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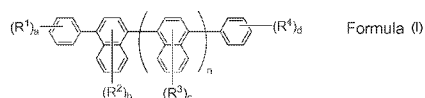
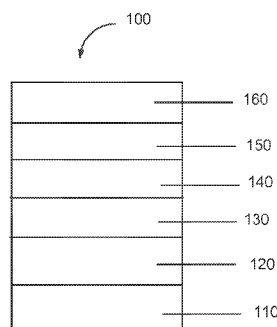


FIG. 1

(57) Abstract: This invention relates to a composition including (a) a dopant capable of electroluminescence having an emission maximum less than 500 nm; (b) a first host compound having Formula I and (c) a second host which is a diarylanthracene compound. In Formula I: R¹ through R⁴ are the same or different at each occurrence and are D, alkyl, electron-withdrawing group, carbocyclic aryl, N,O,S-heteroaryl, or deuterated analogs of alkyl, electron-withdrawing group, carbocyclic aryl, N,O,S-heteroaryl; a and d are independently an integer from 1-5; b and c are independently an integer from 0-6; and n is an integer from 1-3. At least one of R¹ and R⁴ is not D.



TITLE

PHOTOACTIVE COMPOSITIONS FOR ELECTRONIC APPLICATIONS

BACKGROUND5 Field of the Disclosure

This invention relates to photoactive compositions including binaphthyl derivative compounds which are useful in electronic devices. It also relates to electronic devices which include the photoactive composition.

10 Description of the Related Art

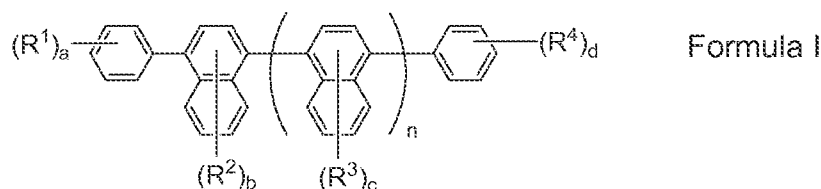
Organic electronic devices that emit light, such as light-emitting diodes that make up displays, are present in many different kinds of electronic equipment. In all such devices, an organic electroactive layer is sandwiched between two electrical contact layers. At least one of the
15 electrical contact layers is light-transmitting so that light can pass through the electrical contact layer. The organic electroactive layer emits light through the light-transmitting electrical contact layer upon application of electricity across the electrical contact layers.

It is well known to use organic electroluminescent compounds as
20 the electroactive component in light-emitting diodes. Simple organic molecules such as anthracene, thiadiazole derivatives, and coumarin derivatives are known to show electroluminescence. Semiconductive conjugated polymers have also been used as electroluminescent components, as has been disclosed in, for example, U.S.
25 Patent 5,247,190, U.S. Patent 5,408,109, and Published European Patent Application 443 861. In many cases the electroluminescent compound is present as a dopant in a host material.

There is a continuing need for new materials for electronic devices.

30 SUMMARY

There is provided a composition comprising:
(a) a dopant capable of electroluminescence having an emission maximum less than 500 nm;
(b) a first host compound having Formula I



wherein:

- 5 R^1 through R^4 are the same or different at each occurrence and are selected from the group consisting of D, alkyl, electron-withdrawing group, carbocyclic aryl, N,O,S-heteroaryl, and deuterated analogs of alkyl, electron-withdrawing group, carbocyclic aryl, and N,O,S-heteroaryl; with the proviso that at
- 10 least one of R^1 and R^4 is not D;
- a and d are independently an integer from 1-5;
- b and c are independently an integer from 0-6; and
- n is an integer from 1-3; and
- (c) a second host compound.
- 15 There is also provided an electronic device comprising a photoactive layer comprising the above composition.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments are illustrated in the accompanying figures to

20 improve understanding of concepts as presented herein.

FIG. 1 includes a schematic diagram of another example of an organic electronic device.

FIG. 2 includes a schematic diagram of another example of an organic electronic device.

25 Skilled artisans appreciate that objects in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions of some of the objects in the figures may be exaggerated relative to other objects to help to improve understanding of embodiments.

DETAILED DESCRIPTION

Many aspects and embodiments are disclosed herein and are exemplary and not limiting. After reading this specification, skilled artisans appreciate that other aspects and embodiments are possible without
5 departing from the scope of the invention.

Other features and benefits of any one or more of the embodiments will be apparent from the following detailed description, and from the claims. The detailed description first addresses Definitions and Clarification of Terms followed by the Photoactive Composition, the
10 Electronic Device, and finally Examples.

1. Definitions and Clarification of Terms

Before addressing details of embodiments described below, some terms are defined or clarified.

As used herein, the phrase "adjacent to," when used to refer to
15 layers in a device, does not necessarily mean that one layer is immediately next to another layer. On the other hand, the phrase "adjacent R groups," is used to refer to R groups that are next to each other in a chemical formula (i.e., R groups that are on atoms joined by a bond).

20 The term "aliphatic ring" is intended to mean a cyclic group that does not have delocalized pi electrons. In some embodiments, the aliphatic ring has no unsaturation. In some embodiments, the ring has one double or triple bond.

The term "alkoxy" refers to the group RO-, where R is an alkyl.

25 The term "alkyl" is intended to mean a group derived from an aliphatic hydrocarbon having one point of attachment, and includes a linear, a branched, or a cyclic group. The term is intended to include heteroalkyls. The term "hydrocarbon alkyl" refers to an alkyl group having no heteroatoms. The term "deuterated alkyl" is a hydrocarbon alkyl having
30 at least one available H replaced by D. In some embodiments, an alkyl group has from 1-20 carbon atoms.

The term "aryl" is intended to mean a group derived from an aromatic compound having one point of attachment. The term "aromatic compound" is intended to mean an organic compound comprising at least

one unsaturated cyclic group having delocalized pi electrons. The term is intended to include heteroaryls. In some embodiments, a heteroaryl has 3-60 ring carbons. The term "aryl" includes groups which have a single ring and those which have multiple rings which can be joined by a single
5 bond or fused together. The term "hydrocarbon aryl" is intended to mean a group derived from aromatic compounds having no heteroatoms in the ring. In some embodiments, a hydrocarbon aryl has 6-60 ring carbons. The term "deuterated aryl" refers to an aryl group having at least one available H bonded directly to the aryl replaced by D. The term "arylene"
10 is intended to mean a group derived from an aromatic hydrocarbon having two points of attachment. In some embodiments, an aryl group has from 3-60 ring carbon atoms.

The term "aryloxy" refers to the group RO-, where R is an aryl.

The term "compound" is intended to mean an electrically uncharged
15 substance made up of molecules that further consist of atoms, wherein the atoms cannot be separated by physical means.

The term "deuterated" is intended to mean that at least one hydrogen has been replaced by deuterium, abbreviated herein as "D". The deuterium is present in at least 100 times the natural abundance
20 level. A "deuterated analog" of compound X has the same structure as compound X, but with at least one D replacing an H.

The term "dopant" is intended to mean a material, within a layer including a host material, that changes the electronic characteristic(s) or the targeted wavelength(s) of radiation emission, reception, or filtering of
25 the layer compared to the electronic characteristic(s) or the wavelength(s) of radiation emission, reception, or filtering of the layer in the absence of such material.

The term "electroactive" when referring to a layer or material, is intended to mean a layer or material that exhibits electronic or electro-
30 radiative properties. In an electronic device, an electroactive material electronically facilitates the operation of the device. Examples of electroactive materials include, but are not limited to, materials which conduct, inject, transport, or block a charge, where the charge can be either an electron or a hole, and materials which emit radiation or exhibit a

change in concentration of electron-hole pairs when receiving radiation. Examples of inactive materials include, but are not limited to, planarization materials, insulating materials, and environmental barrier materials.

The term "electron-withdrawing" as it refers to a substituent group is intended to mean a group which decreases the electron density of an aromatic ring.

The phrase "group derived from" as it refers to a compound is intended to mean the radical formed from the compound by the removal of a hydrogen. Thus, a phenyl group is a group derived from benzene.

The prefix "hetero" indicates that one or more carbon atoms have been replaced with a different atom. In some embodiments, the different atom is N, O, or S.

The term "host material" is intended to mean a material to which a dopant is added. The host material may or may not have electronic characteristic(s) or the ability to emit, receive, or filter radiation. In some embodiments, the host material is present in higher concentration.

The term "layer" is used interchangeably with the term "film" and refers to a coating covering a desired area. The term is not limited by size. The area can be as large as an entire device or as small as a specific functional area such as the actual visual display, or as small as a single sub-pixel. Layers and films can be formed by any conventional deposition technique, including vapor deposition, liquid deposition (continuous and discontinuous techniques), and thermal transfer. Continuous deposition techniques, include but are not limited to, spin coating, gravure coating, curtain coating, dip coating, slot-die coating, spray coating, and continuous nozzle coating. Discontinuous deposition techniques include, but are not limited to, ink jet printing, gravure printing, and screen printing.

The term "luminescence" refers to light emission that cannot be attributed merely to the temperature of the emitting body, but results from such causes as chemical reactions, electron bombardment, electromagnetic radiation, and electric fields. The term "luminescent" refers to a material capable of luminescence.

The term "N-heterocycle" or "N-heteroaryl" refers to a heteroaromatic compound or group having at least one nitrogen in an aromatic ring.

5 The term "N,O,S-heterocycle" or "N,O,S-heteroaryl" refers to a heteroaromatic compound or group having at least one heteroatom in an aromatic ring, where the heteroatom is N, O, or S. The N,O,S-heterocycle may have more than one type of heteroatom.

10 The term "O-heterocycle" or "O-heteroaryl" refers to a heteroaromatic compound or group having at least one oxygen in an aromatic ring.

The term "organic electronic device" or sometimes just "electronic device" is intended to mean a device including one or more organic semiconductor layers or materials.

15 The term "organometallic" refers to a material in which there is a carbon-metal bond.

20 The term "photoactive" refers to a material that emits light when activated by an applied voltage (such as in a light emitting diode or chemical cell) or responds to radiant energy and generates a signal with or without an applied bias voltage (such as in a photodetector or a photovoltaic cell).

The term "S-heterocycle" or "S-heteroaryl" refers to a heteroaromatic compound or group having at least one sulfur in an aromatic ring.

25 The term "siloxane" refers to the group $(\text{RO})_3\text{Si}-$, where R is H, D, C1-20 alkyl, or fluoroalkyl.

The term "silyl" refers to the group $\text{R}_3\text{Si}-$, where R is H, D, C1-20 alkyl, fluoroalkyl, or aryl. In some embodiments, one or more carbons in an R alkyl group are replaced with Si.

30 All groups can be substituted or unsubstituted unless otherwise indicated. In some embodiments, the substituents are selected from the group consisting of D, halide, alkyl, alkoxy, aryl, aryloxy, cyano, silyl, siloxane, and NR_2 , where R is alkyl or aryl.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of

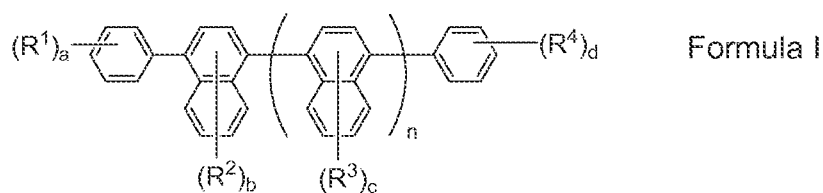
ordinary skill in the art to which this invention belongs. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, suitable methods and materials are described below. In case of conflict, the present specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

The IUPAC numbering system is used throughout, where the groups from the Periodic Table are numbered from left to right as 1-18 (CRC Handbook of Chemistry and Physics, 81st Edition, 2000).

2. Photoactive Composition

The photoactive composition comprises:

- (a) a dopant capable of electroluminescence having an emission maximum less than 500 nm;
- (b) a first host compound having Formula I



wherein:

R¹ through R⁴ are the same or different at each occurrence and are selected from the group consisting of D, alkyl, electron-withdrawing group, carbocyclic aryl, N,O,S-heteroaryl, and deuterated analogs of alkyl, electron-withdrawing group, carbocyclic aryl, and N,O,S-heteroaryl; with the proviso that at least one of R¹ and R⁴ is not D;

a and d are independently an integer from 1-5;

b and c are independently an integer from 0-6; and

n is an integer from 1-3; and

(c) a second host compound.

In some embodiments, the photoactive composition consists essentially of (a) a dopant capable of electroluminescence having an emission maximum less than 500 nm, (b) a first host compound having Formula I, and (c) a second host compound.

5 The amount of dopant present in the photoactive composition is generally in the range of 3-20% by weight, based on the total weight of the composition; in some embodiments, 5-15% by weight. The ratio of first host having Formula I to second host is generally in the range of 1:20 to 20:1; in some embodiments, 5:15 to 15:5. In some embodiments, the first
10 host material having Formula I is present in an amount of 10-40% by weight, based on the total weight of the composition; in some embodiments, 15-30 by weight.

The photoactive compositions described herein can be formed into films using liquid deposition techniques.

15 (a) Dopant

The dopant is a material which is capable of electroluminescence having an emission maximum less than 500 nm. In some embodiments, the blue emission has color coordinates of $0.1 < x < 0.25$ and $y < 0.22$, according to the C.I.E. chromaticity scale (Commission Internationale de
20 L'Eclairage, 1931).

In some embodiments, the dopant is deuterated. In some embodiments, the dopant is at least 10% deuterated. By this it is meant that at least 10% of the H are replaced by D. In some embodiments, the dopant is at least 20% deuterated; in some embodiments, at least 30%
25 deuterated; in some embodiments, at least 40% deuterated; in some embodiments, at least 50% deuterated; in some embodiments, at least 60% deuterated; in some embodiments, at least 70% deuterated; in some embodiments, at least 80% deuterated; in some embodiments, at least 90% deuterated; in some embodiments, 100% deuterated.

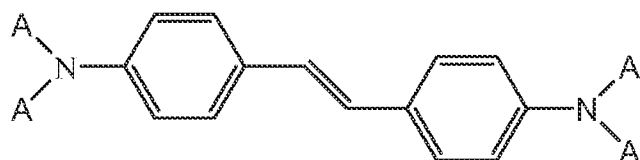
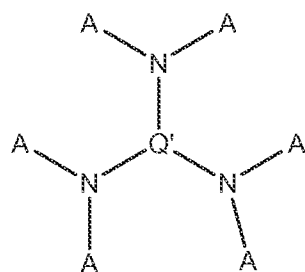
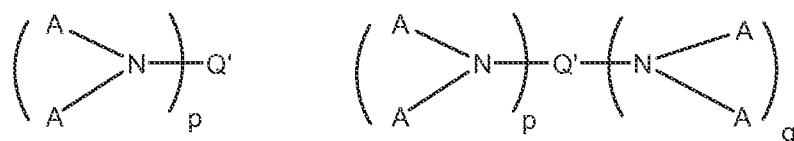
30 Electroluminescent ("EL") materials which can be used as a dopant in the photoactive layer, include, but are not limited to, small molecule organic luminescent compounds, luminescent metal complexes, conjugated polymers, deuterated analogs thereof, and mixtures thereof.

Examples of blue light-emitting materials include, but are not limited to, complexes of Ir having phenylpyridine, phenylimidazole, phenyltriazole, pyrazolo-pyridine, or pyrazolo-phenanthridine ligands; diarylanthracenes; diaminoanthracenes; diaminochrysenes; diaminopyrenes;

- 5 diamino-benzofluorenes; polyfluorene polymers; and deuterated analogs thereof. Blue light-emitting materials have been disclosed in, for example, US patent 6,875,524, and published US applications 2007-0292713 and 2007-0063638.

10 In some embodiments, the dopant is a small molecule organic luminescent compound. In some embodiments, the dopant is selected from the group consisting of a non-polymeric spirobifluorene compound, a fluoranthene compound, and deuterated analogs thereof.

In some embodiments, the dopant is a compound having aryl amine groups. In some embodiments, the photoactive dopant is selected from
15 the formulae below:



20

where:

A is the same or different at each occurrence and is an aromatic group having from 3-60 carbon atoms;

Q' is a single bond or an aromatic group having from 3-60 carbon atoms;

5 p and q are independently an integer from 1-6.

In some embodiments of the above formulas, at least one of A and Q' in each formula has at least three condensed rings. In some embodiments, p and q are equal to 1.

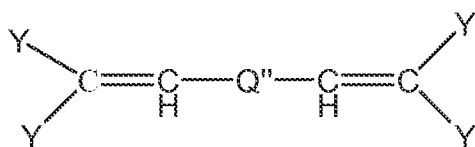
10 In some embodiments of the above formulas, deuteration is present.

In some embodiments, Q' is a styryl or styrylphenyl group, or a deuterated analog thereof.

In some embodiments, Q' is an aromatic group or deuterated aromatic group having at least two condensed rings. In some
15 embodiments, Q' is selected from the group consisting of naphthalene, anthracene, chrysene, pyrene, tetracene, xanthene, perylene, coumarin, rhodamine, quinacridone, rubrene, benzofluorene, and deuterated analogs thereof.

In some embodiments, A is selected from the group consisting of
20 phenyl, biphenyl, tolyl, naphthyl, naphthylphenyl, anthracenyl, and deuterated analogs thereof.

In some embodiments, the dopant has the formula below:



25

where:

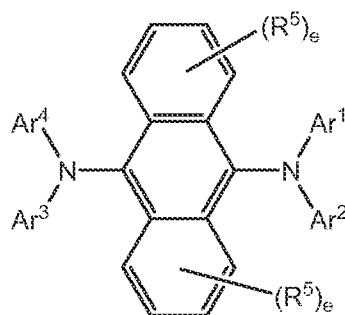
Y is the same or different at each occurrence and is an aromatic group having 3-60 carbon atoms;

30 Q'' is an aromatic group, a divalent triphenylamine residue group, or a single bond.

In some embodiments, the dopant is an aryl acene. In some embodiments, the dopant is a non-symmetrical aryl acene.

In some embodiments, the dopant is selected from the group consisting of amino-substituted chrysenes, amino-substituted anthracenes, amino-substituted benzofluorenes, and deuterated analogs thereof.

In some embodiments, the dopant has Formula II



Formula II

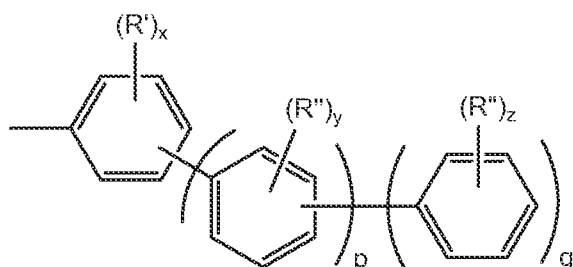
wherein:

R^5 is the same or different at each occurrence and is selected from the group consisting of D, alkyl, alkoxy, aryl, silyl, siloxy, and deuterated analogs of alkyl, alkoxy, silyl, siloxy, and aryl, where adjacent R^5 groups may be joined together to form a 5- or 6-membered aliphatic ring or deuterated aliphatic ring;

Ar^1 through Ar^4 are the same or different and are selected from the group consisting of aryl groups and deuterated aryl groups; and

e is the same or different at each occurrence and is an integer from 0 to 4.

In some embodiments of Formula II, Ar^1 through Ar^4 are selected from the group consisting of phenyl, naphthyl, styryl, carbazolyl, an N,O,S-heterocycle, substituted derivatives thereof, deuterated analogs thereof, and a group of Formula a



Formula a

wherein:

5 R' and R'' are the same or different at each occurrence and are selected from the group consisting of D, alkyl, aryl, silyl, alkoxy, aryloxy, cyano, vinyl, allyl, and a deuterated analog of alkyl, aryl, silyl, alkoxy, aryloxy, vinyl, and allyl, or adjacent R groups can be joined together to form a 6-membered aromatic or deuterated aromatic ring;

10 x is an integer from 0-5, with the proviso that when x = 5, p = q = 0;

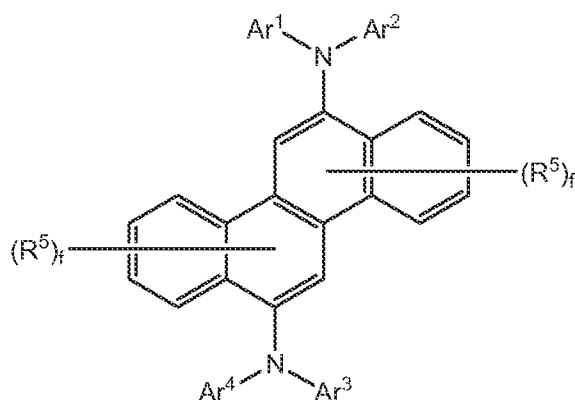
y is an integer from 0-5, with the proviso that when y = 5, q = 0;

z is an integer from 0-5;

p is an integer from 0-5; and

q is 0 or 1.

15 In some embodiments, the dopant has Formula III



Formula III

20 wherein:

R⁵ is the same or different at each occurrence and is selected from the group consisting of D, alkyl, alkoxy, aryl, silyl, siloxy, and deuterated analogs of alkyl, alkoxy, silyl, siloxy, and aryl, where

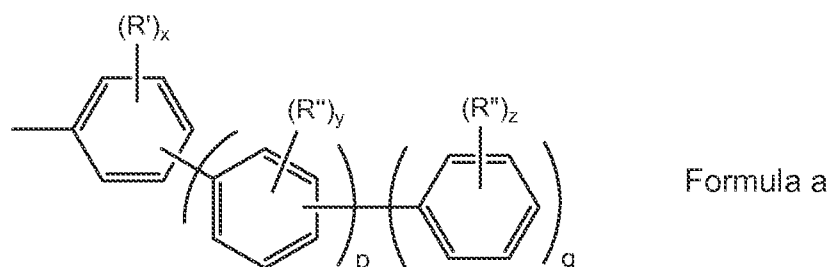
adjacent R^5 groups may be joined together to form a 5- or 6-membered aliphatic ring or deuterated aliphatic ring;

Ar^1 through Ar^4 are the same or different and are selected from the group consisting of aryl groups and deuterated aryl groups; and

5 f is the same or different at each occurrence and is an integer from 0 to 5.

