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(54) **OLED WITH MULTI-EMISSIVE MATERIAL LAYER**

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(51) **Int. Cl.**

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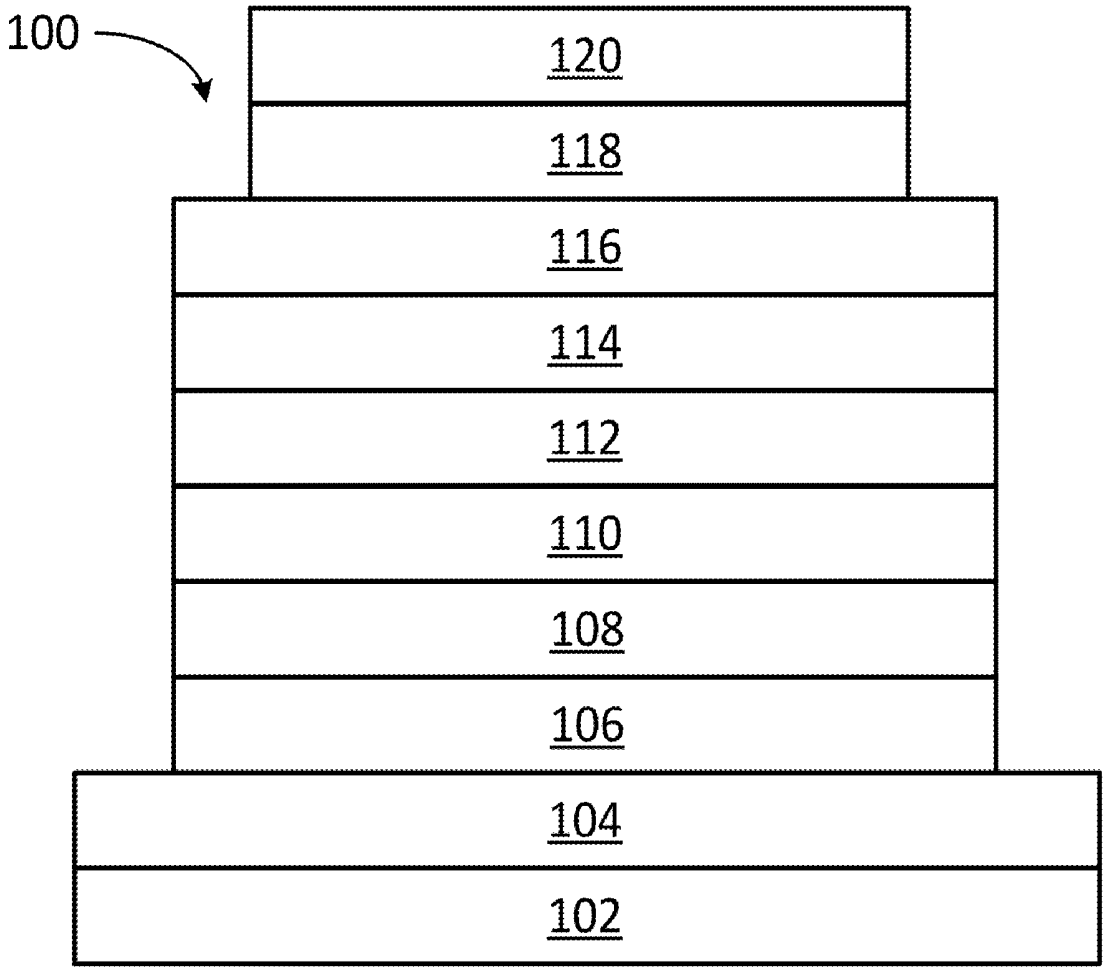
C09K 11/06	(2006.01)
C09K 11/02	(2006.01)
H01L 51/50	(2006.01)
H01L 51/50	(2006.01)

(52) **U.S. Cl.**

CPC ***H01L 51/0087*** (2013.01); ***C09K 11/06*** (2013.01); ***H01L 51/0072*** (2013.01); ***C09K 11/025*** (2013.01); ***H01L 51/0084*** (2013.01); *C09K 2211/1014* (2013.01); *C09K 2211/1011* (2013.01); *C09K 2211/1007* (2013.01); *C09K 2211/1044* (2013.01); *C09K 2211/185* (2013.01); *H01L 51/504* (2013.01); *H01L 51/5096* (2013.01); *C09K 2211/1074* (2013.01)

(57) **ABSTRACT**

The present invention relates to organic light emitting devices with a multi-emissive material layer (EML), where a multi-EML generally refers to an emissive layer having at least two layers of emissive material, each layer having a different emitter concentration (e.g. a first EML in direct contact with a second EML, and the emitter concentration of the first EML (hole favorable) exceeds that of the second EML (electron favorable)).



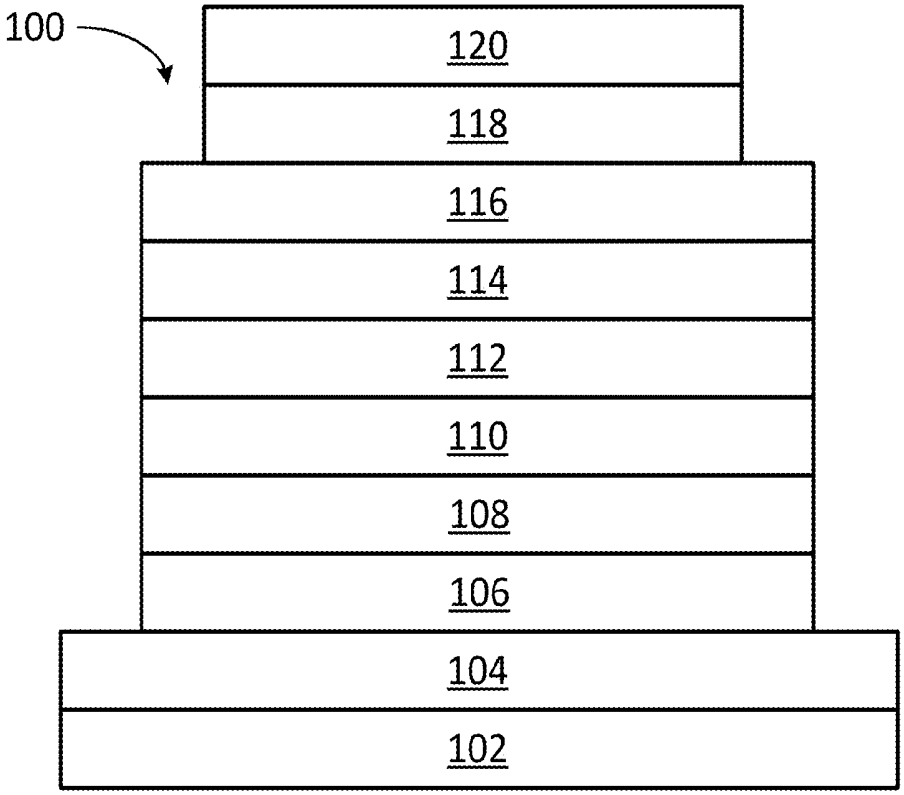

100
120
118
116
114
112
110
108
106
104
102

FIG. 1A

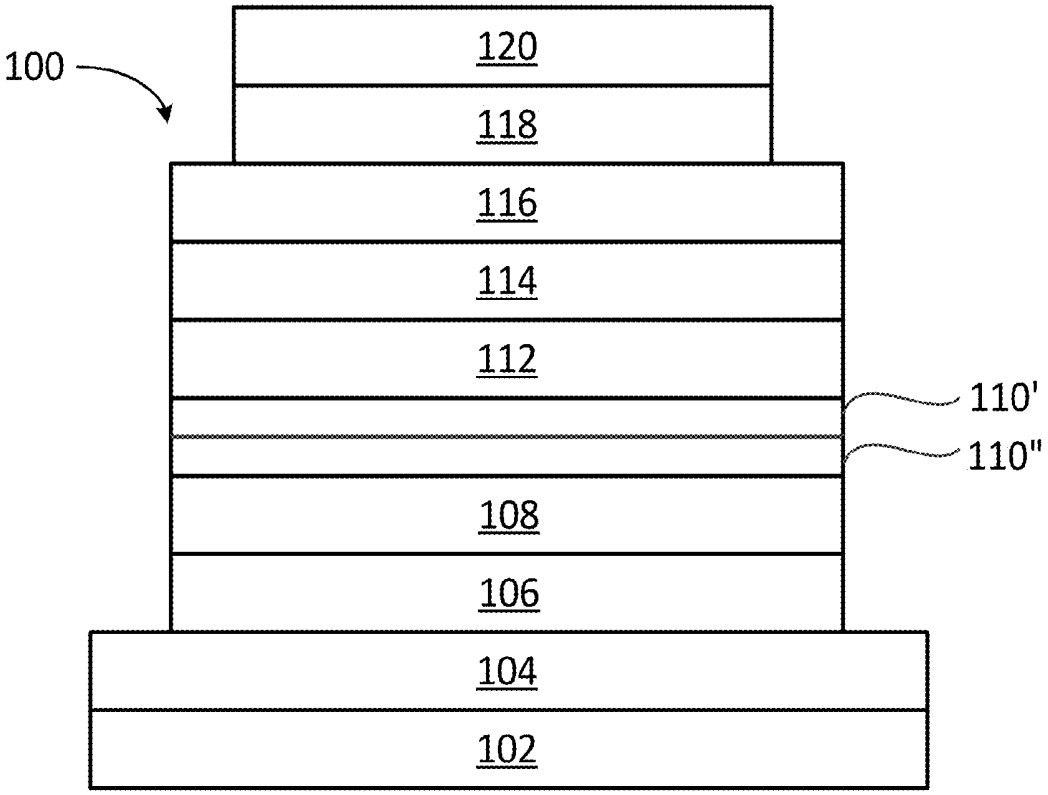

100
120
118
116
114
112
110'
110"
108
106
104
102

FIG. 1B

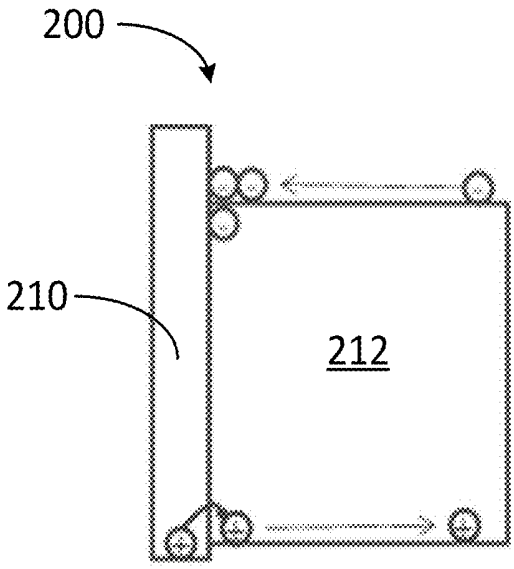


FIG. 2A

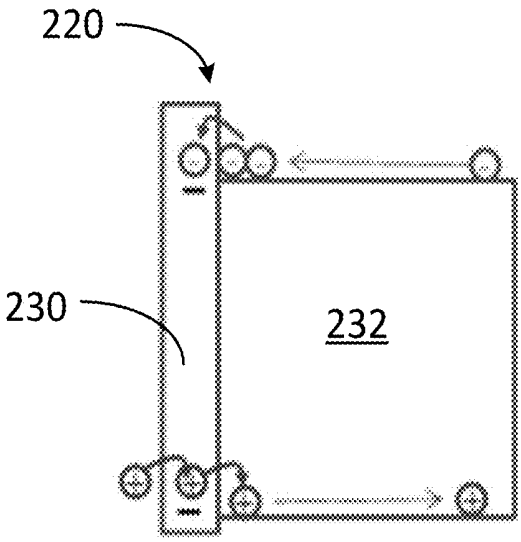


FIG. 2B

FIG. 3A

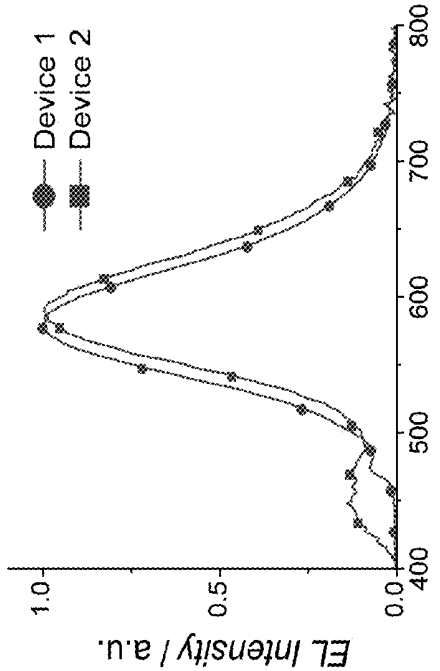


FIG. 3B

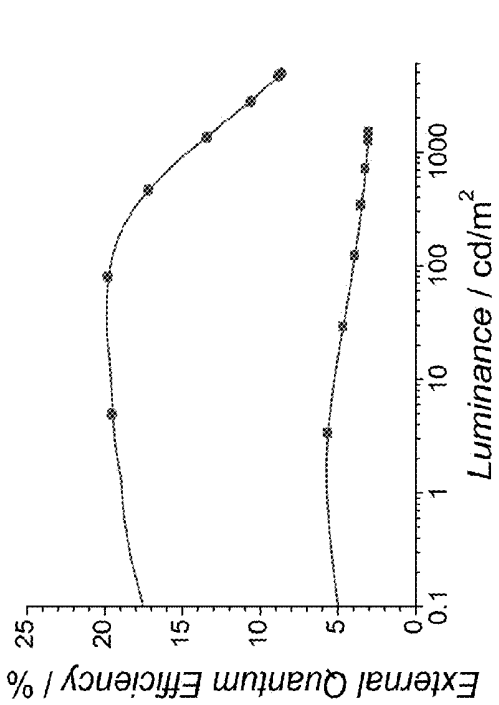


FIG. 3C

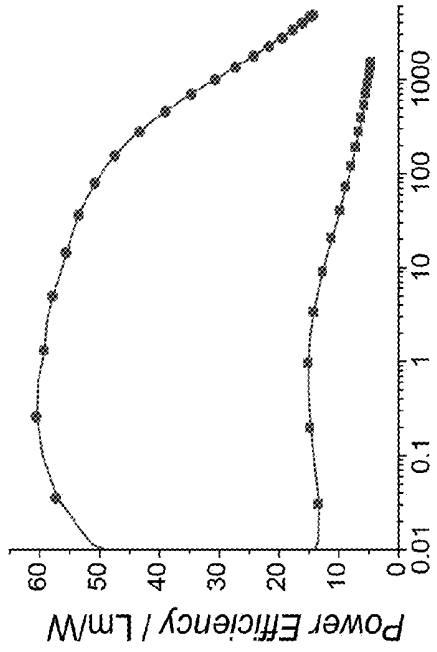
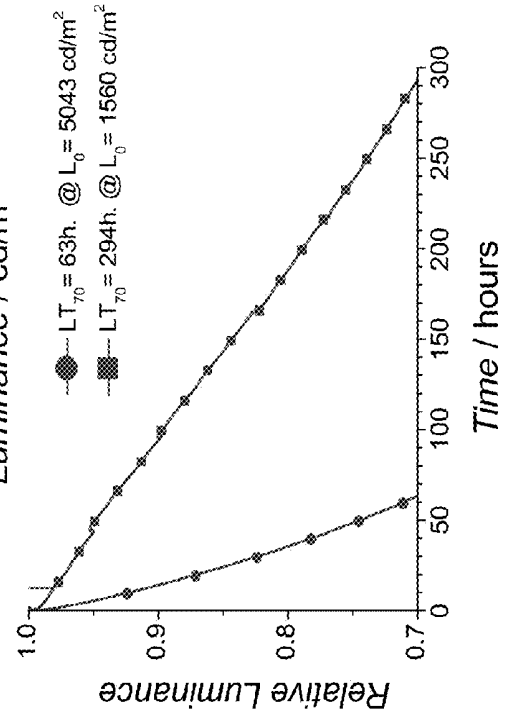


FIG. 3D



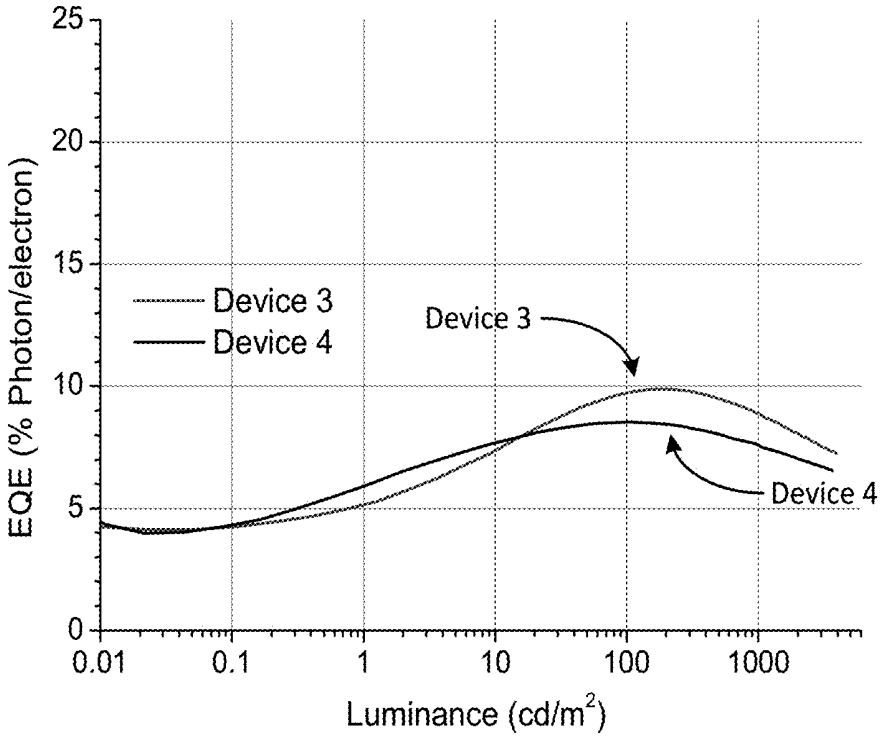

EQE (% Photon/electron)
Luminance (cd/m²)
Device 3
Device 4
Device 3
Device 4
0
5
10
15
20
25
0.01
0.1
1
10
100
1000

FIG. 4A

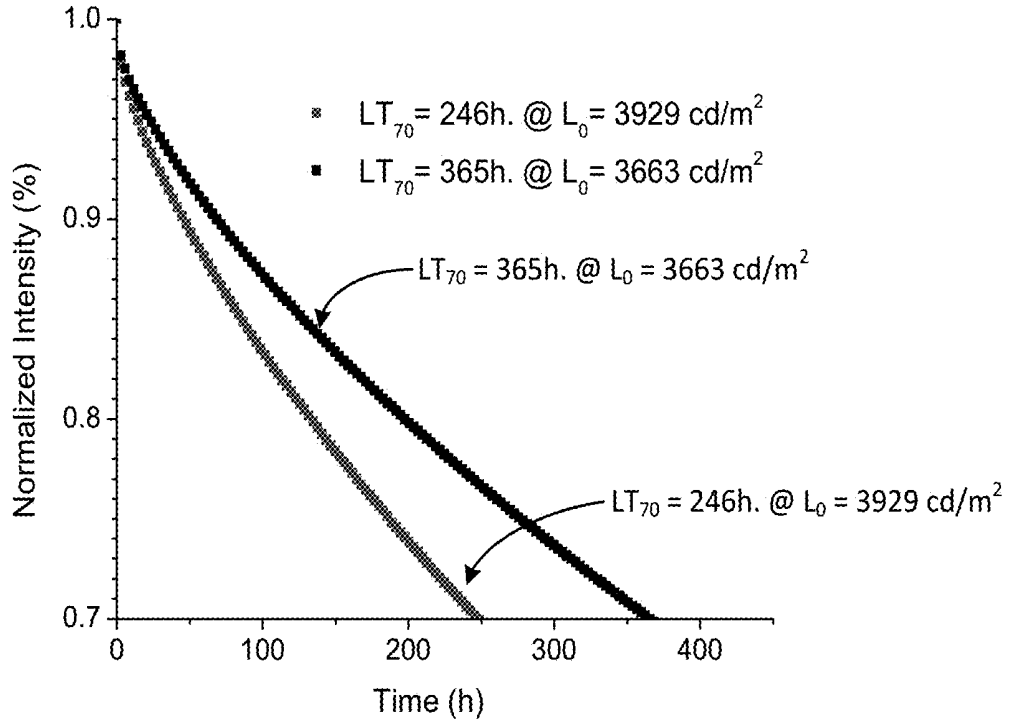

Normalized Intensity (%)
Time (h)
LT70 = 246h. @ L0 = 3929 cd/m²
LT70 = 365h. @ L0 = 3663 cd/m²
LT70 = 365h. @ L0 = 3663 cd/m²
LT70 = 246h. @ L0 = 3929 cd/m²
0.7
0.8
0.9
1.0
0
100
200
300
400

FIG. 4B

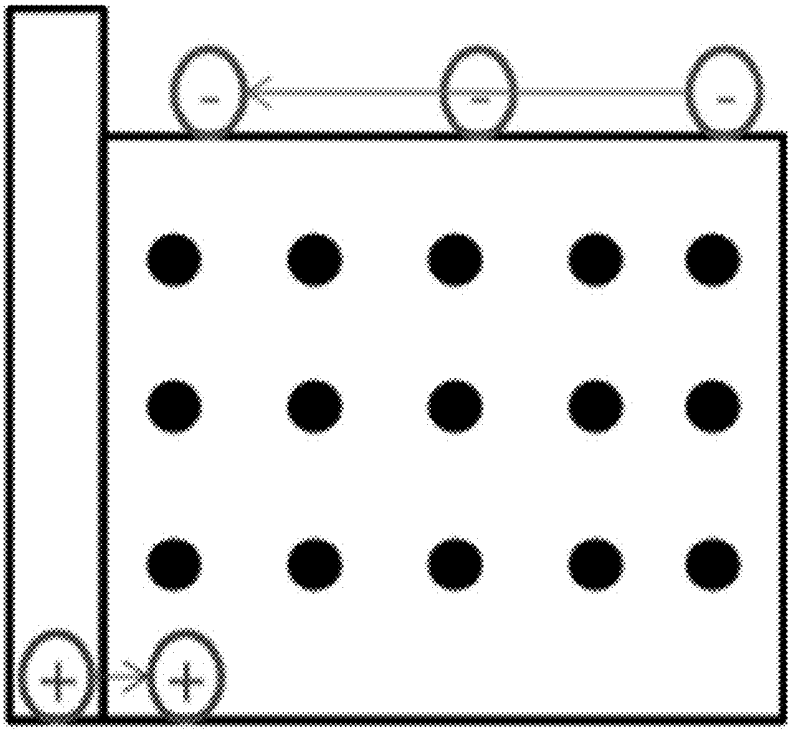


FIG. 5A

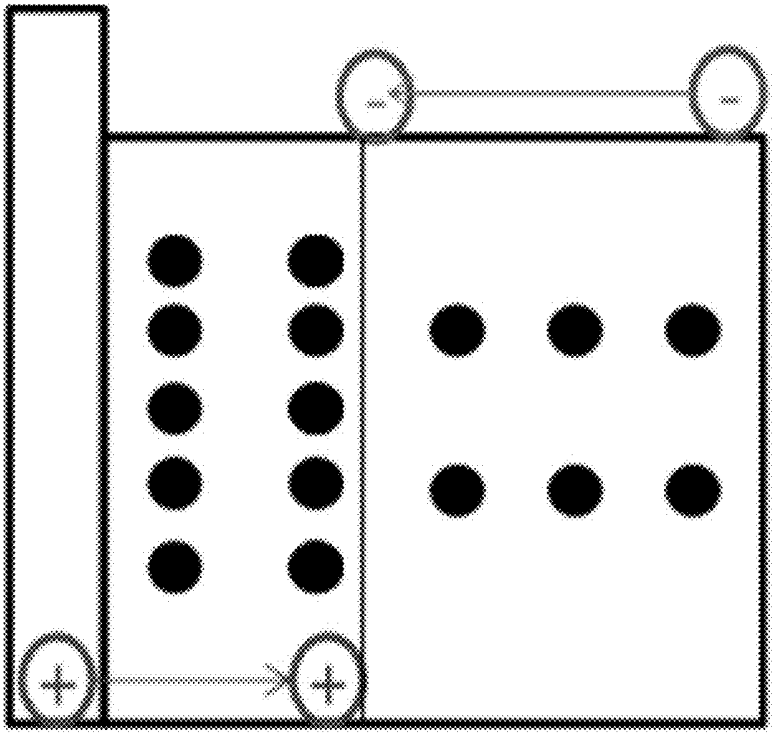


FIG. 5B

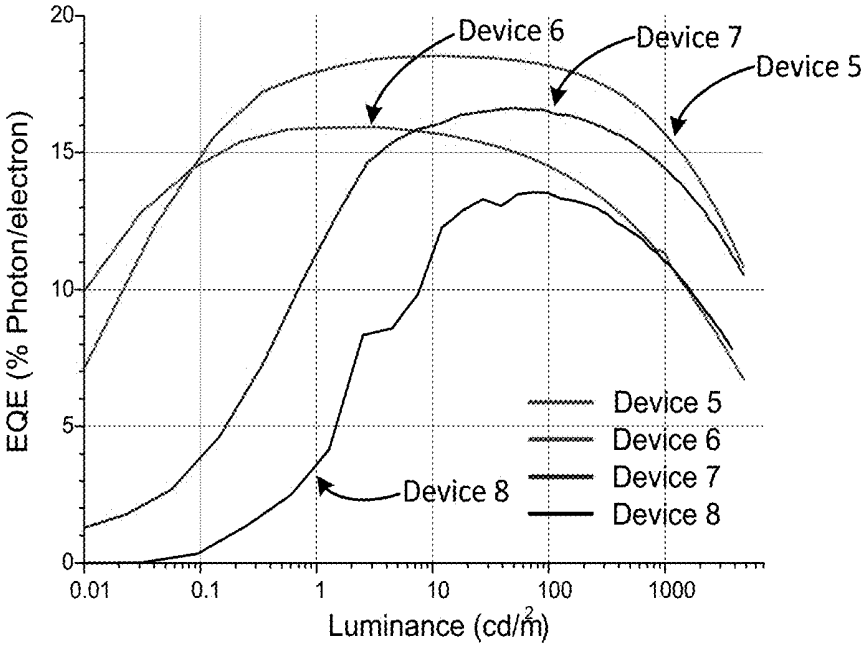

EQE (% Photon/electron)
Luminance (cd/m²)
Device 6
Device 7
Device 5
Device 8
Device 5
Device 6
Device 7
Device 8
20
15
10
5
0
0.01
0.1
1
10
100
1000

FIG. 6A

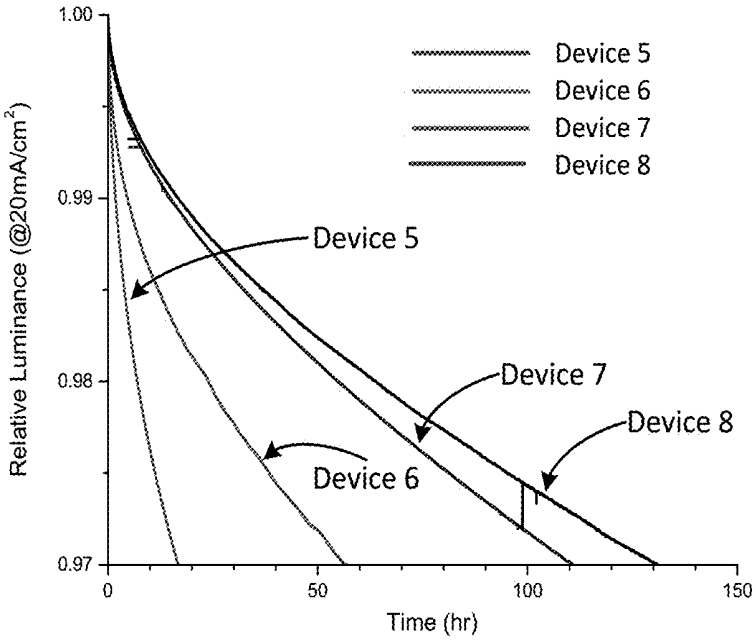

Relative Luminance (@20mA/cm²)
Time (hr)
Device 5
Device 6
Device 7
Device 8
Device 5
Device 7
Device 8
Device 6
1.00
0.99
0.98
0.97
0
50
100
150

FIG. 6B

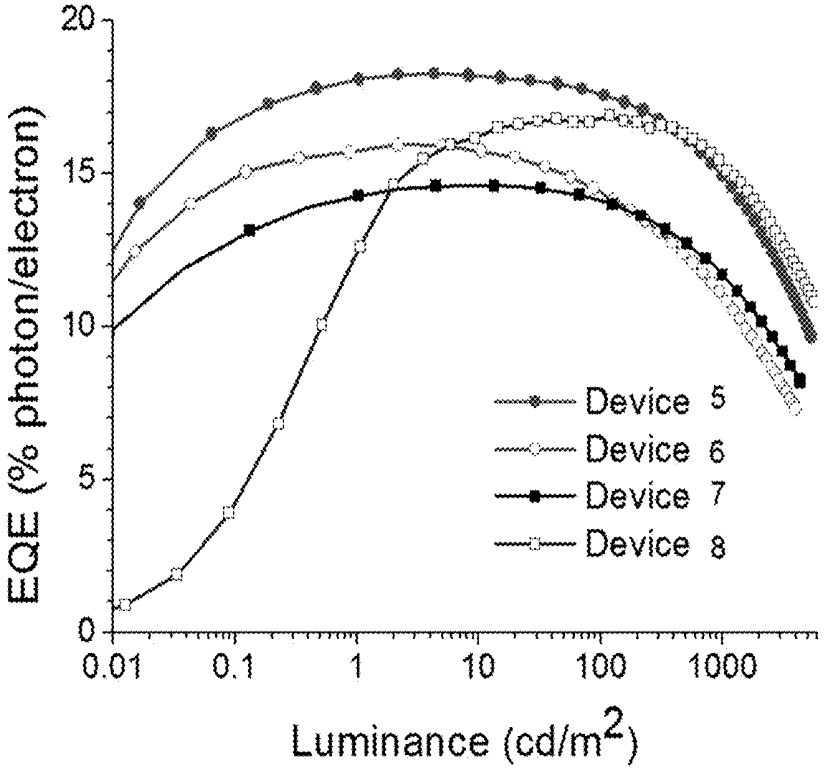

EQE (% photon/electron)
Luminance (cd/m2)
Device 5
Device 6
Device 7
Device 8
0
5
10
15
20
0.01
0.1
1
10
100
1000

FIG. 6C

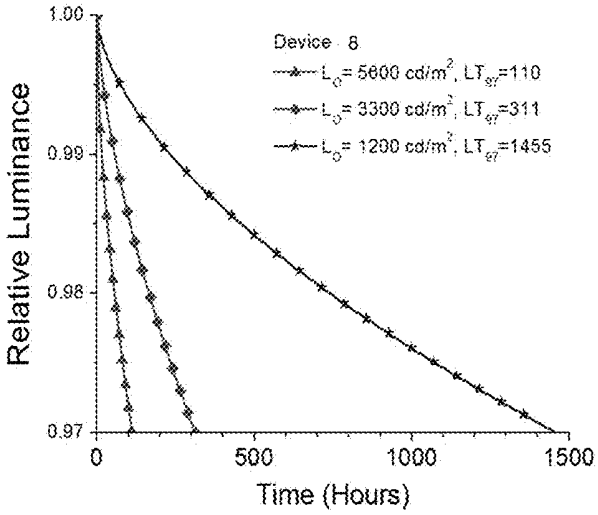

Relative Luminance
Time (Hours)
Device 8
L0= 5600 cd/m2, LT97=110
L0= 3300 cd/m2, LT97=311
L0= 1200 cd/m2, LT97=1455
1.00
0.99
0.98
0.97
0
500
1000
1500

FIG. 6D

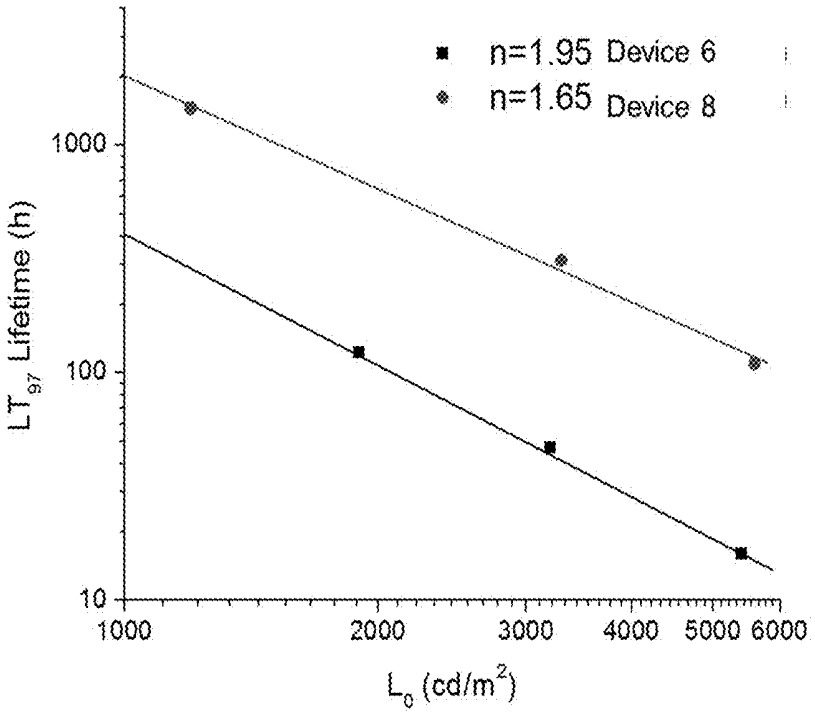

n=1.95 Device 6
n=1.65 Device 8
1000
100
10
LT97 Lifetime (h)
1000
2000
3000
4000
5000
6000
L0 (cd/m2)

FIG.6E

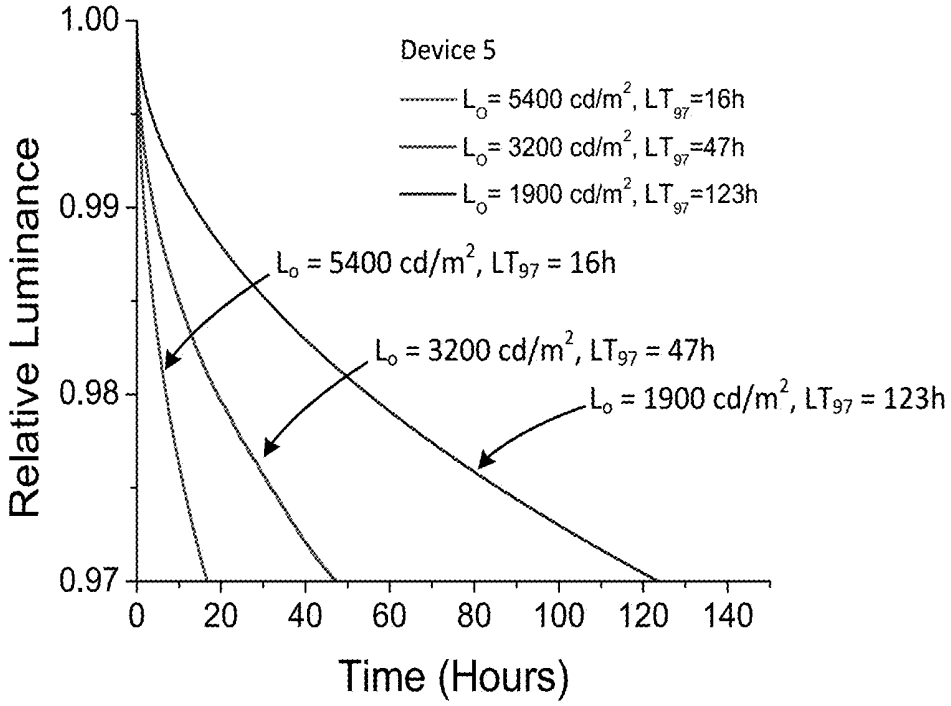

Device 5
L_O= 5400 cd/m^2, LT_{97}=16h
L_O= 3200 cd/m^2, LT_{97}=47h
L_O= 1900 cd/m^2, LT_{97}=123h
L_o = 5400 cd/m^2, LT_{97} = 16h
L_o = 3200 cd/m^2, LT_{97} = 47h
L_o = 1900 cd/m^2, LT_{97} = 123h
Relative Luminance
1.00
0.99
0.98
0.97
0
20
40
60
80
100
120
140
Time (Hours)

