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

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CPC ***H01L 51/0071*** (2013.01); ***C07D 345/00*** (2013.01); ***C07D 421/14*** (2013.01); ***C07F 5/027*** (2013.01); ***H01L 51/0061*** (2013.01); ***H01L 51/0067*** (2013.01); ***H01L 51/0069*** (2013.01); ***H01L 51/0072*** (2013.01); ***H01L 51/0085*** (2013.01); ***H01L 51/0087*** (2013.01); ***H01L 51/0088*** (2013.01); *H01L 51/506* (2013.01); *H01L 51/5012* (2013.01); *H01L 51/5016* (2013.01); *H01L 51/5076* (2013.01); *Y10S 428/917* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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(57) **ABSTRACT**

The present invention provides organoselenium compounds comprising dibenzoselenophene, benzo[b]selenophene or benzo[c]selenophene and their uses in organic light emitting devices.

15 Claims, 2 Drawing Sheets

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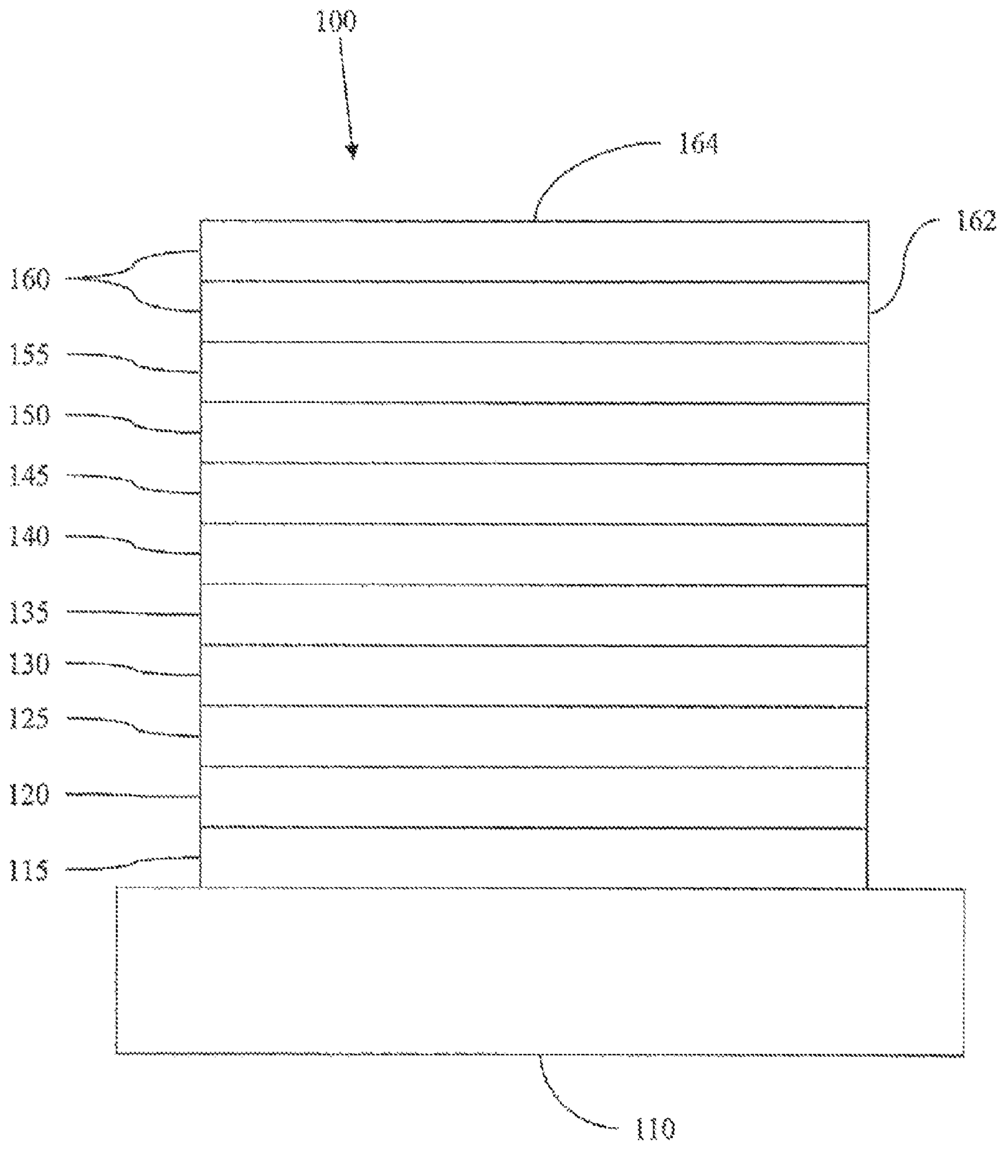


Figure 1

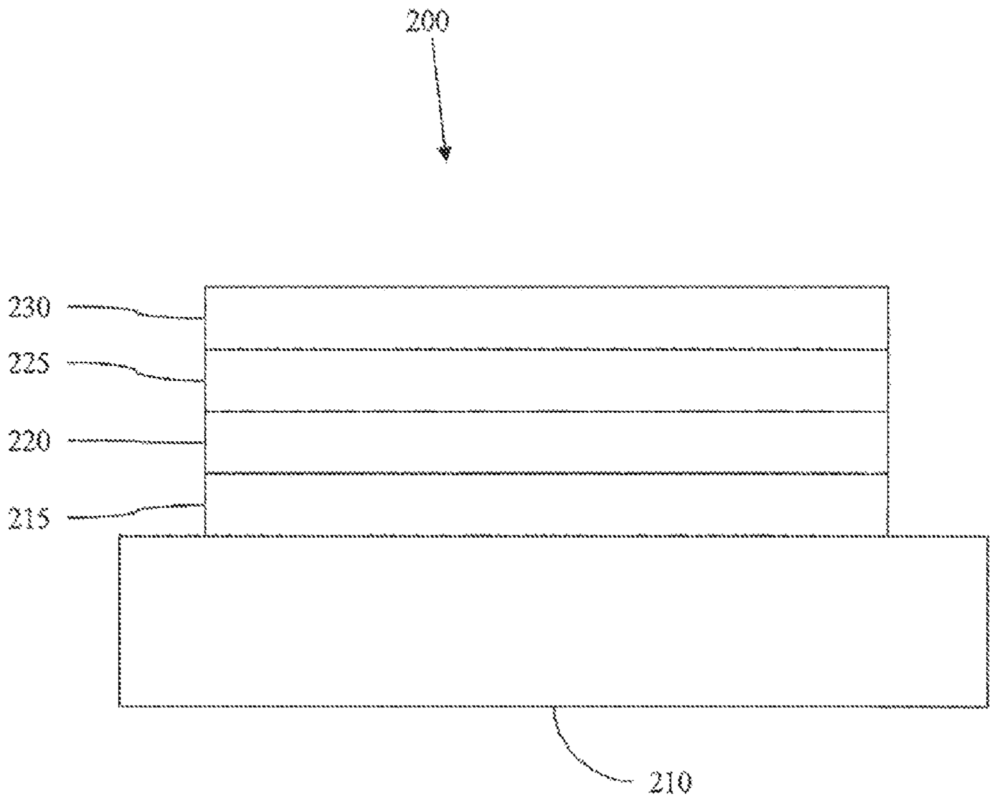


Figure 2

ORGANIC ELECTROLUMINESCENT MATERIALS AND DEVICES

RELATED APPLICATIONS

This application is a division of application Ser. No. 13/775,584, filed on Feb. 25, 2013, now U.S. Pat. No. 8,945,727, which is a continuation of application Ser. No. 12/565,966, filed on Sep. 24, 2009, now U.S. Pat. No. 8,426,035, which claims the benefit under 35 U.S.C. §119(e) of U.S. Provisional Application No. 61/100,229, filed Sep. 25, 2008; the contents of which are incorporated herein by reference in their entirety.

The claimed invention was made by, on behalf of and/or connection with one or more of the following parties to a joint university corporation research agreement: Regents of the University of Michigan, Princeton University. The 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 INVENTIONS

The present invention relates to organoselenium materials comprising dibenzoselenophene, benzo[b]selenophene or benzo[c]selenophene and their uses in organic light emitting devices.

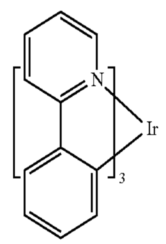
BACKGROUND

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.

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.

One application for phosphorescent emissive molecules is to full color display. Industry standards for such a display call for pixels adapted to emit particular colors, related 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.

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



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

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.

As used herein, "top" to 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 farther 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.

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.

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 omissive material, although an ancillary ligand may alter the properties of a photoactive ligand.

As used herein, and as would 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, as LUMO energy level corresponds to an electron affinity (EA) having a smaller absolute value (an EA that is loss 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.

As used herein, and as would be generally understood by one skilled in 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.

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

The present invention provides an organic light emitting device, comprising an organic layer positioned between an anode layer and a cathode layer. The organic layer comprises an organoselenium material selected from the group consisting of a compound comprising a dibenzoselenophene, a compound comprising a benzo[b]selenophene, and a compound comprising benzo[c]selenophene. Organoselenium compounds that can be used in the organic light emitting device of the invention are disclosed herein below. The invention also provides such organoselenium compounds.

In one embodiment, the organoselenium material is a host material, and the organic layer further comprises a dopant material. The dopant material can be a phosphorescent or fluorescent dopant material. In a preferred embodiment, the dopant material is a phosphorescent dopant material, such as any of the phosphorescent dopant material disclosed in Table 1 below.

In one embodiment, the organic light emitting device of the invention farther comprises one or more organic layers selected from the group consisting of a hole injecting layer, an electron injecting layer, a hole transporting layer, an electron transporting layer, a hole blocking layer, an exciton blocking layer, and an electron blocking layer.

In one embodiment, the hole transporting layer or the electron transporting layer comprises an organoselenium material.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows an organic light emitting device.

FIG. **2** shows an inverted organic light emitting device that does not have a separate electron transport layer.

DETAILED DESCRIPTION

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

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.

More recently, OLEDs having emissive materials that emit light from triplet states ("phosphorescence") have been demonstrated. Baido 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.

FIG. **1** shows an organic fight 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**, and a cathode **160**. 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.

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.sub.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.

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**.

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 different organic materials as described, for example, with respect to FIGS. **1** and **2**.

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.

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. patent application Ser. No. 10/233,470, 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 inkjet 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 bare 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 to the ability of small molecules to undergo solution processing.

Devices fabricated in accordance with embodiments of the invention may be incorporated into a wide variety of consumer products, including at panel displays, computer 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, mico-displays, vehicles, is 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.).

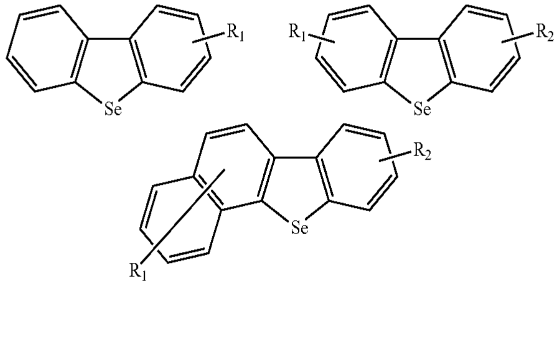
The materials and structures described herein may have applications in devices other than OLEDs. For example, other optoelectronic devices such as organic solar cells and organic photodetectors may employ the materials and structures. More generally, organic devices, such as organic transistors, may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

The terms halo, halogen, alkyl, cycloalkyl, alkenyl, alkynyl, arylkyl, heterocyclic group, aryl, aromatic group, and heteroaryl are known to the art, and are defined in U.S. Pat. No. 7,279,704 at cols. 31-32, which are incorporated herein by reference.

The present invention provides an organoselenium compound comprising dibenzoselenophene, benzo[b]selenophene and/or benzo[c]selenophene. The present invention also provides OLED devices in which such material is used, e.g., as a host material.

The organoselenium compound of the invention can comprise one, two, three, four or more a mixture moieties, benzo[b]selenophene moieties benzo[b]selenophene moieties or a mixture thereof. The dibenzoselenophene moieties, benzo[b]selenophene moieties, benzo[c]selenophene moieties or a mixture thereof can be linked directly or through one or more other molecular moieties.