In some embodiments of Formula III, Ar^1 through Ar^4 are selected from the group consisting of phenyl, naphthyl, styryl, carbazolyl, an N,O,S-heterocycle, substituted derivatives thereof, deuterated analogs thereof,

10 and a group of Formula a



wherein:

15 R' and R'' are the same or different at each occurrence and are selected from the group consisting of D, alkyl, aryl, silyl, alkoxy, aryloxy, cyano, vinyl, allyl, and a deuterated analog of alkyl, aryl, silyl, alkoxy, aryloxy, vinyl, and allyl, or adjacent R groups can be joined together to form a 6-membered aromatic or deuterated aromatic ring;

20 x is an integer from 0-5, with the proviso that when $x = 5$, $p = q = 0$;

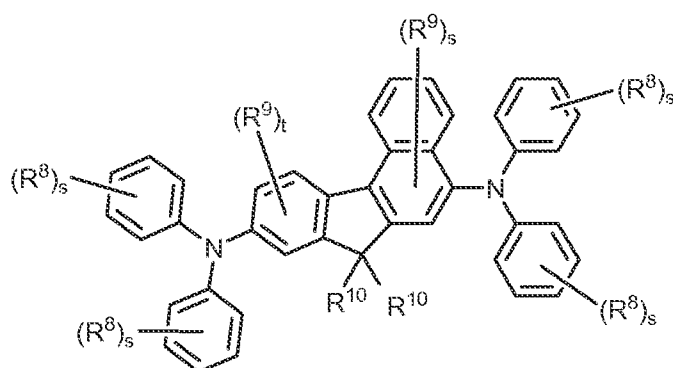
y is an integer from 0-5, with the proviso that when $y = 5$, $q = 0$;

z is an integer from 0-5;

p is an integer from 0-5; and

25 q is 0 or 1.

In some embodiments, the dopant has Formula VI



Formula VI

wherein:

- 5 R^8 and R^9 are the same or different at each occurrence and are selected from the group consisting of D, alkyl, alkoxy, aryl, heteroaryl, silyl, siloxy, and deuterated alkyl, deuterated alkoxy, deuterated aryl, deuterated heteroaryl, deuterated silyl, and deuterated siloxy, where adjacent R^8 groups can be joined
- 10 together to form a fused aromatic ring;
- R^{10} is the same or different at each occurrence and is selected from the group consisting of alkyl, aryl, and deuterated analogs thereof, where two alkyl R^{10} groups can be joined together to make a cycloalkyl spiro ring, and where two R^{10} phenyl groups
- 15 can be joined to form a spiro fluorene group;
- s is the same or different at each occurrence and is an integer from 0 to 5; and
- t is an integer from 0 to 3.

20 In some embodiments of Formula VI, there is at least one R^8 present which is an aryl, heteroaryl, or deuterated analog thereof.

In some embodiments of Formula VI, there is at least one R^8 present which is heteroaryl or deuterated heteroaryl. In some embodiments, the heteroaryl or deuterated heteroaryl group has at least one ring atom which is selected from the group consisting of N, O, and S.

25 In some embodiments of Formula VI, there is at least one R^8 present which is selected from the group consisting of pyrrole, pyridine, carbazole, imidazole, benzimidazole, imidazolobenzimidazole, triazole,

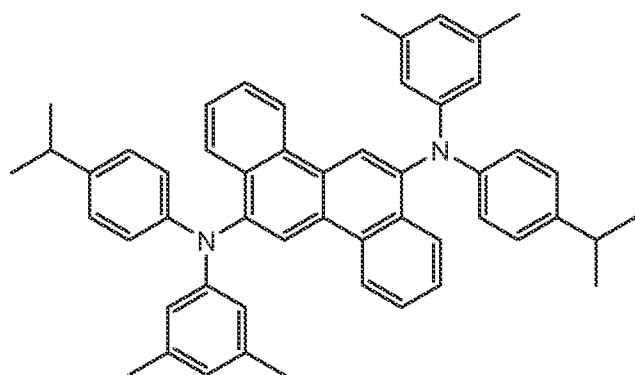
benzotriazole, triazolopyridine, indolocarbazole, phenanthroline, quinoline, isoquinoline, quinoxaline, furan, benzofuran, dibenzofuran, thiophene, benzothiophene, dibenzothiophene, oxazole, benzoxazole, thiazole, benzothiazole, substituted derivatives thereof, and deuterated analogs thereof.

In some embodiments of Formula VI, there is at least one R^8 present which is selected from the group consisting of phenyl, naphthyl, phenyl substituted with one or more alkyl groups, naphthyl substituted with one or more alkyl groups, and deuterated analogs thereof.

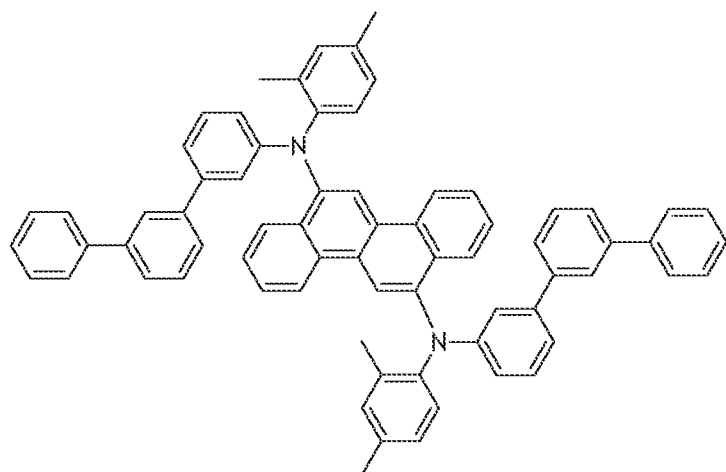
Any of the above embodiments of the dopant can be combined with one or more of the other embodiments of the dopant, so long as they are not mutually exclusive. The skilled person would understand which embodiments were mutually exclusive and would thus readily be able to determine the combinations of embodiments that are contemplated by the present application.

Examples of small molecule organic blue dopants include, but are not limited to compounds D1 through D12 shown below.

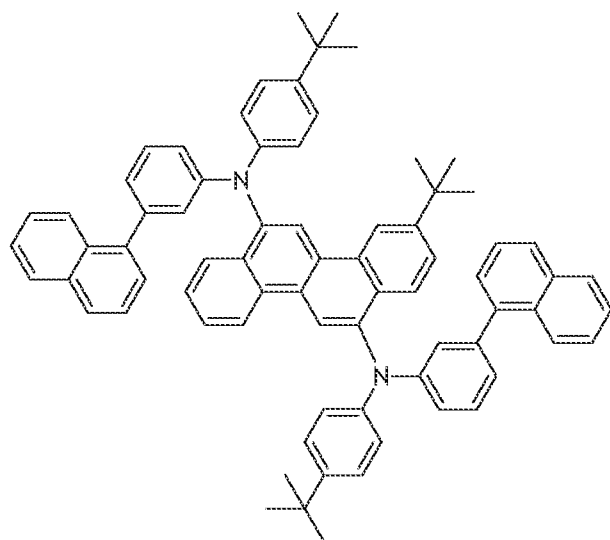
D1:



D2:

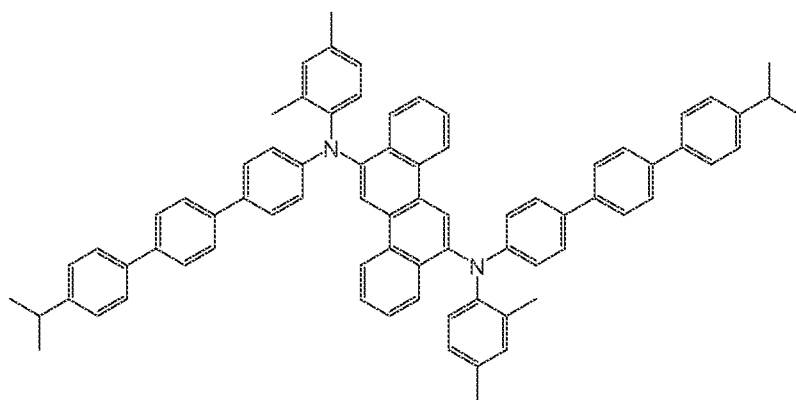


D3:

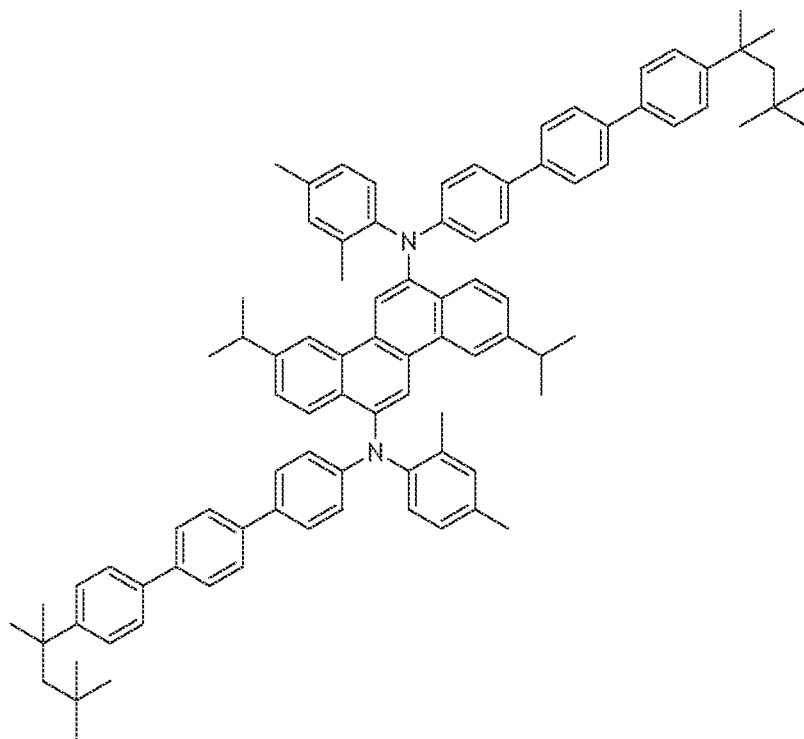


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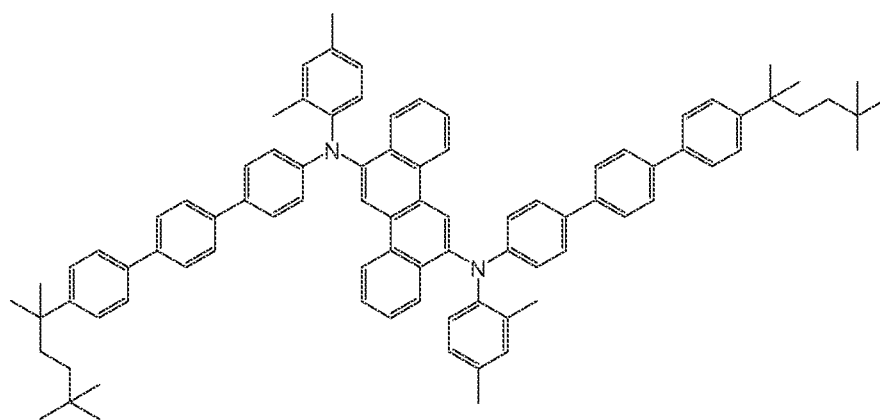
D4:



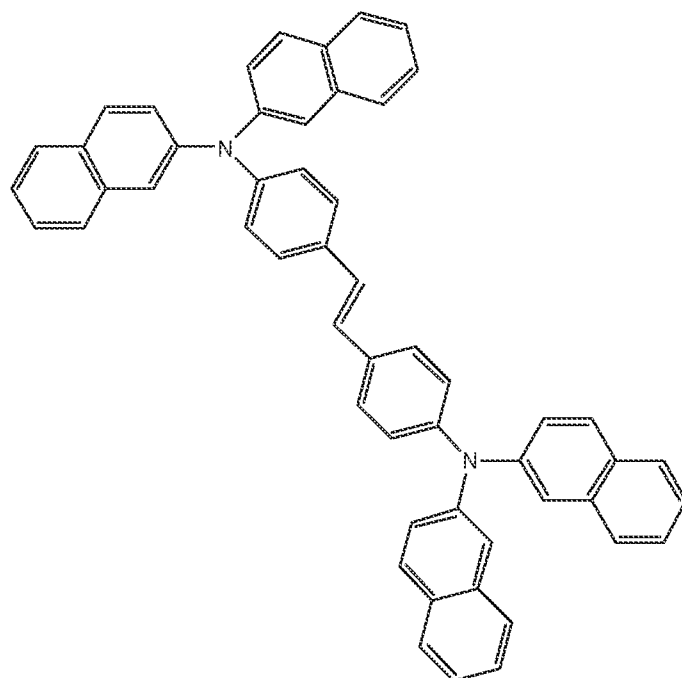
5 D5:



10 D6:

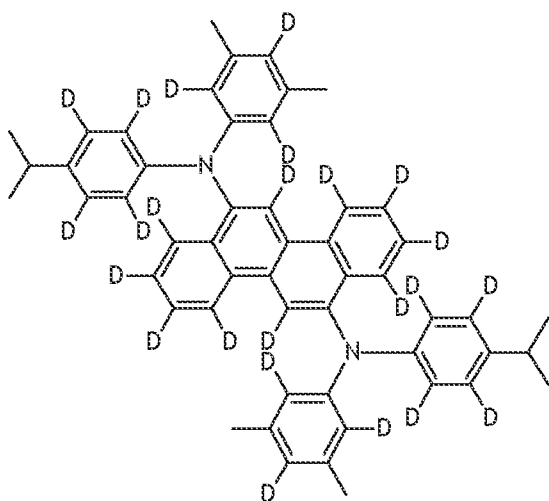


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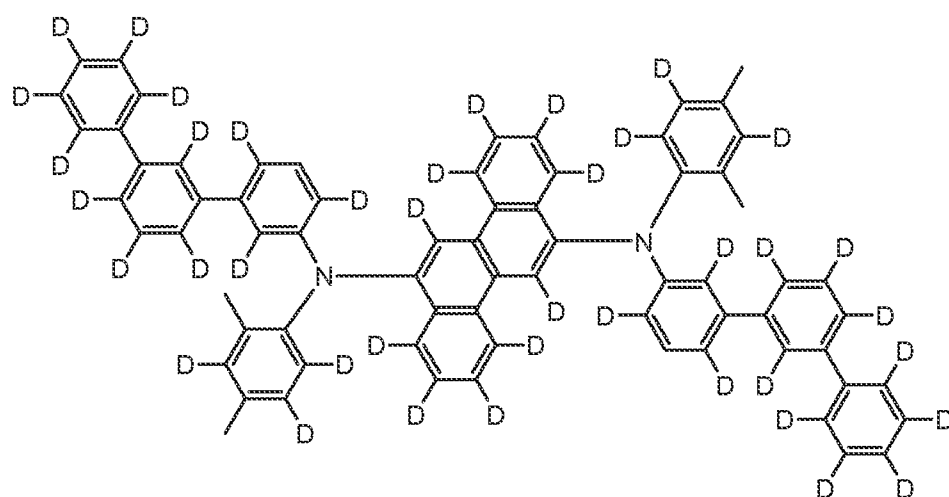


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D8:

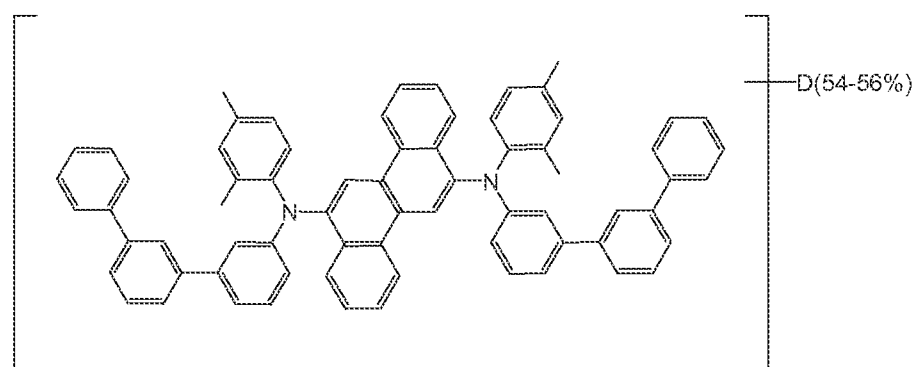


D9:



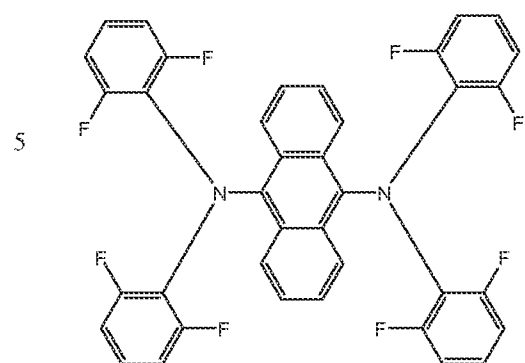
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D10:

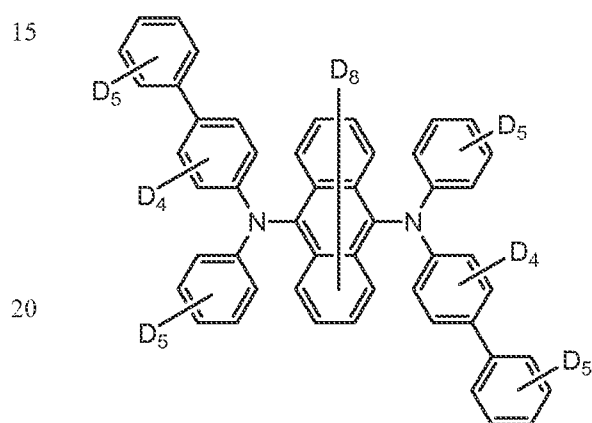


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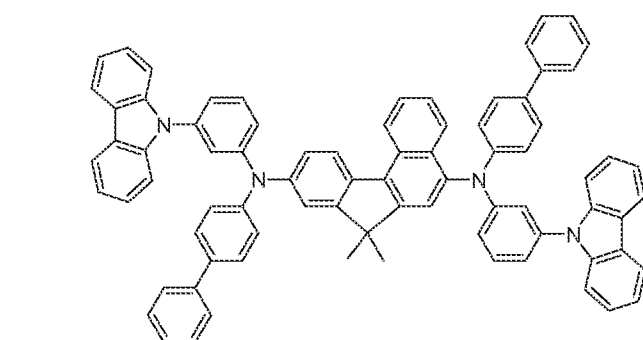
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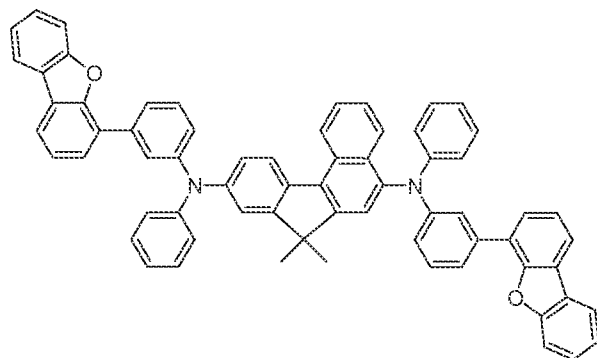
D12:



D13:

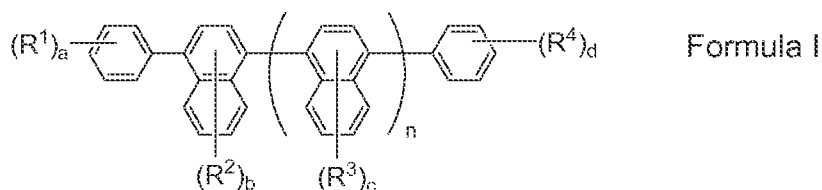


D14:



5 (b) First Host

The first host has Formula I



10 wherein:

R^1 through R^4 are the same or different at each occurrence and are selected from the group consisting of D, alkyl, electron-withdrawing group, carbocyclic aryl, N,O,S-heteroaryl, and deuterated analogs of alkyl, electron-withdrawing group, carbocyclic aryl, and N,O,S-heteroaryl; with the proviso that at least one of R^1 and R^4 is not D;

a and d are independently an integer from 1-5;

b and c are independently an integer from 0-6; and

n is an integer from 1-3.

20 In some embodiments, the compound is at least 10% deuterated. By this is meant that at least 10% of the H are replaced by D. In some embodiments, the compound is at least 20% deuterated; in some embodiments, at least 30% deuterated; in some embodiments, at least 40% deuterated; in some embodiments, at least 50% deuterated; in some
25 embodiments, at least 60% deuterated; in some embodiments, at least

70% deuterated; in some embodiments, at least 80% deuterated; in some embodiments, at least 90% deuterated. In some embodiments, the compounds are 100% deuterated.

In some embodiments, there are no amino groups present.

5 In some embodiments, there are no carbazolyl groups present.

In some embodiments, $n = 1$.