FIG. 7A

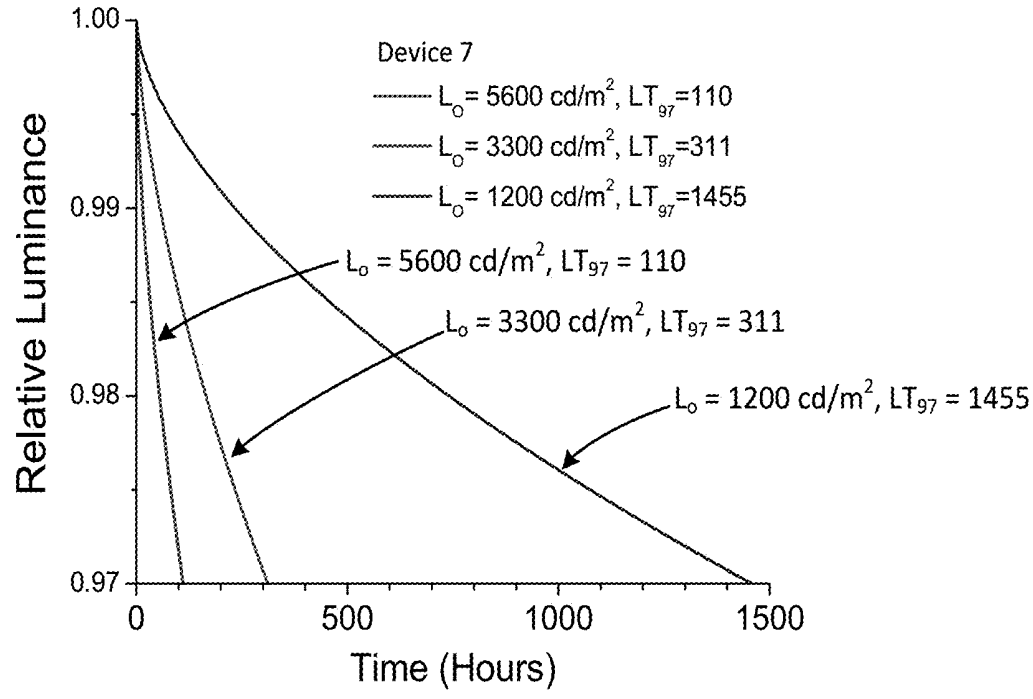

Device 7
L_O= 5600 cd/m^2, LT_{97}=110
L_O= 3300 cd/m^2, LT_{97}=311
L_O= 1200 cd/m^2, LT_{97}=1455
L_o = 5600 cd/m^2, LT_{97} = 110
L_o = 3300 cd/m^2, LT_{97} = 311
L_o = 1200 cd/m^2, LT_{97} = 1455
Relative Luminance
1.00
0.99
0.98
0.97
0
500
1000
1500
Time (Hours)

FIG. 7B

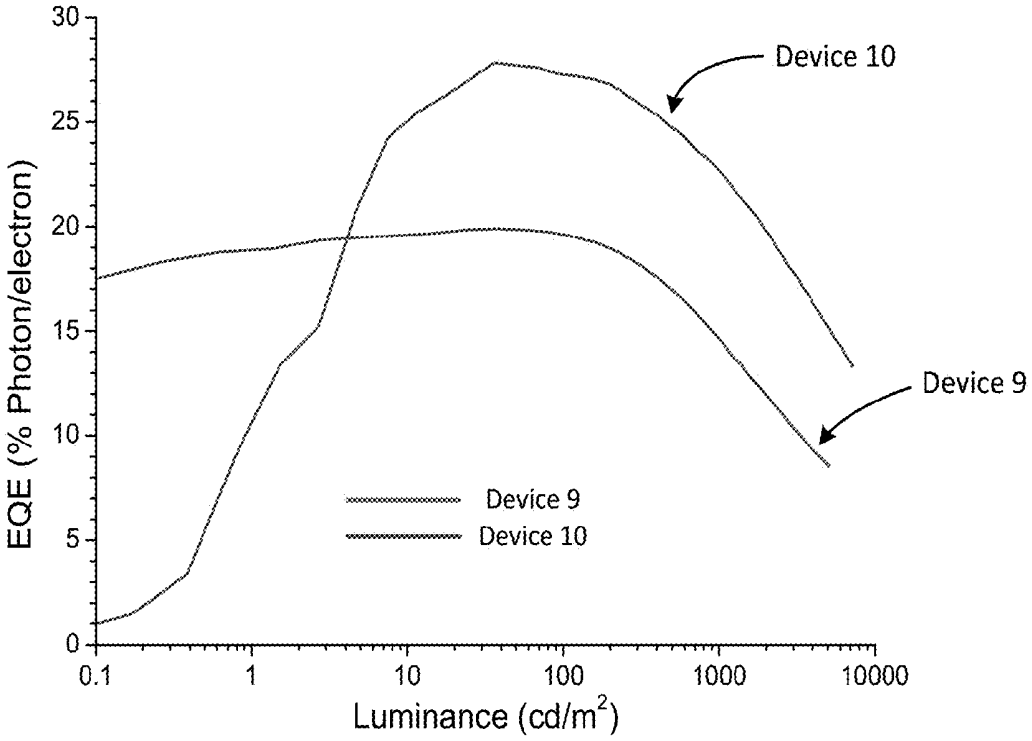

30
25
20
15
10
5
0
EQE (% Photon/electron)
0.1
1
10
100
1000
10000
Luminance (cd/m^2)
Device 10
Device 9
Device 9
Device 10

FIG. 8A

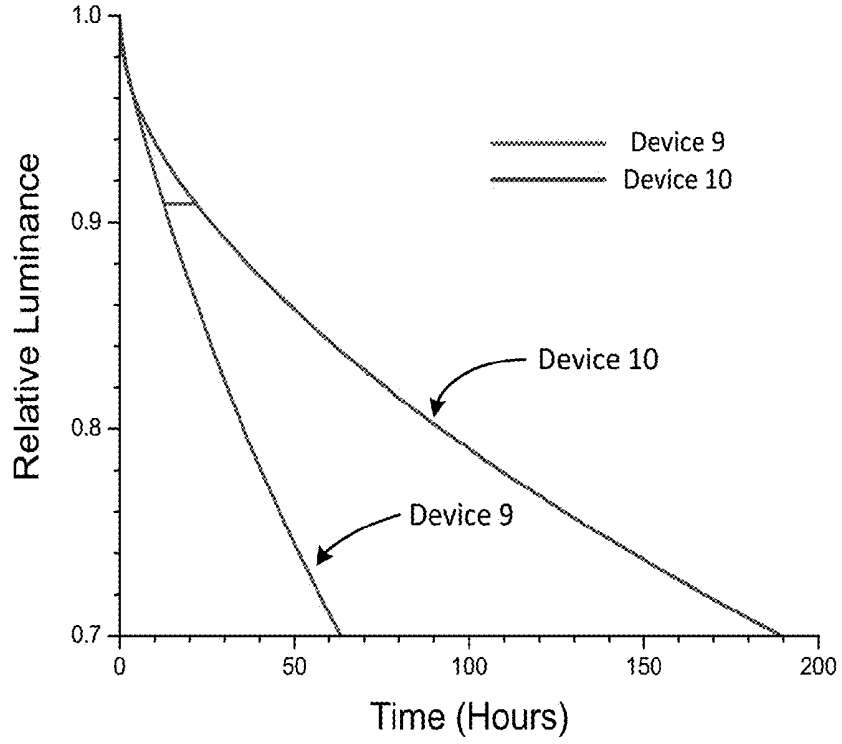

1.0
0.9
0.8
0.7
Relative Luminance
0
50
100
150
200
Time (Hours)
Device 9
Device 10
Device 10
Device 9

FIG. 8B

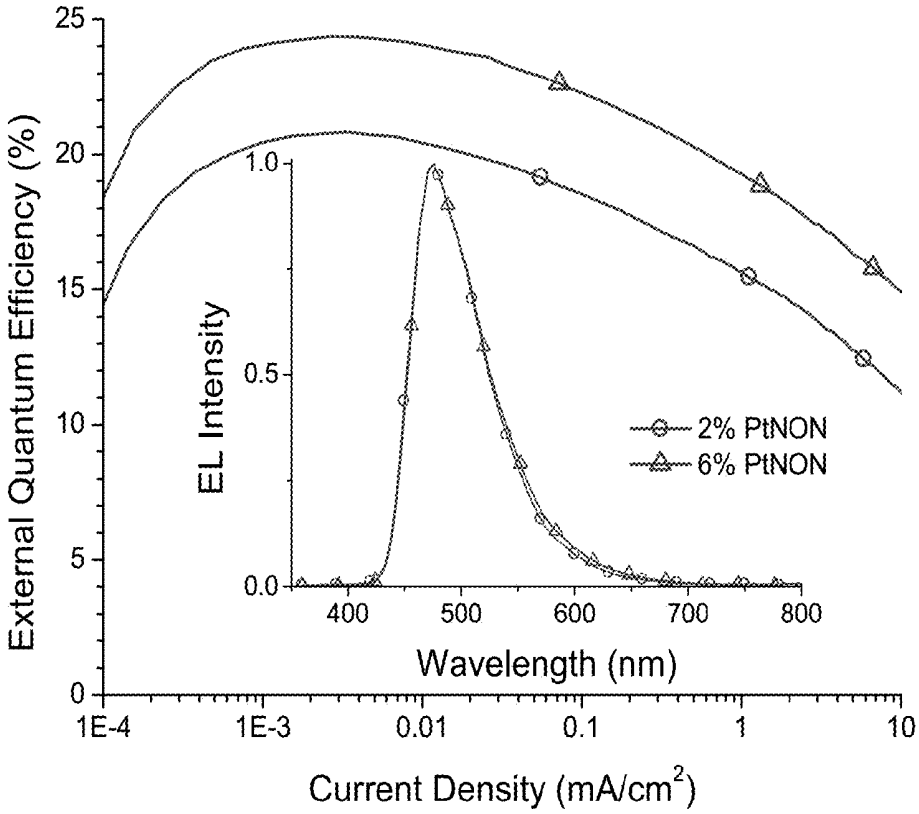

External Quantum Efficiency (%)
25
20
15
10
5
0
1E-4
1E-3
0.01
0.1
1
10
Current Density (mA/cm^2)
EL Intensity
1.0
0.5
0.0
400
500
600
700
800
Wavelength (nm)
2% PtNON
6% PtNON

FIG. 9A

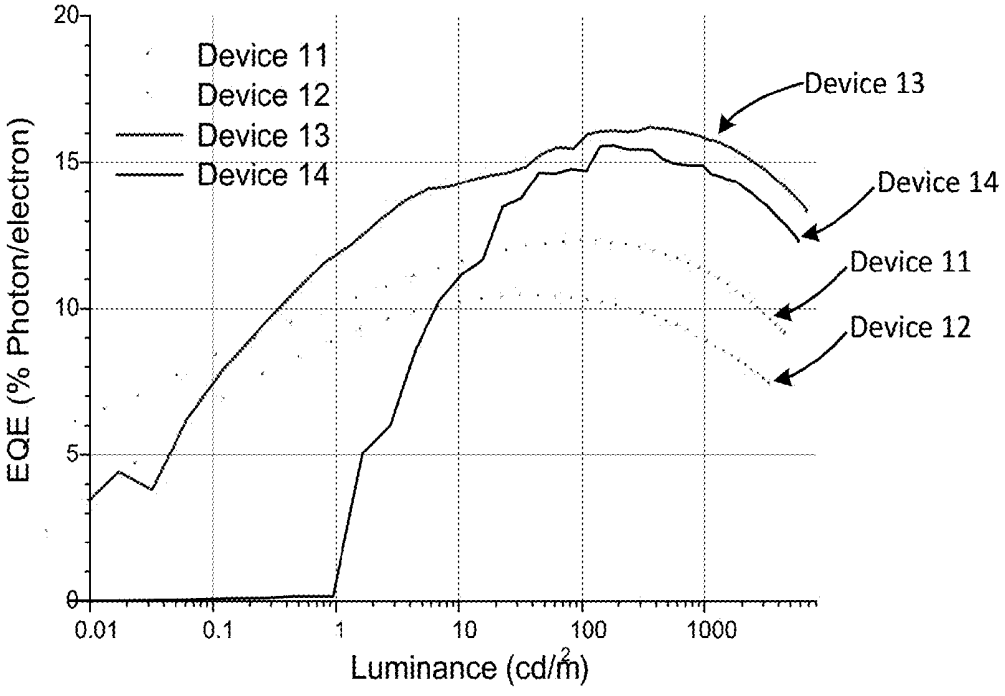

EQE (% Photon/electron)
20
15
10
5
0
0.01
0.1
1
10
100
1000
Luminance (cd/m^2)
Device 11
Device 12
Device 13
Device 14
Device 13
Device 14
Device 11
Device 12

FIG. 9B

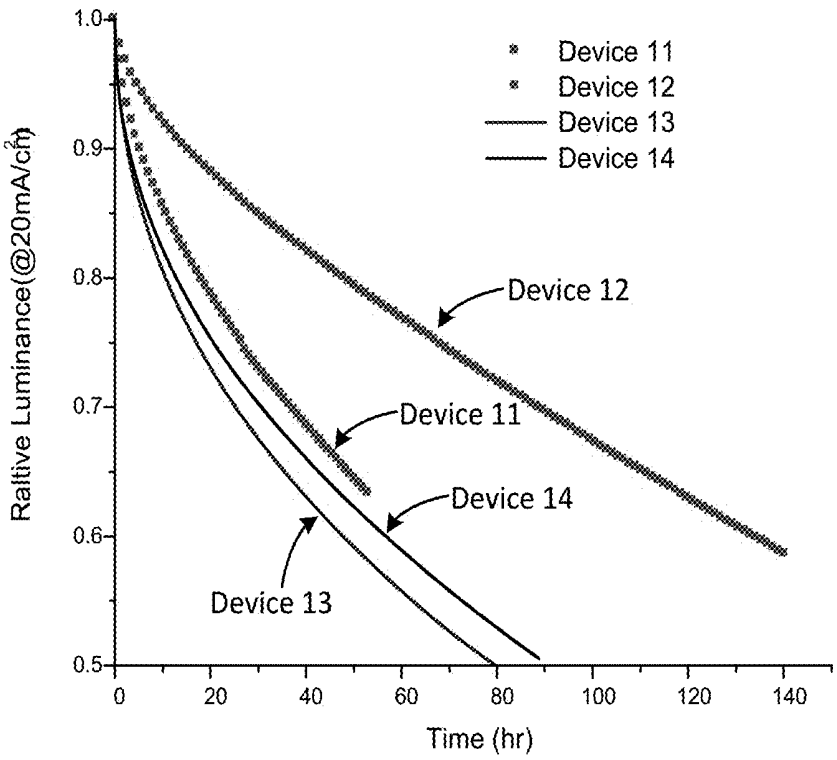

Device 11
Device 12
Device 13
Device 14
Raltive Luminance(@20mA/cm²)
1.0
0.9
0.8
0.7
0.6
0.5
0
20
40
60
80
100
120
140
Time (hr)
Device 12
Device 11
Device 14
Device 13

FIG. 9C

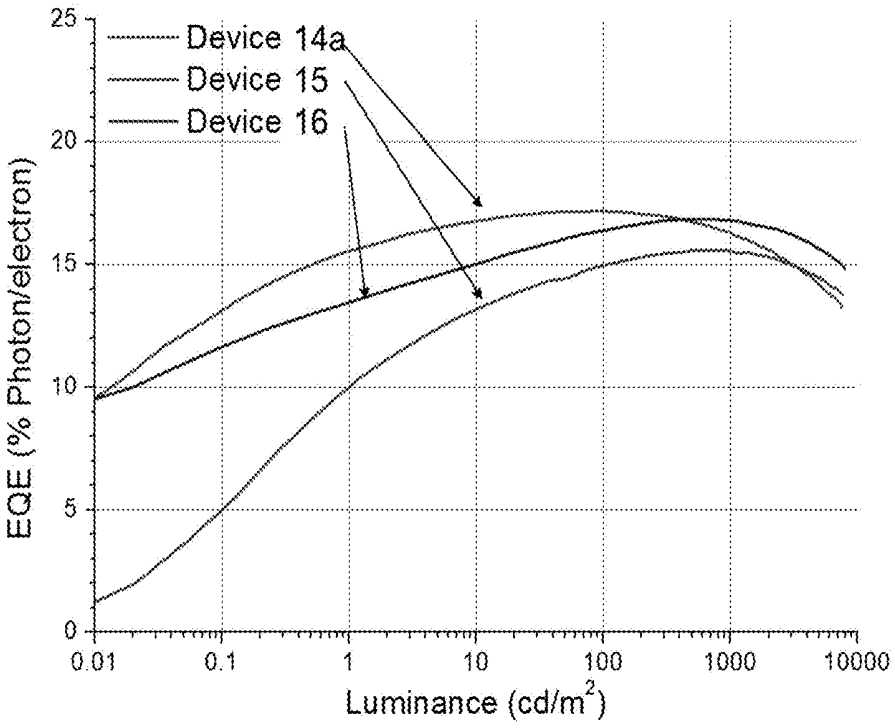

Device 14a
Device 15
Device 16
EQE (% Photon/electron)
Luminance (cd/m^2)
25
20
15
10
5
0
0.01
0.1
1
10
100
1000
10000

FIG. 9D

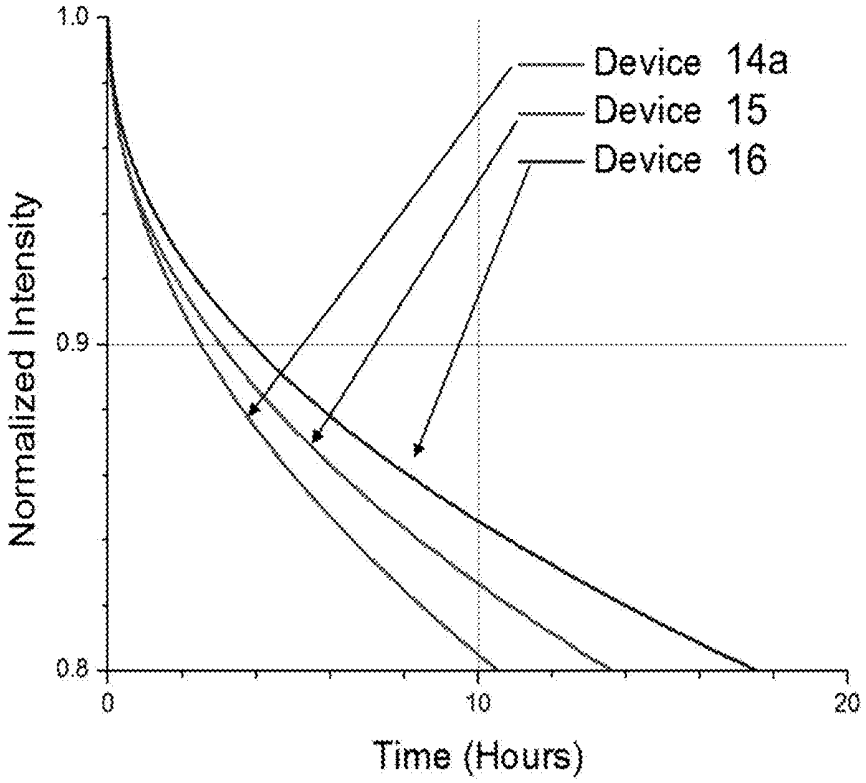

1.0
0.9
0.8
Normalized Intensity
0
10
20
Time (Hours)
Device 14a
Device 15
Device 16

FIG. 9E

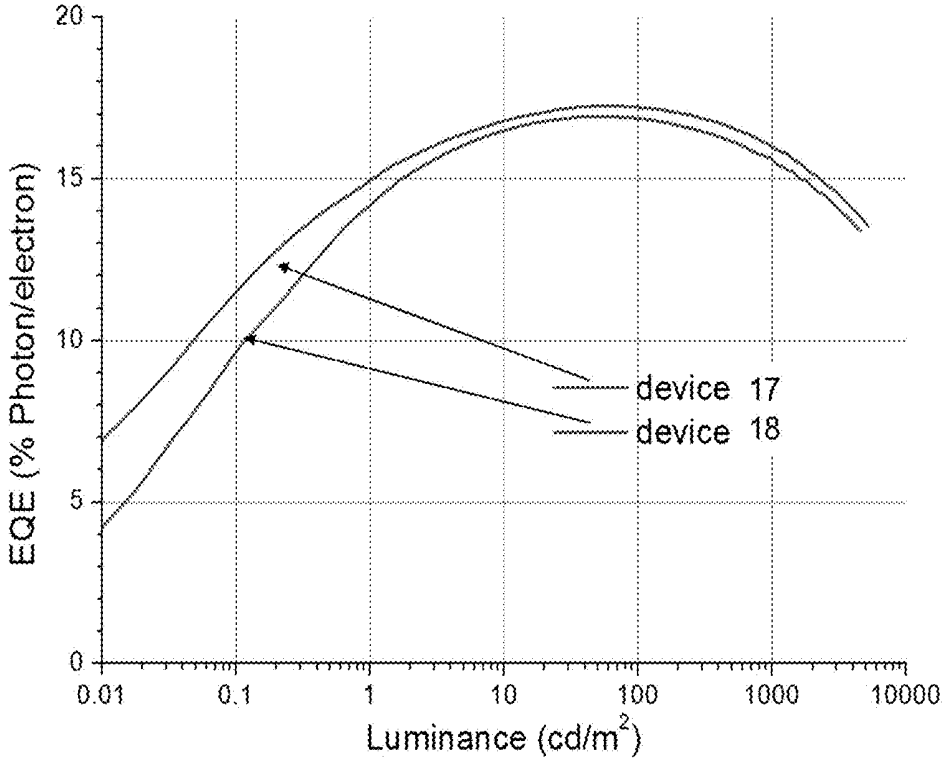


FIG. 10A

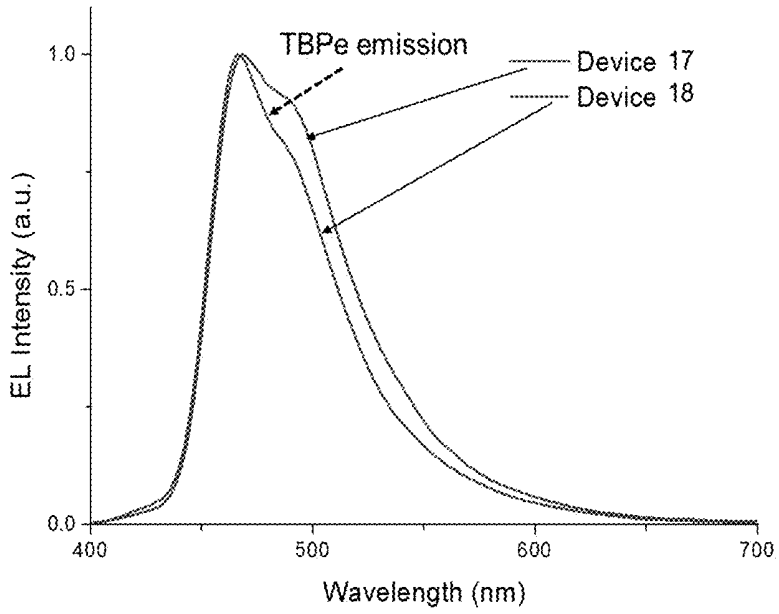


FIG. 10B

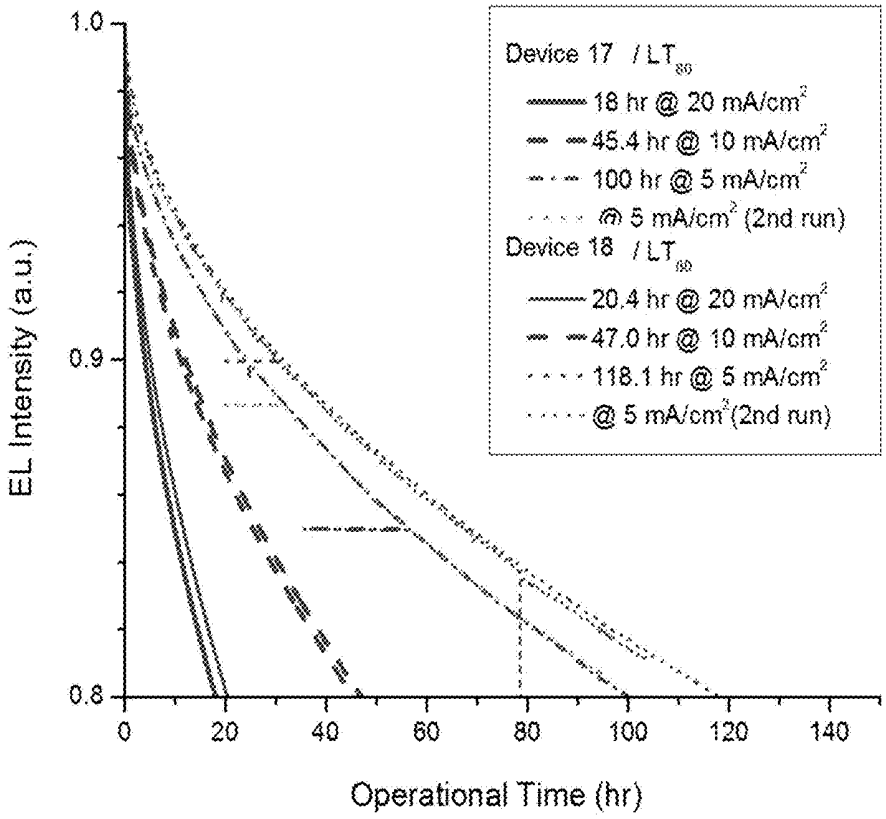

1.0
0.9
0.8
EL Intensity (a.u.)
0
20
40
60
80
100
120
140
Operational Time (hr)
Device 17 / LT80
18 hr @ 20 mA/cm2
45.4 hr @ 10 mA/cm2
100 hr @ 5 mA/cm2
@ 5 mA/cm2 (2nd run)
Device 18 / LT80
20.4 hr @ 20 mA/cm2
47.0 hr @ 10 mA/cm2
118.1 hr @ 5 mA/cm2
@ 5 mA/cm2(2nd run)

FIG. 11

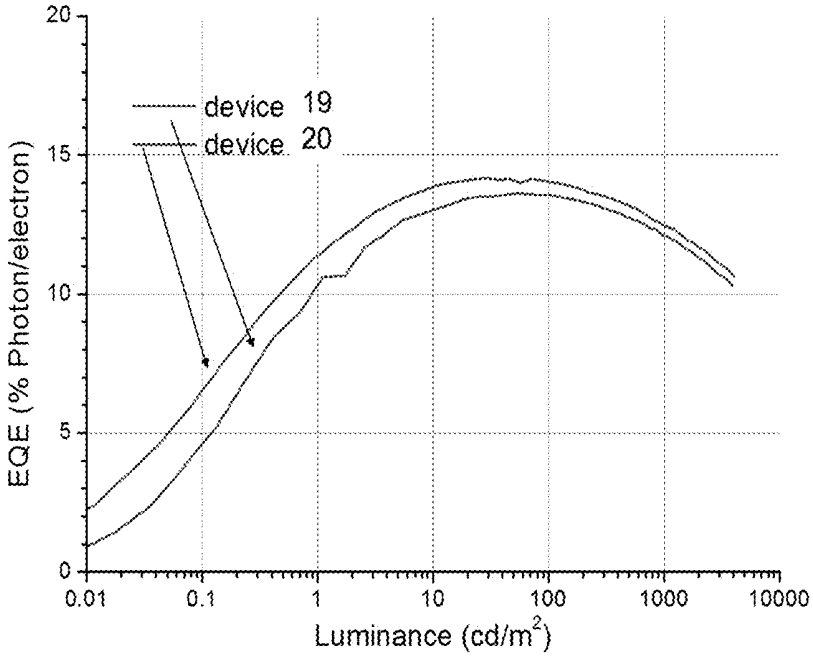


FIG. 12A

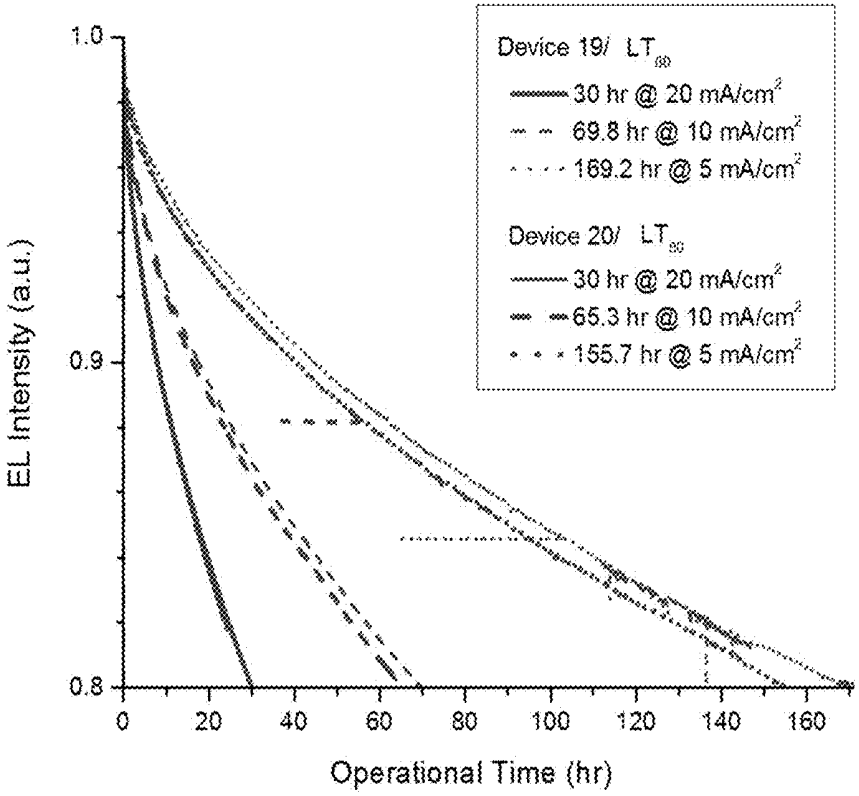


FIG.12B

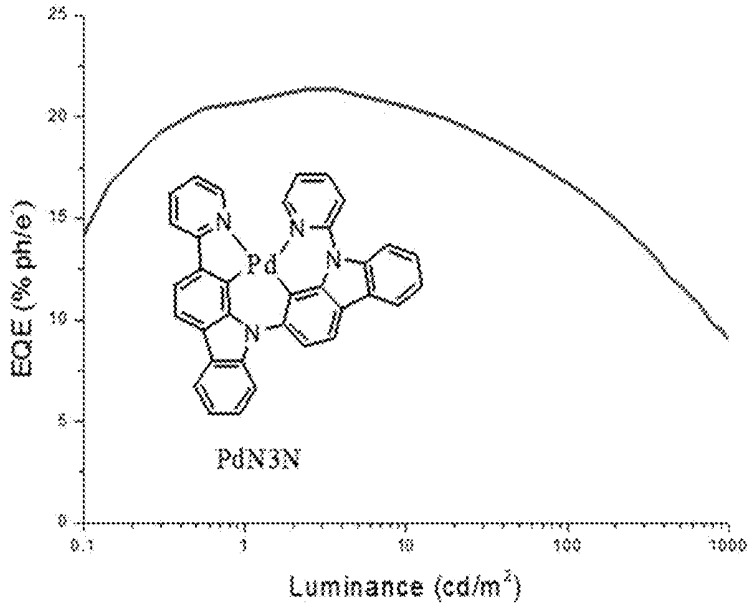

EQE (% ph/e)
Luminance (cd/m²)
PdN3N

FIG. 13

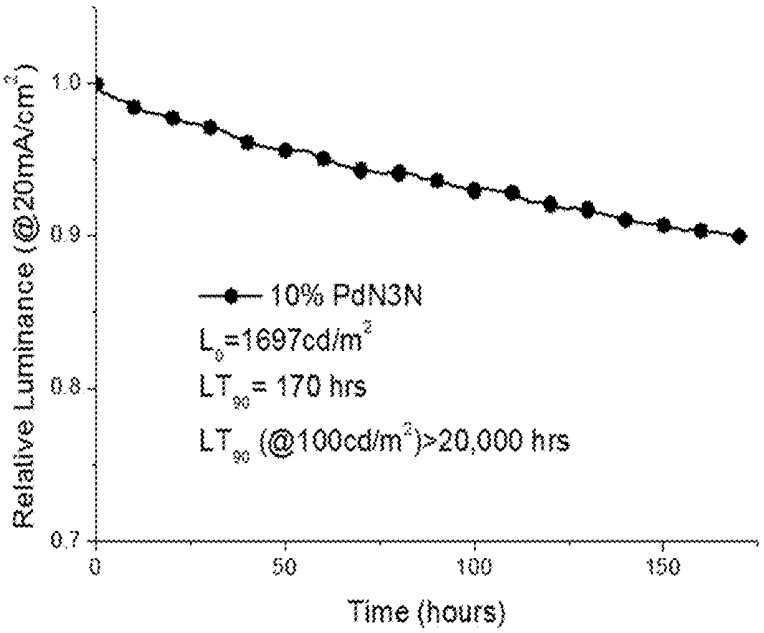

Relative Luminance (@20mA/cm²)
Time (hours)
10% PdN3N
L0=1697cd/m²
LT90= 170 hrs
LT90 (@100cd/m²)>20,000 hrs