In one embodiment, the organoselenium compound is selected from the groups consisting of



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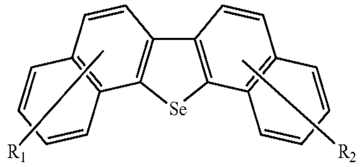

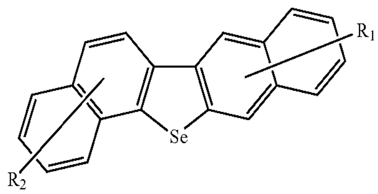

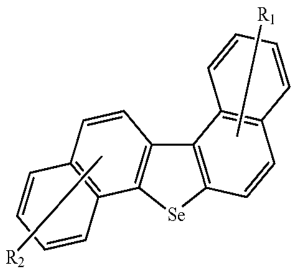

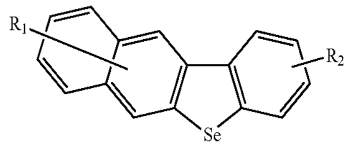

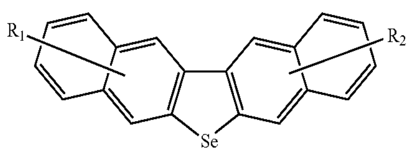

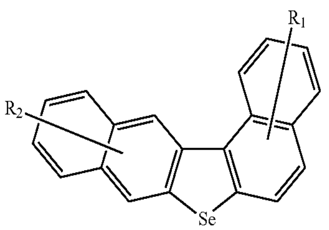

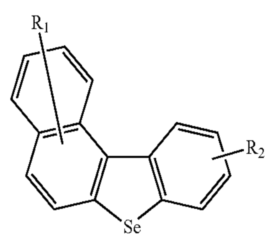

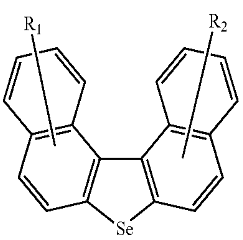

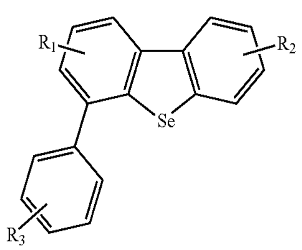

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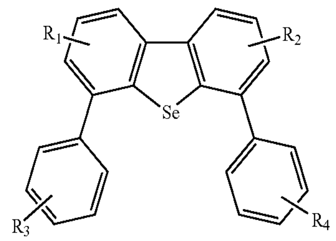

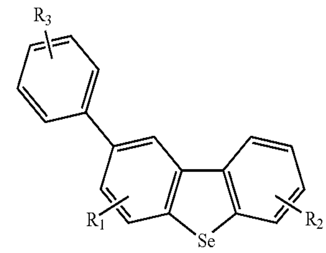

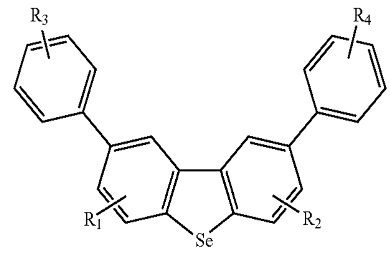

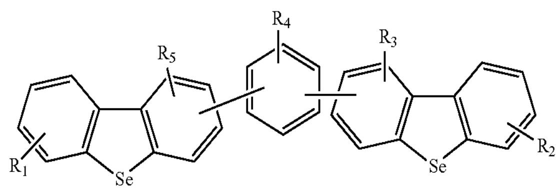

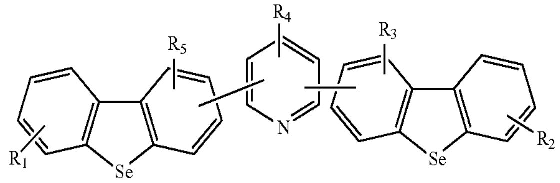

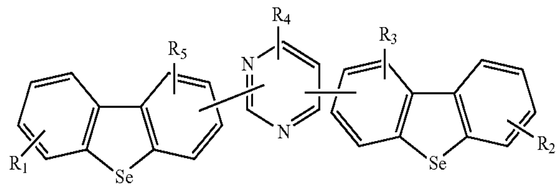

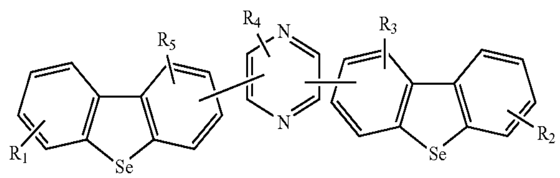

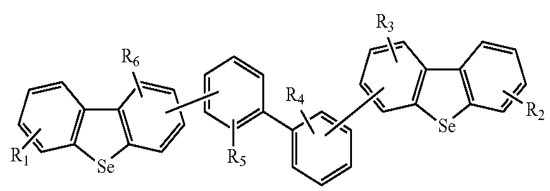

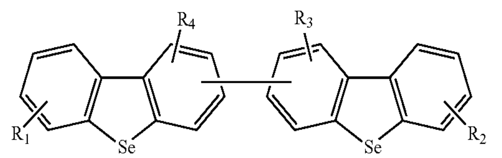

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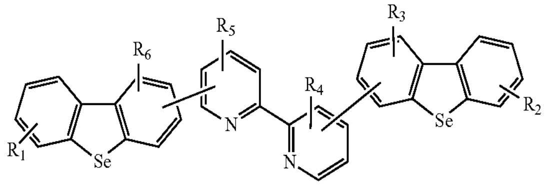

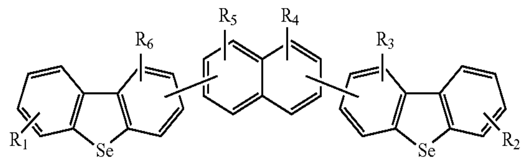

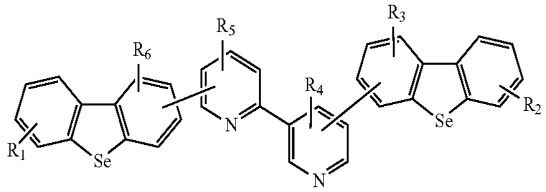

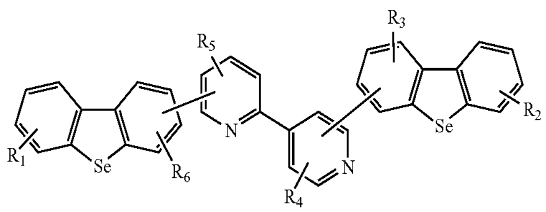

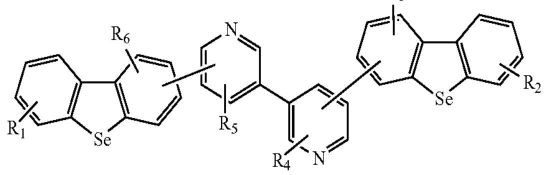

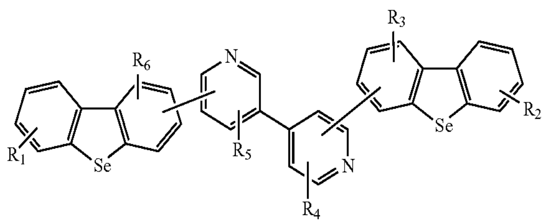

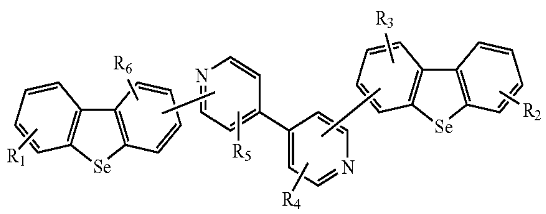

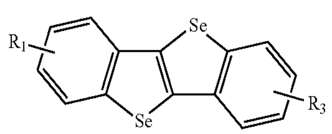

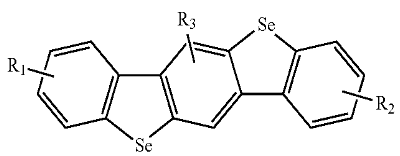

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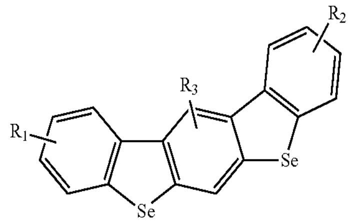

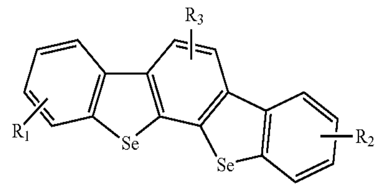

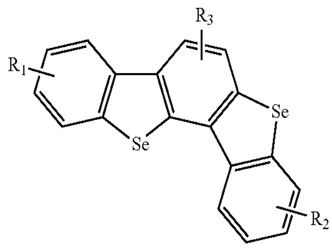

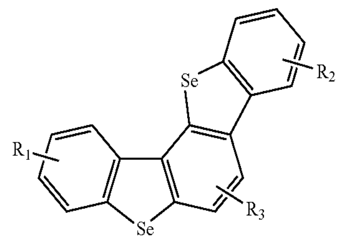

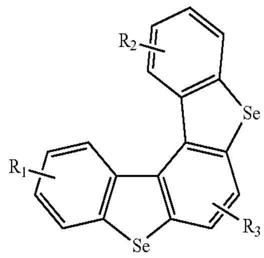

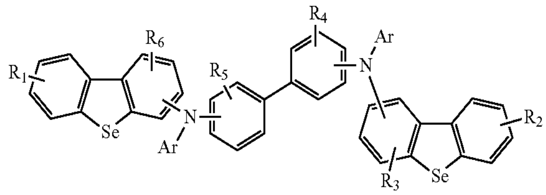

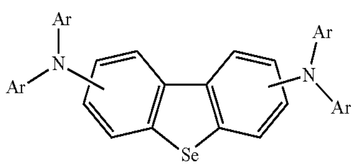

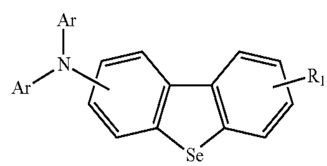

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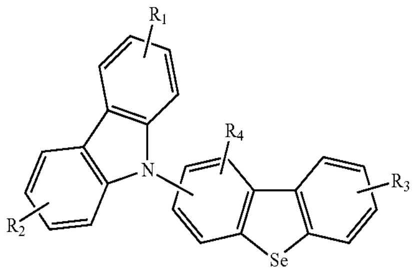

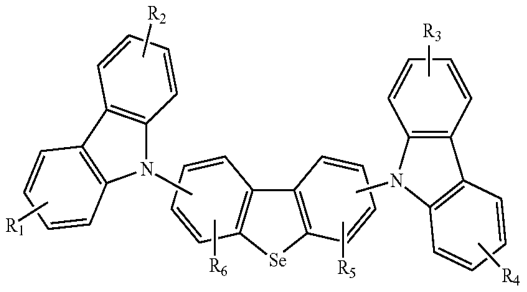

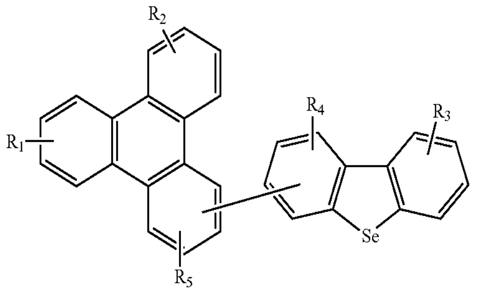

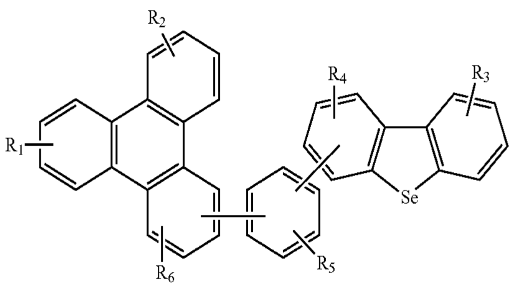

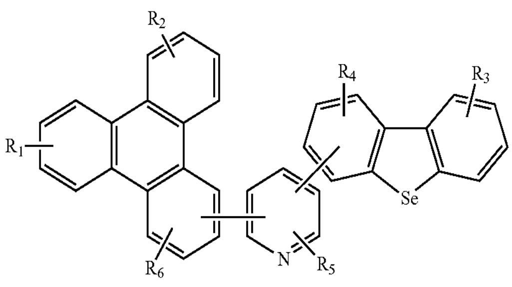

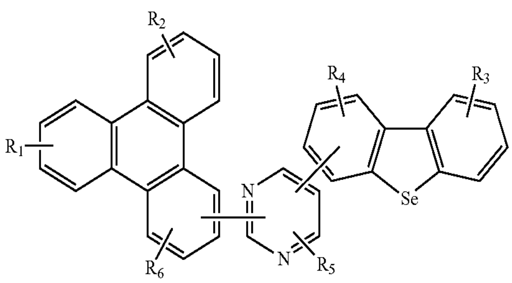

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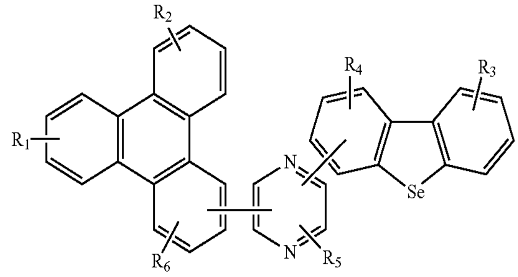

