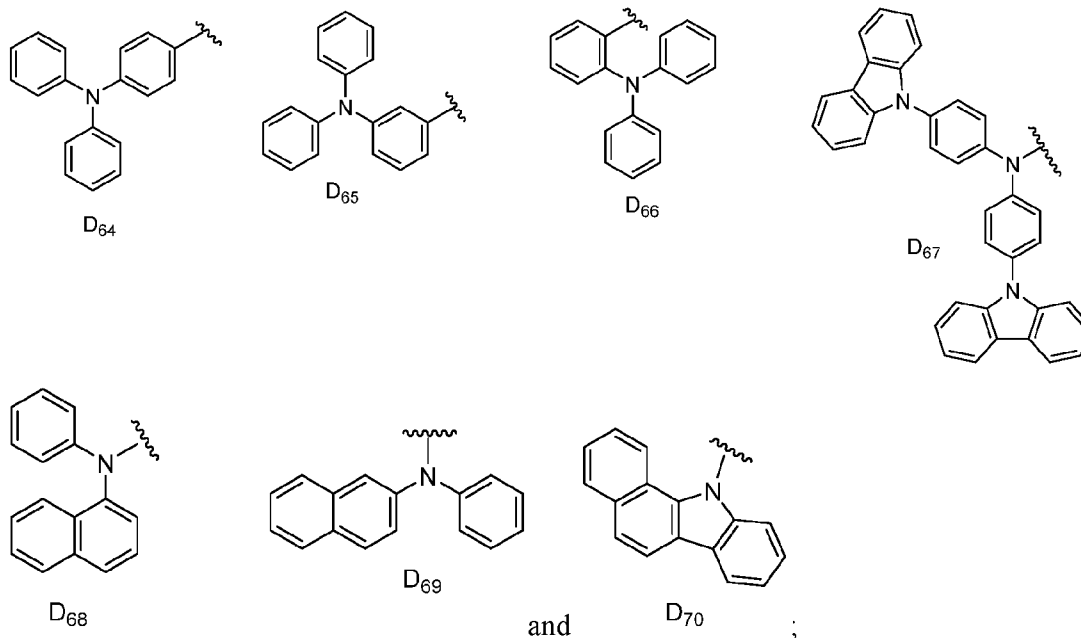
wherein

$D^A$  and  $D^B$  are independently selected from



D<sub>21</sub>D<sub>22</sub>D<sub>23</sub>D<sub>24</sub>D<sub>25</sub>D<sub>26</sub>D<sub>27</sub>D<sub>28</sub>D<sub>29</sub>D<sub>30</sub>D<sub>31</sub>D<sub>32</sub>D<sub>33</sub>D<sub>34</sub>D<sub>35</sub>D<sub>36</sub>D<sub>37</sub>D<sub>38</sub>D<sub>39</sub>D<sub>40</sub>D<sub>41</sub>D<sub>42</sub>D<sub>43</sub>





i is 1, 2, or 3;

j is 1, 2, 3, 4, or 5;

5      k is 0, 1, 2, 3, or 4;

i + j + k is less than or equal to 6;

m is 1, 2, or 3;

n is 1, 2, 3, or 4;

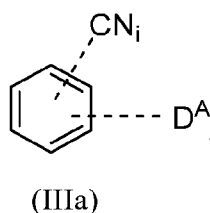
p is 0, 1, 2, or 3; and

10      m + n + p is less than or equal to 5

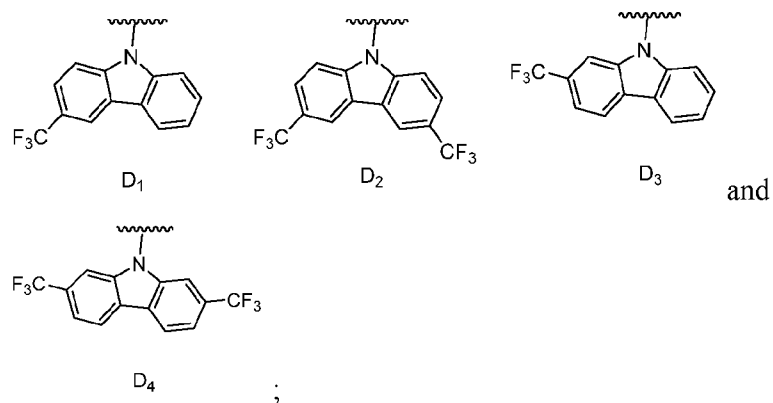
59. The compound of claim 58, wherein D<sup>A</sup> is independently selected from D1, D2, D3, D4, D5, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, and D19.

15      60. The compound of claim 58, wherein D<sup>A</sup> is independently selected from D20, D21, D22, D23, D24, D25, D26, D27, D28, D29, D30, D31, D32, D33, D34, D35, D36, D37, D38, and D39.

61. The compound of claim 58, wherein D<sup>A</sup> is independently selected from D40, D41, D42, D43, D44, D45, D46, D47, D48, D49, D50, D51, D52, D53, D54, D55, D56, D57, D58, and D59.
- 5 62. The compound of claim 58, wherein D<sup>A</sup> is independently selected from D60, D61, D62, D63, D64, D65, D66, D67, D68, D69, and D70.
63. The compound of any one of claims 58-63, wherein D<sup>B</sup> is independently selected from D1, D2, D3, D4, D5, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, and D19.
- 10 64. The compound of any one of claims 58-63, wherein D<sup>B</sup> is independently selected from D20, D21, D22, D23, D24, D25, D26, D27, D28, D29, D30, D31, D32, D33, D34, D35, D36, D37, D38, and D39.
65. The compound of any one of claims 58-63, wherein D<sup>B</sup> is independently selected from D40, D41, D42, D43, D44, D45, D46, D47, D48, D49, D50, D51, D52, D53, D54, D55, D56, D57, D58, and D59.
- 15 66. The compound of any one of claims 58-63, wherein D<sup>B</sup> is independently selected from D60, D61, D62, D63, D64, D65, D66, D67, D68, D69, and D70.
67. The compound of claim 58, wherein the compound of Formula (III) is represented by Formula (IIIa)



- 20 wherein
- D<sup>A</sup> is independently selected from

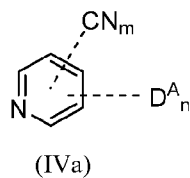


i is 1, 2, or 3;

j is 1, 2, 3, 4, or 5; and

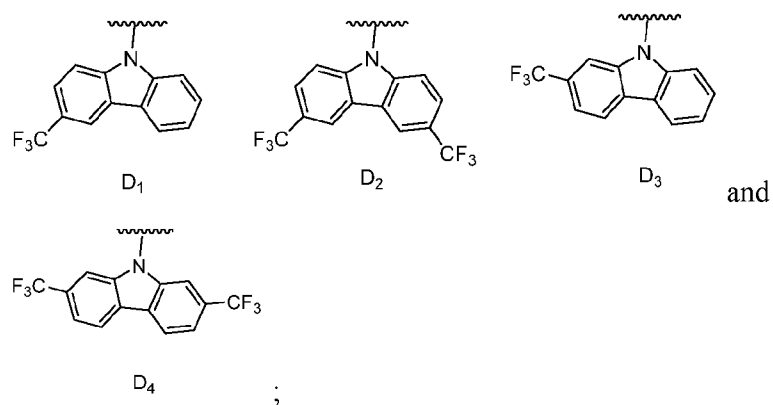
5                      i + j is less than or equal to 6.

68. The compound of claim 58, wherein the compound of Formula (IV) is represented by Formula (IVa)



wherein

10                      D<sup>A</sup> is independently selected from



m is 1, 2, or 3;

n is 1, 2, 3, or 4;

m + n is less than or equal to 5.

69. The compound of claim 67 or 68, wherein D<sup>A</sup> is D1.

70. The compound of claim 67 or 68, wherein D<sup>A</sup> is D2.

5 71. The compound of claim 67 or 68, wherein D<sup>A</sup> is D3.

72. The compound of claim 67 or 68, wherein D<sup>A</sup> is D4.

73. The compound of claim 58, wherein i is 1, and j is 4.

74. The compound of claim 58, wherein i is 1, and j is 5.

75. The compound of claim 58, wherein i is 2, and j is 3.

10 76. The compound of claim 58, wherein i is 1, and j is 5.