FIG. 14

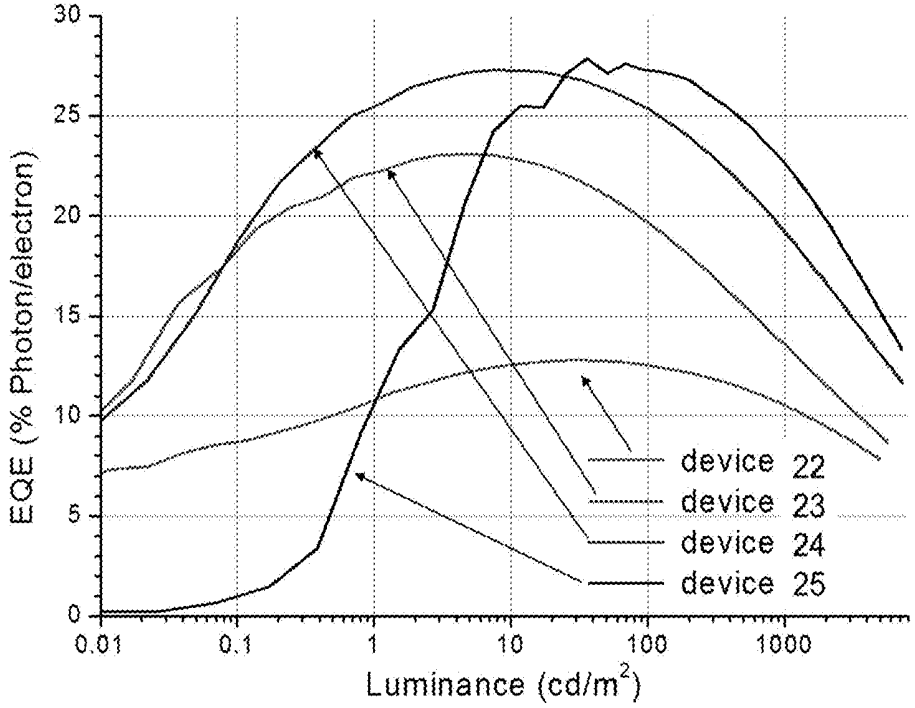


FIG. 15A

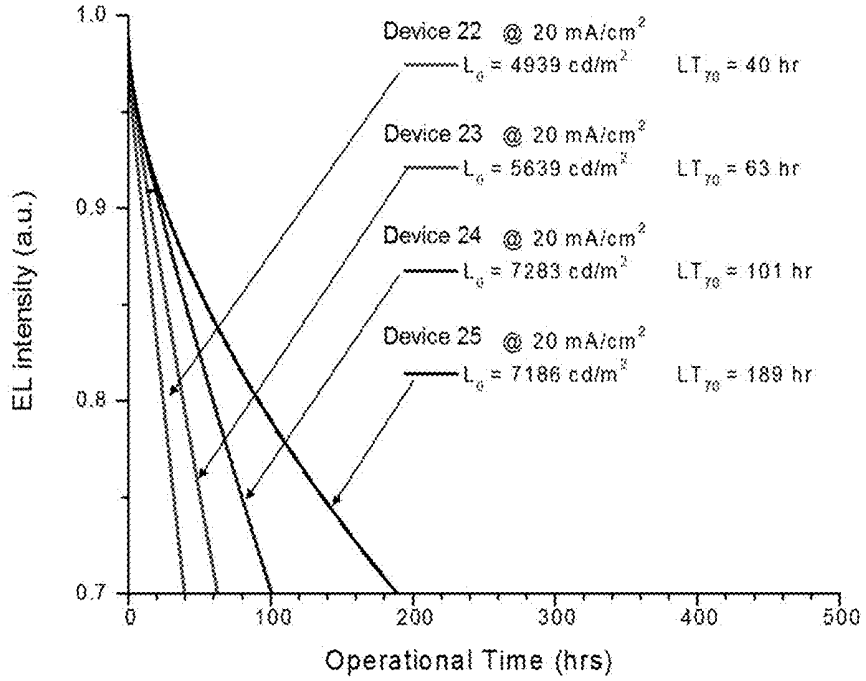


FIG. 15B

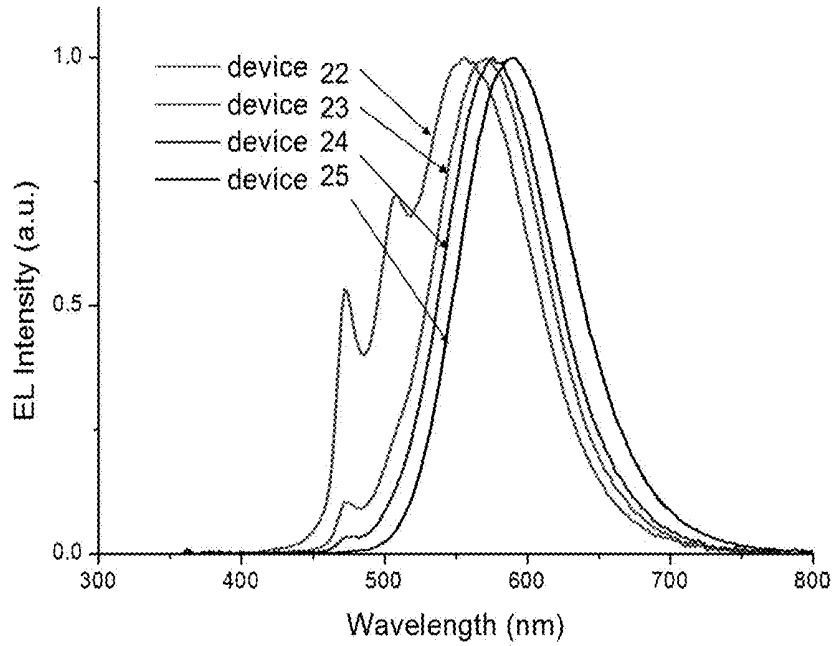


FIG. 15C

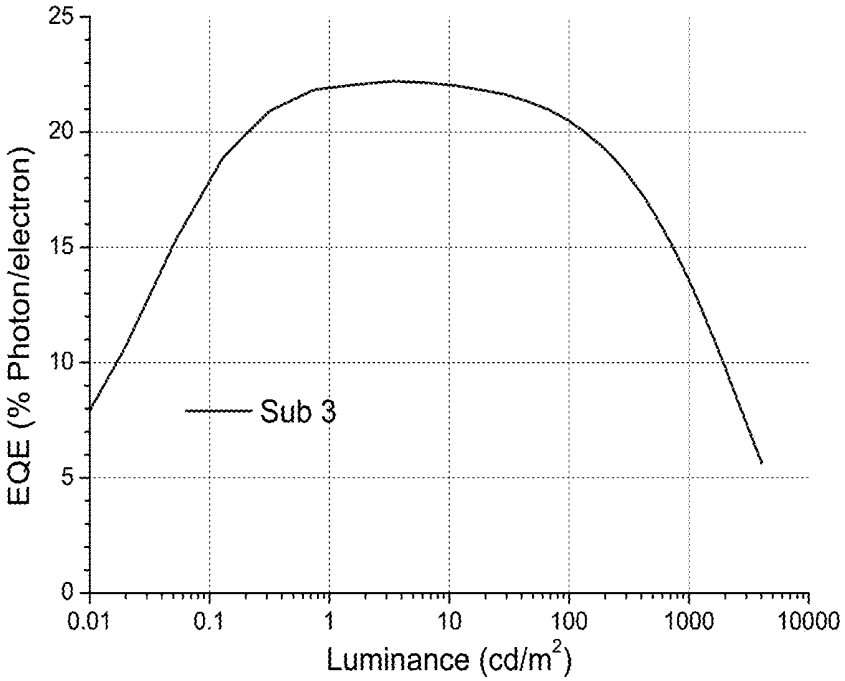


FIG. 16A

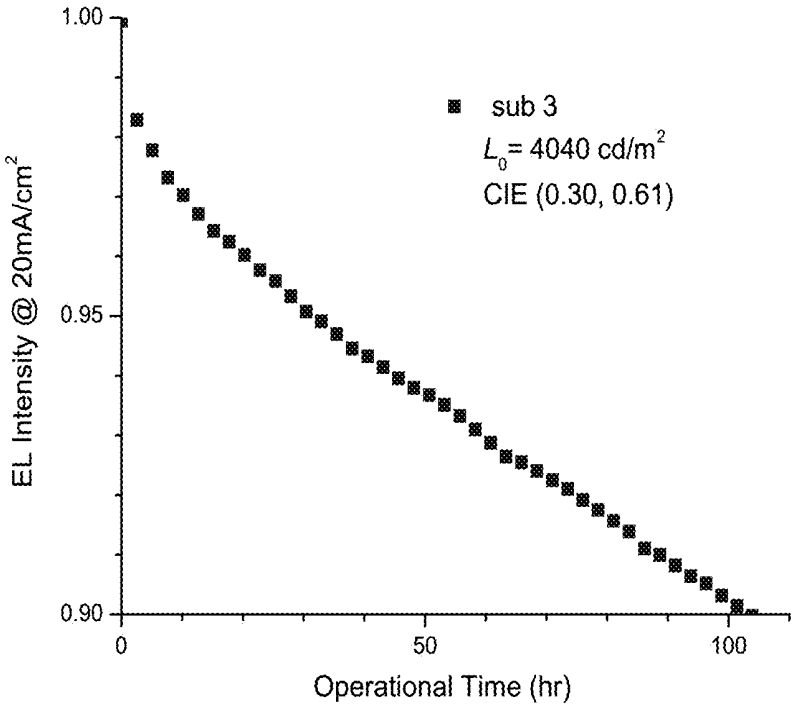

1.00
0.95
0.90
EL Intensity @ 20mA/cm^2
0
50
100
Operational Time (hr)
sub 3
L_0= 4040 cd/m^2
CIE (0.30, 0.61)

FIG. 16B

OLED WITH MULTI-EMISSIVE MATERIAL LAYER

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to U.S. Provisional Patent Application Nos. 62/323,383 filed on Apr. 15, 2016 and 62/377,747 filed on Aug. 22, 2016, which are hereby incorporated by reference in their entireties.

STATEMENT OF GOVERNMENT INTEREST

[0002] This invention was made with government support under DE-EE0007090 awarded by the Department of Energy. The government has certain rights in the invention.

TECHNICAL FIELD

[0003] The present invention relates to organic light emitting devices with a multi-emissive material layer (EML), where a multi-EML generally refers to an emissive layer having at least two layers of emissive material, each layer having a different emitter concentration (e.g. a first EML in direct contact with a second EML, and the emitter concentration of the first EML (hole favorable) exceeds that of the second EML (electron favorable)).

BACKGROUND

[0004] Compounds capable of absorbing and/or emitting light can be ideally suited for use in a wide variety of optical and electroluminescent devices, including, for example, photo-absorbing devices such as solar- and photo-sensitive devices, organic light emitting diodes (OLEDs), photo-emitting devices, and devices capable of both photo-absorption and emission and as markers for bio-applications. Much research has been devoted to the discovery and optimization of organic and organometallic materials for use in optical and electroluminescent devices. Generally, research in this area aims to accomplish a number of goals, including improvements in absorption and emission efficiency and improvements in the stability of devices, as well as improvements in processing ability. Despite significant advances in research devoted to optical and electro-optical materials, however, many currently available materials exhibit a number of disadvantages, including poor processing ability, inefficient emission or absorption, and less than ideal stability.

SUMMARY

[0005] The present disclosure relates to OLEDs with a multi-emissive material layer (EML), where a multi-EML generally refers to an emissive layer including at least a first EML including a first emitter in direct contact with a second EML including a second emitter, where the concentration of the first emitter in the first EML (hole favorable) exceeds the concentration of the second emitter in the second EML (electron favorable). In some cases, a multi-EML includes a third EML including a third emitter, where the concentration of the second emitter in the second EML exceeds the concentration of the third emitter in the third EML. In certain cases, a multi-EML includes a fourth EML including a fourth emitter, where the concentration of the third emitter in the third EML exceeds the concentration of the fourth emitter in the fourth EML. An OLED with a multi-EML typically has a doped electron blocking layer (EBL). OLEDs described herein have improved device efficiency and operational lifetime.

[0006] Variations, modifications, and enhancements of the described embodiments and other embodiments can be made based on what is described and illustrated. In addition, one or more features of one or more embodiments may be combined. The details of one or more implementations and various features and aspects are set forth in the accompanying drawings, the description, and the claims below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIGS. **1**A and **1**B depict cross-sectional views of exemplary OLEDs.

[0008] FIGS. **2**A and **2**B depict charge transporting and trapping for OLEDs with undoped and doped electron blocking layers, respectively.

[0009] FIGS. **3**A-**3**D show electroluminescent spectra, external quantum efficiency (EQE) versus luminance, power efficiency versus luminance, and operational lifetime, respectively, for OLEDs with undoped and doped electron blocking layers.

[0010] FIGS. **4**A and **4**B show EQE versus luminance and operation lifetime, respectively, for OLEDs with doped electron blocking layers, with and without an undoped electron blocking layer.

[0011] FIG. **5**A depicts charge transporting and trapping for a device having a single EML. FIG. **5**B depicts charge transporting and trapping for a device having a multi-EML.

[0012] FIGS. **6**A and **6**B show EQE versus current density and relative luminance versus operational time at a constant current of 20 mA/cm^2, respectively, for red-emitting OLEDs.

[0013] FIGS. **6**C and **6**D show EQE versus current density and relative luminance versus operational time, respectively, at a constant current of 20 mA/cm^2 for PtN3N devices. FIG. **6**E shows the LT_{97} lifetime versus current density for PtN3N devices.

[0014] FIGS. **7**A and **7**B show relative luminance versus operational time at various brightnesses for red-emitting OLEDS.

[0015] FIGS. **8**A and **8**B show EQE versus brightness and relative luminance versus operational time at the constant current of 20 mA/cm^2, respectively, for excimer-based white OLEDs.

[0016] FIG. **9**A shows EQE versus current density and electroluminescent spectra for blue-emitting devices. FIGS. **9**B and **9**C show plots of external quantum efficiency versus current density and relative luminance versus operational time at a constant current of 20 mA/cm^2 for blue-emitting devices.

[0017] FIGS. **9**D and **9**E show plots of EQE versus luminance and relative luminance versus operational time, respectively, at a constant current of 20 mA/cm^2 for PtNON.

[0018] FIGS. **10**A and **10**B show plots of EQE versus luminance and relative luminance versus wavelength, respectively, for devices with doped TBPe layer.

[0019] FIG. **11** shows a plot of relative intensity versus operational time for PtNON devices with doped TBPe layer.

[0020] FIGS. **12**A and **12**B show plots of EQE versus luminance and EL intensity versus operational time, respectively, for devices with doped TBPe layer.

[0021] FIG. **13** shows a plot of EQE versus luminance for PdN3N device.

[0022] FIG. **14** shows a plot of the relative intensity versus time for PdN3N device.

[0023] FIGS. **15**A and **15**B show plots of EQE versus luminance and EL intensity versus operational time, respectively, for Pd3O3 devices. FIG. **15**C shows a plot of El intensity versus wavelength for Pd3O3 devices.

[0024] FIGS. **16**A and **16**B show plots of EQE versus luminance and EL intensity versus operational time, respectively, for PdN3N devices.

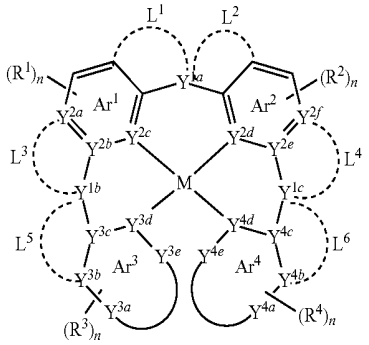
DETAILED DESCRIPTION

[0025] FIG. **1**A depicts a cross-sectional view of an OLED **100** with an EBL. OLED **100** includes substrate **102**, anode **104**, hole injection layer (HIL) **106**, hole transporting layer (HTL) **108**, electron blocking layer (EBL) **110**, emissive material layer (EML) **112**, hole blocking layer (HBL) **114**, electron transporting layer (ETL) **116**, hole injection layer (HIL) **118**, cathode **120**. Anode **104** is typically a transparent material, such as indium tin oxide (ITO). HIL **106** may include any suitable hole injecting material known in the art. The hole transporting material in HTL **108** may include any suitable hole-transporter known in the art. EBL **110** includes an electron blocking material as described herein, and may be doped or undoped. EML **112** typically includes an emitter and a host. The host may be any suitable host material known in the art. The emission color of an OLED is determined by the emission energy (optical energy gap) of the emissive material in EML **112**, which can be tuned by tuning the electronic structure of the emitting compounds, the host material, or both. EML **112** may be a single EML or a multi-EML. As used herein, "a single EML" generally refers to an EML having a uniform concentration of emitter throughout, and "a multi-EML" generally refers to an emissive layer having at least two layers of emissive material, each layer having a different emitter concentration (e.g. a first EML in direct contact with a second EML, and the emitter concentration of the first EML (hole favorable) exceeds that of the second EML (electron favorable)). As depicted in FIG. **1**A, first EML **112'** in direct contact with second EML **112"**, and the emitter concentration of the first EML (hole favorable) exceeds that of the second EML (electron favorable). HBL **114** is typically undoped, and may include any hole blocking material known in the art. ETL **116** may include any suitable electron-transporter known in the art. HIL **118** typically includes a buffer material, such as lithium fluoride (LiF). Cathode **120** is typically a metal, such as aluminum (Al). As depicted in FIG. **1**B, EBL **110** may include undoped layer **110'** and doped layer **110"**.

[0026] The electron blocking material, the dopant, or both in EBL **110** may be selected to extend the operational lifetime of an OLED with a doped EBL. In one example, the electron blocking material in EBL **110** is selected to confine excitons inside EML **112**, thereby reducing or eliminating exciton quenching by HTL **108** and extending the operational lifetime of the OLED. In another example, the electron blocking material in EBL **110** is selected to alleviate charge imbalance in EML **112**, thereby extending the operational lifetime of the OLED.

[0027] Organometallic complexes having Formula I may be used as emitters in the devices described herein:

(Formula I)



[0028] wherein:

[0029] M is Pt, Pd, or Ir;

[0030] R^1, R^2, R^3, R^4, R^8, R^9, and R^{10} each independently represents hydrogen, halogen, hydroxy, amino, nitro, thiol, substituted or unsubstituted C_1-C_4 alkyl, substituted or unsubstituted alkoxy, or substituted or unsubstituted aryl;

[0031] Y^{1a} represents O, S, S═O, O═S═O, Se, Se═O, O═Se═O, N, NR^{5a}, P, PR^{5a}, As, AsR^{5a}, O═NR^{5a}, O═PR^{5a}, O═AsR^{5a}, B, BR^{5a}, SiR^{5a}, $SiR^{5a}R^{5b}$, CR^{5a}, or $CR^{5a}R^{5b}$;

[0032] Y^{1b} and Y^{1c} each independently represents O, S, S═O, O═S═O, Se, Se═O, O═Se═O, N, NR^{5a}, P, PR^{5a}, As, AsR^{5a}, O═NR^{5a}, O═PR^{5a}, O═AsR^{5a}, B, BR^{5a}, SiR^{5a}, $SiR^{5a}R^{5b}$, CR^{5a}, $CR^{5a}R^{5b}$, or a single bond, wherein if Y^{1b} represents a single bond, Y^{2e} and Y^{4c} are directly linked by a single bond, and if Y^{1c} represents a single bond, Y^{2b} and Y^{3c} are directly linked by a single bond;

[0033] Y^{2a}, Y^{2b}, Y^{2c}, Y^{2d}, Y^{2e}, and Y^{2f} each independently represents C or N;

[0034] R^{5a}, R^{5b}, and R^{5c} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl;

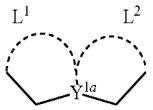
[0035] R^{6a}, R^{6b}, and R^{6c} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl;

[0036] R^{7a}, R^{7b}, and R^{7c} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl;

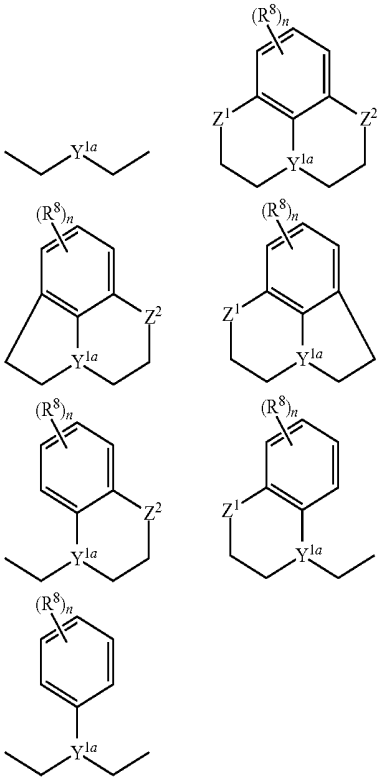
[0037] Y^{3a}, Y^{3b}, Y^{3c}, Y^{3d}, and Y^{3e} each independently represents C, N, Si, O, or S;

[0038] Y^{4a}, Y^{4b}, Y^{4c}, Y^{4d}, and Y^{4e} each independently represents C, N, Si, O, or S;

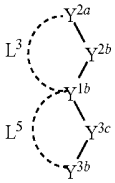
[0039] each of L^1, L^2, L^3, L^4, L^5, and L^6 is independently absent or represents a linking group;



represents one of the following:



[0040] wherein Z^1, Z^2 independently represents O, S, S═O, O═S═O, Se, Se═O, O═Se═O, NR^{5a}, PR^{5a}, AsR^{5a}, O═NR^{5a}, O═PR^{5a}, O═AsR^{5a}, BR^{5a}, $SiR^{5a}R^{5b}$, or $CR^{5a}R^{5b}$;



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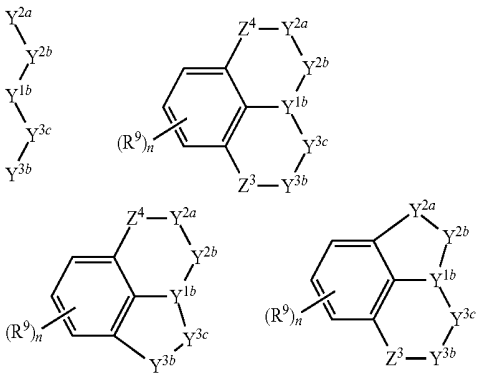

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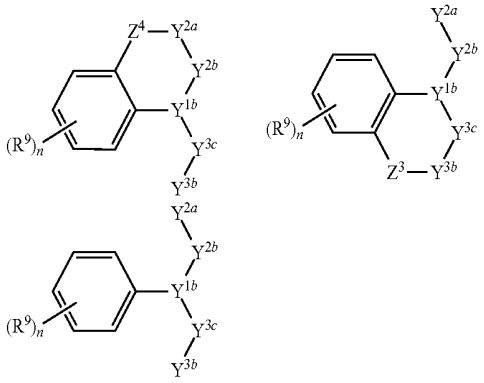
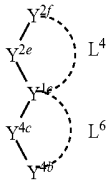
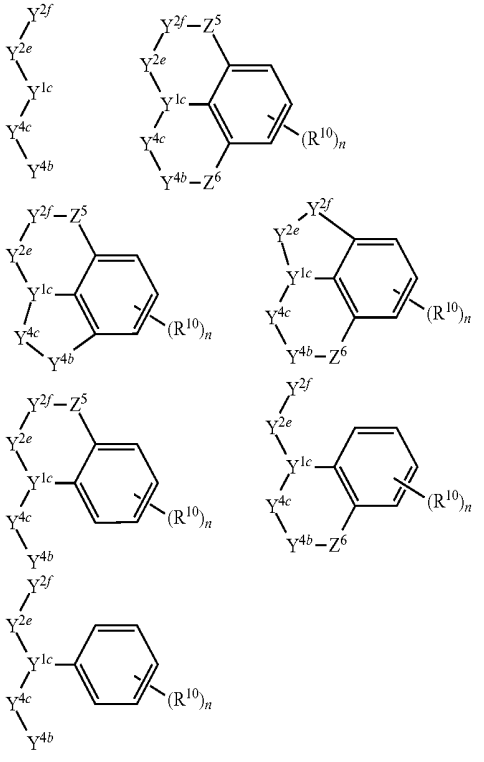


[0041] wherein Z^3 and Z^4 each independently represents O, S, S═O, O═S═O, Se, Se═O, O═Se═O, NR^{6a}, PR^{6a}, AsR^{6a}, O═NR^{6a}, O═PR^{6a}, O═AsR^{6a}, BR^{6a}, $SiR^{6a}R^{6b}$, or $CR^{6a}R^{6b}$;



represents one of the following:



[0042] wherein Z^5 and Z^6 each independently represents O, S, S═O, O═S═O, Se, Se═O, O═Se═O, NR^{7a}, PR^{7a}, AsR^{7a}, O═NR^{7a}, O═PR^{7a}, O═AsR^{7a}, BR^{7a}, $SiR^{7a}R^{7b}$, or $CR^{7a}R^{7b}$;

[0043] Ar^3 and Ar^4 each independently represents a substituted or unsubstituted 5-membered ring or a 6-membered aromatic ring; and

[0044] n is 0, 1, 2, 3, 4, or 5.

[0045] In some implementations, wherein M is Pt(II) or Pd(II).

[0046] In some implementations, R^2, R^3, R^4, R^8, R^9, and R^{10} each independently represents hydrogen, halogen, hydroxy, amino, substituted or unsubstituted C_1-C_4 alkyl, or substituted or unsubstituted alkoxy. In some implementations, R^2, R^3, R^4, R^8, R^9, and R^{10} each independently represents hydrogen, halogen, hydroxy, or substituted or unsubstituted C_1-C_4 alkyl. In some implementations, R^2, R^3, R^4, R^8, R^9, and R^{10} each independently represents hydrogen or substituted or unsubstituted C_1-C_4 alkyl.

[0047] In some implementations, Y^{1a} represents O, S, S═O, O═S═O, Se, N, NR^{5a}, P, PR^{5a}, As, AsR^{5a}, B, BR^{5a}, SiR^{5a}, $SiR^{5a}R^{5b}$, CR^{5a}, or $CR^{5a}R^{5b}$. In some implementations, Y^{1a} represents O, S, N, NR^{5a}, P, PR^{5a}, SiR^{5a}, $SiR^{5a}R^{5b}$, CR^{5a}, or $CR^{5a}R^{5b}$. In some implementations, Y^{1a} represents O, S, NR^{5a}, PR^{5a}, $SiR^{5a}R^{5b}$, or $CR^{5a}R^{5b}$.

[0048] In some implementations, Y^{1b} and Y^{1c} each independently represents O, S, S═O, O═S═O, Se, N, NR^{5a}, P, PR^{5a}, As, AsR^{5a}, B, BR^{5a}, SiR^{5a}, $SiR^{5a}R^{5b}$, CR^{5a}, $CR^{5a}R^{5b}$, or a single bond, wherein if Y^{1b} represents a single bond, Y^{2e} and Y^{4c} are directly linked by a single bond, and if Y^{1c} represents a single bond, Y^{2b} and Y^{3c} are directly linked by a single bond.

[0049] In some implementations, Y^{1b} and Y^{1c} each independently represents O, S, N, NR^{5a}, P, PR^{5a}, SiR^{5a}, $SiR^{5a}R^{5b}$, CR^{5a}, $CR^{5a}R^{5b}$, or a single bond, wherein if Y^{1b} represents a single bond, Y^{2e} and Y^{4c} are directly linked by a single bond, and if Y^{1c} represents a single bond, Y^{2b} and Y^{3c} are directly linked by a single bond.

[0050] In some implementations, Y^{1b} and Y^{1c} each independently represents N, P, SiR^{5a}, or CR^{5a}, or a single bond, wherein if Y^{1b} represents a single bond, Y^{2e} and Y^{4c} are directly linked by a single bond, and if Y^{1c} represents a single bond, Y^{2b} and Y^{3c} are directly linked by a single bond.

[0051] In some implementations, Y^{2a}, Y^{2b}, Y^{2c}, Y^{2d}, Y^{2c}, and Y^{2f} each independently represents C. In some implementations, Y^{2a}, Y^{2b}, Y^{2c}, Y^{2d}, Y^{2e}, and Y^{2f} each independently represents N.

[0052] In some implementations, R^{5a}, R^{5b}, and R^{5c} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl. In some implementations, R^{5a}, R^{5b}, and R^{5c} each independently represents substituted or unsubstituted aryl.

[0053] In some implementations, R^{6a}, R^{6b}, and R^{6c} each independently represents substituted or unsubstituted C_1-C_4 alkyl. In some implementations, R^{6a}, R^{6b}, and R^{6c} each independently represents or substituted or unsubstituted aryl.

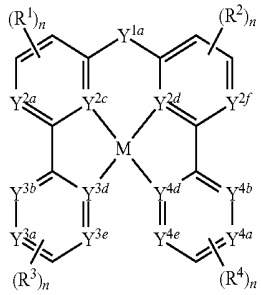
[0054] In some implementations, R^{7a}, R^{7b}, and R^{7c} each independently represents substituted or unsubstituted C_1-C_4 alkyl. In some implementations, R^{7a}, R^{7b}, and R^{7c} each independently represents or substituted or unsubstituted aryl.

[0055] In some implementations, Y^{3a}, Y^{3b}, Y^{3c}, Y^{3d}, and Y^{3e} each independently represents C or Si. In some implementations, Y^{3a}, Y^{3b}, Y^{3c}, Y^{3d}, and Y^{3e} each independently represents O or S. In some implementations, Y^{3a}, Y^{3b}, Y^{3c}, Y^{3d}, and Y^{3e} each independently represents C or N.

[0056] In some implementations, Y^{4a}, Y^{4b}, Y^{4c}, Y^{4d}, and Y^{4e} each independently represents C or Si. In some implementations, Y^{4a}, Y^{4b}, Y^{4c}, Y^{4d}, and Y^{4e} each independently represents O or S. In some implementations, Y^{4a}, Y^{4b}, Y^{4c}, Y^{4d}, and Y^{4e} each independently represents C or N.

[0057] In some implementations, the organometallic complex is represented by Formula II:

(Formula II)



[0058] wherein:

[0059] M is Pt, Pd, or Ir;

[0060] R^1, R^2, R^3, and R^4 each independently represents hydrogen, halogen, hydroxy, amino, nitro, thiol, substituted or unsubstituted C_1-C_4 alkyl, substituted or unsubstituted alkoxy, or substituted or unsubstituted aryl;

[0061] Y^{1a} represents O, S, S═O, O═S═O, Se, Se═O, O═Se═O, NR^{5a}, PR^{5a}, AsR^{5a}, O═NR^{5a}, O═PR^{5a}, O═AsR^{5a}, BR^{5a}, $SiR^{5a}R^{5b}$, or $CR^{5a}R^{5b}$;

[0062] Y^{2a}, Y^{2c}, Y^{2d}, and Y^{2f} each independently represents C or N;

[0063] R^{5a}, R^{5b}, and R^{5c} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl;

[0064] Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents C, N, or Si;

[0065] Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents C, N, or Si;

[0066] n is 0, 1, 2, 3, or 4.

[0067] In some implementations, the organometallic complex is represented by Formula II wherein:

[0068] M is Pt or Pd;

[0069] R^1, R^2, R^3, and R^4 each independently represents hydrogen, halogen, hydroxy, amino, nitro, thiol, substituted or unsubstituted C_1-C_4 alkyl, substituted or unsubstituted alkoxy, or substituted or unsubstituted aryl;

[0070] Y^{1a} represents O, S, NR^{5a}, PR^{5a}, $SiR^{5a}R^{5b}$, or $CR^{5a}R^{5b}$;

[0071] Y^{2a}, Y^{2c}, Y^{2d}, and Y^{2f} each independently represents C or N;

[0072] R^{5a}, R^{5b}, and R^{5c} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl;

[0073] Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents C or N;

[0074] Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents C or N;

[0075] n is 0, 1, or 2.

[0076] In some implementations, the organometallic complex is represented by Formula II wherein M is Pt or Pd.

[0077] In some implementations, the organometallic complex is represented by Formula II wherein R^1, R^2, R^3, and R^4 each independently represents hydrogen, halogen, hydroxy, amino, substituted or unsubstituted C_1-C_4 alkyl, substituted or unsubstituted alkoxy, or substituted or unsubstituted aryl. In some implementations, the organometallic complex is represented by Formula II wherein R^1, R^2, R^3, and R^4 each independently represents hydrogen, halogen, hydroxy, amino, substituted or unsubstituted C_1-C_4 alkyl. In some implementations, the organometallic complex is represented by Formula II wherein R^1, R^2, R^3, and R^4 each independently represents hydrogen or substituted or unsubstituted C_1-C_4 alkyl.

[0078] In some implementations, the organometallic complex is represented by Formula II wherein Y^{1a} represents O, S, S═O, O═S═O, Se, NR^{5a}, PR^{5a}, AsR^{5a}, BR^{5a}, $SiR^{5a}R^{5b}$, or $CR^{5a}R^{5b}$. In some implementations, the organometallic complex is represented by Formula II wherein Y^{1a} represents O, S, NR^{5a}, PR^{5a}, $SiR^{5a}R^{5}$b, or $CR^{5a}R^{5b}$. In some implementations, the organometallic complex is represented by Formula II wherein Y^{1a} represents O, S, NR^{5a}, $SiR^{5a}R^{5b}$, or $CR^{5a}R^{5b}$. In some implementations, the organometallic complex is represented by Formula II wherein Y^{1a} represents O, NR^{5a}, or $CR^{5a}R^{5b}$.

[0079] In some implementations, the organometallic complex is represented by Formula II wherein Y^{2a}, Y^{2c}, Y^{2d}, and Y^{2f} each independently represents C. In some implementations, the organometallic complex is represented by Formula II wherein Y^{2a}, Y^{2c}, Y^{2d}, and Y^{2f} each independently represents N.

[0080] In some implementations, the organometallic complex is represented by Formula II wherein R^{5a}, R^{5b}, and R^{5c} each independently represents substituted or unsubstituted C_1-C_4 alkyl. In some implementations, the organometallic complex is represented by Formula II wherein R^{5a}, R^{5b}, and R^{5c} each independently represents substituted or unsubstituted aryl.

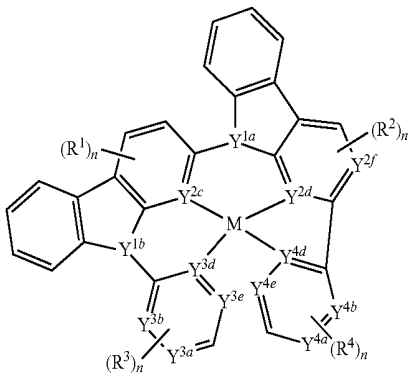
[0081] In some implementations, the organometallic complex is represented by Formula II wherein Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents C or N. In some implementations, the organometallic complex is represented by Formula II wherein Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents C or Si.

[0082] In some implementations, the organometallic complex is represented by Formula II wherein Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents C or N. In some implementations, the organometallic complex is represented by Formula II wherein Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents C or Si.

[0083] In some implementations, the organometallic complex is represented by Formula II wherein n is 0, 1, 2, or 3. In some implementations, the organometallic complex is represented by Formula II wherein n is 1. In some implementations, the organometallic complex is represented by Formula II wherein n is 0.

[0084] In some implementations, the organometallic complex is represented by Formula III:

(Formula III)



[0085] wherein:

[0086] M is Pt, Pd, or Ir;

[0087] R^1, R^2, R^3, and R^4 each independently represents hydrogen, halogen, hydroxy, amino, nitro, thiol, substituted or unsubstituted C_1-C_4 alkyl, substituted or unsubstituted alkoxy, or substituted or unsubstituted aryl;

[0088] Y^{1a} represents N, P, As, B, SiR^{5a}, or CR^{5a};

[0089] Y^{1b} represents N, P, As, B, SiR^{5a}, or CR^{5a};

[0090] Y^{2c}, Y^{2d}, and Y^{2f} each independently represents C or N;

[0091] R^{5a} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl;

[0092] Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents C, N, or Si;

[0093] Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents C, N, or Si; and

[0094] n is 0, 1, 2, 3, 4, or 5.

[0095] In some implementations, the organometallic complex is represented by Formula III wherein:

[0096] M is Pt or Pd;

[0097] R^1, R^2, R^3, and R^4 each independently represents hydrogen, halogen, hydroxy, amino, nitro, thiol, substituted or unsubstituted C_1-C_4 alkyl, substituted or unsubstituted alkoxy, or substituted or unsubstituted aryl;

[0098] Y^{1a} represents N, P, SiR^{5a}, or CR^{5a};

[0099] Y^{1b} represents N, P, SiR^{5a}, or CR^{5a};

[0100] Y^{2c}, Y^{2d}, Y^{3d}, and Y^{2f} each independently represents C or N;

[0101] R^{5a} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl;

[0102] Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents C or N;

[0103] Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents C or N; and

[0104] n is 0, 1, or 2.

[0105] In some implementations, the organometallic complex is represented by Formula III wherein M is Pt or Pd. In some implementations, the organometallic complex is represented by Formula III wherein R^1, R^2, R^3, and R^4 each independently represents hydrogen, halogen, hydroxy, amino, substituted or unsubstituted C_1-C_4 alkyl, substituted or unsubstituted alkoxy, or substituted or unsubstituted aryl.

In some implementations, the organometallic complex is represented by Formula III wherein R^1, R^2, R^3, and R^4 each independently represents hydrogen, halogen, hydroxy, amino, or substituted or unsubstituted C_1-C_4 alkyl. In some implementations, the organometallic complex is represented by Formula III wherein R^1, R^2, R^3, and R^4 each independently represents hydrogen or substituted or unsubstituted C_1-C_4 alkyl.

[0106] In some implementations, the organometallic complex is represented by Formula III wherein Y^{1a} represents N, P, SiR^{5a}, or CR^{5a}. In some implementations, the organometallic complex is represented by Formula III wherein Y^{1a} represents N or P. In some implementations, the organometallic complex is represented by Formula III wherein Y^{1a} represents SiR^{5a}or CR^{5a}. In some implementations, the organometallic complex is represented by Formula III wherein Y^{1a} represents N or CR^{5a}.

