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(54) **ORGANIC ELECTROLUMINESCENT MATERIALS AND DEVICES**

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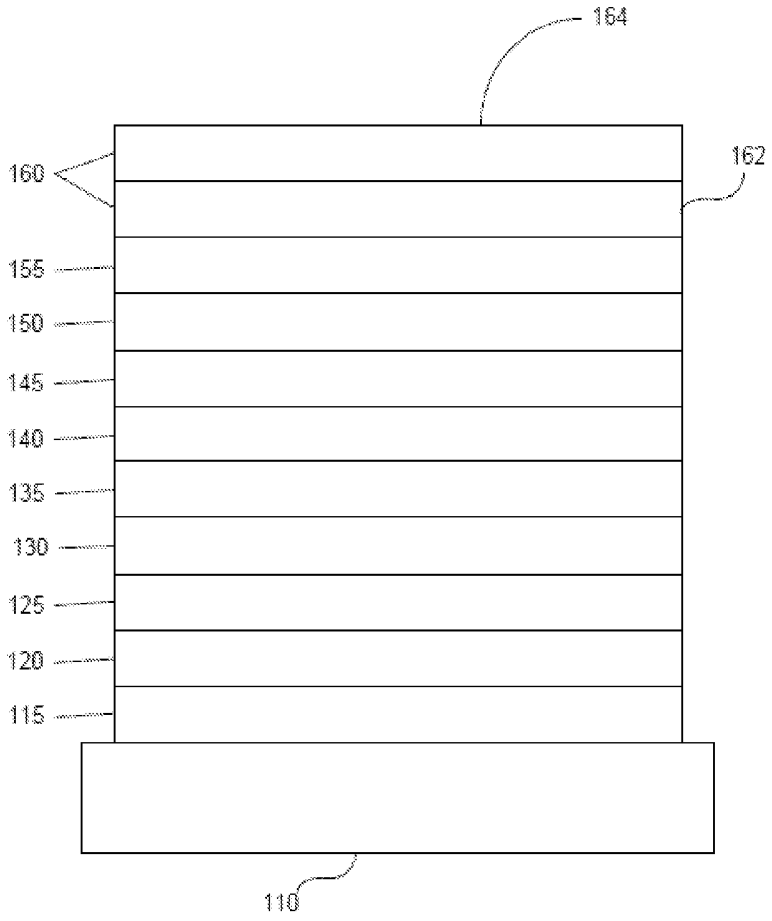
(57) **ABSTRACT**

A mixture containing three different compounds that is useful as a stable co-evaporation source material for a vacuum deposition tool is disclosed. The mixture comprises a first compound; a second compound; and a third compound that are all organic compounds and have different chemical structures from each other and each has an evaporation temperature T**1**, T**2**, and T**3**, respectively, in the range of 150 to 350° C. T**1**, T**2**, and T**3** differ from each other by less than 20° C. The first compound has a concentration C**1** in the first mixture and a concentration C**2** in a film deposited by evaporating the first mixture in a high vacuum deposition tool under a predefined deposition condition where |(C**1**-C**2**)/C**1**| is less than 5%.



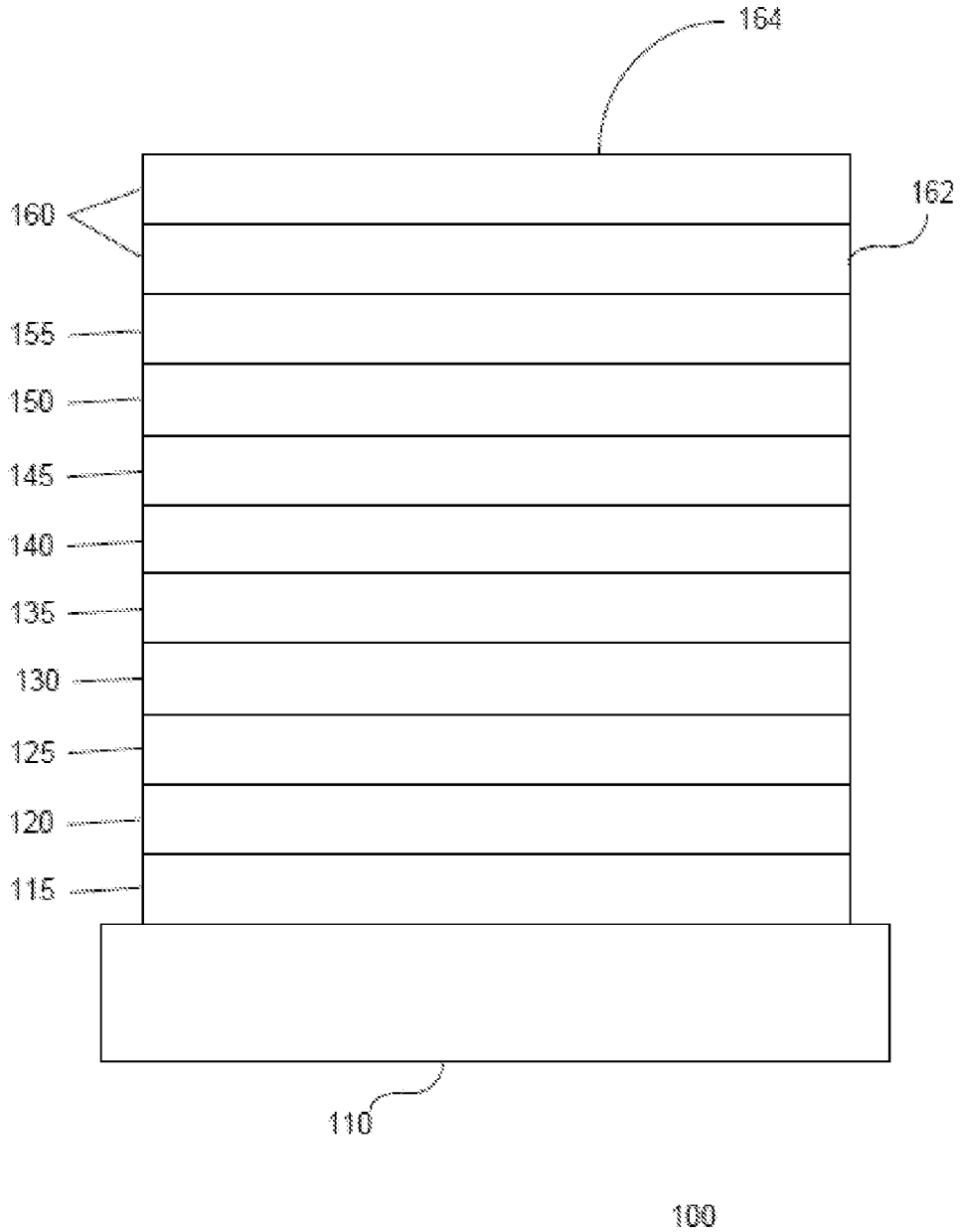


FIG. 1

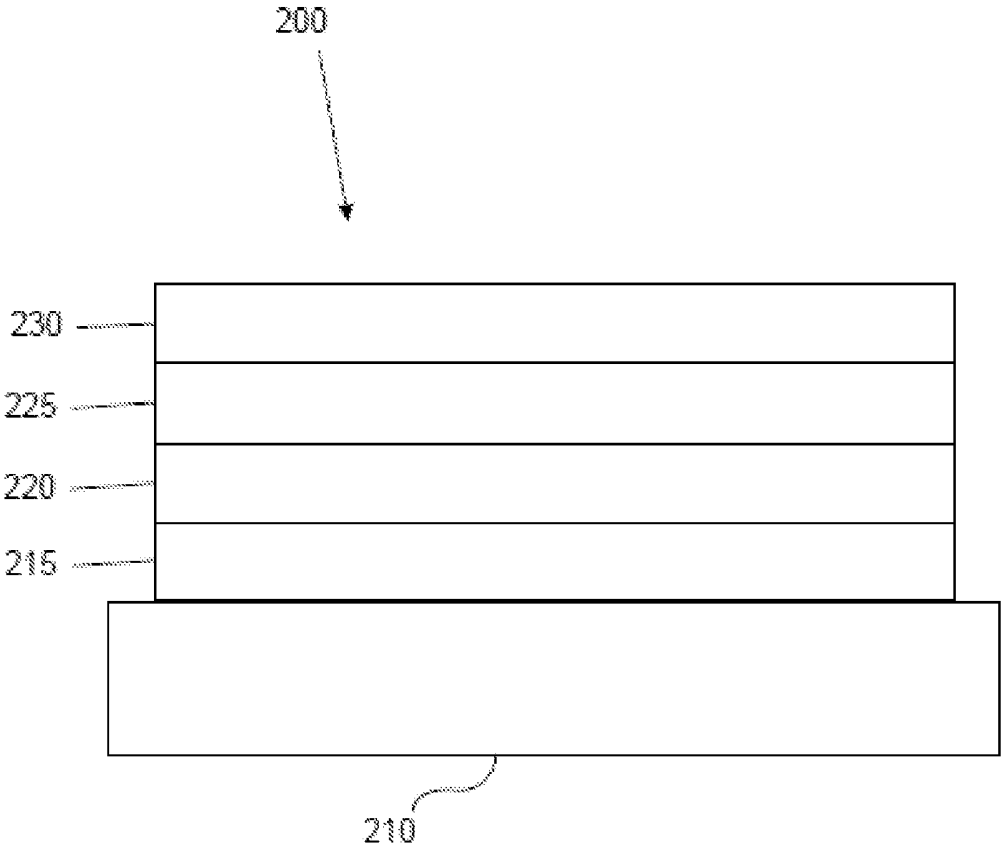


FIG. 2

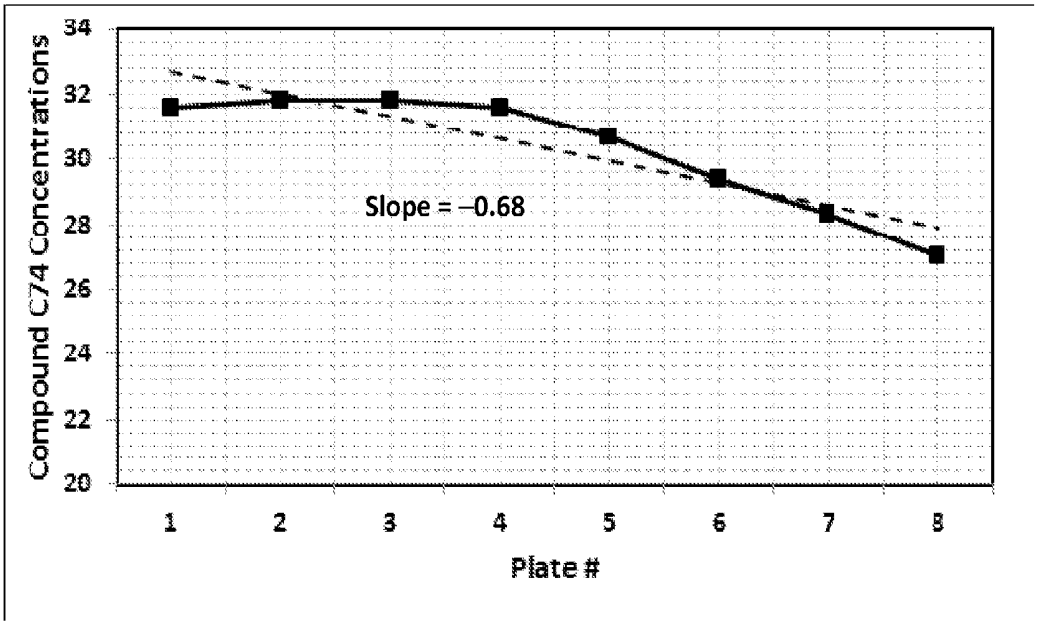

Compound C74 Concentrations
34
32
30
28
26
24
22
20
Slope = –0.68
1
2
3
4
5
6
7
8
Plate #

FIG. 3

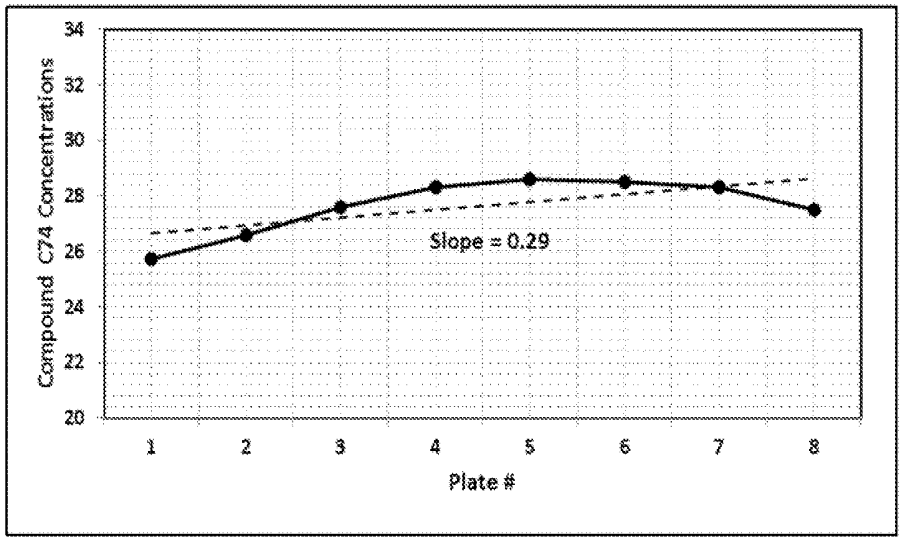

Compound C74 Concentrations
34
32
30
28
26
24
22
20
Slope = 0.29
1
2
3
4
5
6
7
8
Plate #

FIG. 4

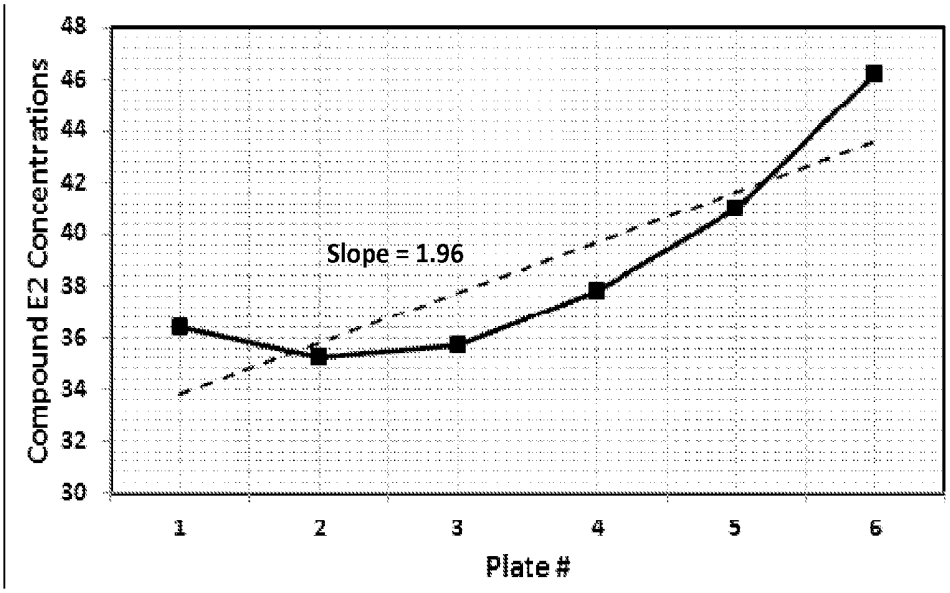

Compound E2 Concentrations
48
46
44
42
40
38
36
34
32
30
Slope = 1.96
1
2
3
4
5
6
Plate #

FIG. 5

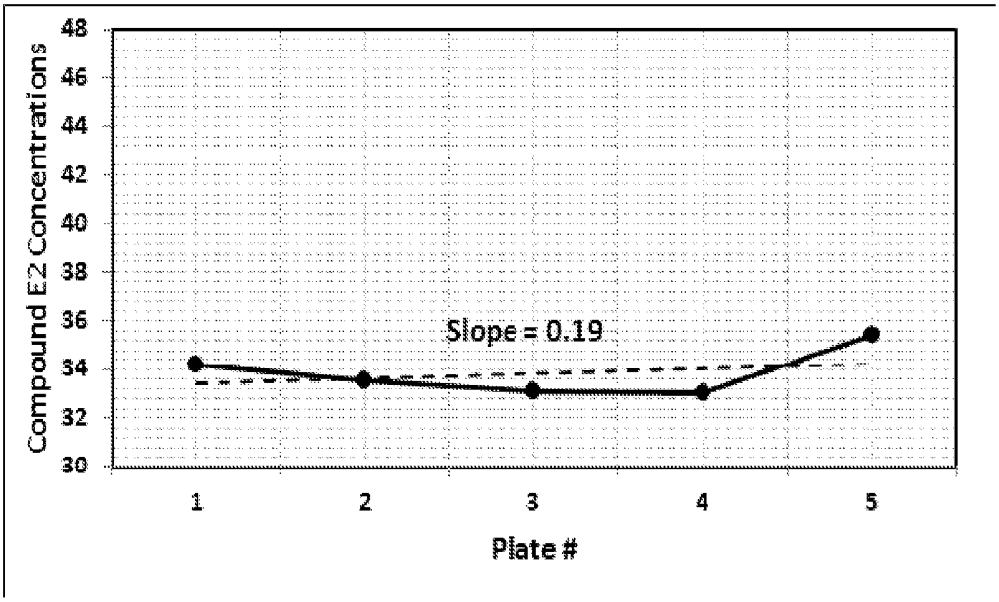

Compound E2 Concentrations
48
46
44
42
40
38
36
34
32
30
Slope = 0.19
1
2
3
4
5
Plate #

FIG. 6

ORGANIC ELECTROLUMINESCENT MATERIALS AND DEVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority under 35 U.S.C. §119(e) to U.S. Provisional Applications No. 62/056,940, filed on Sep. 29, 2014, the entire contents of which are incorporated herein by reference.

PARTIES TO A JOINT RESEARCH AGREEMENT

[0002] The claimed invention was made by, on behalf of, and/or in connection with one or more of the following parties to a joint university corporation research agreement: The Regents of the University of Michigan, Princeton University, University of Southern California, and Universal Display Corporation. The agreement was in effect on and before the date the claimed invention was made, and the claimed invention was made as a result of activities undertaken within the scope of the agreement.

FIELD OF THE INVENTION

[0003] The present invention relates to organic light emitting devices (OLEDs), and more specifically to organic materials used in such devices. More specifically, the present invention relates to a novel evaporation source comprising a mixture of two organic compounds that allows stable co-evaporation of the two organic compounds in fabrication of various layers in phosphorescent organic light emitting devices (PHOLEDs).

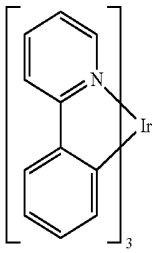
BACKGROUND

[0004] Opto-electronic devices that make use of organic materials are becoming increasingly desirable for a number of reasons. Many of the materials used to make such devices are relatively inexpensive, so organic opto-electronic devices have the potential for cost advantages over inorganic devices. In addition, the inherent properties of organic materials, such as their flexibility, may make them well suited for particular applications such as fabrication on a flexible substrate. Examples of organic opto-electronic devices include organic light emitting devices (OLEDs), organic phototransistors, organic photovoltaic cells, and organic photodetectors. For OLEDs, the organic materials may have performance advantages over conventional materials. For example, the wavelength at which an organic emissive layer emits light may generally be readily tuned with appropriate dopants.

[0005] OLEDs make use of thin organic films that emit light when voltage is applied across the device. OLEDs are becoming an increasingly interesting technology for use in applications such as flat panel displays, illumination, and backlighting. Several OLED materials and configurations are described in U.S. Pat. Nos. 5,844,363, 6,303,238, and 5,707,745, which are incorporated herein by reference in their entirety.

[0006] One application for phosphorescent emissive molecules is a full color display. Industry standards for such a display call for pixels adapted to emit particular colors, referred to as "saturated" colors. In particular, these standards call for saturated red, green, and blue pixels. Color may be measured using CIE coordinates, which are well known to the art.

[0007] One example of a green emissive molecule is tris(2-phenylpyridine)iridium, denoted $Ir(ppy)_3$, which has the following structure:



[0008] In this, and later figures herein, we depict the dative bond from nitrogen to metal (here, Ir) as a straight line.

[0009] As used herein, the term "organic" includes polymeric materials as well as small molecule organic materials that may be used to fabricate organic opto-electronic devices. "Small molecule" refers to any organic material that is not a polymer, and "small molecules" may actually be quite large. Small molecules may include repeat units in some circumstances. For example, using a long chain alkyl group as a substituent does not remove a molecule from the "small molecule" class. Small molecules may also be incorporated into polymers, for example as a pendent group on a polymer backbone or as a part of the backbone. Small molecules may also serve as the core moiety of a dendrimer, which consists of a series of chemical shells built on the core moiety. The core moiety of a dendrimer may be a fluorescent or phosphorescent small molecule emitter. A dendrimer may be a "small molecule," and it is believed that all dendrimers currently used in the field of OLEDs are small molecules.

[0010] As used herein, "top" means furthest away from the substrate, while "bottom" means closest to the substrate. Where a first layer is described as "disposed over" a second layer, the first layer is disposed further away from substrate. There may be other layers between the first and second layer, unless it is specified that the first layer is "in contact with" the second layer. For example, a cathode may be described as "disposed over" an anode, even though there are various organic layers in between.

[0011] As used herein, "solution processible" means capable of being dissolved, dispersed, or transported in and/or deposited from a liquid medium, either in solution or suspension form.

[0012] A ligand may be referred to as "photoactive" when it is believed that the ligand directly contributes to the photoactive properties of an emissive material. A ligand may be referred to as "ancillary" when it is believed that the ligand does not contribute to the photoactive properties of an emissive material, although an ancillary ligand may alter the properties of a photoactive ligand.

[0013] As used herein, and as would be generally understood by one skilled in the art, a first "Highest Occupied Molecular Orbital" (HOMO) or "Lowest Unoccupied Molecular Orbital" (LUMO) energy level is "greater than" or "higher than" a second HOMO or LUMO energy level if the first energy level is closer to the vacuum energy level. Since ionization potentials (IP) are measured as a negative energy relative to a vacuum level, a higher HOMO energy level corresponds to an IP having a smaller absolute value (an IP that is less negative). Similarly, a higher LUMO energy level

corresponds to an electron affinity (EA) having a smaller absolute value (an EA that is less negative). On a conventional energy level diagram, with the vacuum level at the top, the LUMO energy level of a material is higher than the HOMO energy level of the same material. A "higher" HOMO or LUMO energy level appears closer to the top of such a diagram than a "lower" HOMO or LUMO energy level.

[0014] As used herein, and as would be generally understood by one skilled in the art, a first work function is "greater than" or "higher than" a second work function if the first work function has a higher absolute value. Because work functions are generally measured as negative numbers relative to vacuum level, this means that a "higher" work function is more negative. On a conventional energy level diagram, with the vacuum level at the top, a "higher" work function is illustrated as further away from the vacuum level in the downward direction. Thus, the definitions of HOMO and LUMO energy levels follow a different convention than work functions.

[0015] More details on OLEDs, and the definitions described above, can be found in U.S. Pat. No. 7,279,704, which is incorporated herein by reference in its entirety.

SUMMARY OF THE INVENTION

[0016] The present disclosure provides a first mixture containing three different compounds that is useful as a stable co-evaporation source material for a vacuum deposition tool. The first mixture comprises: a first compound; a second compound; and a third compound. The first compound, the second compound, and the third compound are all organic compounds and have different chemical structures from each other. The first compound, the second compound, and the third compound each has an evaporation temperature T**1**, T**2**, and T**3**, respectively, and is in the range of 150 to 350° C., wherein T**1**, T**2**, and T**3** differ from each other by less than 20° C. The first compound has a concentration C**1** in the first mixture and a concentration C**2** in a film deposited by evaporating the first mixture in a high vacuum deposition tool with a chamber base pressure between 1×10^{-6} Torr to 1×10^{-9} Torr under a first deposition condition which is defined as depositing at a 2 Å/sec deposition rate onto a surface positioned at a predefined distance from the first mixture evaporation source, wherein |(C**1**-C**2**)/C**1**| is less than 5%. The first compound has a concentration C**1'** in a second mixture of the first and second compounds or has a concentration C**1"** in a third mixture of the first and third compounds, and the first compound has a concentration C**2'** in a film formed by evaporating the second mixture under the first deposition condition or has a concentration C**2"** in a film formed by evaporating the third mixture under the first deposition condition, and at least one of |(C**1'**-C**2'**)/C**1'**| and |(C**1"**-C**2"**)/C**1"**| is greater than 5%.

[0017] According to an embodiment, a method of fabricating a first device is disclosed. The method comprises: providing a first container that contains a first mixture, the first mixture comprising: a first compound; a second compound; and a third compound, wherein the first compound, the second compound, and the third compound are all organic compounds and have different chemical structures from each other, wherein the first compound, the second compound, and the third compound each has an evaporation temperature T**1**, T**2**, and T**3**, respectively, and is in the range of 150 to 350° C., wherein the T**1**, T**2**, and T**3** differ from each other by less than 20° C.; providing a substrate having a first electrode disposed thereon; depositing an organic layer over the first electrode by evaporating the first mixture in the first container in a high vacuum deposition tool under a first deposition condition which is defined as depositing at a 2 Å/sec deposition rate with a chamber base pressure between 1×10^{-6} Torr to 1×10^{-9} Torr onto a surface positioned at a predefined distance from the first mixture, wherein the first compound has a concentration C**1** in the first mixture and a concentration C**2** in the emissive layer and |(C**1**-C**2**)/C**1**| is less than 5%; and depositing a second electrode over the emissive layer.

[0018] According to an embodiment of the present disclosure, a first device comprising a first organic light emitting device is also disclosed. The first organic light emitting device comprises: an anode; a cathode; and an organic layer, disposed between the anode and the cathode, comprising a mixture of a first compound, a second compound, and a third compound,

[0019] wherein the first compound, the second compound, and the third compound are all organic compounds and have different chemical structures from each other,

[0020] wherein the first compound, the second compound, and the third compound each has an evaporation temperature T**1**, T**2**, and T**3**, respectively, and is in the range of 150 to 350° C.,

[0021] wherein the T**1**, T**2**, and T**3** differ from each other by less than 20° C.,

[0022] wherein the first compound has a concentration C**1** in the first mixture and a concentration C**2** in a film deposited by evaporating the first mixture in a high vacuum deposition tool under a first deposition condition which is defined as depositing at a 2 Å/sec deposition rate with a chamber base pressure between 1×10^{-6} Torr to 1×10^{-9} Torr onto a surface positioned at a predefined distance from the first mixture,

[0023] wherein |(C**1**-C**2**)/C**1**| is less than 5%,

[0024] wherein the first compound has a concentration C**1'** in a second mixture of the first and second compounds or has a concentration C**1"** in a third mixture of the first and third compounds, and the first compound has a concentration C**2'** in a film formed by evaporating the second mixture under the first deposition condition or has a concentration C**2"** in a film formed by evaporating the third mixture under the first deposition condition, and

[0025] wherein at least one of |(C**1'**-C**2'**)/C**1'**| and |(C**1"**-C**2"**)/C**1"**| is greater than 5%.

[0026] In fabricating OLEDs, the disclosed first mixture can be deposited as a thin film by thermal vapor deposition where the first mixture is used as a single-source co-evaporation material. This allows for a simpler OLED device fabrication process.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] FIG. **1** shows an organic light emitting device that can incorporate the inventive host material disclosed herein.

[0028] FIG. **2** shows an inverted organic light emitting device that can incorporate the inventive host material disclosed herein.

[0029] FIG. **3** shows HPLC composition (%) evolution of Compound C74 in sequentially deposited films from premixture BPM1.

[0030] FIG. **4** shows HPLC composition (%) evolution of Compound C74 in sequentially deposited films from premixture TPM1.

[0031] FIG. **5** shows HPLC composition (%) evolution of Compound E2 in sequentially deposited films from premixture BPM2.

[0032] FIG. **6** shows HPLC composition (%) evolution of Compound E2 in sequentially deposited films from premixture TPM2.

DETAILED DESCRIPTION

[0033] Generally, an OLED comprises at least one organic layer disposed between and electrically connected to an anode and a cathode. When a current is applied, the anode injects holes and the cathode injects electrons into the organic layer(s). The injected holes and electrons each migrate toward the oppositely charged electrode. When an electron and hole localize on the same molecule, an "exciton," which is a localized electron-hole pair having an excited energy state, is formed. Light is emitted when the exciton relaxes via a photoemissive mechanism. In some cases, the exciton may be localized on an excimer or an exciplex. Non-radiative mechanisms, such as thermal relaxation, may also occur, but are generally considered undesirable.

[0034] The initial OLEDs used emissive molecules that emitted light from their singlet states ("fluorescence") as disclosed, for example, in U.S. Pat. No. 4,769,292, which is incorporated by reference in its entirety. Fluorescent emission generally occurs in a time frame of less than 10 nanoseconds.

[0035] More recently, OLEDs having emissive materials that emit light from triplet states ("phosphorescence") have been demonstrated. Baldo et al., "Highly Efficient Phosphorescent Emission from Organic Electroluminescent Devices," Nature, vol. 395, 151-154, 1998; ("Baldo-I") and Baldo et al., "Very high-efficiency green organic light-emitting devices based on electrophosphorescence," Appl. Phys. Lett., vol. 75, No. 3, 4-6 (1999) ("Baldo-II"), which are incorporated by reference in their entireties. Phosphorescence is described in more detail in U.S. Pat. No. 7,279,704 at cols. 5-6, which are incorporated by reference.

[0036] FIG. **1** shows an organic light emitting device **100**. The figures are not necessarily drawn to scale. Device **100** may include a substrate **110**, an anode **115**, a hole injection layer **120**, a hole transport layer **125**, an electron blocking layer **130**, an emissive layer **135**, a hole blocking layer **140**, an electron transport layer **145**, an electron injection layer **150**, a protective layer **155**, a cathode **160**, and a barrier layer **170**. Cathode **160** is a compound cathode having a first conductive layer **162** and a second conductive layer **164**. Device **100** may be fabricated by depositing the layers described, in order. The properties and functions of these various layers, as well as example materials, are described in more detail in U.S. Pat. No. 7,279,704 at cols. 6-10, which are incorporated by reference.

[0037] More examples for each of these layers are available. For example, a flexible and transparent substrate-anode combination is disclosed in U.S. Pat. No. 5,844,363, which is incorporated by reference in its entirety. An example of a p-doped hole transport layer is m-MTDATA doped with F_4-TCNQ at a molar ratio of 50:1, as disclosed in U.S. Patent Application Publication No. 2003/0230980, which is incorporated by reference in its entirety. Examples of emissive and host materials are disclosed in U.S. Pat. No. 6,303,238 to Thompson et al., which is incorporated by reference in its entirety. An example of an n-doped electron transport layer is BPhen doped with Li at a molar ratio of 1:1, as disclosed in U.S. Patent Application Publication No. 2003/0230980, which is incorporated by reference in its entirety. U.S. Pat. Nos. 5,703,436 and 5,707,745, which are incorporated by reference in their entireties, disclose examples of cathodes including compound cathodes having a thin layer of metal such as Mg:Ag with an overlying transparent, electrically-conductive, sputter-deposited ITO layer. The theory and use of blocking layers is described in more detail in U.S. Pat. No. 6,097,147 and U.S. Patent Application Publication No. 2003/0230980, which are incorporated by reference in their entireties. Examples of injection layers are provided in U.S. Patent Application Publication No. 2004/0174116, which is incorporated by reference in its entirety. A description of protective layers may be found in U.S. Patent Application Publication No. 2004/0174116, which is incorporated by reference in its entirety.

[0038] FIG. **2** shows an inverted OLED **200**. The device includes a substrate **210**, a cathode **215**, an emissive layer **220**, a hole transport layer **225**, and an anode **230**. Device **200** may be fabricated by depositing the layers described, in order. Because the most common OLED configuration has a cathode disposed over the anode, and device **200** has cathode **215** disposed under anode **230**, device **200** may be referred to as an "inverted" OLED. Materials similar to those described with respect to device **100** may be used in the corresponding layers of device **200**. FIG. **2** provides one example of how some layers may be omitted from the structure of device **100**.

[0039] The simple layered structure illustrated in FIGS. **1** and **2** is provided by way of non-limiting example, and it is understood that embodiments of the invention may be used in connection with a wide variety of other structures. The specific materials and structures described are exemplary in nature, and other materials and structures may be used. Functional OLEDs may be achieved by combining the various layers described in different ways, or layers may be omitted entirely, based on design, performance, and cost factors. Other layers not specifically described may also be included. Materials other than those specifically described may be used. Although many of the examples provided herein describe various layers as comprising a single material, it is understood that combinations of materials, such as a mixture of host and dopant, or more generally a mixture, may be used. Also, the layers may have various sublayers. The names given to the various layers herein are not intended to be strictly limiting. For example, in device **200**, hole transport layer **225** transports holes and injects holes into emissive layer **220**, and may be described as a hole transport layer or a hole injection layer. In one embodiment, an OLED may be described as having an "organic layer" disposed between a cathode and an anode. This organic layer may comprise a single layer, or may further comprise multiple layers of different organic materials as described, for example, with respect to FIGS. **1** and **2**.

[0040] Structures and materials not specifically described may also be used, such as OLEDs comprised of polymeric materials (PLEDs) such as disclosed in U.S. Pat. No. 5,247,190 to Friend et al., which is incorporated by reference in its entirety. By way of further example, OLEDs having a single organic layer may be used. OLEDs may be stacked, for example as described in U.S. Pat. No. 5,707,745 to Forrest et al, which is incorporated by reference in its entirety. The OLED structure may deviate from the simple layered structure illustrated in FIGS. **1** and **2**. For example, the substrate may include an angled reflective surface to improve outcoupling, such as a mesa structure as described in U.S. Pat. No. 6,091,195 to Forrest et al., and/or a pit structure as described in U.S. Pat. No. 5,834,893 to Bulovic et al., which are incorporated by reference in their entireties.

[0041] Unless otherwise specified, any of the layers of the various embodiments may be deposited by any suitable method. For the organic layers, preferred methods include thermal evaporation, ink-jet, such as described in U.S. Pat. Nos. 6,013,982 and 6,087,196, which are incorporated by reference in their entireties, organic vapor phase deposition (OVPD), such as described in U.S. Pat. No. 6,337,102 to Forrest et al., which is incorporated by reference in its entirety, and deposition by organic vapor jet printing (OVJP), such as described in U.S. Pat. No. 7,431,968, which is incorporated by reference in its entirety. Other suitable deposition methods include spin coating and other solution based processes. Solution based processes are preferably carried out in nitrogen or an inert atmosphere. For the other layers, preferred methods include thermal evaporation. Preferred patterning methods include deposition through a mask, cold welding such as described in U.S. Pat. Nos. 6,294,398 and 6,468,819, which are incorporated by reference in their entireties, and patterning associated with some of the deposition methods such as ink-jet and OVJD. Other methods may also be used. The materials to be deposited may be modified to make them compatible with a particular deposition method. For example, substituents such as alkyl and aryl groups, branched or unbranched, and preferably containing at least 3 carbons, may be used in small molecules to enhance their ability to undergo solution processing. Substituents having 20 carbons or more may be used, and 3-20 carbons is a preferred range. Materials with asymmetric structures may have better solution processibility than those having symmetric structures, because asymmetric materials may have a lower tendency to recrystallize. Dendrimer substituents may be used to enhance the ability of small molecules to undergo solution processing.

[0042] Devices fabricated in accordance with embodiments of the present invention may further optionally comprise a barrier layer. One purpose of the barrier layer is to protect the electrodes and organic layers from damaging exposure to harmful species in the environment including moisture, vapor and/or gases, etc. The barrier layer may be deposited over, under or next to a substrate, an electrode, or over any other parts of a device including an edge. The barrier layer may comprise a single layer, or multiple layers. The barrier layer may be formed by various known chemical vapor deposition techniques and may include compositions having a single phase as well as compositions having multiple phases. Any suitable material or combination of materials may be used for the barrier layer. The barrier layer may incorporate an inorganic or an organic compound or both. The preferred barrier layer comprises a mixture of a polymeric material and a non-polymeric material as described in U.S. Pat. No. 7,968,146, PCT Pat. Application Nos. PCT/US2007/023098 and PCT/US2009/042829, which are herein incorporated by reference in their entireties. To be considered a "mixture", the aforesaid polymeric and non-polymeric materials comprising the barrier layer should be deposited under the same reaction conditions and/or at the same time. The weight ratio of polymeric to non-polymeric material may be in the range of 95:5 to 5:95. The polymeric material and the non-polymeric material may be created from the same precursor material. In one example, the mixture of a polymeric material and a non-polymeric material consists essentially of polymeric silicon and inorganic silicon.

[0043] Devices fabricated in accordance with embodiments of the invention may be incorporated into a wide variety of consumer products, including flat panel displays, computer monitors, medical monitors, televisions, billboards, lights for interior or exterior illumination and/or signaling, heads up displays, fully transparent displays, flexible displays, laser printers, telephones, cell phones, personal digital assistants (PDAs), laptop computers, digital cameras, camcorders, viewfinders, micro-displays, 3-D displays, vehicles, a large area wall, theater or stadium screen, or a sign. Various control mechanisms may be used to control devices fabricated in accordance with the present invention, including passive matrix and active matrix. Many of the devices are intended for use in a temperature range comfortable to humans, such as 18° C. to 30° C., and more preferably at room temperature (20-25° C.), but could be used outside this temperature range, for example, from −40° C. to +80° C.

[0044] The materials and structures described herein may have applications in devices other than OLEDs. For example, other optoelectronic devices such as organic solar cells and organic photodetectors may employ the materials and structures. More generally, organic devices, such as organic transistors, may employ the materials and structures.

[0045] The term "halo" or "halogen" as used herein includes fluorine,chlorine, bromine, and iodine.

[0046] The term "alkyl" as used herein contemplates both straight and branched chain alkyl radicals. Preferred alkyl groups are those containing from one to fifteen carbon atoms and includes methyl, ethyl, propyl, isopropyl, butyl, isobutyl, tert-butyl, and the like. Additionally, the alkyl group may be optionally substituted.

[0047] The term "cycloalkyl" as used herein contemplates cyclic alkyl radicals. Preferred cycloalkyl groups are those containing 3 to 7 carbon atoms and includes cyclopropyl, cyclopentyl, cyclohexyl, and the like. Additionally, the cycloalkyl group may be optionally substituted.

[0048] The term "alkenyl" as used herein contemplates both straight and branched chain alkene radicals. Preferred alkenyl groups are those containing two to fifteen carbon atoms. Additionally, the alkenyl group may be optionally substituted.

[0049] The term "alkynyl" as used herein contemplates both straight and branched chain alkyne radicals. Preferred alkynyl groups are those containing two to fifteen carbon atoms. Additionally, the alkynyl group may be optionally substituted.

[0050] The terms "aralkyl" or "arylalkyl" as used herein are used interchangeably and contemplate an alkyl group that has as a substituent an aromatic group. Additionally, the aralkyl group may be optionally substituted.

[0051] The term "heterocyclic group" as used herein contemplates aromatic and non-aromatic cyclic radicals. Hetero-aromatic cyclic radicals also refer to heteroaryl. Preferred hetero-non-aromatic cyclic groups are those containing 3 or 7 ring atoms which includes at least one hetero atom, and includes cyclic amines such as morpholino, piperidino, pyrrolidino, and the like, and cyclic ethers, such as tetrahydrofuran, tetrahydropyran, and the like. Additionally, the heterocyclic group may be optionally substituted.

[0052] The term "aryl" or "aromatic group" as used herein contemplates single-ring groups and polycyclic ring systems. The polycyclic rings may have two or more rings in which two carbons are common to two adjoining rings (the rings are "fused") wherein at least one of the rings is aromatic, e.g., the

other rings can be cycloalkyls, cycloalkenyls, aryl, heterocycles, and/or heteroaryls. Additionally, the aryl group may be optionally substituted.

[0053] The term "heteroaryl" as used herein contemplates single-ring hetero-aromatic groups that may include from one to three heteroatoms, for example, pyrrole, furan, thiophene, imidazole, oxazole, thiazole, triazole, pyrazole, pyridine, pyrazine and pyrimidine, and the like. The term heteroaryl also includes polycyclic hetero-aromatic systems having two or more rings in which two atoms are common to two adjoining rings (the rings are "fused") wherein at least one of the rings is a heteroaryl, e.g., the other rings can be cycloalkyls, cycloalkenyls, aryl, heterocycles, and/or heteroaryls. Additionally, the heteroaryl group may be optionally substituted.

[0054] The alkyl, cycloalkyl, alkenyl, alkynyl, aralkyl, heterocyclic group, aryl, and heteroaryl may be optionally substituted with one or more substituents selected from the group consisting of hydrogen, deuterium, halogen, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, cyclic amino, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acid, ether, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

[0055] As used herein, "substituted" indicates that a substituent other than H is bonded to the relevant position, such as carbon. Thus, for example, where R^1 is mono-substituted, then one R^1 must be other than H. Similarly, where R^1 is di-substituted, then two of R^1 must be other than H. Similarly, where R^1 is unsubstituted, R^1 is hydrogen for all available positions.

[0056] The "aza" designation in the fragments described herein, i.e. aza-dibenzofuran, aza-dibenzothiophene, etc. means that one or more of the C—H groups in the respective fragment can be replaced by a nitrogen atom, for example, and without any limitation, azatriphenylene encompasses both dibenzo[f,h]quinoxaline and dibenzo[f,h]quinoline. One of ordinary skill in the art can readily envision other nitrogen analogs of the aza-derivatives described above, and all such analogs are intended to be encompassed by the terms as set forth herein.

[0057] It is to be understood that when a molecular fragment is described as being a substituent or otherwise attached to another moiety, its name may be written as if it were a fragment (e.g. naphthyl, dibenzofuryl) or as if it were the whole molecule (e.g. naphthalene, dibenzofuran). As used herein, these different ways of designating a substituent or attached fragment are considered to be equivalent.

[0058] Often, the emissive layer (EML) of OLED devices exhibiting good lifetime and efficiency requires more than two components (e.g. 3 or 4 components). For example, an OLED emissive layer can require a hole-transporting co-host (h-host), an electron-transporting co-host (e-host), and an emissive dopant. For this purpose, 3 or 4 source materials are required to fabricate such an EML, which is very complicated and costly compared to a standard two-component EML with a single host and an emitter, which requires only two sources. Conventionally, in order to fabricate such EML requiring two or more components, a separate evaporation source for each component is required. Because the relative concentrations of the components of the EML is important for the device performance, the rate of deposition of each component is measured individually during the deposition in order to monitor the relative concentrations. This makes the fabrication process complicated and costly. Thus, it is desirable to premix the materials for the two or more components and evaporate them from a single source in order to reduce the complexity of the fabrication process.

[0059] However, the co-evaporation must be stable, i.e. the composition of the deposited film should remain constant throughout the manufacturing process, as any composition change may affect the device performance adversely. In order to obtain a stable co-evaporation from a mixture of compounds under vacuum, one would assume that the materials must have the same evaporation temperature under the same condition.

[0060] However, this may not be the only parameter one has to consider. When the two or more compounds are mixed together, they may interact with each other and their evaporation properties may differ from their individual properties. On the other hand, materials with slightly different evaporation temperatures may form a stable co-evaporation mixture. Therefore, it is extremely difficult to achieve a stable co-evaporation mixture. "Evaporation temperature" of a material is measured in a high vacuum deposition tool with a chamber base pressure, between 1×10^{-6} Torr to 1×10^{-9} Torr, at a 2 Å/sec deposition rate on a surface positioned at a set distance away from the evaporation source of the material being evaporated, e.g. sublimation crucible in a VTE tool. The various measured values such as temperature, pressure, deposition rate, etc. disclosed herein are expected to have nominal variations because of the expected tolerances in the measurements that produced these quantitative values as understood by one of ordinary skill in the art.

[0061] This disclosure describes a novel mixture of two or more organic compounds, particularly a mixture of three compounds, that can be used as a stable co-evaporation source in vacuum deposition processes. Many factors other than temperatures can contribute to the evaporation, such as miscibility of different materials, different phase transition. The inventors found that when two or more materials have similar evaporation temperature, and similar mass loss rate or similar vapor pressure, the two or more materials can co-evaporate consistently. Mass loss rate is defined as percentage of mass lost over time (minute) and is determined by measuring the time it takes to lose the first 10% of the mass as measured by thermal gravity analysis (TGA) under same experimental condition at a same constant given temperature for each compound after the composition reach a steady evaporation state. The constant given temperature is one temperature point that is chosen so that the value of mass loss rate is between about 0.05 to 0.50 percentage/min. Skilled person in this field should appreciate that in order to compare two parameters, the experimental condition should be consistent. The method of measuring mass loss rate and vapor pressure is well known in the art and can be found, for example, in Bull. et al. Mater. Sci. 2011, 34, 7.

[0062] Searching for a high-performance mixture for stable single-source co-evaporation could be a tedious process. A process of searching for a stable mixture would include identifying compounds with similar evaporation temperatures and monitoring the composition of the evaporated mixture. It is often the case that the mixture materials show slight separation as evaporation goes on. Adjusting the evaporation temperature by changing the chemical structure often, unfortunately, lead to much reduced device performance due to the change in chemical, electrical and/or optical properties.

Chemical structure modifications also impact the evaporation temperature much more significantly than needed, resulting in unstable mixtures.

[0063] To address these difficulties, the present disclosure describes a method where a mixture of three compounds is used as a single source for evaporation. We envision two scenarios as detailed below.

[0064] In one scenario, two of the three component compounds have their concentrations changing in the opposite directions during evaporation, i.e. the concentration of the first component increases while the second component decreases, but the overall concentration of these two components, and consequently, the concentration of the third component, remain constant. Therefore, the constant overall concentration of the first two components together with the constant concentration of the third component are expected to ensure that the device performance remain unchanged throughout the manufacturing process. For an EML requiring h-host, e-host and dopant, the first two components with changing concentrations could be two h-hosts, two e-hosts or two dopants.

[0065] In another scenario, the introduction of the third component compound assists the co-evaporation of the first and the second components. This third component could be called a carrier compound or co-evaporation assisting compound. Some of the mechanisms to realize this co-evaporation are intermolecular interaction between the first and second components by, for instance, van der Waals force, electrostatic force, hydrogen bond, chemical bond. An analogy in nature is the oil-water-surfactant system, where surfactant as the third component greatly facilitates the intermixing between oil and water. The third component is also an essential component for EML, and could be an h-host, an e-host or a dopant.

[0066] According to an embodiment, a first mixture useful as a stable single-source co-evaporation mixture of three compounds is disclosed. The first mixture comprises: a first compound; a second compound; and a third compound,

[0067] wherein the first compound, the second compound, and the third compound are all organic compounds and have different chemical structures from each other,

[0068] wherein the first compound, the second compound, and the third compound each has an evaporation temperature T**1**, T**2**, and T**3**, respectively, and is in the range of 150 to 350° C.,

[0069] wherein the T**1**, T**2**, and T**3** differ from each other by less than 20° C.

[0070] Furthermore, the first compound has a concentration C**1** in the first mixture and a concentration C**2** in a film deposited by evaporating the first mixture in a high vacuum deposition tool under a first deposition condition which is defined as depositing at a 2 Å/sec deposition rate with a chamber base pressure between 1×10^{-6} Torr to 1×10^{-9} Torr onto a surface positioned at a predefined distance from the first mixture. The absolute value of (C**1**-C**2**)/C**1**, represented herein as |(C**1**-C**2**)/C**1**|, is less than 5%, the first compound has a concentration C**1**' in a second mixture of the first and second compounds or has a concentration C**1**" in a third mixture of the first and third compounds, and the first compound has a concentration C**2**' in a film formed by evaporating the second mixture under the first deposition condition or has a concentration C**2**" in a film formed by evaporating the third mixture under the first deposition condition, and at least one of |(C**1**'-C**2**')/C**1**'| and |(C**1**"-C**2**")/C**1**"| is greater than 5%.

[0071] Ine some embodiments of the disclosed mixture, both of |(C**1**'-C**2**')/C**1**'| and |(C"-C**2**")/C**1**"| are larger than 5%.

[0072] In a preferred embodiment, |(C**1**-C**2**)/C**1**| is less than 3%.

[0073] One of ordinary skill in this field should realize that the concentration of each component is expressed as a relative percentage. The concentration of each component in the mixture can be measured by suitable analytical methods such as high pressure liquid chromatography (HPLC) and nuclear magnetic resonance spectroscopy (NMR).

[0074] The inventors used HPLC and the percentage was calculated by dividing the integration area under the HPLC trace of each component by the total integration area. HPLC can use different detectors such as UV-vis, photo diode array detector, refractive index detector, fluorescence detector, and light scattering detector. Due to different materials properties, each component in the mixture may respond differently. Therefore, the measured concentration may differ from their real concentration in the mixture, however the relative ratio value of (C**1**-C**2**)/C**1** is independent of these variables as long as the experimental condition is kept consistent, for example, all concentrations should be calculated under the exact same HPLC parameters for each component. It is sometimes preferred to select a measurement condition that gives calculated concentration close to the real concentration. However, it is not necessary. It is important to select a detecting condition that accurately detects each component. For example, fluorescence detector should not be used if one of the components does not fluoresce.

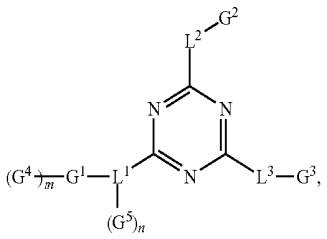
[0075] In another embodiment of the mixture disclosed herein, T**1**, T**2**, and T**3** are in the range of 200 to 350° C.

[0076] In another embodiment, the second compound has a concentration C**3** in the first mixture, and the second compound has a concentration C**4** in a film formed by evaporating the first mixture under the first condition, wherein |(C**3**-C**4**)/C**3**| is less than 5%.

[0077] In other embodiments, the first compound, the second compound, and the third compound are each independently selected from the group consisting of a h-host, an e-host, and an emitter. The emitter can be a phosphorescent emitter or a fluorescent emitter.

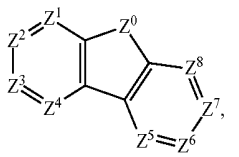
[0078] The e-host material can be selected from the group consisting of a compound having a structure of

Formula I



and a compound having a structure of

Formula II



[0079] wherein G^1 is selected from the group consisting of dibenzofuran, dibenzothiophene, dibenzoselenophene, and fluorene;

[0080] wherein L^1, L^2 and L^3 are each independently selected from the group consisting of direct bond, phenyl, biphenyl, terphenyl, pyridine, pyrimidine, and combinations thereof;

[0081] wherein G^4 is selected from the group consisting of phenyl, biphenyl, terphenyl, naphthalene, phenanthrene, pyridine, pyrimidine, pyrazine, quinoline, isoquinoline, phenanthroline, fluorene, and combinations thereof;

[0082] wherein G^2, G^3, and G^5 are each independently selected from the group consisting of phenyl, biphenyl, terphenyl, fluorene, naphthalene, phenanthrene, pyridine, pyrimidine, pyrazine, quinoline, isoquinoline, phenanthroline, aza-fluorene, and combinations thereof;

[0083] wherein G^2, G^3, G^4, and G^5 are each optionally further substituted with one or more unfused substituents selected from the group consisting of deuterium, alkyl, alkoxyl, cycloalkyl, cycloalkoxyl, halogen, nitro, nitrite, silyl, phenyl, biphenyl, terphenyl, pyridine, and combinations thereof;

[0084] wherein m is an integer from 0 to 7,

[0085] wherein n is an integer from 0 to 4;

[0086] wherein, when m or n is larger than 1, each G^4 or G^5 can be same or different;

[0087] wherein when n is 0, m is equal to or greater than 1, and each G^4 is selected from the group consisting of phenyl, and biphenyl;

[0088] wherein when n is equal to or greater than 1, L^1 is not a direct bond;

[0089] wherein when m and n are both 0, L^1 is biphenyl;

[0090] wherein when G^4 is present and is fluorene, L^1 is not a direct bond;

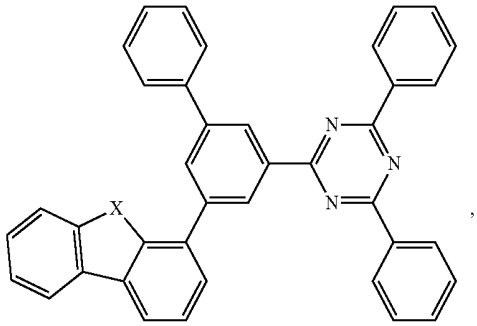
[0091] wherein Z^0 is selected from the group consisting of O, S, Se, NR^1 and CR^2R^3;

[0092] wherein Z^1 to Z^8 are each independently selected from the group consisting of N and CR^4, and at least one of Z^1 to Z^8 is N; and

[0093] wherein R^1, R^2, R^3 and R^4 are each independently selected from the group consisting of hydrogen, deuterium, alkyl, alkoxyl, cycloalkyl, cycloalkoxyl, halogen, nitro, nitrile, silyl, aryl, heteraryl and combinations thereof.

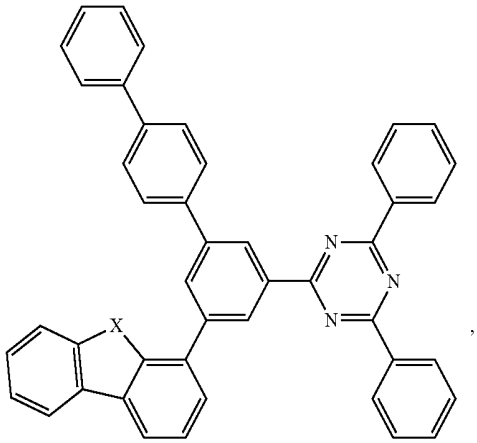
[0094] In some embodiments, the e-host is selected from the group consisting of:

Compound A1 through A3, each represented by the formula



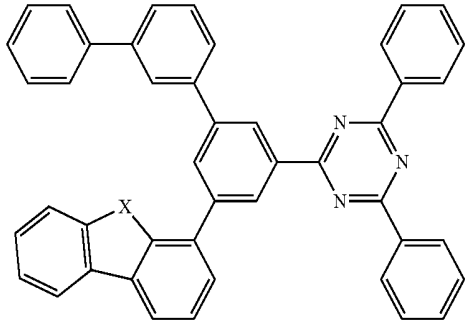
wherein in Compound A1: X = O,
in Compound A2: X = S,
in Compound A3: X = Se

Compound A4 through A6, each represented by the formula



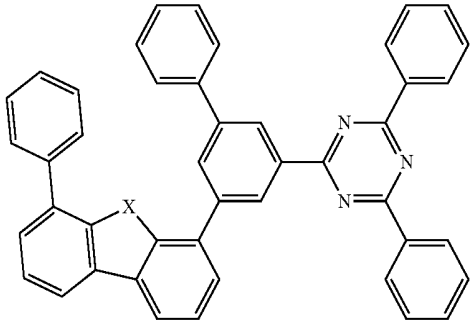
wherein in Compound A4: X = O,
in Compound A5: X = S,
in Compound A6: X = Se

Compound A7 through A9, each represented by the formula



wherein in Compound A7: X = O,
in Compound A8: X = S,
in Compound A9: X = Se

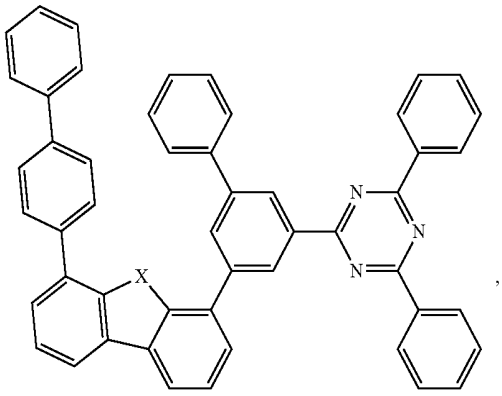
Compound A10 through A12, each represented by the formula



wherein in Compound A10: X = O,
in Compound A11: X = S,
in Compound A12: X = Se

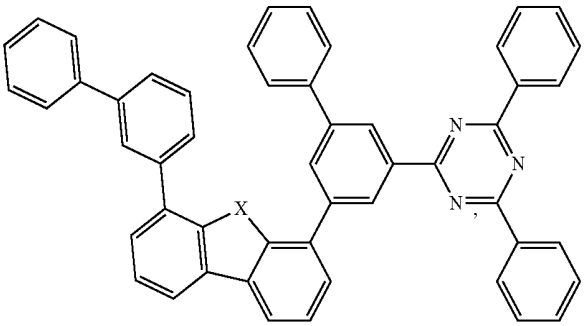
-continued

Compound A13 through A15, each represented by the formula



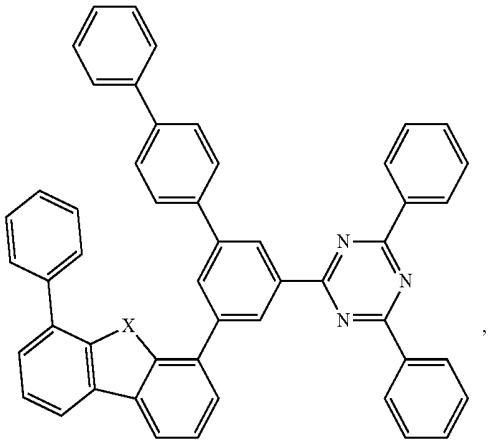
wherein in Compound A13: X = O,
in Compound A14: X = S,
in Compound A15: X = Se

Compound A16 through A18, each represented by the formula



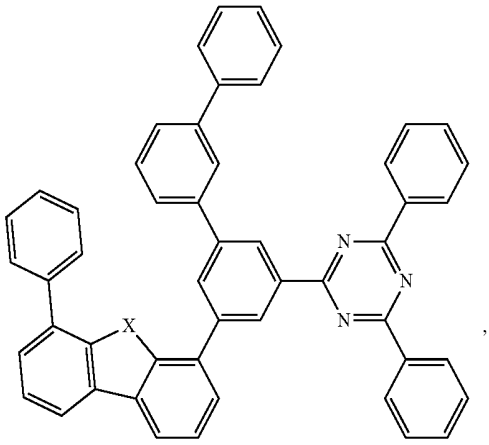
wherein in Compound A16: X = O,
in Compound A17: X = S,
in Compound A18: X = Se

Compound A19 through A21, each represented by the formula



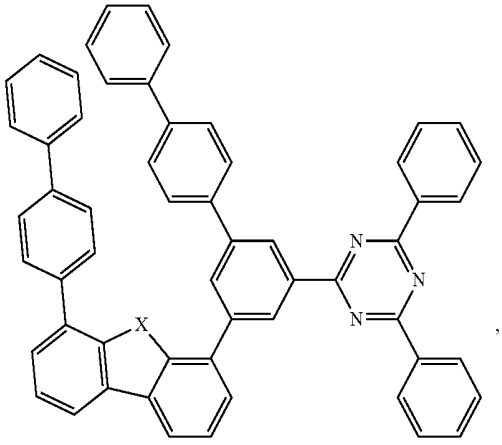
wherein in Compound A19: X = O,
in Compound A20: X = S,
in Compound A21: X = Se

Compound A22 through A24, each represented by the formula



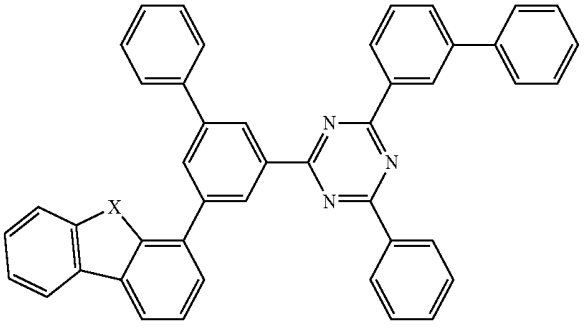
wherein in Compound A22: X = O,
in Compound A23: X = S,
in Compound A24: X = Se

Compound A25 through A27, each represented by the formula



wherein in Compound A25: X = O,
in Compound A26: X = S,
in Compound A27: X = Se

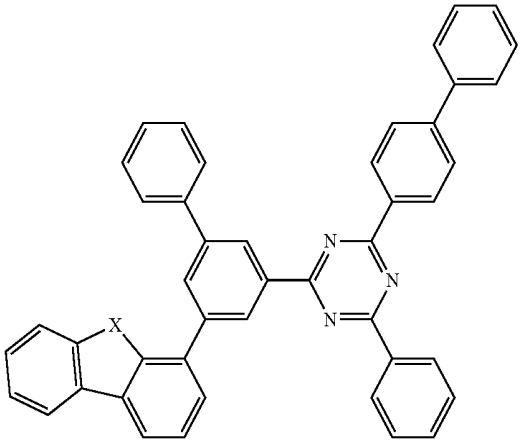
Compound A28 through A30, each represented by the formula



wherein in Compound A28: X = O,
in Compound A29: X = S,
in Compound A30: X = Se

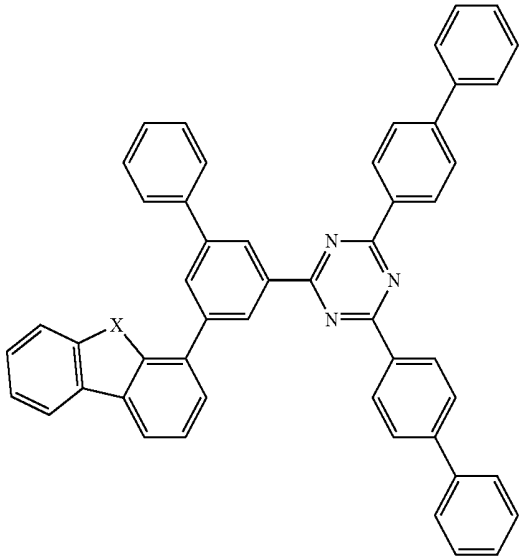
-continued

Compound A31 through A33, each represented by the formula



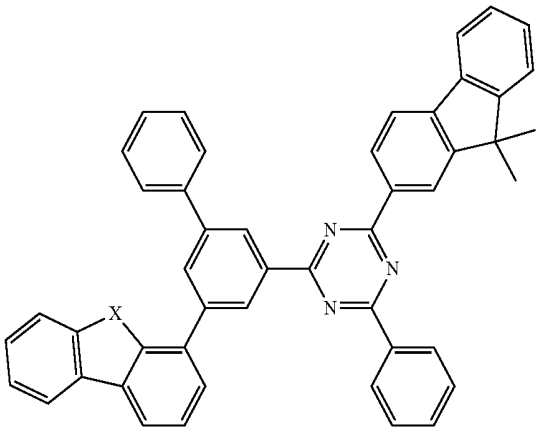
wherein in Compound A31: X = O,
in Compound A32: X = S,
in Compound A33: X = Se

Compound A34 through A36, each represented by the formula



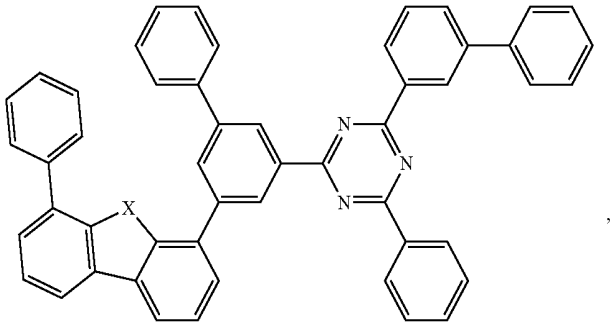
wherein in Compound A34: X = O,
in Compound A35: X = S,
in Compound A36: X = Se

Compound A37 through A39, each represented by the formula



wherein in Compound A37: X = O,
in Compound A38: X = S,
in Compound A39: X = Se

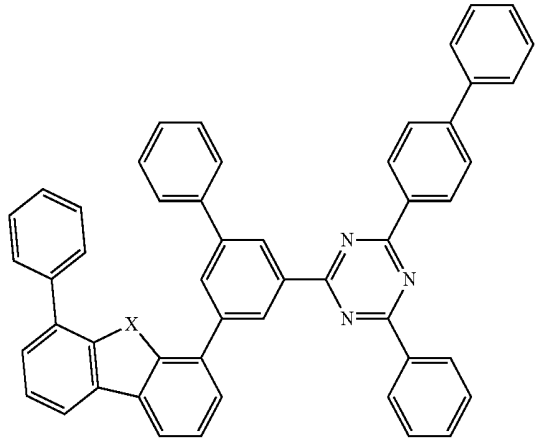
Compound A40 through A42, each represented by the formula



wherein in Compound A40: X = O,
in Compound A41: X = S,
in Compound A42: X = Se

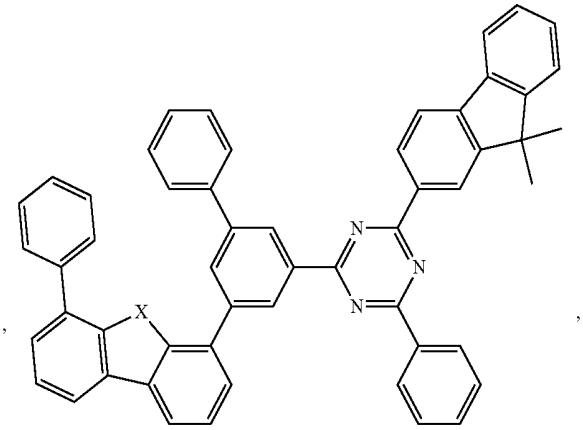
-continued

Compound A43 through A45, each represented by the formula



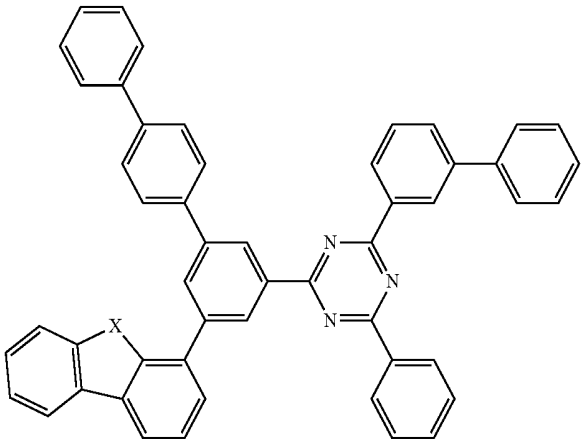
wherein in Compound A43: X = O,
in Compound A44: X = S,
in Compound A45: X = Se

Compound A46 through A48, each represented by the formula



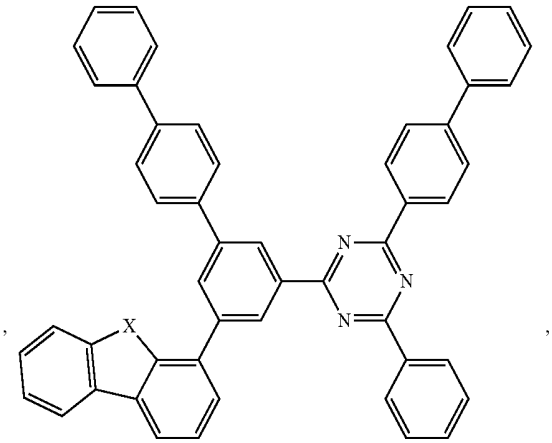
wherein in Compound A46: X = O,
in Compound A47: X = S,
in Compound A48: X = Se

Compound A49 through A51, each represented by the formula



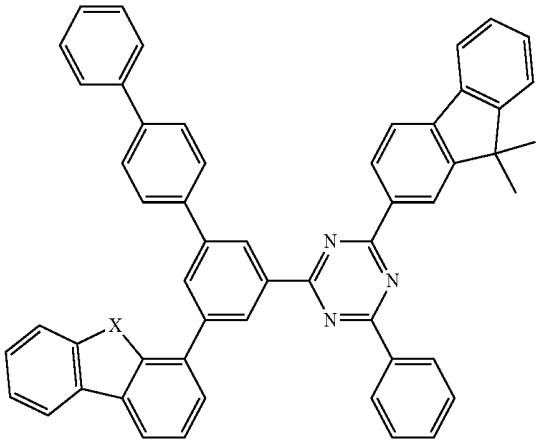
wherein in Compound A49: X = O,
in Compound A50: X = S,
in Compound A51: X = Se

Compound A52 through A54, each represented by the formula



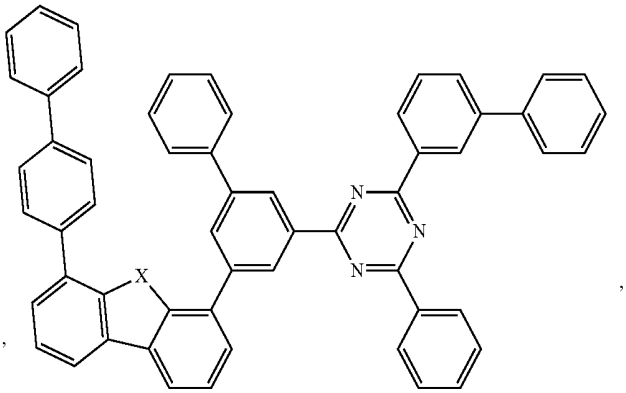
wherein in Compound A52: X = O,
in Compound A53: X = S,
in Compound A54: X = Se

Compound A55 through A57, each represented by the formula



wherein in Compound A55: X = O,
in Compound A56: X = S,
in Compound A57: X = Se

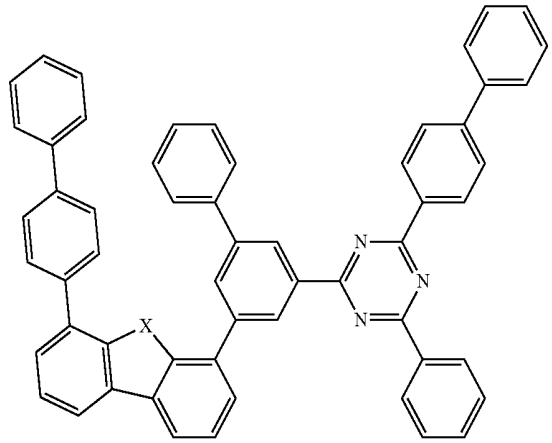
Compound A58 through A60, each represented by the formula



wherein in Compound A58: X = O,
in Compound A59: X = S,
in Compound A60: X = Se

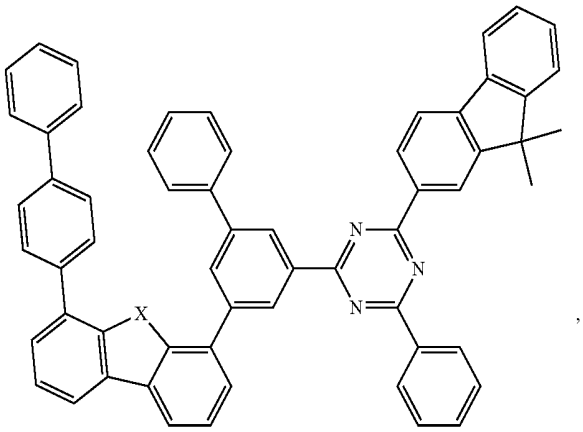
-continued

Compound A61 through A63, each represented by the formula



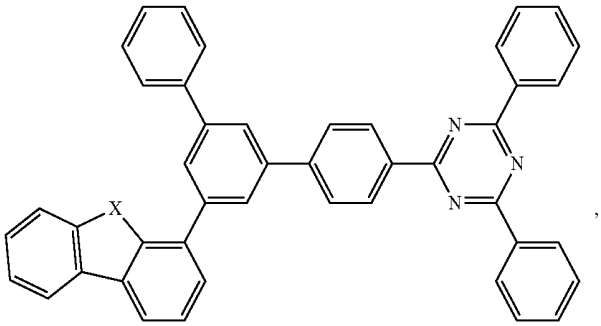
wherein in Compound A61: X = O,
in Compound A62: X = S,
in Compound A63: X = Se

Compound A64 through A66, each represented by the formula



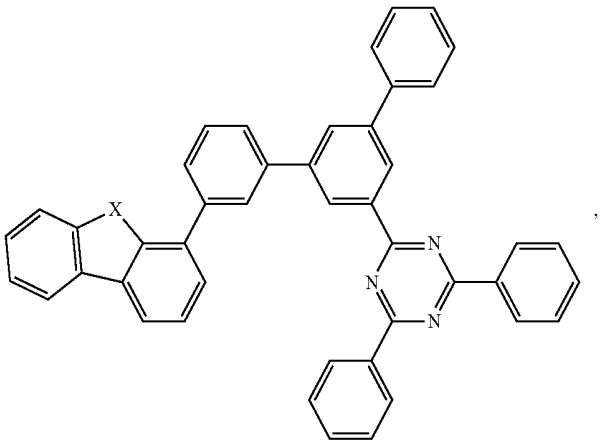
wherein in Compound A64: X = O,
in Compound A65: X = S,
in Compound A66: X = Se

Compound A67 through A69, each represented by the formula



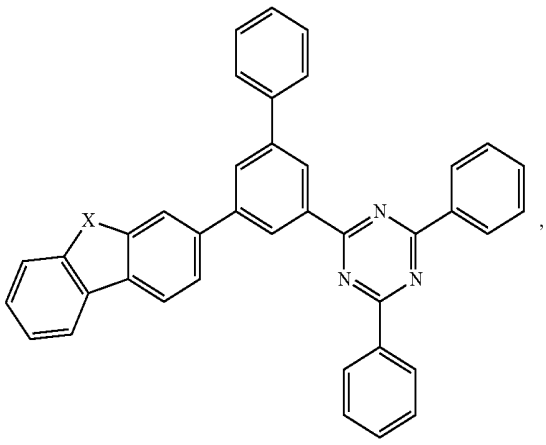
wherein in Compound A67: X = O,
in Compound A68: X = S,
in Compound A69: X = Se

Compound A70 through A72, each represented by the formula



wherein in Compound A70: X = O,
in Compound A71: X = S,
in Compound A72: X = Se

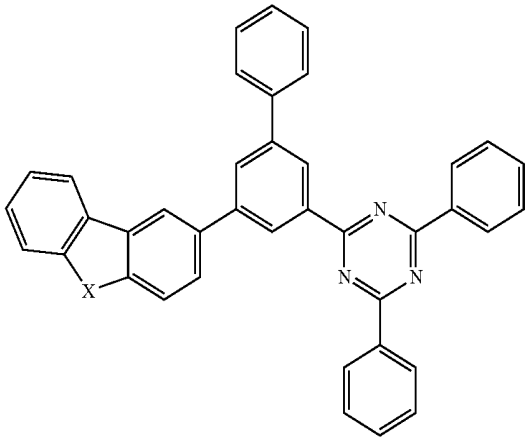
Compound A73 through A75, each represented by the formula



wherein Compound A73: X = O,
in Compound A74: X = S,
in Compound A75: X = Se

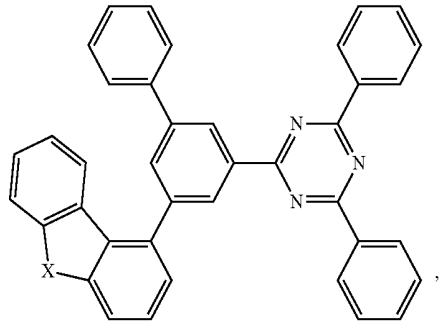
-continued

Compound A76 through A78, each represented by the formula



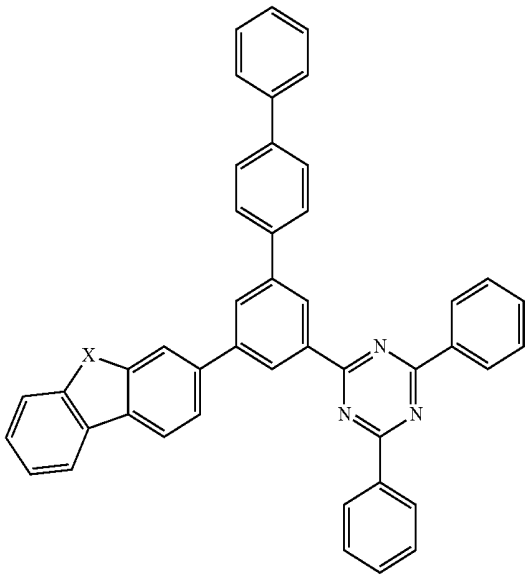
wherein Compound A76: X = O,
in Compound A77: X = S,
in Compound A78: X = Se

Compound A79 through A81, each represented by the formula



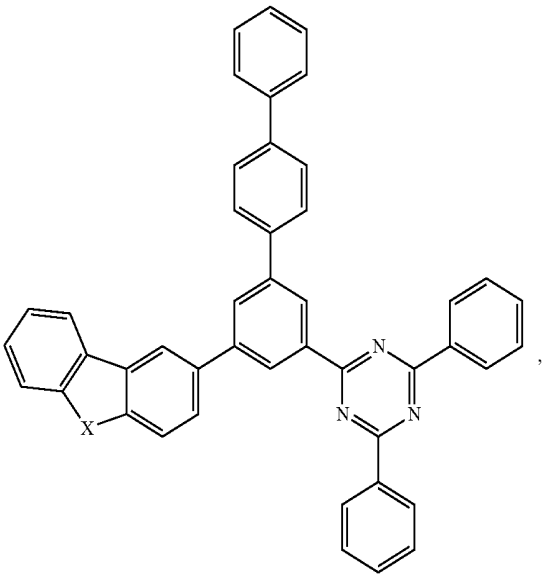
wherein in Compound A79: X = O,
in Compound A80: X = S,
in Compound A81: X = Se

Compound A82 through A84, each represented by the formula



wherein in Compound A82: X = O,
in Compound A83: X = S,
in Compound A84: X = Se

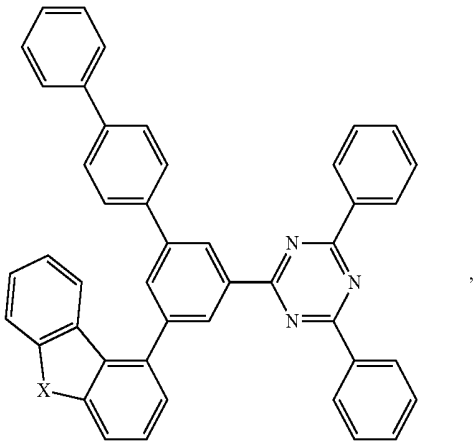
Compound A85 through A87, each represented by the formula



wherein in Compound A85: X = O,
in Compound A86: X = S,
in Compound A87: X = Se

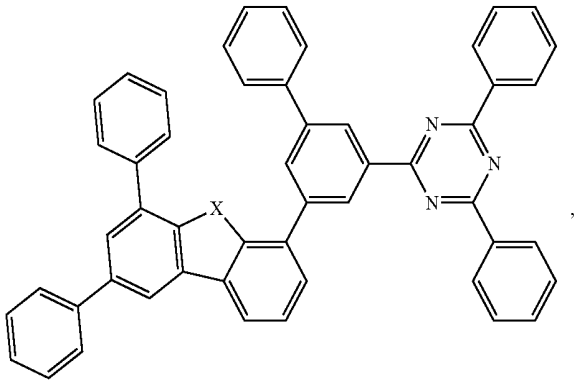
-continued

Compound A88 through A90, each represented by the formula



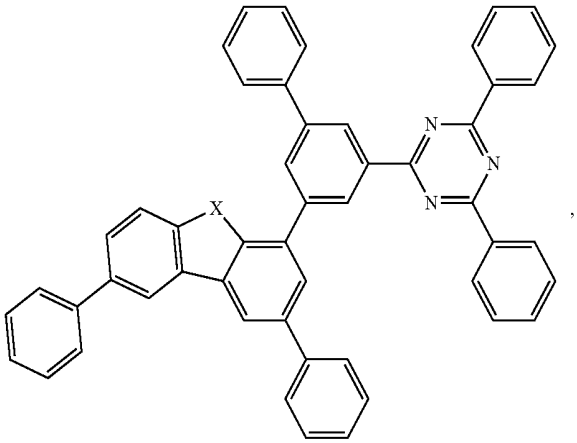
wherein in Compound A88: X = O,
in Compound A89: X = S,
in Compound A90: X = Se

Compound A91 through A93, each represented by the formula



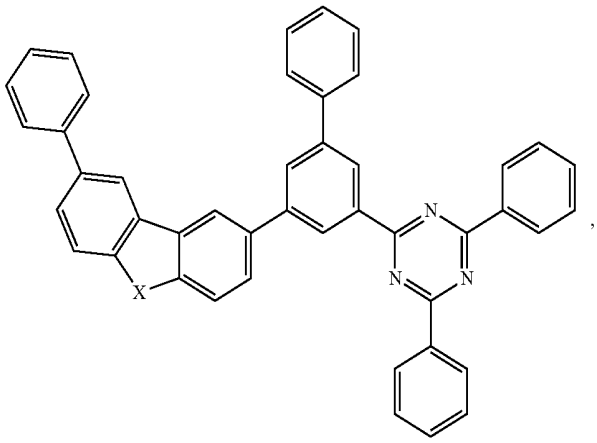
wherein Compound A91: X = O,
in Compound A92: X = S,
in Compound A93: X = Se

Compound A94 through A96, each represented by the formula



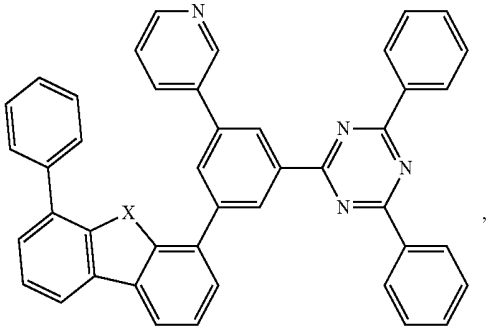
wherein Compound A94: X = O,
in Compound A95: X = S,
in Compound A96: X = Se

Compound A97 through A99, each represented by the formula



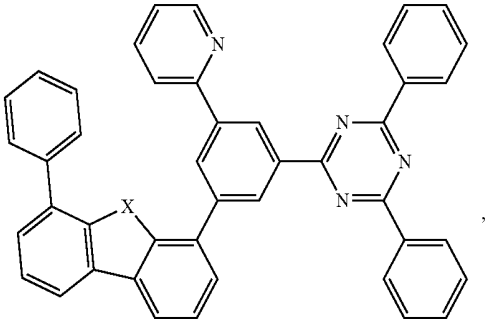
wherein in Compound A97: X = O,
in Compound A98: X = S,
in Compound A99: X = Se

Compound A100 through A102, each represented by the formula



wherein in Compound A100: X = O,
in Compound A101: X = S,
in Compound A102: X = Se

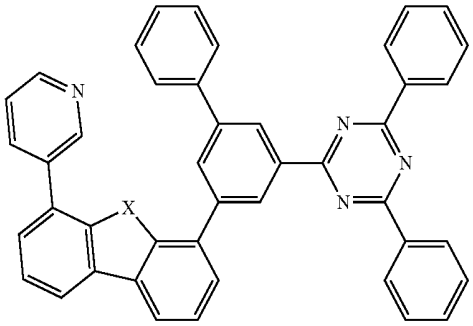
Compound A103 through A105, each represented by the formula



wherein in Compound A103: X = O,
in Compound A104: X = S,
in Compound A105: X = Se

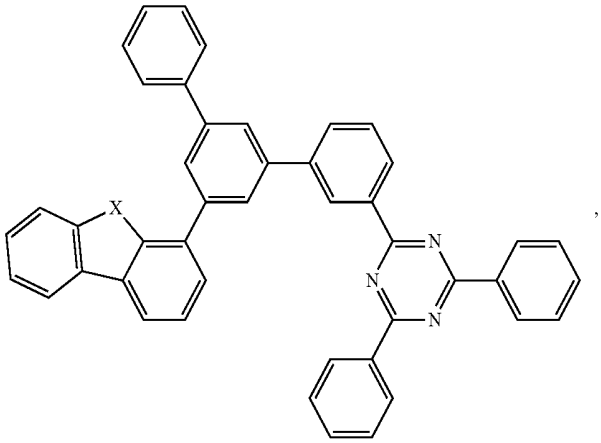
-continued

Compound A106 through A108, each represented by the formula



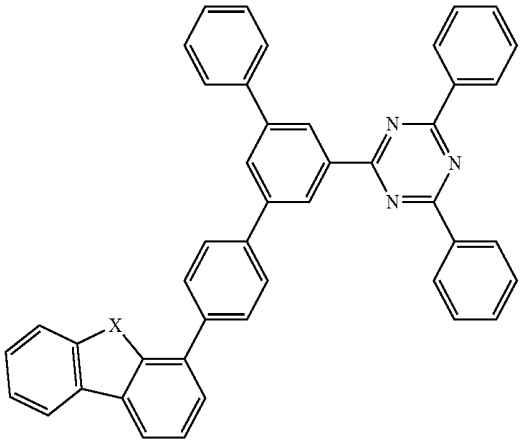
wherein in Compound A106: X = O,
in Compound A107: X = S,
in Compound A108: X = Se

Compound A109 through A111, each represented by the formula



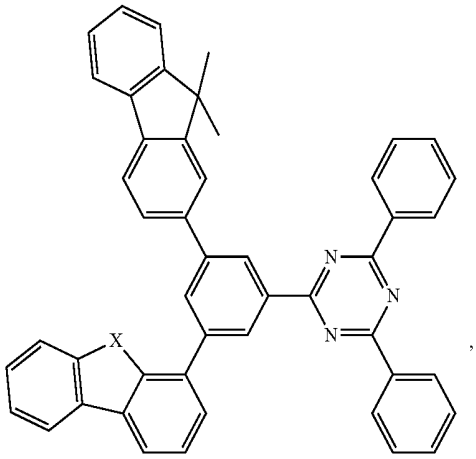
wherein in Compound A109: X = O,
in Compound A110: X = S,
in Compound A111: X = Se

Compound A112 through A114, each represented by the formula

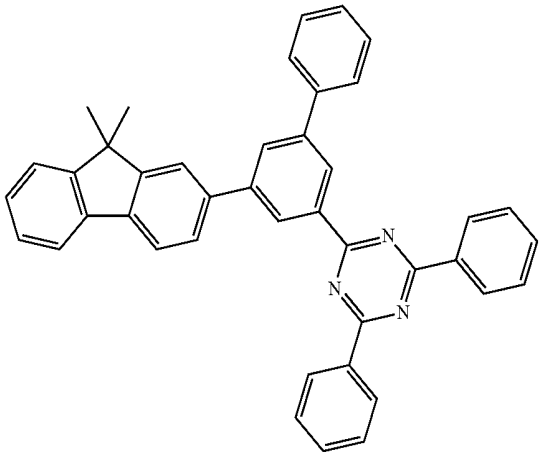


wherein in Compound A112: X = O,
in Compound A113: X = S,
in Compound A114: X = Se

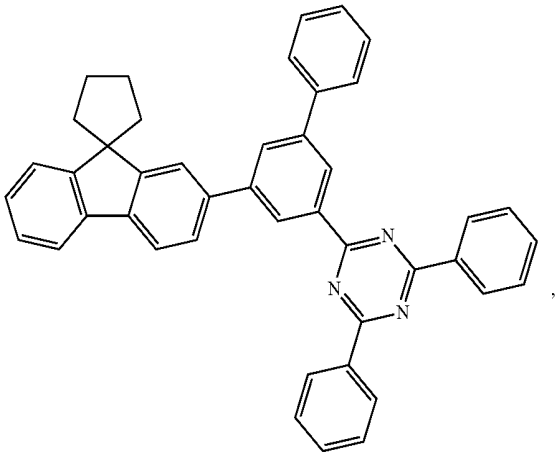
Compound A115 through A117, each represented by the formula



wherein in Compound A115: X = O,
in Compound A116: X = S,
in Compound A117: X = Se

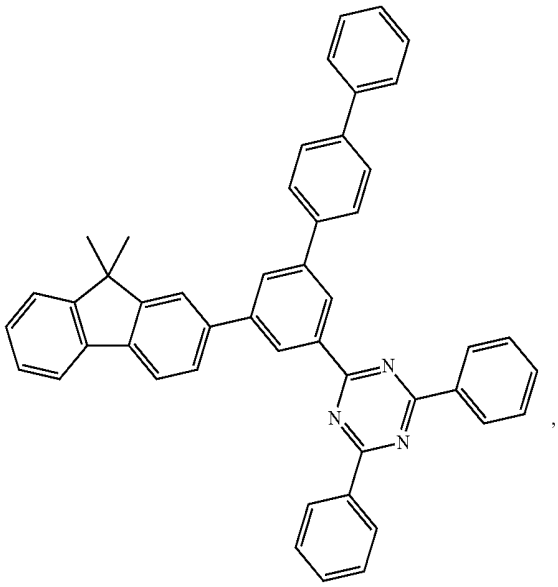


Compound B1

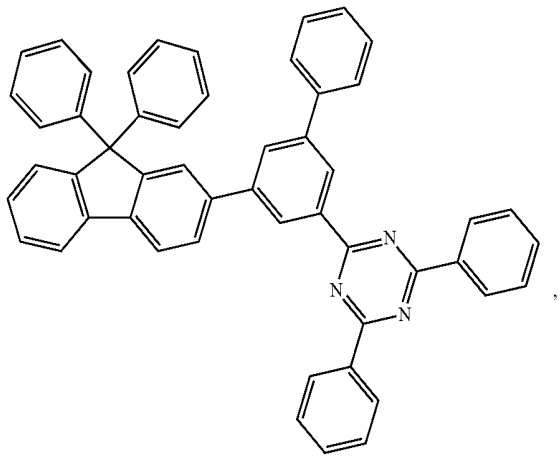


Compound B2

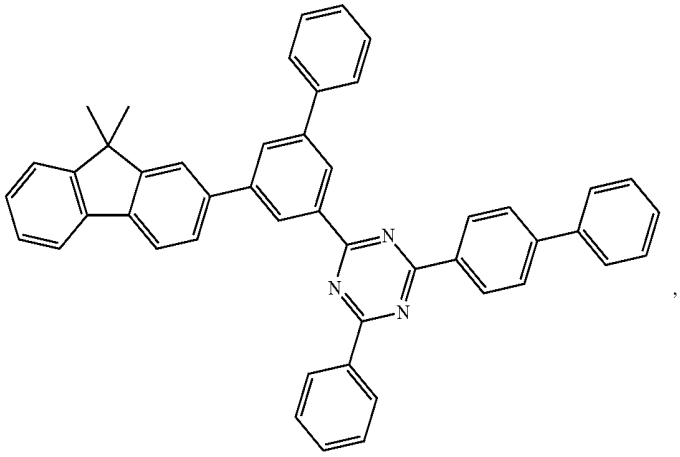
-continued



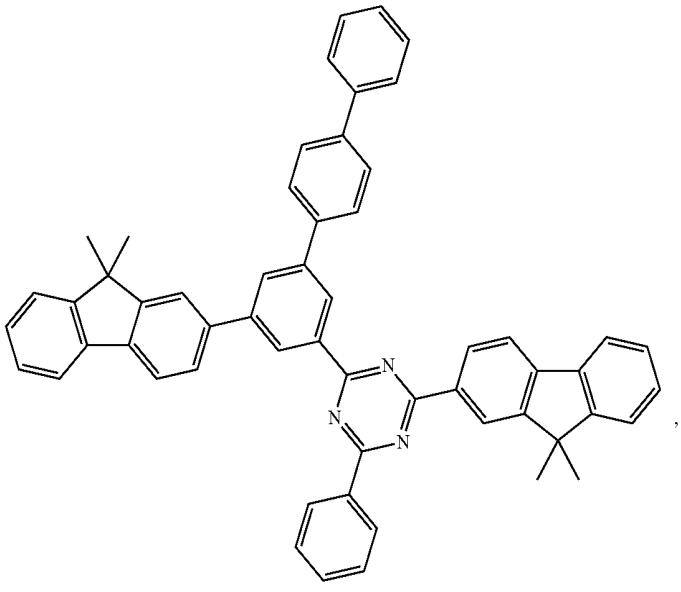
Compound B3



Compound B4

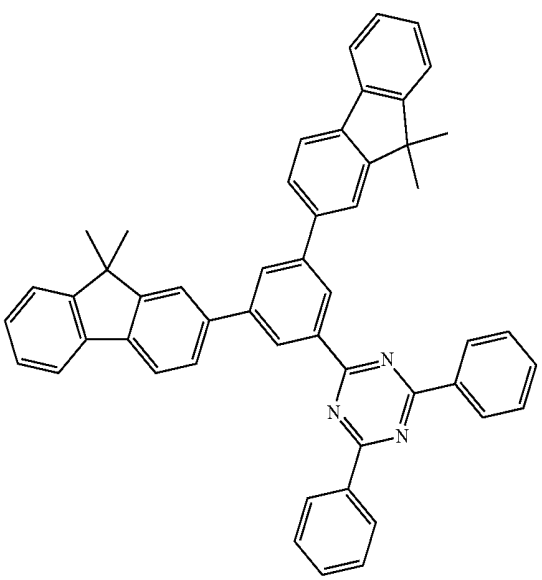


Compound B5

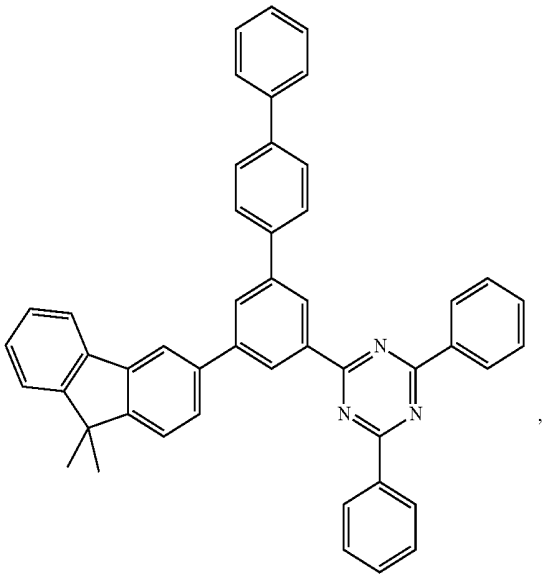


Compound B6

-continued

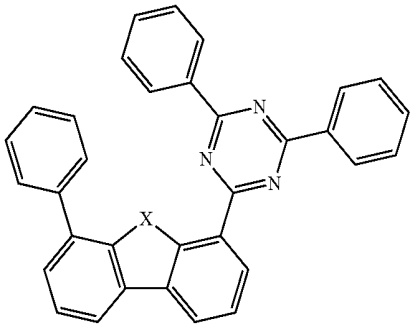


Compound B7



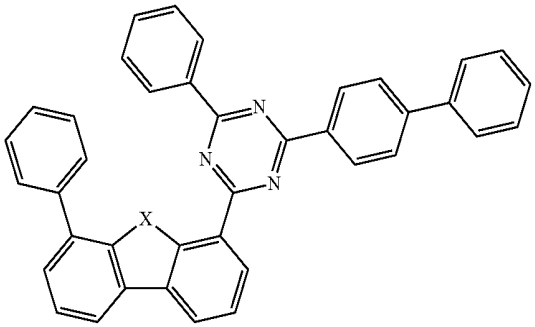
Compound B8

Compound C1 through C3, each represented by the formula



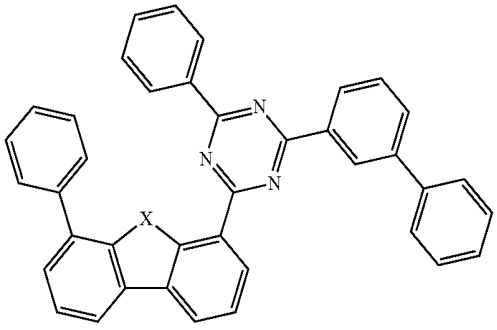
wherein Compound C1: X = O,
in Compound C2: X = S,
in Compound C3: X = Se