77. The compound of claim 58, wherein m is 1, and n is 4.

78. The compound of claim 58, wherein m is 2, and n is 2.

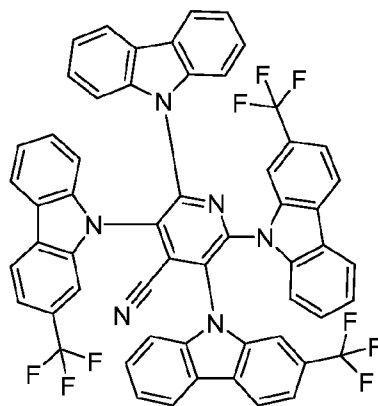
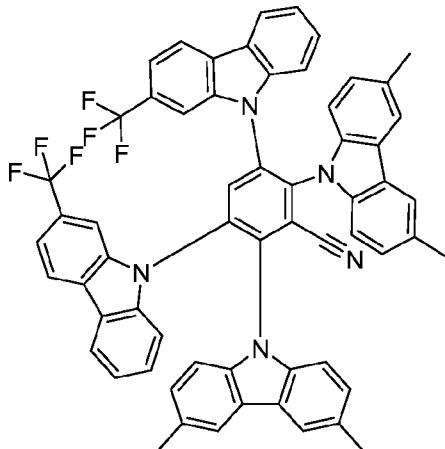
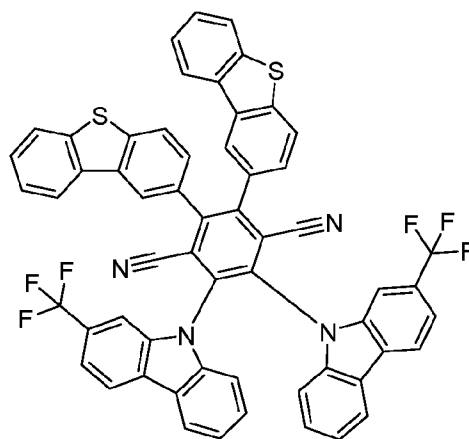
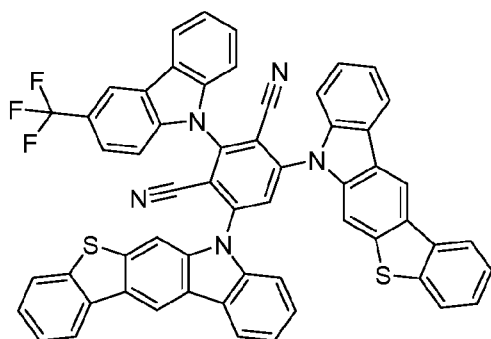
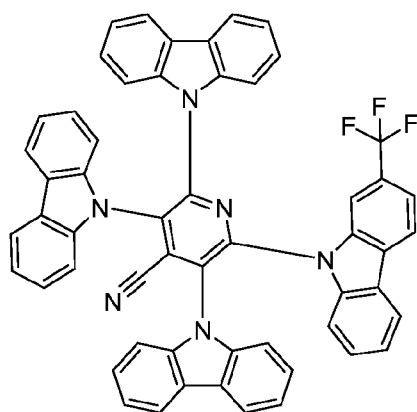
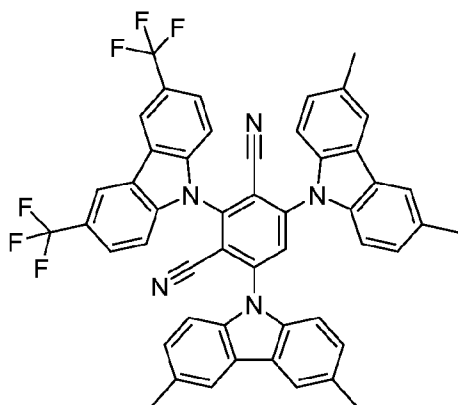
79. The compound of claim 58, wherein m is 2, and n is 3.

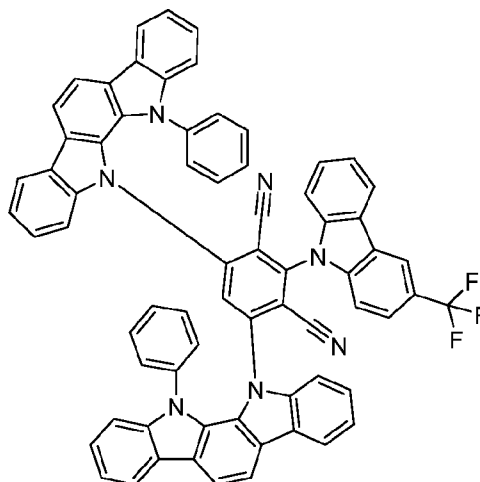
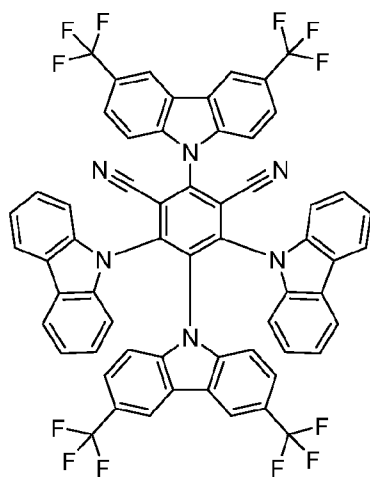
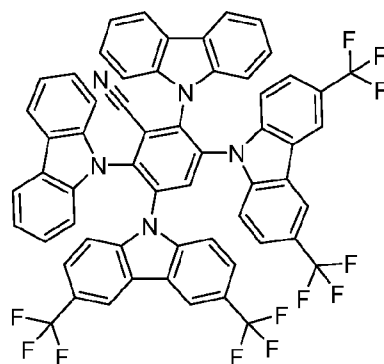
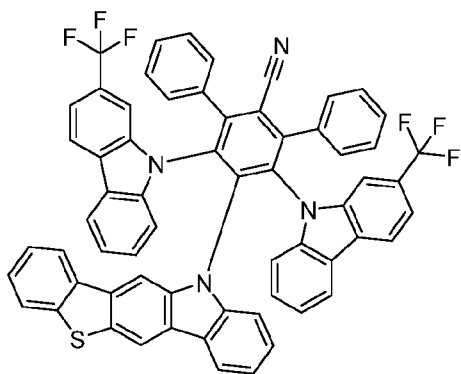
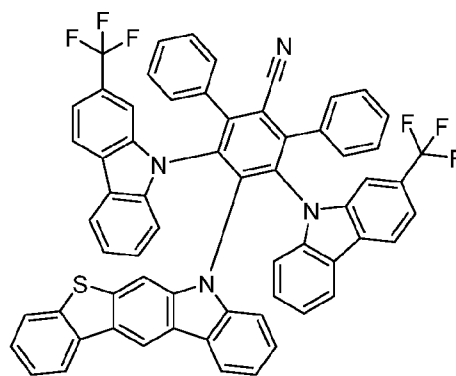
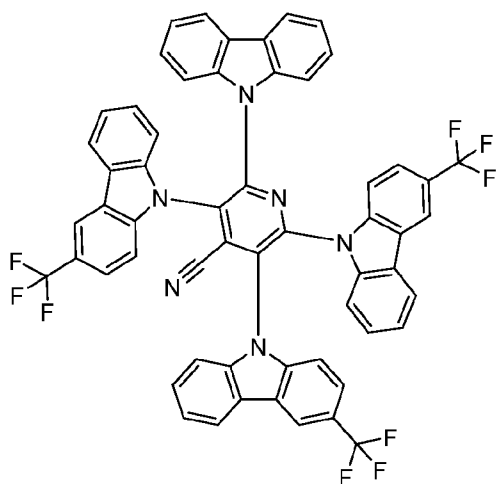
80. The compound of claim 58, wherein m is 2, and m is 3.