[0107] In some implementations, the organometallic complex is represented by Formula III wherein Y^{1b} represents N, P, SiR^{5a}, or CR^{5a}. In some implementations, the organometallic complex is represented by Formula III wherein Y^{1b} represents N or P. In some implementations, the organometallic complex is represented by Formula III wherein Y^{1b} represents SiR^{5a}or CR^{5a}. In some implementations, the organometallic complex is represented by Formula III wherein Y^{1b} represents N or CR^{5a}.

[0108] In some implementations, the organometallic complex is represented by Formula III wherein Y^{2c}, Y^{2d}, and Y^{2f} each independently represents C. In some implementations, the organometallic complex is represented by Formula III wherein Y^{2c}, Y^{2d}, and Y^{2f} each independently represents N.

[0109] In some implementations, the organometallic complex is represented by Formula III wherein R^{5a} each independently represents substituted or unsubstituted C_1-C_4 alkyl. In some implementations, the organometallic complex is represented by Formula III wherein R^{5a} each independently represents substituted or unsubstituted aryl.

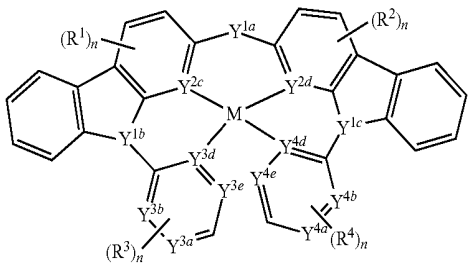
[0110] In some implementations, the organometallic complex is represented by Formula III wherein Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents C or N. In some implementations, the organometallic complex is represented by Formula III wherein Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents C or Si. In some implementations, the organometallic complex is represented by Formula III wherein Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents N.

[0111] In some implementations, the organometallic complex is represented by Formula III wherein Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} represents C or N. In some implementations, the organometallic complex is represented by Formula III wherein Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents C or Si. In some implementations, the organometallic complex is represented by Formula III wherein Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents N.

[0112] In some implementations, the organometallic complex is represented by Formula III wherein n is 0, 1, 2, or 3. In some implementations, the organometallic complex is represented by Formula III wherein n is 0. In some implementations, the organometallic complex is represented by Formula III wherein n is 1.

[0113] In some implementations, the organometallic complex is represented by Formula IV:

(Formula IV)



[0114] wherein:

[0115] M is Pt, Pd, or Ir;

[0116] R^1, R^2, R^3, or R^4 each independently represents hydrogen, halogen, hydroxy, amino, nitro, thiol, substituted or unsubstituted C_1-C_4 alkyl, substituted or unsubstituted alkoxy, or substituted or unsubstituted aryl;

[0117] Y^{1a} represents O, S, S═O, O═S═O, Se, Se═O, O═Se═O, NR^{5a}, PR^{5a}, AsR^{5a}, O═NR^{5a}, O═PR^{5a}, O═AsR^{5a}, BR^{5a}, $SiR^{5a}R^{5b}$, or $CR^{5a}R^{5b}$;

[0118] Y^{1b} and Y^{1c} each independently represents N, P, As, B, SiR^{5a}, or CR^{5a},

[0119] Y^{2c} or Y^{2d} each independently represents C or N;

[0120] R^{5a} and R^{5b} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl;

[0121] Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents C, N, or Si;

[0122] Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents C, N, or Si; and

[0123] n is 0, 1, 2, 3, 4, or 5.

[0124] In some implementations, the organometallic complex is represented by Formula IV wherein:

[0125] M is Pt or Pd;

[0126] R^1, R^2, R^3, or R^4 each independently represents hydrogen, halogen, hydroxy, amino, nitro, thiol, substituted or unsubstituted C_1-C_4 alkyl, substituted or unsubstituted alkoxy, or substituted or unsubstituted aryl;

[0127] Y^{1a} represents O, S, NR^{5a}, PR^{5a}, $SiR^{5a}R^{5b}$, or $CR^{5a}R^{5b}$;

[0128] Y^{1b} and Y^{1c} each independently represents N, P, SiR^{5a}, or CR^{5a},

[0129] Y^{2c} or Y^{2d} each independently represents C or N;

[0130] R^{5a} and R^{5b} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl;

[0131] Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents C or N;

[0132] Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents C or N; and

[0133] n is 0, 1, or 2.

[0134] In some implementations, the organometallic complex is represented by Formula IV wherein M is Pt or Pd.

[0135] In some implementations, the organometallic complex is represented by Formula IV wherein R^1, R^2, R^3, or R^4 each independently represents hydrogen, halogen, hydroxy, amino, substituted or unsubstituted C_1-C_4 alkyl, substituted or unsubstituted alkoxy, or substituted or unsubstituted aryl. In some implementations, the organometallic complex is

represented by Formula IV wherein R^1, R^2, R^3, or R^4 each independently represents hydrogen, halogen, hydroxy, amino, substituted or unsubstituted C_1-C_4 alkyl. In some implementations, the organometallic complex is represented by Formula IV wherein R^1, R^2, R^3, or R^4 each independently represents hydrogen or substituted or unsubstituted C_1-C_4 alkyl.

[0136] In some implementations, the organometallic complex is represented by Formula IV wherein Y^{1a} represents O, S, S═O, O═S═O, Se, Se═O, O═Se═O, NR^{5a}, PR^{5a}, AsR^{5a}, BR^{5a}, $SiR^{5a}R^{5b}$, or $CR^{5a}R^{5b}$. In some implementations, the organometallic complex is represented by Formula IV wherein Y^{1a} represents O, S, S═O, O═S═O, NR^{5a}, PR^{5a}, BR^{5a}, $SiR^{5a}R^{5b}$, or $CR^{5a}R^{5b}$. In some implementations, the organometallic complex is represented by Formula IV wherein Y^{1a} represents O, S, NR^{5a}, PR^{5a}, $SiR^{5a}R^{5b}$, or $CR^{5a}R^{5b}$. In some implementations, the organometallic complex is represented by Formula IV wherein Y^{1a} represents O, NR^{5a}, or $CR^{5a}R^{5b}$.

[0137] In some implementations, the organometallic complex is represented by Formula IV wherein Y^{1b} and Y^{1c} each independently represents N, P, SiR^{5a}, or CR^{5a}. In some implementations, the organometallic complex is represented by Formula IV wherein Y^{1b} and Y^{1c} each independently represents N or P. In some implementations, the organometallic complex is represented by Formula IV wherein Y^{1b} and Y^{1c} each independently represents SiR^{5a}or CR^{5a}. In some implementations, the organometallic complex is represented by Formula IV wherein Y^{1b} and Y^{1c} each independently represents N or CR^{5a}.

[0138] In some implementations, the organometallic complex is represented by Formula IV wherein Y^{2c} or Y^{2d} each independently represents C. In some implementations, the organometallic complex is represented by Formula IV wherein Y^{2c} or Y^{2d} each independently represents N.

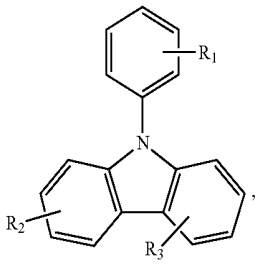
[0139] In some implementations, the organometallic complex is represented by Formula IV wherein R^{5a} and R^{5b} each independently represents substituted or unsubstituted C_1-C_4 alkyl. In some implementations, the organometallic complex is represented by Formula IV wherein R^{5a} and R^{5b} each independently represents substituted or unsubstituted aryl.

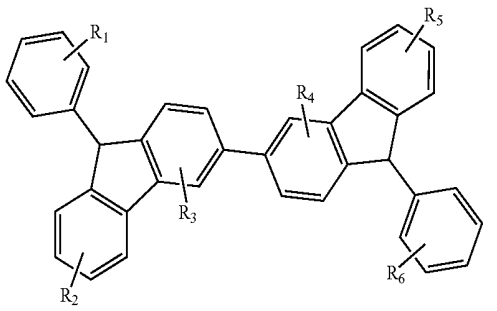
[0140] In some implementations, the organometallic complex is represented by Formula IV wherein Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents C or N. In some implementations, the organometallic complex is represented by Formula IV wherein Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents C or Si. In some implementations, the organometallic complex is represented by Formula IV wherein Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents N.

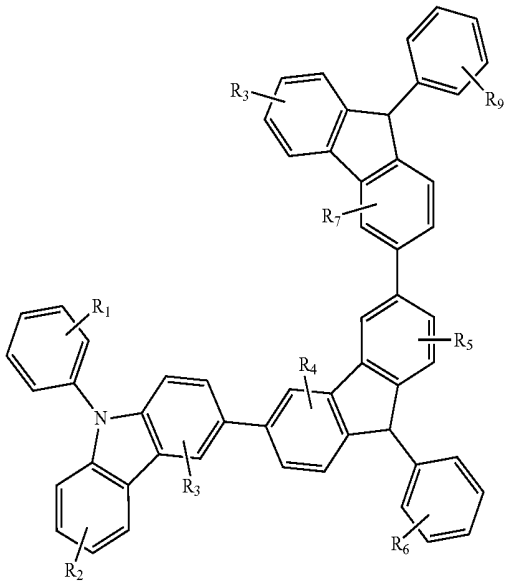
[0141] In some implementations, the organometallic complex is represented by Formula IV wherein Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents C, N, or Si. In some implementations, the organometallic complex is represented by Formula IV wherein Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents C or N. In some implementations, the organometallic complex is represented by Formula IV wherein Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents C or Si. In some implementations, the organometallic complex is represented by Formula IV wherein Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents N.

[0142] In some implementations, the organometallic complex is represented by Formula IV wherein n is 0, 1, 2, or 3. In some implementations, the organometallic complex is represented by Formula IV wherein n is 0. In some implementations, the organometallic complex is represented by Formula IV wherein n is 1.

[0143] Suitable electron blocking materials include carbazole based host materials, such as those shown below.

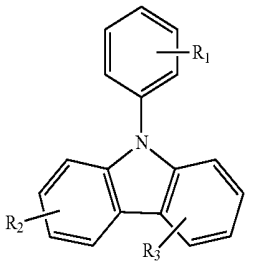






where each of R^1-R^9 is independently hydrogen, nitro, hydroxyl, halogen, or substituted or unsubstituted amino, thio, alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkane, cycloalkane, heterocyclyl, alkoxy, haloalkyl, arylalkane, or arylalkene.

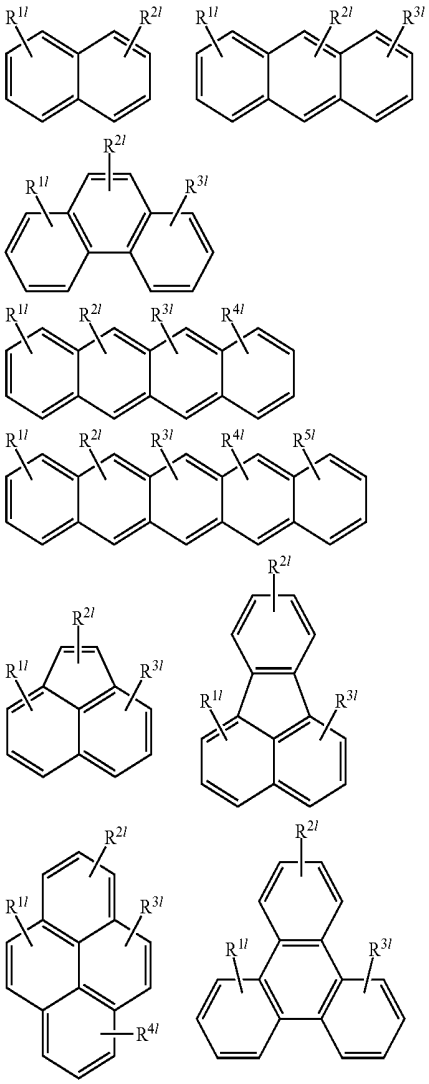
[0144] In some implementations, suitable electron blocking materials include carbazole based host materials, such as those shown below.



where each of R^1-R^3 is independently hydrogen, nitro, hydroxyl, halogen, or substituted or unsubstituted amino, thio, alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkane, cycloalkane, heterocyclyl, alkoxy, haloalkyl, arylalkane, or arylalkene.

[0145] As described herein, a doped electron blocking material includes a fluorescent dopant. Suitable fluorescent dopants include those shown below.

[0146] 1. Aromatic Hydrocarbons and their Derivatives



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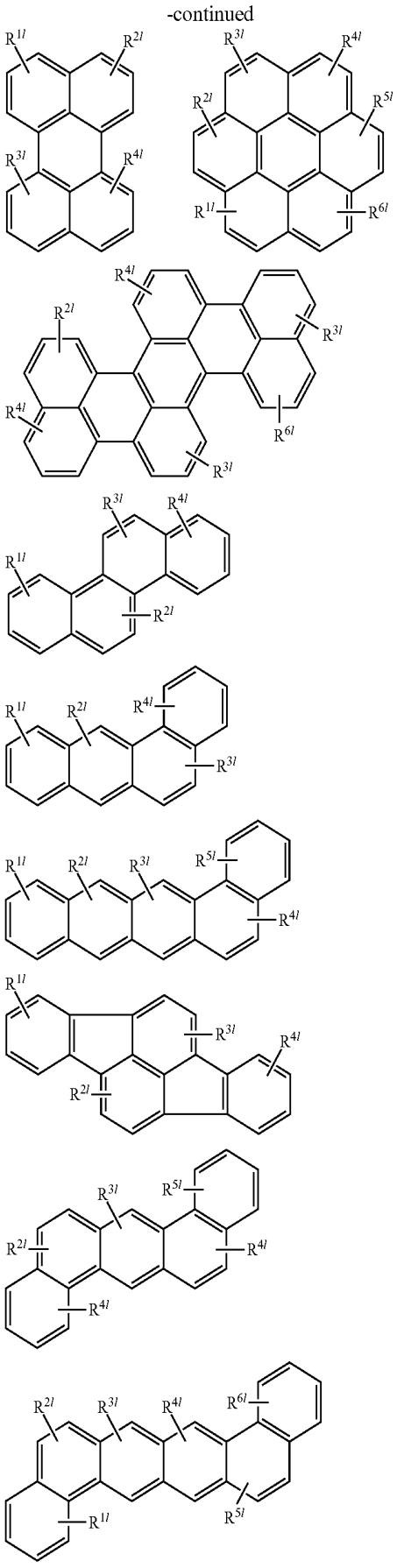

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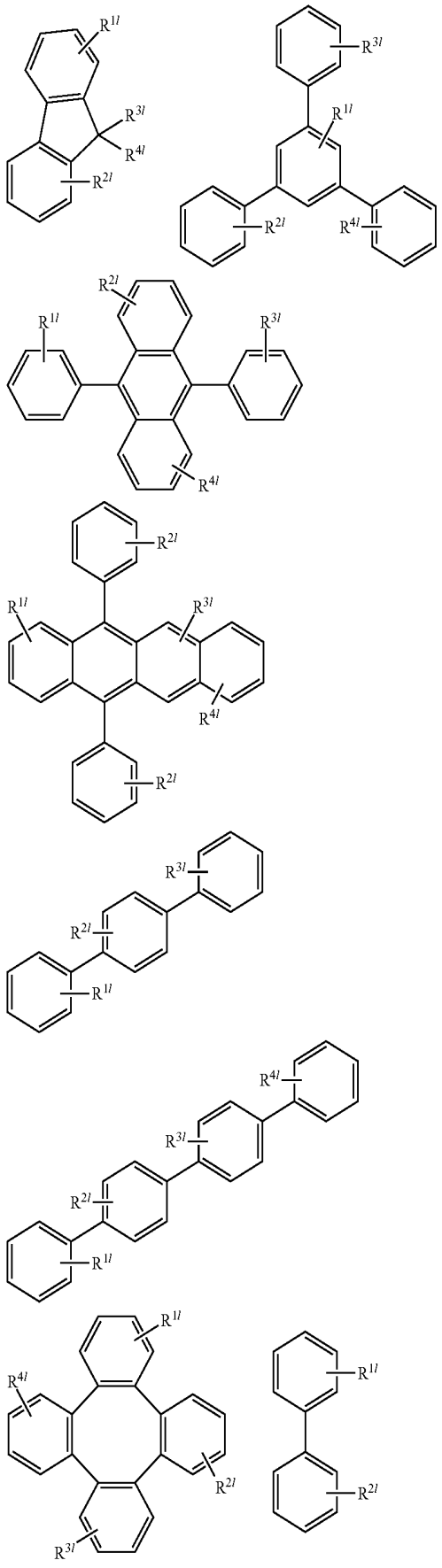

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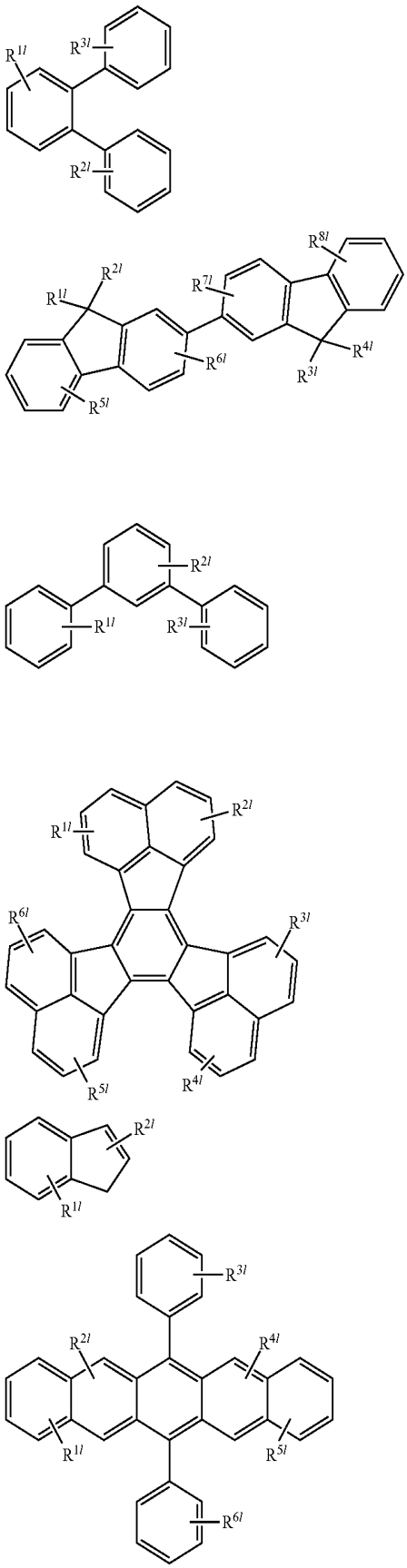

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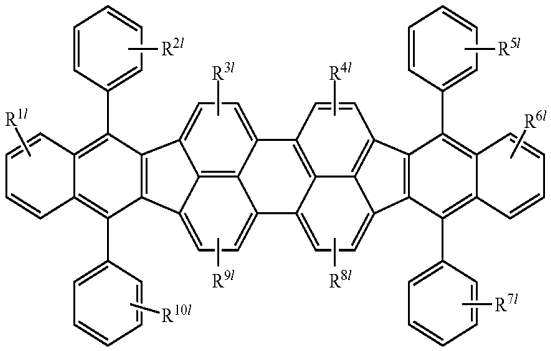
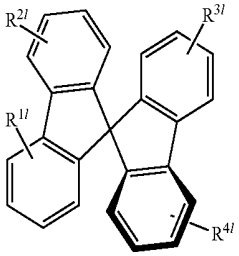
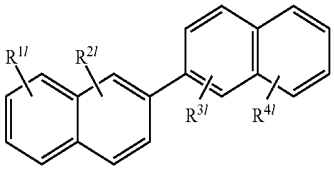
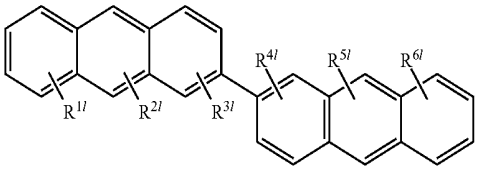
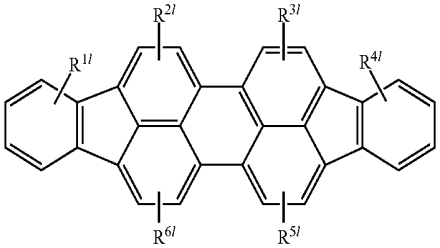
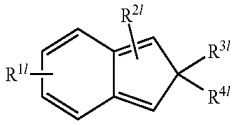


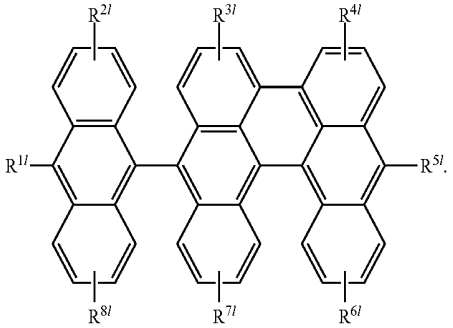




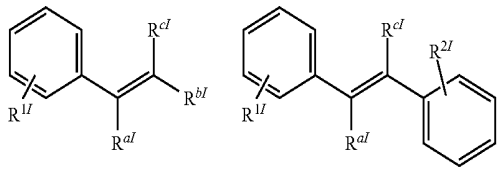


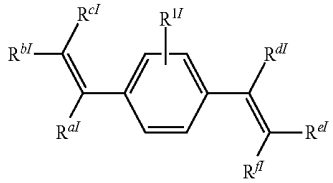


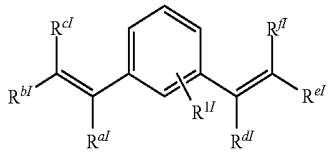


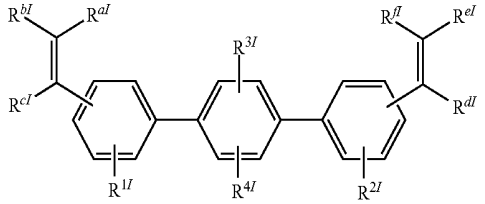


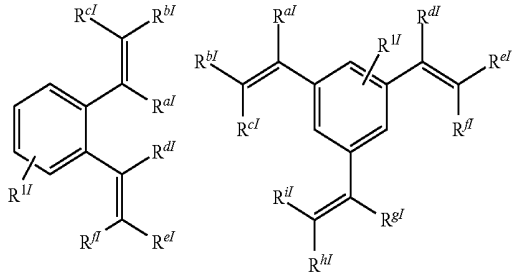
[0147] 2. Arylethylene, Arylacetylene and their Derivatives

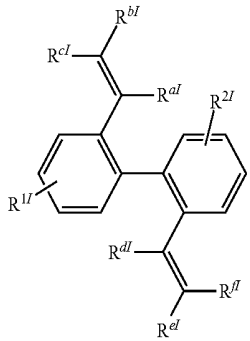


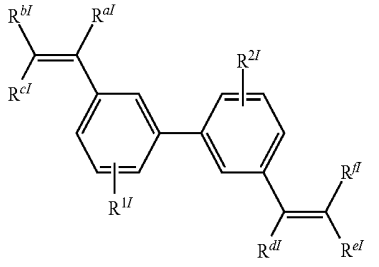












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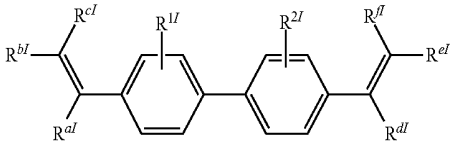

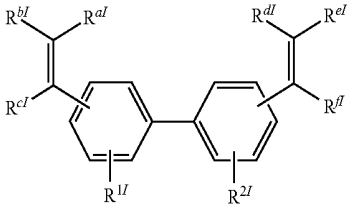

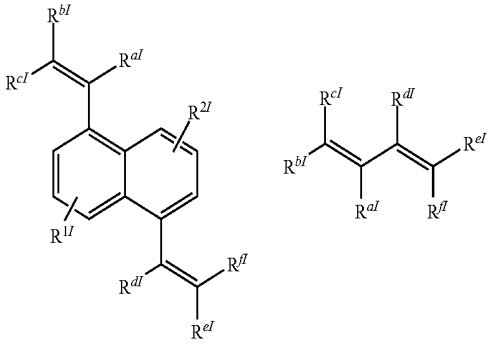

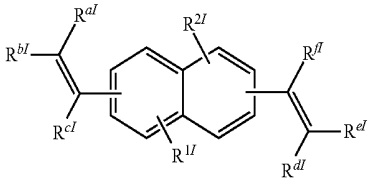

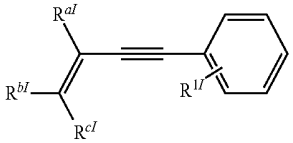

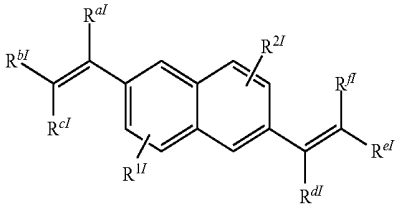

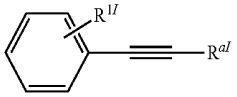

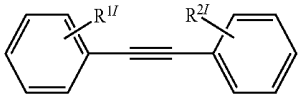

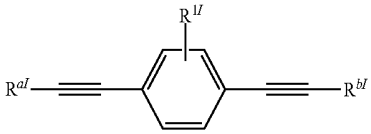

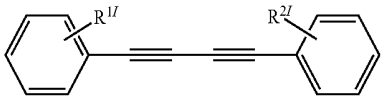

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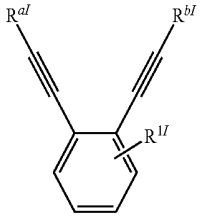
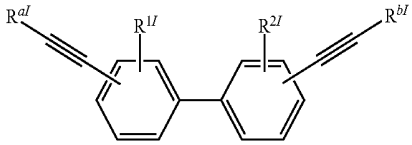
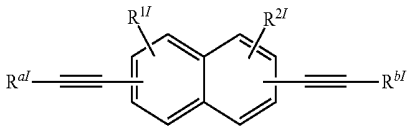
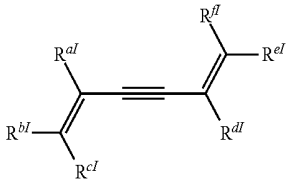
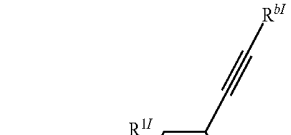
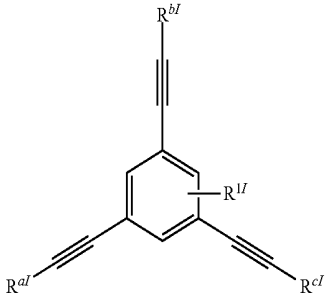




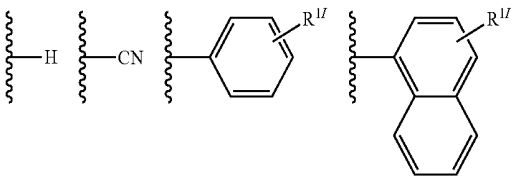


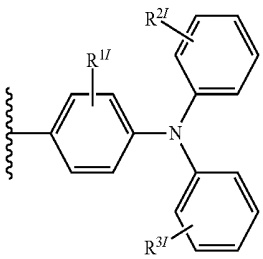






where each of R^{aI}, R^{bI}, R^{cI}, R^{dI}, R^{eI}, R^{fI}, R^{gI}, R^{hI} and R^{iI} can be one of the following structure:





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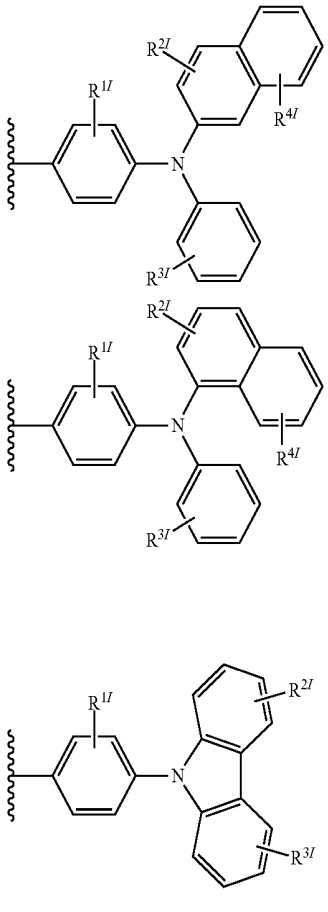

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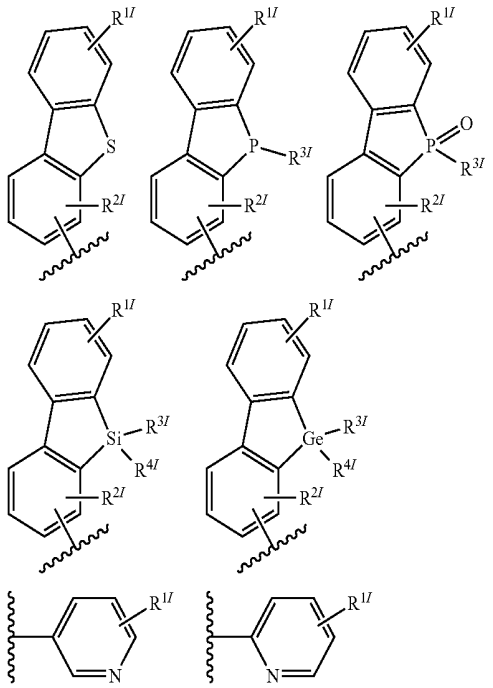
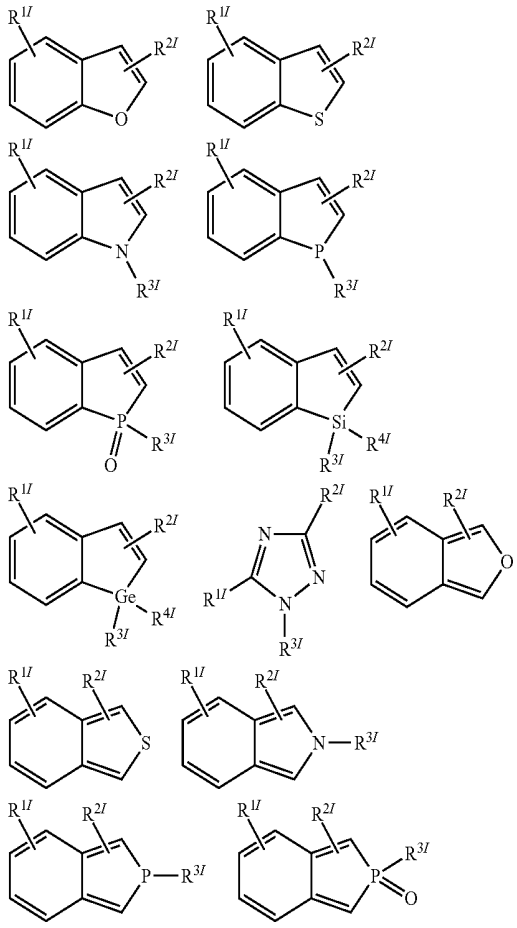


[0148] 3. Heterocyclic Compounds and their Derivatives



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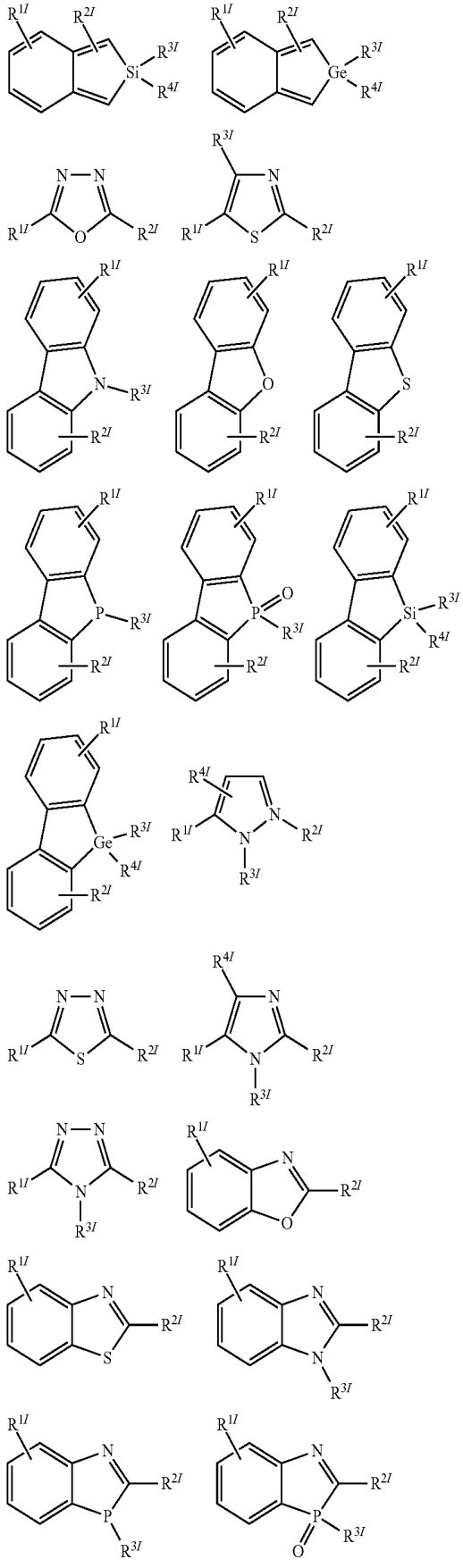

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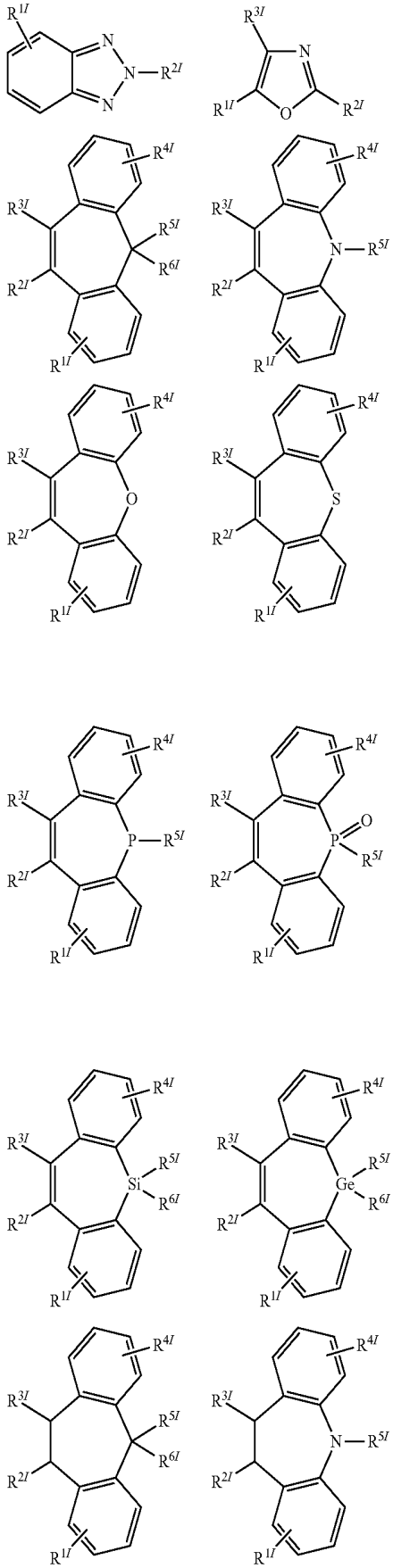

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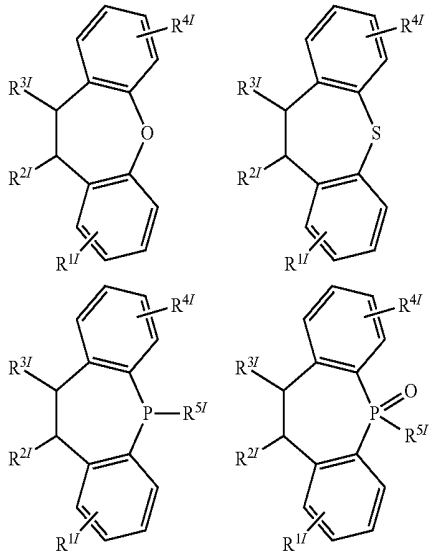