Compound C4 through C6, each represented by the formula



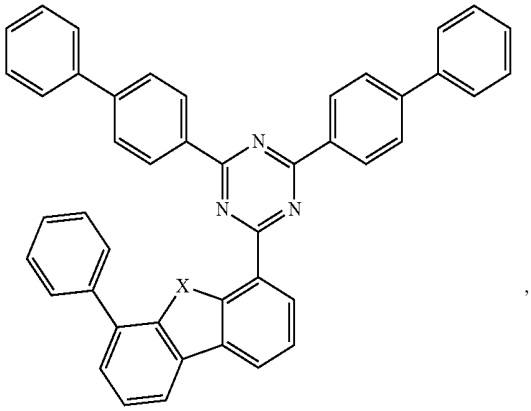
wherein Compound C4: X = O,
in Compound C5: X = S,
in Compound C6: X = Se

Compound C7 through C9, each represented by the formula



wherein Compound C7: X = O,
in Compound C8: X = S,
in Compound C9: X = Se

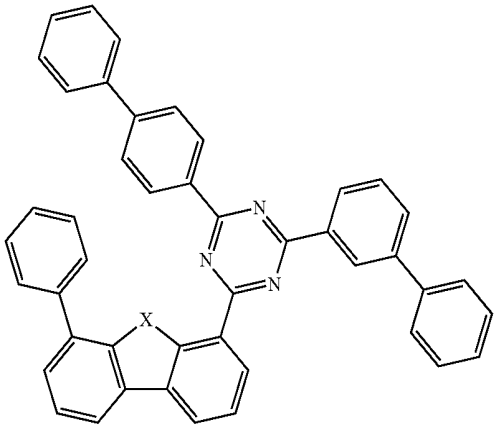
Compound C10 through C12, each represented by the formula



wherein Compound C10: X = O,
in Compound C11: X = S,
in Compound C12: X = Se

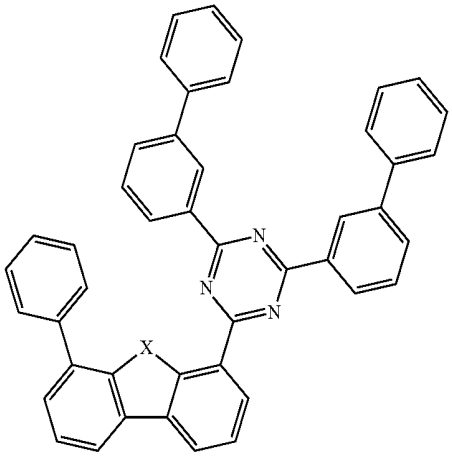
-continued

Compound C13 through C15, each represented by the formula



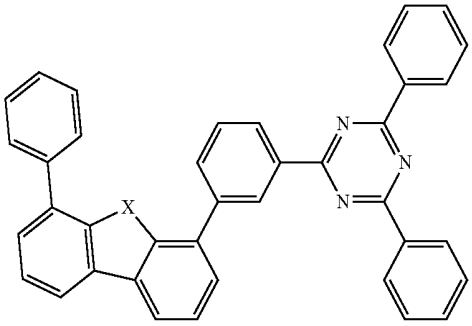
wherein Compound C13: X = O,
in Compound C14: X = S,
in Compound C15: X = Se

Compound C16 through C18, each represented by the formula



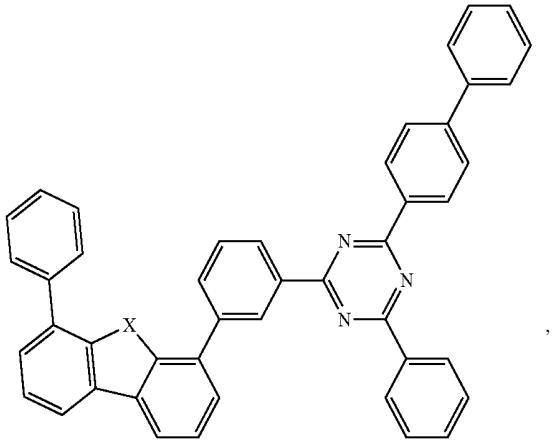
wherein Compound C16: X = O,
in Compound C17: X = S,
in Compound C18: X = Se

Compound C19 through C21, each represented by the formula



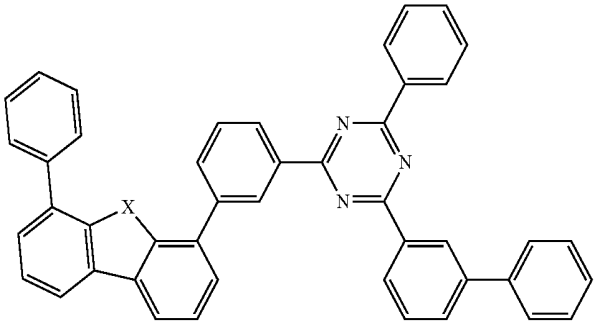
wherein in Compound C19: X = O,
in Compound C20: X = S,
in Compound C21: X = Se

Compound C22 through C24, each represented by the formula



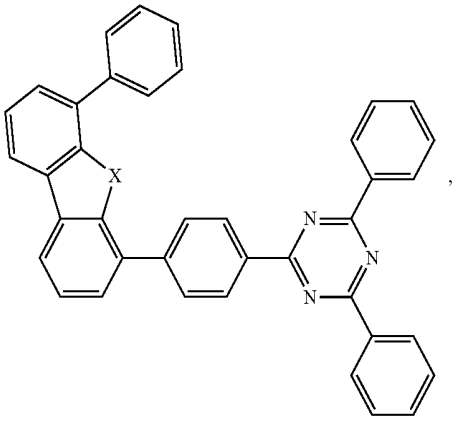
wherein in Compound C22: X = O,
in Compound C23: X = S,
in Compound C24: X = Se

Compound C25 through C27, each represented by the formula



wherein in Compound C25: X = O,
in Compound C26: X = S,
in Compound C27: X = Se

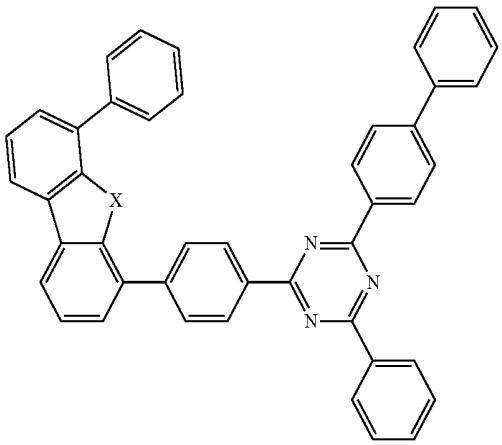
Compound C28 through C30, each represented by the formula



wherein in Compound C28: X = O,
in Compound C29: X = S,
in Compound C30: X = Se

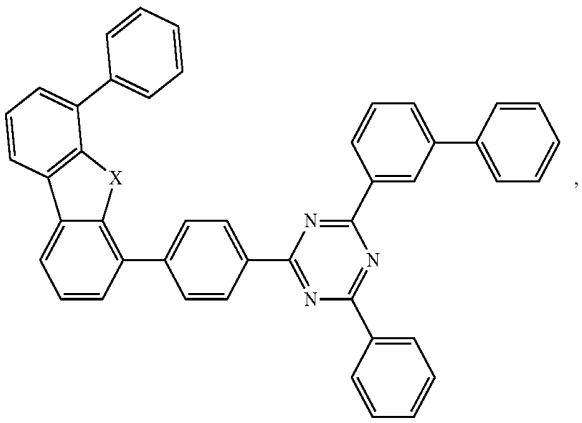
-continued

Compound C31 through C33, each represented by the formula



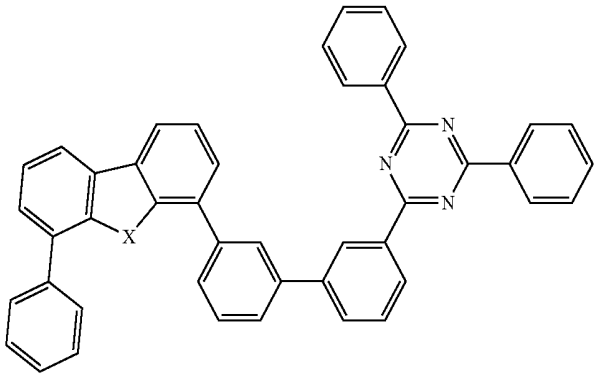
wherein in Compound C31: X = O,
in Compound C32: X = S,
in Compound C33: X = Se

Compound C34 through C36, each represented by the formula



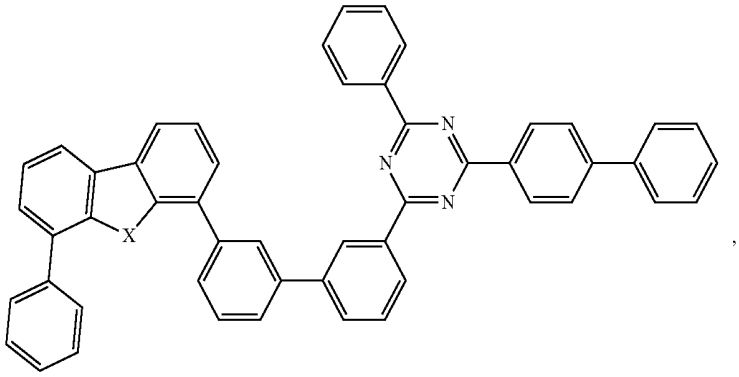
wherein in Compound C34: X = O,
in Compound C35: X = S,
in Compound C36: X = Se

Compound C37 through C39, each represented by the formula



wherein in Compound C37: X = O,
in Compound C38: X = S,
in Compound C39: X = Se

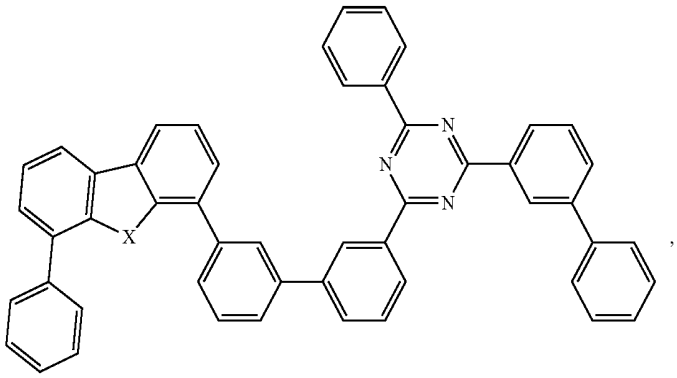
Compound C40 through C42, each represented by the formula



wherein in Compound C40: X = O,
in Compound C41: X = S,
in Compound C42: X = Se

-continued

Compound C43 through C45, each represented by the formula



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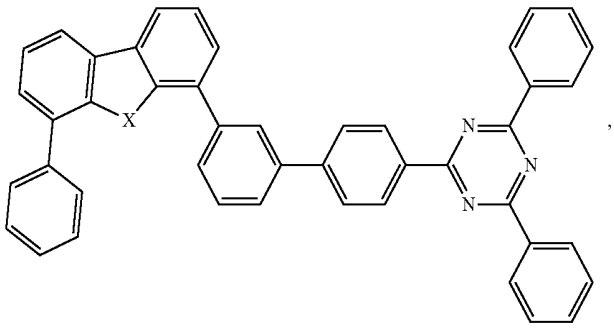
wherein in Compound C43: X = O,
in Compound C44: X = S,
in Compound C45: X = Se

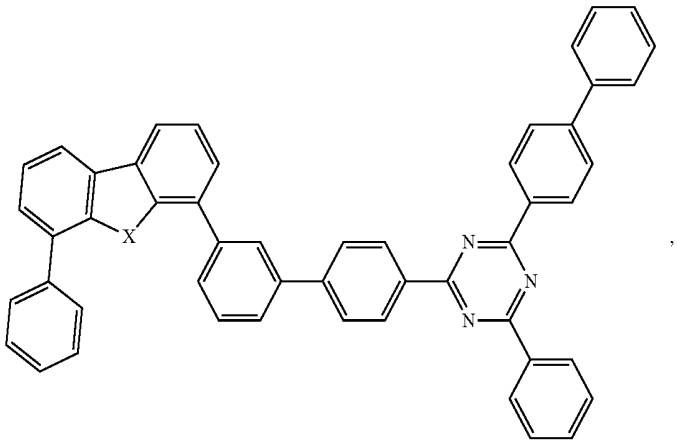
Compound C46 through C48, each represented by the formula



,

wherein in Compound C46: X = O,
in Compound C47: X = S,
in Compound C48: X = Se

Compound C49 through C51, each represented by the formula

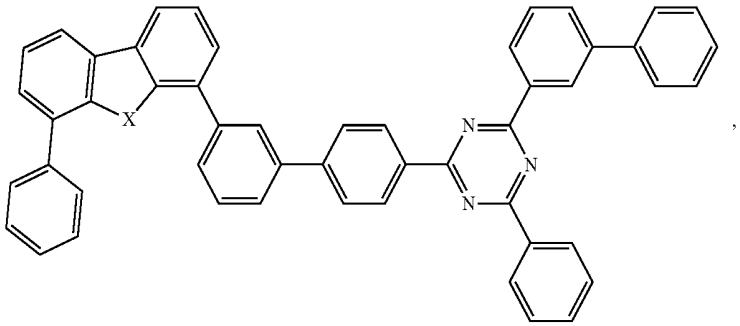


,

wherein in Compound C49: X = O,
in Compound C50: X = S,
in Compound C51: X = Se

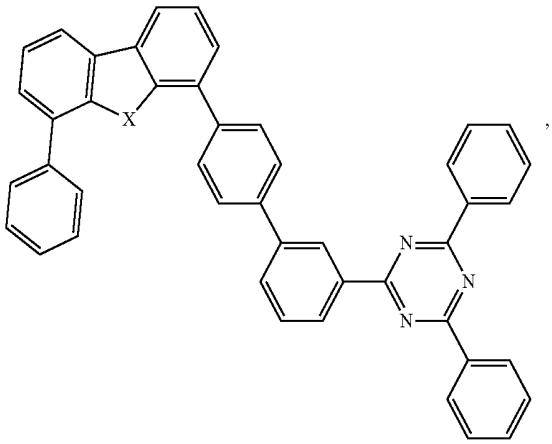
-continued

Compound C52 through C54, each represented by the formula



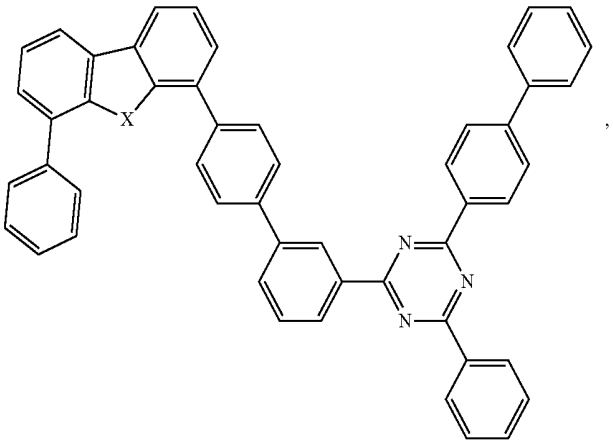
wherein in Compound C52: X = O,
in Compound C53: X = S,
in Compound C54: X = Se

Compound C55 through C57, each represented by the formula



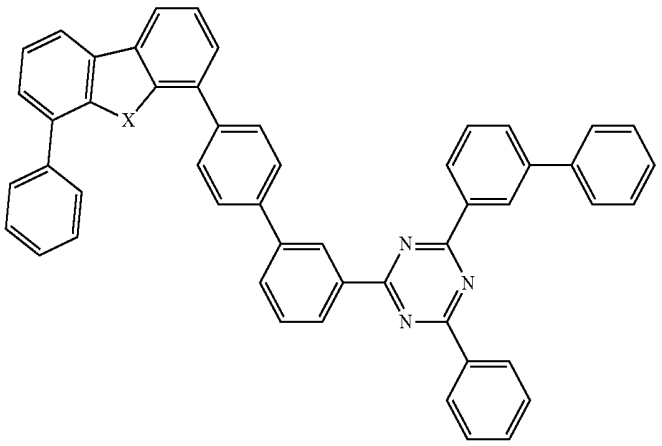
wherein in Compound C55: X = O,
in Compound C56: X = S,
in Compound C57: X = Se

Compound C58 through C60, each represented by the formula



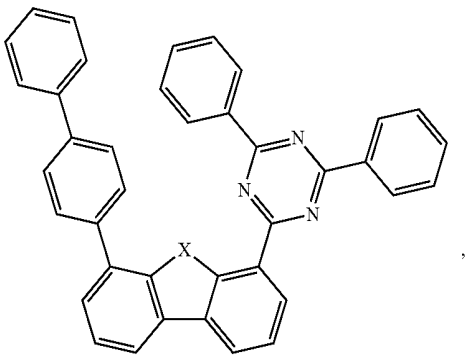
wherein in Compound C58: X = O,
in Compound C59: X = S,
in Compound C60: X = Se

Compound C61 through C63, each represented by the formula



wherein in Compound C61: X = O,
in Compound C62: X = S,
in Compound C63: X = Se

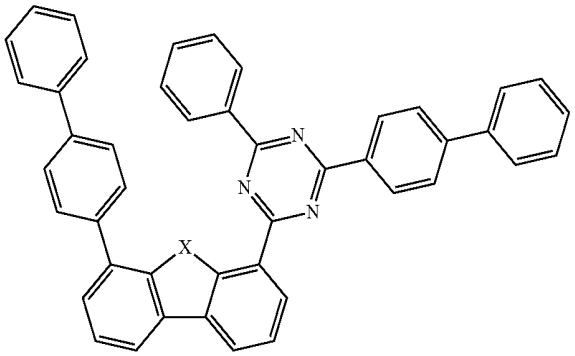
Compound C64 through C66, each represented by the formula



wherein in Compound C64: X = O,
in Compound C65: X = S,
in Compound C66: X = Se

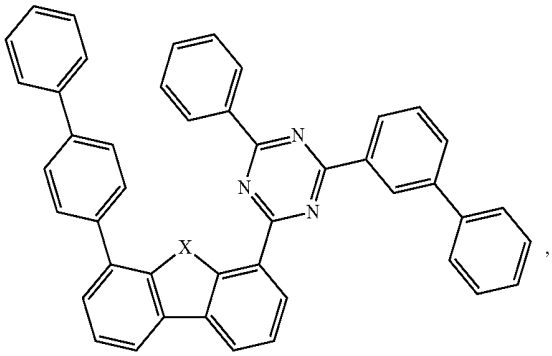
-continued

Compound C67 through C69, each represented by the formula



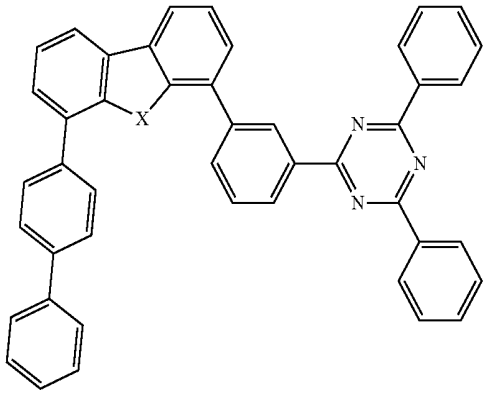
wherein in Compound C67: X = O,
in Compound C68: X = S,
in Compound C69: X = Se

Compound C70 through C72, each represented by the formula



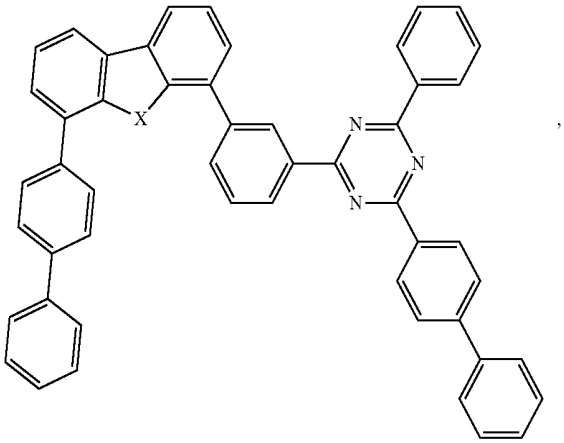
wherein in Compound C70: X = O,
in Compound C71: X = S,
in Compound C72: X = Se

Compound C73 through C75, each represented by the formula



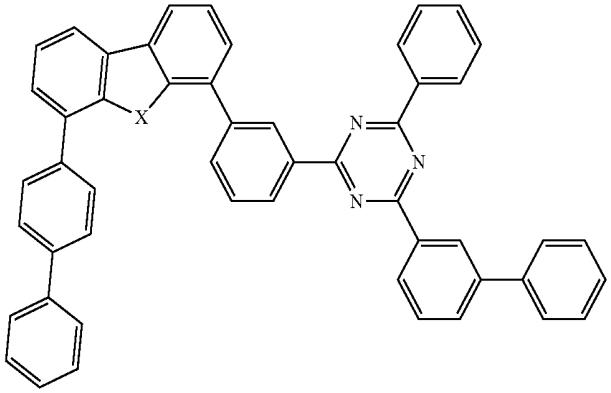
wherein in Compound C73: X = O,
in Compound C74: X = S,
in Compound C75: X = Se

Compound C76 through C78, each represented by the formula



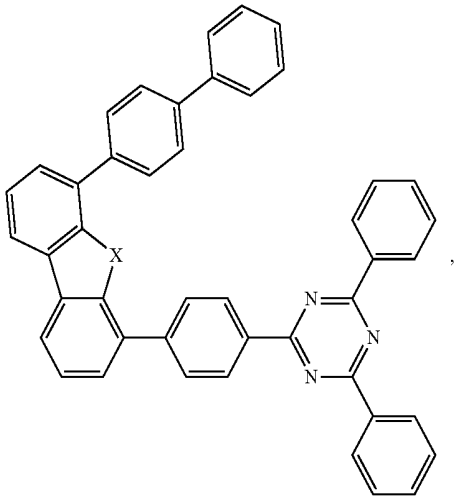
wherein in Compound C76: X = O,
in Compound C77: X = S,
in Compound C78: X = Se

Compound C79 through C81, each represented by the formula



wherein in Compound C79: X = O,
in Compound C80: X = S,
in Compound C81: X = Se

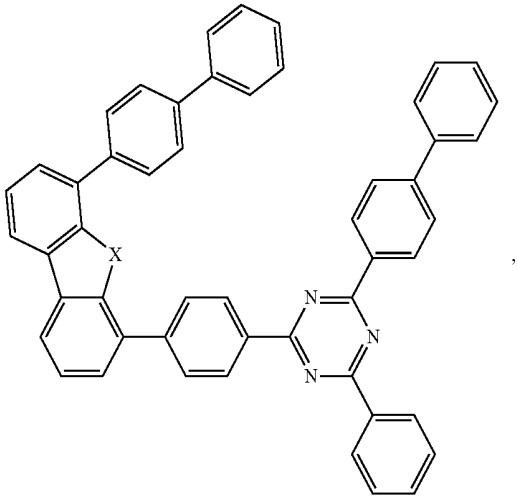
Compound C82 through C84, each represented by the formula



wherein in Compound C82: X = O,
in Compound C83: X = S,
in Compound C84: X = Se

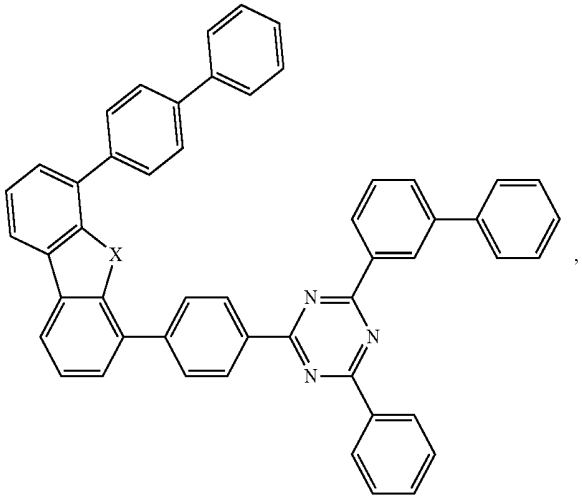
-continued

Compound C85 through C87, each represented by the formula



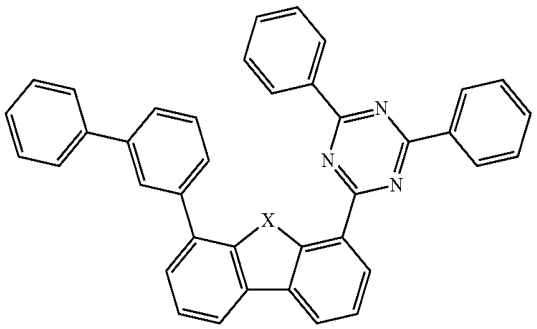
wherein in Compound C85: X = O,
in Compound C86: X = S,
in Compound C87: X = Se

Compound C88 through C90, each represented by the formula



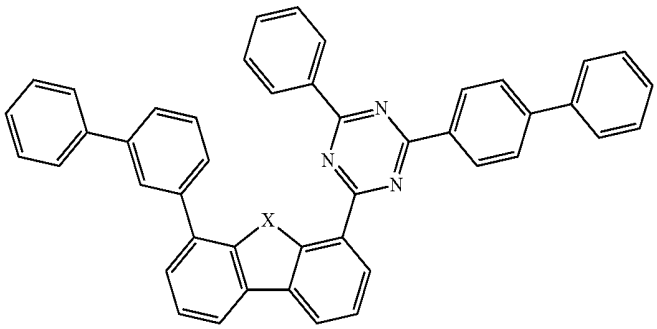
wherein in Compound C88: X = O,
in Compound C89: X = S,
in Compound C90: X = Se

Compound C91 through C93, each represented by the formula



wherein in Compound C91: X = O,
in Compound C92: X = S,
in Compound C93: X = Se

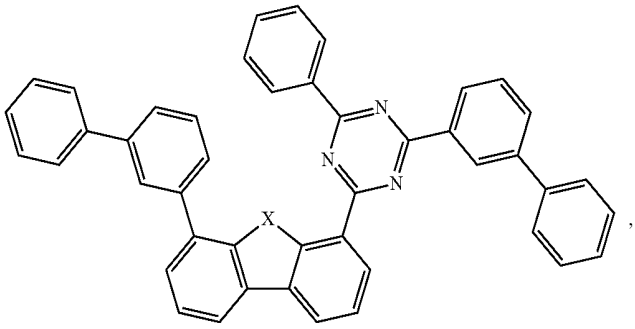
Compound C94 through C96, each represented by the formula



wherein in Compound C94: X = O,
in Compound C95: X = S,
in Compound C96: X = Se

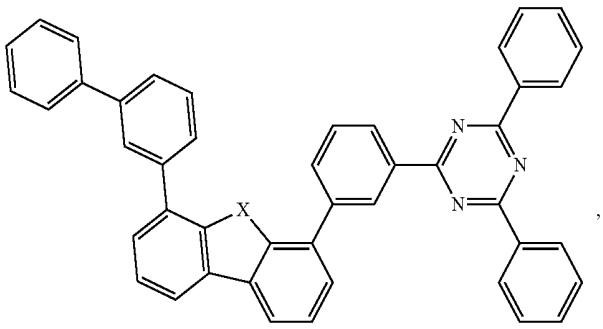
-continued

Compound C97 through C99, each represented by the formula



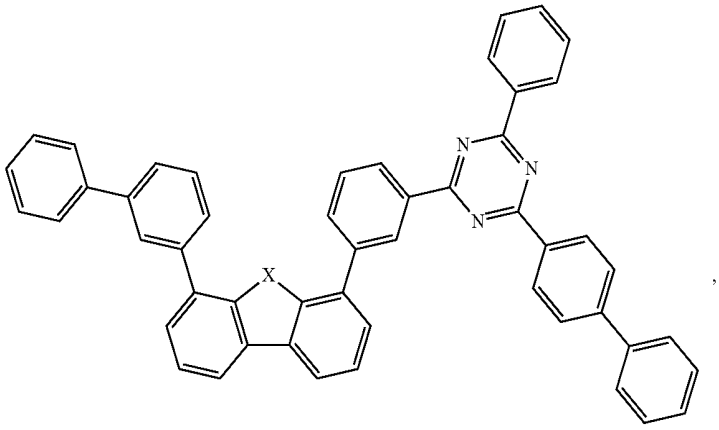
wherein in Compound C97: X = O,
in Compound C98: X = S,
in Compound C99: X = Se

Compound C100 through C102, each represented by the formula



wherein in Compound C100: X = O,
in Compound C101: X = S,
in Compound C102: X = Se

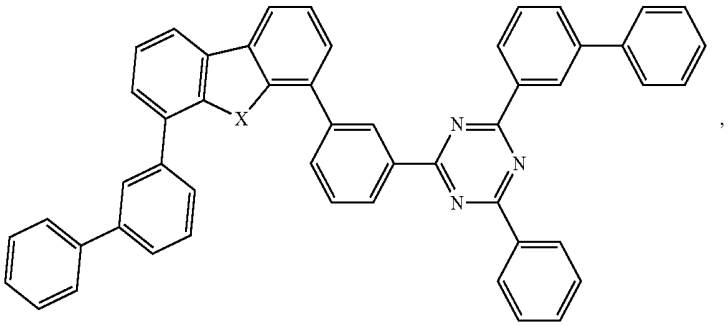
Compound C103 through C105, each represented by the formula



wherein in Compound C103: X = O,
in Compound C104: X = S,
in Compound C105: X = Se

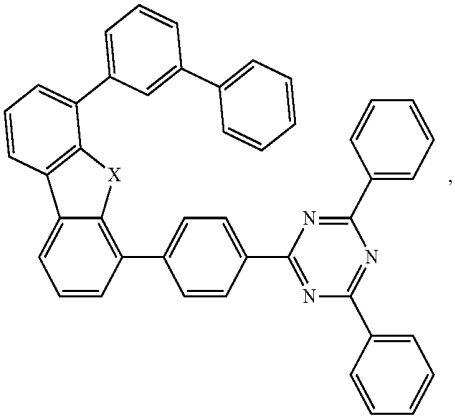
-continued

Compound C106 through C108, each represented by the formula



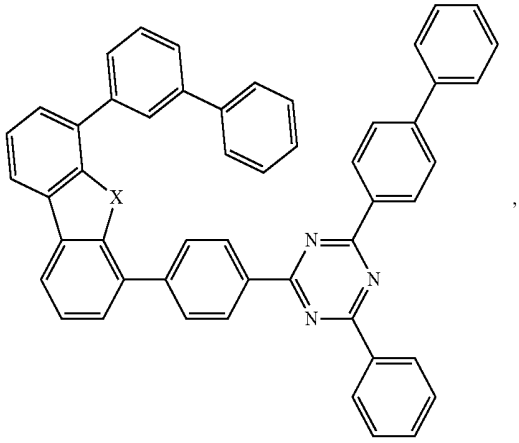
wherein in Compound C106: X = O,
in Compound C107: X = S,
in Compound C108: X = Se

Compound C109 through C111, each represented by the formula



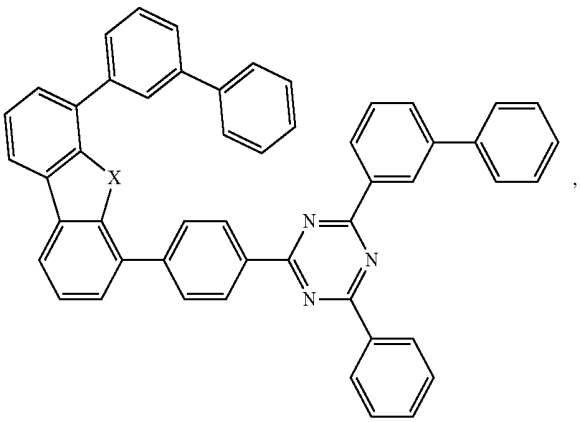
wherein in Compound C109: X = O,
in Compound C110: X = S,
in Compound C111: X = Se

Compound C112 through C114, each represented by the formula



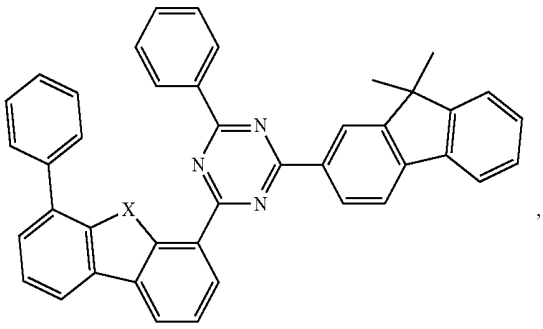
wherein in Compound C112: X = O,
in Compound C113: X = S,
in Compound C114: X = Se

Compound C115 through C117, each represented by the formula



wherein in Compound C115: X = O,
in Compound C116: X = S,
in Compound C117: X = Se

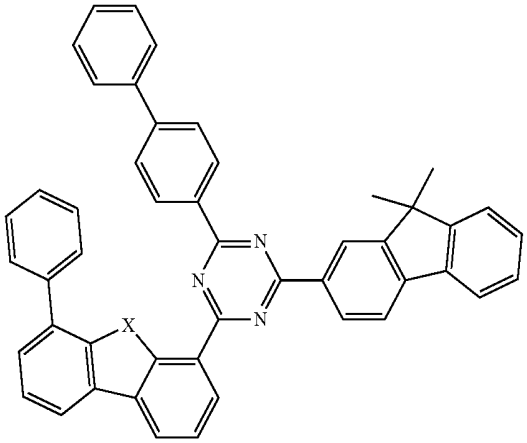
Compound C118 through C120, each represented by the formula



wherein in Compound C118: X = O,
in Compound C119: X = S,
in Compound C120: X = Se

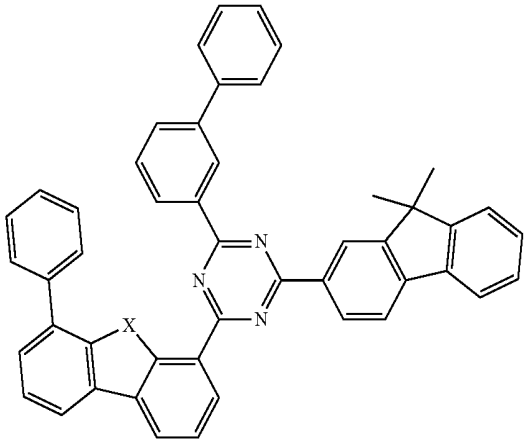
-continued

Compound C121 through C123, each represented by the formula



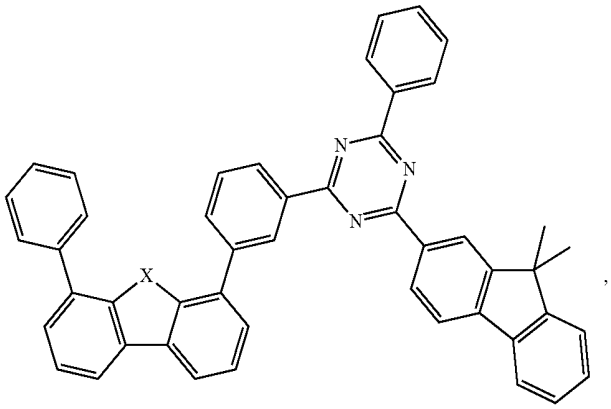
wherein in Compound C121: X = O,
in Compound C122: X = S,
in Compound C123: X = Se

Compound C124 through C126, each represented by the formula



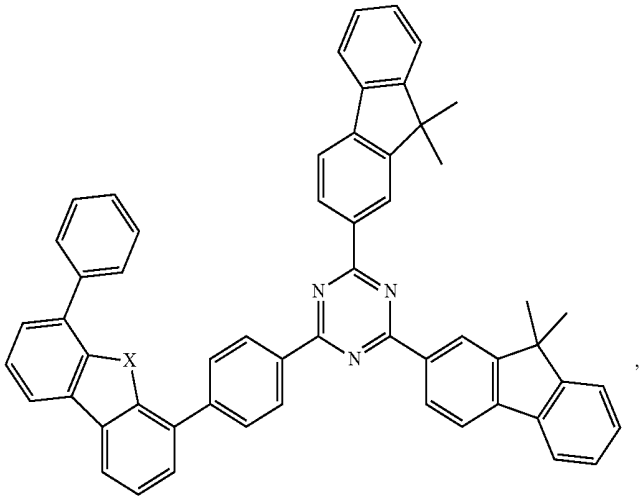
wherein in Compound C124: X = O,
in Compound C125: X = S,
in Compound C126: X = Se

Compound C127 through C129, each represented by the formula



wherein in Compound C127: X = O,
in Compound C128: X = S,
in Compound C129: X = Se

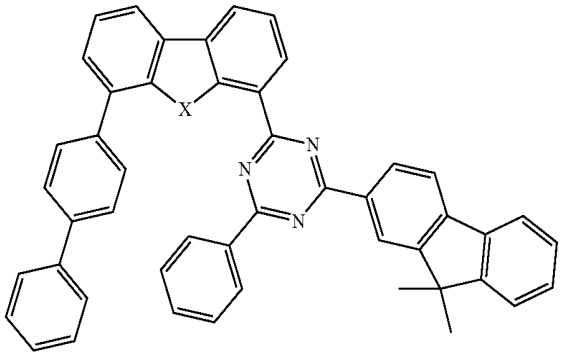
Compound C130 through C132, each represented by the formula



wherein in Compound C130: X = O,
in Compound C131: X = S,
in Compound C132: X = Se

-continued

Compound C133 through C135, each represented by the formula



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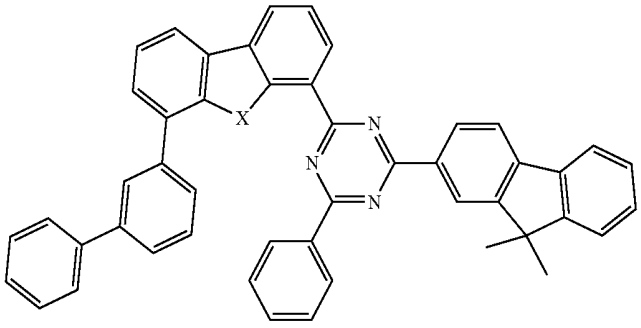
wherein in Compound C133: X = O,
in Compound C134: X = S,
in Compound C135: X = Se

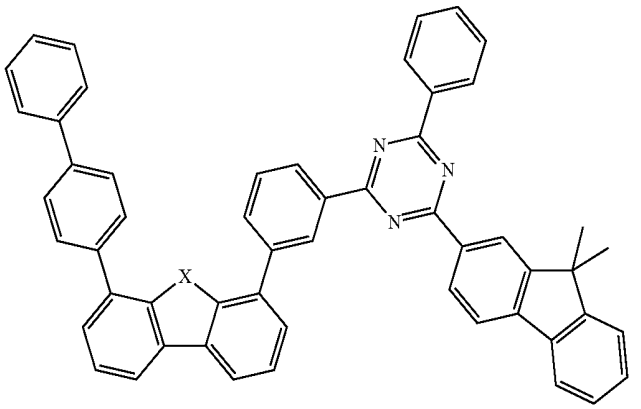
Compound C136 through C138, each represented by the formula



,

wherein in Compound C136: X = O,
in Compound C137: X = S,
in Compound C138: X = Se

Compound C139 through C141, each represented by the formula

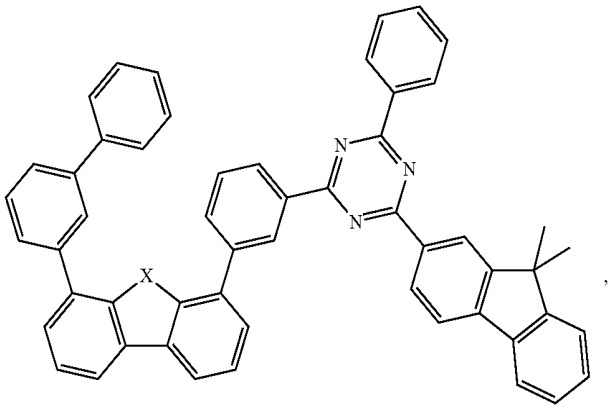


,

wherein in Compound C139: X = O,
in Compound C140: X = S,
in Compound C141: X = Se

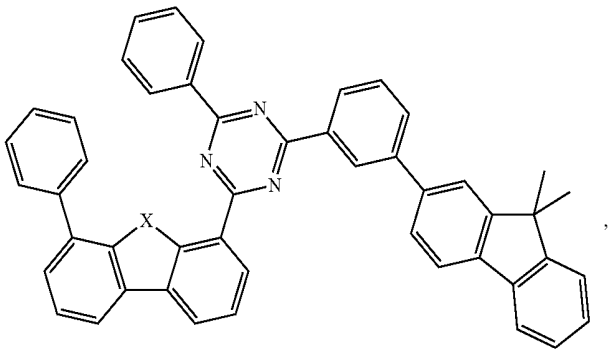
-continued

Compound C142 through C144, each represented by the formula



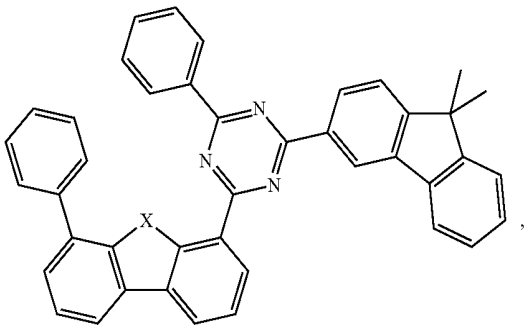
wherein in Compound C142: X = O,
in Compound C143: X = S,
in Compound C144: X = Se

Compound C145 through C147, each represented by the formula



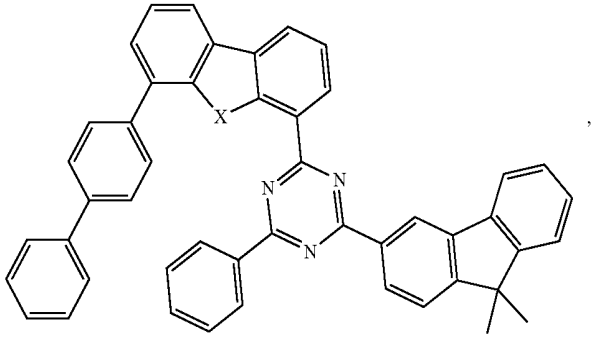
wherein in Compound C145: X = O,
in Compound C146: X = S,
in Compound C147: X = Se

Compound C148 through C150, each represented by the formula



wherein in Compound C148: X = O,
in Compound C149: X = S,
in Compound C150: X = Se

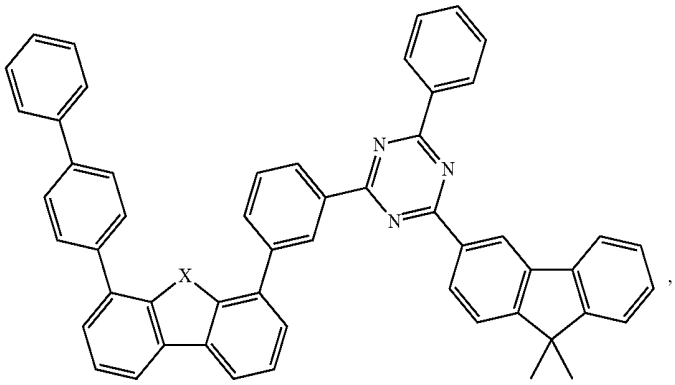
Compound C151 through C153, each represented by the formula



wherein in Compound C151: X = O,
in Compound C152: X = S,
in Compound C152: X = Se

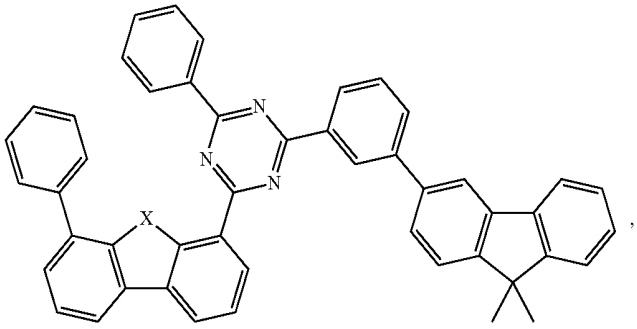
-continued

Compound C154 through C156, each represented by the formula



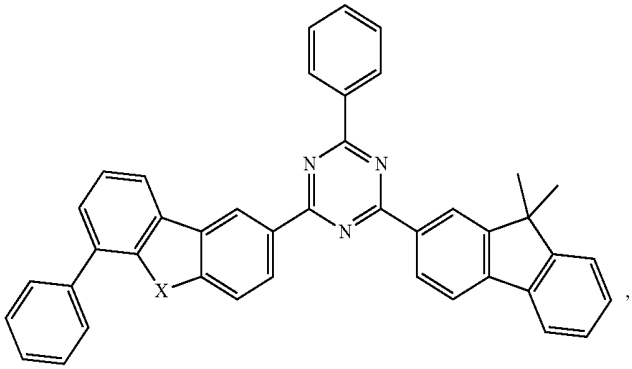
wherein in Compound C154: X = O,
in Compound C155: X = S,
in Compound C156: X = Se

Compound C157 through C159, each represented by the formula



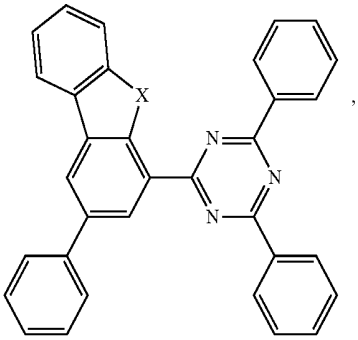
wherein in Compound C157: X = O,
in Compound C158: X = S,
in Compound C159: X = Se

Compound C160 through C162, each represented by the formula



wherein in Compound C160: X = O,
in Compound C161: X = S,
in Compound C162: X = Se

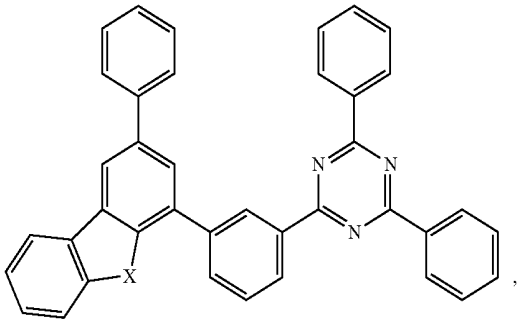
Compound C163 through C165, each represented by the formula



wherein in Compound C163: X = O,
in Compound C164: X = S,
in Compound C165: X = Se

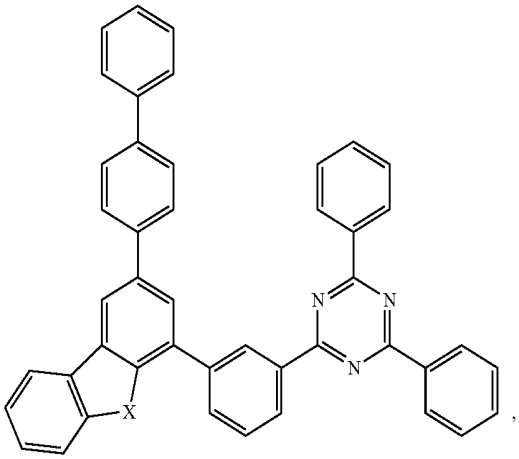
-continued

Compound C166 through C168, each represented by the formula



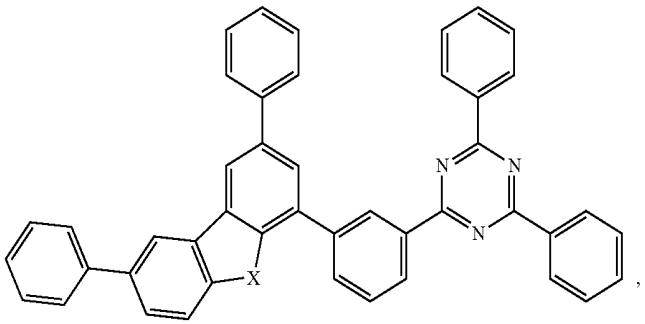
wherein in Compound C166: X = O,
in Compound C167: X = S,
in Compound C168: X = Se

Compound C169 through C171, each represented by the formula



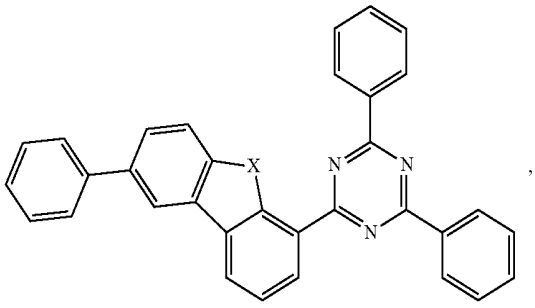
wherein in Compound C169: X = O,
in Compound C170: X = S,
in Compound C171: X = Se

Compound C172 through C174, each represented by the formula



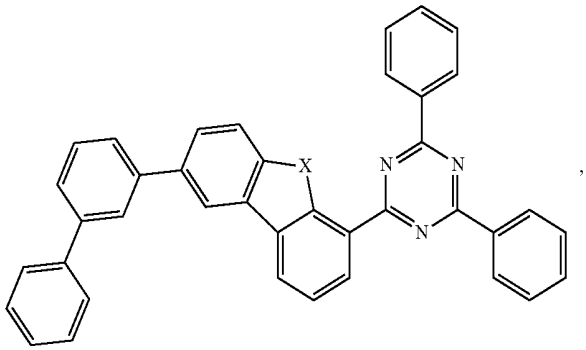
wherein in Compound C172: X = O,
in Compound C173: X = S,
in Compound C174: X = Se

Compound C175 through C177, each represented by the formula



wherein in Compound C175: X = O,
in Compound C176: X = S,
in Compound C177: X = Se

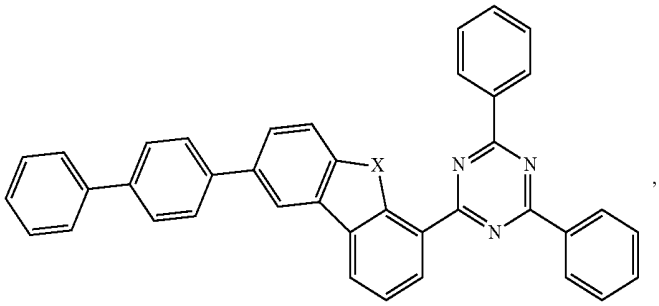
Compound C178 through C180, each represented by the formula



wherein in Compound C178: X = O,
in Compound C179: X = S,
in Compound C180: X = Se

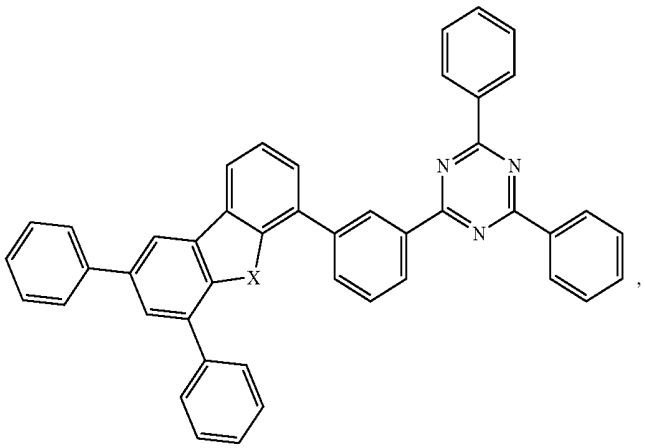
-continued

Compound C181 through C183, each represented by the formula



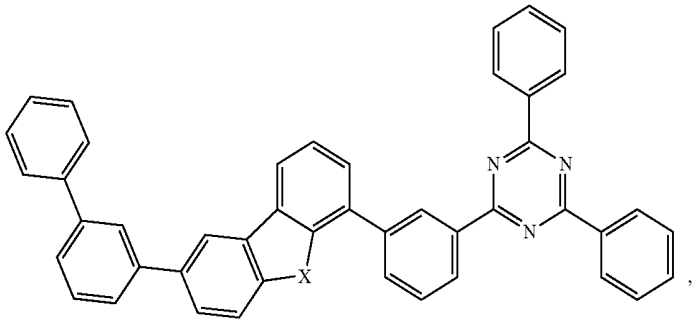
wherein in Compound C181: X = O,
in Compound C182: X = S,
in Compound C183: X = Se

Compound C184 through C186, each represented by the formula



wherein in Compound C184: X = O,
in Compound C185: X = S,
in Compound C186: X = Se

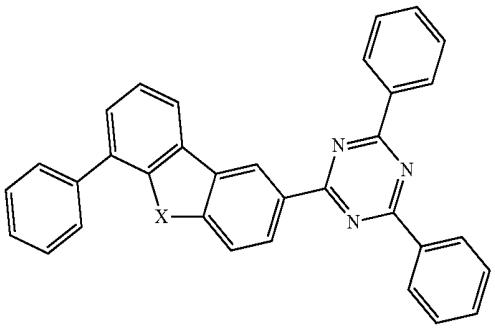
Compound C187 through C189, each represented by the formula



wherein in Compound C187: X = O,
in Compound C188: X = S,
in Compound C189: X = Se

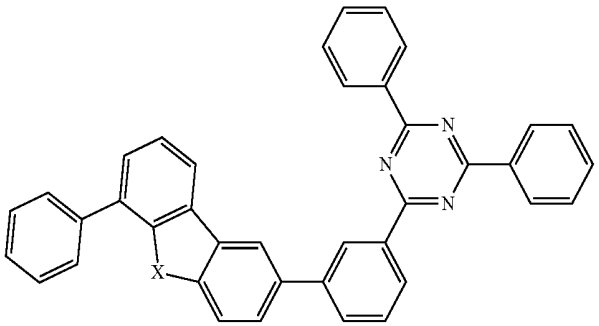
-continued

Compound C190 through C192, each represented by the formula



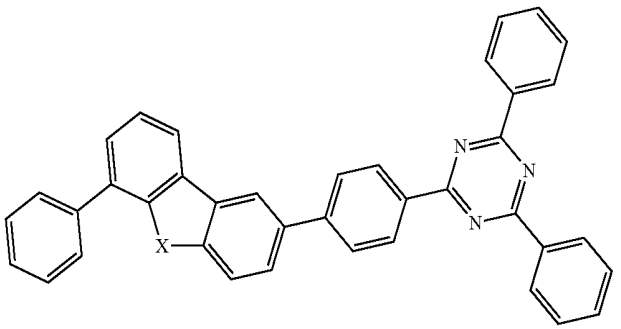
wherein in Compound C190: X = O,
in Compound C191: X = S,
in Compound C192: X = Se

Compound C193 through C195, each represented by the formula



wherein in Compound C193: X = O,
in Compound C194: X = S,
in Compound C195: X = Se

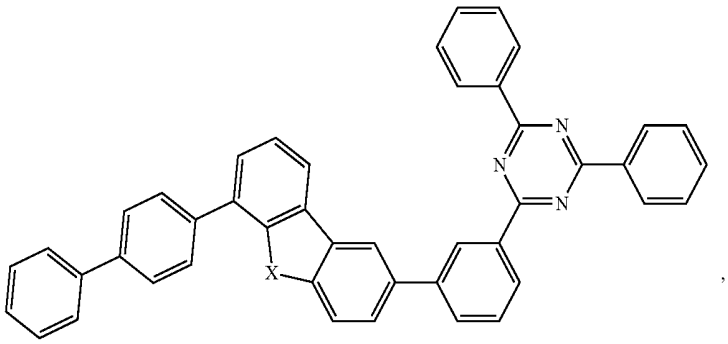
Compound C196 through C198, each represented by the formula



wherein in Compound C196: X = O,
in Compound C197: X = S,
in Compound C198: X = Se

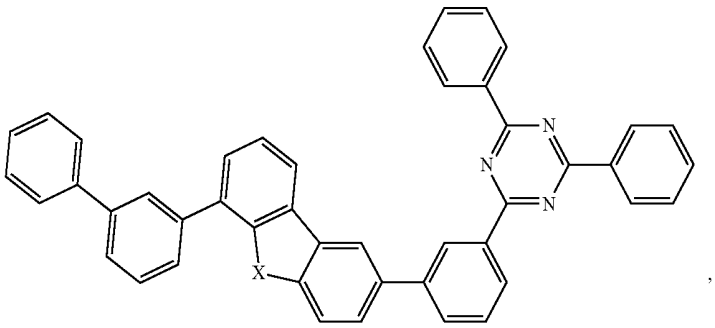
-continued

Compound C199 through C201, each represented by the formula



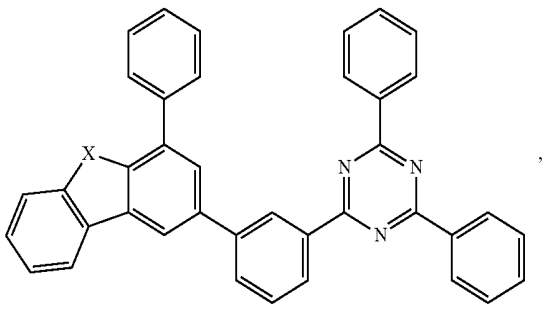
wherein in Compound C199: X = O,
in Compound C200: X = S,
in Compound C201: X = Se

Compound C202 through C204, each represented by the formula



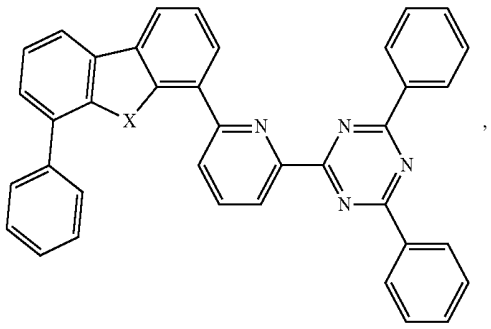
wherein in Compound C202: X = O,
in Compound C203: X = S,
in Compound C204: X = Se

Compound C205 through C207, each represented by the formula



wherein in Compound C205: X = O,
in Compound C206: X = S,
in Compound C207: X = Se

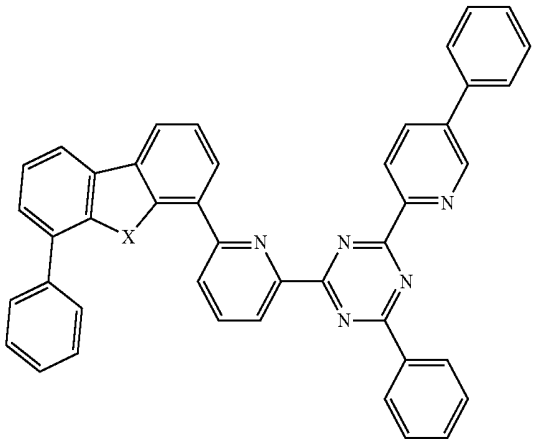
Compound C208 through C210, each represented by the formula



wherein in Compound C208: X = O,
in Compound C209: X = S,
in Compound C210: X = Se

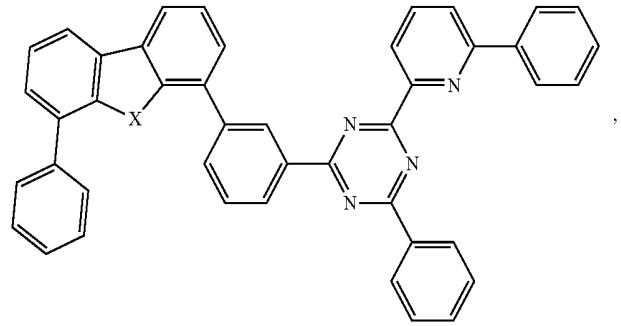
-continued

Compound C211 through C213, each represented by the formula



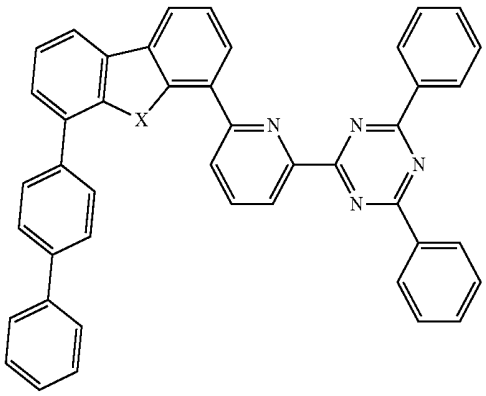
wherein in Compound C211: X = O,
in Compound C212: X = S,
in Compound C213: X = Se

Compound C214 through C216, each represented by the formula



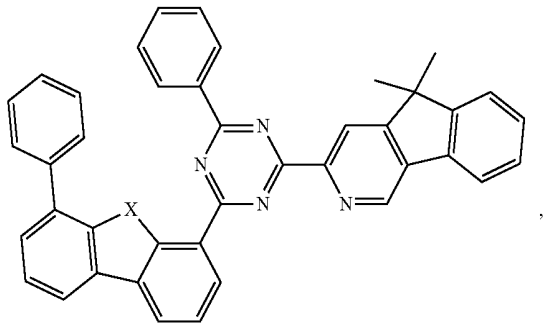
wherein in Compound C214: X = O,
in Compound C215: X = S,
in Compound C216: X = Se

Compound C217 through C219, each represented by the formula



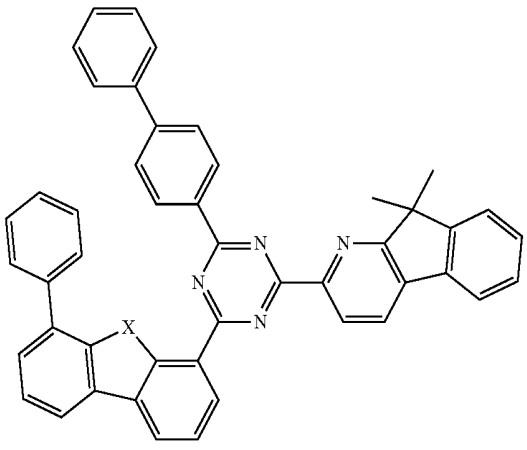
wherein in Compound C217: X = O,
in Compound C218: X = S,
in Compound C219: X = Se

Compound C220 through C222, each represented by the formula



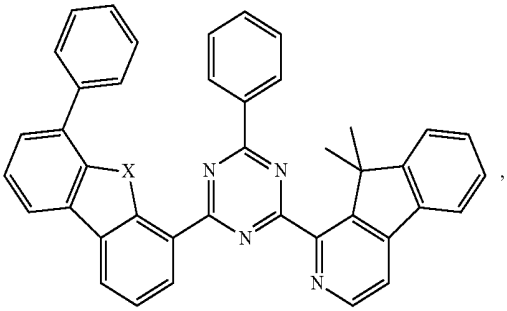
wherein in Compound C220: X = O,
in Compound C221: X = S,
in Compound C222: X = Se

Compound C223 through C225, each represented by the formula



wherein in Compound C223: X = O,
in Compound C224: X = S,
in Compound C225: X = Se

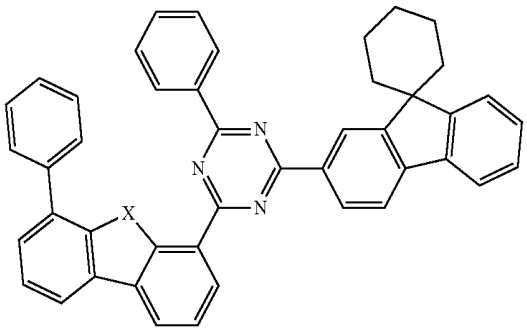
Compound C226 through C228, each represented by the formula



wherein in Compound C226: X = O,
in Compound C227: X = S,
in Compound C228: X = Se

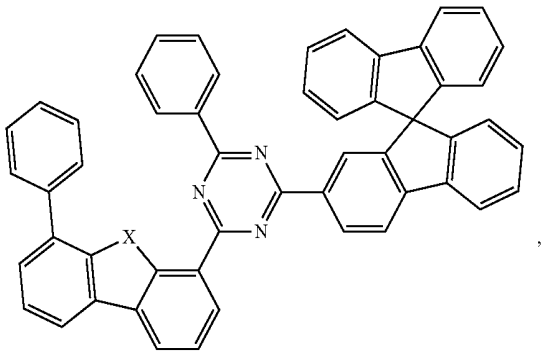
-continued

Compound C229 through C231, each represented by the formula



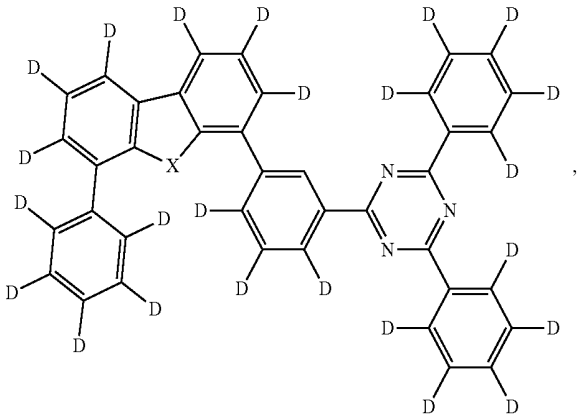
wherein in Compound C229: X = O,
in Compound C230: X = S,
in Compound C231: X = Se

Compound C232 through C234, each represented by the formula



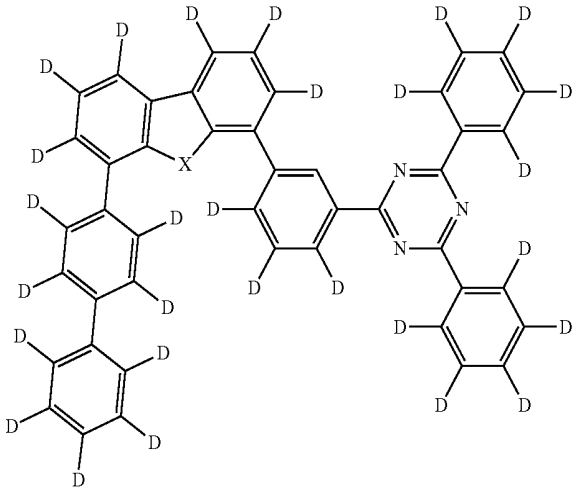
wherein in Compound C232: X = O,
in Compound C233: X = S,
in Compound C234: X = Se

Compound C235 through C237, each represented by the formula



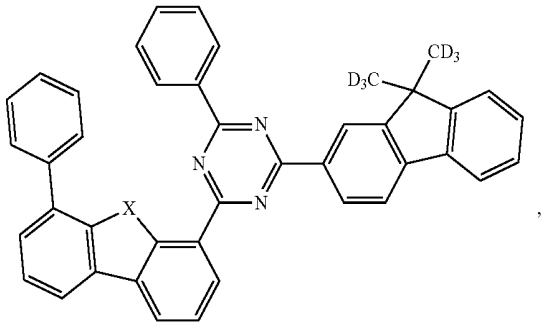
wherein in Compound C235: X = O,
in Compound C236: X = S,
in Compound C237: X = Se

Compound C238 through C240, each represented by the formula



wherein in Compound C238: X = O,
in Compound C239: X = S,
in Compound C240: X = Se

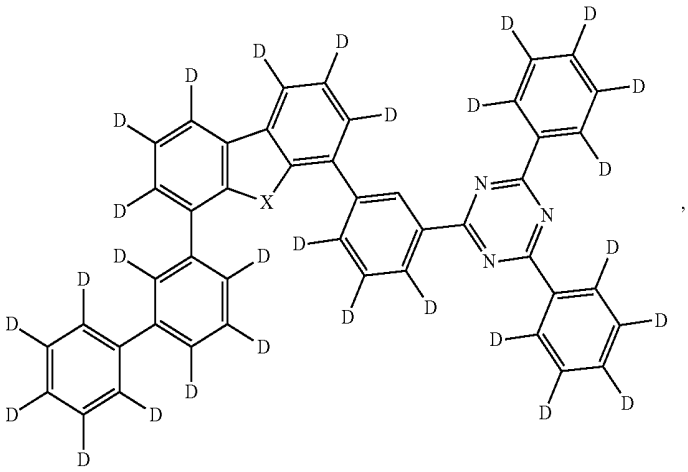
Compound C241 through C243, each represented by the formula



wherein in Compound C241: X = O,
in Compound C242: X = S,
in Compound C243: X = Se

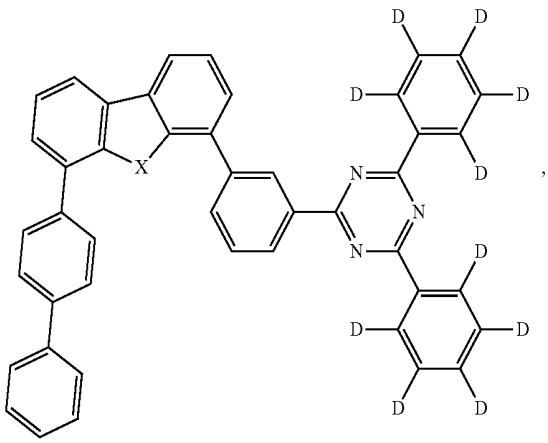
-continued

Compound C244 through C246, each represented by the formula



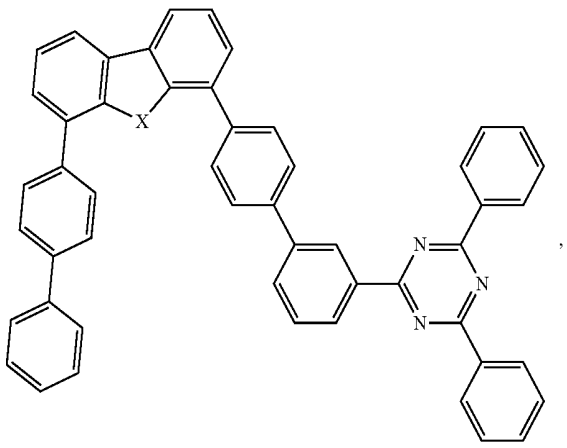
wherein in Compound C244: X = O,
in Compound C245: X = S,
in Compound C246: X = Se

Compound C247 through C249, each represented by the formula



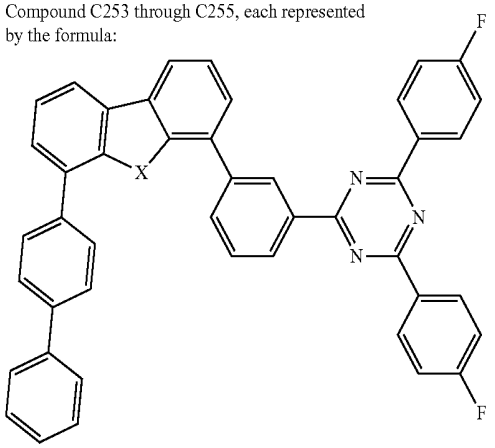
wherein in Compound C247: X = O,
in Compound C248: X = S,
in Compound C249: X = Se

Compound C250 through C252, each represented by the formula



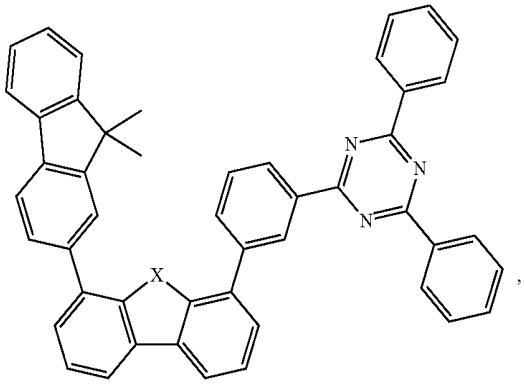
wherein in Compound C250: X = O,
in Compound C251: X = S,
in Compound C252: X = Se

Compound C253 through C255, each represented by the formula:



wherein in Compound C253: X = O,
in Compound C254: X = S,
in Compound C255: X = Se

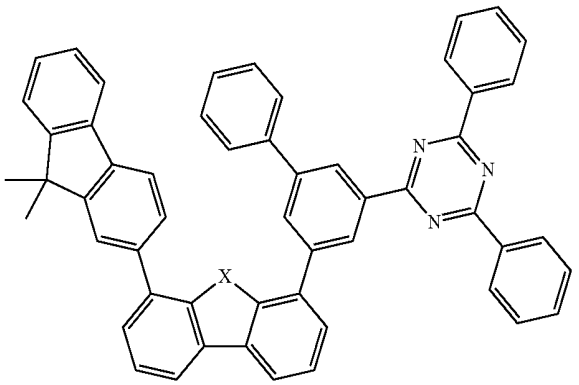
Compound D1 through D3, each represented by the formula:



where in Compound D1: X = O,
in Compound D2, X = S, and
in Compound D3, X = Se

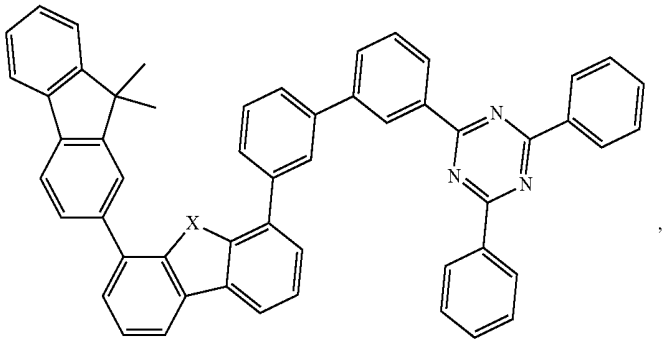
-continued

Compound D4 through D6, each represented by the formula:



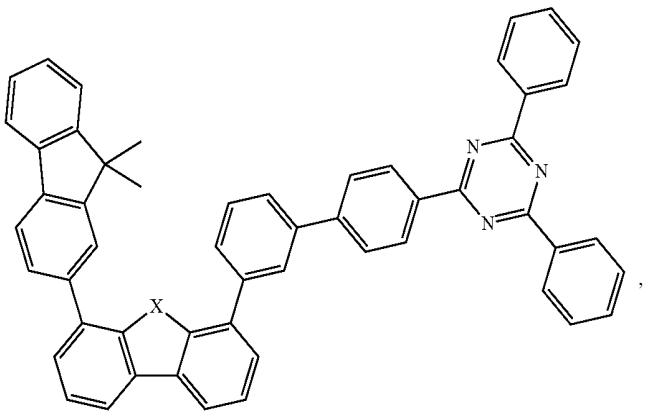
where in Compound D4: X = O,
in Compound D5, X = S, and
in Compound D6, X = Se

Compound D7 through D9, each represented by the formula:



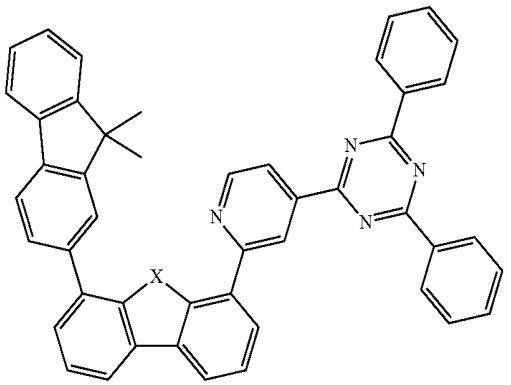
where in Compound D7: X = O,
in Compound D8, X = S, and
in Compound D9, X = Se

Compound D10 through D12, each represented by the formula:



where in Compound D10: X = O,
in Compound D11, X = S, and
in Compound D12, X = Se

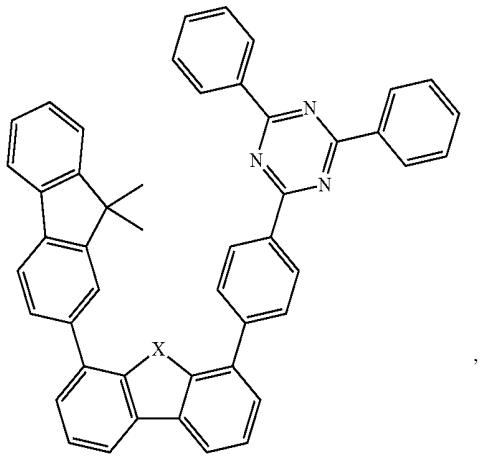
Compound D13 through D15, each represented by the formula:



where in Compound D13: X = O,
in Compound D14, X = S, and
in Compound D15, X = Se

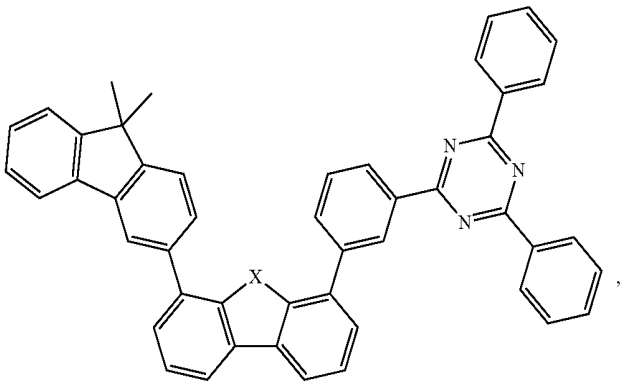
-continued

Compound D16 through D18, each represented by the formula:



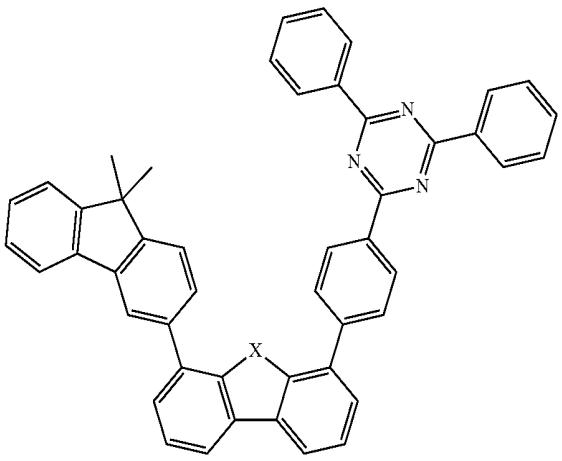
where in Compound D16: X = O,
in Compound D17, X = S, and
in Compound D18, X = Se

Compound D19 through D21, each represented by the formula:



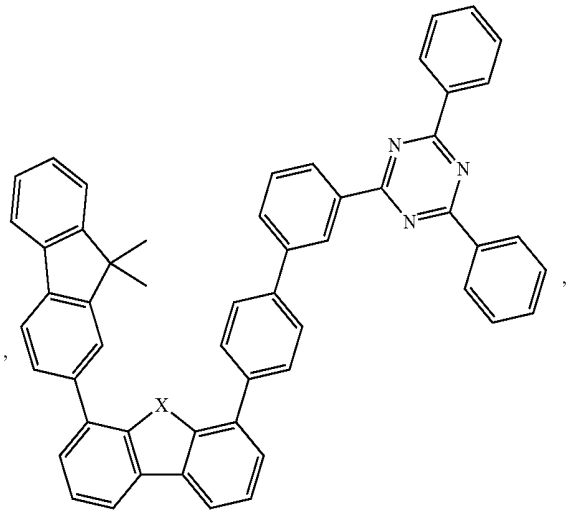
where in Compound D19: X = O,
in Compound D20, X = S, and
in Compound D21, X = Se

Compound D22 through D24, each represented by the formula:



where in Compound D22: X = O,
in Compound D23, X = S, and
in Compound D24, X = Se

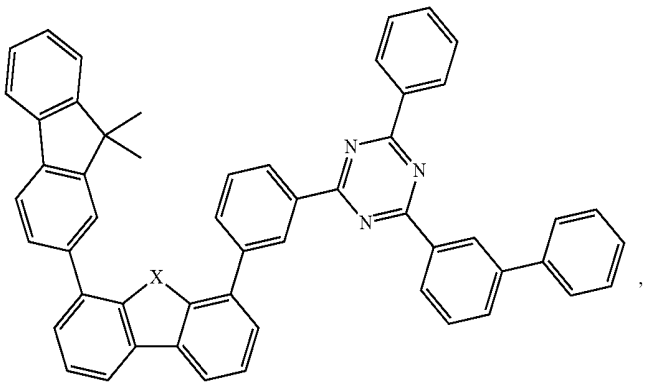
Compound D25 through D27, each represented by the formula:



where in Compound D25: X = O,
in Compound D26, X = S, and
in Compound D27, X = Se

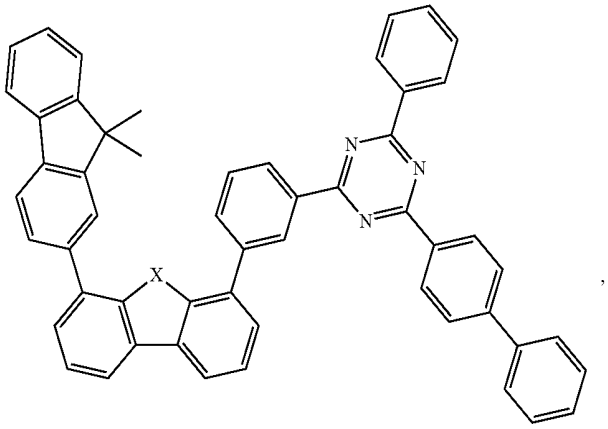
-continued

Compound D28 through D30, each represented by the formula:



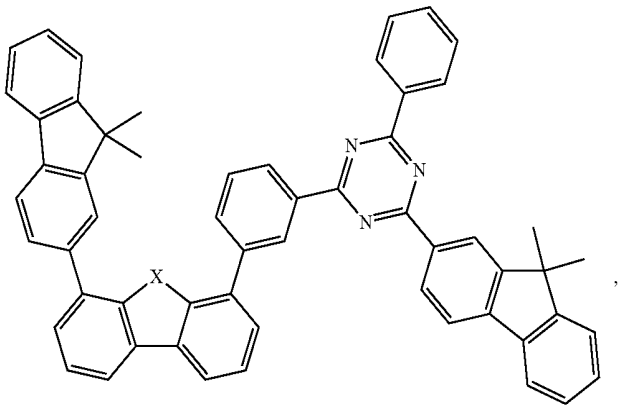
where in Compound D28: X = O,
in Compound D29, X = S, and
in Compound D30, X = Se

Compound D31 through D33, each represented by the formula:



where in Compound D31: X = O,
in Compound D32, X = S, and
in Compound D33, X = Se

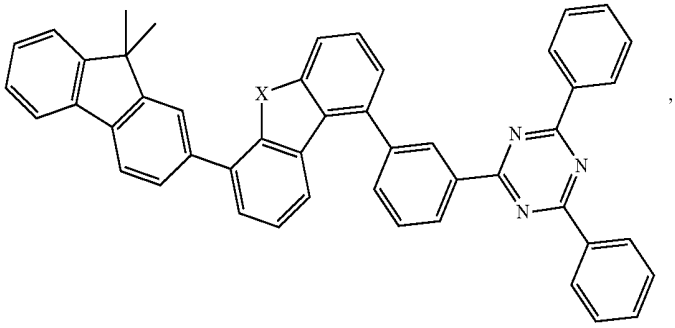
Compound D34 through D36, each represented by the formula:



where in Compound D34: X = O,
in Compound D35, X = S, and
in Compound D36, X = Se

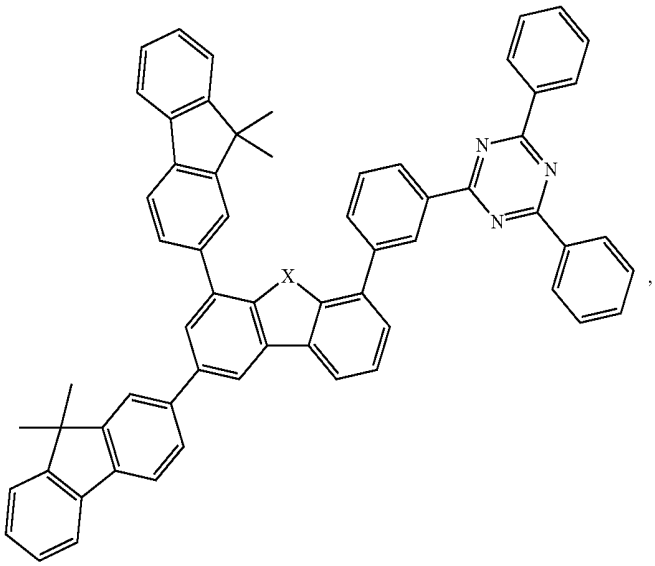
-continued

Compounds D37 through D39, each represented by the formula:



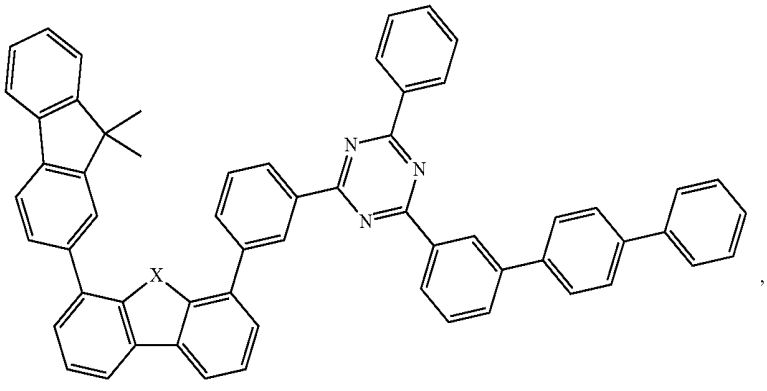
where in Compound D37: X = O,
in Compound D38, X = S, and
in Compound D39, X = Se

Compound D40 through D42, each represented by the formula:



where in Compound D40: X = O,
in Compound D41, X = S, and
in Compound D42, X = Se

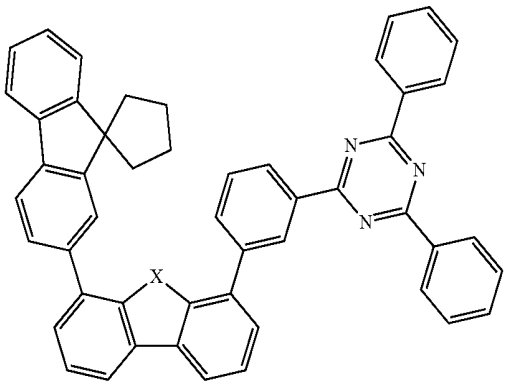
Compound D43 through D45, each represented by the formula:



where in Compound D43: X = O,
in Compound D44, X = S, and
in Compound D45, X = Se

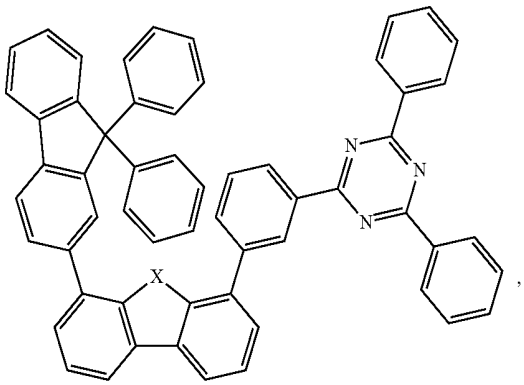
-continued

Compound D46 through D48, each represented by the formula:



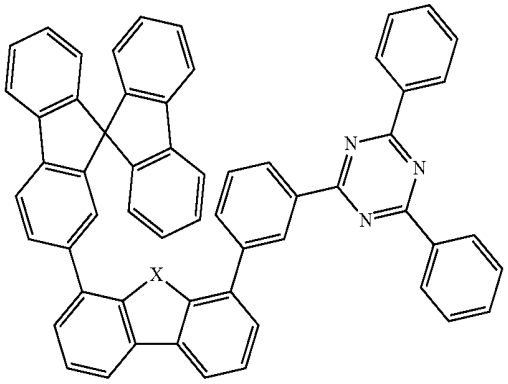
where in Compound D46: X = O,
in Compound D47, X = S, and
in Compound D48, X = Se

Compound D49 through D51, each represented by the formula:



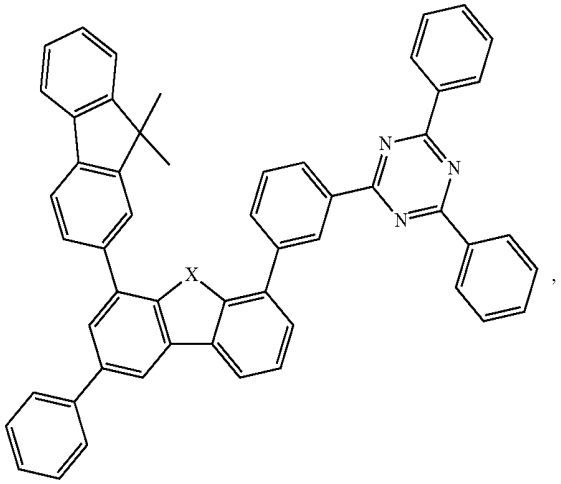
where in Compound D49: X = O,
in Compound D50, X = S, and
in Compound D51, X = Se

Compound D49 through D51, each represented by the formula:



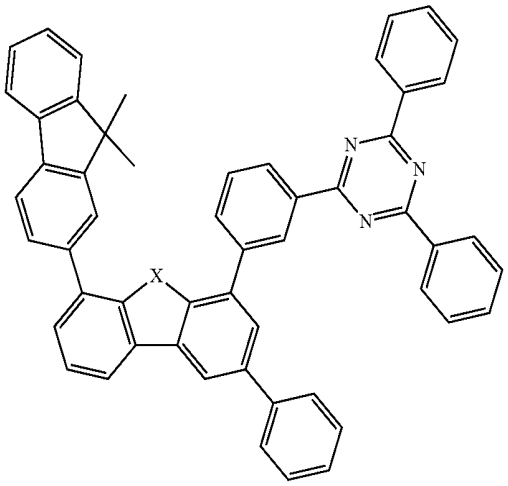
where in Compound D52: X = O,
in Compound D53, X = S, and
in Compound D54, X = Se

Compound D55 through D57, each represented by the formula:



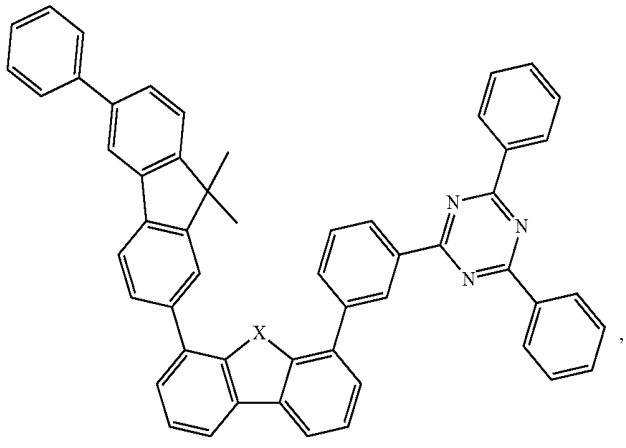
where in Compound D55: X = O,
in Compound D56, X = S, and
in Compound D57, X = Se