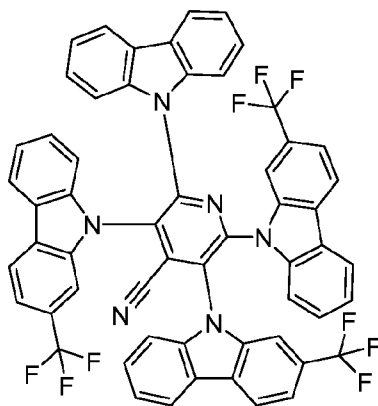
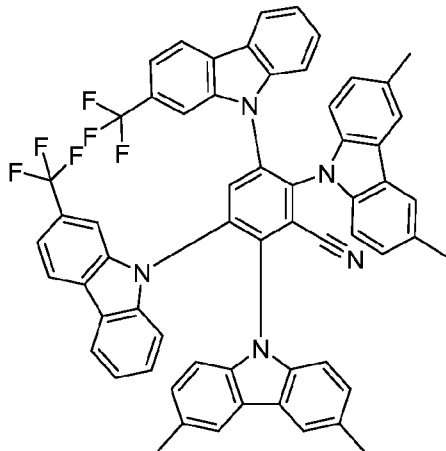
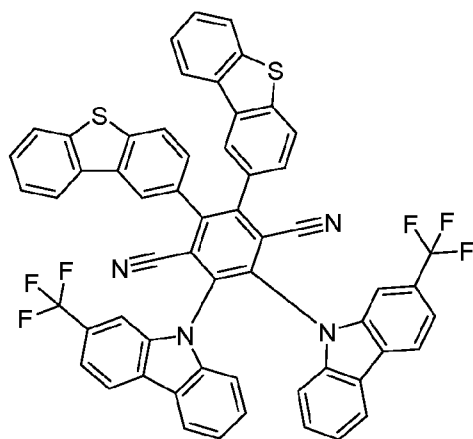
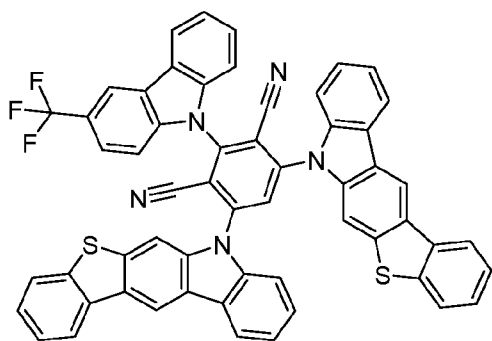
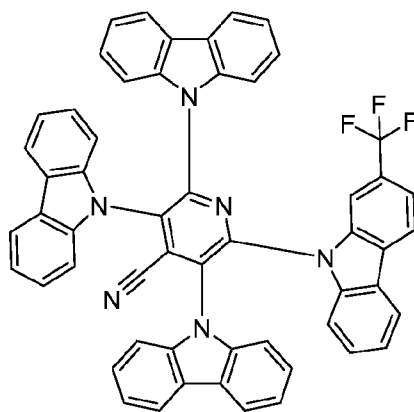
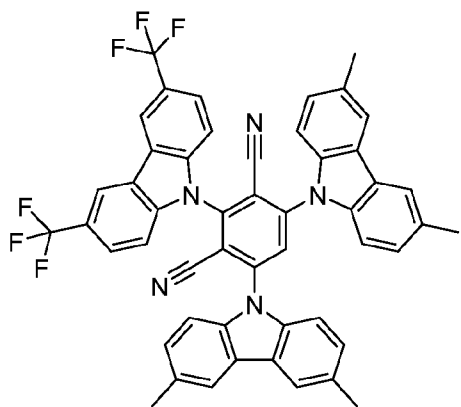
15 81. The compound of claim 58, wherein m is 4, and m is 1.

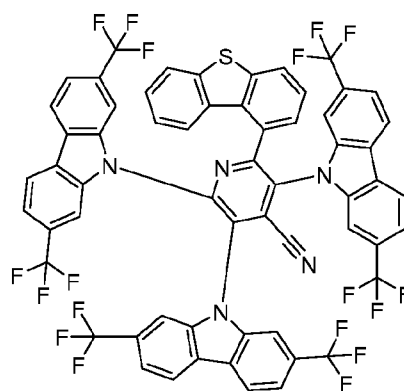
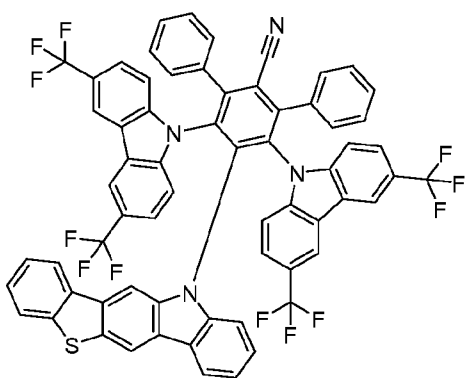
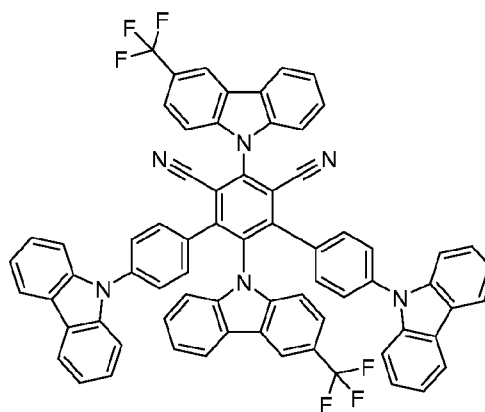
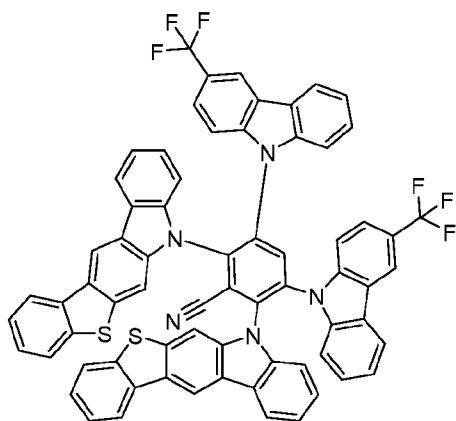
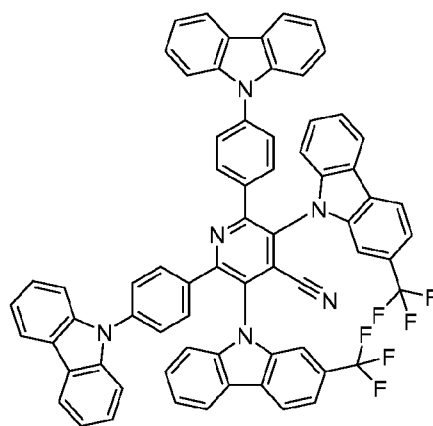
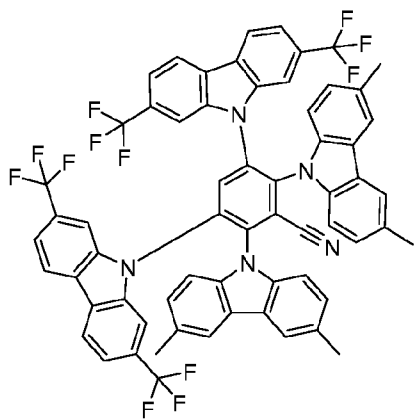
82. The compound of claim 58, wherein the compound of Formula (III) or Formula (IV) is selected from

