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

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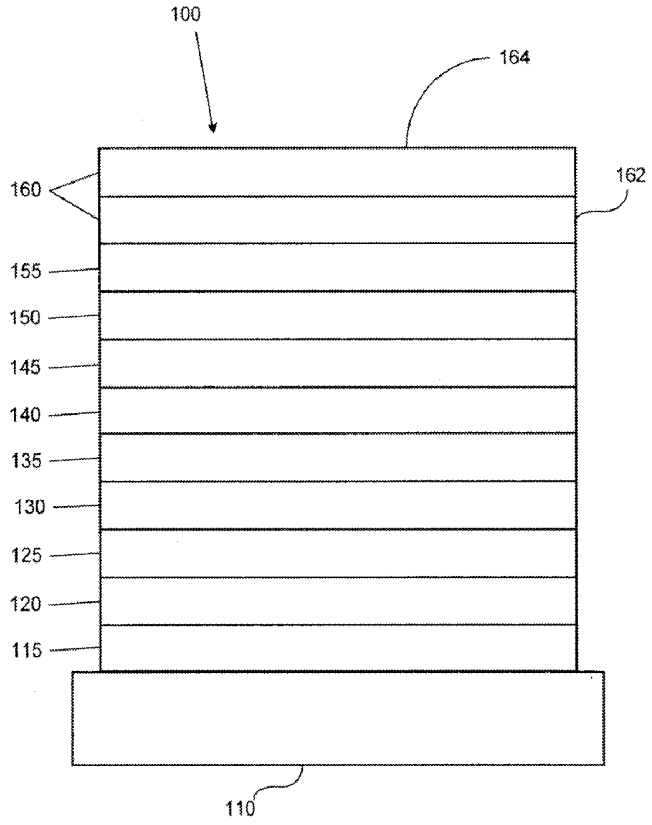
(57) **ABSTRACT**

A composition formed of a first mixture of a first compound and a second compound wherein the first compound has different chemical structure than the second compound; the first compound is capable of functioning as a hole transporting material in an organic light emitting device at room temperature; the first compound comprises at least one carbazole group; the first compound has a evaporation temperature T1 of 150 to 350° C.; the second compound has evaporation temperature T2 of 150 to 350° C.; the absolute value of T1−T2 is less than 20° C.; the first compound having a concentration C1 in said first mixture, and the first compound having a concentration C2 in a film formed by evaporating the first mixture in a vacuum deposition tool at a constant pressure between 1×10^{-6} Torr to 1×10^{-9} Torr, at a 2 Å/sec deposition rate on a surface positioned at a predefined distance away from the mixture being evaporated; and wherein the absolute value of (C1−C2)/C1 is less than 5%.



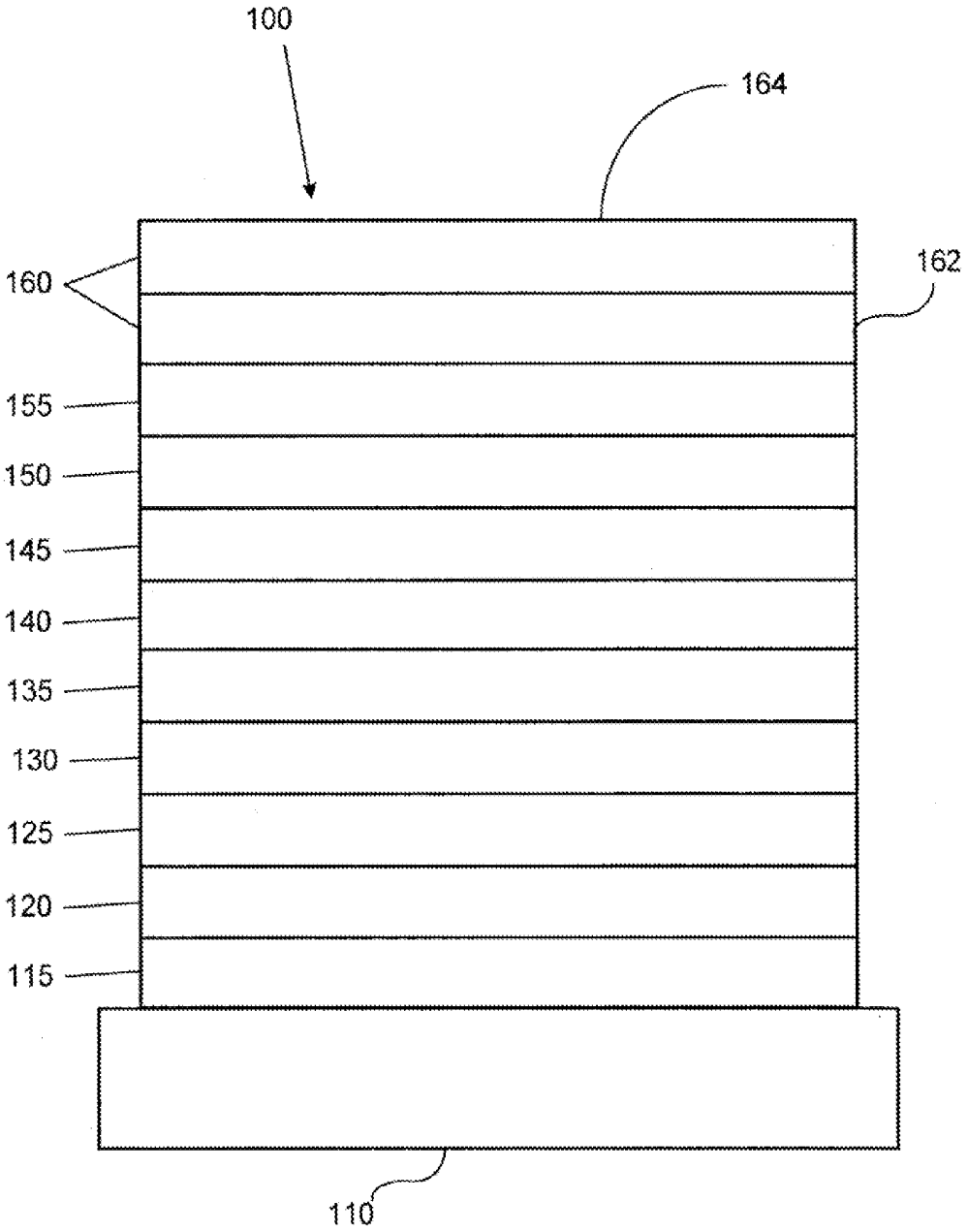


FIG. 1

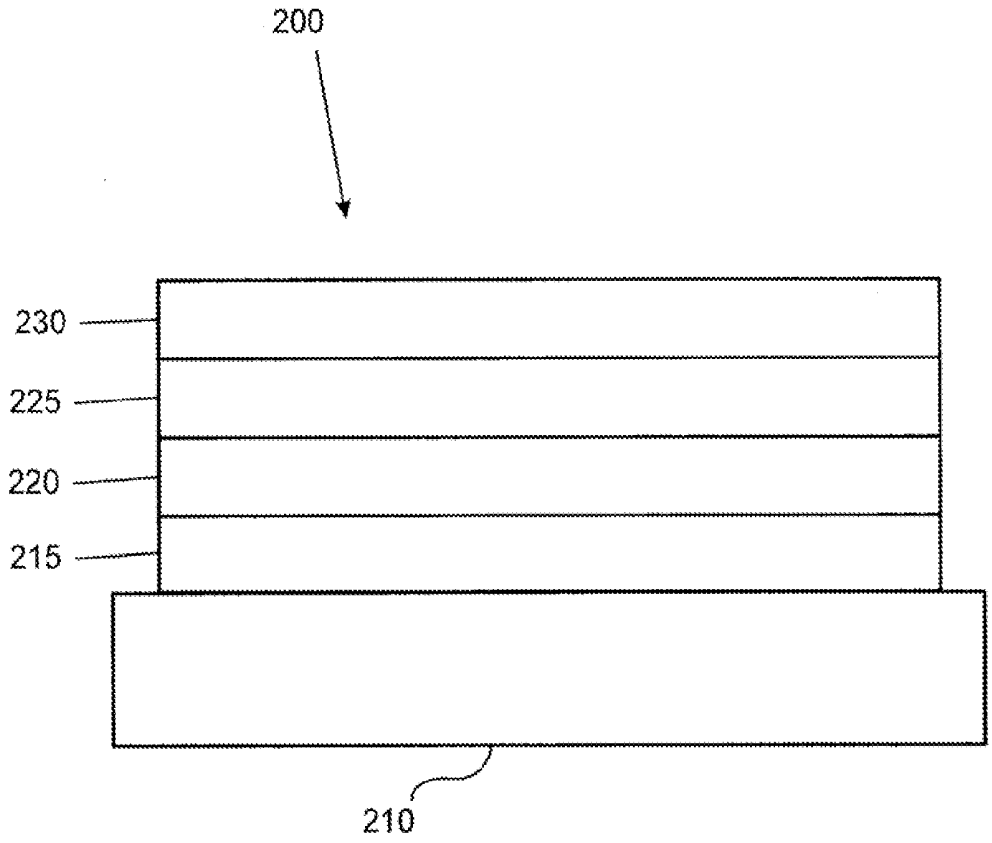
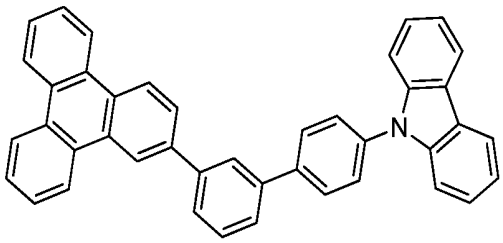
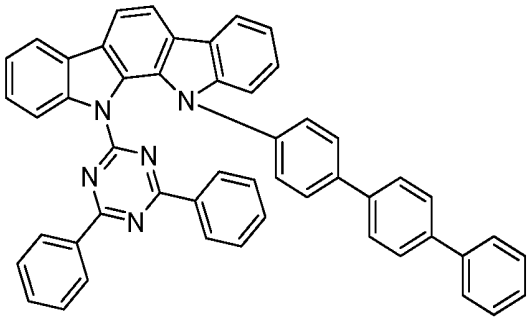


FIG. 2



Compound 2



Compound E2

FIG. 3

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. 61/940,603, filed on Feb. 17, 2014, No. 61/920,544, filed on Dec. 24, 2013, No. 61/894,160, filed on Oct. 22, 2013, No. 61/874,444, filed on Sep. 6, 2013, and No. 61/867,858, filed on Aug. 20, 2014, the entire contents of which are incorporated herein by reference. 1

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: Regents of the University of Michigan, Princeton University, University of Southern California, and the 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 novel premixed host systems for phosphorescent organic light emitting devices (PHOLEDs).

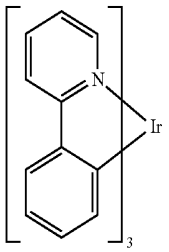
BACKGROUND

[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 novel host composition comprising a mixture of a first compound and a second compound that is a stable co-evaporation mixture is disclosed. In the mixture, the first compound has different chemical structure than the second compound. The first compound is capable of functioning as a hole transporting material in an organic light emitting device at room temperature. Hole transporting material normally has a HOMO level between −5.0 and −6.0 eV. The first compound comprises at least one carbazole group, and can have an evaporation temperature T1 of 150 to 350° C. The second compound can have a evaporation temperature T2 of 150 to 350° C. In order to form the inventive composition comprising a mixture of a first compound and a second compound, the absolute value of T1−T2, the difference between T1 and T2, should be less than 20° C.

[0017] According to an embodiment of the present disclosure, a first device comprising a phosphorescent organic light-emitting device incorporating the novel host composition is disclosed. The phosphorescent organic light-emitting device comprises: an anode; a cathode; and an organic layer, disposed between the anode and the cathode, comprising a first organic composition comprising a mixture of a first compound and a second compound, wherein the first compound has different chemical structure than the second compound;

[0018] wherein the first compound is capable of functioning as a hole transporting material in an organic light emitting device at room temperature;

[0019] wherein the first compound comprises at least one carbazole group;

[0020] wherein the first compound has evaporation temperature of T1 of 150 to 350° C.;

[0021] wherein the second compound has evaporation temperature of T2 of 150 to 350° C.;

[0022] wherein the absolute value of T1−T2 is less than 20° C.;

[0023] wherein the first compound has a concentration C1 in said mixture, and the first compound has a concentration C2 in a film formed by evaporating the mixture in a vacuum deposition tool at a constant pressure between 1×10^{-6} Torr to 1×10^{-9} Torr, at a 2 Å/sec deposition rate on a surface positioned at a predefined distance away from the mixture being evaporated; and wherein the absolute value of (C1−C2)/C1 is less than 5%.

[0024] According to an embodiment of the present disclosure, a method of fabricating an organic light emitting device comprising a first electrode, a second electrode, and a first organic layer disposed between the first electrode and the second electrode, wherein the first organic layer comprises a first organic composition further comprising a mixture of a first compound and a second compound, is disclosed. The method comprises:

[0025] providing a substrate having the first electrode disposed thereon;

[0026] depositing the first organic composition over the first electrode; and

[0027] depositing the second electrode over the first organic layer, wherein the first compound has different chemical structure than the second compound;

[0028] wherein the first compound is capable of functioning as a hole transporting material in an organic light emitting device at room temperature;

[0029] wherein the first compound comprises at least one carbazole group;

[0030] wherein the first compound has evaporation temperature T1 of 150 to 350° C.;

[0031] wherein the second compound has evaporation temperature T2 of 150 to 350° C.;

[0032] wherein the absolute value of T1−T2 is less than 20° C.;

[0033] wherein the first compound has a concentration C1 in said mixture, and the first compound has a concentration C2 in a film formed by evaporating the mixture in a vacuum deposition tool at a constant pressure between 1×10^{-6} Torr to 1×10^{-9} Torr, at a 2 Å/sec deposition rate on a surface positioned at a predefined distance away from the mixture being evaporated; and wherein the absolute value of (C1−C2)/C1 is less than 5%.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] FIG. **1** shows an organic light emitting device that can incorporate the inventive host material disclosed herein.

[0035] FIG. **2** shows an inverted organic light emitting device that can incorporate the inventive host material disclosed herein.

[0036] FIG. **3** shows Compounds 2 and E2 representing the first and second compounds which are example components of the novel organic host composition disclosed herein.

DETAILED DESCRIPTION

[0037] 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 mecha-

nisms, such as thermal relaxation, may also occur, but are generally considered undesirable.

[0038] 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.

[0039] 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.

[0040] 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.

[0041] 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.

[0042] 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**.

[0043] 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**.

[0044] 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.

[0045] 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.

[0046] 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.

[0047] 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 degrees C. to 30 degrees C., and more preferably at room temperature (20-25 degrees C.), but could be used outside this temperature range, for example, from −40 degree C. to +80 degree C.

[0048] 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.

[0049] The term "halo" or "halogen" as used herein includes fluorine, chlorine, bromine, and iodine.

[0050] 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.

[0051] 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.

[0052] 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.

[0053] The term "alkynyl" as used herein contemplates both straight and branched chain alkyne radicals. Preferred alkyl groups are those containing two to fifteen carbon atoms. Additionally, the alkynyl group may be optionally substituted.

[0054] 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.

[0055] 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, piperdino, pyrrolidino, and the like, and cyclic ethers, such as tetrahydrofuran, tetrahydropyran, and the like. Additionally, the heterocyclic group may be optionally substituted.

[0056] 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.

[0057] 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.

[0058] 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, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acid, ether, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

[0059] 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.

[0060] The "aza" designation in the fragments described herein, i.e. aza-dibenzofuran, aza-dibenzonethiophene, 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.

[0061] 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.

[0062] 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 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. Premixing two or more materials and evaporating them from one source can reduce the complexity of the fabrication process. Selected hole transporting hosts and another type of hosts, such as electron transporting hosts can be mixed and co-evaporated from one crucible and achieve stable evaporation.

[0063] However, the co-evaporation must be stable, i.e. the composition of the evaporated film should remain constant during the manufacturing process. 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. However, this may not be the only parameter one has to consider. When the two 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. So far, there have been very few stable co-evaporation mixture examples despite that there have been tens of thousands of hosts materials available in the literature. "Evaporation temperature" of a material is measured in a vacuum deposition tool at a constant 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.

[0064] This disclosure describes the new class of hole transporting and electron transporting hosts which can be premixed to provide a stable co-evaporation mixture that is useful as a host material for green phosphorescent emitters. 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 materials have similar evaporation temperature, and similar mass loss rate or similar vapor pressure, the two 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.

[0065] Current state of the art green phosphorescent host materials consist of two components: a hole transporting cohost (h-host) and an electron transporting cohost (e-host). Some examples of such green phosphorescent host materials are disclosed for example in U.S. Pat. No. 6,803,720. In order to fabricate EML of a PHOLED with such host material, three evaporation sources are required: one for h-host, another one for c-host, and a third one for the emitter. The concentration of the cohost and the emitter is critical for the device performance and typically, the rate of deposition of each component is measured individually during the deposition. This makes the fabrication process complicated and costly. Thus, it is desired to mix at least two of the components to reduce the number of sources.

[0066] The host compounds Compound 2 and Compound E2 show stable premixability, which means they can be premixed and codeposited from one source without changing the composition. Uniform co-evaporation of the two hosts is critical for the consistency of the devices performance fabricated from this mixture.

[0067] The premixability of these two compounds was tested by high pressure liquid chromotography (HPLC) analysis of evaporated films. For this purpose, the 0.15 g of Compound 2 and 0.15 g of Compound E2 were mixed and ground. 0.3 g of the mixture was loaded into the evaporation source of the VTE vacuum chamber. The chamber was pumped down to 10^{-7} Torr pressure. The premixed components were deposited at the rate of 2 Å/s onto glass substrates. The substrates were replaced continuously after deposition of 600 Å film without stopping the deposition process so that the source is maintained at proper temperature and avoid cooling the source. The deposited films were analyzed by HPLC and results are shown in Table 1 below. Seven such substrate samples were taken and are labeled as Plate1 to Plate7 in Table 1. The composition of the components Compound 2 and Compound E2 did not change significantly from Plate1 to

Plate7. Some fluctuations in the concentrations do not reveal any trend and can be explained by the accuracy of sample collection and HPLC analysis. Normally, the change of the concentration before and after depositions within 5% throughout the process is considered to be good and useful for commercial OLED application.

TABLE 1

HPLC composition (%) of sequentially deposited films from premixed hosts, (h-host:e-host), with ratio 1:1. (HPLC Conditions C18, 100 45 min, Detected wavelength 254 nm)

Films (600 Å)	Compound 2 (h-host)	Compound E2 (e-host)
Plate1	54.1	45.9
Plate2	57.3	42.7
Plate3	56.9	43.1
Plate4	56.7	43.3
Plate5	56.4	43.6
Plate6	56.1	43.9
Plate7	54.6	45.4

[0068] This is evidence that Compound 2 and Compound E2 form a stable co-evaporation mixture. Inventors conclude that other hosts from these families can be premixed to be used as hosts for PHOLEDs. Table 2 below shows some representative examples which the inventors believe are suitable for pre-mixing and evaporation from a common source based on the compounds' evaporation temperature and their similar chemical structures.

TABLE 2

Examples of possible premix pairs.

Mixture number	Hole transporting host	Electron transporting host
1	Compound 2	Compound E2
2	Compound 3	Compound E4
3	Compound 1	Compound E5
4	Compound 6	Compound E7
5	Compound 7	Compound E7
6	Compound 9	Compound E8
7	Compound 17	Compound E8
8	Compound 15	Compound E18

HOMO and LUMO levels of selected compounds for the possible premix pairs are listed in Table 3 below. The HOMO/LUMO levels were obtained through differential pulse voltammetry in DMF solutions at a concentration of 10^{-3} M, with 0.1 M tetrabutylammonium hexafluorophosphate as the supporting electrolyte. A glass carbon disk, a platinum wire and a silver wire are used as the working, counter and pseudo reference electrodes, respectively. Ferrocene is added into the solution to serve as the internal standard for each measurement. The resultant oxidation potential (E_{ox}) and reduction potential (E_{red}), adjusted to ferrocene, are used to calculate the HOMO/LUMO levels as −4.8 eV−qE_{ox} and −4.8 eV−qE_{red}, respectively, where q is the electron charge.

TABLE 3

HOMO and LUMO levels of selected compounds for premix pairs.

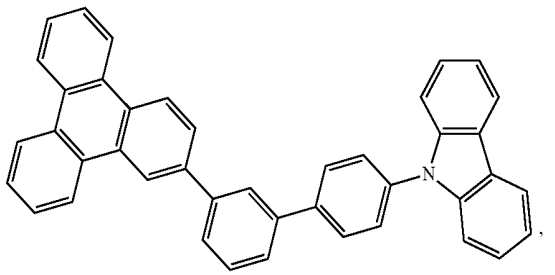
Compound	HOMO (eV)	LUMO (eV)
Compound 1	−5.7	−2.1
Compound 2	−5.7	−2.1
Compound E2	−5.6	−2.7
Compound E69	−5.6	−2.7

Having HOMO and LUMO levels at −5.7 eV and −2.1 eV, respectively, both Compounds 1 and 2 are considered as hole-transporting hosts. On the other hand, Compounds E2 and E69 have deep LUMO levels at −2.7 eV and are used as electron-transporting hosts.

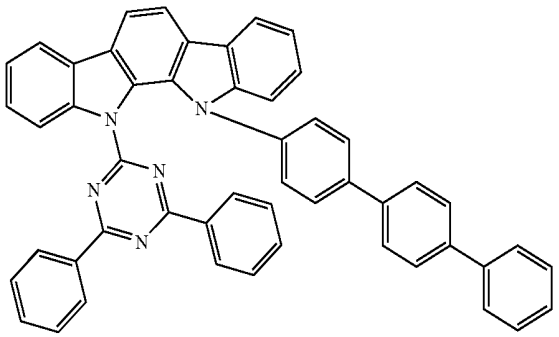
Structures of the Host Compounds:

[0069]

Compound 2



Compound E2



[0070] According to an embodiment of the present disclosure, a novel host composition comprising a mixture of a first compound and a second compound that is a stable co-evaporation mixture is disclosed. In the mixture, the first compound has different chemical structure than the second compound. The first compound is capable of functioning as a hole transporting material in an organic light emitting device at room temperature. The first compound can have a HOMO level between −5.0 and −6.0 eV. The first compound comprises at least one carbazole group, and can have a evaporation temperature T1 of 150 to 350° C. The second compound can have a evaporation temperature T2 of 150 to 350° C. In order to form the inventive composition comprising a mixture of a first compound and a second compound, the absolute value of T1−T2, the difference between T1 and T2, should be less than 20° C. Preferably, the absolute value of T1−T2 is less than 10° C. and more preferably less than 5° C.

[0071] The the first compound has a concentration C1 in the mixture, and the first compound has a concentration C2 in a film formed by evaporating the mixture in a vacuum deposition tool, such as a VTE tool, at a constant pressure between 1×10^{-6} Torr to 1×10^{-9} Torr, at a 2 Å/sec deposition rate on a surface positioned at a predefined distance away from the evaporation source of the mixture being evaporated; and wherein the absolute value of (C1−C2)/C1 is less than 5%. The concentrations C1 and C2 are relative concentrations of the first compound. Therefore, the conditional requirement for the two compounds forming the mixture described above means that the relative concentration of the first compound in the as-deposited film (C2) should be as close to the original relative concentration of the first compound (C1) in the evaporation source mixture. 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 a suitable analytical methods such as high pressure liquid chromatography (HPLC) and nuclear magnetic resonance spectroscopy (NMR).

[0072] The inventors used HPLC and the percentage was calculated by deviding 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 (C1−C2)/C1 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.

[0073] In another embodiment of the host composition, the first compound has a evaporation temperature T1 of 200 to 350° C. and the second compound has a evaporation temperature T2 of 200 to 350° C. Preferably, the absolute value of (C1−C2)/C1 is less than 3%.

[0074] In one embodiment of the host composition, the first compound has a vapor pressure of P1 at T1, the second compound has vapor pressure of P2 at T2, and the ratio of P1/P2 is within the range of 0.90 to 1.10.

[0075] The first compound has a first mass loss rate and the second compound has a second mass loss rate, wherein the ratio between the first mass loss rate and the second mass loss rate is within the range of 0.90 to 1.10, including the endpoints. In one embodiment, the ratio between the first mass loss rate and the second mass loss rate is within the range of 0.95 to 1.05, including the endpoints. Preferably, the ratio between the first mass loss rate and the second mass loss rate is within the range of 0.97 to 1.03, including the endpoints.

[0076] According to an embodiment of the host composition, the first compound comprises at least one of the chemical groups selected from the group consisting of triphenylene, dibenzothiophene, dibenzofuran, and dibenzoselenophene.

[0077] The second compound is capable of functioning as an electron transporting material in an organic light emitting device at room temperature. The second compound can have a LUMO level between −2.3 and −3.3 eV. The second compound comprises at least one of the chemical groups selected from the group consisting of aza-triphenylene, aza-carbazole, aza-dibenzothiophene, aza-dibenzofuran, aza-dibenzoselenophene, and non-fused N-containing six-member aromatic rings.

[0078] In one embodiment, the first compound has HOMO energy level higher than −5.7 eV. In another embodiment, the first compound has HOMO energy level higher than −5.5 eV. Preferably, the first compound has HOMO energy level higher than −5.8 eV.

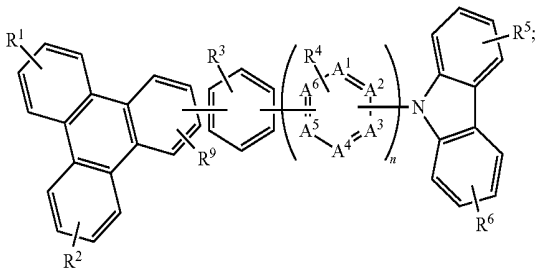
[0079] Preferably, the first compound and the second compound each has a purity in excess of 99% as determined by high pressure liquid chromatography.

[0080] According to one embodiment, the novel composition can further comprise a third compound. The third compound has a different chemical structure than the first compound and the second compound, wherein the third compound has an evaporation temperature T3 of 150 to 350° C.; and wherein the absolute value of T1−T3 is less than 20° C.

[0081] According to one embodiment, the composition is in liquid form at a temperature lower than T1 and T2. In other words, where T1 and T2 are not equal, the composition is in liquid form at at temperature lower than the lower of T1 and T2.

[0082] In one embodiment of the host composition, the first compound has the formula (I):

(I)



wherein

R^1, R^2, R^3, R^4, R^5, and R^6 each represent mono, di, tri, tetra substitutions, or no substitution;

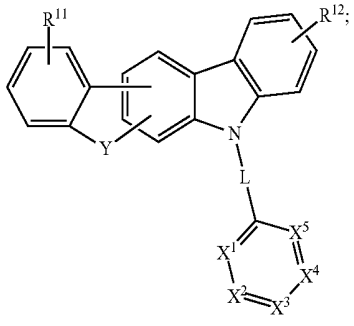
R^9 represents mono, di, tri substitutions, or no substitution;

R^1, R^2, R^3, R^4, R^5, R^6, and R^9 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 acid, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof;

A^1, A^2, A^3, A^4, A^5, and A^6 are each independently selected from N or C; and

n is an integer from 1 to 20;

wherein the second compound has the formula (II):



(II)

wherein

R^{11} and R^{12} each represent mono, di, tri, tetra substitutions, or no substitution;

Y is selected from the group consisting of O, S. Se, NR', and CR"R'";

L is a single bond or comprises an aryl or heteroaryl group having from 5-24 carbon atoms, which is optionally further substituted;

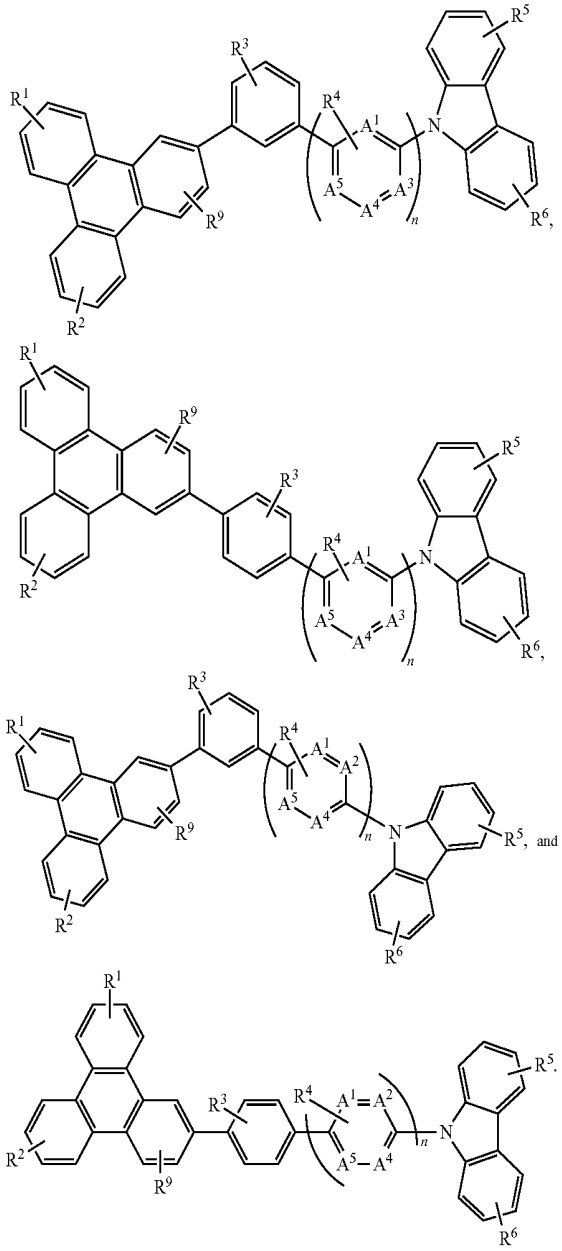
X^1, X^2, X^3, X^4, and X^5 are each independently selected from group consisting of CR and N;

at least one of X^1, X^2, X^3, X^4, and X^5 is N; and

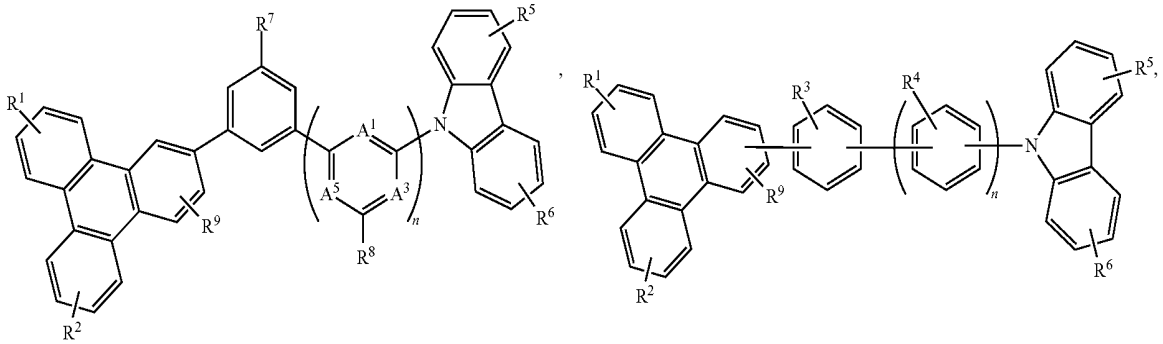
R, R', R", and R'" are each independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acid, ester, nitrile, isonitrile,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

[0083] In one embodiment, in the formula (II) for the second compound, X^1, X^3, and X^5 are N; and X^2 and X^4 are CR.

[0084] According to an embodiment of the host composition, the first compound has the formula selected from the group consisting of:



[0085] In another embodiment of the host composition, the first compound has the formula selected from the group consisting of:



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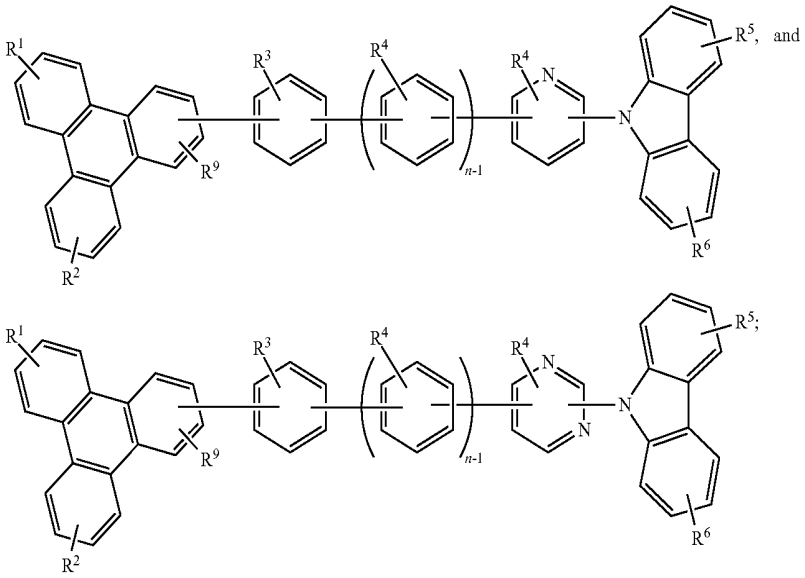
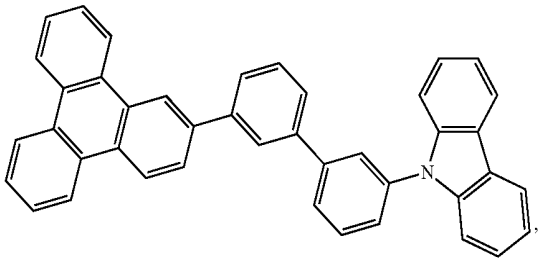


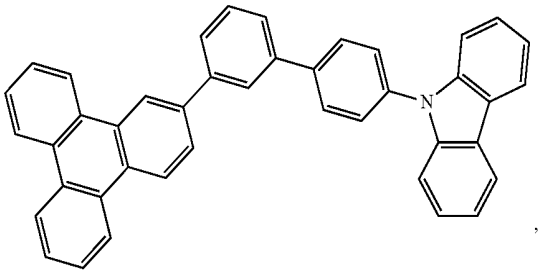
wherein R^7 and R^8 are each independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acid, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

[0086] In one embodiment, the first compound is selected from the group consisting of:

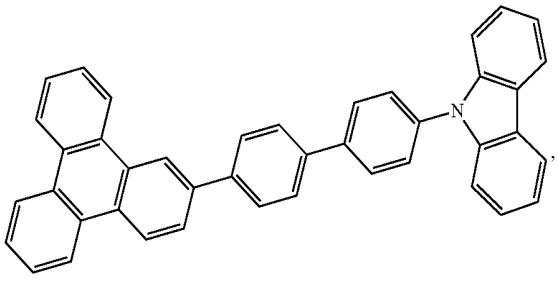
Compound 1



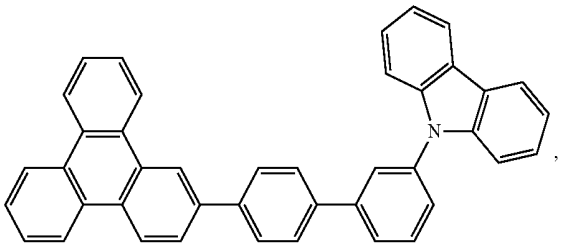
Compound 2



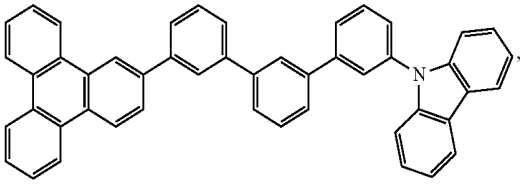
Compound 3



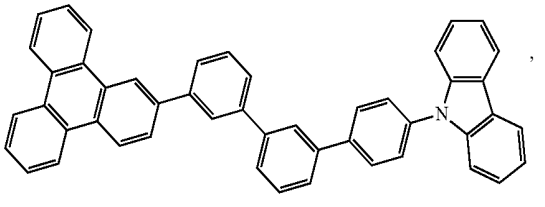
Compound 4



Compound 5



Compound 6



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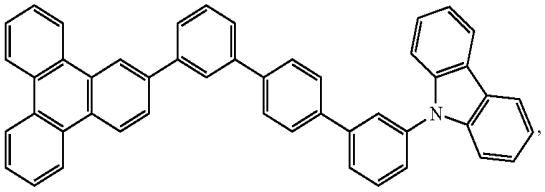
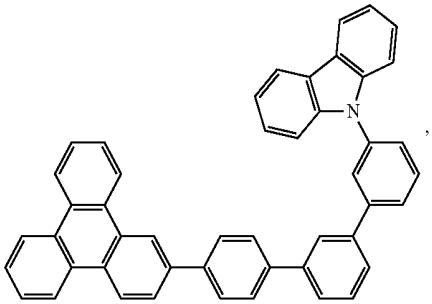
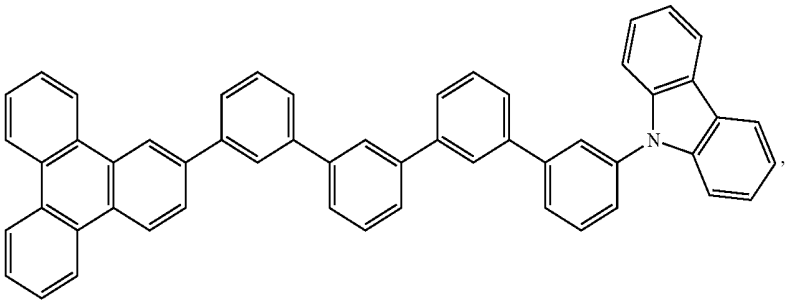
Compound 7



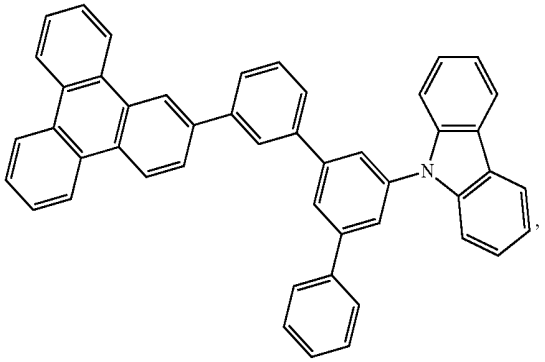
Compound 8



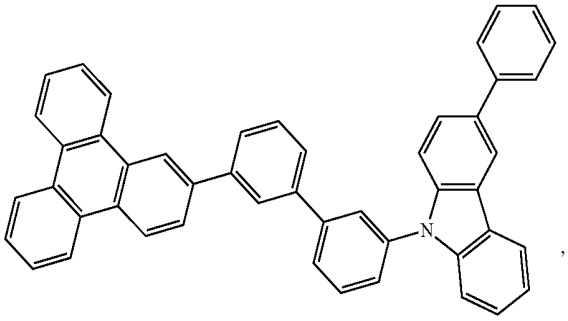
Compound 9



Compound 10



Compound 11



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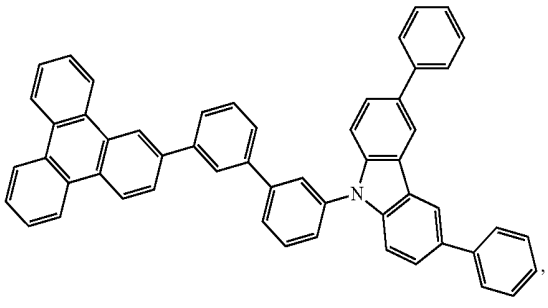

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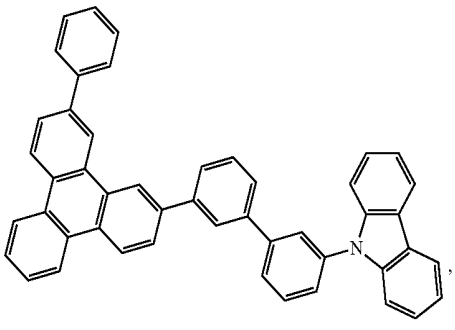

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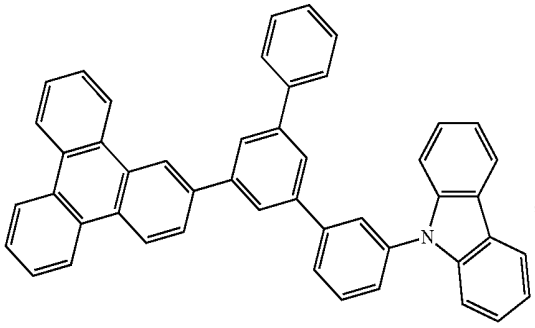
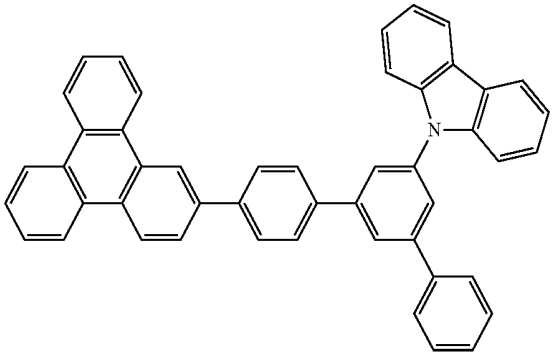
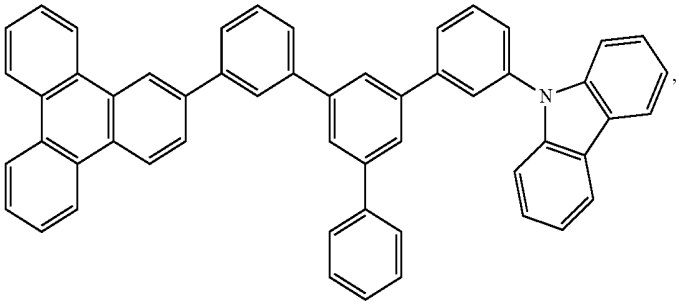
Compound 14



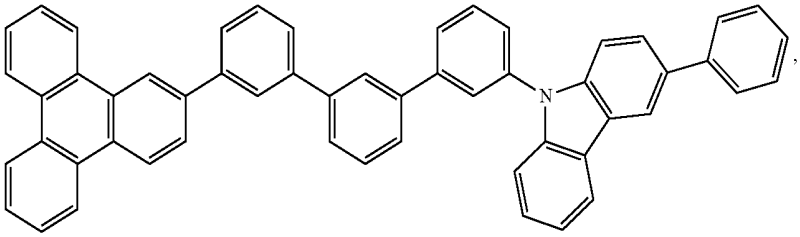
Compound 15



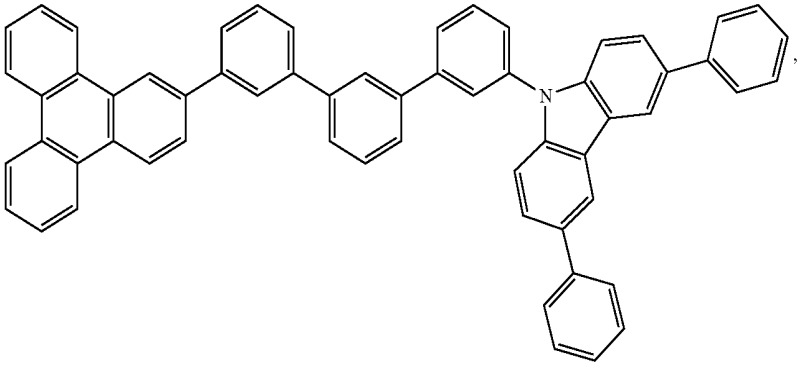
Compound 16



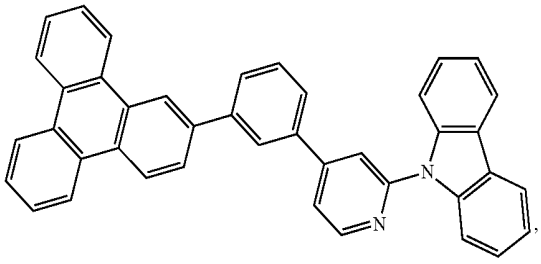
Compound 17



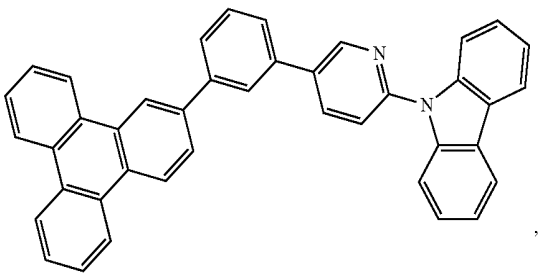
Compound 18



Compound 19



Compound 20



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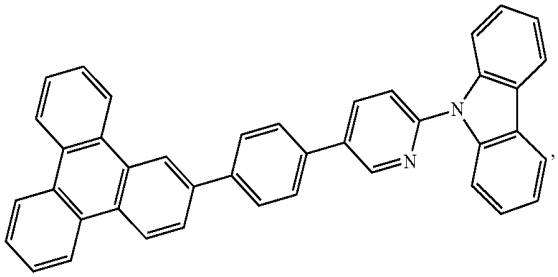
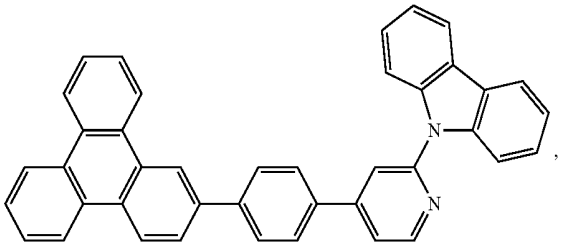
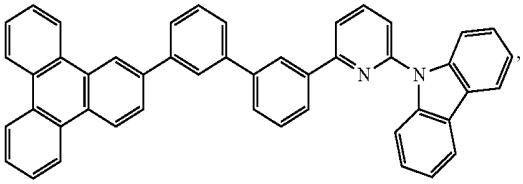
Compound 21