In some embodiments, $n = 2$.

In some embodiments, $R^1 = R^4$ and $a = d$.

In some embodiments, $R^2 = R^3$ and $b = c$.

10 In some embodiments, $R^1 \neq R^4$.

In some embodiments, $R^2 \neq R^3$.

In some embodiments, $a = 1$.

In some embodiments, $a = 2$.

In some embodiments, $a = 3$.

15 In some embodiments, $b = 1$.

In some embodiments, $b = 2$.

In some embodiments, $b = 3$.

In some embodiments, $c = 1$.

In some embodiments, $c = 2$.

20 In some embodiments, $c = 3$.

In some embodiments, $d = 1$.

In some embodiments, $d = 2$.

In some embodiments, $d = 3$.

In some embodiments, R^1 is deuterated.

25 In some embodiments, at least one $R^1 = D$.

In some embodiments, at least one R^1 is an alkyl.

In some embodiments, R^1 is an alkyl having 1-12 carbons.

In some embodiments, R^1 is an alkyl having 1-6 carbons.

30 In some embodiments, at least one R^1 is an electron-withdrawing group ("EWG").

In some embodiments, the EWG is selected from the group consisting of fluoro, cyano, perfluoroalkyl, nitro, $-\text{SO}_2\text{R}$, where R is alkyl or perfluoroalkyl, and combinations thereof.

In some embodiments, at least one R^1 is selected from the group consisting of CN and perfluoroalkyl.

In some embodiments, at least one R^1 is a carbocyclic aryl.

In some embodiments, at least one R^1 is selected from the group
5 consisting of phenyl, biphenyl, terphenyl, naphthyl, phenanthryl, anthracenyl, phenylnaphthylene, naphthylphenylene, substituted derivatives thereof, and a group having Formula a, as defined above.

In some embodiments, at least one R^1 is selected from the group consisting of phenyl, biphenyl, and naphthyl.

10 In some embodiments, at least one R^1 has Formula a, as defined above.

In some embodiments, at least one R^1 is an alkyl-substituted carbocyclic aryl.

In some embodiments, at least one R^1 is an alkyl-substituted
15 carbocyclic aryl having 6-24 ring carbons and 1-12 alkyl carbons.

In some embodiments, at least one R^1 is an alkyl-substituted carbocyclic aryl having 6-18 ring carbons and 1-12 alkyl carbons.

In some embodiments, at least one R^1 is an N-heteroaryl.

In some embodiments, the N-heteroaryl is derived from a compound
20 selected from the group consisting of pyrrole, diazoles, benzodiazoles, pyridine, diazines, triazines, substituted derivatives thereof, and deuterated analogs thereof.

In some embodiments, R^1 is selected from the group consisting of a group derived from imidazole, benzimidazole, pyrazine, pyrimidine,
25 pyridazine, and 1,3,5-triazine.

In some embodiments, at least one R^1 is an O-heteroaryl.

In some embodiments, the O-heteroaryl is derived from a compound selected from the group consisting of benzopyran, dibenzopyran, benzofuran, dibenzofuran, substituted derivatives thereof, and deuterated
30 analogs thereof.

In some embodiments, at least one R^1 is selected from the group consisting of a group derived from dibenzopyran and a group derived from dibenzofuran.

In some embodiments, at least one R^1 is an S-heteroaryl.

In some embodiments, the S-heteroaryl is derived from a compound selected from the group consisting of benzothiophene, dibenzothiophene, substituted derivatives thereof, and deuterated analogs thereof.

5 In some embodiments, at least one R^1 is an S-heteroaryl is derived from a dibenzothiophene.

In some embodiments, R^2 is deuterated.

In some embodiments, at least one $R^2 = D$.

In some embodiments, at least one R^2 is an alkyl.

10 In some embodiments, R^2 is an alkyl having 1-12 carbons.

In some embodiments, R^2 is an alkyl having 1-6 carbons.

In some embodiments, at least one R^2 is selected from the group consisting of CN and perfluoroalkyl.

In some embodiments, at least one R^2 is a carbocyclic aryl.

15 In some embodiments, at least one R^2 is selected from the group consisting of phenyl, biphenyl, terphenyl, naphthyl, phenanthryl, anthracenyl, phenylnaphthylene, naphthylphenylene, substituted derivatives thereof, and a group having Formula a, as defined above.

In some embodiments, at least one R^2 is selected from the group
20 consisting of phenyl, biphenyl, and naphthyl.

In some embodiments, at least one R^2 has Formula a, as defined above.

In some embodiments, at least one R^2 is an alkyl-substituted carbocyclic aryl.

25 In some embodiments, at least one R^2 is an alkyl-substituted carbocyclic aryl having 6-24 ring carbons and 1-12 alkyl carbons.

In some embodiments, at least one R^2 is an alkyl-substituted carbocyclic aryl having 6-18 ring carbons and 1-12 alkyl carbons.

In some embodiments, R^2 is selected from the group consisting of a
30 group derived from imidazole, benzimidazole, pyrazine, pyrimidine, pyridazine, and 1,3,5-triazine.

In some embodiments, at least one R^2 is an O-heteroaryl.

In some embodiments, at least one R^2 is selected from the group consisting of a group derived from dibenzopyran and a group derived from dibenzofuran.

In some embodiments, at least one R^2 is an S-heteroaryl.

5 In some embodiments, at least one R^2 is an S heteroaryl derived from dibenzothiophene.

In some embodiments, R^3 is deuterated.

In some embodiments, at least one $R^3 = D$.

In some embodiments, at least one R^3 is an alkyl.

10 In some embodiments, R^3 is an alkyl having 1-12 carbons.

In some embodiments, R^3 is an alkyl having 1-6 carbons.

In some embodiments, at least one R^3 is selected from the group consisting of CN and perfluoroalkyl.

In some embodiments, at least one R^3 is a carbocyclic aryl.

15 In some embodiments, at least one R^3 is selected from the group consisting of phenyl, biphenyl, terphenyl, naphthyl, phenanthryl, anthracenyl, phenylnaphthylene, naphthylphenylene, substituted derivatives thereof, and a group having Formula a, as defined above.

In some embodiments, at least one R^3 is selected from the group
20 consisting of phenyl, biphenyl and naphthyl.

In some embodiments, at least one R^3 has Formula a, as defined above.

In some embodiments, at least one R^3 is an alkyl-substituted carbocyclic aryl.

25 In some embodiments, at least one R^3 is an alkyl-substituted carbocyclic aryl having 6-24 ring carbons and 1-12 alkyl carbons.

In some embodiments, at least one R^3 is an alkyl-substituted carbocyclic aryl having 6-18 ring carbons and 1-12 alkyl carbons.

In some embodiments, R^3 is selected from the group consisting of a
30 group derived from imidazole, benzimidazole, pyrazine, pyrimidine, pyridazine, and 1,3,5-triazine.

In some embodiments, at least one R^3 is an O-heteroaryl.

In some embodiments, at least one R^3 is selected from the group consisting of a group derived from dibenzopyran and a group derived from dibenzofuran.

In some embodiments, at least one R^3 is an S-heteroaryl.

5 In some embodiments, at least one R^3 is an S heteroaryl derived from dibenzothiophene.

In some embodiments, R^4 is deuterated.

In some embodiments, at least one $R^4 = D$.

In some embodiments, at least one R^4 is an alkyl.

10 In some embodiments, R^4 is an alkyl having 1-12 carbons.

In some embodiments, R^4 is an alkyl having 1-6 carbons.

In some embodiments, at least one R^4 is an electron-withdrawing group ("EWG").

15 In some embodiments, at least one R^4 is selected from the group consisting of CN and perfluoroalkyl.

In some embodiments, at least one R^4 is a carbocyclic aryl.

In some embodiments, at least one R^4 is selected from the group consisting of phenyl, biphenyl, terphenyl, naphthyl, phenanthryl, anthracenyl, phenylnaphthylene, naphthylphenylene, substituted
20 derivatives thereof, and a group having Formula a, as defined above.

In some embodiments, at least one R^4 is selected from the group consisting of phenyl, biphenyl and naphthyl.

In some embodiments, at least one R^4 has Formula a, as defined above.

25 In some embodiments, at least one R^4 is an alkyl-substituted carbocyclic aryl.

In some embodiments, at least one R^4 is an alkyl-substituted carbocyclic aryl having 6-24 ring carbons and 1-12 alkyl carbons.

30 In some embodiments, at least one R^4 is an alkyl-substituted carbocyclic aryl having 6-18 ring carbons and 1-12 alkyl carbons.

In some embodiments, at least one R^4 is an N-heteroaryl.

In some embodiments, R^4 is selected from the group consisting of a group derived from imidazole, benzimidazole, pyrazine, pyrimidine, pyridazine, and 1,3,5-triazine.

In some embodiments, at least one R^4 is an O-heteroaryl.

In some embodiments, at least one R^4 is selected from the group consisting of a group derived from dibenzopyran and a group derived from dibenzofuran.

5 In some embodiments, at least one R^4 is an S-heteroaryl.

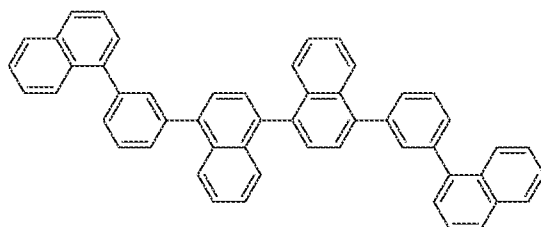
In some embodiments, at least one R^4 is an S heteroaryl derived from dibenzothiophene.

Any of the above embodiments of Formula I can be combined with one or more of the other embodiments of Formula I, so long as they are not mutually exclusive. For example, the embodiment in which R^1 is deuterated can be combined with the embodiment in which R^1 is an alkyl having 1-6 carbons, whereby R^1 is a deuterated alkyl having 1-6 carbons. The same is true for the other non-mutually-exclusive embodiments discussed above. The skilled person would understand which
10
15
embodiments were mutually exclusive and would thus readily be able to determine the combinations of embodiments that are contemplated by the present application.

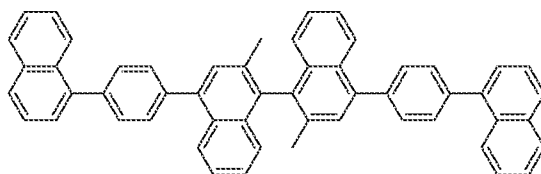
Some non-limiting examples of compounds having Formula I are given below.

20

Compound 1

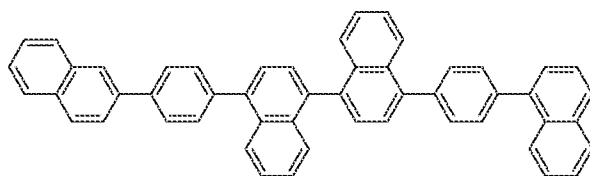


Compound 2



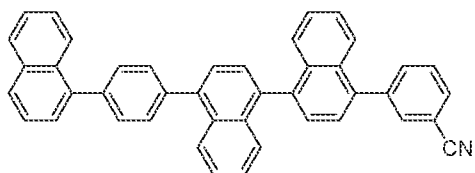
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Compound 3

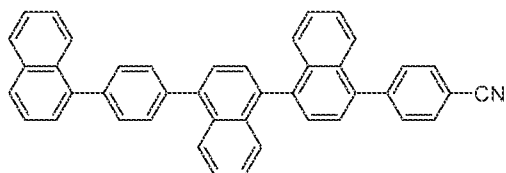


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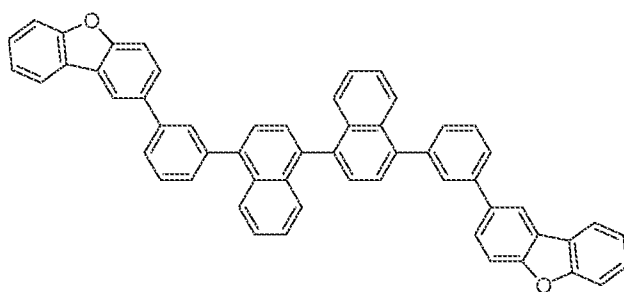
Compound 4



Compound 5

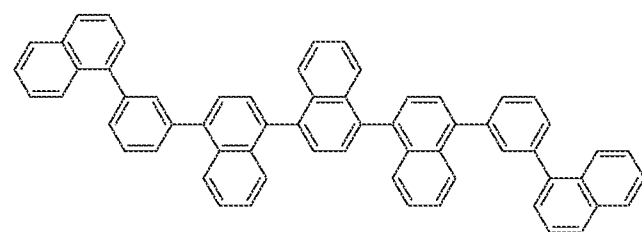


Compound 6

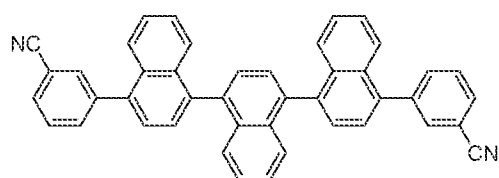


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Compound 7

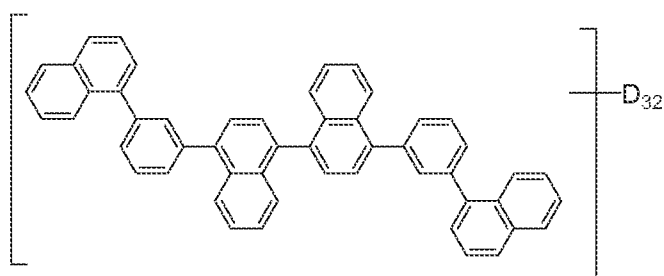


Compound 8

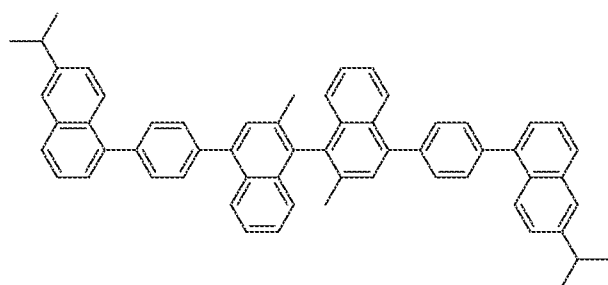


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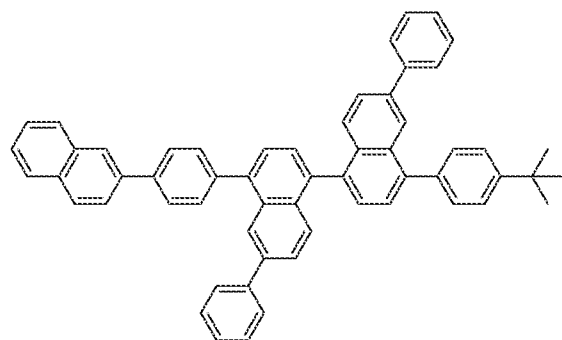
Compound 9



Compound 10

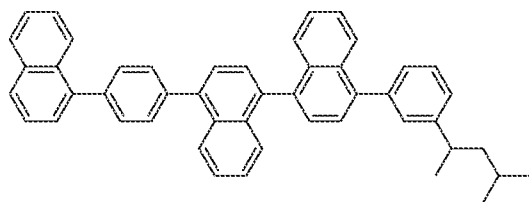


Compound 11

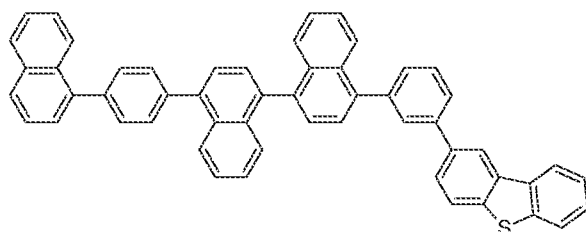


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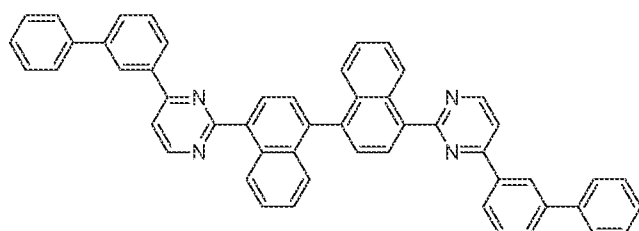
Compound 12



Compound 13



Compound 14



5

The compounds having Formula I can be prepared by known
 10 coupling and substitution reactions. Such reactions are well-known and
 have been described extensively in the literature. Exemplary references
 include: Yamamoto, *Progress in Polymer Science*, Vol. 17, p 1153 (1992);
 Colon et al., *Journal of Polymer Science, Part A, Polymer chemistry*
Edition, Vol. 28, p. 367 (1990); US Patent 5,962,631, and published PCT
 15 application WO 00/53565; T. Ishiyama et al., *J. Org. Chem.* **1995** 60,
 7508-7510; M. Murata et al., *J. Org. Chem.* **1997** 62, 6458-6459; M.
 Murata et al., *J. Org. Chem.* **2000** 65, 164-168; L. Zhu, et al., *J. Org.*
Chem. **2003** 68, 3729-3732; Stille, J. K. *Angew. Chem. Int. Ed. Engl.*
1986, 25, 508; Kumada, M. *Pure. Appl. Chem.* **1980**, 52, 669; Negishi, E.
 20 *Acc. Chem. Res.* **1982**, 15, 340; Hartwig, J., *Synlett* 2006, No. 9, pp. 1283-

1294; Hartwig, J., *Nature* **455**, No. 18, pp. 314-322; Buchwald, S. L., et al., *Adv. Synth. Catal.*, **2006**, 348, 23-39; Buchwald, S. L., et al., *Acc. Chem. Res.* (**1998**), 37, 805-818; and Buchwald, S. L., et al., *J. Organomet. Chem.* 576 (1999), 125-146. Exemplary preparations are given in the
5 examples.

The deuterated analog compounds can be prepared in a similar manner using deuterated precursor materials or, more generally, by treating the non-deuterated compound with deuterated solvent, such as d₆-benzene, in the presence of a Lewis acid H/D exchange catalyst, such
10 as aluminum trichloride or ethyl aluminum chloride, or acids such as CF₃COOH, DCl, etc. Deuteration reactions have also been described in published PCT application WO 2011/053334.

(c) Second Host

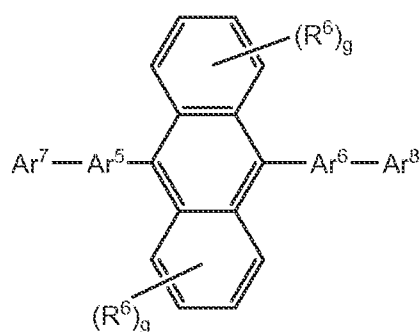
In some embodiments, the second host is a compound that has a
15 band gap of 3 eV or greater.

In some embodiments, the second host is selected from the group consisting of indolocarbazoles, chrysenes, phenanthrenes, triphenylenes, phenanthrolines, triazines, naphthalenes, anthracenes, tetraphenes, dibenzoanthracenes, pyrenes, quinolines, isoquinolines, quinoxalines,
20 phenylpyridines, dibenzofurans, benzodifurans, metal quinolate complexes, and deuterated analogs thereof.

In some embodiments, the second host is selected from the group consisting of aryl-substituted anthracenes, aryl-substituted tetraphenes, aryl-substituted dibenzoanthracenes, aryl-substituted pyrenes, and
25 deuterated analogs thereof.

In some embodiments, the second host is deuterated. In some embodiments, the second host is at least 10% deuterated; in some embodiments, at least 20% deuterated; in some embodiments, at least 30% deuterated; in some embodiments, at least 40% deuterated; in some
30 embodiments, at least 50% deuterated; in some embodiments, at least 60% deuterated; in some embodiments, at least 70% deuterated; in some embodiments, at least 80% deuterated; in some embodiments, at least 90% deuterated. In some embodiments, the second host is 100% deuterated.

In some embodiments, the second host has Formula IV



Formula IV

5 wherein:

R^6 is the same or different at each occurrence and is selected from the group consisting of D, alkyl, alkoxy, aryl, aryloxy, siloxane, silyl, and deuterated analogs of alkyl, alkoxy, aryl, aryloxy, siloxane and silyl, and where adjacent R^6 groups can be joined together to form a 6-membered fused aromatic or fused deuterated aromatic ring;

Ar^5 and Ar^6 are the same or different and are selected from the group consisting of aryl groups and deuterated aryl groups;

Ar^7 and Ar^8 are the same or different and are selected from the group consisting of H, D, aryl groups, and deuterated aryl groups; and

g is the same or different at each occurrence and is an integer from 0-4.

In some embodiments of Formula IV, the compound is deuterated.

In some embodiments of Formula IV, all $R^6 = H$ or D.

In some embodiments of Formula IV, all $R^6 = D$.

In some embodiments of formula IV, R^6 is a deuterated group.

In some embodiments of Formula IV, at least one R^6 is alkyl having 1-12 carbons.

In some embodiments of Formula IV, at least one R^6 is silyl having 3-12 carbons.

In some embodiments of formula IV, Ar^5 is a deuterated group.

In some embodiments of formula IV, Ar^6 is a deuterated group.

In some embodiments of formula IV, Ar^7 is a deuterated group.

In some embodiments of formula IV, Ar^8 is a deuterated group.

In some embodiments of Formula IV, $Ar^5 = Ar^6$.

In some embodiments of Formula IV, $Ar^5 \neq Ar^6$.

5 In some embodiments of Formula IV, $Ar^7 = Ar^2$.

In some embodiments of Formula IV, $Ar^7 \neq Ar^8$.