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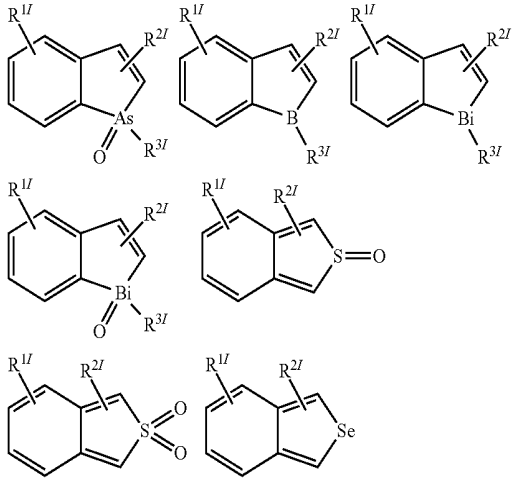

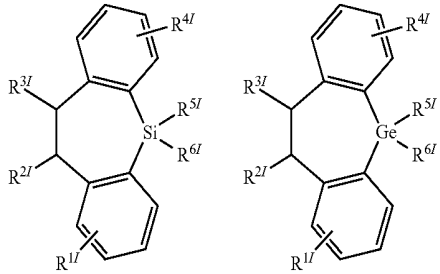

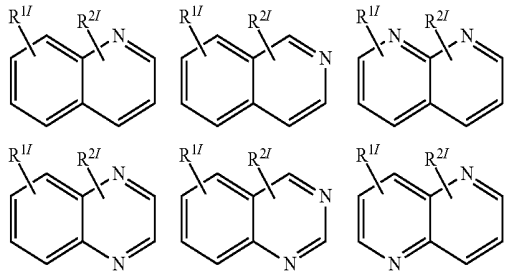

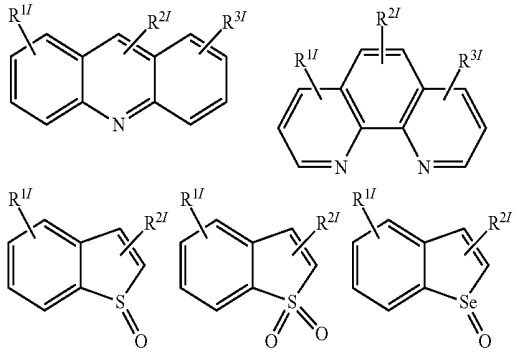

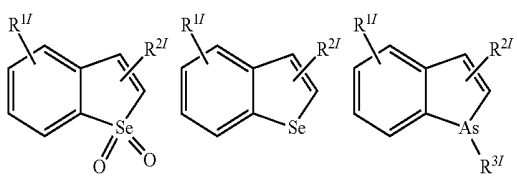

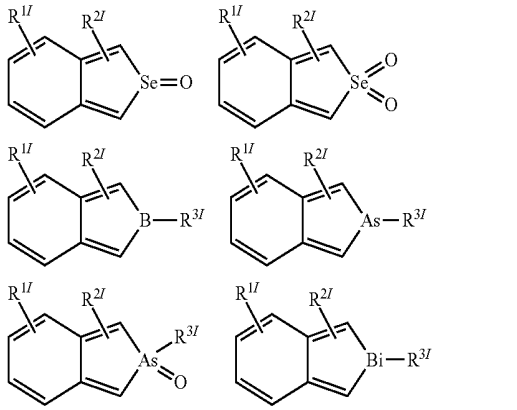

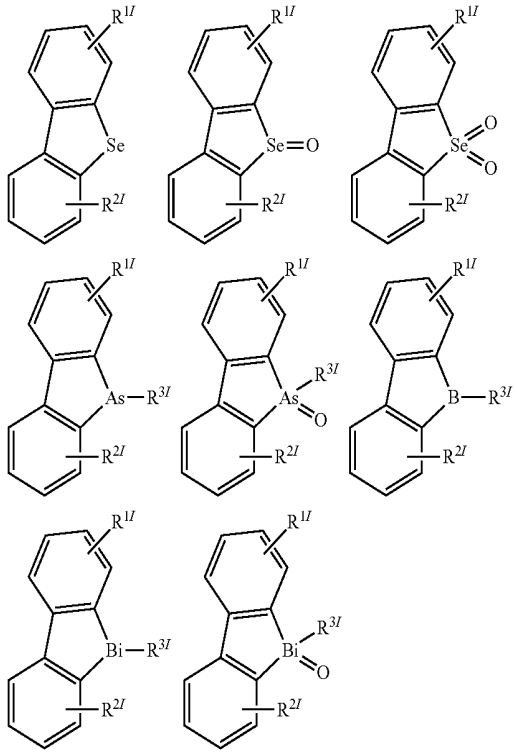

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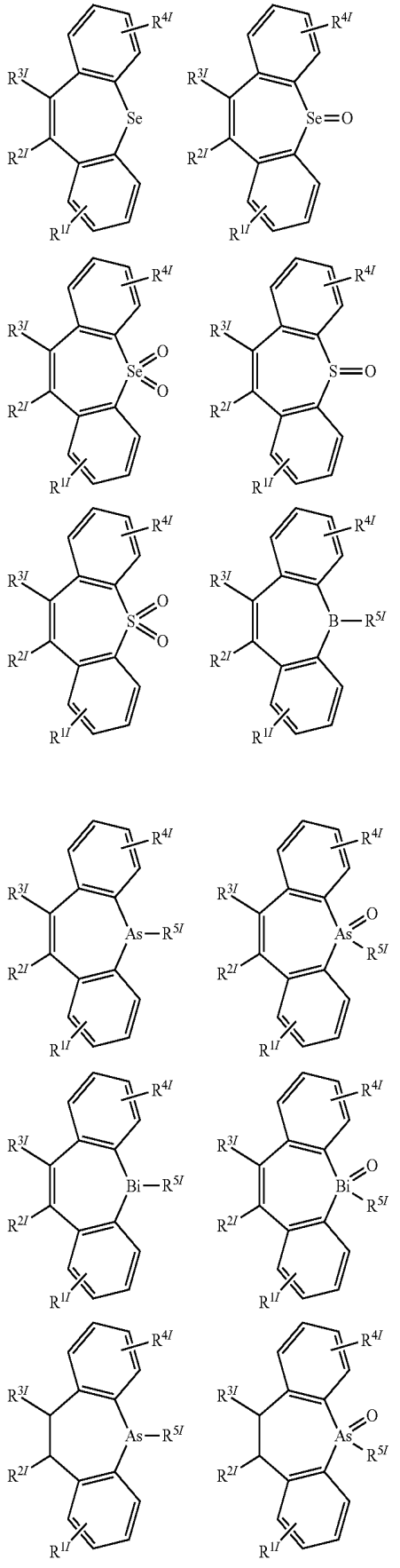

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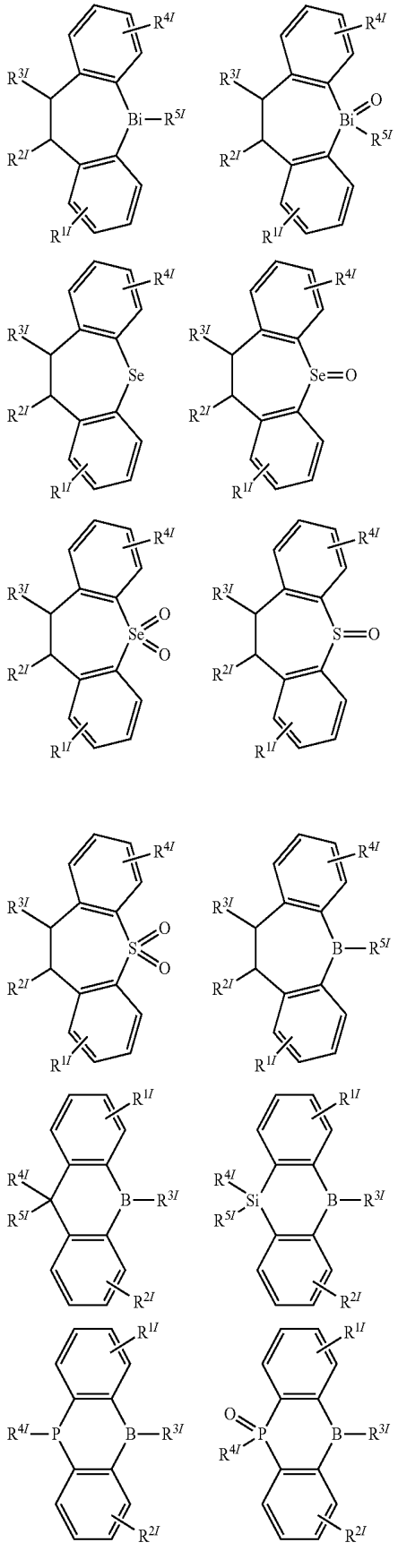

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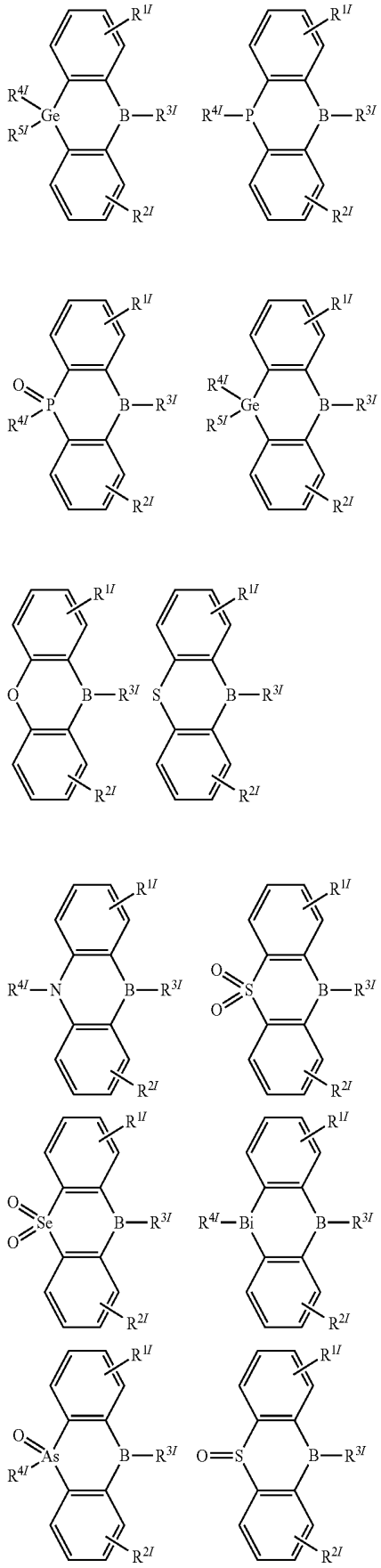

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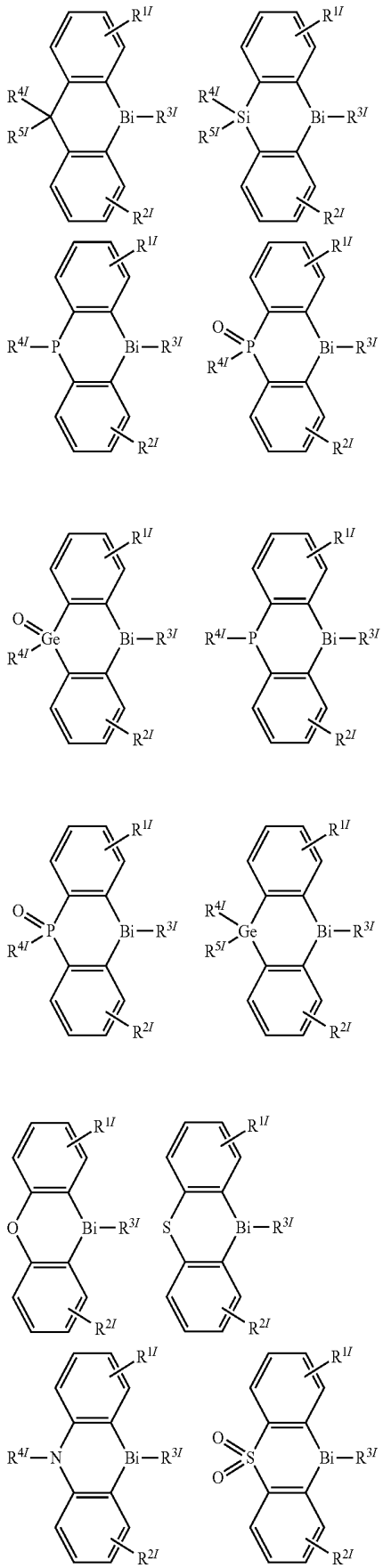

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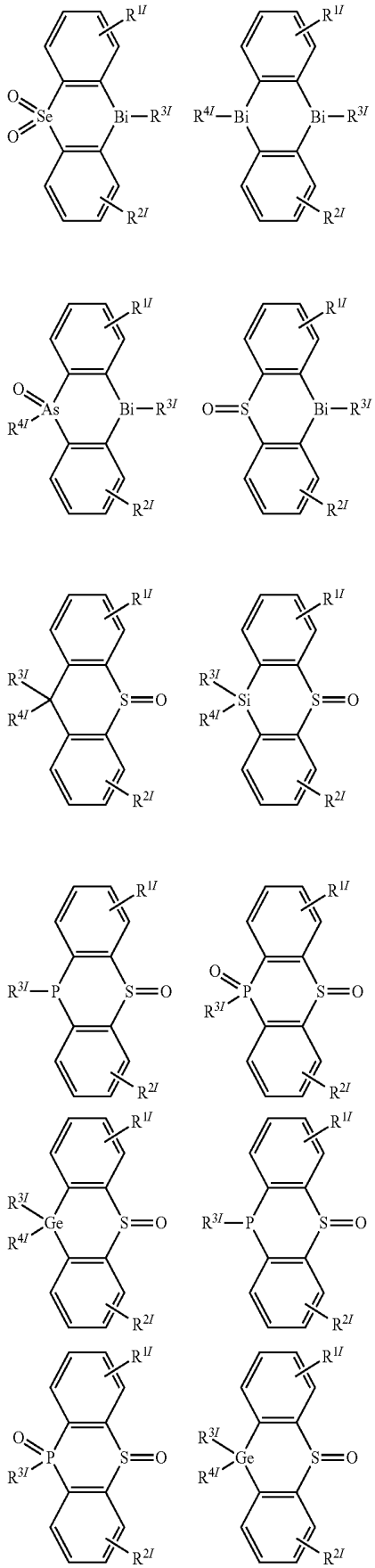

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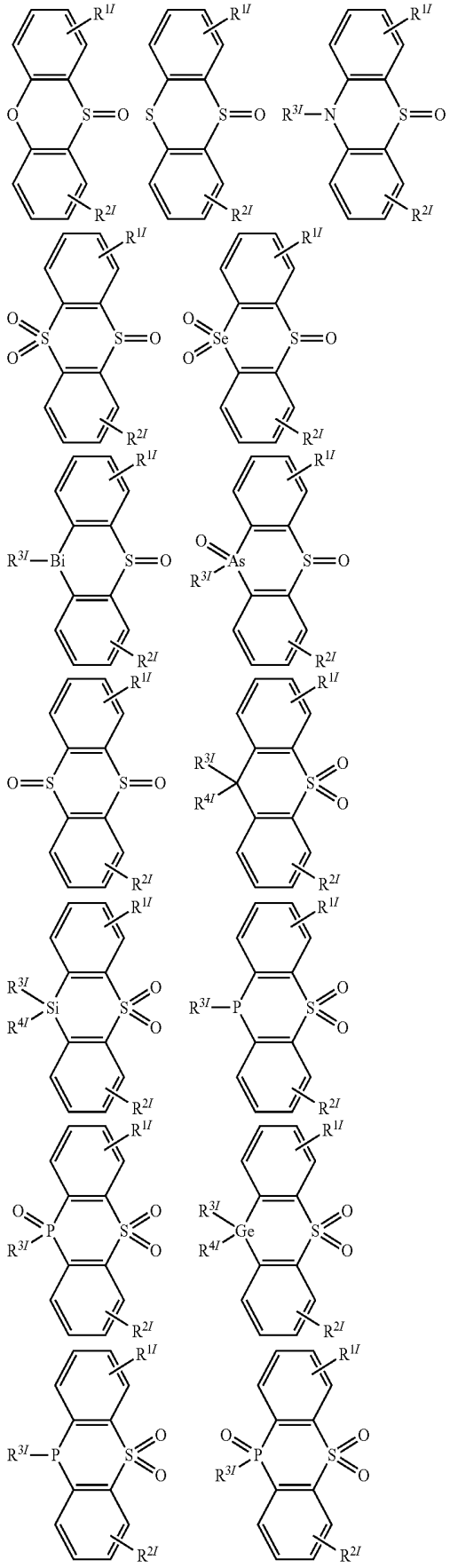

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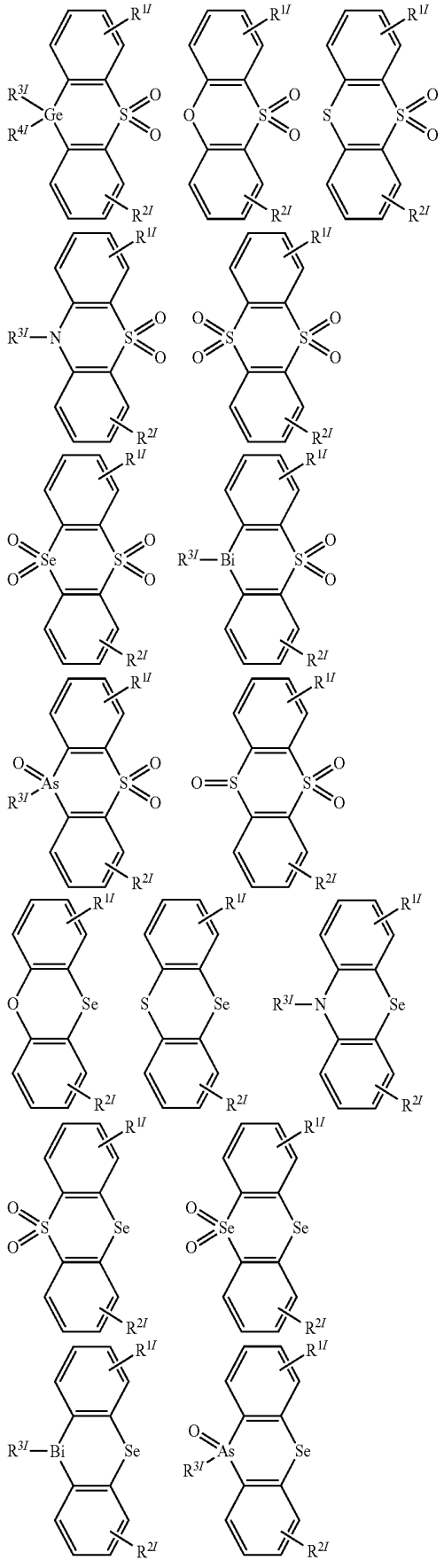

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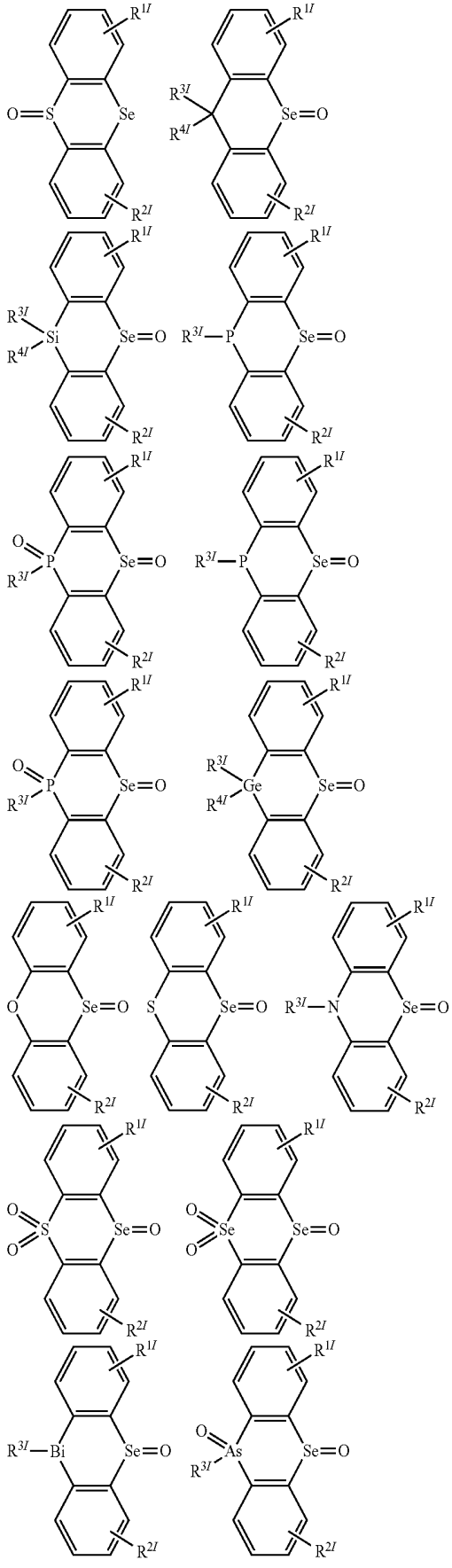

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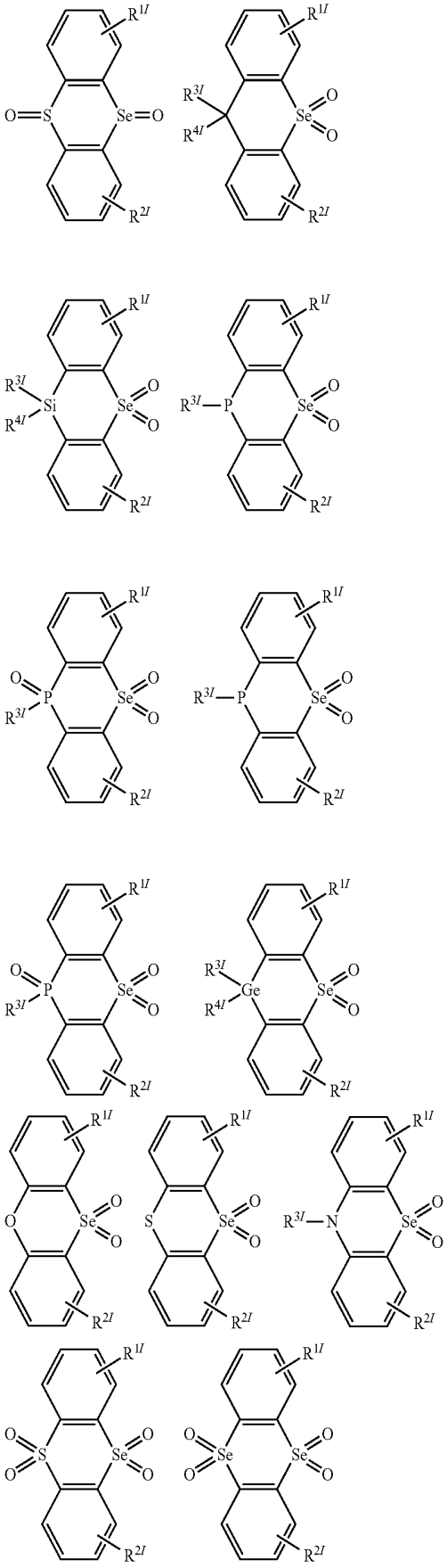

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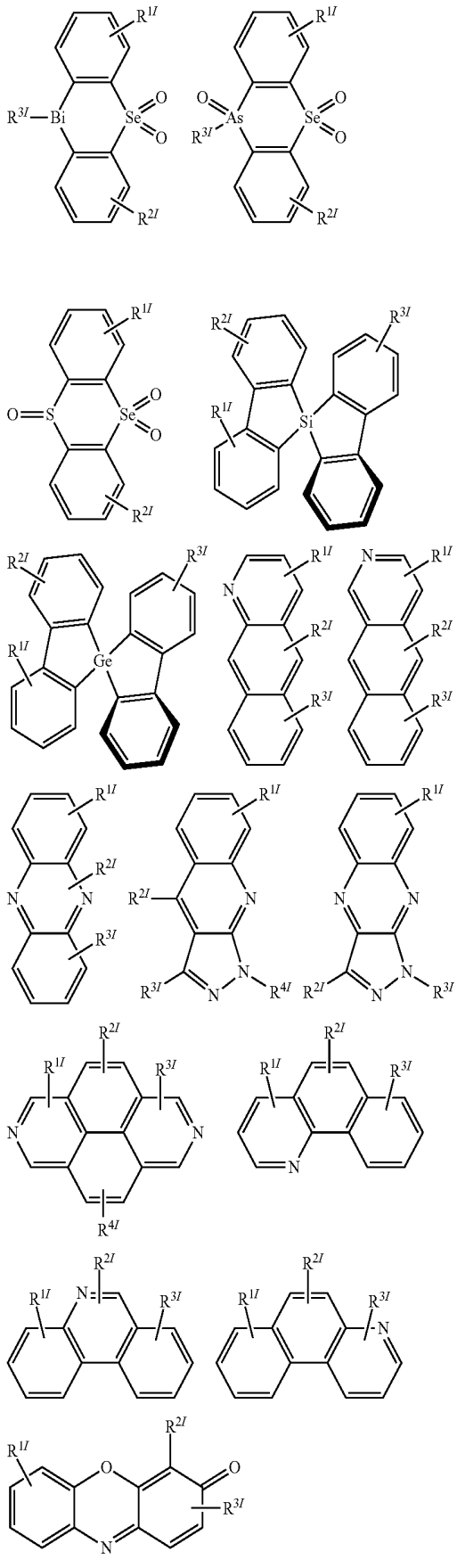

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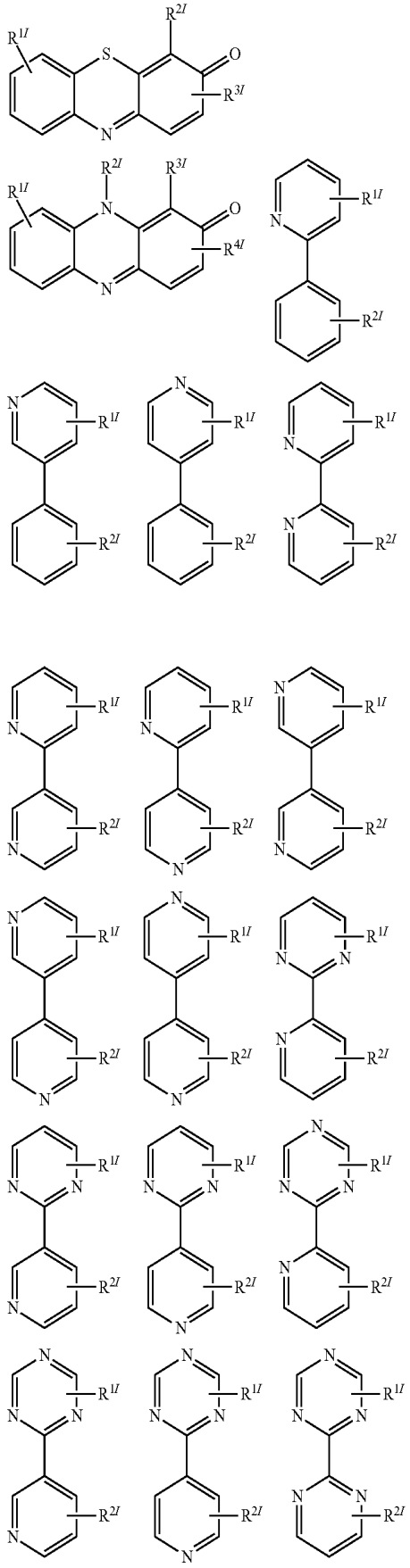

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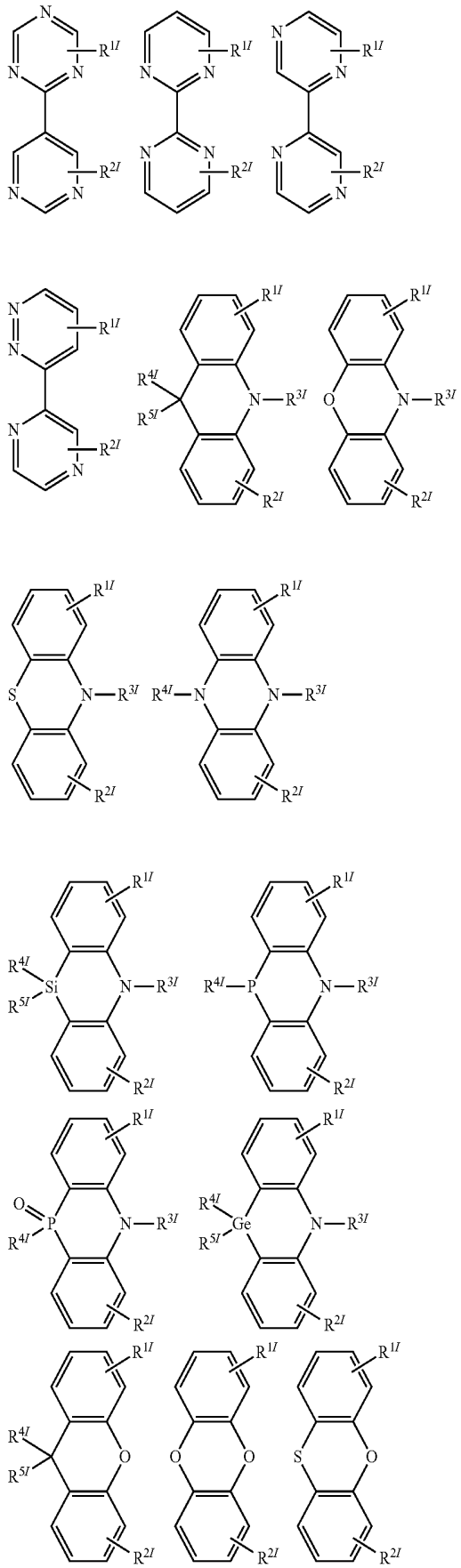

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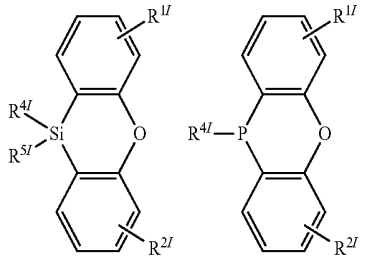

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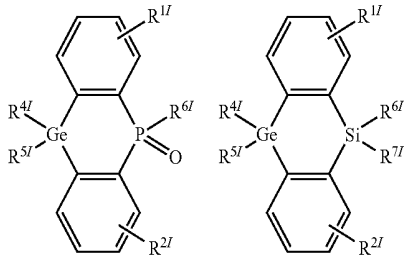

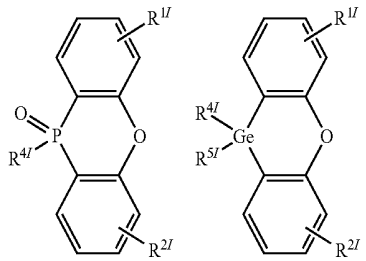

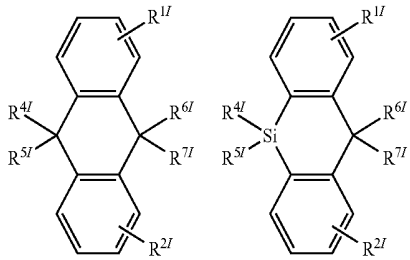

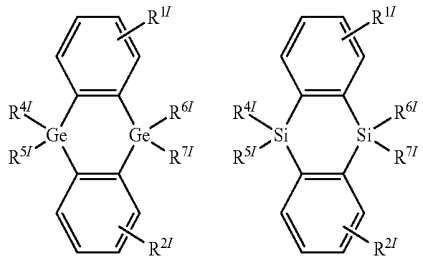

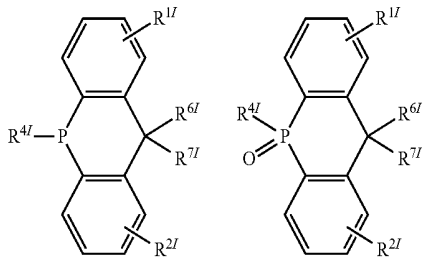

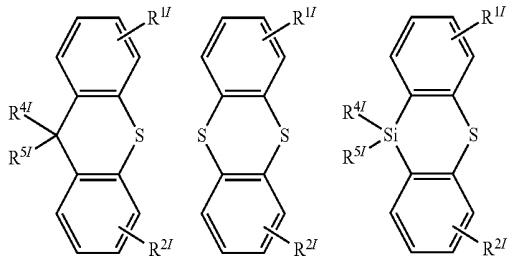

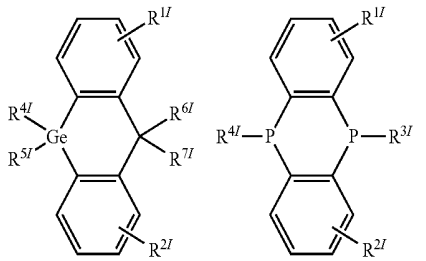

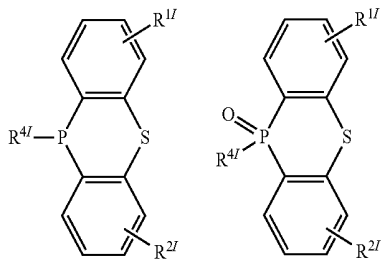

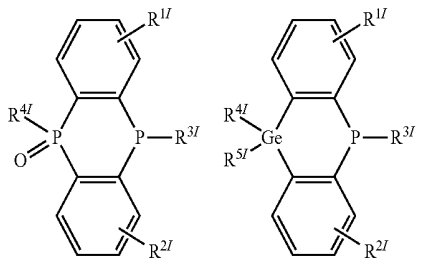

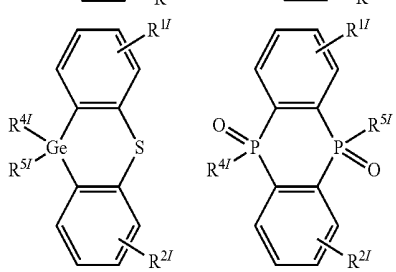

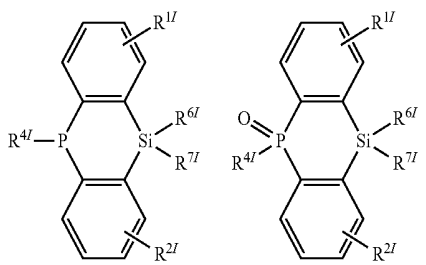

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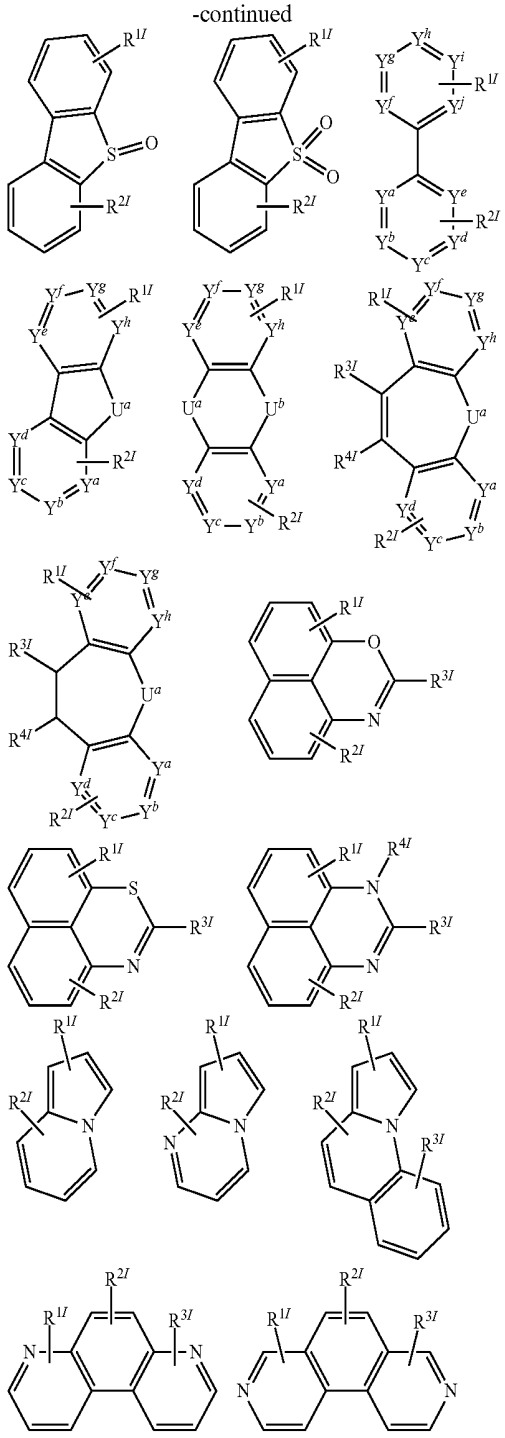


where:

[0149] each of R^{11}, R^{21}, R^{31}, R^{41}, R^{51}, R^{61}, R^{71}, and R^{81} is independently a mono-, di-, or tri-substitution, and if present each of R^{11}, R^{21}, R^{31}, R^{41}, R^{51}, R^{61}, R^{71}, and R^{81} is independently hydrogen, deuterium, halogen, hydroxyl, thiol, nitro, cyano, nitrile, isonitrile, sulfinyl, mercapto, sulfo, carboxyl, hydrazino; substituted or unsubstituted: aryl, cycloalkyl, cycloalkenyl, heterocyclyl, heteroaryl, substituted or unsubstituted alkyl, alkenyl, alkynyl, amino, monoalkylamino, dialkylamino, monoarylamino, diarylamino, alkoxy, aryloxy, haloalkyl, aralkyl, ester, alkoxycarbonyl, acylamino, alkoxycarbonylamino, aryloxycarbonylamino, sulfonylamino, sulfamoyl, carbamoyl, alkylthio, ureido, phosphoramide, or silyl,

[0150] each of Y^a, Y^b, Y^c, Y^d, Y^e, Y^f, Y^g, Y^h, Y^i, Y^j, Y^k, Y^l, Y^m, Y^n, Y^o, and Y^p is independently C, N, or B,

[0151] each of U^a, U^b, and U^c is independently CH_2, CR^1R^2, C═O, CH_2, SiR^1R^2, GeH_2, GeR^1R^2, NH, NR^3, PH, PR^3, R^3P═O, AsR^3, R^3As═O, O, S, S═O, SO_2, Se, Se═O, SeO_2, BH, BR^3, R^3Bi═O, BiH, or BiR^3, and

[0152] each of W, W^a, W^b, and W^c is independently CH, CR', SiR^1, GeH, GeR^1, N, P, B, Bi, or Bi═O.