Compound D58 through D60, each represented by the formula:



where in Compound D58: X = O,
in Compound D59, X = S, and
in Compound D60, X = Se

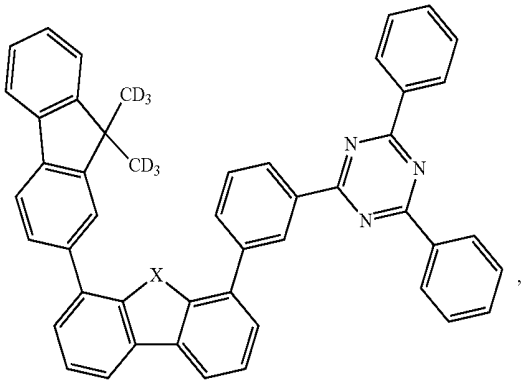
Compound D61 through D63, each represented by the formula:



where in Compound D61: X = O,
in Compound D62, X = S, and
in Compound D63, X = Se

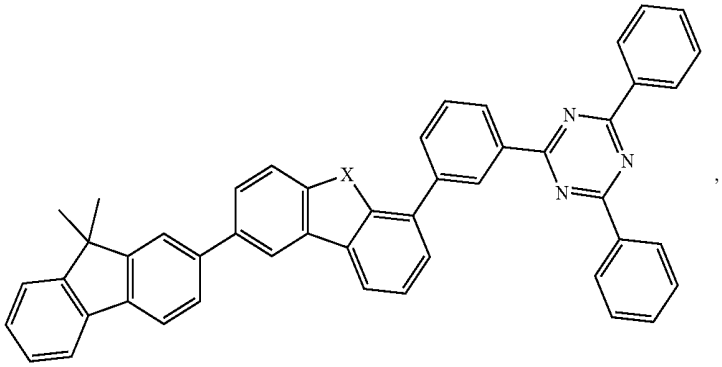
-continued

Compound D64 through D66, each represented by the formula:



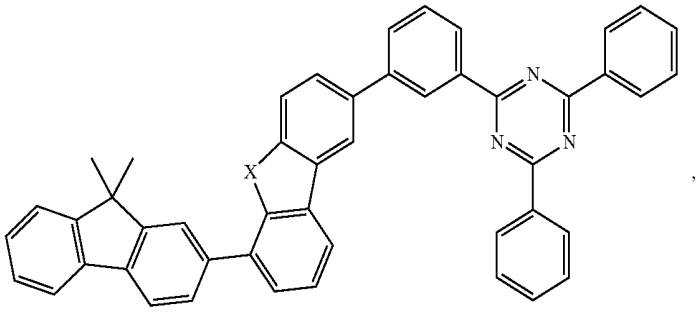
where in Compound D64: X = O,
in Compound D65, X = S, and
in Compound D66, X = Se

Compound D67 through D69, each represented by the formula:



where in Compound D67: X = O,
in Compound D68, X = S, and
in Compound D69, X = O

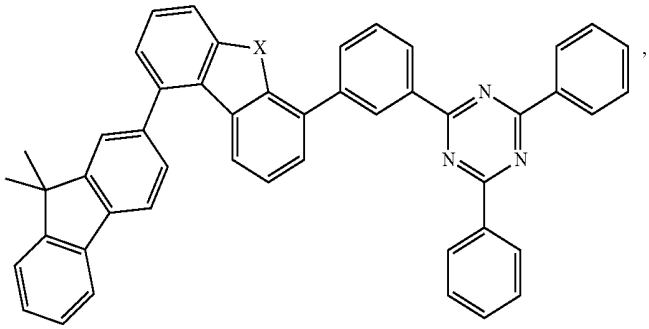
Compounds D70 through D72, each represented by the formula:



where in Compound D70: X = O,
in Compound D71, X = S, and
in Compound D72, X = Se

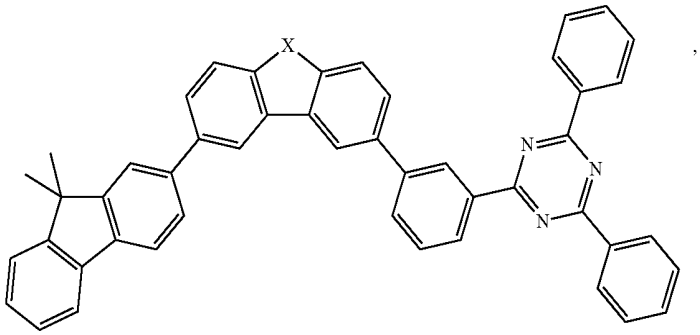
-continued

Compounds D73 through D75, each represented by the formula:



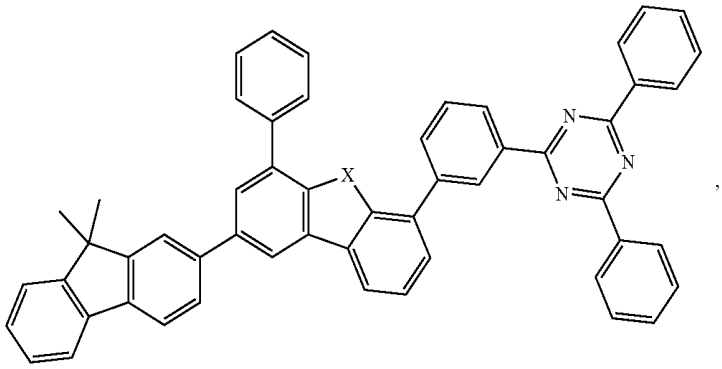
where in Compound D73: X = O,
in Compound D74, X = S, and
in Compound D75, X = Se

Compounds D76 through D78, each represented by the formula:



where in Compound D76: X = O,
in Compound D77, X = S, and
in Compound D78, X = Se

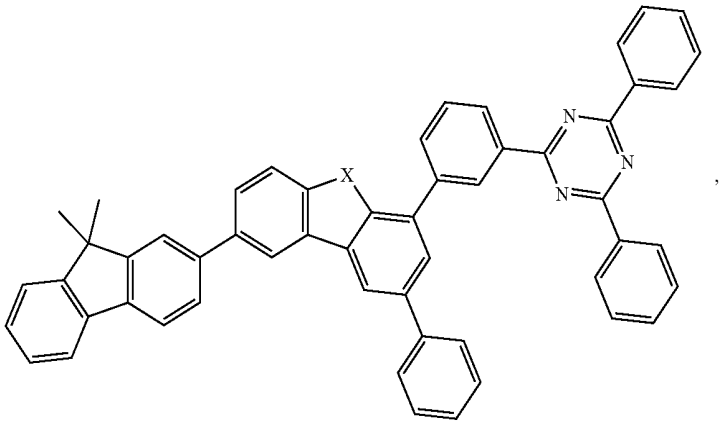
Compounds D79 through D81, each represented by the formula:



where in Compound D79: X = O,
in Compound D80, X = S, and
in Compound D81, X = Se

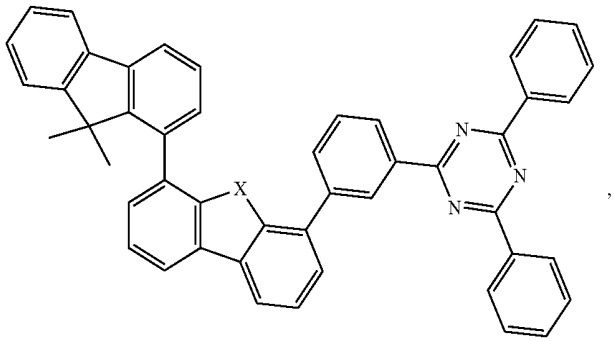
-continued

Compounds D82 through D84, each represented by the formula:



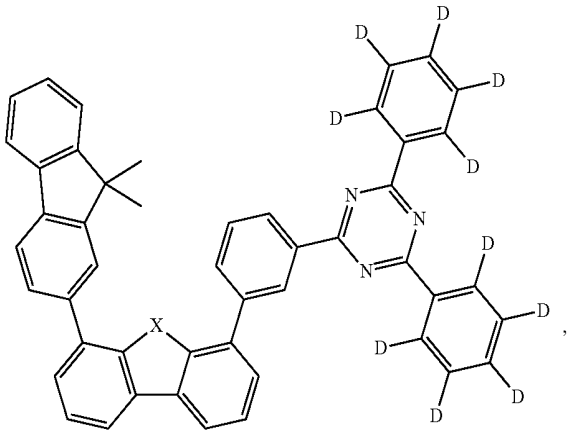
where in Compound D82: X = O,
in Compound D83, X = S, and
in Compound D84, X = Se

Compounds D85 through D87, each represented by the formula:



where in Compound D85: X = O,
in Compound D86, X = S, and
in Compound D87, X = Se

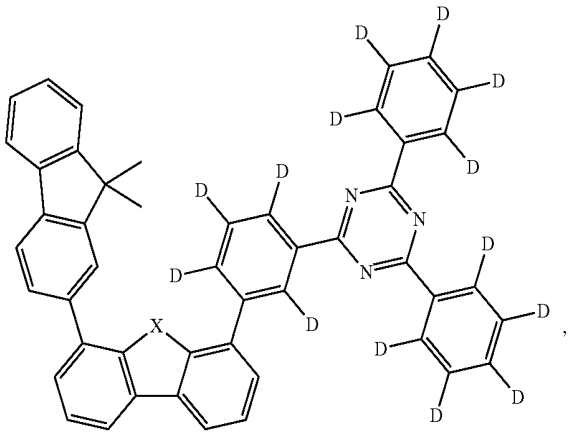
Compounds D88 through D90, each represented by the formula:



where in Compound D88: X = O,
in Compound D89, X = S, and
in Compound D90, X = Se

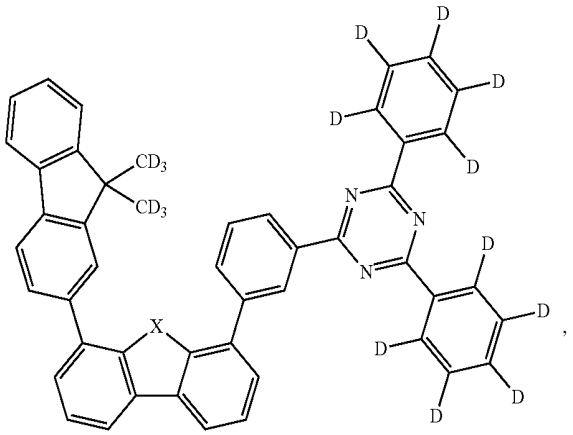
-continued

Compounds D91 through D93, each represented by the formula:



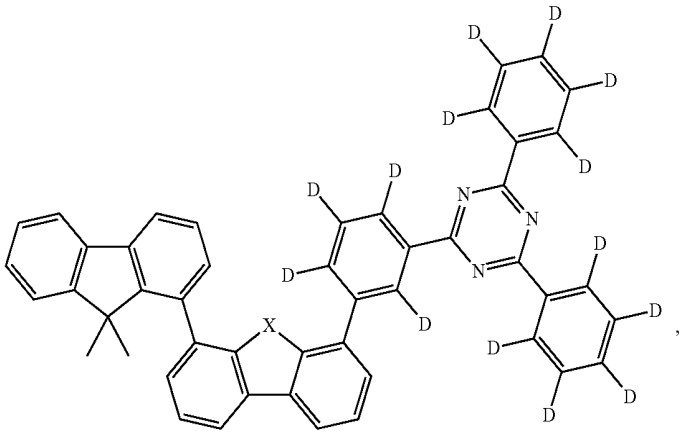
where in Compound D91: X = O,
in Compound D92, X = S, and
in Compound D93, X = Se

Compounds D94 through D96, each represented by the formula:



where in Compound D94: X = O,
in Compound D95, X = S, and
in Compound D96, X = Se

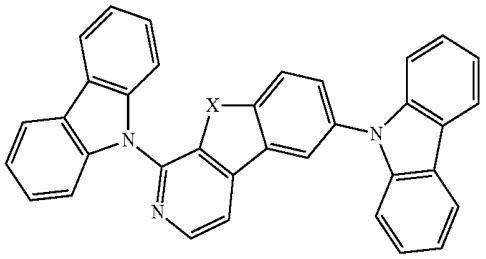
Compounds D97 through D99, each represented by the formula:



where in Compound D97: X = O,
in Compound D98, X = S, and
in Compound D99, X = Se

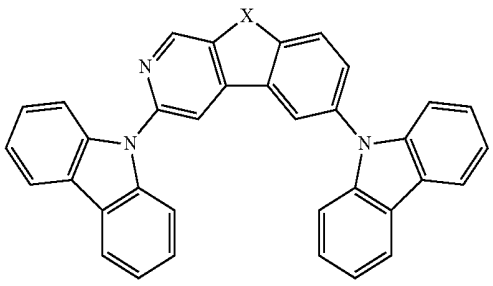
-continued

Compounds E1 through E3, each represented by the formula:



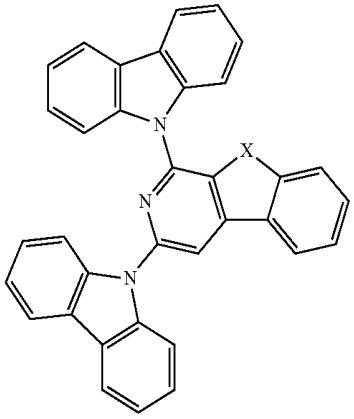
where in Compound E1: X = O,
in Compound E2, X = S, and
in Compound E3, X = Se

Compounds E4 through E6, each represented by the formula:



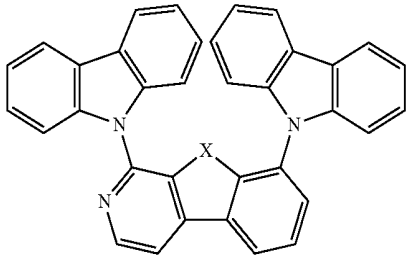
where in Compound E4: X = O,
in Compound E5, X = S, and
in Compound E6, X = Se

Compounds E7 through E9, each represented by the formula:



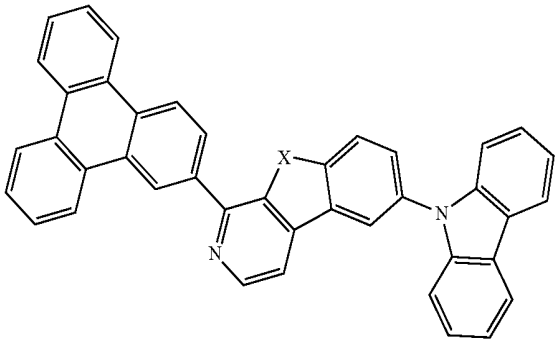
where in Compound E7: X = O,
in Compound E8, X = S, and
in Compound E9, X = Se

Compounds E10 through E12, each represented by the formula:



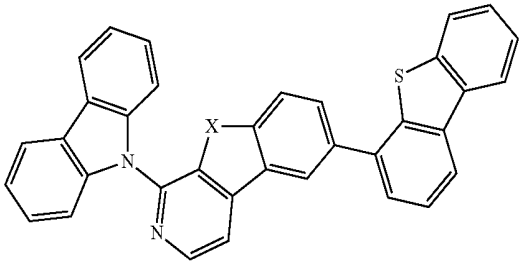
where in Compound E10: X = O,
in Compound E11, X = S, and
in Compound E10, X = Se

Compounds E13 through E15, each represented by the formula:



where in Compound E13: X = O,
in Compound E14, X = S, and
in Compound E15, X = Se

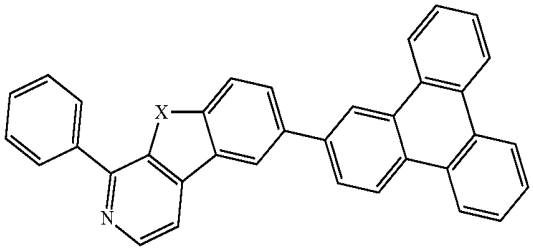
Compounds E16 through E18, each represented by the formula:



where in Compound E16: X = O,
in Compound E17, X = S, and
in Compound E18, X = Se

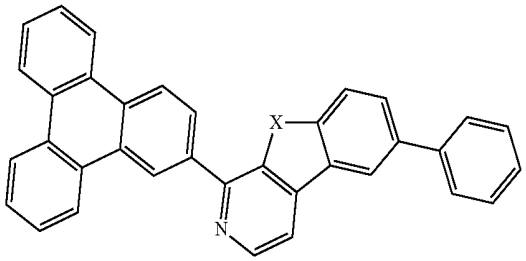
-continued

Compounds E19 through E21, each represented by the formula:



, and

Compounds E22 through E24, each represented by the formula:

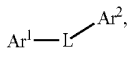


where in Compound E19: X = O, in Compound E20, X = S, and in Compound E21, X = Se

where in Compound E22: X = O, in Compound E23, X = S, and in Compound E24, X = Se

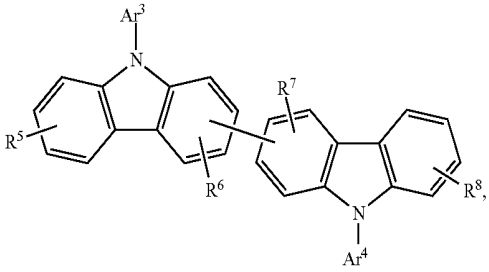
[0095] In some embodiments, the h-host material can be selected from the group consisting of a compound having a structure of

Formula III



and a compound having a structure of

Formula IV



[0096] wherein Ar^1 is selected from the group consisting of triphenylene, tetraphenylene, pyrene, naphthalene, fluoranthene, chrysene, phenanthrene, and combinations thereof;

[0097] wherein L is selected from the group consisting of a direct bond, phenyl, biphenyl, terphenyl, naphthalene, pyridine, dibenzofuran, dibenzothiophene, dibenzoselenophene, and combinations thereof;

[0098] wherein Ar^2 is selected from the group consisting of benzene, biphenyl, terphenyl, naphthalene, pyridine, dibenzofuran, dibenzothiophene, dibenzoselenophene, fluorene, carbazole, and combinations thereof;

[0099] wherein Ar^1, Ar^2 and L are each independently and optionally further substituted with one or more substitutions selected from the group consisting of deuterium, halogen, alkyl, aryl, non-aza-heteroaryl, and combinations thereof;

[0100] wherein R^5 and R^8 each independently represent mono, di, tri, or tetra substitution, or no substitution;

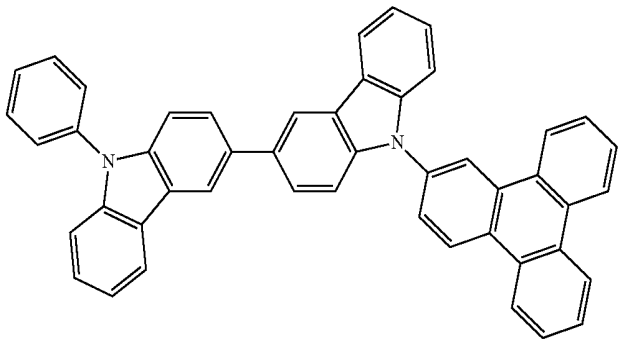
[0101] wherein R^6 and R^7 each independently represent mono, di, or tri substitution, or no substitution;

[0102] wherein R^5, R^6, R^7, R^8, Ar^3 and Ar^4 are each independently selected from the group consisting of hydrogen, deuterium, halogen, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, benzene, furan, thiophene, selenophene, pyrole, biphenyl, terphenyl, naphthalene, triphenylene, anthracene, phenanthracene, tetraphenylene, pyrene, fluoranthene, chrysene, fluorene, carbazole, benzofuran, benzothiophene, benzoselenophene, dibenzofuran, dibenzothiophene, dibenzoselenophene, indole, carbazole, and combinations thereof; and

[0103] wherein any two adjacent substituents are optionally joined or fused into a ring.

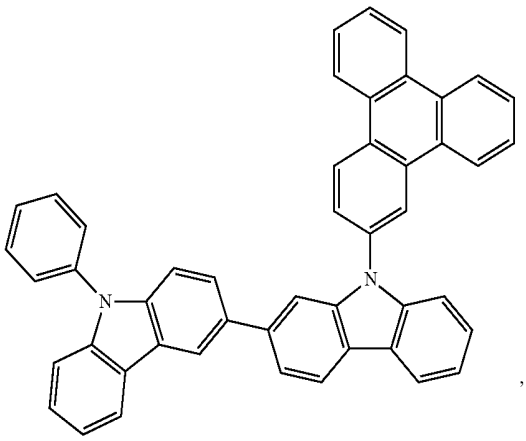
[0104] The h-host material can be selected from the group consisting of:

Compound F1



-continued

Compound F2



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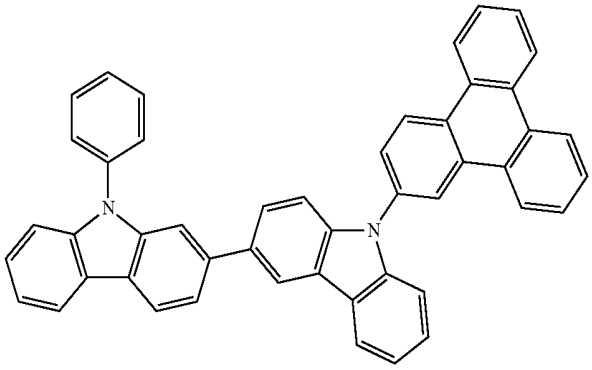
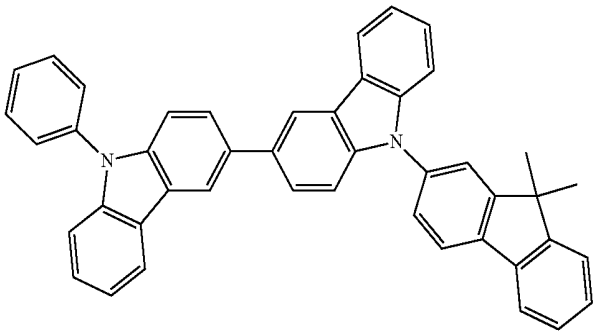
Compound F3



,

Compound F4



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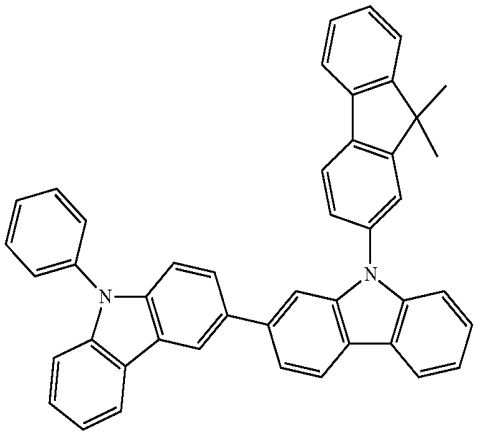
Compound F5



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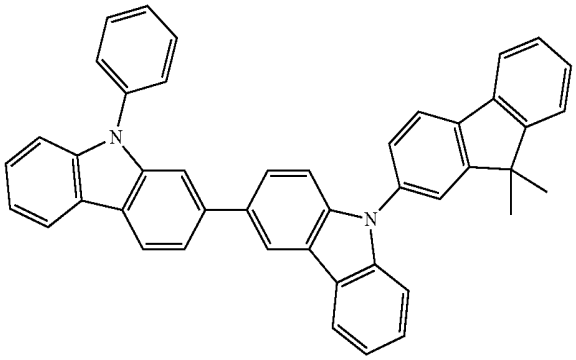
Compound F6



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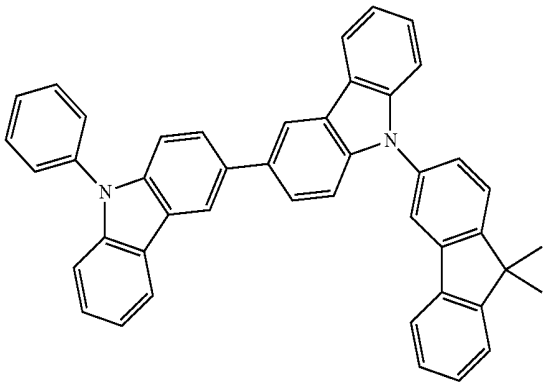
Compound F7



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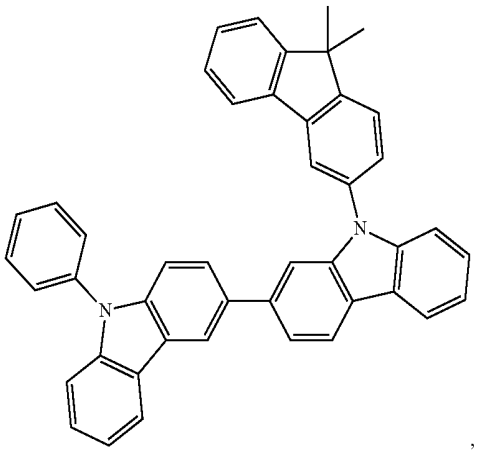
Compound F8



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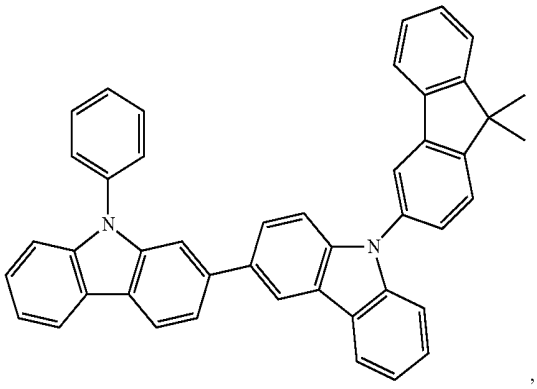
Compound F9



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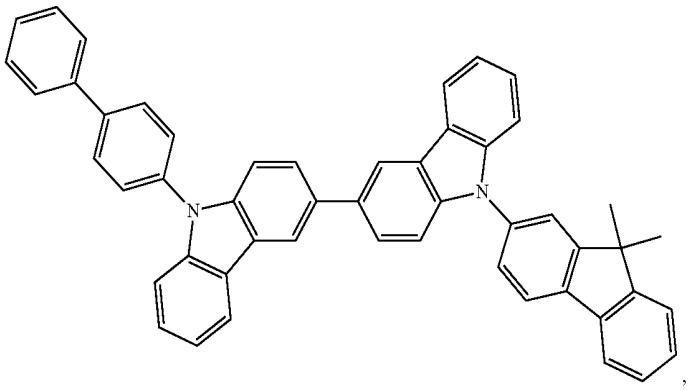
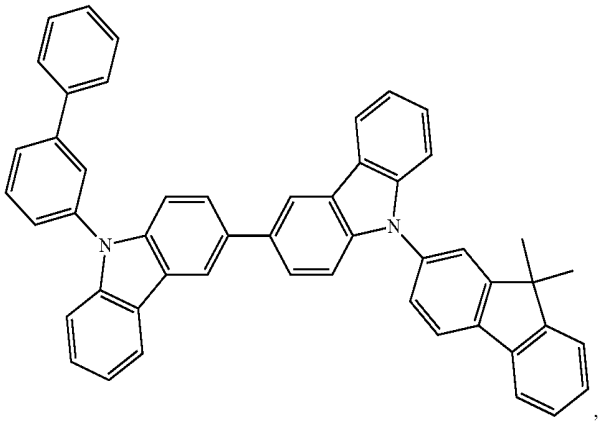
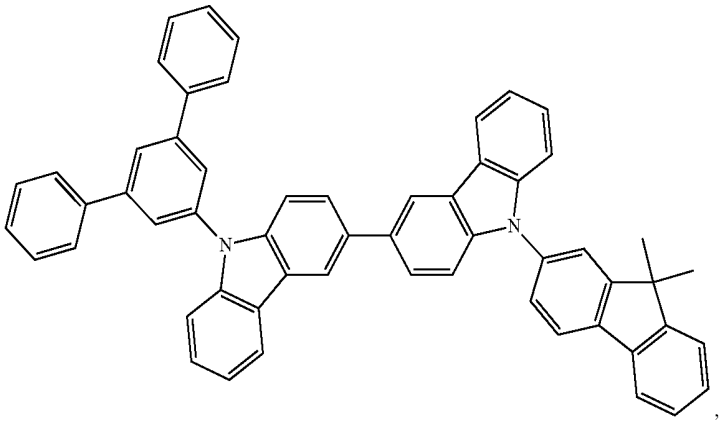
Compound F10



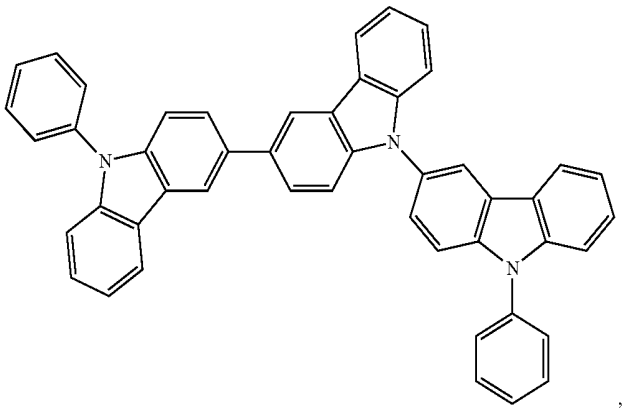
Compound F11



Compound F12



Compound F13



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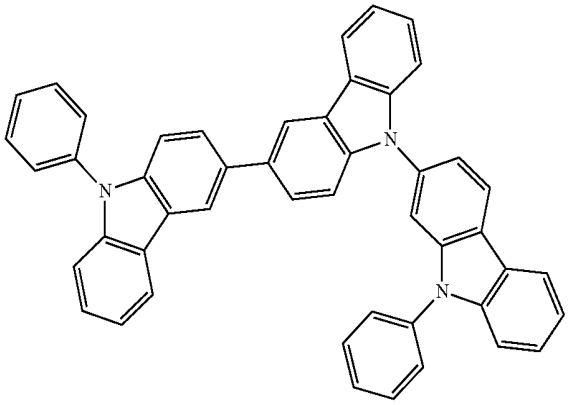
Compound F14



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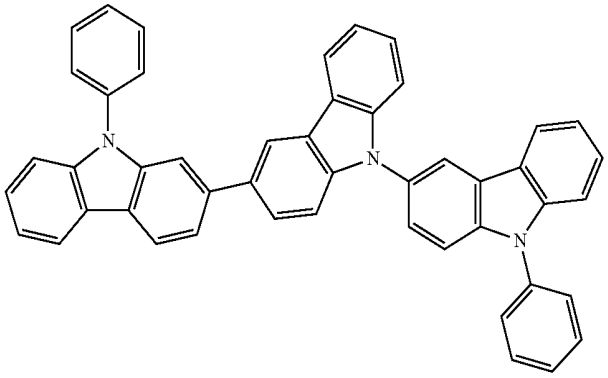
Compound F15



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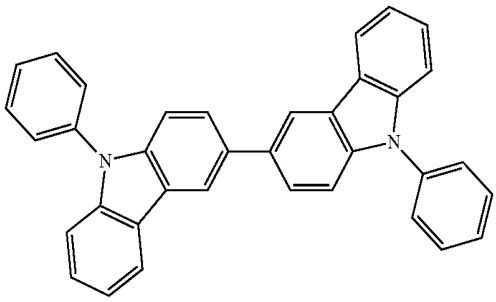
Compound F16



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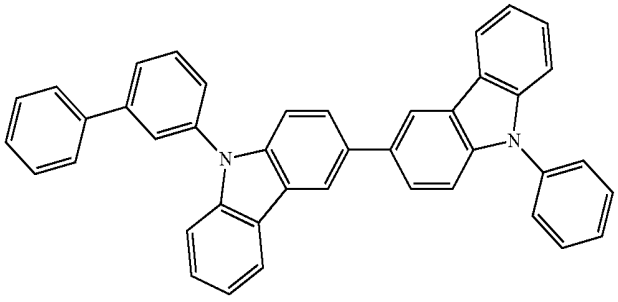
Compound F17



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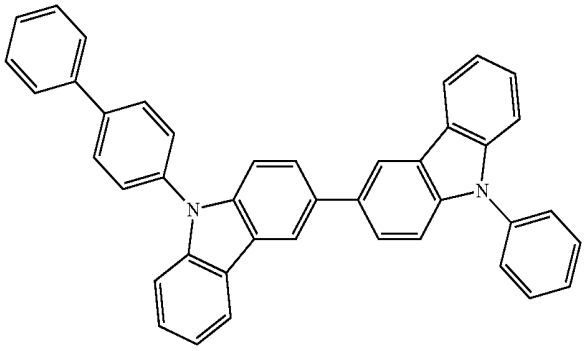
Compound F18



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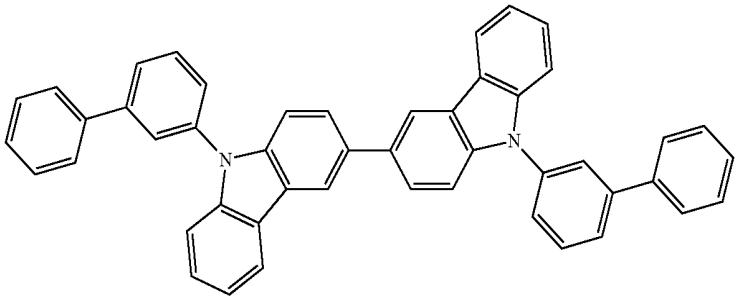
Compound F19



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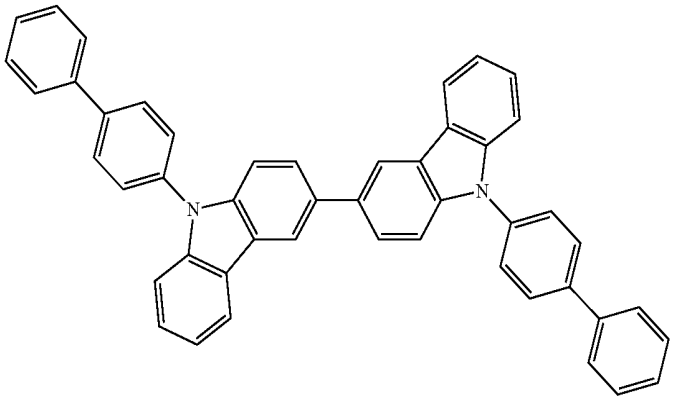
Compound F20



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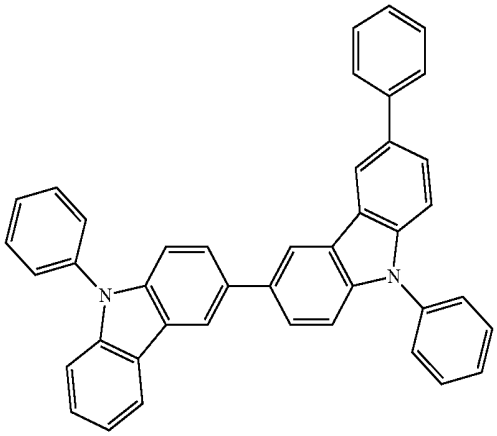
Compound F21



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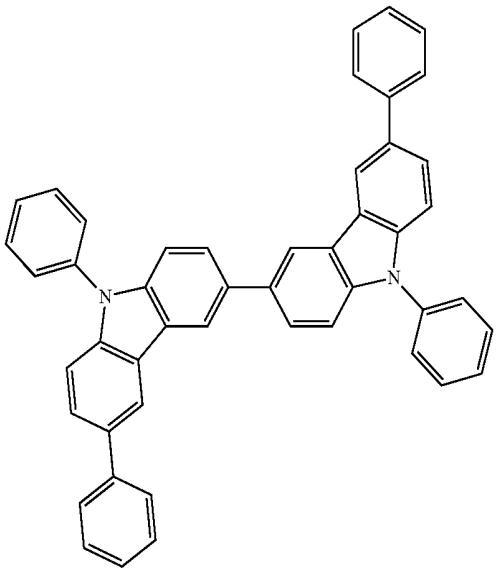
Compound F22



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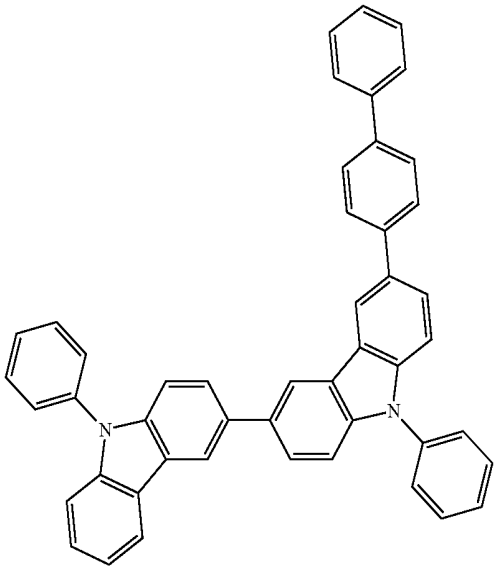
Compound F23



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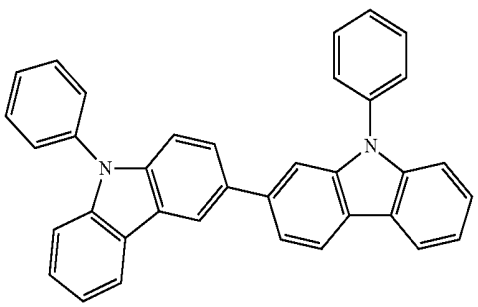
Compound F24



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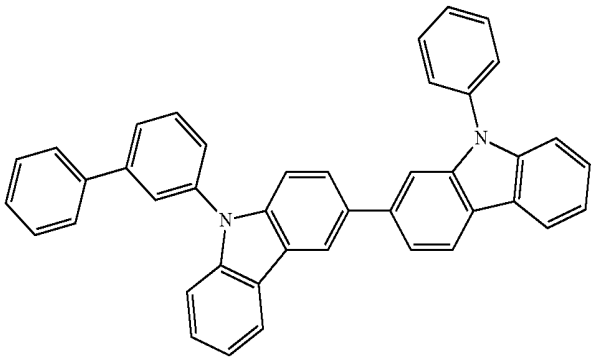
Compound F25



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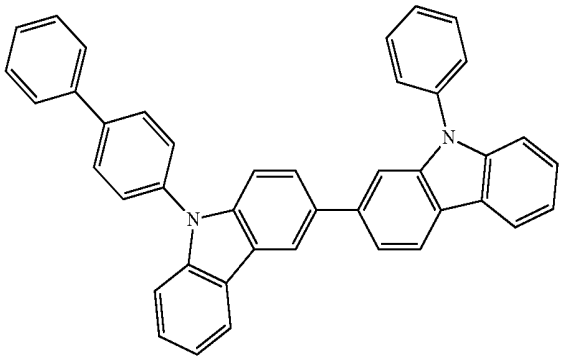
Compound F26



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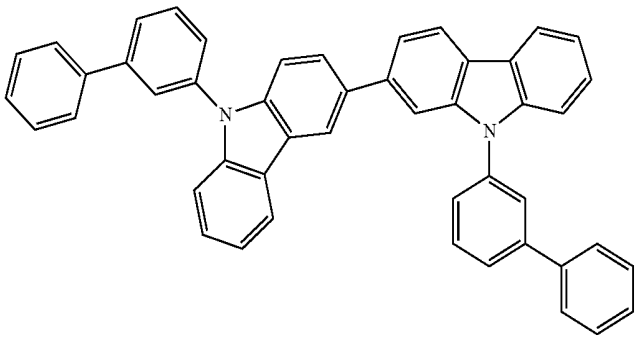
Compound F27



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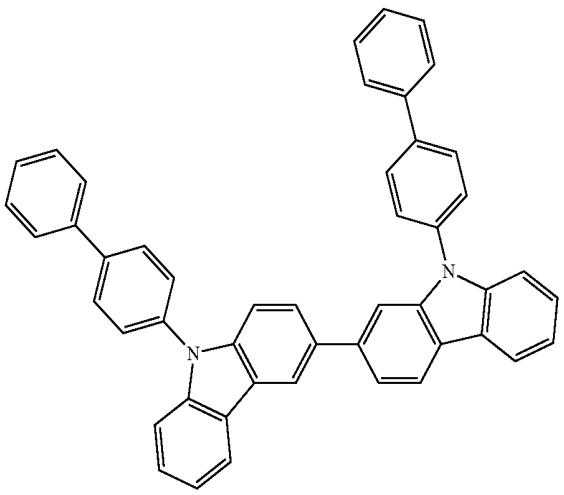
Compound F28



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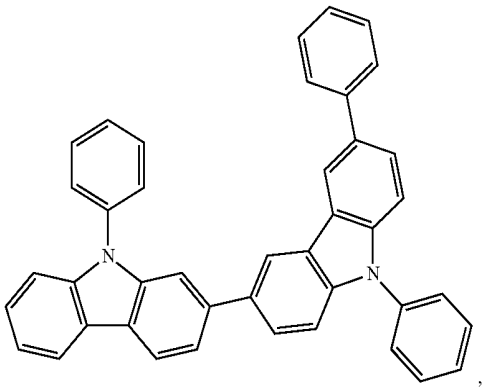
Compound F29



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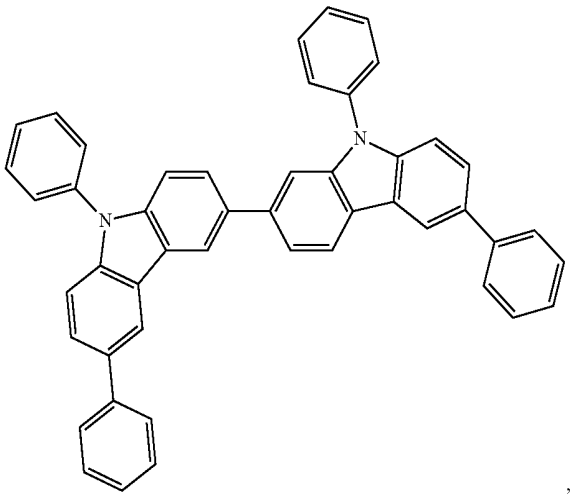
Compound F30



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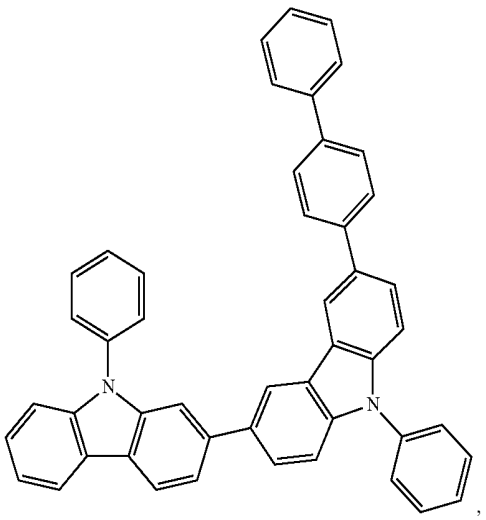
Compound F31



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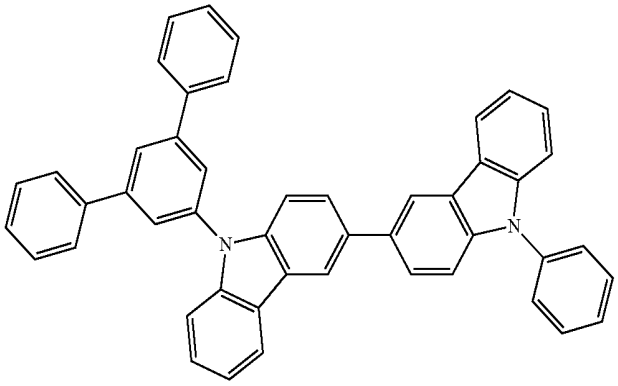
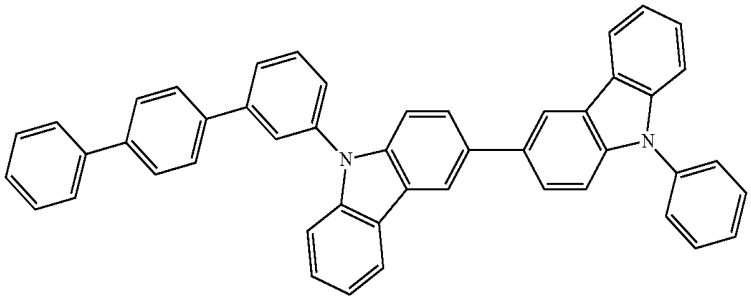
Compound F32



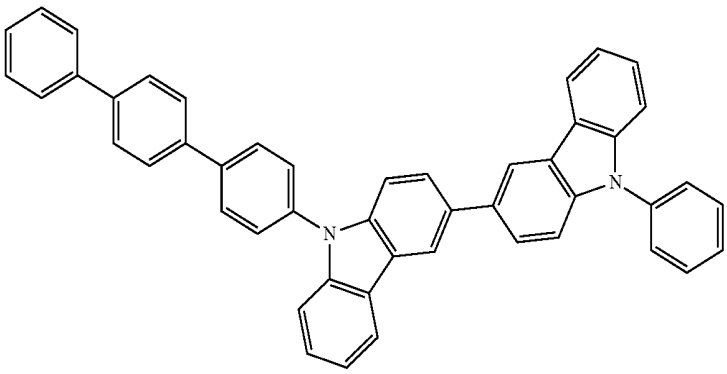
,

Compound F33



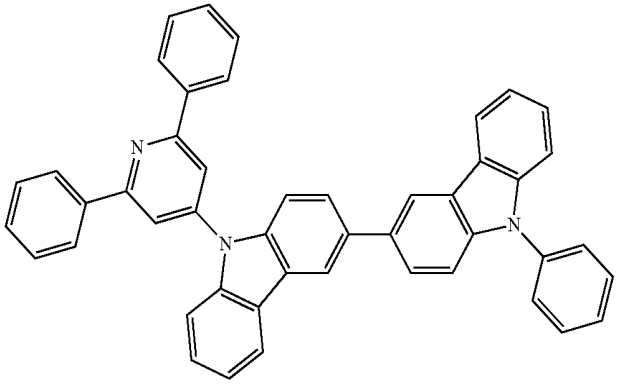
,

Compound F34



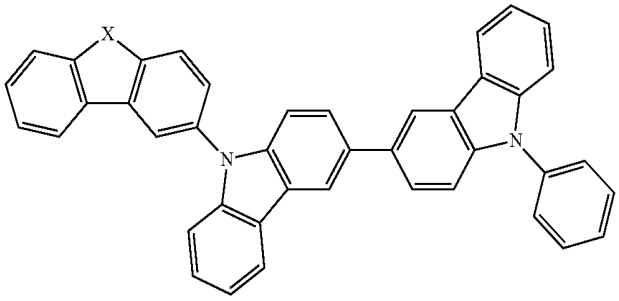
,

Compound F35



-continued

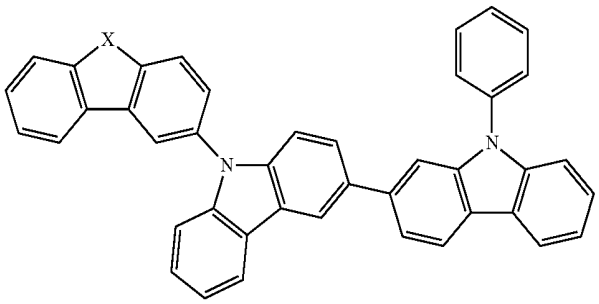
Compounds G1 through G3, each represented by the formula:



,

wherein in Compound G1: X = O,
In Compound G2, X = S, and
In Compound G3, X = Se

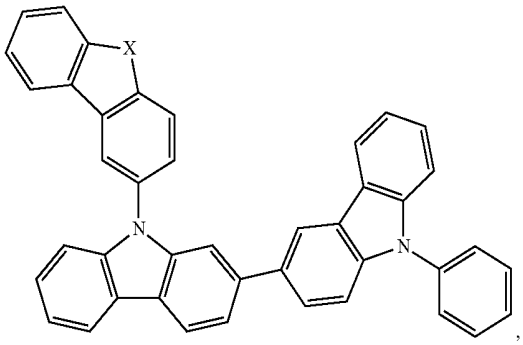
Compounds G4 through G6, each represented by the formula:



,

wherein in Compound G4: X = O,
In Compound G5, X = S, and
In Compound G6, X = Se

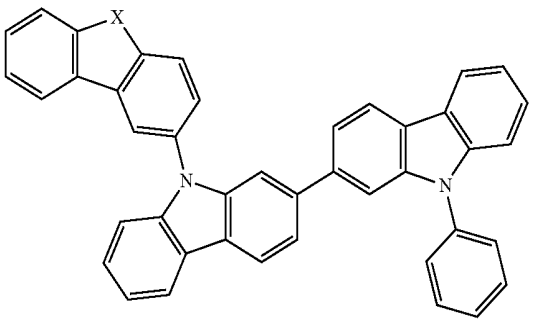
Compounds G7 through G9, each represented by the formula:



,

wherein in Compound G7: X = O,
In Compound G8, X = S, and
In Compound G9, X = Se

Compounds G10 through G12, each represented by the formula:

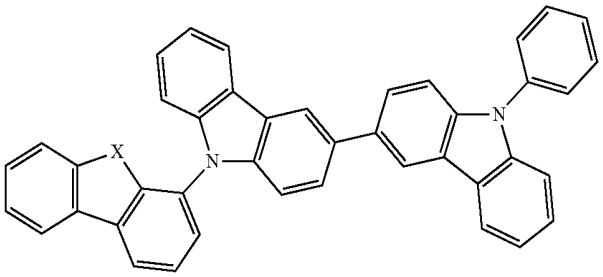


,

wherein in Compound G10: X = O,
In Compound G11, X = S, and
In Compound G12, X = Se

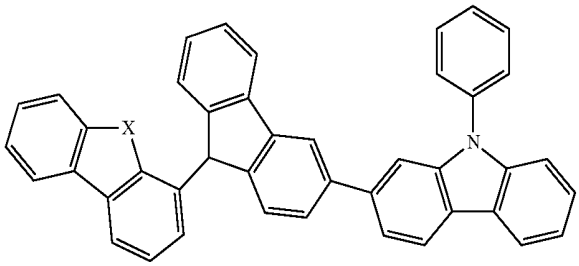
-continued

Compounds G13 through G15, each represented by the formula:



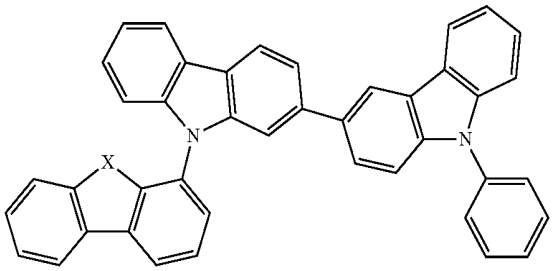
wherein in Compound G13: X = O,
In Compound G14, X = S, and
In Compound G15, X = Se

Compounds G16 through G18, each represented by the formula:



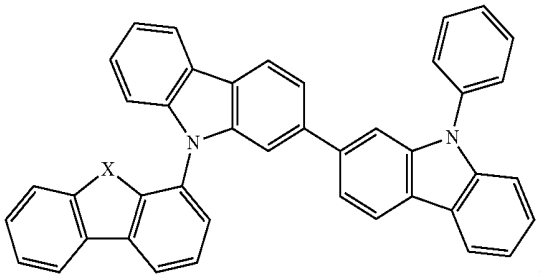
wherein in Compound G16: X = O,
In Compound G17, X = S, and
In Compound G18, X = Se

Compounds G19 through G21, each represented by the formula:



wherein in Compound G19: X = O,
In Compound G20, X = S, and
In Compound G21, X = Se

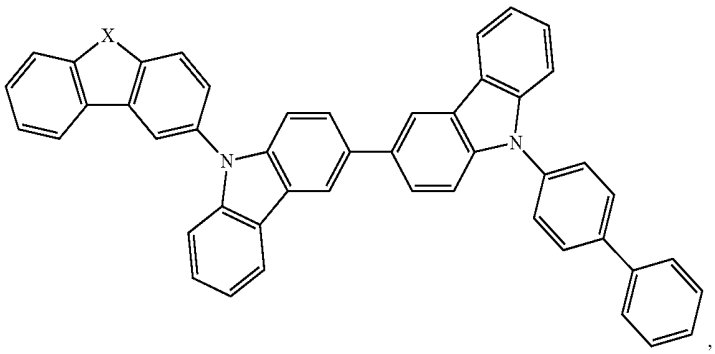
Compounds G22 through G24, each represented by the formula:



wherein in Compound G22: X = O,
In Compound G23, X = S, and
In Compound G24, X = Se

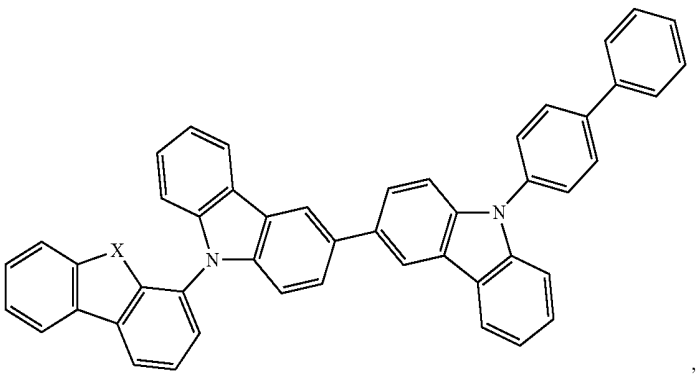
-continued

Compounds G25 through G27, each represented by the formula:



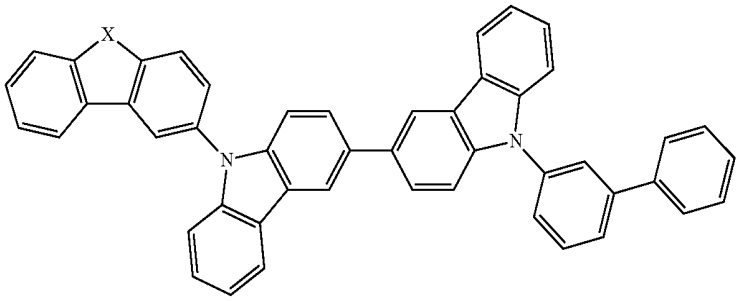
wherein in Compound G25: X = O,
In Compound G26, X = S, and
In Compound G27, X = Se

Compounds G28 through G30, each represented by the formula:



wherein in Compound G28: X = O,
In Compound G29, X = S, and
In Compound G30, X = Se

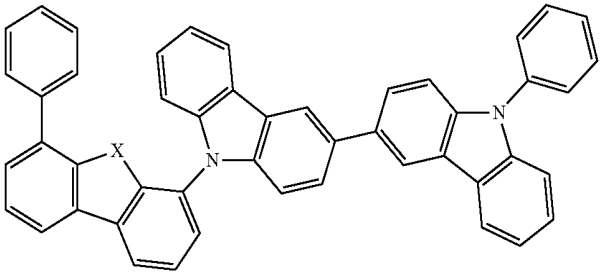
Compounds G31 through G33, each represented by the formula:



wherein in Compound G31: X = O,
In Compound G32, X = S, and
In Compound G33, X = Se

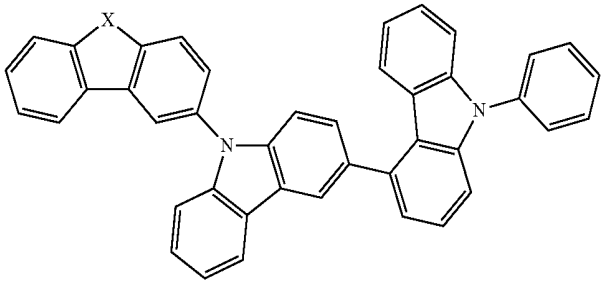
-continued

Compounds G34 through G36, each represented by the formula:



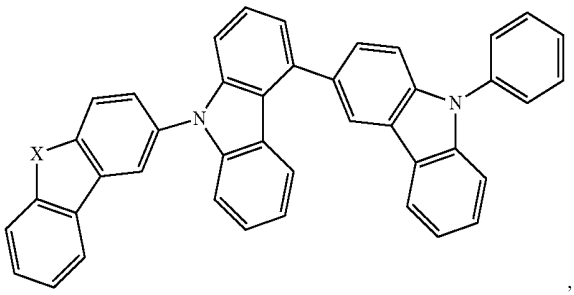
wherein in Compound G34: X = O,
In Compound G35, X = S, and
In Compound G36, X = Se

Compounds G37 through G39, each represented by the formula:



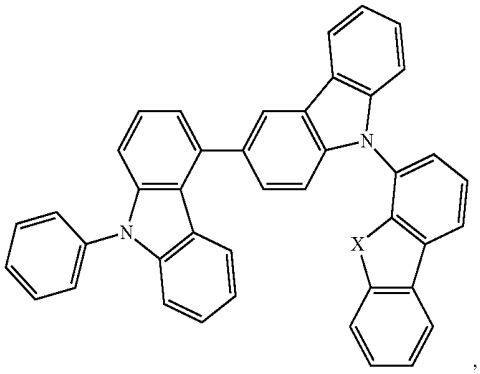
wherein in Compound G37: X = O,
In Compound G38, X = S, and
In Compound G39, X = Se

Compounds G40 through G42, each represented by the formula:



wherein in Compound G40: X = O,
In Compound G41, X = S, and
In Compound G42, X = Se

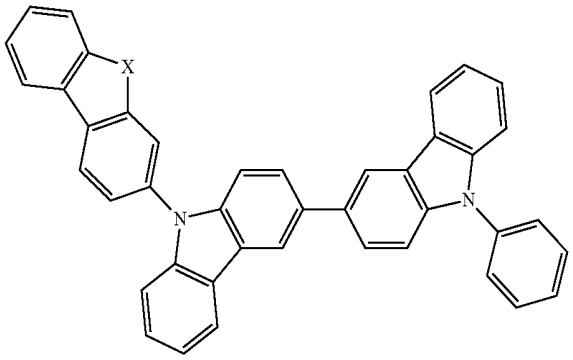
Compounds G43 through G45, each represented by the formula:



wherein in Compound G43: X = O,
In Compound G44, X = S, and
In Compound G45, X = Se

-continued

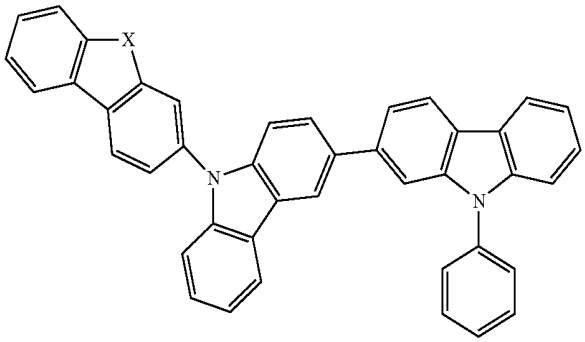
Compounds G46 through G48, each represented by the formula:



,

wherein in Compound G46: X = O,
In Compound G47, X = S, and
In Compound G48, X = Se

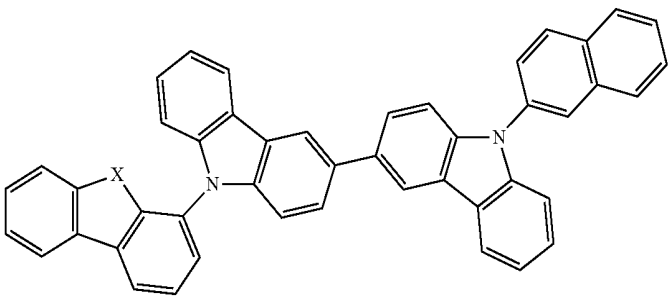
Compounds G49 through G51, each represented by the formula:



,

wherein in Compound G49: X = O,
In Compound G50, X = S, and
In Compound G51, X = Se

Compounds G52 through G54, each represented by the formula:

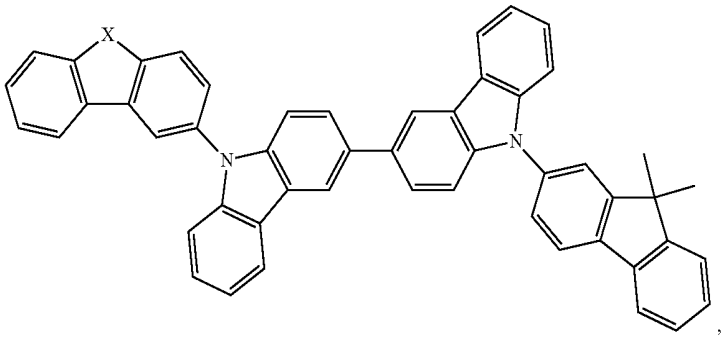


,

wherein in Compound G49: X = O,
In Compound G50, X = S, and
In Compound G51, X = Se

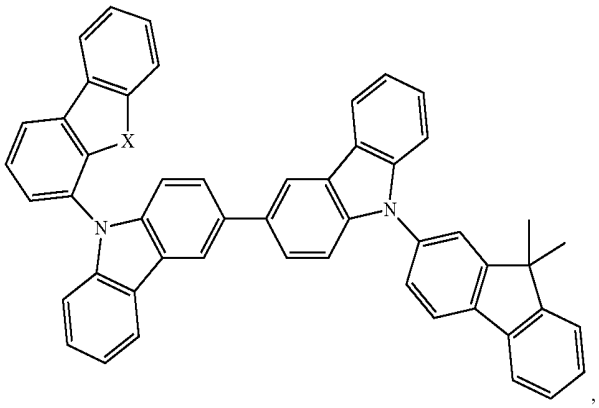
-continued

Compounds G55 through G56, each represented by the formula:



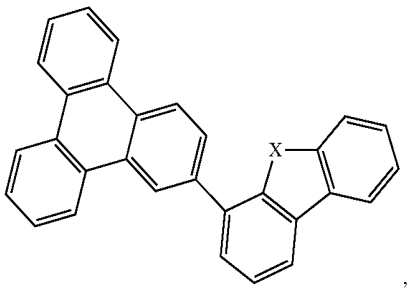
wherein in Compound G55: X = O,
In Compound G56, X = S, and
In Compound G57, X = Se

Compounds G58 through G60, each represented by the formula:



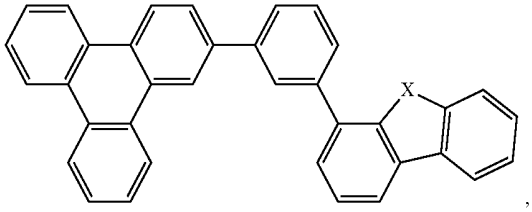
wherein in Compound G58: X = O,
In Compound G59, X = S, and
In Compound G60, X = Se

Compound H1 through H3, each represented by the formula



wherein in Compound H1: X = O,
In Compound H2: X = S,
In Compound H3: X = Se

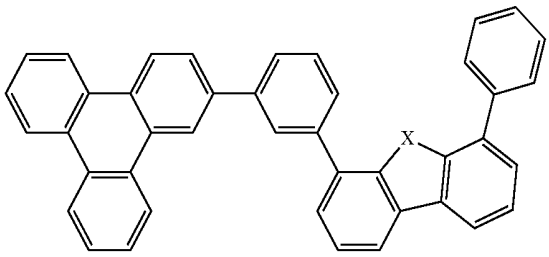
Compound H4 through H6, each represented by the formula



wherein in Compound H4: X = O,
In Compound H5: X = S,
In Compound H6: X = Se

-continued

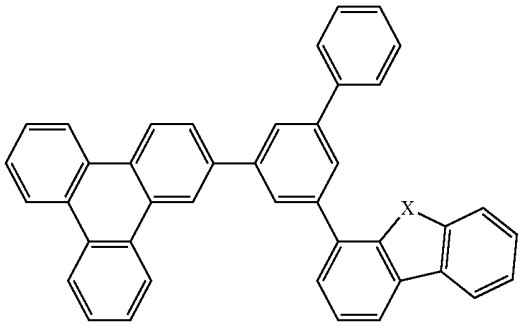
Compound H7 through H9, each represented by the formula



,

wherein in Compound H7: X = O,
In Compound H8: X = S,
In Compound H9: X = Se

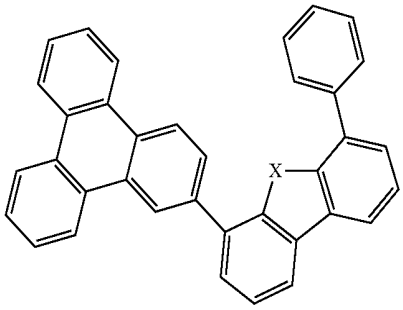
Compound H10 through H12, each represented by the formula



,

wherein in Compound H10: X = O,
In Compound H11: X = S,
In Compound H12: X = Se

Compound H13 through H15, each represented by the formula

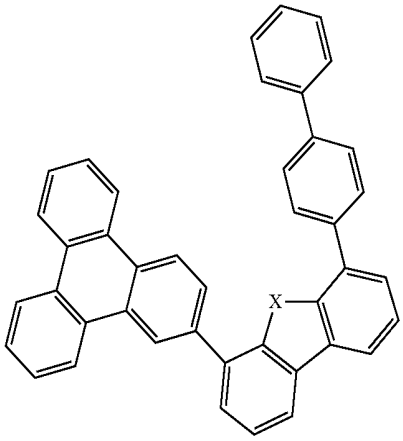


,

wherein in Compound H13: X = O,
In Compound H14: X = S,
In Compound H15: X = Se

-continued

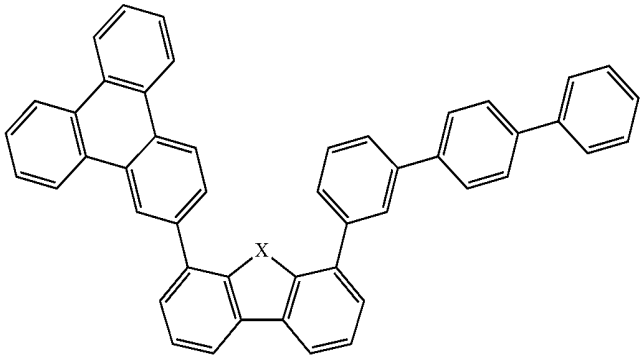
Compound H16 through H18, each represented by the formula



,

wherein in Compound H16: X = O,
In Compound H17: X = S,
In Compound H18: X = Se

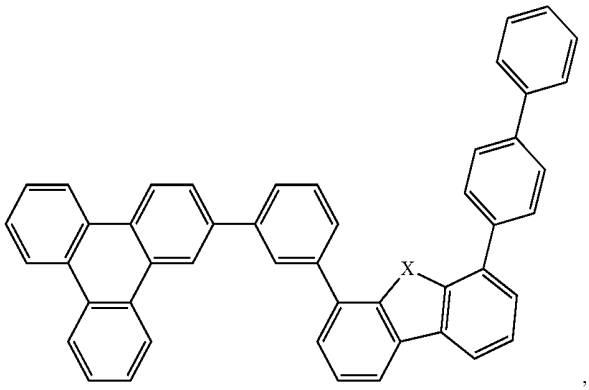
Compound H19 through H21, each represented by the formula



,

wherein in Compound H19: X = O,
In Compound H20: X = S,
In Compound H21: X = Se

Compound H22 through H24, each represented by the formula

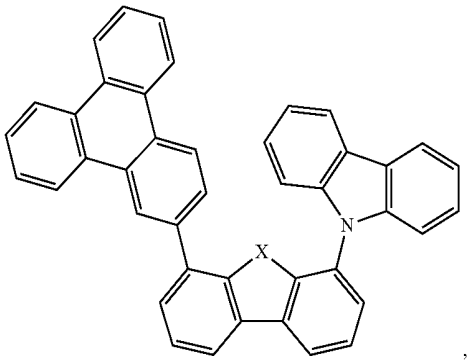


,

wherein in Compound H22: X = O,
In Compound H23: X = S,
In Compound H24: X = Se

-continued

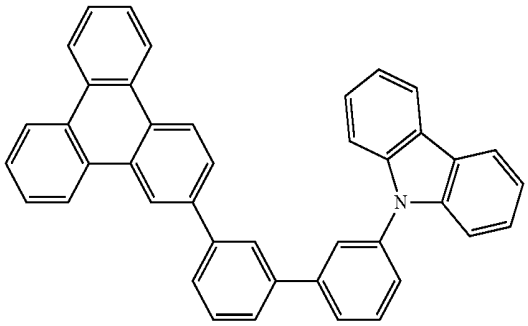
Compound H25 through H27, each represented by the formula



,

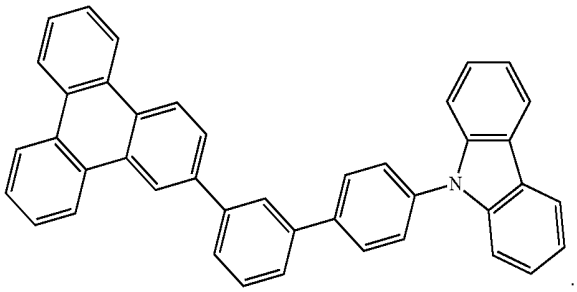
wherein in Compound H25: X = O,
In Compound H26: X = S,
In Compound H27: X = Se

Compound H28



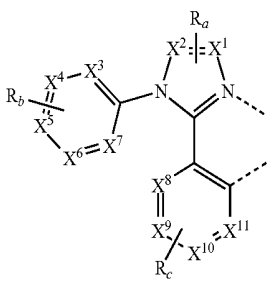
, and

Compound H29



.

[0105] The emitter material can be a transition metal complex having at east one ligand selected from the group consisting of:



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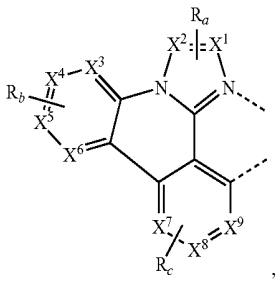
-continued



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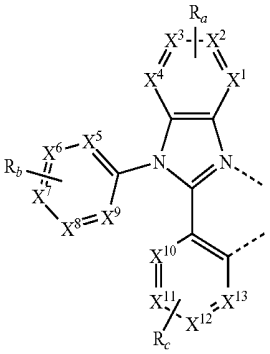

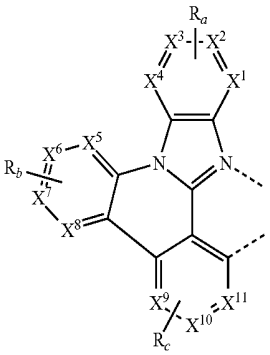

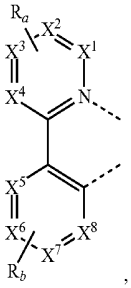

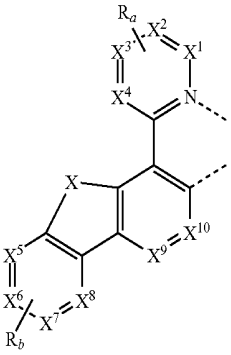

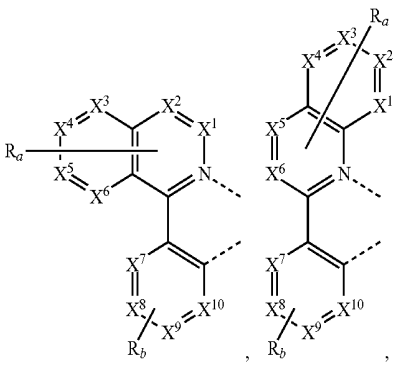

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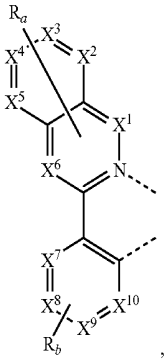
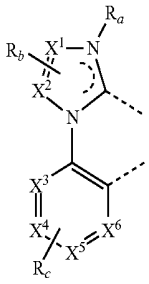
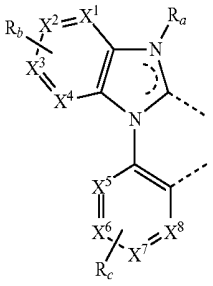
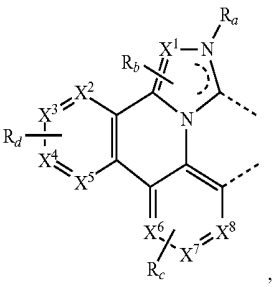
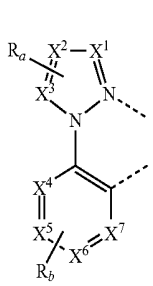
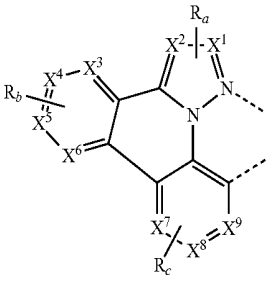


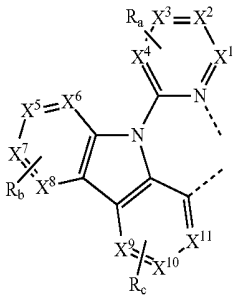


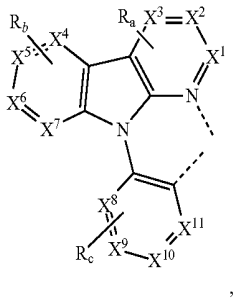


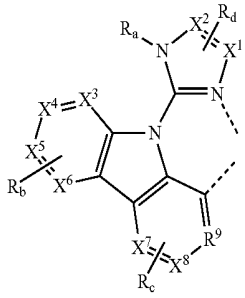












, and

;

[0106] wherein each X^1 to X^{13} are independently selected from the group consisting of carbon and nitrogen;

[0107] wherein X is selected from the group consisting of BR', NR', PR', O, S, Se, C═O, S═O, SO_2, CR'R", SiR'R", and GeR'R";

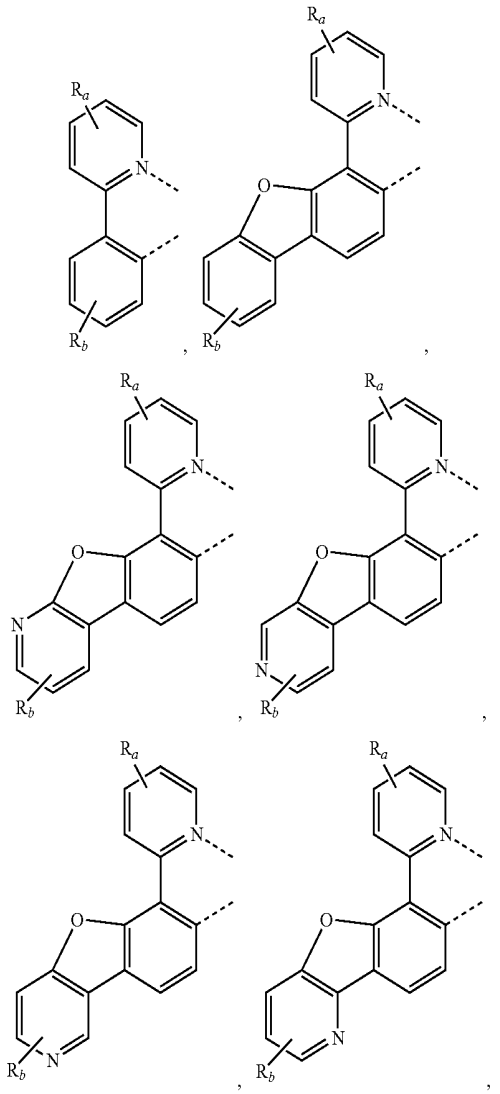
[0108] wherein R' and R" are optionally fused or joined to form a ring;

[0109] wherein each R_a, R_b, R_c, and R_d may represent from mono substitution to the possible maximum number of substitution, or no substitution;

[0110] wherein R', R", R_a, R_b, R_c, and R_d are each independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrite, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof; and

[0111] wherein any two adjacent substituents of R_a, R_b, R_c, and R_d are optionally fused or joined to form a ring or form a multidentate ligand.

[0112] In other embodiments, the emitter is a transition metal complex having at least one ligand selected from the group consisting of:



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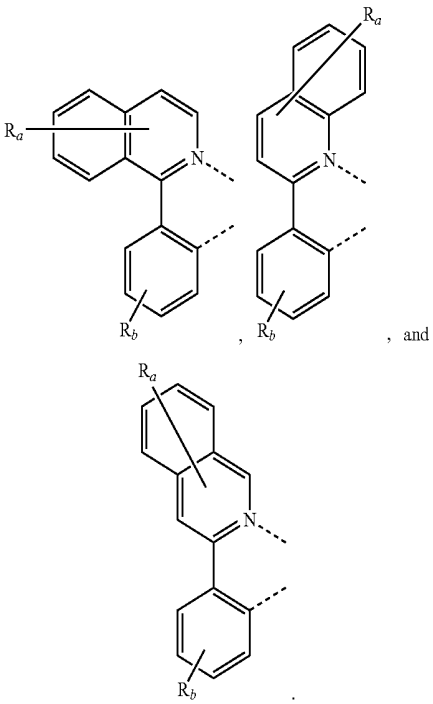
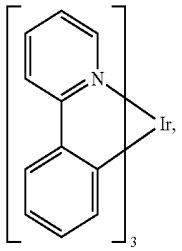
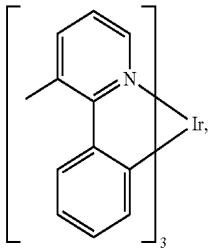


[0113] In other embodiments, the emitter is selected from the group consisting of:

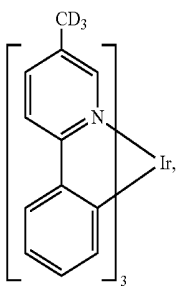
Emitter 1



Emitter 2



Emitter 3



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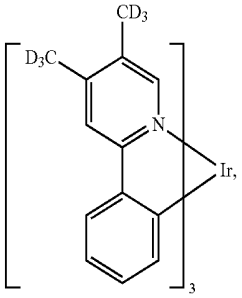

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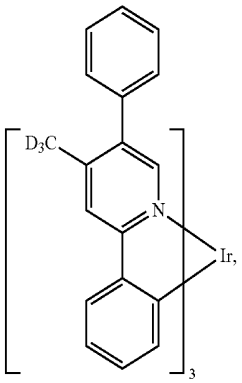
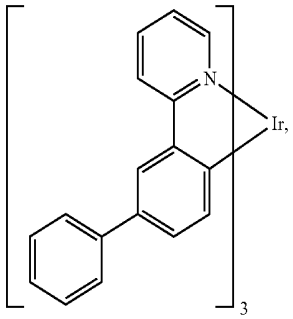
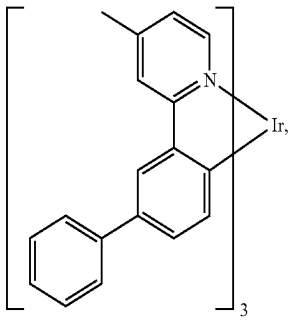


Emitter 6



Emitter 7



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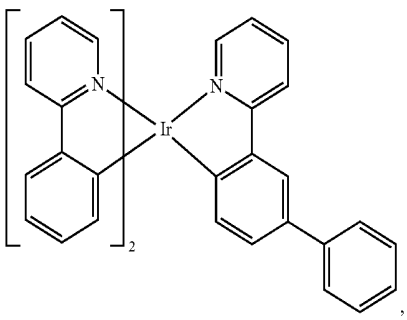

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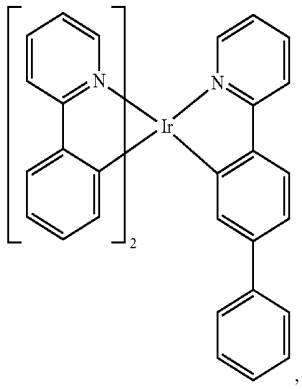

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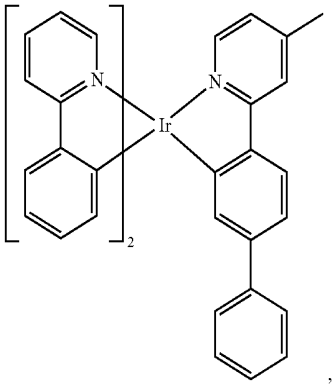

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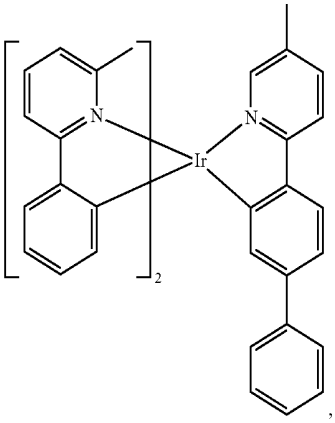

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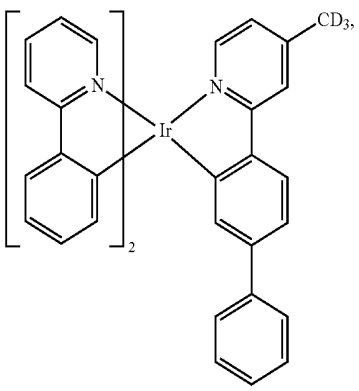

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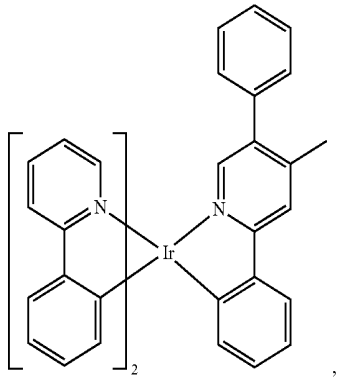

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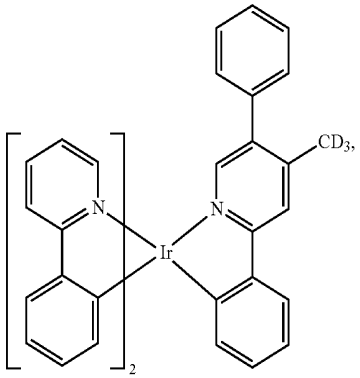

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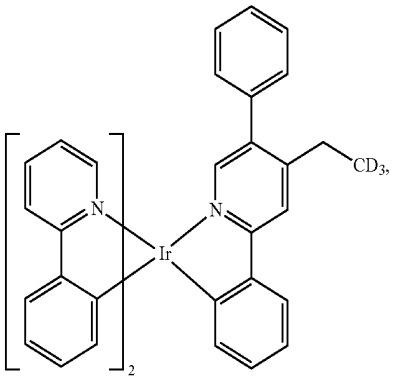

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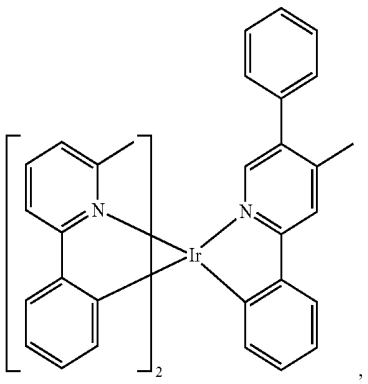

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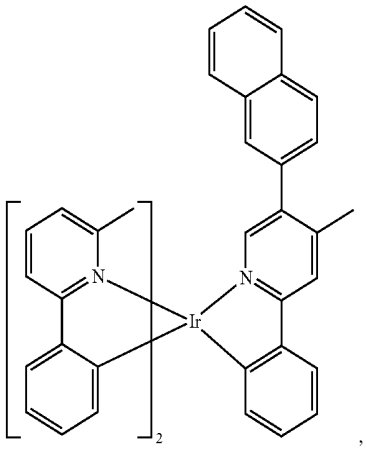

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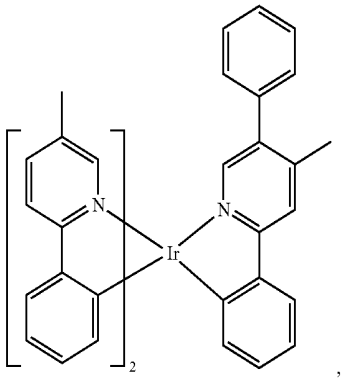

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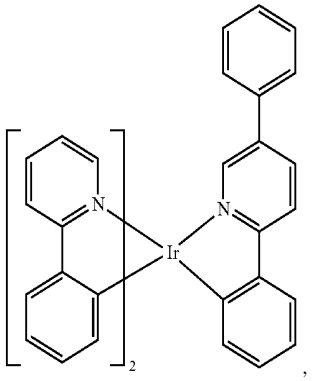

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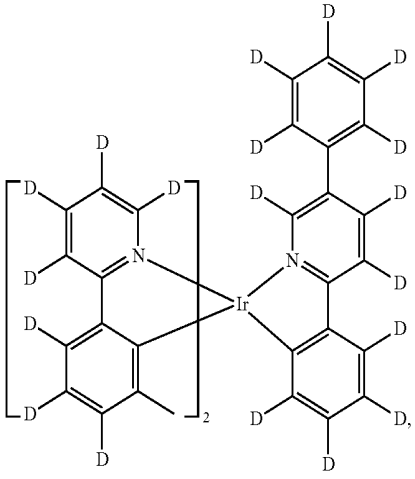

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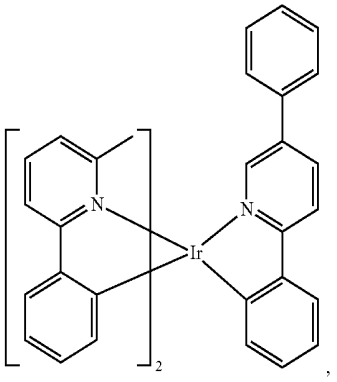

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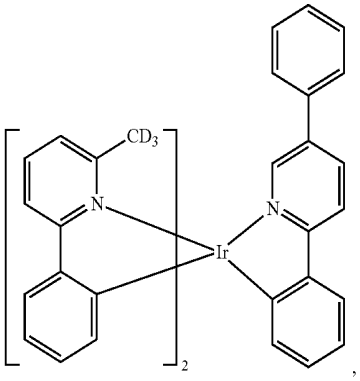

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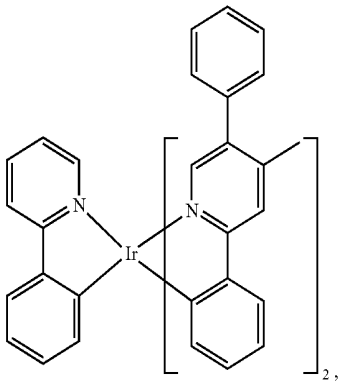

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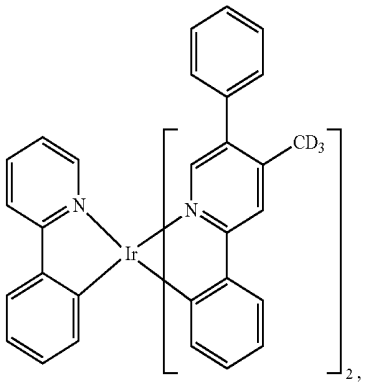

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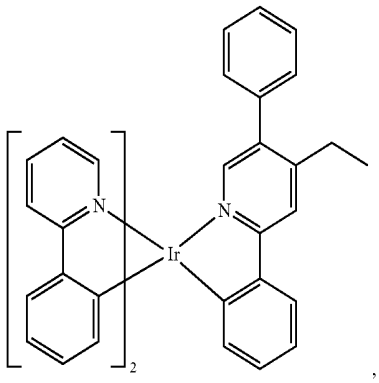

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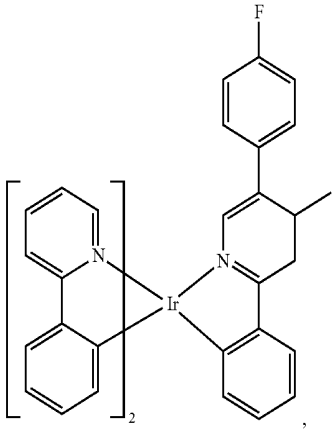

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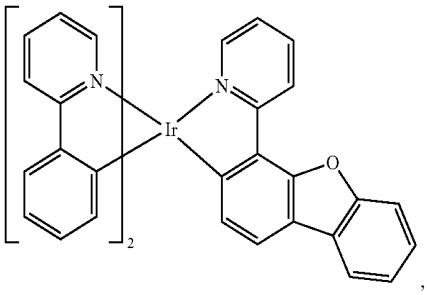

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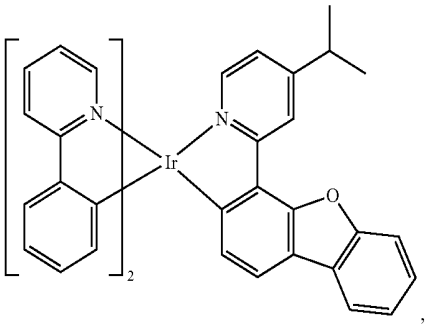

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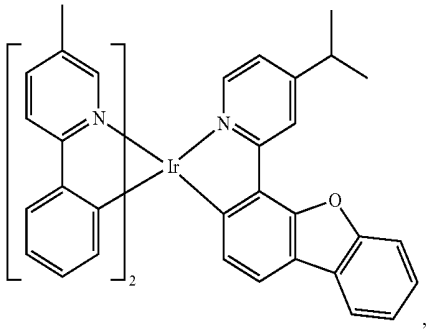

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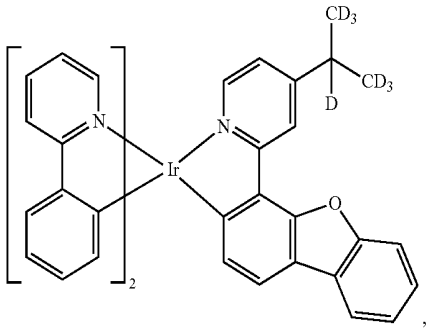

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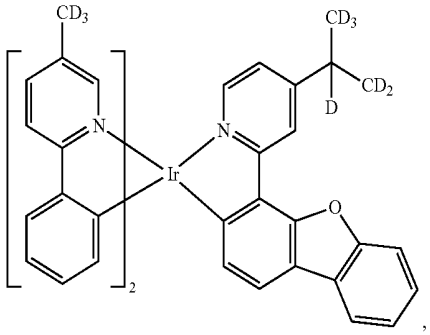

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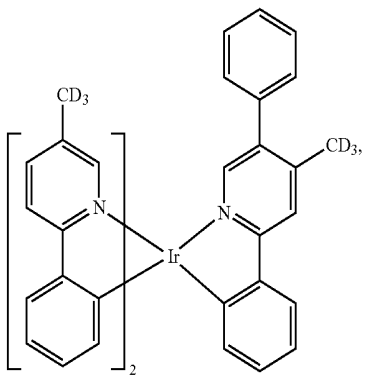

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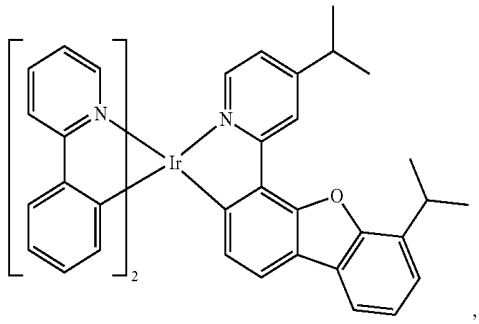

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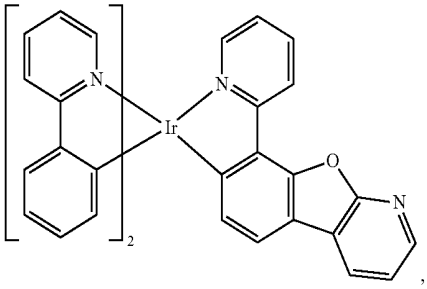

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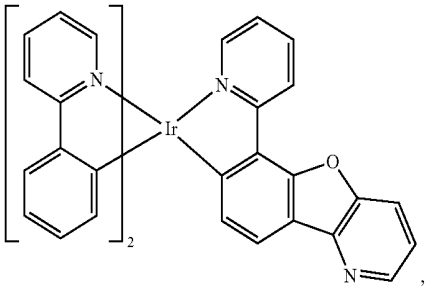

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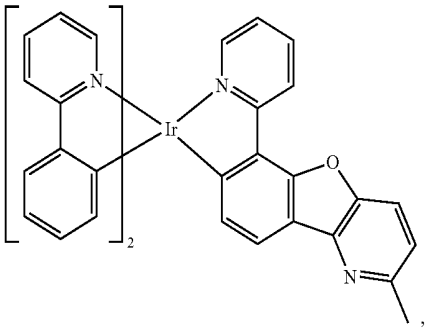

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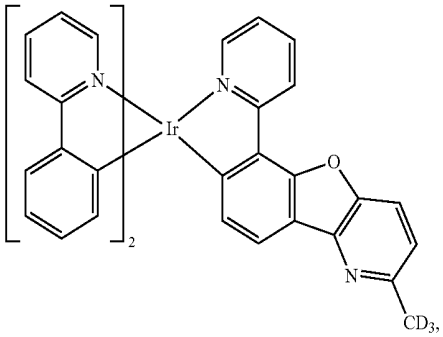