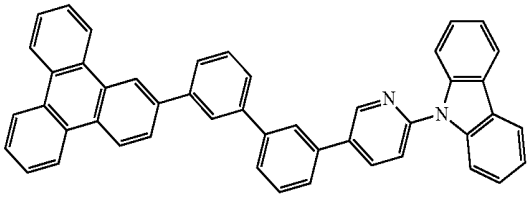
Compound 22



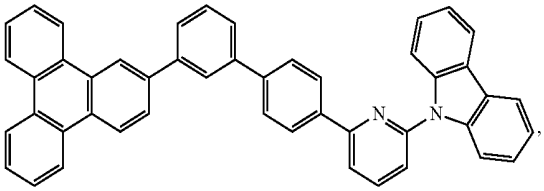
Compound 23



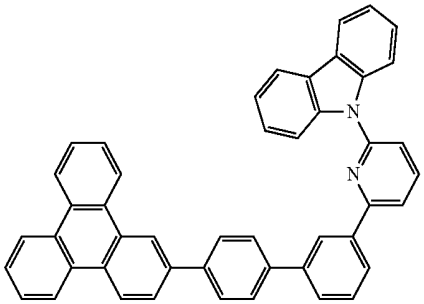
Compound 24



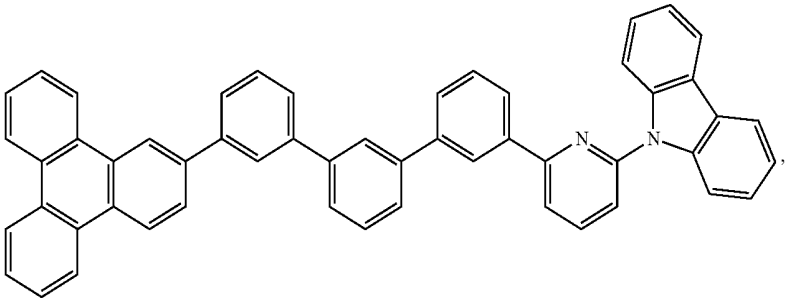
Compound 25



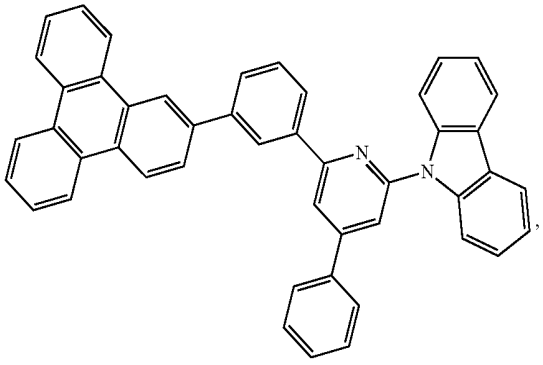
Compound 26



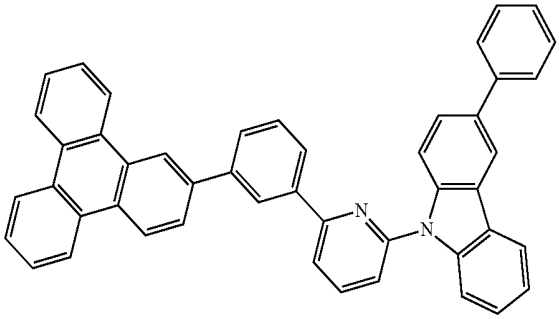
Compound 27



Compound 28



Compound 29



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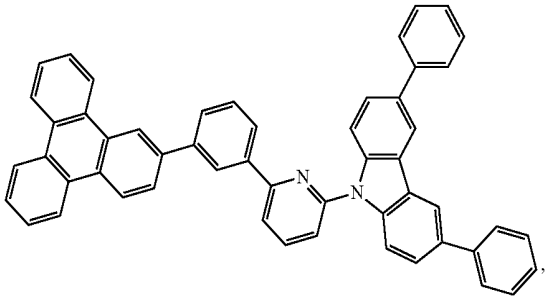
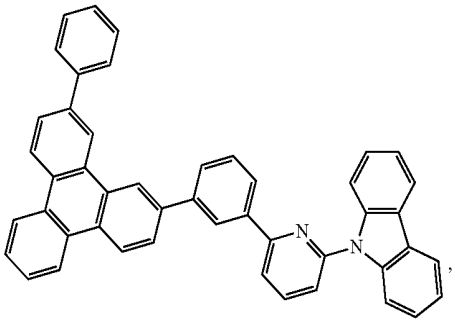
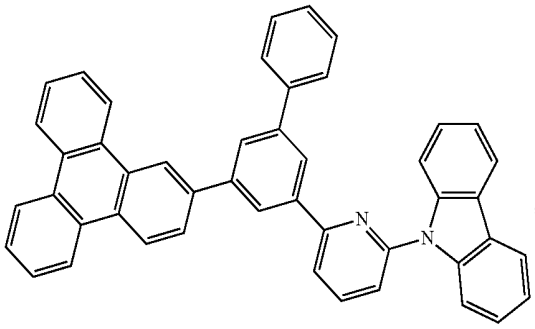
Compound 30



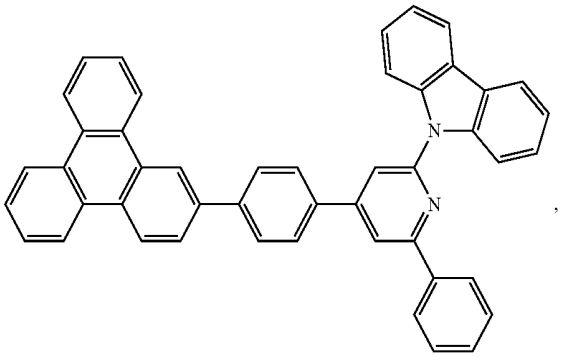
Compound 31



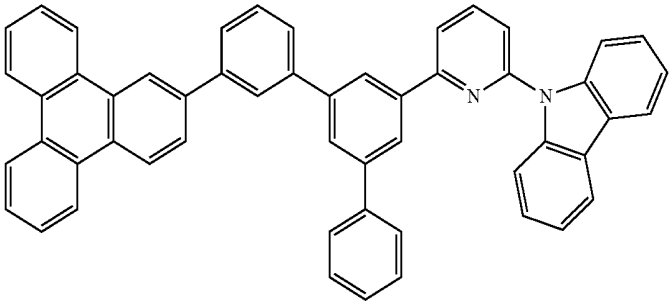
Compound 32



Compound 33



Compound 34



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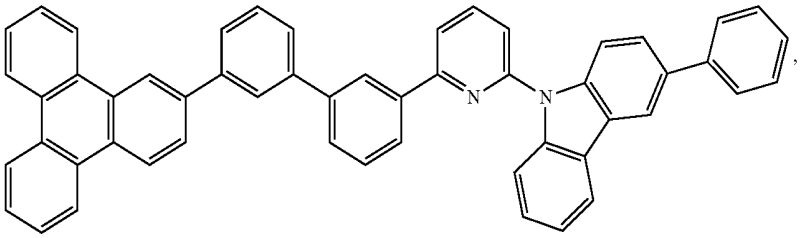
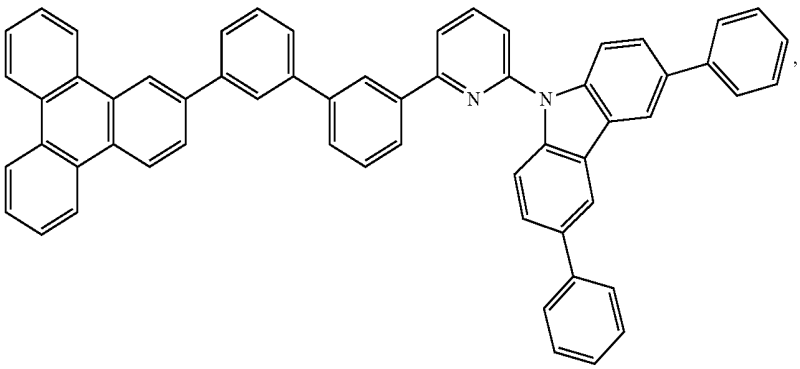


Compound 36



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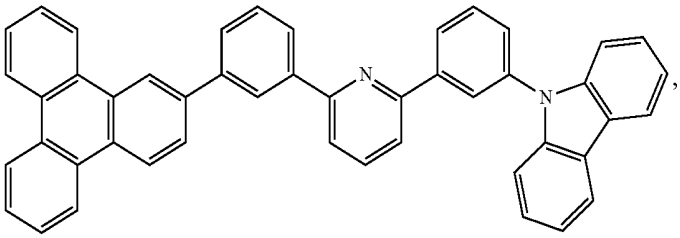
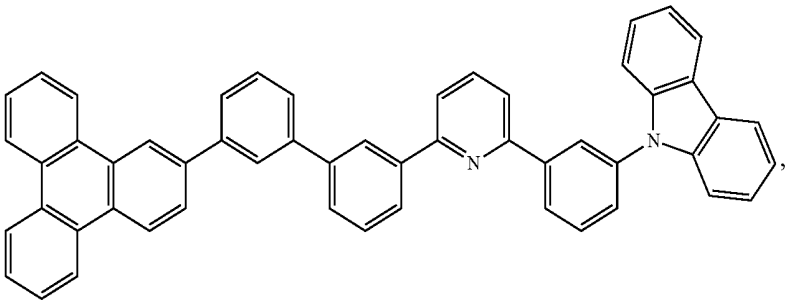
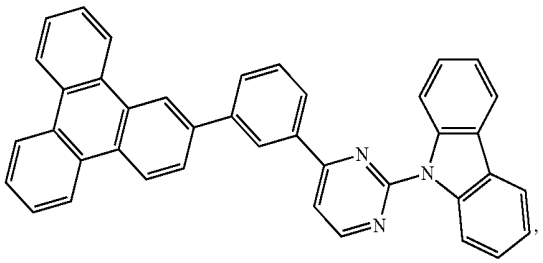
Compound 37



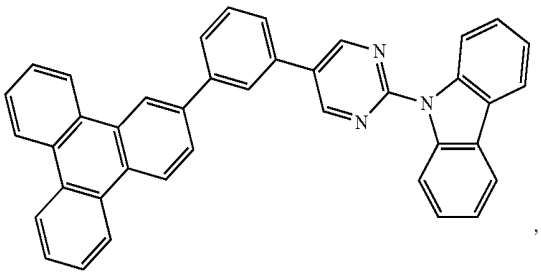
Compound 38



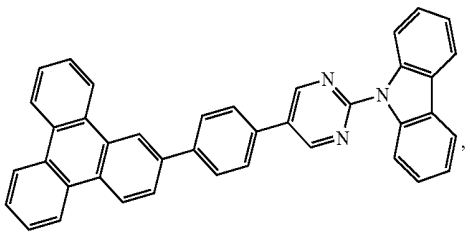
Compound 39



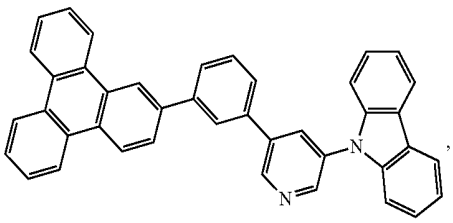
Compound 40



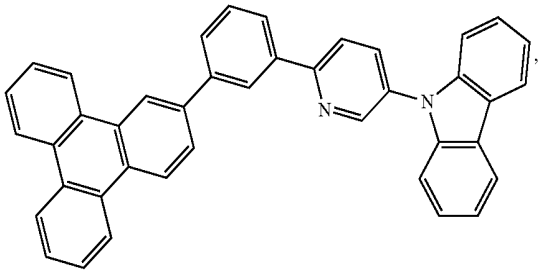
Compound 41



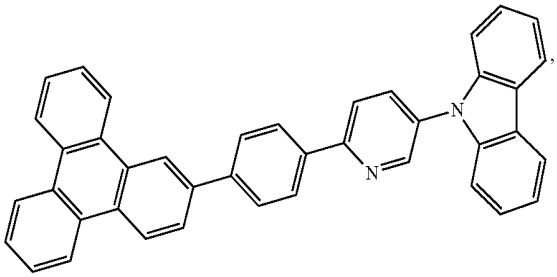
Compound 42



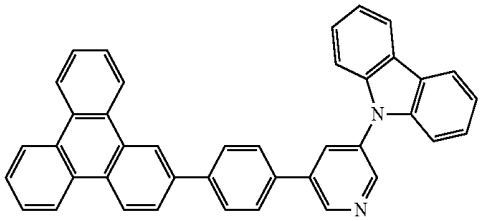
Compound 43



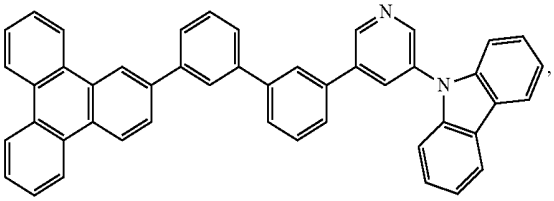
Compound 44



Compound 45



Compound 46



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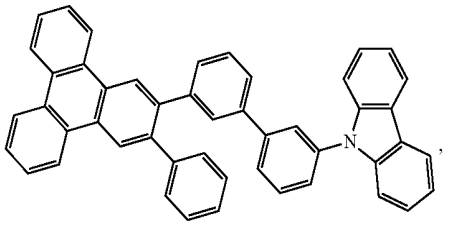
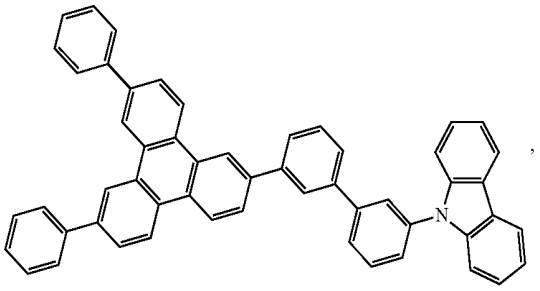
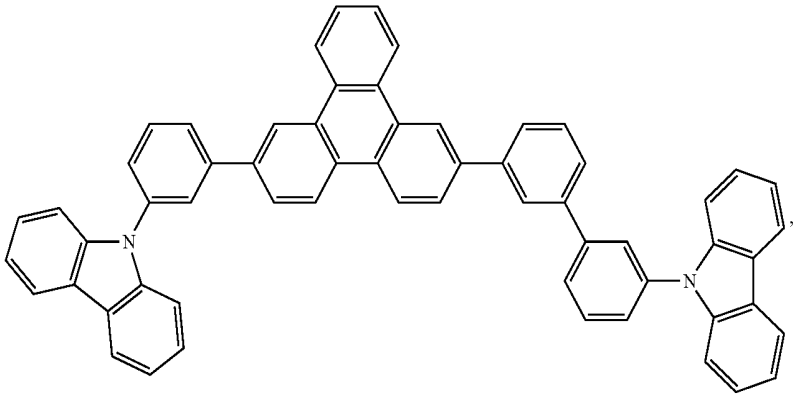
Compound 47



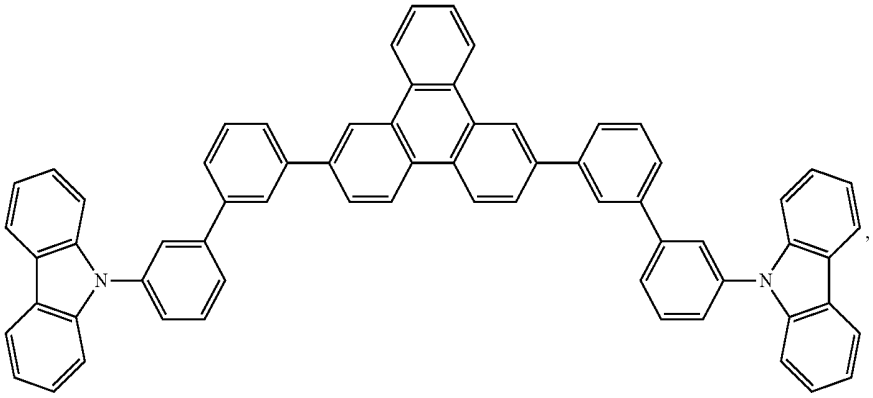
Compound 48



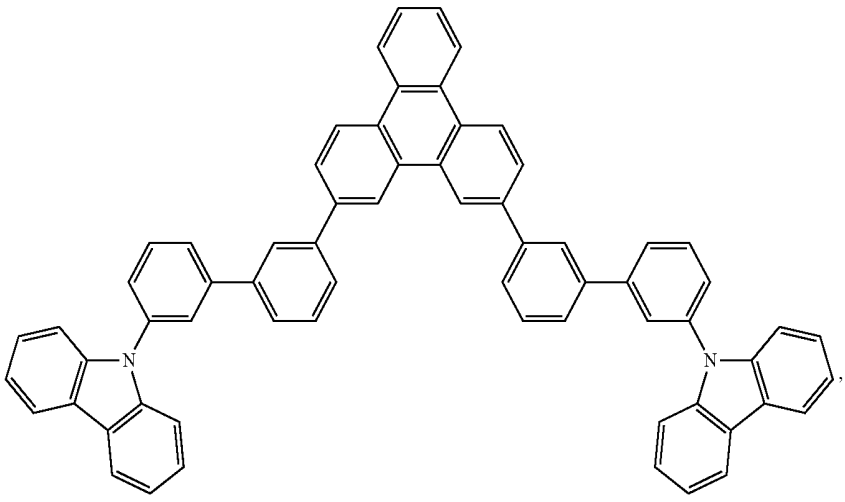
Compound 49



Compound 50



Compound 51



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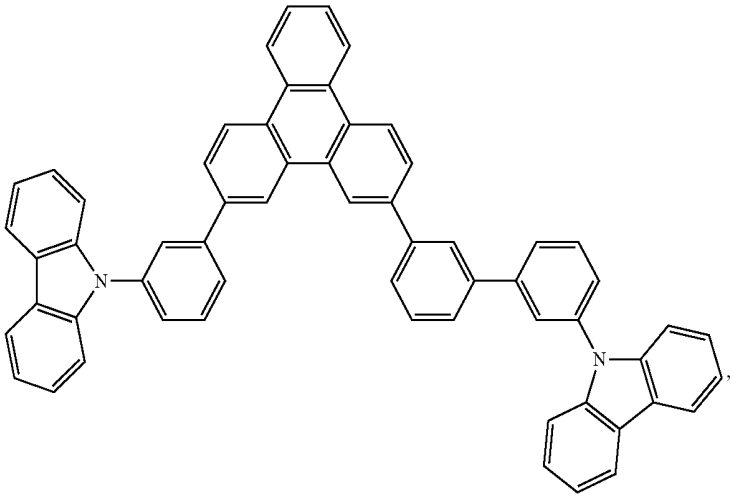
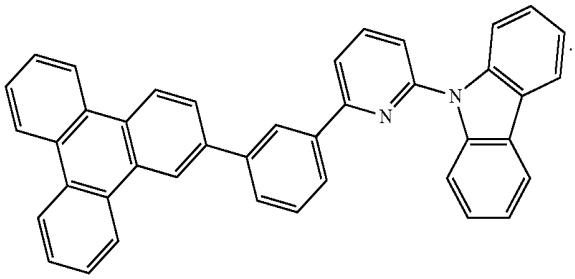
Compound 52



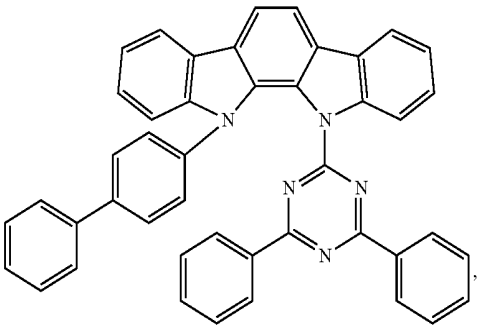
, and

Compound 53



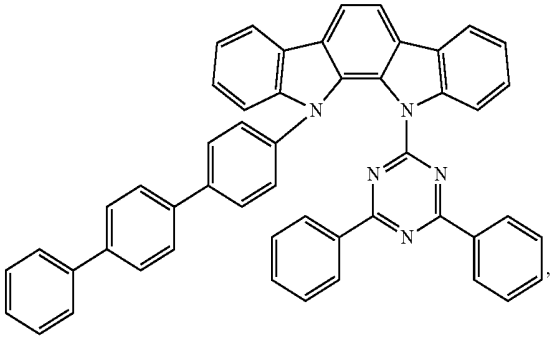
[0087] In one embodiment of the host composition, the second compound is selected from the group consisting of:

Compound E1



,

Compound E2



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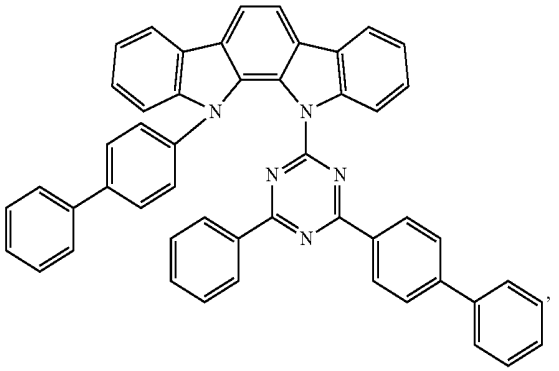
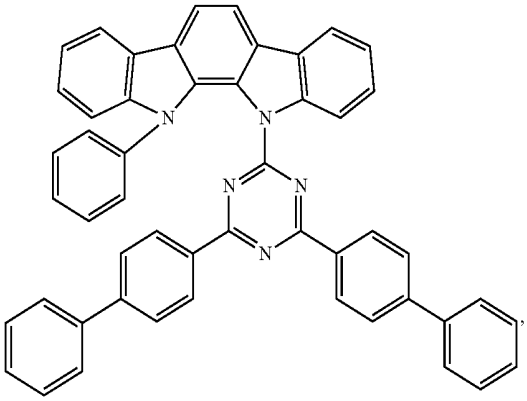
Compound E3



,

Compound E4



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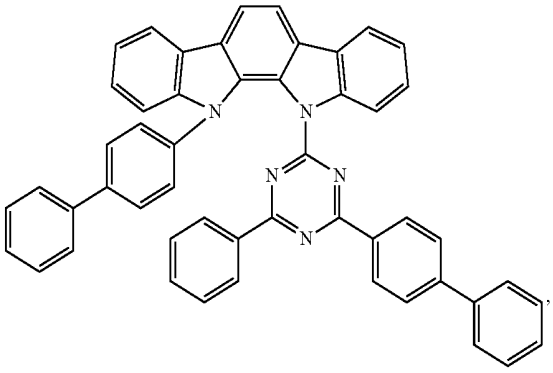
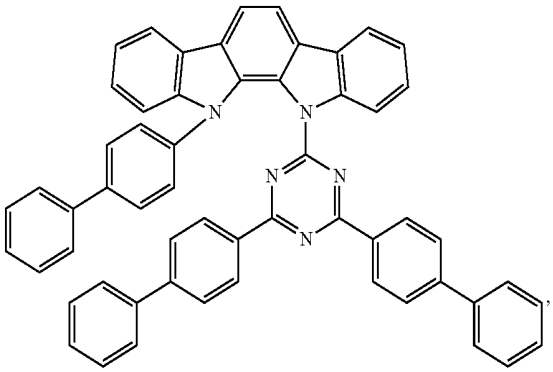
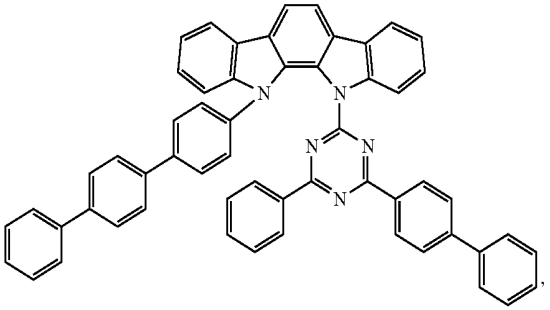
Compound E5



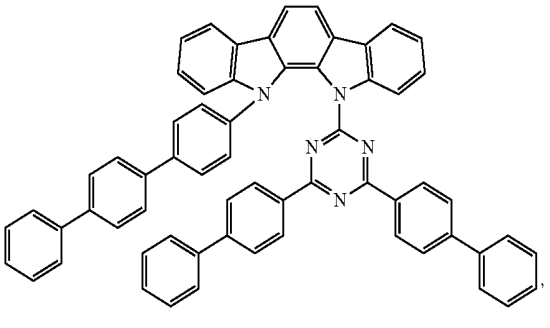
Compound E6



Compound E7



Compound E8



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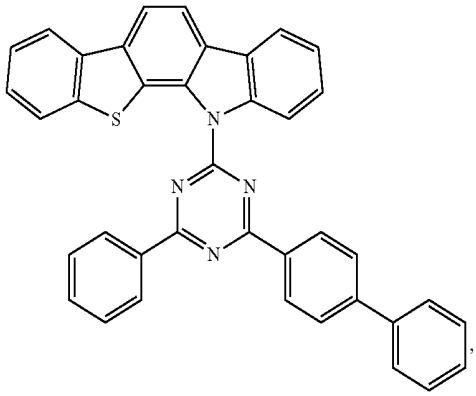
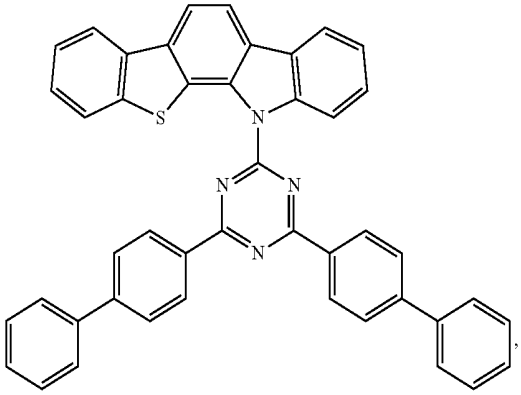
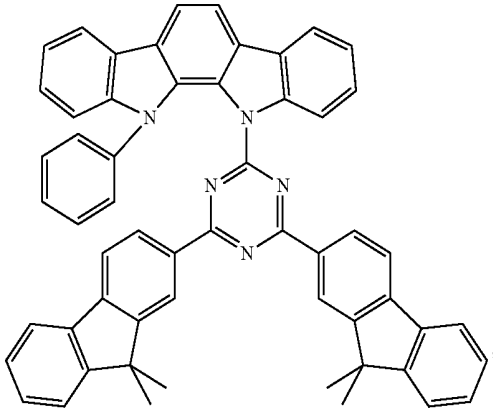
Compound E9



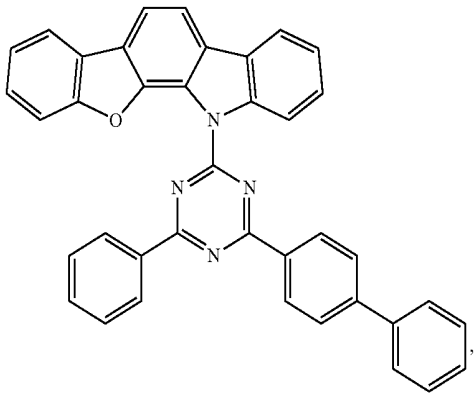
Compound E10



Compound E11



Compound E12



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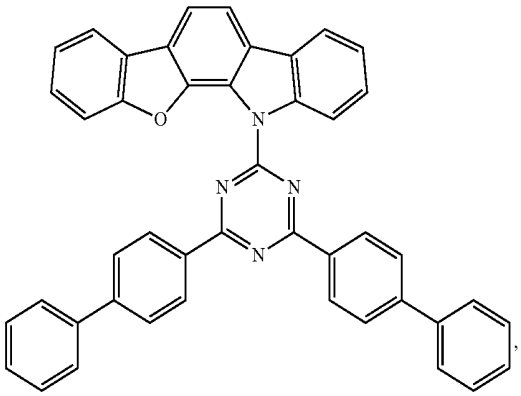
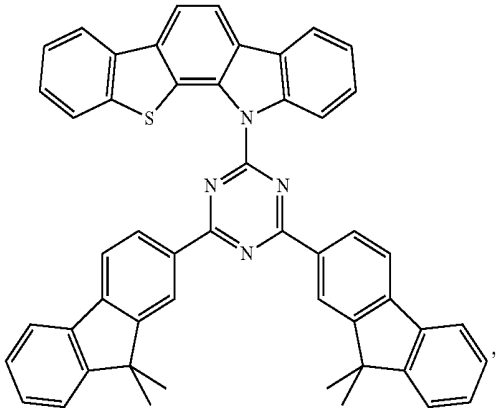
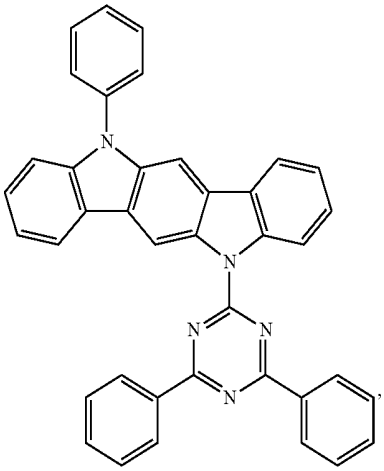
Compound E13



Compound E14



Compound E15



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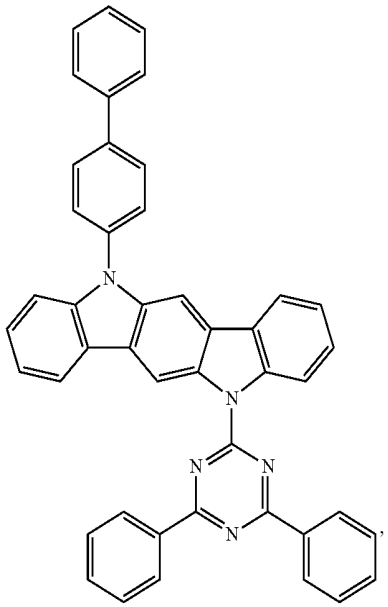
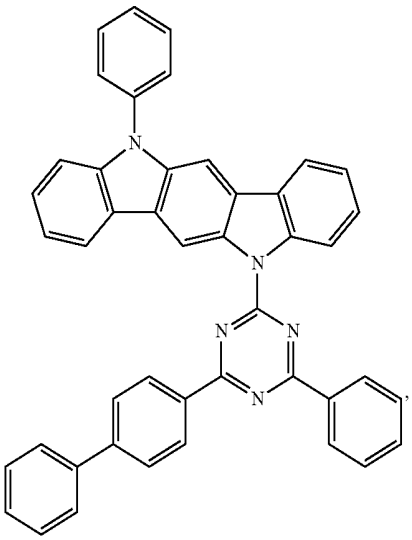
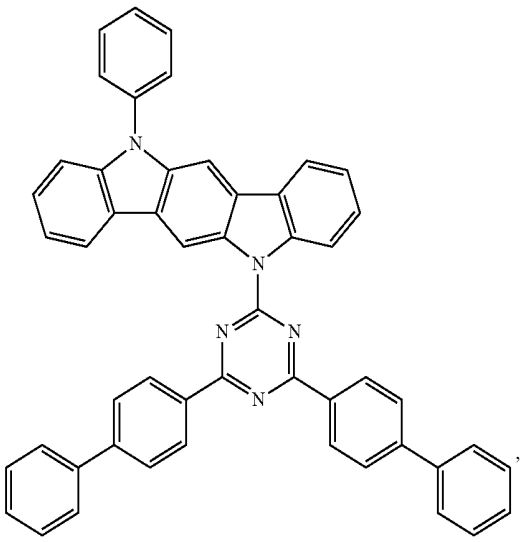
Compound E16



Compound E17



Compound E18



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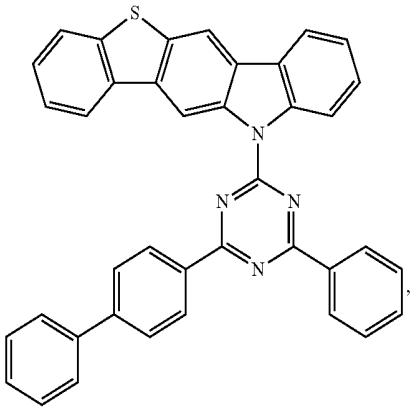
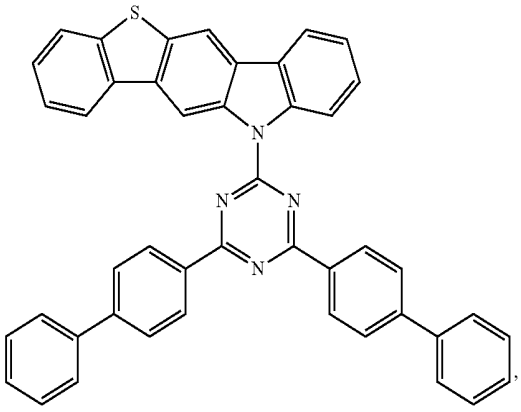
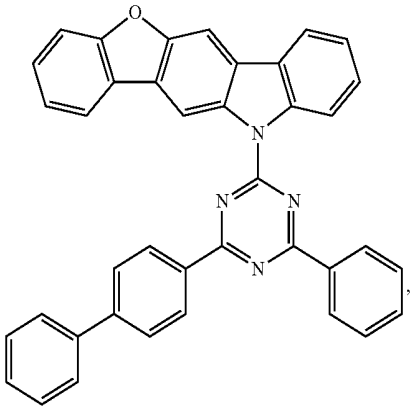
Compound E19



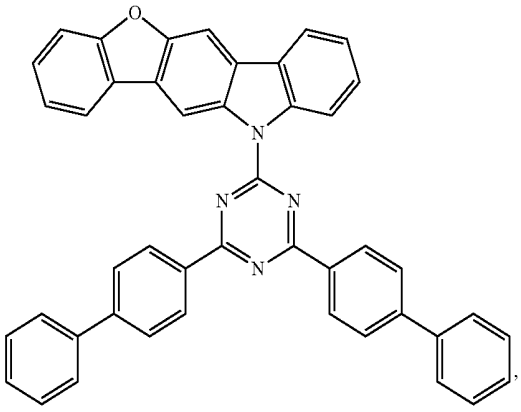
Compound E20



Compound E21



Compound E22



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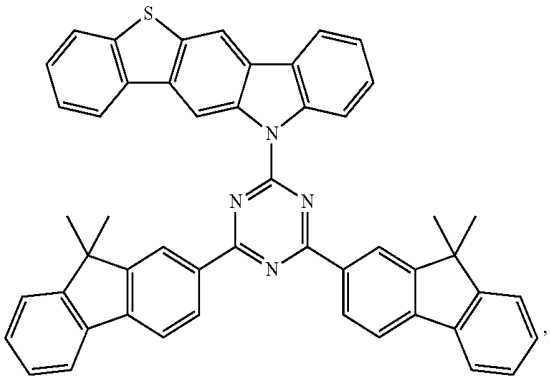
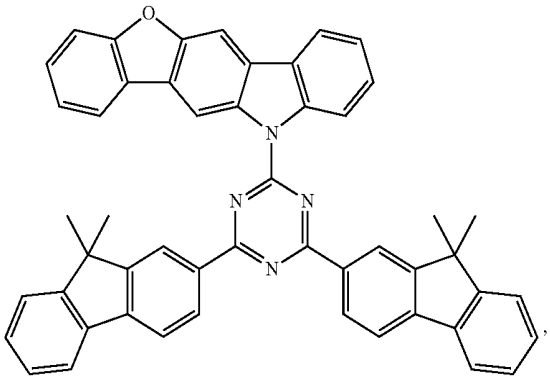
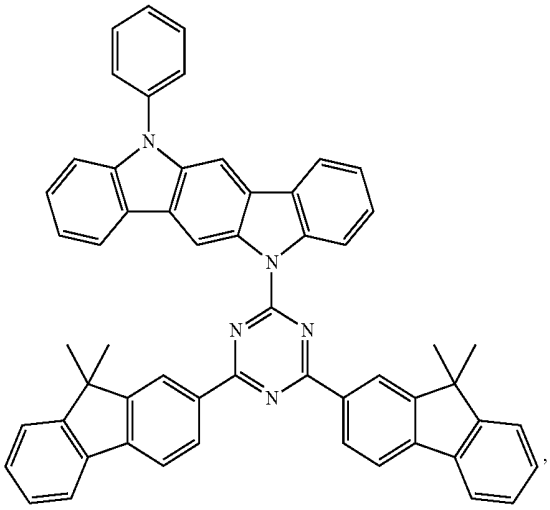
Compound E23



Compound E24



Compound E25



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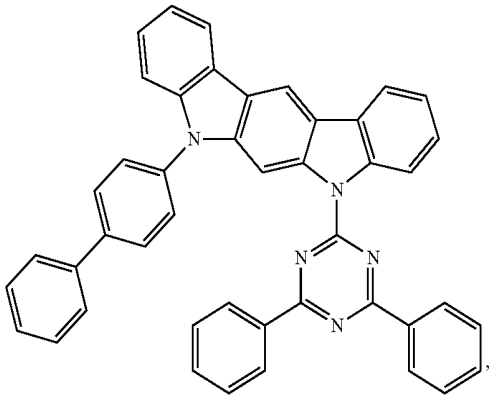
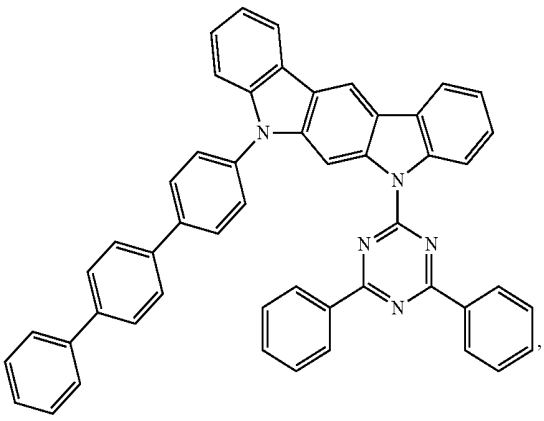
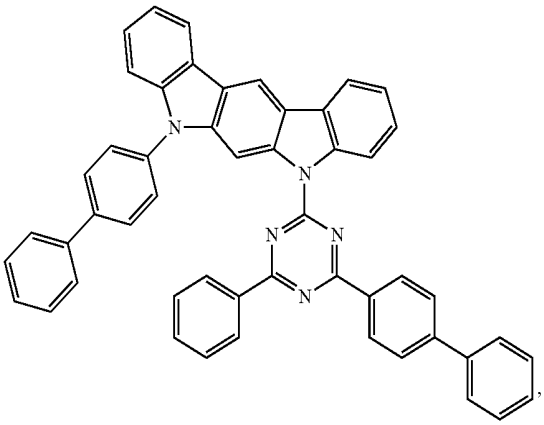
Compound E26



Compound E27



Compound E28



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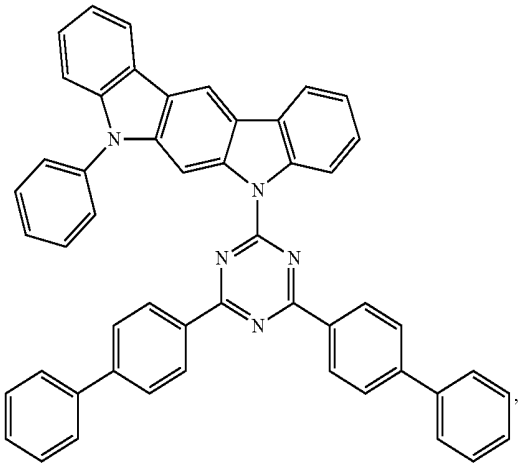
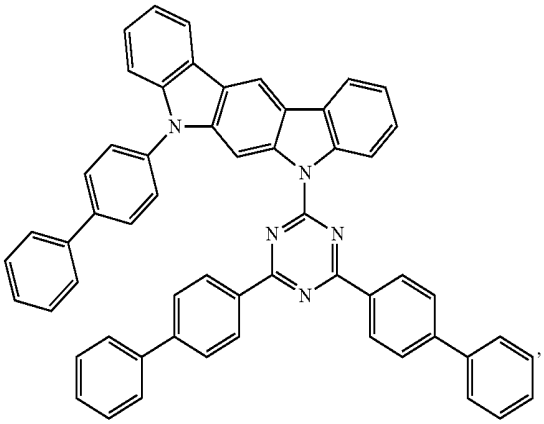
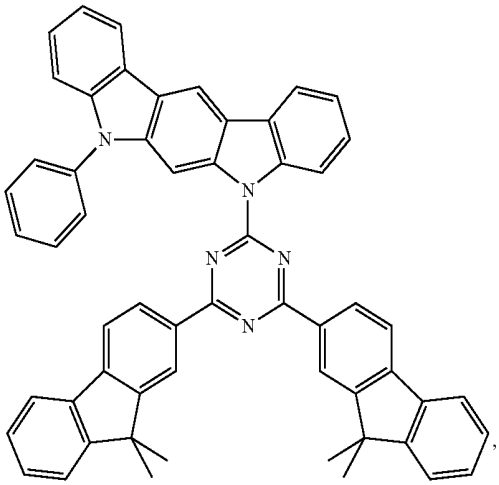


Compound E30



Compound E31



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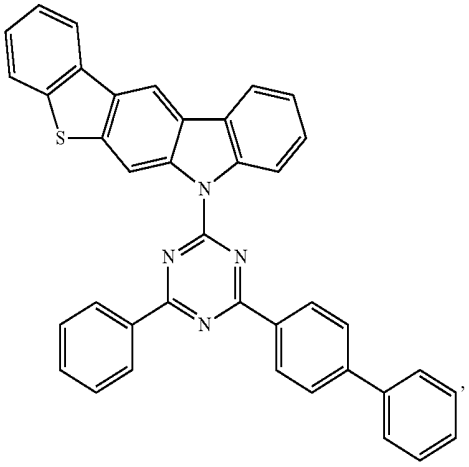
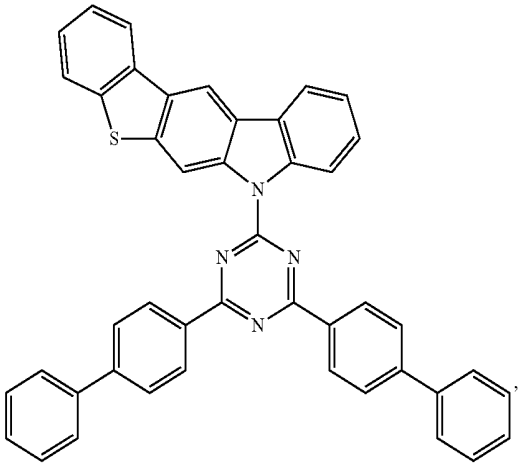
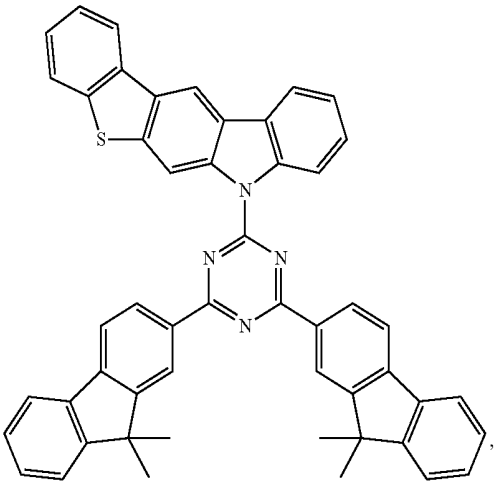