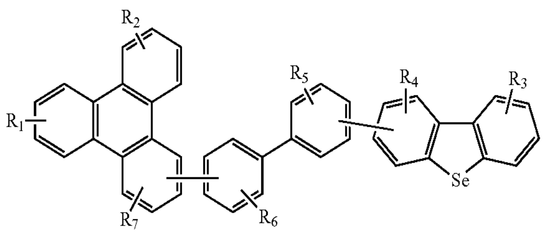

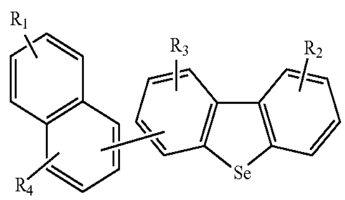

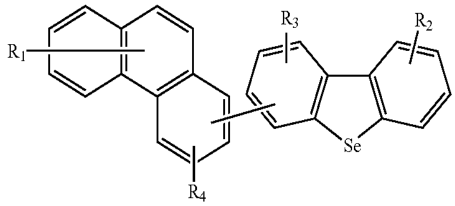

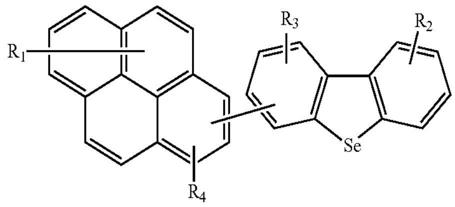

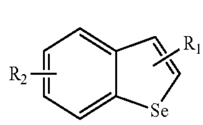

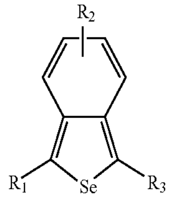

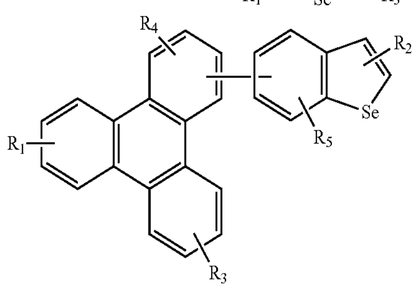

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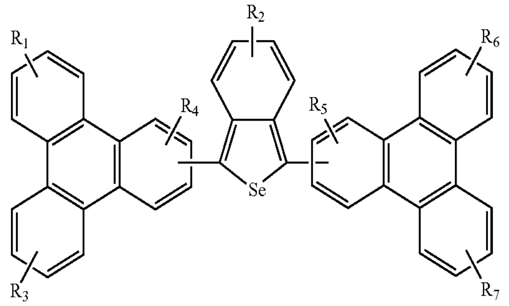
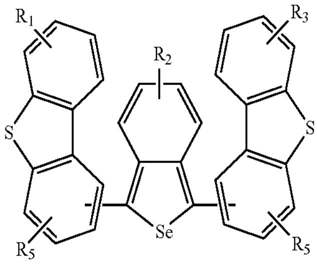


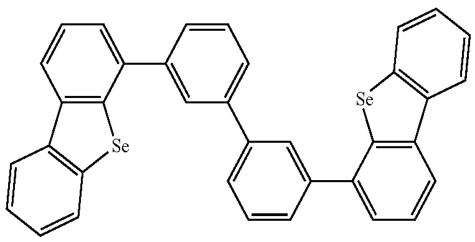


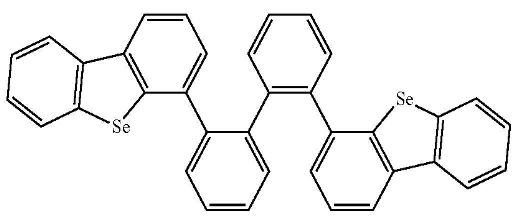
wherein each R_1, R_2, R_3, R_4, R_5, R_6 and R_7 indicates an optional substituent to any possible position in the relevant moiety. Ar indicates an aromatic group, and each line linking two molecular moieties indicates attachment between the two moieties at any possible positions on the respective moieties. Each R_1, R_2, R_3, R_4, R_5, R_6 and R_7 may represent multiple substitions

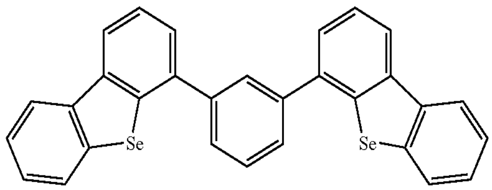
Suitable substituents include but are not limited to halo, alkyl, heteroalkyl, cycloalkyl, alkenyl, alkynyl, arylkyl, heterocyclic group, aryl, and heteroaryl. Preferably the substituent is selected from the group consisting of heterocyclic group, aryl, aromatic group, and heteroaryl. In one embodiment, the substituent is an aromatic group, including but not limited to benzene and substituted benzene; polyaromatic group such as benzocyclopropene, benzocyclopropane, benzocyclobutadiene, and benzocyclobutene, naphthalene, anthracene, tetracene, pentacene, phenanthrene, triphenylene, belicnes, corannulene, azulene, acenaphthylene, fluorene, chrysene, fluoranthene, pyrene, benzopyrene, coronene, hexacene, picene, perylene; and heteroaromatic group such as furan, benzofuran, isobenzofuran, pyrrole, indole, isoindole, thiophene, benzothiophene, benzo[c]thiophene, imidazole, benzimidazole, purine, pyrazole, indazole, oxazole, benzoxazolo, isoxazole, benzisoxazole, thiazole, benzothiazole, pyridine, quinoline, isoquinoline, pyrazine, quinoxaline, acridine, pyrimidine, quinazoline, pyridazine, cinnoline; and derivatives thereof.

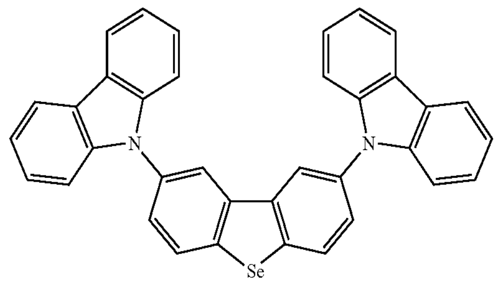
The linkage between two molecular moieties as indicated by the line linking the two molecular moieties can be a single bond or multiple bonds. In one embodiment, the linkage is a single bond between two atoms in respective molecular moieties. In another embodiment, the linkage is via multiple bonds, e.g., via a used ring.

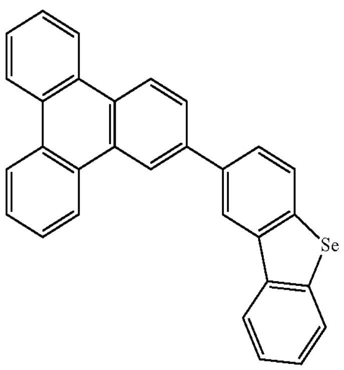
In another embodiment, the invention provides an organoselenium compound selected from the group consisting of:

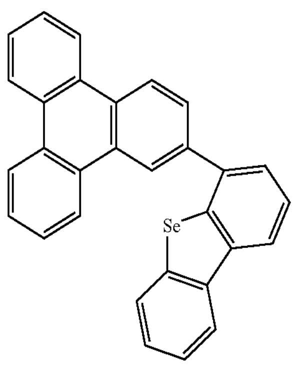


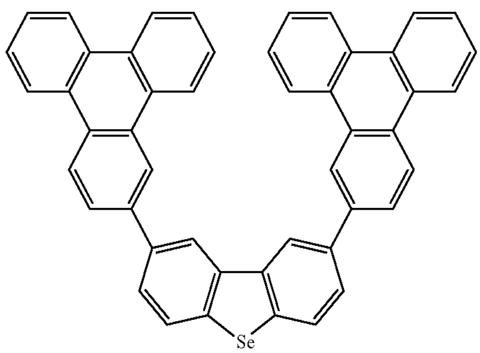












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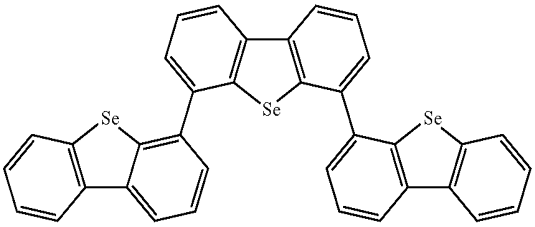

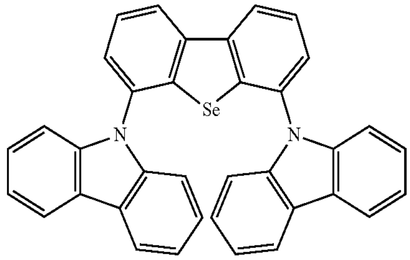

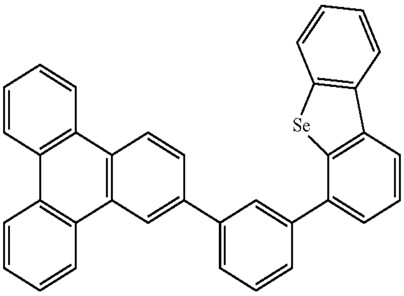

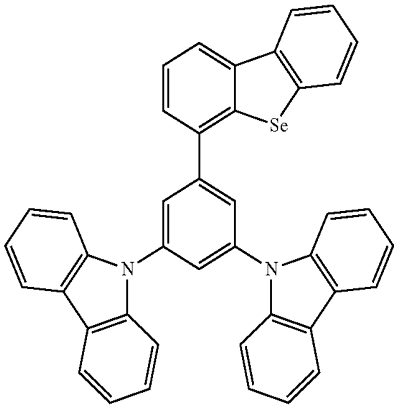

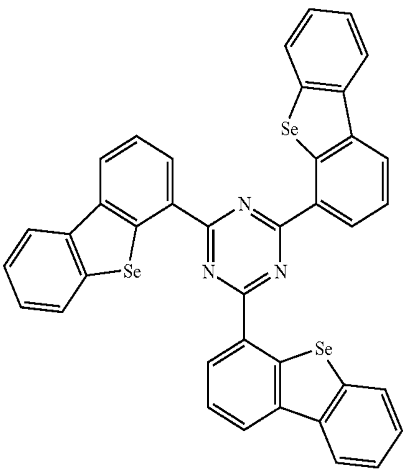

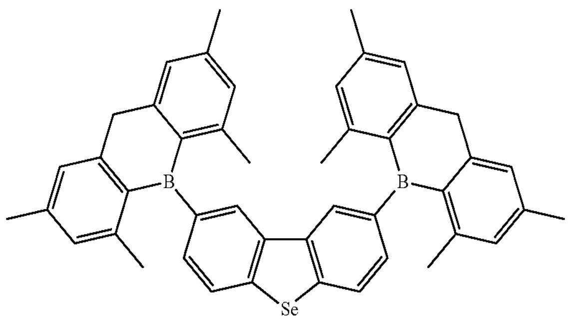

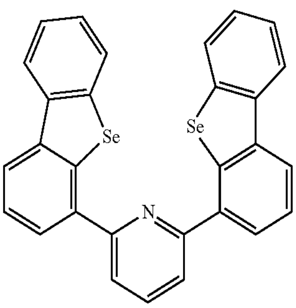

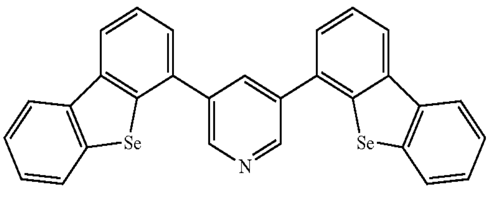

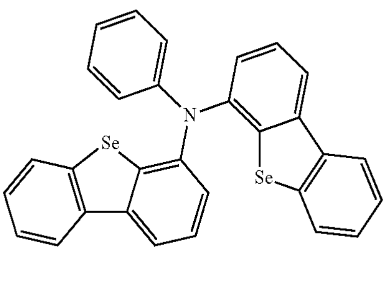

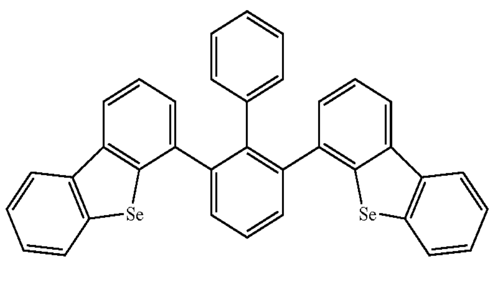

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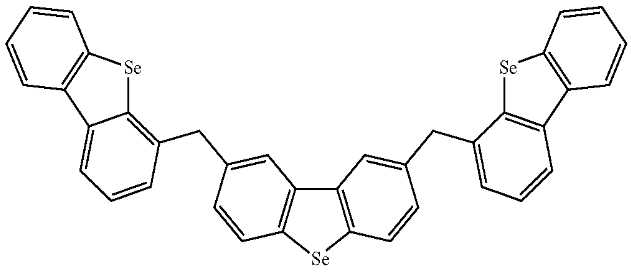