[0153] FIGS. **2**A and **2**B depict charge transporting and trapping for OLEDs with an undoped EBL and a doped EBL, respectively. FIG. **2**A depicts a portion of OLED **200** with undoped EBL **210** and EML **212**. FIG. **2**B depicts a portion of OLED **220** with doped EBL **230** and EML **232**. As depicted in FIG. **2**B, the presence of a dopant in EBL **230** may alleviate charge imbalance inside EML **232** by improving the hole injection from EBL **230** to EML **232** or partially transporting stacked electrons at the EBL/EML interface. The dopant concentration is typically selected to reduce or prevent quenching of excitons from the emissive material.

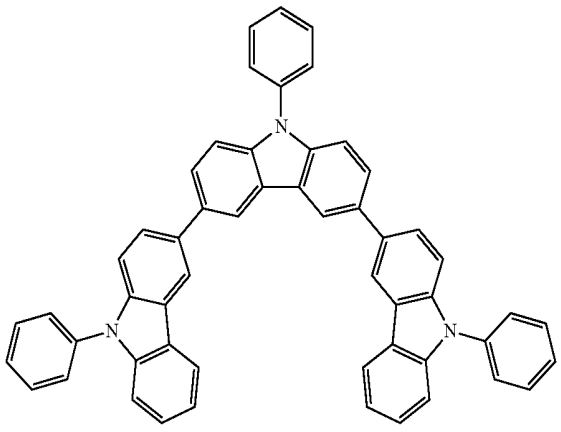
[0154] Components in the devices described herein are listed below.

[0155] ITO (Anode): indium tin oxide

[0156] HATCN (HIL): dipyrazino[2,3f:2',3'-h]quinoxaline 2,3,6,7,10,11-hexacarbonitrile

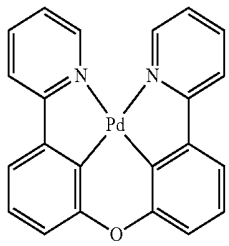
[0157] NPD (HTL): N,N'-di-1-naphthyl-N,N-diphenyl-1,1'-biphenyl-4,4'diamine

[0158] TrisPCz (EBL): 9,9',9"-triphenyl-9H,9'H,9"H-3,3':6',3"-tercarbazole



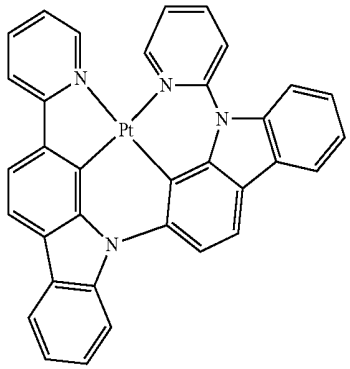
Pd3O3 (EML Emitting Material):

[0159]



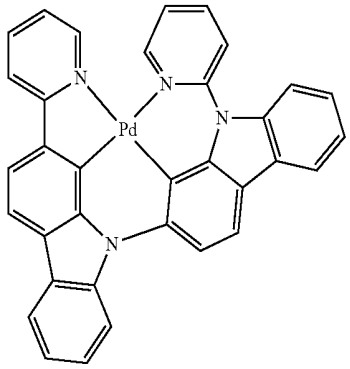
PtN3N (EML Emitting Material)

[0160]



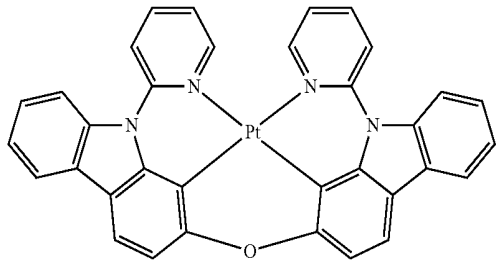
PdN3N (EML Emitting Material)

[0161]



PtNON (EML Emitting Material)

[0162]



[0163] mCBP (EML host): 3,3-di(9H-carbazol-9-yl)biphenyl

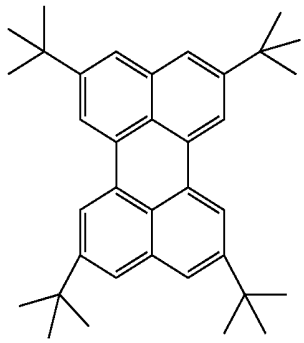
[0164] BAlq (HBL): bis(2-methyl-8-quinolinolate)-4-(phenyl phenolato) aluminum

[0165] BPyTP (ETL): 2,7-di(2,2'-bipyridin-5-yl)triphenylene

[0166] LiF (HIL): lithium fluoride

[0167] Al (Cathode): aluminum

[0168] TBPe (a blue fluorescent emitter): 2,5,8,11-tetra-tert-butylperylene



[0169] Devices 1 and 2 were prepared with the structures below.

[0170] Device 1: ITO/HATCN/NPD/TrisPCz/10% Pd3O3:mCBP/BAlq/BPyTP/LiF/Al

[0171] Device 2: ITO/HATCN/NPD/10% Pd3O3:mCBP/BAlq/BPyTP/LiF/Al

Thus, Device 1 includes an EBL formed of TrisPCz, and Device 2 does not include an EBL. FIGS. **3**A-**3**D show electroluminescent spectra, external quantum efficiency (EQE) versus luminance, power efficiency versus luminance, and operational lifetime, respectively, for Pd3O3 in Device 1 (circles) and Device 2 (squares). The device operational lifetime was measured at a constant drive current of 20 mA/cm^2.

[0172] Pd3O3 is a planar deep blue emitting palladium complex for use in excimer based white devices. As shown in FIG. **3**A, the electroluminescent spectra for Devices 1 and 2 were similar. As shown in FIGS. **3**B and **3**C, Device 1 with Pd3O3 was very efficient, reaching peak EQEs and power efficiencies of 19.9% and 60.5 lm/W. The roll-off for these devices was also less significant than most reported excimer-based white OLEDs with EQE values of 14.6% at 1000 cd/m^2. The device operational lifetimes of Devices 1 and 2 were measured at accelerated conditions by driving the devices at a constant current of 20 mA/cm^2.

[0173] As shown in FIG. **3**D, Device 1 also demonstrated an operational lifetime to 70% of initial luminance (LT_{70}) of 63 hours at a brightness of 5043 cd/m^2. Furthermore, extrapolating these accelerated testing results to practical luminance of 1000 cd/m^2 yields a lifetime of 986 h. On the other hand, the operational lifetime of Device 2 (LT_{70}=294 hours at 20 mA/cm^2) is longer than Device 1 (LT_{70}=63 hours). The efficiency of Device 2 is lower than that of Device 1, possibly due to exciton formation in the NPD layer and possible exciton quenching by the NPD layer. Thus, it is thought that having an EBL that confines the excitons inside the EML and also alleviates the charge imbalance in the EML may extend the operational lifetime of Pd3O3 based devices.

[0174] Devices 3 and 4 were prepared with the following structures.

[0175] Device 3: ITO/HATCN/NPD/TrisPCz (6 nm)/4% TBPe:TrisPCz (4 nm)/10% Pd3O3:mCBP/BAlq/BPyTP/LiF/Al

[0176] Device 4: ITO/HATCN/NPD/4% TBPe:TrisPCz (4 nm)/10% Pd3O3:mCBP/BAlq/BPyTP/LiF/Al

Thus, Device 3 includes an undoped EBL (TrisPCz) and a doped EBL (4% TBPe:TrisPCz), while Device 4 includes a doped EBL only.

[0177] FIGS. **4**A and **4**B show EQE versus luminance and operational lifetime, respectively, for Devices 3 and 4. The device operational lifetime was measured at a constant drive current of 20 mA/cm^2. The addition of TBPe is believed to alleviate the charge imbalance inside of the Pd3O3-containing EML by improving the hole injection from EBL to EML, or partially transporting stacked electron at the EBL/EML interface.

[0178] Notably, the dopant concentration of TBPe should be relatively low to reduce or prevent possible quenching of Pd3O3 excitons. As shown in FIGS. **4**A and **4**B, Device 4 has a peak efficiency of over 8% and LT_{70} of 365 hours with the brightness of 3663 cd/cm^2. Extrapolating these accelerated testing results to practical luminance of 1000 cd/m^2 yields LT_{70} of 3300 hours for Device 4. The estimated LT_{50} of Device 4 at 1000 cd/m^2 is expected to exceed 7000 hours, which is close to a desired lifetime target of excimer-based white OLEDs (LT_{50}=10000 hours at 1000 cd/m^2). Thus, Device 4, with a doped EBL, is shown to improve the efficiency as well as the operational lifetime of Device 2.

[0179] Higher efficiency in organic light emitting diodes (OLEDs) may be achieved by confining electron and hole recombination within the EML. To achieve this, electron transporting/hole blocking and hole transporting/electron blocking layers that preferentially transport one charge type while blocking the other may be used. FIGS. **6**A and **6**B show EQE versus current density and relative luminance versus operational time at a constant current of 20 mA/cm^2 for the following red-emitting PtN3N devices:

[0180] Device 5: ITO/HATCN/NPD/TrisPCz/10% PtN3N:CBP(25 nm)/BAlq/BPyTP/LiF/Al

[0181] Device 6: ITO/HATCN/NPD/10% PtN3N:CBP(25 nm)/BAlq/BPyTP/LiF/Al

[0182] Device 7: ITO/HATCN/NPD/TrisPCz/20% PtN3N:CBP(10 nm)/6% PtN3N:CBP(20 nm)/BAlq/BPyTP/LiF/Al

[0183] Device 8: ITO/HATCN/NPD/20% PtN3N:CBP(10 nm)/6% PtN3N:CBP(20 nm)/BAlq/BPyTP/LiF/Al

[0184] As can be seen in the comparison of Device 5 (single EML, with EBL) and Device 6 (single EML, no EBL) in FIGS. **5**A and **5**B, the addition of the EBL (TrisPCz) shows an enhancement in the peak EQE of the device. This enhancement may be attributed to the EBL's ability to confine electrons within the emissive layer. This confinement, however, may lead to charge buildup at the EML-EBL interface and result in a faster device degradation process.

[0185] Higher efficiency in OLEDs may be achieved by confining electron and hole recombination within the EML. To achieve this, electron transporting/hole blocking and hole transporting/electron blocking layers that preferentially transport one charge type while blocking the other may be used. The addition of an electron blocking layer (EBL) including a carbazole compound shows an enhancement in the peak EQE of the device. This enhancement may be attributed to the role of the EBL in confining electrons within the emissive layer. This confinement, however, may lead to charge buildup at the EML-EBL interface, thereby resulting in a faster device degradation process.

[0186] Exciton formation may be at least partially contained inside of the emissive layer by controlling hole-electron recombination with a multi-EML, with or without a charge-blocking layer. As described herein, a multi-EML generally refers a first EML in direct contact with a second EML, where the emitter concentration of the first EML (hole favorable) exceeds that of the second EML (electron favorable). FIG. **5**A depicts charge transporting and trapping for a device having a single EML. FIG. **5**B depicts charge transporting and trapping for a device having a multi-EML. In contrast to the device in FIG. **5**A, in which electrons and holes recombine at an anode/emissive layer interface, the difference in emitter concentration in the first EML and second EML of the device depicted in FIG. **5**B shifts the recombination zone to an interior of the emissive layer (i.e., at the interface of the first EML and the second EML), which tends to confine exciton formation in the emissive layer.

[0187] FIGS. **6**A and **6**B show EQE versus current density and relative luminance versus operational time at the constant current of 20 mA/cm^2, respectively, for red-emitting PtN3N devices having the following structures:

[0188] Device 5: ITO/HATCN/NPD/TrisPCz/10% PtN3N:CBP(25 nm)/BAlq/BPyTP/LiF/Al

[0189] Device 6: ITO/HATCN/NPD/10% PtN3N:CBP(25 nm)/BAlq/BPyTP/LiF/Al

[0190] Device 7: ITO/HATCN/NPD/TrisPCz/20% PtN3N:CBP(10 nm)/6% PtN3N:CBP(20 nm)/BAlq/BPyTP/LiF/Al

[0191] Device 8: (ITO/HATCN/NPD/20% PtN3N:CBP (10 nm)/6% PtN3N:CBP(20 nm)/BAlq/BPyTP/LiF/Al)

[0192] Comparison of Devices 5 (single EML, with EBL) and 6 (single EML, no EBL) as well as Devices 7 (multi-EML, with EBL) and 8 (multi-EML, no EBL) in FIGS. **6**A and **6**B show that the Devices 5 and 7 (with EBL) yield an accelerated lifetime more than 4 times longer than the corresponding devices with a standard EML (Device 5). As seen in FIG. **6**A, Devices 5 and 7 show device efficiency of about 15% when tested at 1000 cd/m^2. In the Devices 6 and 8, the enhancement in lifetime observed is closer to 2.5 times that of the corresponding devices with. These devices also exhibit comparable efficiencies at 1000 cd/m^2. By comparing Device 5 (single EML, with EBL) and Device 7 (multi-EML, with EBL) in FIG. **6**A, the EML modification improves the device operation stability of PtN3N based devices with a TrisPCz EBL while maintaining the device efficiency of close to 15% at 1000 cd/m^2. Additional data can be seen in FIGS. **6**C and **6**D which also show EQE versus current density and relative luminance versus operational time, respectively, at the constant current of 20 mA/cm^2. FIG. **6**E shows the LT_{97} lifetime versus current density for PtN3N devices.

[0193] FIGS. **7**A and **7**B show relative luminance versus operational time at 5400 cd/m^2, 3200 cd/m^2, and 1900 cd/m^2 for Devices 5 and 7.

[0194] FIGS. **8**A and **8**B show EQE versus brightness and relative luminance versus operational time at the constant current of 20 mA/cm^2, respectively, for excimer-based white OLEDs employing Pd3O3 devices with the following structures:

[0195] Device 9: ITO/HATCN/NPD/TrisPCz/10% Pd3O3:CBP(25 nm)/BAlq/BPyTP/LiF/Al)

[0196] Device 10 (ITO/HATCN/NPD/TrisPCz/20% Pd3O3:CBP(10 nm)/6% Pd3O3:CBP(20 nm)/BAlq/BPyTP/LiF/Al)

[0197] As shown in FIGS. **8**A and **8**B, Device 10 achieved an efficiency of over 22% at 1000 cd/m^2 and demonstrated an operational lifetime to 70% of initial luminance (LT_{70}) of

190 hours at the brightness of 8500 cd/m^2. Device 9, with single dopant concentration, demonstrated a lower device efficiency and lower LT_{70} of 63 hours at the lower brightness.

[0198] FIG. **9**A shows EQE versus current density and electroluminescent spectra for blue PtNON devices with 2% (circles) and 6% (triangles) doping concentrations in the structure:

[0199] ITO/HATCN/NPD/TAPC/x% PtNON: 26mCPy/DPPS/BmPyPB/LiF/Al

[0200] FIGS. **9**B and **9**C show plots of EQE versus luminance and relative luminance versus operational time at a constant current of 20 mA/cm^2 for PtNON devices having the following structures:

[0201] Device 11: ITO/HATCN/NPD/TrisPCz/10% PtNON:mCBP(25 nm)/mCBT/BPyTP/LiF/Al

[0202] Device 12: ITO/HATCN/NPD/10% PtNON: mCBP(25 nm)/mCBT/BPyTP/LiF/Al)

[0203] Device 13: ITO/HATCN/NPD/TrisPCz/20% PtNON:mCBP(10 nm)/6% PtNON:mCBP(20 nm)/mCBT/BPyTP/LiF/Al

[0204] Device 14: ITO/HATCN/NPD/20% PtNON:mCBP (10 nm)/6% PtNON:mCBP(20 nm)/mCBT/BPyTP/LiF/Al

[0205] Device architecture with dual EMLs have improved device efficiency using PtNON-based blue phosphorescent OLED with a limited set of potential stable charge-transporting and host materials. One PtNON device (Device 13) have achieved device efficiency over 16% at 1000 cd/m^2. Device 13 demonstrated a very good operational lifetime to 50% of initial luminance (LT_{50}) of 80 h at the brightness of 6700 cd/m^2. Furthermore, extrapolating these accelerated testing results to practical luminance of 1000 cd/m^2 yields lifetimes of 2030 hr for Device 13.

[0206] FIGS. **9**D and **9**E show plots of EQE versus luminance and relative luminance versus operational time, respectively, at a constant current of 20 mA/cm^2 for PtNON devices similar to Device 13 having the following EML modifications:

[0207] Device 14a EML: 20 wt % PtNON (10 nm)/6 wt % PtNON (20 nm)/

[0208] Device 15 EML: 20 wt % PtNON (5 nm)/16 wt % PtNON (5 nm)/12 wt % PtNON (5 nm)/10 wt % PtNON (5 nm)/8wt % PtNON (5 nm)/6 wt % PtNON (5 nm)/

[0209] Device 16 EML: 20 wt % PtNON (10 nm)/10 wt % PtNON (10 nm)/6 wt % PtNON (10 nm)

[0210] FIGS. **10**A and **10**B show plots of EQE versus luminance and relative luminance versus wavelength, respectively, for devices with doped TBPe layer, where the devices have similar structures as Device 13 with some EML modifications:

[0211] Device 17 EML: 20 wt % PtNON (10 nm)/2 wt % TBPe:mCBP(2 nm)/10 wt % PtNON (4 nm)/2 wt % TBPe:mCBP(2 nm)/10 wt % PtNON (4 nm)/6 wt % PtNON (10 nm)

[0212] Device 18 EML: 20 wt % PtNON (10 nm)/2 wt % TBPe:mCBP(2 nm)/10 wt % PtNON (4 nm)/2 wt % TBPe:mCBP(2 nm)/10 wt % PtNON (4 nm)/2 wt % TBPe:mCBP(2 nm)/6 wt % PtNON (10 nm)

[0213] The device efficiency remains similar for PtNON devices with doped TBPe layer, and EL spectra are blue shifted due to efficient energy transfer from PtNON to blue fluorescent emitter TBPe. FIG. **11** shows a plot of relative intensity versus operational time for PtNON devices with doped TBPe layer (Device 17 and Device 18). Unexpectedly, such devices have longer operational lifetime than PtNON only devices with improved color purity and similar device. Device 18 has better operational lifetime than Device 16 at the various current densities.

[0214] FIGS. **12**A and **12**B show plots of EQE versus luminance and EL intensity versus operational time, respectively, for devices with doped TBPe layer, where the devices have similar structures as Device 13 with some EML modifications:

[0215] Device 19 EML: 20 wt % PtNON (4 nm)/2 wt % TBPe:mCBP(2 nm)/20 wt % PtNON (4 nm)/2 wt % TBPe:mCBP(2 nm)/10 wt % PtNON (4 nm)/2 wt % TBPe:mCBP(2 nm)/10 wt % PtNON (4 nm)/6 wt % PtNON (10 nm)

[0216] Device 20 EML: 20 wt % PtNON (4 nm)/2 wt % TBPe:mCBP(2 nm)/20 wt % PtNON (4 nm)/2 wt % TBPe:mCBP(2 nm)/10 wt % PtNON (4 nm)/2 wt % TBPe:mCBP(2 nm)/10 wt % PtNON (4 nm)/2 wt % TBPe:mCBP(2 nm)/6 wt % PtNON (10 nm)

[0217] Although the device efficiencies drop slightly for Device 19 and Device 20, the operational lifetime further improved with more doped TBPe layers.

[0218] FIG. **13** shows a plot of EQE versus luminance for PdN3N device having the following structure:

[0219] Device 21a: ITO/HATCN/NPD(30 nm)/TAPC(10 nm)/6% PdN3N:CBP (25 nm)/DPPS(10 nm)/BmPyPB (30 nm)LiF/Al.

[0220] FIG. **14** shows a plot of the relative intensity versus time for PdN3N device having the following structure:

[0221] Device 21b: HATCN (10 nm)NPD(40 nm)/6% PdN3N:CBP (25 nm)/BAlq(10 nm)/Alq3(40 nm)/LiF/Al

[0222] FIGS. **15**A and **15**B show plots of EQE versus luminance and EL intensity versus operational time, respectively, for Pd3O3 devices having the structures ITO/HATCN (10 nm)/NPD (40 nm)/TrisPCz (10 nm)/EML/BAlq (10 nm)/BPyTP (40 nm)/LiF (1 nm)/Al, where the EML is varied as follows:

[0223] Device 22: 6% Pd3O3: 26mCPy (30 nm)

[0224] Device 23: 10% Pd3O3: 26mCPy (10 nm)/6% Pd3O3: 26mCPy (20 nm)

[0225] Device 24: 20% Pd3O3: 26mCPy (10 nm)/6% Pd3O3: 26mCPy (20 nm)

[0226] Device 25: 20% Pd3O3: 26mCP (10 nm)/6% Pd3O3: 26mCP (20 nm)

FIG. **15**C shows a plot of El intensity versus wavelength for Pd3O3 devices (Device 22, Device 23, Device 24, and Device 25).

[0227] FIGS. **16**A and **16**B show plots of EQE versus luminance and EL intensity versus operational time, respectively, for PdN3N devices having the following structures:

Device 26:

HATCN(10 nm)NPD(40 nm)/TrisPCz(10 nm)/20% PdN3N:CBP(10 nm)/6% PdN3N:CBP(20 nm)/Balq(10 nm)/BPyTP (40 nm)/LiF/Al

[0228] Further modifications and alternative embodiments of various aspects will be apparent to those skilled in the art in view of this description. Accordingly, this description is to be construed as illustrative only. It is to be understood that the forms shown and described herein are to be taken as examples of embodiments. Elements and materials may be substituted for those illustrated and described herein, parts and processes may be reversed, and certain features may be utilized independently, all as would be apparent to one

skilled in the art after having the benefit of this description. Changes may be made in the elements described herein without departing from the spirit and scope as described in the following claims.

What is claimed is:

1. An organic light emitting device comprising:

an anode;

a cathode;

an emissive layer between the anode and the cathode, the emissive layer comprising a first emissive layer in direct contact with a second emissive layer, the first emissive layer comprising a first emitter and the second emissive layer comprising a second emitter, and the concentration of the first emitter in the first emissive layer exceeds the concentration of the second emitter in the second emissive layer.

2. The organic light emitting device of claim **1**, wherein the emissive layer comprises a third emissive layer comprising a third emitter, wherein the third emissive layer is in direct contact with the second emissive layer, and the concentration of the second emitter in the second emissive layer exceeds the concentration of the third emitter in the third emissive layer.

3. The organic light emitting device of claim **2**, wherein the emissive layer comprises a fourth emissive layer comprising a fourth emitter, wherein the fourth emissive layer is in direct contact with the third emissive layer, and the concentration of the third emitter in the third emissive layer exceeds the concentration of the fourth emitter in the fourth emissive layer.

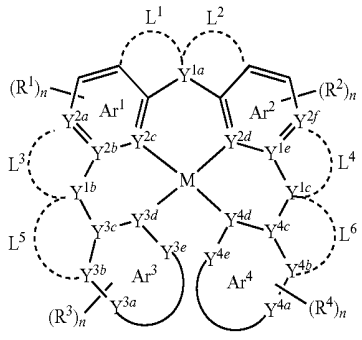
4. The organic light emitting device of claim **1**, wherein the first emitter and the second emitter are the same.

5. The organic light emitting device of claim **1**, wherein the first and second emissive layers comprise a host material.

6. The organic light emitting device of claim **1**, wherein at least one of the first and second emitters emits red or blue light.

7. The organic light emitting device of claim **1**, wherein each of the first emitter and the second emitter comprises an organometallic complex represented by Formula I:

(Formula I)



wherein:

M is Pt, Pd, or Ir;

R^1, R^2, R^3, R^4, R^8, R^9, and R^{10} each independently represents hydrogen, halogen, hydroxy, amino, nitro, thiol, substituted or unsubstituted C_1-C_4 alkyl, substituted or unsubstituted alkoxy, or substituted or unsubstituted aryl;

Y^{1a} represents O, S, S═O, O═S═O, Se, Se═O, O═Se═O, N, NR^{5a}, P, PR^{5a}, As, AsR^{5a}, O═NR^{5a}, O═PR^{5a}, O═AsR^{5a}, B, BR^{5a}, SiR^{5a}, $SiR^{5a}R^{5b}$, CR^{5a}, or $CR^{5a}R^{5b}$;

Y^{1b} and Y^{1c} each independently represents O, S, S═O, O═S═O, Se, Se═O, O═Se═O, N, NR^{5a}, P, PR^{5a}, As, AsR^{5a}, O═NR^{5a}, O═PR^{5a}, O═AsR^{5a}, B, BR^{5a}, SiR^{5a}, $SiR^{5a}R^{5b}$, CR^{5a}, $CR^{5a}R^{5b}$, or a single bond, wherein if Y^{1b} represents a single bond, Y^{2e} and Y^{4c} are directly linked by a single bond, and if Y^{1c} represents a single bond, Y^{2b} and Y^{3c} are directly linked by a single bond;

Y^{2a}, Y^{2b}, Y^{2c}, Y^{2d}, Y^{2e}, and Y^{2f} each independently represents C or N;

R^{5a}, R^{5b}, and R^{5c} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl;

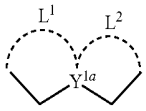
R^{6a}, R^{6b}, and R^{6c} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl;

R^{7a}, R^{7b}, and R^{7c} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl;

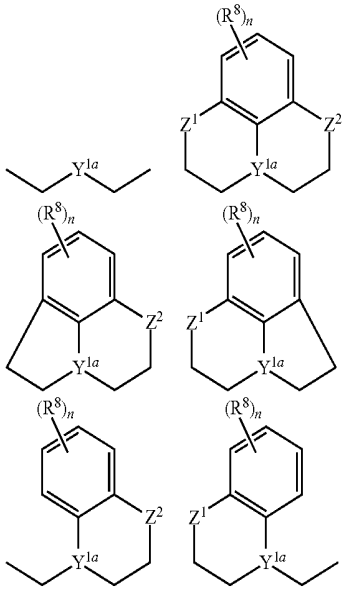
Y^{3a}, Y^{3b}, Y^{3c}, Y^{3d}, and Y^{3e} each independently represents C, N, Si, O, or S;

Y^{4a}, Y^{4b}, Y^{4c}, Y^{4d}, and Y^{4e} each independently represents C, N, Si, O, or S;

each of L^1, L^2, L^3, L^4, L^5, and L^6 is independently absent or represents a linking group;



represents one of the following:



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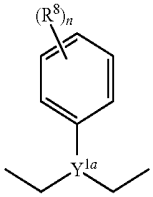
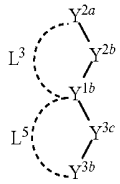
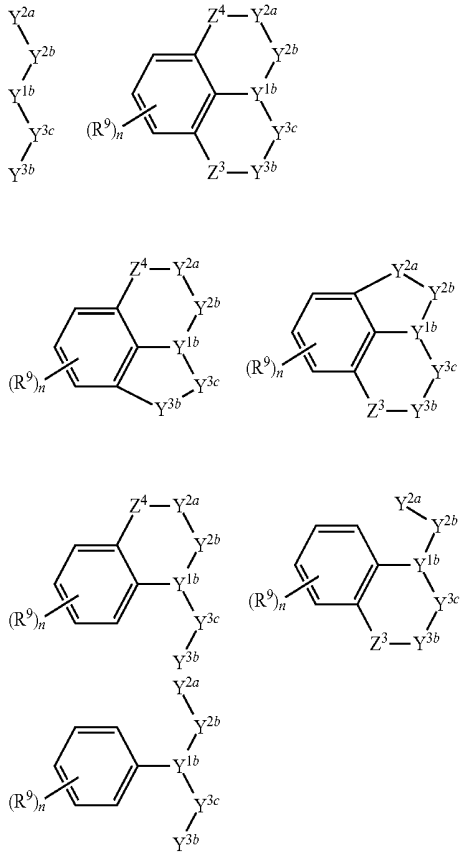


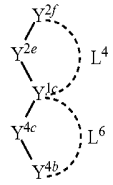
wherein Z^1, Z^2 independently represents O, S, S═O, O═S═O, Se, Se═O, O═Se═O, NR^{5a}, PR^{5a}, AsR^{5a}, $O{=}NR^{5a}$, $O{=}PR^{5a}$, $O{=}AsR^{5a}$, BR^{5a}, $SiR^{5a}R^{5b}$, or $CR^{5a}R^{5b}$;



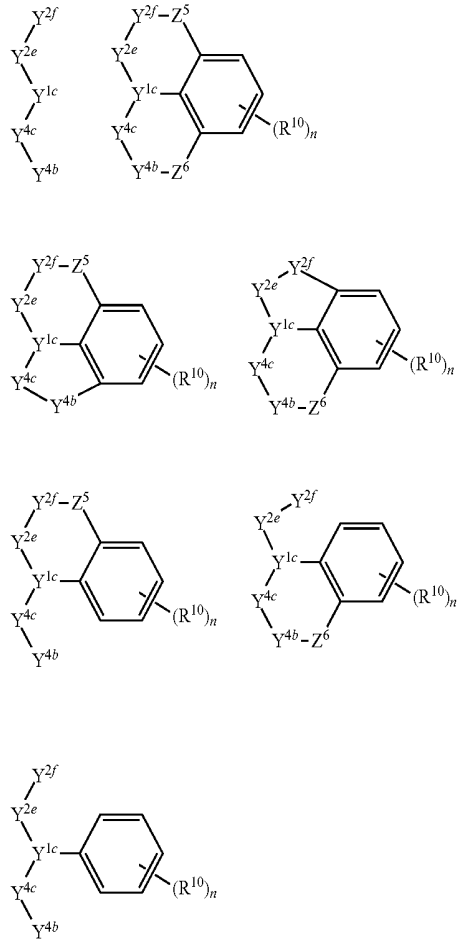
represents one of the following:



wherein Z^3 and Z^4 each independently represents O, S, S═O, O═S═O, Se, Se═O, O═Se═O, NR^{6a}, PR^{6a}, AsR^{6a}, $O{=}NR^{6a}$, $O{=}PR^{6a}$, $O{=}AsR^{6a}$, BR^{6a}, $SiR^{6a}R^{6b}$, or $CR^{6a}R^{6b}$;



represents one of the following:



wherein Z^5 and Z^6 each independently represents O, S, S═O, O═S═O, Se, Se═O, O═Se═O, NR^{7a}, PR^{7a}, AsR^{7a}, $O{=}NR^{7a}$, $O{=}PR^{7a}$, $O{=}AsR^{7a}$, BR^{7a}, $SiR^{7a}R^{7b}$, or $CR^{7a}R^{7b}$;

Ar^3 and Ar^4 each independently represents a substituted or unsubstituted 5-membered ring or a 6-membered aromatic ring; and

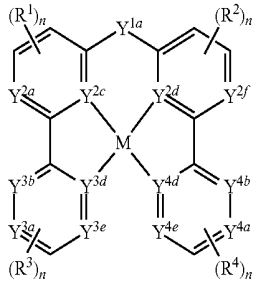
n is 0, 1, 2, 3, 4, 5, or 6.

8. The organic light emitting device of claim **1**, wherein each of the first emitter and the second emitter comprises an organometallic complex, wherein the metal in each of the organometallic complex is Pt(II), Pd(II), or Ir(III).

9. The organic light emitting device of claim **7**, wherein M is Pt(II) or Pd(II).

10. The organic light emitting device of claim **7**, wherein the organometallic complex is represented by Formula II:

(Formula II)



wherein:

M is Pt, Pd, or Ir;

R^1, R^2, R^3, and R^4 each independently represents hydrogen, halogen, hydroxy, amino, nitro, thiol, substituted or unsubstituted C_1-C_4 alkyl, substituted or unsubstituted alkoxy, or substituted or unsubstituted aryl;

Y^{1a} represents O, S, S═O, O═S═O, Se, Se═O, O═Se═O, NR^{5a}, PR^{5a}, AsR^{5a}, O═NR^{5a}, O═PR^{5a}, O═AsR^{5a}, BR^{5a}, $SiR^{5a}R^{5b}$, or $CR^{5a}R^{5b}$;

Y^{2a}, Y^{2c}, Y^{2d}, and Y^{2f} each independently represents C or N;

R^{5a}, R^{5b}, and R^{5c} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl;

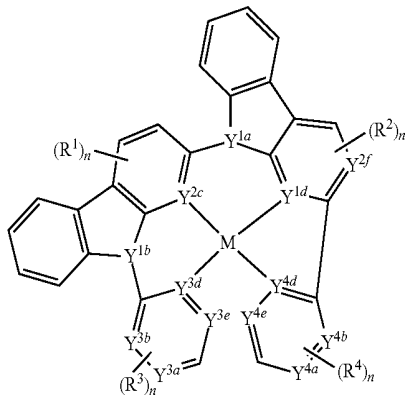
Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents C, N, or Si;

Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents C, N, or Si;

n is 0, 1, 2, 3, or 4.

11. The organic light emitting device of claim **7**, wherein the organometallic complex is represented by Formula III:

(Formula III)



wherein:

M is Pt, Pd, or Ir;

R^1, R^2, R^3, and R^4 each independently represents hydrogen, halogen, hydroxy, amino, nitro, thiol, substituted or unsubstituted C_1-C_4 alkyl, substituted or unsubstituted alkoxy, or substituted or unsubstituted aryl;

Y^{1a} represents N, P, As, B, SiR^{5a}, or CR^{5a};

Y^{1b} represents N, P, As, B, SiR^{5a}, or CR^{5a};

Y^{2c}, Y^{2d}, and Y^{2f} each independently represents C or N;

R^{5a} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl;

Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents C, N, or Si;

Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents C, N, or Si; and

n is 0, 1, 2, 3, 4, or 5.