Compound E33



Compound E34



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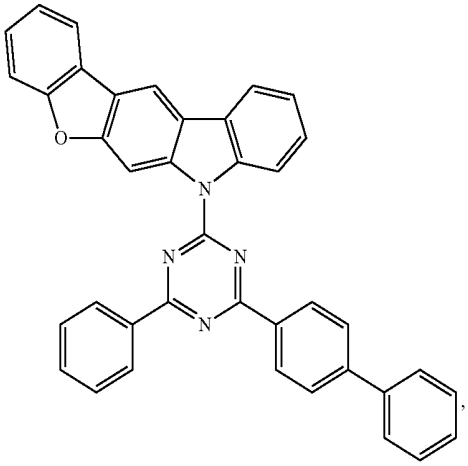
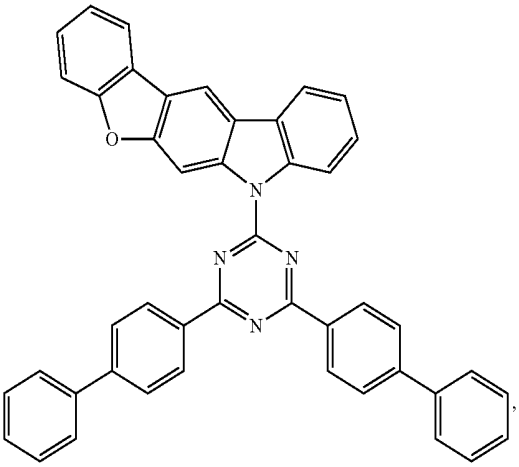
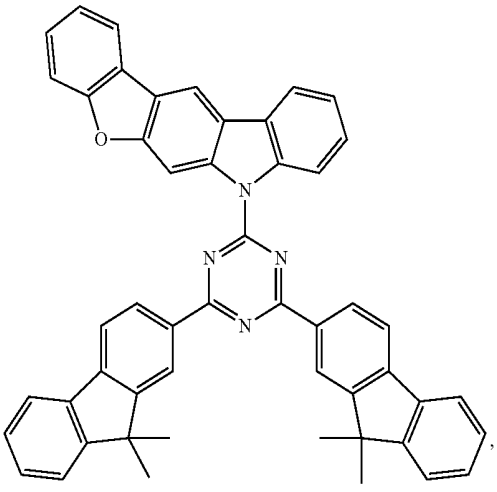


Compound E36



Compound E37



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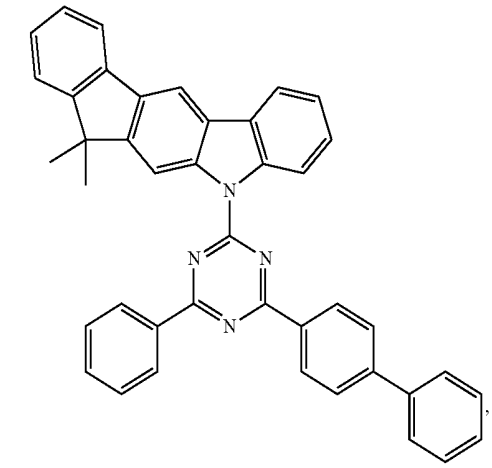

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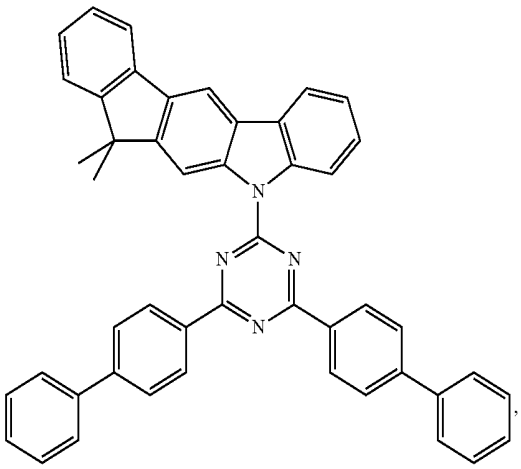

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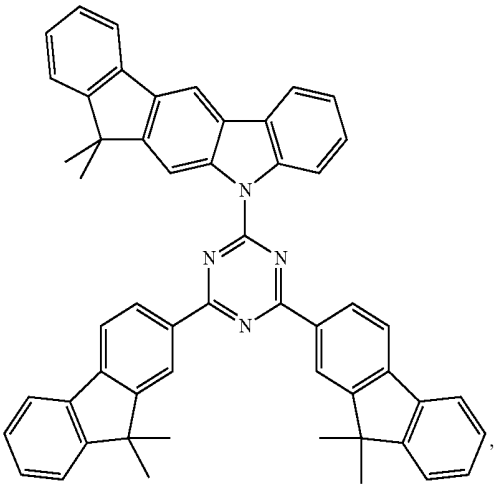
Compound E40



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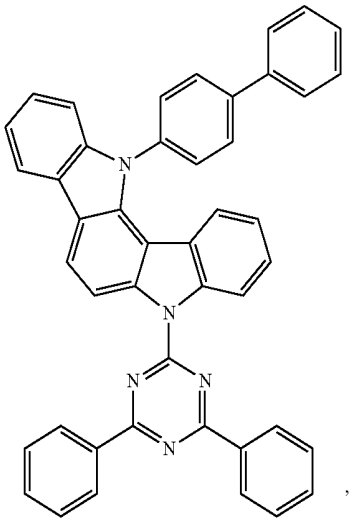

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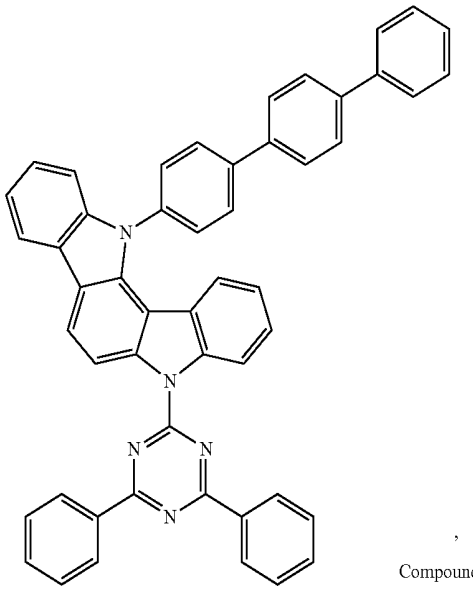

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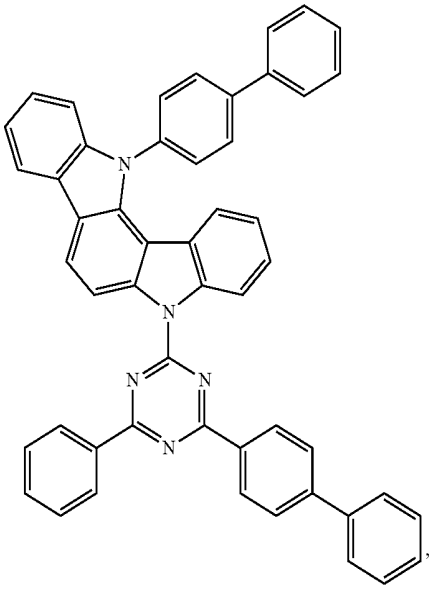
Compound E43



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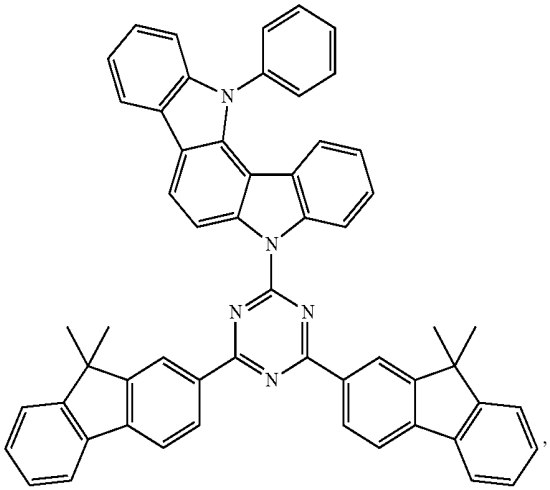
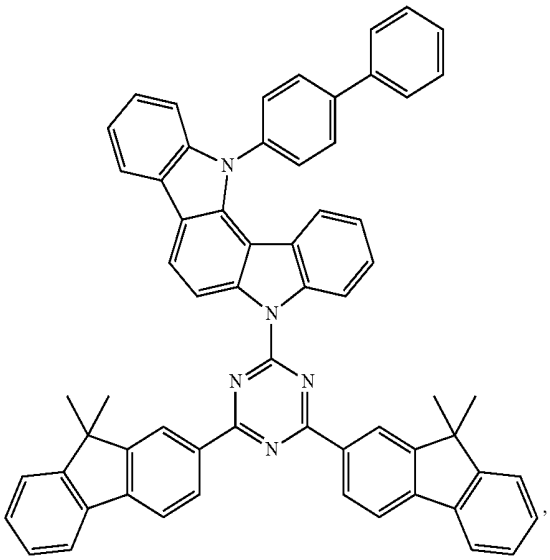
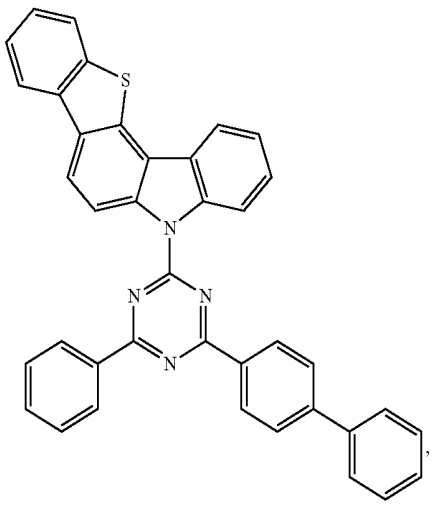
Compound E44



Compound E45



Compound E46



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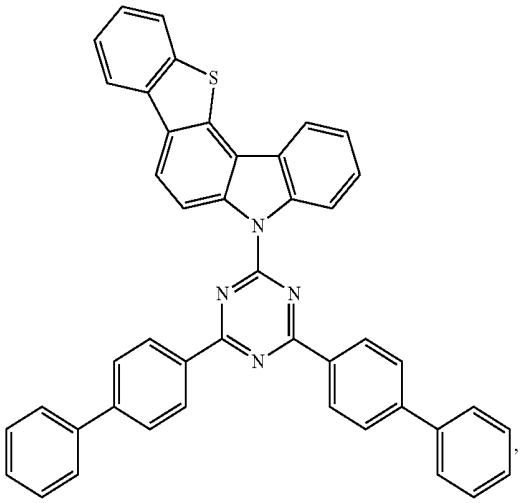
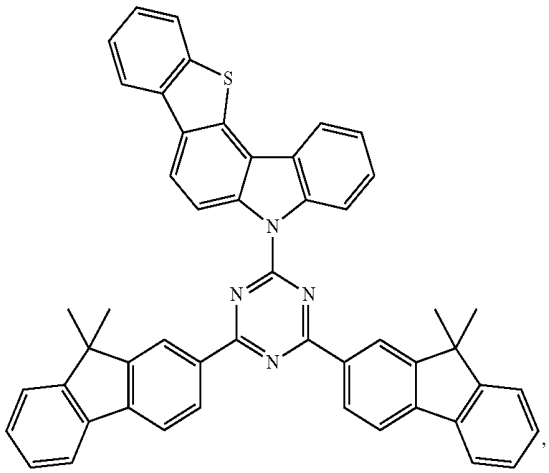
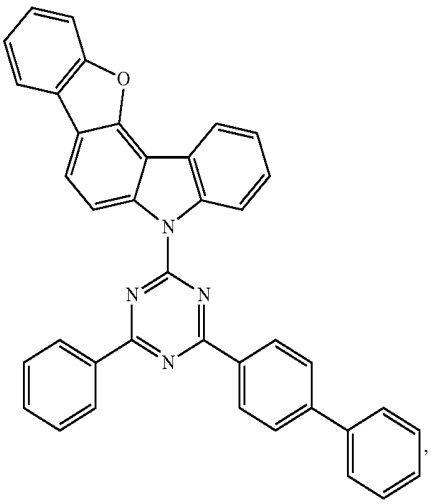
Compound E47



Compound E48



Compound E49



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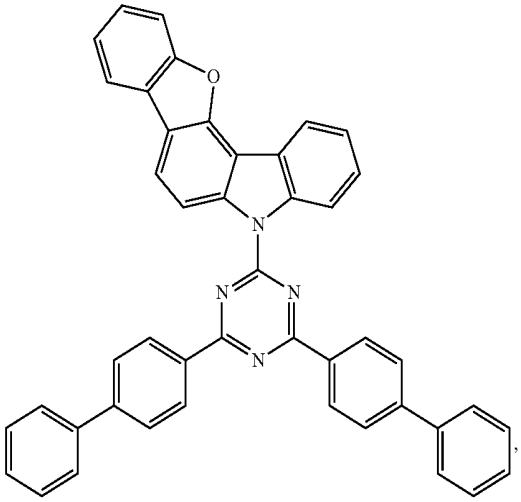
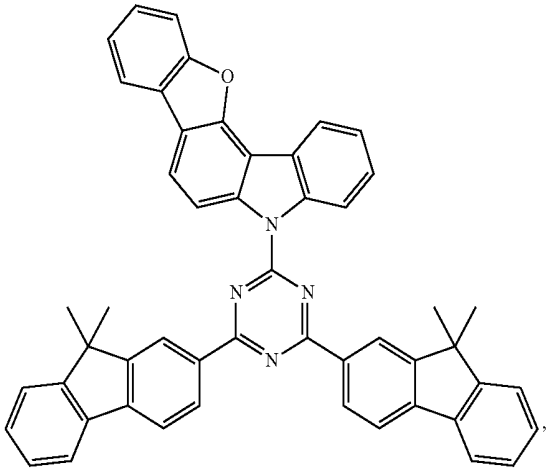
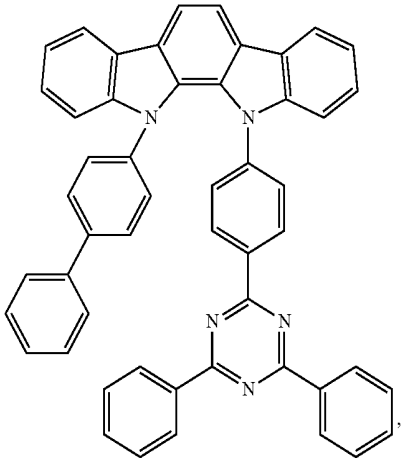
Compound E50



Compound E51



Compound E52



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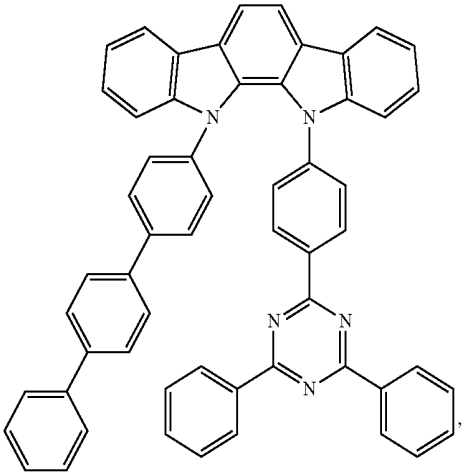
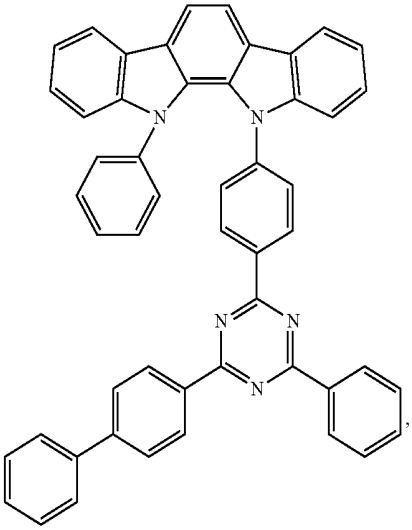
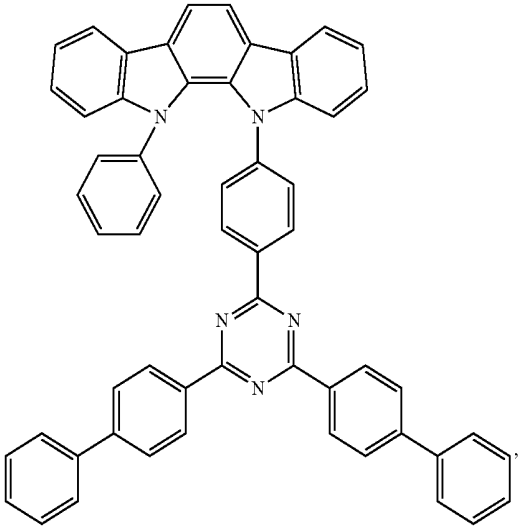


Compound E54



Compound E55



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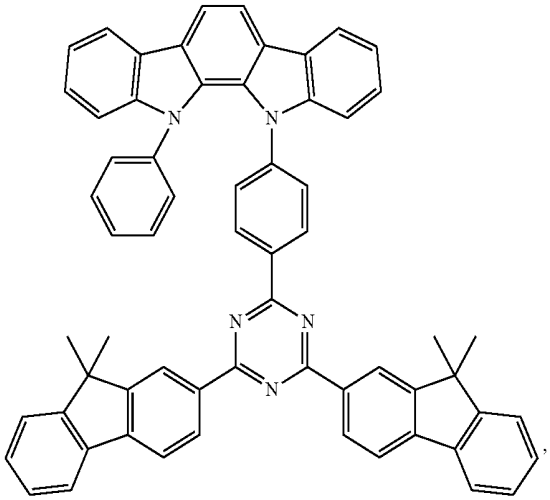
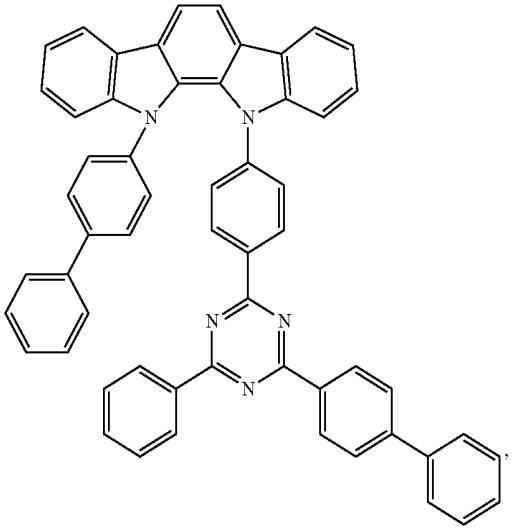
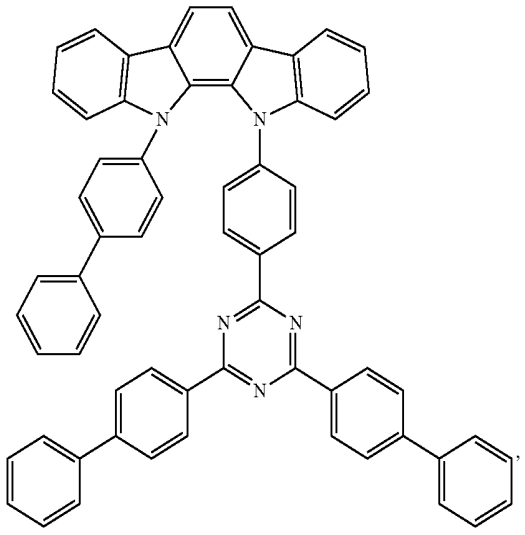
Compound E56



Compound E57



Compound E58



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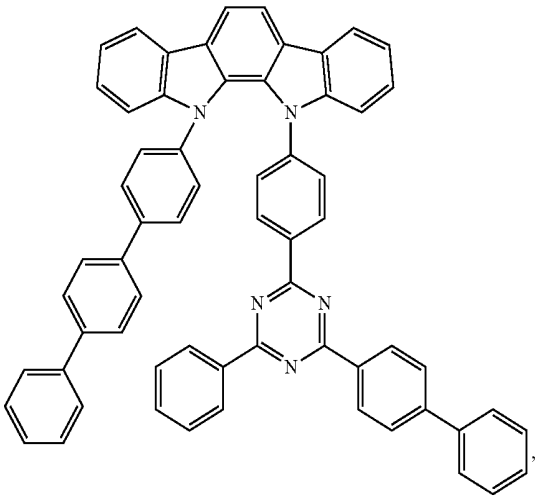
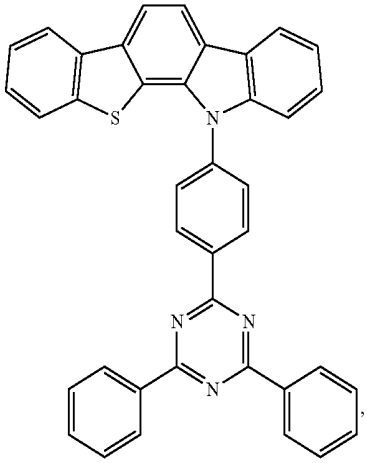
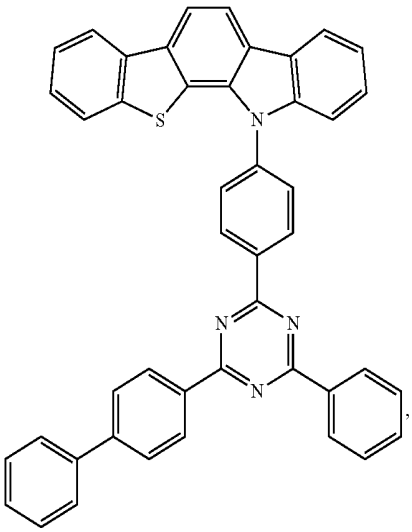
Compound E59



Compound E60



Compound E61



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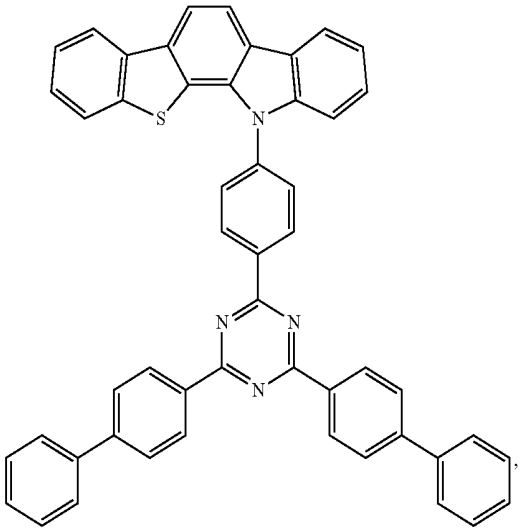
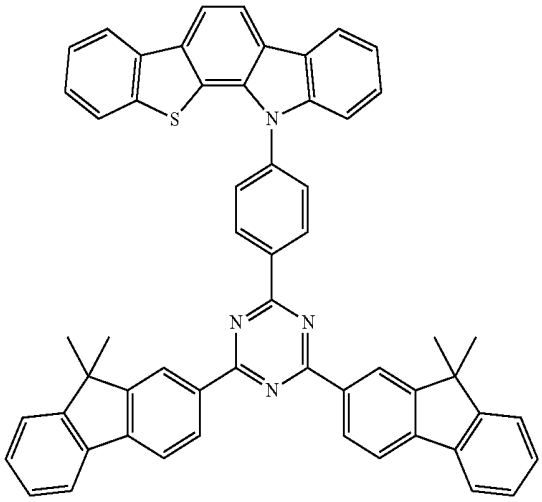
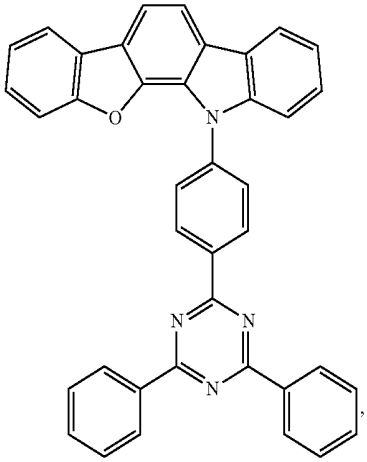
Compound E62



Compound E63



Compound E64



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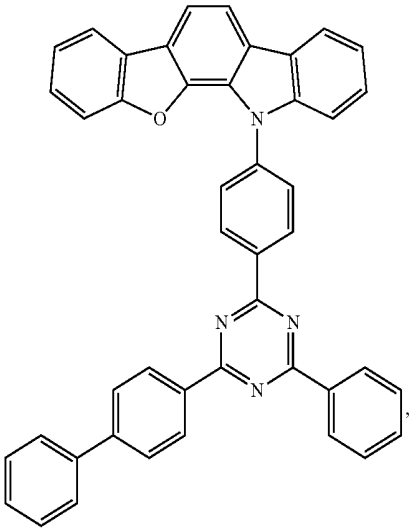
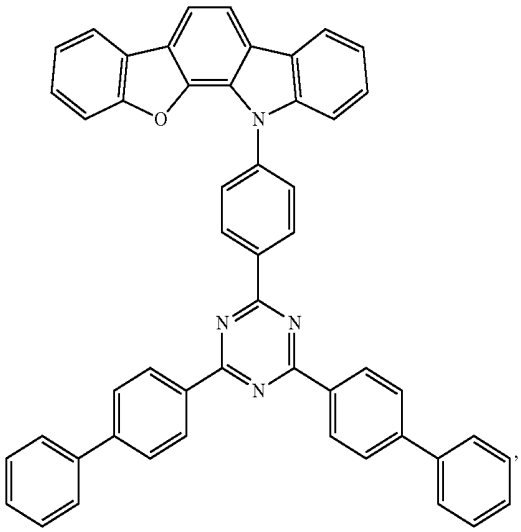
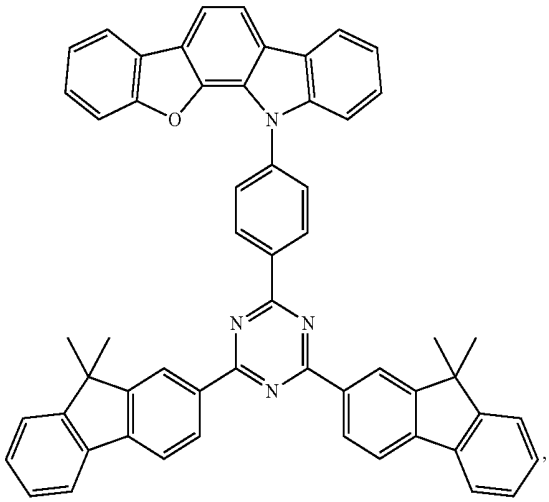
Compound E65



Compound E66



Compound E67



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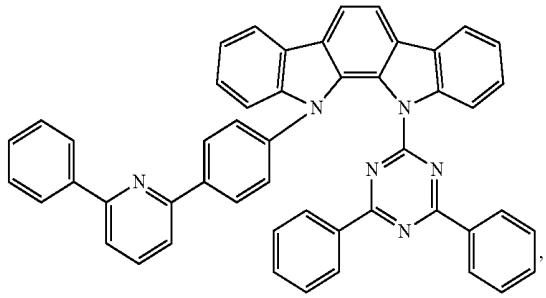
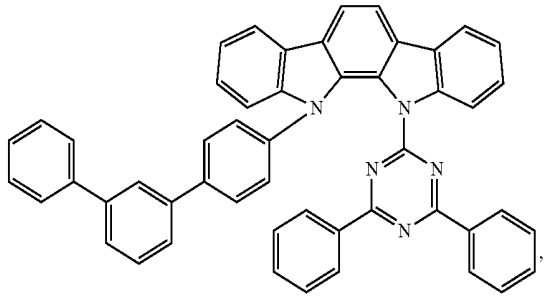
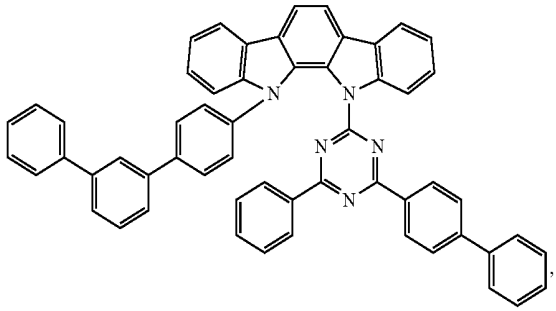
Compound E68



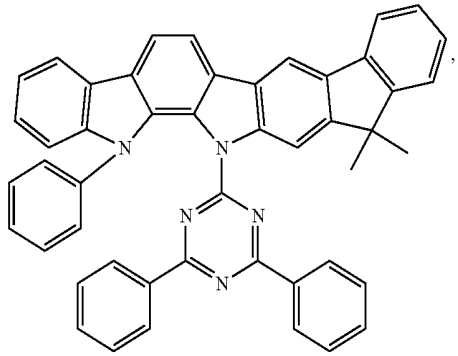
Compound E69



Compound E70



Compound E71



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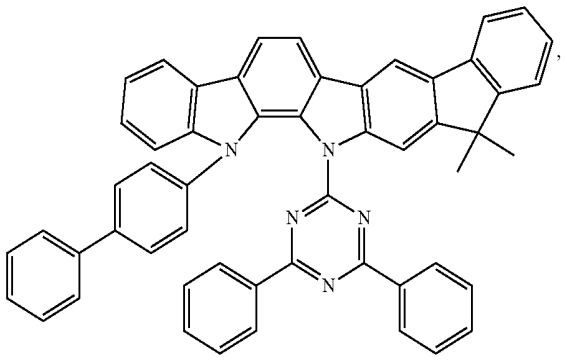
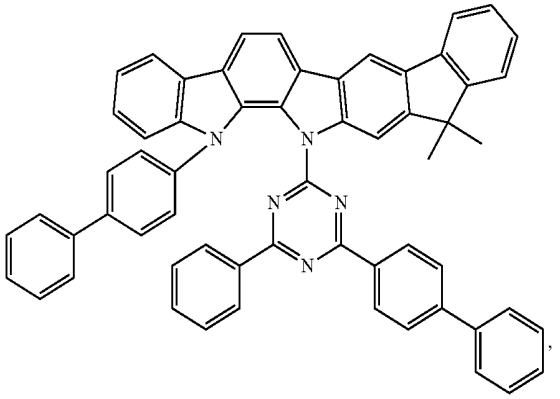
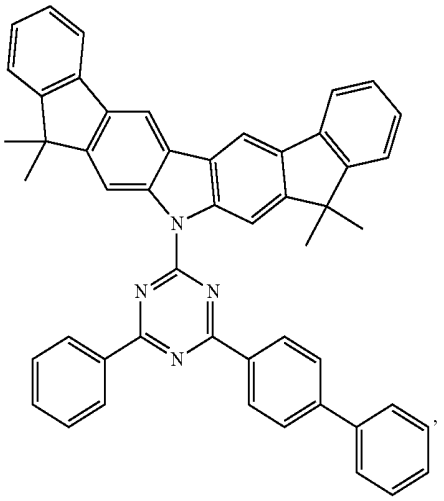
Compound E72



Compound E73



Compound E74



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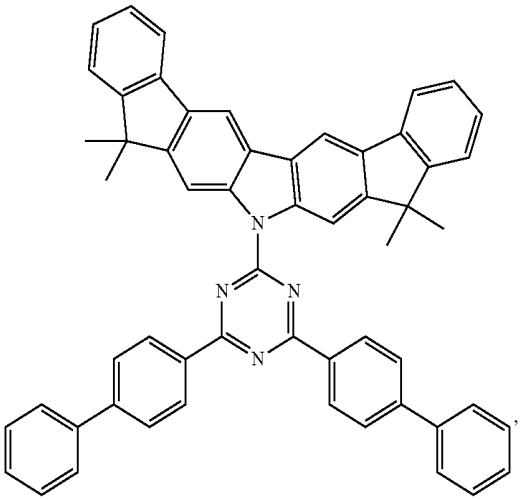
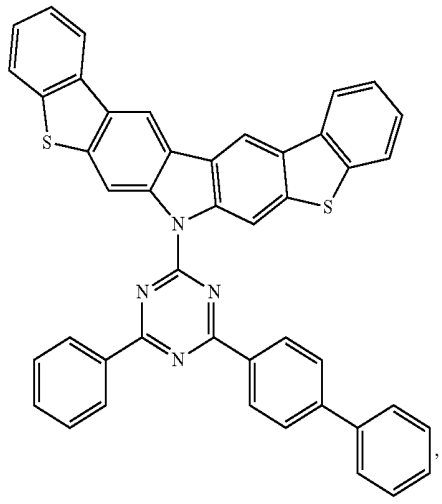
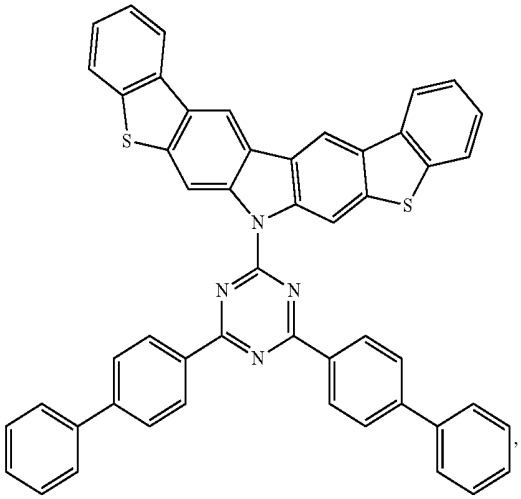
Compound E75



Compound E76



Compound E77



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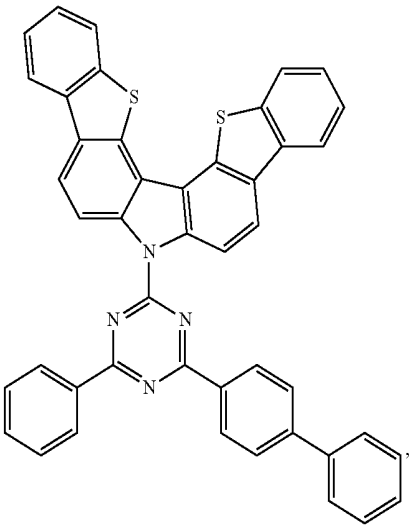
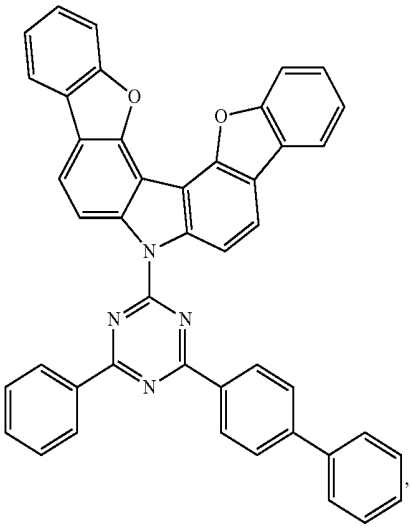
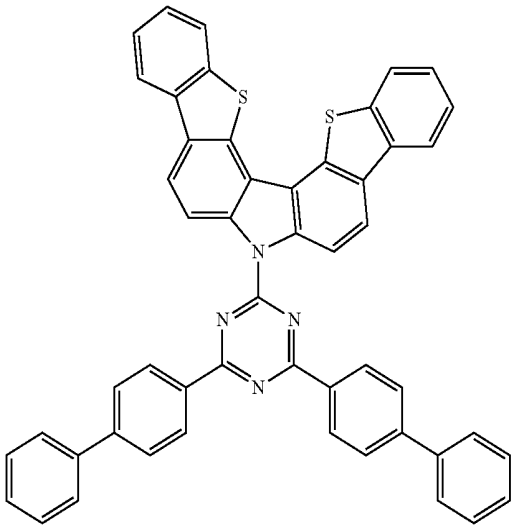
Compound E78



Compound E79



Compound E80



and

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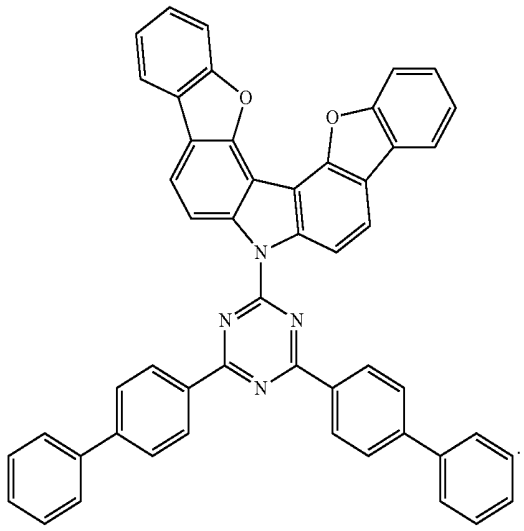
Compound E81



[0088] In one embodiment of the host composition, the mixture of the first compound and the second compound is selected from the group consisting of: (Compound 2 and Compound E2), (Compound 3 and Compound E4), (Compound 1 and Compound E5), (Compound 6 and Compound E7), (Compound 7 and Compound E7), (Compound 9 and Compound E8), (Compound 17 and Compound E8), and (Compound 15 and Compound E18).

[0089] According to another aspect of the present disclosure, a first device comprising a phosphorescent organic light-emitting device is disclosed. The phosphorescent organic light-emitting device comprises: an anode; a cathode; and an organic layer, disposed between the anode and the cathode, comprising a first organic composition comprising a mixture of a first compound and a second compound, wherein the first compound has different chemical structure than the second compound;

[0090] wherein the first compound is capable of functioning as a hole transporting material in an organic light emitting device at room temperature;

[0091] wherein the first compound comprises at least one carbazole group;

[0092] wherein the first compound has an evaporation temperature T1 of 150 to 350° C.;

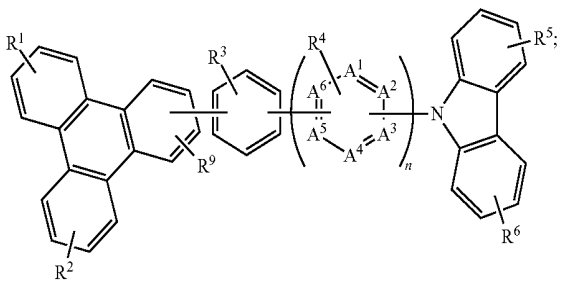
[0093] wherein the second compound has an evaporation temperature T2 of 150 to 350° C.;

[0094] wherein the absolute value of T1−T2 is less than 20° C.;

[0095] wherein the first compound has a concentration C1 in said mixture, and the first compound has a concentration C2 in a film formed by evaporating the mixture in a vacuum deposition tool at a constant pressure between 1×10^{-6} Torr to 1×10^{-9} Torr, at a 2 Å/sec deposition rate on a surface at a predefined distance away from the evaporation source of the mixture being evaporated; and wherein the absolute value of (C1−C2)/C1 is less than 5%.

[0096] In one embodiment of the first device, the first compound has a structure according to the formula (I):

(I)



[0097] wherein R^1, R^2, R^3, R^4, R^5, and R^6 each represent mono, di, tri, tetra substitutions, or no substitution;

[0098] R^9 represents mono, di, tri substitutions, or no substitution;

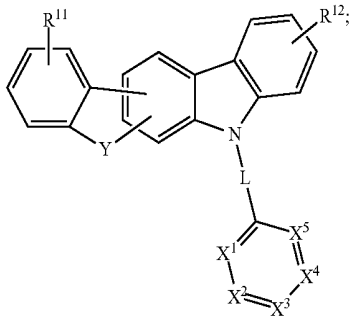
[0099] R^1, R^2, R^3, R^4, R^5, R^6, and R^9 are each independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acid, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof;

[0100] A^1, A^2, A^3, A^4, A^5, and A^6 are each independently selected from N or C; and

[0101] n is an integer from 1 to 20;

[0102] wherein the second compound has the formula (II):

(II)



[0103] wherein R^{11} and R^{12} each represent mono, di, tri, tetra substitutions, or no substitution;

[0104] Y is selected from the group consisting of O, S, Se, NR', and CR"R'";

[0105] L is a single bond or comprises an aryl or heteroaryl group having from 5-24 carbon atoms, which is optionally further substituted;

[0106] X^1, X^2, X^3, X^4, and X^5 are each independently selected from group consisting of CR and N;

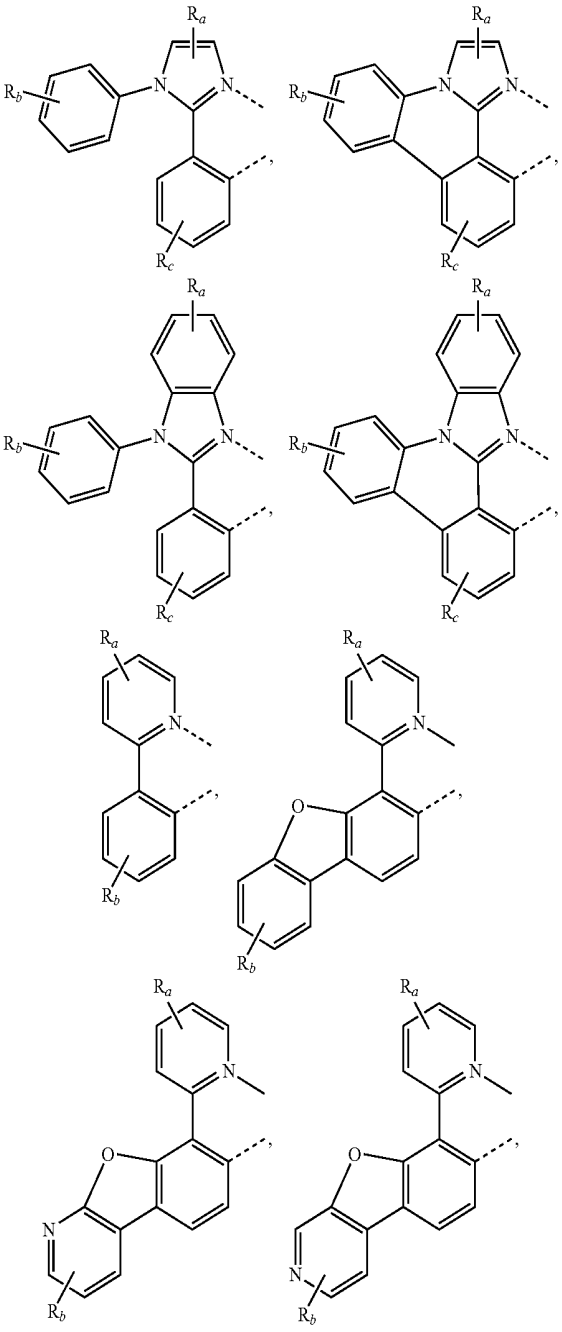
[0107] at least one of X^1, X^2, X^3, X^4, and X^5 is N; and

[0108] R, R', R", and R'" 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 acid, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

[0109] In one embodiment of the first device, in the formula (II) for the second compound, X^1, X^3, and X^5 are N; and wherein X^2 and X^4 are CR.

[0110] In one embodiment of the first device, the organic layer is an emissive layer and the first composition is a host. In one embodiment, the organic layer is a hole transporting layer.