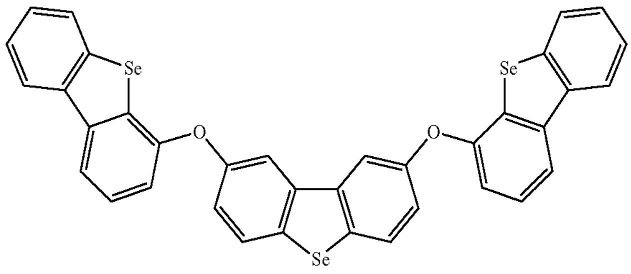

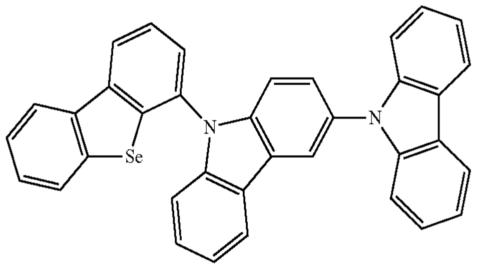

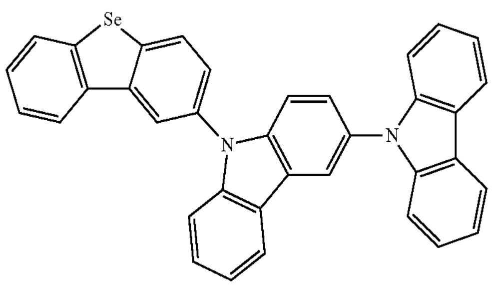

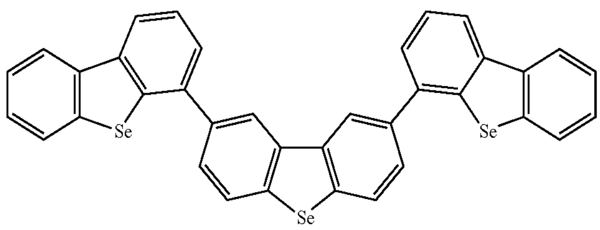

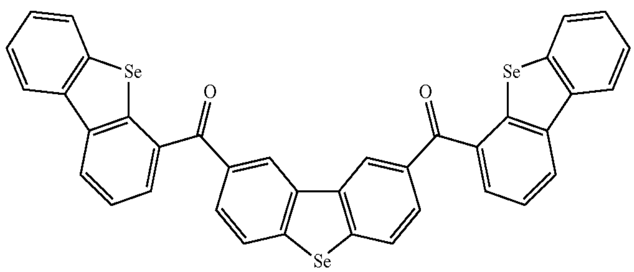

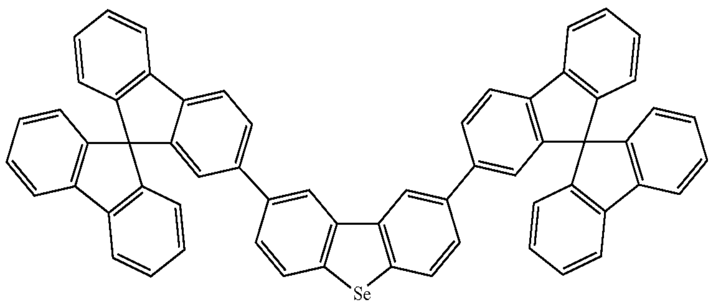

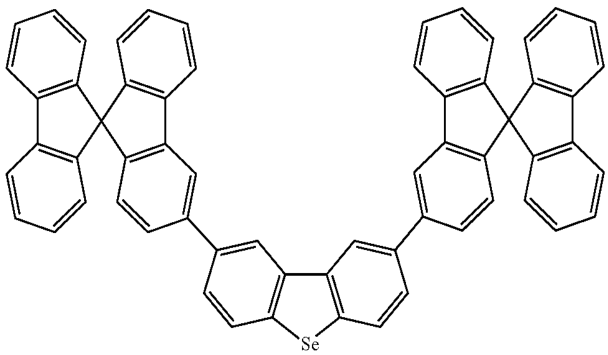

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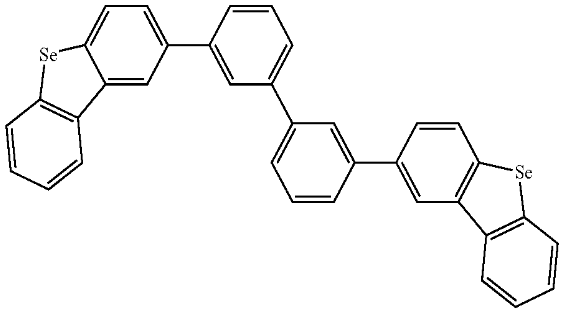

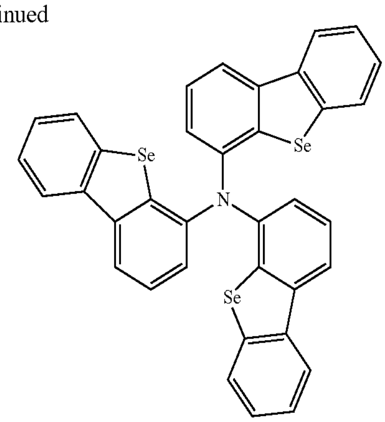

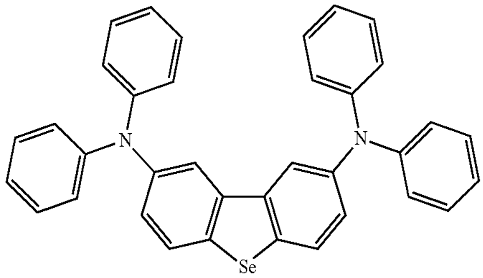

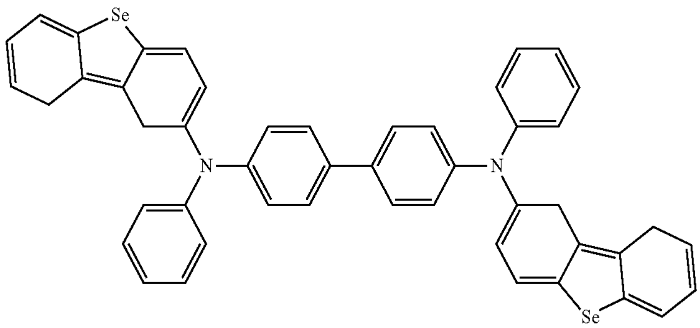

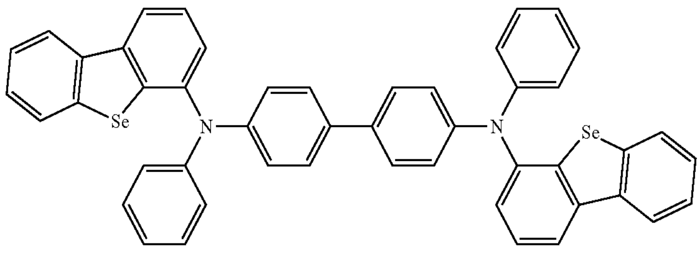

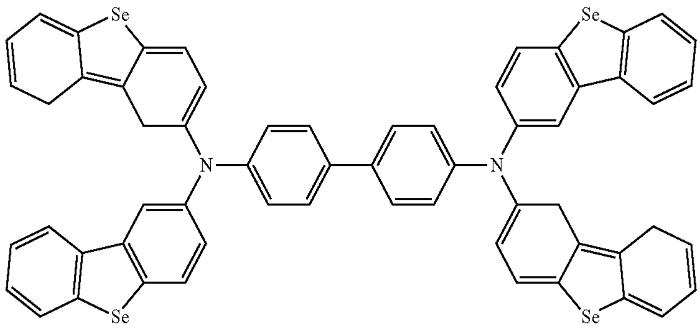

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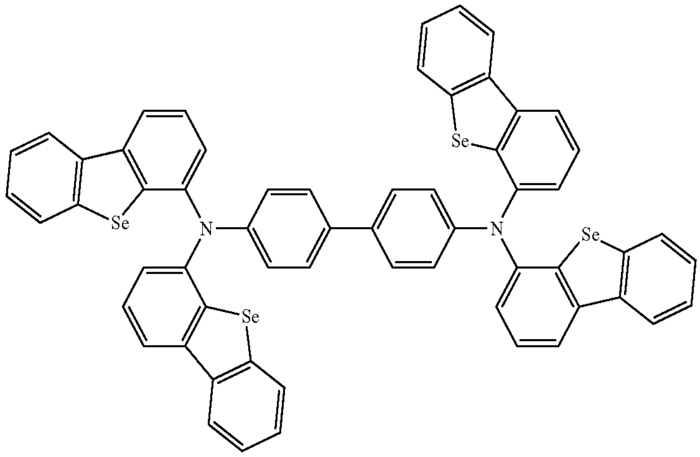