12. The organic light emitting device of claim **11**, wherein:

M is Pt or Pd;

R^1, R^2, R^3, and R^4 each independently represents hydrogen, halogen, hydroxy, amino, nitro, thiol, substituted or unsubstituted C_1-C_4 alkyl, substituted or unsubstituted alkoxy, or substituted or unsubstituted aryl;

Y^{1a} represents N, P, SiR^{5a}, or CR^{5a};

Y^{1b} represents N, P, SiR^{5a}, or CR^{5a};

Y^{2c}, Y^{2d}, and Y^{2f} each independently represents C or N;

R^{5a} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl;

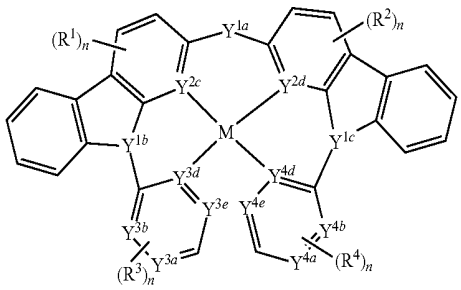
Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents C or N;

Y^{4a}, Y^{4b}, Y^{4d}, and Y^{4e} each independently represents C or N; and

n is 0, 1, or 2.

13. The organic light emitting device of claim **7**, wherein the organometallic complex is represented by Formula IV:

(Formula IV)



wherein:

M is Pt, Pd, or Ir;

R^1, R^2, R^3, or R^4 each independently represents hydrogen, halogen, hydroxy, amino, nitro, thiol, substituted or unsubstituted C_1-C_4 alkyl, substituted or unsubstituted alkoxy, or substituted or unsubstituted aryl;

Y^{1a} represents O, S, S═O, O═S═O, Se, Se═O, O═Se═O, NR^{5a}, PR^{5a}, AsR^{5a}, O═NR^{5a}, O═PR^{5a}, O═AsR^{5a}, BR^{5a}, $SiR^{5a}R^{5b}$, or $CR^{5a}R^{5b}$;

Y^{1b} and Y^{1c} each independently represents N, P, As, B, SiR^{5a}, or CR^{5a},

Y^{2c} or Y^{2d} each independently represents C or N;

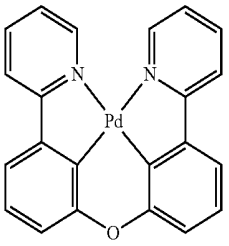
R^{5a} and R^{5b} each independently represents substituted or unsubstituted C_1-C_4 alkyl or substituted or unsubstituted aryl;

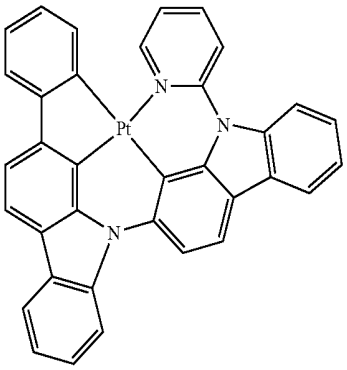
Y^{3a}, Y^{3b}, Y^{3d}, and Y^{3e} each independently represents C, N, or Si;

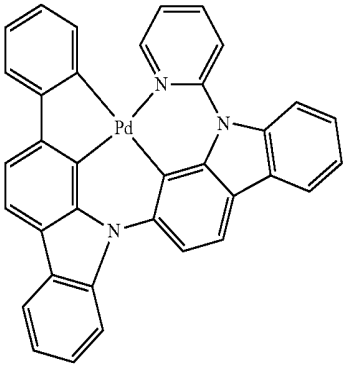
Y^{4a}, Y^{3b}, Y^{3d}, and Y^{4e} each independently represents C, N, or Si; and

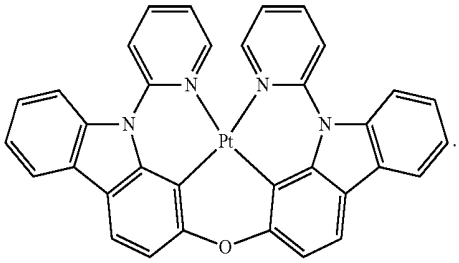
n is 0, 1, 2, 3, 4, or 5.

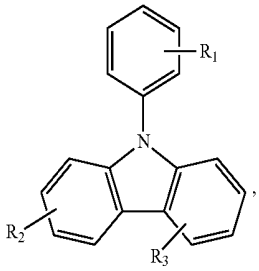
14. The organic light emitting device of claim **7**, wherein the organometallic complex has one of the following structures:

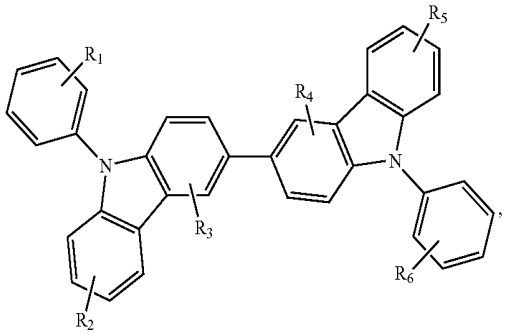


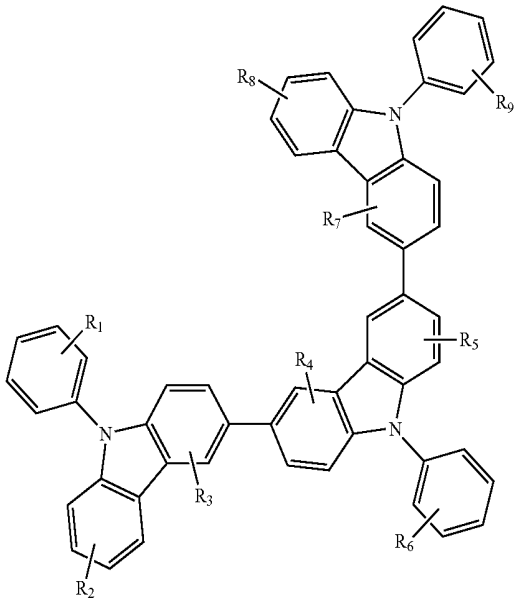












15. The organic light emitting device of claim **1**, comprising an electron blocking layer between the anode and the emissive layer.

16. The organic light emitting device of claim **15**, wherein the electron blocking layer comprises a host material and a dopant.

17. The organic light emitting device of claim **16**, wherein host material comprises a carbazole-based material.

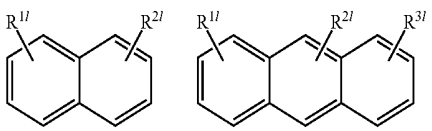
18. The organic light emitting device of claim **17**, wherein the carbazole-based material comprises one of the following structures:

wherein each of R^1-R^9 is independently hydrogen, nitro, hydroxyl, halogen, or substituted or unsubstituted amino, thio, alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkane, cycloalkane, heterocyclyl, alkoxy, haloalkyl, arylalkane, or arylalkene.

19. The organic light emitting device of claim **16**, wherein the dopant is a fluorescent material.

20. The organic light emitting device of claim **19**, wherein the fluorescent material comprises one of the following structures:

1. Aromatic Hydrocarbons and Their Derivatives



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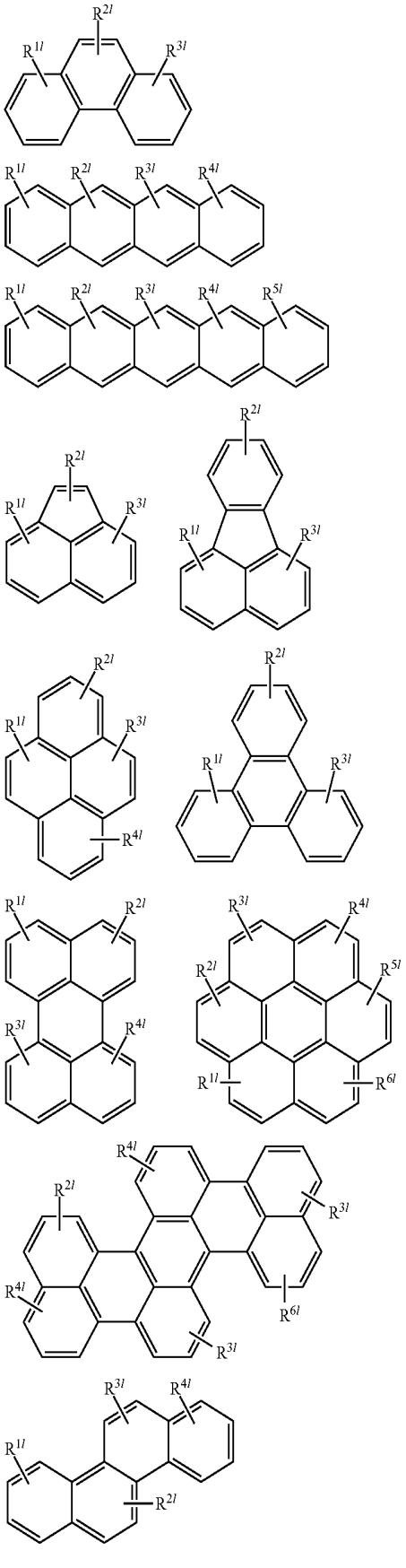

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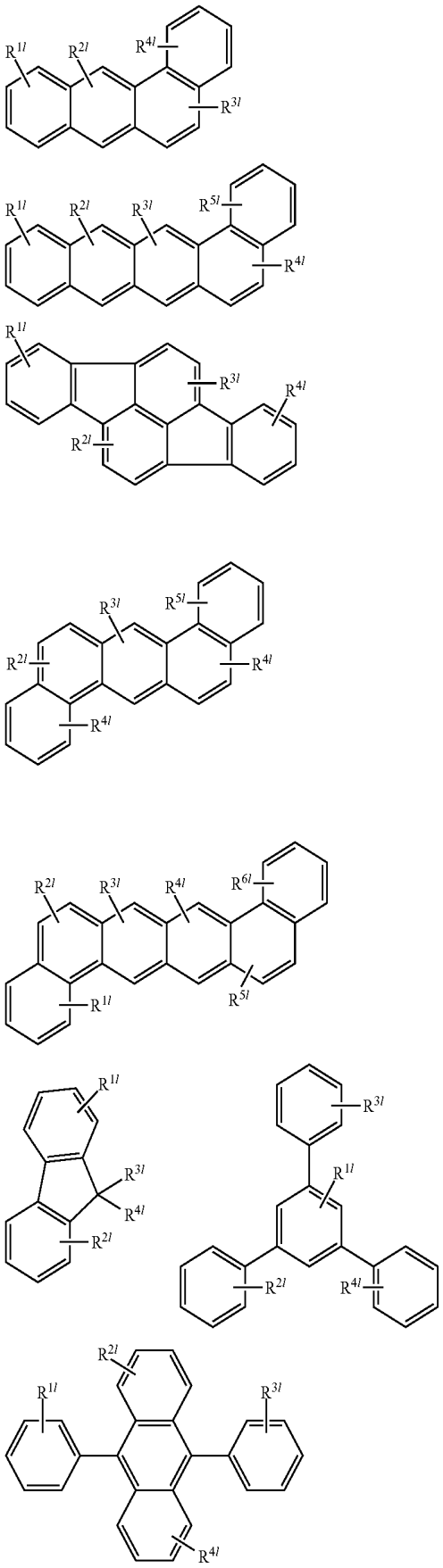

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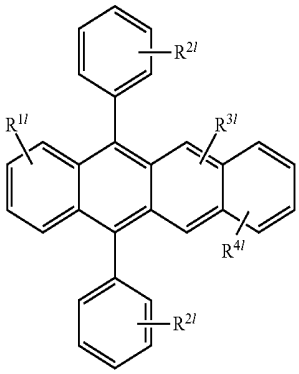

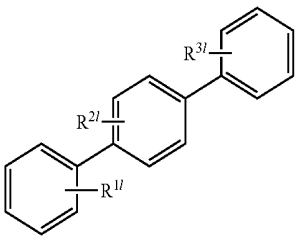

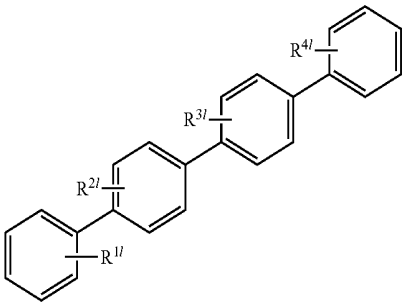

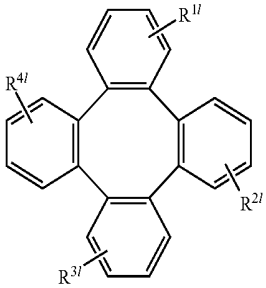

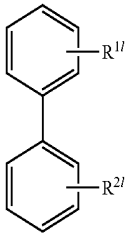

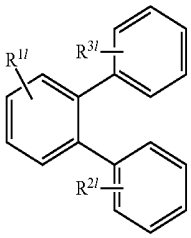

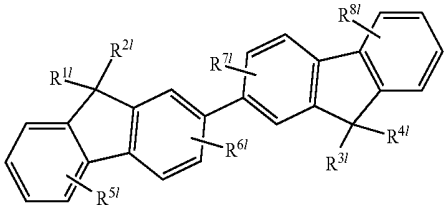

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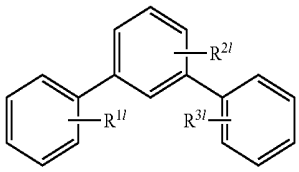

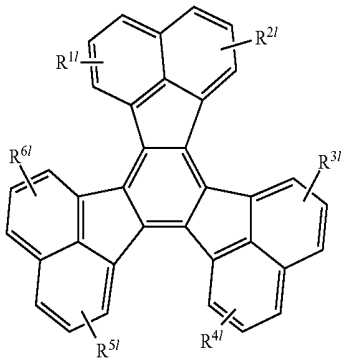

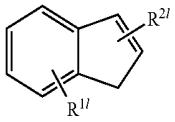

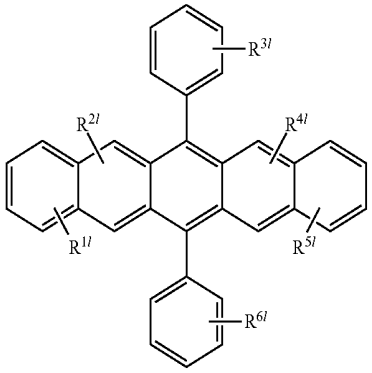

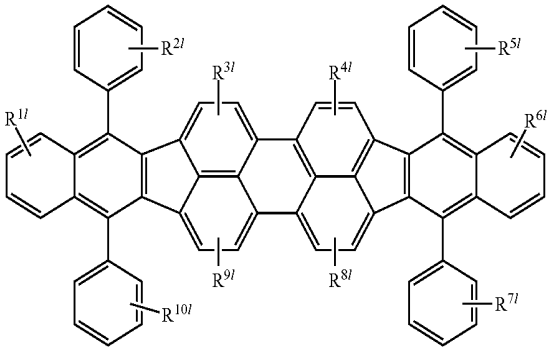

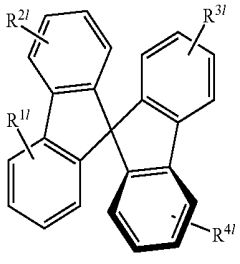

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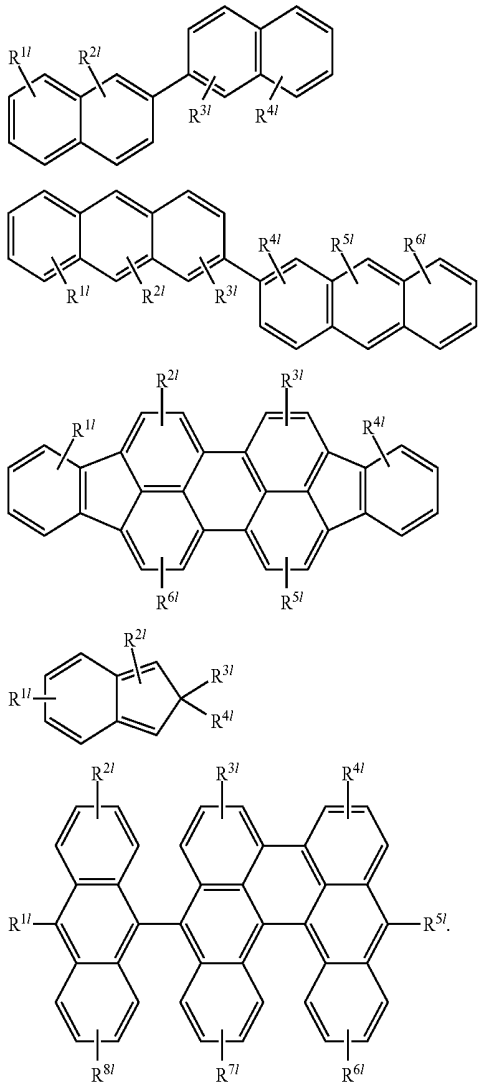

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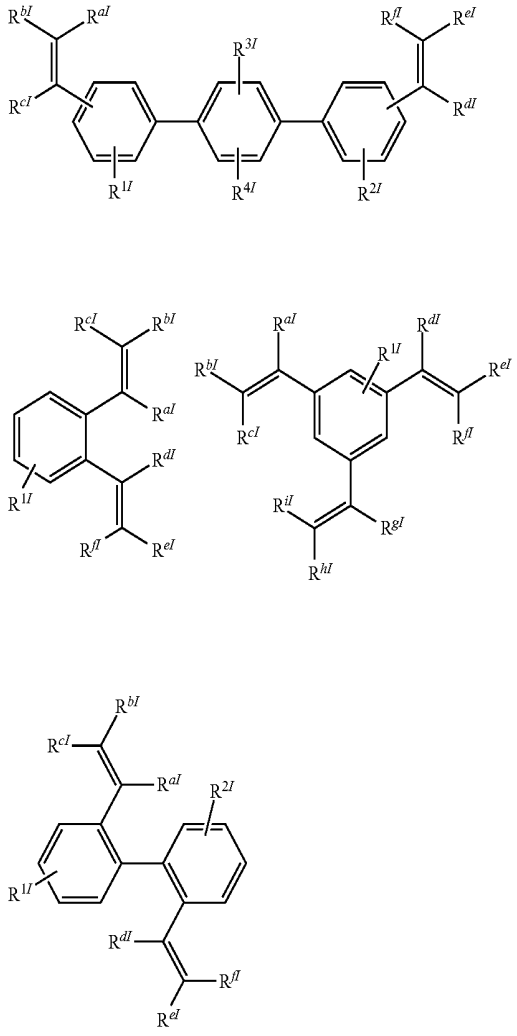
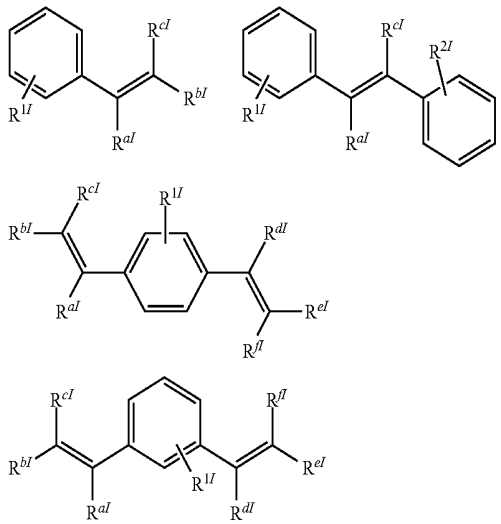
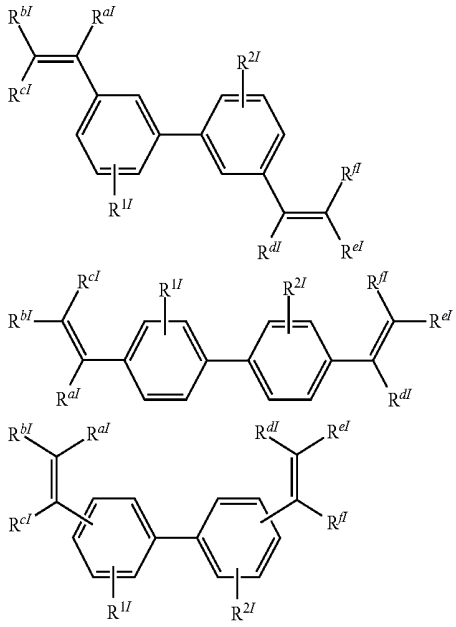


2. Arylethylene, Arylacetylene and Their Derivatives





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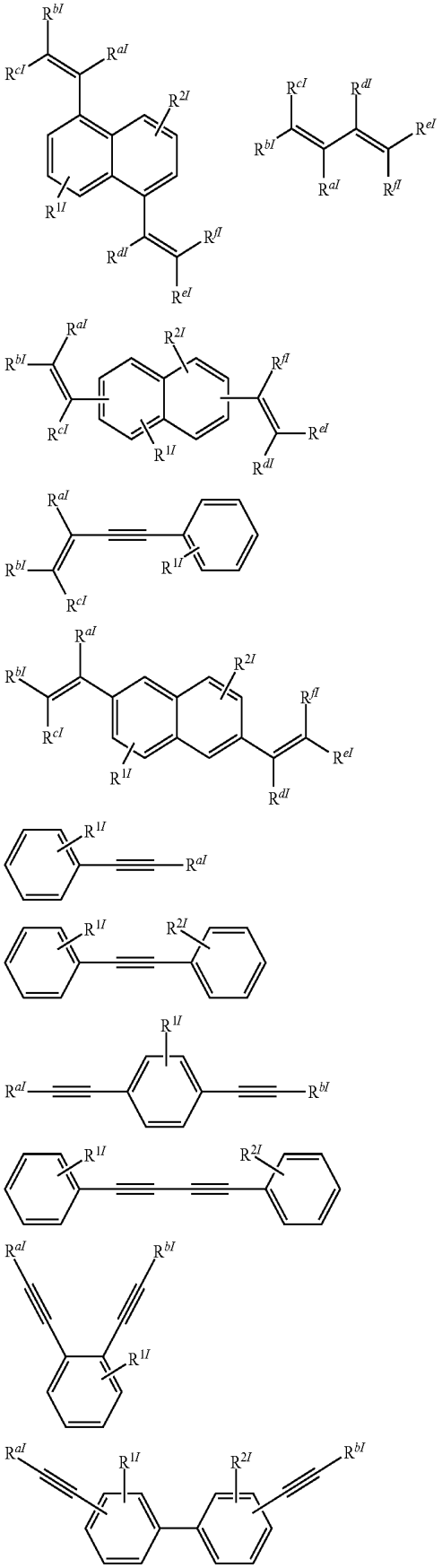

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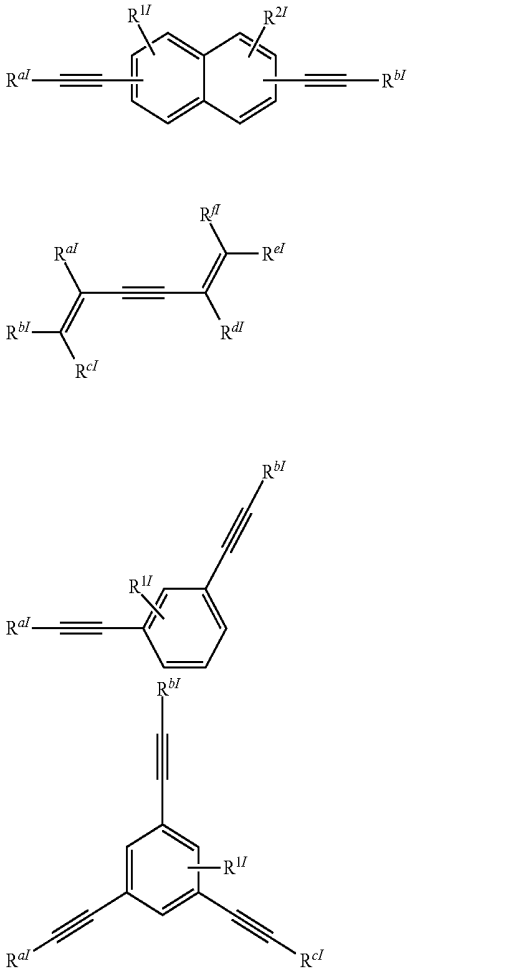
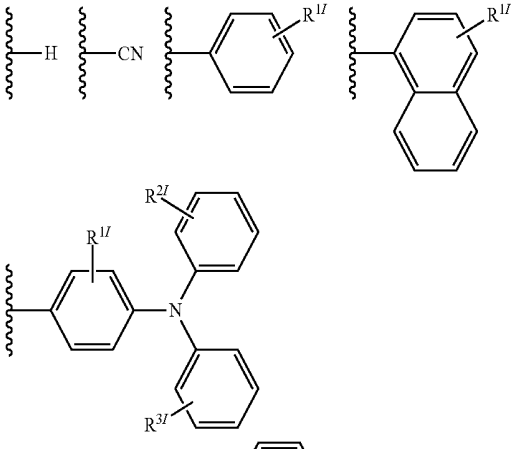


where each of R^{aI}, R^{bI}, R^{cI}, R^{dI}, R^{eI}, R^{fI}, R^{gI}, R^{hI} and R^{iI} can be one of the following structure:



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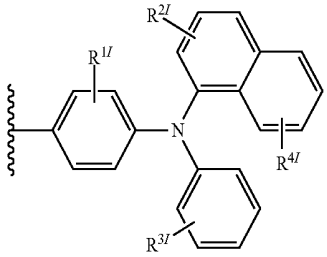

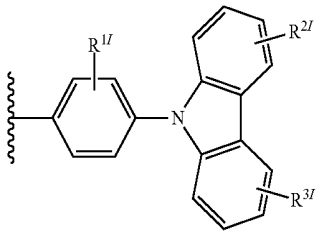

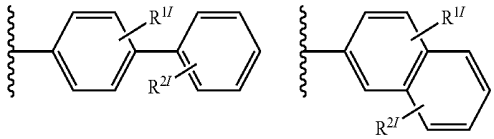

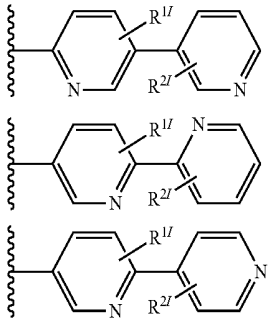

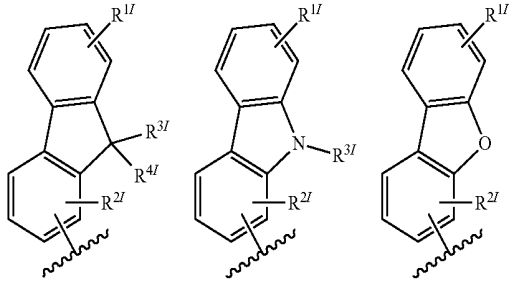

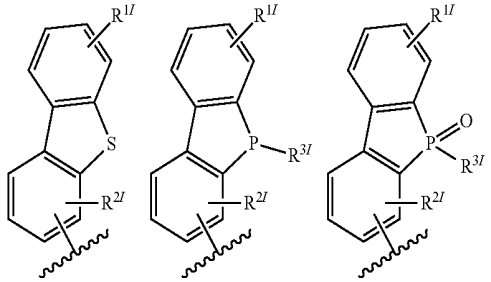

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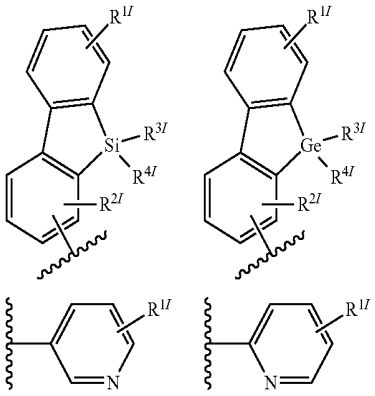
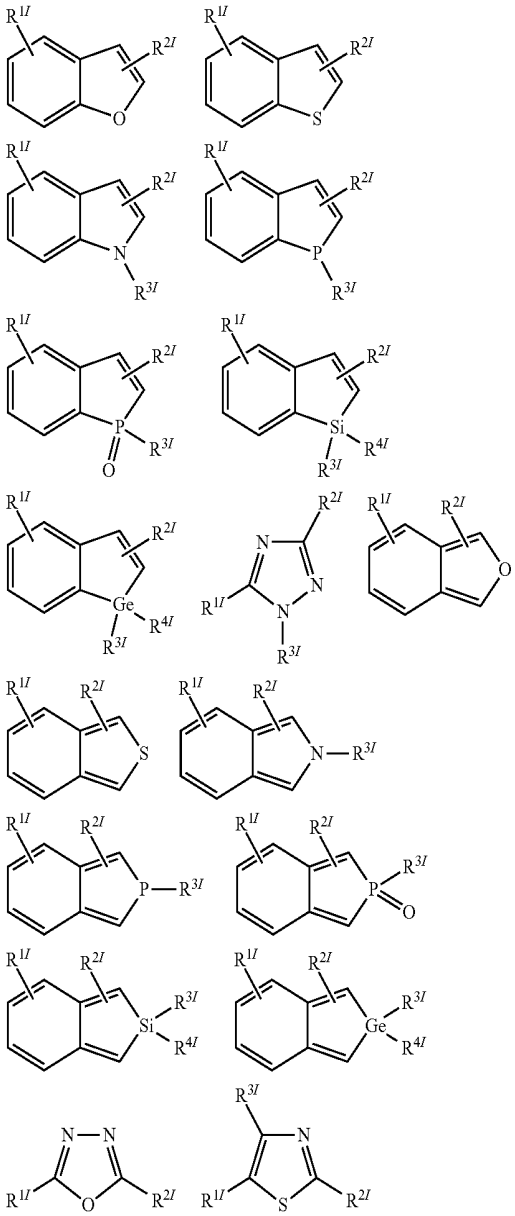


3. Heterocyclic Compounds and Their Derivatives



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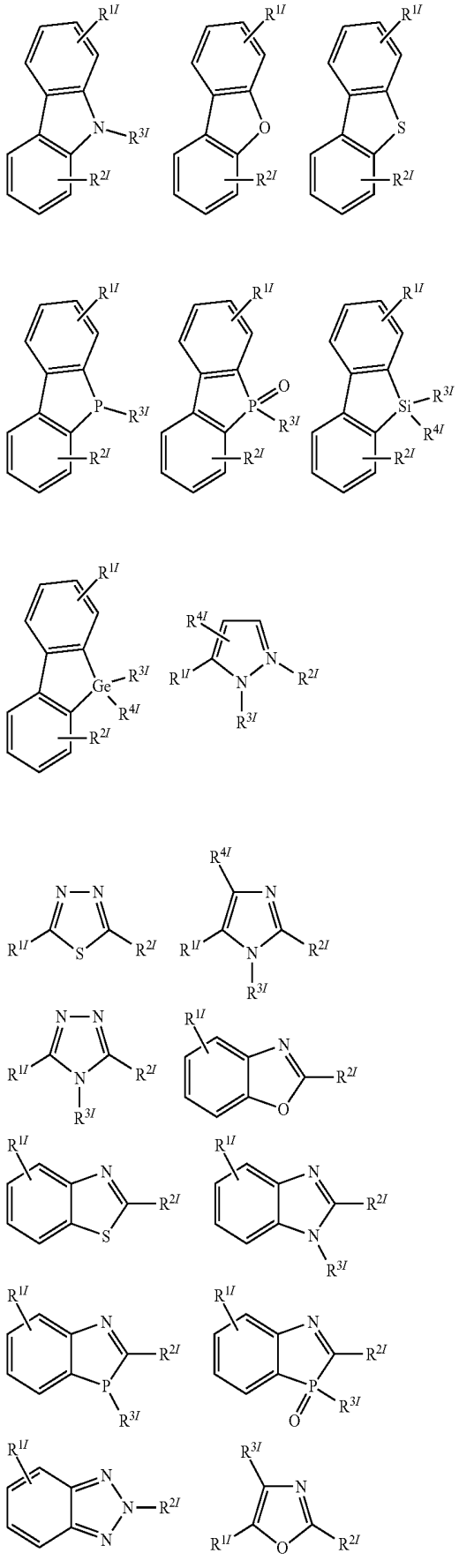

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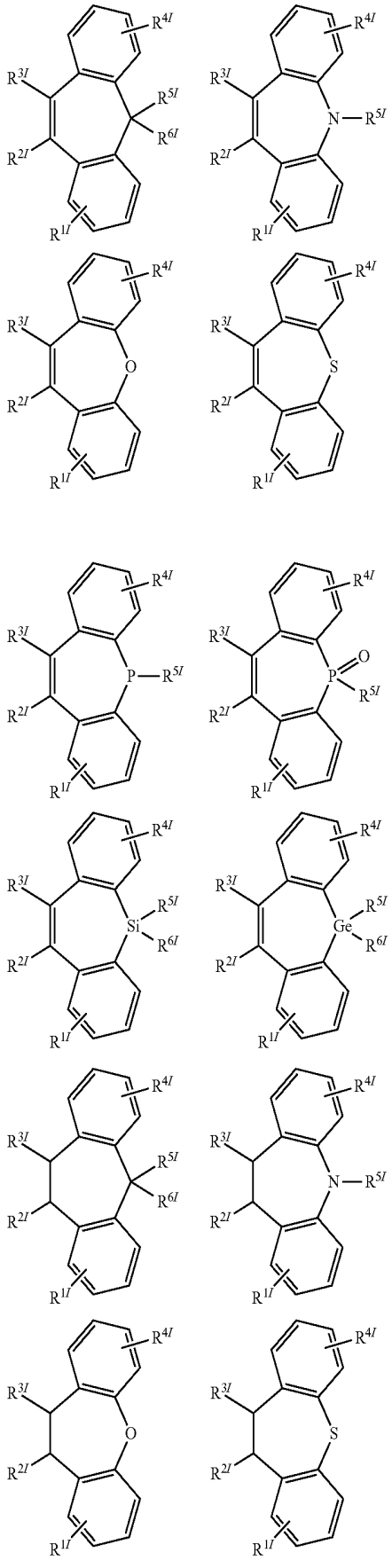

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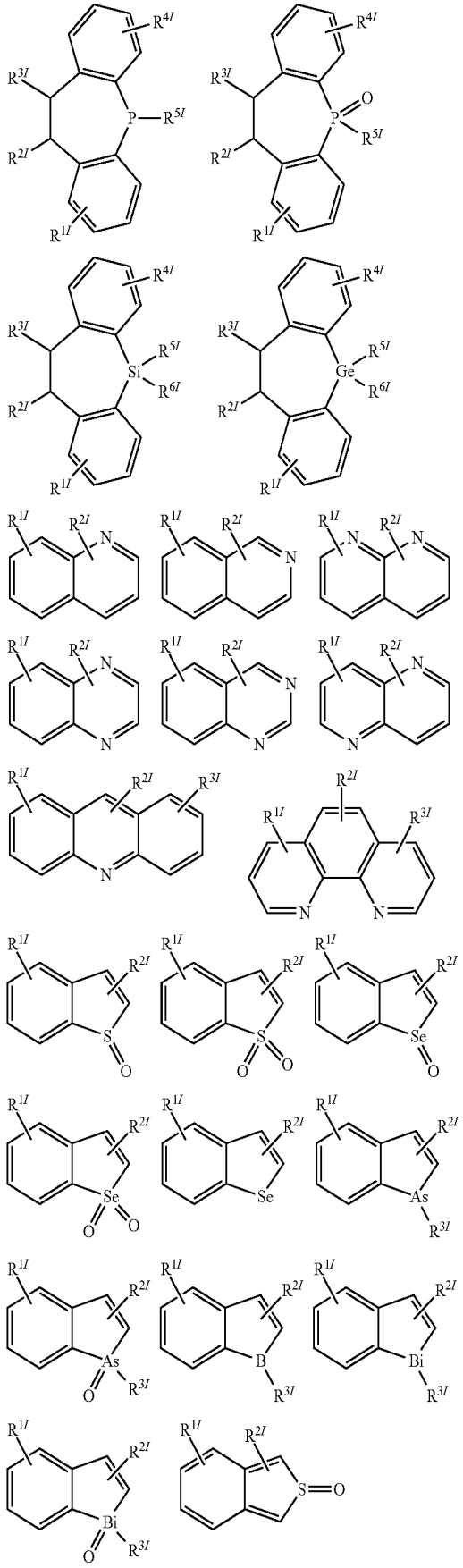