In some embodiments of Formula IV, Ar^5 and Ar^6 are selected from the group consisting of phenyl, naphthyl, phenanthryl, anthracenyl, and deuterated analogs thereof.

10 In some embodiments of Formula IV, Ar^5 and Ar^6 are selected from the group consisting of phenyl, naphthyl, and deuterated analogs thereof.

In some embodiments of Formula IV, Ar^3 and Ar^4 are selected from the group consisting of phenyl, naphthyl, phenanthryl, anthracenyl, phenylnaphthylene, naphthylphenylene, deuterated derivatives thereof,
15 and a group having Formula a, as described above.

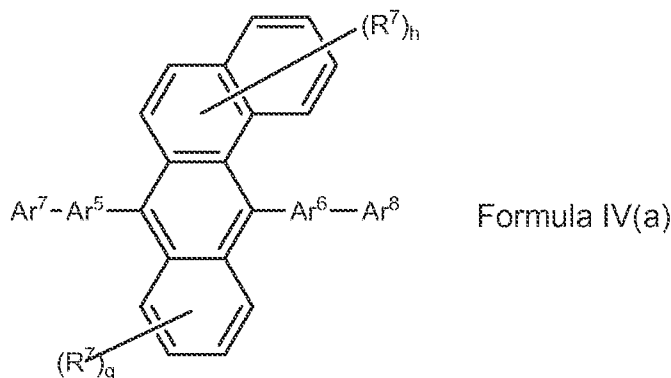
In some embodiments of Formula IV, Ar^7 and Ar^8 are selected from the group consisting of phenyl, biphenyl, terphenyl, naphthyl, phenylnaphthylene, naphthylphenylene, and deuterated derivatives thereof.

20 In some embodiments of Formula IV, Ar^7 and Ar^8 have Formula a, as described above.

In some embodiments of Formula IV, at least one of Ar^5 through Ar^8 is a heteroaryl group.

Any of the above embodiments of Formula IV can be combined with
25 one or more of the other embodiments of Formula IV, so long as they are not mutually exclusive. The skilled person would understand which embodiments were mutually exclusive and would thus readily be able to determine the combinations of embodiments that are contemplated by the present application.

30 In some embodiments, the second host is a tetraphene having Formula IV(a)



wherein:

5 R^7 is the same or different at each occurrence and is selected from the group consisting of D, alkyl, alkoxy, aryl, aryloxy, siloxane, silyl, and deuterated analogs of alkyl, alkoxy, aryl, aryloxy, siloxane and silyl,;

Ar^5 and Ar^6 are the same or different and are selected from the group consisting of aryl groups and deuterated aryl groups;

10 Ar^7 and Ar^8 are the same or different and are selected from the group consisting of H, D, aryl groups, and deuterated aryl groups;

g is an integer from 0-4; and

15 h is the same or different at each occurrence and is an integer from 0-6.

In some embodiments of Formula IV(a), the compound is deuterated.

In some embodiments of Formula IV(a), all $R^7 = H$ or D.

20 In some embodiments of Formula IV(a), all $R^7 = D$.

In some embodiments of Formula IV(a), R^7 is a deuterated group.

In some embodiments of Formula IV(a), at least one R^7 is alkyl having 1-12 carbons.

In some embodiments of Formula IV(a), at least one R^7 is silyl having 3-12 carbons.

25 In some embodiments of Formula IV(a), Ar^5 is a deuterated group.

In some embodiments of Formula IV(a), Ar^6 is a deuterated group.

In some embodiments of Formula IV(a), Ar⁷ is a deuterated group.

In some embodiments of Formula IV(a), Ar⁸ is a deuterated group.

In some embodiments of Formula IV(a), Ar⁵ = Ar⁶.

In some embodiments of Formula IV(a), Ar⁵ ≠ Ar⁶.

5 In some embodiments of Formula IV(a), Ar⁷ = Ar⁸.

In some embodiments of Formula IV(a), Ar⁷ ≠ Ar⁸.

In some embodiments of Formula IV(a), Ar⁵ and Ar⁶ are selected from the group consisting of phenyl, naphthyl, phenanthryl, anthracenyl, and deuterated analogs thereof.

10 In some embodiments of Formula IV(a), Ar⁵ and Ar⁶ are selected from the group consisting of phenyl, naphthyl, and deuterated analogs thereof.

In some embodiments of Formula IV(a), Ar³ and Ar⁴ are selected from the group consisting of phenyl, naphthyl, phenanthryl, anthracenyl, phenylnaphthylene, naphthylphenylene, deuterated derivatives thereof, and a group having Formula a, as described above.

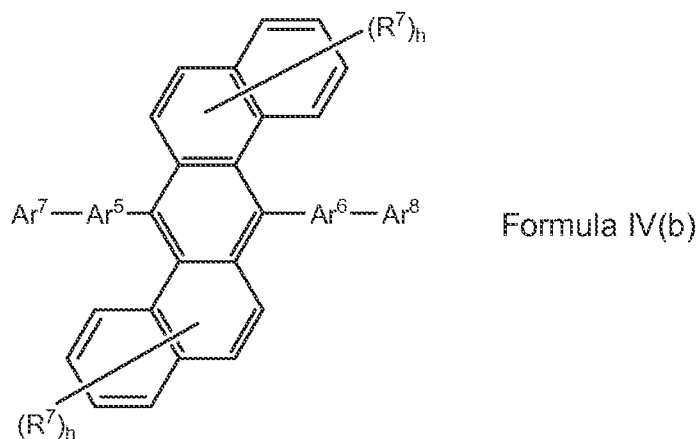
15 In some embodiments of Formula IV(a), Ar⁷ and Ar⁸ are selected from the group consisting of phenyl, biphenyl, terphenyl, naphthyl, phenylnaphthylene, naphthylphenylene, and deuterated derivatives thereof.

20 In some embodiments of Formula IV(a), Ar⁷ and Ar⁸ have Formula a, as described above.

In some embodiments of Formula IV(a), at least one of Ar⁵ through Ar⁸ is a heteroaryl group.

25 Any of the above embodiments of Formula IV(a) can be combined with one or more of the other embodiments of Formula IV(a), so long as they are not mutually exclusive. The skilled person would understand which embodiments were mutually exclusive and would thus readily be able to determine the combinations of embodiments that are contemplated by the present application.

30 In some embodiments, the second host is a dibenzoanthracene having Formula IV(b)



wherein:

R^7 is the same or different at each occurrence and is selected from the group consisting of D, alkyl, alkoxy, aryl, aryloxy, siloxane, silyl, and deuterated analogs of alkyl, alkoxy, aryl, aryloxy, siloxane and silyl,;

Ar^5 and Ar^6 are the same or different and are selected from the group consisting of aryl groups and deuterated aryl groups;

Ar^7 and Ar^8 are the same or different and are selected from the group consisting of H, D, aryl groups, and deuterated aryl groups; and

h is the same or different at each occurrence and is an integer from 0-6.

In some embodiments of Formula IV(b), the compound is deuterated.

In some embodiments of Formula IV(b), all $\text{R}^7 = \text{H}$ or D.

In some embodiments of Formula IV(b), all $\text{R}^7 = \text{D}$.

In some embodiments of Formula IV(b), R^7 is a deuterated group.

In some embodiments of Formula IV(b), at least one R^7 is alkyl having 1-12 carbons.

In some embodiments of Formula IV(b), at least one R^7 is silyl having 3-12 carbons.

In some embodiments of Formula IV(b), Ar^5 is a deuterated group.

In some embodiments of Formula IV(b), Ar^6 is a deuterated group.

In some embodiments of Formula IV(b), Ar^7 is a deuterated group.

In some embodiments of Formula IV(b), Ar⁸ is a deuterated group.

In some embodiments of Formula IV(b), Ar⁵ = Ar⁶.

In some embodiments of Formula IV(b), Ar⁵ ≠ Ar⁶.

In some embodiments of Formula IV(b), Ar⁷ = Ar².

5 In some embodiments of Formula IV(b), Ar⁷ ≠ Ar².

In some embodiments of Formula IV(b), Ar⁵ and Ar⁶ are selected from the group consisting of phenyl, naphthyl, phenanthryl, anthracenyl, and deuterated analogs thereof.

10 In some embodiments of Formula IV(b), Ar⁵ and Ar⁶ are selected from the group consisting of phenyl, naphthyl, and deuterated analogs thereof.

In some embodiments of Formula IV(b), Ar³ and Ar⁴ are selected from the group consisting of phenyl, naphthyl, phenanthryl, anthracenyl, phenylnaphthylene, naphthylphenylene, deuterated derivatives thereof, and a group having Formula a, as described above.

15 In some embodiments of Formula IV(b), Ar⁷ and Ar⁸ are selected from the group consisting of phenyl, biphenyl, terphenyl, naphthyl, phenylnaphthylene, naphthylphenylene, and deuterated derivatives thereof.

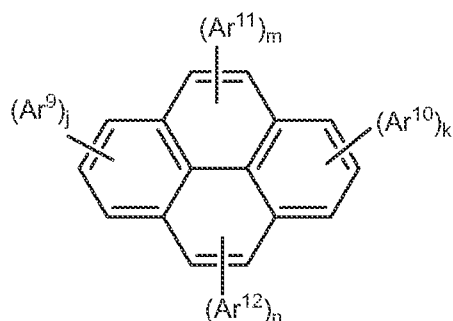
20 In some embodiments of Formula IV(b), Ar⁷ and Ar⁸ have Formula a, as described above.

In some embodiments of Formula IV(b), at least one of Ar⁵ through Ar⁸ is a heteroaryl group.

25 Any of the above embodiments of Formula IV(b) can be combined with one or more of the other embodiments of Formula IV(b), so long as they are not mutually exclusive. The skilled person would understand which embodiments were mutually exclusive and would thus readily be able to determine the combinations of embodiments that are contemplated by the present application.

30 In some embodiments, the second host is a pyrene compound.

In some embodiments, the second host has Formula V



Formula V

wherein:

Ar⁹ through Ar¹² are the same or different at each occurrence and
 5 are selected from the group consisting of D, aryl, and deuterated
 aryl;

j is an integer from 1-3;

k is an integer from 0-3;

m and n are the same or different and are integers from 0-2;

10 with the proviso that at least one Ar⁹ is not D.

In some embodiments of Formula V, the compound is deuterated.

In some embodiments of Formula V, the compound is at least 50%
 deuterated.

In some embodiments of Formula V, j = k = 1.

15 In some embodiments of Formula V, j = k = 2.

In some embodiments of Formula V, m = n = 0.

In some embodiments of Formula V, Ar⁹ is a deuterated group.

In some embodiments of Formula V, Ar⁹ is an aryl having 6-30 ring
 carbons.

20 In some embodiments of Formula V, Ar⁹ is selected from the group
 consisting of phenyl, biphenyl, terphenyl, quaterphenyl, naphthyl,
 binaphthyl, naphthylphenyl, and phenylnaphthyl.

In some embodiments of Formula V, Ar¹⁰ is a deuterated group.

25 In some embodiments of Formula V, Ar¹⁰ is an aryl having 6-30 ring
 carbons.

In some embodiments of Formula V, Ar¹⁰ is selected from the group
 consisting of phenyl, biphenyl, terphenyl, quaterphenyl, naphthyl,
 binaphthyl, naphthylphenyl, and phenylnaphthyl.

In some embodiments of Formula V, Ar¹¹ is D.

In some embodiments of Formula V, Ar¹¹ is phenyl.

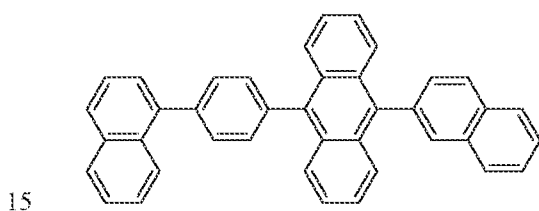
In some embodiments of Formula V, Ar¹² is D.

In some embodiments of Formula V, Ar¹² is phenyl.

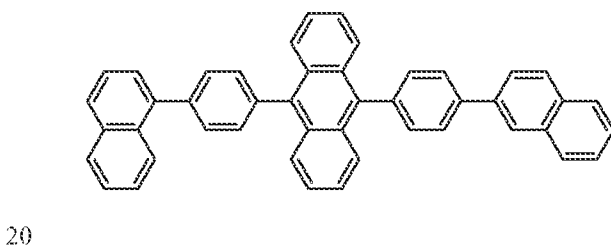
5 Any of the above embodiments of Formula V can be combined with one or more of the other embodiments of Formula V, so long as they are not mutually exclusive. The skilled person would understand which embodiments were mutually exclusive and would thus readily be able to determine the combinations of embodiments that are contemplated by the
10 present application.

Some examples of second host compounds include, but are not limited to those shown below.

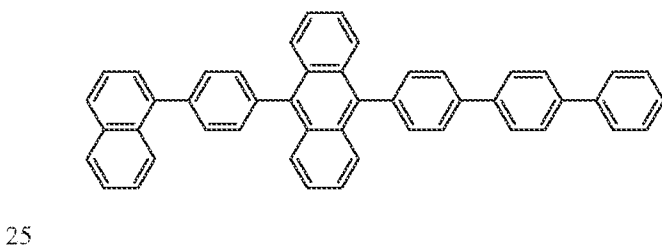
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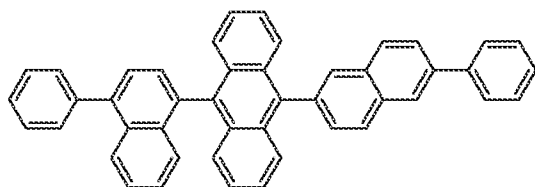
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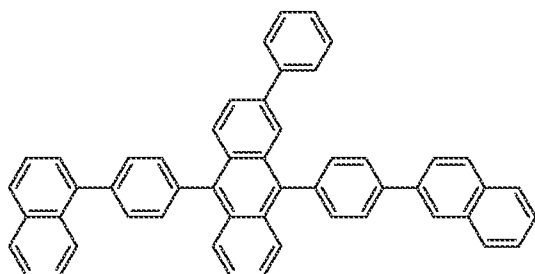
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H4:

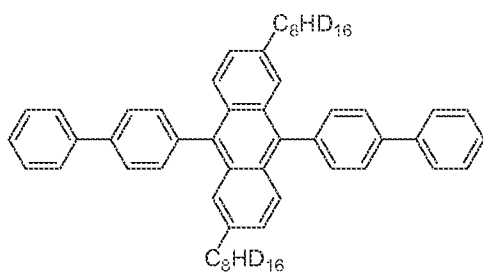


5 H5:



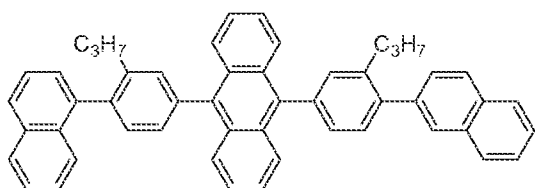
H6:

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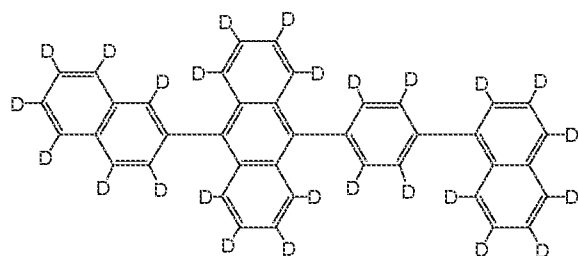


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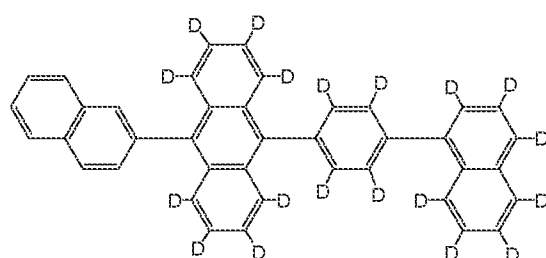
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H8:

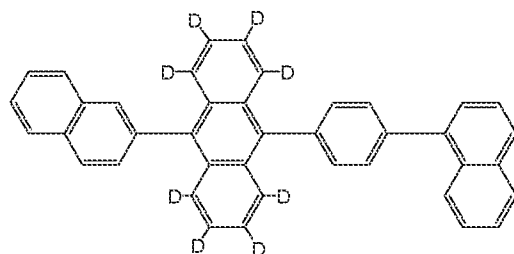


5 H9:

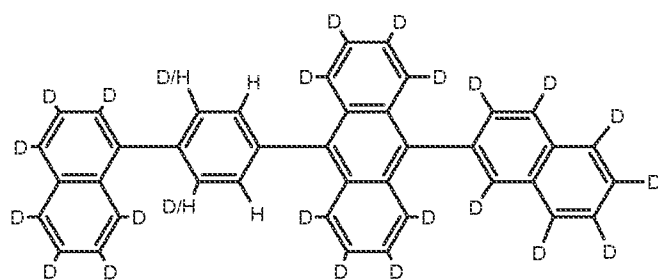


H10:

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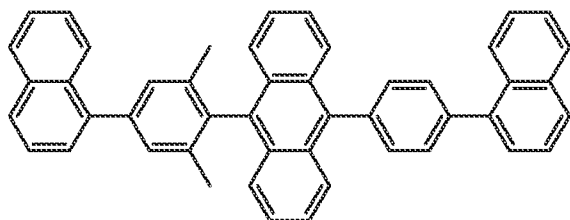


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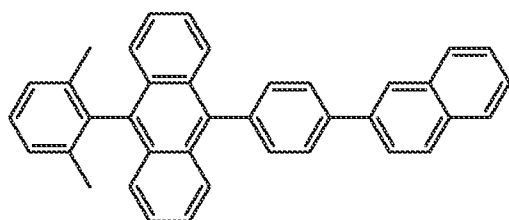


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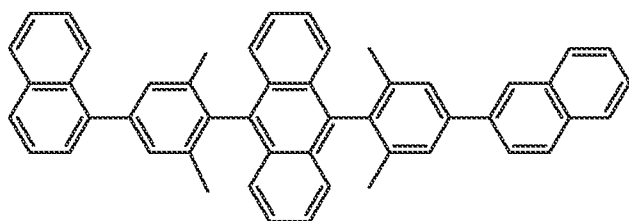
H12:



5 H13:

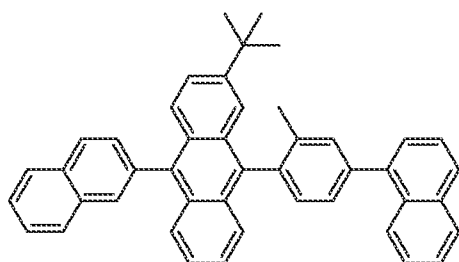


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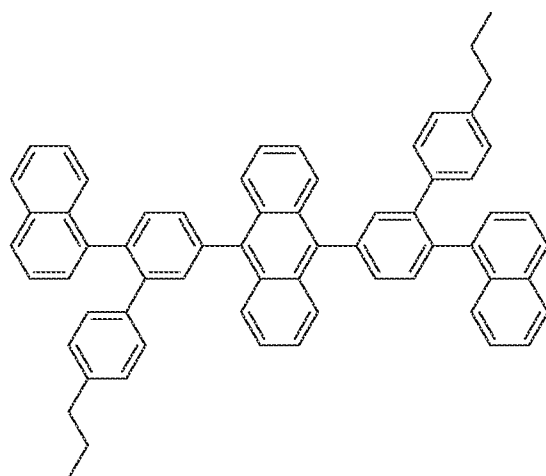


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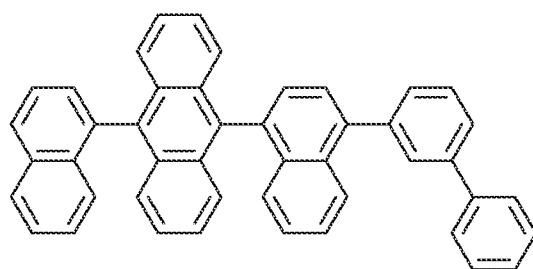
H15:



H16:

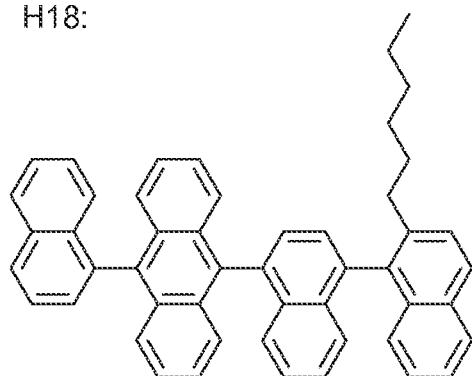


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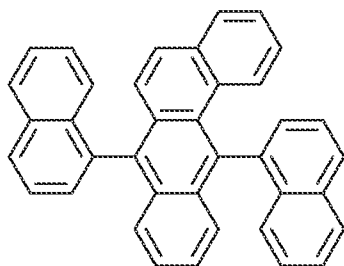
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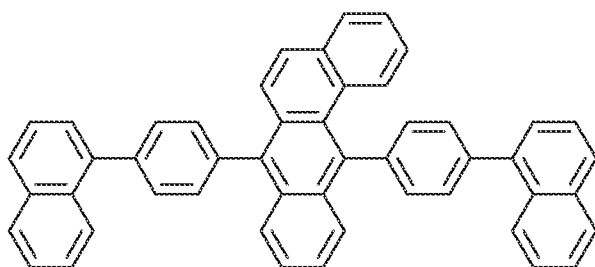