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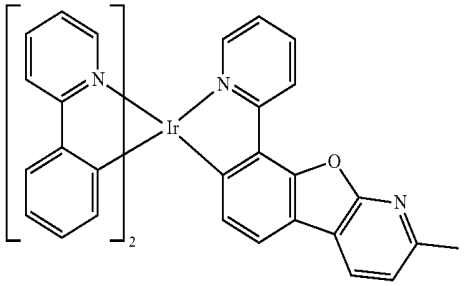

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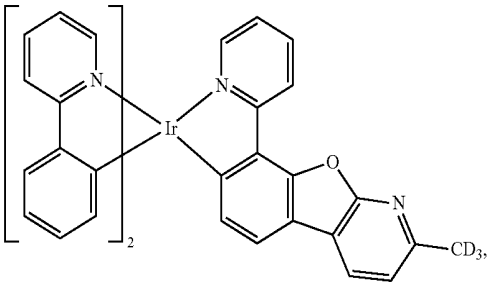

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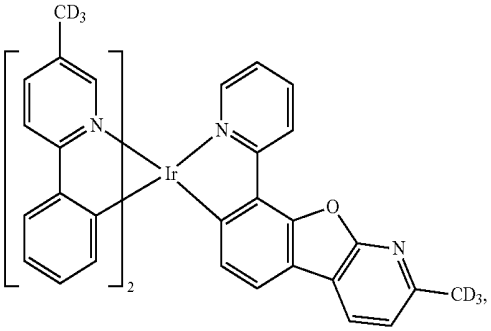

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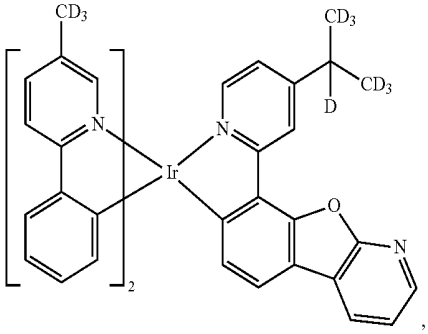

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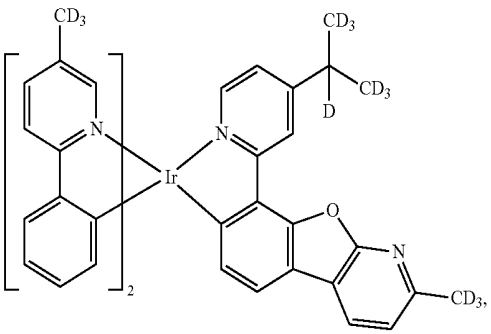

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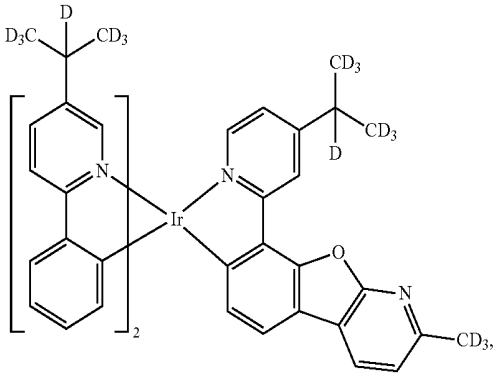

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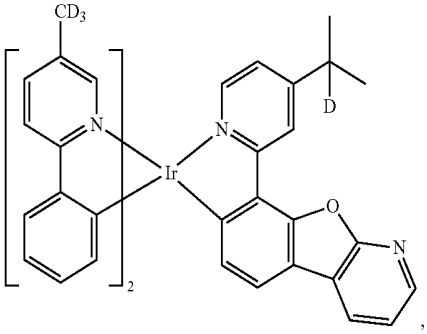
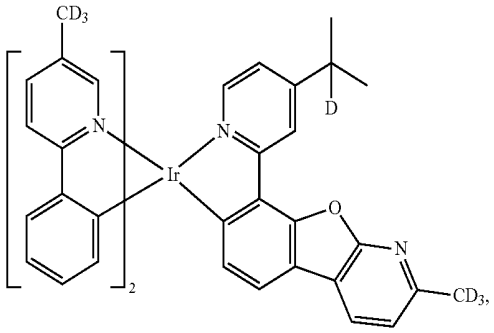


Emitter 45



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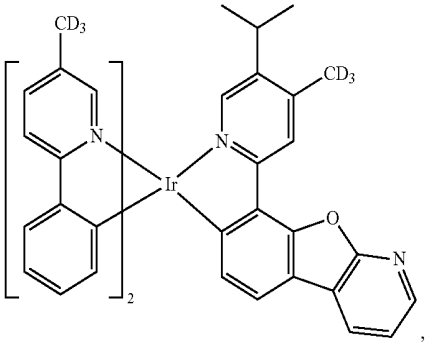

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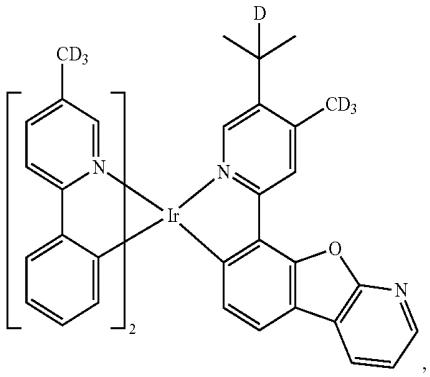
Emitter 47



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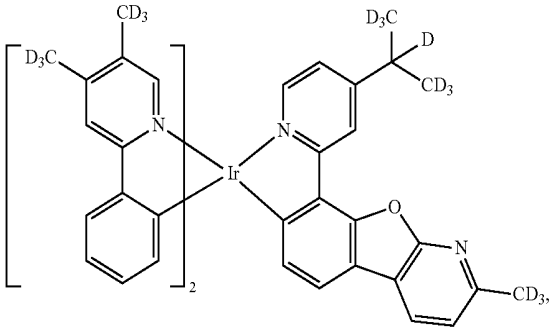
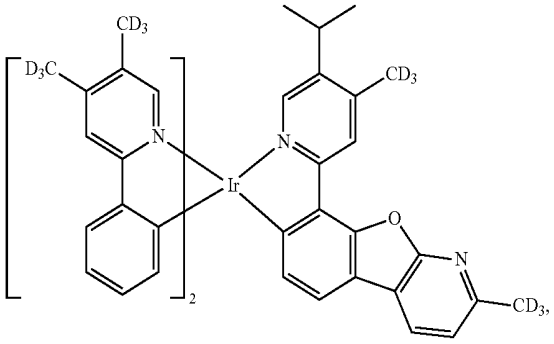
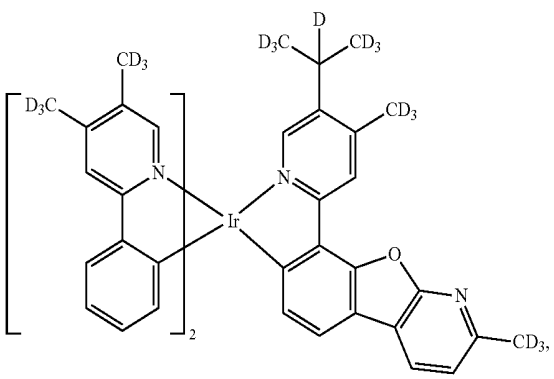


Emitter 49



Emitter 50



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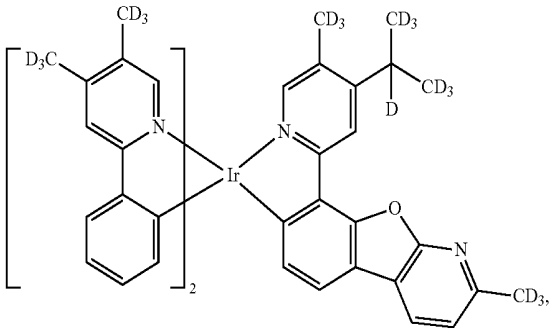
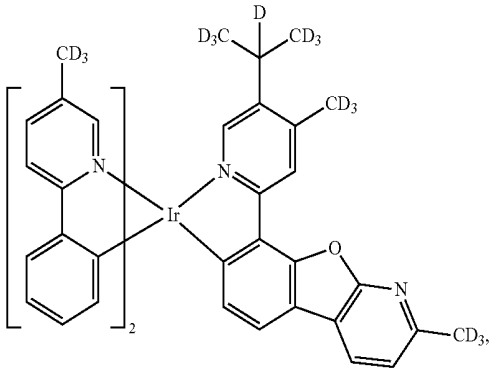


Emitter 52



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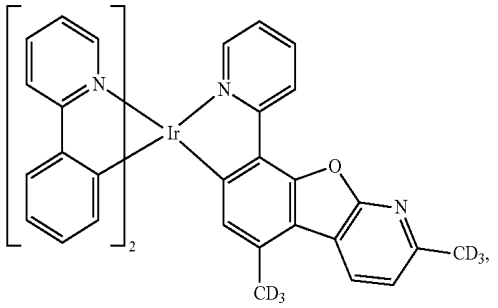

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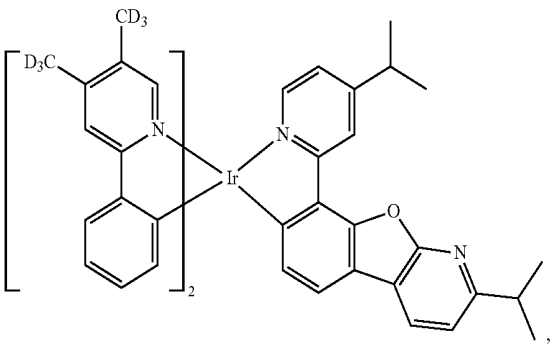

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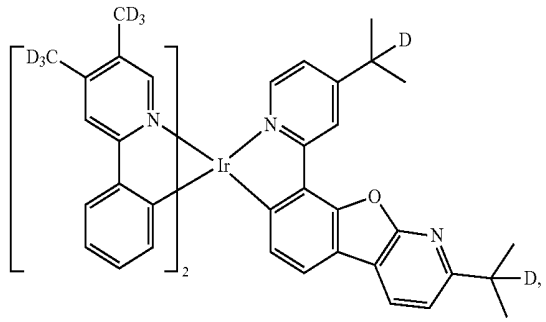

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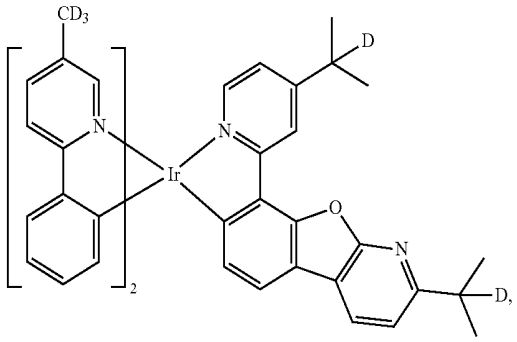

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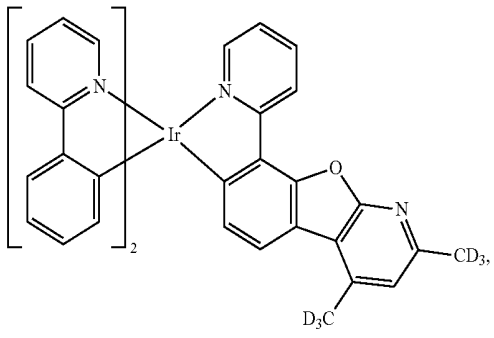

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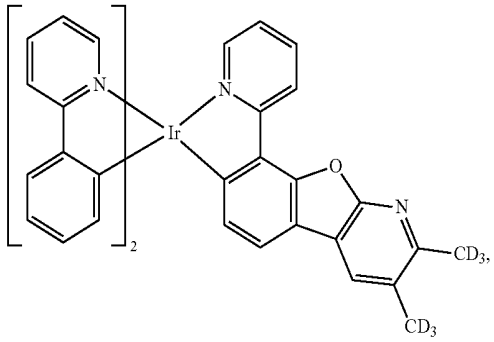

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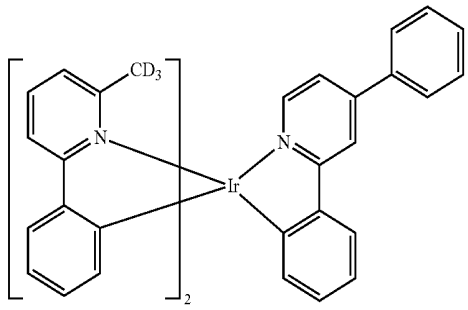

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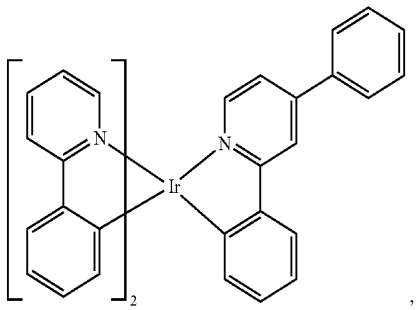

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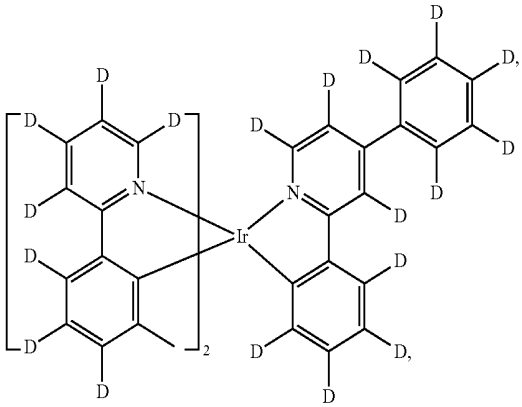

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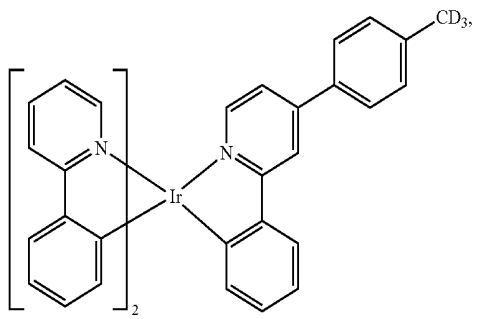

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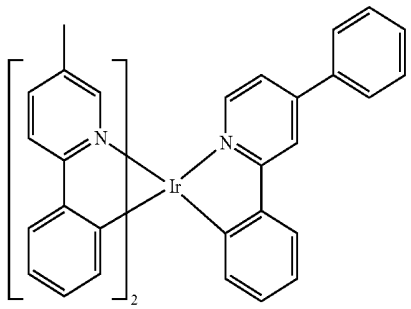

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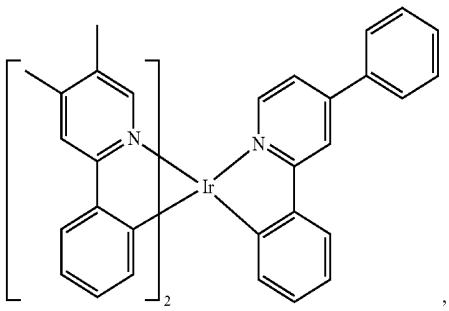

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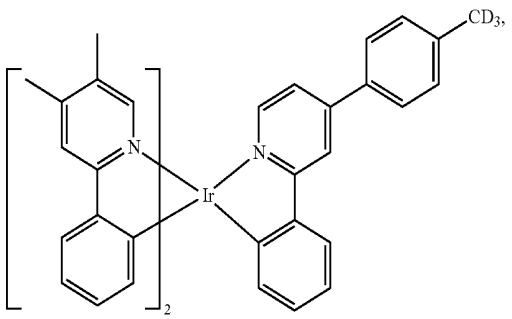

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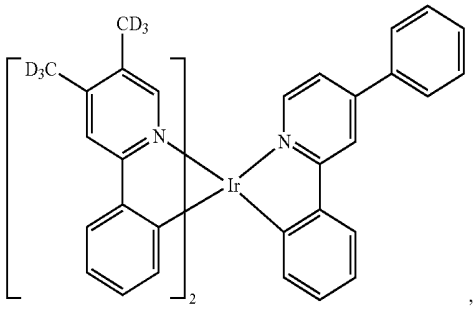

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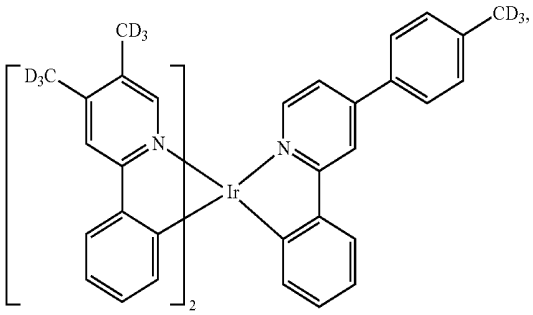

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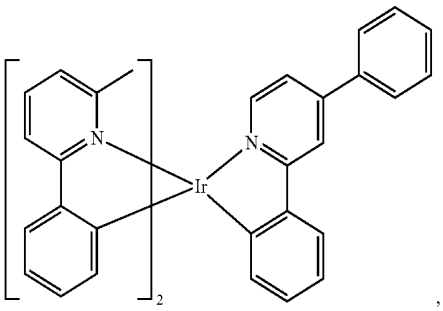

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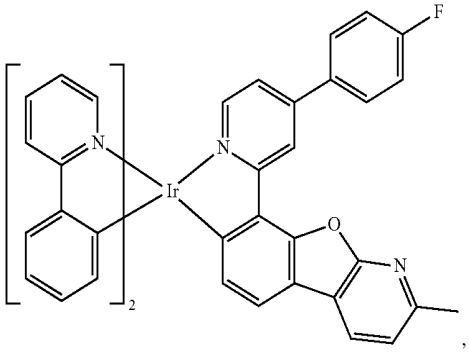

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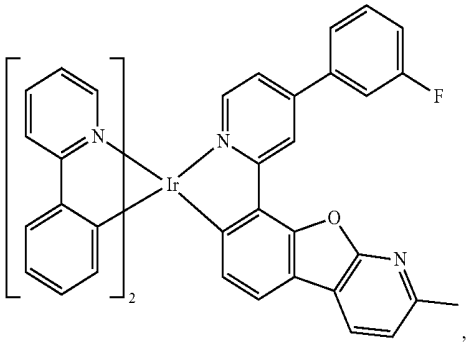

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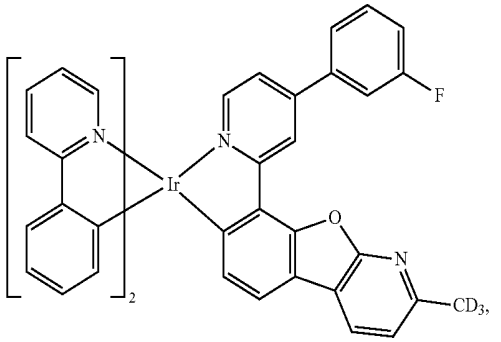

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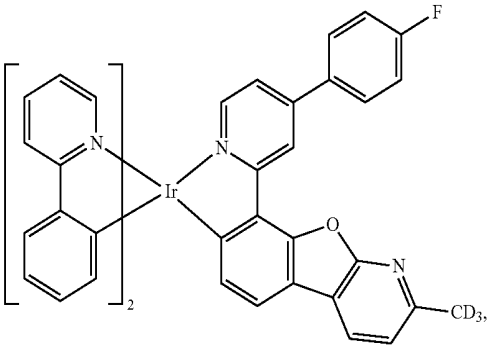

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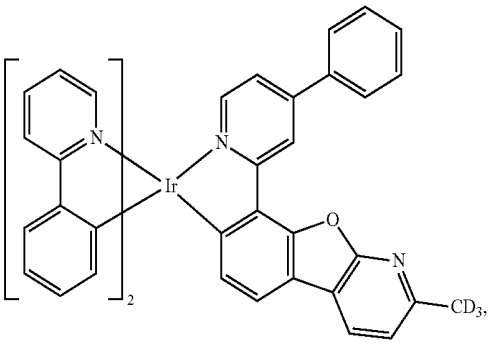

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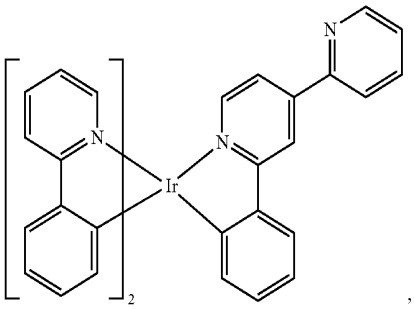

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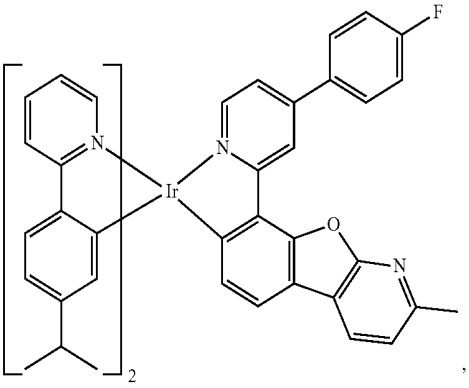

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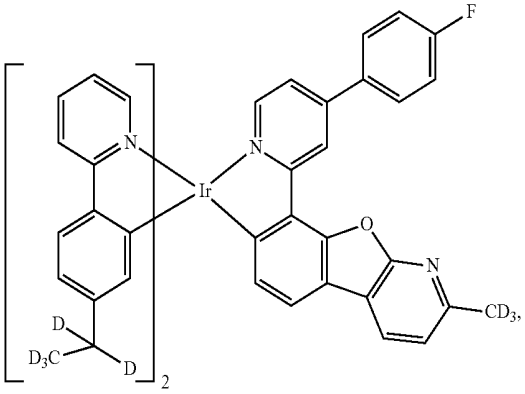

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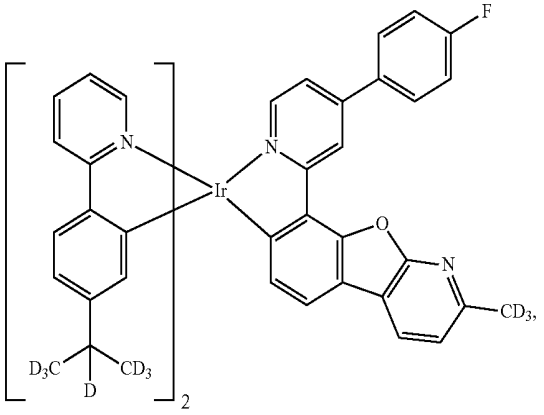

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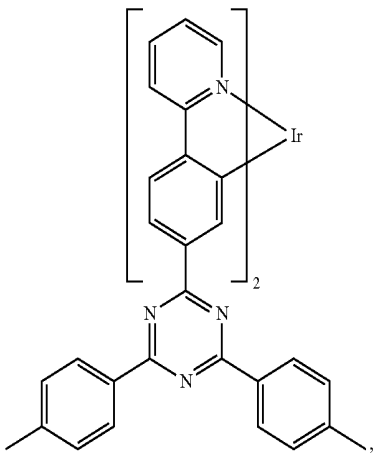

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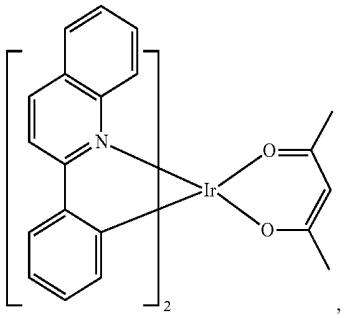

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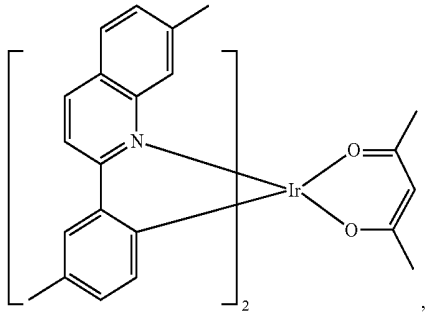

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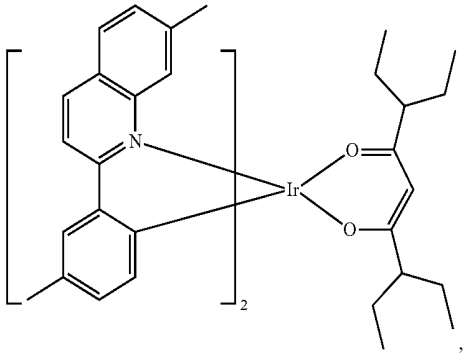

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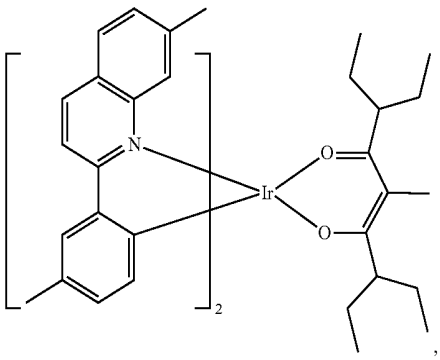

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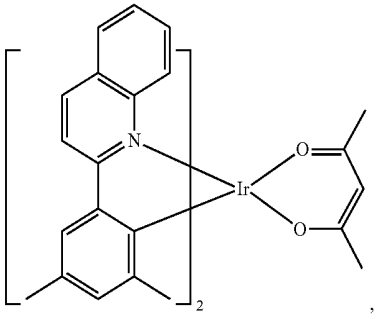

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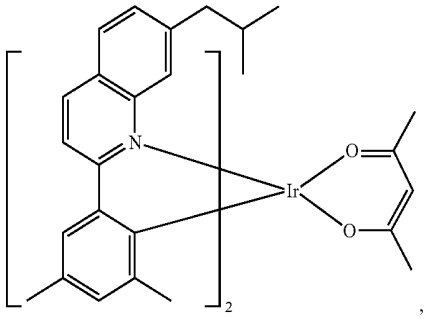

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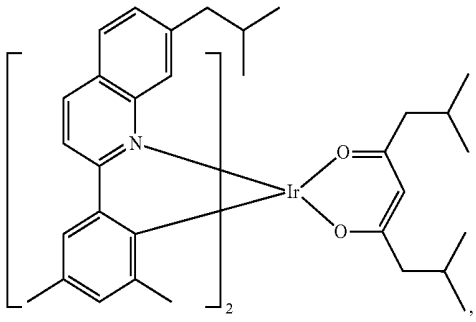

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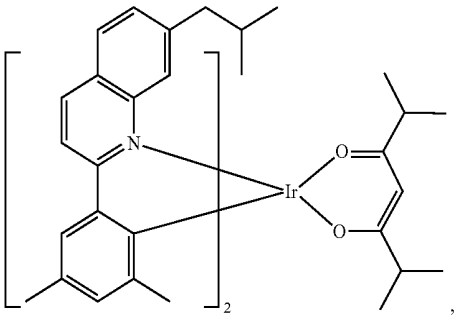

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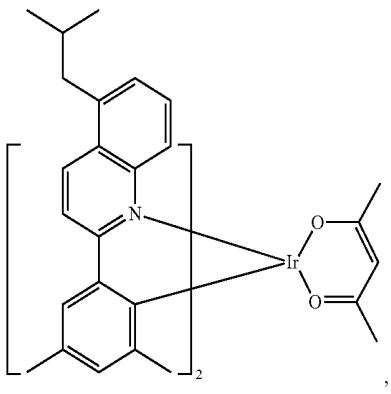

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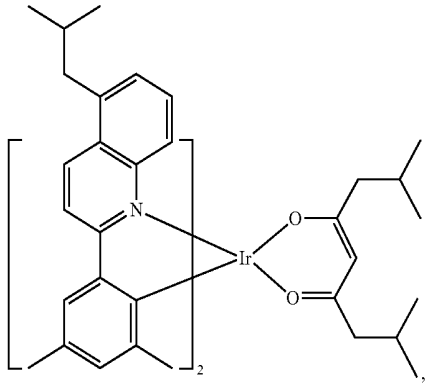

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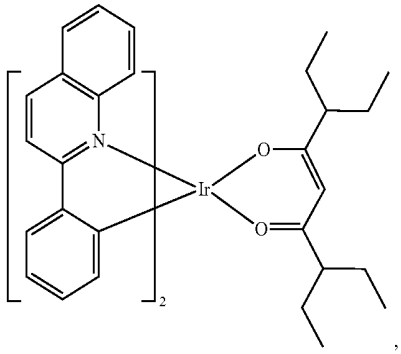

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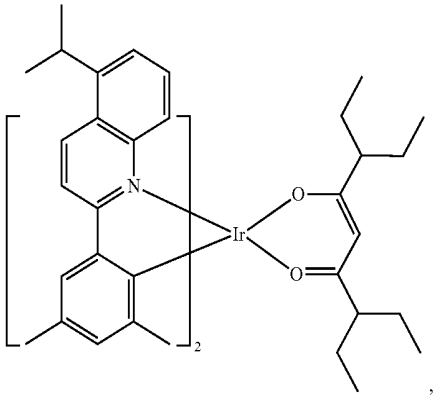

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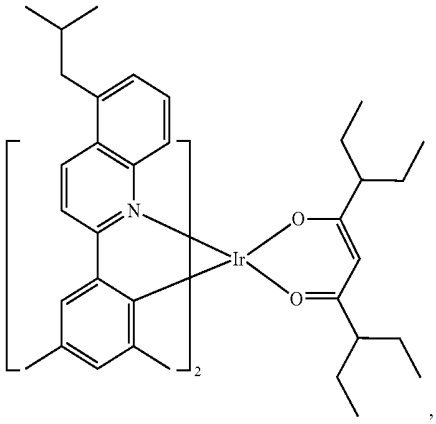

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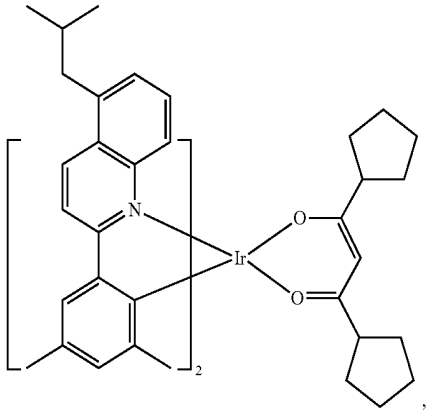

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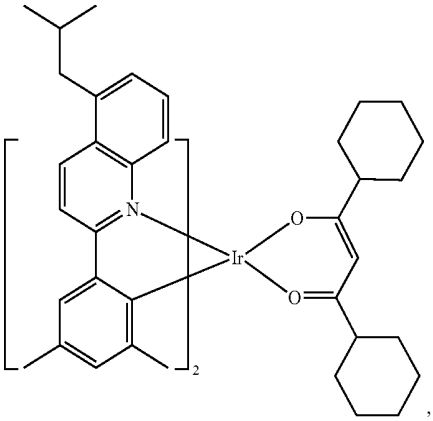

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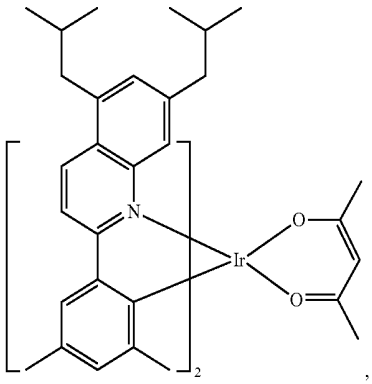

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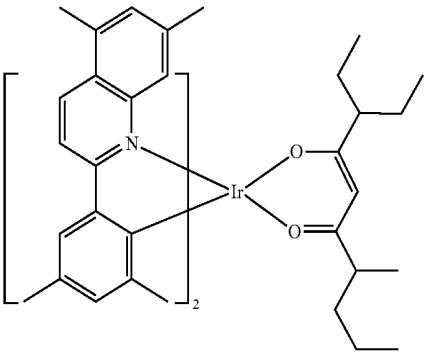

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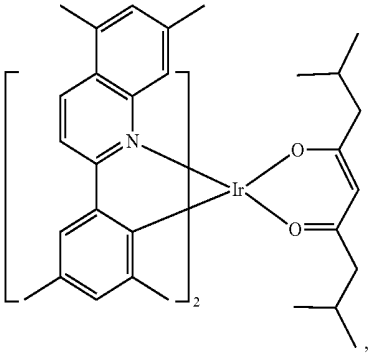

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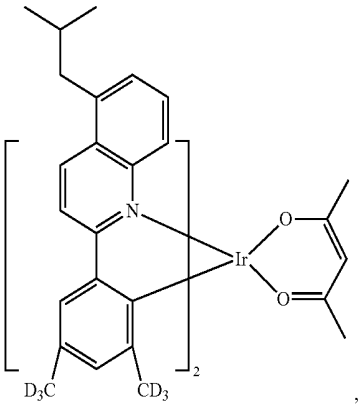

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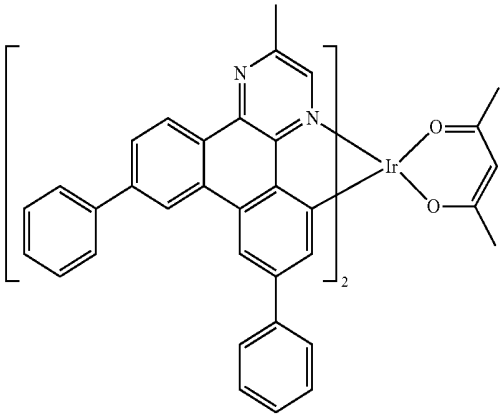

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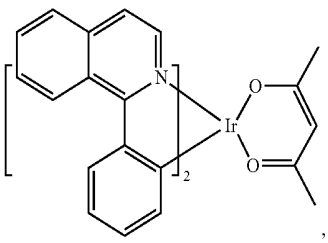

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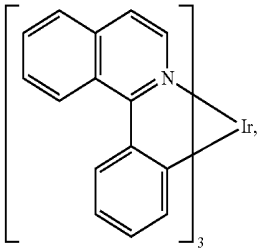

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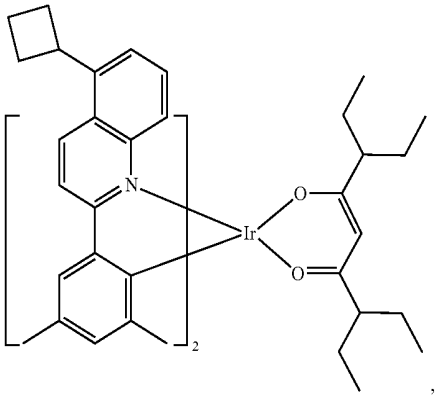

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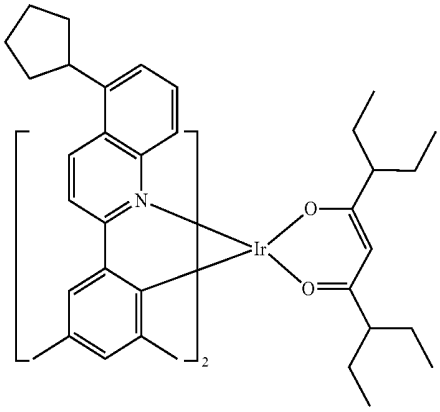

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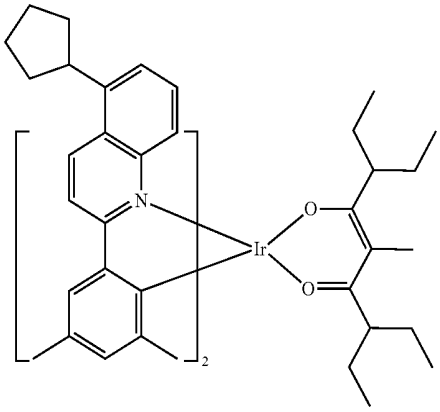

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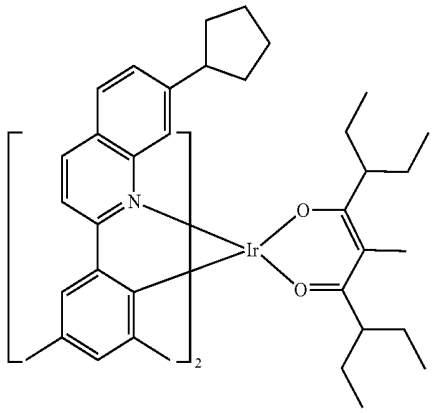

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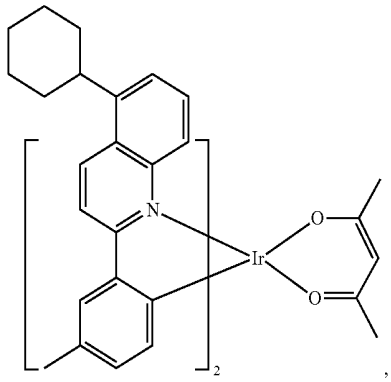

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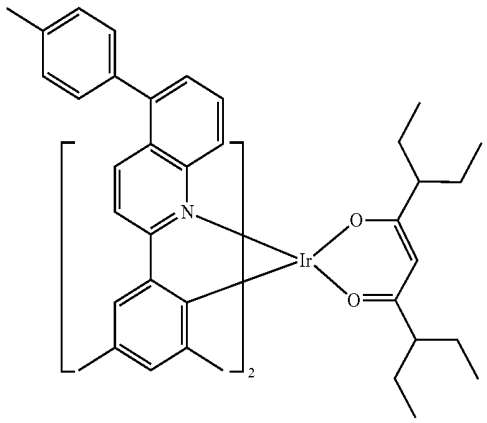

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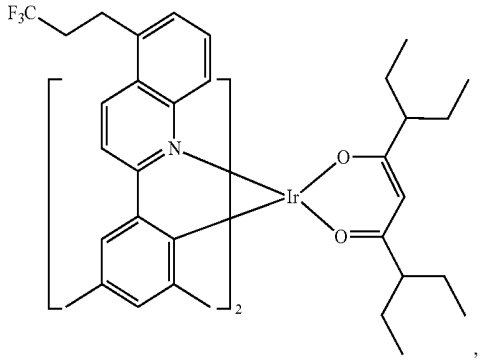

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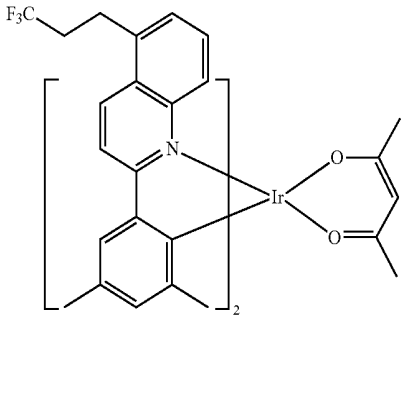

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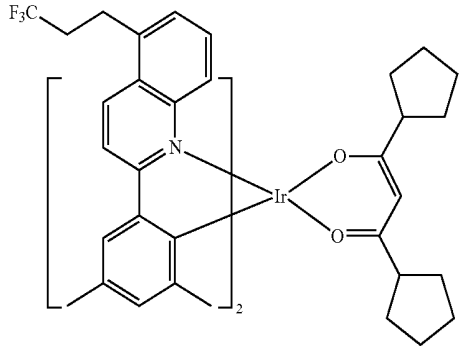

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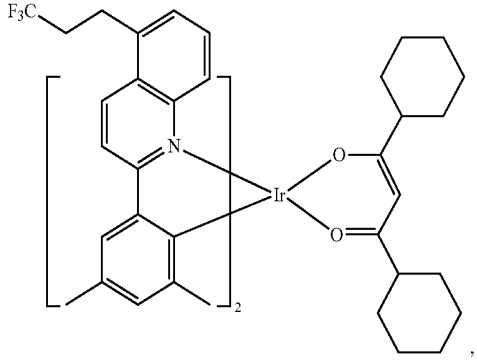

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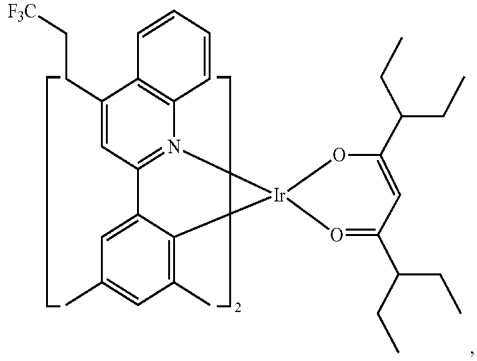

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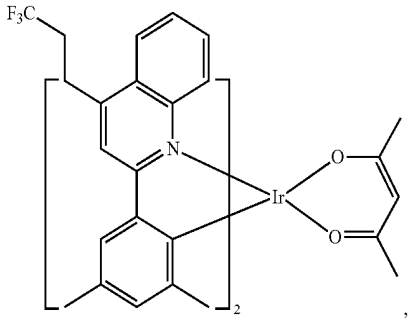

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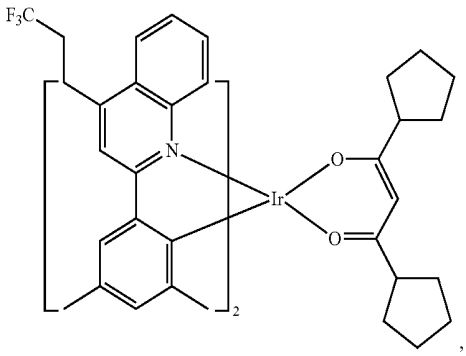

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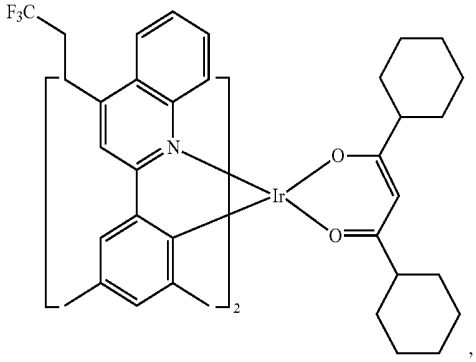

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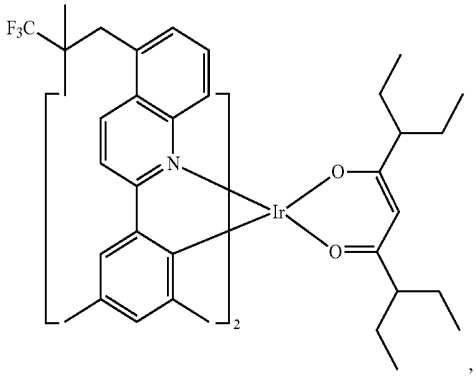

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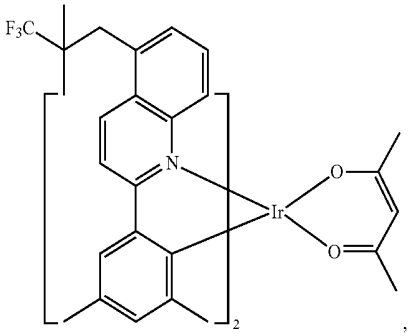

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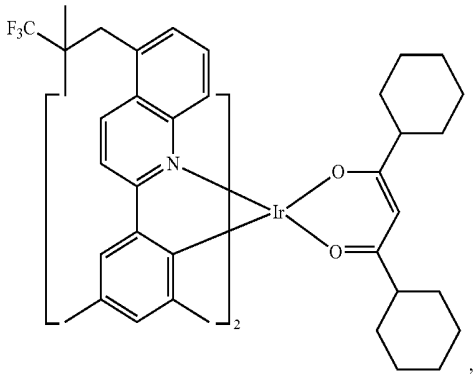

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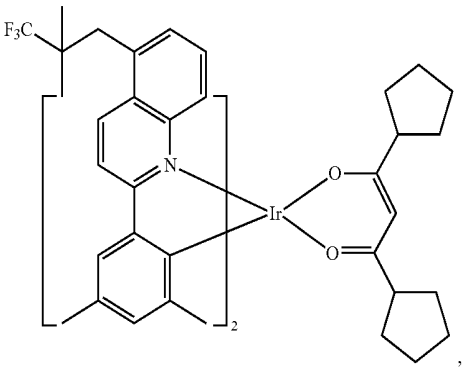

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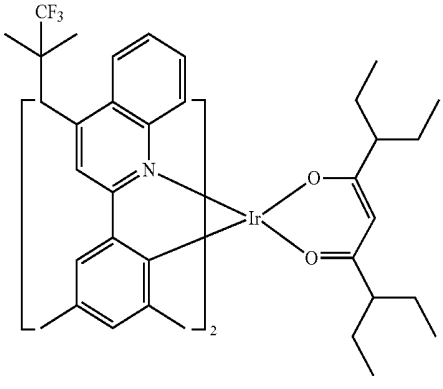

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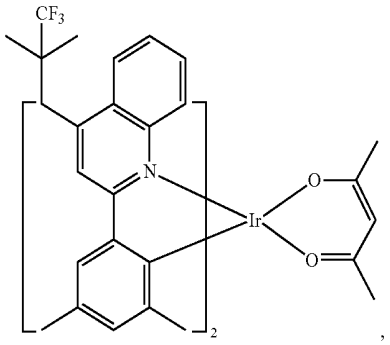

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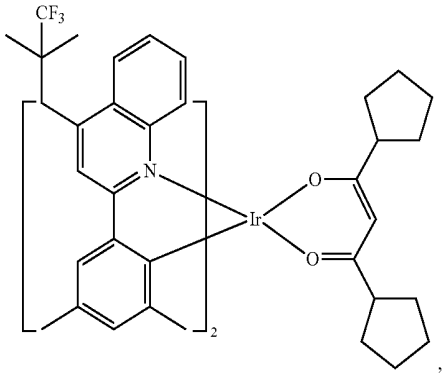

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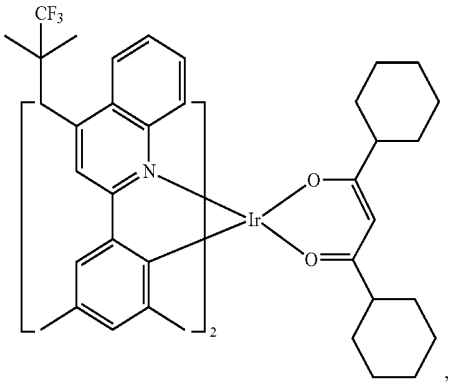

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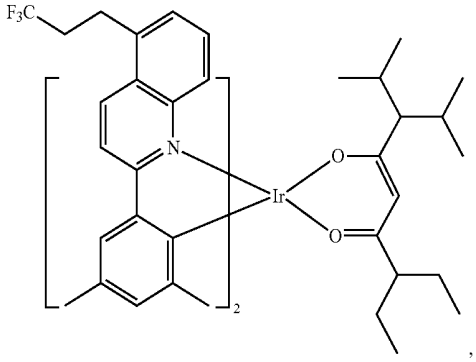

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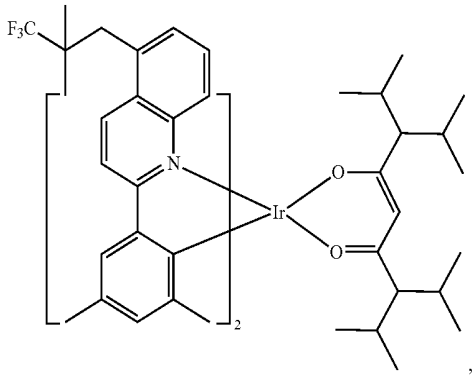

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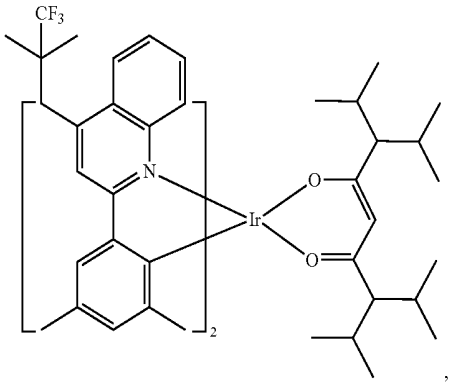

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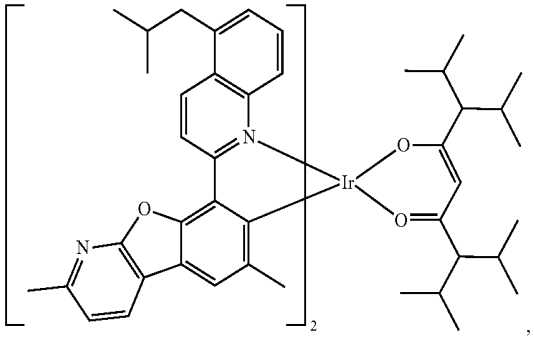

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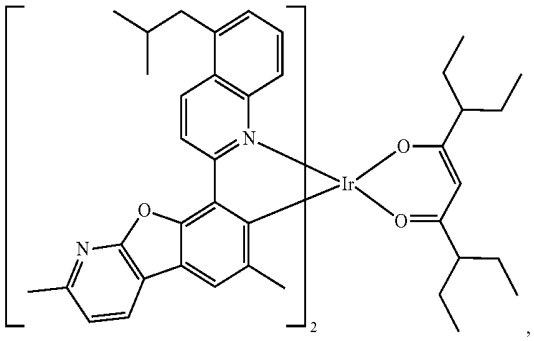

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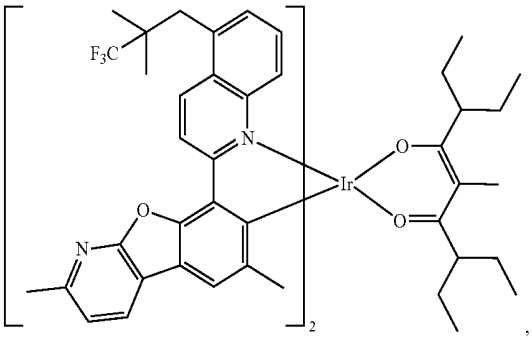

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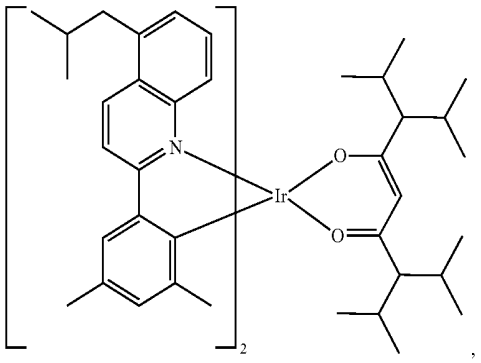

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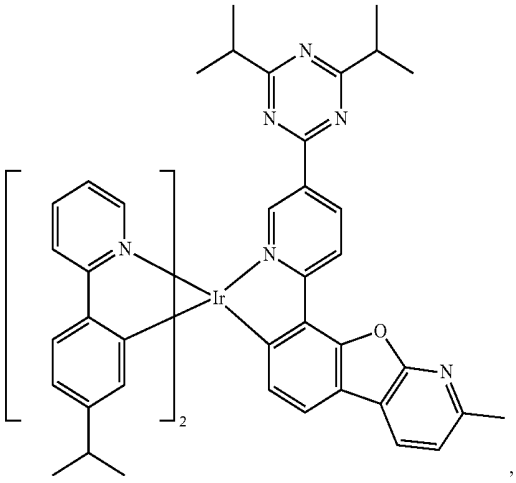

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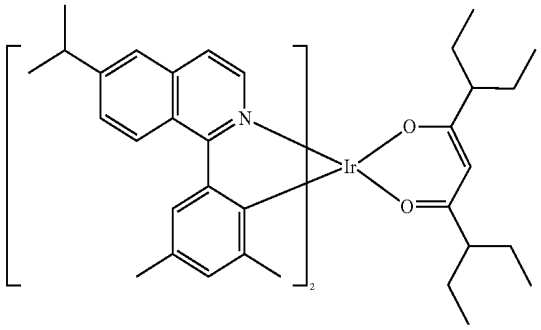

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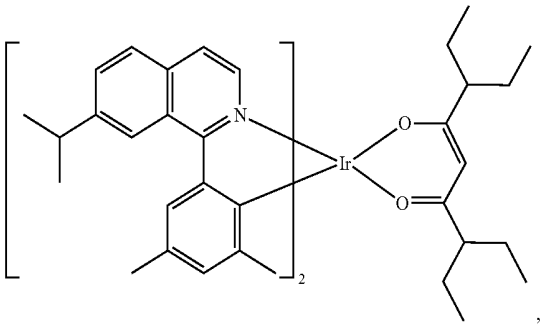

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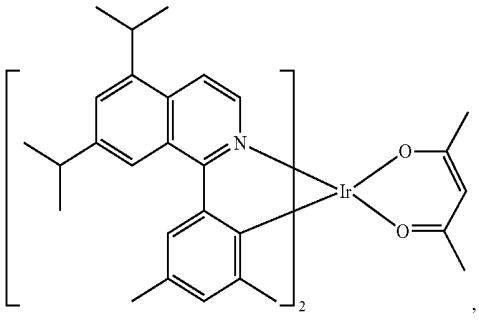

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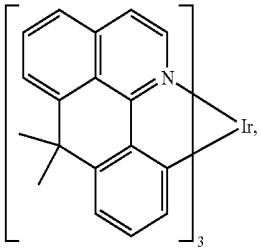

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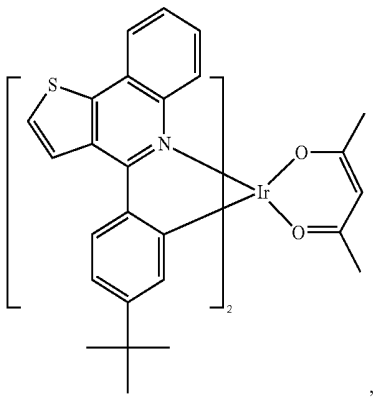

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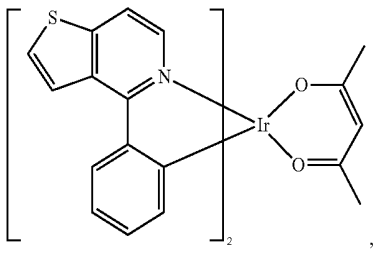

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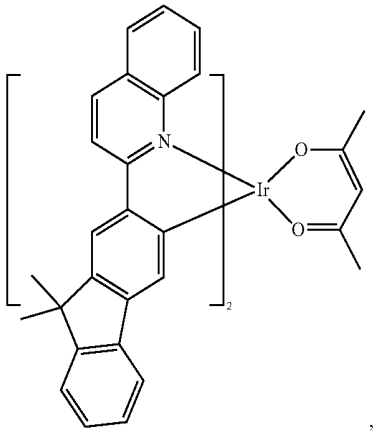

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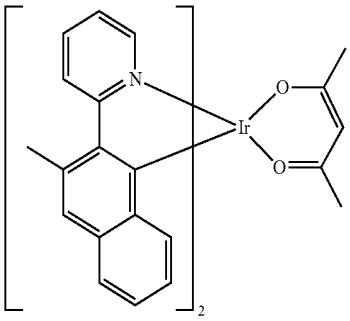

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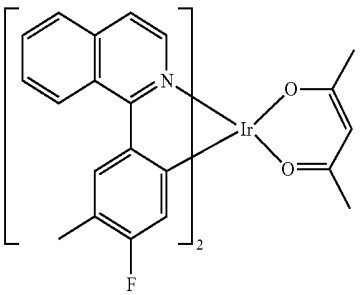

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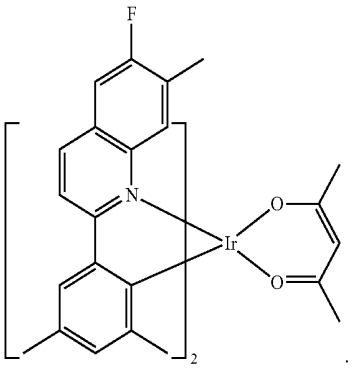
Emitter 140



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[0114] According to some embodiments, the first mixture comprises a h-host, an e-host, and an emitter. In other embodiments, the first mixture comprises a first h-host, a second h-host, and an e-host. The possible materials for the h-host, the e-host, and the emitter are as defined above.

[0115] In some embodiments, the first mixture is selected from the following group of three-component mixtures consisting of (Compound A11, Compound A14, and Compound H26), (Compound A11, Compound C74, and Compound H17), (Compound A14, Compound C65, and Compound H5), (Compound C74, Compound H8, and Compound H17), (Compound C83, Compound H17, and Emitter 2), (Compound C83, Compound F20, and Compound F18), (Compound 83, Compound G2, and Compound G26), (Compound A5, Compound C239, and Emitter 65), and (Compound E2, Compound H5, and Emitter 25). The chemical structures of the specific compounds in this list are as defined above.

[0116] According to another aspect of the present disclosure, a method for fabricating a device using the disclosed first mixture is disclosed. The method comprises: providing a first container that contains a first mixture, the first mixture comprising:

[0117] a first compound;

[0118] a second compound; and

[0119] a third compound,

[0120] wherein the first compound, the second compound, and the third compound are all organic compounds and have different chemical structures from each other,

[0121] wherein the first compound, the second compound, and the third compound each has an evaporation temperature T**1**, T**2**, and T**3**, respectively, and is in the range of 150 to 350° C.,

[0122] wherein the T**1**, T**2**, and T**3** differ from each other by less than 20° C.;

[0123] providing a substrate having a first electrode disposed thereon;

[0124] depositing an organic layer over the first electrode by evaporating the first mixture in the first container in a high vacuum deposition tool under a first deposition condition which is defined as depositing at a 2 Å/sec deposition rate with a chamber base pressure between 1×10^{-6} Torr to 1×10^{-9} Torr onto a surface positioned at a predefined distance from the first mixture,

[0125] wherein the first compound has a concentration C**1** in the first mixture and a concentration C**2** in the emissive layer and |(C**1**-C**2**)/C**1**| is less than 5%; and

[0126] depositing a second electrode over the emissive layer. All of the variations for the first mixture described above are applicable to this method.

[0127] According to another aspect of the present disclosure, a first device comprising first organic light emitting device is disclosed. The organic light emitting device comprises:

[0128] an anode;

[0129] a cathode; and

[0130] an organic layer, disposed between the anode and the cathode, comprising a first mixture of a first compound, a second compound, and a third compound,

[0131] wherein the first compound, the second compound, and the third compound are all organic compounds and have different chemical structures from each other,

[0132] wherein the first compound, the second compound, and the third compound each has an evaporation temperature T**1**, T**2**, and T**3**, respectively, and is in the range of 150 to 350° C.,

[0133] wherein the T**1**, T**2**, and T**3** differ from each other by less than 20° C.,

[0134] wherein the first compound has a concentration C**1** in the first mixture and concentration C**2** in a film deposited by evaporating the first mixture in a high vacuum deposition tool under a first deposition condition which is defined as depositing at a 2 Å/sec deposition rate with a chamber base

pressure between 1×10^{-6} Torr to 1×10^{-9} Torr onto a surface positioned at a predefined distance from the first mixture,

[0135] wherein |(C1-C2)/C1| is less than 5%,

[0136] wherein the first compound has a concentration C1' in a second mixture of the first and second compounds or has a concentration C1" in a third mixture of the first and third compounds, and the first compound has a concentration C2' in a film formed by evaporating the second mixture under the first deposition condition or has a concentration C2" in a film formed by evaporating the third mixture under the first deposition condition, and

[0137] wherein at least one of |(C1'-C2')/C1'| and |(C1"-C2")/C1"| is greater than 5%.

[0138] In one embodiment of the first device, the organic layer is an emissive layer. In another embodiment of the first device, the organic layer is a non-emissive layer.

[0139] In one embodiment of the first device, the organic layer further comprises a phosphorescent emitting material.

[0140] In one embodiment of the first device, the organic layer further comprises a host material.

[0141] In one embodiment of the first device, the first compound functions as a phosphorescent emitting material at room temperature.

[0142] In one embodiment fo the first device, the first compound functions as a host material at room temperature.

[0143] In one embodiment of the first device, the first device further comprises a second organic light emitting device separate from the first organic light emitting device.

[0144] In one embodiment of the first device, the first organic light emitting device comprises a first emissive layer and a second emissive layer, wherein the first emissive layer is deposited by evaporating the first mixture.

[0145] In one embodiment of the first device, the organic layer is a hole transporting layer.

[0146] In one embodiment of the first device, the first device is a consumer product. In another embodiment, the first device is an organic light-emitting device. In another embodiment, the first device can comprise a lighting panel.

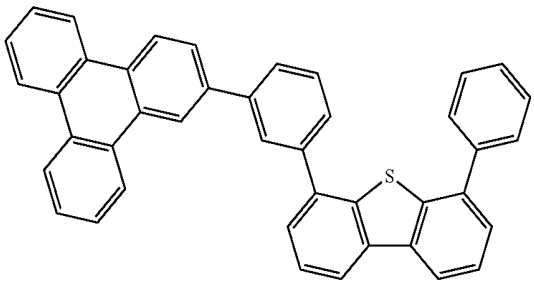
EXAMPLES

[0147] The feasibility of manufacturing multicomponent films with stable compositions was demonstrated by compositional analysis of films fabricated by single-source co-evaporation of the premixture of these components.

Comparative Premixture Example 1

[0148] A bicomponent premixture (BPM1) was prepared by physically mixing and grinding of Compound H8 and Compound C74 at a weight ratio of 2:1, and loaded into an evaporation source. The premixed compositions were thermally co-evaporated at a rate of 2 Å/s in a high vacuum chamber with a base pressure of less than 10^{-7} Torr, and deposited onto glass substrates. The substrates were replaced continuously after deposition of 500 Å of film without stopping the deposition and cooling the source till the depletion of the evaporation source. The compositions of films were analyzed by high-performance liquid chromatography (HPLC) and the results are collected in Table 1. The concentrations of Compound C74 in each film were plotted in FIG. **1**.

Compound H8



Compound C74

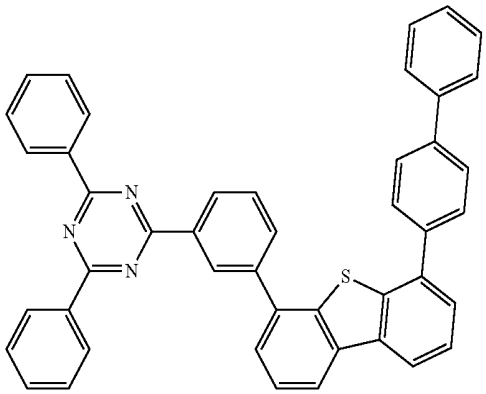


TABLE 1

HPLC composition (%) of sequentially deposited films from premixture (BPM1) (HPLC Conditions C18, 100 45 min, Detected wavelength 254 nm) (Due to different absorption coefficients, the HPLC composition may or may not agree with the weight ratio.)

Films	Compound H8	Compound C74
Plate1	68.4	31.6
Plate2	68.2	31.8
Plate3	68.2	31.8
Plate4	68.4	31.6
Plate5	69.3	30.7
Plate6	70.6	29.4
Plate7	71.7	28.3
Plate8	73.0	27.0

[0149] FIG. **3** shows HPLC composition (%) evolution of Compound C74 in sequentially deposited films from premixture BPM1. The dashed line in the plot of FIG. **3** represents a linear fit of the data presented in solid line, which shows a slope of −0.68.

Premixture Example 1

[0150] A tricomponent premixture (TPM1) was prepared by physically mixing and grinding of Compound H8, Compound C74 and Compound H17 at a weight ratio of 1:1:1, and loaded into an evaporation source. The film preparation and concentration evaluation follow the same procedures as in BPM1. The compositions of films are collected in Table 2 and the concentrations of Compound C74 in each film were plotted in FIG. **2**.

Compound H17

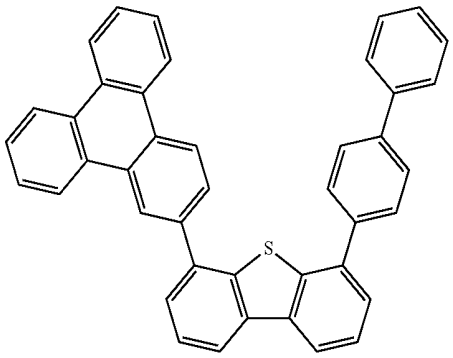


TABLE 2

HPLC composition (%) of sequentially deposited films from premixture (TPM1) (HPLC Conditions C18, 100 45 min, Detected wavelength 254 nm) (Due to different absorption coefficients, the HPLC composition may or may not agree with the weight ratio.)

Films	Compound H8	Compound H17	Compound C74
Plate1	36.9	37.4	25.7
Plate2	35.2	38.2	26.6
Plate3	34.3	38.1	27.6
Plate4	33.0	38.7	28.3
Plate5	31.3	40.1	28.6
Plate6	30.3	41.2	28.5
Plate7	30.0	41.7	28.3
Plate8	29.0	43.5	27.5

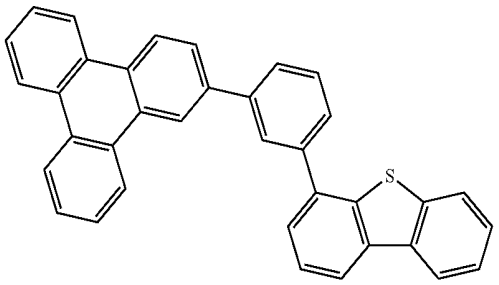
[0151] FIG. **4** shows HPLC composition (%) evolution of Compound C74 in sequentially deposited films from premixture TPM1. The dashed line in the plot of FIG. **4** is a linear fit of the data presented in solid line, which shows a slope of 0.29.

[0152] The absolute value of slope in the concentration plot indicates the extent of concentration separation during sequential deposition of films from a premixture. The data in FIGS. **3** and **4** suggest that TPM1 has less concentration separation for Compound C74 than BPM1. This evaporation stability in TPM1 was achieved through the introduction of Compound H17, which shows opposite trend of concentration evolution against Compound H8 during sequential evaporation as revealed in Table 2.

Comparative Premixture Example 2

[0153] A bicomponent premixture (BPM2) was prepared by physically mixing and grinding of Compound H5 and Compound E2 at a weight ratio of 1:1, and loaded into an evaporation source. The film preparation and concentration evaluation follow the same procedures as in BPM 1. The compositions of films are collected in Table 3 and the concentrations of Compound E2 in each film were plotted in FIG. **5**.

Compound H5



Compound E2

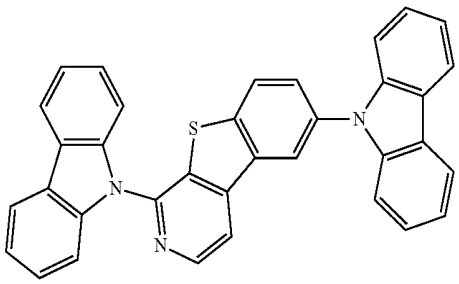


TABLE 3

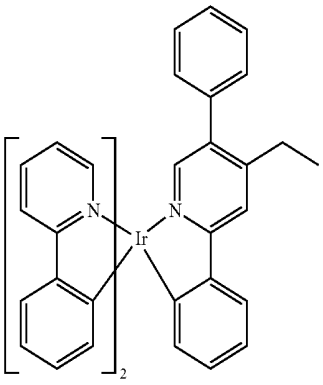
HPLC composition (%) of sequentially deposited films from premixture (BPM2) (HPLC Conditions C81, 100 45 min, Detected wavelength 254 nm) (Due to different absorption coefficients, the HPLC composition may or may not agree with the weight ratio.)

Films	Compound H5	Compound E2
Plate1	63.6	36.4
Plate2	64.8	35.2
Plate3	64.3	35.7
Plate4	62.2	37.8
Plate5	59.0	41.0
Plate6	53.8	46.2

[0154] FIG. **5** shows HPLC composition (%) evolution of Compound E2 in sequentially deposited films from premixture BPM2. The dashed line in the plot of FIG. **5** is a linear fit of the data presented in solid line, which shows a slope of 1.96.

Premixture Example 2

[0155] A tricomponent premixture (TPM2) was prepared by physically mixing and grinding of Compound H5, Compound E2 and Emitter 25 at a weight ratio of 2:2:1, and loaded into an evaporation source. The film preparation and concentration evaluation follow the same procedures as in BPM1. The compositions of films are collected in Table 4 and the concentrations of Emitter 25 in each film were plotted in FIG. **6**.



Emitter 25

TABLE 4

HPLC composition (%) of sequentially deposited films from premixture (TPM2) (HPLC Conditions C18, 100 45 min, Detected wavelength 254 nm) (Due to different absorption coefficients, the HPLC composition may or may not agree with the weight ratio.)

Films	Compound H5	Emitter 25	Compound E2
Plate1	54.4	11.4	34.2
Plate2	55.5	11.0	33.5
Plate3	56.7	10.2	33.1
Plate4	57.5	9.5	33.0
Plate5	55.2	9.4	35.4

[0156] FIG. **6** shows HPLC composition (%) evolution of Compound E2 in sequentially deposited films from premixture TPM2. The dashed line in the plot of FIG. **6** is a linear fit of the data presented in solid line, which shows a slope of 0.19.

[0157] The data in FIGS. **5** and **6** suggest that TPM2 has less concentration separation and is a more stable premixture than BPM2. This evaporation stability in TPM2 was achieved through the introduction of Emitter 25, which assists the co-evaporation of Compound H5 and Compound E2. Indeed, a comparison of data in Tables 3 and 4 suggests that there is much less concentration separation for both Compounds H5 and E2 in TPM2.

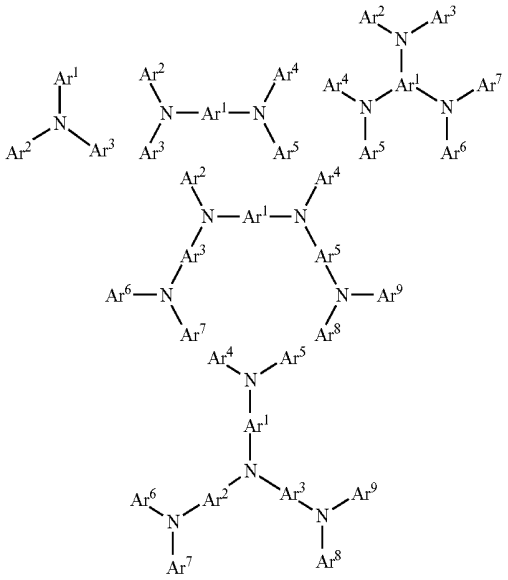
Combination with Other Materials

[0158] The materials described herein as useful tzar a particular layer in an organic tight emitting device may be used in combination with a wide variety of other materials present in the device. For example, emissive dopants disclosed herein may be used in conjunction with a wide variety of hosts, transport layers, blocking layers, injection layers, electrodes and other layers that may be present. The materials described or referred to below are non-limiting examples of materials that may be useful in combination with the compounds disclosed herein, and one of skill in the art can readily consult the literature to identify other materials that may be useful in combination.

HIL/HTL:

[0159] A hole injecting/transporting material to be used in the present invention is not particularly limited, and any compound may be used as long as the compound is typically used as a hole injecting/transporting material. Examples of the material include, but not limit to: a phthalocyanine or porphyrin derivative; an aromatic amine derivative; an indolocarbazole derivative; a polymer containing fluorohydrocarbon; a polymer with conductivity dopants; a conducting polymer, such as PEDOT/PSS; a self-assembly monomer derived from compounds such as phosphonic acid and silane derivatives; a metal oxide derivative, such as MoO_x; a p-type semiconducting organic compound, such as 1,4,5,8,9,12-Hexaazatriphenylenehexacarbonitrile; a metal complex, and a cross-linkable compounds.

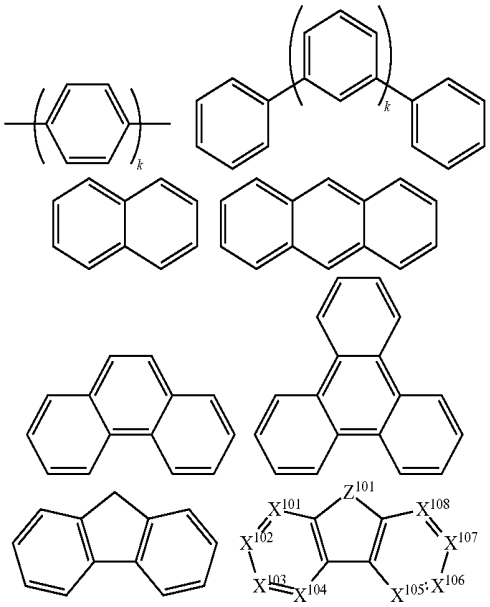
[0160] Examples of aromatic amine derivatives used in HIL or HTL include, but not limit to the following general structures:



[0161] Each of Ar^1 to Ar^9 is selected from the group consisting aromatic hydrocarbon cyclic compounds such as benzene, biphenyl, triphenyl, triphenylene, naphthalene, anthracene, phenalene, phenanthrene, fluorene, pyrene, chrysene, perylene, azulene; group consisting aromatic heterocyclic compounds such as dibenzothiophene, dibenzofuran, dibenzoselenophene, furan, thiophene, benzofuran, benzothiophene, benzoselenophene, carbazole, indolocarbazole, pyridylindole, pyrrolodipyridine, pyrazole, imidazole, triazole, oxazole, thiazole, oxadiazole, oxatriazole, dioxazole, thiadiazole, pyridine, pyridazine, pyrimidine, pyrazine, triazine, oxazine, oxathiazine, oxadiazine, indole, benzimidazole, indazole, indoxazine, benzoxazole, benzisoxazole, benzothiazole, quinoline, isoquinoline, cinnoline, quinazoline, quinoxaline, naphthyridine, phthalazine, pteridine, xanthene, acridine, phenazine, phenothiazine, phenoxazine, benzofuropyridine, furodipyridine, benzothienopyridine, thienodipyridine, benzoselenophenopyridine, and selenophenodipyridine; and group consisting 2 to 10 cyclic structural units which are groups of the same type or different types selected from the aromatic hydrocarbon cyclic group and the aromatic heterocyclic group and are bonded to each other directly or via at least one of oxygen atom, nitrogen atom, sulfur atom, silicon atom, phosphorus atom, boron atom, chain structural unit and the aliphatic cyclic group. Wherein each Ar is further substituted by a substituent selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl,

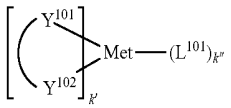
cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

[0162] In one aspect, Ar^1 to Ar^9 is independently selected from the group consisting of:



wherein k is an integer from 1 to 20; X^{101} to X^{108} is C (including CH) or N; Z^{101} is NAr^1, or S; Ar^1 has the same group defined above.

[0163] Examples of metal complexes used in HIL or HTL include, but not limit to the following general formula:



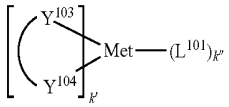
wherein Met is a metal, which can have an atomic weight greater than 40; (Y^{101}-Y^{102}) is a bidentate ligand, Y^{101} and Y^{102} are independently selected from C, N, O, P, and S; L^{101} is an ancillary ligand; k' is an integer value from 1 to the maximum number of ligands that may be attached to the metal; and k'+k" is the maximum number of ligands that may be attached to the metal.

[0164] In one aspect, (Y_{101}-Y^{102}) is a 2-phenylpyridine derivative. In another aspect, (Y^{101}-Y^{102}) is a carbene ligand. In another aspect, Met is selected from Ir, Pt, Os, and Zn. In a further aspect, the metal complex has a smallest oxidation potential in solution vs. Fc^-/Fc couple less than about 0.6 V.

Host:

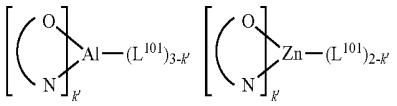
[0165] The light emitting layer of the organic EL device of the present invention preferably contains at least a metal complex as light emitting material, and may contain a host material using the metal complex as a dopant material. Examples of the host material are not particularly limited, and any metal complexes or organic compounds may be used as long as the triplet energy of the host is larger than that of the dopant. While the Table below categorizes host materials as preferred for devices that emit various colors, any host material may be used with any dopant so long as the triplet criteria is satisfied.

[0166] Examples of metal complexes used as host are preferred to have the following general formula:



wherein Met is a metal; (Y^{103}-Y^{104}) is a bidentate ligand, Y^{103} and Y^{104} are independently selected from C, N, O, P, and S; L^{101} is an another ligand; k' is an integer value from 1 to the maximum number of ligands that may be attached to the metal; and k'+k" is the maximum number of ligands that may be attached to the metal.

[0167] In one aspect, the metal complexes are:

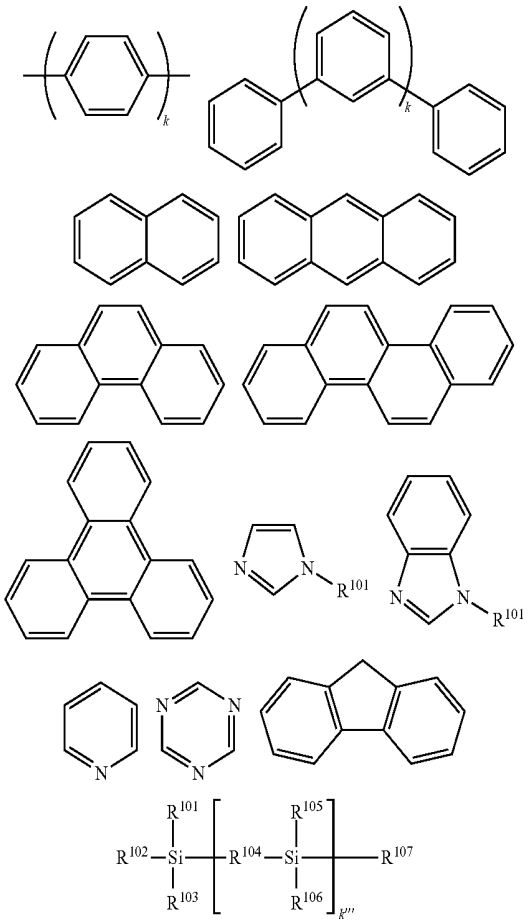


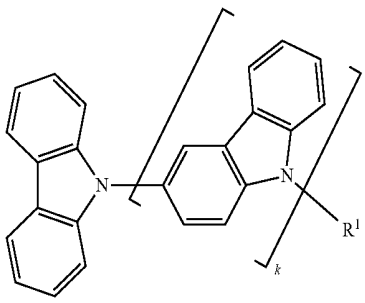
wherein (O—N) is a bidentate ligand, having metal coordinated to atoms O and N.

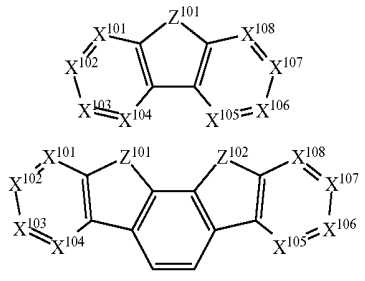
[0168] In another aspect, Met is selected from Ir and Pt. In a further aspect, (Y^{103}-Y^{104}) is a carbene ligand.

[0169] Examples of organic compounds used as host are selected from the group consisting aromatic hydrocarbon cyclic compounds such as benzene, biphenyl, triphenyl, triphenylene, naphthalene, anthracene, phenalene, phenanthrene, fluorene, pyrene, chrysene, perylene, azulene; group consisting aromatic heterocyclic compounds such as dibenzothiophene, dibenzofuran, dibenzoselenophene, furan, thiophene, benzofuran, benzothiophene, benzoselenophene, carbazole, indolocarbazole, pyridylindole, pyrrolodipyridine, pyrazole, imidazole, triazole, oxazole, thiazole, oxadiazole, oxatriazole, dioxazole, thiadiazole, pyridine, pyridazine, pyrimidine, pyrazine, triazine, oxazine, oxathiazine, oxadiazine, indole, benzimidazole, indazole, indoxazine, benzoxazole, benzisoxazole, benzothiazole, quinoline, isoquinoline, cinnoline, quinazoline, quinoxaline, naphthyridine, phthalazine, pteridine, xanthene, acridine, phenazine, phenothiazine, phenoxazine, benzofuropyridine, furodipyridine, benzothienopyridine, thienodipyridine, benzoselenophenopyridine, and selenophenodipyridine; and group consisting 2 to 10 cyclic structural units which are groups of the same type or different types selected from the aromatic hydrocarbon cyclic group and the aromatic heterocyclic group and are bonded to each other directly or via at least one of oxygen atom, nitrogen atom, sulfur atom, silicon atom, phosphorus atom, boron atom, chain structural unit and the aliphatic cyclic group. Wherein each group is further substituted by a substituent selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrite, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

[0170] In one aspect, host compound contains at least one of the following groups in the molecule:







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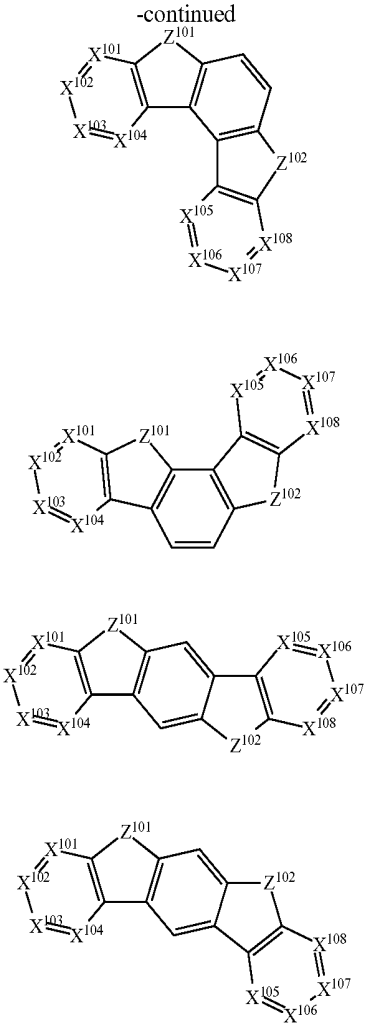


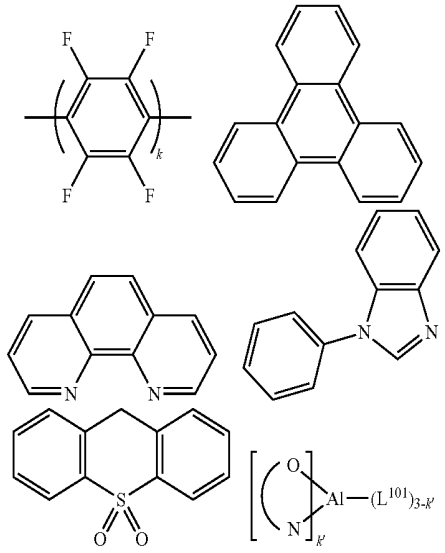
wherein R^{101} to R^{107} is independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof, when it is aryl or heteroaryl, it has the similar definition as Ar's mentioned above. k is an integer from 0 to 20 or 1 to 20; k''' is an integer from 0 to 20. X^{101} to X^{108} is selected from C (including CH) or N. Z^{101} and Z^{102} is selected from NR^{101}, O, or S.

HBL:

[0171] A hole blocking layer (HBL) may be used to reduce the number of holes and/or excitons that leave the emissive layer. The presence of such a blocking layer in a device may result in substantially higher efficiencies as compared to a similar device lacking a blocking layer. Also, a blocking layer may be used to confine emission to a desired region of an OLED.

[0172] In one aspect, compound used in HBL contains the same molecule or the same functional groups used as host described above.

[0173] In another aspect, compound used in HBL contains at least one of the following groups in the molecule:

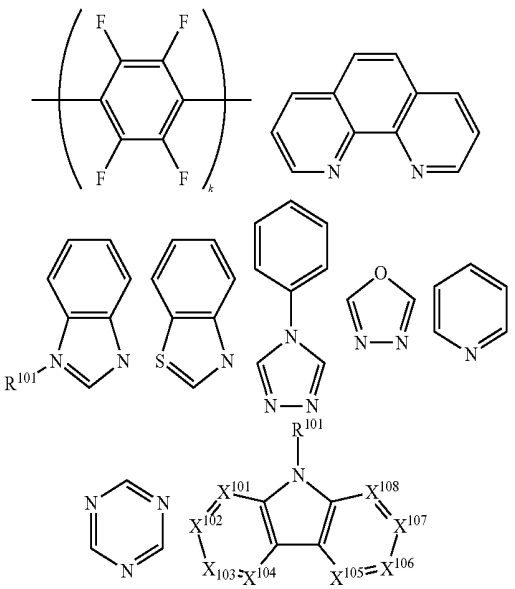


wherein k is an integer from 1 to 20; L^{101} is an another ligand, k' is an integer from 1 to 3.

ETL:

[0174] Electron transport layer (ETL) may include a material capable of transporting electrons. Electron transport layer may be intrinsic (undoped), or doped. Doping may be used to enhance conductivity. Examples of the ETL material are not particularly limited, and any metal complexes or organic compounds may be used as long as they are typically used to transport electrons.

[0175] In one aspect, compound used in ETL contains at least one of the following groups in the molecule:



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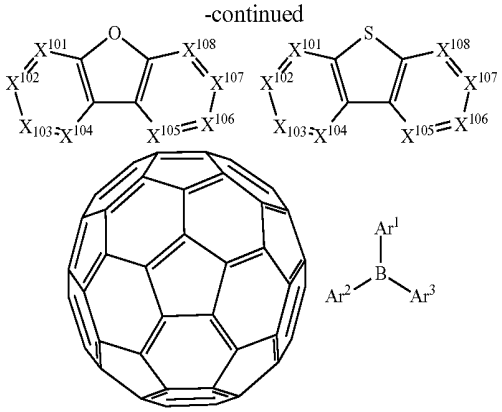
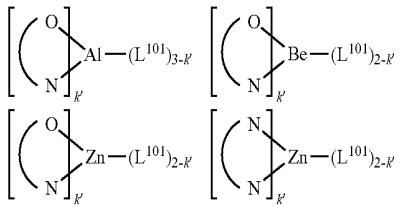


wherein R^{101} is selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof, when it is aryl or heteroaryl, it has the similar definition as Ar's mentioned above. Ar^1 to Ar^3 has the similar definition as Ar's mentioned above. k is an integer from 1 to 20. X^{101} to X^{108} is selected from C (including CH) or N.

[0176] In another aspect, the metal complexes used in ETL contains, but not limit to the following general formula:



wherein (O—N) or (N—N) is a bidentate ligand, having metal coordinated to atoms O, N or N, N; L^{101} is another ligand; k' is an integer value from 1 to the maximum number of ligands that may be attached to the metal.

[0177] In any above-mentioned compounds used in each layer of the OLED device, the hydrogen atoms can be partially or fully deuterated. Thus, any specifically listed substituent, such as, without limitation, methyl, phenyl, pyridyl, etc. also encompasses undeuterated, partially deuterated, and fully deuterated versions thereof. Similarly, classes of substituents such as, without limitation, alkyl, aryl, cycloalkyl, heteroaryl, etc. also encompass undeuterated, partially deuterated, and fully deuterated versions thereof.

[0178] In addition to and/or in combination with the materials disclosed herein, many hole injection materials, hole transporting materials, host materials, dopant materials, exiton/hole blocking layer materials, electron transporting and electron injecting materials may be used in an OLED. Non-limiting examples of the materials that may be used in an OLED in combination with materials disclosed herein are listed in Table A below. Table A lists non-limiting classes of materials, non-limiting examples of compounds for each class, and references that disclose the materials.