[0111] In one embodiment of the first device, the organic layer can further comprise a phosphorescent emissive dopant. The phosphorescent emissive dopant can be a transition metal complex having at least one ligand or part of the ligand, if the ligand is more than bidentate, selected from the group consisting of:



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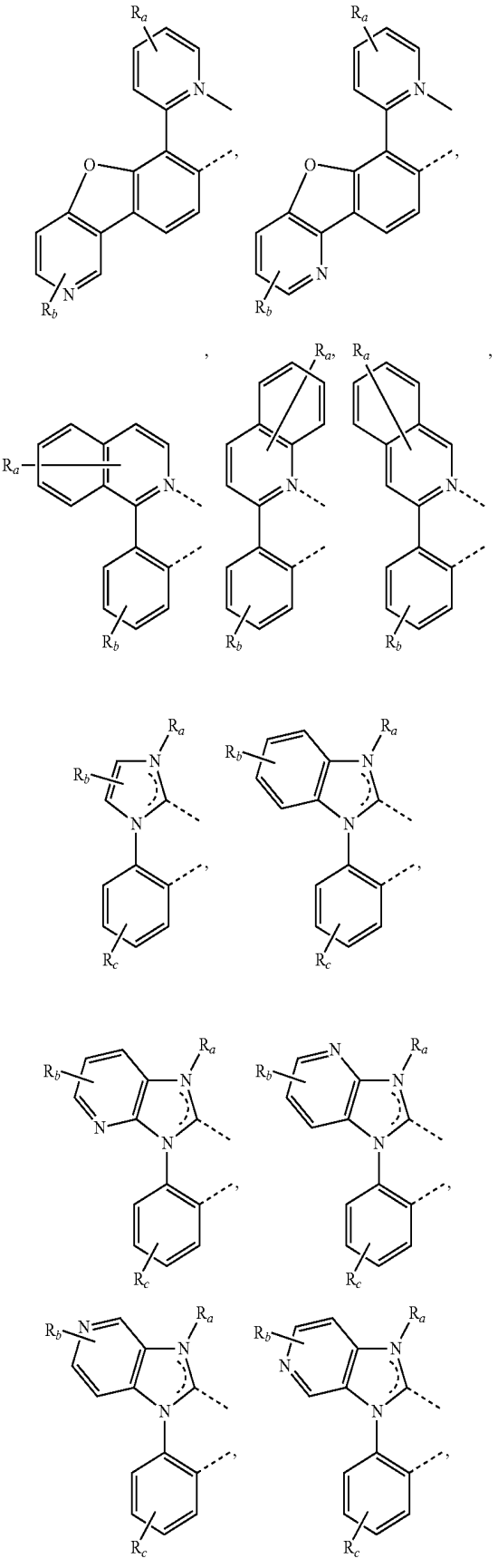

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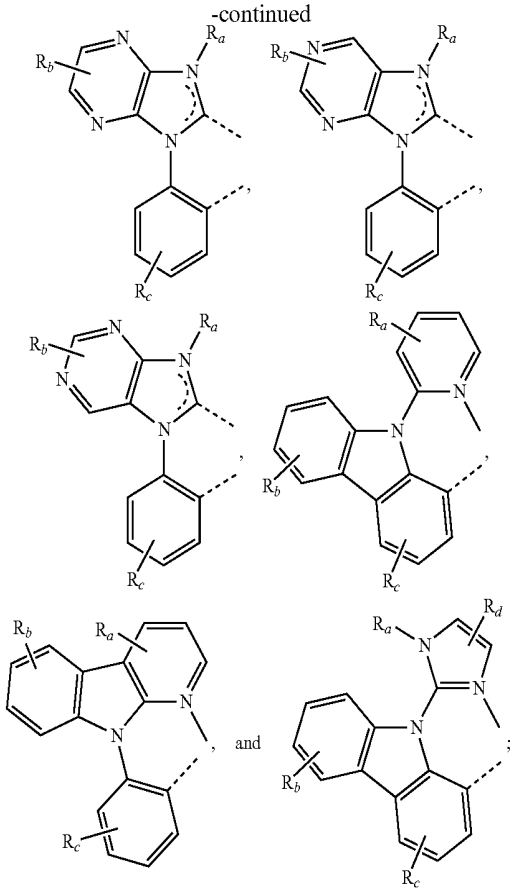


wherein R_a, R_b, R_c, and R_d may represent mono, di, tri, or tetra substitution, or no substitution;

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

[0112] According to another aspect of the present disclosure, a method of fabricating an organic light emitting device comprising a first electrode, a second electrode, and a first organic layer disposed between the first electrode and the second electrode, wherein the first organic layer comprises a first organic composition further comprising a mixture of a first compound and a second compound, is disclosed. The method comprises:

[0113] providing a substrate having the first electrode disposed thereon;

[0114] depositing the first organic composition over the first electrode; and

[0115] depositing the second electrode over the first organic layer, wherein the first compound has different chemical structure than the second compound;

[0116] wherein the first compound is capable of functioning as a hole transporting material in an organic light emitting device at room temperature;

[0117] wherein the first compound comprises at least one carbazole group;

[0118] wherein the first compound has evaporation temperature T1 of 150 to 350° C.;

[0119] wherein the second compound has evaporation temperature T2 of 150 to 350° C.;

[0120] wherein the absolute value of T1−T2 is less than 20° C.;

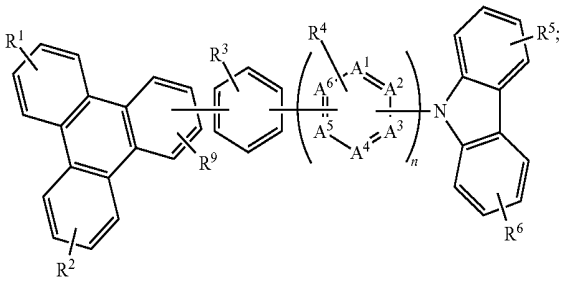
[0121] wherein the first compound has a concentration C1 in said mixture, and the first compound has a concentration C2 in a film formed by evaporating the mixture in a vacuum deposition tool at a constant pressure between 1×10^{-6} Torr to 1×10^{-9} Torr, at a 2 Å/sec deposition rate on a surface positioned at a predefined distance away from the evaporation source of the mixture being evaporated; and

[0122] wherein the absolute value of (C1−C2)/C1 is less than 5%.

[0123] In one embodiment of the method, the first organic composition is deposited in a vacuum thermal evaporation system having a pressure level in the range of 1×10^{-8} Torr to 1×10^{-12} Torr. In one embodiment, the first organic composition leaves a residue corresponding to less than 5 wt % of the first organic composition's original charge in the vacuum thermal evaporation system's sublimation crucible after the first organic composition is depleted during the deposition of the first organic composition over the first electrode.

[0124] In one embodiment of the method, the first compound has the formula (I):

(I)



wherein R^1, R^2, R^3, R^4, R^5, and R^6 each represent mono, di, tri, tetra substitutions, or no substitution;

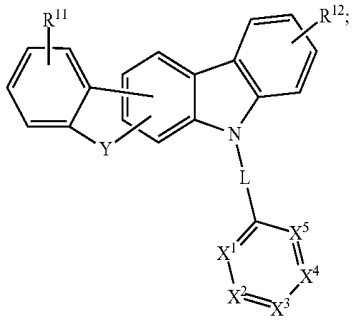
R^9 represents mono, di, tri substitutions, or no substitution;

R^1, R^2, R^3, R^4, R^5, R^6, and R^9 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 acid, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof;

A^1, A^2, A^3, A^4, A^5, and A^6 are each independently selected from N or C; and

n is an integer from 1 to 20;

wherein the second compound has the formula (II):



(II)

wherein R^{11} and R^{12} each represent mono, di, tri, tetra substitutions, or no substitution;

Y is selected from the group consisting of O, S, Se, NR', and CR"R'";

L is a single bond or comprises an aryl or heteroaryl group having from 5-24 carbon atoms, which is optionally further substituted;

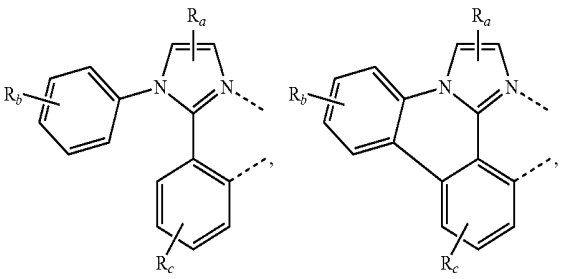
X^1, X^2, X^3, X^4, and X^5 are each independently selected from group consisting of CR and N;

at least one of X^1, X^2, X^3, X^4, and X^5 is N; and

R, R', R", and R'" 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 acid, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

[0125] In one embodiment of the first device, the organic layer is an emissive layer and the first organic composition is a host material. The organic layer can further comprise a phosphorescent emissive dopant.

[0126] In one embodiment of the first device, the phosphorescent emissive dopant is a transition metal complex having at least one ligand selected from the group consisting of:



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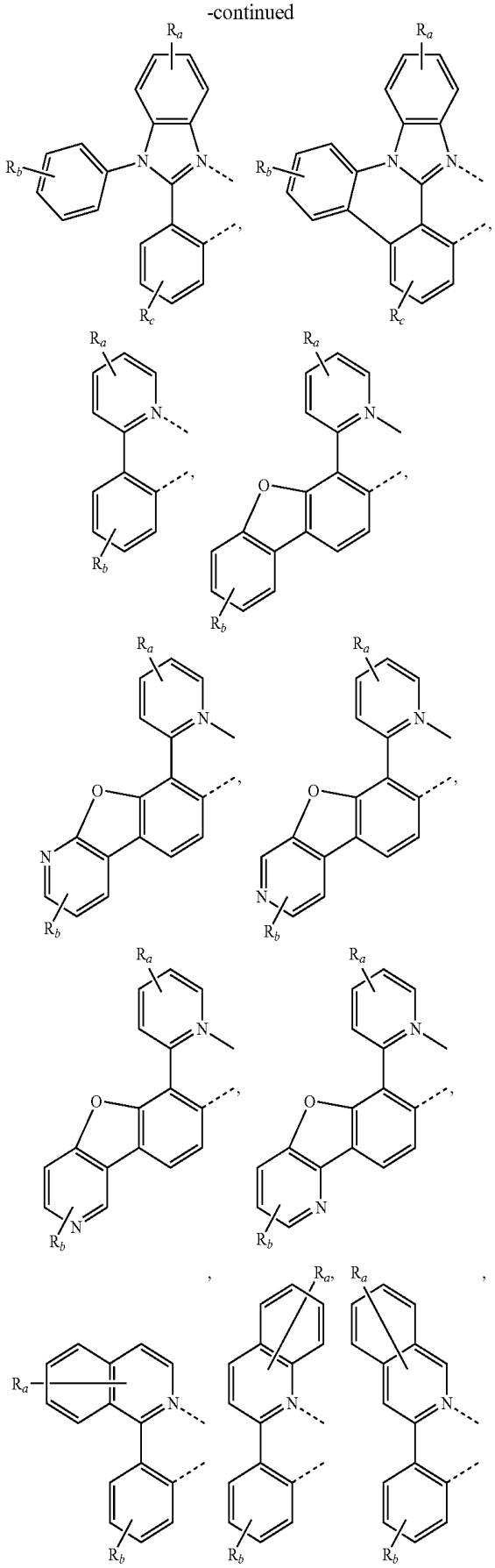

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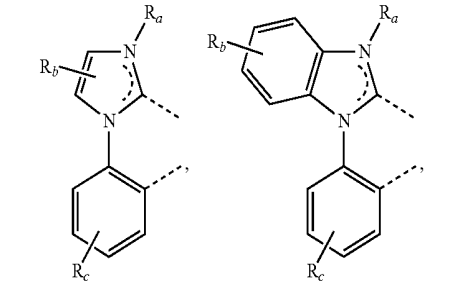

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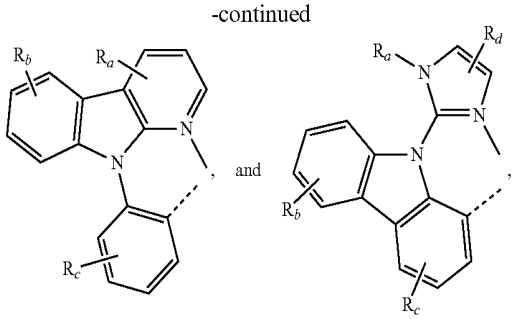


wherein R_a, R_b, R_c, and R_d may represent mono, di, tri, or tetra substitution, or no substitution;

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

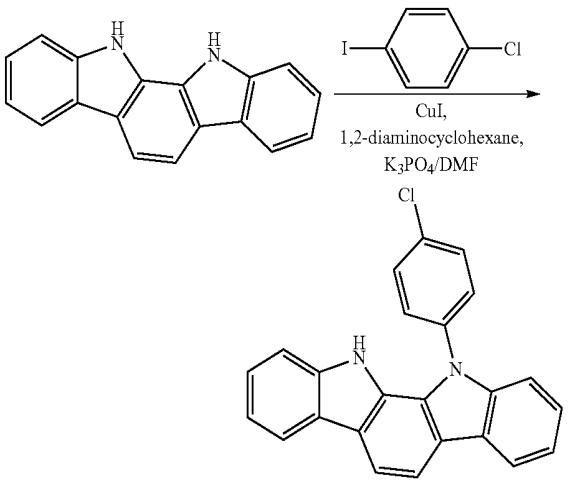
[0127] In one embodiment of the first device, the organic layer is a blocking layer and the organic composition is a blocking material in the organic layer. In another embodiment, the organic layer is an electron transporting layer and the organic composition is an electron transporting material in the organic layer.

[0128] 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.

Synthesis of the Novel Compounds

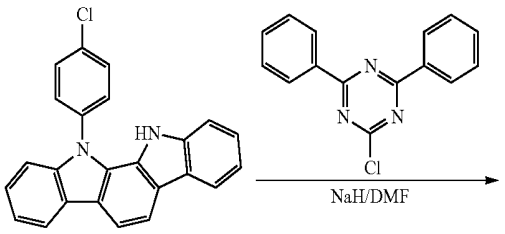
[0129] Synthesis of Compound E2

(A)



A solution of 11,12-dihydroindolo[2,3-a]carbazole (7.44 g, 29.0 mmol), 1-chloro-4-iodobenzene (20.77 g, 87 mmol), CuI (0.829 g, 4.35 mmol), cyclohexane-1,2-diamine (1.058 ml, 8.71 mmol), and K_3PO_4 (15.40 g, 72.6 mmol) in DMF (200 Ml) was heated under nitrogen at 145° C. overnight. After cooling to room temperature, the reaction mixture was diluted with EtOAc and water. The organic layer was isolated, washed with brine and water, dried over $MgSO_4$ and evaporated. The residue was purified by column chromatography on silica gel with hexane/EtOAc (95/5, v/v) as eluent to yield 11-(4-chlorophenyl)-11,12-dihydroindolo[2,3-a]carbazole (7.3 g, 68%) as a solid.

(B)



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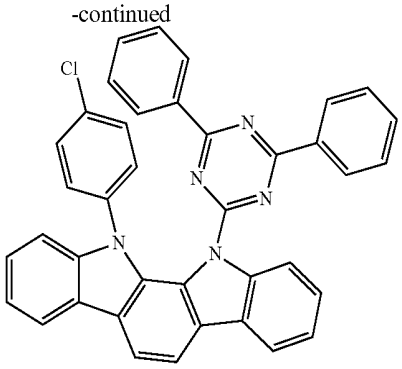
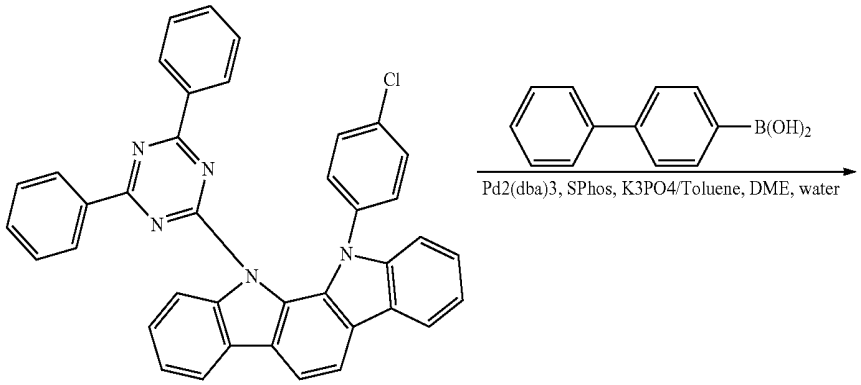
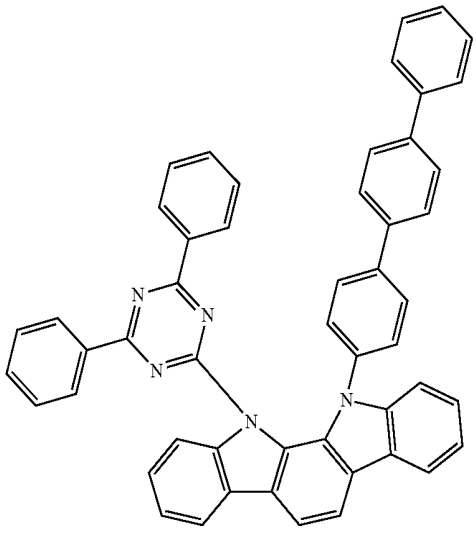


NaH (1.178 g, 29.4 mmol) in one portion was added to a solution of 11-(4-chlorophenyl)-11,12-dihydroindolo[2,3-a]carbazole (7.2 g, 19.63 mmol) in DMF (120 ml), at room temperature. The reaction mixture was stirred at room temperature for 2 hours. Then, 2-chloro-4,6-diphenyl-1,3,5-triazine (6.83 g, 25.5 mmol) was added to the reaction mixture. The reaction mixture was stirred overnight and the resulting solid was collected by filtration. The solid was dissolved in boiling toluene and the insoluble portion was removed by filtration. The filtrate was concentrated and the precipitation was collected by filtration to yield 11-(4-chlorophenyl)-12-(4,6-diphenyl-1,3,5-triazin-2-yl)-11,12-dihydroindolo[2,3-a]carbazole (8.6 g, 73.3% yield) as a yellow powder.

(C)





A solution of 11-(4-chlorophenyl)-12-(4,6-diphenyl-1,3,5-triazin-2-yl)-11,12-dihydroindolo[2,3-a]carbazole (4 g, 6.69 mmol), [1,1'-biphenyl]-4-ylboronic acid (3.97 g, 20.06 mmol), $Pd_2(dba)_3$ (0.61 g, 0.67 mmol), SPhos (0.55 g, 1.34 mmol), and K_3PO_4 (8.52 g, 40.1 mmol) in toluene (400 ml), DME (100 ml), and water (20 ml) was refluxed at 110° C. under nitrogen for 6 days. The hot reaction mixture was then filtered through a filter paper. The filtrate was evaporated; the residue was redissolved in boiling toluene, and filtered through a short plug of silica gel. Upon evaporation of the solvent, the solid was triturated with boiling EtOAc, toluene and xylene to yield Compound E2 (2.3 g, 48%) as a yellow solid.

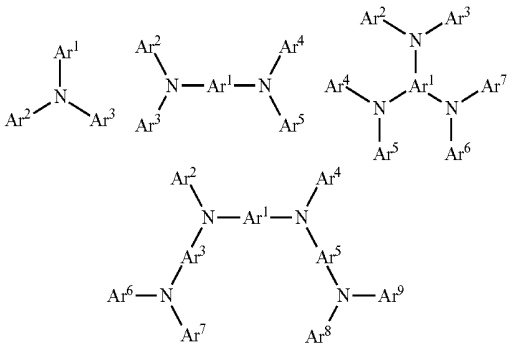
Combination with Other Materials

[0130] The materials described herein as useful for a particular layer in an organic light 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:

[0131] 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.

[0132] Examples of aromatic amine derivatives used in HIL or HTL include, but not limit to the following general structures:



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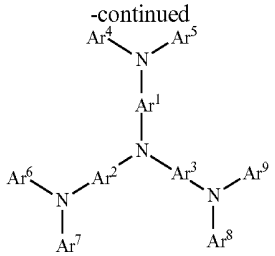
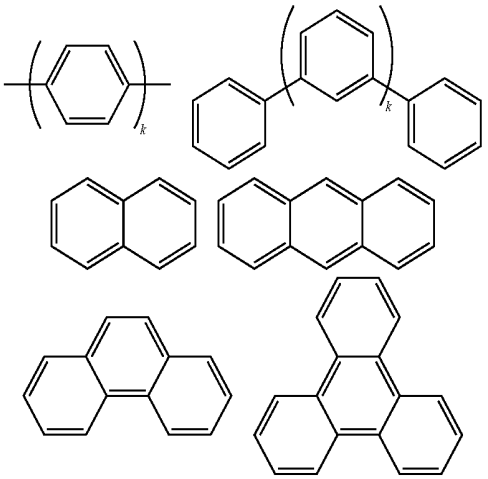


[0133] Each of Ar^1 to Ar^9 is selected from the group consisting aromatic hydrocarbon cyclic compounds such as benzene, biphenyl, triphenyl, triphenylene, naphthalene, anthracene, phenalene, phenanthrene, fluorene, pyrene, chrysene, perylene, azulene; group consisting aromatic heterocyclic compounds 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.

[0134] In one aspect, Ar^1 to Ar^9 is independently selected from the group consisting of:



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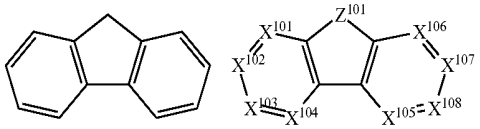
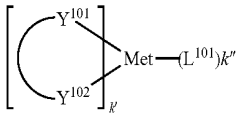


wherein k is an integer from 1 to 20; X^{101} to X^{108} is C (including CH) or N; Z^{101} is NAr^1, O, or S; Ar^1 has the same group defined above.

[0135] Examples of metal complexes used in HIL or HTL include, but not limit to the following general formula:



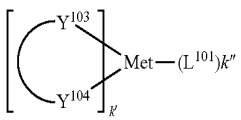
wherein Met is a metal, which can have an atomic weight greater than 40; (Y^{101}-Y^{102}) is a bidentate ligand, Y^{101} and Y^{102} are independently selected from C, N, O, P, and S; L^{101} is an ancillary ligand; k' is an integer value from 1 to the maximum number of ligands that may be attached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

[0136] 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:

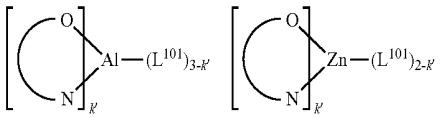
[0137] The light emitting layer of the organic EL device of the present invention preferably contains at least a metal complex as light emitting material, and may contain a host material using the metal complex as a dopant material. Examples of the host material are not particularly limited, and any 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.

[0138] 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.

[0139] In one aspect, the metal complexes are:

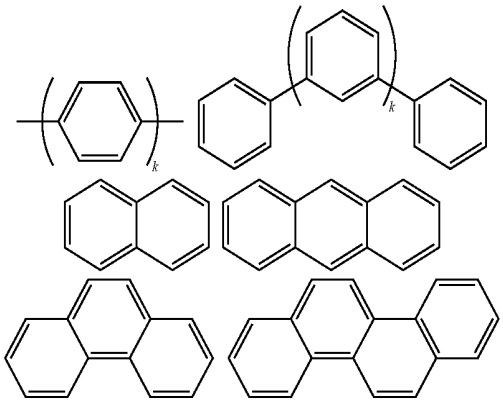


wherein (O—N) is a bidentate ligand, having metal coordinated to atoms O and N.

[0140] In another aspect, Met is selected from Ir and Pt. In a further aspect, (Y^{103}-Y^{104}) is a carbene ligand.

[0141] 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, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

[0142] In one aspect, host compound contains at least one of the following groups in the molecule:



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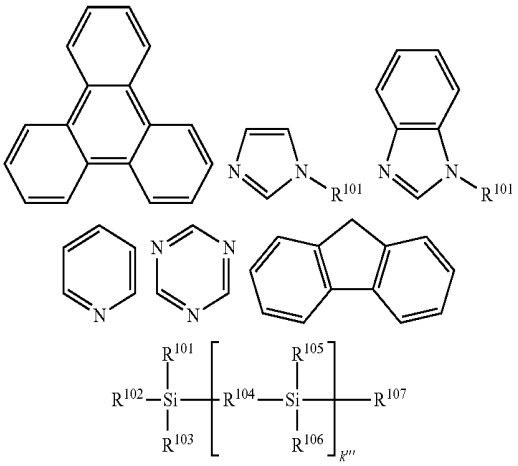

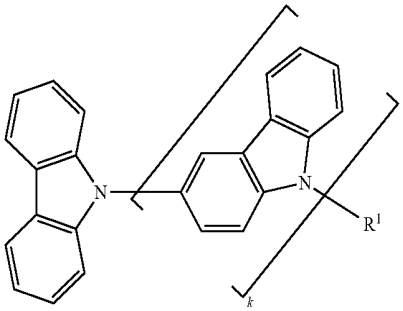

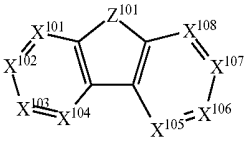

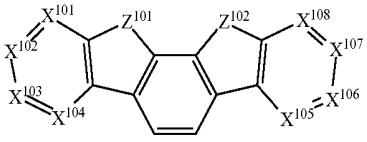

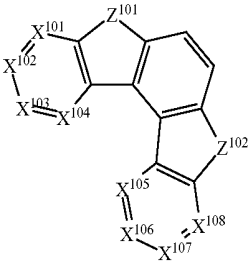

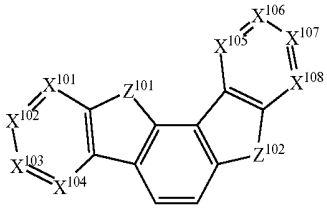

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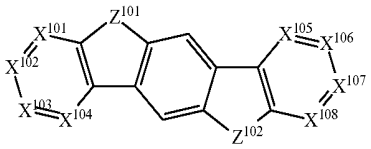
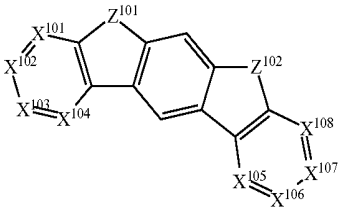




wherein R^{101} to R^{107} is independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, 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.

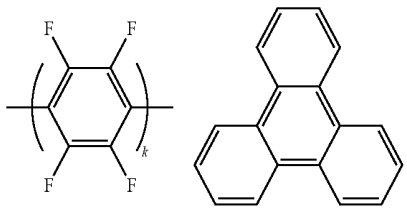
Z^{101} and Z^{102} is selected from NR^{101}, O, or S.

HBL:

[0143] 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.

[0144] In one aspect, compound used in HBL contains the same molecule or the same functional groups used as host described above.

[0145] In another aspect, compound used in HBL contains at least one of the following groups in the molecule:



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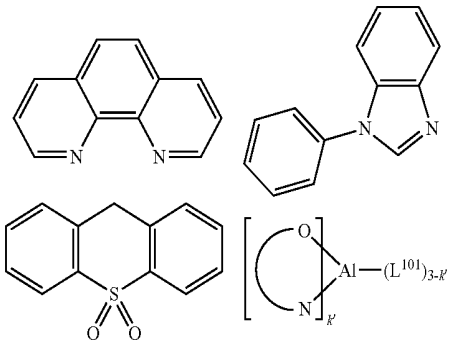
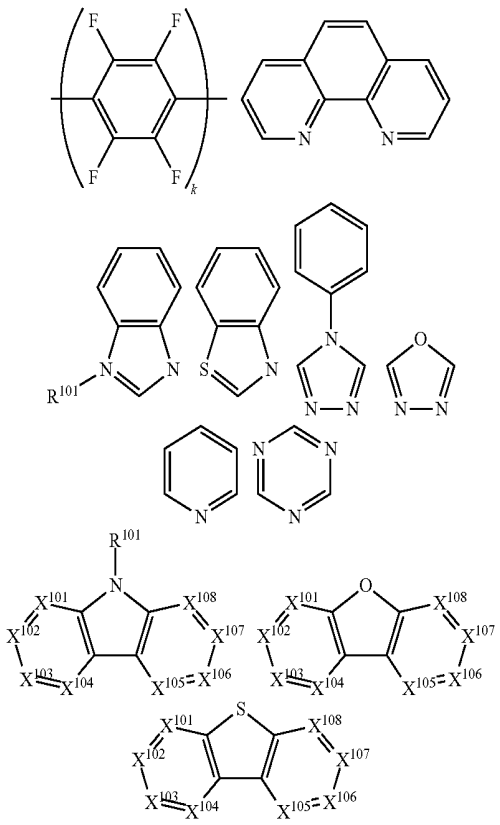


wherein k is an integer from 1 to 20; L^{101} is an another ligand, k' is an integer from 1 to 3.

ETL:

[0146] 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.

[0147] In one aspect, compound used in ETL contains at least one of the following groups in the molecule:



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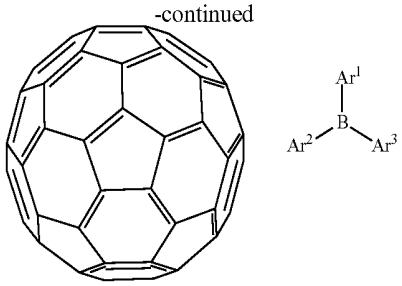
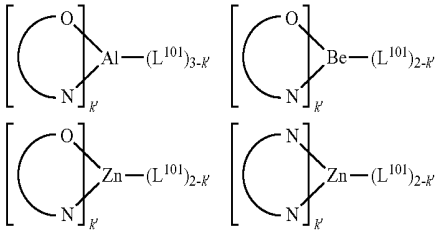


wherein R^{101} is selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, 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.

[0148] 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.

[0149] 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. 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.

[0150] 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 4 below. Table 4 lists non-limiting classes of materials, non-limiting examples of compounds for each class, and references that disclose the materials.

TABLE 4

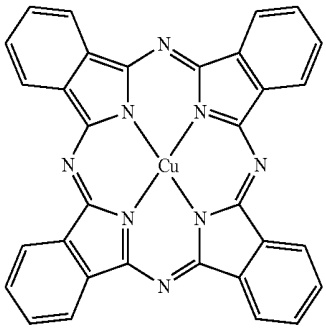
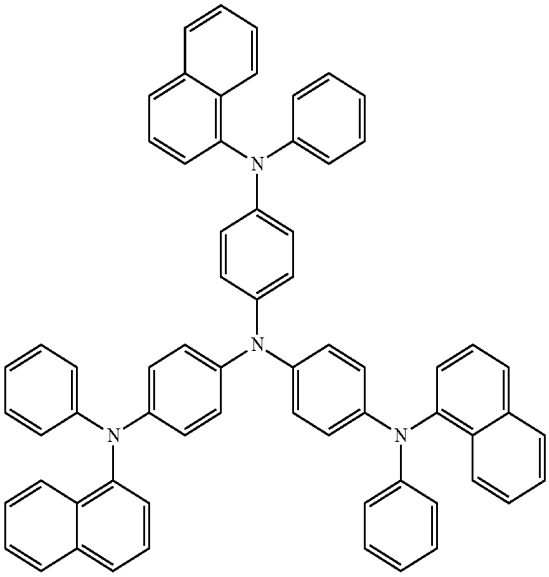
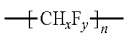
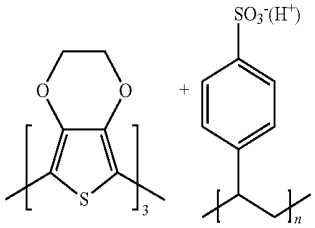
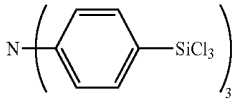
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Phthalocyanine and porphryin compounds		Appl. Phys. Lett. 69, 2160 (1996)
Starburst triarylamines		J. Lumin. 72-74, 985 (1997)
CF_x Fluorohydrocarbon polymer		Appl. Phys. Lett. 78, 673 (2001)
Conducting polymers (e.g., PEDOT:PSS, polyaniline,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

TABLE 4-continued

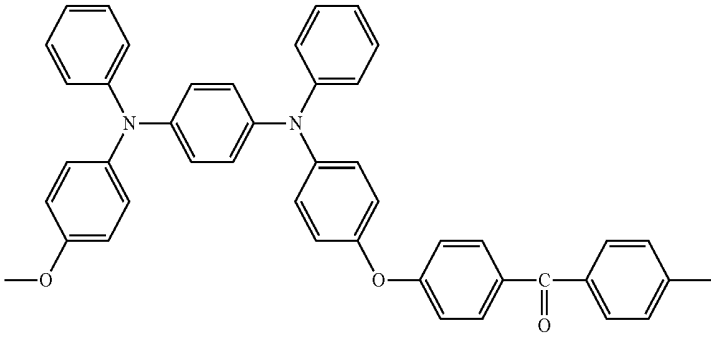
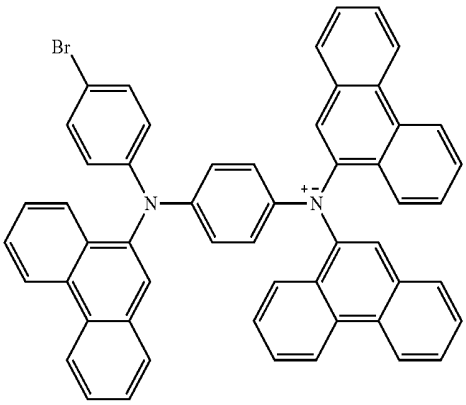
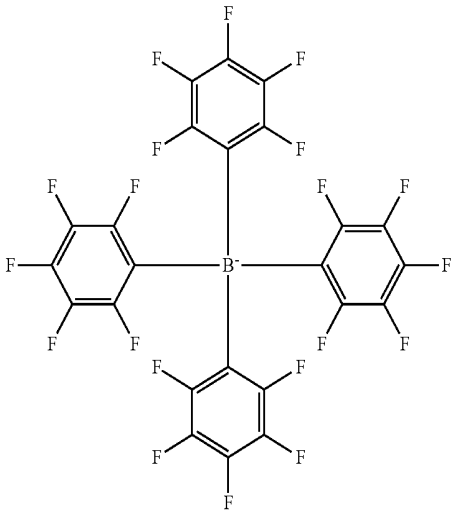
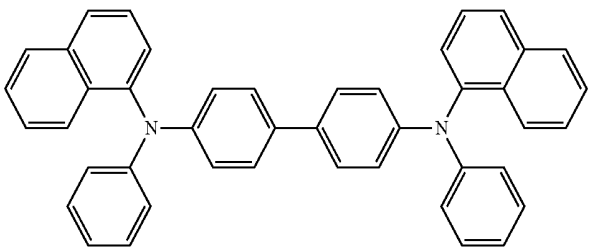
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Triarylamine or polythiophene polymers with conductivity dopants	 and  	EP1725079A1
Organic compounds with conductive inorganic compounds, such as molybdenum and tungsten oxides		US20050123751 SID Symposium Digest, 37, 923 (2006) WO2009018009

TABLE 4-continued

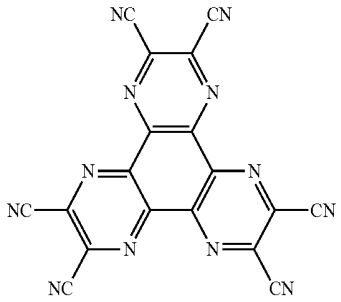
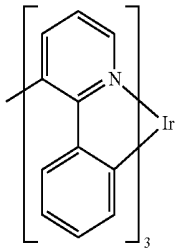
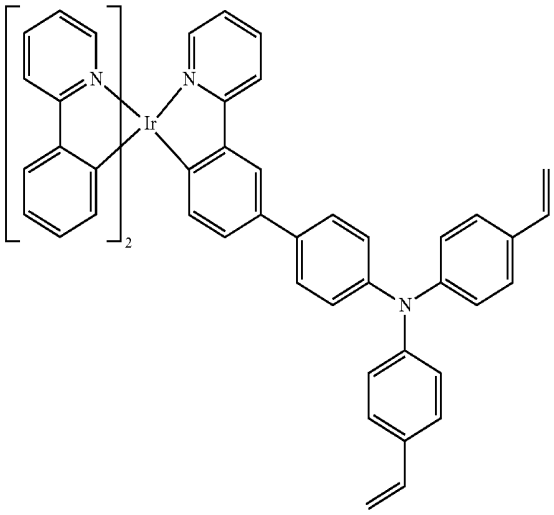
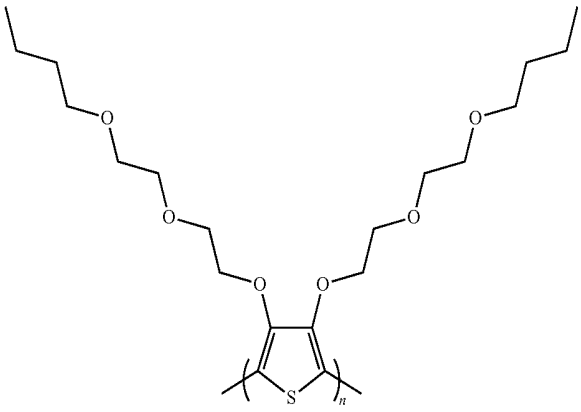
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
n-type semiconducting organic complexes		US20020158242
Metal organometallic complexes		US20060240279
Cross-linkable compounds		US20080220265
Polythiophene based polymers and copolymers		WO2011075644 EP2350216

TABLE 4-continued

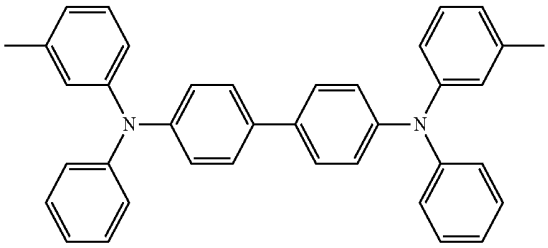
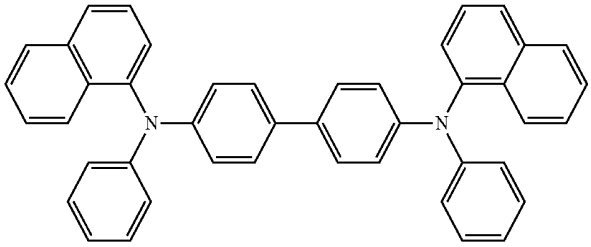
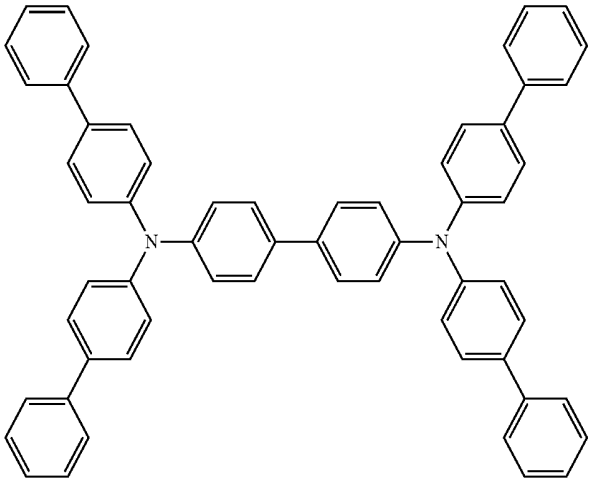
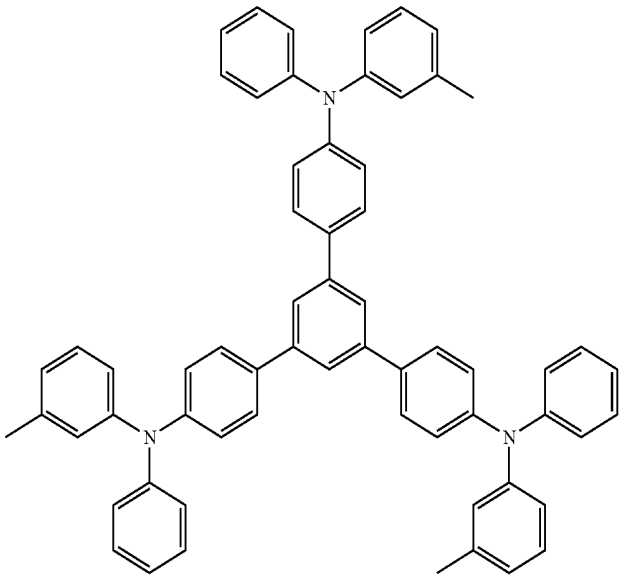
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Hole transporting materials		
Triarylamines (e.g., TPD, α-NPD)		Appl. Phys. Lett. 51, 913 (1987)
		U.S. Pat. No. 5,061,569
		EP650955
		J. Mater. Chem. 3, 319 (1993)

TABLE 4-continued

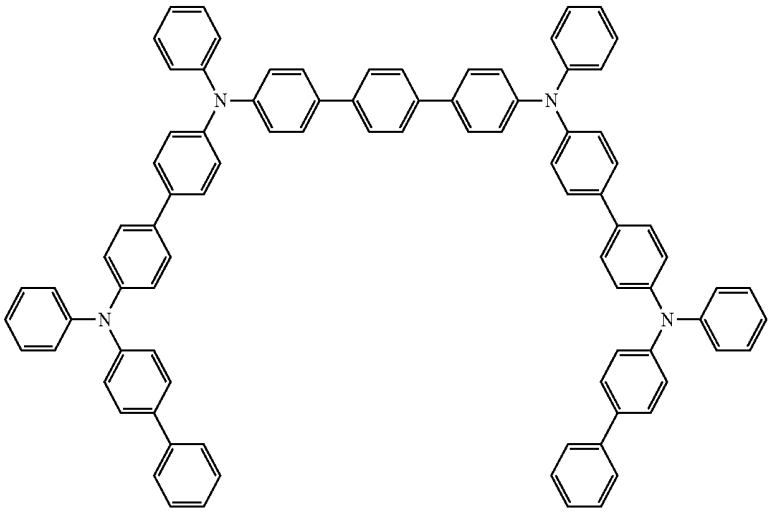
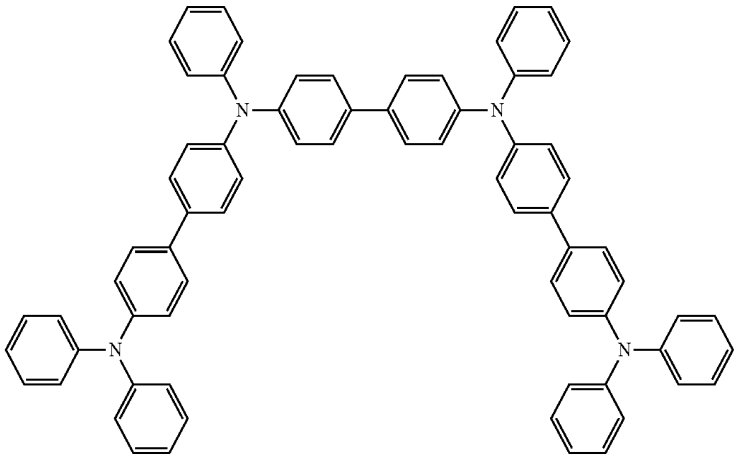
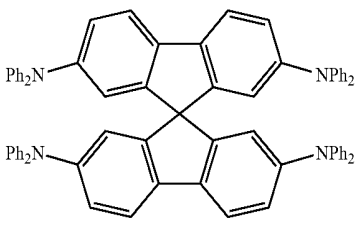
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Appl. Phys. Lett. 90, 183503 (2007)
		Appl. Phys. Lett. 90, 183503 (2007)
Triaylamine on spirofluorene core		Synth. Met. 91, 209 (1997)