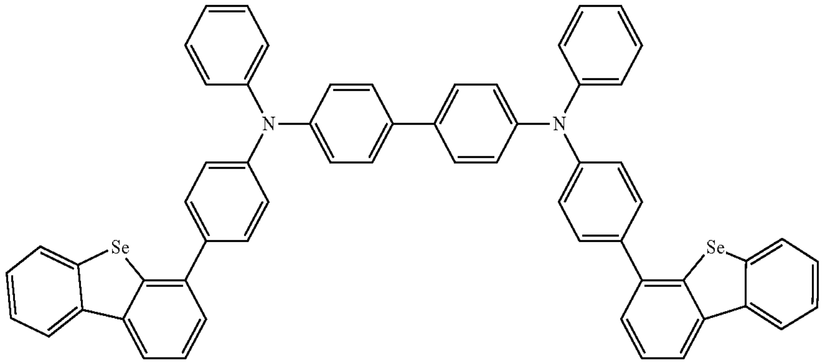

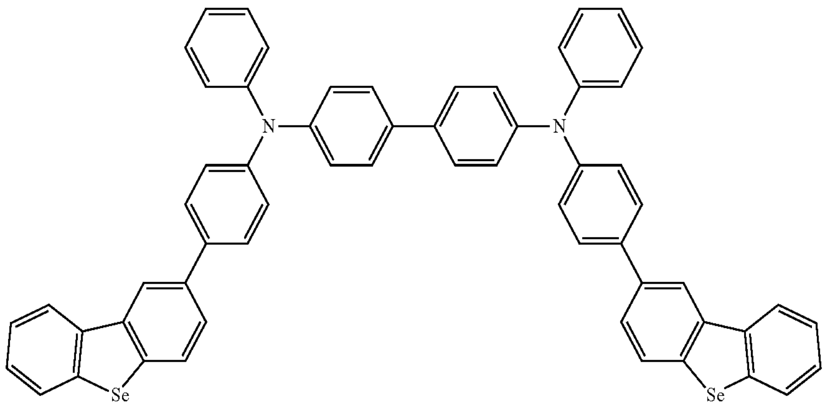

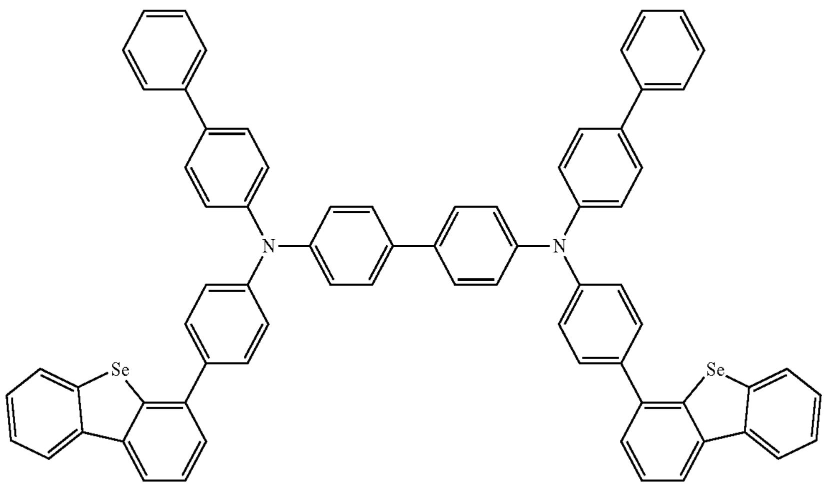

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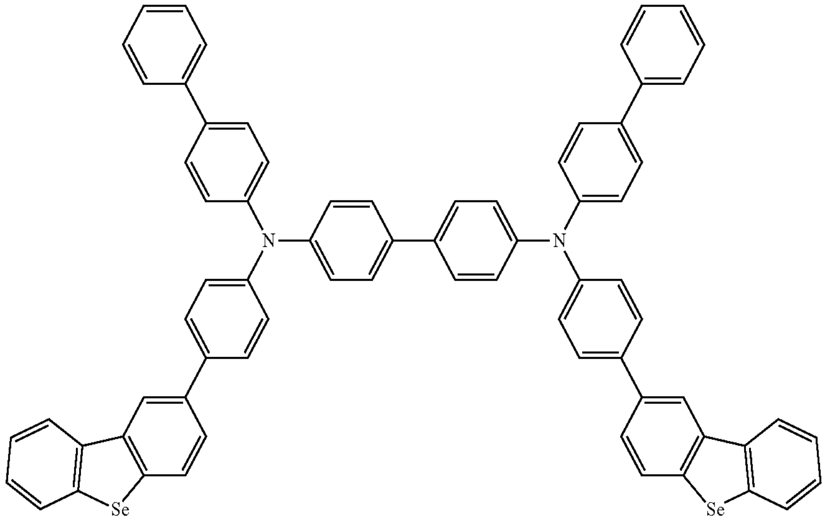

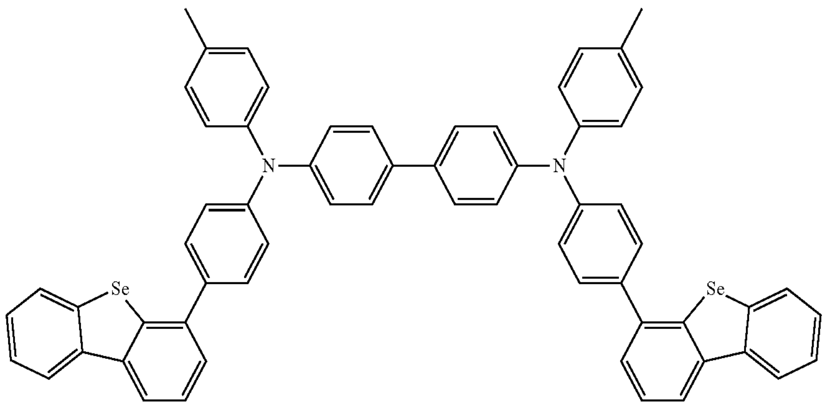

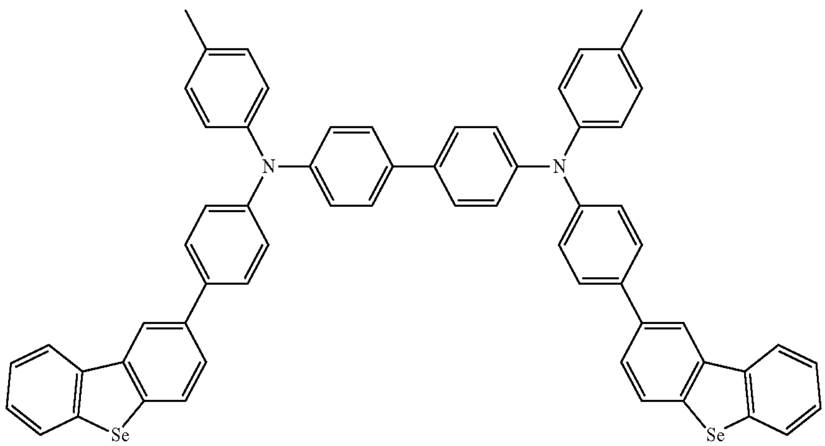

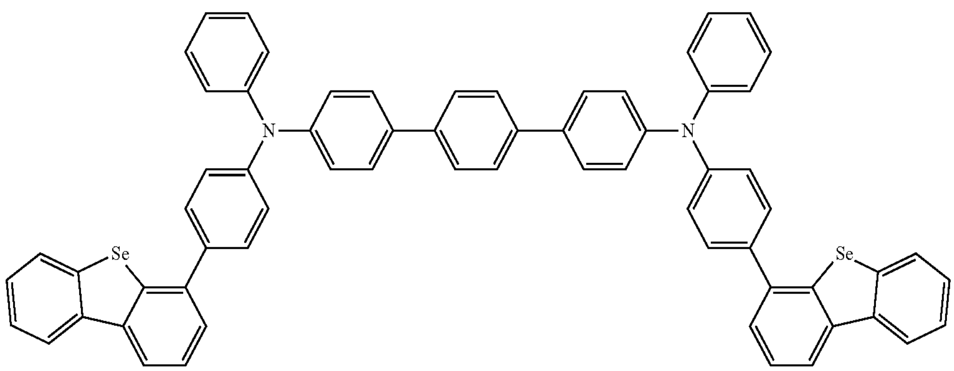

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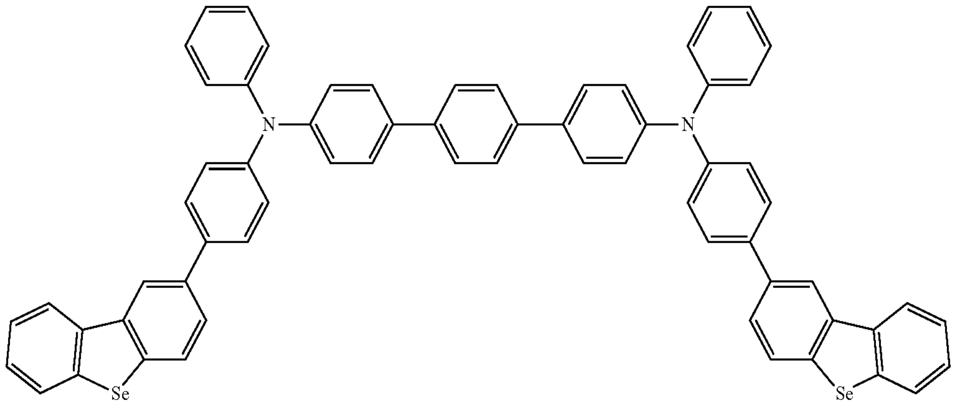

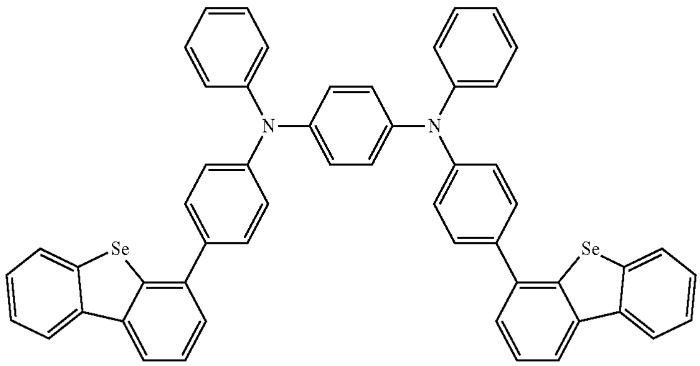

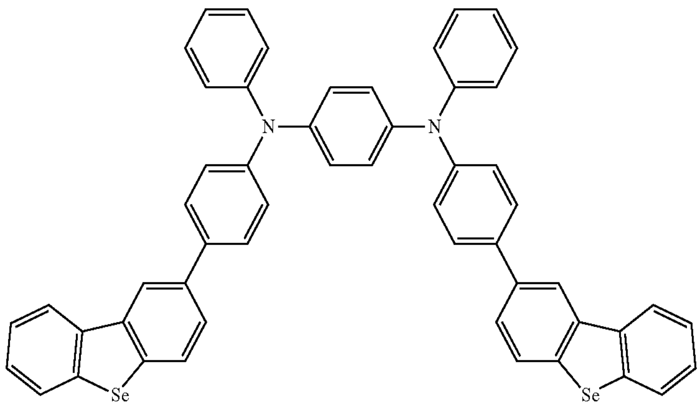

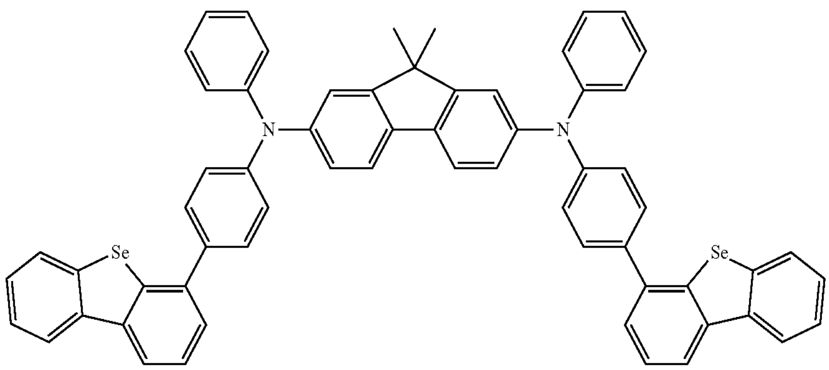

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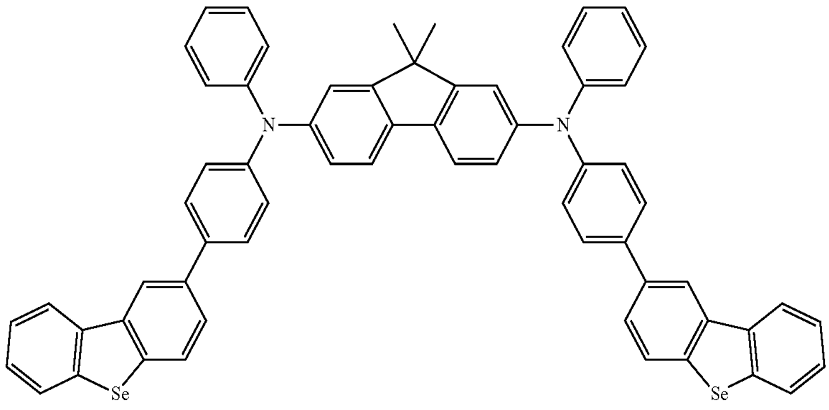