TABLE A

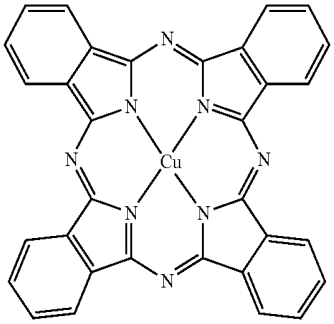
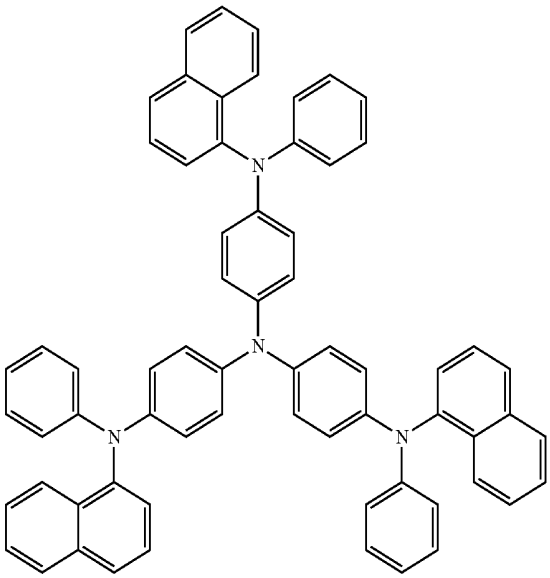
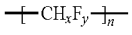
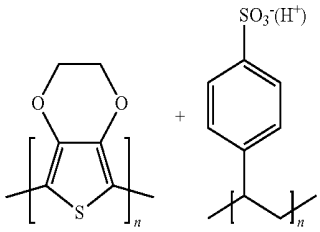
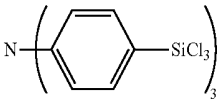
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Phthalocyanine and porphryin compounds		Appl. Phys. Lett. 69, 2160 (1996)
Starburst triarylamines		J. Lumin. 72-74, 985 (1997)
CF_x Fluorohydrocarbon polymer		Appl. Phys. Lett. 78, 673 (2001)
Conducting polymers (e.g., PEDOT:PSS, polyaniline, polypthiophene)		Synth. Met. 87, 171 (1997) WO2007002683
Phosphonic acid and sliane SAMs		US20030162053

TABLE A-continued

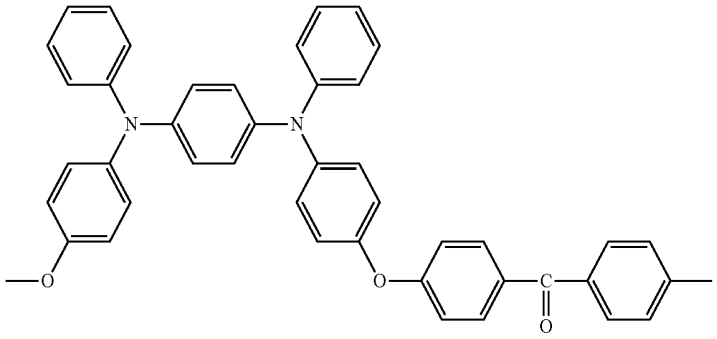
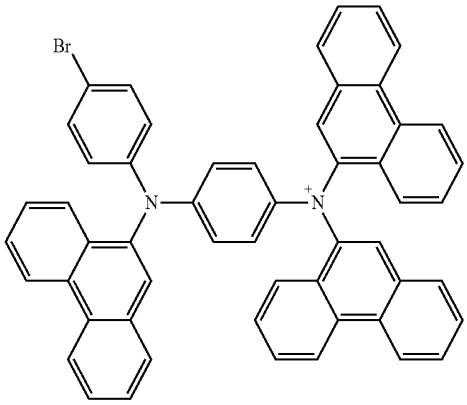
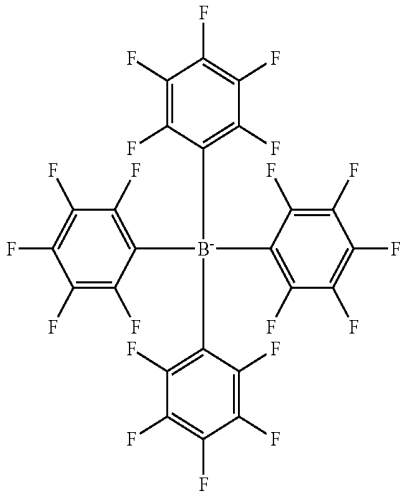
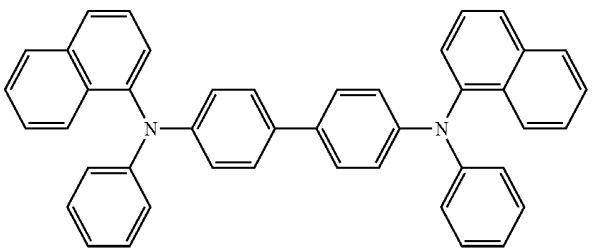
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Triarylamine or polythiophene polymers with conductivity dopants	 and  	EP1725079A1
Organic compounds with conductive inorganic compounds, such as molybdenum and tungsten oxides	 + MoO_x	US20050123751 SID Symposium Digest, 37, 923 (2006) WO2009018009

TABLE A-continued

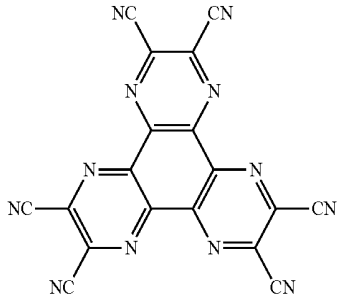
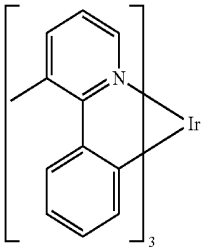
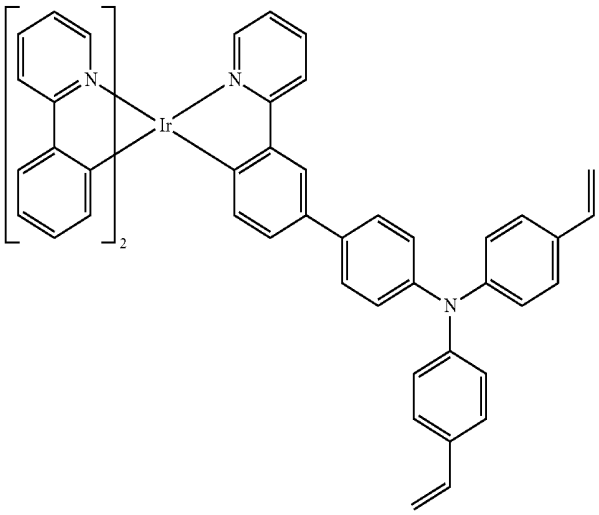
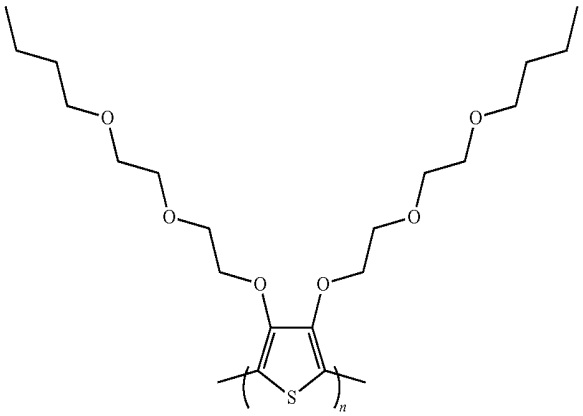
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
n-type semiconducting organic complexes		US20020158242
Metal organometallic complexes		US20060240279
Cross-linkable compounds		US20080220265
Polythiophene based polymers and copolymers		WO 2011075644 EP2350216

TABLE A-continued

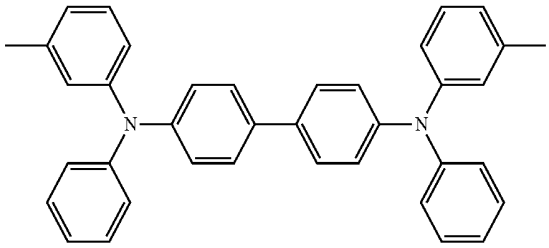
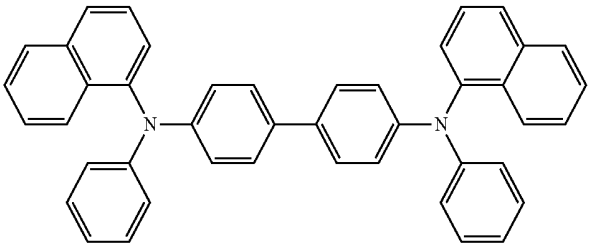
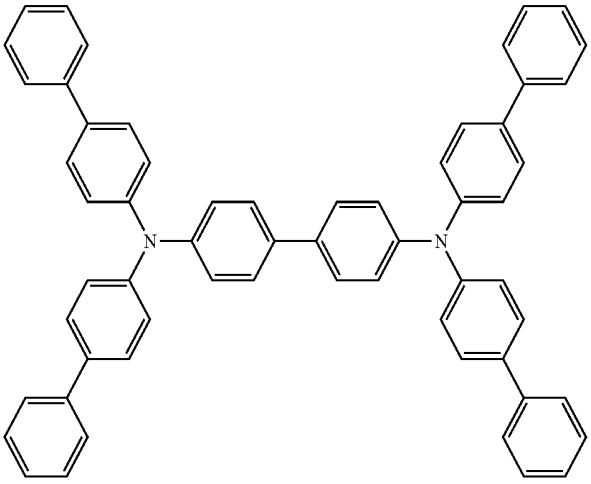
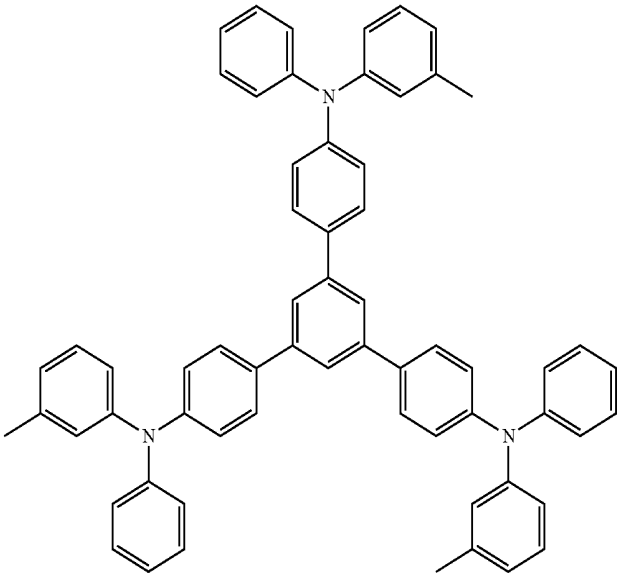
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Hole transporting materials		
Triarylamines (e.g., TPD, α-NPD)		Appl. Phys. Lett. 51, 913 (1987)
		U.S. Pat. No. 5,061,569
		EP650955
		J. Mater. Chem. 3, 319 (1993)

TABLE A-continued

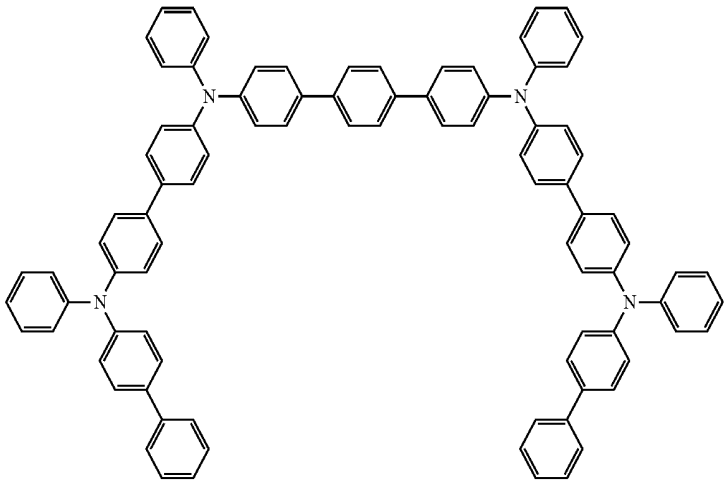
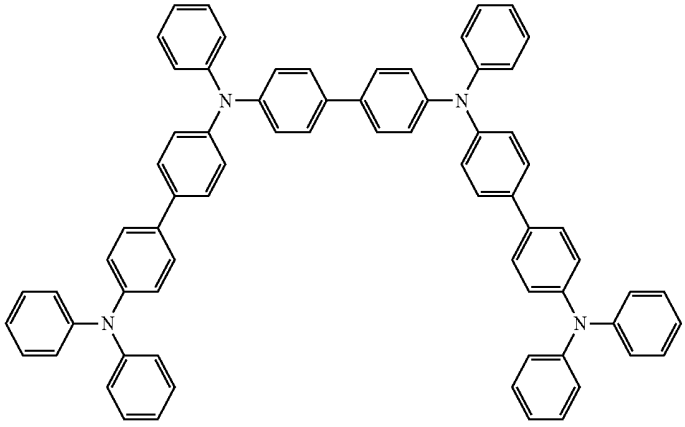
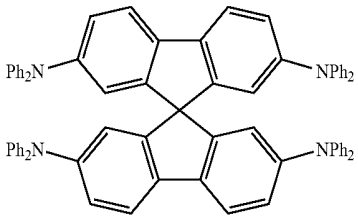
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Appl. Phys. Lett. 90, 183503 (2007)
		Appl. Phys. Lett. 90, 183503 (2007)
Triaylamine on spirofluorene core		Synth. Met. 91, 209 (1997)

TABLE A-continued

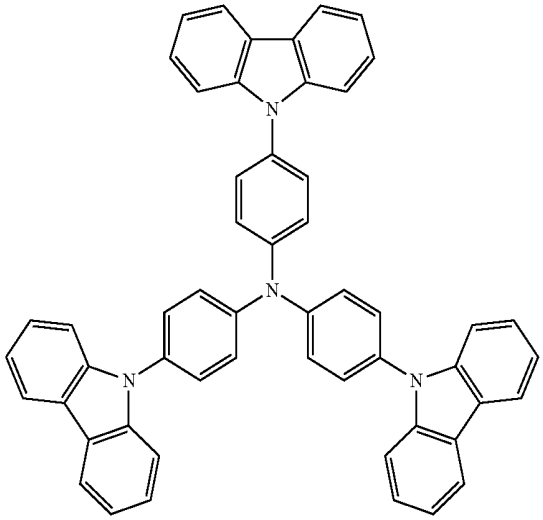
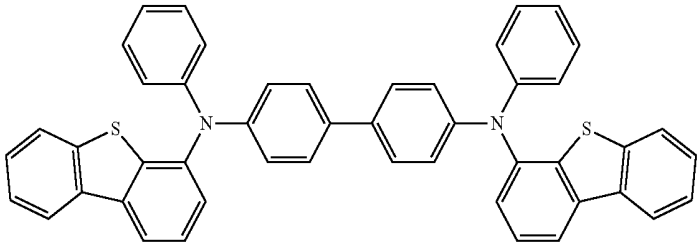
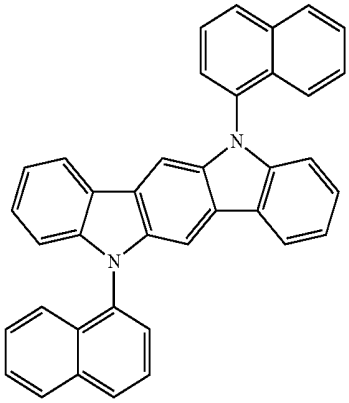
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Arylamine carbazole compounds		Adv. Mater. 6, 677 (1994), US20080124572
Triarylamine with (di)benzothiophene/ (di)benzofuran		US20070278938, US20080106190 US20110163302
Indolocarbazoles		Synth. Met. 111, 421 (2000)

TABLE A-continued

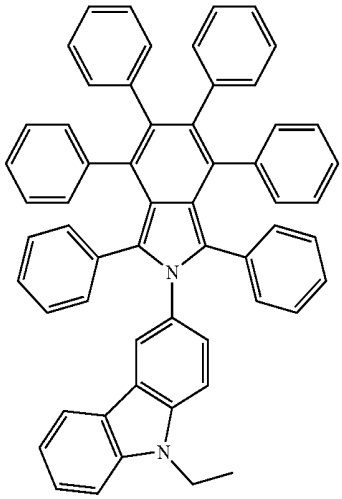
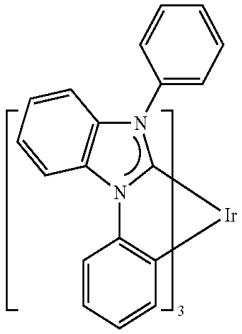
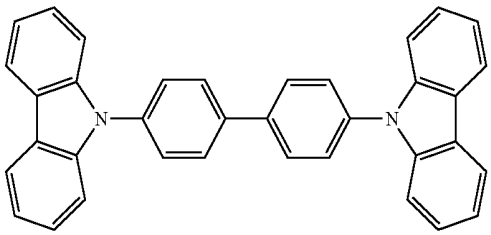
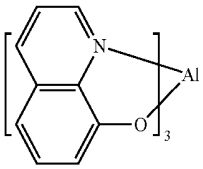
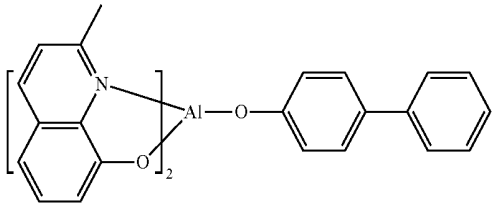
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Isoindole compounds		Chem. Mater. 15, 3148 (2003)
Metal carbene complexes		US20080018221
Phosphorescent OLED hosts materials		
Red hosts		
Arylcarbazoles		Appl. Phys. Lett. 78, 1622 (2001)
Metal 8-hydroxyquinolates (e.g., Alq_3, BAlq)		Nature 395, 151 (1998)
		US20060202194

TABLE A-continued

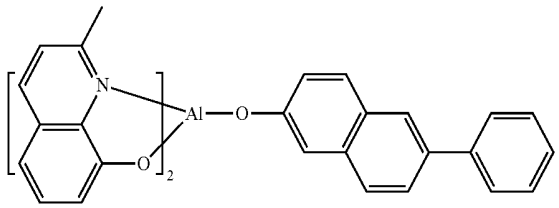
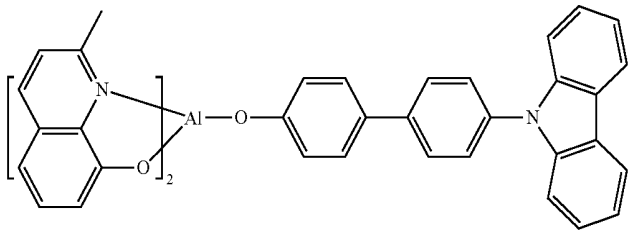
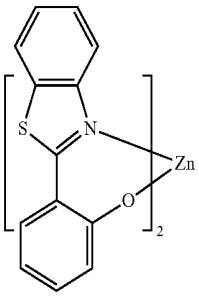
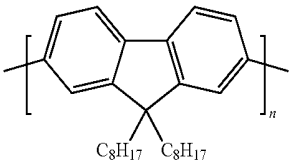
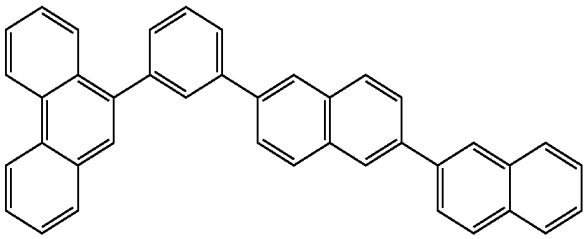
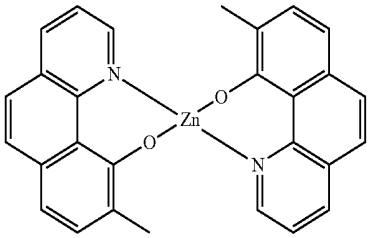
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2005014551
		WO2006072002
Metal phenoxy-benzothiazole compounds		Appl. Phys. Lett. 90, 123509 (2007)
Conjugated oligomers and polymers (e.g., polyfluorene)		Org. Electron. 1, 15 (2000)
Aromatic fused rings		WO2009066779, WO2009066778. WO2009063833, US20090045731, US20090045730. WO2009008311, US20090008605, US20090009065
Zinc complexes		WO2010056066

TABLE A-continued

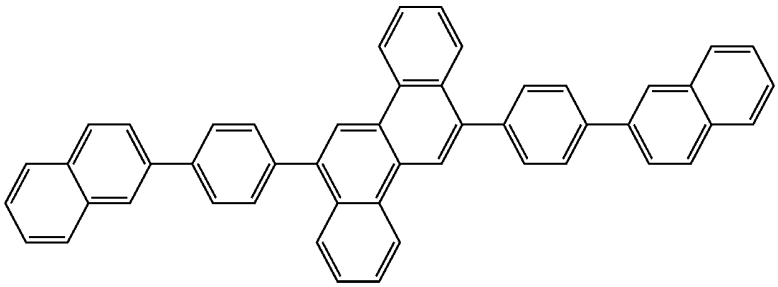
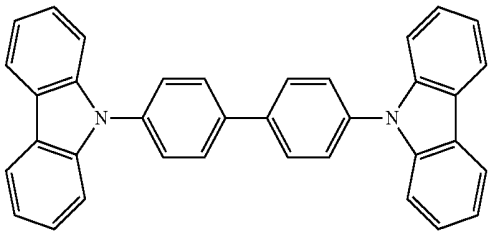
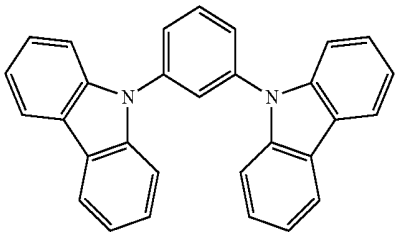
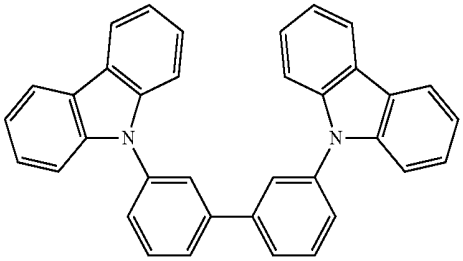
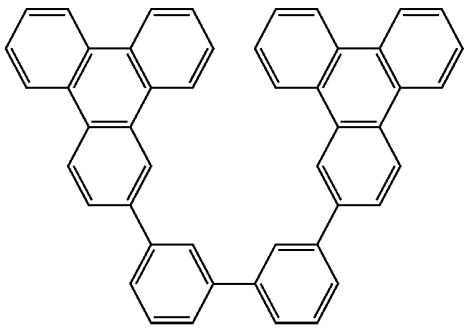
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Chrysene based compounds		WO2011086863
Green hosts		
Arylcarbazoles		Appl. Phys. Lett. 78, 1622 (2001)
		US20030175553
		WO2001039234
Aryltriphenylene compounds		US20060280965

TABLE A-continued

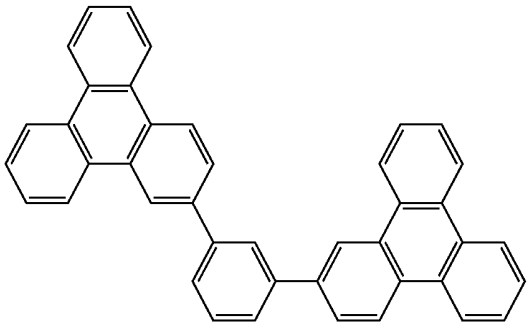
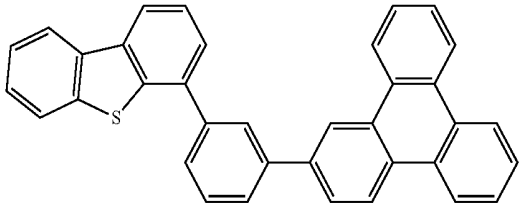
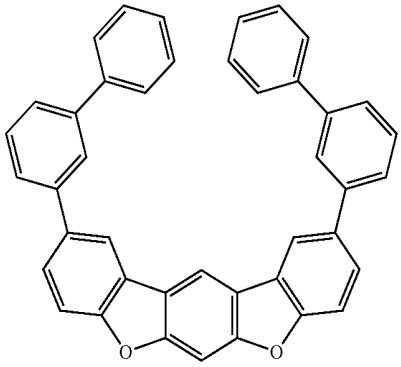
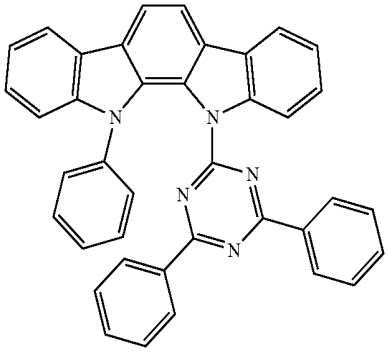
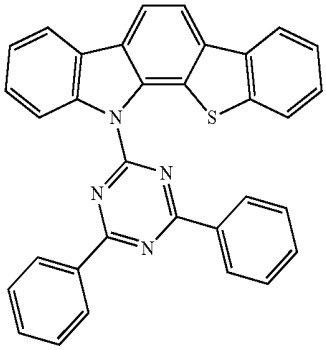
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20060280965
		WO2009021126
Poly-fused heteroaryl compounds		US20090309488 US20090302743 US20100012931
Donor acceptor type molecules		WO2008056746
		WO2010107244

TABLE A-continued

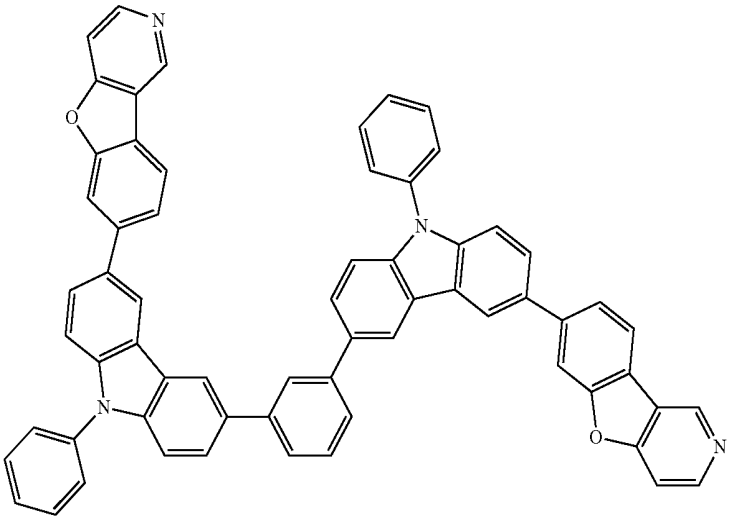
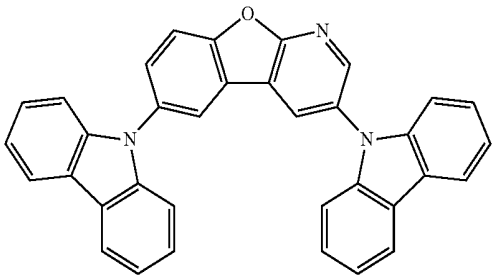
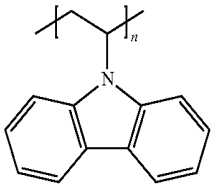
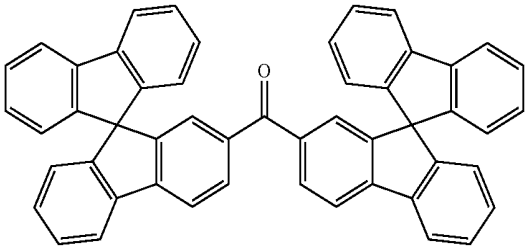
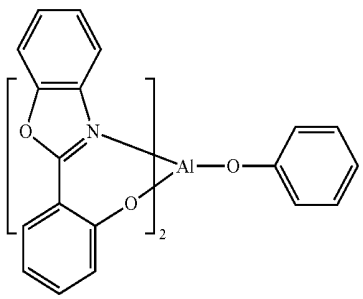
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Aza-carbazole/ DBT/DBF		JP2008074939
		US20100187984
Polymers (e.g., PVK)		Appl. Phys. Lett. 77, 2280 (2000)
Spirofluorene compounds		WO2004093207
Metal phenoxy-benzooxazole compounds		WO2005089025

TABLE A-continued

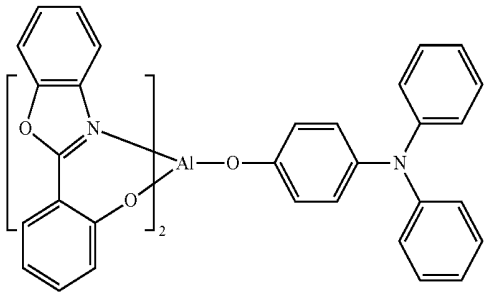
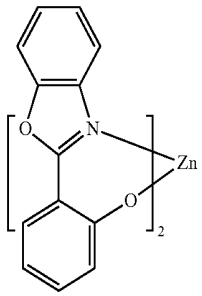
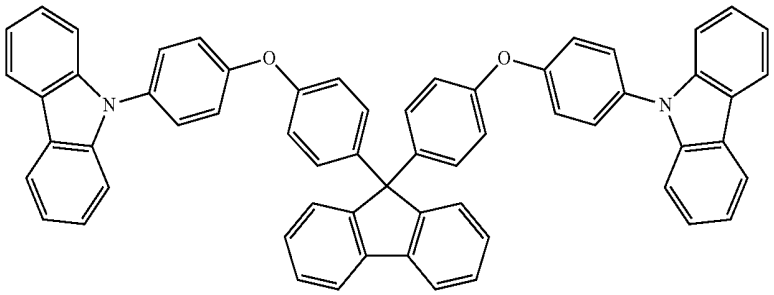
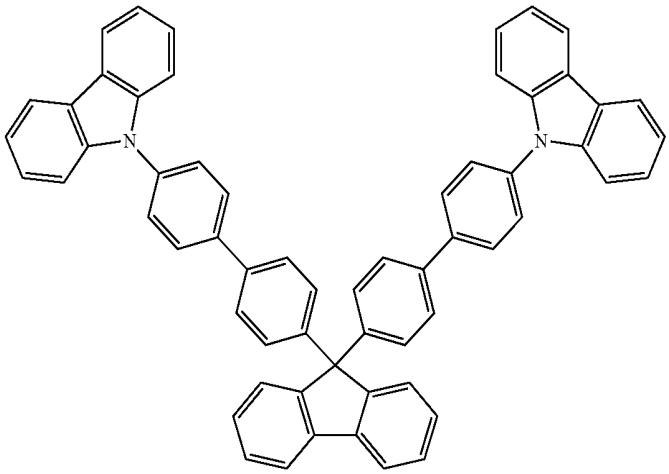
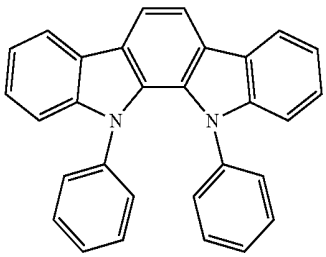
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2006132173
		JP200511610
Spirofluorene-carbazole compounds		JP2007254297
		JP2007254297
Indolocarbazoles		WO2007063796

TABLE A-continued

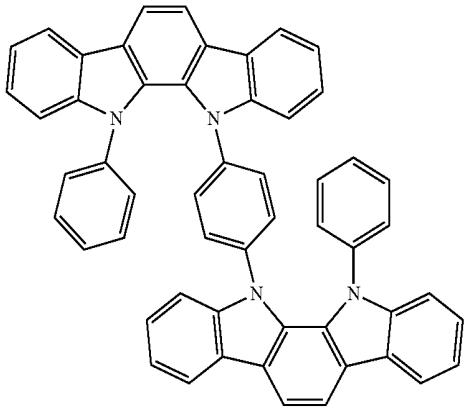
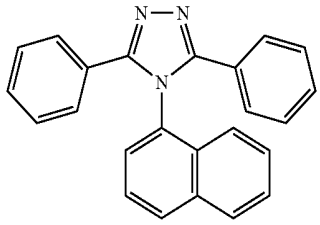
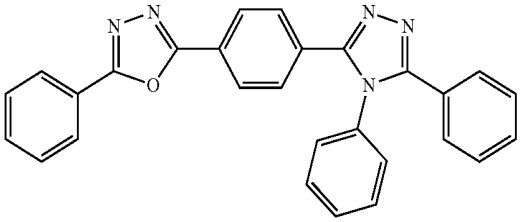
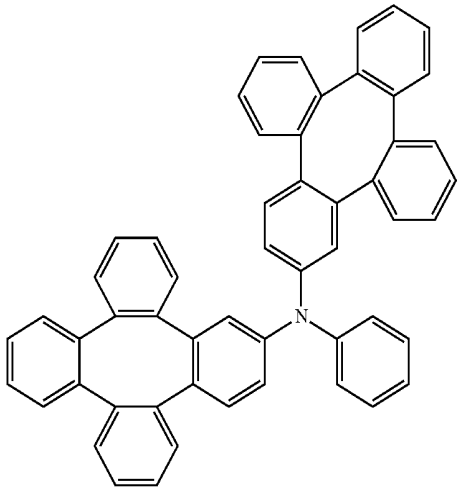
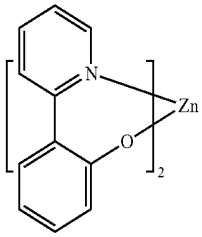
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2007063754
5-member ring electron deficient heterocycles (e.g., triazole, oxadiazole)		J. Appl. Phys. 90, 5048 (2001)
		WO2004107822
Tetraphenylene complexes		US20050112407
Metal phenoxypyridine compounds		WO2005030900

TABLE A-continued

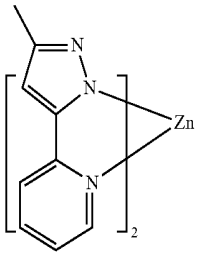
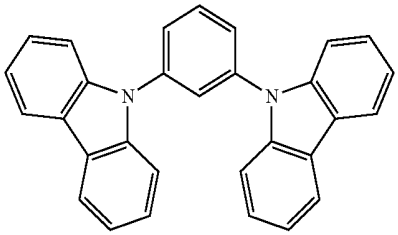
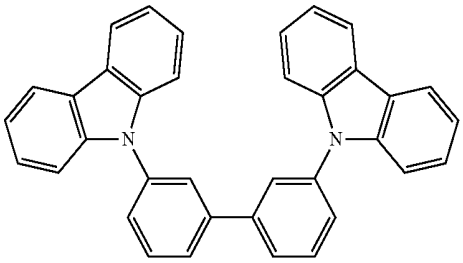
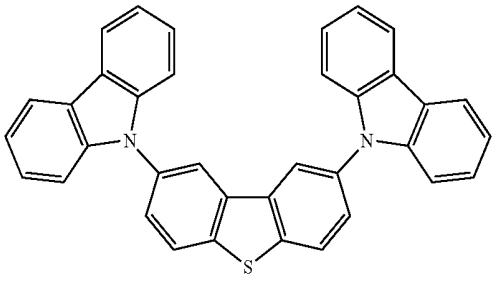
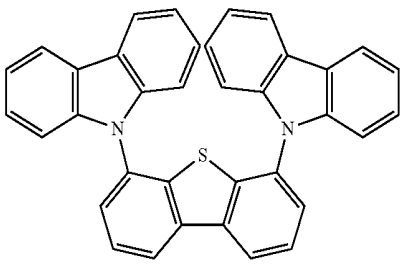
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Metal coordination complexes (e.g., Zn, Al with N^N ligands)		US20040137268, US20040137267
Blue hosts		
Arylcarbazoles		Appl. Phys. Lett, 82, 2422 (2003)
		US20070190359
Dibenzothiophene/ Dibenzofuran-carbazole compounds		WO2006114966, US20090167162
		US20090167162

TABLE A-continued

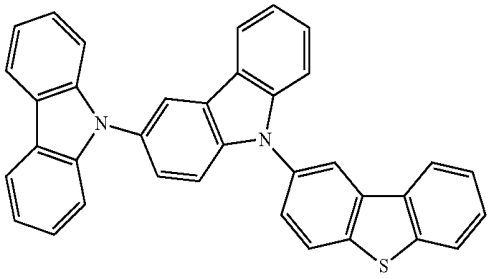
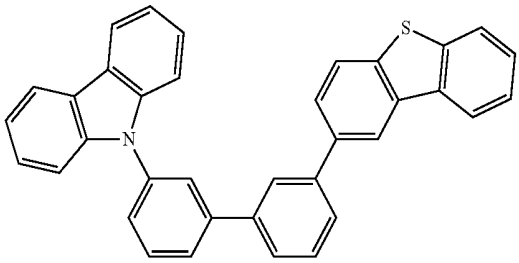
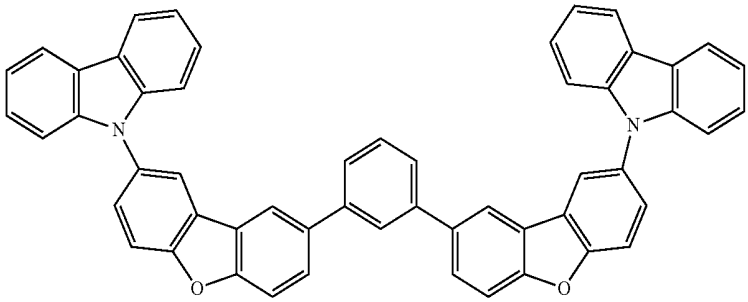
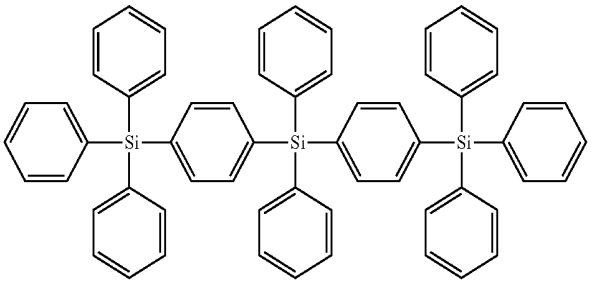
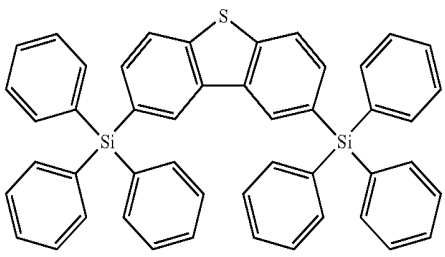
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2009086028
		US20090030202, US20090017330
		US20100084966
Silicon aryl compounds		US20050238919
		WO2009003898

TABLE A-continued

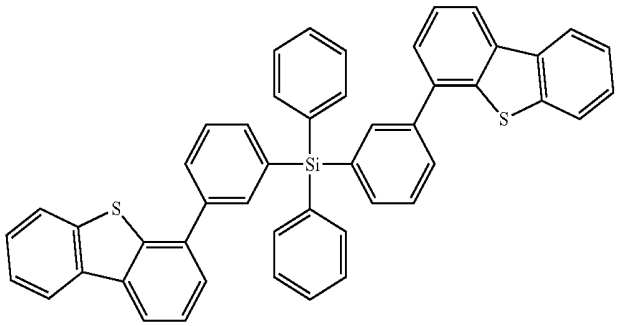
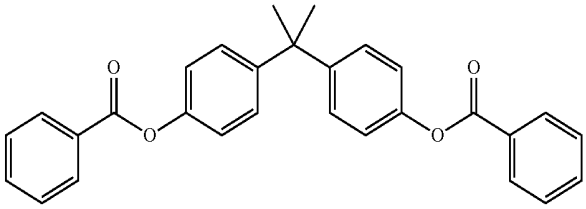
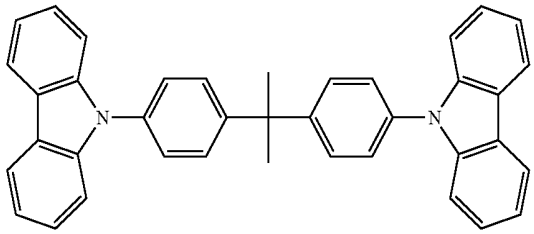
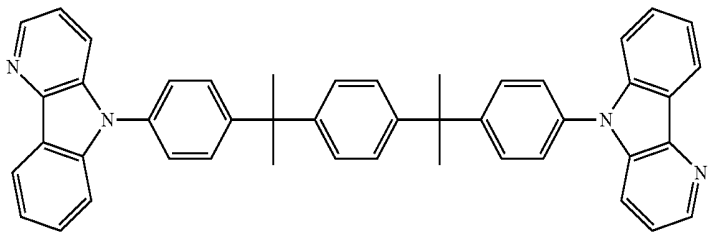
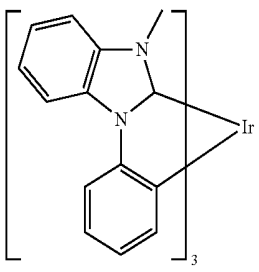
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Silicon/Germanium aryl compounds		EP2034538A
Aryl benzoyl ester		WO2006100298
Carbazole linked by non-conjugated groups		US20040115476
Aza-carbazoles		US20060121308
High triplet metal organometallic complex		U.S. Pat. No. 7,154,114

TABLE A-continued

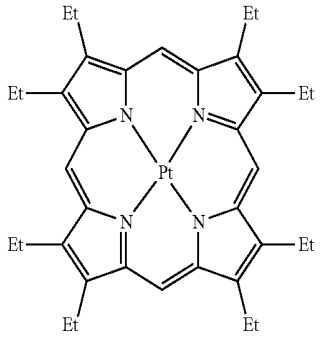
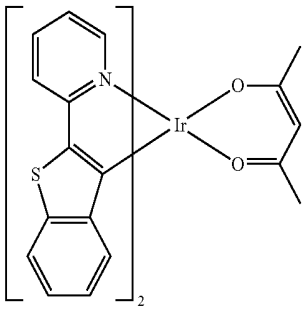
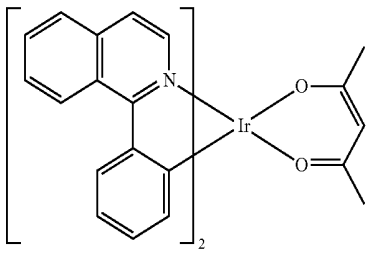
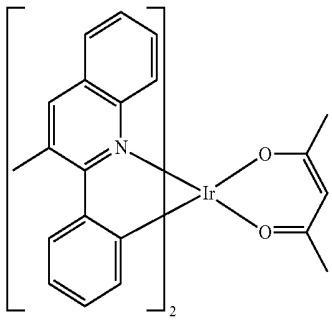
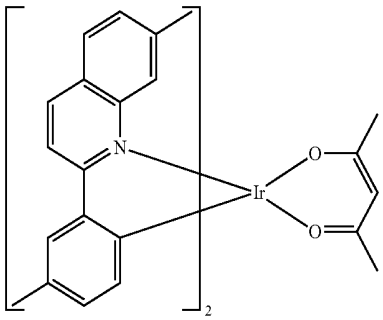
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Phosphorescent dopants Red dopants	
Heavy metal porphyrins (e.g., PtOEP)		Nature 395, 151 (1998)
Iridium(III) organometallic complexes		Appl. Phys. Lett. 78, 1622 (2001)
		US20030072964
		US20030072964
		US20060202194

TABLE A-continued

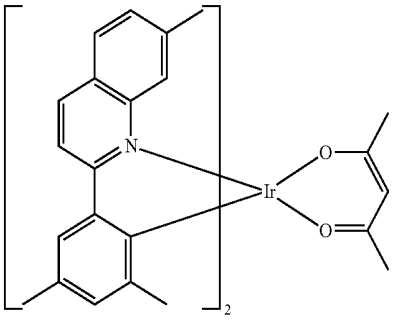
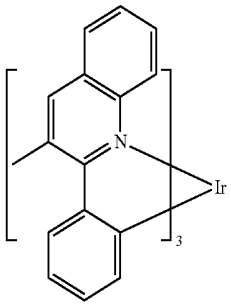
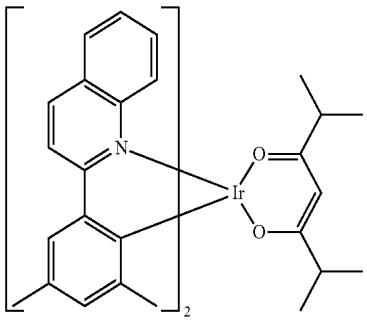
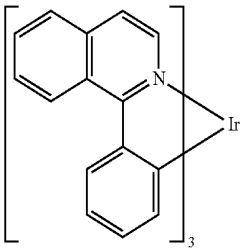
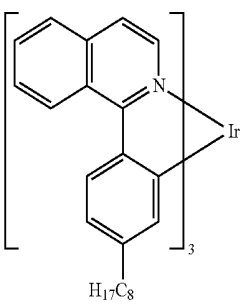
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20060202194
		US20070087321
		US20080261076 US20100090591
		US20070087321
		Adv. Mater. 19, 739 (2007)

TABLE A-continued

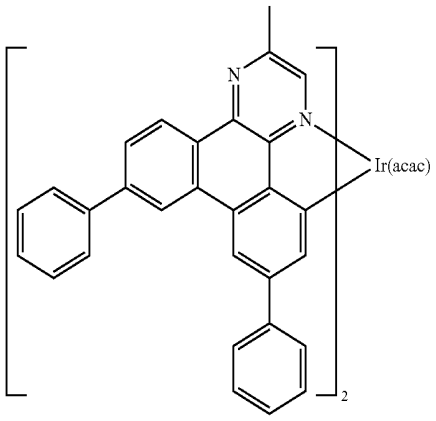
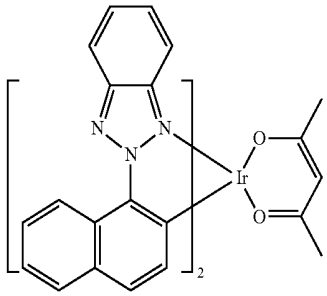
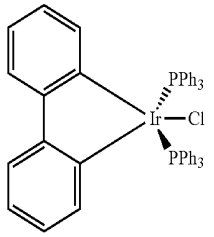
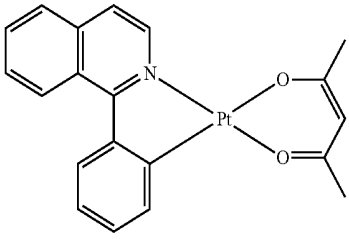
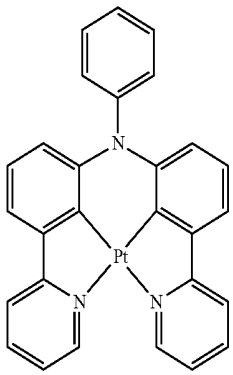
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2009100991
		WO2008101842
		U.S. Pat. No. 7,232,618
Platinum(II) organometallic complexes		WO2003040257
		US20070103060

TABLE A-continued

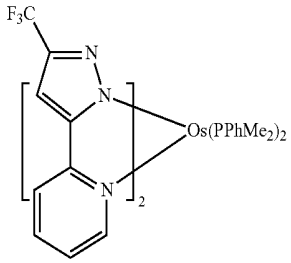
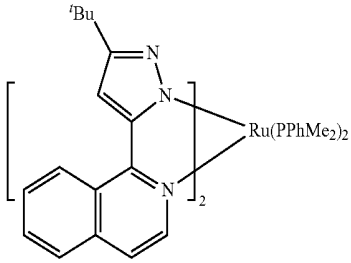
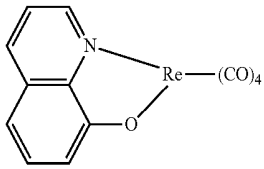
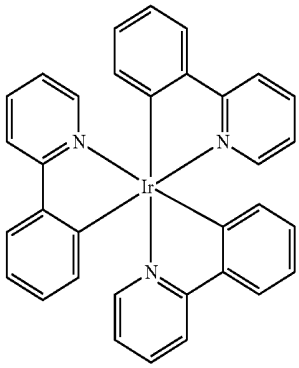
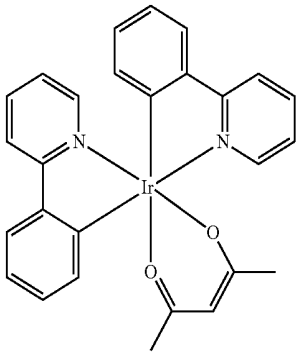
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Osmium(III) complexes		Chem. Mater. 17, 3532 (2005)
Ruthenium(II) complexes		Adv. Mater. 17, 1059 (2005)
Rhenium (I), (II), and (III) complexes		US20050244673
	Green dopants	
Iridium(III) organometallic complexes		Inorg. Chem. 40, 1704 (2001)
	and its derivatives	
		US20020034656

TABLE A-continued

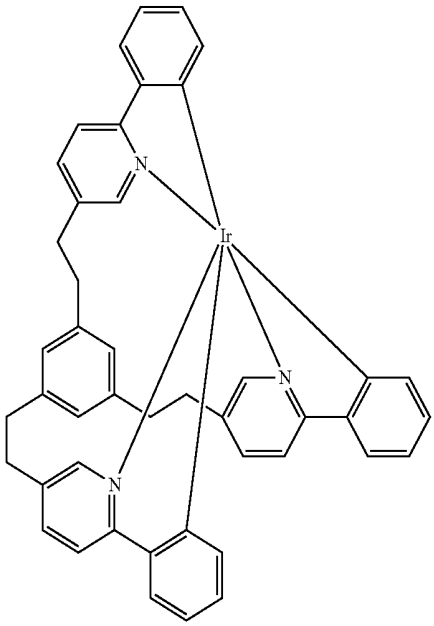
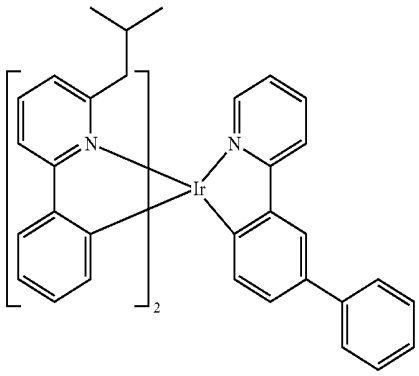
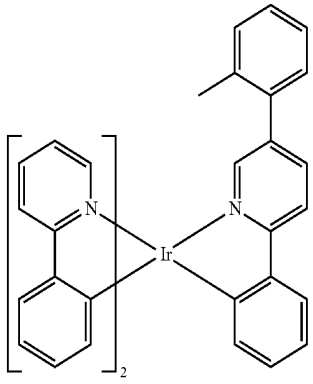
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		U.S. Pat. No. 7,332,232
		US20090108737
		WO2010028151

TABLE A-continued

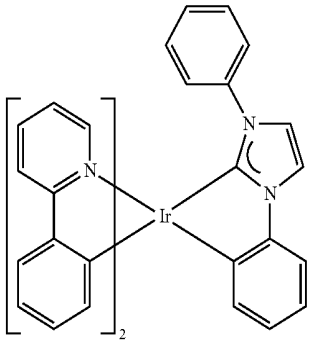
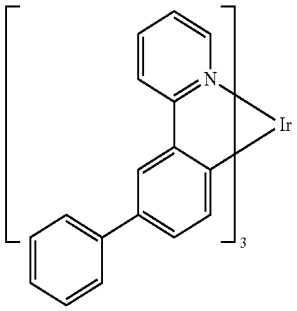
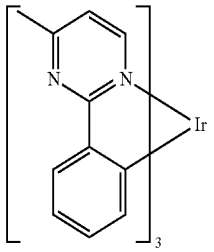
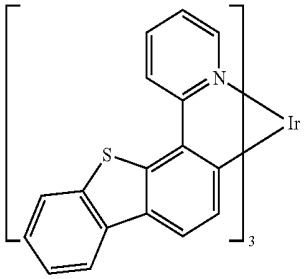
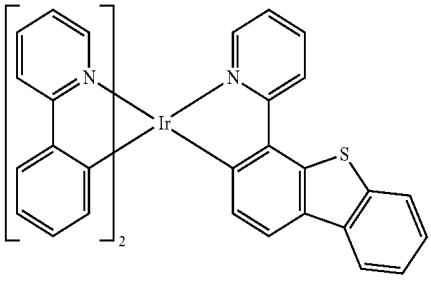
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		EP1841834B
		US20060127696
		US20090039776
		U.S. Pat. No. 6,921,915
		US20100244004

TABLE A-continued

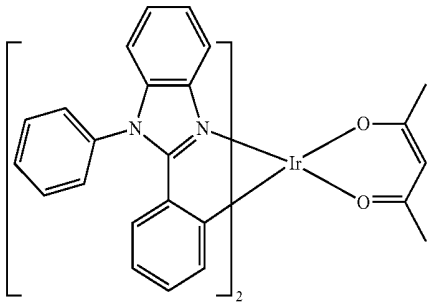
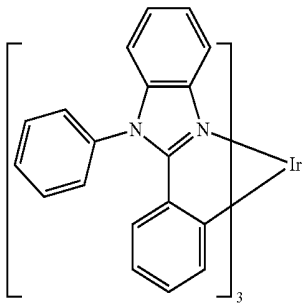
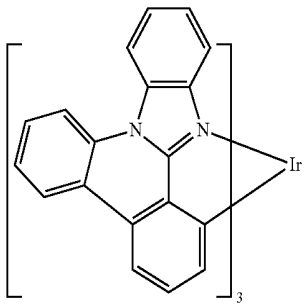
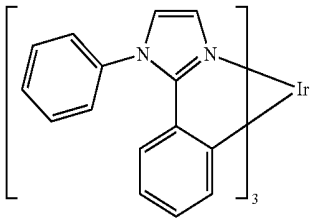
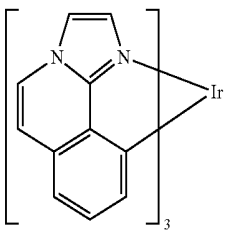
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		U.S. Pat. No. 6,687,266
		Chem. Mater. 16, 2480 (2004)
		US20076190359
		US 20060008670 JP2007123392
		WO2010086089, WO2011044988

TABLE A-continued

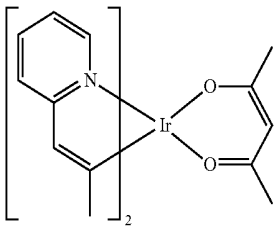
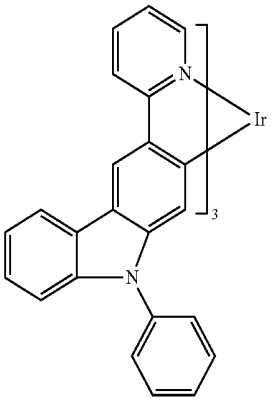
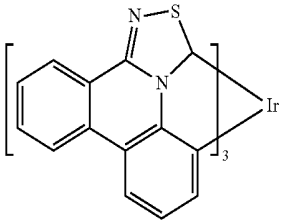
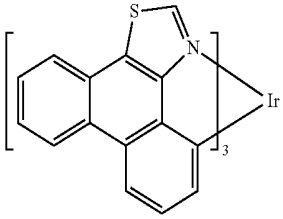
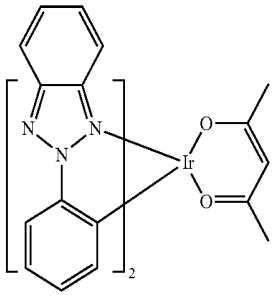
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Adv. Mater. 16, 2003 (2004)
		Angew. Chem. Int. Ed. 2006, 45, 7800
		WO2009050290
		US20090165846
		US20080015355

TABLE A-continued

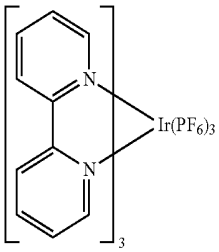
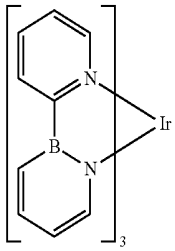
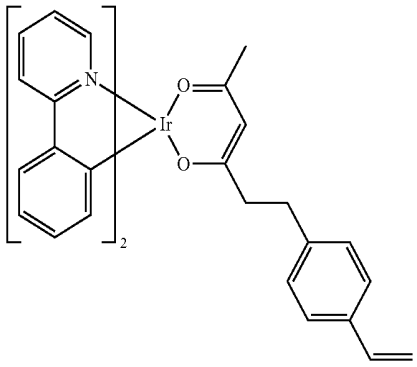
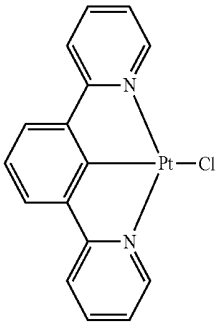
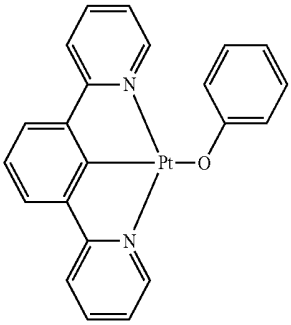
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20010015432
		US20100295032
Monomer for polymeric metal organometallic compounds		U.S. Pat. No. 7,250,226, U.S. Pat. No. 7,396,598
Pt(II) organometallic complexes, including polydentated ligands		Appl. Phys. Lett. 86, 153505 (2005)
		Appl. Phys. Lett. 86, 153505 (2005)

TABLE A-continued

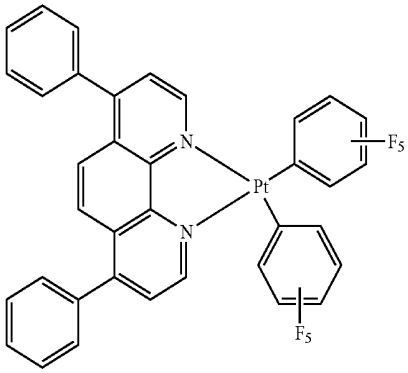
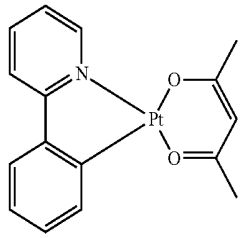
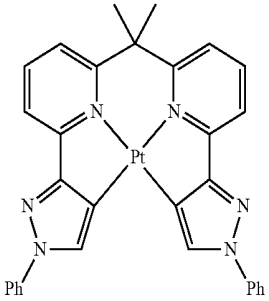
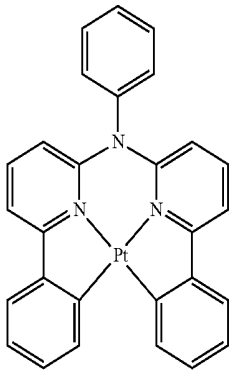
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Chem. Lett. 34, 592 (2005)
		WO2002015645
		US20060263635
		US20060182992 US20070103060

TABLE A-continued

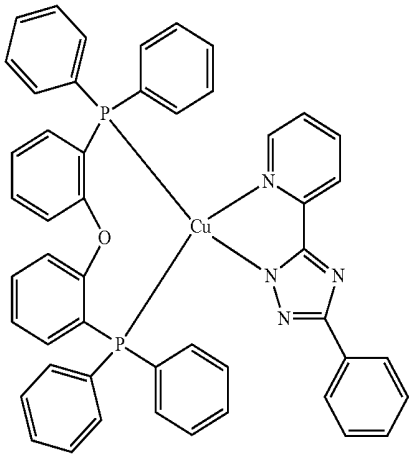
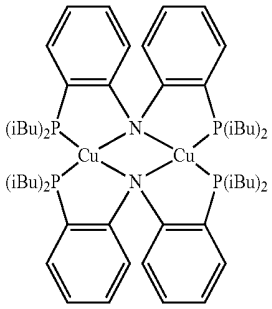
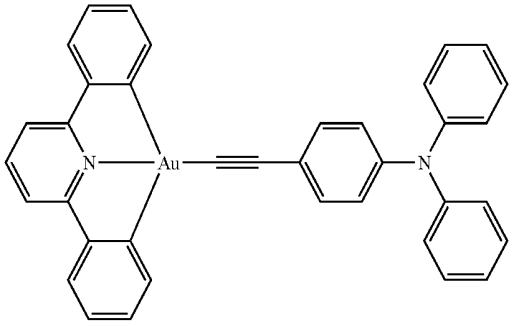
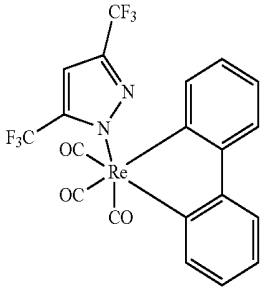
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Cu complexes		WO2009000673
		US20070111026
Gold complexes		Chem. Commun. 2906 (2005)
Rhenium(III) complexes		Inorg. Chem. 42, 1248 (2003)

TABLE A-continued

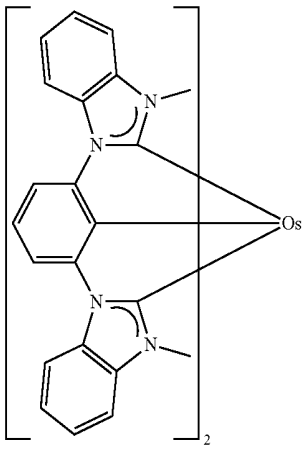
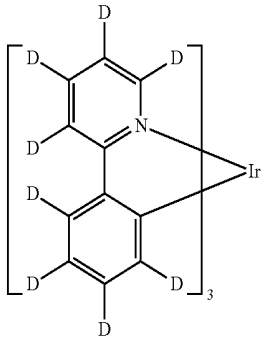
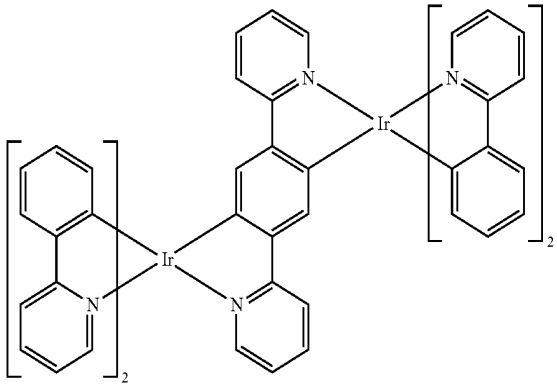
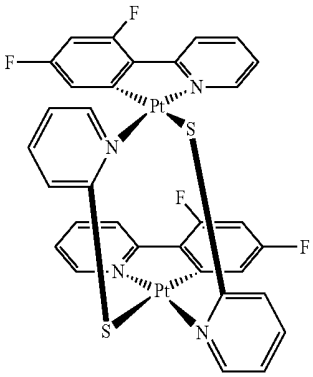
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Osmium(II) complexes		U.S. Pat. No. 7,279,704
Deuterated organometallic complexes		US20030138657
Organometallic complexes with two or more metal centers		US20030152802
		U.S. Pat. No. 7,090,928

TABLE A-continued

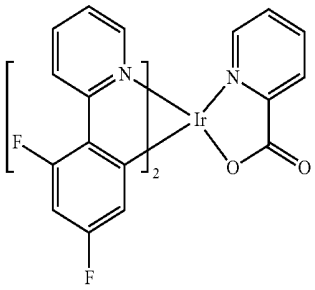
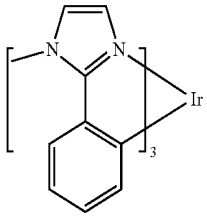
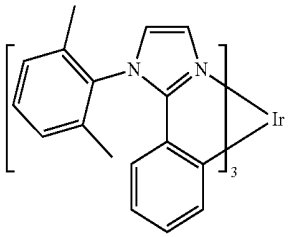
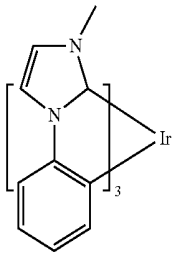
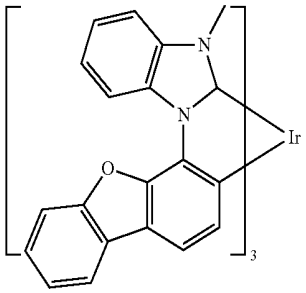
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Blue dopants	
Iridium(III) organometallic complexes		WO2002002714
		WO2006009024
		US20060251923 US20110057559 US20110204333
		U.S. Pat. No. 7,393,599, WO2006056418, US20050260441, WO2005019373
		U.S. Pat. No. 7,534,505

TABLE A-continued

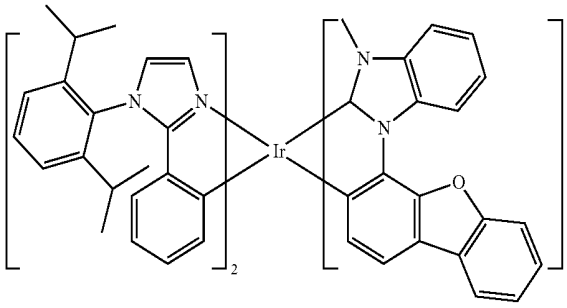
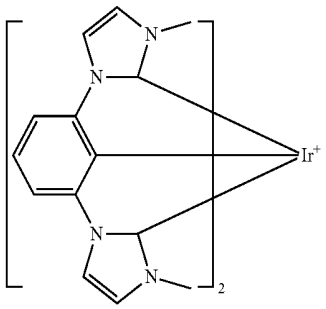
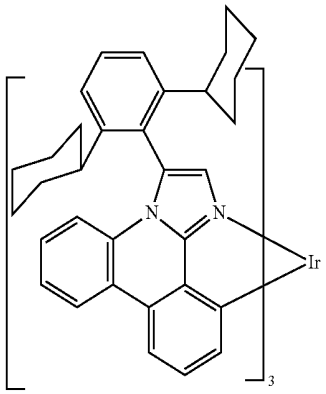
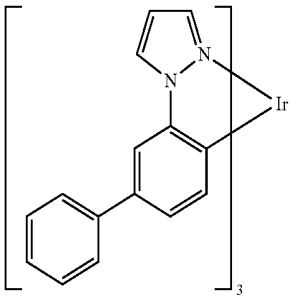
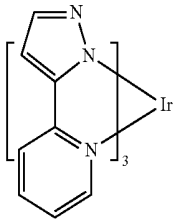
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2011051404
		U.S. Pat. No. 7,445,855
		US20070190359, US20080297033 US20100148663
		U.S. Pat. No. 7,338,722
		US20020134984

TABLE A-continued

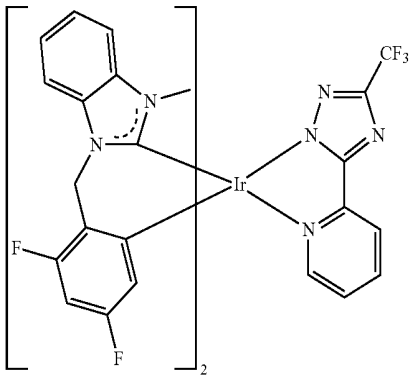
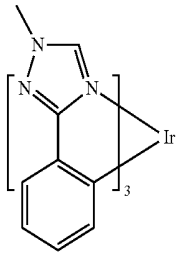
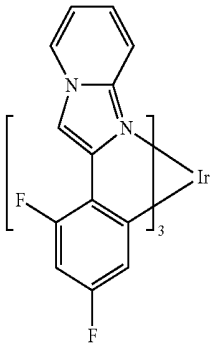
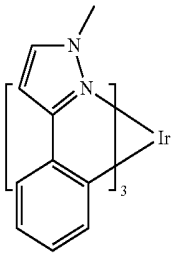
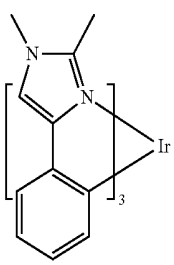
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Angew. Chem. Int. Ed. 47, 4542 (2008)
		Chem. Mater. 18, 5119 (2006)
		Inorg. Chem. 46, 4308 (2007)
		WO2005123873
		WO2005123873

TABLE A-continued

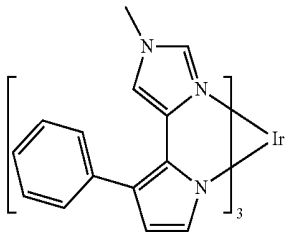
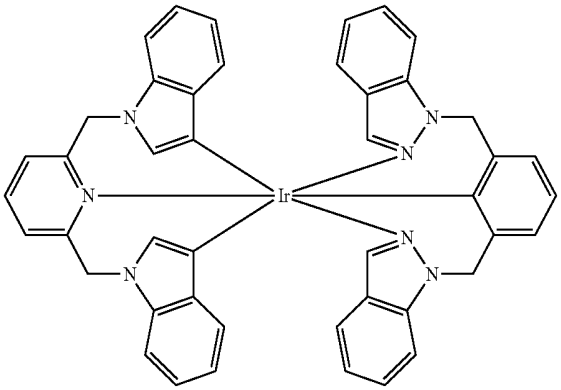
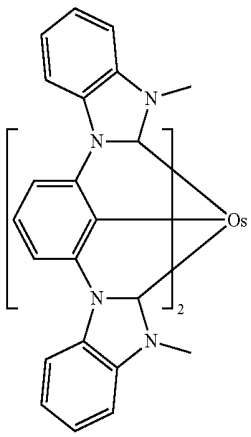
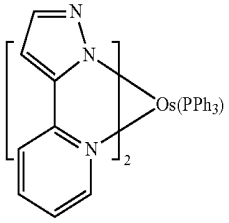
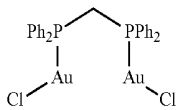
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2007004380
		WO2006082742
Osmium(II) complexes		U.S. Pat. No. 7,279,704
		Organometallics 23, 3745 (2004)
Gold complexes		Appl. Phys. Lett. 74, 1361 (1999)

TABLE A-continued

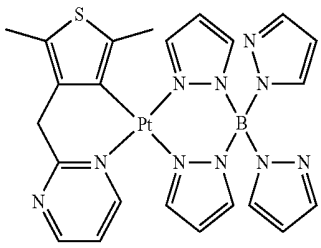
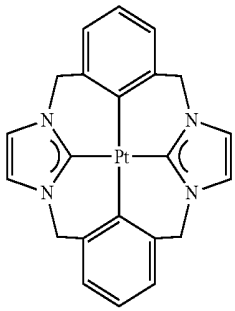
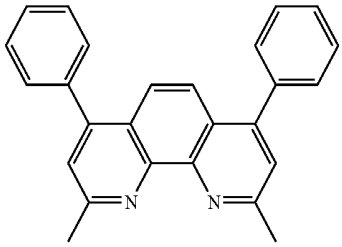
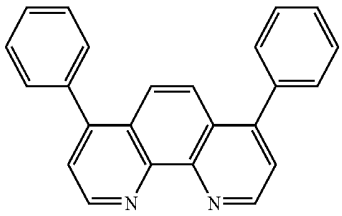
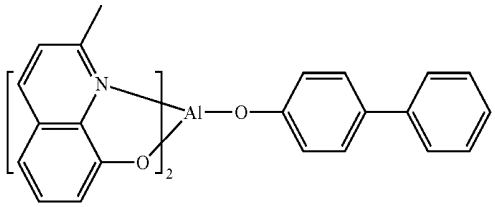
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Platinum(II) complexes		WO2006098120, WO2006103874
Pt tetradentate complexes with at least one metal-carbene bond		U.S. Pat. No. 7,655,323
	Exciton/hole blocking layer materials	
Bathocuprine compounds (e.g., BCP, BPhen)		Appl. Phys. Lett. 75, 4 (1999)
		Appl. Phys. Lett. 79, 449 (2001)
Metal 8-hydroxyquinolates (e.g., BAlq)		Appl. Phys. Lett. 81, 162 (2002)

TABLE A-continued

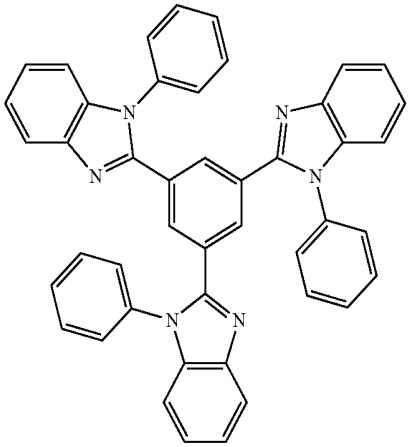
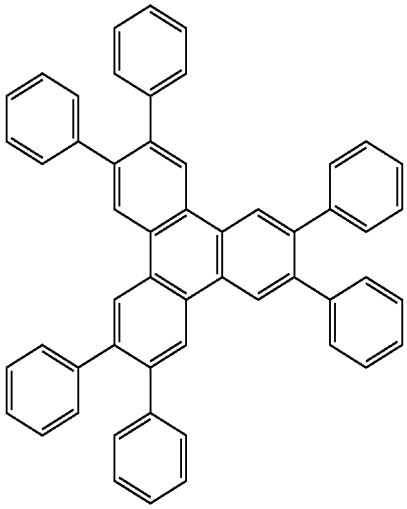
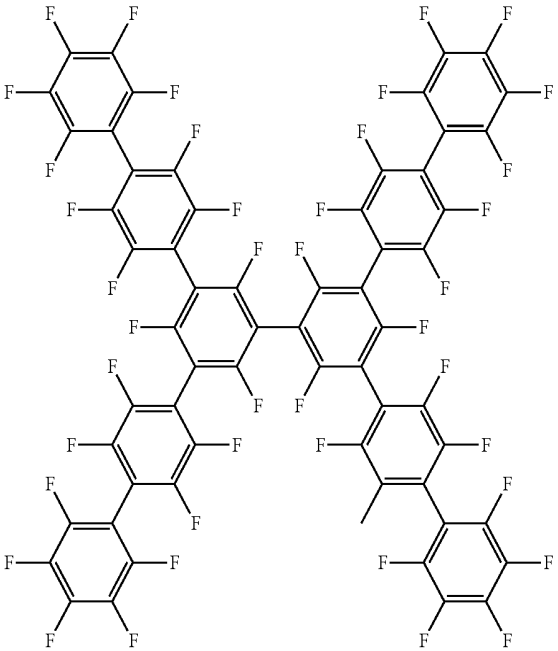
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
5-member ring electron deficient heterocycles such as triazole, oxadiazole, imidazole, benzoimidazole		Appl. Phys. Lett. 81, 162 (2002)
Triphenylene compounds		US20050025993
Fluorinated aromatic compounds		Appl. Phys. Lett. 79, 156 (2001)

TABLE A-continued

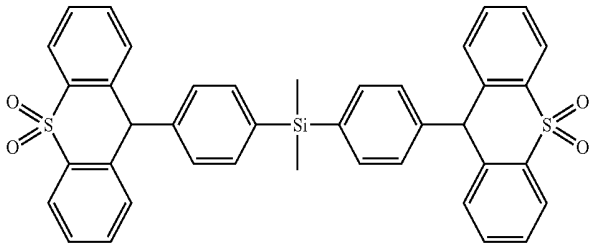
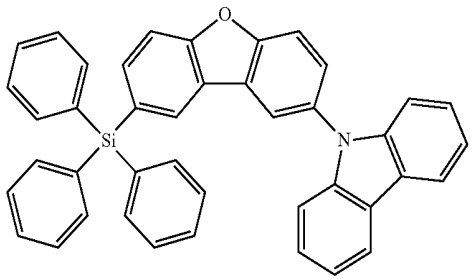
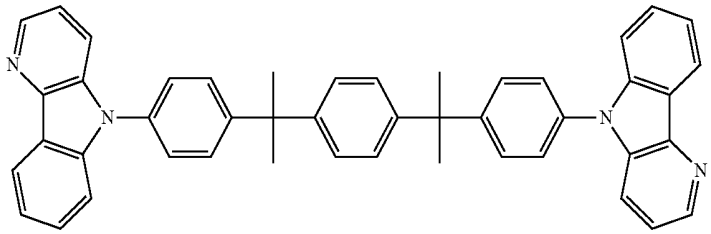
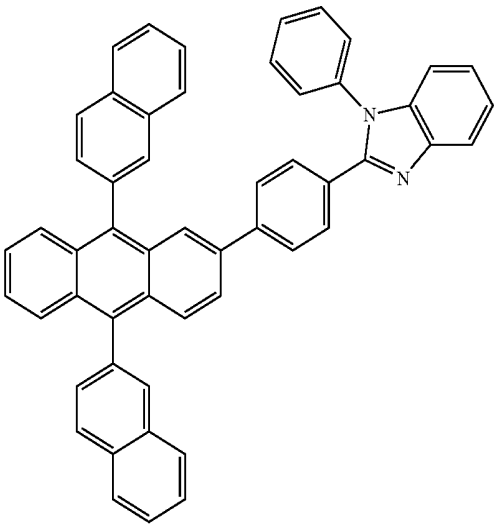
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Phenothiazine-S-oxide		WO2008132085
Silylated five-membered nitrogen, oxygen, sulfur or phosphorus dibenzoheterocycles		WO2010079051
Aza-carbazoles		US20060121308
Electron transporting materials		
Anthracene-benzoimidazole compounds		WO2003060956

TABLE A-continued

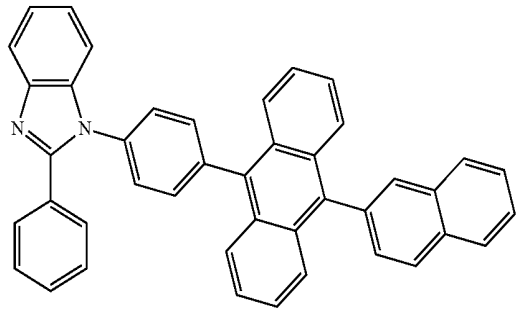
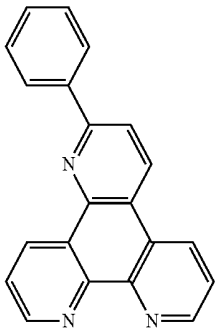
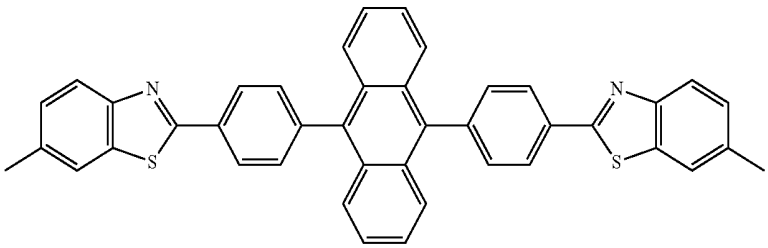
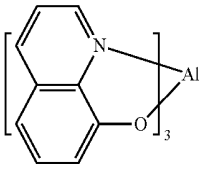
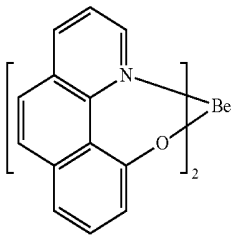
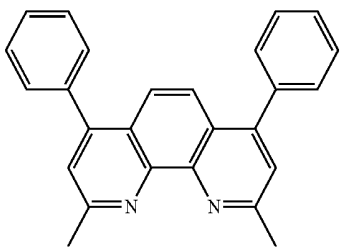
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20090179554
Aza triphenylene derivatives		US20090115316
Anthracene-benzothiazole compounds		Appl. Phys. Lett. 89, 063504 (2006)
Metal 8-hydroxyquinolates (e.g., Alq_3, Zrq_4)		Appl. Phys. Lett. 51, 913 (1987) U.S. Pat. No. 7,230,107
Metal hydroxy-benoquinolates		Chem. Lett. 5, 905 (1993)
Bathocuprine compounds such as BCP, BPhen, etc		Appl. Phys. Lett. 91, 263503 (2007)

TABLE A-continued

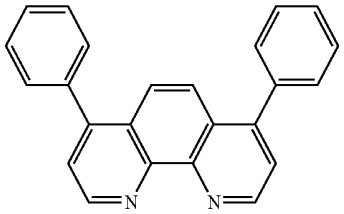
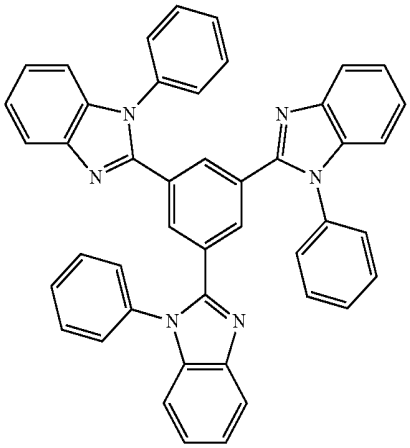
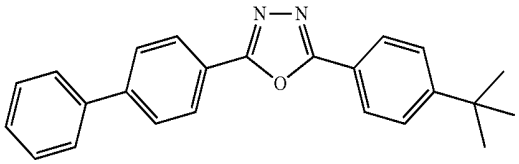
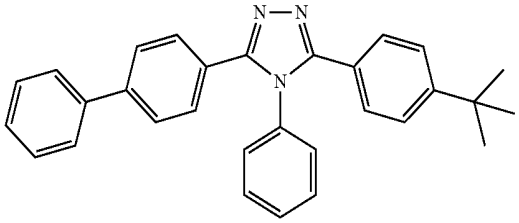
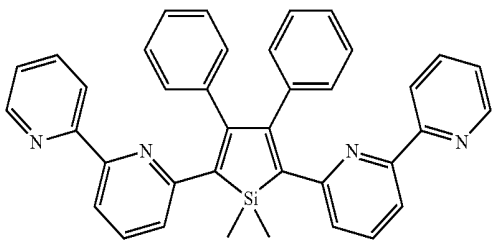
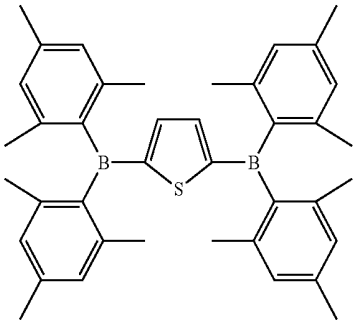
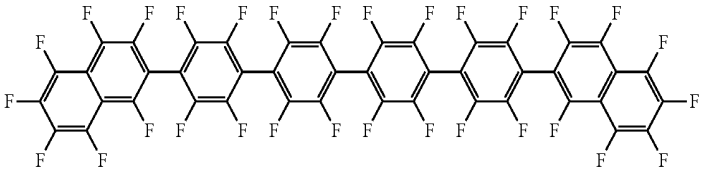
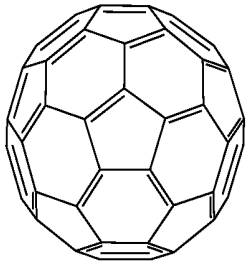
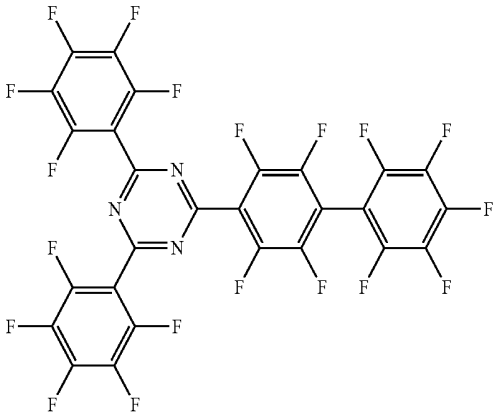
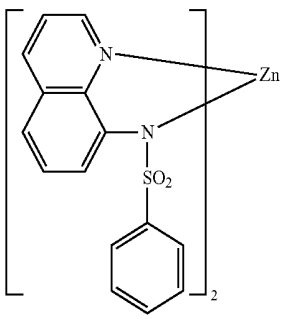
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Appl. Phys. Lett. 79, 449 (2001)
5-member ring electron deficient heterocycles (e.g., triazole, oxadiazole, imidazole, benzoimidazole)		Appl. Phys. Lett. 74, 865 (1999)
		Appl. Phys. Lett. 55, 1489 (1989)
		Jpn. J. Apply. Phys. 32, L917 (1993)
Silole compounds		Org. Electron. 4, 113 (2003)

TABLE A-continued

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Arylborane compounds		J. Am. Chem. Soc. 120, 9714 (1998)
Fluorinated aromatic compounds		J. Am. Chem. Soc. 122, 1832 (2000)
Fullerene (e.g. C60)		US20090101870
Triazine complexes		US20040036077
Zn (N^N) complexes		U.S. Pat. No. 6,528,187

[0179] It is understood that the various embodiments described herein are by way of example only, and are not intended to limit the scope of the invention. For example, many of the materials and structures described herein may be substituted with other materials and structures without deviating from the spirit of the invention. The present invention as claimed may therefore include variations from the particular examples and preferred embodiments described herein, as will be apparent to one of skill in the art. It is understood that various theories as to why the invention works are not intended to be limiting.

1. A first mixture comprising:

a first compound;

a second compound; and

a third compound,

wherein the first compound, the second compound, and the third compound are all organic compounds and have different chemical structures from each other,

wherein the first compound, the second compound, and the third compound each has an evaporation temperature T**1**, T**2**, and T**3**, respectively, and is in the range of 150 to 350° C.,

wherein the T**1**, T**2**, and T**3** differ from each other by less than 20° C.,

wherein the first compound has a concentration C**1** in the first mixture and a concentration C**2** in a film deposited by evaporating the first mixture in a high vacuum deposition tool under a first deposition condition which is defined as depositing at a 2 Å/sec deposition rate with a chamber base pressure between 1×10^{-6} Torr to 1×10^{-9} Torr onto a surface positioned at a predefined distance from the first mixture,

wherein |(C**1**-C**2**)/C**1**| is less than 5%,

wherein the first compound has a concentration C**1**' in a second mixture of the first and second compounds or has a concentration C**1**" in a third mixture of the first and third compounds, and the first compound has a concentration C**2**' in a film formed by evaporating the second mixture under the first deposition condition or has a concentration C**2**" in a film formed by evaporating the third mixture under the first deposition condition, and

wherein at least one of |(C**1**'-C**2**')/C**1**'| and |(C**1**"-C**2**")/C**1**"| is greater than 5%.

2. The first mixture of claim **1**, wherein both of |(C**1**'-C**2**')/C**1**'| and |(C"-C**2**")/C**1**"| are larger than 5%.

3. The first mixture of claim **1**, wherein T**1**, T**2**, and T**3** are in the range of 200 to 350° C.

4. The first mixture of claim **1**, wherein |(C**1**-C**2**)/C**1**| is less than 3%.

5. The first mixture of claim **1**, wherein the second compound has a concentration C**3** in the first mixture, and the second compound has a concentration C**4** in a film formed by evaporating the first mixture under the first condition;

wherein |(C**3**-C**4**)/C**3**| is less than 5%.

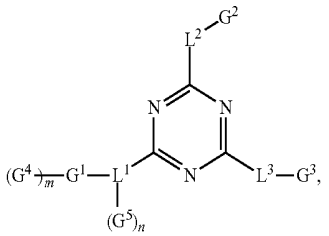
6. The first mixture of claim **1**, wherein the second compound has a concentration C**3** in the first mixture, and the second compound has a concentration C**4** in a film formed by evaporating the first mixture under the first condition;

wherein |(C**3**-C**4**)/C**3**| is larger than 5%.

7. The first mixture of claim **1**, wherein the first compound, the second compound, and the third compound are each independently selected from the group consisting of a h-host, an e-host, and an emitter.

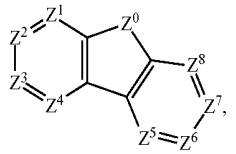
8. The first mixture of claim **7**, wherein the e-host material is selected from the group consisting of a compound having a structure of

Formula I



and and compound having a structure

Formula II



wherein G^1 is selected from the group consisting of dibenzofuran, dibenzothiophene, dibenzoselenophene, and fluorene;

wherein L^1, L^2 and L^3 are each independently selected from the group consisting of direct bond, phenyl, biphenyl, terphenyl, pyridine, pyrimidine, and combinations thereof;

wherein G^4 is selected from the group consisting of phenyl, biphenyl, terphenyl, naphthalene, phenanthrene, pyridine, pyrimidine, pyrazine, quinoline, isoquinoline, phenanthroline, fluorene, and combinations thereof;

wherein G^2, G^3, and G^5 are each independently selected from the group consisting of phenyl, biphenyl, terphenyl, fluorene, naphthalene, phenanthrene, pyridine, pyrimidine, pyrazine, quinoline, isoquinoline, phenanthroline, aza-fluorene, and combinations thereof;

wherein G^2, G^3, G^4, and G^5 are each optionally further substituted with one or more unfused substituents selected from the group consisting of deuterium, alkyl, alkoxyl, cycloalkyl, cycloalkoxyl, halogen, nitro, nitrile, silyl, phenyl, biphenyl, terphenyl, pyridine, and combinations thereof;

wherein m is an integer from 0 to 7,

wherein n is an integer from 0 to 4;

wherein, when m or n is larger than 1, each G^4 or G^5 can be same or different;

wherein when n is 0, m is equal to or greater than 1, and each G^4 is selected from the group consisting of phenyl, and biphenyl;

wherein when n is equal to or greater than 1, L^1 is not a direct bond;

wherein when m and n are both 0, L^1 is biphenyl;

wherein when G^4 is present and is fluorene, L^1 is not a direct bond;

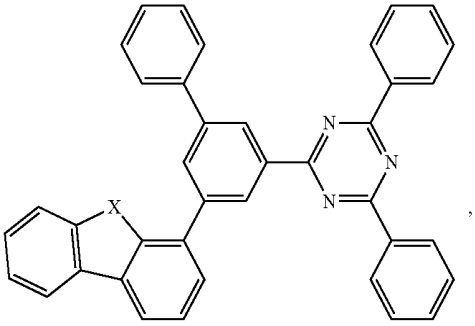
wherein Z^0 is selected from the group consisting of O, S, Se, NR^1 and CR^2R^3;

wherein Z^1 to Z^8 are each independently selected from the group consisting of N and CR^4, and at least one of Z^1 to Z^8 is N; and

wherein R^1, R^2, R^3 and R^4 are each independently selected from the group consisting of hydrogen, deuterium, alkyl, alkoxyl, cycloalkyl, cycloalkoxyl, halogen, nitro, nitrile, silyl, aryl, heteraryl and combinations thereof.