TABLE 4-continued

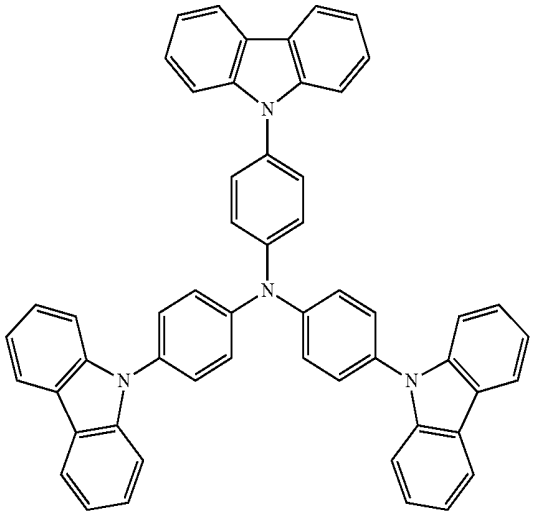
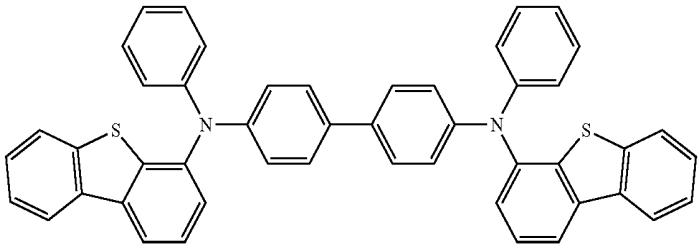
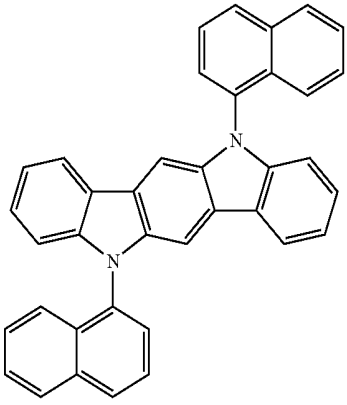
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Arylamine carbazole compounds		Adv. Mater. 6, 677 (1994), US20080124572
Triarylamine with (di)benzothiophene/ (di)benzofuran		US20070278938, US20080106190 US20110163302
Indolocarbazoles		Synth. Met, 111, 421 (2000)

TABLE 4-continued

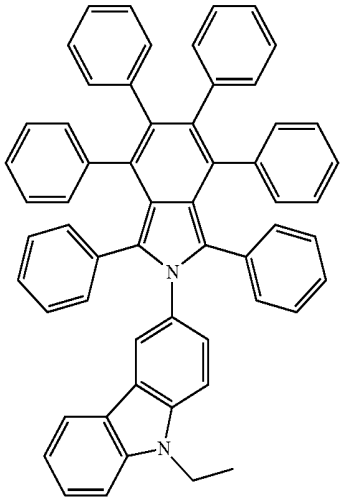
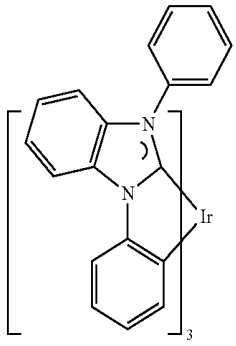
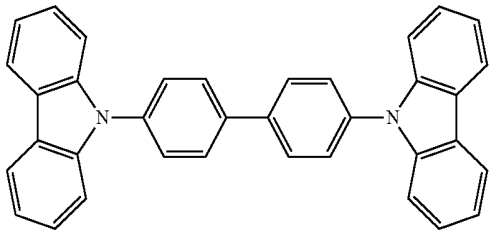
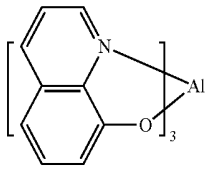
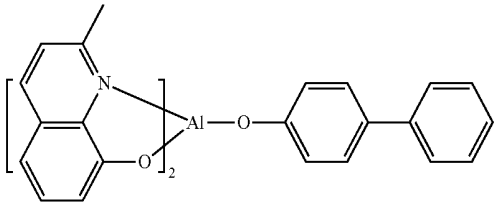
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Isoindole compounds		Chem. Mater. 15, 3148 (2003)
Metal carbene complexes		US20080018221
Phosphorescent OLED host materials		
Red hosts		
Arylcarbazoles		Appl. Phys. Lett. 78, 1622 (2001)
Metal 8-hydroxyquinolates (e.g., Alq_3, BAlq)		Nature 395, 151 (1998)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

TABLE 4-continued

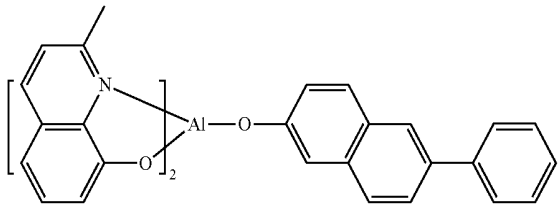
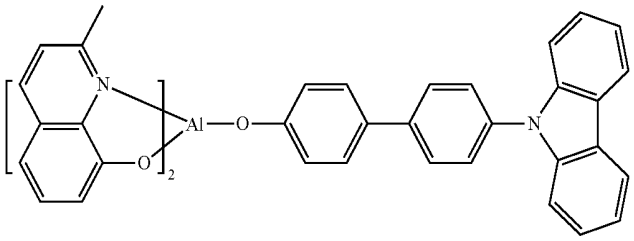
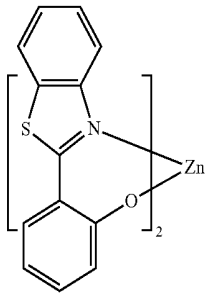
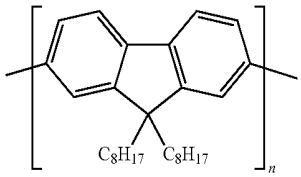
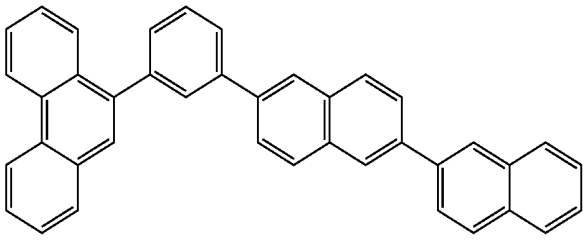
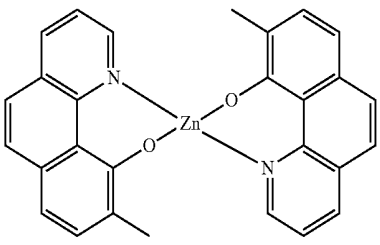
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2005014551
		WO2006072002
Metal phenoxy-benzothiazole compounds		Appl. Phys. Lett. 90, 123509 (2007)
Conjugated oligomers and polymers (e.g., polyfluorene)		Org. Electron. 1, 15 (2000)
Aromatic fused rings		WO2009066779, WO2009066778, WO2009063833, US20090045731,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

TABLE 4-continued

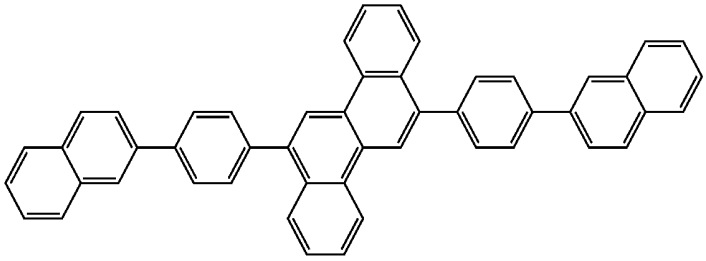
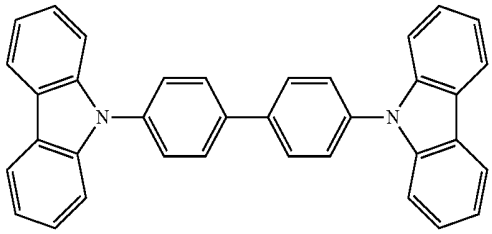
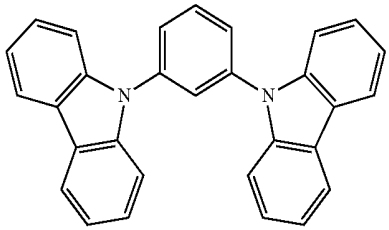
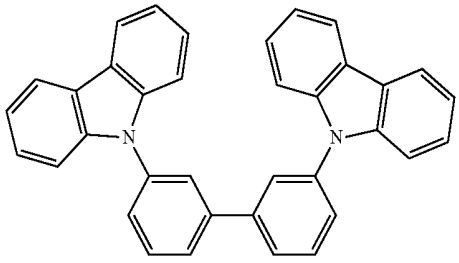
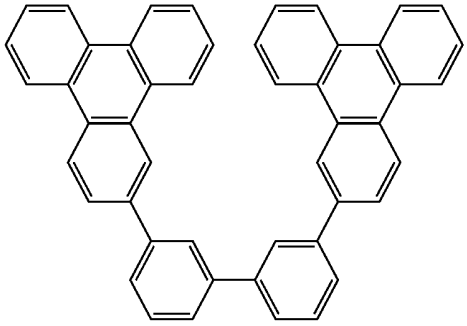
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Chrysene based compounds		WO2011086863
	Green hosts	
Arylcarbazoles		Appl. Phys, Lett. 78, 1622 (2001)
		US20030175553
		WO2001039234
Aryltriphenylene compounds		US20060280965

TABLE 4-continued

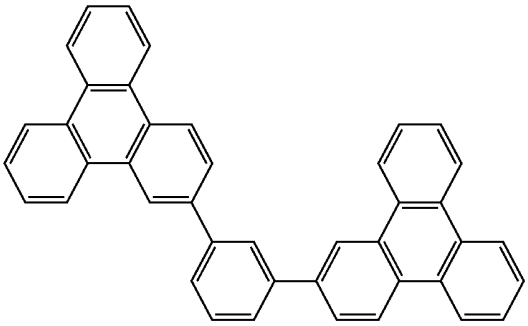
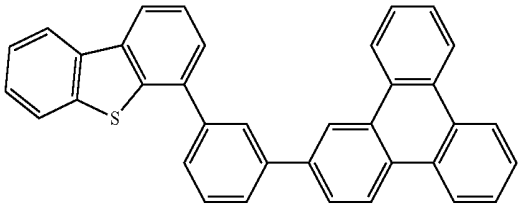
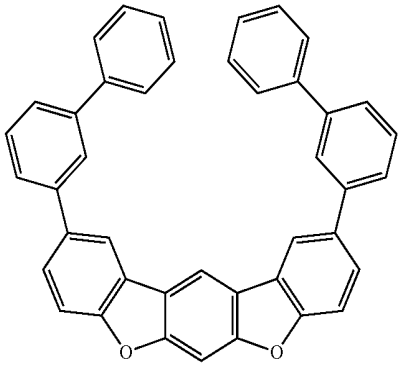
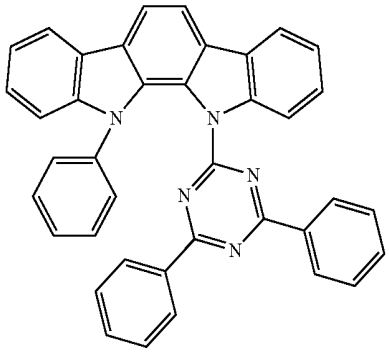
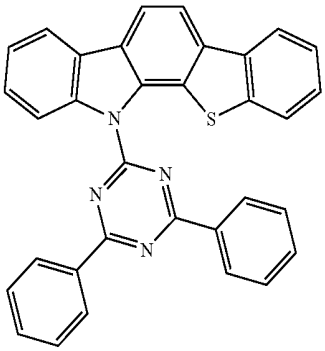
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20060280965
		WO2009021126
Poly-fused heteroaryl compounds		US20090309488 US20090302743 US20100012931
Donor acceptor type molecules		WO2008056746
		WO2010107244

TABLE 4-continued

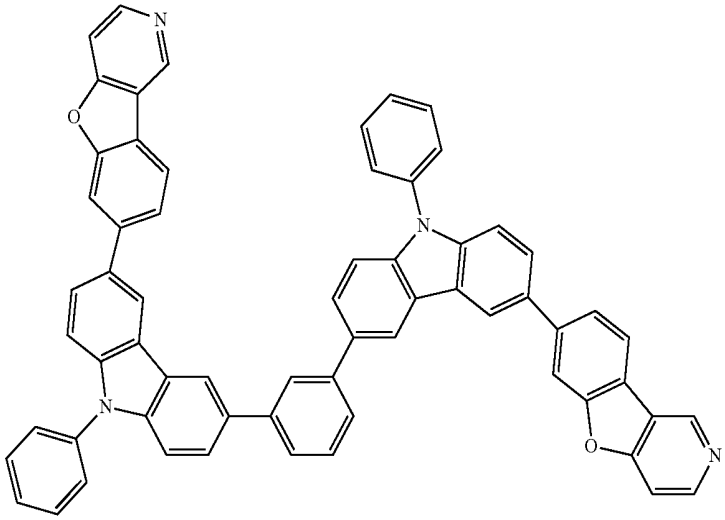
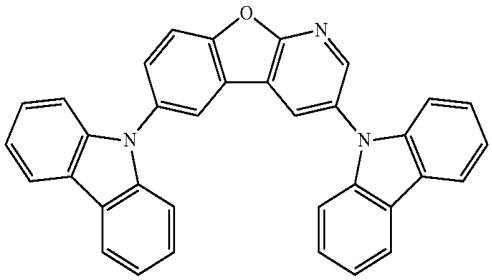
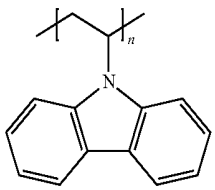
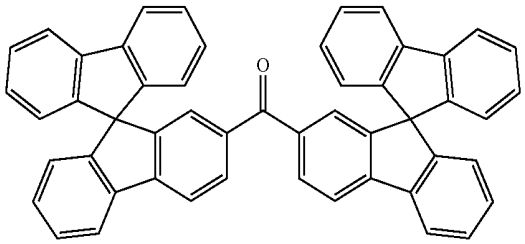
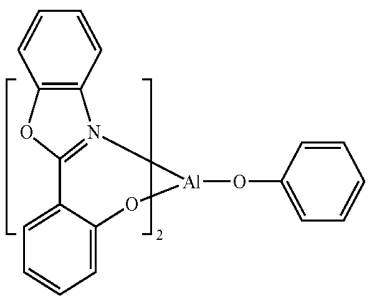
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Aza-carbazole/ DBT/DBF		JP2008074939
		US20100187984
Polymers (e.g., PVK)		Appl. Phys. Lett. 77, 2280 (2000)
Spirofluorene compounds		WO2004093207
Metal phenoxy-benzooxazole compounds		WO2005089025

TABLE 4-continued

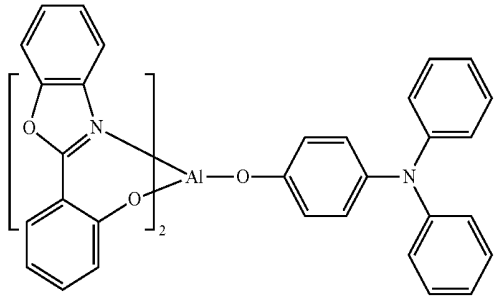
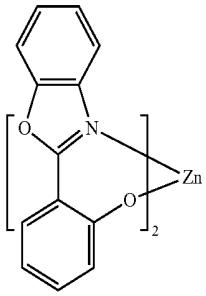
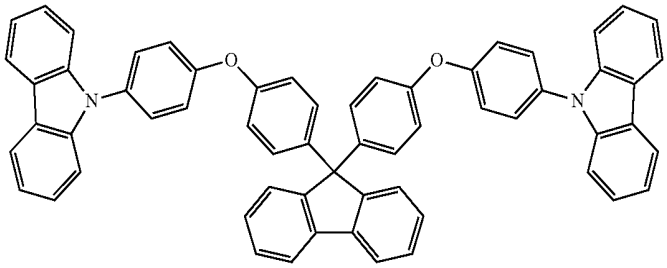
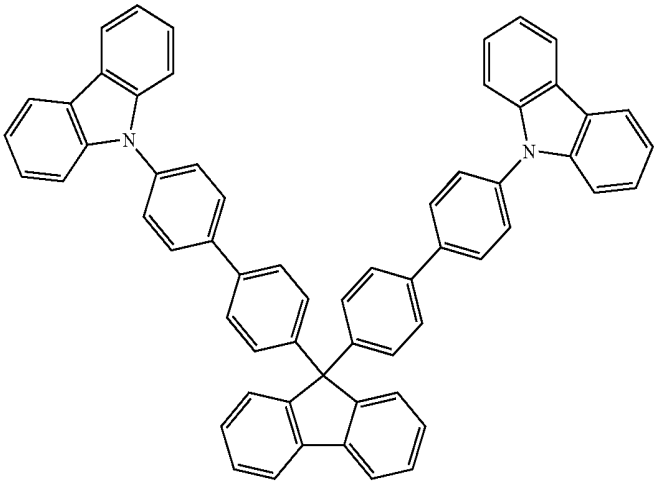
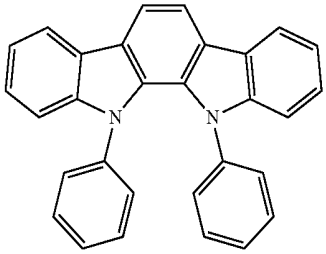
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2006132173
		JP200511610
Spirofluorene-carbazole compounds		JP2007254297
		JP2007254297
Indolocabazoles		WO2007063796

TABLE 4-continued

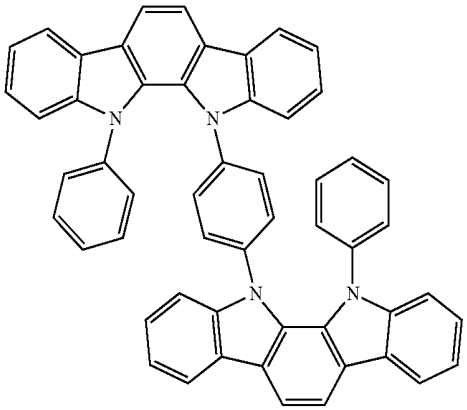
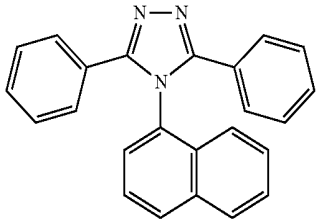
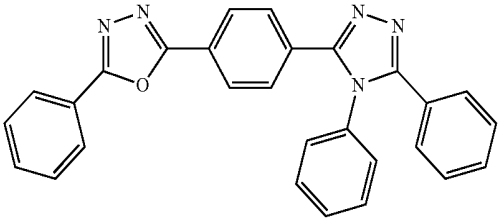
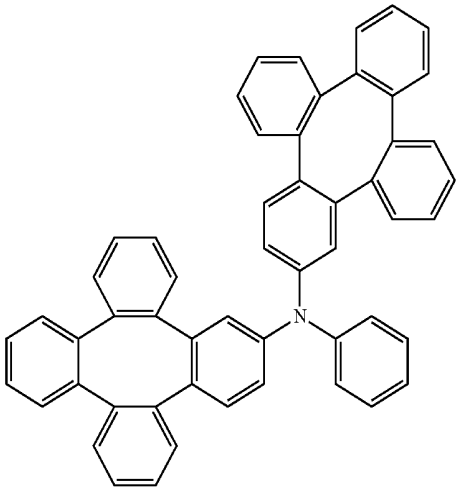
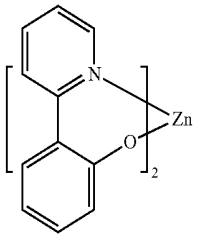
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2007063754
5-member ring electron deficient heterocycles (e.g., triazole, oxadiazole)		J. Appl. Phys. 90, 5048 (2001)
		WO2004107822
Tetraphenylene complexes		US20050112407
Metal phenoxypyridine compounds		WO2005030900

TABLE 4-continued

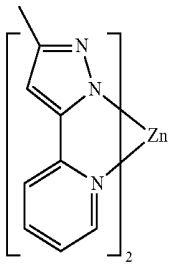
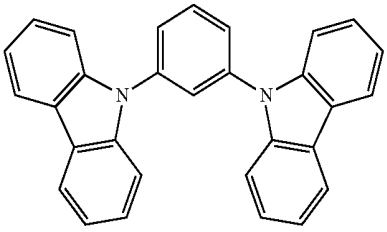
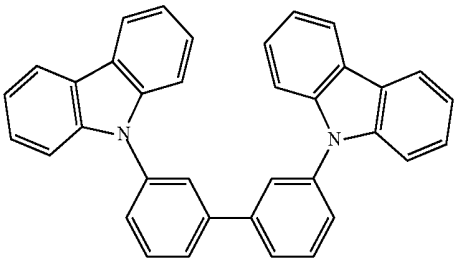
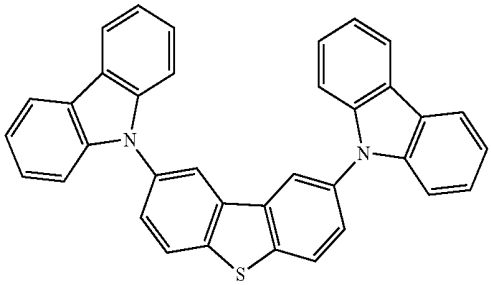
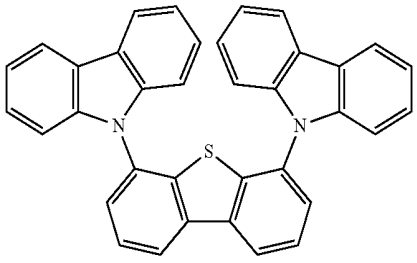
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Metal coordination complexes (e.g., Zn, Al with N^N ligands)		US20040137268, US20040137267
Blue hosts		
Arylcarbazoles		Appl. Phys, Lett, 82, 2422 (2003)
		US20070190359
Dibenzothiophene/ Dibenzofuran-carbazole compounds		WO2006114966, US20090167162
		US20090167162

TABLE 4-continued

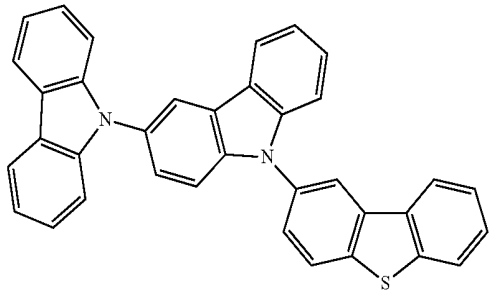
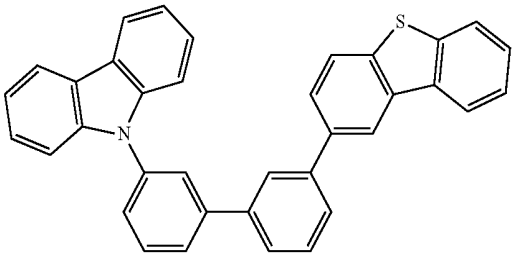
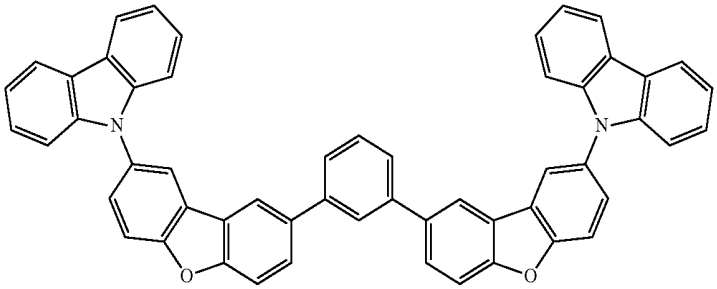
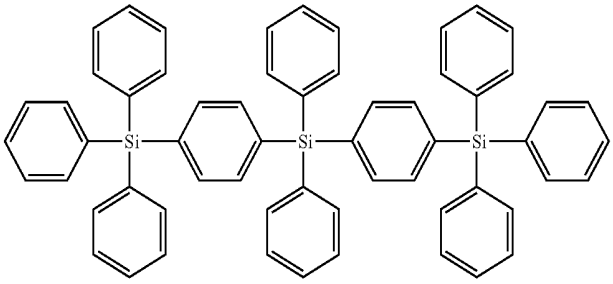
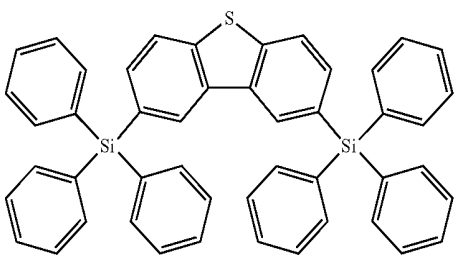
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2009086028
		US20090030202, US20090017330
		US20100084966
Silicon aryl compounds		US20050238919
		WO2009003898

TABLE 4-continued

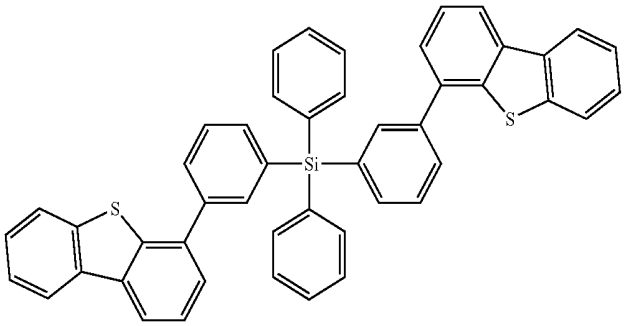
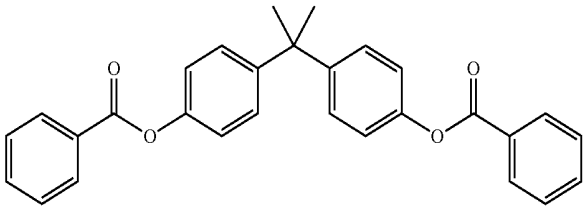
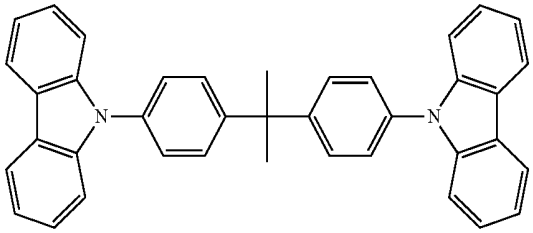
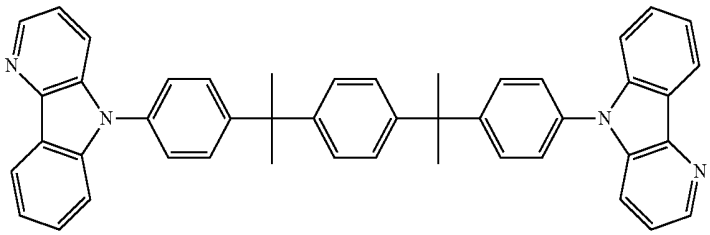
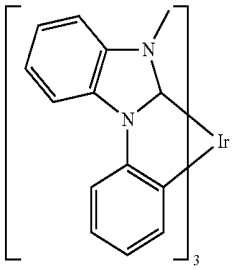
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Silicon/Germanium aryl compounds		EP2034538A
Aryl benzoyl ester		WO2006100298
Carbazole linked by non-conjugated groups		US20040115476
Aza-carbazoles		US20060121308
High triplet metal organometallic complex		U.S. Pat. No. 7,154,114

TABLE 4-continued

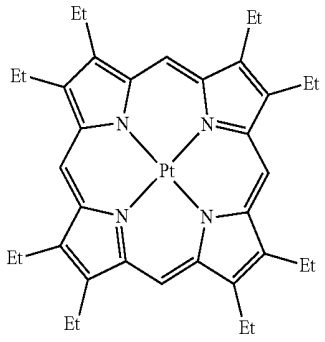
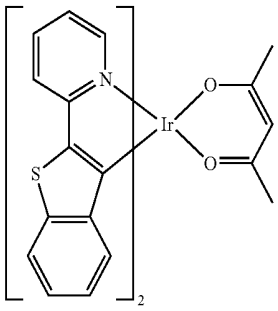
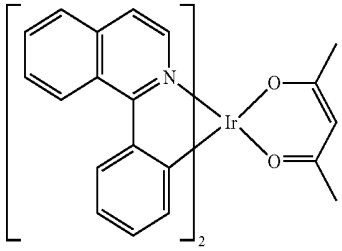
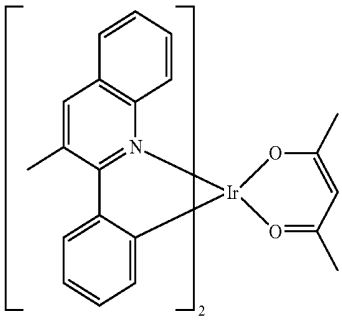
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Phosphorescent dopants		
Red dopants		
Heavy metal porphyrins (e.g., PtOEP)		Nature 395, 151 (1998)
Iridium(III) organometallic complexes		Appl. Phys. Lett. 78, 1622 (2001)
		US20030072964
		US20030072964

TABLE 4-continued

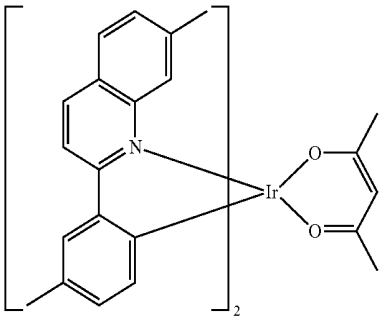
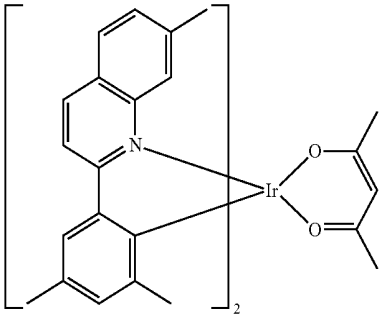
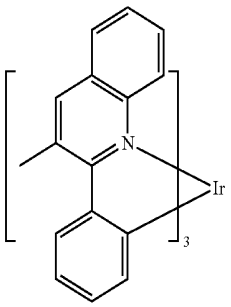
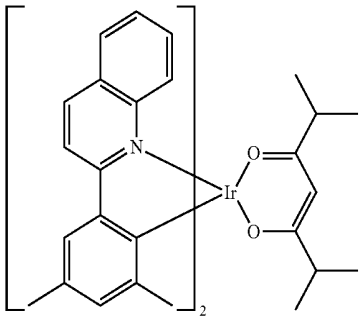
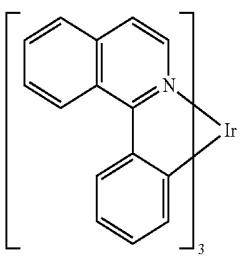
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20060202194
		US20060202194
		US20070087321
		US20080261076 US20100090591
		US20070087321

TABLE 4-continued

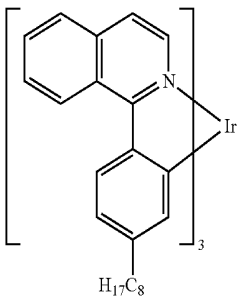
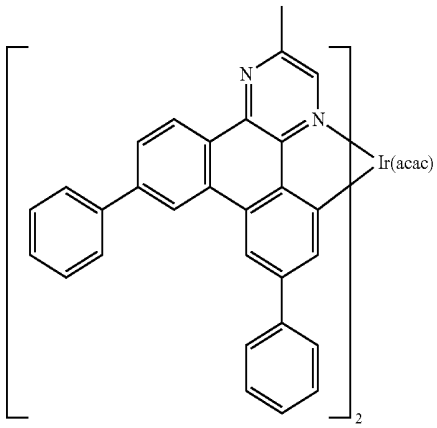
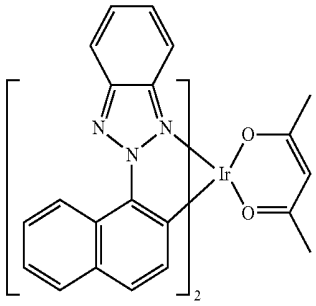
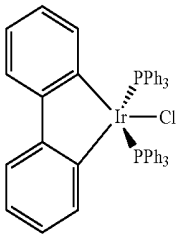
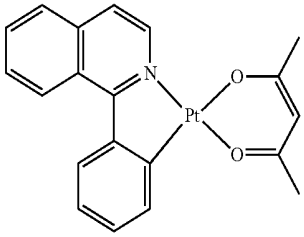
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Adv. Mater. 19, 739 (2007)
		WO2009100991
		WO2008101842
		U.S. Pat. No. 7,232,618
Platinum(II) organometallic complexes		WO2003040257

TABLE 4-continued

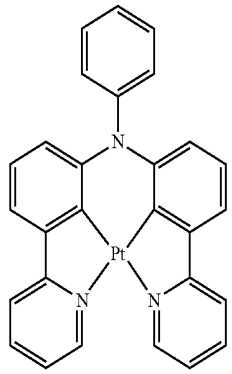
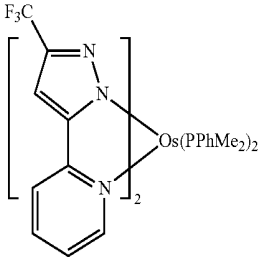
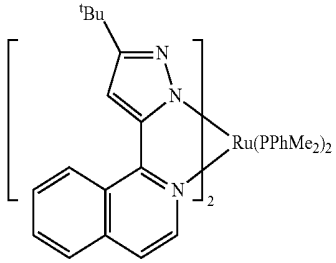
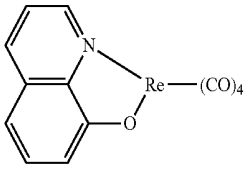
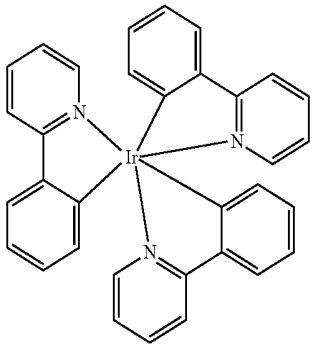
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20070103060
Osminum(III) complexes		Chem. Mater. 17, 3532 (2005)
Ruthenium(II) complexes		Adv. Mater. 17, 1059 (2005)
Rhenium (I), (II), and (III) complexes		US20050244673
	Green dopants	
Iridium(III) organometallic complexes		Inorg. Chem. 40, 1704 (2001)
	and its derivatives	

TABLE 4-continued

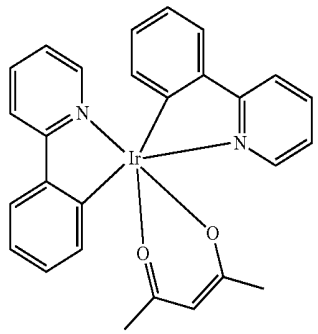
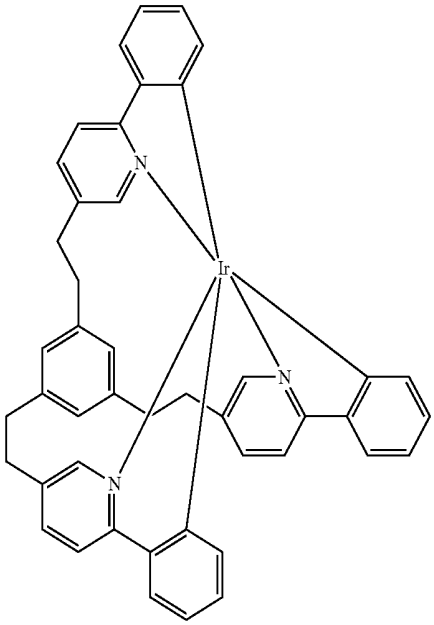
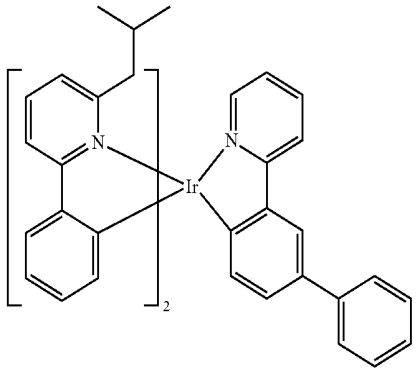
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20020034656
		U.S. Pat. No. 7,332,232
		US20090108737

TABLE 4-continued

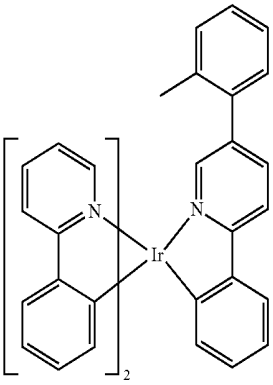
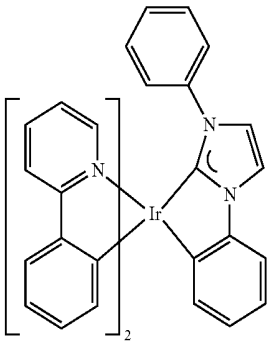
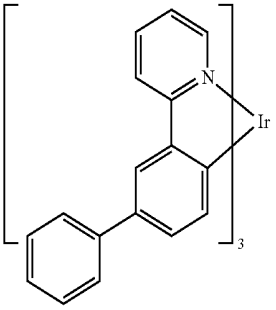
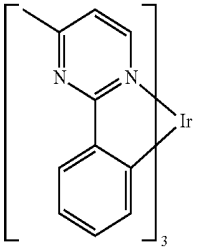
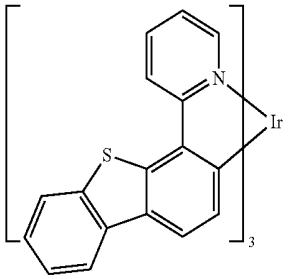
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2010028151
		EP1841834B
		US20060127696
		US20090039776
		U.S. Pat. No. 6,921,915

TABLE 4-continued

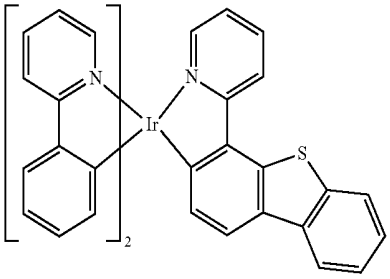
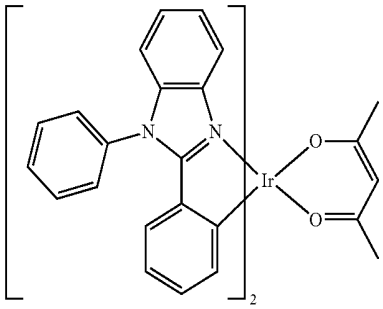
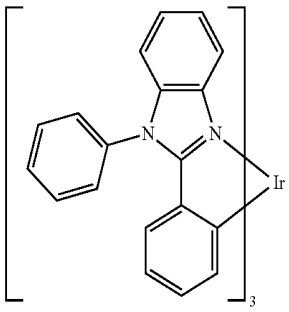
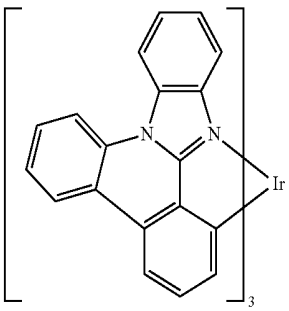
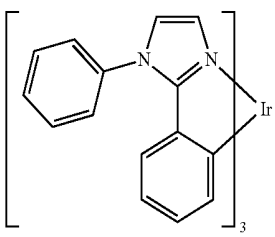
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20100244004
		U.S. Pat. No. 6,687,266
		Chem. Mater. 16, 2480 (2004)
		US20070190359
		US20060008670 JP2007123392

TABLE 4-continued

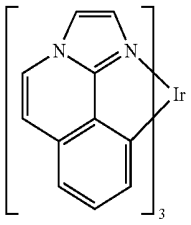
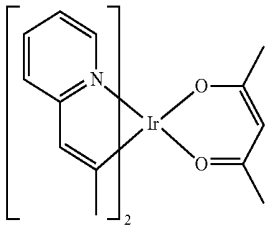
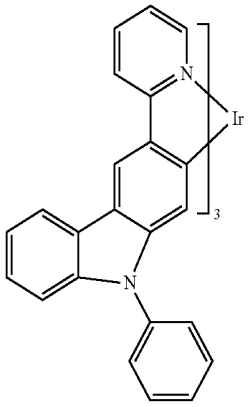
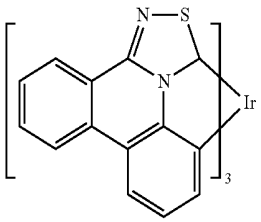
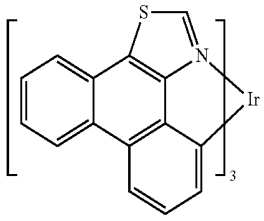
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2010086089, WO2011044988
		Adv. Mater. 16, 2003 (2004)
		Angew. Chem. Int. Ed. 2006, 45, 7800
		WO2009050290
		US20090165846

TABLE 4-continued

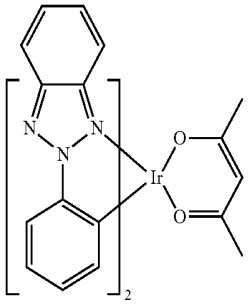
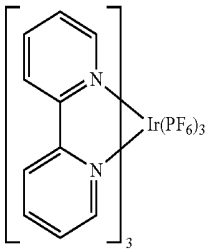
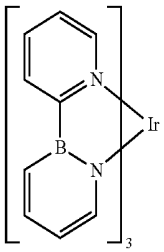
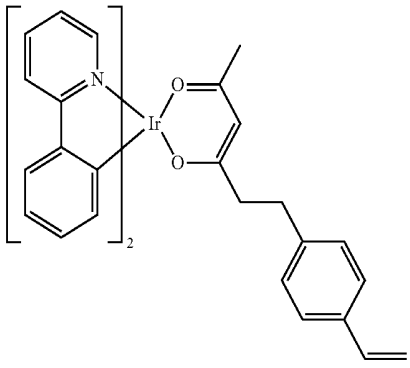
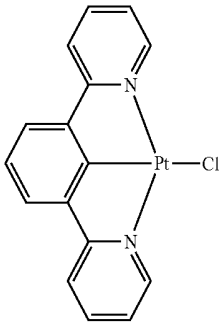
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20080015355
		US20010015432
		US20100295032
Monomer for polymeric metal organometallic compounds		U.S. Pat. No. 7,250,226, U.S. Pat. No. 7,396,598
Pt(II) organometallic complexes, including polydentated ligands		Appl. Phys. Lett. 86, 153505 (2005)

TABLE 4-continued

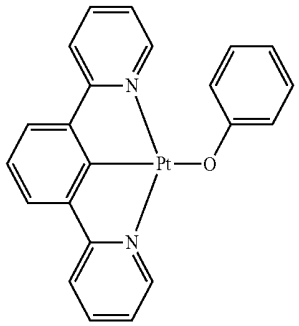
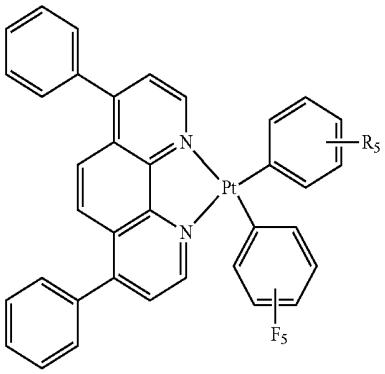
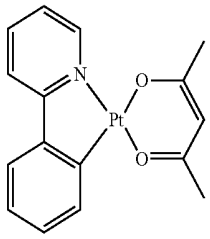
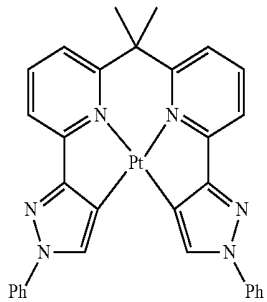
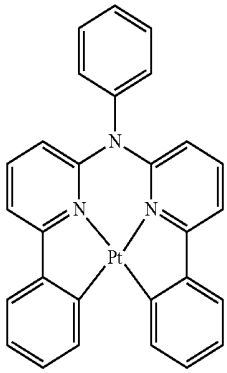
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Appl. Phys. Lett. 86, 153505 (2005)
		Chem. Lett. 34, 592 (2005)
		WO2002015645
		US20060263635
		US20060182992 US20070103060