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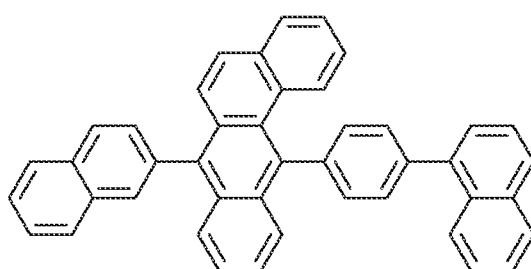
H19:



H20:

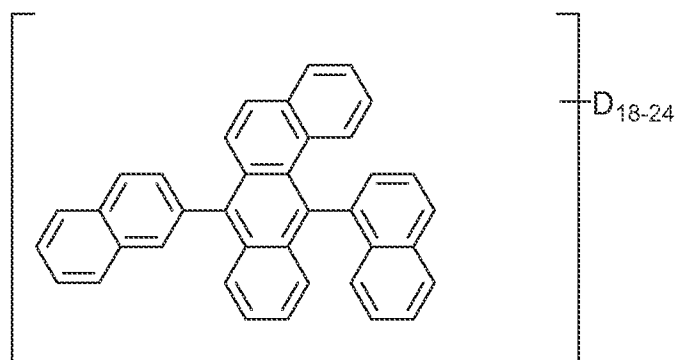


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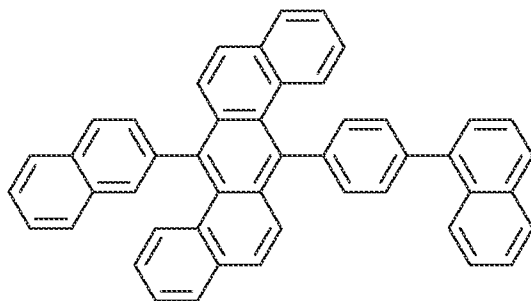
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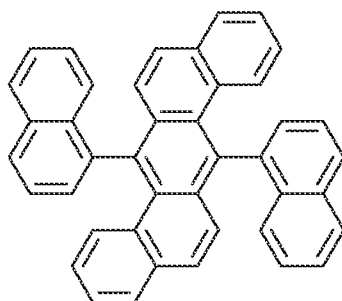


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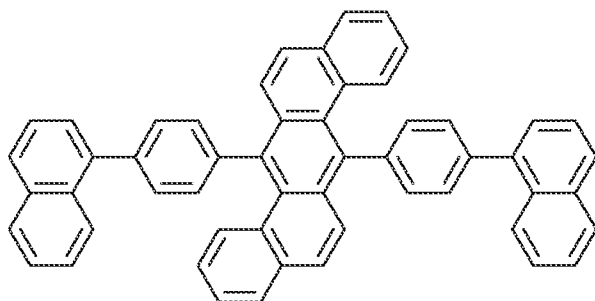


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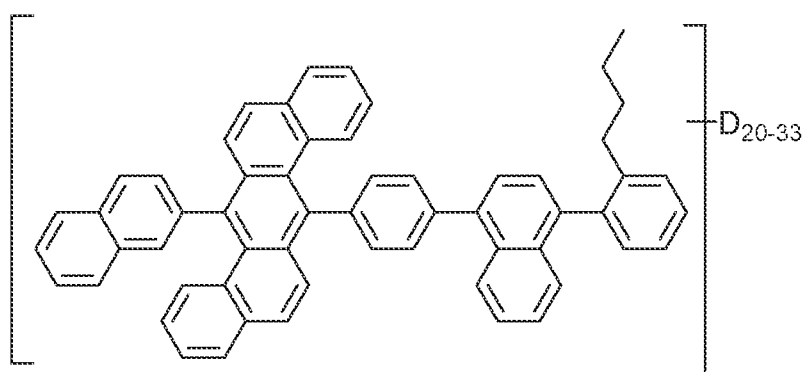


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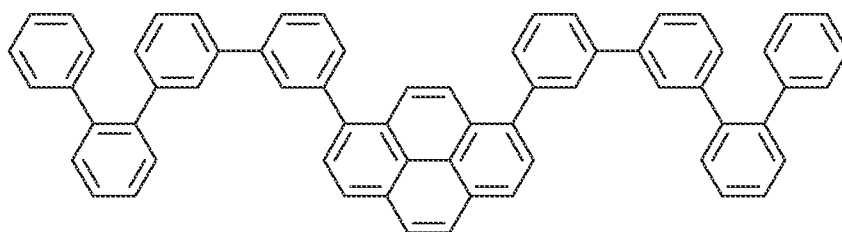
H25:



H26:

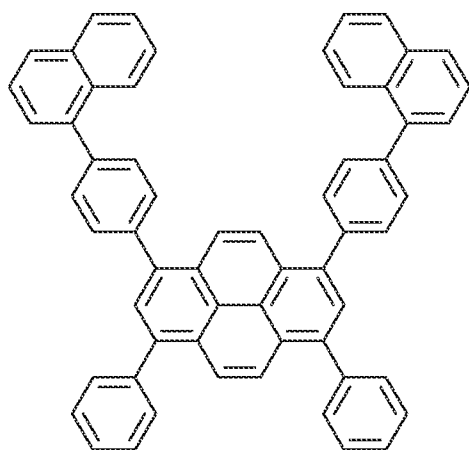


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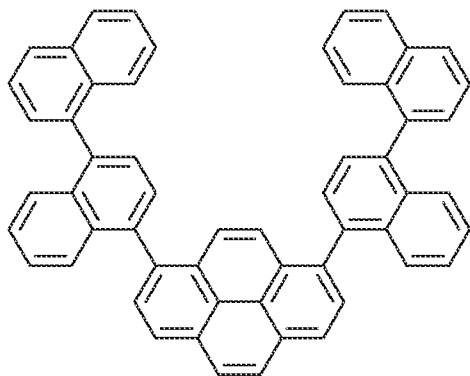


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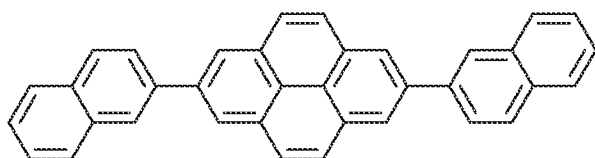
H28:



H29:

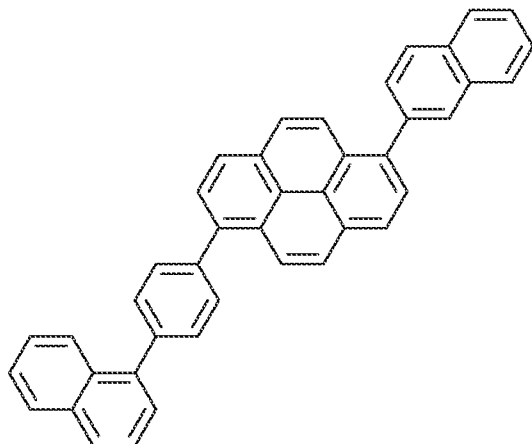


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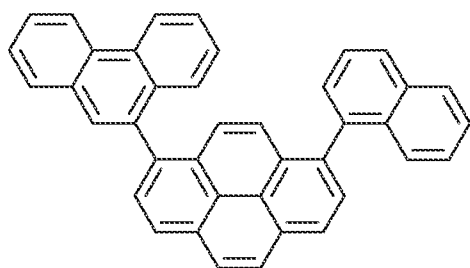


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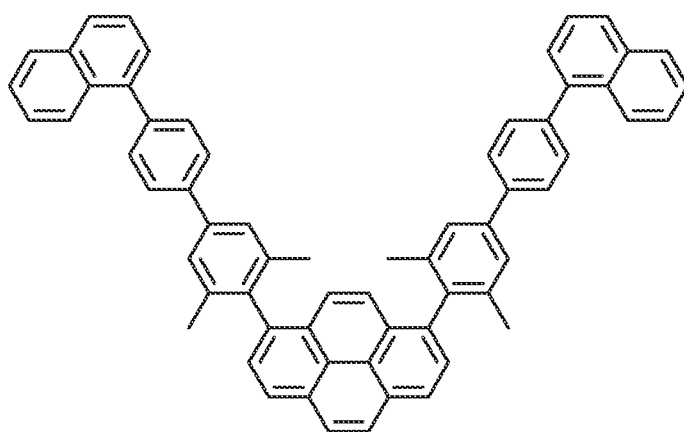
H31:



H32:

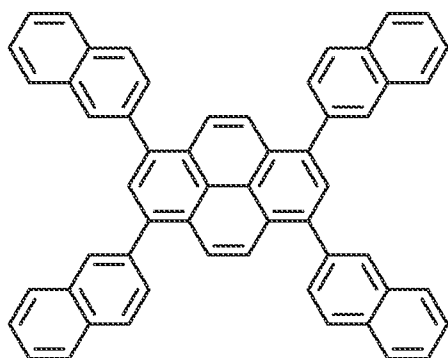


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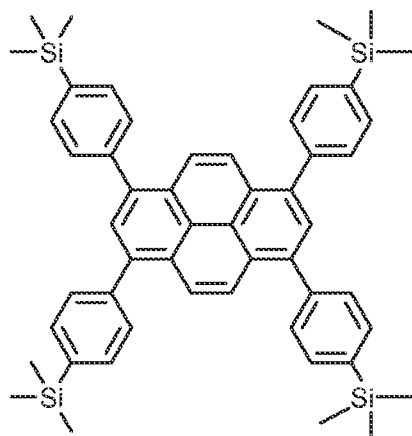


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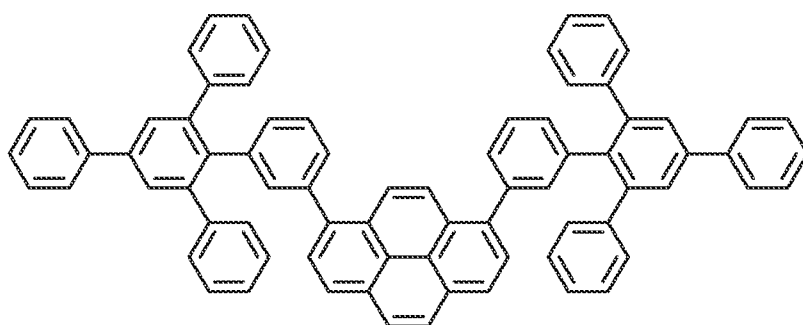
H34:



H35:

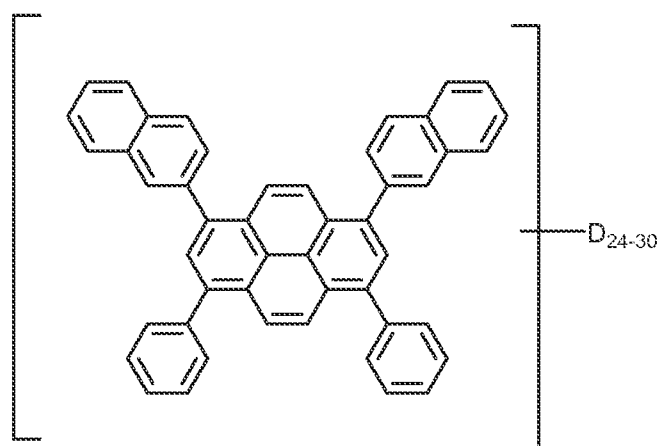


H36:



5

H37:



10

3. Organic Electronic Device

Organic electronic devices that may benefit from having one or more layers comprising the deuterated materials described herein include, but are not limited to, (1) devices that convert electrical energy into radiation (e.g., a light-emitting diode, light-emitting diode display, light-emitting luminaire, or diode laser), (2) devices that detect signals through electronics processes (e.g., photodetectors, photoconductive cells, photoresistors, photoswitches, phototransistors, phototubes, IR detectors), (3) devices that convert radiation into electrical energy, (e.g., a photovoltaic device or solar cell), and (4) devices that include one or more electronic components that include one or more organic semi-conductor layers (e.g., a thin film transistor or diode). The compounds of the invention often can be useful in applications such as oxygen sensitive indicators and as luminescent indicators in bioassays.

In some embodiments, an organic electronic device comprises at least one layer comprising the photoactive composition as discussed above.

An example of an organic electronic device structure is shown in FIG. 1. The device 100 has a first electrical contact layer, an anode layer 110 and a second electrical contact layer, a cathode layer 160, and a photoactive layer 140 between them. Adjacent to the anode may be a hole injection layer 120. Adjacent to the hole injection layer may be a hole transport layer 130, comprising hole transport material. Adjacent to the cathode may be an electron transport layer 150, comprising an electron transport material. Devices may use one or more additional hole injection or hole transport layers (not shown) next to the anode 110 and/or one or more additional electron injection or electron transport layers (not shown) next to the cathode 160.

Layers 120 through 150 are individually and collectively referred to as the electroactive layers.

In some embodiments, the photoactive layer 140 is pixellated, as shown in FIG. 2. Layer 140 is divided into pixel or subpixel units 141, 142, and 143 which are repeated over the layer. Each of the pixel or subpixel units represents a different color. In some embodiments, the subpixel

units are for red, green, and blue. Although three subpixel units are shown in the figure, two or more than three may be used.

In some embodiments, the different layers have the following range of thicknesses: anode 110, 500-5000 Å, in one embodiment 1000-2000 Å; hole injection layer 120, 50-2600 Å, in one embodiment 200-1000 Å; hole transport layer 130, 50-2000 Å, in one embodiment 200-1000 Å; electroactive layer 140, 10-2000 Å, in one embodiment 100-1000 Å; layer 150, 50-2000 Å, in one embodiment 100-1000 Å; cathode 160, 200-10000 Å, in one embodiment 300-5000 Å. The location of the electron-hole recombination zone in the device, and thus the emission spectrum of the device, can be affected by the relative thickness of each layer. The desired ratio of layer thicknesses will depend on the exact nature of the materials used. In some embodiments, the devices have additional layers to aid in processing or to improve functionality.

Depending upon the application of the device 100, the photoactive layer 140 can be a light-emitting layer that is activated by an applied voltage (such as in a light-emitting diode or light-emitting electrochemical cell), or a layer of material that responds to radiant energy and generates a signal with or without an applied bias voltage (such as in a photodetector). Examples of photodetectors include photoconductive cells, photoresistors, photoswitches, phototransistors, and phototubes, and photovoltaic cells, as these terms are described in Markus, John, *Electronics and Nucleonics Dictionary*, 470 and 476 (McGraw-Hill, Inc. 1966). Devices with light-emitting layers may be used to form displays or for lighting applications, such as white light luminaires.

In some embodiments, an electronic device comprises at least one photoactive layer positioned between two electrical contact layers, wherein the photoactive layer comprises (a) a dopant capable of electroluminescence having an emission maximum less than 500 nm, (b) a compound having Formula I, and (c) a second host comprising a diarylanthracene compound.

In some embodiments, an electronic device comprises at least one photoactive layer positioned between two electrical contact layers, wherein the photoactive layer consists essentially of (a) a dopant capable of

electroluminescence having an emission maximum less than 500 nm, (b) a compound having Formula I, and (c) a second host comprising a diarylanthracene compound.

Any of the dopants represented by the embodiments, specific
5 embodiments, specific examples, and combination of embodiments discussed above can be used in the photoactive layer of the device.

Any of the compounds of Formula I represented by the
embodiments, specific embodiments, specific examples, and combination
of embodiments discussed above can be used in the photoactive layer of
10 the device.

Any of the second host compounds represented by the
embodiments, specific embodiments, specific examples, and combination
of embodiments discussed above can be used in the photoactive layer of
the device.

15

Other Device Layers

The other layers in the device can be made of any materials that are known to be useful in such layers.

The anode 110, is an electrode that is particularly efficient for
20 injecting positive charge carriers. It can be made of, for example, materials containing a metal, mixed metal, alloy, metal oxide or mixed-metal oxide, or it can be a conducting polymer, or mixtures thereof. Suitable metals include the Group 11 metals, the metals in Groups 4-6, and the Group 8-10 transition metals. If the anode is to be light-
25 transmitting, mixed-metal oxides of Groups 12, 13 and 14 metals, such as indium-tin-oxide, are generally used. The anode 110 can also comprise an organic material such as polyaniline as described in "Flexible light-emitting diodes made from soluble conducting polymer," *Nature* vol. 357, pp 477-479 (11 June 1992). At least one of the anode and cathode is
30 desirably at least partially transparent to allow the generated light to be observed.

The hole injection layer 120 comprises hole injection material and may have one or more functions in an organic electronic device, including but not limited to, planarization of the underlying layer, charge transport

and/or charge injection properties, scavenging of impurities such as oxygen or metal ions, and other aspects to facilitate or to improve the performance of the organic electronic device. Hole injection materials may be polymers, oligomers, or small molecules. They may be vapour
 5 deposited or deposited from liquids which may be in the form of solutions, dispersions, suspensions, emulsions, colloidal mixtures, or other compositions.

The hole injection layer can be formed with polymeric materials, such as polyaniline (PANI) or polyethylenedioxythiophene (PEDOT), which
 10 are often doped with protonic acids. The protonic acids can be, for example, poly(styrenesulfonic acid), poly(2-acrylamido-2-methyl-1-propanesulfonic acid), and the like.

The hole injection layer can comprise charge transfer compounds, and the like, such as copper phthalocyanine and the tetrathiafulvalene-
 15 tetracyanoquinodimethane system (TTF-TCNQ).

In some embodiments, the hole injection layer comprises at least one electrically conductive polymer and at least one fluorinated acid polymer. Such materials have been described in, for example, published U.S. patent applications US 2004/0102577, US 2004/0127637,
 20 US 2005/0205860, and published PCT application WO 2009/018009.

Examples of other hole transport materials for layer 130 have been summarized for example, in Kirk-Othmer Encyclopedia of Chemical Technology, Fourth Edition, Vol. 18, p. 837-860, 1996, by Y. Wang. Both hole transporting molecules and polymers can be used. Commonly used
 25 hole transporting molecules are: N,N'-diphenyl-N,N'-bis(3-methylphenyl)-[1,1'-biphenyl]-4,4'-diamine (TPD), 1,1-bis[(di-4-tolylamino)phenyl]cyclohexane (TAPC), N,N'-bis(4-methylphenyl)-N,N'-bis(4-ethylphenyl)-[1,1'-(3,3'-dimethyl)biphenyl]-4,4'-diamine (ETPD), tetrakis-(3-methylphenyl)-N,N,N',N'-2,5-phenylenediamine (PDA), a-phenyl-4-N,N-diphenylaminostyrene (TPS), p-(diethylamino)benzaldehyde
 30 diphenylhydrazone (DEH), triphenylamine (TPA), bis[4-(N,N-diethylamino)-2-methylphenyl](4-methylphenyl)methane (MPMP), 1-phenyl-3-[p-(diethylamino)styryl]-5-[p-(diethylamino)phenyl] pyrazoline (PPR or DEASP), 1,2-trans-bis(9H-carbazol-9-yl)cyclobutane (DCZB),

N,N,N',N'-tetrakis(4-methylphenyl)-(1,1'-biphenyl)-4,4'-diamine (TTB),
N,N'-bis(naphthalen-1-yl)-N,N'-bis-(phenyl)benzidine (α -NPB), and
porphyrinic compounds, such as copper phthalocyanine. Commonly used
hole transporting polymers are polyvinylcarbazole, (phenylmethyl)-
5 polysilane, and polyaniline. It is also possible to obtain hole transporting
polymers by doping hole transporting molecules such as those mentioned
above into polymers such as polystyrene and polycarbonate. In some
cases, triarylamine polymers are used, especially triarylamine-fluorene
copolymers. In some cases, the polymers and copolymers are
10 crosslinkable. In some embodiments, the hole transport layer further
comprises a p-dopant. In some embodiments, the hole transport layer is
doped with a p-dopant. Examples of p-dopants include, but are not limited
to, tetrafluorotetracyanoquinodimethane (F4-TCNQ) and perylene-
3,4,9,10-tetracarboxylic-3,4,9,10-dianhydride (PTCDA).

15 In some embodiments, the electron transport layer 150 comprises
the compound having at least one unit of Formula I. Examples of other
electron transport materials which can be used in layer 150 include, but
are not limited to, metal chelated oxinoid compounds, including metal
quinolate derivatives such as tris(8-hydroxyquinolato)aluminum (AlQ),
20 bis(2-methyl-8-quinolinolato)(p-phenylphenolato) aluminum (BAIq),
tetrakis-(8-hydroxyquinolato)hafnium (HfQ) and tetrakis-(8-
hydroxyquinolato)zirconium (ZrQ); and azole compounds such as 2- (4-
biphenyl)-5-(4-t-butylphenyl)-1,3,4-oxadiazole (PBD), 3-(4-biphenyl)-4-
phenyl-5-(4-t-butylphenyl)-1,2,4-triazole (TAZ), and 1,3,5-tri(phenyl-2-
25 benzimidazole)benzene (TPBI); quinoxaline derivatives such as 2,3-bis(4-
fluorophenyl)quinoxaline; phenanthrolines such as 4,7-diphenyl-1,10-
phenanthroline (DPA) and 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline
(DDPA); and mixtures thereof. In some embodiments, the electron
transport layer further comprises an n-dopant. N-dopant materials are well
30 known. The n-dopants include, but are not limited to, Group 1 and 2
metals; Group 1 and 2 metal salts, such as LiF, CsF, and Cs₂CO₃; Group
1 and 2 metal organic compounds, such as Li quinolate; and molecular n-
dopants, such as leuco dyes, metal complexes, such as W₂(hpp)₄ where

hpp=1,3,4,6,7,8-hexahydro-2H-pyrimido-[1,2-a]-pyrimidine and cobaltocene, tetrathianaphthacene, bis(ethylenedithio)tetrathiafulvalene, heterocyclic radicals or diradicals, and the dimers, oligomers, polymers, dispiro compounds and polycycles of heterocyclic radical or diradicals.