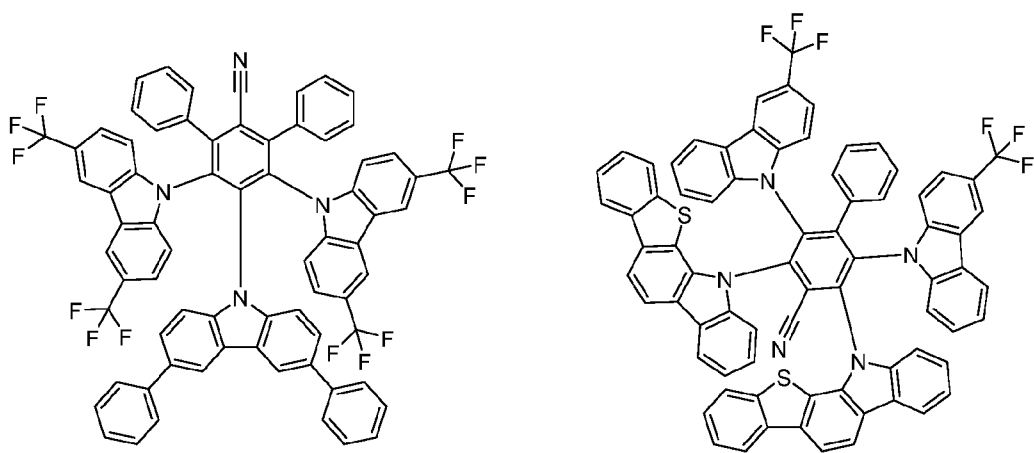




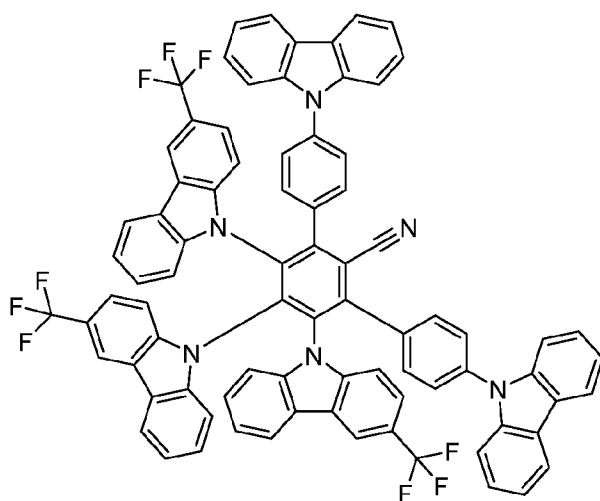




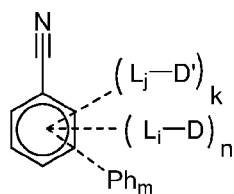




and



83. A compound of Formula (V):



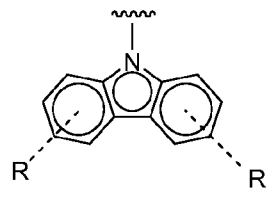
(V)

5

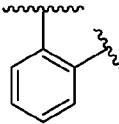
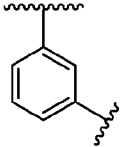
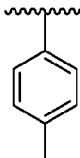
wherein

Ph is phenyl;

D and D' are independently selected from



R is independently selected from aryl, alkyl, and heteroaryl;

L is independently selected from , , and  ;

n, and m, are each independently an integer greater than 0;

k is 0, 1, or 2, or 3;

$n + m + k = 5$ ; and

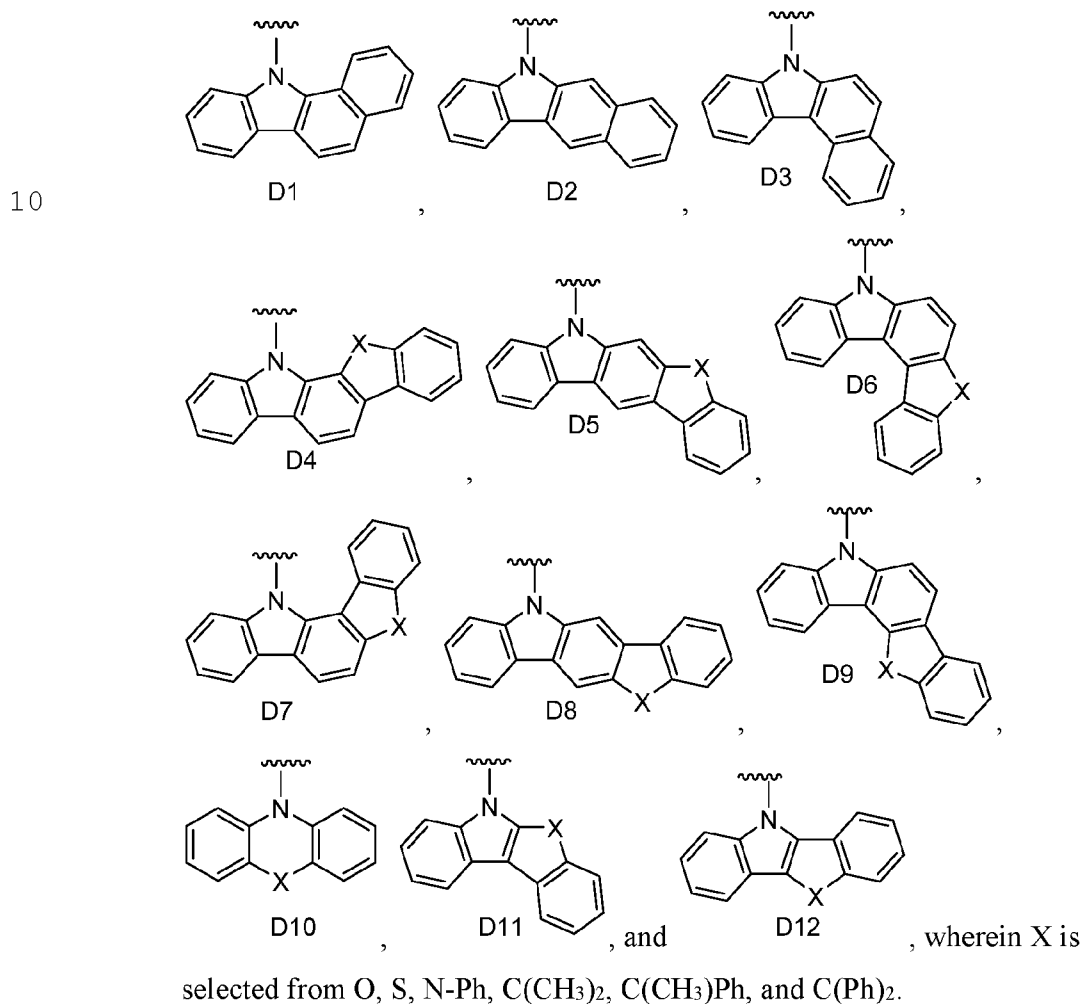
5 i and j are independently 0 or 1.

84. The compound of claim 83, wherein R is aryl.

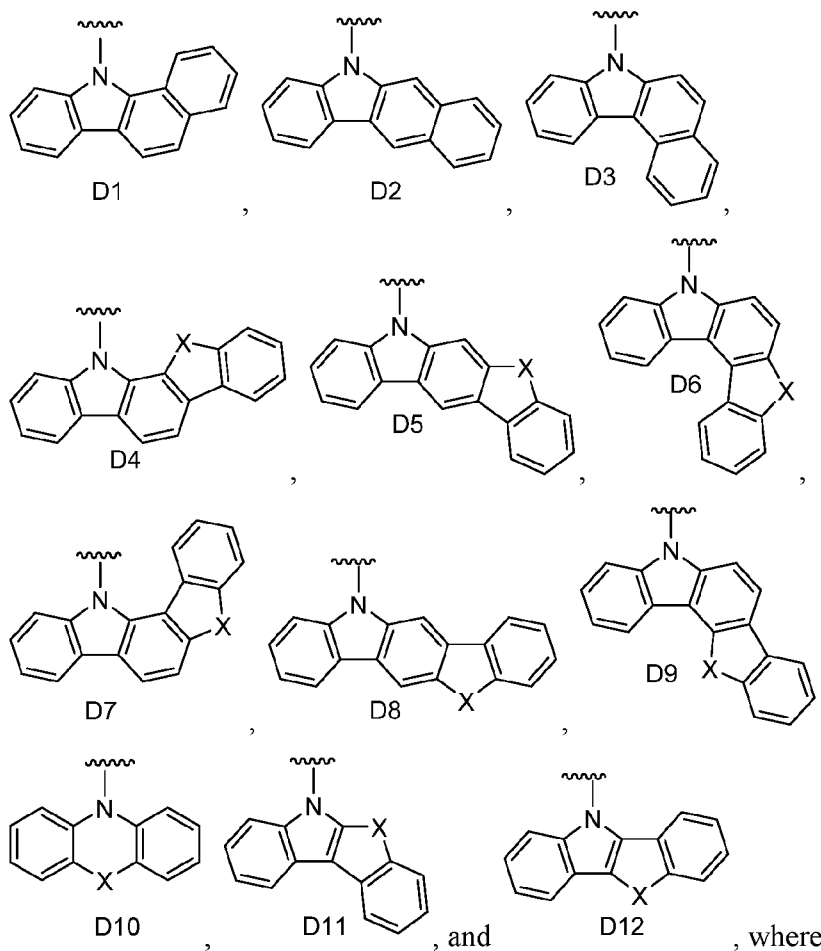
85. The compound of claim 83, wherein R is alkyl.