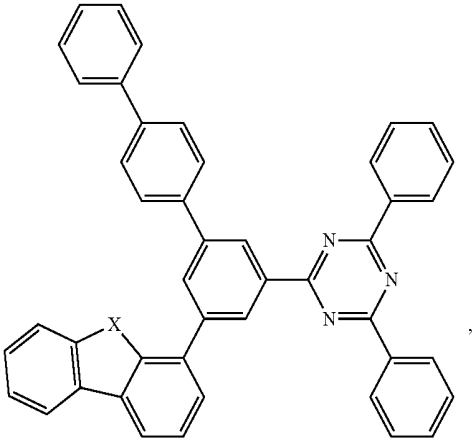
9. The first mixture of claim **7**, wherein the e-host is selected from the group consisting of:

Compound A1 through A3, each represented by the formula



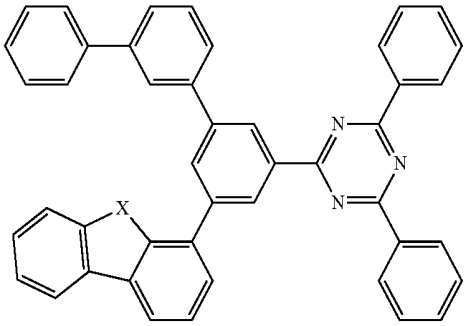
wherein in Compound A1: X = O,
in Compound A2: X = S,
in Compound A3: X = Se

Compound A4 through A6, each represented by the formula



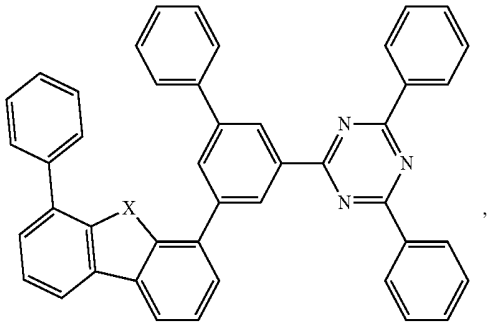
wherein in Compound A4: X = O,
in Compound A5: X = S,
in Compound A6: X = Se

Compound A7 through A9, each represented by the formula



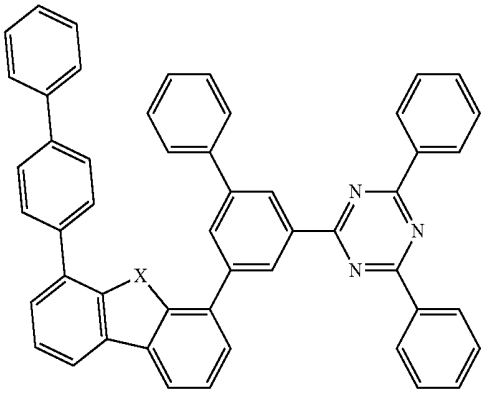
wherein in Compound A7: X = O,
in Compound A8: X = S,
in Compound A9: X = Se

Compound A10 through A12, each represented by the formula



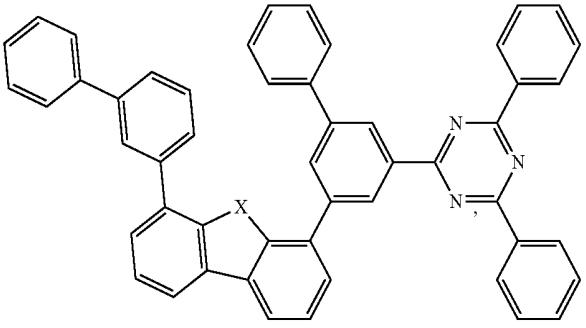
wherein in Compound A10: X = O,
in Compound A11: X = S,
in Compound A12: X = Se

Compound A13 through A15, each represented by the formula



wherein in Compound A13: X = O,
in Compound A14: X = S,
in Compound A15: X = Se

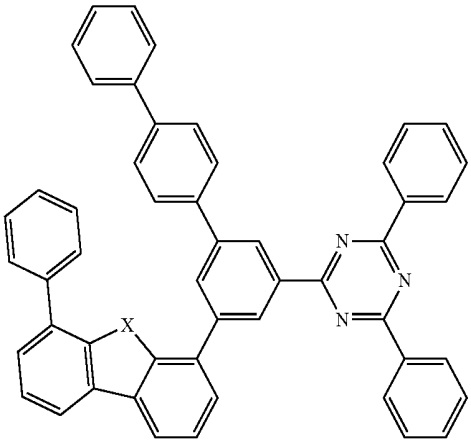
Compound A16 through A18, each represented by the formula



wherein in Compound A16: X = O,
in Compound A17: X = S,
in Compound A18: X = Se

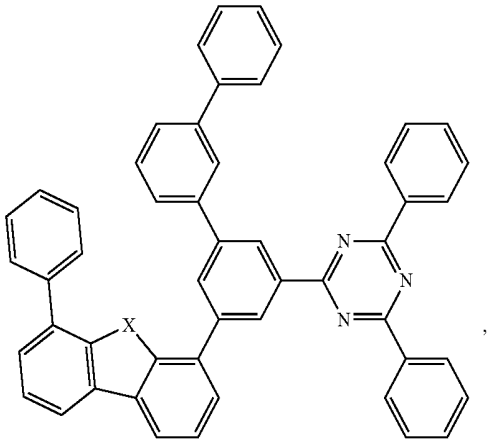
-continued

Compound A19 through A21, each represented by the formula



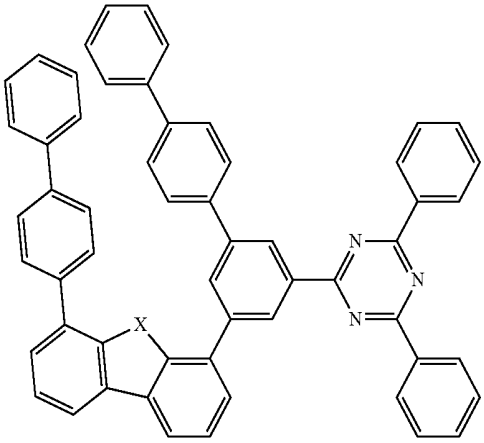
wherein in Compound A19: X = O,
in Compound A20: X = S,
in Compound A21: X = Se

Compound A22 through A24, each represented by the formula



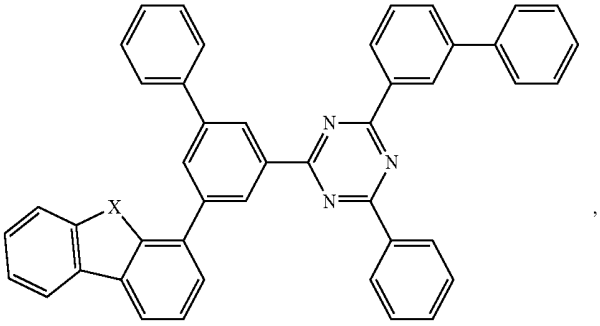
wherein in Compound A22: X = O,
in Compound A23: X = S,
in Compound A24: X = Se

Compound A25 through A27, each represented by the formula



wherein in Compound A25: X = O,
in Compound A26: X = S,
in Compound A27: X = Se

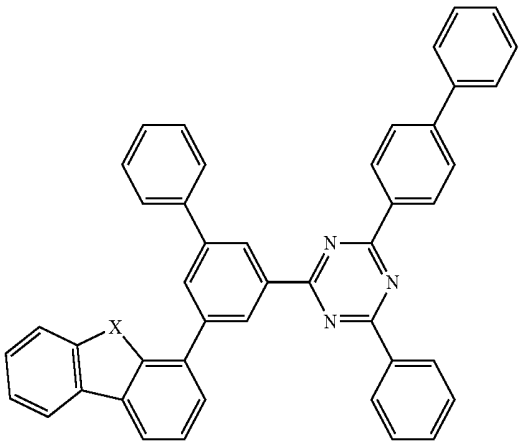
Compound A28 through A30, each represented by the formula



wherein in Compound A28: X = O,
in Compound A29: X = S,
in Compound A30: X = Se

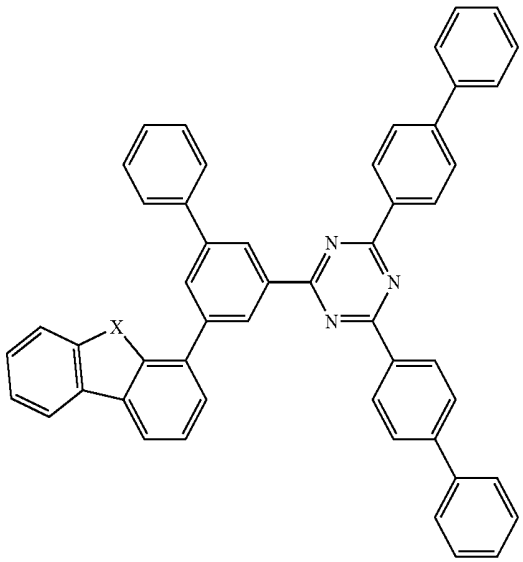
-continued

Compound A31 through A33, each represented by the formula



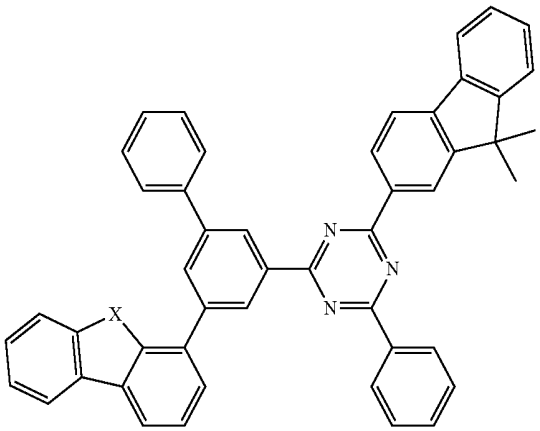
wherein in Compound A31: X = O,
in Compound A32: X = S,
in Compound A33: X = Se

Compound A34 through A36, each represented by the formula



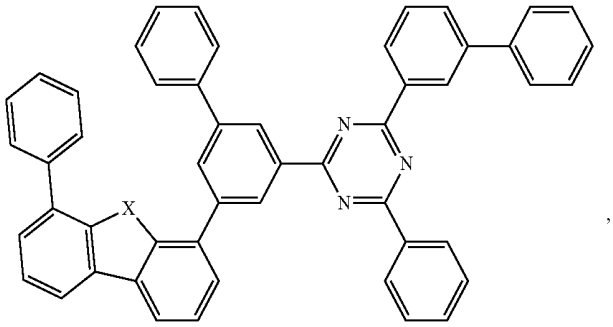
wherein in Compound A34: X = O,
in Compound A35: X = S,
in Compound A36: X = Se

Compound A37 through A39, each represented by the formula



wherein in Compound A37: X = O,
in Compound A38: X = S,
in Compound A39: X = Se

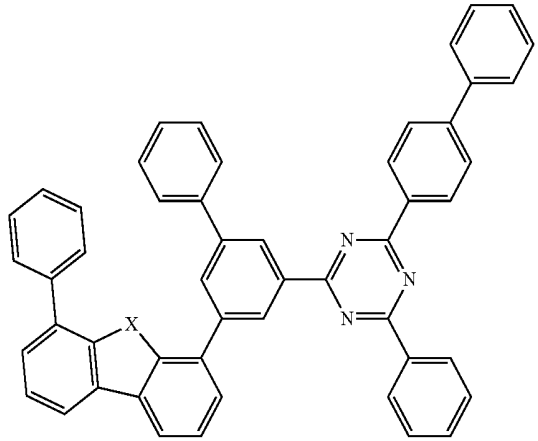
Compound A40 through A42, each represented by the formula



wherein in Compound A40: X = O,
in Compound A41: X = S,
in Compound A42: X = Se

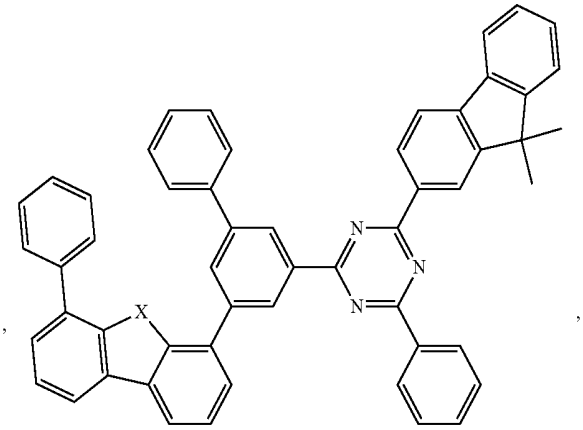
-continued

Compound A43 through A45, each represented by the formula



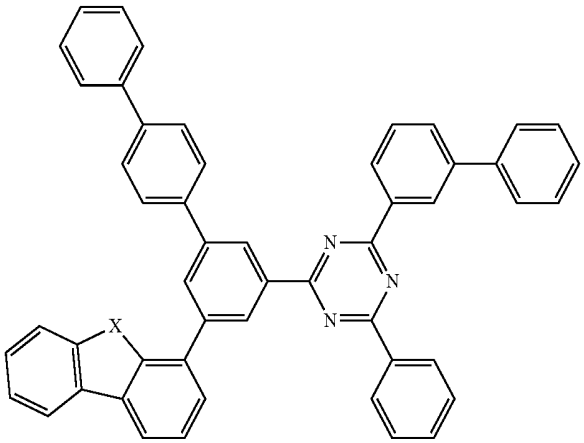
wherein in Compound A43: X = O,
in Compound A44: X = S,
in Compound A45: X = Se

Compound A46 through A48, each represented by the formula



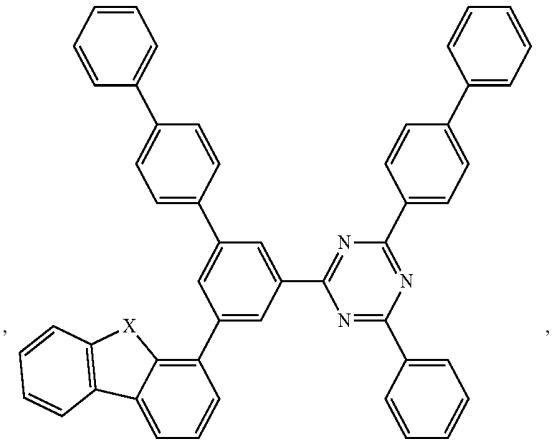
wherein in Compound A46: X = O,
in Compound A47: X = S,
in Compound A48: X = Se

Compound A49 through A51, each represented by the formula



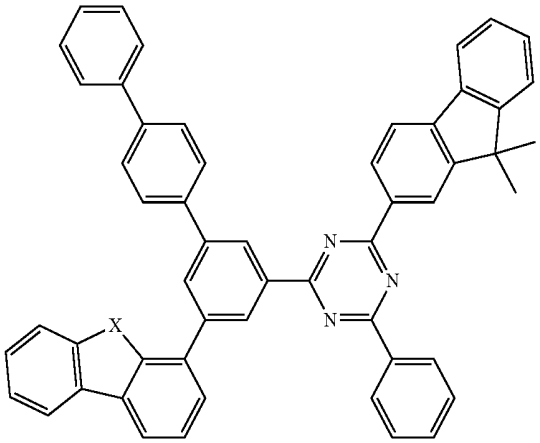
wherein in Compound A49: X = O,
in Compound A50: X = S,
in Compound A51: X = Se

Compound A52 through A54, each represented by the formula



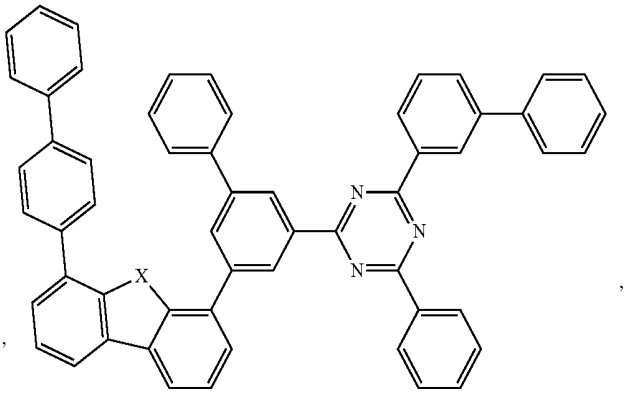
wherein in Compound A52: X = O,
in Compound A53: X = S,
in Compound A54: X = Se

Compound A55 through A57, each represented by the formula



wherein in Compound A55: X = O,
in Compound A56: X = S,
in Compound A57: X = Se

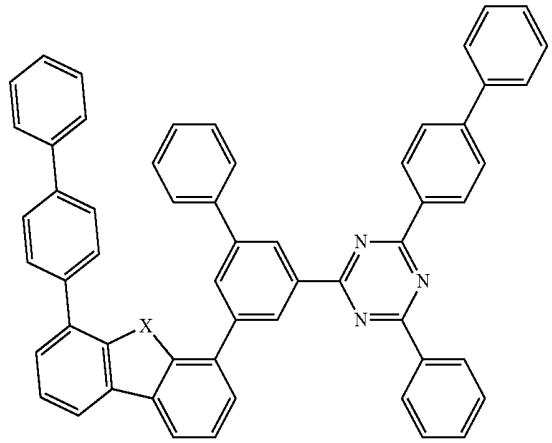
Compound A58 through A60, each represented by the formula



wherein in Compound A58: X = O,
in Compound A59: X = S,
in Compound A60: X = Se

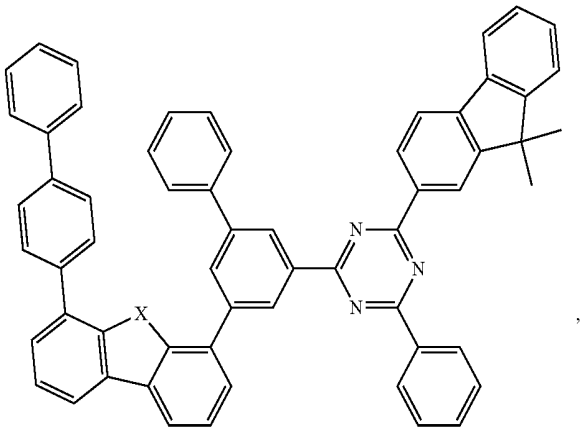
-continued

Compound A61 through A63, each represented by the formula



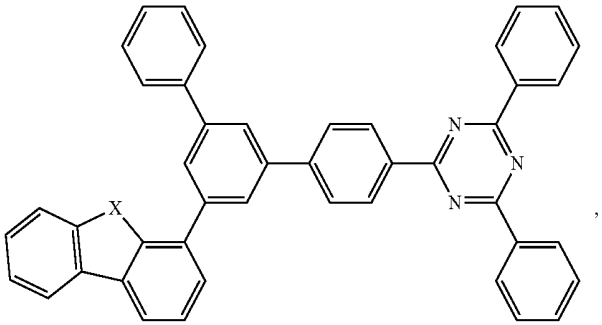
wherein in Compound A61: X = O,
in Compound A62: X = S,
in Compound A63: X = Se

Compound A64 through A66, each represented by the formula



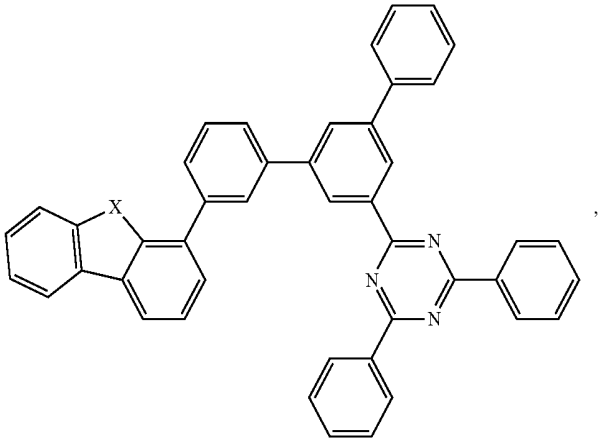
wherein in Compound A64: X = O,
in Compound A65: X = S,
in Compound A66: X = Se

Compound A67 through A69, each represented by the formula



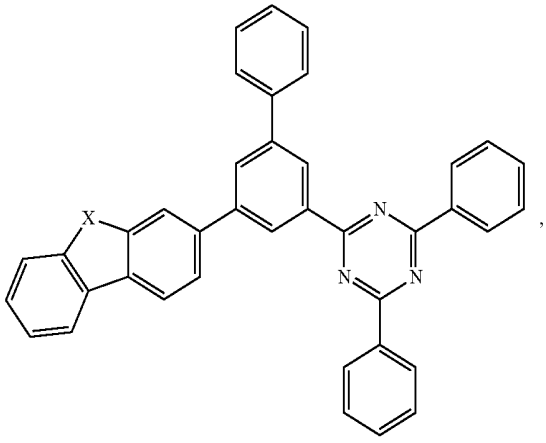
wherein in Compound A67: X = O,
in Compound A68: X = S,
in Compound A69: X = Se

Compound A70 through A72, each represented by the formula



wherein in Compound A70: X = O,
in Compound A71: X = S,
in Compound A72: X = Se

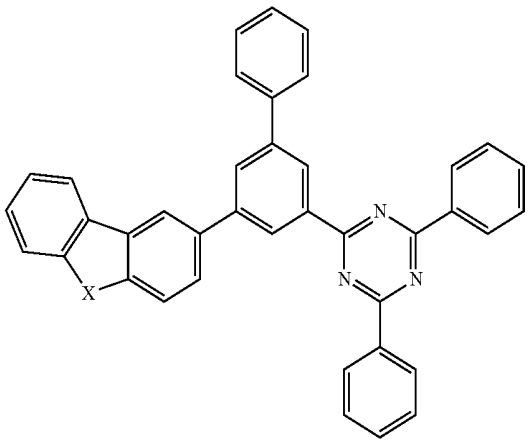
Compound A73 through A75, each represented by the formula



wherein Compound A73: X = O,
in Compound A74: X = S,
in Compound A75: X = Se

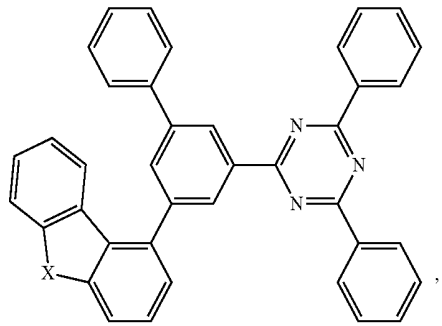
-continued

Compound A76 through A78, each represented by the formula



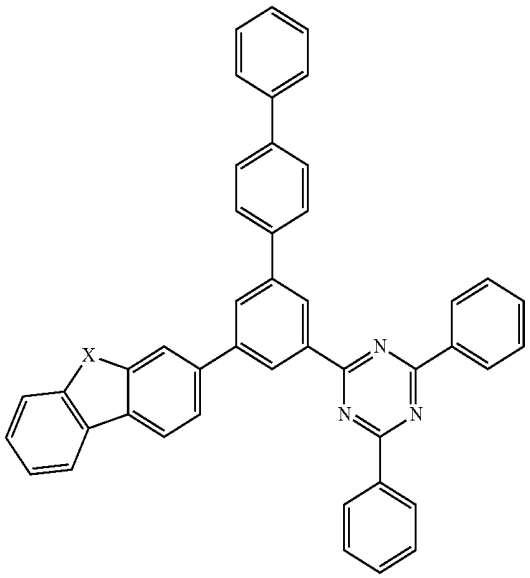
wherein Compound A76: X = O,
in Compound A77: X = S,
in Compound A78: X = Se

Compound A79 through A81, each represented by the formula



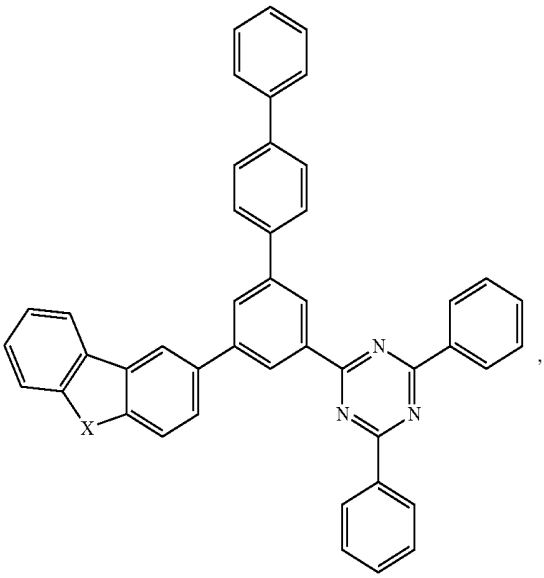
wherein in Compound A79: X = O,
in Compound A80: X = S,
in Compound A81: X = Se

Compound A82 through A84, each represented by the formula



wherein in Compound A82: X = O,
in Compound A83: X = S,
in Compound A84: X = Se

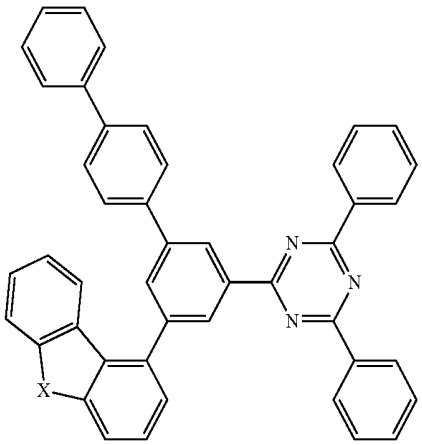
Compound A85 through A87, each represented by the formula



wherein in Compound A85: X = O,
in Compound A86: X = S,
in Compound A87: X = Se

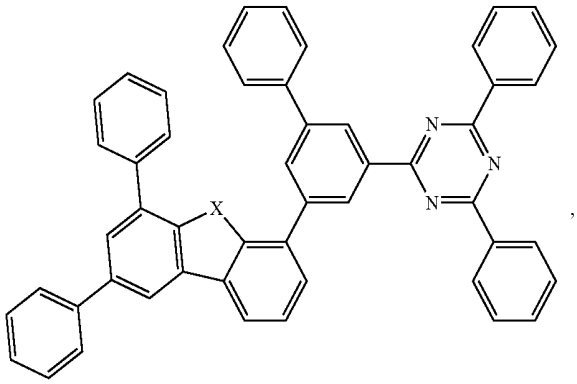
-continued

Compound A88 through A90, each represented by the formula



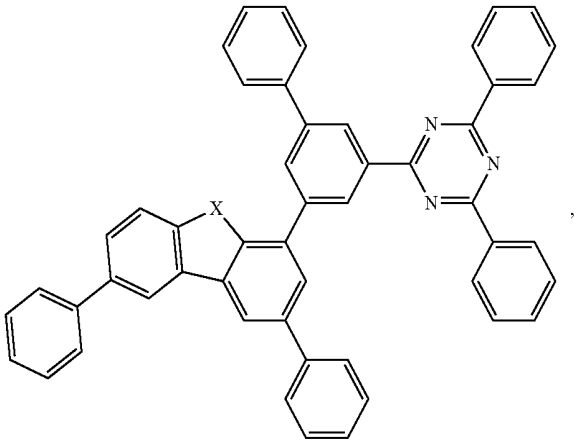
wherein in Compound A88: X = O,
in Compound A89: X = S,
in Compound A90: X = Se

Compound A91 through A93, each represented by the formula



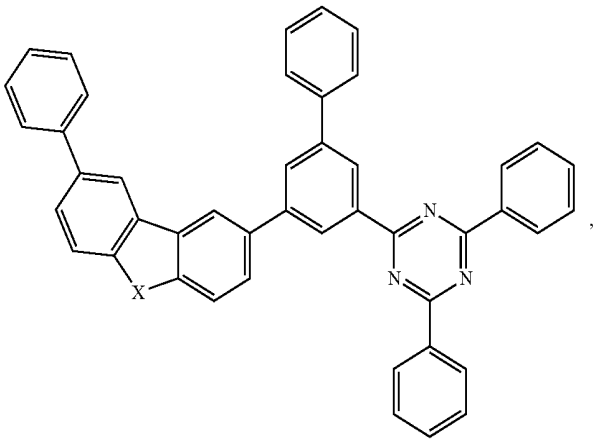
wherein Compound A91: X = O,
in Compound A92: X = S,
in Compound A93: X = Se

Compound A94 through A96, each represented by the formula



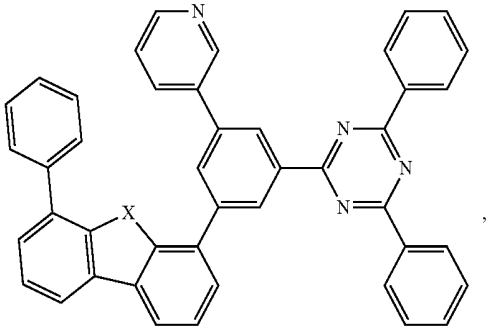
wherein Compound A94: X = O,
in Compound A95: X = S,
in Compound A96: X = Se

Compound A97 through A99, each represented by the formula



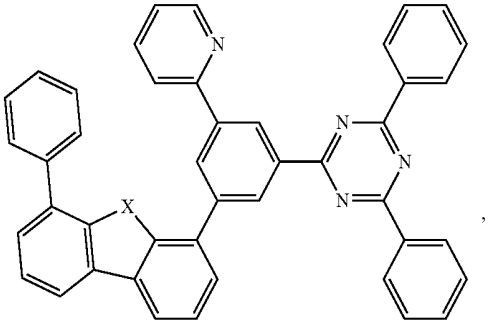
wherein in Compound A97: X = O,
in Compound A98: X = S,
in Compound A99: X = Se

Compound A100 through A102, each represented by the formula



wherein in Compound A100: X = O,
in Compound A101: X = S,
in Compound A102: X = Se

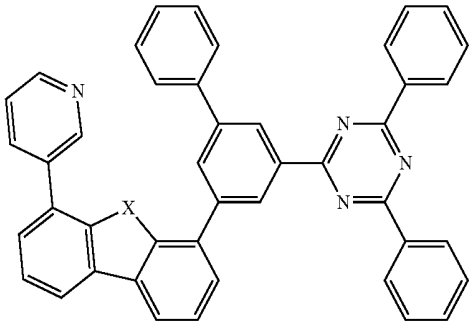
Compound A103 through A105, each represented by the formula



wherein in Compound A103: X = O,
in Compound A104: X = S,
in Compound A105: X = Se

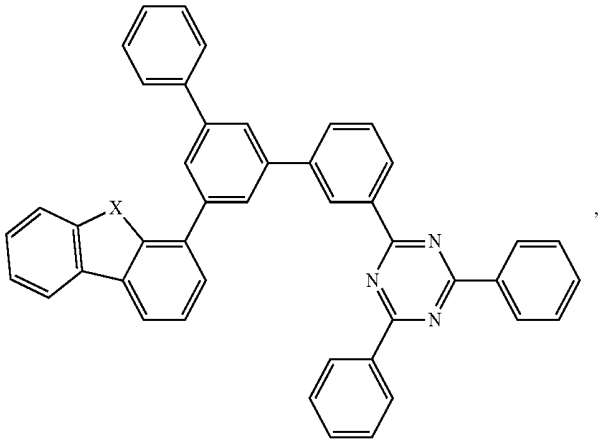
-continued

Compound A106 through A108, each represented by the formula



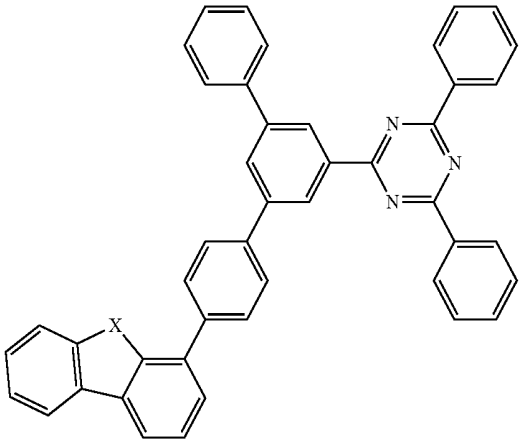
wherein in Compound A106: X = O,
in Compound A107: X = S,
in Compound A108: X = Se

Compound A109 through A111, each represented by the formula



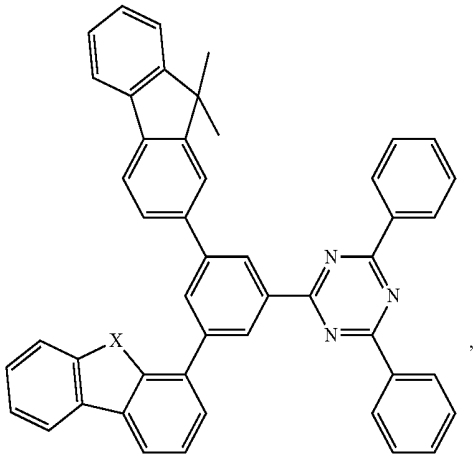
wherein in Compound A109: X = O,
in Compound A110: X = S,
in Compound A111: X = Se

Compound A112 through A114, each represented by the formula

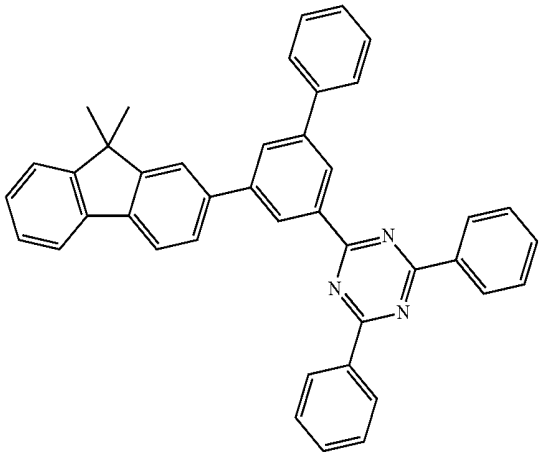


wherein in Compound A112: X = O,
in Compound A113: X = S,
in Compound A114: X = Se

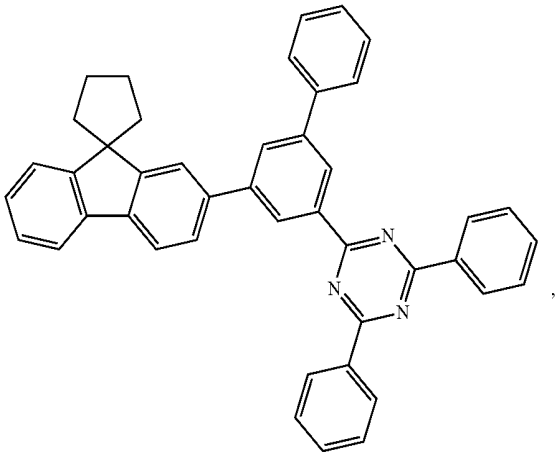
Compound A115 through A117, each represented by the formula



wherein in Compound A115: X = O,
in Compound A116: X = S,
in Compound A117: X = Se

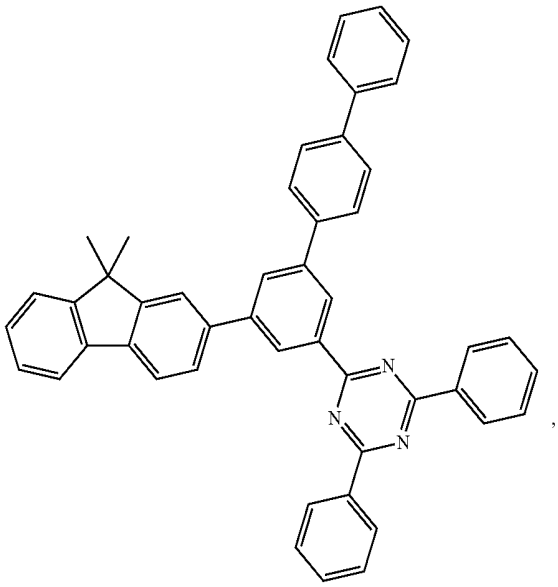


Compound B1

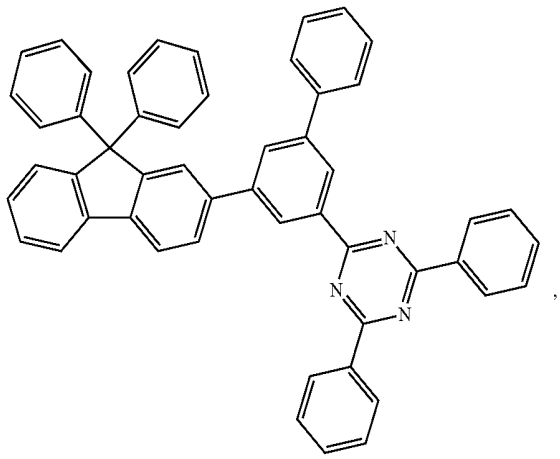


Compound B2

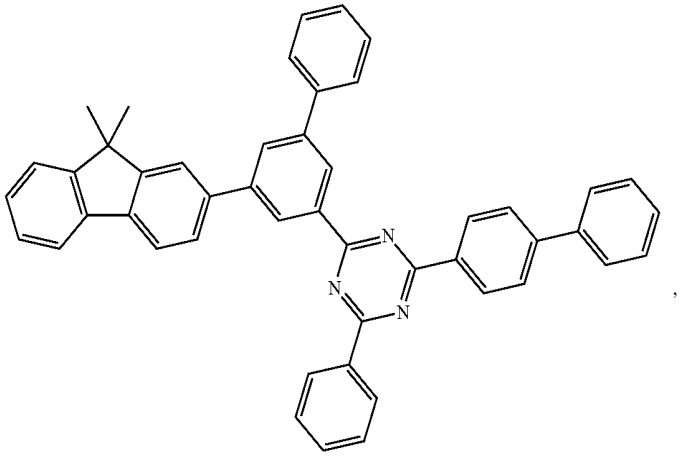
-continued



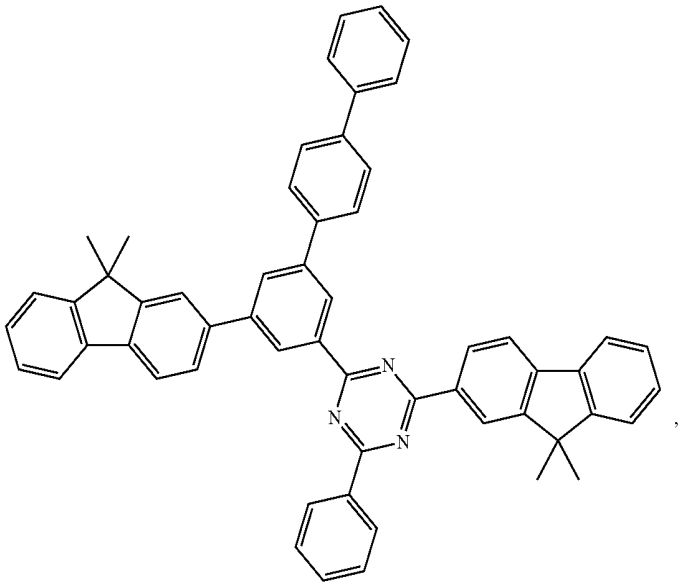
Compound B3



Compound B4

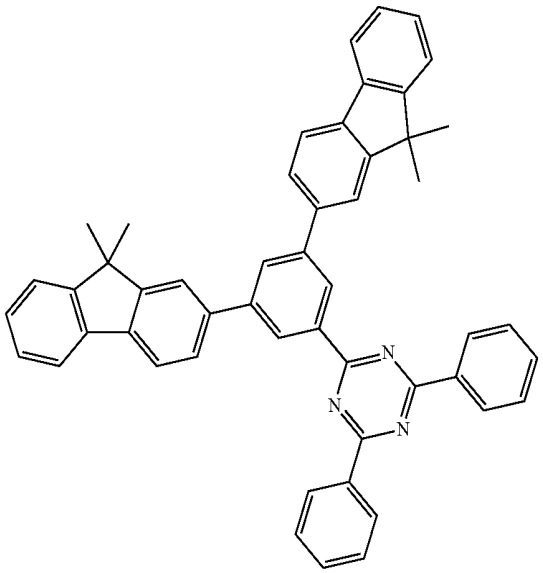


Compound B5

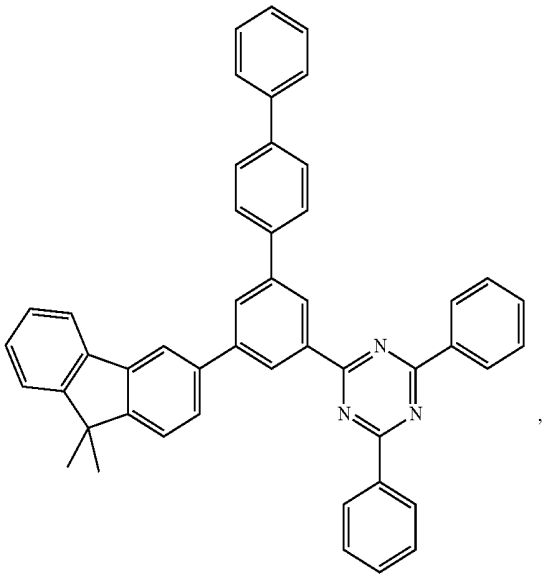


Compound B6

-continued

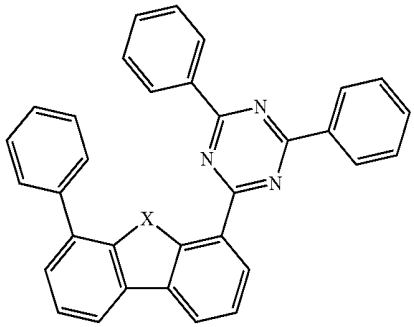


Compound B7



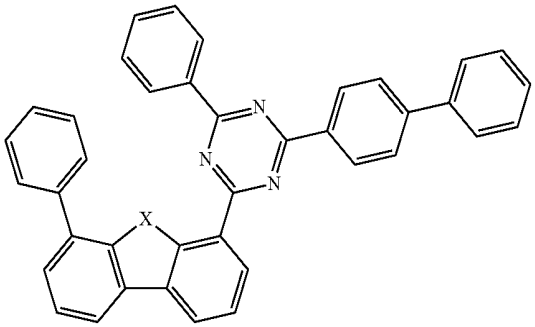
Compound B8

Compound C1 through C3, each represented by the formula



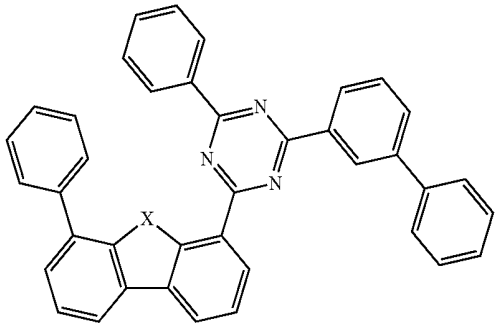
wherein Compound C1: X = O,
in Compound C2: X = S,
in Compound C3: X = Se

Compound C4 through C6, each represented by the formula



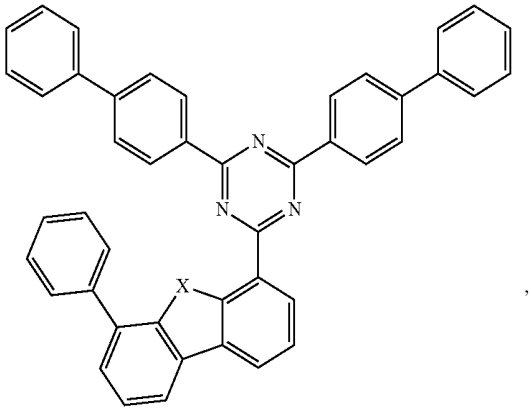
wherein Compound C4: X = O,
in Compound C5: X = S,
in Compound C6: X = Se

Compound C7 through C9, each represented by the formula



wherein Compound C7: X = O,
in Compound C8: X = S,
in Compound C9: X = Se

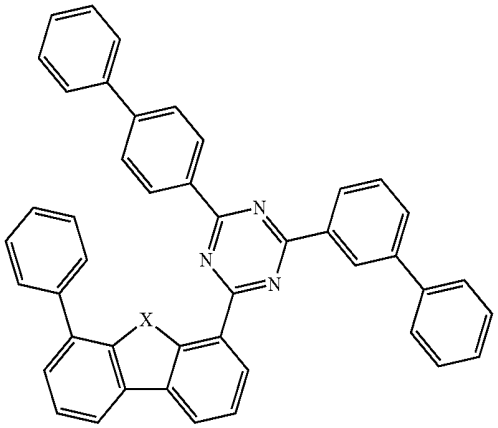
Compound C10 through C12, each represented by the formula



wherein Compound C10: X = O,
in Compound C11: X = S,
in Compound C12: X = Se

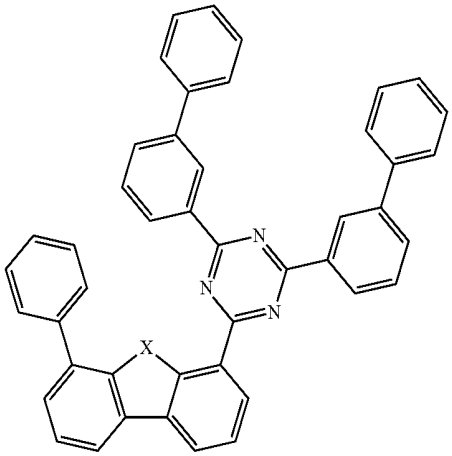
-continued

Compound C13 through C15, each represented by the formula



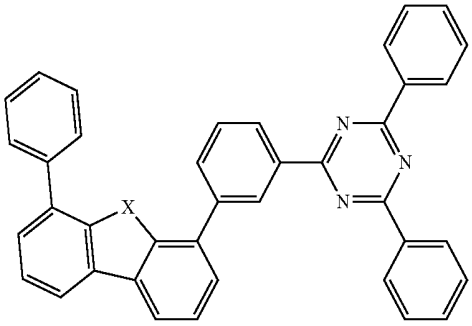
wherein Compound C13: X = O,
in Compound C14: X = S,
in Compound C15: X = Se

Compound C16 through C18, each represented by the formula



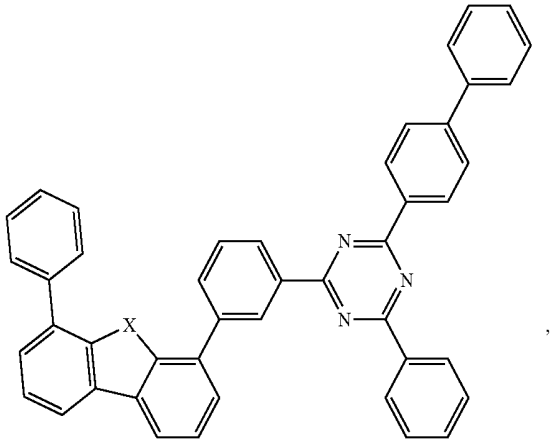
wherein Compound C16: X = O,
in Compound C17: X = S,
in Compound C18: X = Se

Compound C19 through C21, each represented by the formula



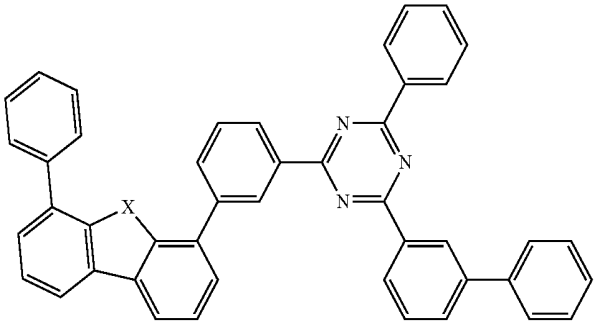
wherein in Compound C19: X = O,
in Compound C20: X = S,
in Compound C21: X = Se

Compound C22 through C24, each represented by the formula



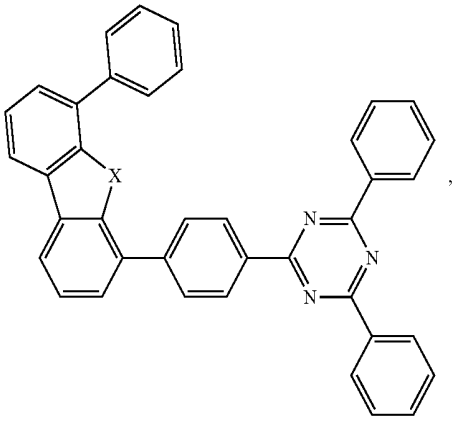
wherein in Compound C22: X = O,
in Compound C23: X = S,
in Compound C24: X = Se

Compound C25 through C27, each represented by the formula



wherein in Compound C25: X = O,
in Compound C26: X = S,
in Compound C27: X = Se

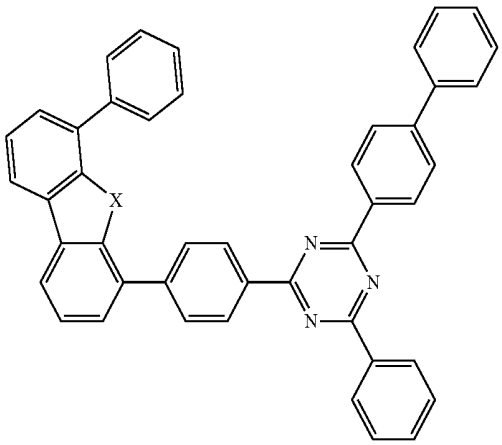
Compound C28 through C30, each represented by the formula



wherein in Compound C28: X = O,
in Compound C29: X = S,
in Compound C30: X = Se

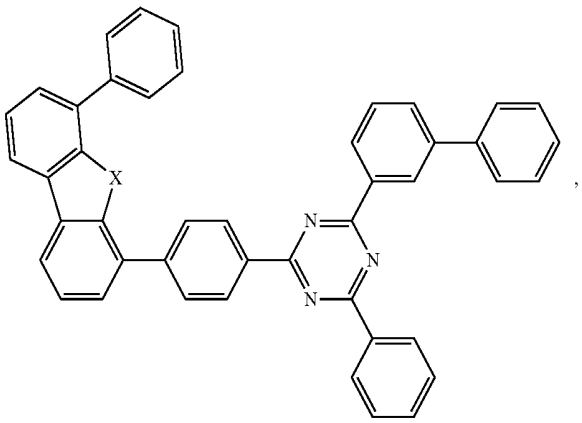
-continued

Compound C31 through C33, each represented by the formula



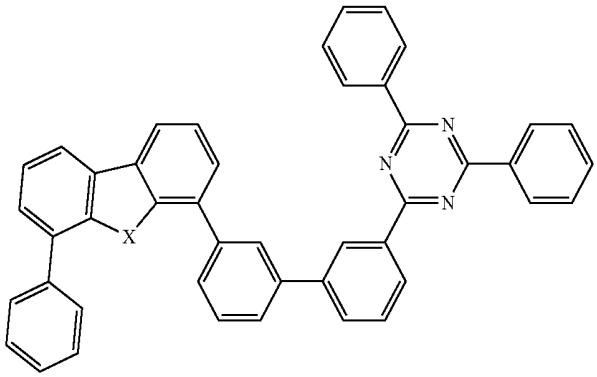
wherein in Compound C31: X = O,
in Compound C32: X = S,
in Compound C33: X = Se

Compound C34 through C36, each represented by the formula



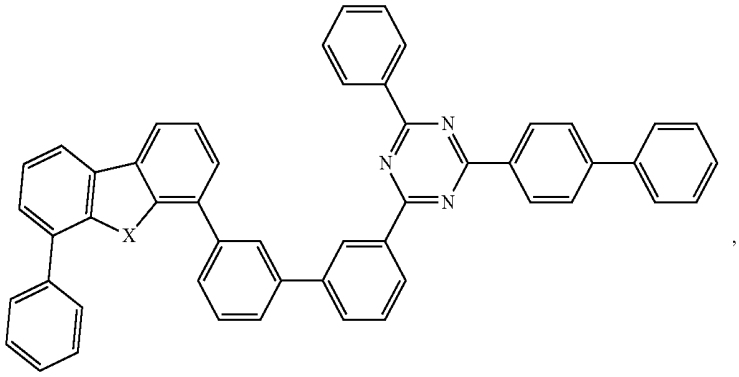
wherein in Compound C34: X = O,
in Compound C35: X = S,
in Compound C36: X = Se

Compound C37 through C39, each represented by the formula



wherein in Compound C37: X = O,
in Compound C38: X = S,
in Compound C39: X = Se

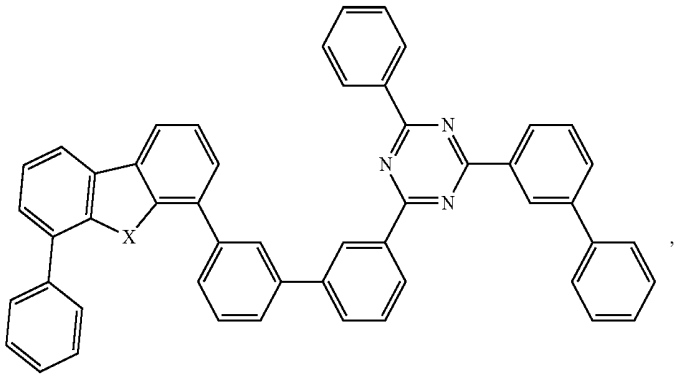
Compound C40 through C42, each represented by the formula



wherein in Compound C40: X = O,
in Compound C41: X = S,
in Compound C42: X = Se

-continued

Compound C43 through C45, each represented by the formula



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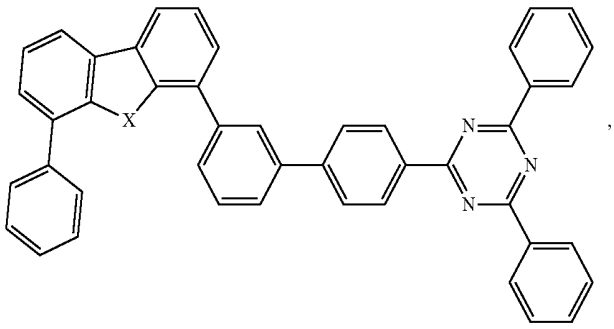
wherein in Compound C43: X = O,
in Compound C44: X = S,
in Compound C45: X = Se

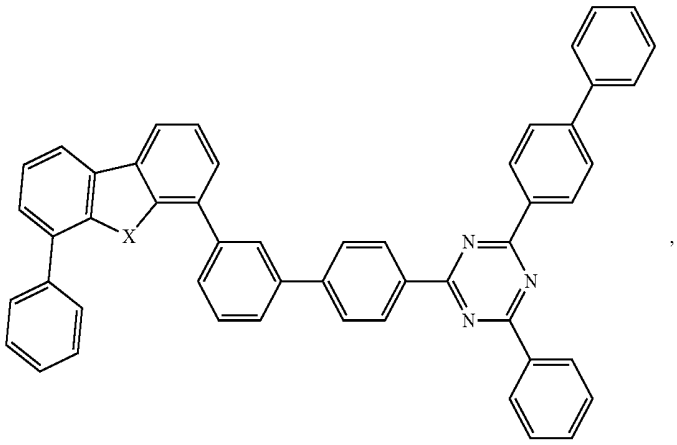
Compound C46 through C48, each represented by the formula



,

wherein in Compound C46: X = O,
in Compound C47: X = S,
in Compound C48: X = Se

Compound C49 through C51, each represented by the formula

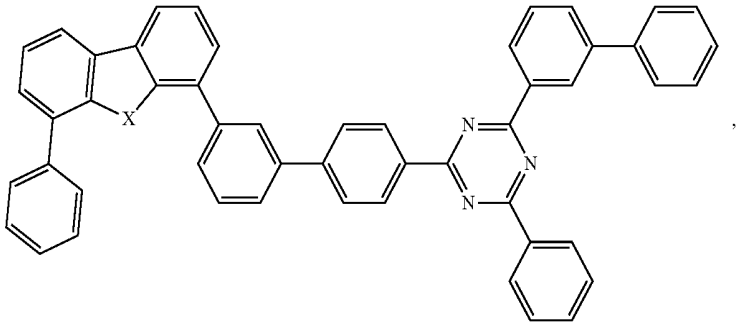


,

wherein in Compound C49: X = O,
in Compound C50: X = S,
in Compound C51: X = Se

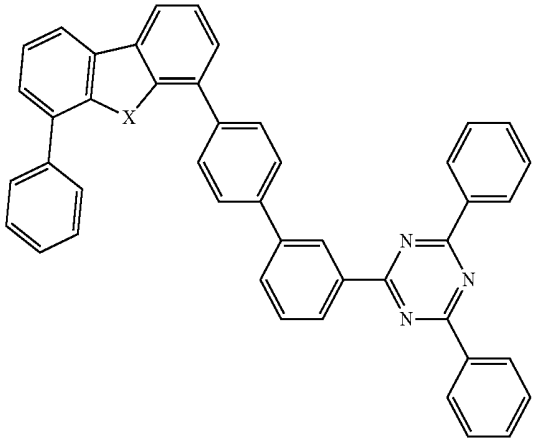
-continued

Compound C52 through C54, each represented by the formula



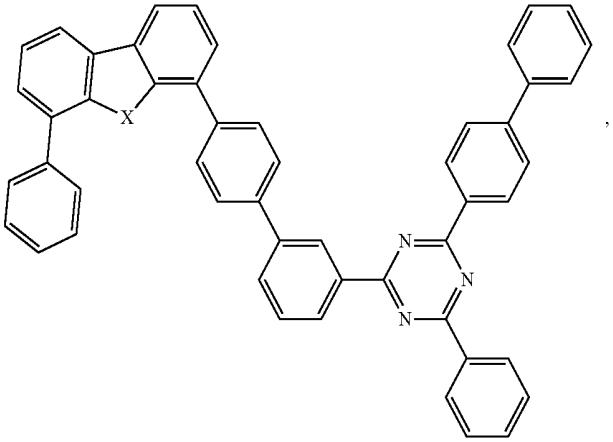
wherein in Compound C52: X = O,
in Compound C53: X = S,
in Compound C54: X = Se

Compound C55 through C57, each represented by the formula



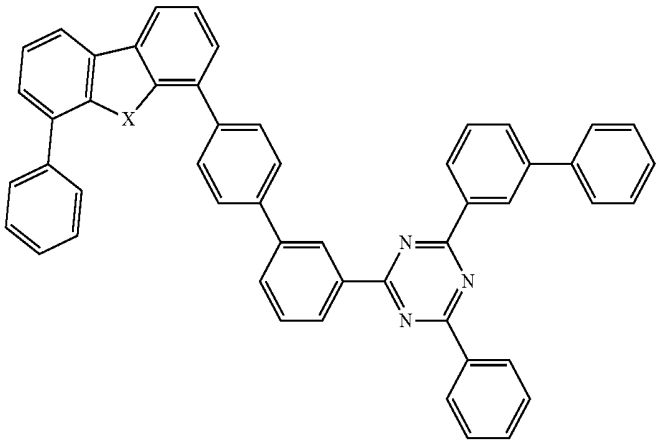
wherein in Compound C55: X = O,
in Compound C56: X = S,
in Compound C57: X = Se

Compound C58 through C60, each represented by the formula



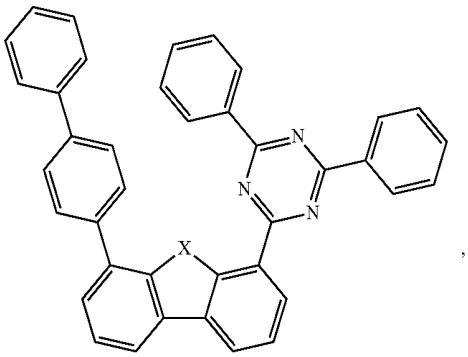
wherein in Compound C58: X = O,
in Compound C59: X = S,
in Compound C60: X = Se

Compound C61 through C63, each represented by the formula



wherein in Compound C61: X = O,
in Compound C62: X = S,
in Compound C63: X = Se

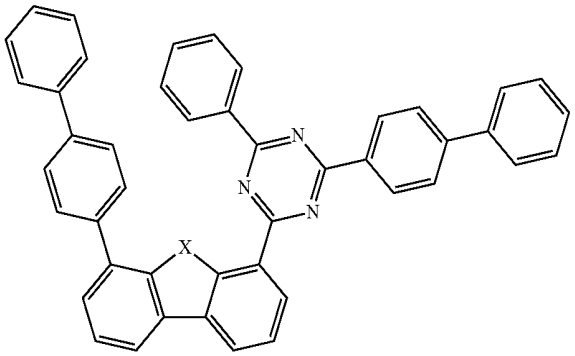
Compound C64 through C66, each represented by the formula



wherein in Compound C64: X = O,
in Compound C65: X = S,
in Compound C66: X = Se

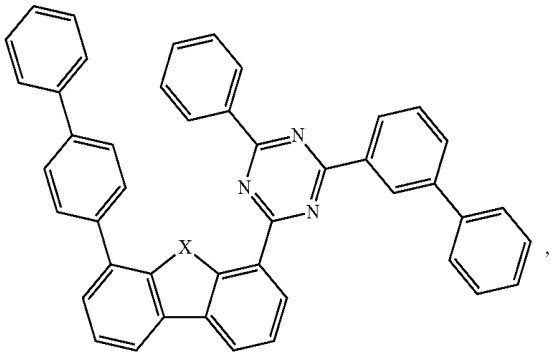
-continued

Compound C67 through C69, each represented by the formula



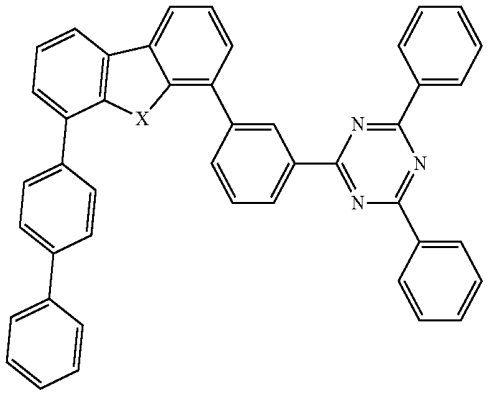
wherein in Compound C67: X = O,
in Compound C68: X = S,
in Compound C69: X = Se

Compound C70 through C72, each represented by the formula



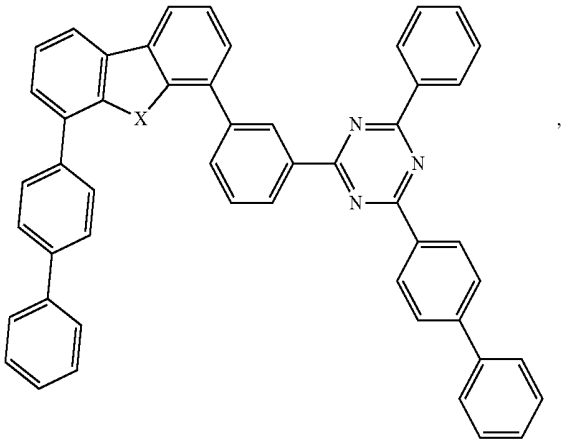
wherein in Compound C70: X = O,
in Compound C71: X = S,
in Compound C72: X = Se

Compound C73 through C75, each represented by the formula



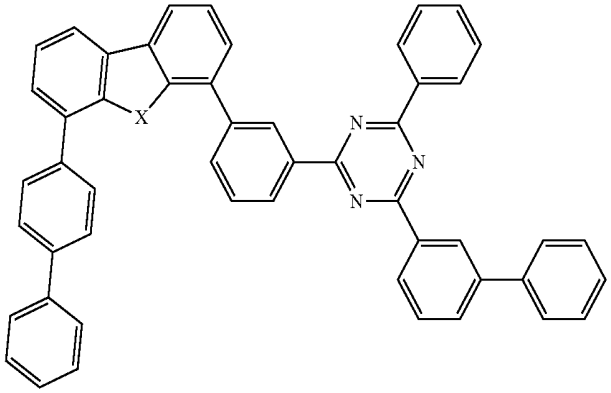
wherein in Compound C73: X = O,
in Compound C74: X = S,
in Compound C75: X = Se

Compound C76 through C78, each represented by the formula



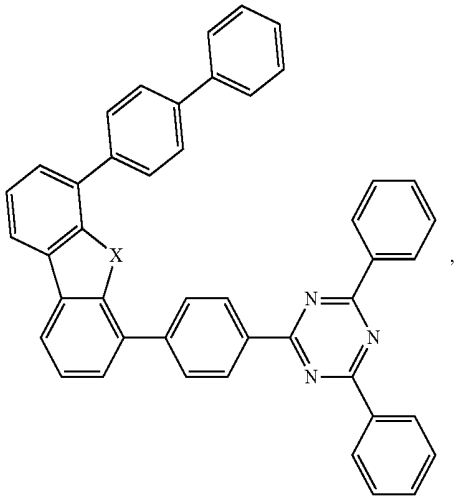
wherein in Compound C76: X = O,
in Compound C77: X = S,
in Compound C78: X = Se

Compound C79 through C81, each represented by the formula



wherein in Compound C79: X = O,
in Compound C80: X = S,
in Compound C81: X = Se

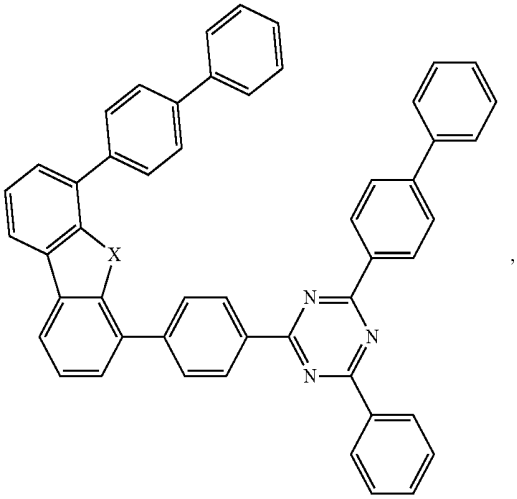
Compound C82 through C84, each represented by the formula



wherein in Compound C82: X = O,
in Compound C83: X = S,
in Compound C84: X = Se

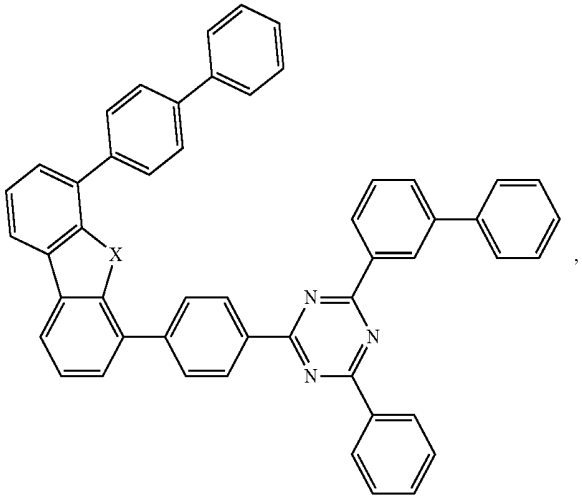
-continued

Compound C85 through C87, each represented by the formula



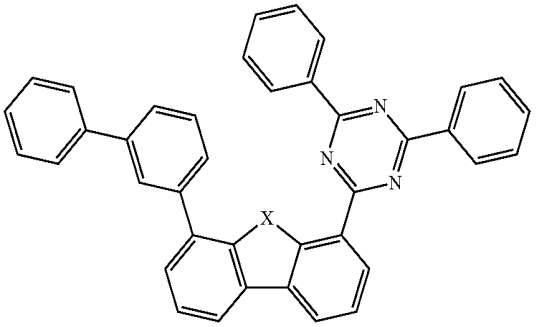
wherein in Compound C85: X = O,
in Compound C86: X = S,
in Compound C87: X = Se

Compound C88 through C90, each represented by the formula



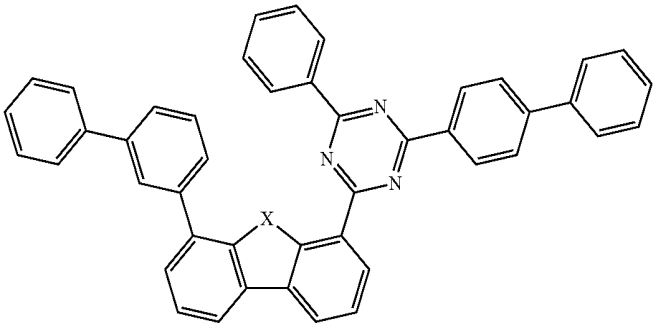
wherein in Compound C88: X = O,
in Compound C89: X = S,
in Compound C90: X = Se

Compound C91 through C93, each represented by the formula



wherein in Compound C91: X = O,
in Compound C92: X = S,
in Compound C93: X = Se

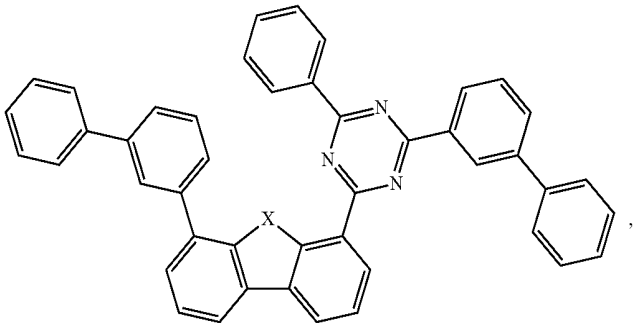
Compound C94 through C96, each represented by the formula



wherein in Compound C94: X = O,
in Compound C95: X = S,
in Compound C96: X = Se

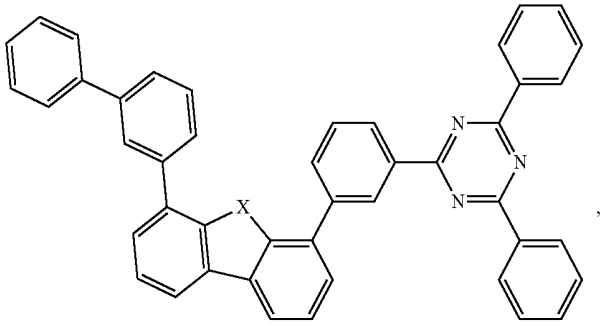
-continued

Compound C97 through C99, each represented by the formula



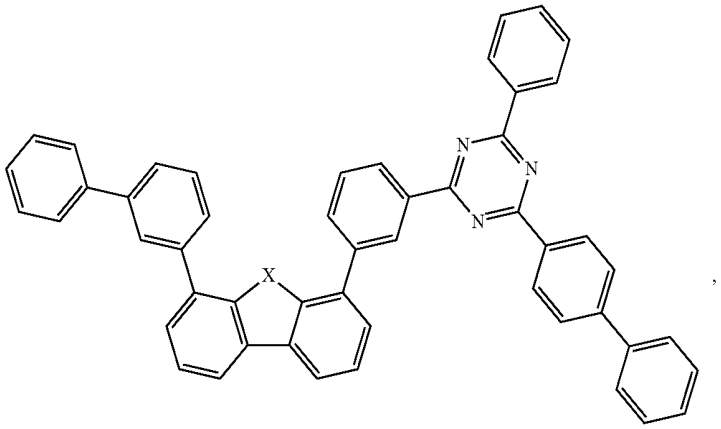
wherein in Compound C97: X = O,
in Compound C98: X = S,
in Compound C99: X = Se

Compound C100 through C102, each represented by the formula



wherein in Compound C100: X = O,
in Compound C101: X = S,
in Compound C102: X = Se

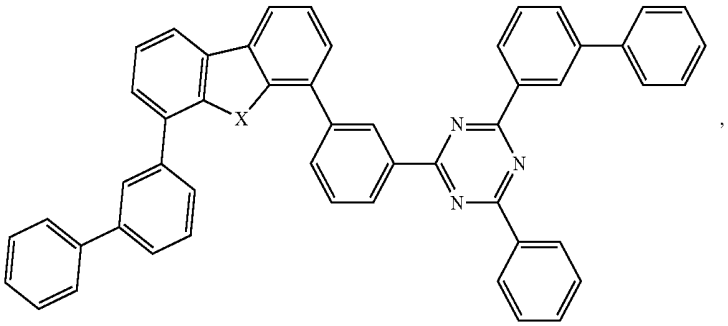
Compound C103 through C105, each represented by the formula



wherein in Compound C103: X = O,
in Compound C104: X = S,
in Compound C105: X = Se

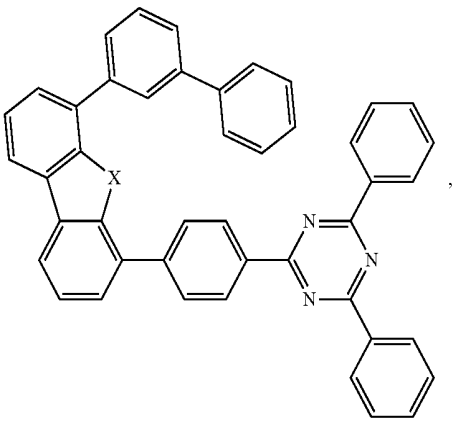
-continued

Compound C106 through C108, each represented by the formula



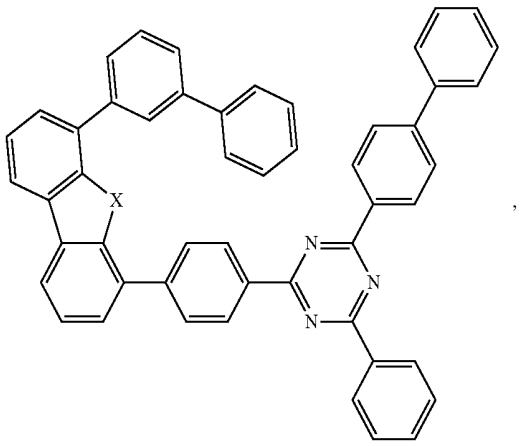
wherein in Compound C106: X = O,
in Compound C107: X = S,
in Compound C108: X = Se

Compound C109 through C111, each represented by the formula



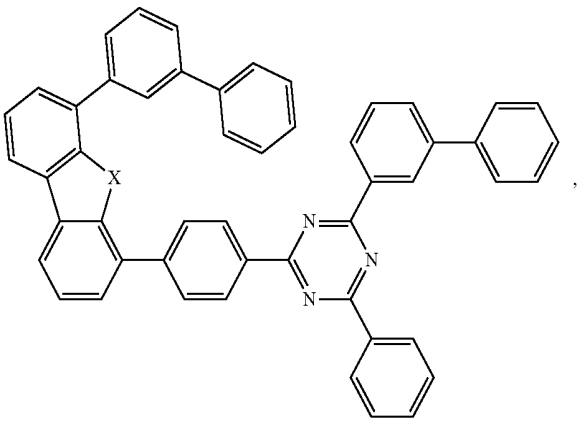
wherein in Compound C109: X = O,
in Compound C110: X = S,
in Compound C111: X = Se

Compound C112 through C114, each represented by the formula



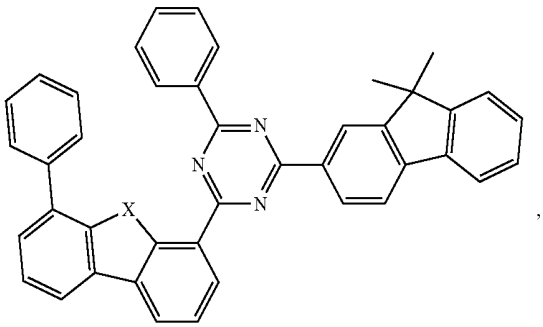
wherein in Compound C112: X = O,
in Compound C113: X = S,
in Compound C114: X = Se

Compound C115 through C117, each represented by the formula



wherein in Compound C115: X = O,
in Compound C116: X = S,
in Compound C117: X = Se

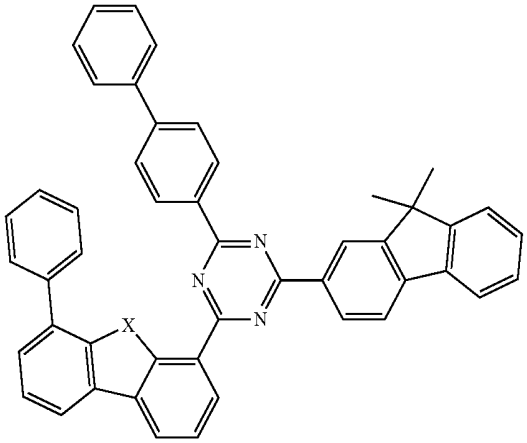
Compound C118 through C120, each represented by the formula



wherein in Compound C118: X = O,
in Compound C119: X = S,
in Compound C120: X = Se

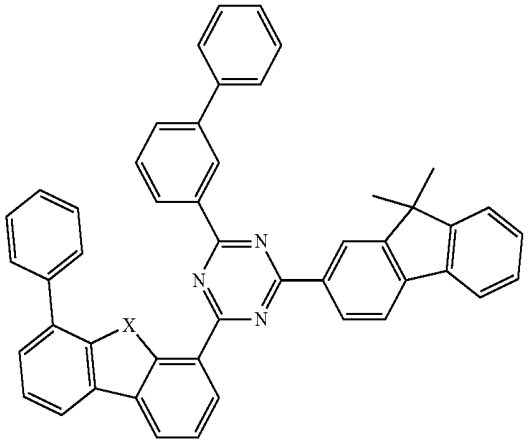
-continued

Compound C121 through C123, each represented by the formula



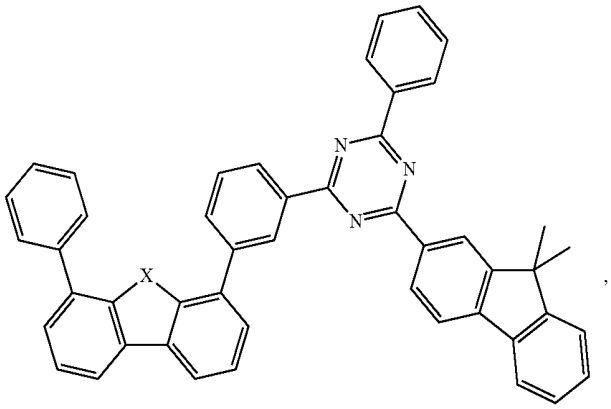
wherein in Compound C121: X = O,
in Compound C122: X = S,
in Compound C123: X = Se

Compound C124 through C126, each represented by the formula



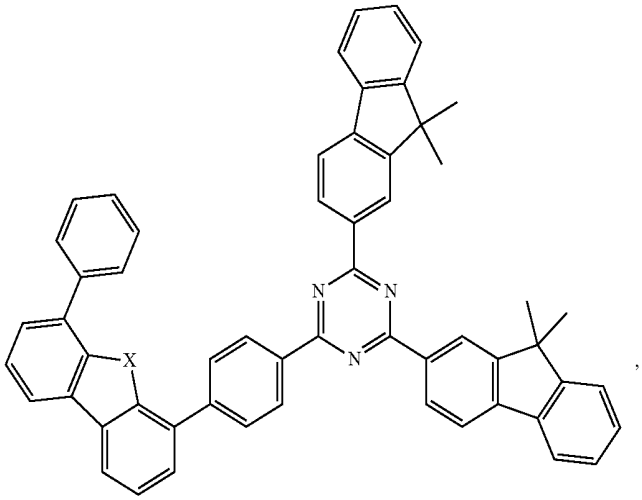
wherein in Compound C124: X = O,
in Compound C125: X = S,
in Compound C126: X = Se

Compound C127 through C129, each represented by the formula



wherein in Compound C127: X = O,
in Compound C128: X = S,
in Compound C129: X = Se

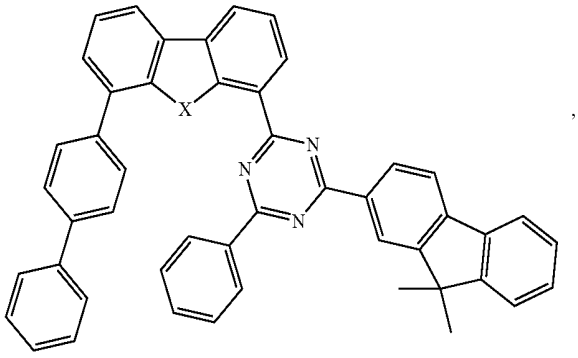
Compound C130 through C132, each represented by the formula



wherein in Compound C130: X = O,
in Compound C131: X = S,
in Compound C132: X = Se

-continued

Compound C133 through C135, each represented by the formula



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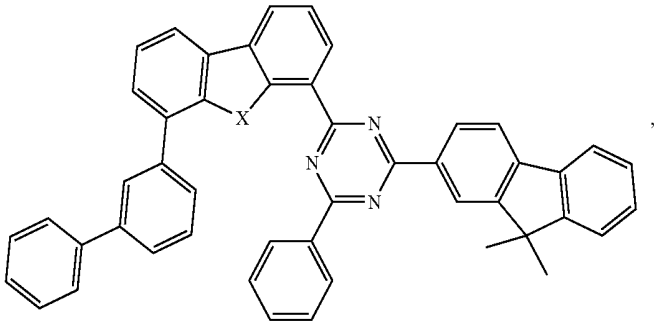
wherein in Compound C133: X = O,
in Compound C134: X = S,
in Compound C135: X = Se

Compound C136 through C138, each represented by the formula



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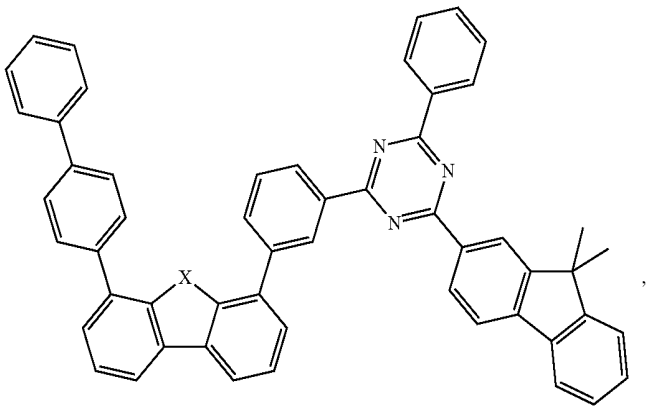
wherein in Compound C136: X = O,
in Compound C137: X = S,
in Compound C138: X = Se

Compound C139 through C141, each represented by the formula

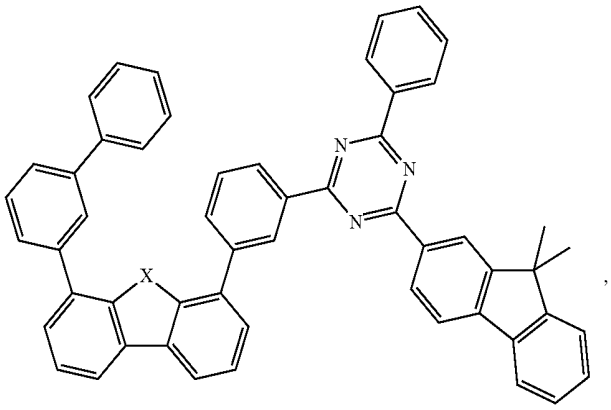


,

wherein in Compound C139: X = O,
in Compound C140: X = S,
in Compound C141: X = Se

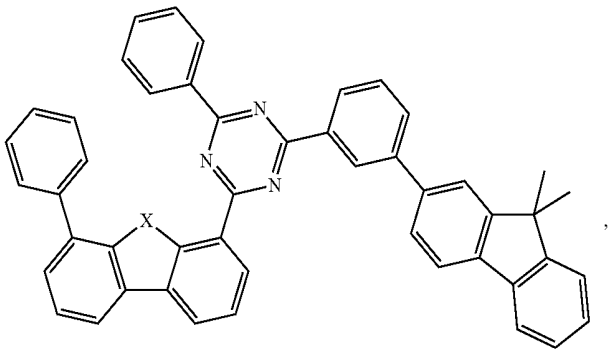
-continued

Compound C142 through C144, each represented by the formula



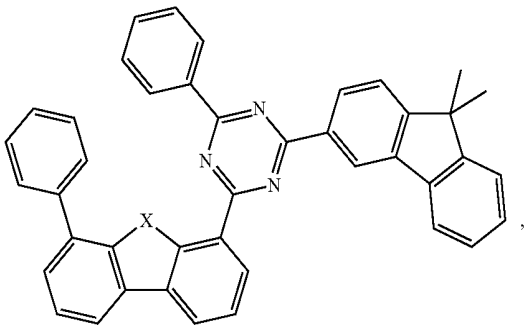
wherein in Compound C142: X = O,
in Compound C143: X = S,
in Compound C144: X = Se

Compound C145 through C147, each represented by the formula



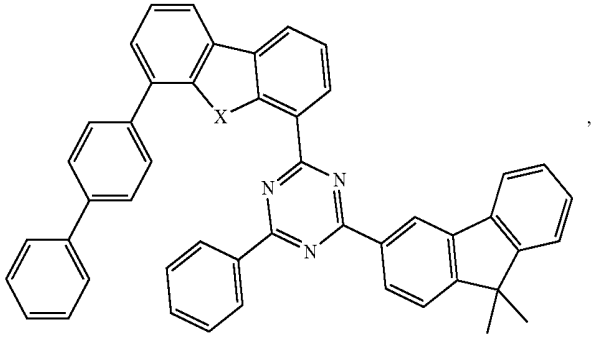
wherein in Compound C145: X = O,
in Compound C146: X = S,
in Compound C147: X = Se

Compound C148 through C150, each represented by the formula



wherein in Compound C148: X = O,
in Compound C149: X = S,
in Compound C150: X = Se

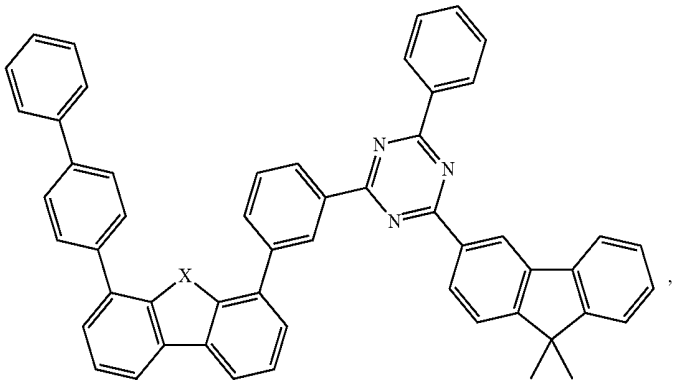
Compound C151 through C153, each represented by the formula



wherein in Compound C151: X = O,
in Compound C152: X = S,
in Compound C152: X = Se

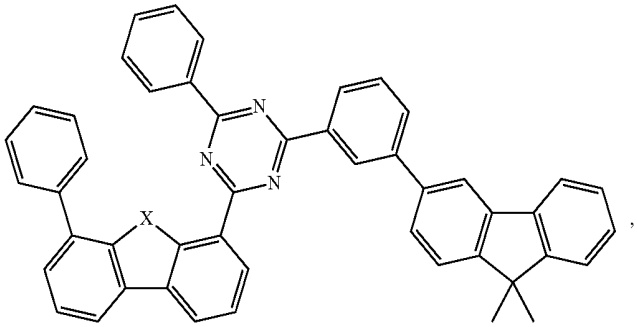
-continued

Compound C154 through C156, each represented by the formula



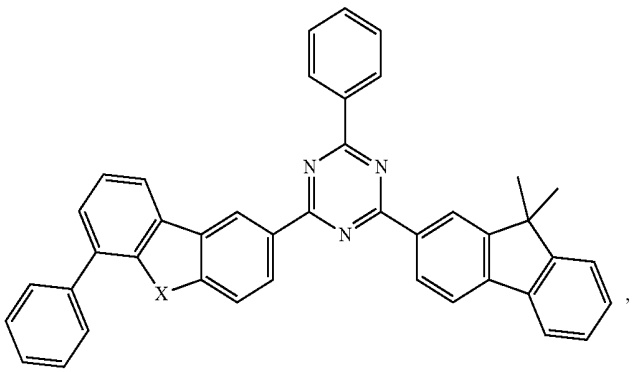
wherein in Compound C154: X = O,
in Compound C155: X = S,
in Compound C156: X = Se

Compound C157 through C159, each represented by the formula



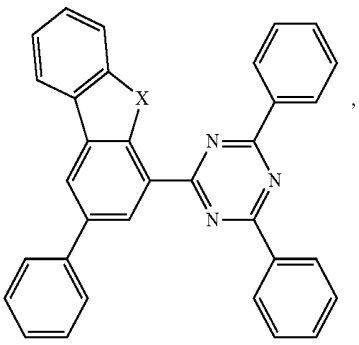
wherein in Compound C157: X = O,
in Compound C158: X = S,
in Compound C159: X = Se

Compound C160 through C162, each represented by the formula



wherein in Compound C160: X = O,
in Compound C161: X = S,
in Compound C162: X = Se

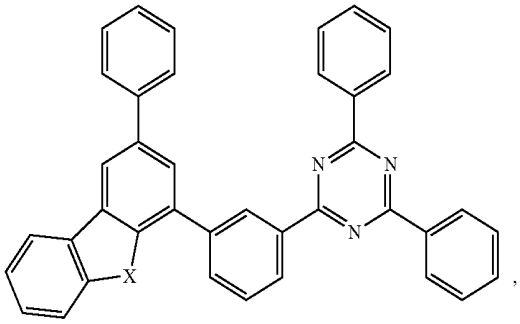
Compound C163 through C165, each represented by the formula



wherein in Compound C163: X = O,
in Compound C164: X = S,
in Compound C165: X = Se

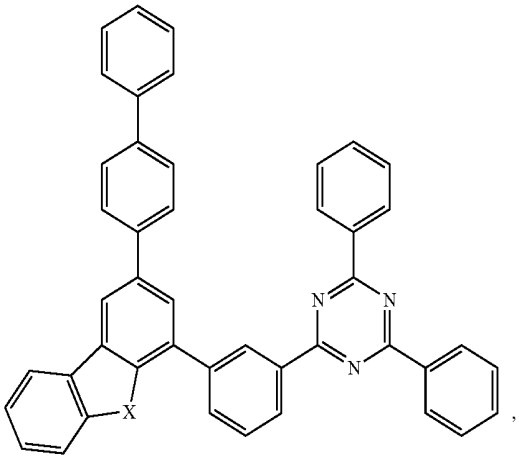
-continued

Compound C166 through C168, each represented by the formula



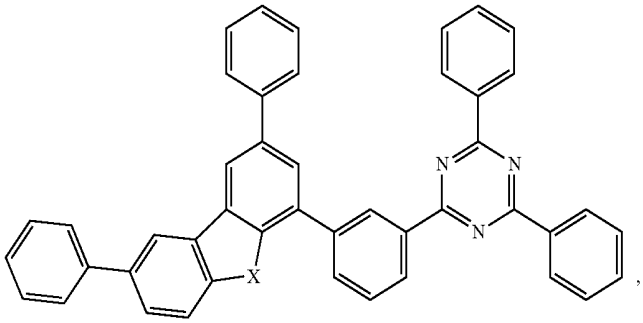
wherein in Compound C166: X = O,
in Compound C167: X = S,
in Compound C168: X = Se

Compound C169 through C171, each represented by the formula



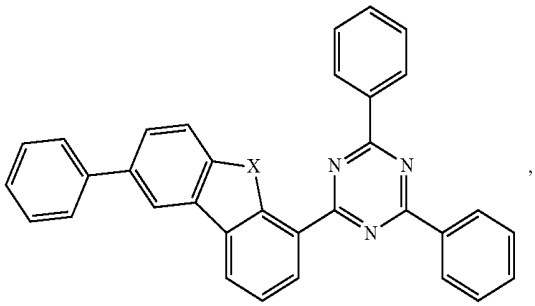
wherein in Compound C169: X = O,
in Compound C170: X = S,
in Compound C171: X = Se

Compound C172 through C174, each represented by the formula



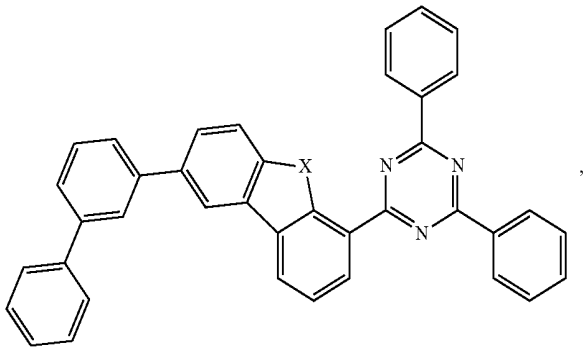
wherein in Compound C172: X = O,
in Compound C173: X = S,
in Compound C174: X = Se

Compound C175 through C177, each represented by the formula



wherein in Compound C175: X = O,
in Compound C176: X = S,
in Compound C177: X = Se

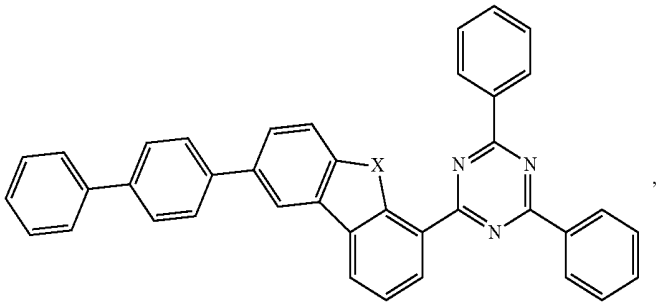
Compound C178 through C180, each represented by the formula



wherein in Compound C178: X = O,
in Compound C179: X = S,
in Compound C180: X = Se

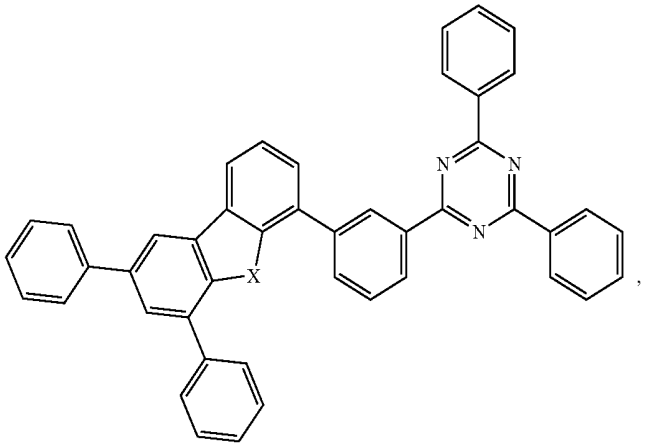
-continued

Compound C181 through C183, each represented by the formula



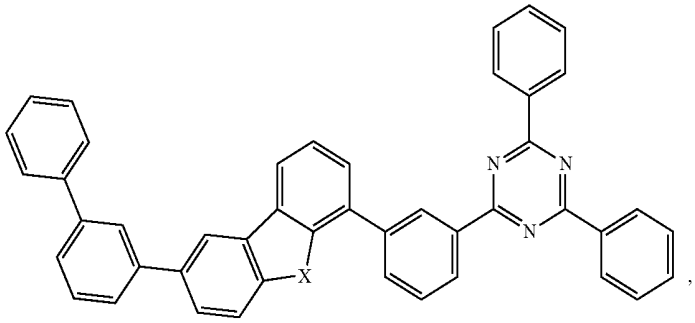
wherein in Compound C181: X = O,
in Compound C182: X = S,
in Compound C183: X = Se

Compound C184 through C186, each represented by the formula



wherein in Compound C184: X = O,
in Compound C185: X = S,
in Compound C186: X = Se

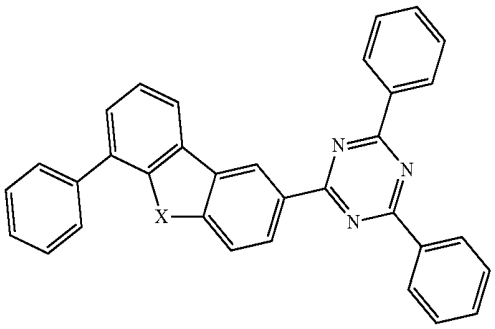
Compound C187 through C189, each represented by the formula



wherein in Compound C187: X = O,
in Compound C188: X = S,
in Compound C189: X = Se

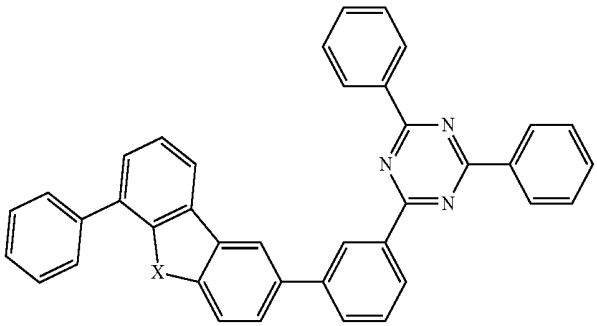
-continued

Compound C190 through C192, each represented by the formula



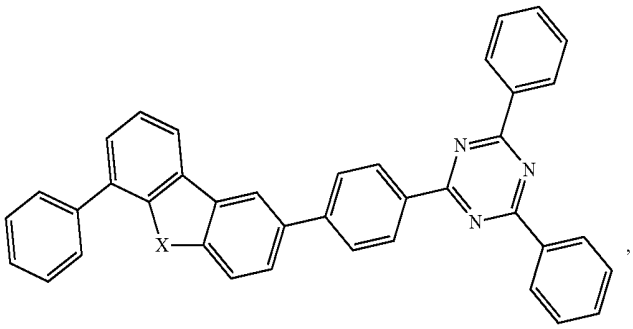
wherein in Compound C190: X = O,
in Compound C191: X = S,
in Compound C192: X = Se

Compound C193 through C195, each represented by the formula



wherein in Compound C193: X = O,
in Compound C194: X = S,
in Compound C195: X = Se

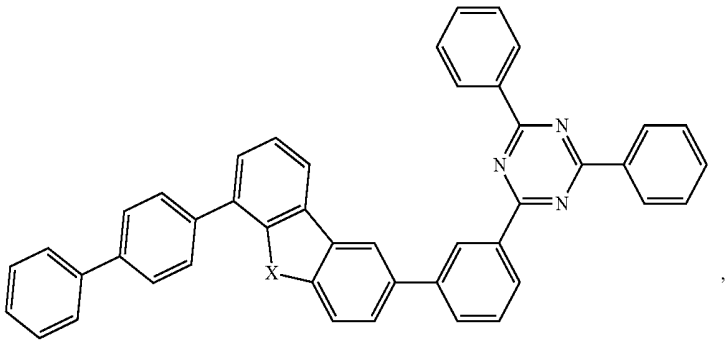
Compound C196 through C198, each represented by the formula



wherein in Compound C196: X = O,
in Compound C197: X = S,
in Compound C198: X = Se

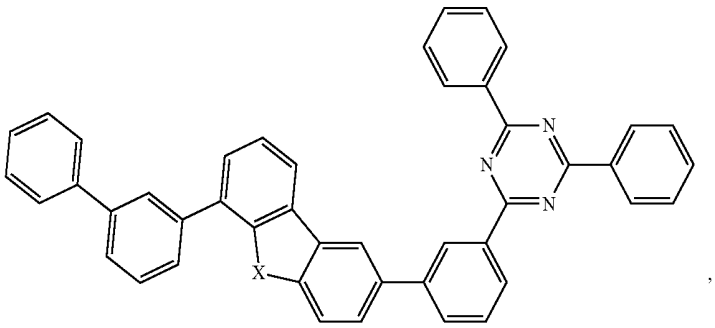
-continued

Compound C199 through C201, each represented by the formula



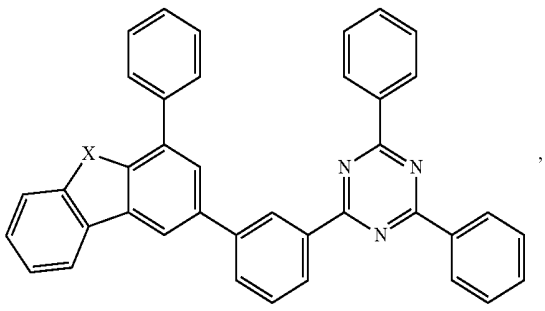
wherein in Compound C199: X = O,
in Compound C200: X = S,
in Compound C201: X = Se

Compound C202 through C204, each represented by the formula



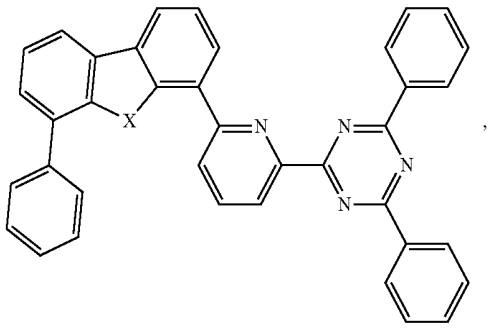
wherein in Compound C202: X = O,
in Compound C203: X = S,
in Compound C204: X = Se

Compound C205 through C207, each represented by the formula



wherein in Compound C205: X = O,
in Compound C206: X = S,
in Compound C207: X = Se

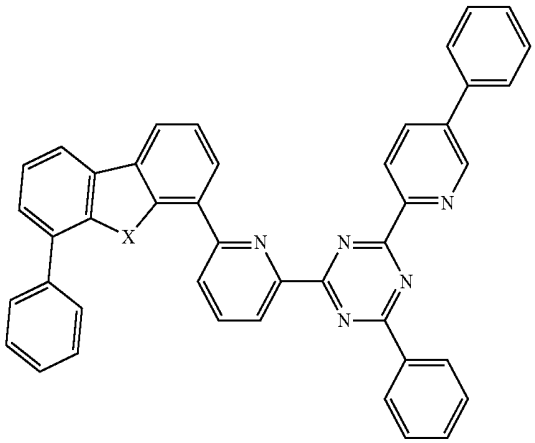
Compound C208 through C210, each represented by the formula



wherein in Compound C208: X = O,
in Compound C209: X = S,
in Compound C210: X = Se

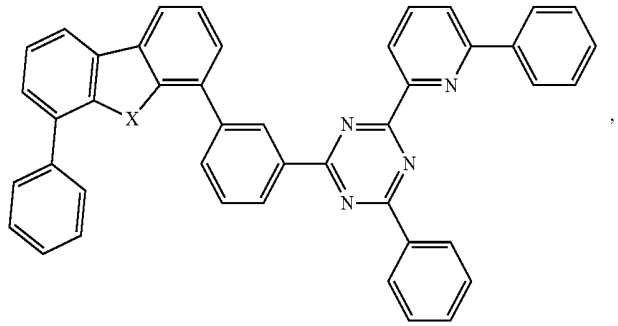
-continued

Compound C211 through C213, each represented by the formula



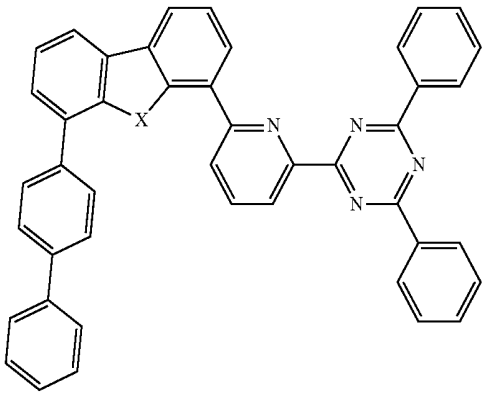
wherein in Compound C211: X = O,
in Compound C212: X = S,
in Compound C213: X = Se