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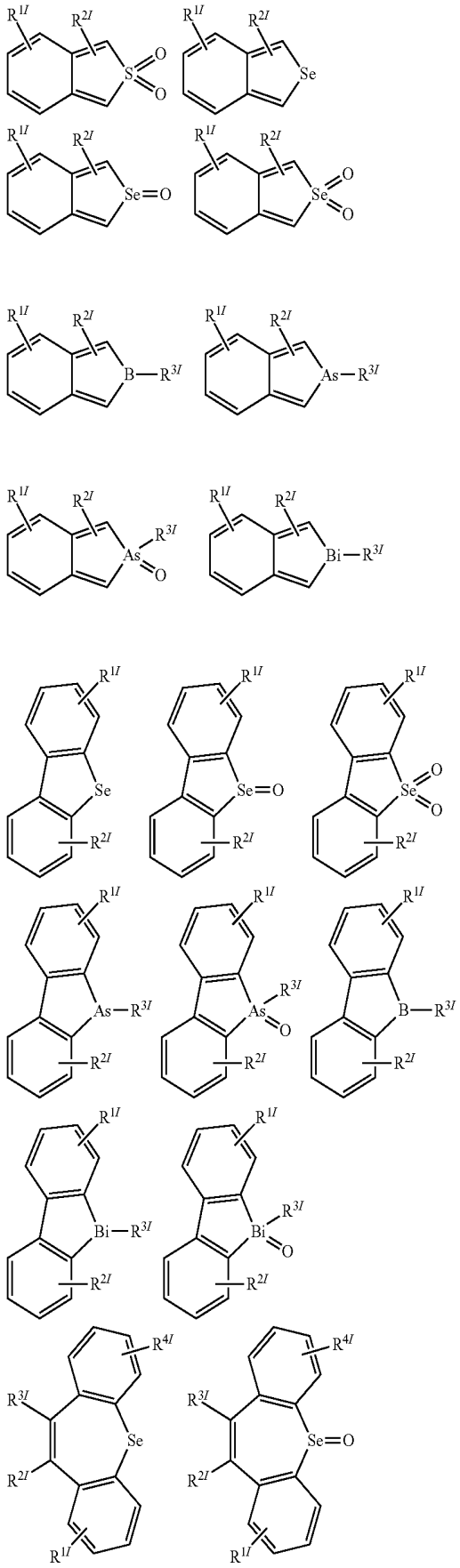

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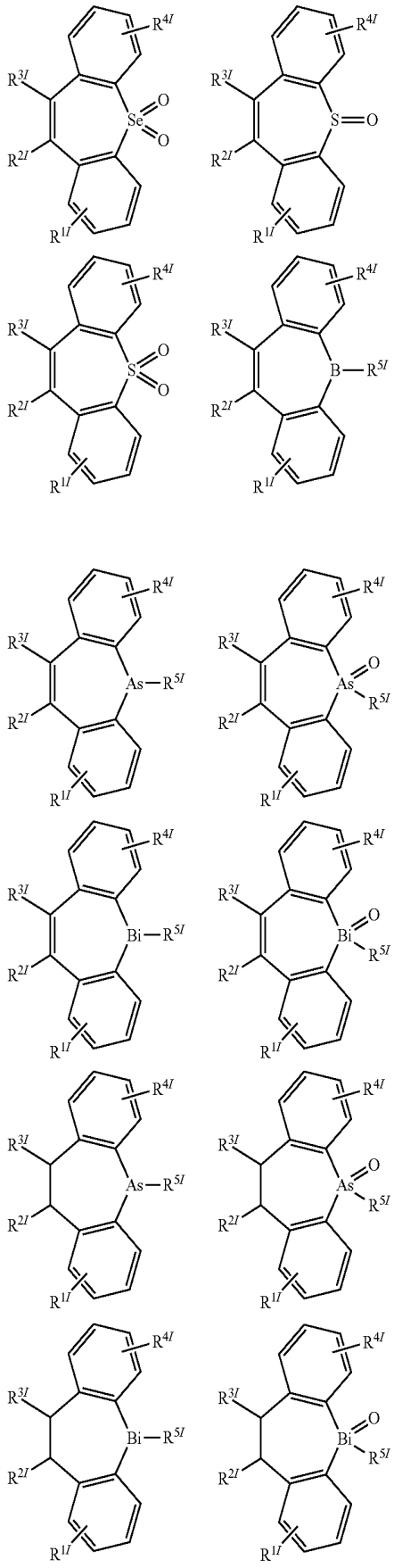

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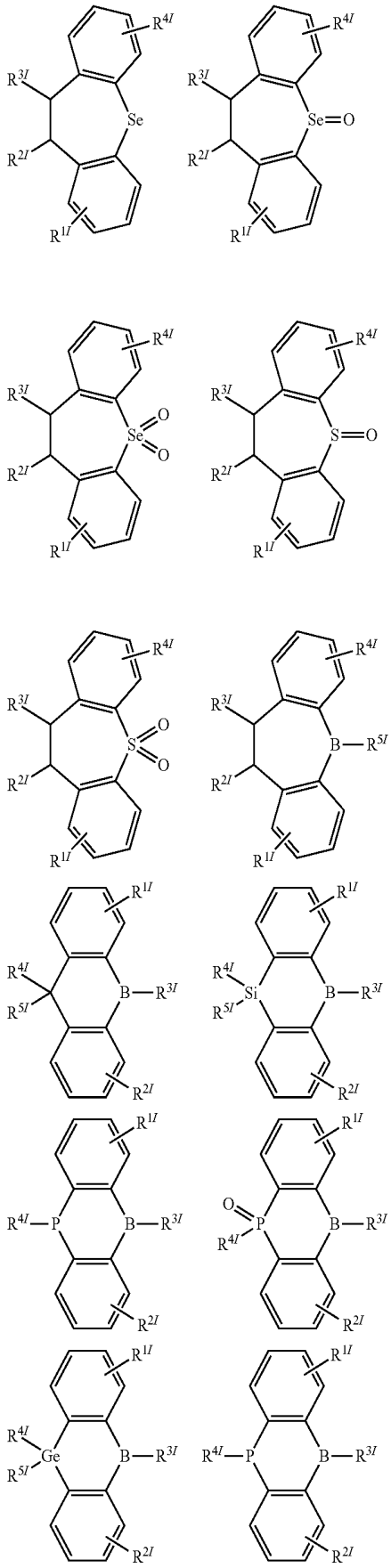

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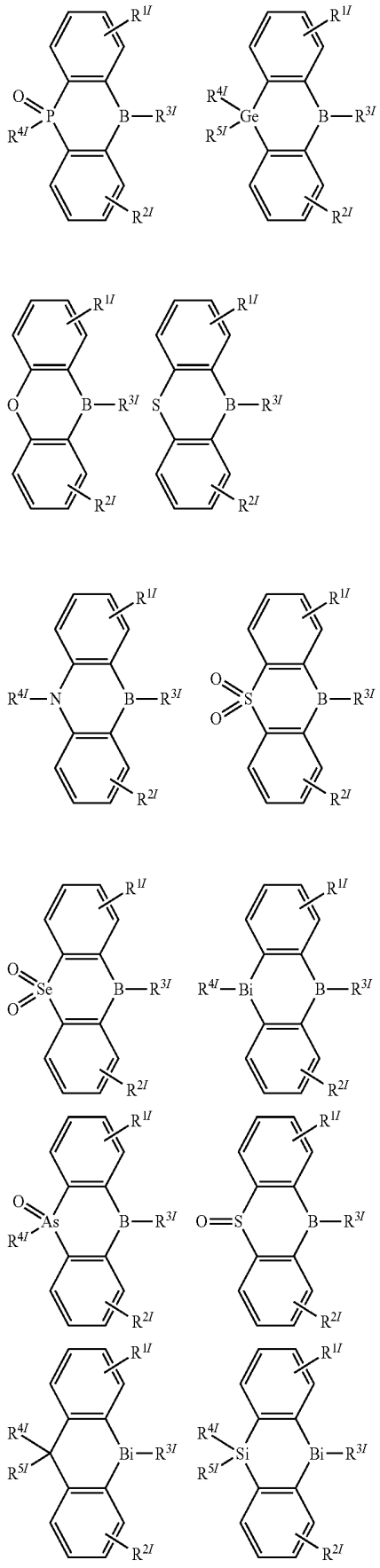

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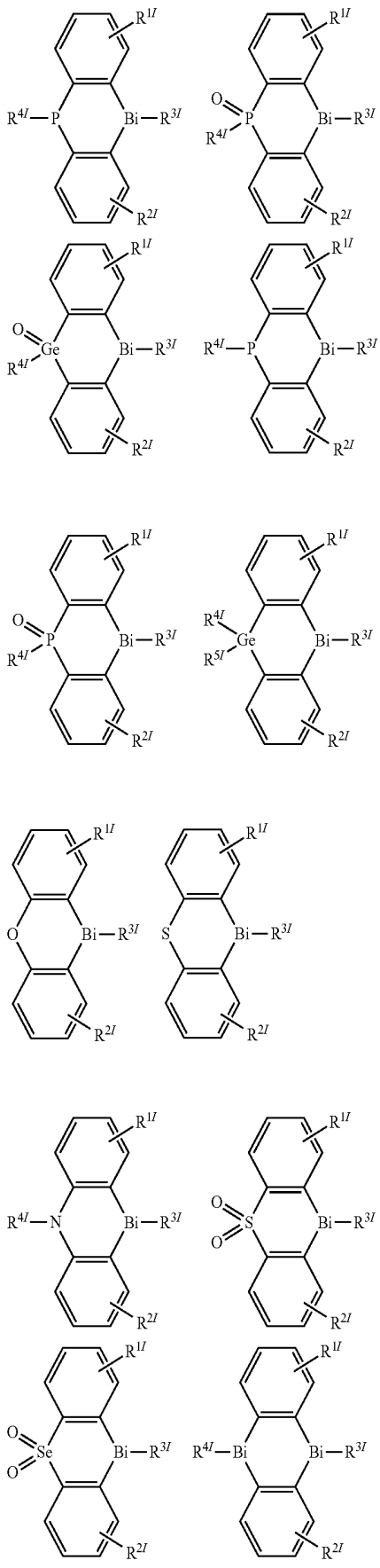

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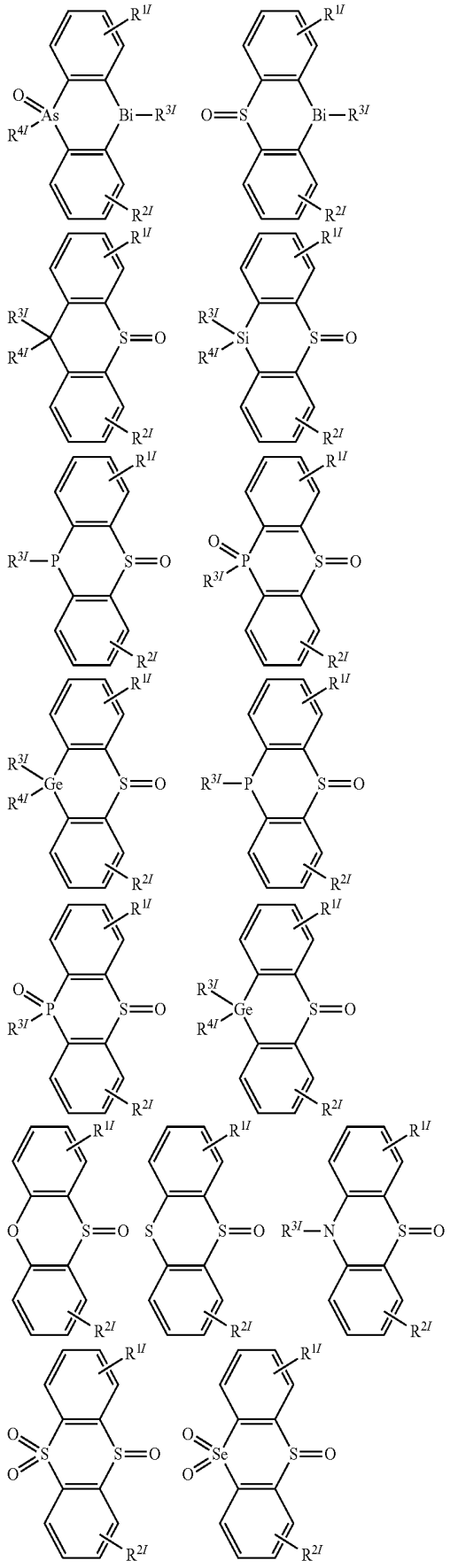

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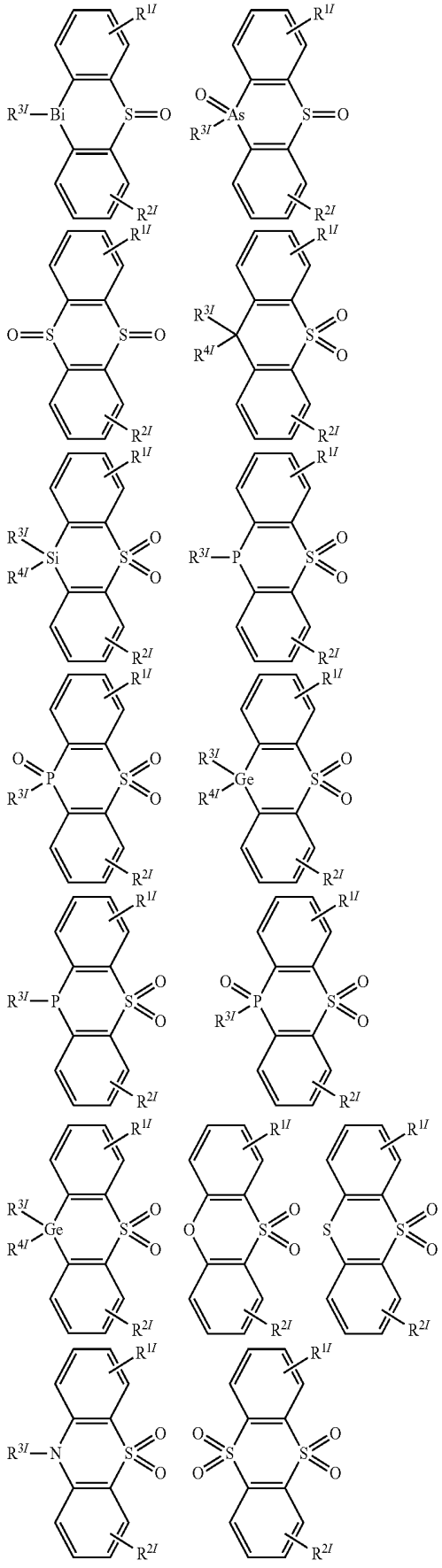

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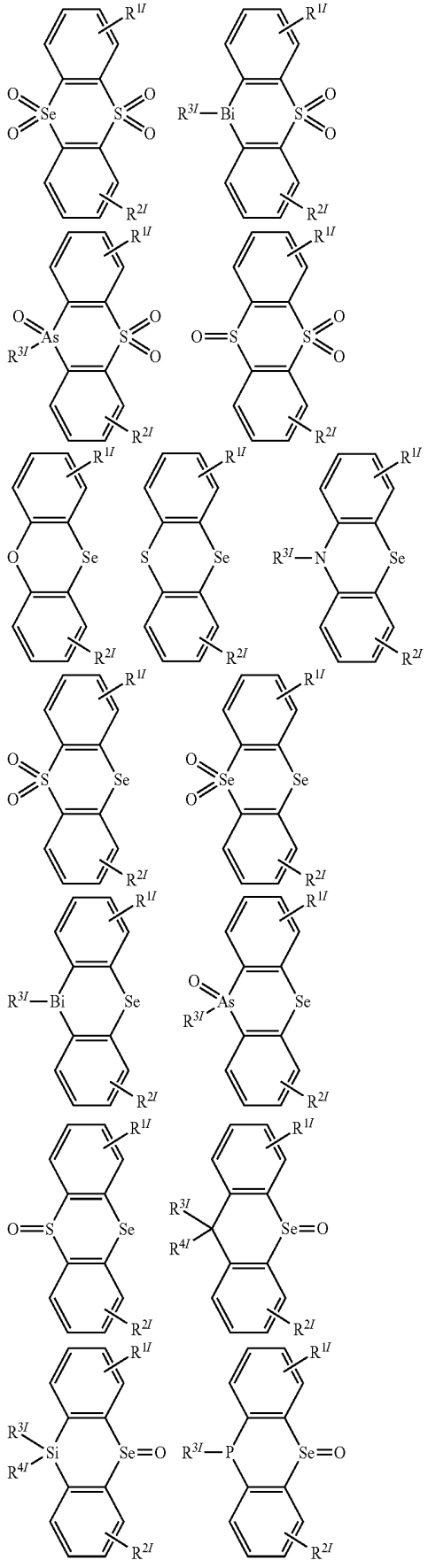

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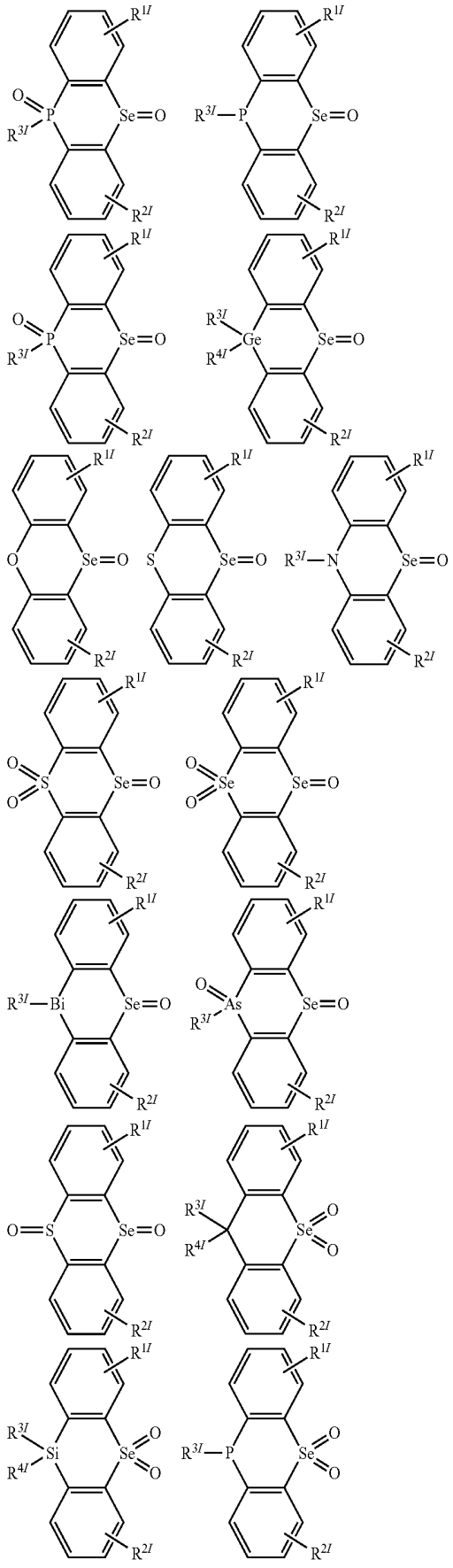

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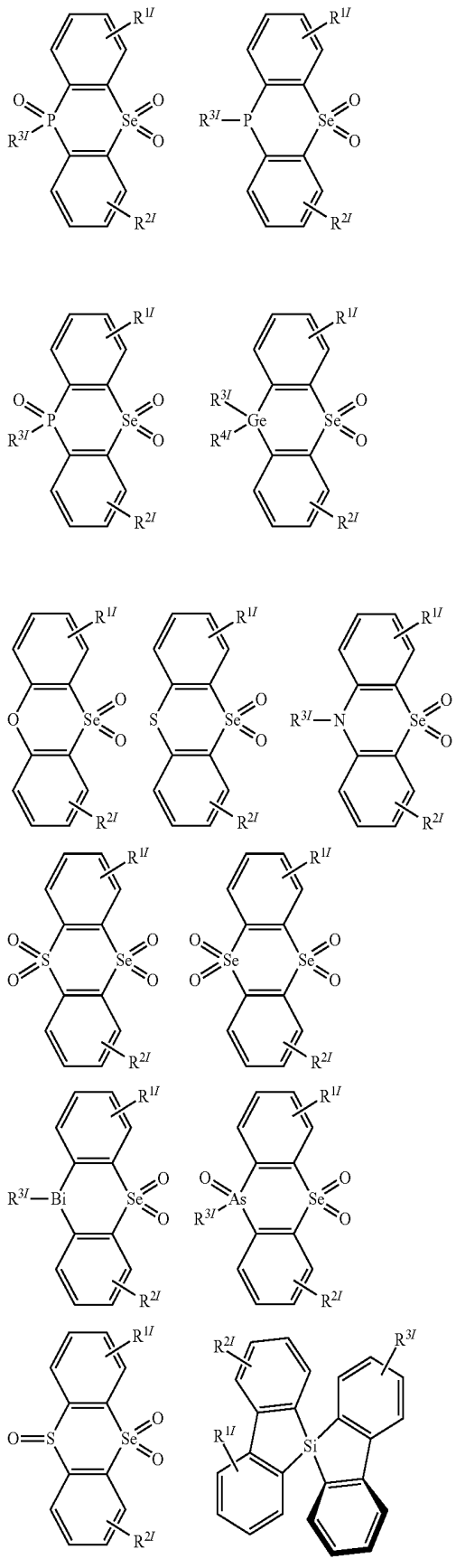

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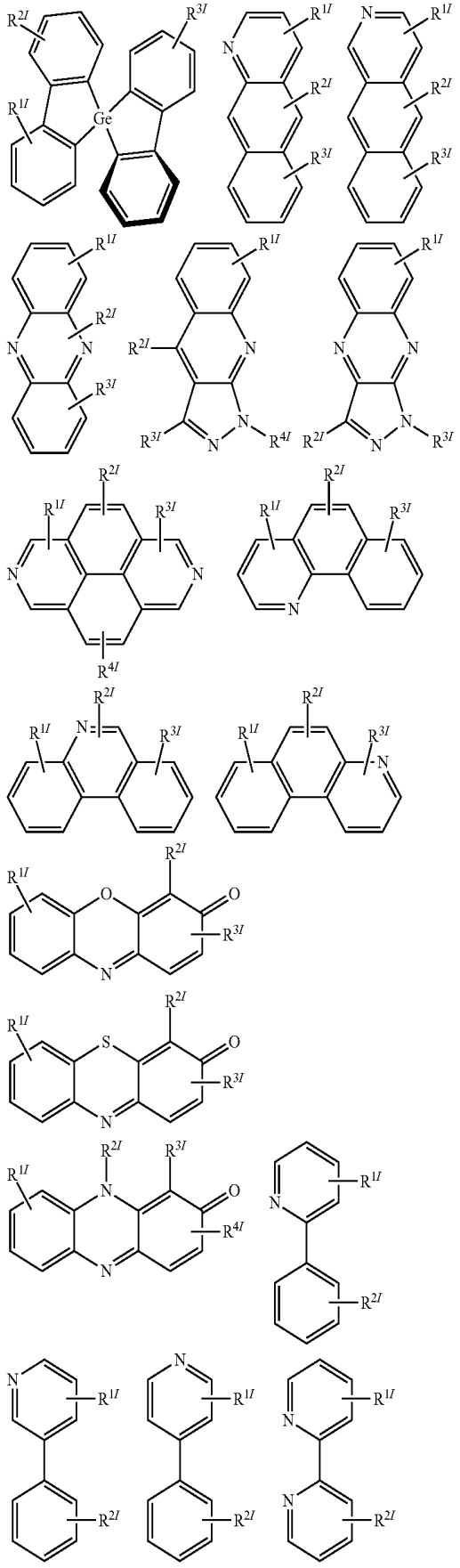

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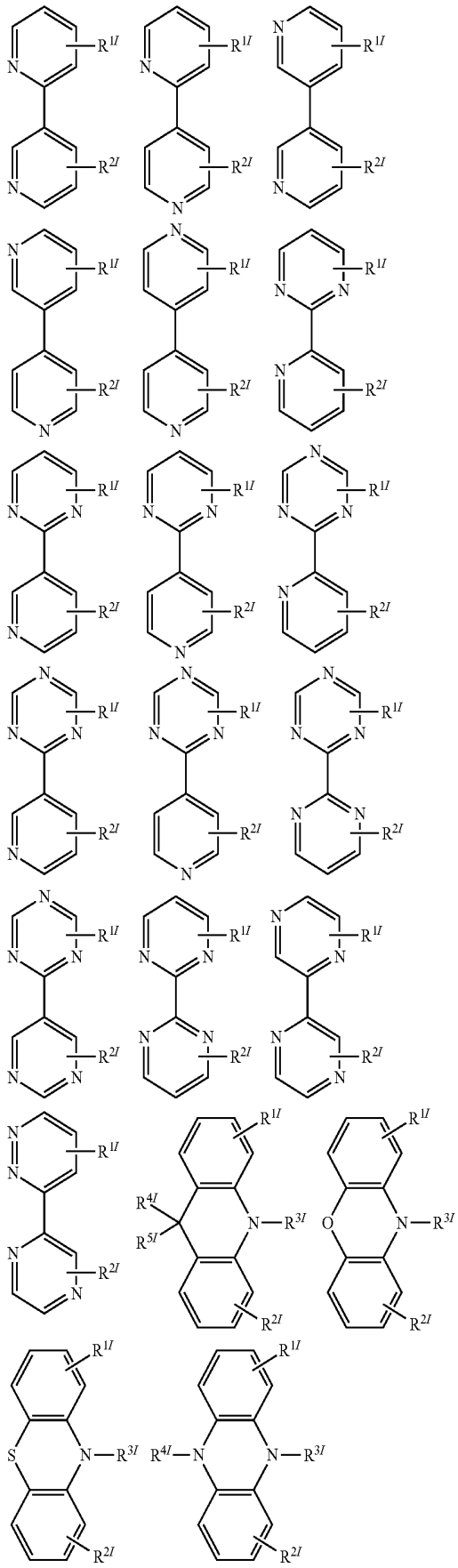

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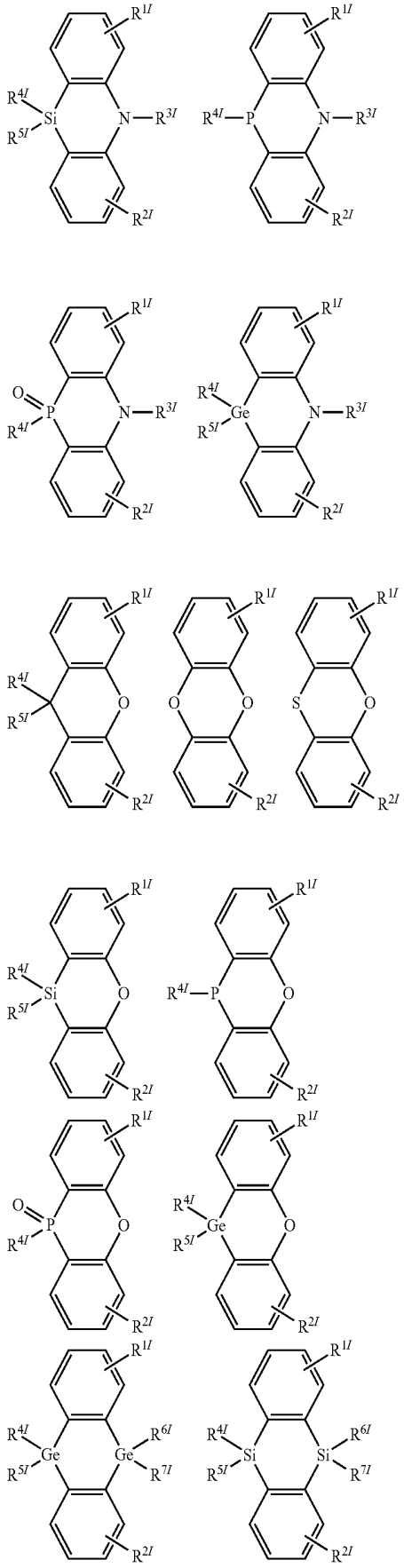

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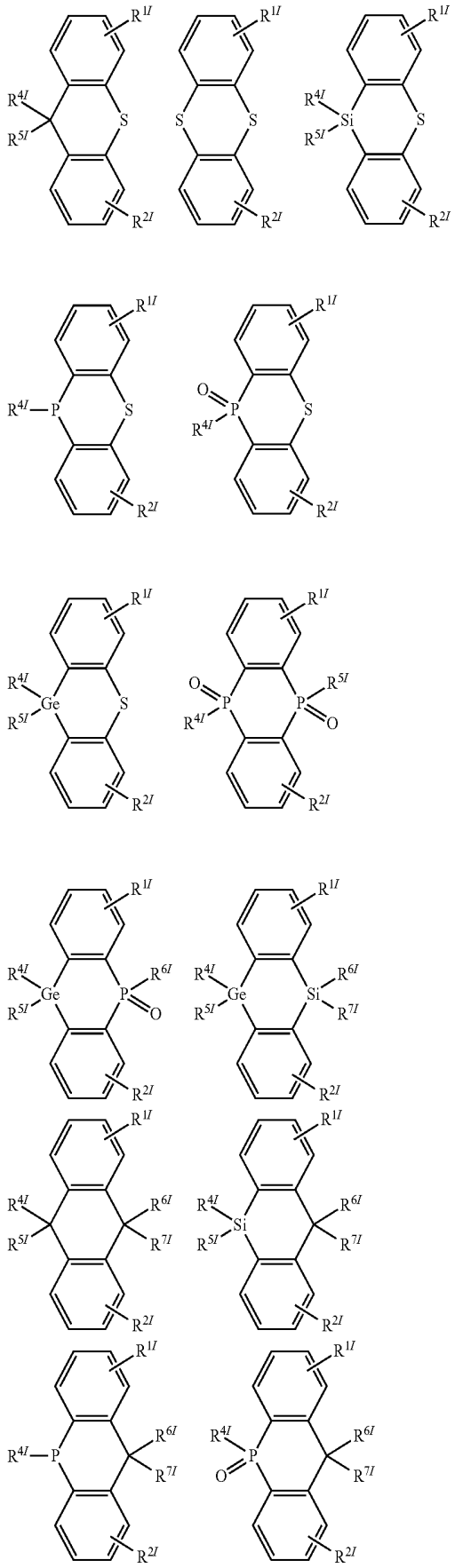

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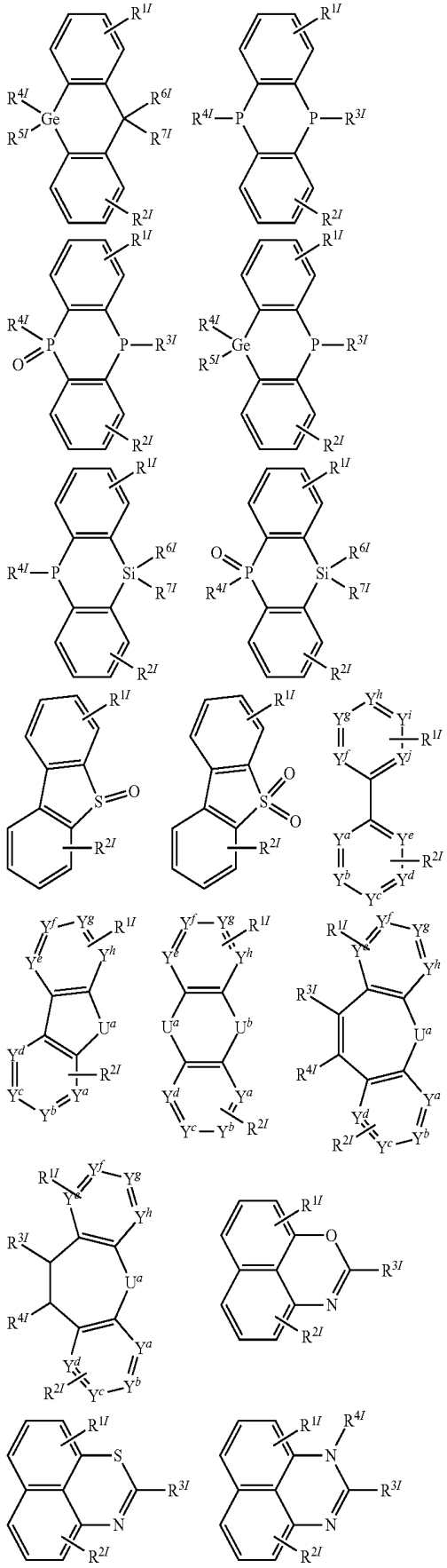

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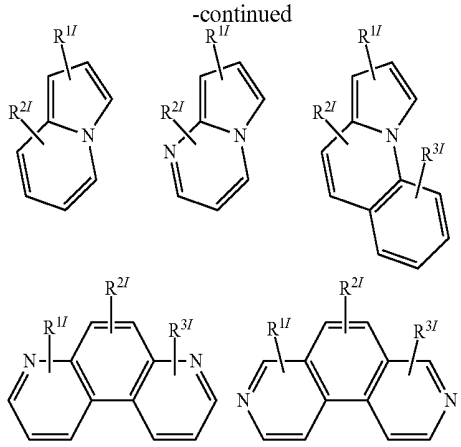

wherein:

each of R^{11}, R^{21}, R^{31}, R^{41}, R^{51}, R^{61}, R^{71}, and R^{81} is independently a mono-, di-, or tri-substitution, and if present each of R^{11}, R^{21}, R^{31}, R^{41}, R^{51}, R^{61}, R^{71}, and R^{81} is independently hydrogen, deuterium, halogen, hydroxyl, thiol, nitro, cyano, nitrile, isonitrile, sulfinyl, mercapto, sulfo, carboxyl, hydrazino; substituted or unsubstituted: aryl, cycloalkyl, cycloalkenyl, heterocyclyl, heteroaryl, substituted or unsubstituted alkyl, alkenyl, alkynyl, amino, monoalkylamino, dialkylamino, monoarylamino, diarylamino, alkoxy, aryloxy, haloalkyl, aralkyl, ester, alkoxycarbonyl, acylamino, alkoxycarbonylamino, aryloxycarbonylamino, sulfonylamino, sulfamoyl, carbamoyl, alkylthio, ureido, phosphoramide, or silyl,

each of Y^a, Y^b, Y^c, Y^d, Y^e, Y^f, Y^g, Y^h, Y^i, Y^j, Y^k, Y^l, Y^m, Y^n, Y^o, and Y^p is independently C, N, or B,

each of U^a, U^b, and U^c is independently CH_2, CR^1R^2, C═O, CH_2, SiR^1R^2, GeH_2, GeR^1R^2, NH, NR^3, PH, PR^3, R^3P═O, AsR^3, R^3As═O, O, S, S═O, SO_2, Se, Se═O, SeO_2, BH, BR^3, R^3Bi═O, BiH, or BiR^3, and

each of W, W^a, W^b, and W^c is independently CH, CR^1, SiR^1, GeH, GeR^1, N, P, B, Bi, or Bi═O.

* * * * *

专利名称(译)	具有多发光材料层的OLED		
公开(公告)号	US20170301871A1	公开(公告)日	2017-10-19
申请号	US15/487476	申请日	2017-04-14
申请(专利权)人(译)	加州大学董事会代表亚利桑那州立大学亚利桑那板		
当前申请(专利权)人(译)	加州大学董事会代表亚利桑那州立大学亚利桑那板		
[标]发明人	LI JIAN		
发明人	LI, JIAN		
IPC分类号	H01L51/00 C09K11/06 C09K11/02 H01L51/50		
CPC分类号	H01L51/0087 C09K11/06 C09K11/025 H01L51/0072 H01L51/0084 C09K2211/185 H01L51/5096 C09K2211/1007 C09K2211/1074 C09K2211/1011 C09K2211/1014 H01L51/504 C09K2211/1044 C09K2211/1029 H01L51/0052 H01L51/0054 H01L51/0055 H01L51/0056 H01L51/0057 H01L51/0058 H01L51/5008		
优先权	62/323383 2016-04-15 US 62/377747 2016-08-22 US		
外部链接	Espacenet USPTO		

摘要(译)

本发明涉及具有多发光材料层（EML）的有机发光器件，其中多EML通常是指具有至少两层发光材料的发光层，每层具有不同的发光体浓度（例如，第一个与第二个EML直接接触的EML，第一个EML（有利孔）的发射极浓度超过第二个EML（电子有利）的发射极浓度。