86. The compound of claim 83, wherein R is heteroaryl.

87. The compound of claim 83, wherein at least one instance of D is selected from



88. The compound of claim 83, wherein at least one instance of D' is selected from



selected from O, S, N-Ph, C(CH<sub>3</sub>)<sub>2</sub>, C(CH<sub>3</sub>)Ph, and C(Ph)<sub>2</sub>.

89. The compound of claim 88, wherein X is O.

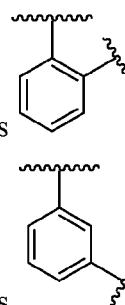
90. The compound of claim 88, wherein X is S.

91. The compound of claim 88, wherein X is C(CH<sub>3</sub>)<sub>2</sub>.

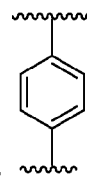
92. The compound of claim 88, wherein X is C(CH<sub>3</sub>)Ph

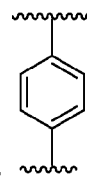
93. The compound of claim 88, wherein X is C(Ph)<sub>2</sub>.

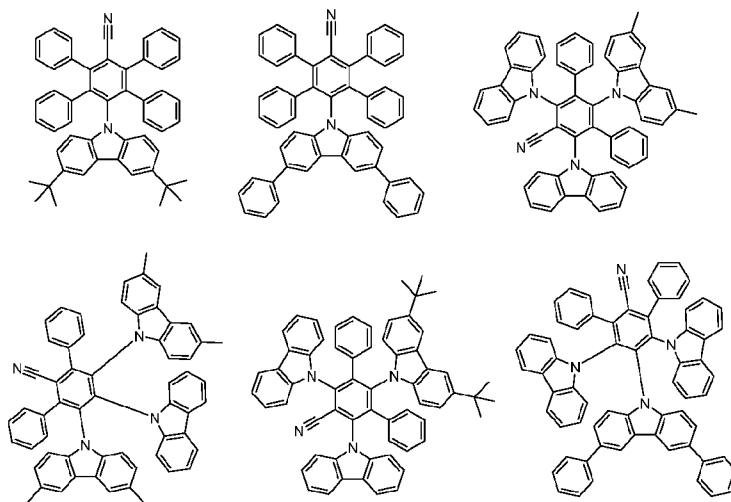
94. The compound of any one of claims 83-93, wherein L is



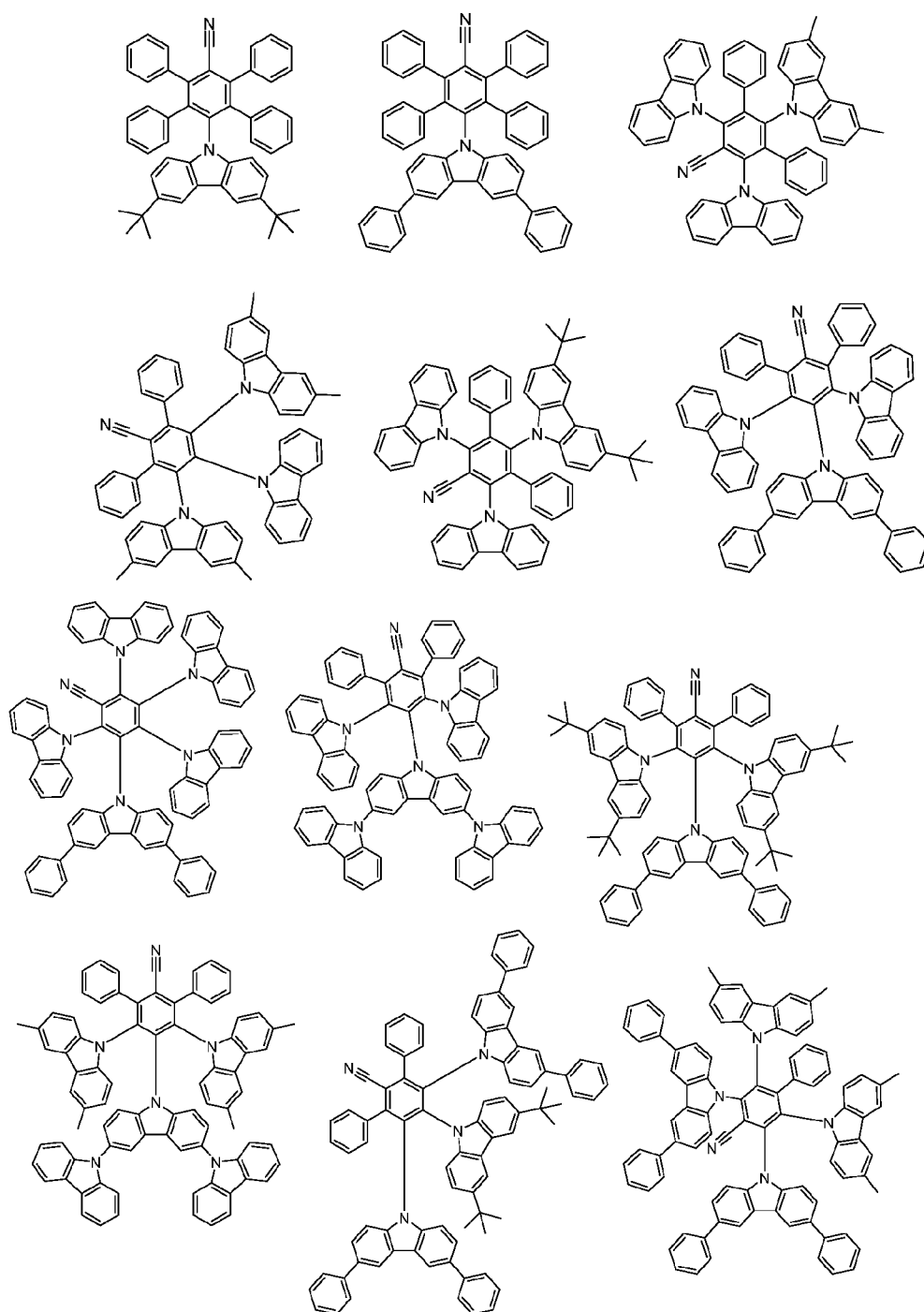
95. The compound of any one of claims 83-93, wherein L is