Compound C214 through C216, each represented by the formula



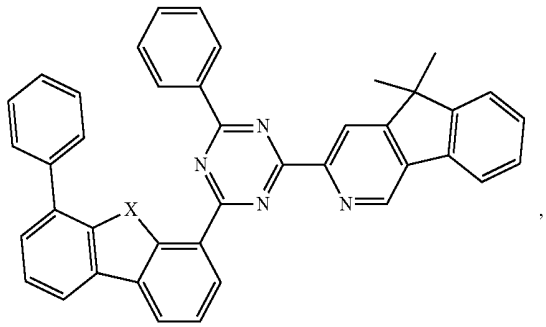
wherein in Compound C214: X = O,
in Compound C215: X = S,
in Compound C216: X = Se

Compound C217 through C219, each represented by the formula



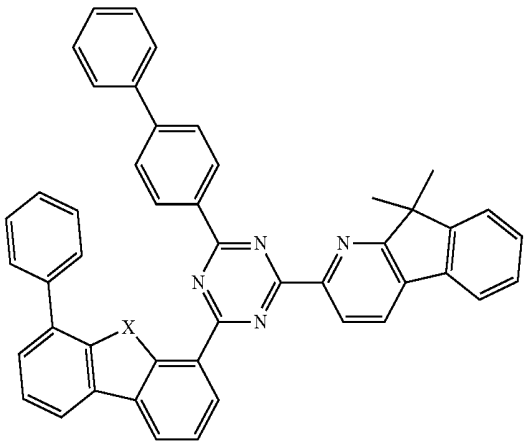
wherein in Compound C217: X = O,
in Compound C218: X = S,
in Compound C219: X = Se

Compound C220 through C222, each represented by the formula



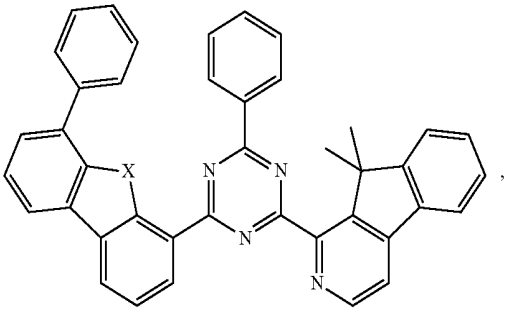
wherein in Compound C220: X = O,
in Compound C221: X = S,
in Compound C222: X = Se

Compound C223 through C225, each represented by the formula



wherein in Compound C223: X = O,
in Compound C224: X = S,
in Compound C225: X = Se

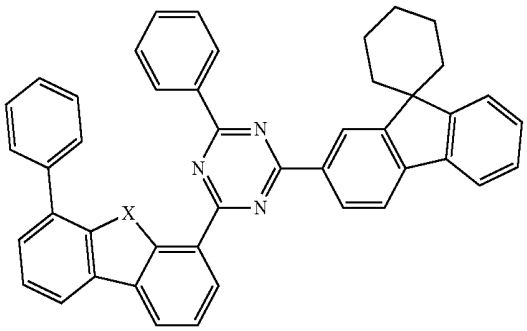
Compound C226 through C228, each represented by the formula



wherein in Compound C226: X = O,
in Compound C227: X = S,
in Compound C228: X = Se

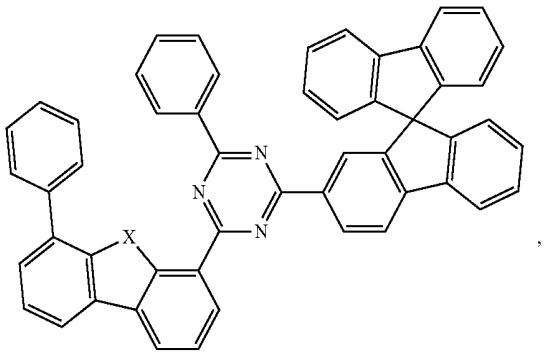
-continued

Compound C229 through C231, each represented by the formula



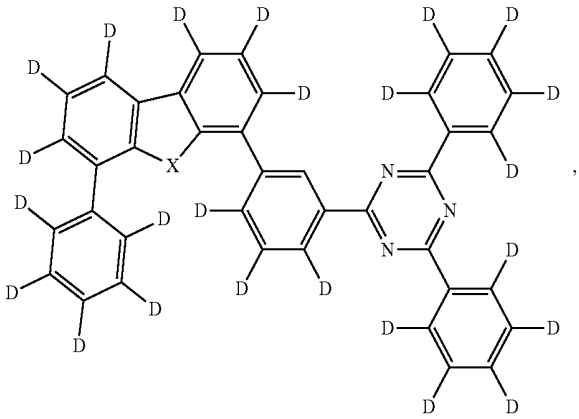
wherein in Compound C229: X = O,
in Compound C230: X = S,
in Compound C231: X = Se

Compound C232 through C234, each represented by the formula



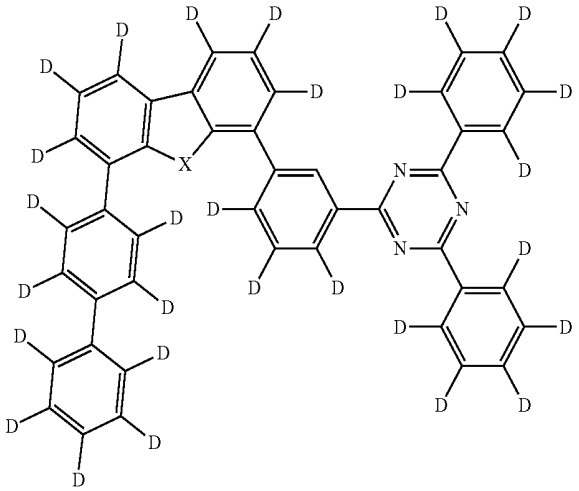
wherein in Compound C232: X = O,
in Compound C233: X = S,
in Compound C234: X = Se

Compound C235 through C237, each represented by the formula



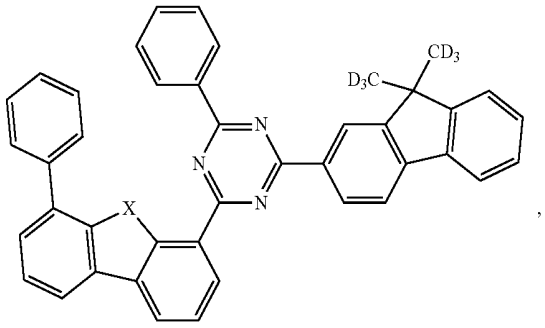
wherein in Compound C235: X = O,
in Compound C236: X = S,
in Compound C237: X = Se

Compound C238 through C240, each represented by the formula



wherein in Compound C238: X = O,
in Compound C239: X = S,
in Compound C240: X = Se

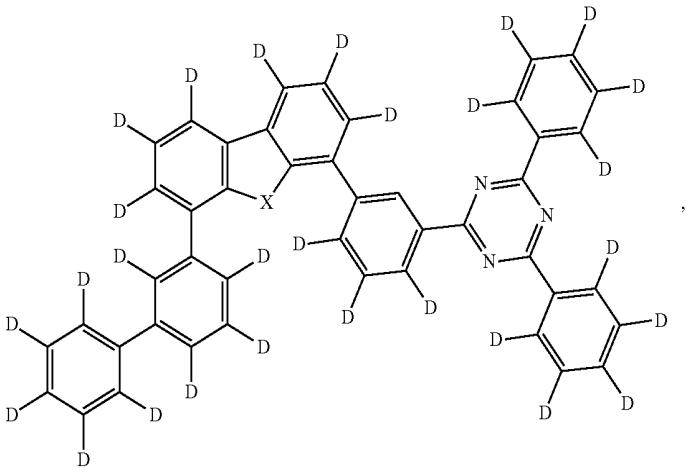
Compound C241 through C243, each represented by the formula



wherein in Compound C241: X = O,
in Compound C242: X = S,
in Compound C243: X = Se

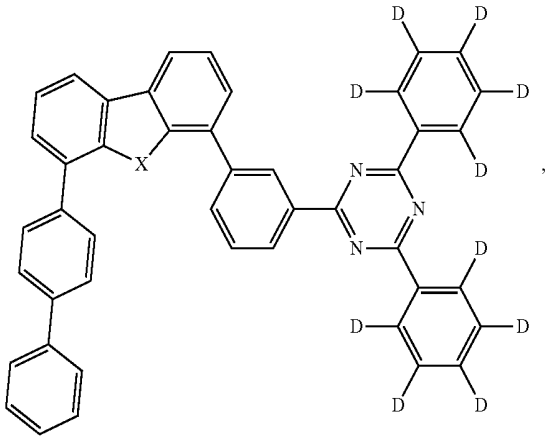
-continued

Compound C244 through C246, each represented by the formula



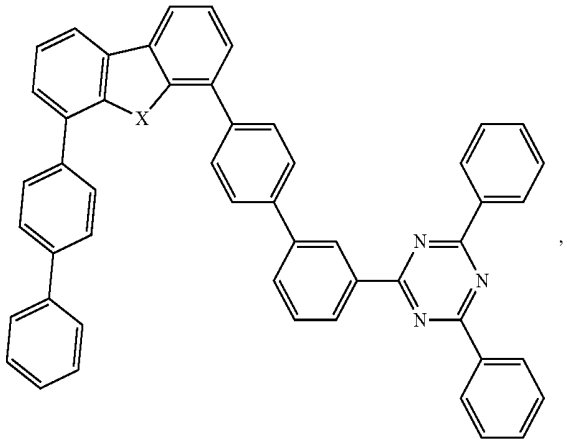
wherein in Compound C244: X = O,
in Compound C245: X = S,
in Compound C246: X = Se

Compound C247 through C249, each represented by the formula



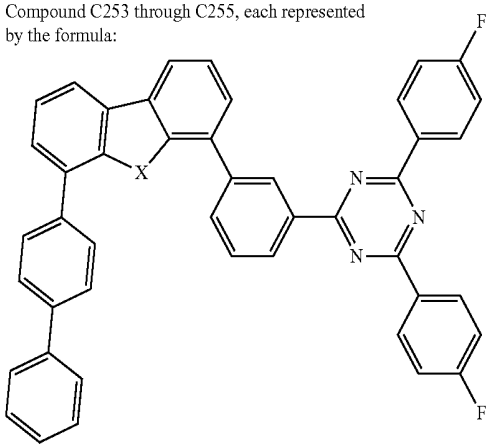
wherein in Compound C247: X = O,
in Compound C248: X = S,
in Compound C249: X = Se

Compound C250 through C252, each represented by the formula



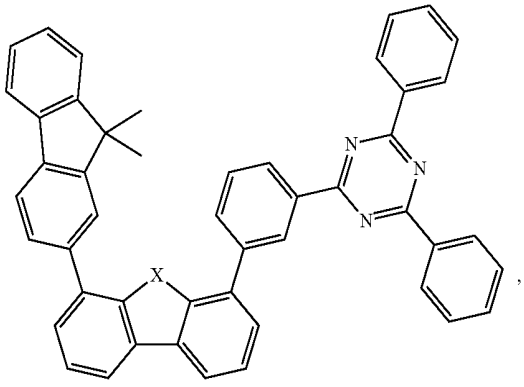
wherein in Compound C250: X = O,
in Compound C251: X = S,
in Compound C252: X = Se

Compound C253 through C255, each represented by the formula:



wherein in Compound C253: X = O,
in Compound C254: X = S,
in Compound C255: X = Se

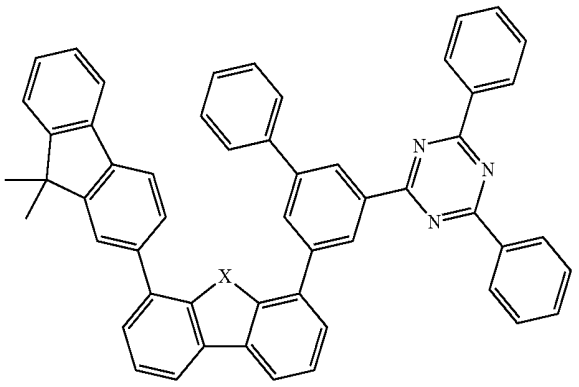
Compound D1 through D3, each represented by the formula:



where in Compound D1: X = O,
in Compound D2, X = S, and
in Compound D3, X = Se

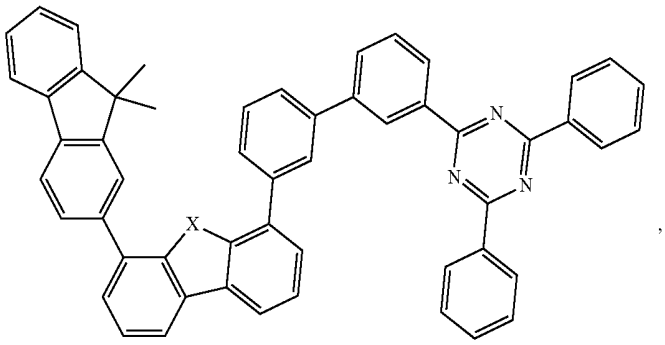
-continued

Compound D4 through D6, each represented by the formula:



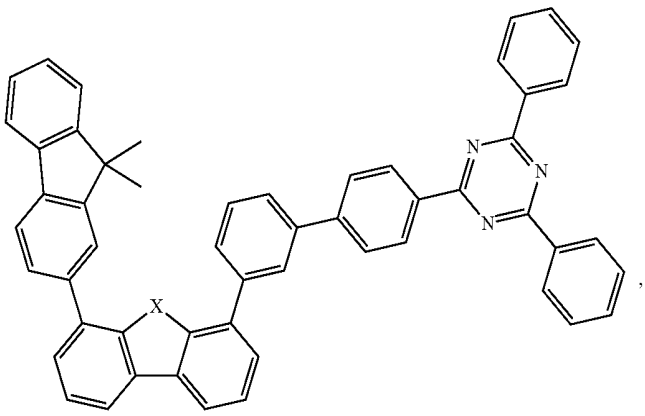
where in Compound D4: X = O,
in Compound D5, X = S, and
in Compound D6, X = Se

Compound D7 through D9, each represented by the formula:



where in Compound D7: X = O,
in Compound D8, X = S, and
in Compound D9, X = Se

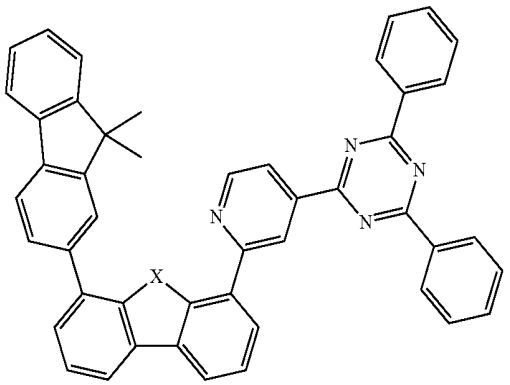
Compound D10 through D12, each represented by the formula:



where in Compound D10: X = O,
in Compound D11, X = S, and
in Compound D12, X = Se

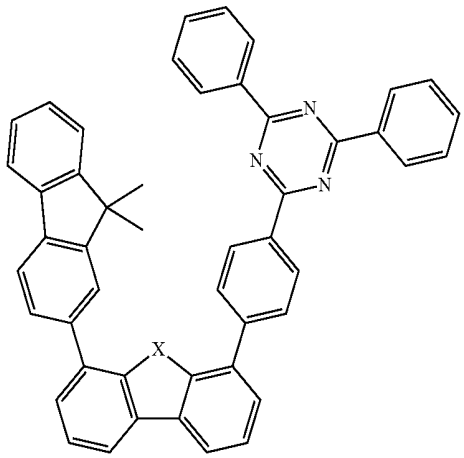
-continued

Compound D13 through D15, each represented by the formula:



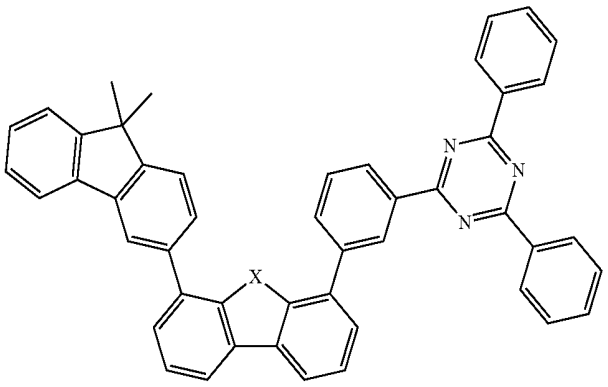
where in Compound D13: X = O,
in Compound D14, X = S, and
in Compound D15, X = Se

Compound D16 through D18, each represented by the formula:



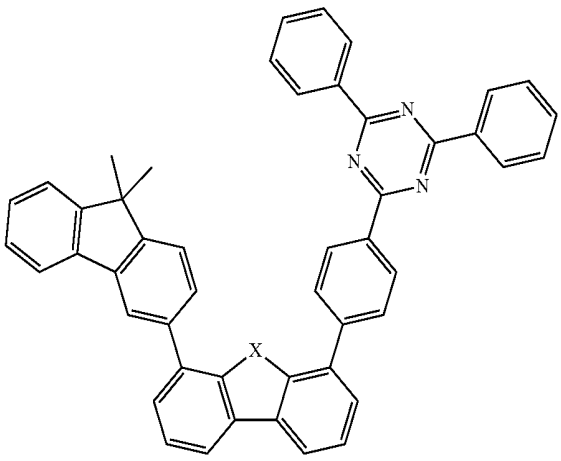
where in Compound D16: X = O,
in Compound D17, X = S, and
in Compound D18, X = Se

Compound D19 through D21, each represented by the formula:



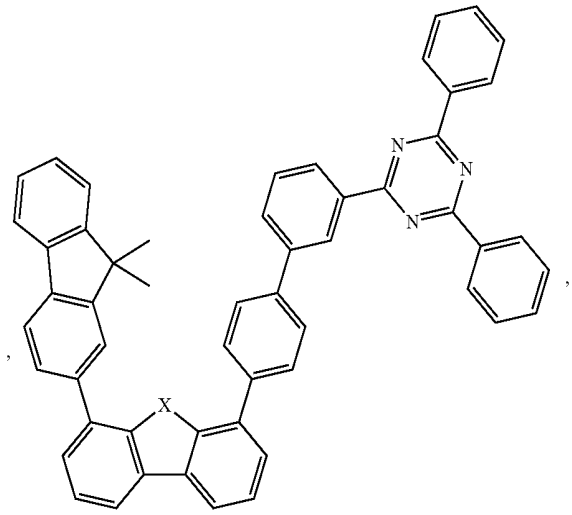
where in Compound D19: X = O,
in Compound D20, X = S, and
in Compound D21, X = Se

Compound D22 through D24, each represented by the formula:



where in Compound D22: X = O,
in Compound D23, X = S, and
in Compound D24, X = Se

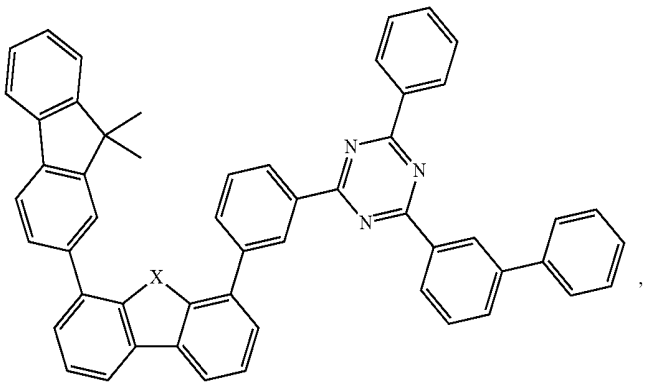
Compound D25 through D27, each represented by the formula:



where in Compound D25: X = O,
in Compound D26, X = S, and
in Compound D27, X = Se

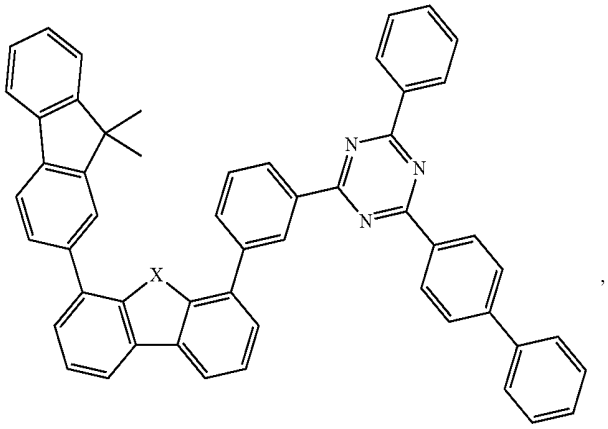
-continued

Compound D28 through D30, each represented by the formula:



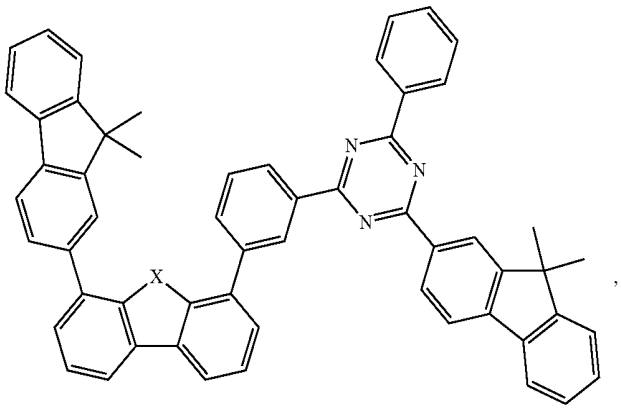
where in Compound D28: X = O,
in Compound D29, X = S, and
in Compound D30, X = Se

Compound D31 through D33, each represented by the formula:



where in Compound D31: X = O,
in Compound D32, X = S, and
in Compound D33, X = Se

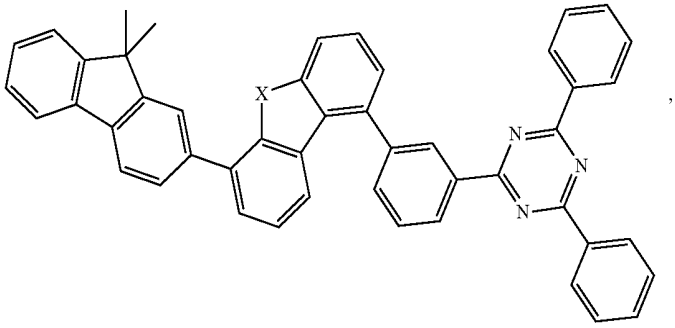
Compound D34 through D36, each represented by the formula:



where in Compound D34: X = O,
in Compound D35, X = S, and
in Compound D36, X = Se

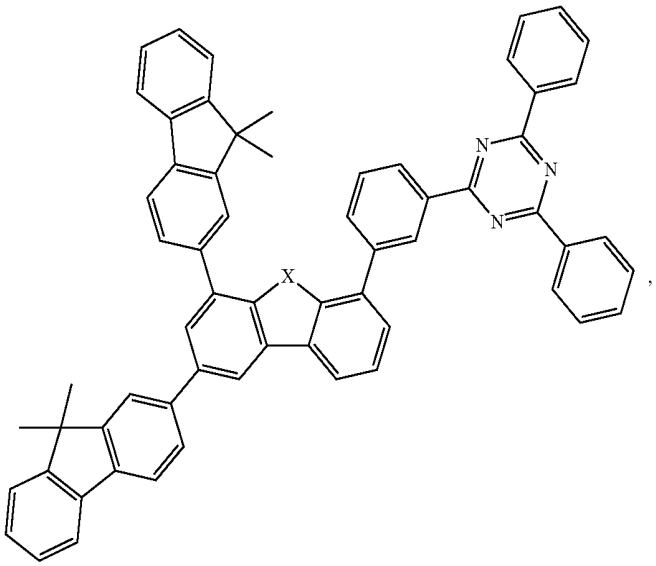
-continued

Compounds D37 through D39, each represented by the formula:



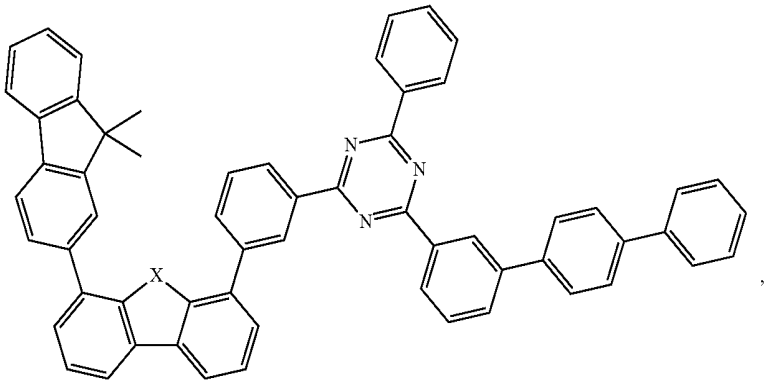
where in Compound D37: X = O,
in Compound D38, X = S, and
in Compound D39, X = Se

Compound D40 through D42, each represented by the formula:



where in Compound D40: X = O,
in Compound D41, X = S, and
in Compound D42, X = Se

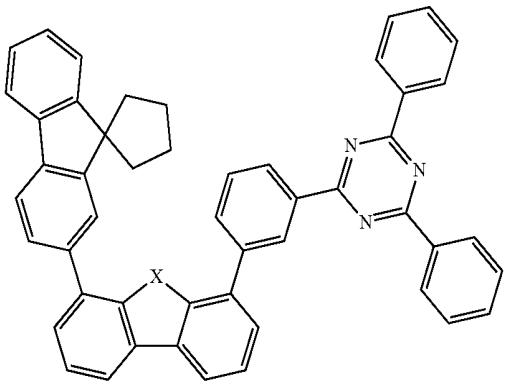
Compound D43 through D45, each represented by the formula:



where in Compound D43: X = O,
in Compound D44, X = S, and
in Compound D45, X = Se

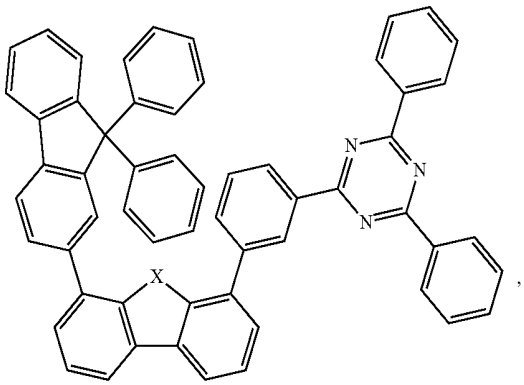
-continued

Compound D46 through D48, each represented by the formula:



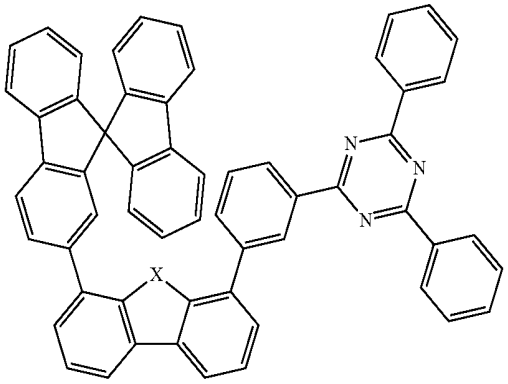
where in Compound D46: X = O,
in Compound D47, X = S, and
in Compound D48, X = Se

Compound D49 through D51, each represented by the formula:



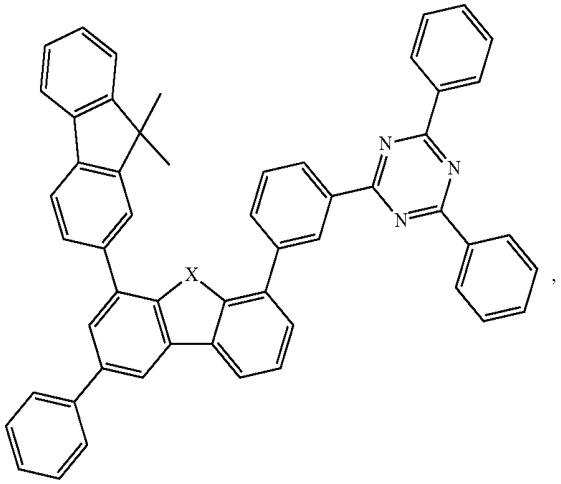
where in Compound D49: X = O,
in Compound D50, X = S, and
in Compound D51, X = Se

Compound D49 through D51, each represented by the formula:



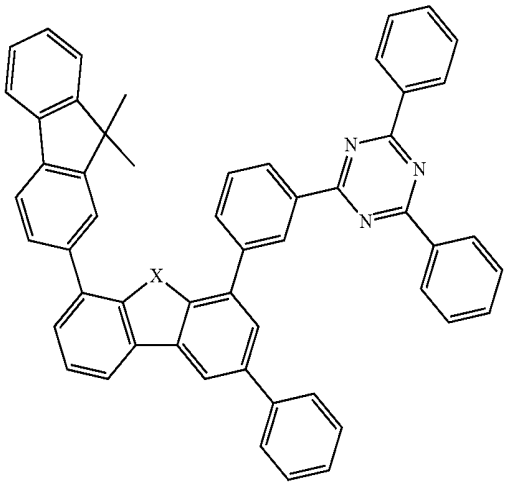
where in Compound D52: X = O,
in Compound D53, X = S, and
in Compound D54, X = Se

Compound D55 through D57, each represented by the formula:



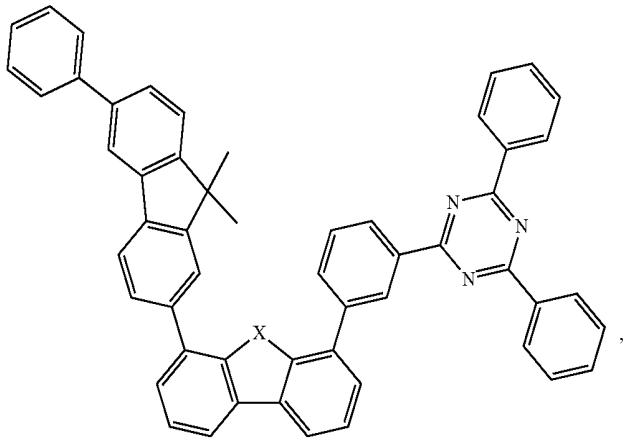
where in Compound D55: X = O,
in Compound D56, X = S, and
in Compound D57, X = Se

Compound D58 through D60, each represented by the formula:



where in Compound D58: X = O,
in Compound D59, X = S, and
in Compound D60, X = Se

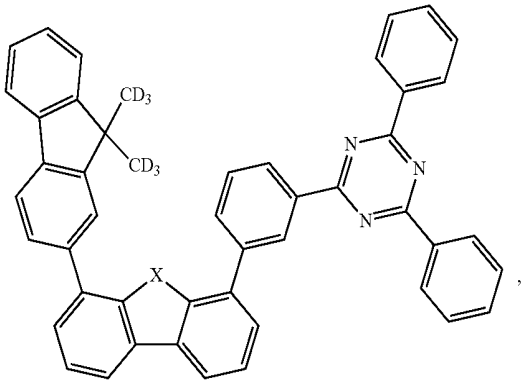
Compound D61 through D63, each represented by the formula:



where in Compound D61: X = O,
in Compound D62, X = S, and
in Compound D63, X = Se

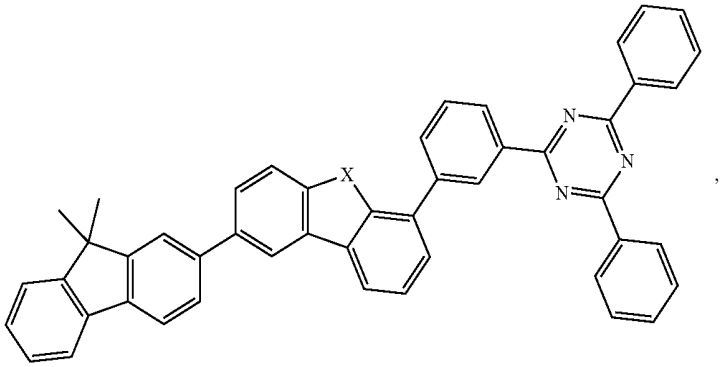
-continued

Compound D64 through D66, each represented by the formula:



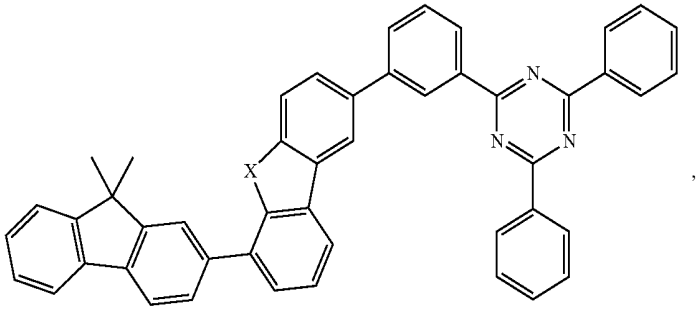
where in Compound D64: X = O,
in Compound D65, X = S, and
in Compound D66, X = Se

Compound D67 through D69, each represented by the formula:



where in Compound D67: X = O,
in Compound D68, X = S, and
in Compound D69, X = O

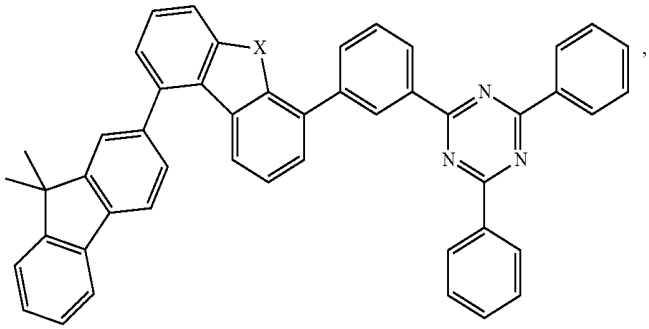
Compounds D70 through D72, each represented by the formula:



where in Compound D70: X = O,
in Compound D71, X = S, and
in Compound D72, X = Se

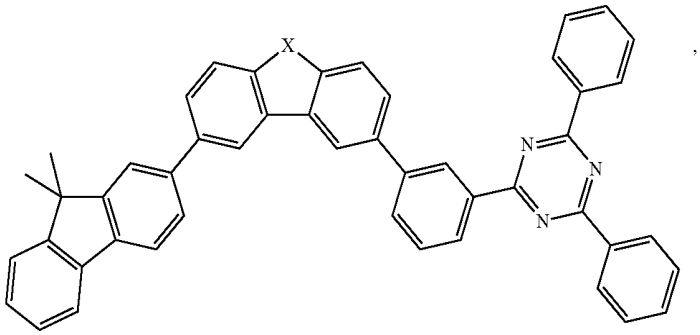
-continued

Compounds D73 through D75, each represented by the formula:



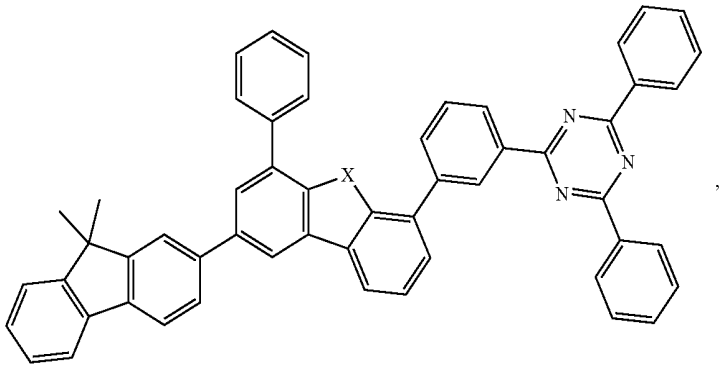
where in Compound D73: X = O,
in Compound D74, X = S, and
in Compound D75, X = Se

Compounds D76 through D78, each represented by the formula:



where in Compound D76: X = O,
in Compound D77, X = S, and
in Compound D78, X = Se

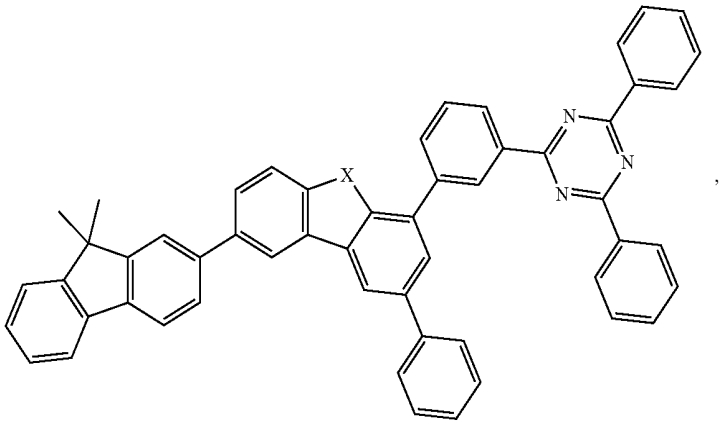
Compounds D79 through D81, each represented by the formula:



where in Compound D79: X = O,
in Compound D80, X = S, and
in Compound D81, X = Se

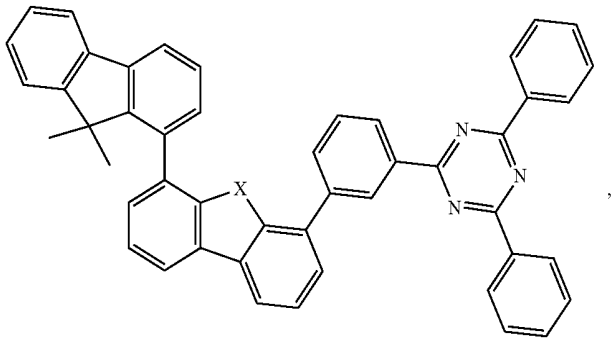
-continued

Compounds D82 through D84, each represented by the formula:



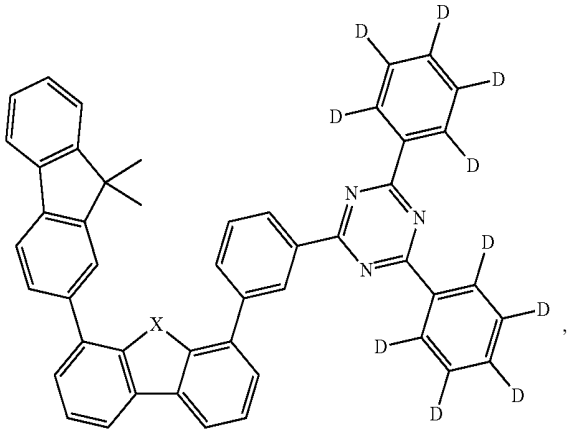
where in Compound D82: X = O,
in Compound D83, X = S, and
in Compound D84, X = Se

Compounds D85 through D87, each represented by the formula:



where in Compound D85: X = O,
in Compound D86, X = S, and
in Compound D87, X = Se

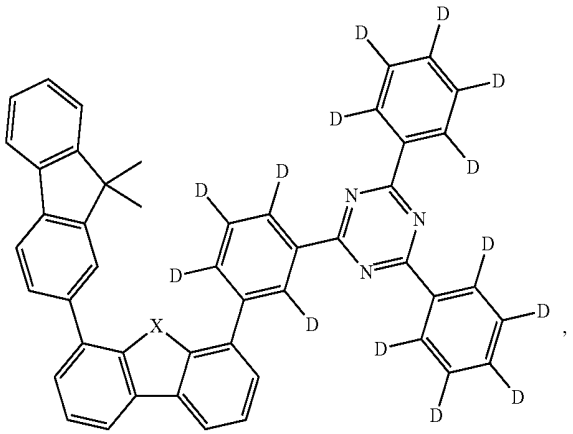
Compounds D88 through D90, each represented by the formula:



where in Compound D88: X = O,
in Compound D89, X = S, and
in Compound D90, X = Se

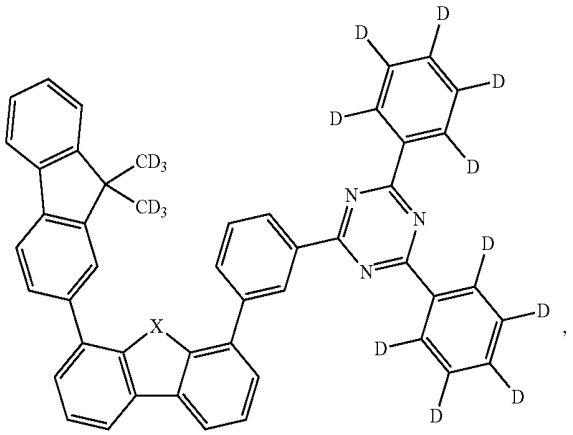
-continued

Compounds D91 through D93, each represented by the formula:



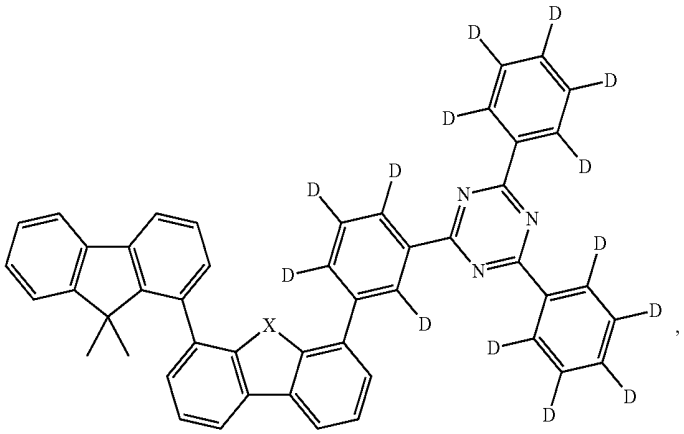
where in Compound D91: X = O,
in Compound D92, X = S, and
in Compound D93, X = Se

Compounds D94 through D96, each represented by the formula:



where in Compound D94: X = O,
in Compound D95, X = S, and
in Compound D96, X = Se

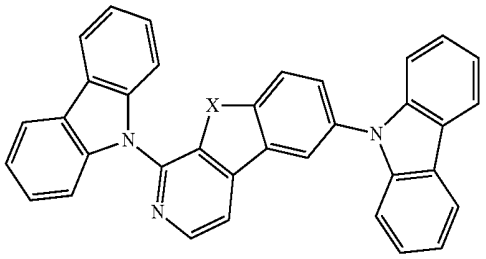
Compounds D97 through D99, each represented by the formula:



where in Compound D97: X = O,
in Compound D98, X = S, and
in Compound D99, X = Se

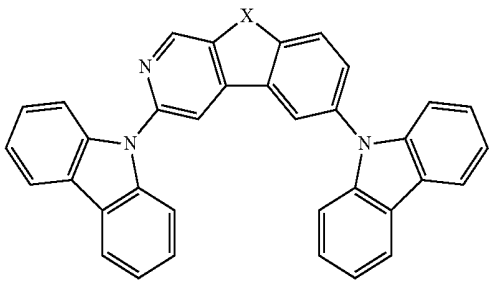
-continued

Compounds E1 through E3, each represented by the formula:



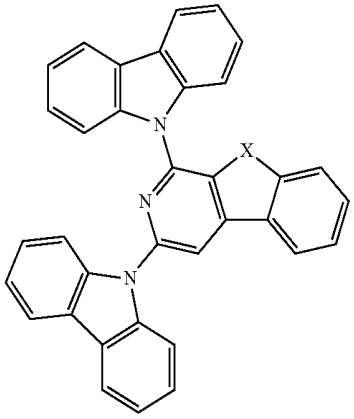
where in Compound E1: X = O,
in Compound E2, X = S, and
in Compound E3, X = Se

Compounds E4 through E6, each represented by the formula:



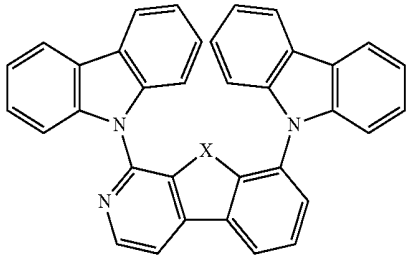
where in Compound E4: X = O,
in Compound E5, X = S, and
in Compound E6, X = Se

Compounds E7 through E9, each represented by the formula:



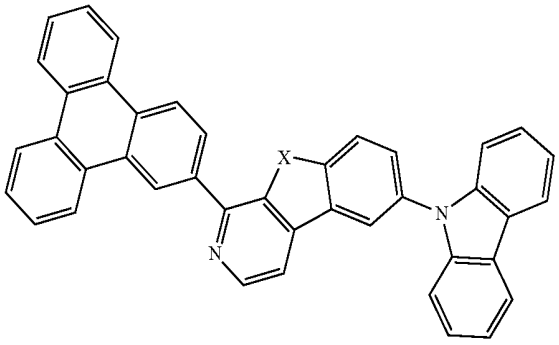
where in Compound E7: X = O,
in Compound E8, X = S, and
in Compound E9, X = Se

Compounds E10 through E12, each represented by the formula:



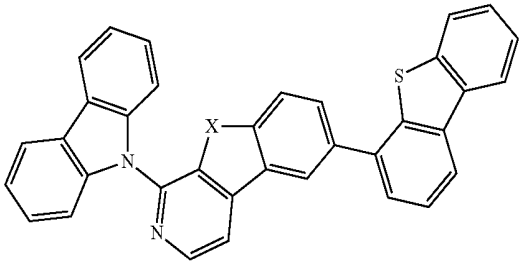
where in Compound E10: X = O,
in Compound E11, X = S, and
in Compound E10, X = Se

Compounds E13 through E15, each represented by the formula:



where in Compound E13: X = O,
in Compound E14, X = S, and
in Compound E15, X = Se

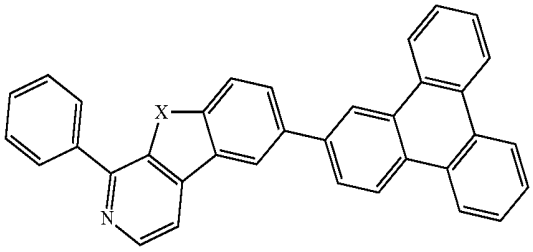
Compounds E16 through E18, each represented by the formula:



where in Compound E16: X = O,
in Compound E17, X = S, and
in Compound E18, X = Se

-continued

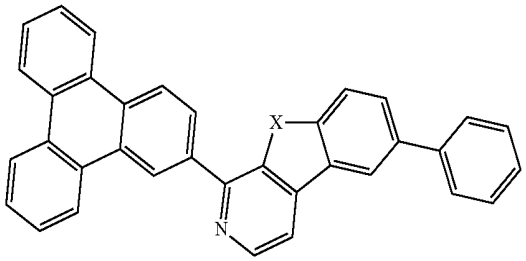
Compounds E19 through E21, each represented by the formula:



where in Compound E19: X = O,
in Compound E20, X = S, and
in Compound E21, X = Se

, and

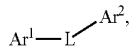
Compounds E22 through E24, each represented by the formula:



where in Compound E22: X = O,
in Compound E23, X = S, and
in Compound E24, X = Se

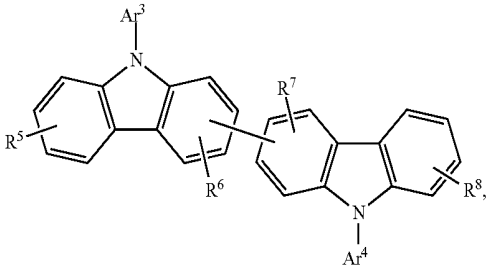
10. The first mixture of claim **7**, wherein the h-host material is selected from the group consisting of a compound having a structure of:

Formula III



and a compound having a structure of

Formula IV



wherein Ar^1 is selected from the group consisting of triphenylene, tetraphenylene, pyrene, naphthalene, fluoranthene, chrysene, phenanthrene, and combinations thereof;

wherein L is selected from the group consisting of a direct bond, phenyl, biphenyl, terphenyl, naphthalene, pyridine, dibenzofuran, dibenzothiophene, dibenzoselenophene, and combinations thereof;

wherein Ar^2 is selected from the group consisting of benzene, biphenyl, terphenyl, naphthalene, pyridine, dibenzofuran, dibenzothiophene, dibenzoselenophene, fluorene, carbazole, and combinations thereof;

wherein Ar^1, Ar^2 and L are each independently and optionally further substituted with one or more substitutions selected from the group consisting of deuterium, halogen, alkyl, aryl, non-aza-heteroaryl, and combinations thereof;

wherein R^5 and R^8 each independently represent mono, di, tri, or tetra substitution, or no substitution;

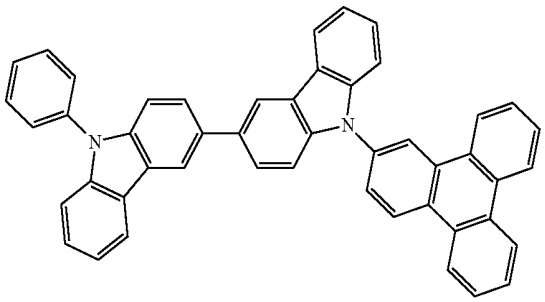
wherein R^6 and R^7 each independently represent mono, di, or tri substitution, or no substitution;

wherein R^5, R^6, R^7, R^8, Ar^3 and Ar^4 are each independently selected from the group consisting of hydrogen, deuterium, halogen, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, benzene, furan, thiophene, selenophene, pyrole, biphenyl, terphenyl, naphthalene, triphenylene, anthracene, phenanthracene, tetraphenylene, pyrene, fluoranthene, chrysene, fluorene, carbazole, benzofuran, benzothiophene, benzoselenophene, dibenzofuran, dibenzothiophene, dibenzoselenophene, indole, carbazole, and combinations thereof; and

wherein any two adjacent substituents are optionally joined or fused into a ring.

11. The first mixture of claim **7**, wherein the h-host is selected from the group consisting of:

Compound F1



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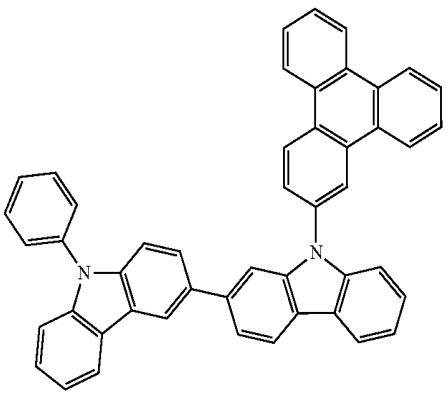
Compound F2



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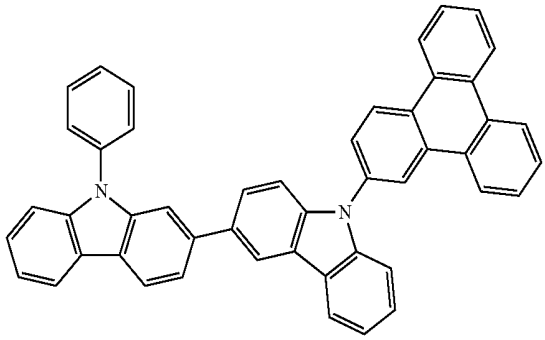
Compound F3



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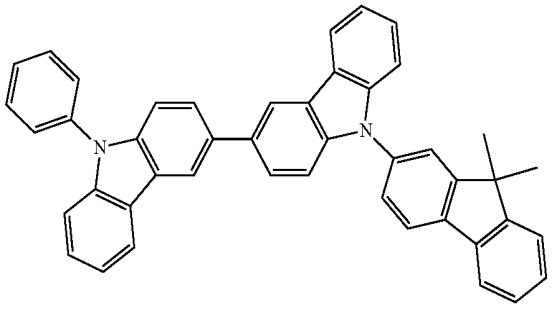
Compound F4



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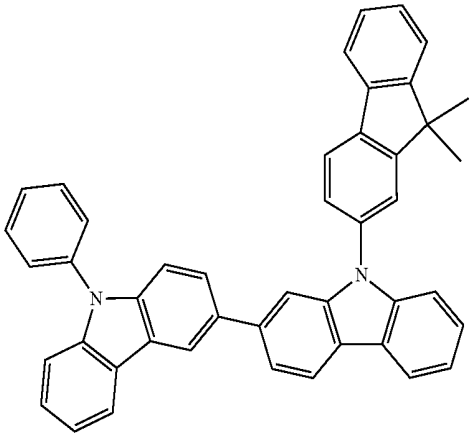
Compound F5



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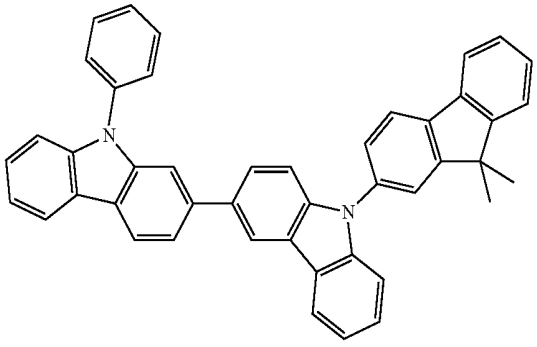
Compound F6



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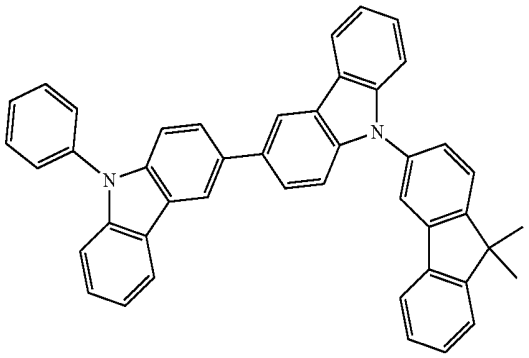
Compound F7



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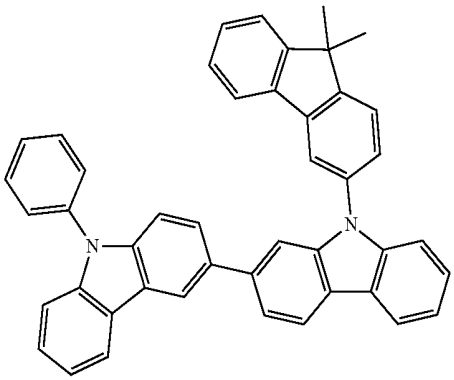
Compound F8



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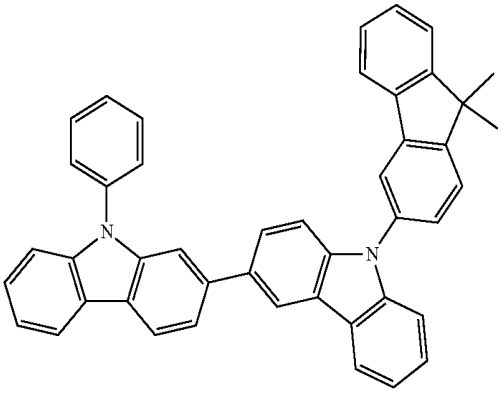
Compound F9



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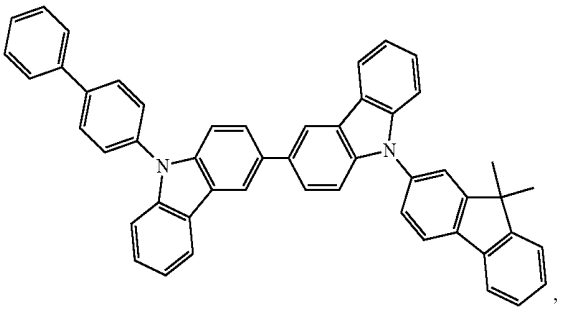
Compound F10



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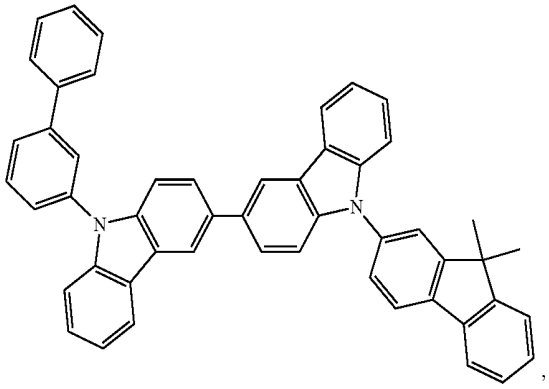
Compound F11



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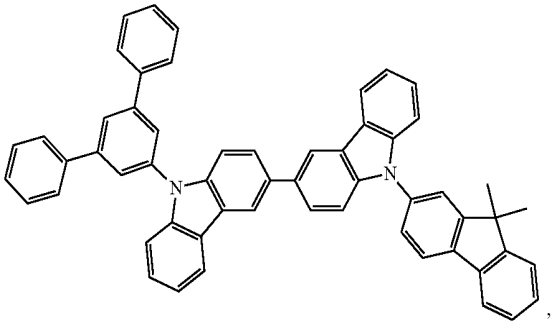
Compound F12



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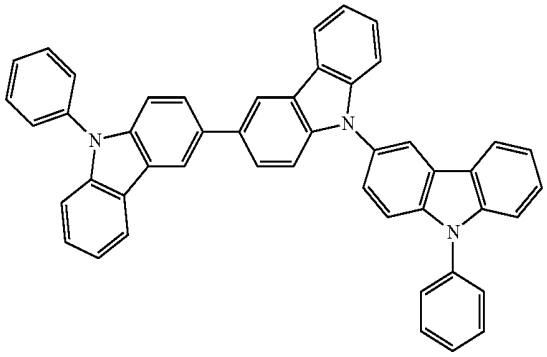
Compound F13



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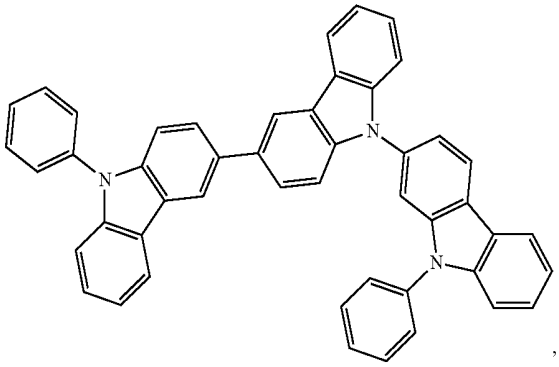
Compound F14



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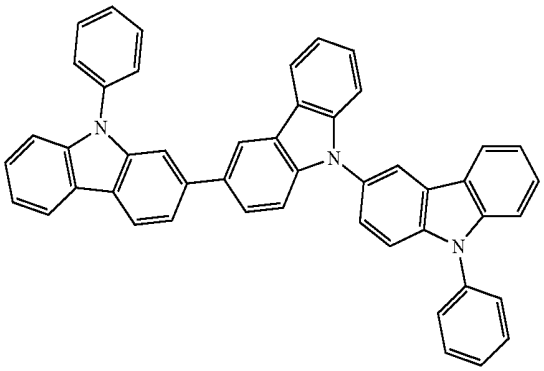
Compound F15



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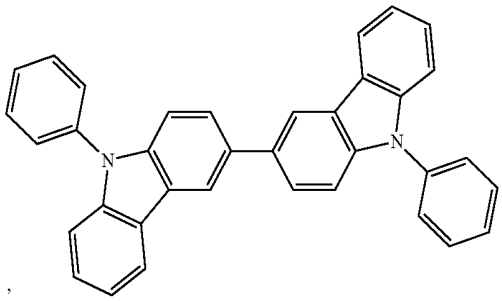
Compound F16



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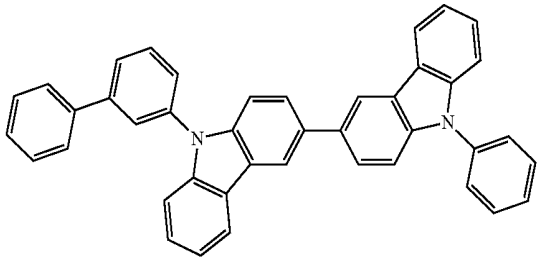
Compound F17



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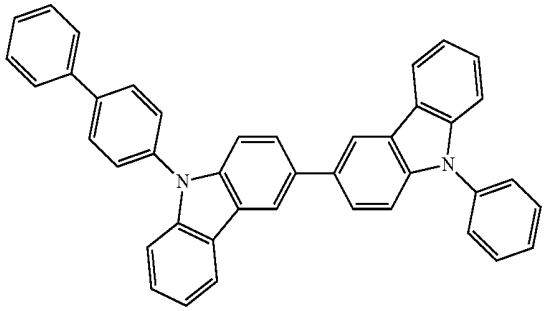
Compound F18



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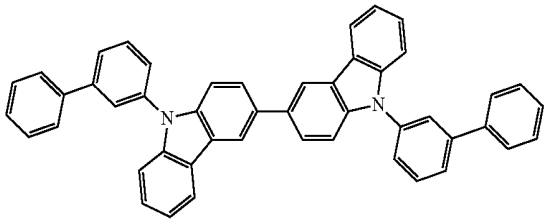
Compound F19



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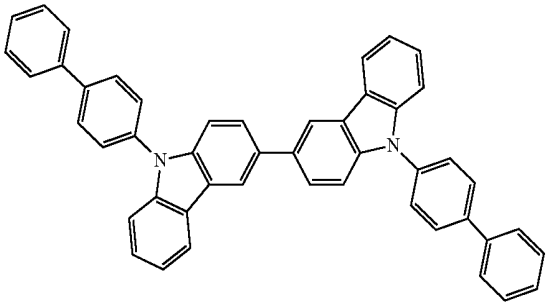
Compound F20



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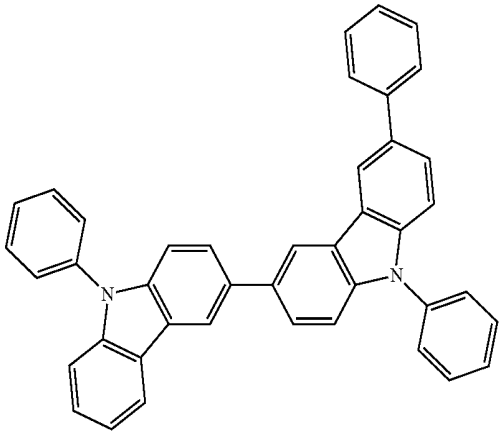
Compound F21



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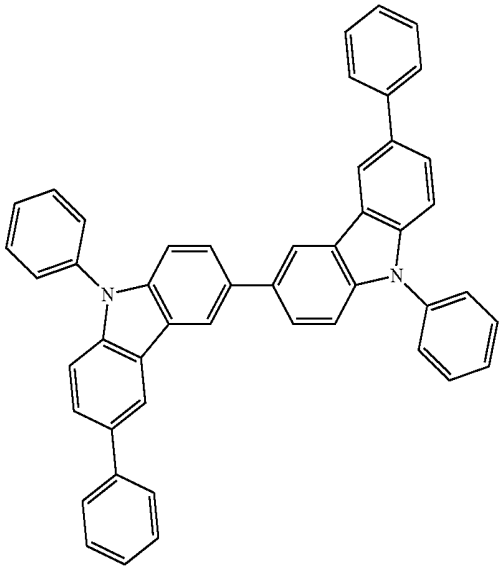
Compound F22



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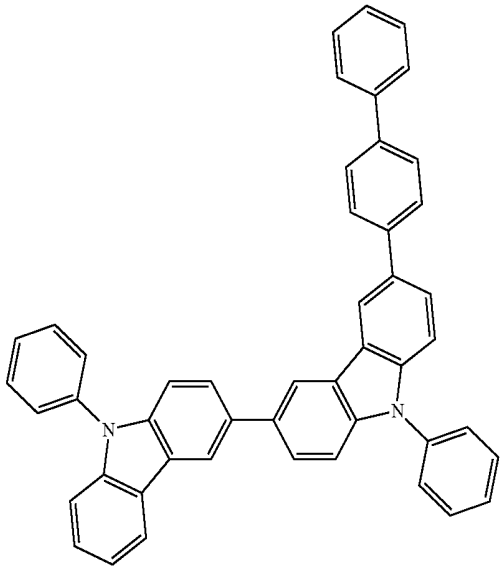
Compound F23



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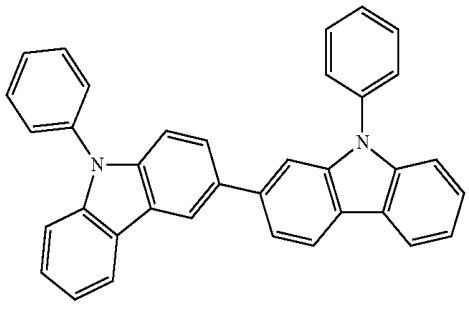
Compound F24



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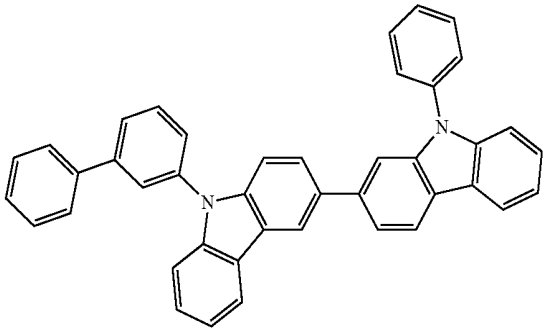
Compound F25



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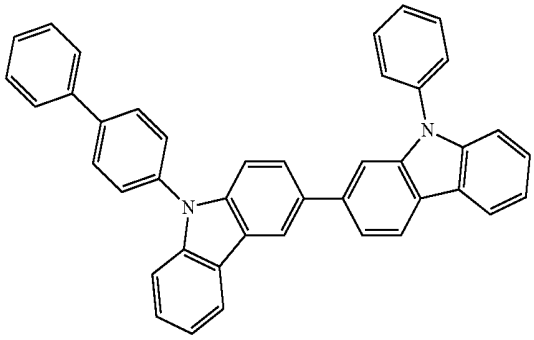
Compound F26



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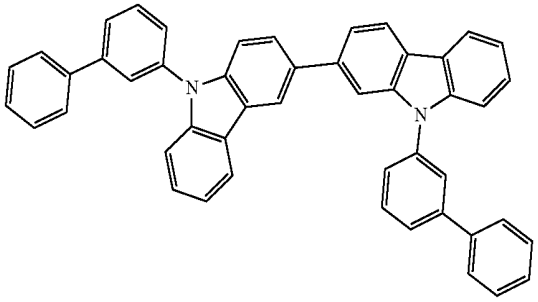
Compound F27



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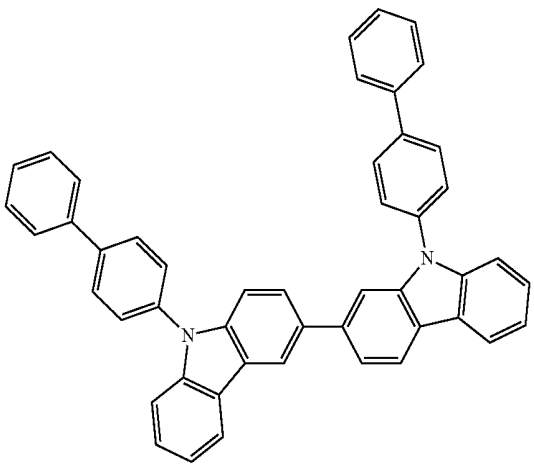
Compound F28



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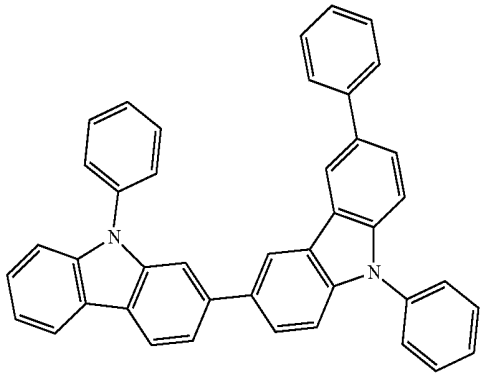
Compound F29



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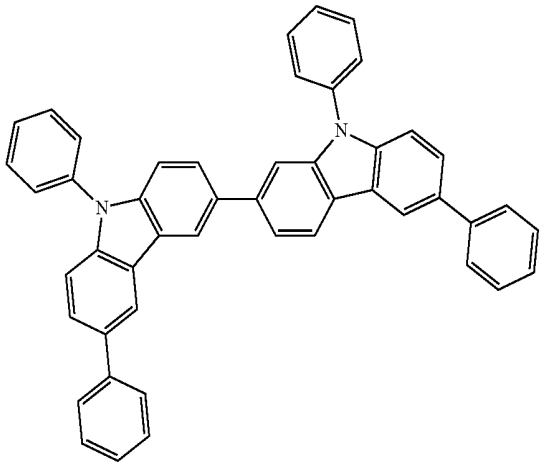
Compound F30



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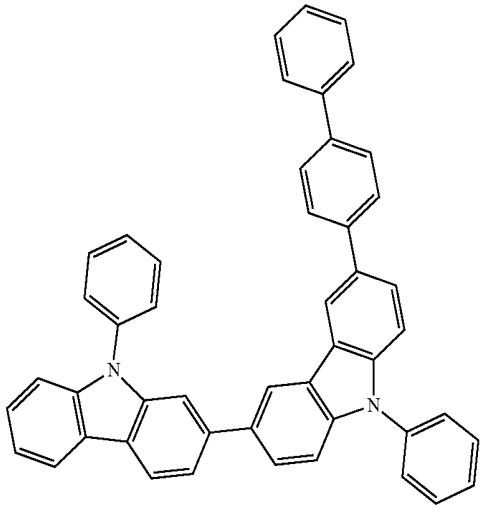
Compound F31



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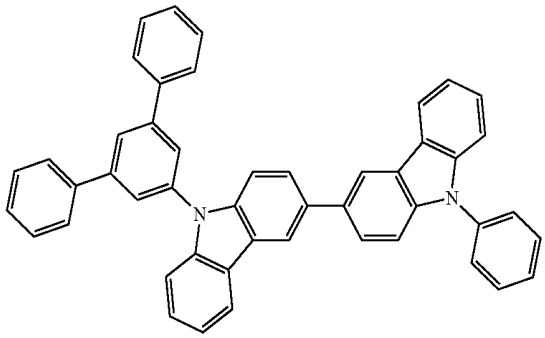
Compound F32



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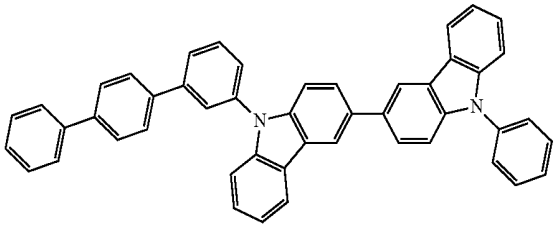
Compound F33



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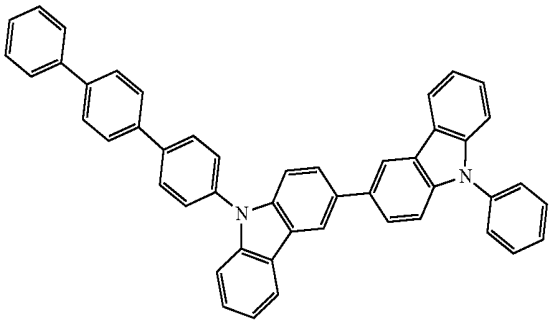
Compound F34



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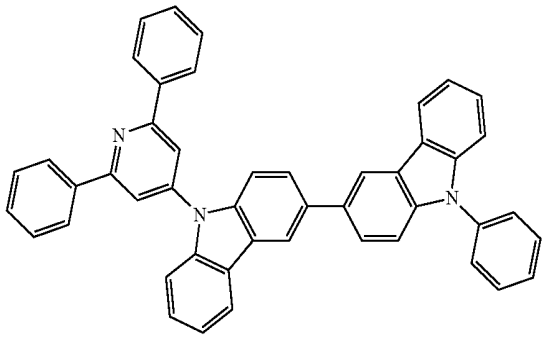
Compound F35



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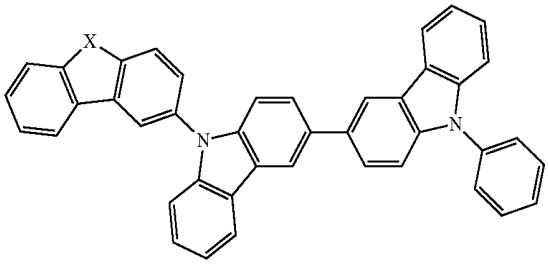
Compounds G1 through G3, each represented by the formula:

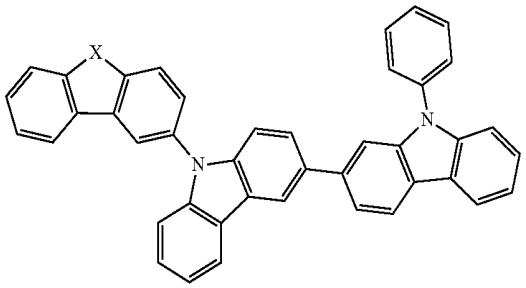


,

where in Compound G1: X = O, in Compound G2, X = S, and in Compound G3, X = Se

-continued

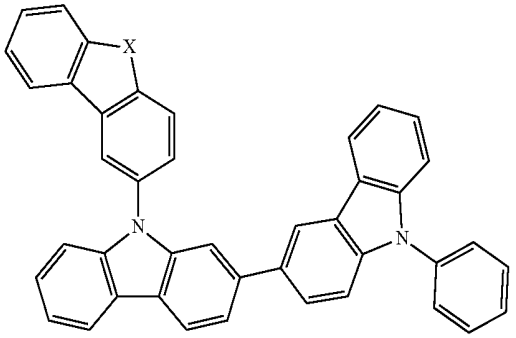
Compounds G4 through G6, each represented by the formula:



,

where in Compound G4: X = O, in Compound G5, X = S, and in Compound G6, X = Se

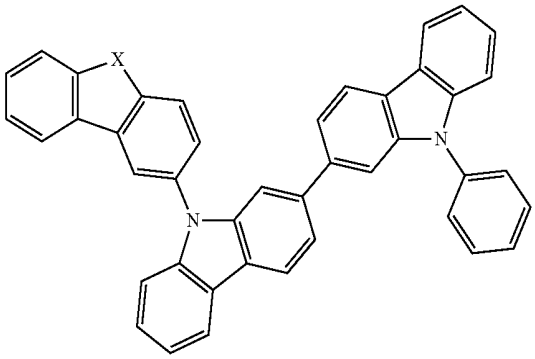
Compounds G7 through G9, each represented by the formula:



,

where in Compound G7: X = O, in Compound G8, X = S, and in Compound G9, X = Se

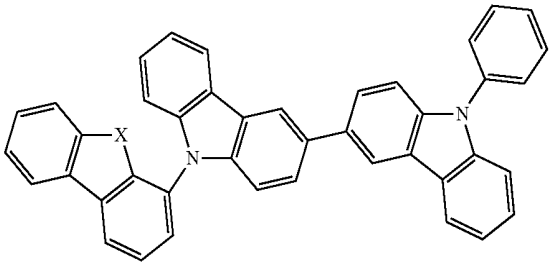
Compounds G10 through G12, each represented by the formula:



,

where in Compound G10: X = O, in Compound G11, X = S, and in Compound G12, X = Se

Compounds G13 through G15, each represented by the formula:

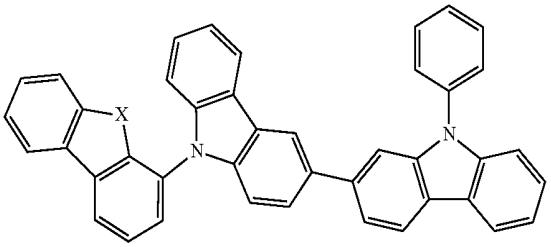


,

where in Compound G13: X = O, in Compound G14, X = S, and in Compound G15, X = Se

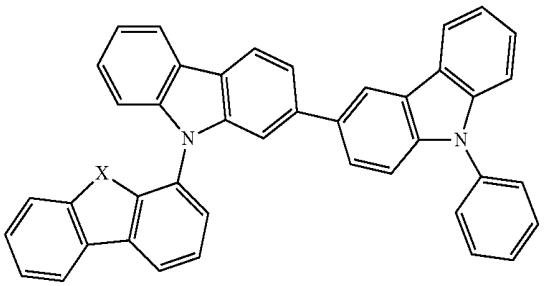
-continued

Compounds G16 through G18, each represented by the formula:



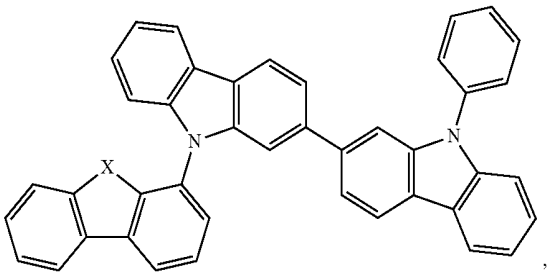
where in Compound G16: X = O, in Compound G17, X = S, and in Compound G18, X = Se

Compounds G19 through G21, each represented by the formula:



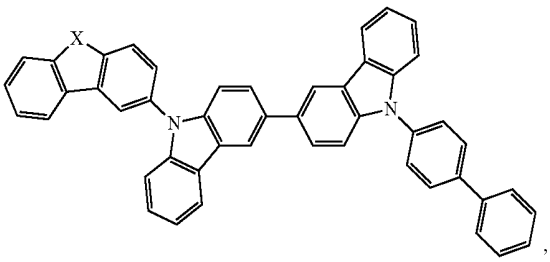
where in Compound G19: X = O, in Compound G20, X = S, and in Compound G21, X = Se

Compounds G22 through G24, each represented by the formula:



where in Compound G22: X = O, in Compound G23, X = S, and in Compound G24, X = Se

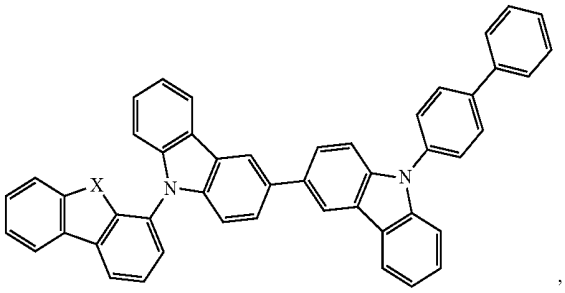
Compounds G25 through G27, each represented by the formula:



where in Compound G25: X = O, in Compound G26, X = S, and in Compound G27, X = Se

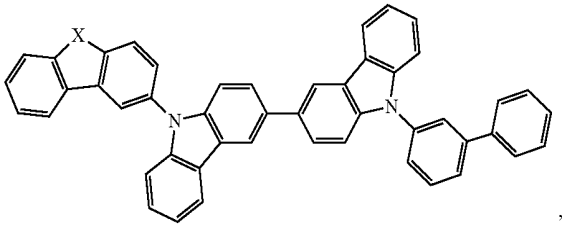
-continued

Compounds G28 through G30, each represented by the formula:



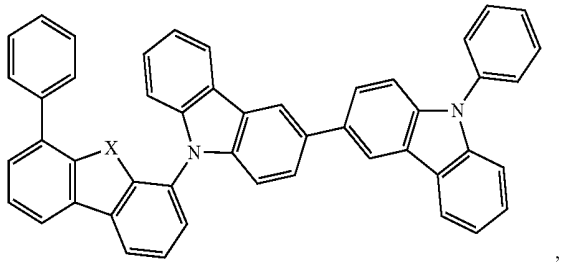
where in Compound G28: X = O, in Compound G29, X = S, and in Compound G30, X = Se

Compounds G31 through G33, each represented by the formula:



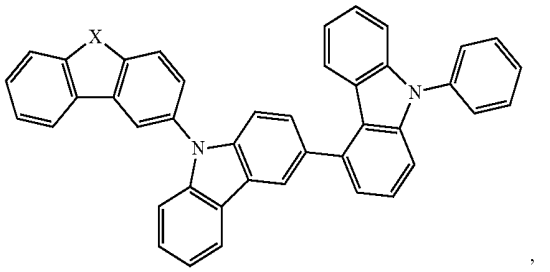
where in Compound G31: X = O, in Compound G32, X = S, and in Compound G33, X = Se

Compounds G34 through G36, each represented by the formula:



where in Compound G34: X = O, in Compound G35, X = S, and in Compound G36, X = Se

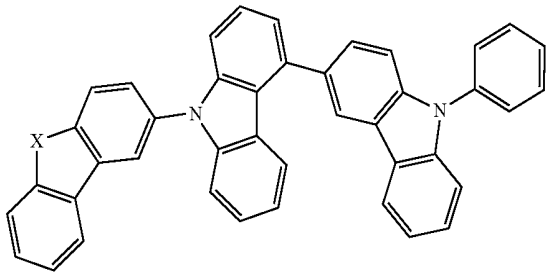
Compounds G37 through G39, each represented by the formula:



where in Compound G37: X = O, in Compound G38, X = S, and in Compound G39, X = Se

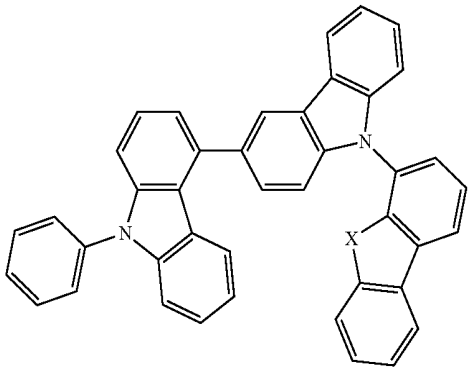
-continued

Compounds G40 through G42, each represented by the formula:



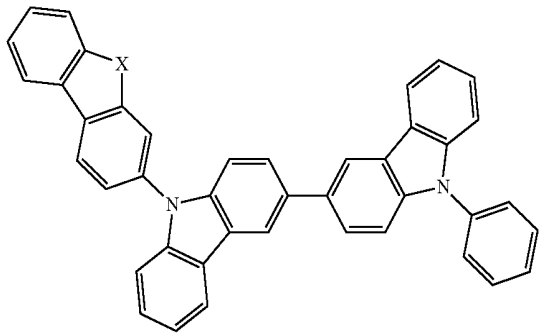
where in Compound G40: X = O, in Compound G41, X = S, and in Compound G42, X = Se

Compounds G43 through G45, each represented by the formula:



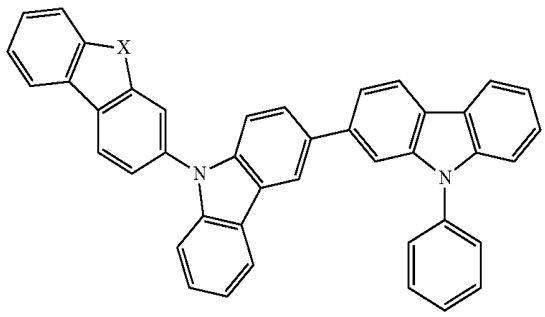
where in Compound G43: X = O, in Compound G44, X = S, and in Compound G45, X = Se

Compounds G46 through G48, each represented by the formula:



where in Compound G46: X = O, in Compound G47, X = S, and in Compound G48, X = Se

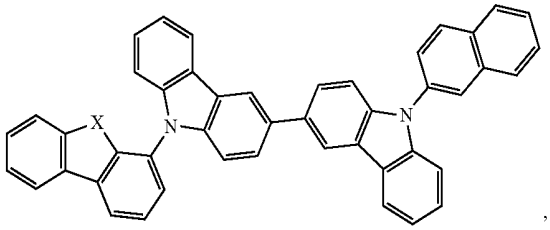
Compounds G49 through G51, each represented by the formula:



where in Compound G49: X = O, in Compound G50, X = S, and in Compound G51, X = Se

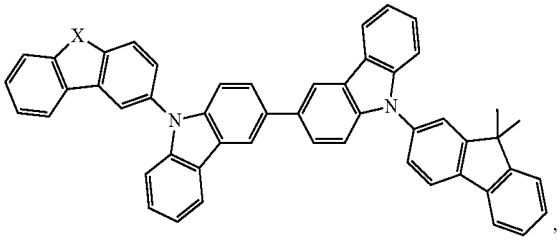
-continued

Compounds G52 through G54, each represented by the formula:



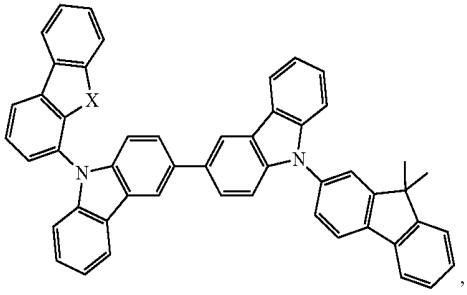
where in Compound G52: X = O, in Compound G53, X = S, and in Compound G54, X = Se

Compounds G55 through G56, each represented by the formula:



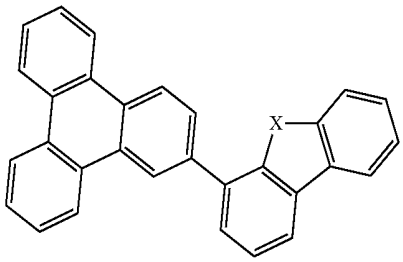
where in Compound G55: X = O, in Compound G56, X = S, and in Compound G57, X = Se

Compounds G58 through G60, each represented by the formula:



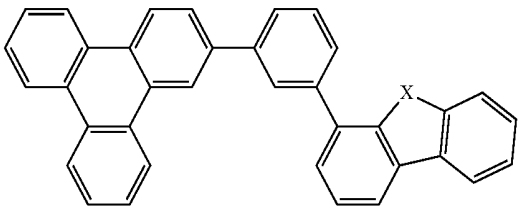
where in Compound G58: X = O, in Compound G59, X = S, and in Compound G60, X = Se

Compound H1 through H3, each represented by the formula



wherein in Compound H1: X = O, in Compound H2: X = S, and in Compound H3: X = Se

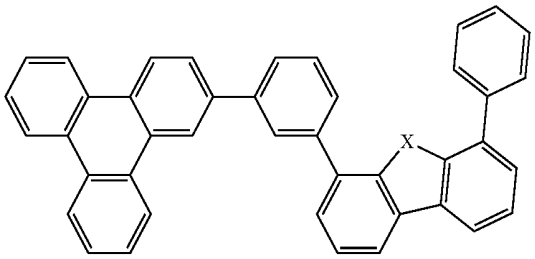
Compound H4 through H6, each represented by the formula



wherein in Compound H4: X = O, in Compound H5: X = S, and in Compound H6: X = Se

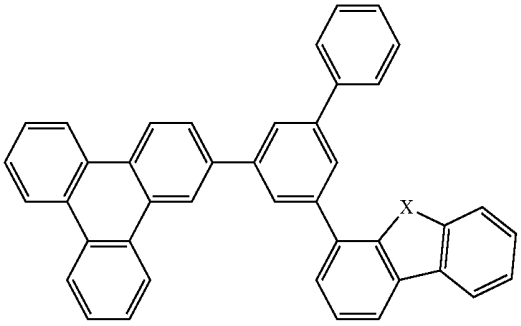
-continued

Compound H7 through H9, each represented by the formula



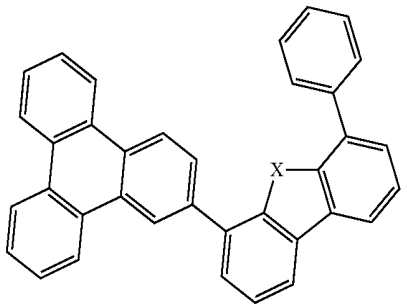
wherein in Compound H7: X = O, in Compound H8: X = S, and in Compound H9: X = Se

Compound H10 through H12, each represented by the formula



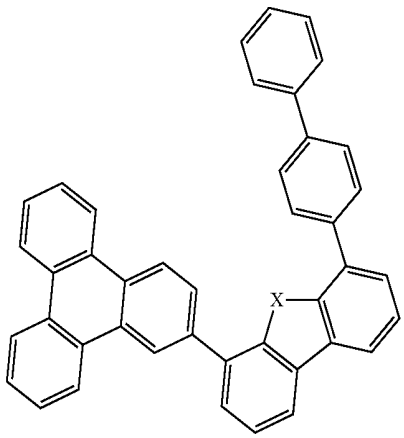
wherein in Compound H10: X = O, in Compound H11: X = S, and in Compound H12: X = Se

Compound H13 through H15, each represented by the formula



wherein in Compound H13: X = O, in Compound H14: X = S, and in Compound H15: X = Se

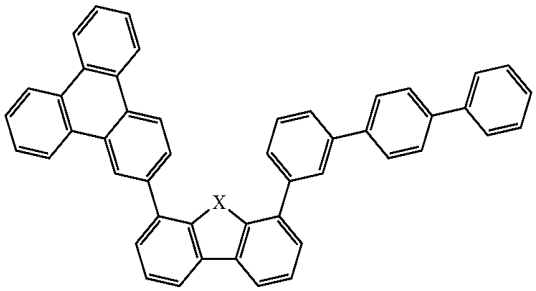
Compound H16 through H18, each represented by the formula



wherein in Compound H16: X = O, in Compound H17: X = S, and in Compound H18: X = Se

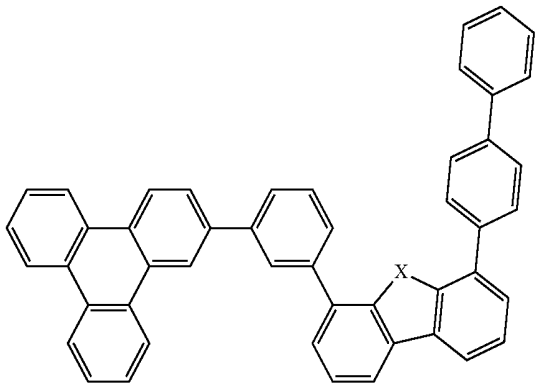
-continued

Compound H19 through H21, each represented by the formula



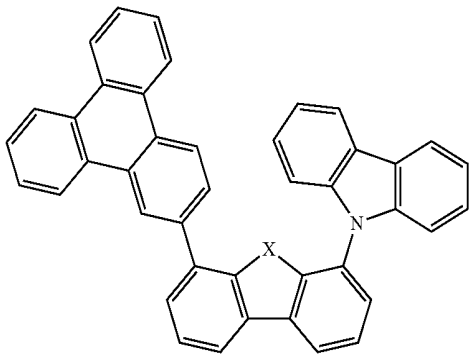
wherein in Compound H19: X = O, in Compound H20: X = S, and in Compound H21: X = Se

Compound H22 through H24, each represented by the formula

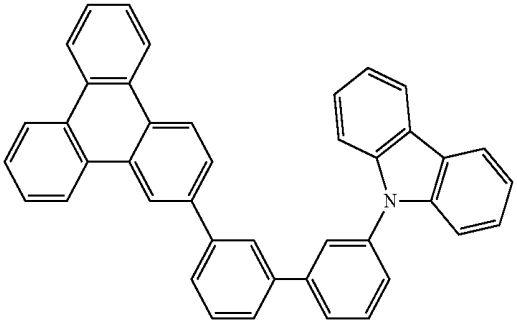


wherein in Compound H22: X = O, in Compound H23: X = S, and in Compound H24: X = Se

Compound H25 through H27, each represented by the formula



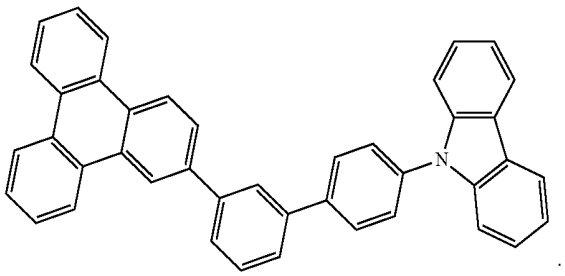
wherein in Compound H25: X = O, in Compound H26: X = S, and in Compound H27: X = Se



, and

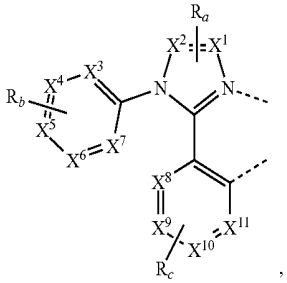
Compound H28

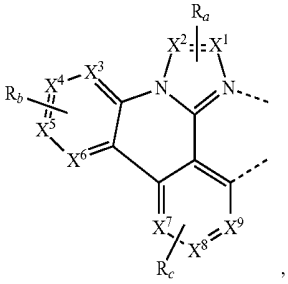
-continued

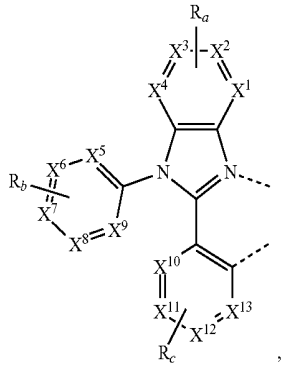


Compound H29

12. The first mixture of claim **7**, wherein the emitter is a transition metal complex having at least one ligand selected from the group consisting of:







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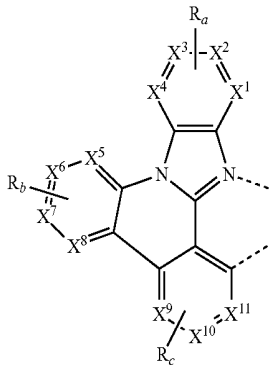

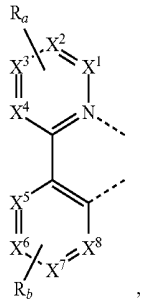

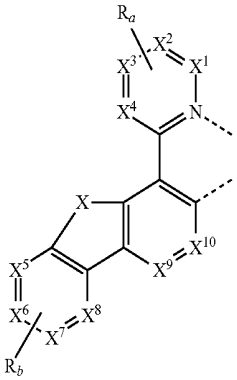

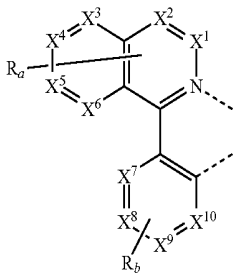

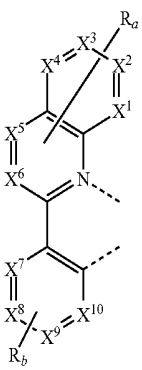

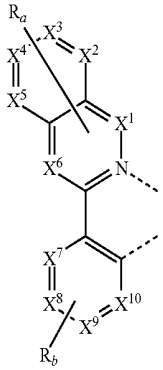

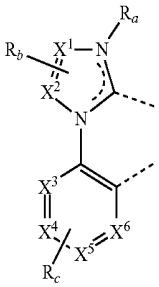

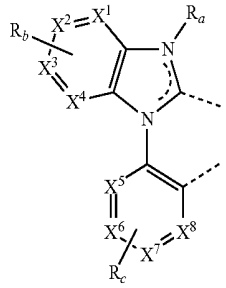

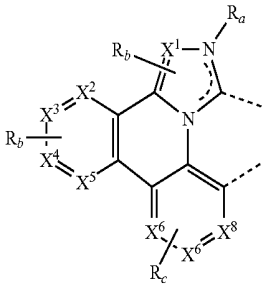

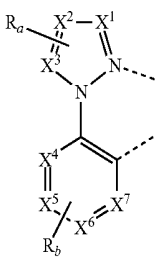

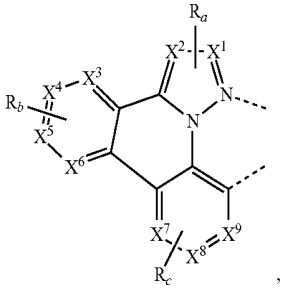

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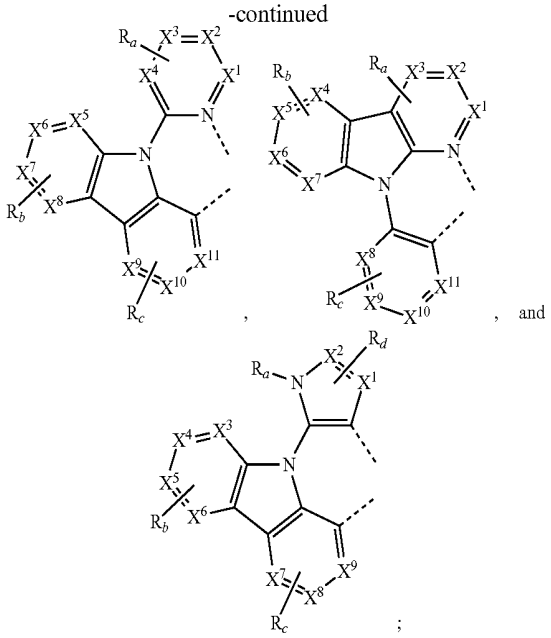


wherein each X^1 to X^{13} are independently selected from the group consisting of carbon and nitrogen;

wherein X is selected from the group consisting of BR', NR', PR', O, S, Se, C═O, S═O, SO_2, CR'R", SiR'R", and GeR'R";

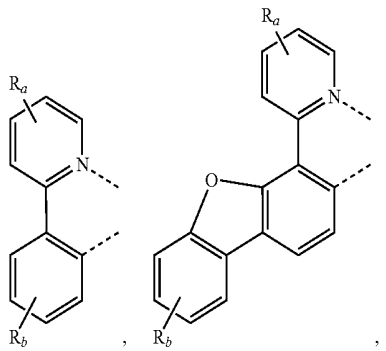
wherein R' and R" are optionally fused or joined to form a ring;

wherein each R_a, R_b, R_c, and R_d may represent from mono substitution to the possible maximum number of substitution, or no substitution;

wherein R', R", R_a, R_b, R_c, and R_d are each independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof; and

wherein any two adjacent substituents of R_a, R_b, R_c, and R_d are optionally fused or joined to form a ring or form a multidentate ligand.