TABLE 4-continued

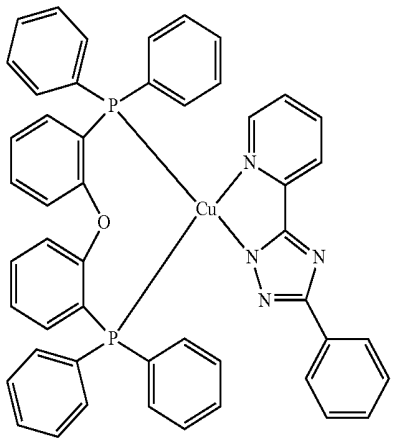
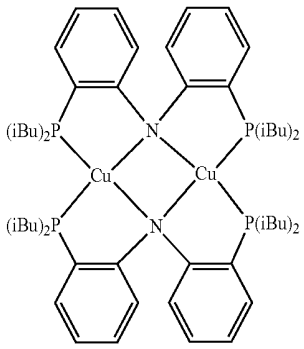
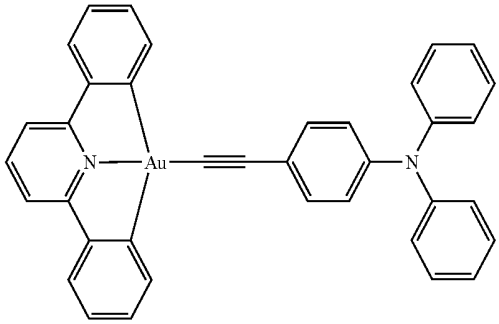
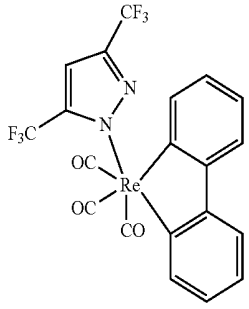
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Cu complexes		WO2009000673
		US20070111026
Gold complexes		Chem. Commun. 2906 (2005)
Rhenium(III) complexes		Inorg. Chem. 42, 1248 (2003)

TABLE 4-continued

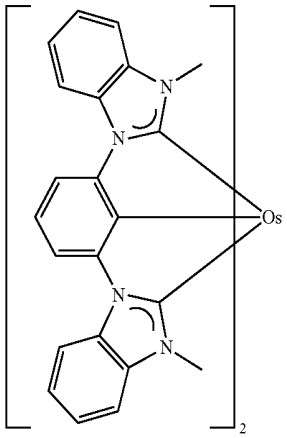
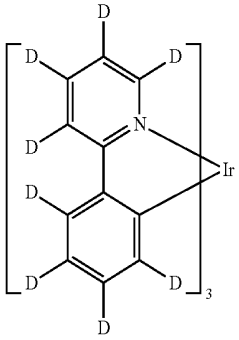
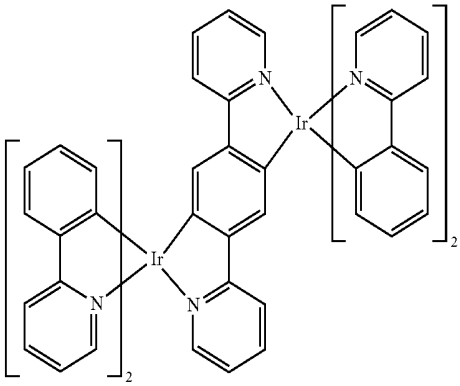
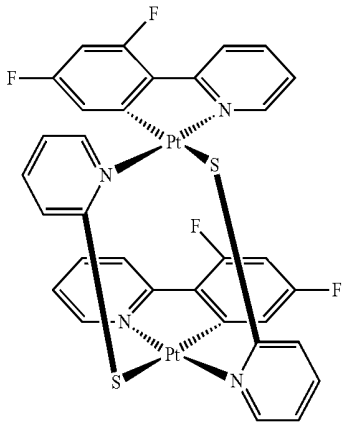
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Osmium(II) complexes		U.S. Pat. No. 7,279,704
Deuterated organometallic complexes		US20030138657
Organometallic complexes with two or more metal centers		US20030152802
		U.S. Pat. No. 7,090,928

TABLE 4-continued

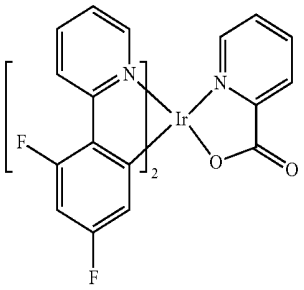
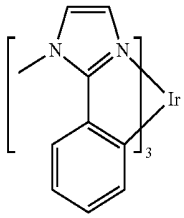
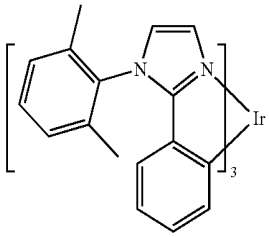
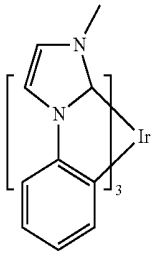
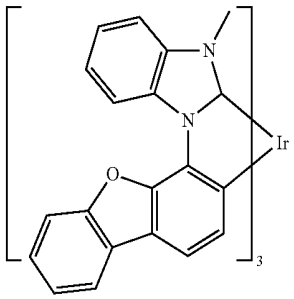
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Blue dopants	
Iridium(III) organometallic complexes		WO2002002714
		WO2006009024
		US20060251923 US20110057559 US20110204333
		U.S. Pat. No. 7,393,599, WO2006056418, US20050260441, WO2005019373
		U.S. Pat. No. 7,534,505

TABLE 4-continued

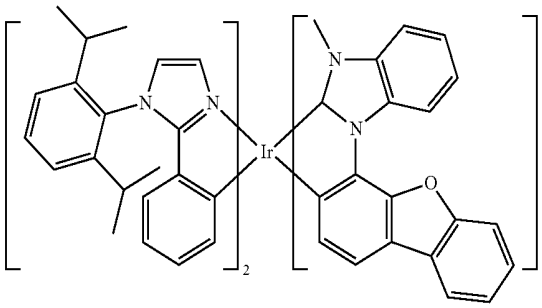
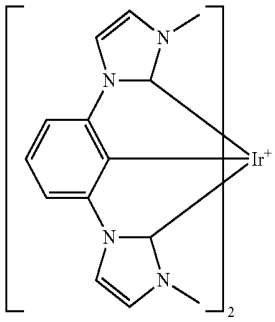
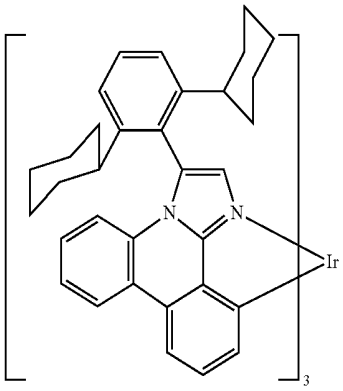
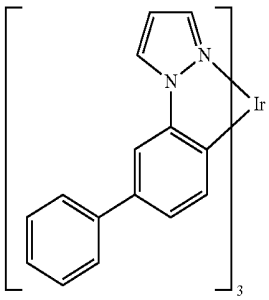
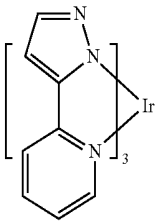
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2011051404
		U.S. Pat. No. 7,445,855
		US20070190359, US20080297033 US20100148663
		U.S. Pat. No. 7,338,722
		US20020134984

TABLE 4-continued

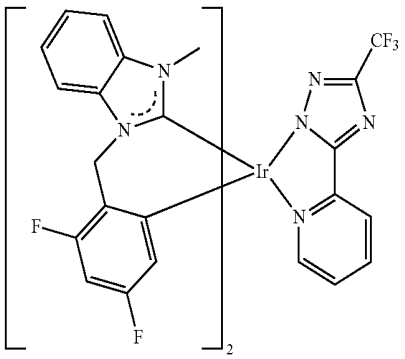
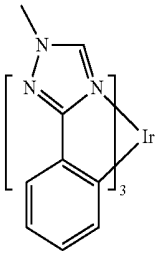
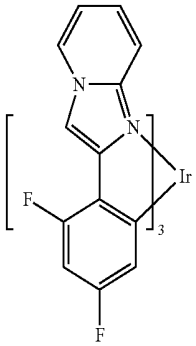
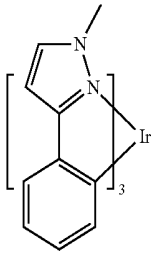
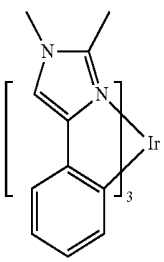
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Angew. Chem. Int. Ed. 47, 4542 (2008)
		Chem. Mater. 18, 5119 (2006)
		Inorg. Chem, 46, 4308 (2007)
		WO2005123873
		WO2005123873

TABLE 4-continued

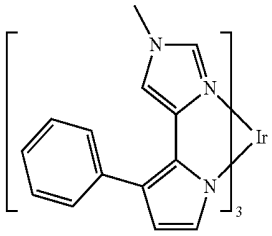
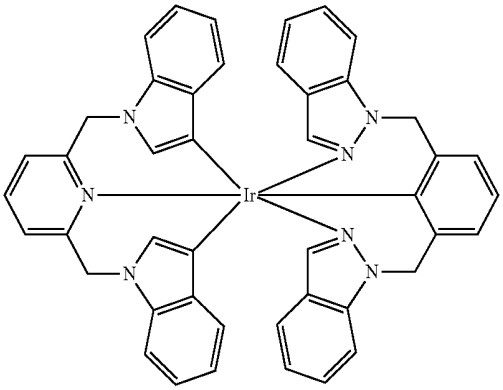
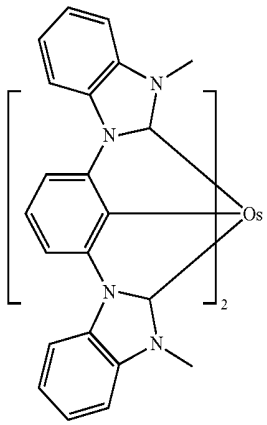
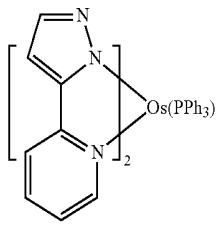
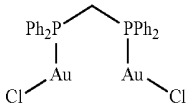
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2007004380
		WO2006082742
Osmium(II) complexes		U.S. Pat. No. 7,279,704
		Organometallics 23, 3745 (2004)
Gold complexes		Appl, Phys, Lett. 74, 1361 (1999)

TABLE 4-continued

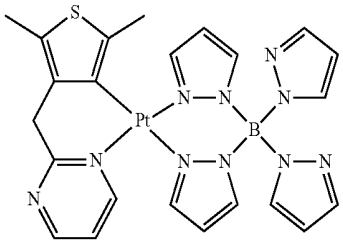
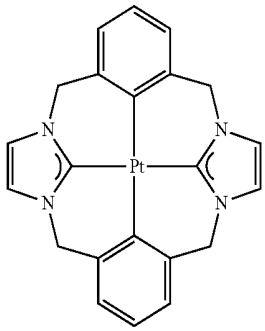
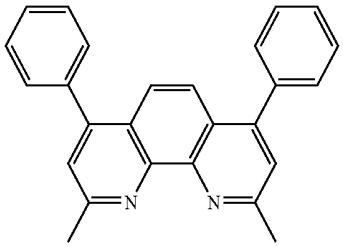
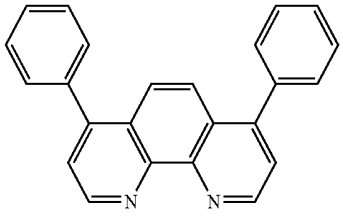
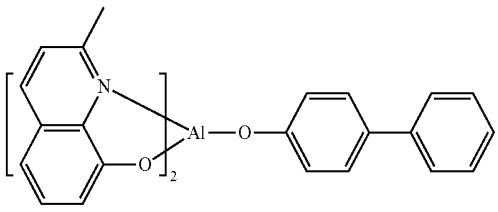
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Platinum(II) complexes		WO2006098120, WO2006103874
Pt tetradentate complexes with at least one metal-carbene bond		U.S. Pat. No. 7,655,323
	Exciton/hole blocking layer materials	
Bathocuprine compounds (e.g., BCP, BPhen)		Appl. Phys. Lett. 75, 4 (1999)
		Appl.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

TABLE 4-continued

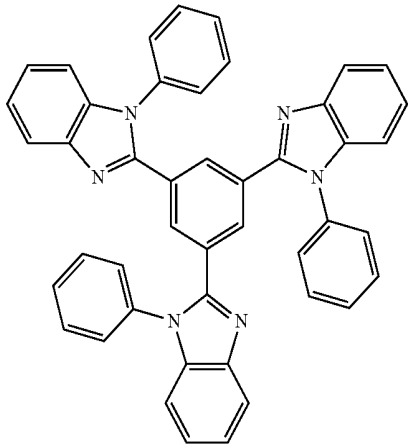
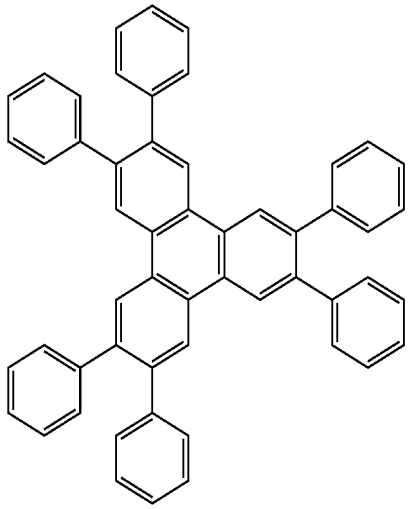
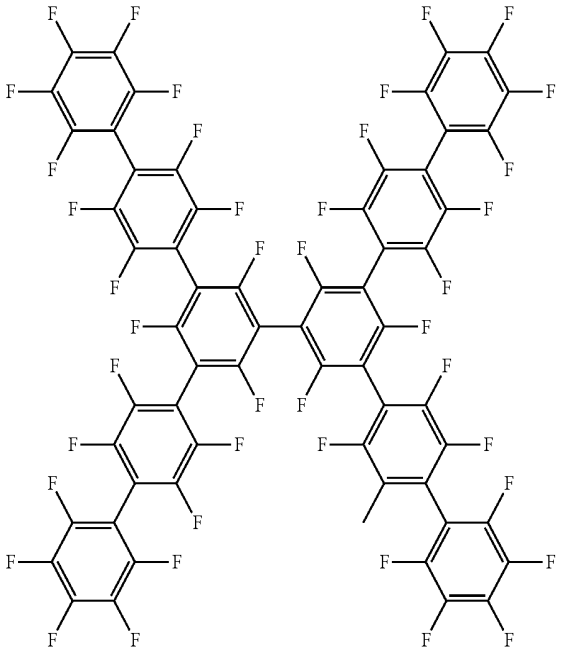
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
5-member ring electron deficient heterocycles such as triazole, oxadiazole, imidazole, benzoimidazole		Appl. Phys. Lett. 81, 162 (2002)
Triphenylene compounds		US20050025993
Fluorinated aromatic compounds		Appl. Phys. Lett. 79, 156 (2001)

TABLE 4-continued

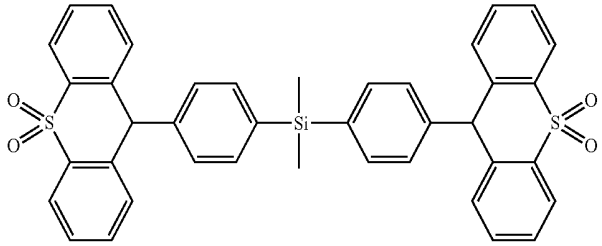
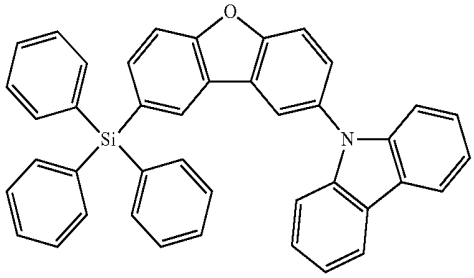
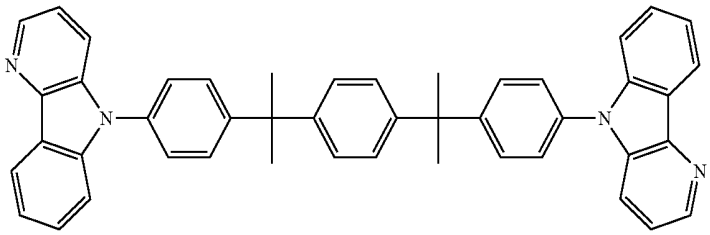
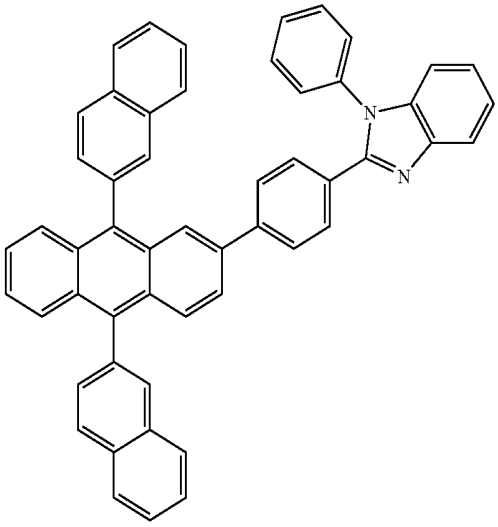
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Phenothiazine-S-oxide		WO2008132085
Silylated five-membered nitrogen, oxygen, sulfur or phosphorus dibenzo-heterocycles		WO2010079051
Aza-carbazoles		US20060121308
Electron transporting materials		
Anthracene-benzoimidazole compounds		WO2003060956

TABLE 4-continued

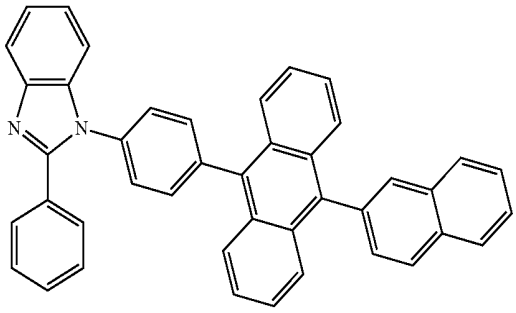
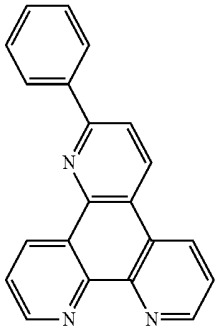
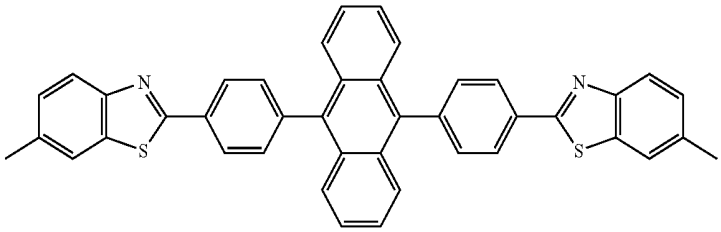
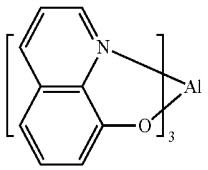
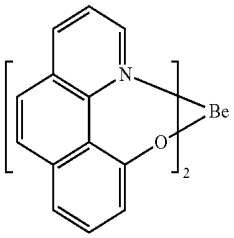
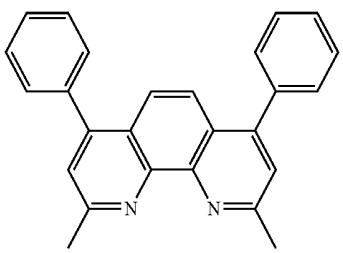
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20090179554
Aza triphenylene derivatives		US20090115316
Anthracene-benzothiazole compounds		Appl. Phys. Lett. 89, 063504 (2006)
Metal 8-hydroxy-quinolates (e.g., Alq_3, Zrq_4)		Appl. Phys. Lett. 51, 913 (1987) U.S. Pat. No. 7,230,107
Metal hydroxy-benoquinolates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

TABLE 4-continued

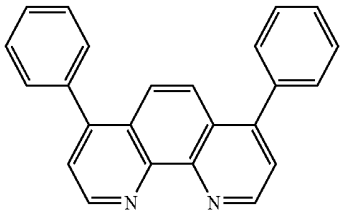
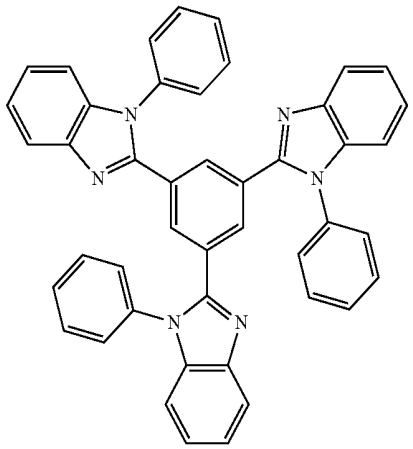
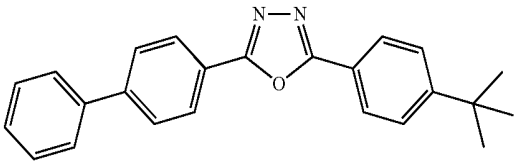
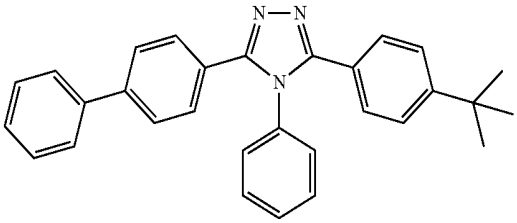
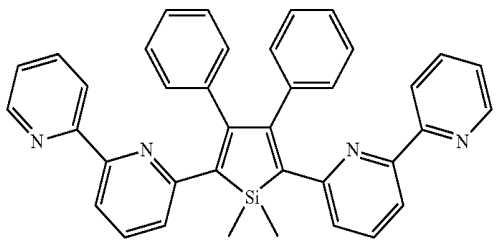
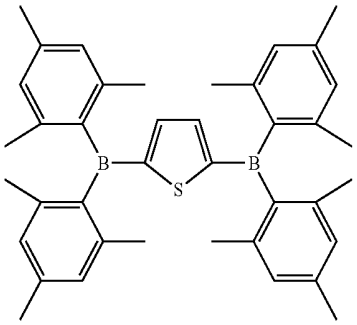
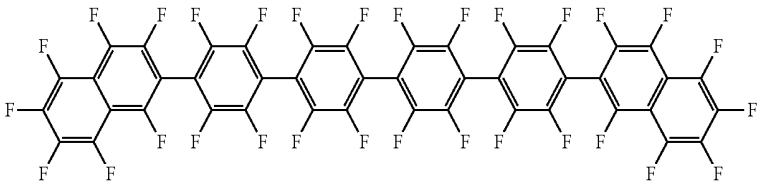
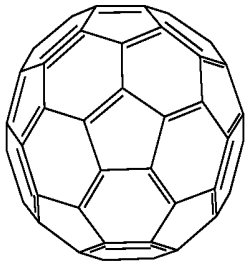
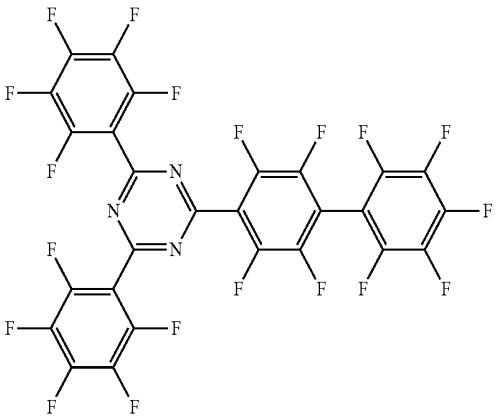
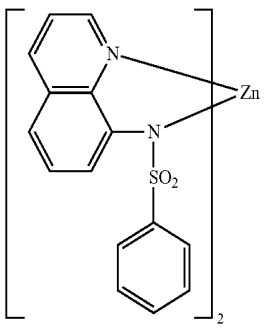
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Appl. Phys. Lett. 79, 449 (2001)
5-member ring electron deficient heterocycles (e.g., triazole, oxadiazole, imidazole, benzoimidazole)		Appl, Phys, Lett. 74, 865 (1999)
		Appl. Phys, Lett. 55, 1489 (1989)
		Jpn. J. Apply. Phys. 32, L917 (1993)
Silole compounds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

TABLE 4-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

[0151] 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 composition comprising:

a mixture of a first compound and a second compound, wherein the first compound has a different chemical structure than the second compound;

wherein the first compound is capable of functioning as a hole transporting material in an organic light emitting device at room temperature;

wherein the first compound comprises at least one carbazole group;

wherein the first compound has an evaporation temperature T1 of 150 to 350° C.;

wherein the second compound has an evaporation temperature T2 of 150 to 350° C.;

wherein absolute value of T1−T2 is less than 20° C.;

wherein the first compound has a concentration C1 in said mixture, and the first compound has a concentration C2 in a film formed by evaporating the mixture in a vacuum deposition tool at a constant pressure between 1×10^{-6} Torr to 1×10^{-9} Torr, at a 2 Å/sec deposition rate on a surface positioned at a predefined distance away from the mixture being evaporated; and

wherein absolute value of (C1−C2)/C1 is less than 5%.

2. The composition of claim **1**, wherein the first compound has evaporation temperature T1 of 200 to 350° C. and the second compound has evaporation temperature of T2 of 200 to 350° C.

3. The composition of claim **1**, wherein the absolute value of (C1−C2)/C1 is less than 3%.

4. The composition of claim **1**, wherein the first compound has a vapor pressure of P1 at T1, the second compound has vapor pressure of P2 at T2; and

wherein the ratio of P1/P2 is within the range of 0.90 to 1.10.

5. The composition of claim **1**, wherein the first compound has a first mass loss rate and the second compound has a second mass loss rate, wherein the ratio between the first mass loss rate and the second mass loss rate is within the range of 0.90 to 1.10.

6.-**7**. (canceled)

8. The composition of claim **1**, wherein the first compound further comprises at least one of the chemical groups selected from the group consisting of triphenylene, dibenzothiophene, dibenzofuran, and dibenzoselenophene.

9. The composition of claim **1**, wherein the second compound is capable of functioning as an electron transporting material in an organic light emitting device at room temperature.

10. The composition of claim **1**, wherein the second compound comprises at least one of the chemical groups selected from the group consisting of aza-triphenylene, aza-carbazole, aza-dibenzothiophene, aza-dibenzofuran, aza-dibenzoselenophene, and non-fused N-containing six-member aromatic rings.

11. The composition of claim **1**, wherein the first compound has HOMO energy level higher than −5.8 eV.

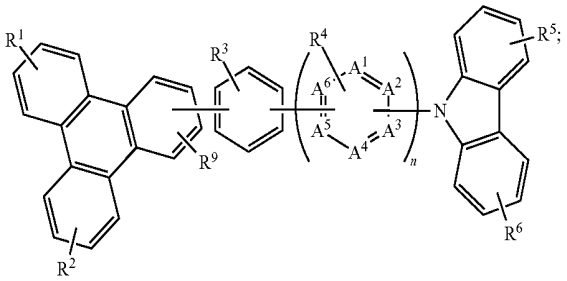
12. (canceled)

13. The composition of claim **1**, wherein the composition further comprises a third compound, wherein the third compound has a different chemical structure than the first and second compounds, wherein the third compound has an evaporation temperature T3 of 150 to 350° C., and wherein absolute value of T1−T3 is less than 20° C.

14. The composition of claim **1**, wherein the composition is in liquid form at a temperature lower than T1 and T2.

15. The composition of claim **1**, wherein the first compound has a structure according to a formula (I):

(I)



wherein

R^1, R^2, R^3, R^4, R^5, and R^6 each represent mono, di, tri, tetra substitutions, or no substitution;

R^9 represents mono, di, tri substitutions, or no substitution;

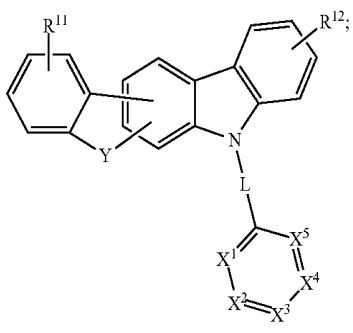
R^1, R^2, R^3, R^4, R^5, R^6, and R^9 are each independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acid, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof;

A^1, A^2, A^3, A^4, A^5, and A^6 are each independently selected from N or C; and

n is an integer from 1 to 20;

wherein the second compound has a structure according to a formula (II):

(II)



wherein

R^{11} and R^{12} each represent mono, di, tri, tetra substitutions, or no substitution;

Y is selected from the group consisting of O, S, Se, NR', and CR"R'";

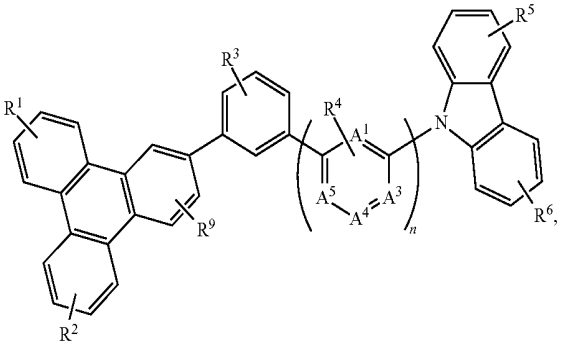
L is a single bond or comprises an aryl or heteroaryl group having from 5-24 carbon atoms, which is optionally further substituted;

X^1, X^2, X^3, X^4, and X^5 are each independently selected from group consisting of CR and N;

at least one of X^1, X^2, X^3, X^4, and X^5 is N; and

R, R', R", and R'" 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 acid, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

16. The composition of claim **1**, wherein the first compound has a formula selected from the group consisting of:



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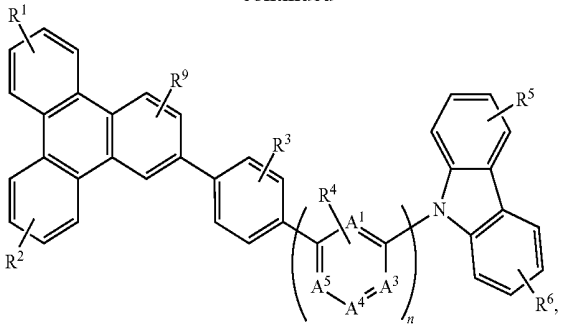
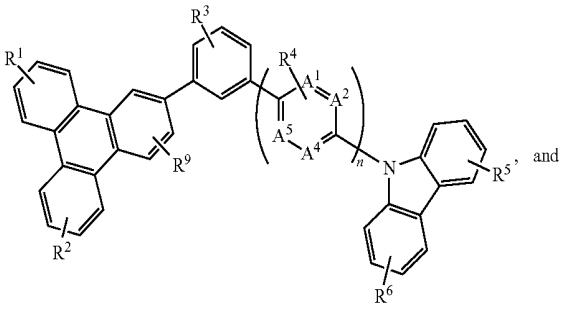
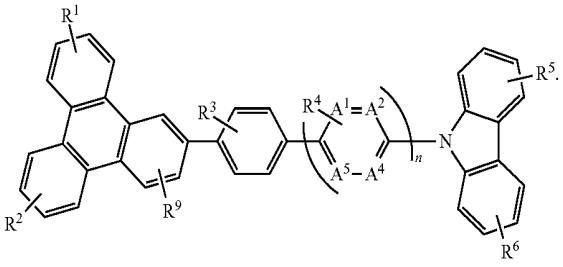
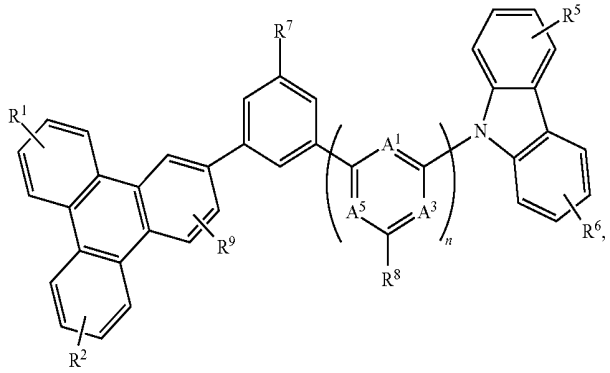




and



6. The composition of claim **1**, wherein the first compound has a formula selected from the group consisting of:



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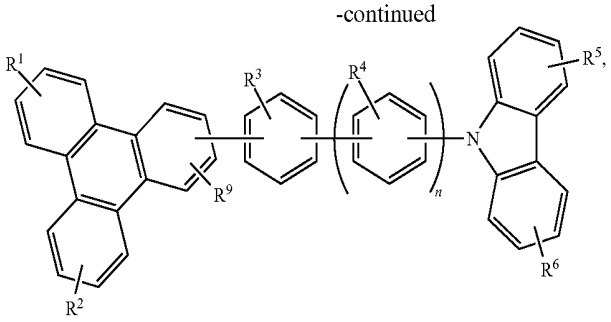
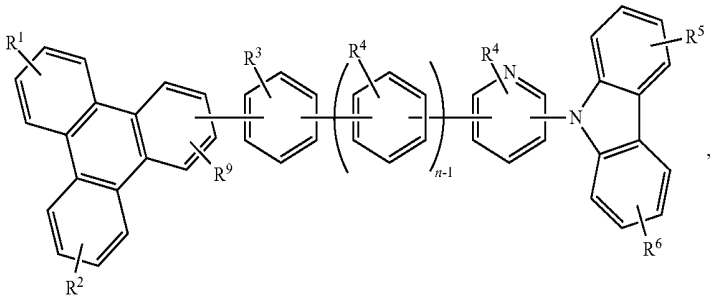
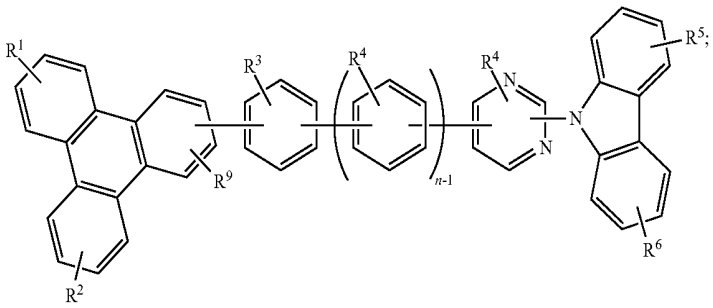




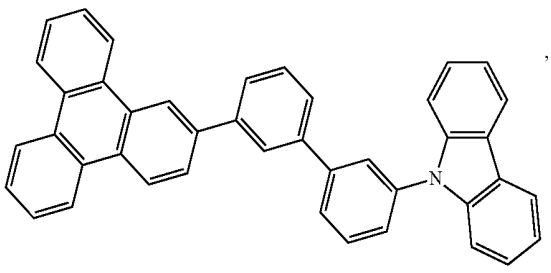
, and



wherein R^7 and R^8 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 acid, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

7. The host composition of claim **1**, wherein the first compound is selected from the group consisting of:

Compound 1



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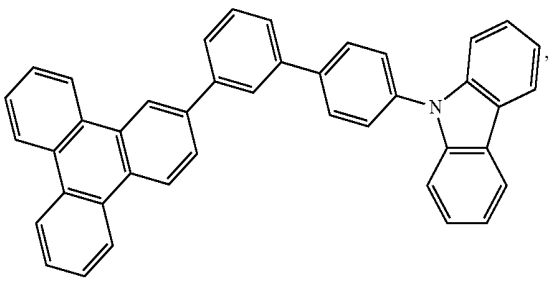
Compound 2



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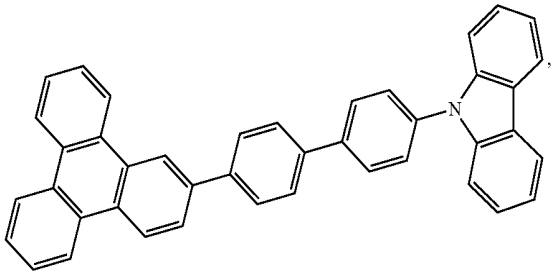
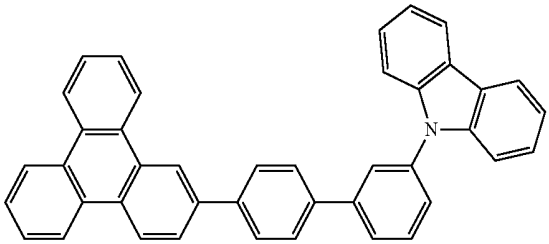
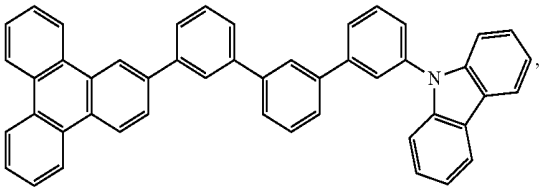
Compound 3



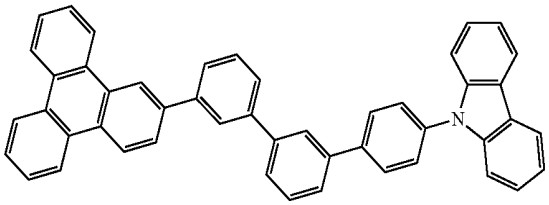
Compound 4



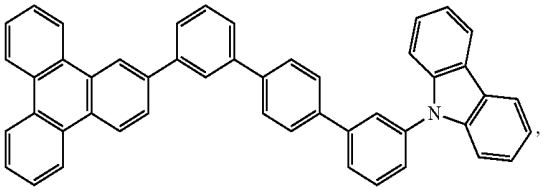
Compound 5



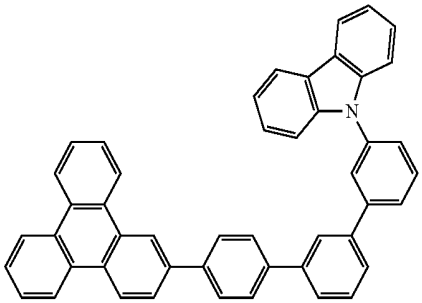
Compound 6



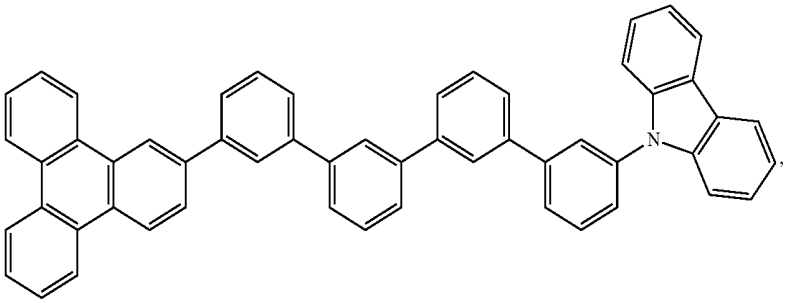
Compound 7



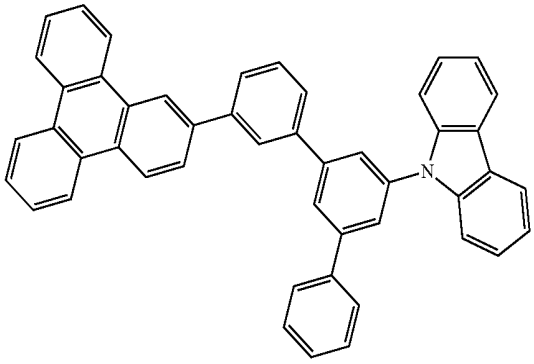
Compound 8



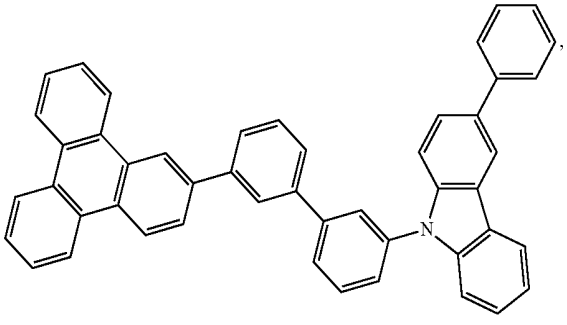
Compound 9



Compound 10



Compound 11



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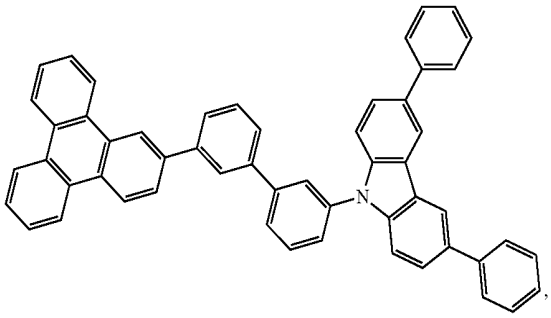
Compound 12



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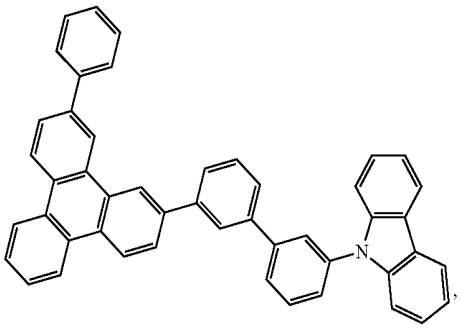

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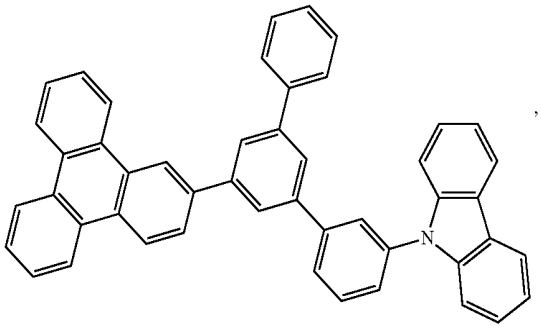
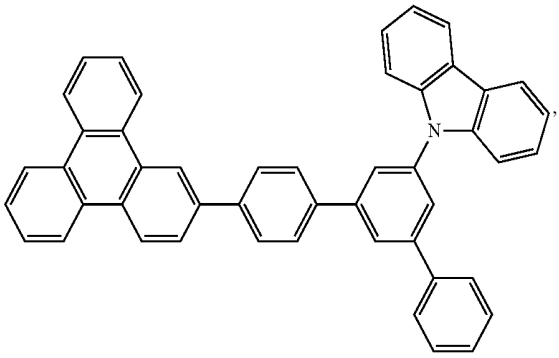
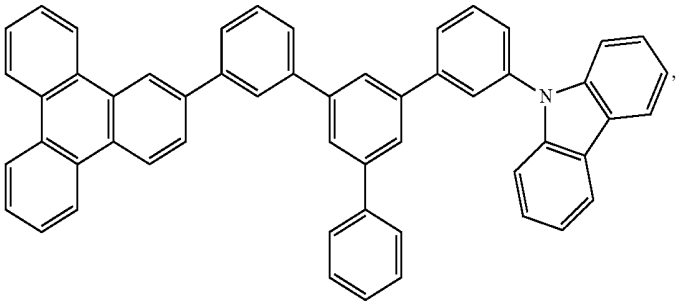


Compound 15



Compound 16



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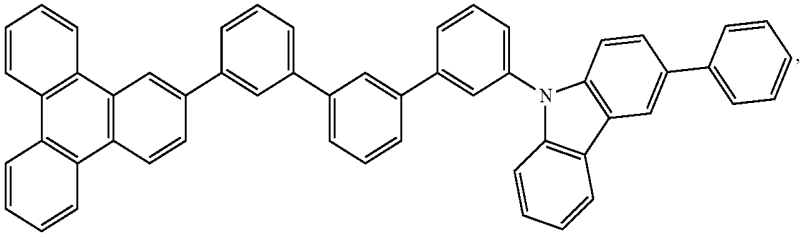
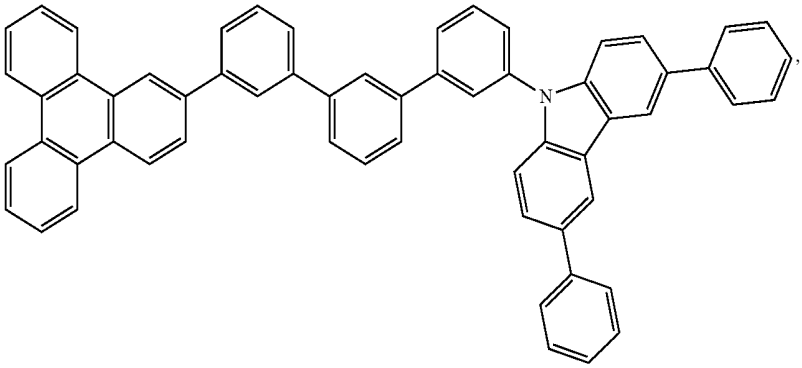