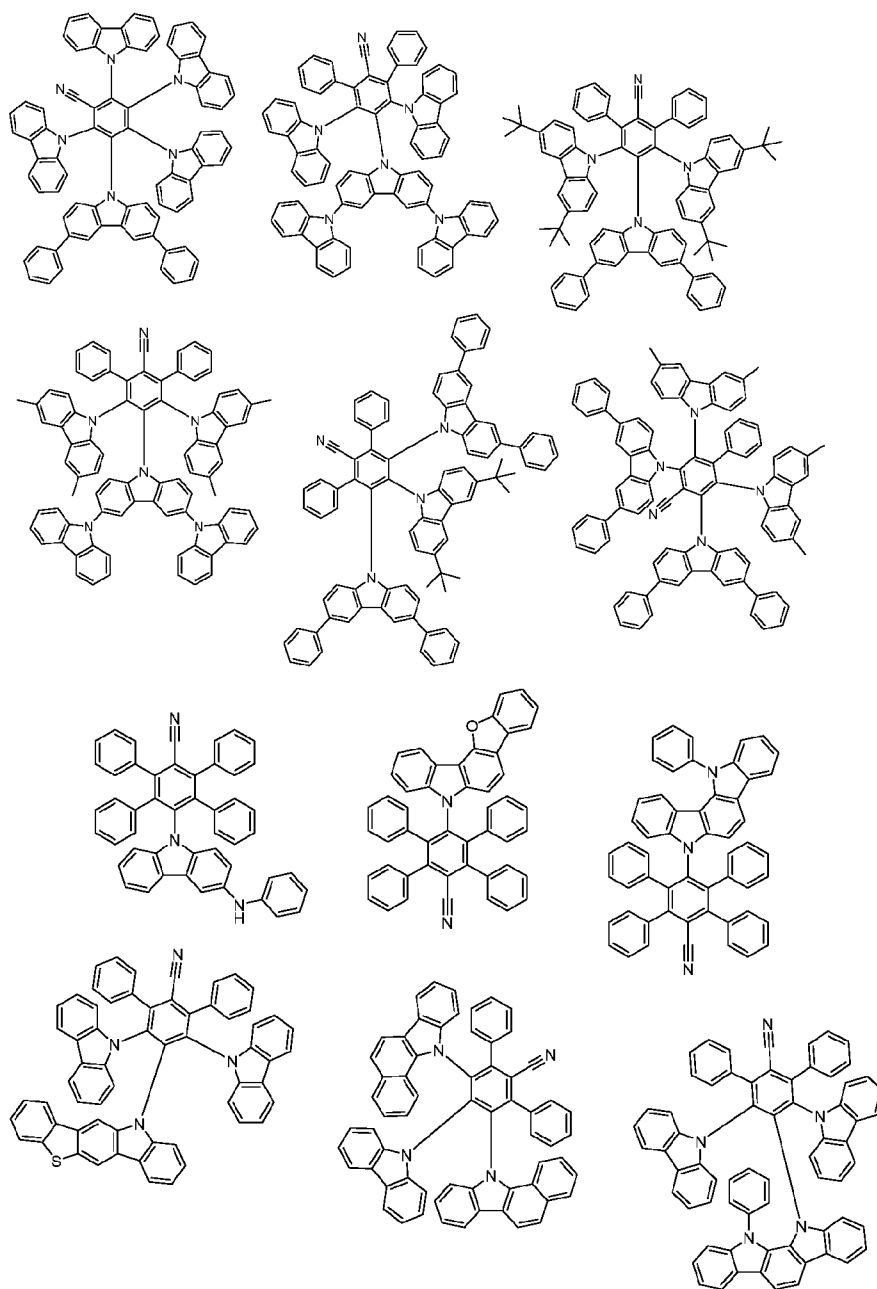


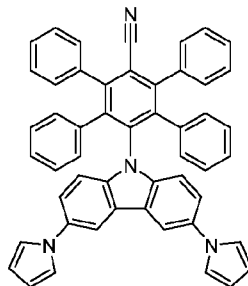
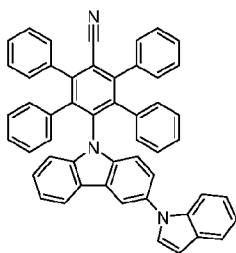
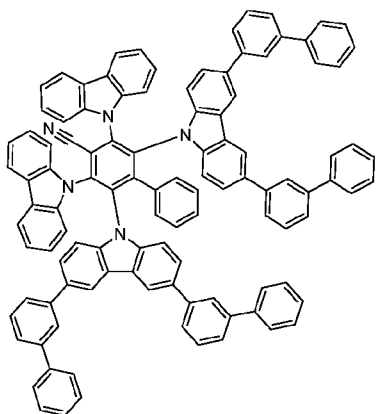
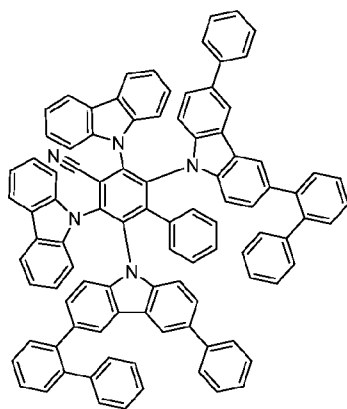
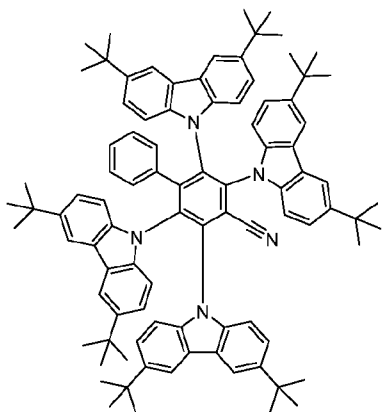
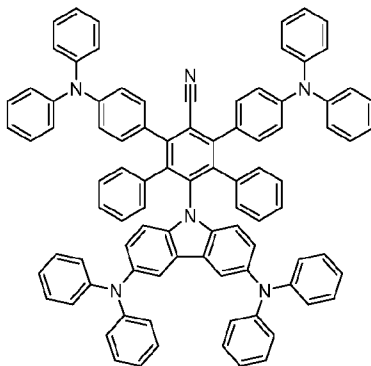
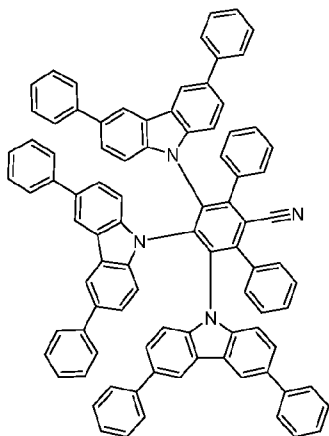
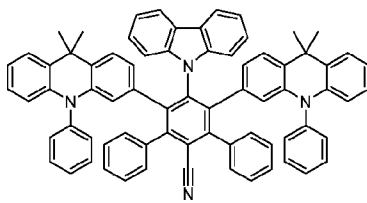
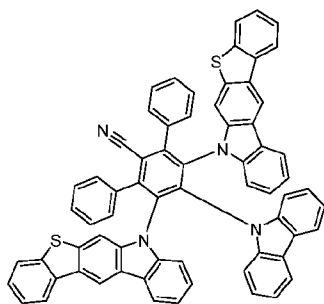
96. The compound of any one of claims 83-93, wherein L is .
97. The compound of any one of claims 83-96, wherein n is 1, m is 1, and k is 3.
98. The compound of any one of claims 83-96, wherein n is 1, m is 2, and k is 2.
99. The compound of any one of claims 83-96, wherein n is 3, m is 1, and k is 1.
- 5 100. The compound of any one of claims 83-96, wherein n is 2, m is 2, and k is 1.
101. The compound of any one of claims 83-96, wherein n is 2, m is 1, and k is 2.
102. The compound of any one of claims 83-96, wherein n is 1, m is 3, and k is 1.
- 10 103. The compound of any one of claims 83-96, wherein i is 0.
104. The compound of any one of claims 83-96, wherein j is 0.
105. The compound of any one of claims 83-96, and 104, wherein i is 1.
106. The compound of any one of claims 83-96, and 105, wherein j is 1.
- 15 107. The compound of any one of claims 83-96, and 103-106, wherein m is 4.
108. The compound of claim 83, selected from