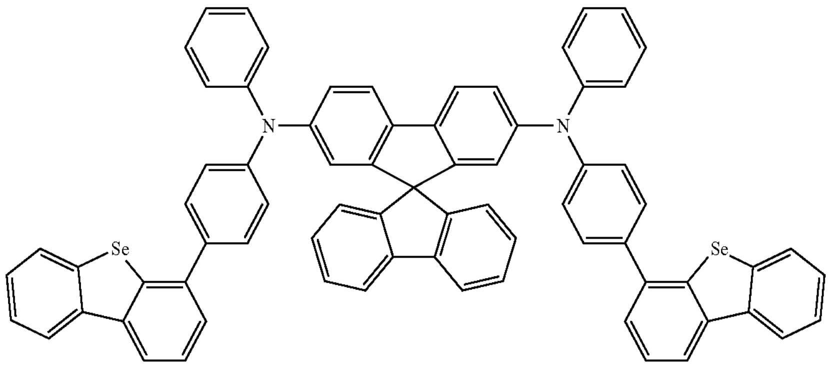

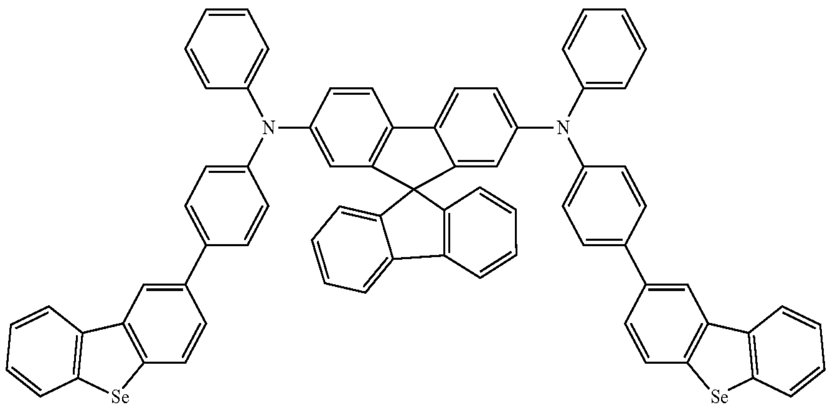

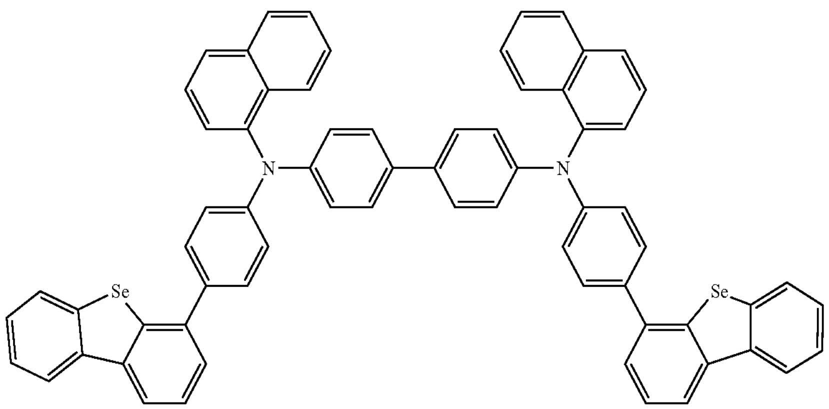

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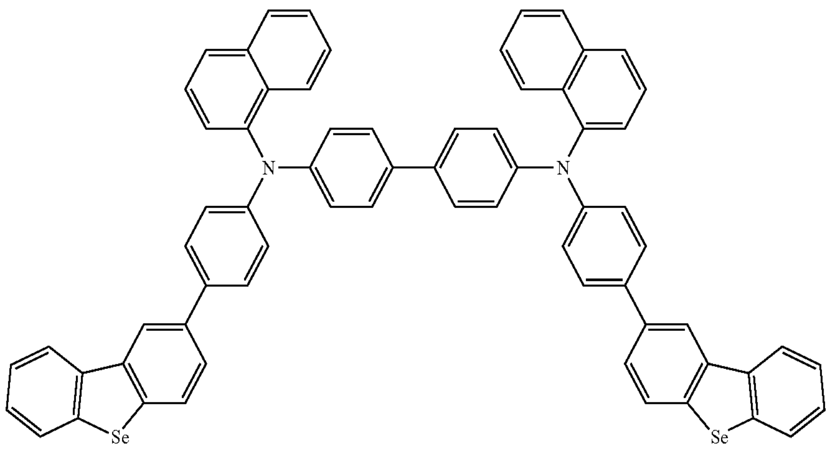

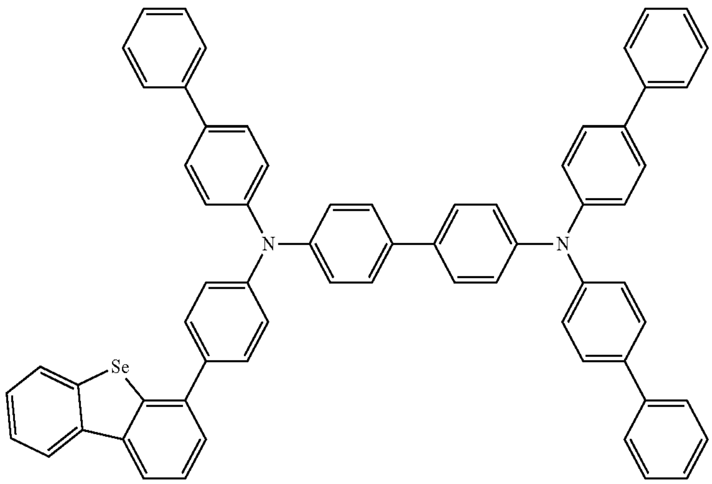

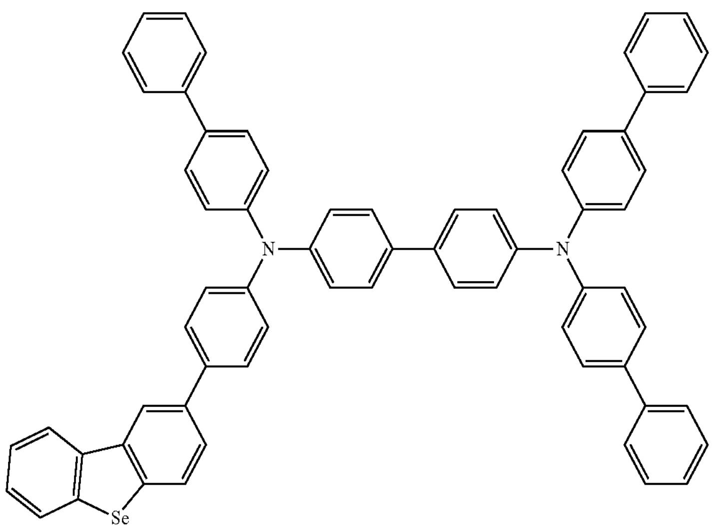

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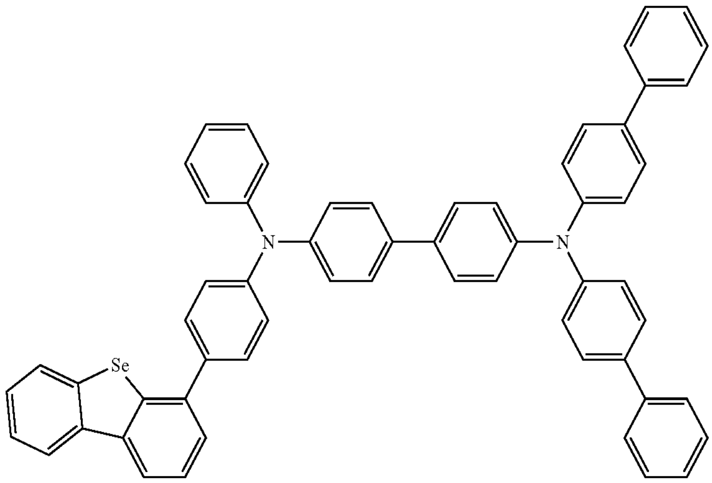

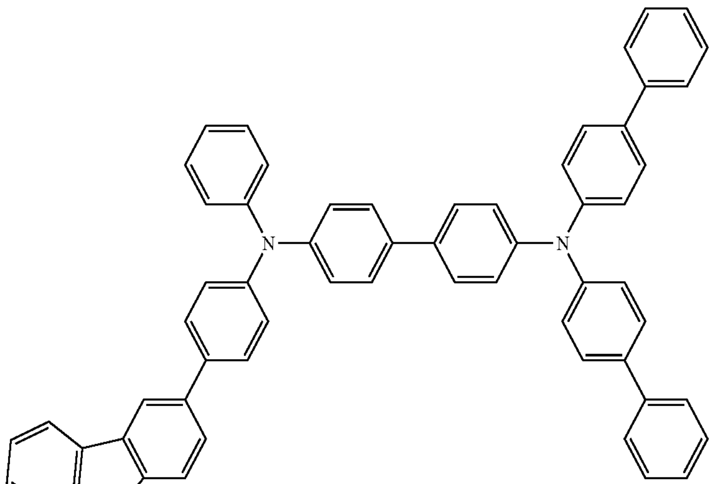

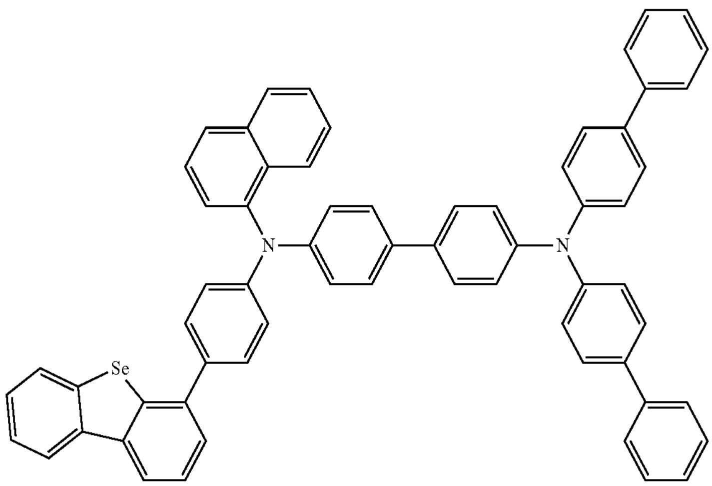

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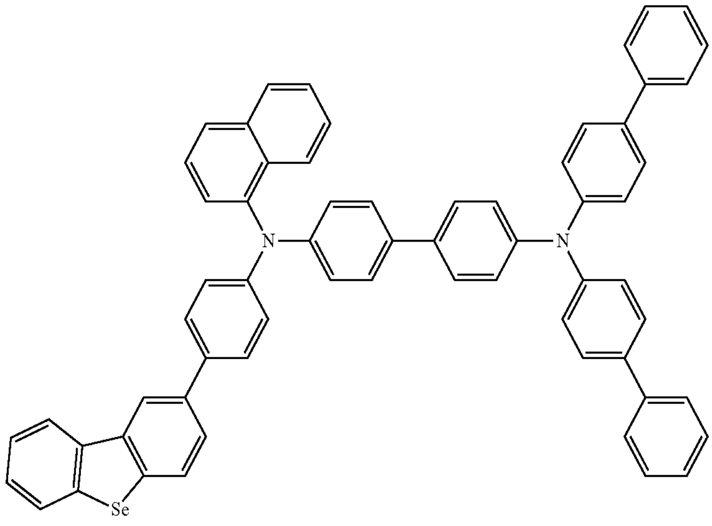

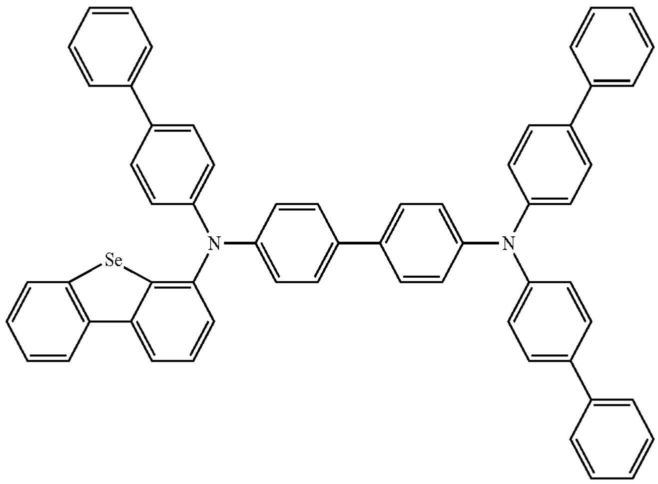

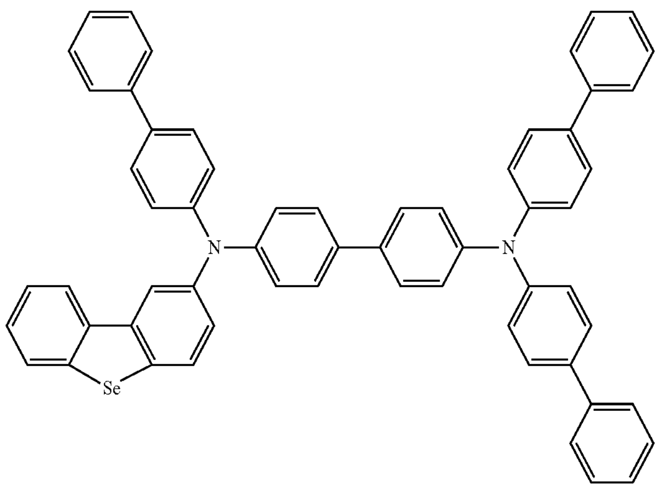

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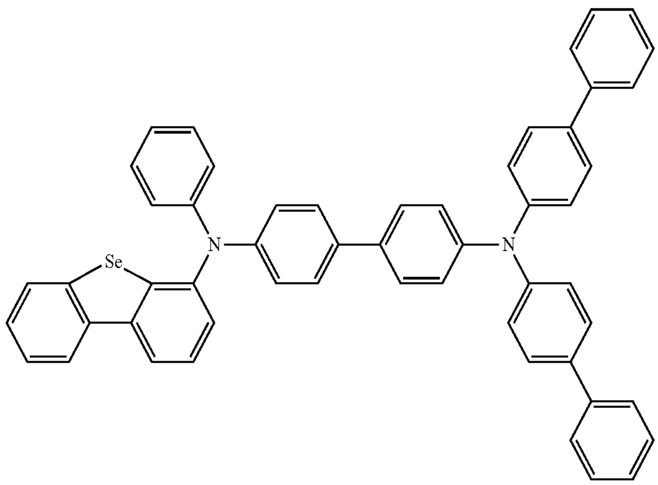