Compound 18



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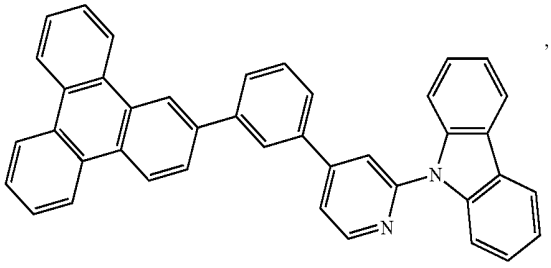
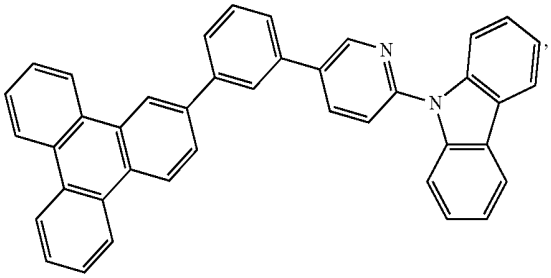
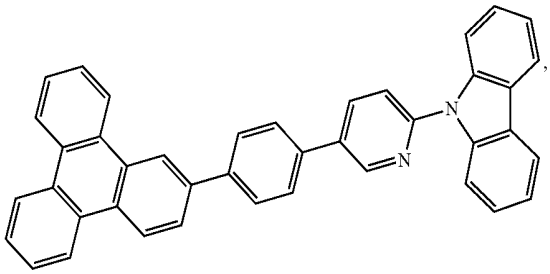


Compound 20



Compound 21



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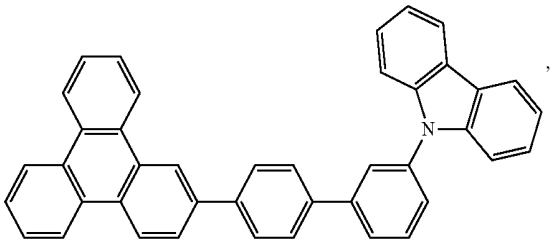
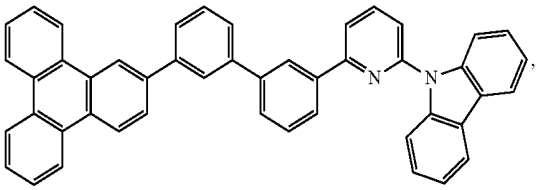
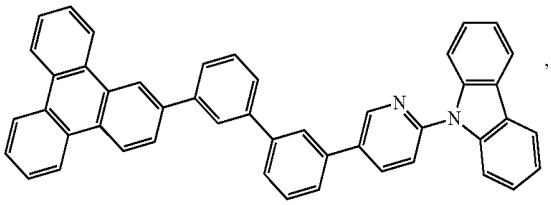


Compound 23



Compound 24



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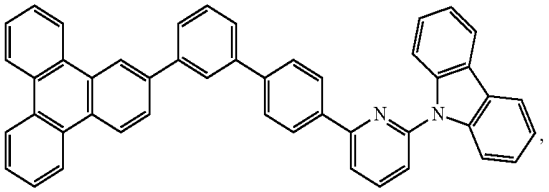
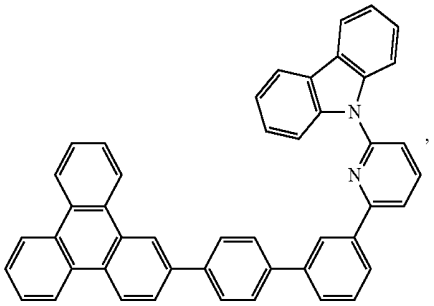
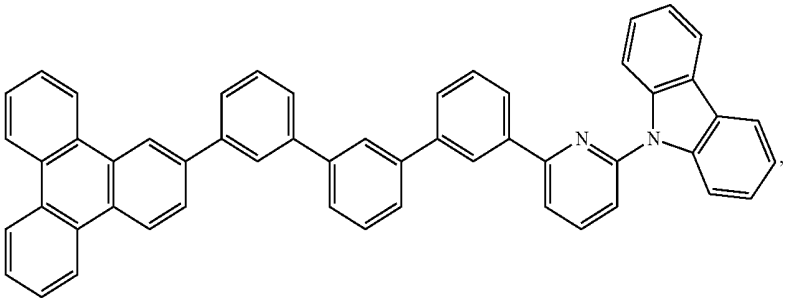


Compound 26



Compound 27



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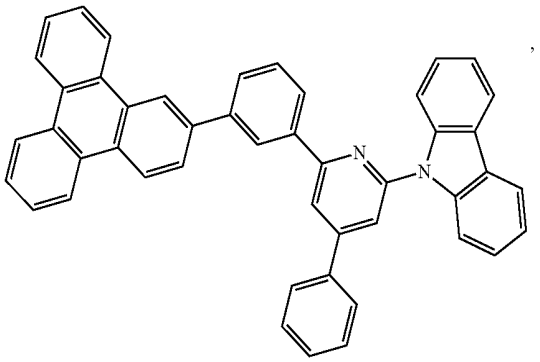
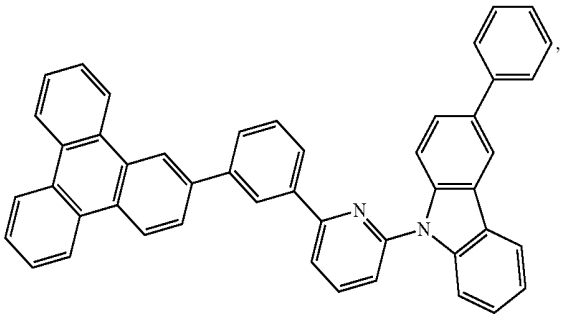
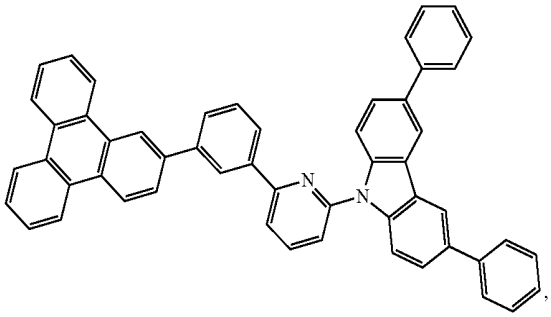
Compound 28



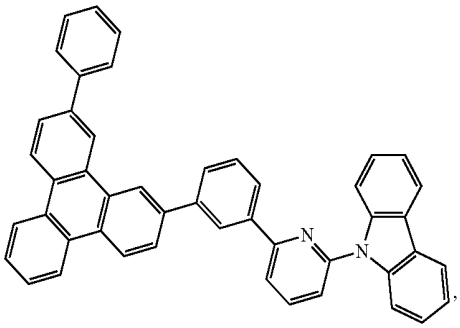
Compound 29



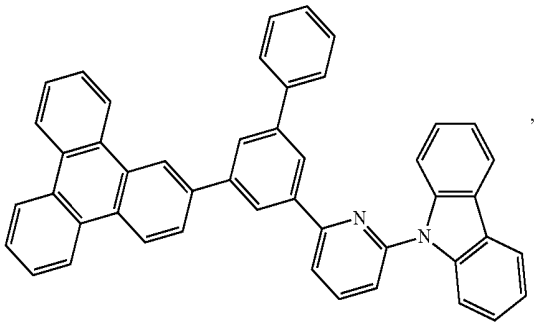
Compound 30



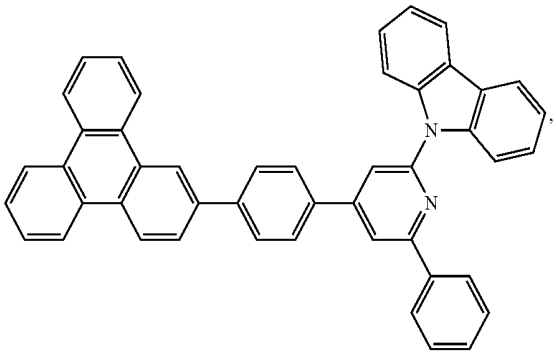
Compound 31



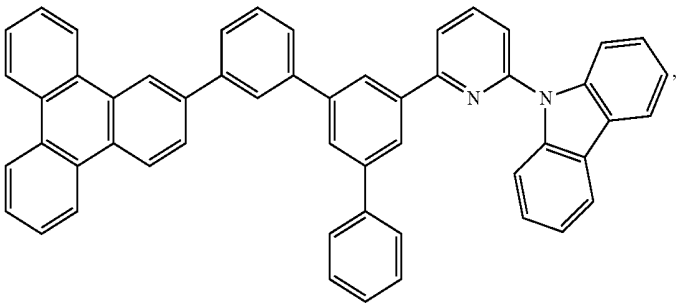
Compound 32



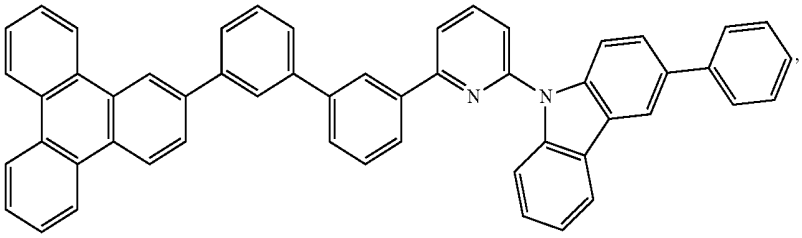
Compound 33



Compound 34



Compound 35



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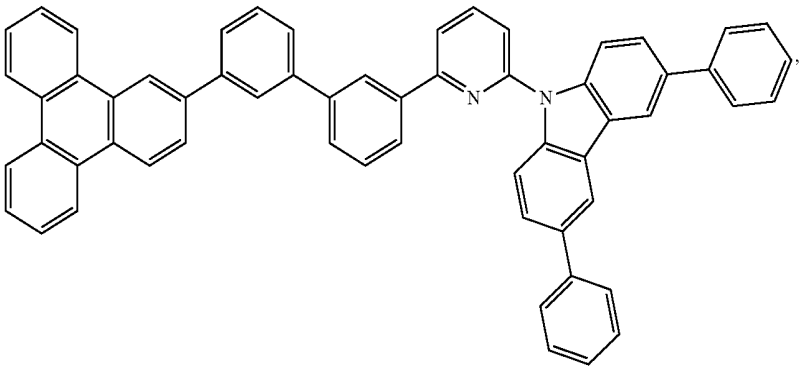
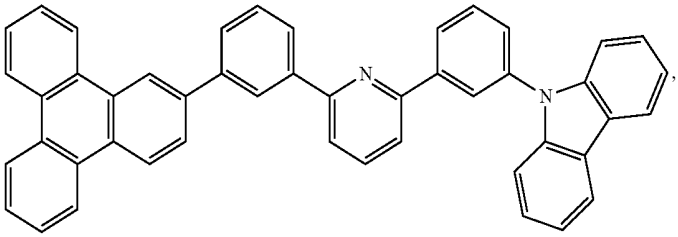
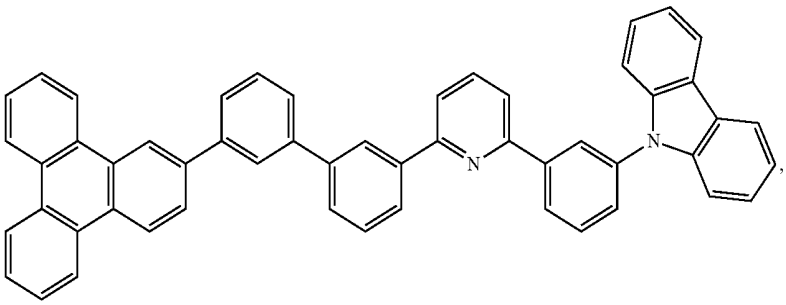
Compound 36



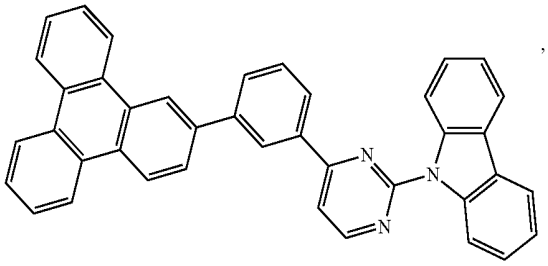
Compound 37



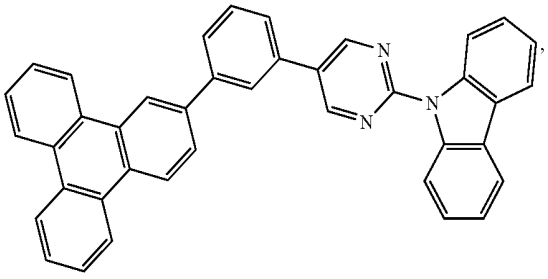
Compound 38



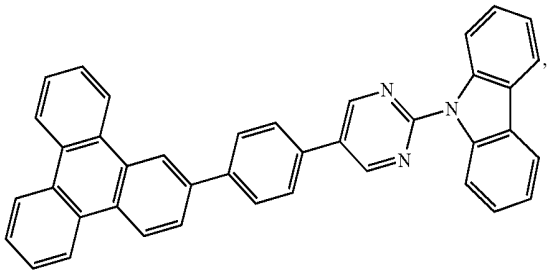
Compound 39



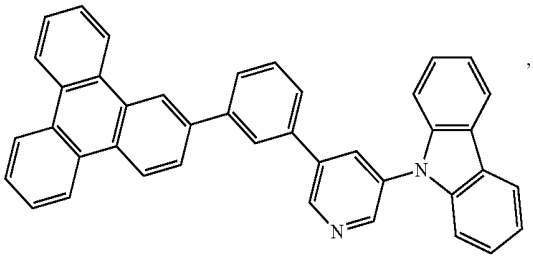
Compound 40



Compound 41



Compound 42



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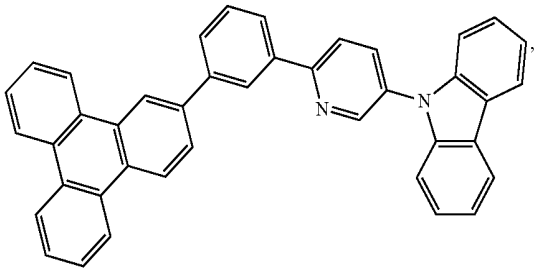
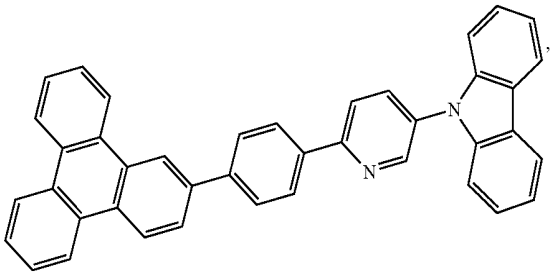
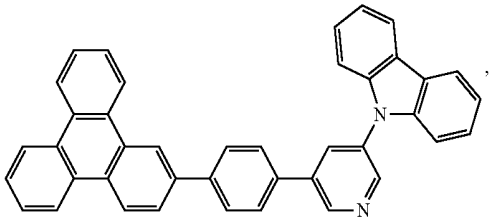
Compound 43



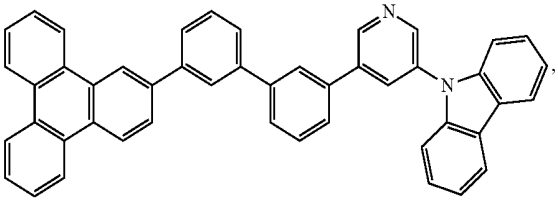
Compound 44



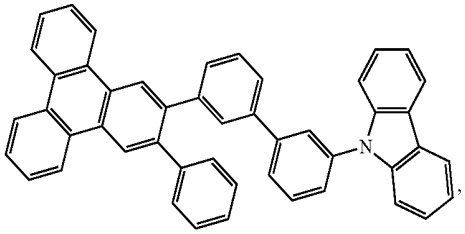
Compound 45



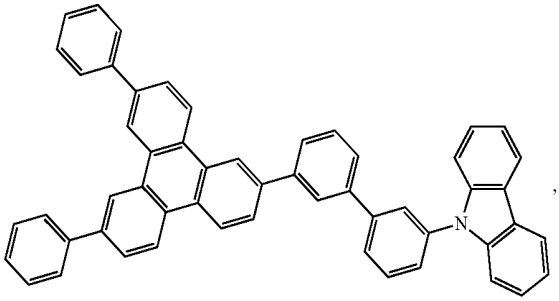
Compound 46



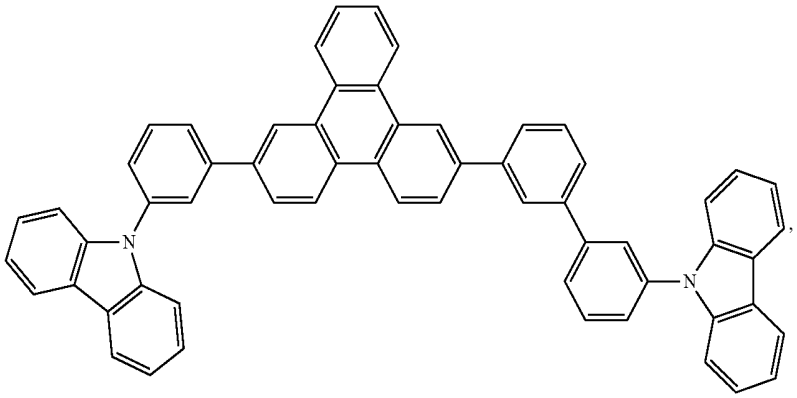
Compound 47



Compound 48

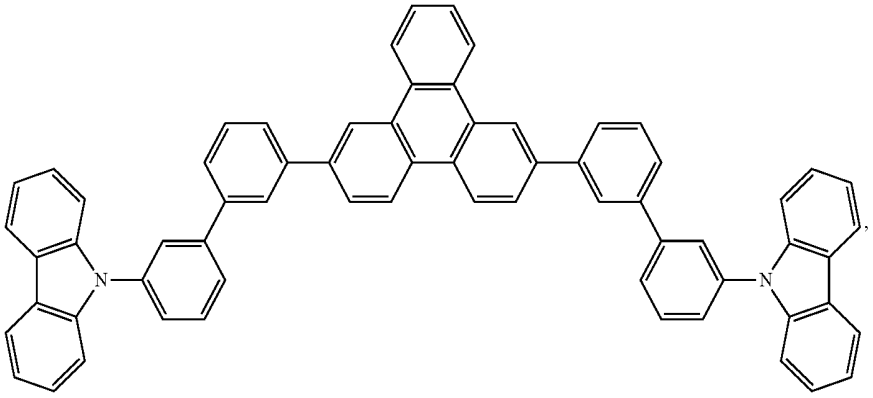


Compound 49

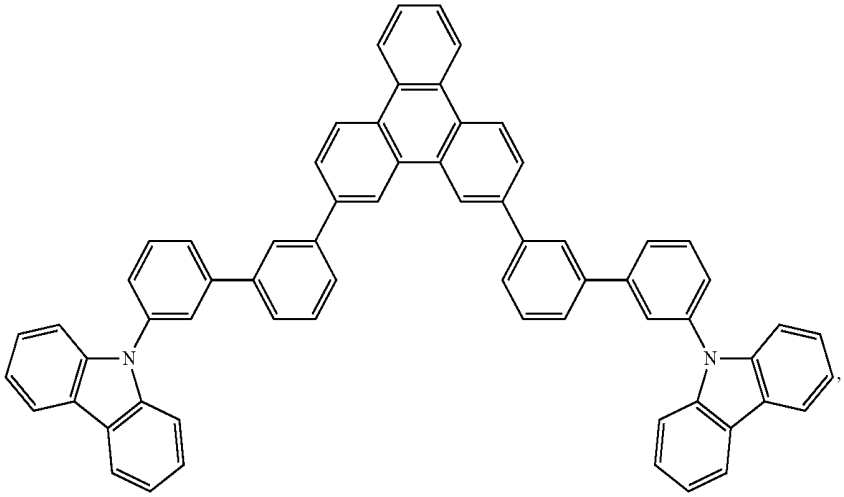


-continued

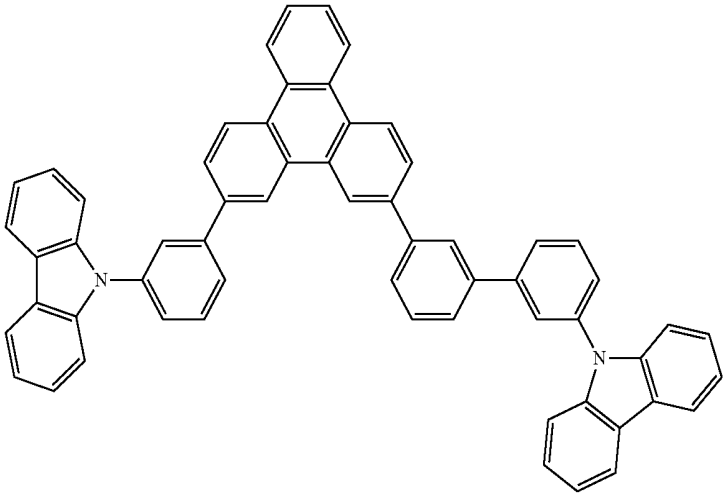
Compound 50



Compound 51

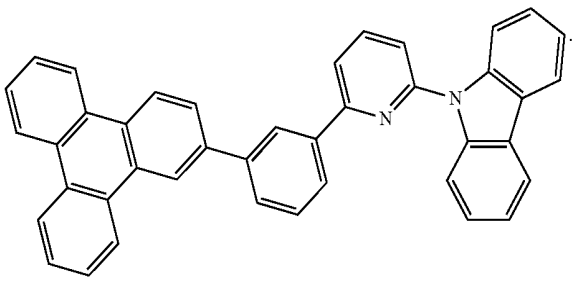


Compound 52



, and

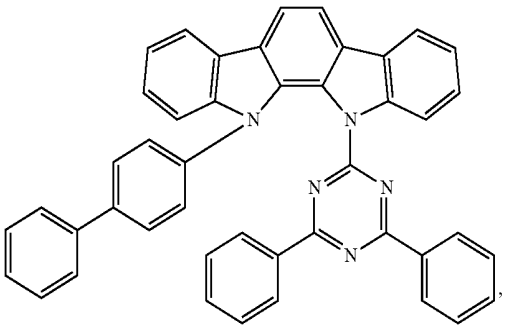
Compound 53



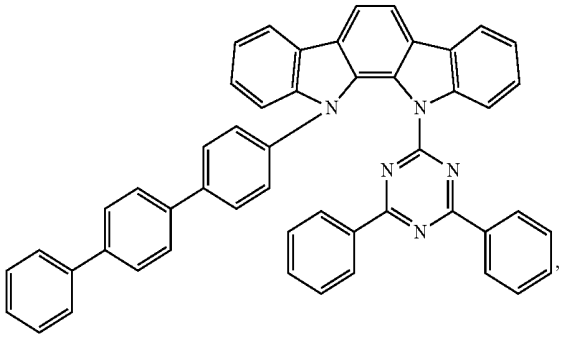
19. The composition of claim **15**, wherein X^1, X^3, and X^5 are N; and wherein X^2 and X^4 are CR.

20. The composition of claim **1**, wherein the second compound is selected from the group consisting of:

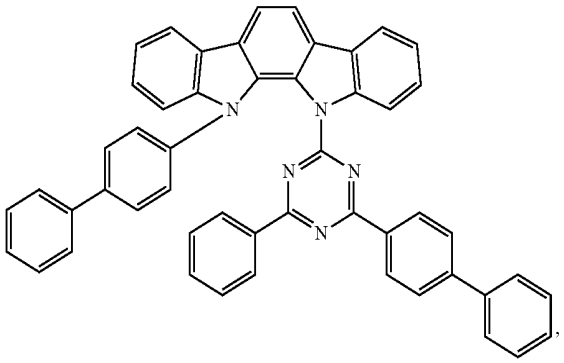
Compound E1



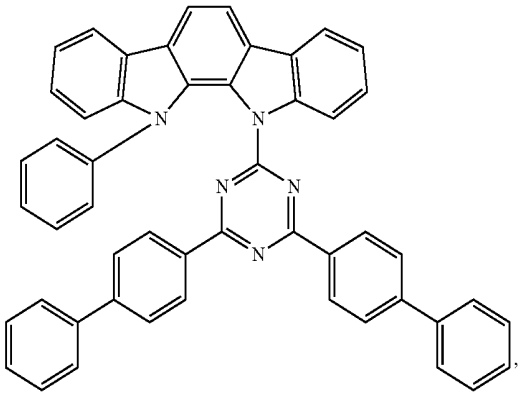
Compound E2



Compound E3

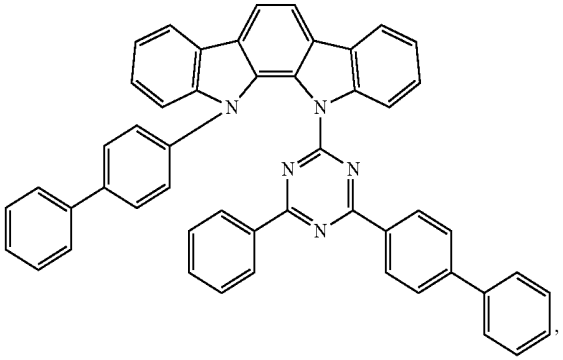


Compound E4

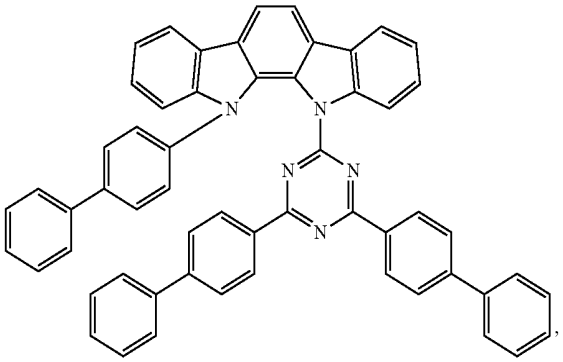


-continued

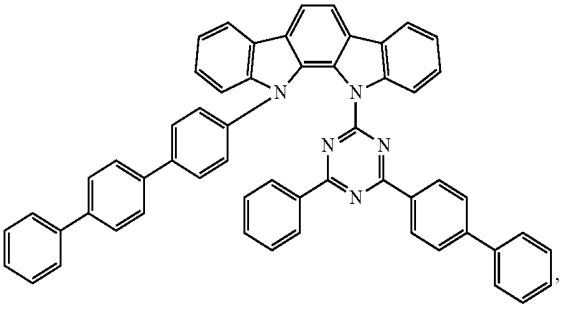
Compound E5



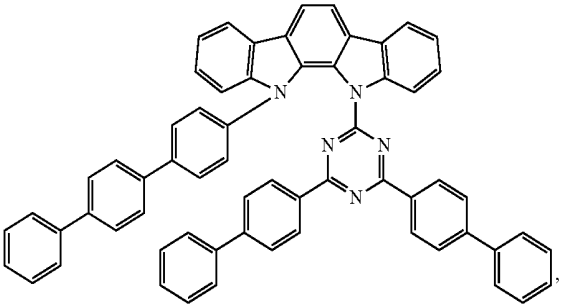
Compound E6



Compound E7



Compound E8



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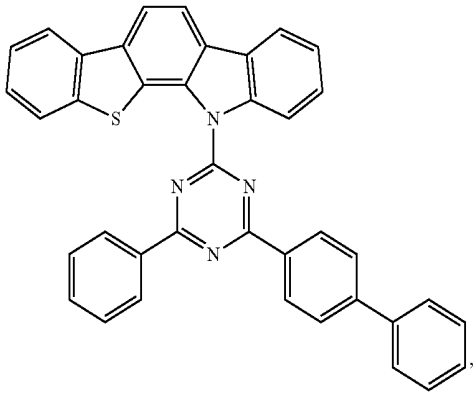
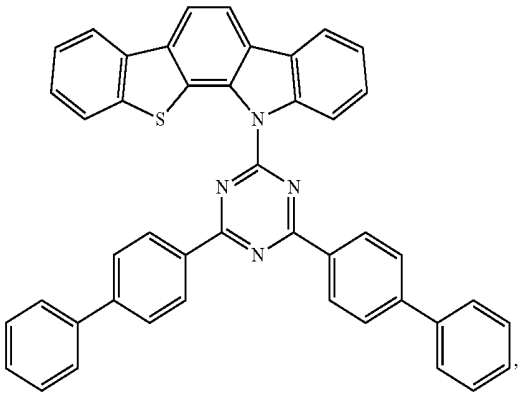
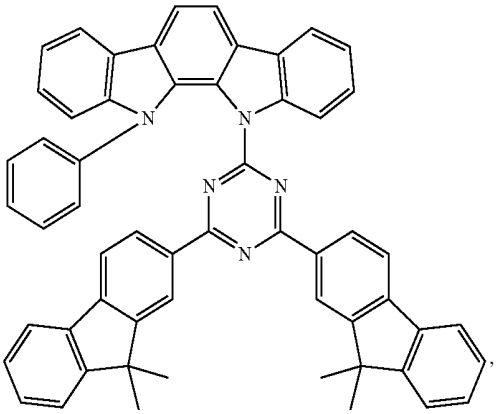
Compound E9



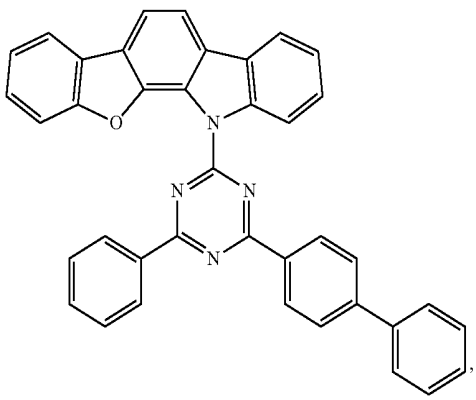
Compound E10



Compound E11



Compound E12



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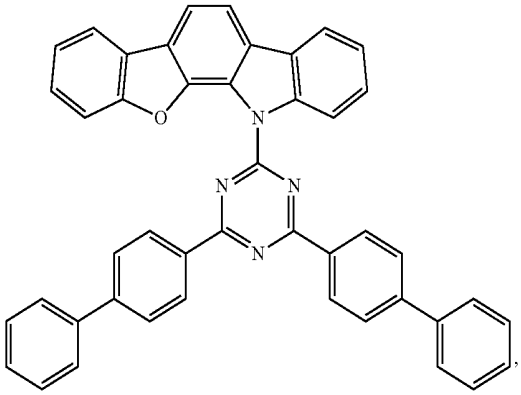
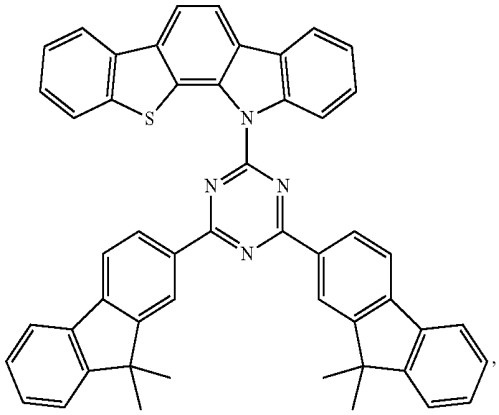
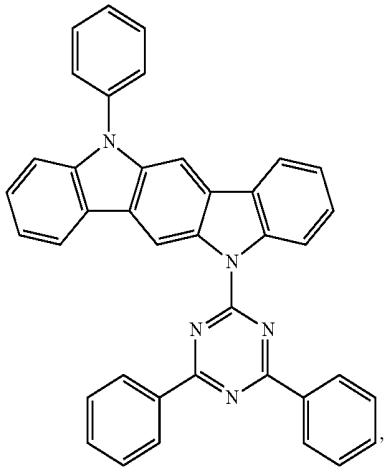
Compound E13



Compound E14



Compound E15



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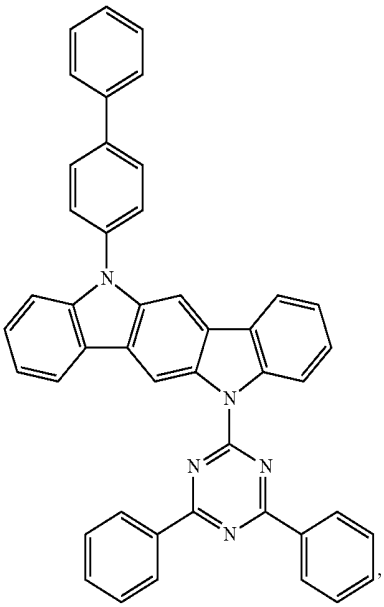
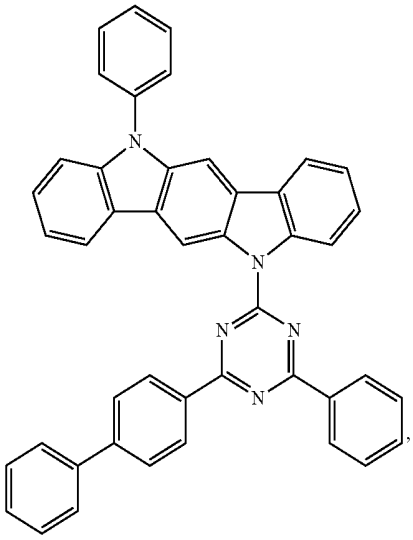
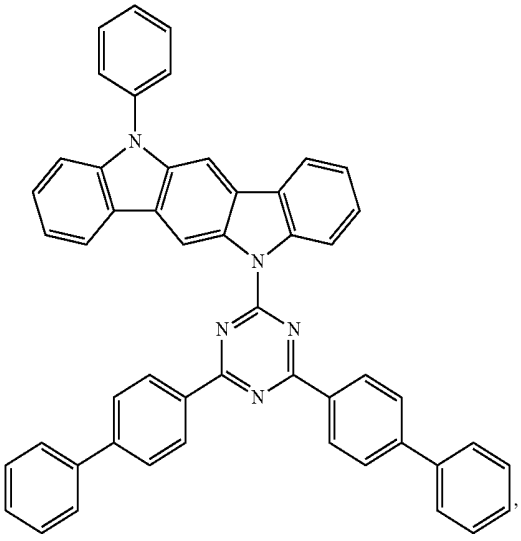
Compound E16



Compound E17



Compound E18



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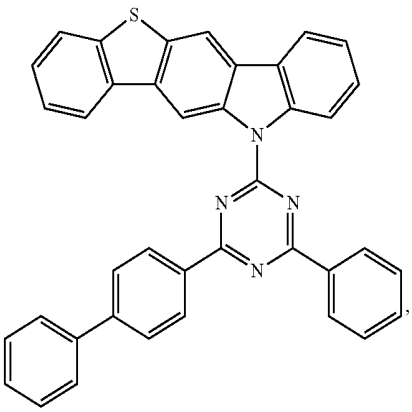
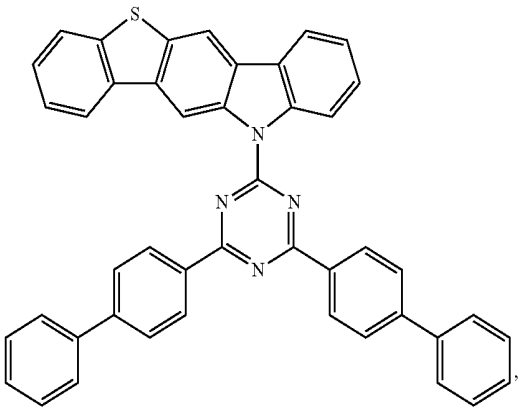
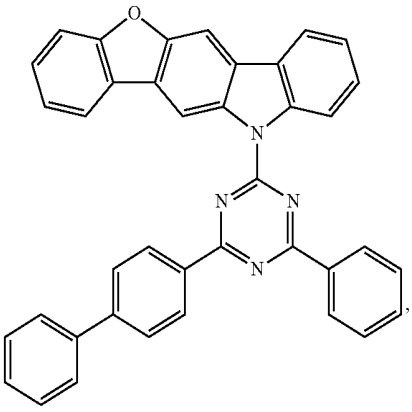
Compound E19



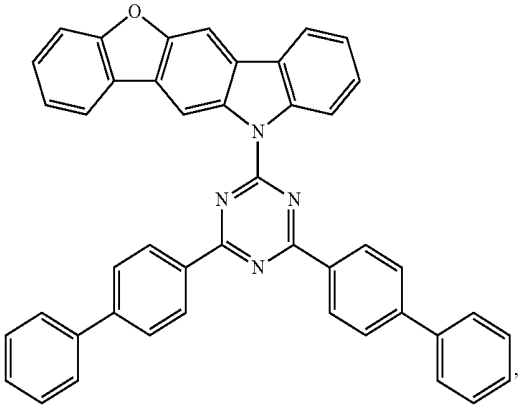
Compound E20



Compound E21



Compound E22



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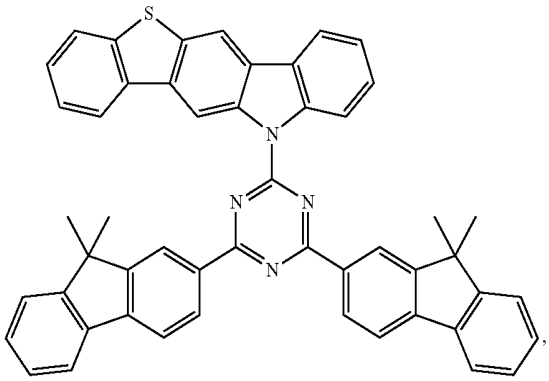
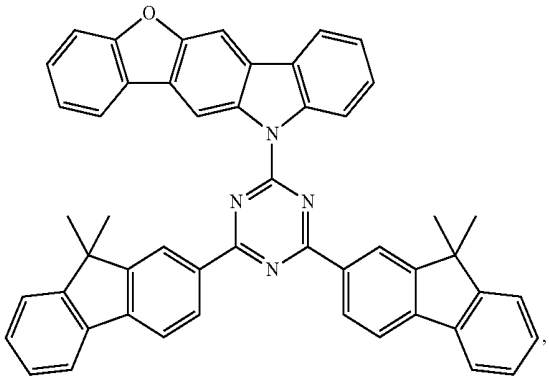
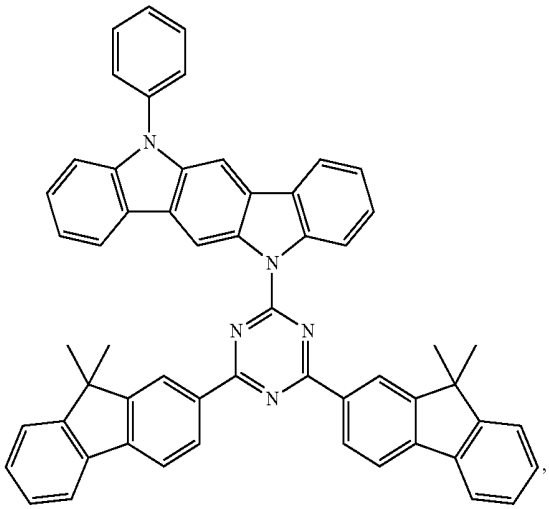
Compound E23



Compound E24



Compound E25



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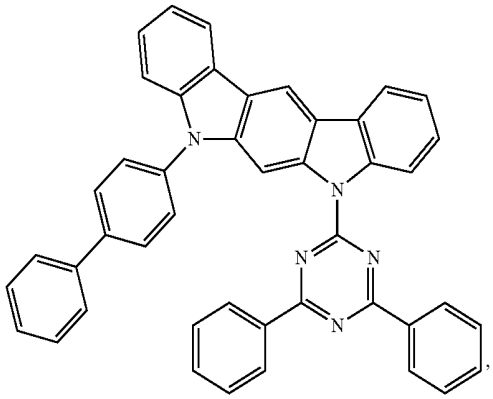
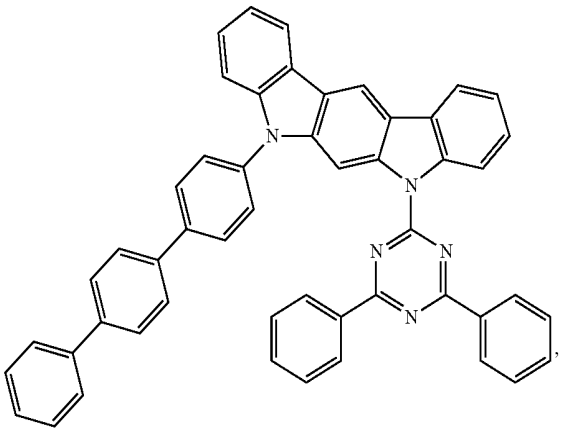
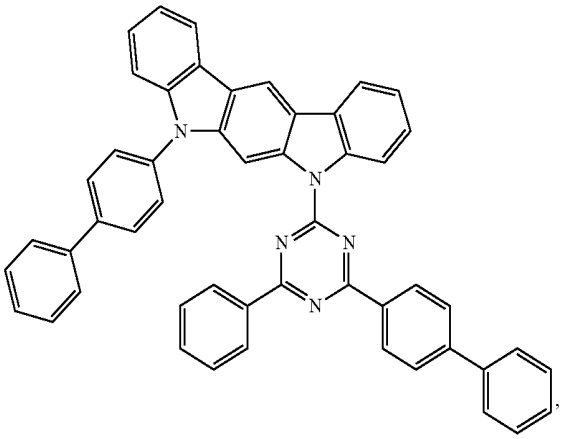
Compound E26



Compound E27



Compound E28



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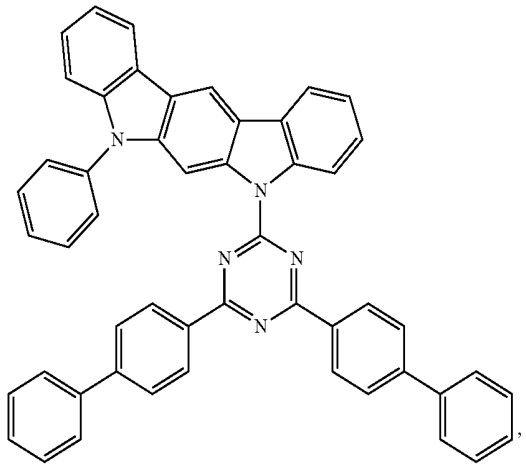
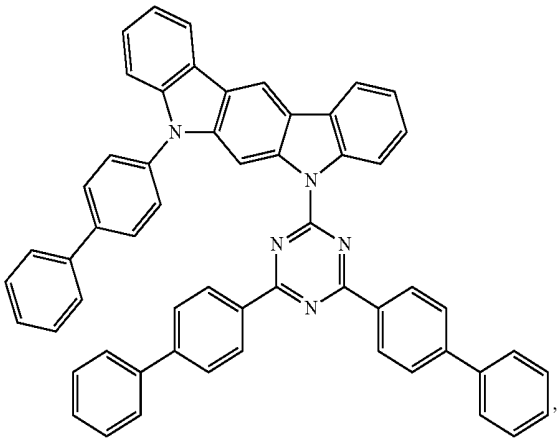
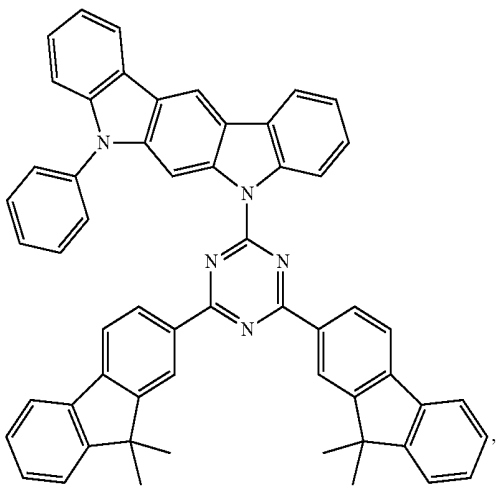
Compound E29