5 Layer 150 can function both to facilitate electron transport, and also serve as a buffer layer or confinement layer to prevent quenching of the exciton at layer interfaces. Preferably, this layer promotes electron mobility and reduces exciton quenching.

 The cathode 160, is an electrode that is particularly efficient for
10 injecting electrons or negative charge carriers. The cathode can be any metal or nonmetal having a lower work function than the anode. Materials for the cathode can be selected from alkali metals of Group 1 (e.g., Li, Cs), the Group 2 (alkaline earth) metals, the Group 12 metals, including the rare earth elements and lanthanides, and the actinides. Materials such as
15 aluminum, indium, calcium, barium, samarium and magnesium, as well as combinations, can be used. Li- or Cs-containing organometallic compounds, LiF, CsF, and Li₂O can also be deposited between the organic layer and the cathode layer to lower the operating voltage.

 It is known to have other layers in organic electronic devices. For
20 example, there can be a layer (not shown) between the anode 110 and hole injection layer 120 to control the amount of positive charge injected and/or to provide band-gap matching of the layers, or to function as a protective layer. Layers that are known in the art can be used, such as copper phthalocyanine, silicon oxy-nitride, fluorocarbons, silanes, or an
25 ultra-thin layer of a metal, such as Pt. Alternatively, some or all of anode layer 110, electroactive layers 120, 130, 140, and 150, or cathode layer 160, can be surface-treated to increase charge carrier transport efficiency. The choice of materials for each of the component layers is preferably determined by balancing the positive and negative charges in the emitter
30 layer to provide a device with high electroluminescence efficiency.

 It is understood that each functional layer can be made up of more than one layer.

 The device can be prepared by a variety of techniques, including sequential vapor deposition of the individual layers on a suitable substrate.

Substrates such as glass, plastics, and metals can be used. Conventional vapor deposition techniques can be used, such as thermal evaporation, chemical vapor deposition, and the like. Alternatively, the organic layers can be applied from solutions or dispersions in suitable solvents, using
5 conventional coating or printing techniques, including but not limited to spin-coating, dip-coating, roll-to-roll techniques, ink-jet printing, screen-printing, gravure printing and the like.

To achieve a high efficiency LED, the HOMO (highest occupied molecular orbital) of the hole transport material desirably aligns with the
10 work function of the anode, and the LUMO (lowest un-occupied molecular orbital) of the electron transport material desirably aligns with the work function of the cathode. Chemical compatibility and sublimation temperature of the materials may also be considerations in selecting the electron and hole transport materials.

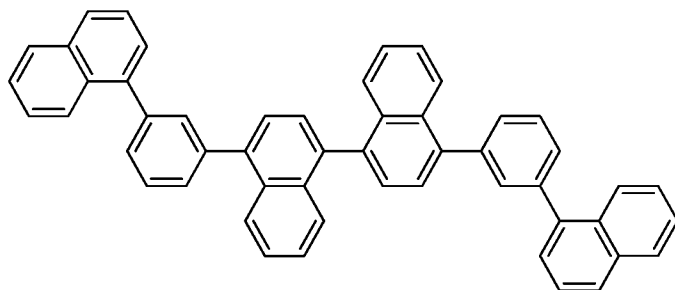
15 It is understood that the efficiency of devices made with the triazine compounds described herein, can be further improved by optimizing the other layers in the device. For example, more efficient cathodes such as Ca, Ba or LiF can be used. Shaped substrates and novel hole transport materials that result in a reduction in operating voltage or increase
20 quantum efficiency are also applicable. Additional layers can also be added to tailor the energy levels of the various layers and facilitate electroluminescence.

EXAMPLES

25 The following examples illustrate certain features and advantages of the present invention. They are intended to be illustrative of the invention, but not limiting. All percentages are by weight, unless otherwise indicated.

30 Synthesis Example 1

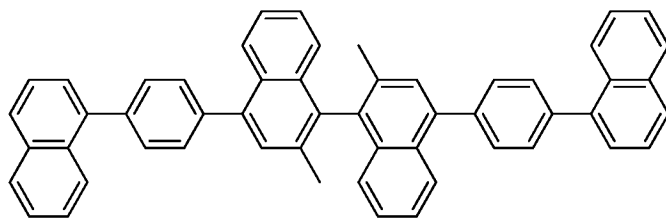
This example illustrates the preparation of Compound 1, 4,4'-bis(3-(naphthalen-1-yl)phenyl)-1,1'-binaphthalene.



To a 500 mL round bottom flask were added 4,4'-dibromo-1,1'-binaphthyl (Reference: Reference: JACS 2010, 132 (51), 17980-2
5 (Supporting Information; 4.12 g, 10 mmol), 3-(naphthalen-1-yl)phenylboronic acid (5.21 g, mmol), sodium carbonate (2 M, 30 mL, 60 mmol), toluene (120 mL) and Aliquat® 336 (0.5 g). The mixture was stirred under nitrogen for 20 min. After which tetrakis(triphenylphosphine) palladium (462 mg, 0.4 mmol) was added and the mixture was stirred
10 under nitrogen for another 15 min. The reaction was stirred and refluxed in an oil bath at 95 °C under nitrogen for 18 hours. After cooling to ambient temperature, some solid was seen formed and it was collected by filtration. The organic phase was separated, washed with water (60 mL), diluted HCl (10%, 60 mL) and saturated brine (60 mL) and dried with MgSO₄. The
15 solution was filtered through a silica gel plug and the solvent was removed by rotary evaporation. The solid collected earlier was triturated with hexane, filtered and combined with the residue from the liquid part. The material was re-dissolved in DCM/hexane and passed through a silica gel column eluted with DCM/hexane. The product containing fractions were
20 collected and the solvent was removed by rotary evaporation. The product was crystallized twice from toluene/EtOH to give the product as a white crystalline material. Yield, 2.60 g in a purity of 99.97%. NMR spectra were consistent with the structure.

25 Synthesis Example 2

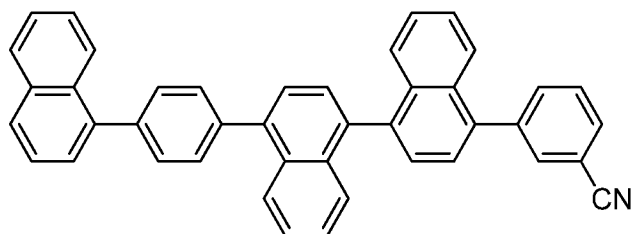
This example illustrates the preparation of Compound 2, 2,2'-Dimethyl-4,4'-di(4-naphthalen-1-yl-phenyl)-binaphthalene.



4,4'-Dibromo-2,2'-dimethyl-1,1'-binaphthalene (0.75g, 1.7mmol), 4-(1-naphthyl)phenylboronic acid (1.06g, 4.26mmol), Aliquat® 336 (70mg, 0.17mmol), 4mL toluene and 4.5mL 2M aqueous sodium carbonate solution were placed in a 40mL vial and stirred while sparging with N₂ for 30 minutes. The vial was then taken into a glove-box. Tetrakis(triphenylphosphine) palladium (59mg, 0.051mmol) was added to the reaction, the vial capped, and the mixture heated at 80 C overnight in the hood. UPLC sample at 2 hours and overnight shows no more starting material, therefore the reaction was cooled and worked up. The two layers were separated and the toluene layer concentrated to give the crude material as a gooey brown solid which was further purified by column chromatography on silica gel (with 0.5 inch Florisil® top layer) using 10% DCM in hexane as eluent, yielding 1g (85%) of a white foamy solid (UPLC purity 98.89% with maybe the presence of the 4,5'-stereoisomer). (NMR# 759999) (D100195-096)

Synthesis Example 3

This example illustrates the preparation of Compound 4, 4-bromo-4'-(4-(naphthalen-1-yl)phenyl)-1,1'-binaphthyl.



4,4'-Dibromo-1,1'-binaphthyl (9.46 g (98%), 22.50 mmol), 4-(naphthalen-1-yl)phenyl-boronic acid (6.20 g, 24.75 mmol), Aliquat® 336 (1.20 g), sodium carbonate (2 M, 34 mL, 67.50 mmol) and toluene (300 mL) were charged to a 1L round bottom flask equipped with stir bar, heating bath and reflux condenser. The system was purged with nitrogen

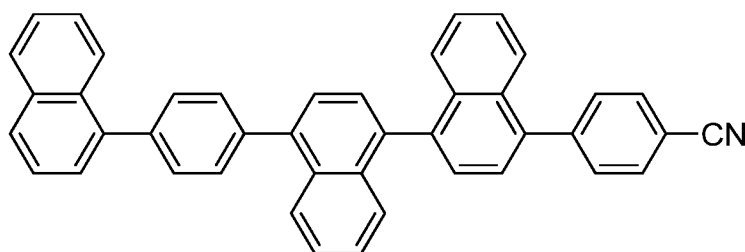
for 20 min. Tetrakis(triphenylphosphine) palladium (520 mg, 0.45 mmol) was added and the system was purged for another 15 min. The reaction was stirred and refluxed in an oil bath at 95 °C under nitrogen for 18 hours. UPLC analysis indicated that the product formed as a major component (~63%) together with about 17% of starting dibromide and 17% of disubstituted by-product. After cooling, the mixture was filtered through a Celite® pad to remove the insoluble materials. The solution was washed with diluted HCl (10%), water and saturated brine. The solvent was removed by rotary evaporation. The residue was re-dissolved in toluene and the solution was passed through a short silica gel column eluted with toluene. The product containing fractions were collected and the solvent was removed by rotary evaporation. The residual solid was re-crystallized three times from toluene/ethanol to give 5.84 g (48.6%) of product as white powder material. UPLC analysis indicated that the purity was ~86%, containing about 14% of di-substituted by-product.

3-(4'-(4-(naphthalen-1-yl)phenyl)-1,1'-binaphthyl-4-yl)benzonitrile
To a 250 mL round bottom flask were added 4-bromo-4'-(4-(naphthalen-1-yl)phenyl)-1,1'-binaphthyl (3.48 g, 6.50 mmol), 3-cyanophenylboronic acid (1.05 g, 7.15 mmol), sodium carbonate (2 M, 10 mL, 20 mmol), toluene (100 mL), and Aliquat® 336 (0.5 g). The mixture was stirred under nitrogen for 20 min. After which tetrakis(triphenylphosphine) palladium (150 mg, 0.13 mmol) was added and the mixture was stirred under nitrogen for another 15 min. The reaction was stirred and refluxed in an oil bath at 95 °C under nitrogen for 18 hours. During the reaction some solid was formed. After cooling, more solid was precipitated from the solution. The solid was filtered, washed with water and ethanol, and then dried in air. The filtrate was washed with water, diluted HCl (10%), and saturated brine. The solid was re-dissolved in toluene (150 mL) with heating and the resulted solution was combined with above filtrate. The solution was dried with MgSO₄ at ambient temperature for 3 hours. The solution was passed through a short silica gel column eluted with toluene. The product containing fractions were collected and the solvent was removed by rotary

evaporation. The residual solid was triturated with hexane and collected with filtration. The crude product was further purified by automated chromatography (CombiFlash®) to give 1.26 g of product as white powder with a purity of 99.95% by UPLC. NMR spectra were consistent with the structure.

Synthesis Example 4

This example illustrates the preparation of Compound 5, 4-(4'-(4-(naphthalen-1-yl)phenyl)-1,1'-binaphthyl-4-yl)benzonitrile.

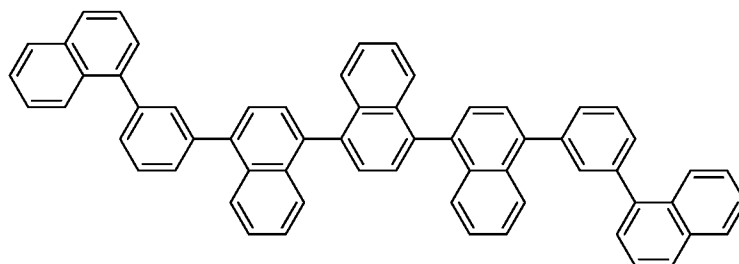


To a 250 mL round bottom flask were added 4-bromo-4'-(4-(naphthalen-1-yl)phenyl)-1,1'-binaphthyl (2.36 g, 4.42 mmol), 4-cyanophenylboronic acid (1.21 g, 5.30 mmol), sodium carbonate (2 M, 10 mL, 20 mmol), toluene (100 mL) and Aliquat® 336 (0.5 g). The mixture was stirred under nitrogen for 20 min. After which tetrakis(triphenylphosphine) palladium (102 mg, 0.09 mmol) was added and the mixture was stirred under nitrogen for another 15 min. The reaction was stirred and refluxed in an oil bath at 98 °C under nitrogen for 18 hours. During the reaction some solid was formed. After cooling, more solid was precipitated from the solution. The solid was filtered, washed with water and ethanol and dried in air. The filtrate was washed with water, diluted HCl (10%) and saturated brine. The solid was re-dissolved in toluene with heating and the resulted solution was combined with above filtrate. The solution was dried with MgSO₄ at ambient temperature for 2 hours. The solution was passed through a short silica gel column eluted with toluene. The product containing fractions were collected and the

volume of the solution was reduced to about 60 mL. Ethanol (40 mL) was added to the solution (with some solids) and the mixture was heated to reflux and then allowed to cool down to ambient temperature. The precipitate was filtered and dried in a vacuum oven overnight. UPLC analysis indicated the purity of the material was about 95%. The material was further purified by automated chromatography (CombiFlash®) to give 1.32 g of product as white powder material. UPLC analysis indicated that the purity was 99.83%. NMR spectra were consistent with the structure.

Synthesis Example 5

This example illustrates the preparation of Compound 7, 4-(3-(naphthalen-1-yl)phenyl)-4'-(4-(3-(naphthalen-1-yl)phenyl)naphthalen-1-yl)-1,1'-binaphthyl.



(a) (4-bromonaphthalen-1-yl)boronic acid

1,4-Bibromonaphthalene (51.6, 180mmol) and 600mL ether were charged to a 1L 3-necked round bottom flask equipped with stir bar and nitrogen feed. This was cooled to -78C and n-butyllithium (2.5M in hexane, 36mL, 88.1 mmol) was added slowly over 10 minutes by syringe.

5 The reaction was stirred for 1 hour before adding triisopropylborate (39mL, 168mmol). After 1 hour the reaction was allowed to warm to room temperature and stirred for 2 hours. The reaction mix was quenched with 2M aqueous hydrochloric acid. The aqueous layer was extracted with ether and the organic layer rinsed with saturated brine. Recrystallized
10 from ether/hexane. Yield 37.5g, 96% pure. UPLC chromatogram and UV were consistent with the structure.

(b) 1,4-diiodonaphthalene

1,4-Dibromonaphthalene (5.72 g, 20 mmol), propane-1,3-diamine (0.30 g, 4.00 mmol), CuI (0.17 g 2 mmol), sodium iodide (12.00 g, 80
15 mmol) and 1-pentanol (150 mL) were charged to a 500mL round bottom flask equipped with stir bar, heating bath, and reflux condenser. The reaction was stirred and refluxed in an oil bath at 130 °C under nitrogen for 18 hours. UPLC analysis indicated that only about 50% of bromide had been converted to iodide. More CuI (308 mg) and NaI (9.69 g) were
20 added and the reaction was continued for another 15 days.* UPLC analysis showed there were still some starting dibromide and monoiodide left.* After cooling, water (100 mL) was added and the mixture was extracted with toluene. The organic layer was filtered through a Celite® plug to remove insoluble materials, then washed with water, aqueous
25 Na₂S₂O₃ solution, water, and saturated brine. The solution was dried with MgSO₄ and filtered through a silica gel plug. The solution was removed and the product was crystallized from DCM/acetonitrile. Yield, 4.1 g (54%) in a purity of 86.8% by UPLC analysis with the monoiodide as the major by-product. ¹H NMR and ¹³C NMR (CDCl₃) spectra were consistent with
30 the structure.

(c) 4-bromo-4'-(4-bromonaphthalen-1-yl)-1,1'-binaphthyl

1,4-Diiodonaphthalene (3.80 g (84%), 10 mmol), 4-bromonaphthalen-1-ylboronic acid (5.02 g, 20 mmol), Aliquat® 336 (0.8 g), Sodium carbonate (2 M, 60 mL, 120 mmol) and toluene (120 mL) were

charged to a 500mL round bottom flask equipped with stir bar, heating bath, and reflux condenser. The system was purged with nitrogen for 20 min. Tetrakis(triphenylphosphine)palladium (0) (462 mg, 0.4 mmol) was added and the system was purged for another 15 min. The reaction was stirred and refluxed at 95 °C under nitrogen for 18 hours. The organic phase was separated, washed with water, diluted HCl (10%), saturated brine, and dried with MgSO₄. The solvent was removed by rotary evaporation. The residue was re-dissolved in DCM/hexane and passed through a short silica gel column. The solvent was removed and the product was crystallized from chloroform/ethanol to give the product as a white crystalline material. Yield, 2.37 g in 82% purity and 1.8 g in 72% purity by UPLC analysis. ¹H NMR and ¹³C NMR (CDCl₃) spectra were consistent with the structure.

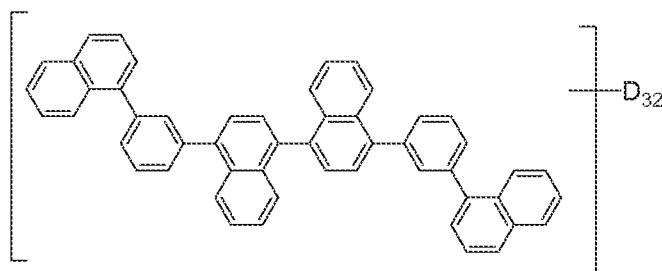
(d) 4-(3-(naphthalen-1-yl)phenyl)-4'-(4-(3-(naphthalen-1-yl)phenyl)naphthalen-1-yl)-1,1'-binaphthyl

To a 250 mL round bottom flask were added 4-bromo-4'-(4-bromonaphthalen-1-yl)-1,1'-binaphthyl (2.69 g, 5.00 mmol), 3-(naphthalen-1-yl)phenylboronic acid (2.60 g, 10.50 mmol), sodium carbonate (2 M, 15 mL, 30 mmol), toluene (80 mL) and Aliquat® 336 (0.6 g). The mixture was stirred under nitrogen for 20 min. After which tetrakis(triphenylphosphine) palladium (231 mg, 0.20 mmol) was added and the mixture was stirred under nitrogen for another 15 min. The reaction was stirred and refluxed in an oil bath at 95 °C under nitrogen for 18 hours. After cooling, the organic phase was separated, washed with water, diluted HCl (10%), and saturated brine and then dried with MgSO₄. The solution was filtered through a silica gel plug and the solvent was removed by removed by rotary evaporation. The material was re-dissolved in DCM (20 mL) and the solution was added dropwise to methanol (300 mL) with stirring. After settling under ambient condition for 2 hours, the precipitate was collected by filtration. The crude product was dried in a vacuum oven overnight to give 2.4 g of off white material in 87% purity based on UPLC analysis. The material was subjected to further separation by automated chromatography (CombiFlash®) to give 992 mg (99.99% pure) product.

More materials was recovered, 875 mg (99.95% pure) and 417 mg (99.79% pure) later. NMR spectra were consistent with the structure.

Synthesis Example 6

5 This example illustrates the preparation of Compound 9.

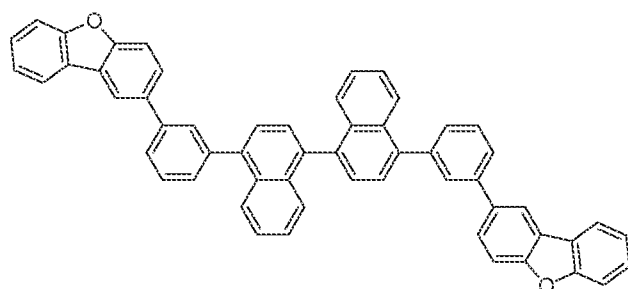


10 Compound 9 was prepared by dissolving Compound 1, from Synthesis Example 1, in d6-benzene and slowly adding d-triflic acid. The solution was stirred overnight in a drybox. The solution was then quenched with 10st% sodium carbonate in D2O. The organic layer was separated, dried with magnesium sulfate, and purified by column chromatography, followed by precipitation.

15

Synthesis Example 7

This example illustrates the preparation of Compound 6.