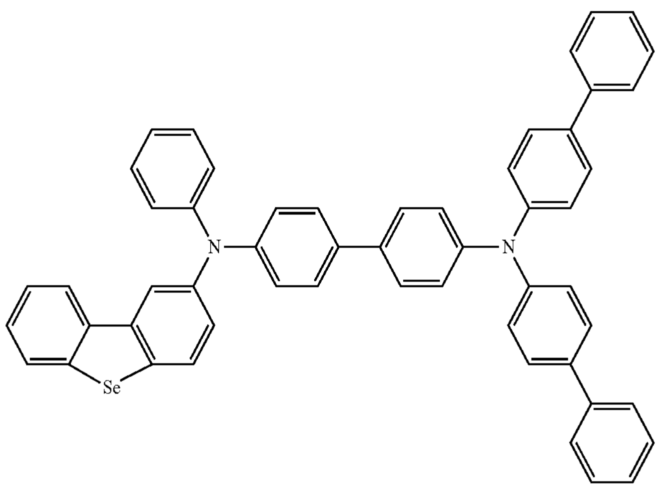

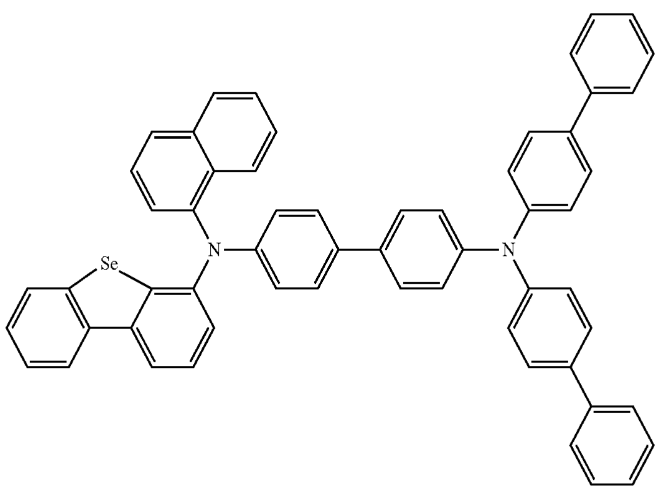

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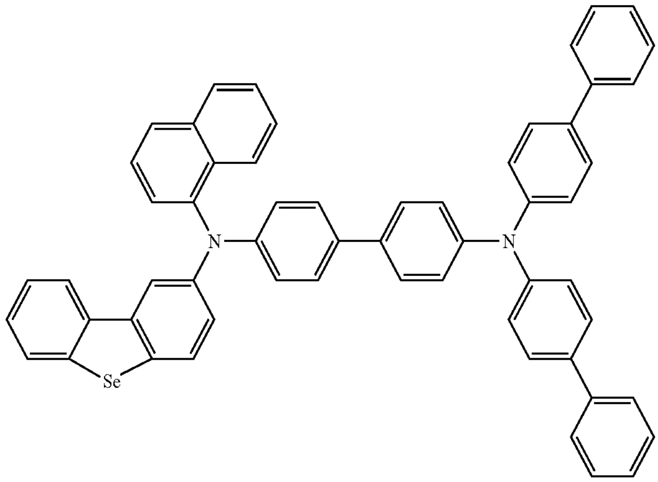

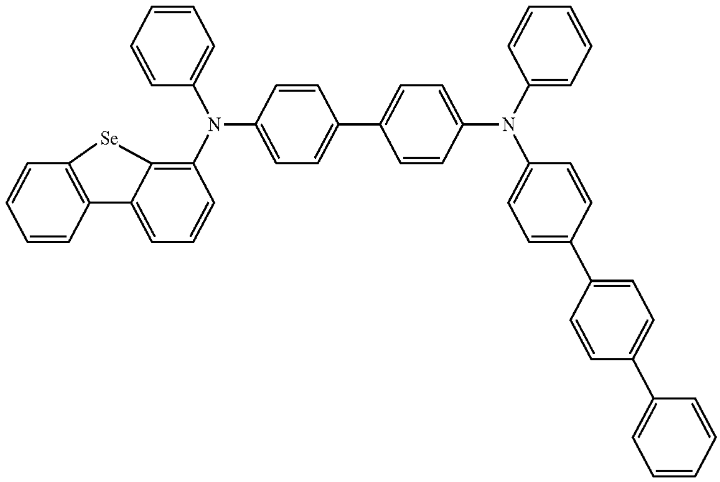

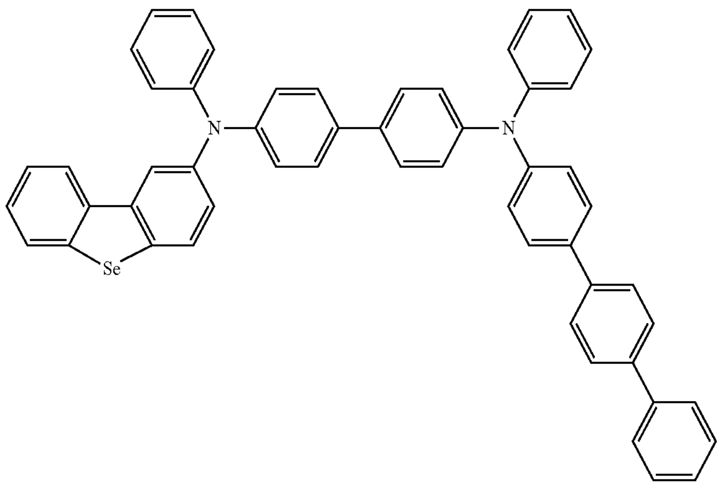

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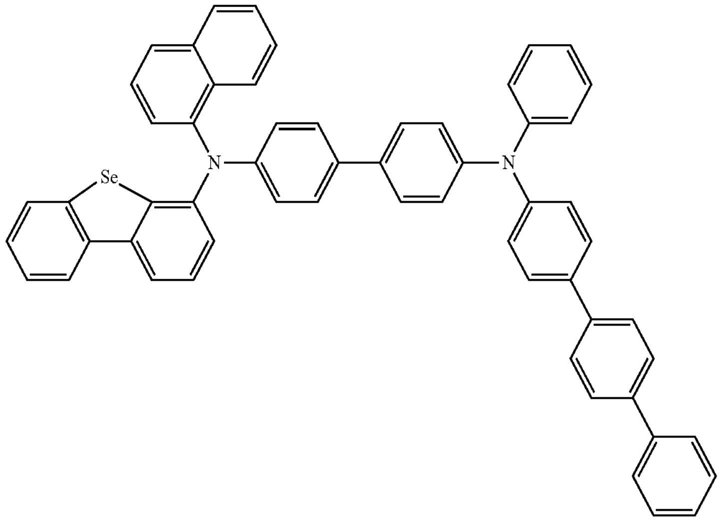

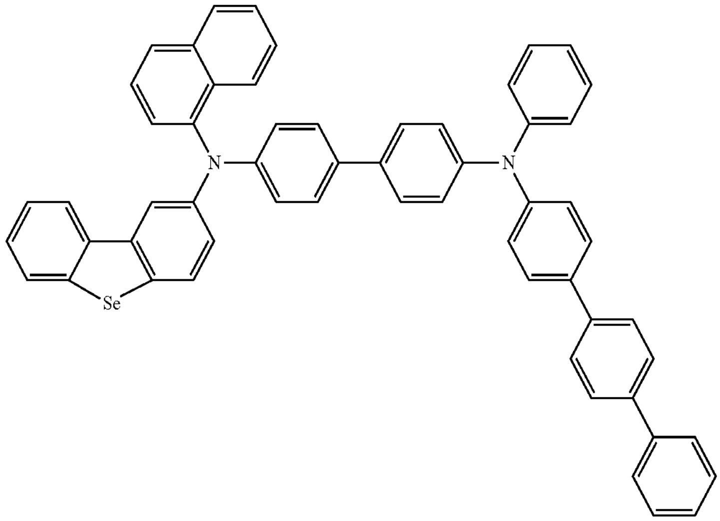

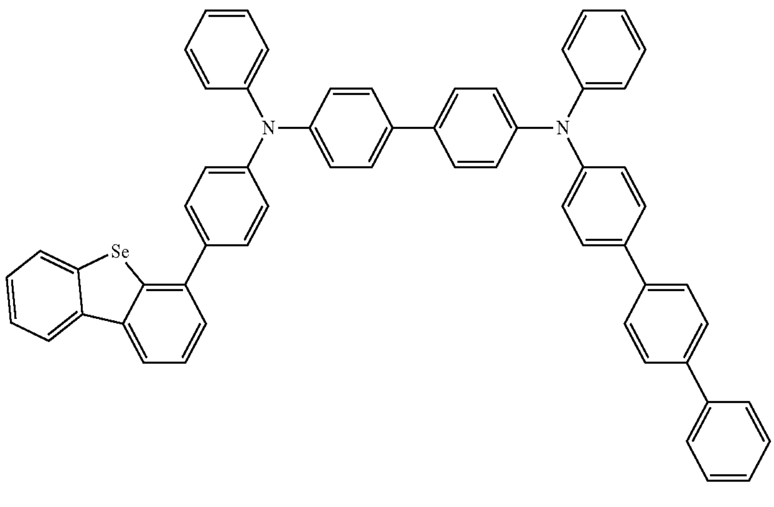

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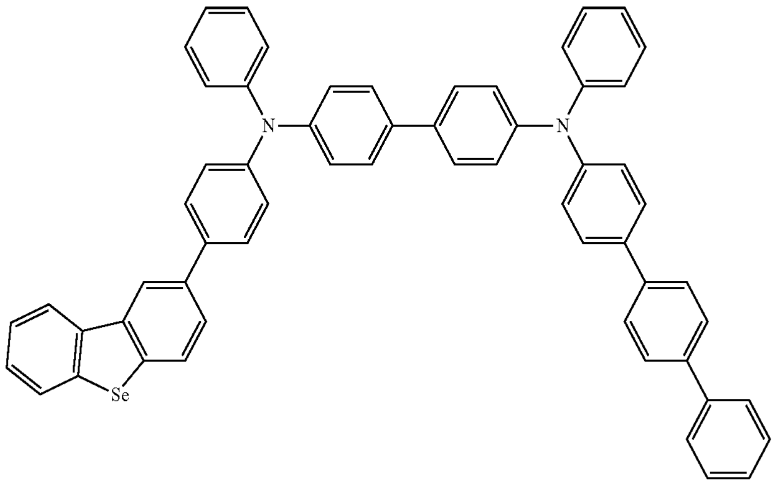