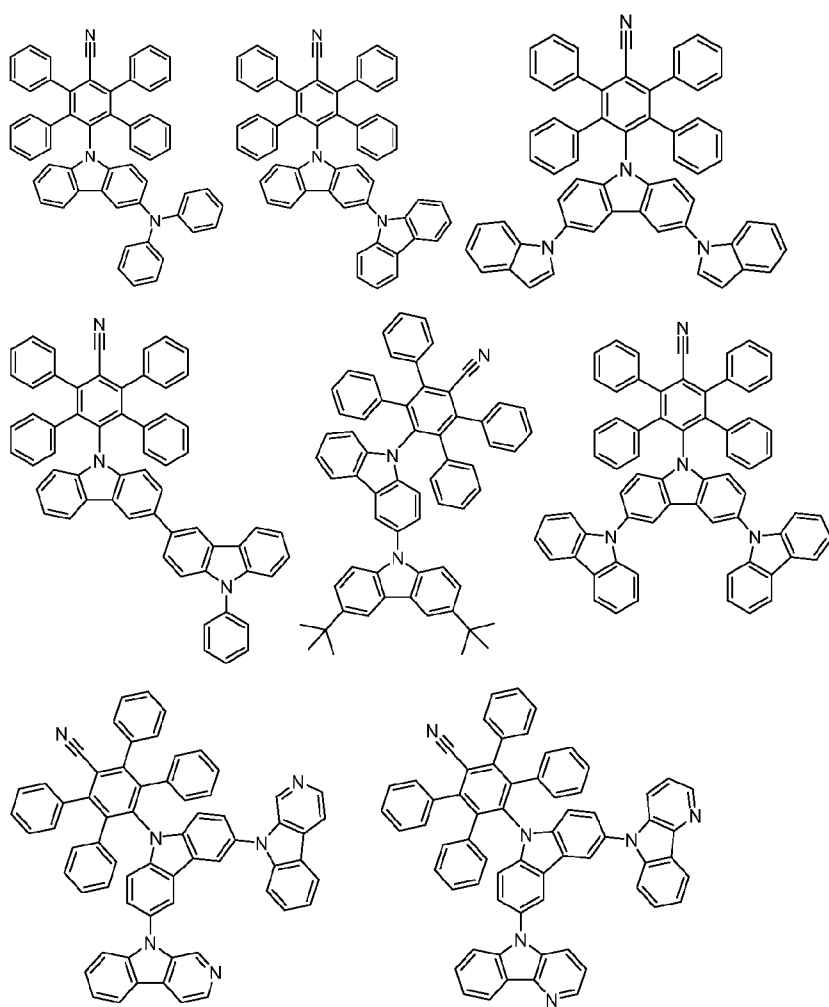


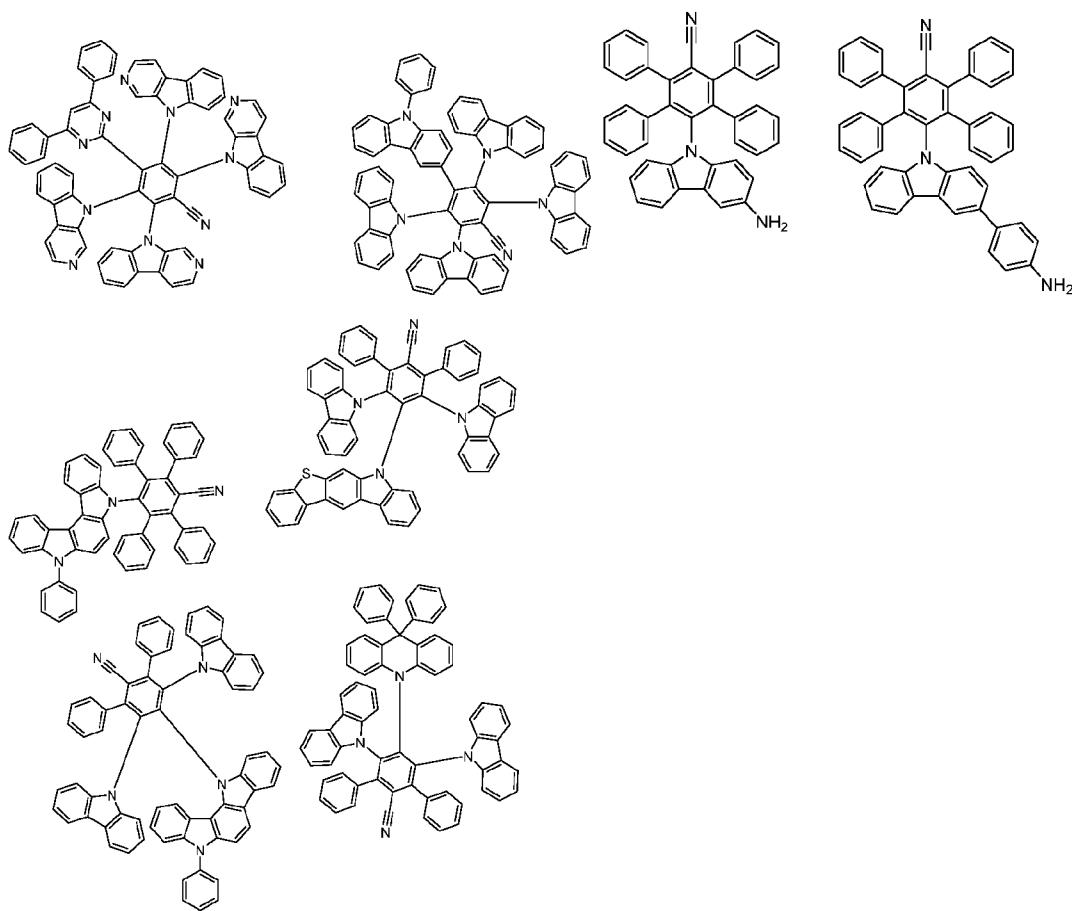






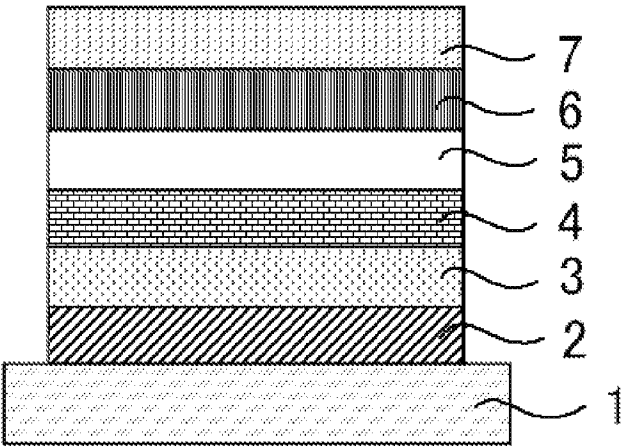






109. An organic light-emitting diode (OLED) comprising an anode, a cathode,  
and at least one organic layer comprising a light-emitting layer between the  
anode and the cathode, wherein the light-emitting layer comprises:  
a host material; and  
a compound of any one of claims 1-108;  
wherein the compound of formula (I), (II), (III), (IV), or (V) is a light-emitting  
material.
110. A screen or a display comprising a compound of any one of claims 1-108.
111. A method of manufacturing an OLED display, the method comprising:  
forming a barrier layer on a base substrate of a mother panel;  
forming a plurality of display units in units of cell panels on the barrier layer;  
forming an encapsulation layer on each of the display units of the cell panels; and  
applying an organic film to an interface portion between the cell panels; wherein  
the organic film comprises a compound of any one of claims 1-108.

FIG. 1



## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2018/039309

A. CLASSIFICATION OF SUBJECT MATTER  
 INV. C09K11/06 H01L51/50  
 ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C09K H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2015/099507 A1 (ROHM & HAAS ELECT MATERIALS [KR]) 2 July 2015 (2015-07-02)	1-16, 18-21, 109-111
A	compounds H1-165 to H1-168, H1-178, H1-180, H1-198, H1-199, H1-200, H1-229, H1-230, H1-231, H1-232, H1-261 to H1-264, H1-274, H1-276 claim 9 paragraph [0298] - paragraph [0301] the whole document	22-24, 27,32, 82, 84-108
X	WO 2010/151011 A1 (DOW ADVANCED DISPLAY MAT LTD [KR]; KIM CHI SIK [KR]; CHO YOUNG JUN [KR]) 29 December 2010 (2010-12-29) paragraph [0053] ----- -/-	1-16, 18-21, 109-111



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

12 September 2018

Date of mailing of the international search report

16/11/2018

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2  
 NL - 2280 HV Rijswijk  
 Tel. (+31-70) 340-2040,  
 Fax: (+31-70) 340-3016

Authorized officer

Ziegler, Jan

## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2018/039309

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2016/036171 A1 (ROHM & HAAS ELECT MATERIALS [KR]) 10 March 2016 (2016-03-10)  H1-146, H1-184, H1-165 to H1-168, H1-178, H1-180, H1-197 to H1-200, H1-229 to H1-232, H1-261 to H1-264, H1-274, H1-276, H1-338 to H1-341, H1-364 to H1-367, H1-377, H1-378, H1-401 to H1-405 the whole document -----	1-16, 18-21, 109-111
X	CN 106 537 633 A (ROHM & HAAS ELECT MATERIALS KOREA LTD) 22 March 2017 (2017-03-22) claim 9 the whole document -----	1-16, 18-21, 109-111
X	US 2011/278555 A1 (INOUE TETSUYA [JP] ET AL) 17 November 2011 (2011-11-17)  page 122; compounds HT-3 the whole document -----	1-16, 18-21, 109-111
X	US 2013/234119 A1 (MIZUKI YUMIKO [JP] ET AL) 12 September 2013 (2013-09-12)  first compound; page 26 first compound; page 27 the whole document -----	1-16, 18-21, 109-111
X	WO 2016/076629 A1 (ROHM & HAAS ELECT MATERIALS [KR]) 19 May 2016 (2016-05-19)  compounds H2-228, H2-229, H2-234, H2-235, H2-239 the whole document -----	1-16, 18-21, 109-111
X	WO 2016/174377 A1 (UNIV COURT UNIV ST ANDREWS [GB]) 3 November 2016 (2016-11-03)  compound 2CzPN the whole document -----	1-16, 18-21, 109-111
X	WO 2017/101675 A1 (KUNSHAN GO-VISIONOX OPTO-ELECTRONICS CO LTD [CN]; UNIV TSINGHUA [CN]) 22 June 2017 (2017-06-22)  compounds 1-2 to 1-4 the whole document -----	1-16, 18-21, 58-81, 109-111
X	WO 2013/085285 A1 (UNIV KOREA RES & BUS FOUND [KR]) 13 June 2013 (2013-06-13)  paragraphs [0061], [0068], [0111] ----- -/--	1-16, 18-21, 109-111



## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2018/039309

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 102 702 132 B (CHINA PETROCHEMICAL DEV CORP) 29 April 2015 (2015-04-29)  paragraph [0044] the whole document  -----	1-16, 18-21, 33-57, 109-111
X	WO 2012/078005 A2 (UNIV KOREA RES & BUS FOUND [KR]; KIM HWAN-KYU [KR]; SONG BOK-JOO [KR];) 14 June 2012 (2012-06-14)  pages 24, 38 the whole document  -----	1-16, 18-21, 33-81, 109-111
X	EP 3 112 439 A1 (KYULUX INC [JP]) 4 January 2017 (2017-01-04)  compounds 1,2  -----	1-16, 18-21, 23,25, 26, 28-32, 58-81, 109-111
X	EP 2 851 408 A1 (UNIV KYUSHU NAT UNIV CORP [JP]) 25 March 2015 (2015-03-25)  pages 102,103 paragraph [0103] paragraph [0105]  -----	1-15,17, 33-81, 109-111
X	WO 2014/146752 A1 (MERCK PATENT GMBH [DE]) 25 September 2014 (2014-09-25)  compounds 42,109 the whole document page 67 - page 86 page 73; compound S25  -----	1-21,23, 25,26, 28-81, 109-111
X	CN 106 316 924 A (UNIV TSINGHUA) 11 January 2017 (2017-01-11)  compounds C1, C3  -----	1-21,23, 25,26, 28-81, 109-111
X	WO 2016/138077 A1 (NITTO DENKO CORP [JP]; ZHENG SHIJUN [US]) 1 September 2016 (2016-09-01)	1-21,23, 25,26, 28-81, 83,103, 104, 109-111
A	claim 18 the whole document  -----  -/--	82, 84-102, 105-108

## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2018/039309

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	EP 3 315 581 A1 (CYNORA GMBH [DE]) 2 May 2018 (2018-05-02) paragraph [0216] the whole document -----	1-111

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US2018/039309

## Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

17, 21-24, 26, 27, 32, 58-108(completely); 1-16, 18-20, 25, 28-31, 33-57  
109-111(partially)

### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

## INTERNATIONAL SEARCH REPORT

International Application No. PCT/ US2018/ 039309

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 17, 21-24, 26, 27, 32, 58-108(completely); 1-16, 18-20, 25, 28-31, 33-57, 109-111(partially)

Z=C in formula (I), X = C in formula (II)

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2. claims: 1-16, 18-20, 25, 28-31, 33-57, 109-111(all partially)

Z=N in formula (I), X = N in formula (II)

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2018/039309

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2015099507 A1	02-07-2015	CN 105829320 A JP 2017502509 A TW 201542559 A WO 2015099507 A1	03-08-2016 19-01-2017 16-11-2015 02-07-2015
WO 2010151011 A1	29-12-2010	KR 20100137188 A TW 201109420 A WO 2010151011 A1	30-12-2010 16-03-2011 29-12-2010
WO 2016036171 A1	10-03-2016	NONE	
CN 106537633 A	22-03-2017	CN 106537633 A CN 108774513 A EP 3172780 A1 JP 2017529686 A KR 20160011582 A US 2017207396 A1	22-03-2017 09-11-2018 31-05-2017 05-10-2017 01-02-2016 20-07-2017
US 2011278555 A1	17-11-2011	CN 102421772 A CN 102439004 A CN 104592206 A EP 2415769 A1 EP 2423209 A1 JP 5074627 B2 JP 5390728 B1 JP 5405630 B2 JP 5562970 B2 JP 2013030781 A JP 2014040423 A JP WO2011132683 A1 JP WO2011132684 A1 KR 20120034648 A KR 20120057561 A KR 20120127746 A TW 201141989 A TW 201141990 A US 2011278555 A1 US 2011279020 A1 US 2012138911 A1 US 2012138912 A1 US 2015008423 A1 US 2015228912 A1 WO 2011132683 A1 WO 2011132684 A1	18-04-2012 02-05-2012 06-05-2015 08-02-2012 29-02-2012 14-11-2012 15-01-2014 05-02-2014 30-07-2014 07-02-2013 06-03-2014 18-07-2013 18-07-2013 12-04-2012 05-06-2012 23-11-2012 01-12-2011 01-12-2011 17-11-2011 17-11-2011 07-06-2012 07-06-2012 08-01-2015 13-08-2015 27-10-2011 27-10-2011
US 2013234119 A1	12-09-2013	NONE	
WO 2016076629 A1	19-05-2016	NONE	
WO 2016174377 A1	03-11-2016	CN 107810184 A EP 3288956 A1 JP 2018522815 A KR 20180022653 A US 2018123052 A1 WO 2016174377 A1	16-03-2018 07-03-2018 16-08-2018 06-03-2018 03-05-2018 03-11-2016
WO 2017101675 A1	22-06-2017	CN 106892857 A EP 3369728 A1	27-06-2017 05-09-2018

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2018/039309

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		KR 20180063264 A	11-06-2018
		TW 201726891 A	01-08-2017
		WO 2017101675 A1	22-06-2017
WO 2013085285	A1	13-06-2013	NONE
CN 102702132	B	29-04-2015	NONE
WO 2012078005	A2	14-06-2012	EP 2711359 A1 26-03-2014
		EP 2711949 A1	26-03-2014
		EP 2712859 A2	02-04-2014
		EP 2712860 A1	02-04-2014
		JP 5914514 B2	11-05-2016
		JP 5989078 B2	07-09-2016
		JP 5989079 B2	07-09-2016
		JP 5989080 B2	07-09-2016
		JP 2014506262 A	13-03-2014
		JP 2015107982 A	11-06-2015
		JP 2015107983 A	11-06-2015
		JP 2015110591 A	18-06-2015
		WO 2012078005 A2	14-06-2012
EP 3112439	A1	04-01-2017	CN 106062126 A 26-10-2016
		EP 3112439 A1	04-01-2017
		JP WO2015129715 A1	30-03-2017
		KR 20160120784 A	18-10-2016
		TW 201542506 A	16-11-2015
		US 2016372682 A1	22-12-2016
		WO 2015129715 A1	03-09-2015
EP 2851408	A1	25-03-2015	CN 104204132 A 10-12-2014
		CN 107522652 A	29-12-2017
		EP 2851408 A1	25-03-2015
		JP 2014135466 A	24-07-2014
		KR 20150005583 A	14-01-2015
		TW 201402776 A	16-01-2014
		US 2015105564 A1	16-04-2015
		US 2017256720 A1	07-09-2017
		WO 2013154064 A1	17-10-2013
WO 2014146752	A1	25-09-2014	CN 105051014 A 11-11-2015
		CN 107739352 A	27-02-2018
		EP 2976329 A1	27-01-2016
		EP 3375785 A1	19-09-2018
		JP 2016516085 A	02-06-2016
		KR 20150132872 A	26-11-2015
		US 2016072076 A1	10-03-2016
		WO 2014146752 A1	25-09-2014
CN 106316924	A	11-01-2017	NONE
WO 2016138077	A1	01-09-2016	NONE
EP 3315581	A1	02-05-2018	CN 108003140 A 08-05-2018
		EP 3315581 A1	02-05-2018
		JP 2018080161 A	24-05-2018
		KR 20180048412 A	10-05-2018
		TW 201829397 A	16-08-2018

## INTERNATIONAL SEARCH REPORT

### Information on patent family members

International application No

PCT/US2018/039309

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		US 2018134686 A1	17-05-2018
-----			