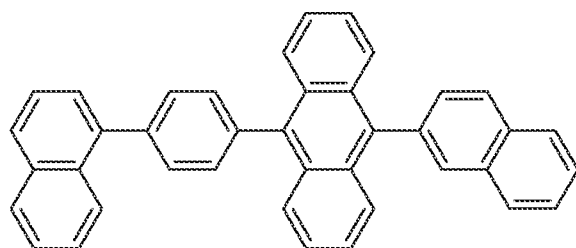


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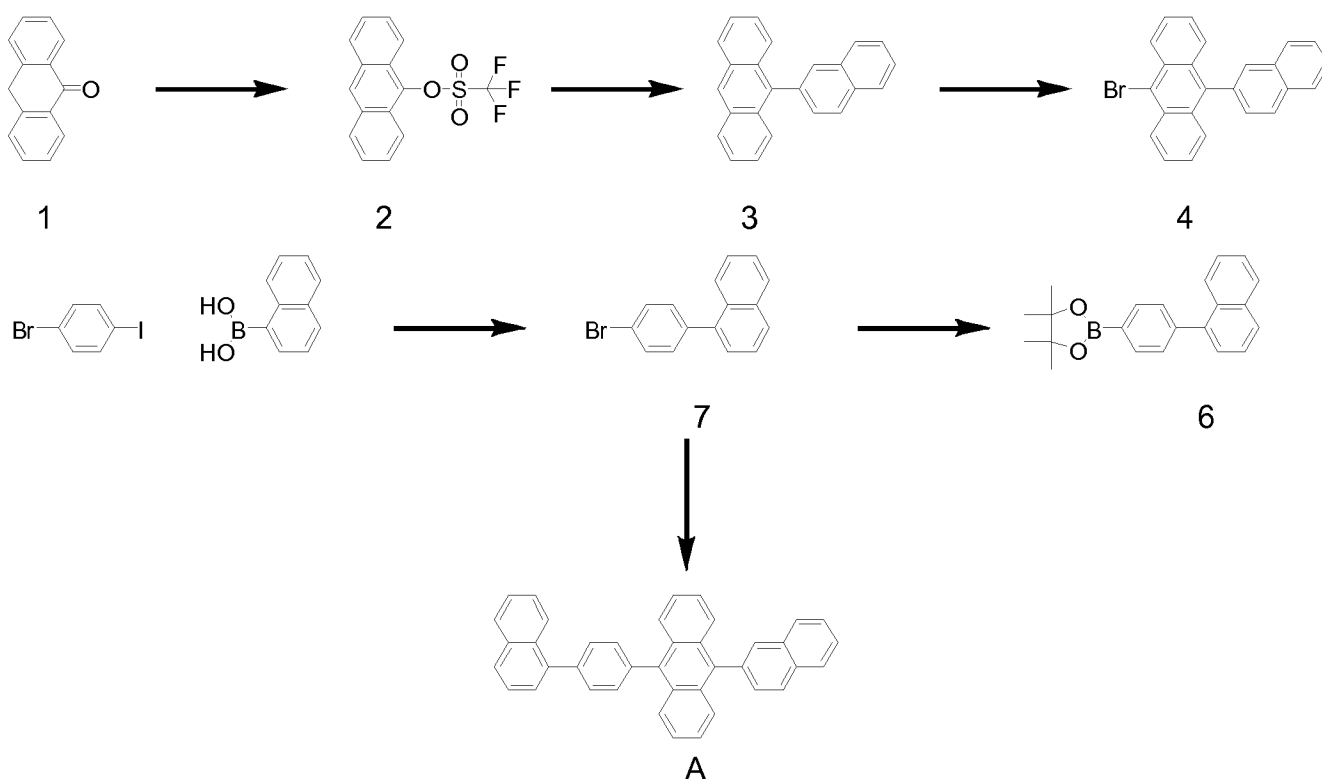
4,4'-Dibromo-1,1'-binaphthalene (2.79 g, .677 mmol), 2-(3-(dibenzo[b,d]furan-2-yl)phenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (5.14 g, 13.88 mmol), Aliquat® 336 (0.8 g), Sodium carbonate (2 M, 20 mL, 40 mmol) and toluene (100 mL) were charged to a 500mL round bottom flask equipped with stir bar, heating bath, and reflux condenser. The system was purged with nitrogen for 20 min. Tetrakis(triphenylphosphine)palladium (0) (235 mg, 0.2 mmol) was added and the system was purged for another 15 min. The reaction was stirred and refluxed in an oil bath at 95 °C under nitrogen for 18 hour. During the time the reaction solution turned to light brown color. After cooling, the organic phase was separated, washed with water (60 mL), diluted HCl (10%, 60 mL) and saturated brine (60 mL), and dried with MgSO₄. The solution was filtered through a Silica gel plug and the solvent was removed by rotary evaporation. The material was re-dissolved in DCM (20 mL) and the solution was added dropwise to methanol (300 mL) with stirring. After setting under ambient condition for 6 hr, the precipitate was collected by filtration. The crude product was dried in a vacuum oven overnight to give 4.7 g of off-white powder in 92.19% purity based on UPLC analysis. The material was subjected to further separation on automated chromatography (CombiFlush) to give 4.2 g of product with a purity of 99.92% by UPLC analysis. NMR spectra were consistent with the structure.

Synthesis Example 8

This example illustrates the preparation of host compound H1.



This compound can be prepared according to the following scheme:



Synthesis of compound 2:

- 5 In a 3L flask fitted with a mechanical stirrer, dropping funnel, thermometer and N₂ bubbler was added anthrone, 54g (275.2mmol) in 1.5L dry methylene chloride. The flask was cooled in an ice bath and 1,8-diazabicyclo[5.4.0]undec-7-ene ("DBU"), 83.7 ml (559.7mmol) was added by dropping funnel over 1.5 hr. The solution turned orange, became
- 10 opaque, then turned deep red. To the still cooled solution was added triflic anhydride, 58ml (345.0mmol) via syringe over about 1.5hr keeping the temperature of the solution below 5^oC. The reaction was allowed to proceed for 3hr at room temperature, after which 1mL additional triflic anhydride was added and stirring at RT continued for 30min. 500 mL
- 15 water was added slowly and the layers separated. The aqueous layer was extracted with 3x 200mL dichloromethane ("DCM") and the combined organics dried over magnesium sulfate, filtered and concentrated by rotary evaporation to give a red oil. Column chromatography on silica gel

followed by crystallization from hexanes afforded 43.1 g (43%) of a tan powder

Synthesis of compound 3:

To a 200 mL Kjeldahl reaction flask equipped with a magnetic stirring bar in a nitrogen-filled glove box were added anthracen-9-yl trifluoromethanesulfonate (6.0 g, 18.40 mmol), Naphthalen-2-yl-boronic acid (3.78 g 22.1 mmol), potassium phosphate tribasic (17.50g, 82.0 mmol), palladium(II) acetate (0.41 g, 1.8 mmol), tricyclohexylphosphine (0.52 g, 1.8 mmol) and THF (100 mL). After removal from the dry box, the reaction mixture was purged with nitrogen and degassed water (50 mL) was added by syringe. A condenser was then added and the reaction was refluxed overnight. The reaction was monitored by TLC. Upon completion the reaction mixture was cooled to room temperature. The organic layer was separated and the aqueous layer was extracted with DCM. The organic fractions were combined, washed with brine and dried with magnesium sulfate. The solvent was removed under reduced pressure. The resulting solid was washed with acetone and hexane and filtered. Purification by column chromatography on silica gel afforded 4.03 g (72%) of product as pale yellow crystalline material.

Synthesis of compound 4:

9-(naphthalen-2-yl)anthracene, 11.17g (36.7mmol) was suspended in 100 mL DCM. N-bromosuccinimide 6.86g (38.5mmol) was added and the mixture stirred with illumination from a 100W lamp. A yellow clear solution formed and then precipitation occurred. The reaction was monitored by TLC. After 1.5 h, the reaction mixture was partially concentrated to remove methylene chloride, and then crystallized from acetonitrile to afford 12.2 g of pale yellow crystals (87%).

Synthesis of compound 7:

To a 500 mL round bottom flask equipped with a stir bar in a nitrogen-filled glove box were added naphthalen-1-yl-1-boronic (14.2g, 82.6mmol), acid, 1-bromo-2-iodobenzene (25.8g, 91.2 mmol), tetrakis(triphenylphosphine) palladium(0) (1.2g, 1.4 mmol), sodium carbonate (25.4g, 240 mmol), and toluene (120 mL). After removal from the dry box, the reaction mixture was purged with nitrogen and degassed water (120 mL) was added by syringe. The reaction flask was then fitted with a condenser and the reaction was refluxed for 15 hours. The reaction

was monitored by TLC. The reaction mixture was cooled to room temperature. The organic layer was separated and the aqueous layer was extracted with DCM. The organic fractions were combined and the solvent was removed under reduced pressure to give a yellow oil. Purification by column chromatography using silica gel afforded 13.6 g of a clear oil (58%).

Synthesis of compound 6:

To a 1-liter flask equipped with a magnetic stirring bar, a reflux condenser that was connected to a nitrogen line and an oil bath, were added 4-bromophenyl-1-naphthalene (28.4g, 10.0 mmol), bis(pinacolate) diboron (40.8g, 16.0 mmol), Pd(dppf)₂Cl₂ (1.64 g, 2.0 mmol), potassium acetate (19.7g, 200 mmol), and DMSO (350 mL). The mixture was bubbled with nitrogen for 15 min and then Pd(dppf)₂Cl₂ (1.64 g, 0.002 mol) was added. During the process the mixture turned to a dark brown color gradually. The reaction was stirred at 120°C (oil bath) under nitrogen for 18 h. After cooling the mixture was poured into ice water and extracted with chloroform (3x). The organic layer was washed with water (3x) and saturated brine (1x) and dried with MgSO₄. After filtration and removal of solvent, the residue was purified by chromatography on a silica gel column. The product containing fractions were combined and the solvent was removed by rotary evaporation. The resulting white solid was crystallized from hexane/chloroform and dried in a vacuum oven at 40 °C to give the product as white crystalline flakes (15.0 g in 45% yield). ¹H and ¹³C-NMR spectra are in consistent with the expected structure.

Synthesis of host compound H1, shown as "A".

To a 250 mL flask in glove box were added (2.00g, 5.23 mmol), 4,4,5,5-tetramethyl-2-(4-(naphthalen-4-yl)phenyl)-1,3,2-dioxaborolane (1.90g, 5.74 mmol), tris(dibenzylideneacetone) dipalladium(0) (0.24 g, 0.26 mmol), and toluene (50 mL). The reaction flask was removed from the dry box and fitted with a condenser and nitrogen inlet. Degassed aqueous sodium carbonate (2 M, 20 mL) was added via syringe. The reaction was stirred and heated to 90°C overnight. The reaction was monitored by HPLC. After cooling to room temperature, the organic layer was separated. The aqueous layer was washed twice with DCM and the

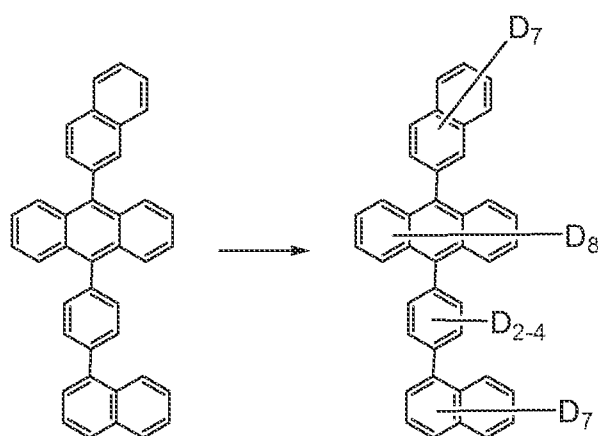
combined organic layers were concentrated by rotary evaporation to afford a grey powder. Purification by filtration over neutral alumina, hexanes precipitation, and column chromatography over silica gel afforded 2.28 g of a white powder (86%).

- 5 The product was further purified as described in published U.S. patent application 2008-0138655, to achieve an HPLC purity of at least 99.9% and an impurity absorbance no greater than 0.01.

The ^1H NMR spectrum confirmed the structure as H1.

10 Synthesis Example 9

This example illustrates the preparation of a host compound H11.

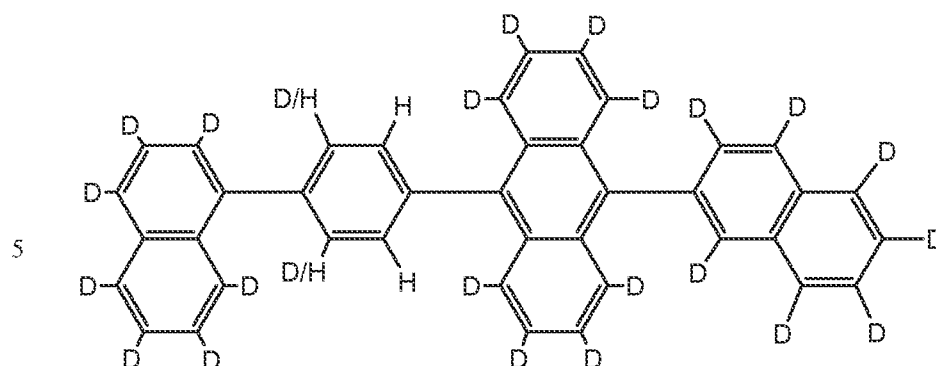


15

H1

H11

- Under an atmosphere of nitrogen, AlCl_3 (0.48g, 3.6 mmol) was added to a perdeuterobenzene or benzene- D_6 (C_6D_6) (100 mL) solution of compound H1 from Synthesis Example 8 (5g, 9.87 mmol). The resulting mixture was stirred at room temperature for six hours after which D_2O (50 mL) was added. The layers were separated followed by washing the water layer with CH_2Cl_2 (2x30 mL). The combined organic layers were dried over magnesium sulfate and the volatiles were removed by rotary evaporation. The crude product was purified via column chromatography.
- 20 The deuterated product H11 was obtained (4.5 g) as a white powder, with the structure given below:
- 25



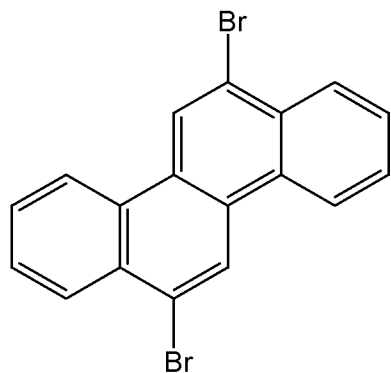
where "D/H" indicates approximately equal probability of H or D at this
 10 atomic position. The structure was confirmed by ^1H NMR, ^{13}C NMR, ^2D
 NMR and ^1H - ^{13}C HSQC (Heteronuclear Single Quantum Coherence).

Synthesis Example 10

This example illustrates the synthesis of dopant D9.

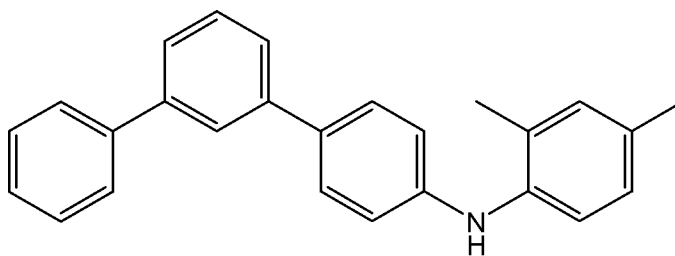
15 Step 1

The non-deuterated analog is prepared first. Take 0.39g of the
 dibromochrysene (1 mM) in glove box and add 0.75g (2.1mM) sec amine
 and 0.22g t-BuONa (2.2mM) with 10mL toluene. Add 0.15g Pd2DBA3
 (0.15mM), 0.06g P(t-Bu)3 (0.30mM) dissolved in toluene. Mix and heat in
 20 glove box in mantle at 110C under nitrogen for 1hr. Solution immediately
 is dark purple but on reaching ~80C it is dark yellow brown with noticeable
 blue luminescence. Warm at ~80C overnight. Cool and work up by
 removing from glove box and filter through a b-alumina/florisil plug eluting
 with toluene. Product is pale yellow and quite soluble. The blue
 25 luminescent material elutes from the column as a pale yellowgreen
 solution. Evaporate to low volume and add methanol to ppt yellow solid
 with blue PL in ~0.5g yield. TLC shows single blue spot running at the
 solvent front in toluene. Material is very soluble in toluene

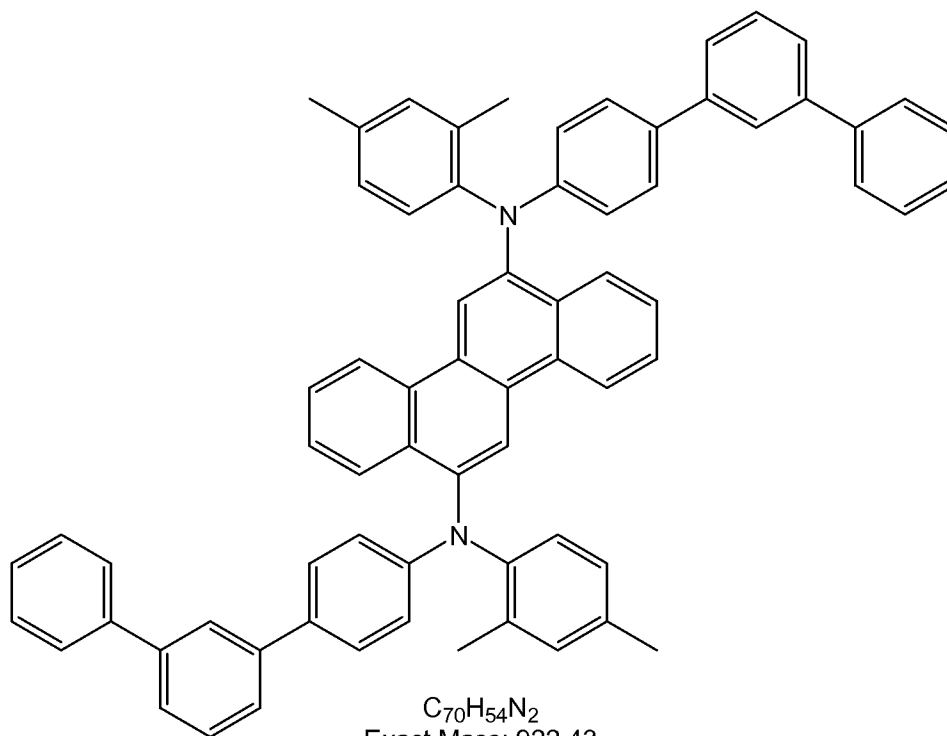


$C_{18}H_{10}Br_2$
 Exact Mass: 383.91
 Mol. Wt.: 386.08
 C, 56.00; H, 2.61; Br, 41.39

Product:



$C_{26}H_{23}N$
 Exact Mass: 349.18
 Mol. Wt.: 349.47
 C, 89.36; H, 6.63; N, 4.01



$C_{70}H_{54}N_2$
 Exact Mass: 922.43
 Mol. Wt.: 923.19
 C, 91.07; H, 5.90; N, 3.03

5

Step 2.

Deuteration to form dopant D9 can be carried out in a manner analogous to that for host H11, described above.

10

Synthesis Example 11

This example illustrates how dopant D10 could be made.

The compound could be made using a procedure analogous to Synthesis Example 10, Step 1, using 6,12-dibromochrysene and the perdeutero analog of the amine compound.

5

Device Examples

(1) Materials

HIJ-1 = an electrically conductive polymer doped with a polymeric fluorinated sulfonic acid. Such materials have been described in, for example, published U.S. patent applications US 2004/0102577, US 2004/0127637, US 2005/0205860, and published PCT application WO 2009/018009.

10

HT-1 = a triarylamine-containing copolymer. Such materials have been described in, for example, published PCT application WO 2009/067419.

ET-1 = a metal quinolate complex.

5

(2) Device fabrication

OLED devices were fabricated by a combination of solution processing and thermal evaporation techniques. Patterned indium tin oxide (ITO) coated glass substrates from Thin Film Devices, Inc were used. These ITO substrates are based on Corning 1737 glass coated with ITO having a sheet resistance of 30 ohms/square and 80% light transmission. The patterned ITO substrates were cleaned ultrasonically in aqueous detergent solution and rinsed with distilled water. The patterned ITO was subsequently cleaned ultrasonically in acetone, rinsed with isopropanol, and dried in a stream of nitrogen.

Immediately before device fabrication the cleaned, patterned ITO substrates were treated with UV ozone for 10 minutes. Immediately after cooling, an aqueous dispersion of HIJ-1 was spin-coated over the ITO surface and heated to remove solvent. A chemical containment layer was formed as described in published U.S. patent application US 2011/0017980. After cooling, the substrates were then spin-coated with a toluene solution of HT-1, and then heated to remove solvent. After cooling the substrates were spin-coated with a methyl benzoate solution of the host(s) and dopant, and heated to remove solvent. The substrates were masked and placed in a vacuum chamber. A layer of ET-1 was deposited by thermal evaporation, followed by a layer of CsF. Masks were then changed in vacuo and a layer of Al was deposited by thermal evaporation. The chamber was vented, and the devices were encapsulated using a glass lid, dessicant, and UV curable epoxy.

30 (3) Device structure

The devices had the following structure on a glass substrate:

Anode = ITO ("ITO"), 50 nm

Hole injection layer = HIJ-1, 50 nm

Hole transport layer = HT-1, 14 nm

Photoactive layer = 40 nm, materials are given in Table 1 below

Electron transport layer = ET-1, 10 nm

Cathode = CsF/Al, 0.7 nm and 100 nm, respectively

5 Table 1. Photoactive Layers

Example	Dopant	First Host	Second Host	Ratio
Example 1	D9	Compound 9	H1	7:20:73
Comparative A	D9	none	H1	7:0:93
Example 2	D9	Compound 9	H11	7:20:73
Comparative B	D9	none	H11	7:0:93
Example 3	D10	Compound 9	H11	7:30:63
Example 4	D10	Compound 6	H11	7:30:63
Example 5	D10	Compound 9	H11	7:20:73
Example 6	D10	Compound 9	H11	7:40:53
Comparative C	D10	none	H11	7:0:93
Comparative D	D10	Compound 9	none	7:93:0

Ratio = weight ratio of dopant: first host: second host

(4) Device characterization

The OLED samples were characterized by measuring their
 10 (1) current-voltage (I-V) curves, (2) electroluminescence radiance versus voltage, and (3) electroluminescence spectra versus voltage. All three measurements were performed at the same time and controlled by a computer. The current efficiency of the device at a certain voltage is determined by dividing the electroluminescence radiance of the LED by
 15 the current density needed to run the device. The unit is a cd/A. The power efficiency is the current efficiency divided by the operating voltage. The unit is lm/W. The color coordinates were determined using either a Minolta CS-100 meter or a Photoresearch PR-705 meter.