Compound E30



Compound E31



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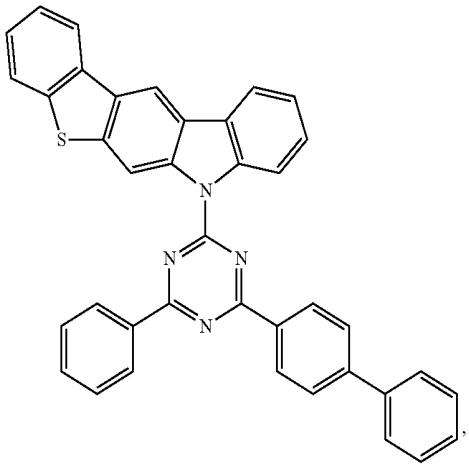
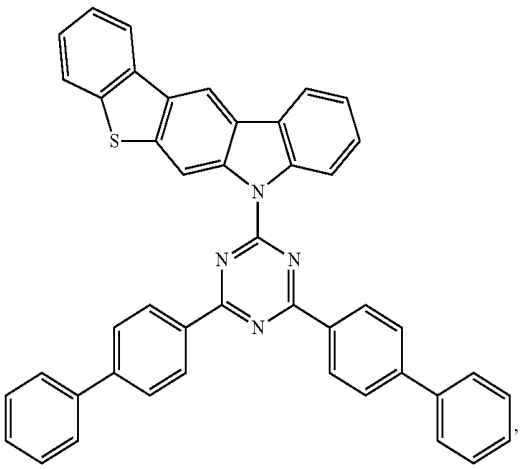
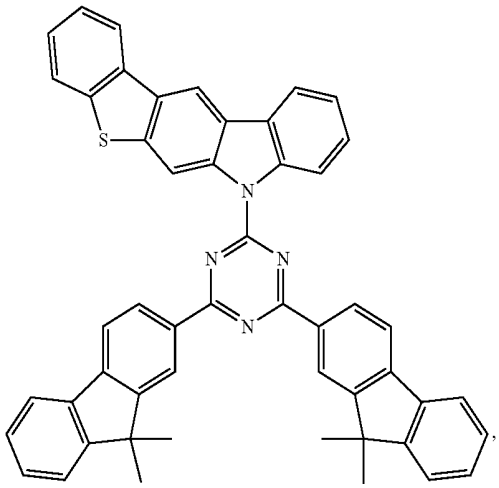
Compound E32



Compound E33



Compound E34



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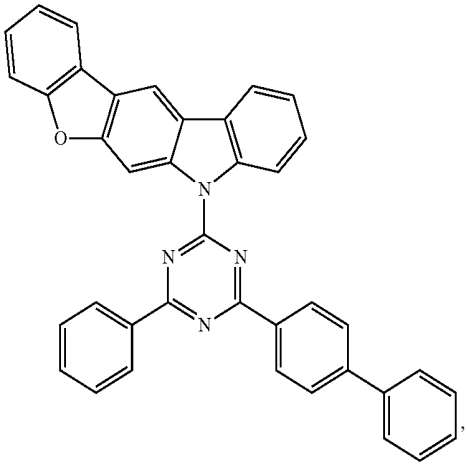
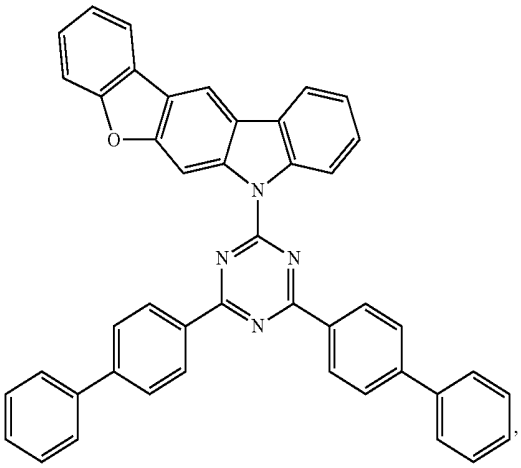
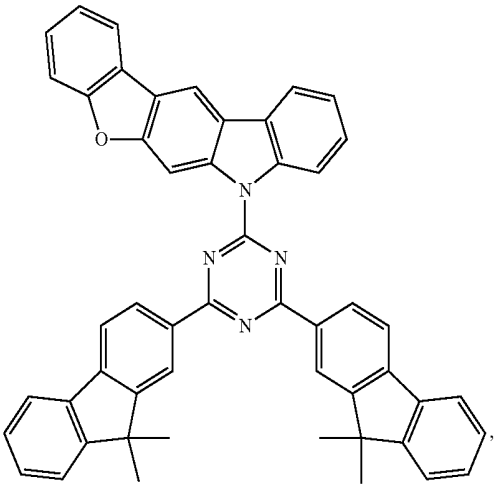
Compound E35



Compound E36



Compound E37



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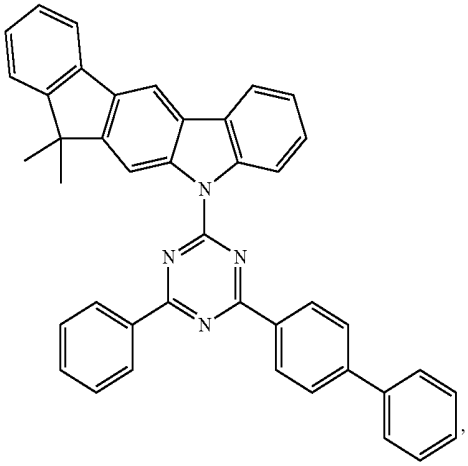
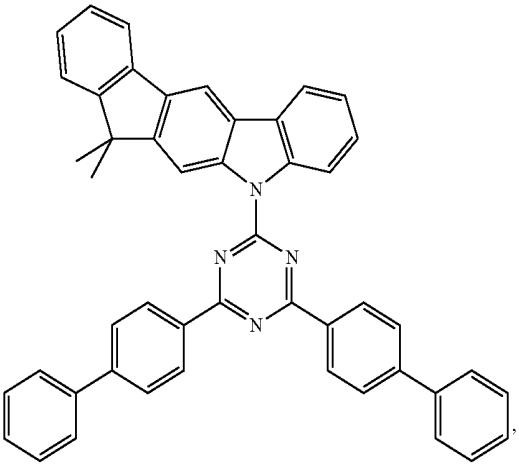
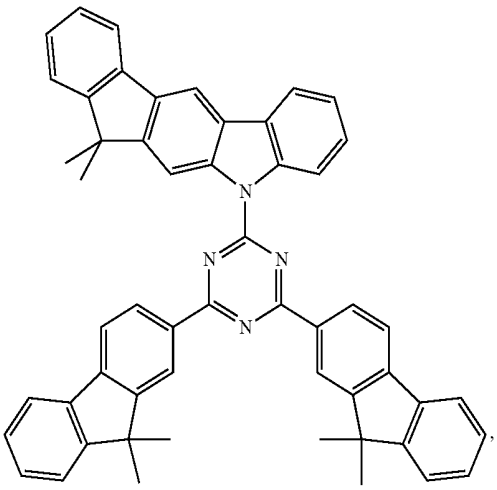
Compound E38



Compound E39

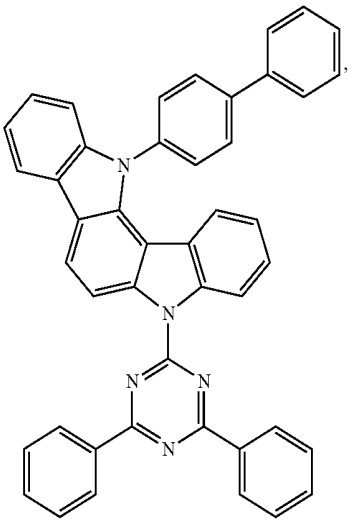


Compound E40

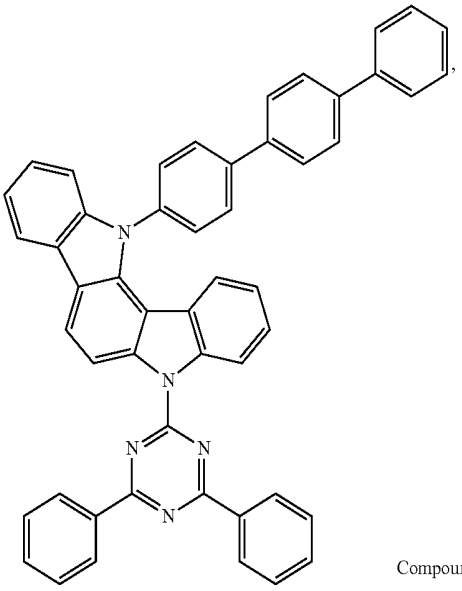


-continued

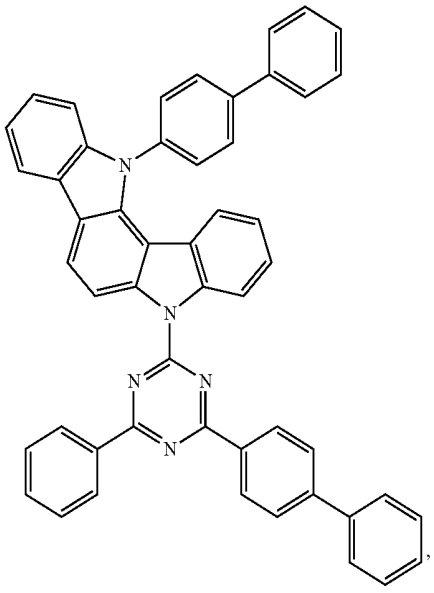
Compound E41



Compound E42



Compound E43



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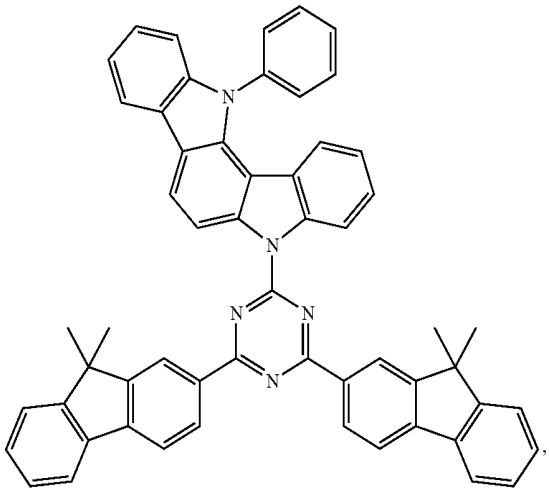
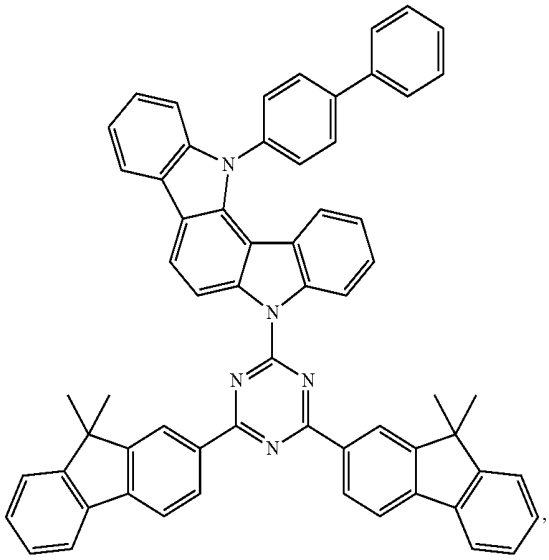
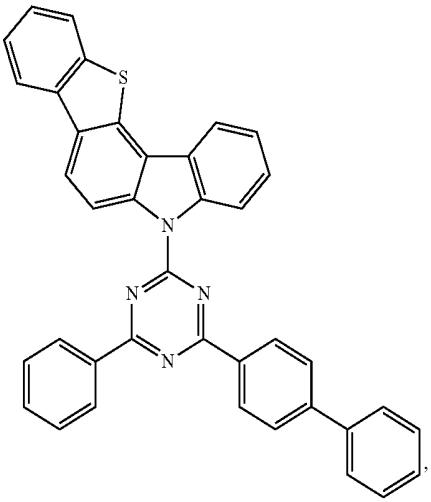
Compound E44



Compound E45



Compound E46



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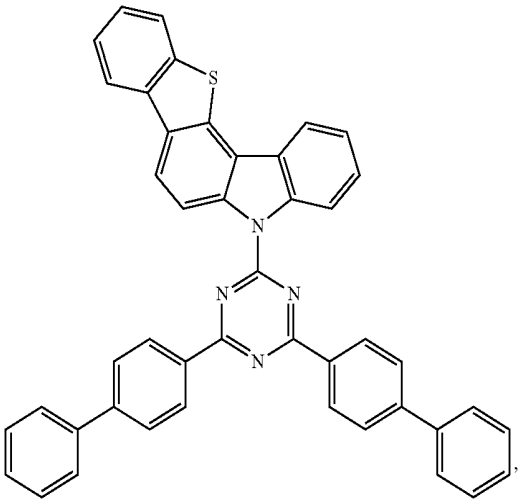
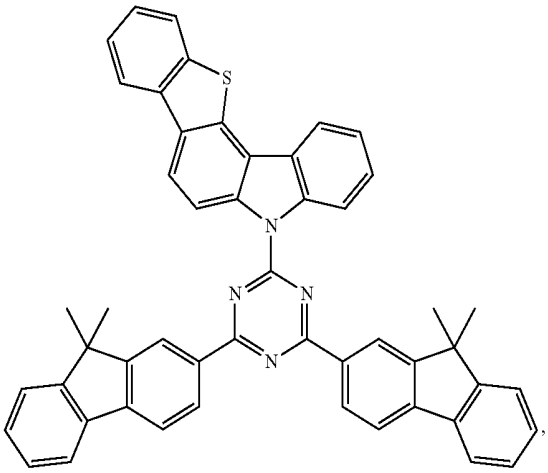
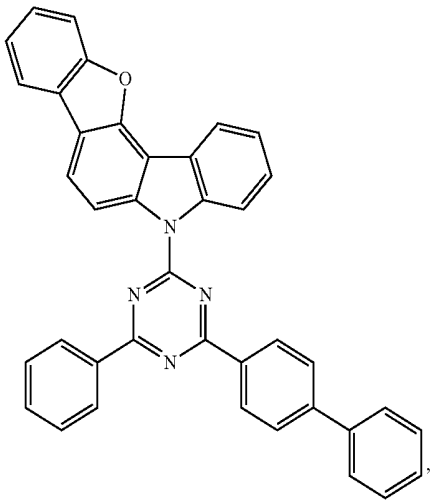
Compound E47



Compound E48



Compound E49



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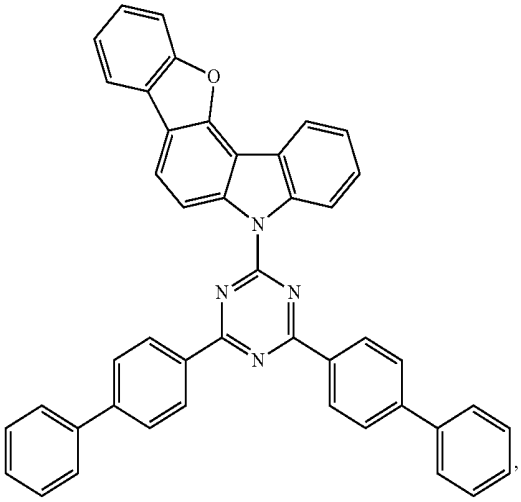
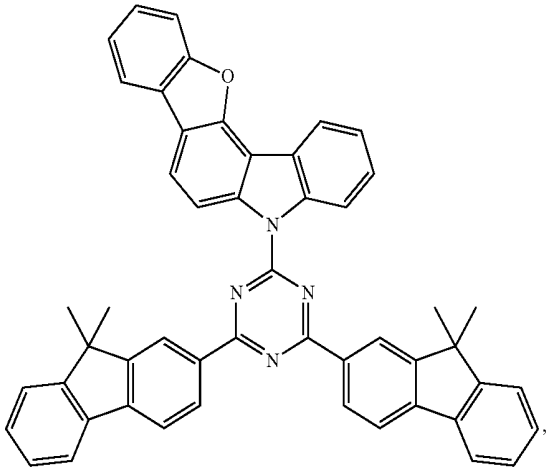
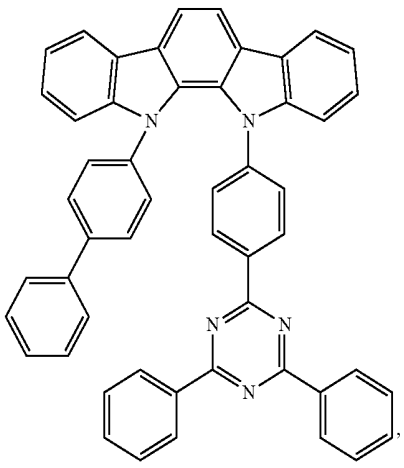
Compound E50



Compound E51



Compound E52



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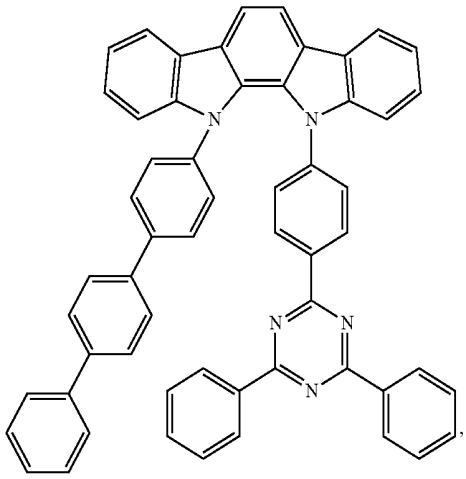
Compound E53



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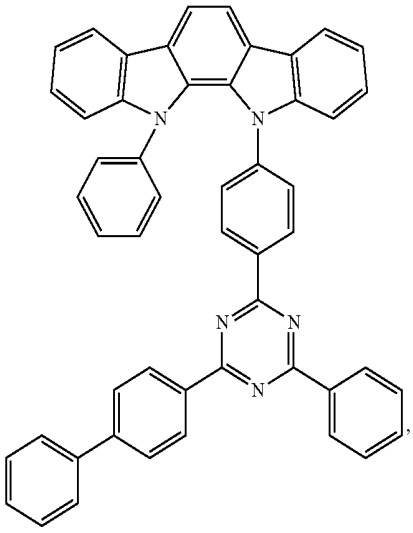

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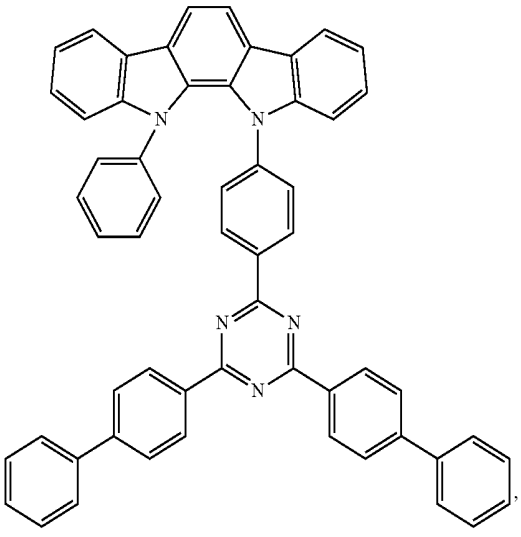

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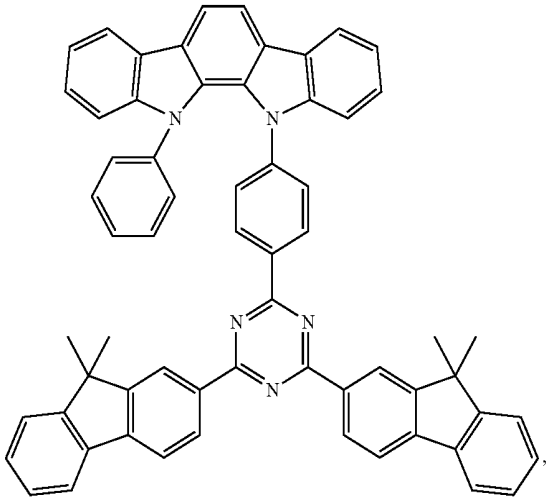

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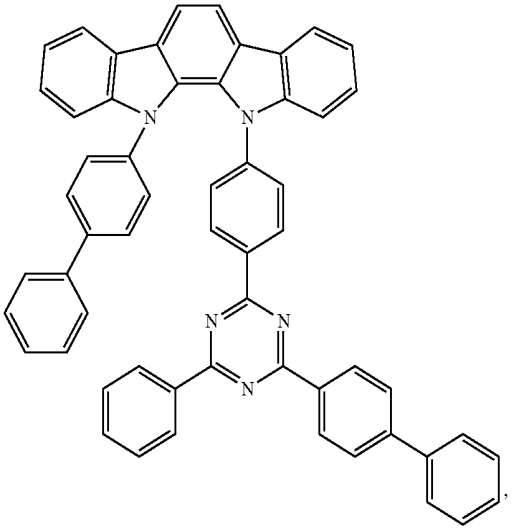

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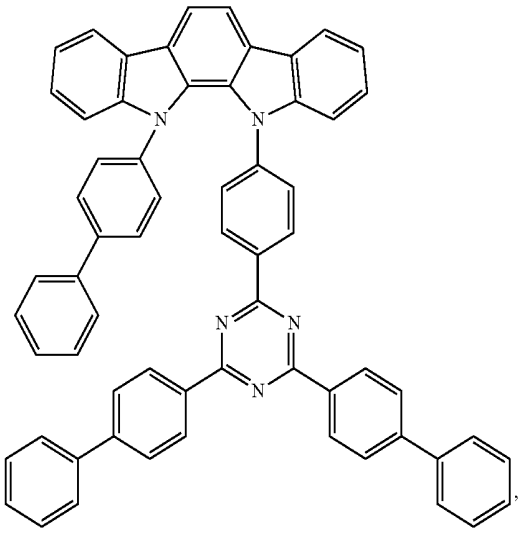

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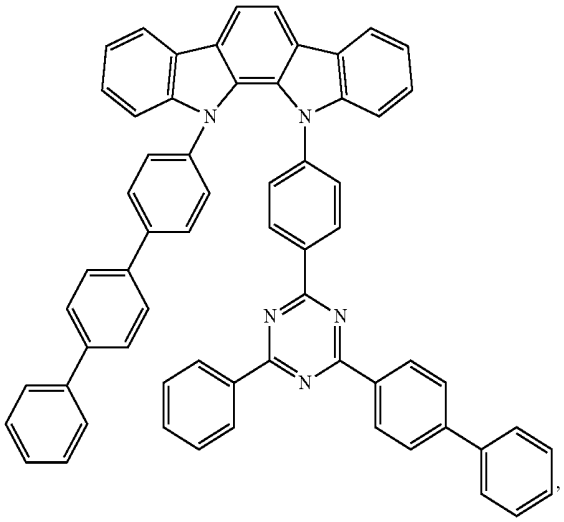

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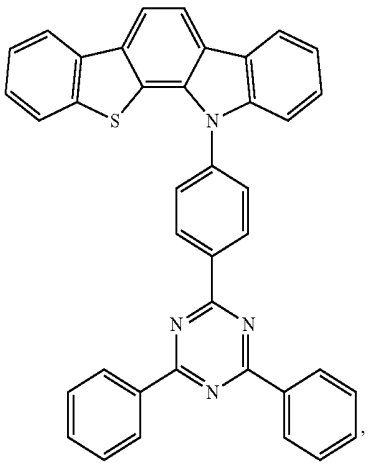
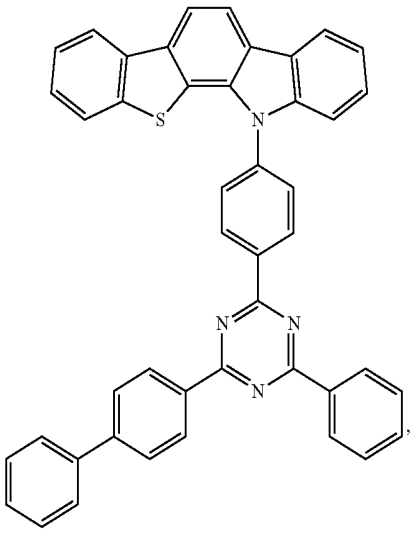


Compound E61



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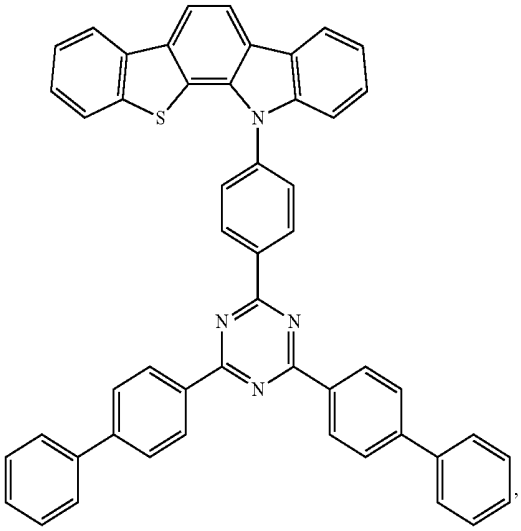

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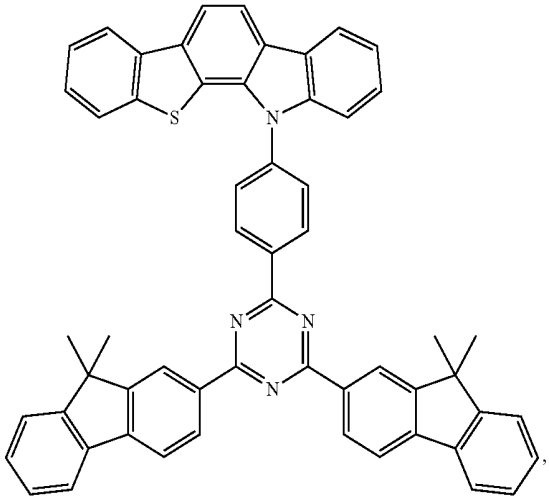

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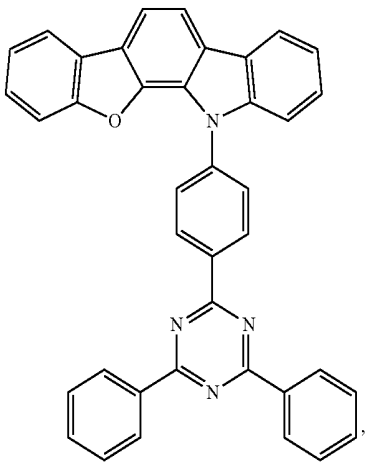

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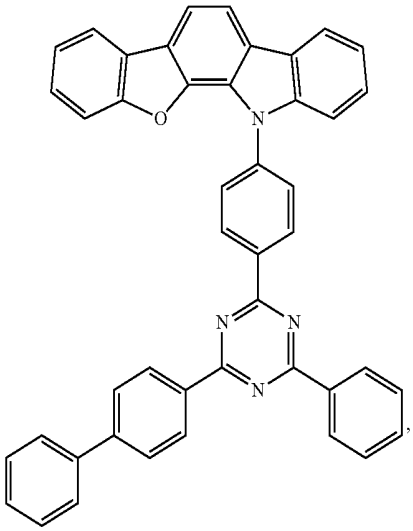

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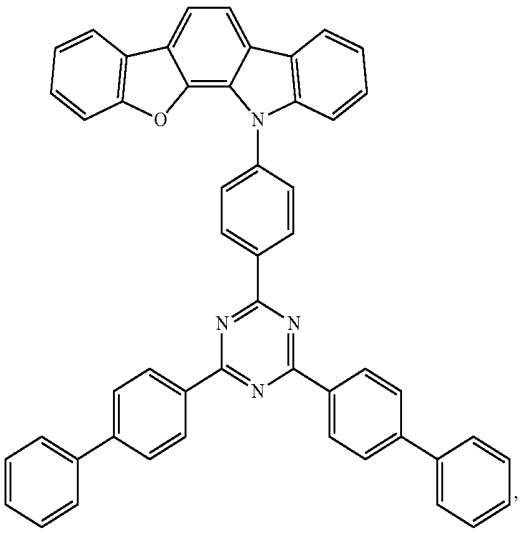

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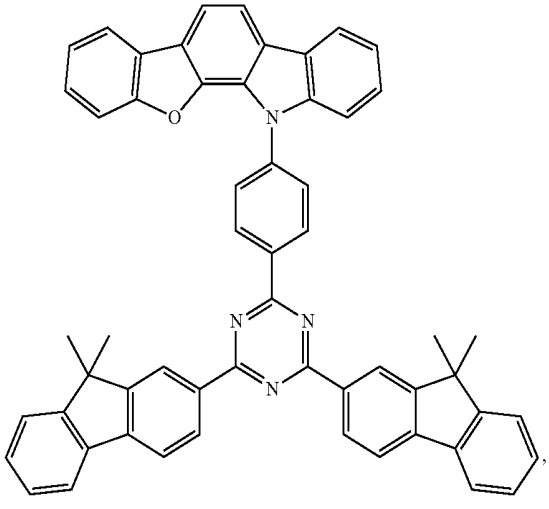

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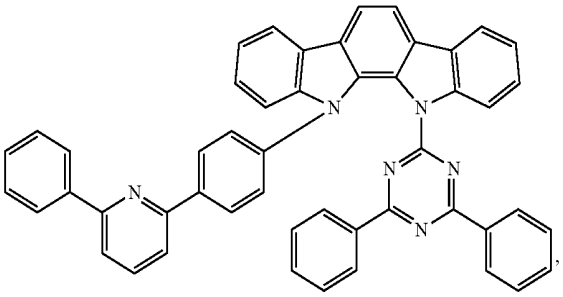

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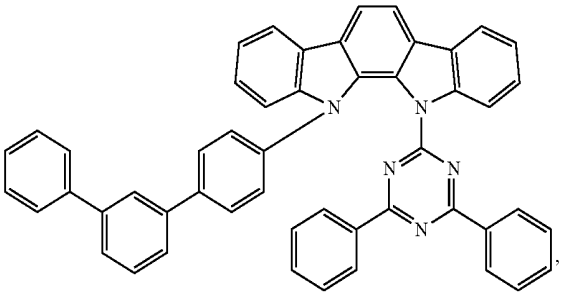

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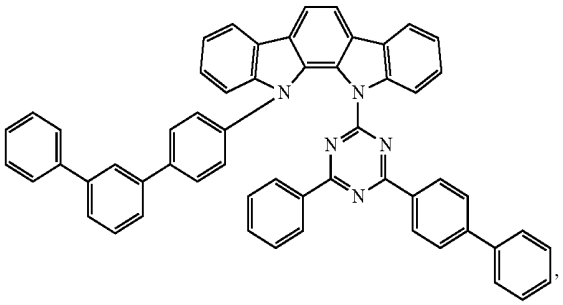

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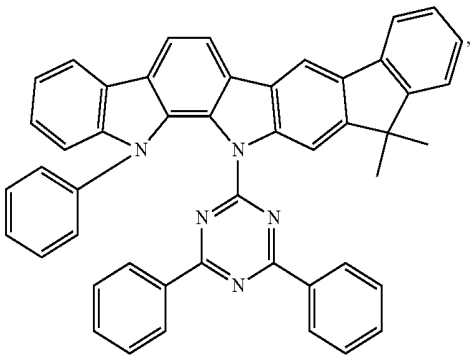

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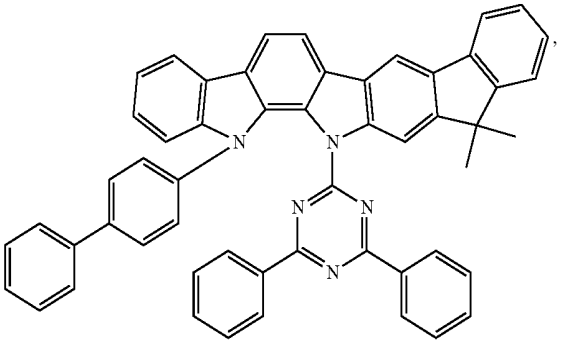

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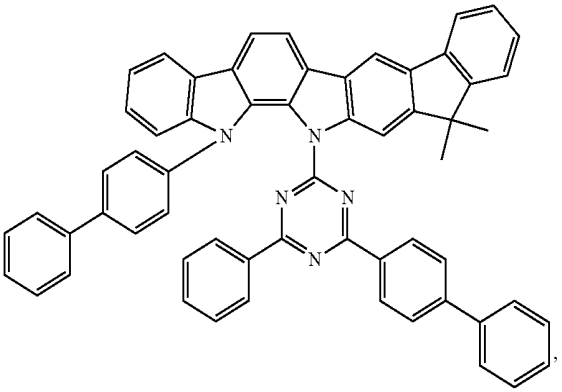

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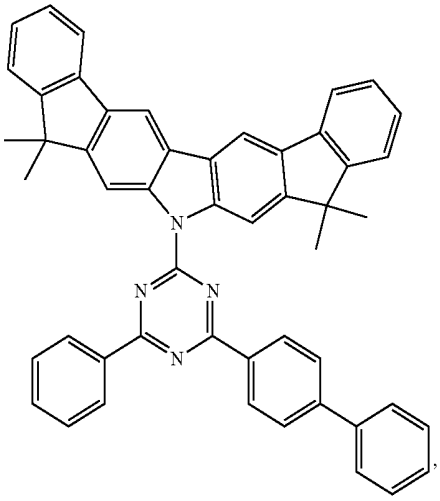

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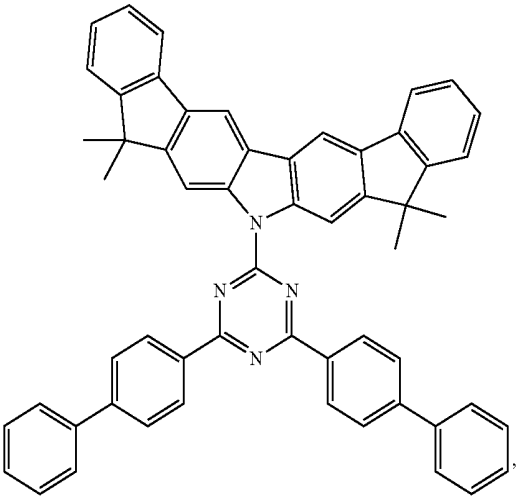

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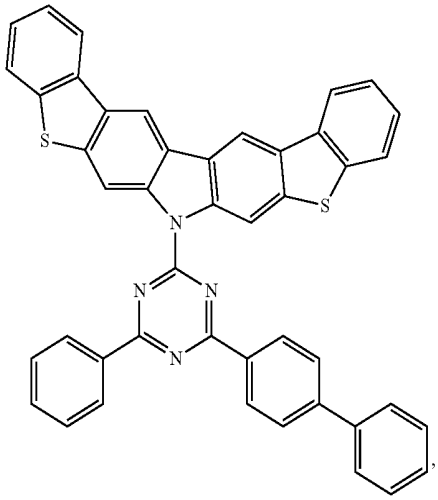

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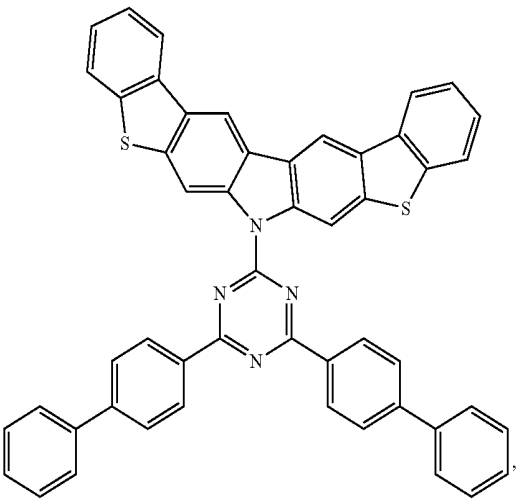

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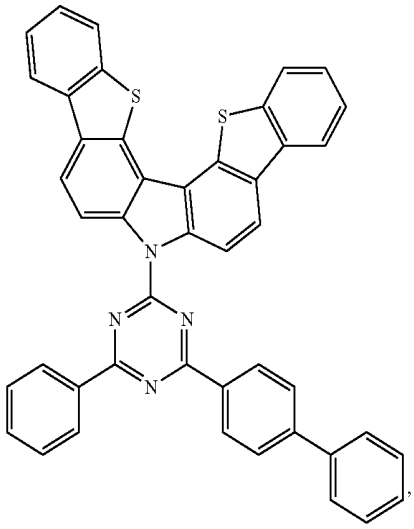

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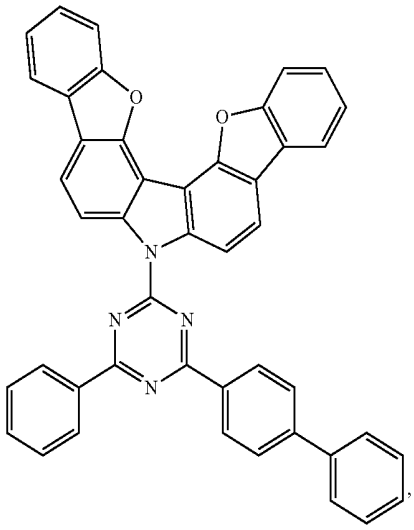

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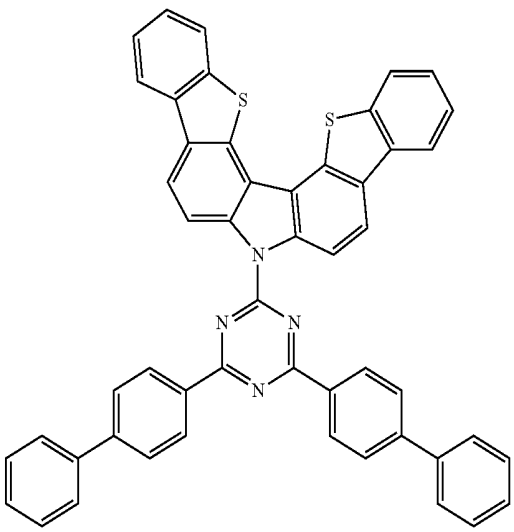

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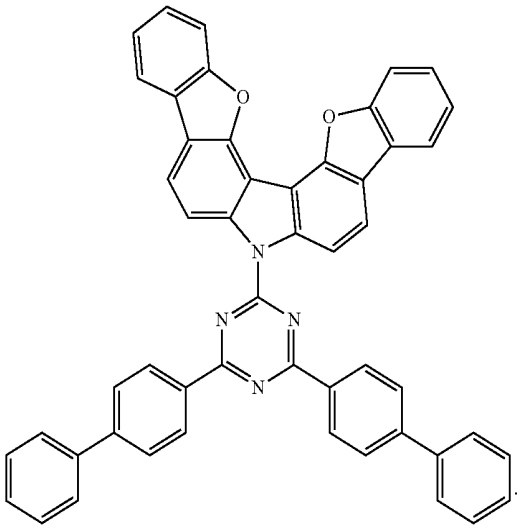
Compound E81



21. The composition of claim **1**, wherein the mixture of the first compound and the second compound is selected from the group consisting of: (Compound 2 and Compound E2), (Compound 3 and Compound E4), (Compound 1 and Compound E5), (Compound 6 and Compound E7), (Compound 7 and Compound E7), (Compound 9 and Compound E8), (Compound 17 and Compound E8), and (Compound 15 and Compound E18).

22. 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 mixture of a first compound and a second compound, wherein the first compound has a different chemical structure than the second compound;

wherein the first compound is capable of functioning as a hole transporting material in an organic light emitting device at room temperature;

wherein the first compound comprises at least one carbazole group;

wherein the first compound has evaporation temperature of T1 of 150 to 350° C.;

wherein the second compound has evaporation temperature of T2 of 150 to 350° C.;

wherein the absolute value of T1−T2 is less than 20° C.;

wherein the first compound has a concentration C1 in said mixture, and the first compound has a concentration C2 in a film formed by evaporating the mixture in a vacuum deposition tool at a constant pressure between 1×10^{-6} Torr to 1×10^{-9} Torr, that can produce a 2 Å/sec deposition rate on a surface positioned at a predefined distance away from the mixture being evaporated; and

wherein the absolute value of (C1−C2)/C1 is less than 5%.

23.-**30**. (canceled)

31. A method of fabricating an organic light emitting device comprising a first electrode, a second electrode, and a first organic layer disposed between the first electrode and the second electrode, wherein the first organic layer comprises a

first organic composition further comprising a first mixture of a first compound and a second compound, the method comprising:

providing a substrate having the first electrode disposed thereon;

depositing the first organic composition over the first electrode; and

depositing the second electrode over the first organic layer, wherein the first compound has a different chemical structure than the second compound;

wherein the first compound is capable of functioning as a hole transporting material in an organic light emitting device at room temperature;

wherein the first compound comprises at least one carbazole group;

wherein the first compound has evaporation temperature T1 of 150 to 350° C.;

wherein the second compound has evaporation temperature T2 of 150 to 350° C.;

wherein the absolute value of T1−T2 is less than 20° C.;

wherein the first compound has a concentration C1 in said mixture, and the first compound has a concentration C2 in a film formed by evaporating the mixture in a vacuum deposition tool at a constant pressure between 1×10^{-6} Torr to 1×10^{-9} Torr, at a 2 Å/sec deposition rate on a surface positioned at a predefined distance away from the mixture being evaporated; and

wherein absolute value of (C1−C2)/C1 is less than 5%.

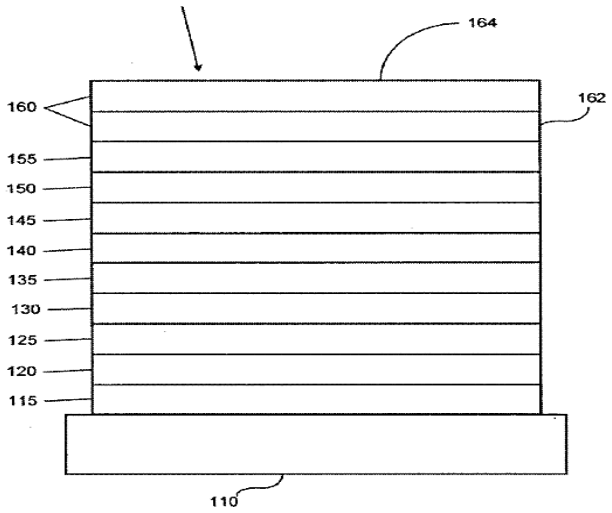
32.-**34**. (canceled)

* * * * *

专利名称(译)	有机电致发光材料和器件		
公开(公告)号	US20150053938A1	公开(公告)日	2015-02-26
申请号	US14/253471	申请日	2014-04-15
[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	ZENG LICHANG ADAMOVICH VADIM WANG TING CHIH XIA CHUANJUN WEAVER MICHAEL S YAMAMOTO HITOSHI ALLEYNE BERT		
发明人	ZENG, LICHANG ADAMOVICH, VADIM WANG, TING-CHIH XIA, CHUANJUN WEAVER, MICHAEL S. YAMAMOTO, HITOSHI ALLEYNE, BERT		
IPC分类号	H01L51/00 H01L51/56 H01L51/50		
CPC分类号	H01L51/0054 H01L51/0072 H01L51/56 H01L51/0071 H01L51/5056 H01L51/0067 H01L51/5016 H01L51/5072 H01L51/5096 H01L2251/5384		
优先权	61/867858 2013-08-20 US 61/874444 2013-09-06 US 61/920544 2013-12-24 US 61/940603 2014-02-17 US 61/894160 2013-10-22 US		
其他公开文献	US9831437		
外部链接	Espacenet USPTO		

摘要(译)

由第一化合物和第二化合物的第一混合物形成的组合物，其中第一化合物具有与第二化合物不同的化学结构;第一化合物能够在室温下用作有机发光器件中的空穴传输材料;第一化合物包含至少一个咔唑基团;第一化合物的蒸发温度T1为150至350℃。第二化合物的蒸发温度T2为150至350℃。 T1-T2的绝对值小于20°C。所述第一混合物中具有浓度C1的第一化合物，以及通过在真空沉积工具中在1×10 -6 Torr至1×10 -9 Torr，在距离被蒸发的混合物预定距离的表面上以2埃/秒的沉积速率;其中（C1-C2）/ C1的绝对值小于5%。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