13. The first mixture of claim **12**, wherein the emitter is a transition metal complex having at least one ligand selected from the group consisting of:



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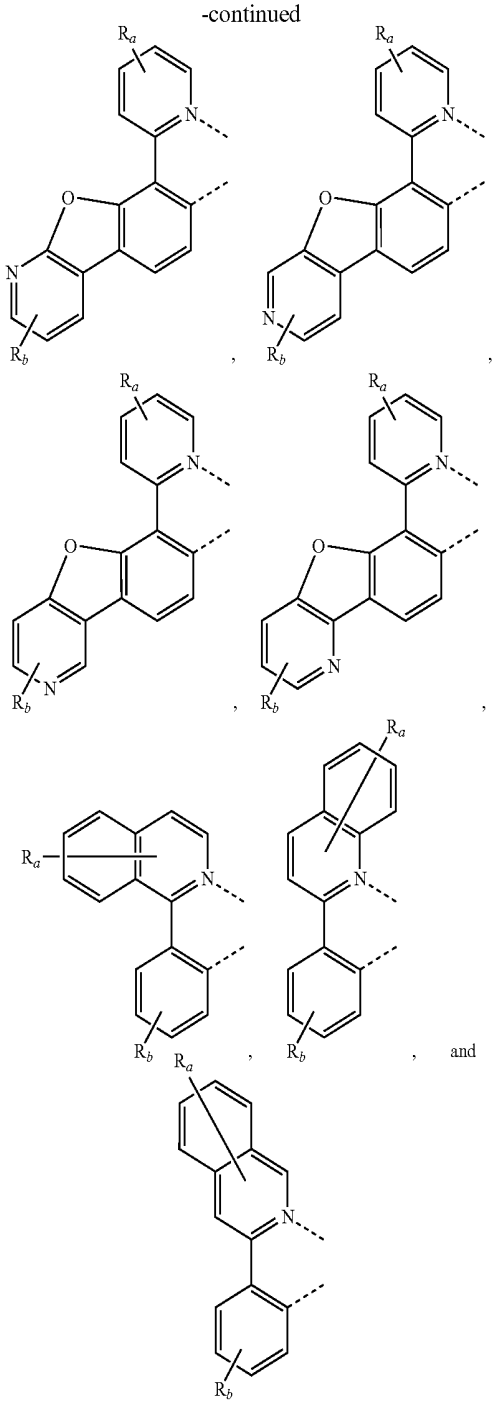
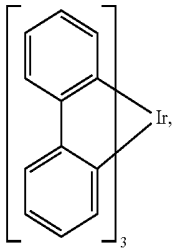


14. The first mixture of claim **12**, wherein the emitter is selected from the group consisting of:

Emitter 1



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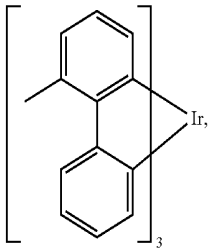
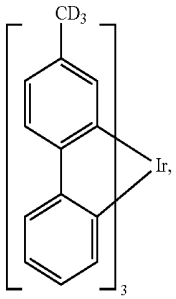
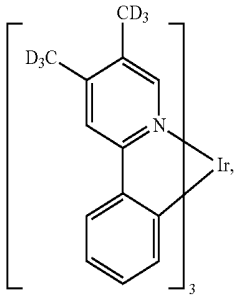
Emitter 2



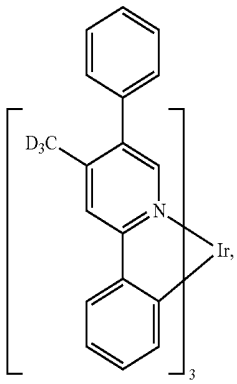
Emitter 3



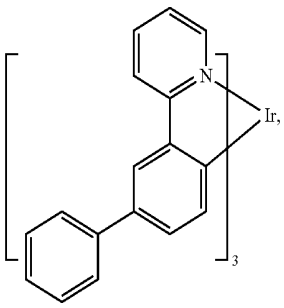
Emitter 4



Emitter 5



Emitter 6



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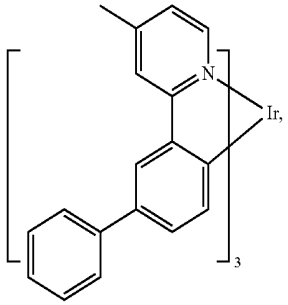
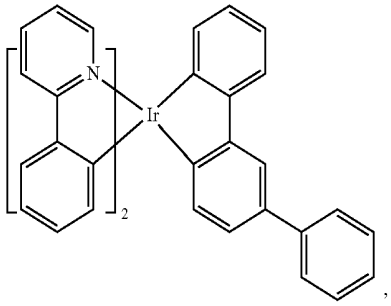
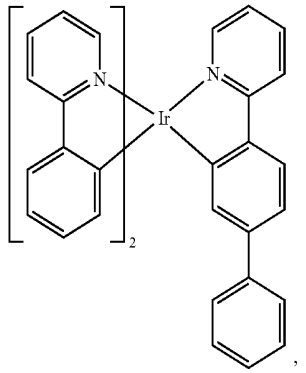
Emitter 7



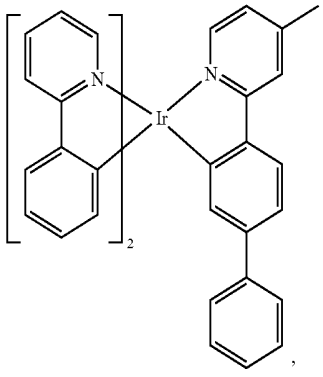
Emitter 8



Emitter 9



Emitter 10



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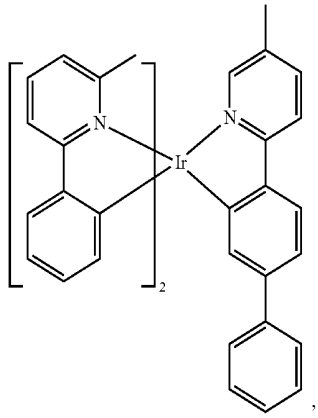
Emitter 11



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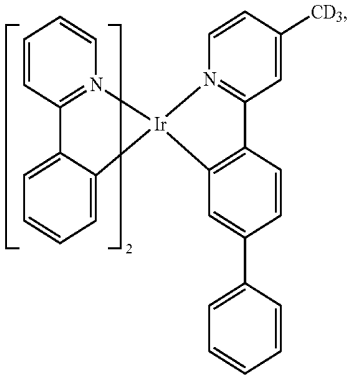

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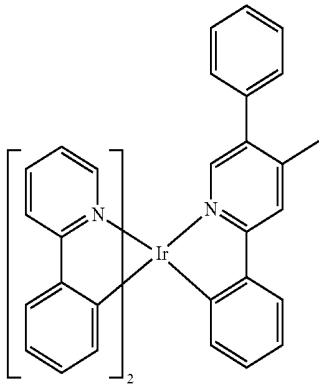

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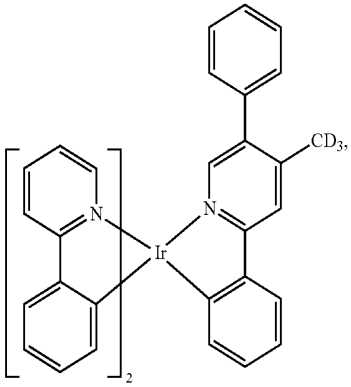

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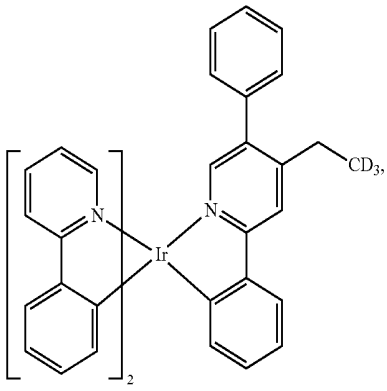

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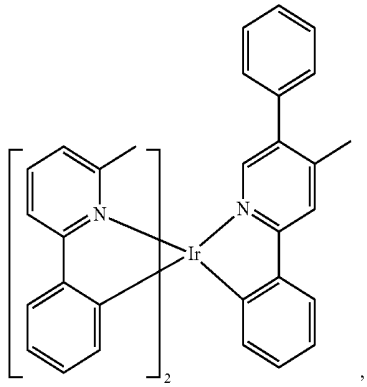

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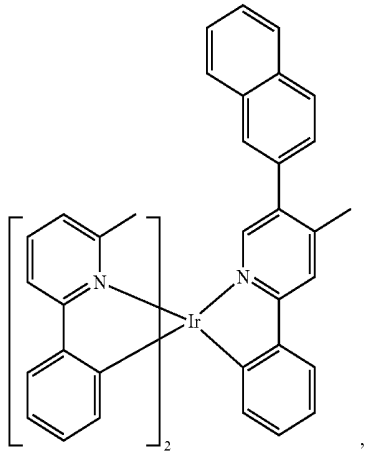

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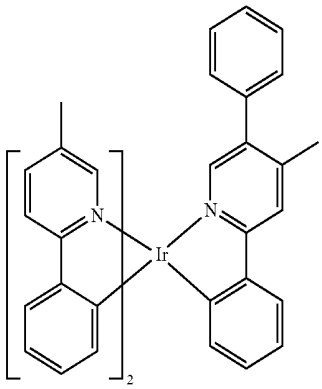

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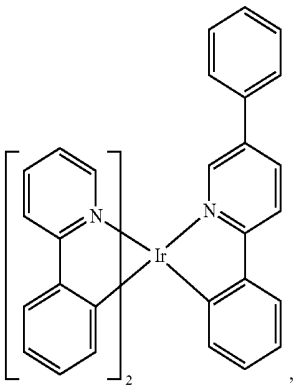

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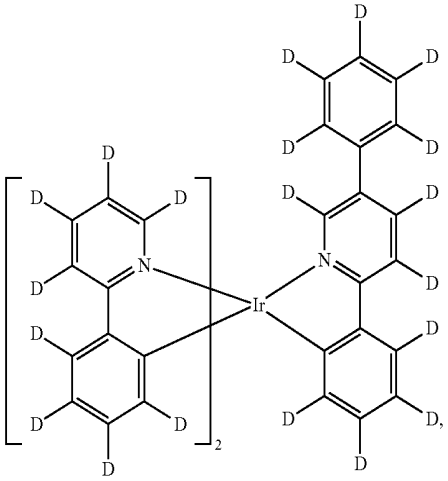

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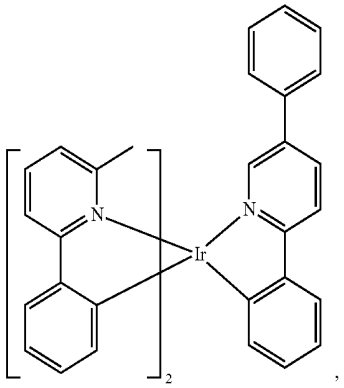

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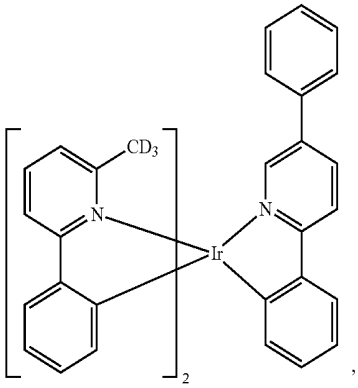

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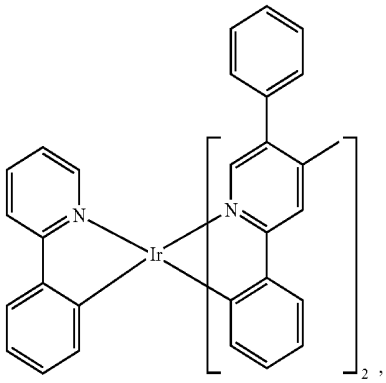
Emitter 23



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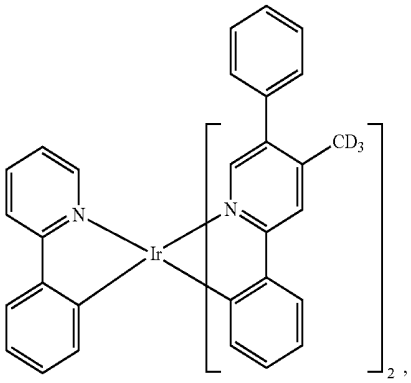

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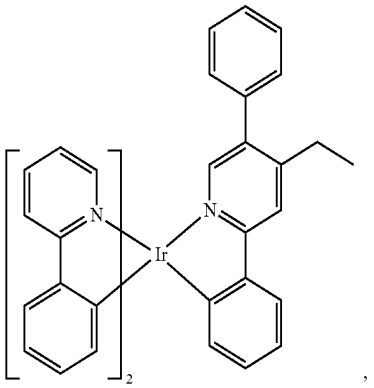

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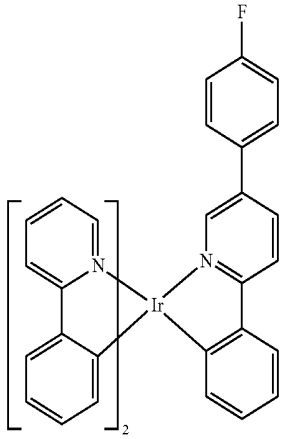

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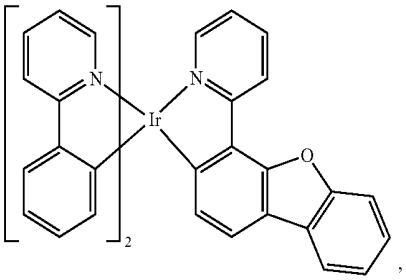

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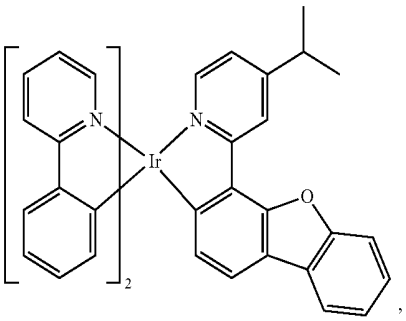

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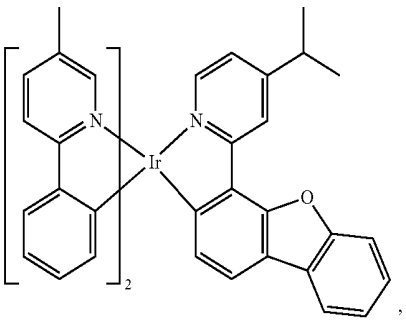

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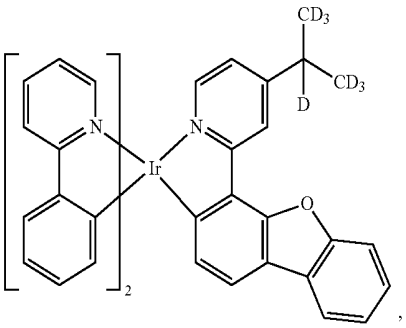

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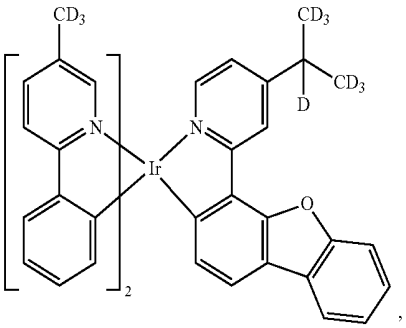

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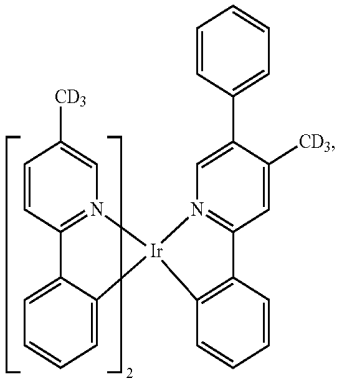

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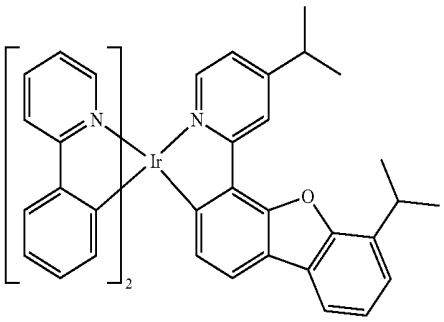

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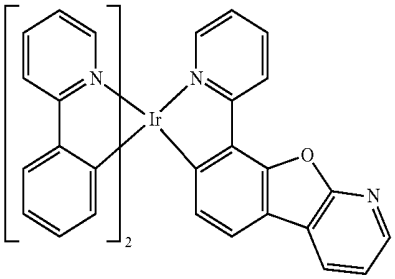

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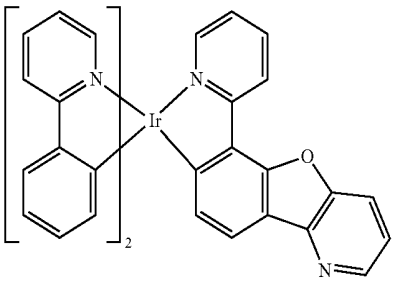

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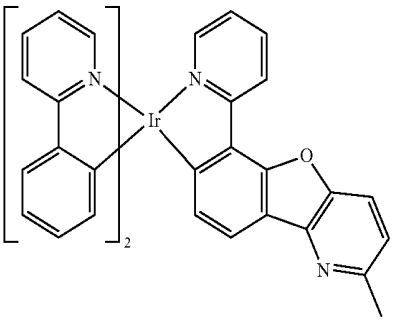

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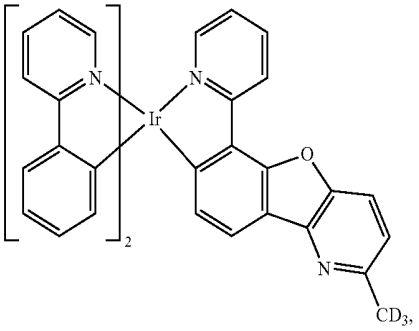

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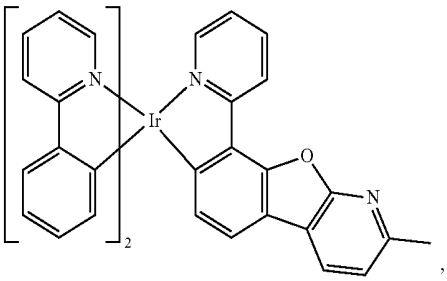

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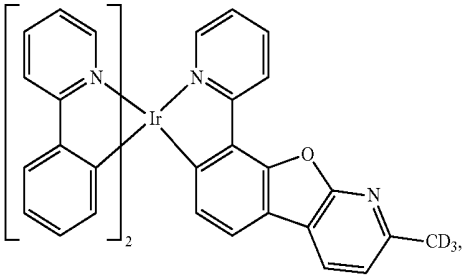

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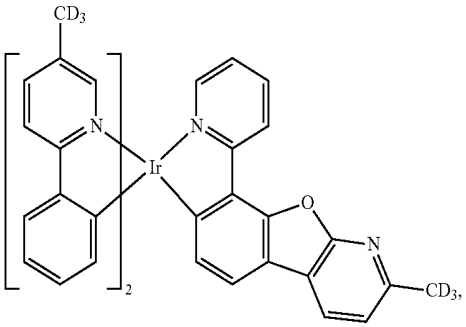

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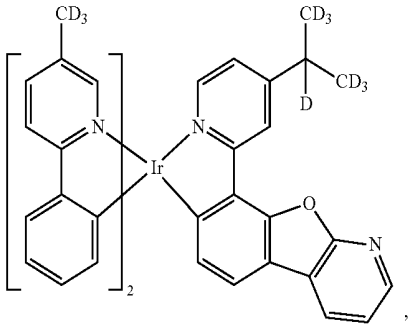

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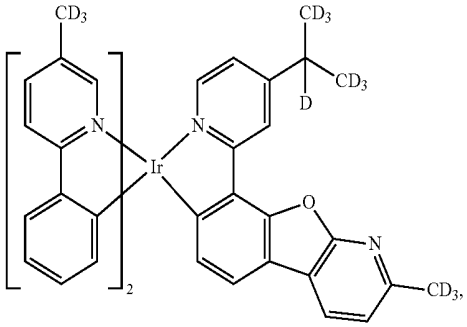

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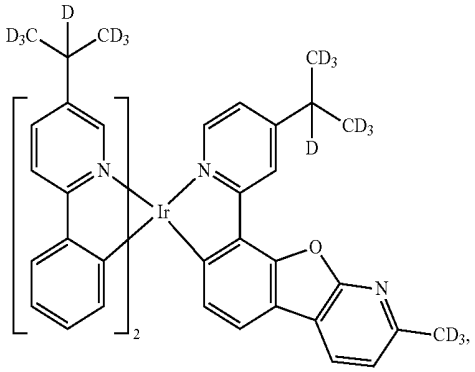

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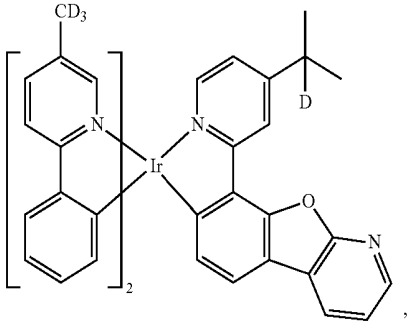

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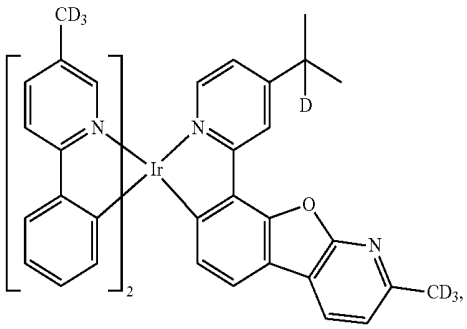

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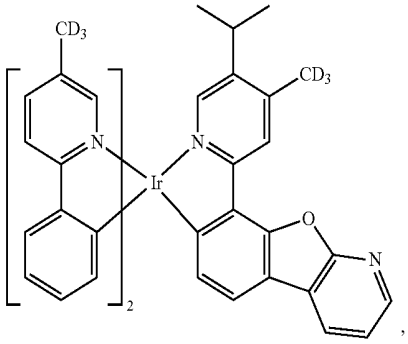

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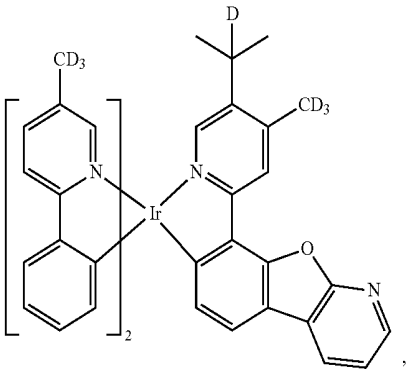

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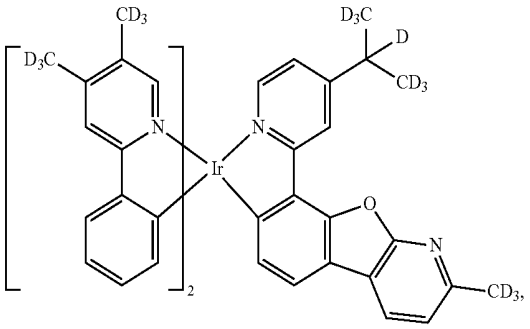

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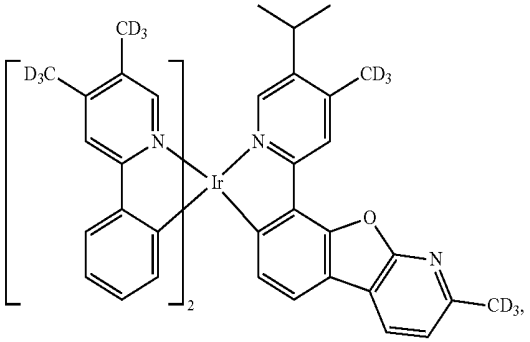

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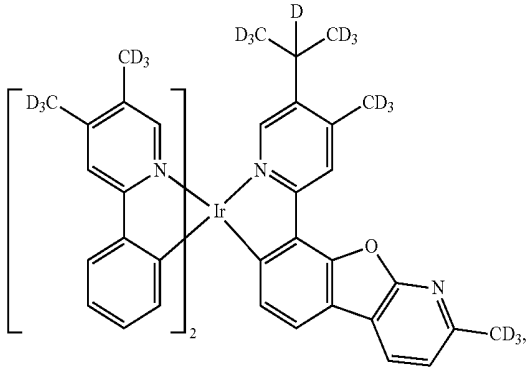

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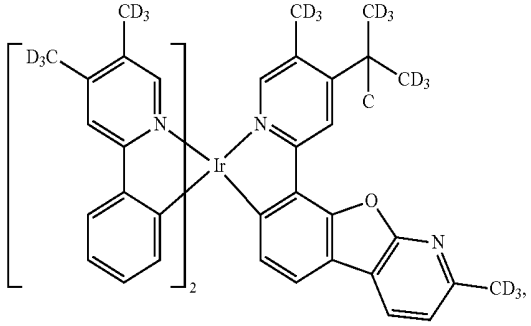

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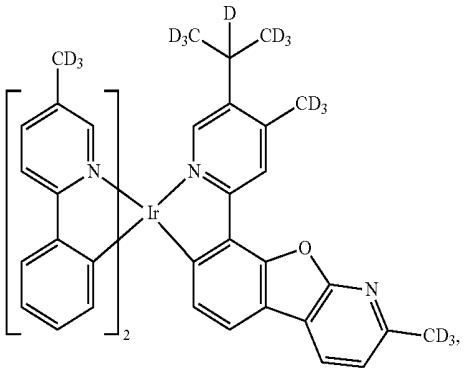

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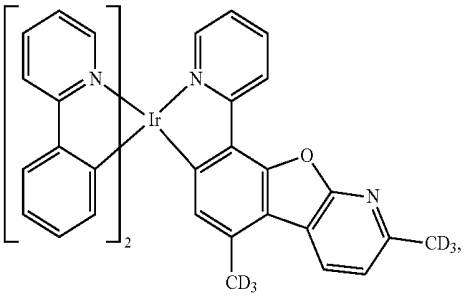

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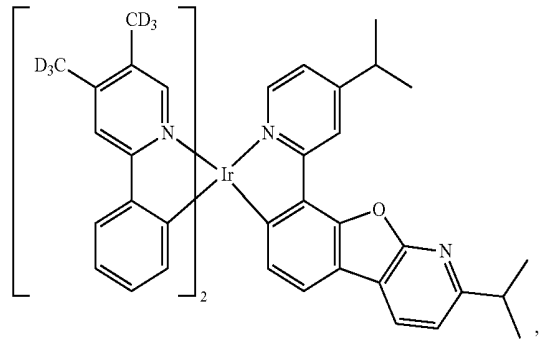

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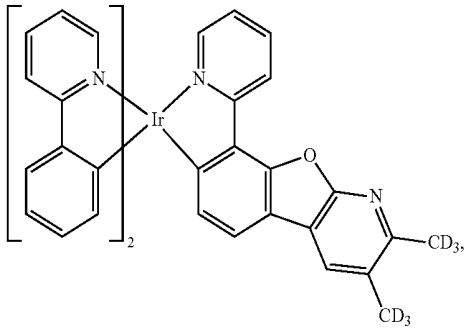

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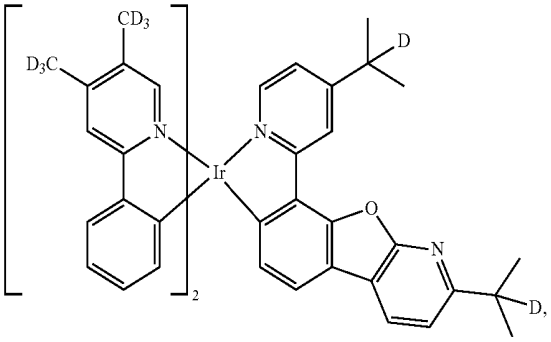

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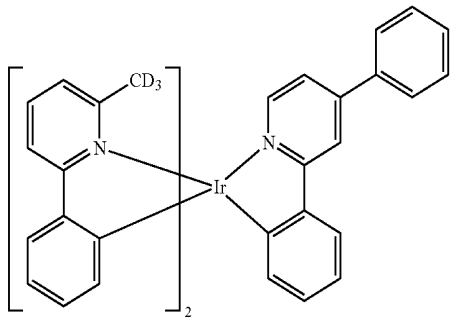

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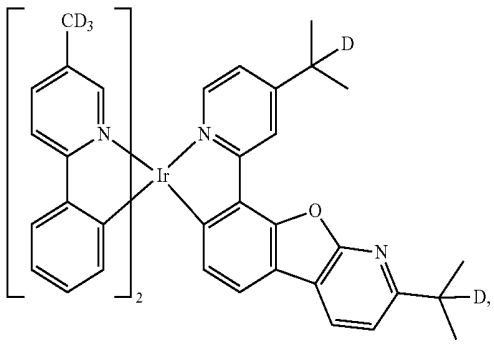

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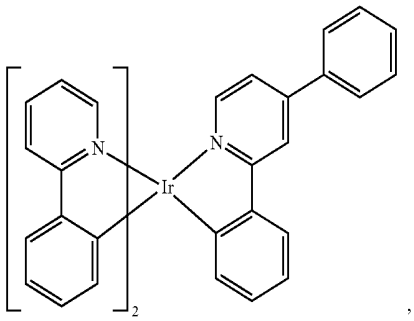

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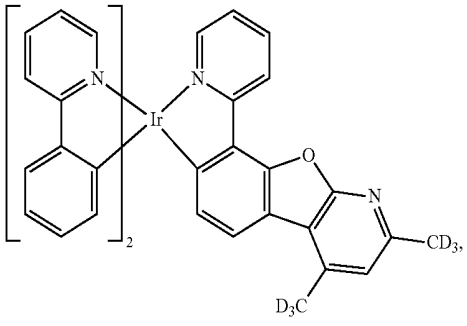

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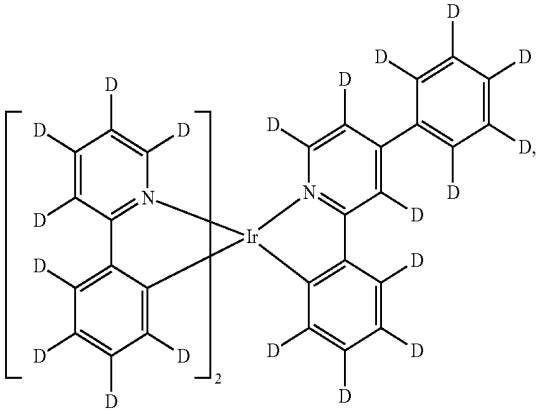

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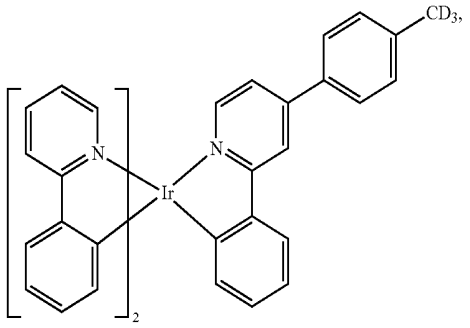

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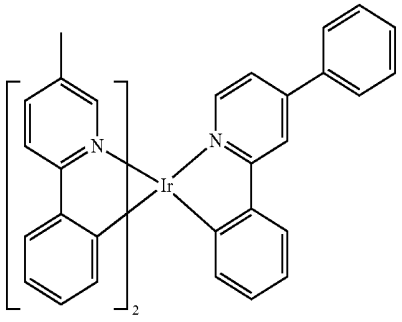

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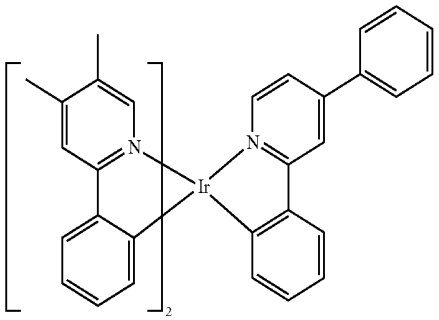

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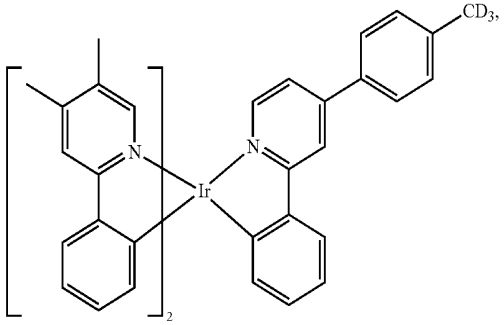

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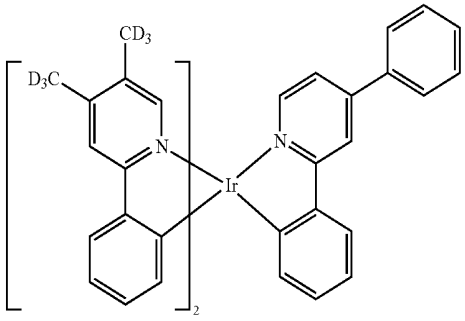

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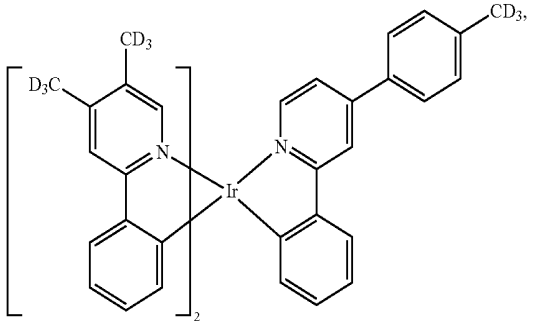

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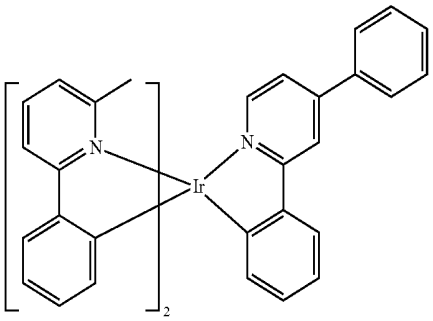

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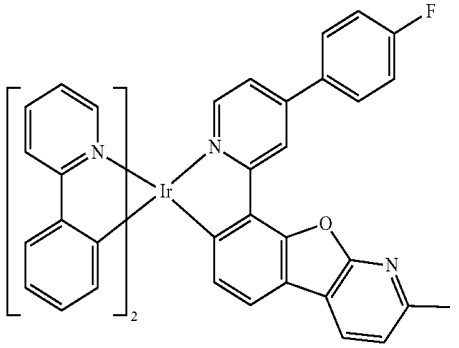

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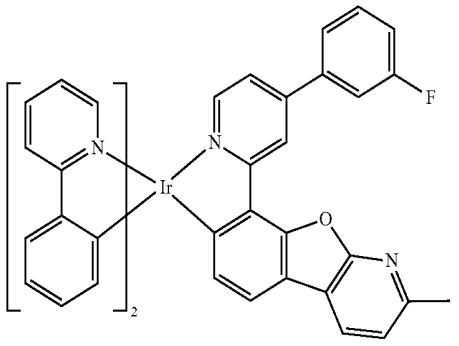
Emitter 70



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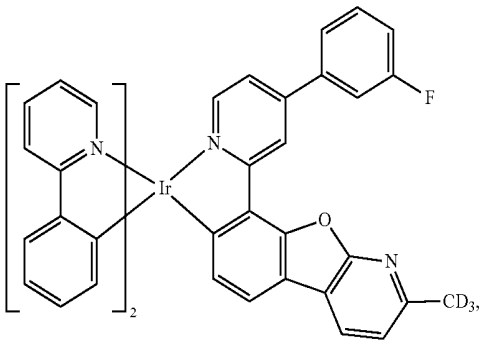
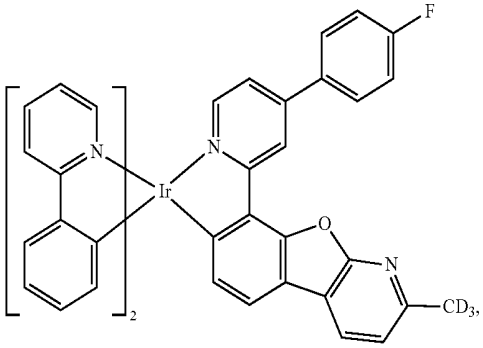
Emitter 71



Emitter 72



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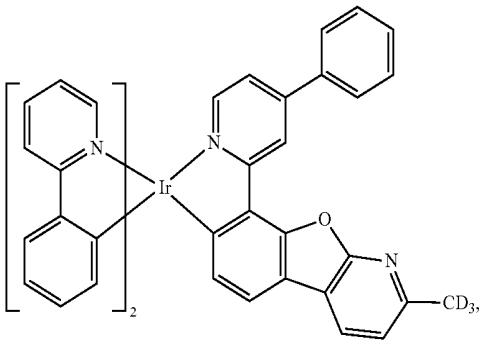

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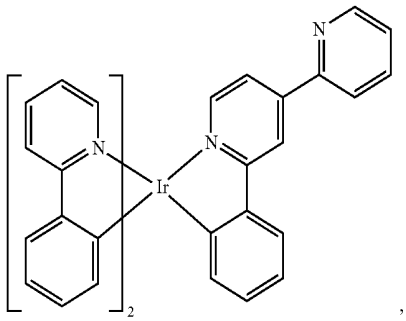

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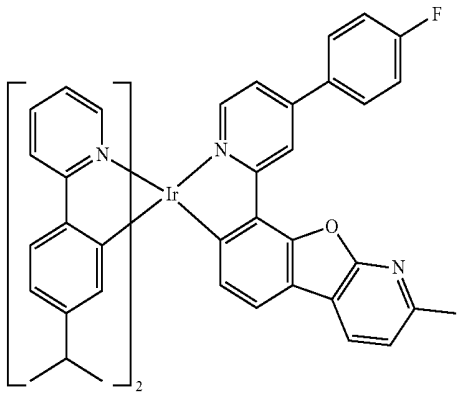

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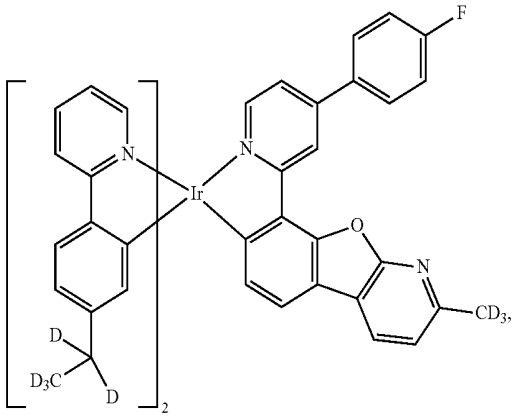

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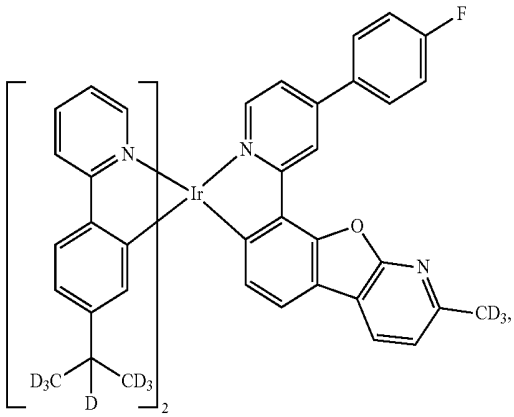

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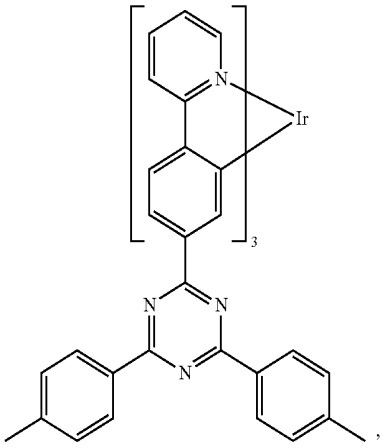

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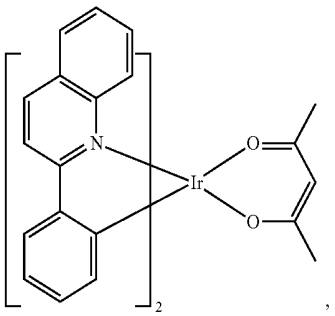
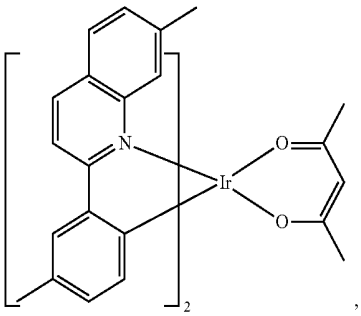


Emitter 80



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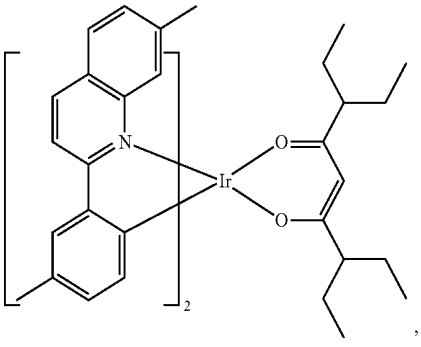

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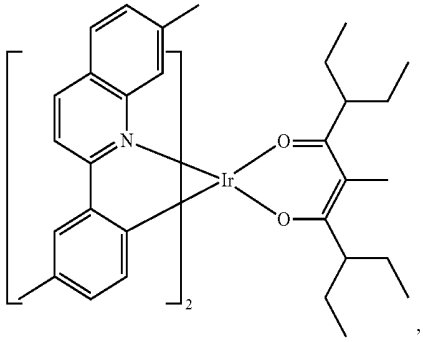

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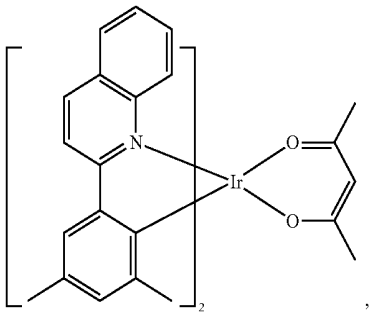

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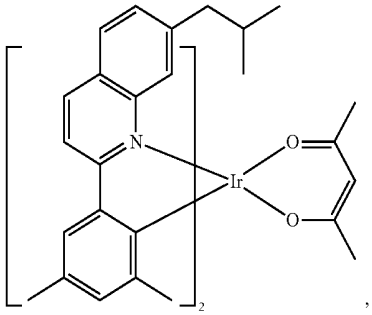

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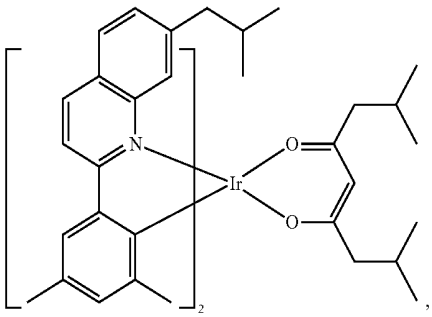

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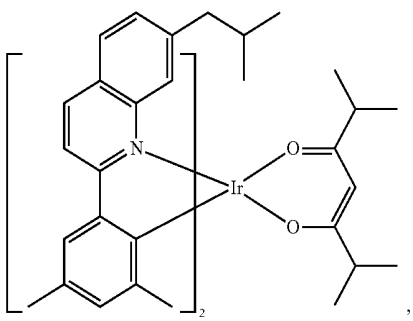

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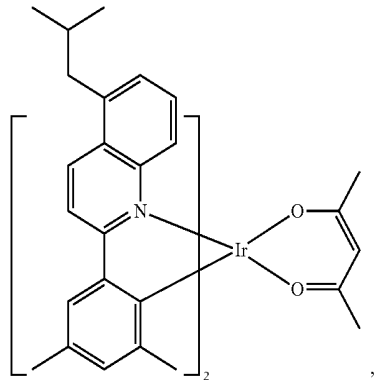
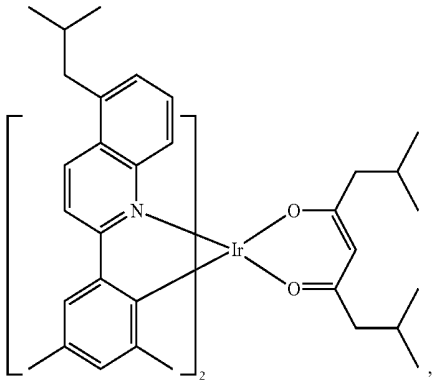


Emitter 88



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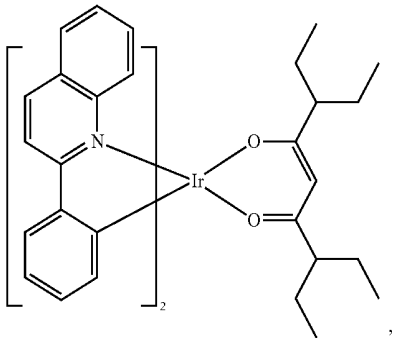

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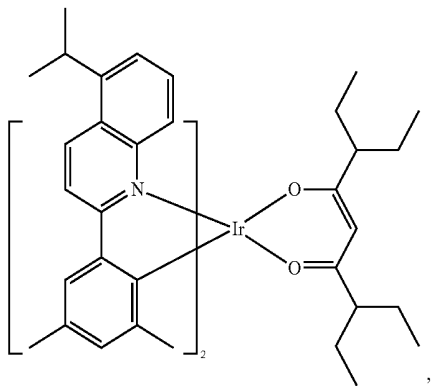

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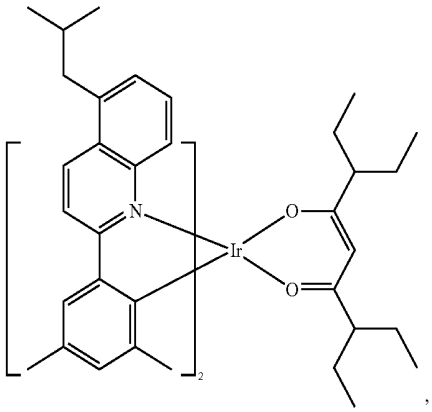

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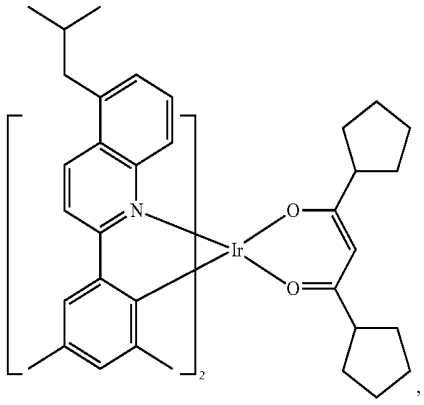

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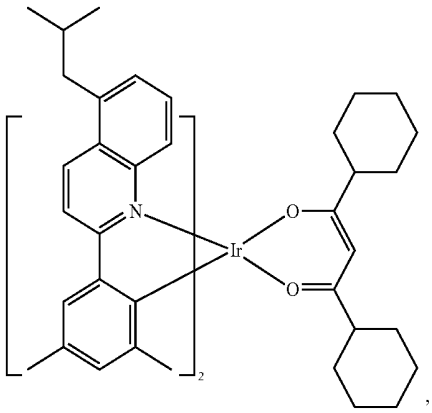

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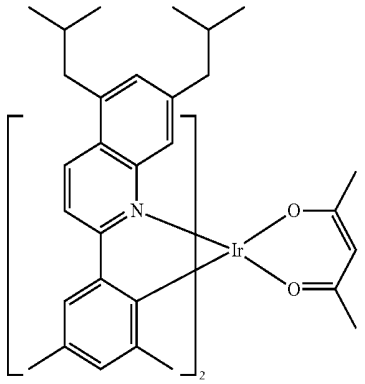

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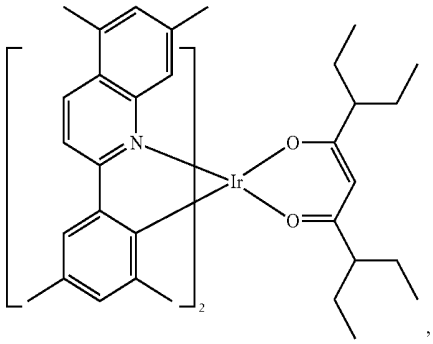

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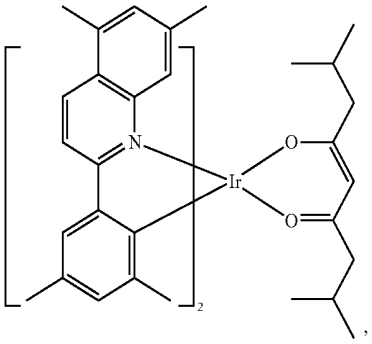
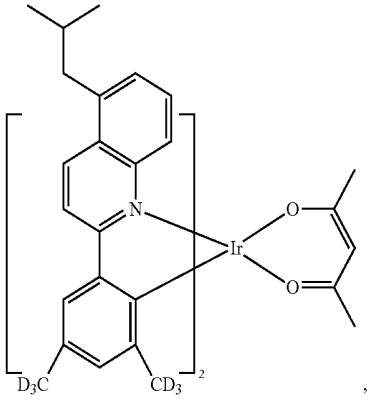


Emitter 97



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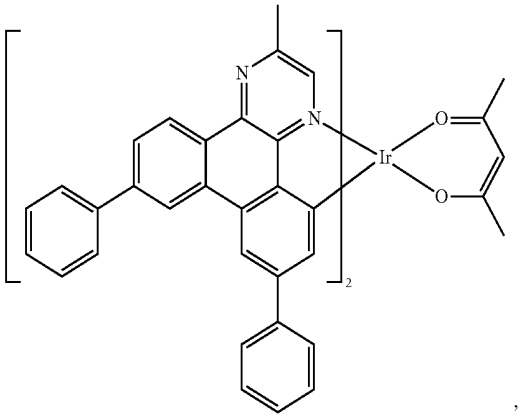

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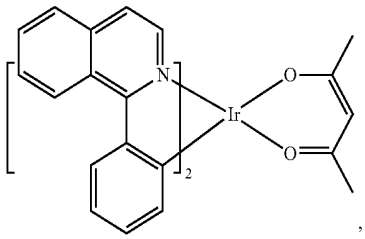

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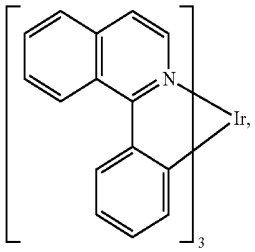

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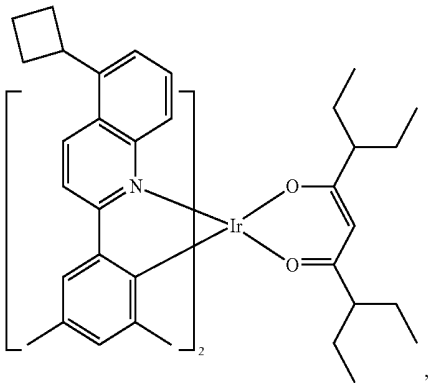
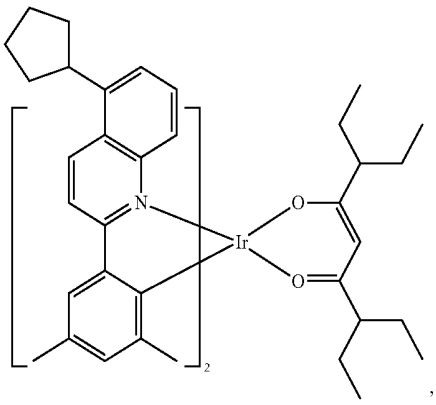


Emitter 102



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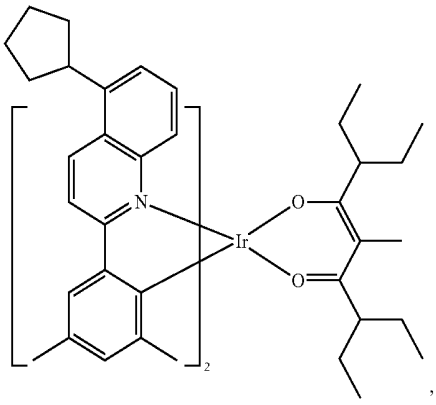

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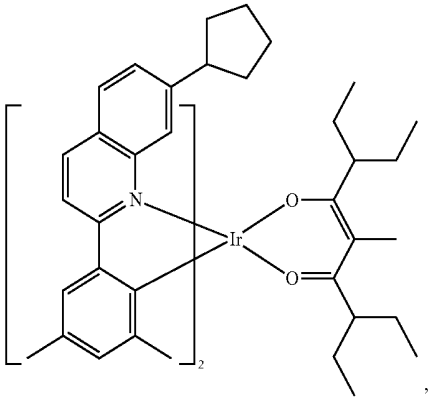
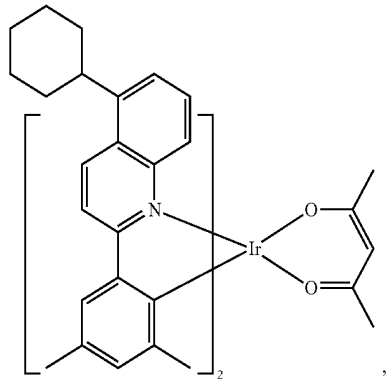
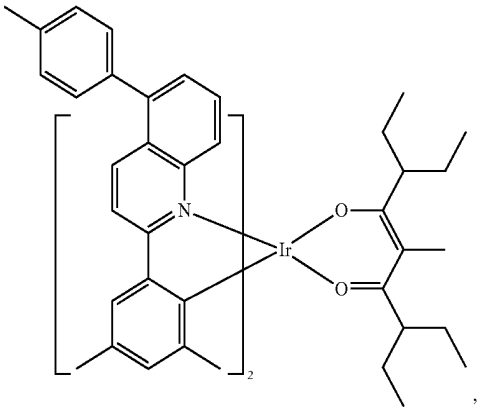
Emitter 104



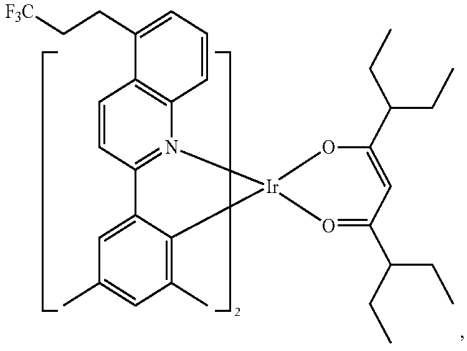
Emitter 105



Emitter 106



Emitter 107



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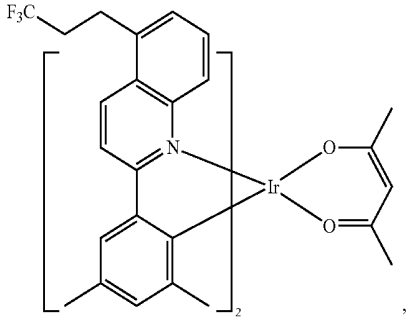
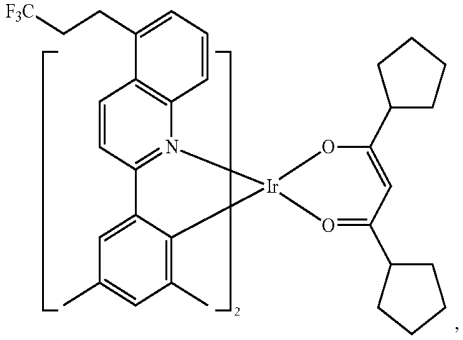
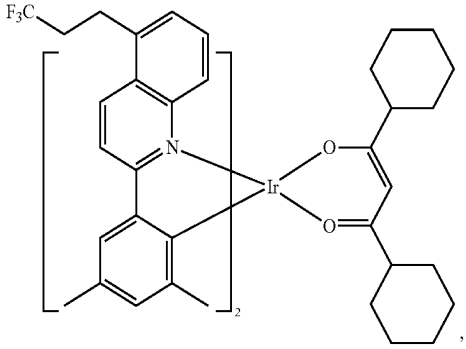
Emitter 108



Emitter 109



Emitter 110



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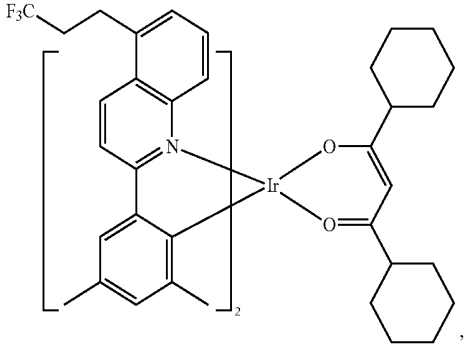

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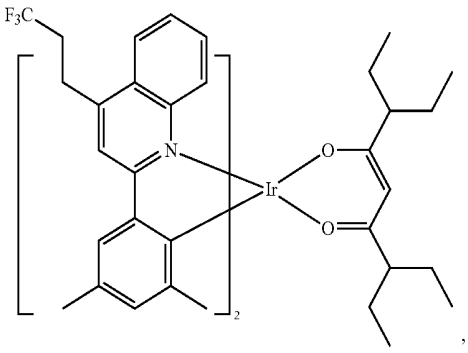
Emitter 111



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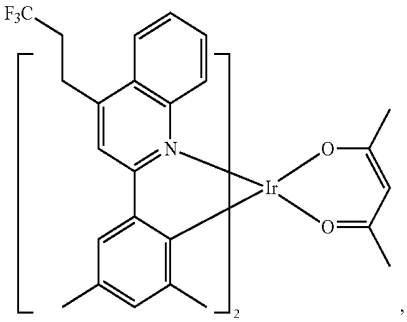

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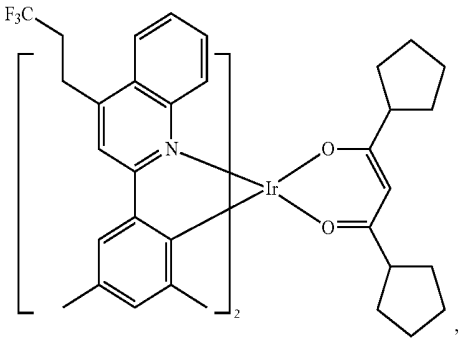

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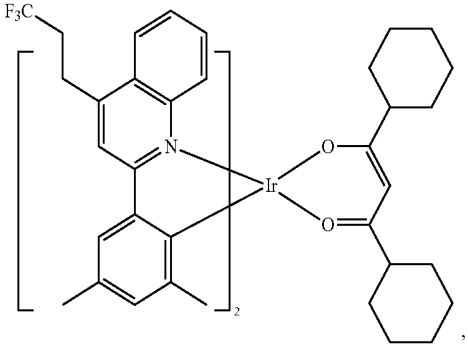

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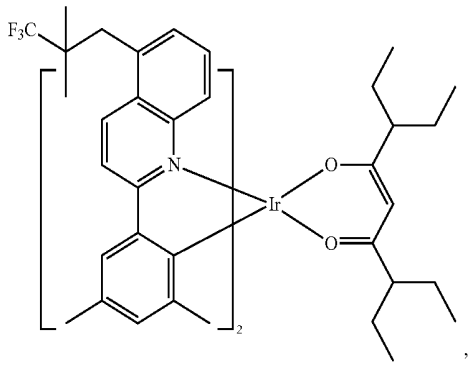
Emitter 115



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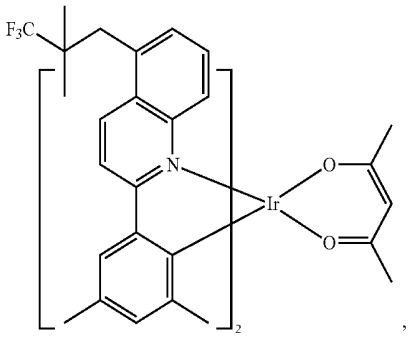

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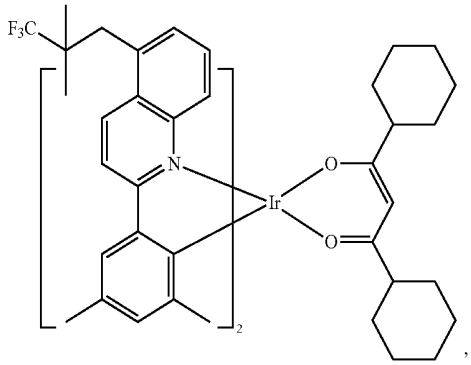

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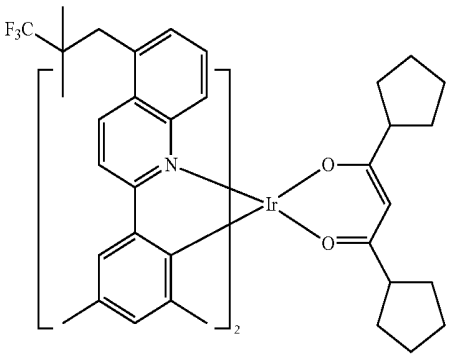

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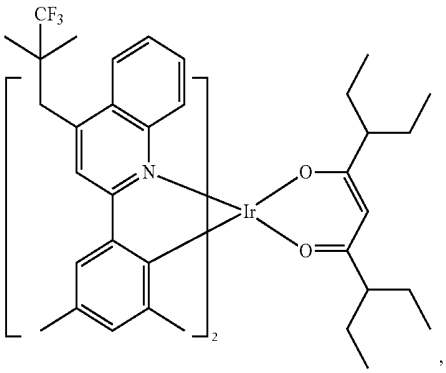

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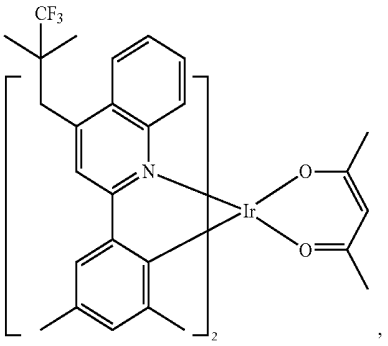

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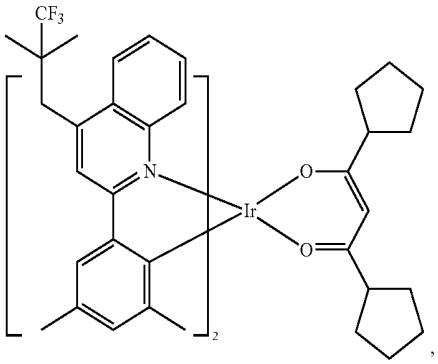

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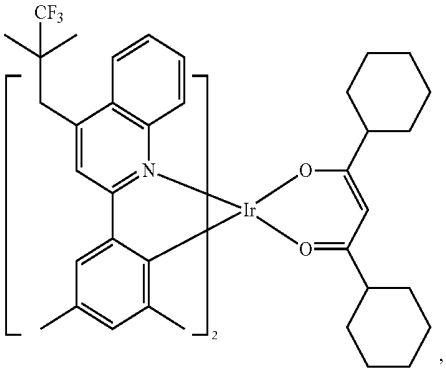

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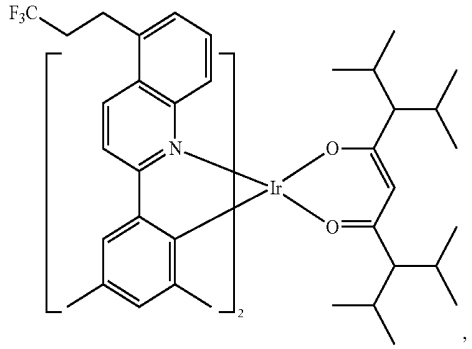
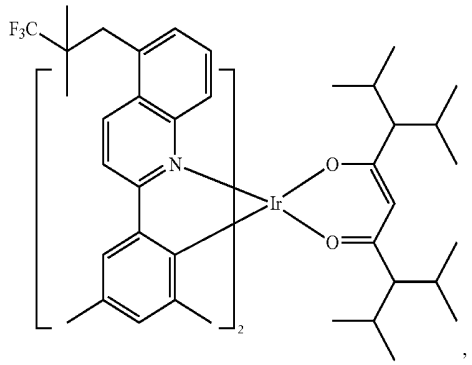


Emitter 124



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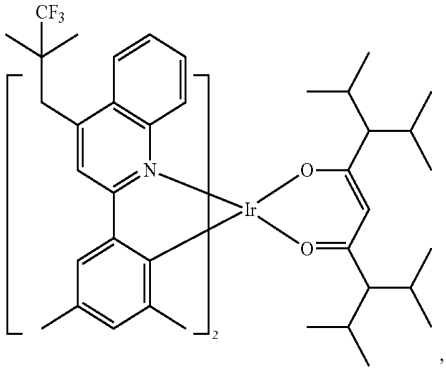

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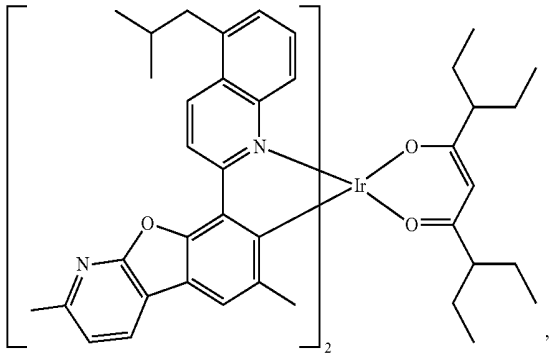

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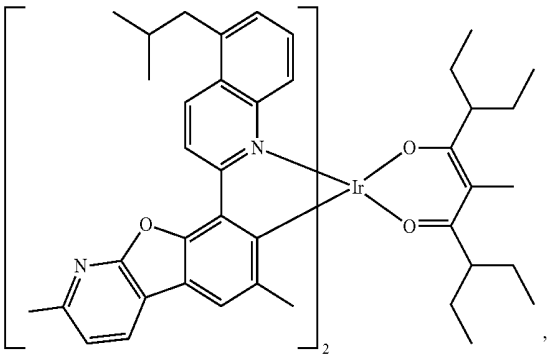
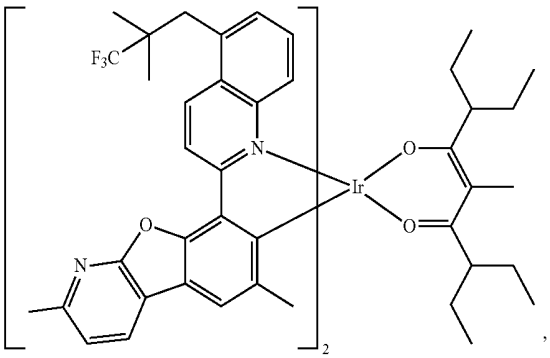
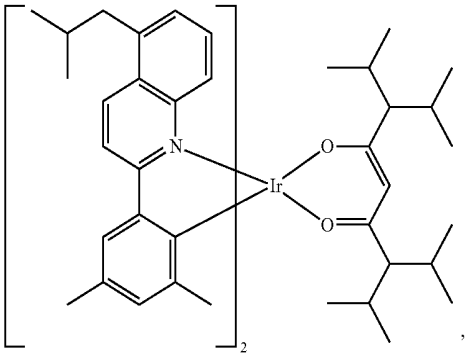
Emitter 127



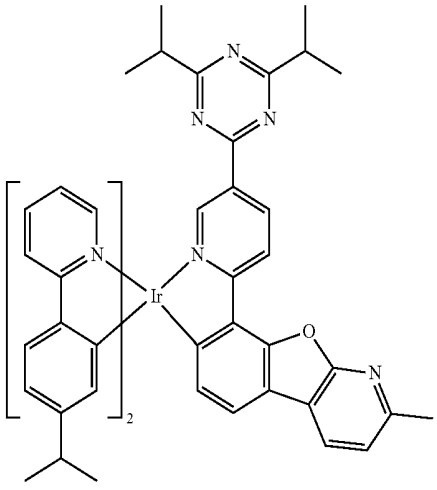
Emitter 128



Emitter 129



Emitter 130



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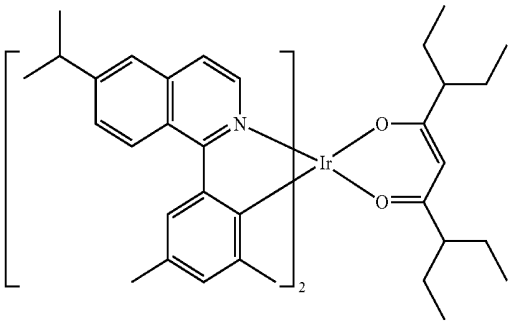
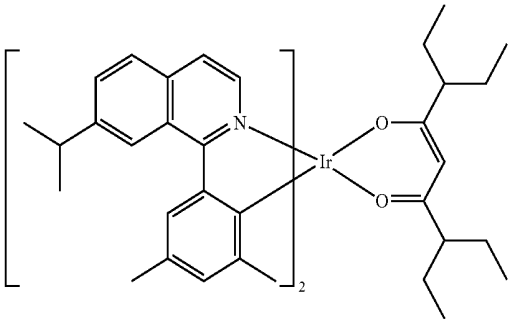
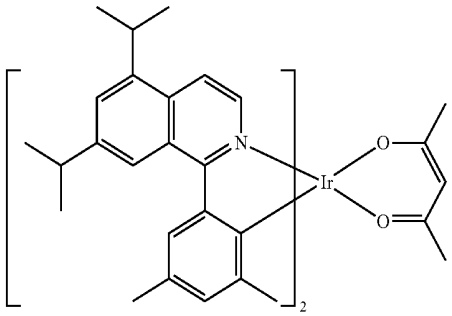
Emitter 131



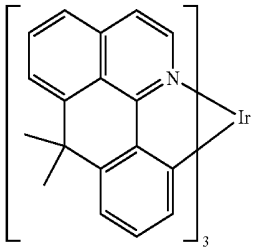
Emitter 132



Emitter 133



Emitter 134



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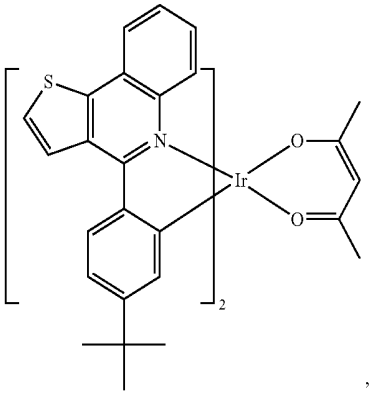

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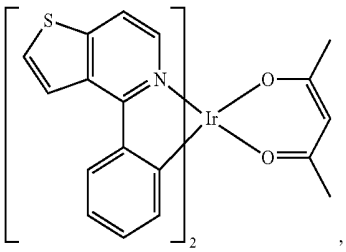
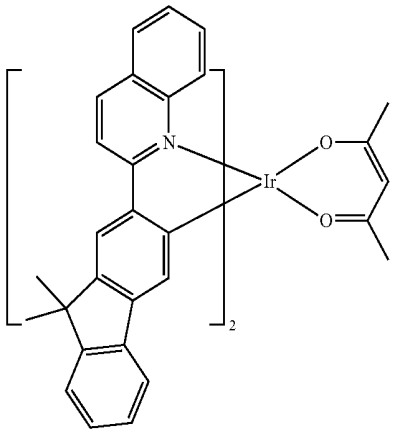
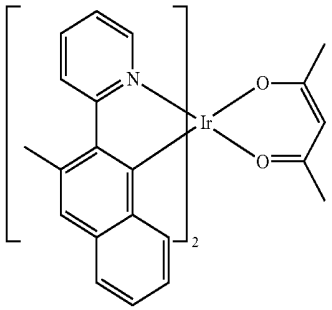
Emitter 136



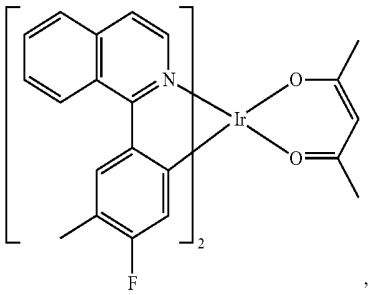
Emitter 137



Emitter 138

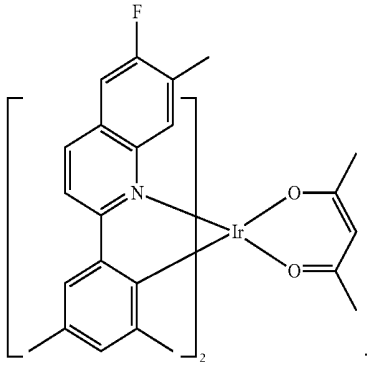


Emitter 139



and

Emitter 140

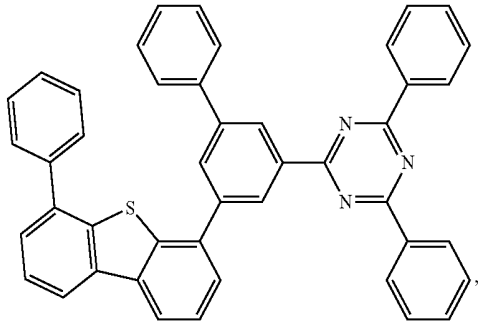


15. The first mixture of claim **1**, wherein the first mixture comprises a h-host, an e-host, and an emitter.

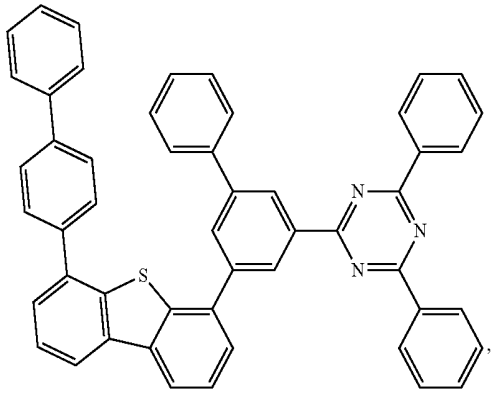
16. The first mixture of claim **1**, wherein the first mixture comprises a first h-host, a second h-host, and an e-host.

17. The first mixture of claim **1**, wherein the first mixture is selected from the following group of three-component mixtures consisting of (Compound A11, Compound A14, and Compound H26), (Compound A11, Compound C74, and Compound H17), (Compound A14, Compound C65, and Compound H5), (Compound C74, Compound H8, and Compound H17), (Compound C83, Compound H17, and Emitter 2), (Compound C83, Compound F20, and Compound F18), (Compound 83, Compound G2, and Compound G26), (Compound A5, Compound C239, and Emitter 65), and (Compound E2, Compound H5, and Emitter 25),

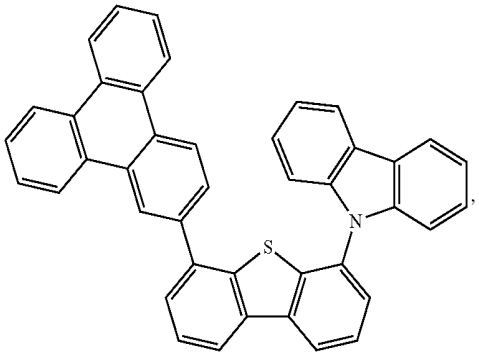
wherein Compound A11 is represented by the formula



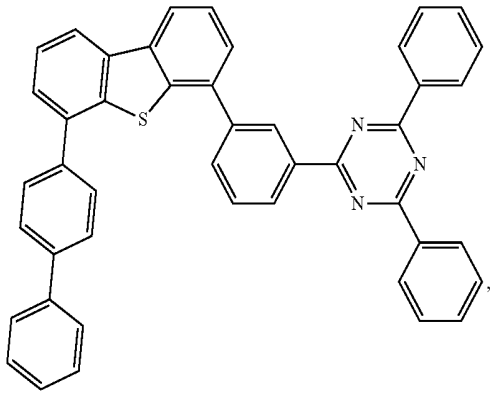
Compound A14 is represented by the formula



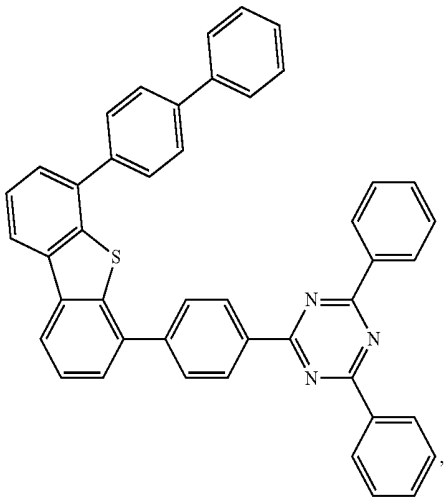
Compound H26 is represented by the formula



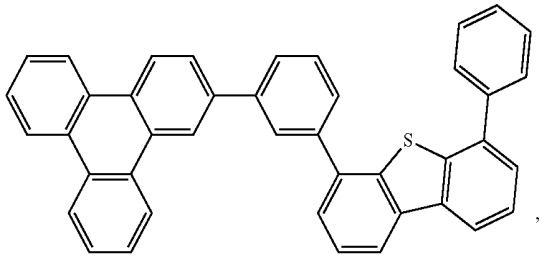
Compound C74 is represented by the formula



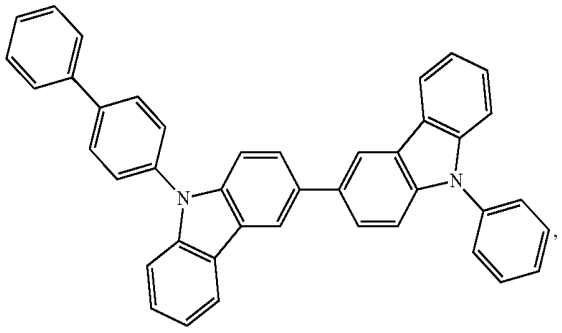
Compound C83 is represented by the formula



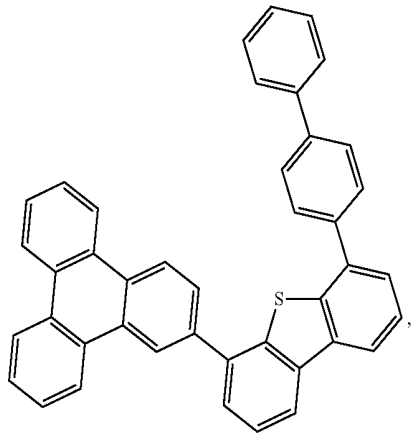
Compound H8 is represented by the formula



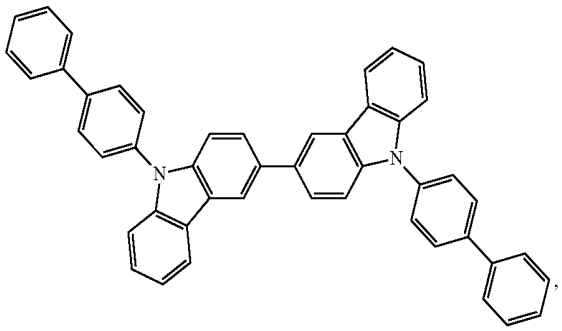
Compound F18 is represented by the formula



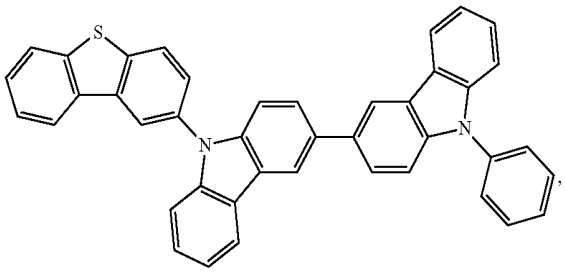
Compound H17 is represented by the formula



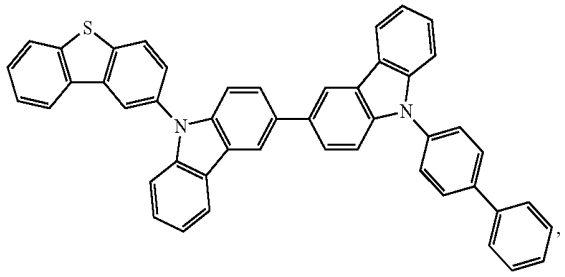
Compound F20 is represented by the formula



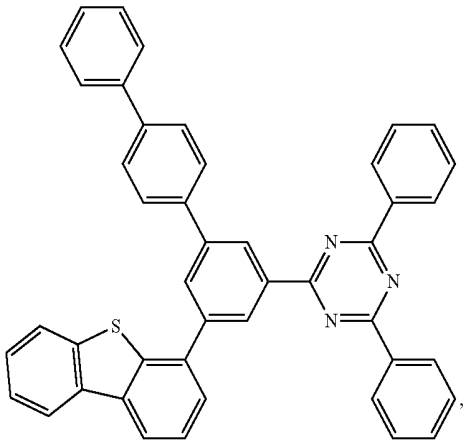
Compound G2 is represented by the formula



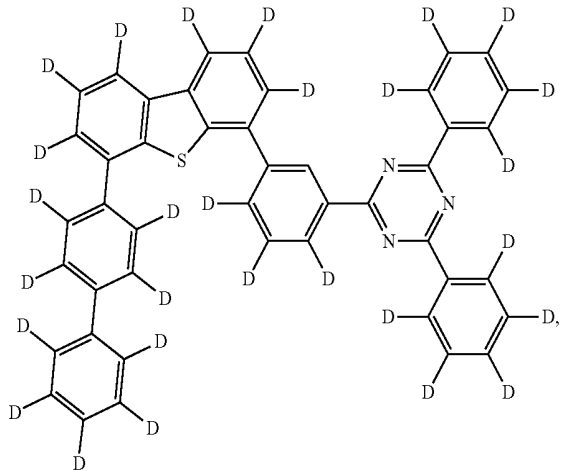
Compound G26 is represented by the formula



Compound A5 is represented by the formula

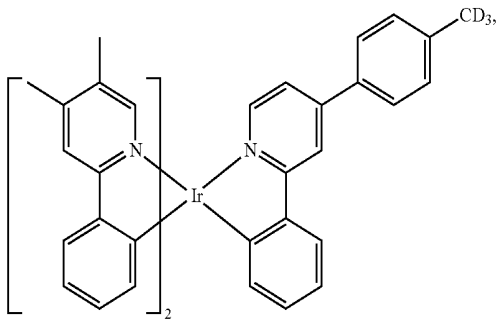


Compound C239 is represented by the formula

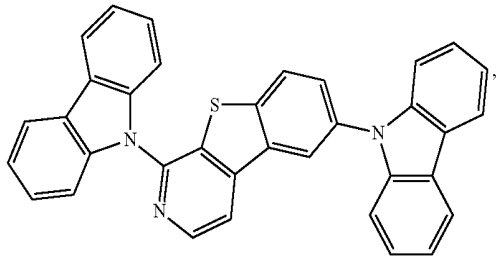


Emitter 65 is

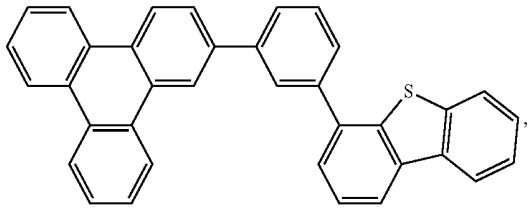
Emitter 65



Compound E2 is represented by the formula

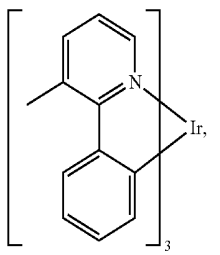


Compound H5 is represented by the formula



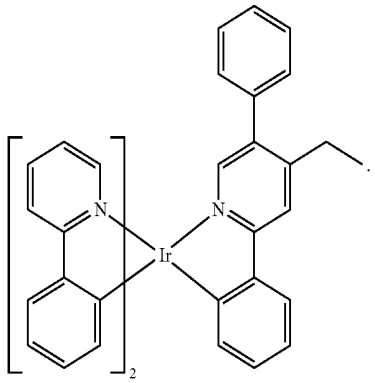
Emitter 2 is

Emitter 2



and Emitter 25 is

Emitter 25



18. A method for fabricating a first device, comprising:

providing a first container that contains a first mixture, the first mixture comprising:

a first compound;

a second compound; and

a third compound,

wherein the first compound, the second compound, and the third compound are all organic compounds and have different chemical structures from each other,

wherein the first compound, the second compound, and the third compound each has an evaporation temperature T**1**, T**2**, and T**3**, respectively, and is in the range of 150 to 350° C.,

wherein the T**1**, T**2**, and T**3** differ from each other by less than 20° C.;

providing a substrate having a first electrode disposed thereon;

depositing an organic layer over the first electrode by evaporating the first mixture in the first container in a high vacuum deposition tool under a first deposition condition which is defined as depositing at a 2 Å/sec deposition rate with a chamber base pressure between 1×10^{-6} Torr to 1×10^{-9} Torr onto a surface positioned at a predefined distance from the first mixture,

wherein the first compound has a concentration C**1** in the first mixture and a concentration C**2** in the emissive layer and |(C**1**-C**2**)/C**1**| is less than 5%; and

depositing a second electrode over the emissive layer.

19.-**22**. (canceled)

23. The method of claim **1**, wherein the first compound, the second compound, and the third compound are each independently selected from the group consisting of a h-host, an e-host, and an emitter.

24.-**33**. (canceled)

34. A first device comprising a first organic light emitting device, the first organic light emitting device comprising:

an anode;

a cathode; and an organic layer, disposed between the anode and the cathode, comprising a first composition comprising a first mixture of a first compound, a second compound, and a third compound,

wherein the first compound, the second compound, and the third compound are all organic compounds and have different chemical structures from each other,

wherein the first compound, the second compound, and the third compound each has an evaporation temperature T**1**, T**2**, and T**3**, respectively, and is in the range of 150 to 350° C.,

wherein the T**1**, T**2**, and T**3** differ from each other by less than 20° C.,

wherein the first compound has a concentration C**1** in the first mixture and a concentration C**2** in a film deposited by evaporating the first mixture in a high vacuum deposition tool under a first deposition condition which is defined as depositing at a 2 Å/sec deposition rate with a chamber base pressure between 1×10^{-6} Torr to 1×10^{-9} Torr onto a surface positioned at a predefined distance from the first mixture,

wherein |(C**1**-C**2**)/C**1**| is less than 5%,

wherein the first compound has a concentration C**1**' in a second mixture of the first and second compounds or has a concentration C**1**" in a third mixture of the first and third compounds, and the first compound has a concentration C**2**' in a film formed by evaporating the second mixture under the first deposition condition or has a concentration C**2**" in a film formed by evaporating the third mixture under the first deposition condition, and wherein at least one of |(C**1**'-C**2**')/C**1**'| and |(C**1**"-C**2**")/C**1**"| is greater than 5%.

* * * * *

专利名称(译)	有机电致发光材料和器件		
公开(公告)号	US20160093808A1	公开(公告)日	2016-03-31
申请号	US14/863768	申请日	2015-09-24
[标]申请(专利权)人(译)	环球展览公司		
申请(专利权)人(译)	通用显示器公司		
当前申请(专利权)人(译)	通用显示器公司		
[标]发明人	ADAMOVICH VADIM ZENG LICHANG WANG TING CHIH XIA CHUANJUN WEAVER MICHAEL S		
发明人	ADAMOVICH, VADIM ZENG, LICHANG WANG, TING-CHIH XIA, CHUANJUN WEAVER, MICHAEL, S.		
IPC分类号	H01L51/00 C09K11/06		
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优先权	62/056940 2014-09-29 US		
外部链接	Espacenet USPTO		

摘要(译)

公开了含有三种不同化合物的混合物，其可用作真空沉积工具的稳定共蒸发源材料。该混合物包含第一化合物;第二种化合物;和第三化合物，它们都是有机化合物并且彼此具有不同的化学结构，并且各自具有蒸发温度T b，T b 2，和T 3， 分别在150至350°C的范围内.T 2，和T 彼此不同第一混合物中的第一化合物具有浓度C b 1，并且通过将第一混合物蒸发至高温而沉积的膜中的浓度C b 在预定的沉积条件下的真空沉积工具，其中|（C b -C b ）/ C b |不到5%。