20 Device Examples 1 and 2 and Comparative Examples A and B

These examples illustrate device performance when a host having Formula I is used in combination with a diarylanthracene second host.

In Example 1, the photoactive layer had a chrysene dopant in a combination of two hosts: a first host having Formula I (Compound 9) and a second diarylanthracene host.

In Comparative Example A, the photoactive layer had the chrysene dopant in a single host which was a diarylanthracene compound.

In Example 2, the photoactive layer had a chrysene dopant in a combination of two hosts: a first host having Formula I (Compound 9) and a second deuterated diarylanthracene host.

In Comparative Example B, the photoactive layer had the chrysene dopant in a single host which was a deuterated diarylanthracene compound.

The results are shown in Table 2.

Table 2. Device Results

Device Example	C.E. (cd/A)	E.Q.E. (%)	V at 15mA/cm ²	C.I.E. x	C.I.E. y	T80 (hours)	T70 (hours)
Ex. 1	4.6	5.7	4.7	0.142	0.089	680	
Comp. A	4.8	5.5	4.7	0.141	0.097	500	
Ex. 2	4.1	5.3	4.6	0.142	0.084	960	1920
Comp. B	4.4	5.4	4.5	0.143	0.09	740	1740

All data @ 1000 nits; C.E. = current efficiency; E.Q.E. is the external quantum efficiency; V is voltage, in volts; CIE_x and CIE_y are the x and y color coordinates according to the C.I.E. chromaticity scale (Commission Internationale de L'Eclairage, 1931); T80 is the time to reach 80% initial luminance at 12 mA/cm² and 32°C; T70 is the time to reach 70% initial luminance at 12 mA/cm² and 32°C.

It can be seen from the data in Table 2, that the devices made with the photoactive composition described herein had more saturated blue color (i.e., a lower y-coordinate) and longer lifetime when compared to the device having only a single diarylanthracene host. There is no deleterious effect from the addition of the first host having Formula I as other device properties are nearly the same.

Examples 3 and 4

These examples illustrate the properties of devices made with the photoactive composition described herein, using two different compounds of Formula I (Compound 9 and Compound 6) and a different dopant (D10). The photoactive layer compositions are given in Table 1, above. The results are given in Table 3.

Table 3. Device Results

Device Example	C.E. (cd/A)	E.Q.E. (%)	V at 15mA/cm ²	C.I.E. x	C.I.E. y	T80 (hours)	T70 (hours)
Ex. 3	4	5.1	4.6	0.143	0.088	1380	2630
Ex. 4	3.9	4.9	4.8	0.144	0.088	1080	1860

All data @ 1000 nits; C.E. = current efficiency; E.Q.E is the external quantum efficiency; V is voltage, in volts; CIE_x and CIE_y are the x and y color coordinates according to the C.I.E. chromaticity scale (Commission Internationale de L'Eclairage, 1931); T80 is the time to reach 80% initial luminance at 12 mA/cm² and 32°C; T70 is the time to reach 70% initial luminance at 12 mA/cm² and 32°C.

It can be seen from the data in Table 3, that good color and lifetime were also achieved with this dopant.

Device Examples 5 and 6 and Comparative Examples C and D

These examples illustrate device performance when a host having Formula I is used in combination with a diarylanthracene second host.

In Examples 5 and 6, the photoactive layer had a chrysene dopant in a combination of two hosts: a first host having Formula I (Compound 9) and a second deuterated diarylanthracene host, in different ratios.

In Comparative Example C, the photoactive layer had the chrysene dopant in a single host which was a deuterated diarylanthracene compound.

In Comparative Example D, the photoactive layer had the chrysene dopant in a single host which was Compound 9.

The results are shown in Table 4.

Table 4. Device Results

Device Example	C.E. (cd/A)	E.Q.E. (%)	V at 15mA/cm ²	C.I.E. x	C.I.E. y	T80 (hours)	T70 (hours)
Ex. 5	4.0	5.3	4.6	0.145	0.083	>1300	>2520
Ex. 6	3.8	5.0	4.7	0.145	0.082	>1300	>2520
Comp. C	4.8	5.8	4.6	0.144	0.091	>960	>2160
Comp. D	2.4	3.4	6.8	0.146	0.075	42	72

All data @ 1000 nits; C.E. = current efficiency; E.Q.E. is the external quantum efficiency; V is voltage, in volts; CIE_x and CIE_y are the x and y color coordinates according to the C.I.E. chromaticity scale (Commission Internationale de L'Eclairage, 1931); T80 is the time to reach 80% initial luminance at 12 mA/cm² and 32°C; T70 is the time to reach 70% initial luminance at 12 mA/cm² and 32°C.

It can be seen from the above data, that the device with the compound having Formula I as a single host had poor performance. The efficiency was lower, the voltage was higher, and the lifetime was significantly lower than in the other devices. Only the color was improved. It is surprising and unexpected that the addition of such a poor host to the anthracene host would result in devices with superior performance, i.e., increased lifetime and better color, without adversely affecting other properties to a large extent.

Note that not all of the activities described above in the general description or the examples are required, that a portion of a specific activity may not be required, and that one or more further activities may be performed in addition to those described. Still further, the order in which activities are listed are not necessarily the order in which they are performed.

In the foregoing specification, the concepts have been described with reference to specific embodiments. However, one of ordinary skill in the art appreciates that various modifications and changes can be made without departing from the scope of the invention as set forth in the claims below. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of invention.

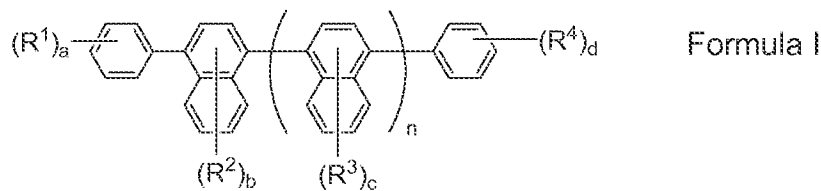
Benefits, other advantages, and solutions to problems have been described above with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any feature(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature of any or all the claims.

It is to be appreciated that certain features are, for clarity, described herein in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features that are, for brevity, described in the context of a single embodiment, may also be provided separately or in any subcombination. Further, reference to values stated in ranges include each and every value within that range.

CLAIMS

What is claimed is:

- 5 1. A composition comprising:
- (a) a dopant capable of electroluminescence having an emission maximum less than 500 nm;
- (b) a first host compound having Formula I



wherein:

R¹ through R⁴ are the same or different at each occurrence and are selected from the group consisting of D, alkyl, electron-withdrawing group, carbocyclic aryl, N,O,S-heteroaryl, and deuterated analogs of alkyl, electron-withdrawing group, carbocyclic aryl, and N,O,S-heteroaryl; with the proviso that at least one of R¹ and R⁴ is not D;

a and d are independently an integer from 1-5;

b and c are independently an integer from 0-6; and

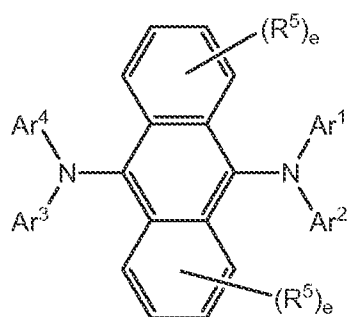
n is an integer from 1-3; and

(c) a second host compound.

2. The composition of Claim 1, wherein the dopant is selected
25 from the group consisting of amino-substituted chrysenes, amino-
substituted anthracenes, and deuterated analogs thereof.

3. The composition of Claim 1, wherein the dopant has Formula

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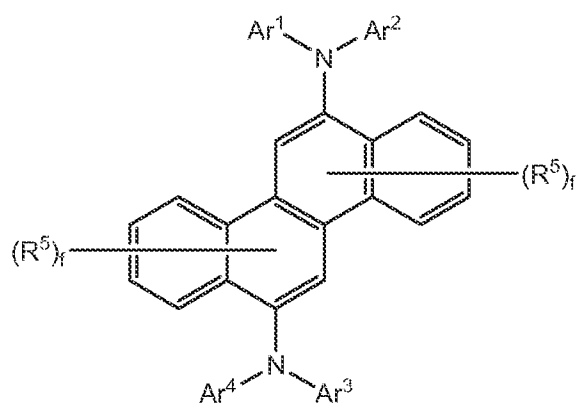


Formula II

wherein:

- 5 R^5 is the same or different at each occurrence and is selected from the group consisting of D, alkyl, alkoxy, aryl, silyl, siloxy, and deuterated analogs of alkyl, alkoxy, silyl, siloxy, and aryl, where adjacent R^5 groups may be joined together to form a 5- or 6-membered aliphatic ring or deuterated aliphatic ring;
- 10 Ar^1 through Ar^4 are the same or different and are selected from the group consisting of aryl groups and deuterated aryl groups; and e is the same or different at each occurrence and is an integer from 0 to 4.

- 15 4. The composition of Claim 1, wherein the dopant has Formula III



Formula III

wherein:

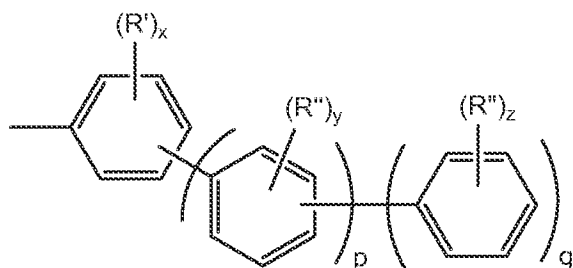
R^5 is the same or different at each occurrence and is selected from the group consisting of D, alkyl, alkoxy, aryl, silyl, siloxy, and deuterated analogs of alkyl, alkoxy, silyl, siloxy, and aryl, where adjacent R^5 groups may be joined together to form a 5- or 6-

membered aliphatic ring or deuterated aliphatic ring;
 Ar^1 through Ar^4 are the same or different and are selected from the group consisting of aryl groups and deuterated aryl groups; and
 f is the same or different at each occurrence and is an integer from 0 to 5.

5. The composition of Claim 1, wherein the first host is at least 10% deuterated.

6. The composition of Claim 1, wherein in Formula I at least one R^1 and R^4 is selected from the group consisting of CN and perfluoroalkyl.

7. The composition of Claim 1, wherein in Formula I at least one R^1 and R^4 is selected from the group consisting of phenyl, biphenyl, terphenyl, naphthyl, phenanthryl, anthracenyl, phenylnaphthylene, naphthylphenylene, substituted derivatives thereof, and a group having Formula a



Formula a

wherein:

R' and R'' are the same or different at each occurrence and are selected from the group consisting of D, alkyl, aryl, silyl, alkoxy, aryloxy, cyano, vinyl, allyl, and a deuterated analog of alkyl, aryl,

silyl, alkoxy, aryloxy, vinyl, and allyl, or adjacent R groups can be joined together to form a 6-membered aromatic or deuterated aromatic ring;

x is an integer from 0-5, with the proviso that when $x = 5$, $p = q = 0$;

5 y is an integer from 0-5, with the proviso that when $y = 5$, $q = 0$;

z is an integer from 0-5;

p is an integer from 0-5; and

q is 0 or 1.

10 8. The composition of Claim 1, wherein in Formula I at least one R^1 and R^4 is an O-heteroaryl derived from a compound selected from the group consisting of benzopyran, dibenzopyran, benzofuran, dibenzofuran, substituted derivatives thereof, and deuterated analogs thereof.

15 9. The composition of Claim 1, wherein in Formula I at least one R^1 and R^4 is an S-heteroaryl derived from a compound selected from the group consisting of benzothiophene, dibenzothiophene, substituted derivatives thereof, and deuterated analogs thereof.

20 10. The composition of Claim 1, wherein at least one R^1 of and R^4 is an alkyl-substituted carbocyclic aryl.

25 11. The composition of Claim 1, wherein in Formula I at least one R^2 and R^3 is an alkyl or deuterated alkyl having 1-6 carbons.

12. The composition of Claim 1, wherein in Formula I at least one R^2 and R^3 is selected from the group consisting of phenyl, biphenyl, and naphthyl.

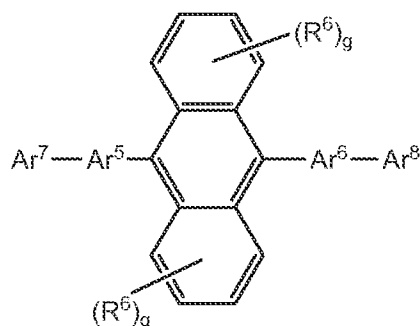
30 13. The composition of Claim 1, wherein in Formula I at least one R^2 and R^3 is an alkyl-substituted carbocyclic aryl.

14. The composition of Claim 1, wherein the second host is selected from the group consisting of indolocarbazoles, chrysenes, phenanthrenes, triphenylenes, phenanthrolines, triazines, naphthalenes, anthracenes, tetraphenes, dibenzoanthracenes, pyrenes, quinolines, isoquinolines, quinoxalines, phenylpyridines, dibenzofurans, benzodifurans, metal quinolate complexes, and deuterated analogs thereof.

15. The composition of Claim 1, wherein the second host is selected from the group consisting of aryl-substituted anthracenes, aryl-substituted tetraphenes, aryl-substituted dibenzoanthracenes, aryl-substituted pyrenes, and deuterated analogs thereof.

16. The composition of Claim 1, wherein the second host is at least 10% deuterated.

17. The composition of Claim 1, wherein the second host has Formula IV



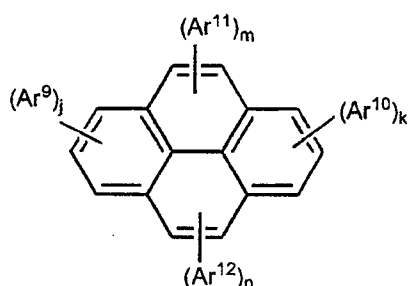
Formula IV

wherein:

R^6 is the same or different at each occurrence and is selected from the group consisting of D, alkyl, alkoxy, aryl, aryloxy, siloxane, silyl, and deuterated analogs of alkyl, alkoxy, aryl, aryloxy, siloxane and silyl, and where adjacent R^6 groups can join together to form a fused aromatic ring or fused deuterated aromatic ring;

Ar⁵ and Ar⁶ are the same or different and are selected from the group consisting of aryl groups and deuterated aryl groups; and Ar⁷ and Ar⁸ are the same or different and are selected from the group consisting of H, D, aryl groups, and deuterated aryl groups.

18. The composition of Claim 1, wherein the second host has Formula V



Formula V

wherein:

Ar⁹ through Ar¹² are the same or different at each occurrence and are selected from the group consisting of D, aryl, and deuterated aryl;

j is an integer from 1-3;

k is an integer from 0-3;

m and n are the same or different and are integers from 0-2;

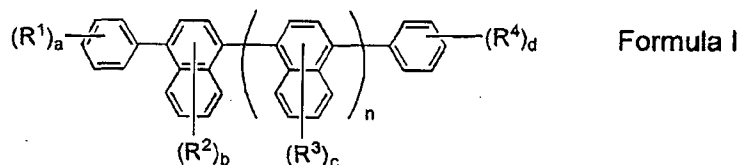
with the proviso that at least one Ar⁹ is not D.

19. An electronic device comprises at least one photoactive layer positioned between two electrical contact layers, wherein the photoactive layer comprises:

(a) a dopant capable of electroluminescence having an emission

maximum less than 500 nm;

(b) a first host compound having Formula I



wherein:

R^1 through R^4 are the same or different at each occurrence and are selected from the group consisting of D, alkyl, electron-withdrawing group, carbocyclic aryl, N,O,S-heteroaryl, and deuterated analogs of alkyl, electron-withdrawing group, carbocyclic aryl, and N,O,S-heteroaryl; with the proviso that at least one of R^1 and R^4 is not D;

a and d are independently an integer from 1-5;

b and c are independently an integer from 0-6; and

n is an integer from 1-3; and

(c) a second host compound.

20. The device of Claim 19, wherein the photoactive composition consists essentially of (a) a dopant capable of electroluminescence having an emission maximum less than 500 nm, (b) a first host compound having Formula I, and (c) a second host compound.

21. The device of Claim 19, wherein the second host is selected from the group consisting of indolocarbazoles, chrysenes, phenanthrenes, triphenylenes, phenanthrolines, triazines, naphthalenes, anthracenes, tetraphenes, dibenzoanthracenes, pyrenes, quinolines, isoquinolines, quinoxalines, phenylpyridines, dibenzofurans, benzodifurans, metal quinolate complexes, and deuterated analogs thereof.

22. The device of Claim 19, wherein the second host is selected from the group consisting of aryl-substituted anthracenes, aryl-substituted tetraphenes, aryl-substituted dibenzoanthracenes, aryl-substituted pyrenes, and deuterated analogs thereof.

FIG. 1

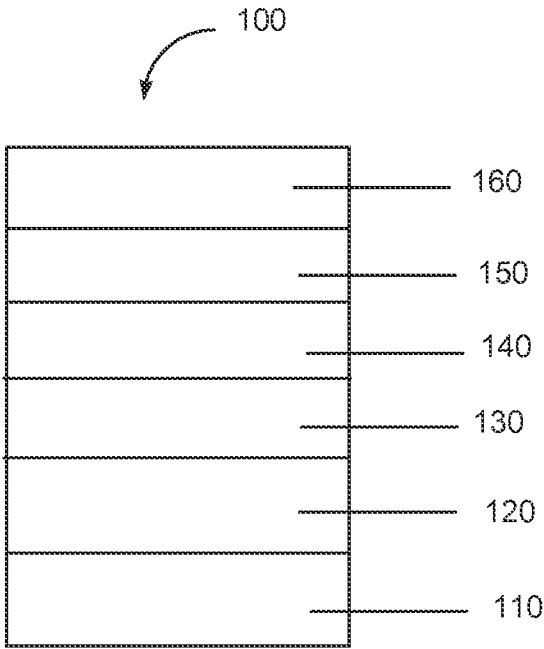
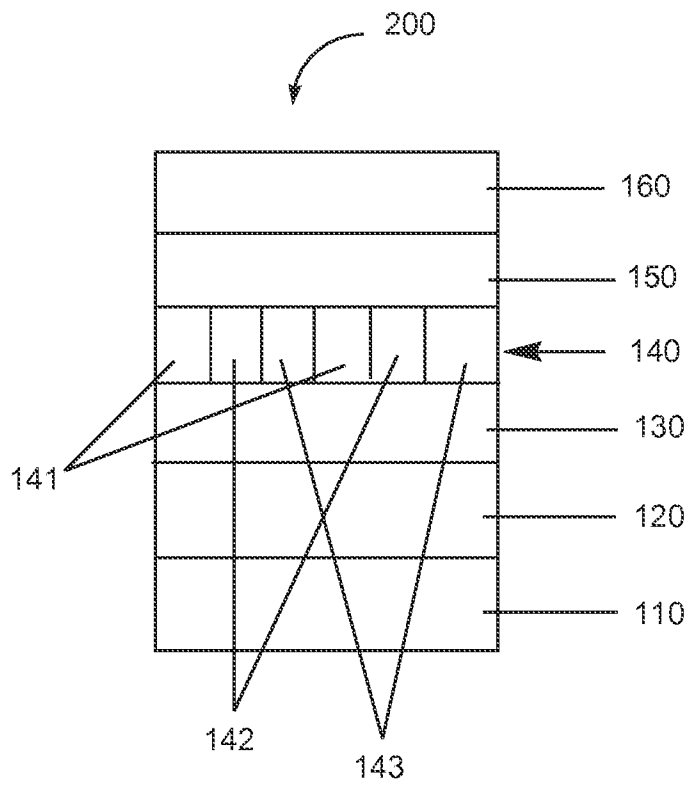


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/069276**A. CLASSIFICATION OF SUBJECT MATTER****C09K 11/06(2006.01)i, H01L 51/50(2006.01)i, H05B 33/14(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHEDMinimum documentation searched (classification system followed by classification symbols)
C09K 11/06; H05B 33/12; H01L 51/50; C07C 15/28; C07B 59/00; C07C 15/24; H05B 33/14Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility modelsElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: OLED, host, dopant, binaphthyl.**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2012-021315 A2 (E. I. DU PONT DE NEMOURS AND COMPANY) 16 February 2012 See pages 9-32.	1-14, 16, 19-21 15, 17, 18, 22
Y A	WO 2013-106041 A2 (E. I. DU PONT DE NEMOURS AND COMPANY) 18 July 2013 See pages 7-33 and Table 1.	15, 17, 18, 22 1-14, 16, 19-21
A	US 6872475 B2 (JIAN PING CHEN et al.) 29 March 2005 See general formula (I).	1-22
A	WO 2008-150822 A2 (E.I. DU PONT DE NEMOURS AND COMPANY) 11 December 2008 See claims 1-19.	1-22



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"P" document published prior to the international filing date but later than the priority date claimed

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search

27 March 2015 (27.03.2015)

Date of mailing of the international search report

30 March 2015 (30.03.2015)

Name and mailing address of the ISA/KR

International Application Division
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/069276

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