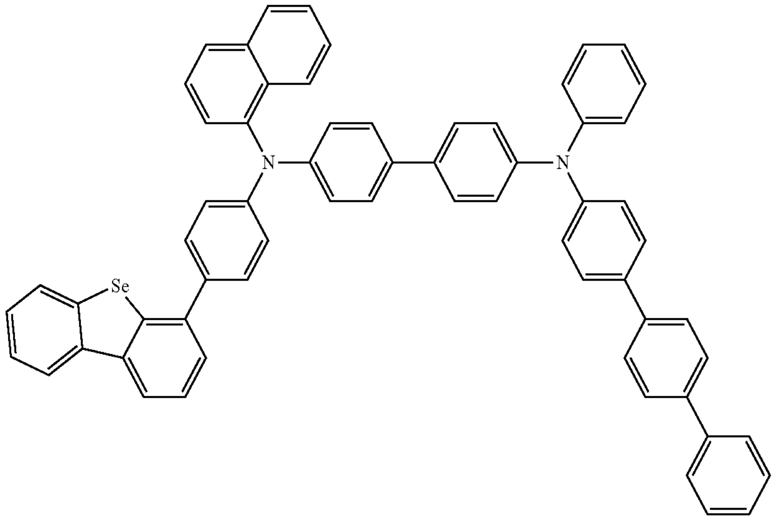

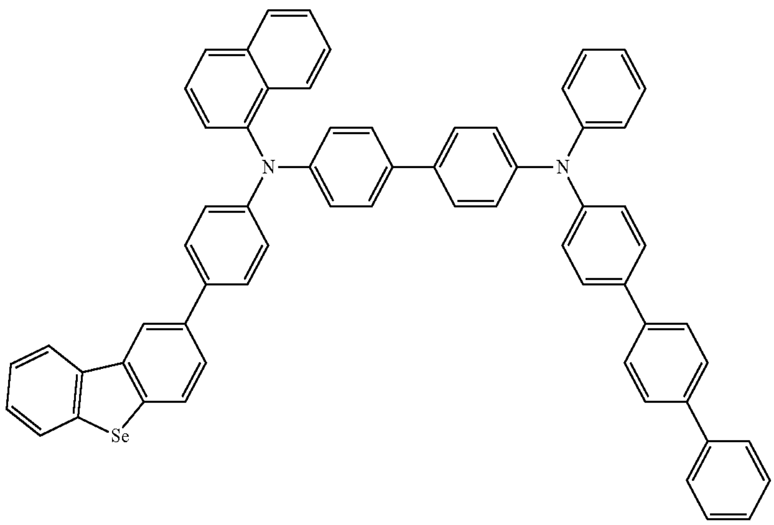

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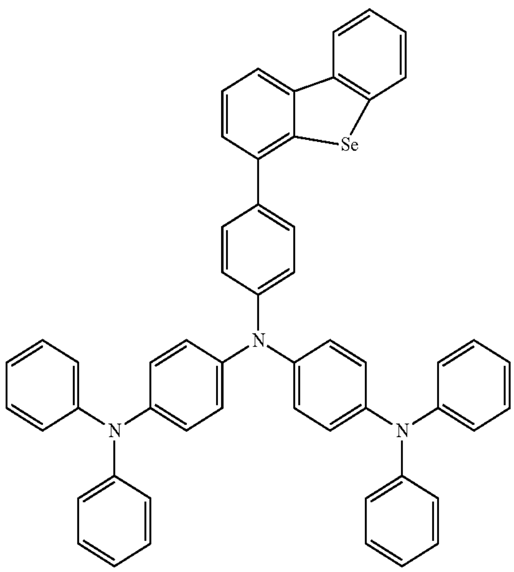

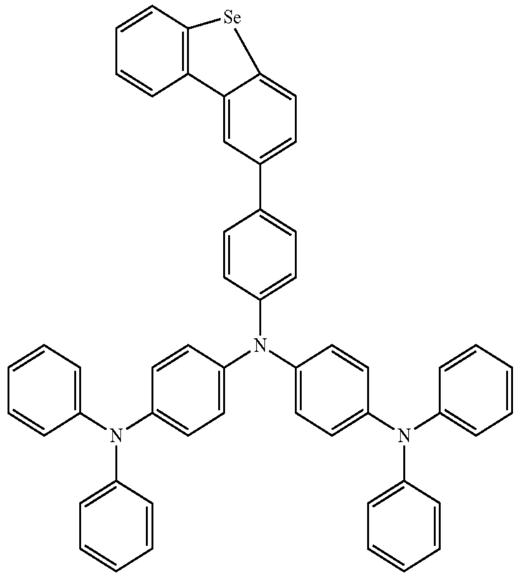

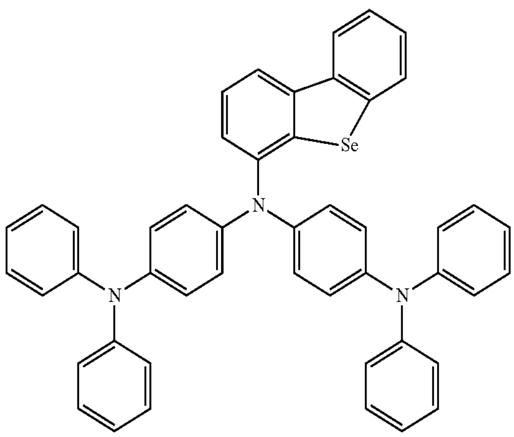

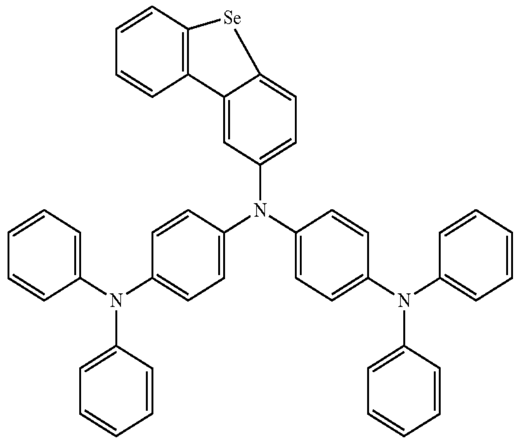

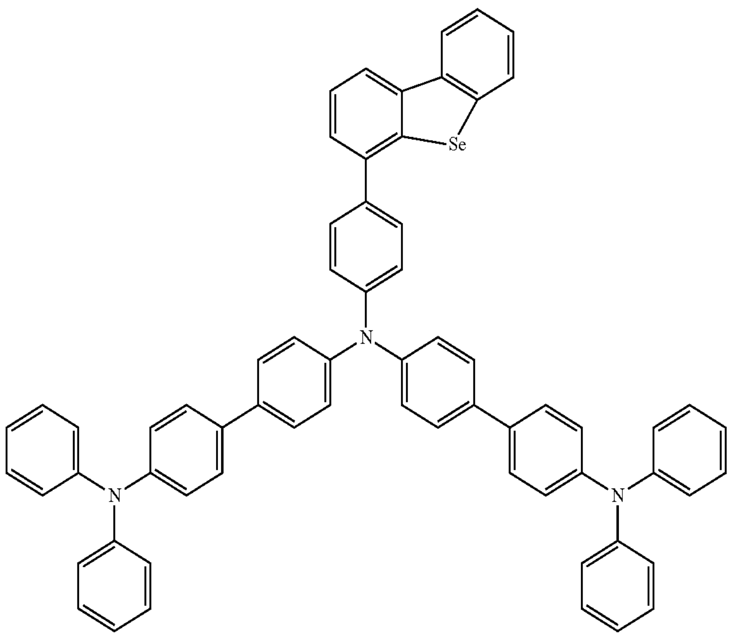

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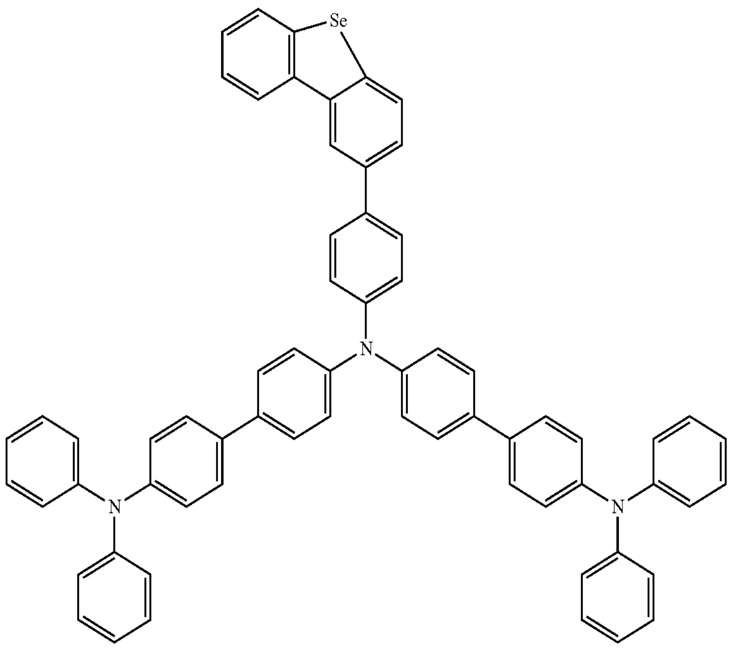
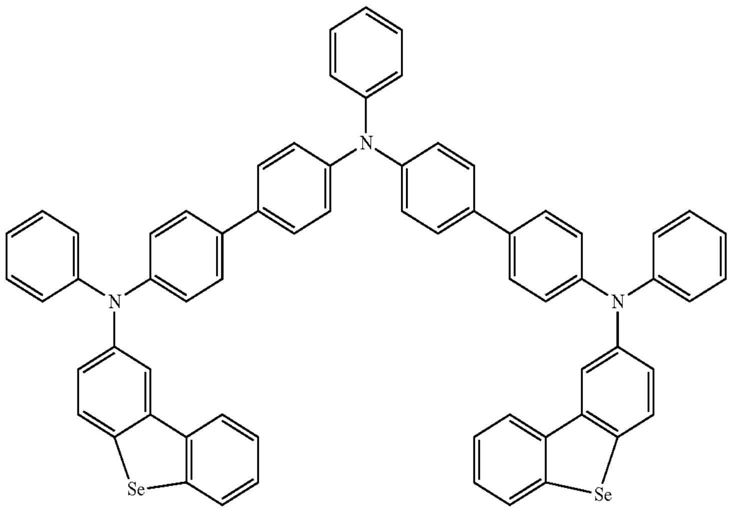
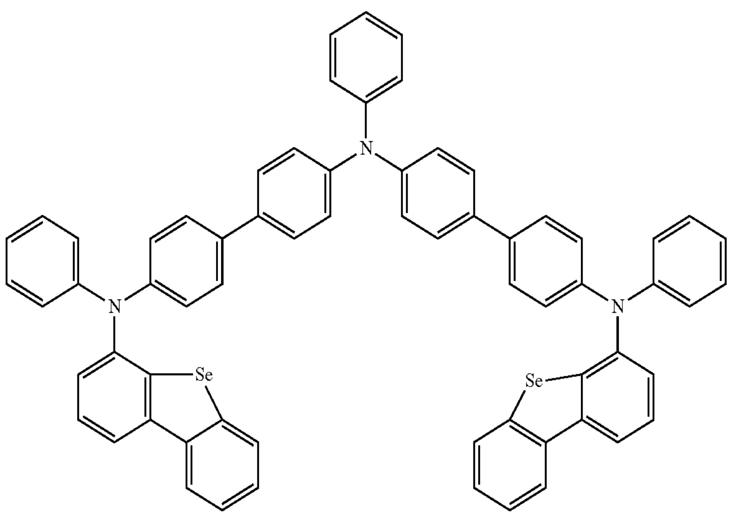


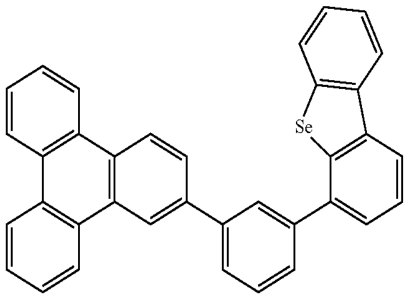




and derivatives thereof. Derivatives, such as compounds substituted by a substituent, including but not limited to halo, alkyl, heteroalkyl, cycloalkyl, alkenyl, alkynyl, arylkyl, heterocyclic group, aryl, and heteroaryl, are contemplated.

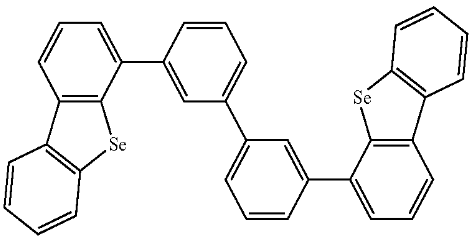
In one embodiment, organoselenium compound is

H-1



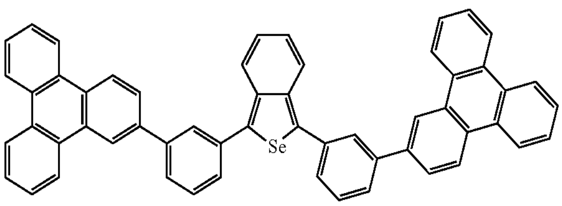
or

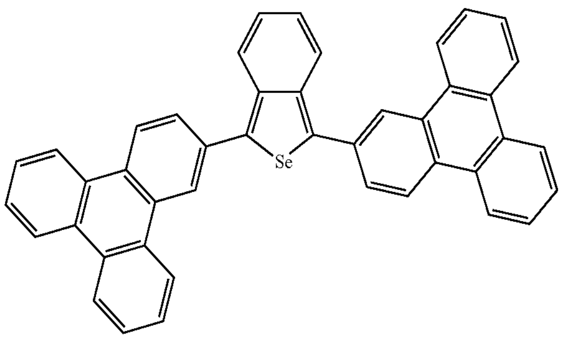
H-2



or a derivatives thereof, such as such as the compound substituted by a substituent, including but not limited to halo, alkyl heteroalkyl, cycloalkyl, alkenyl, alkynyl, arylkyl, heterocyclic group, aryl, and heteroaryl.

In still another embodiment, the organoselenium compound is selected from the group consisting of:





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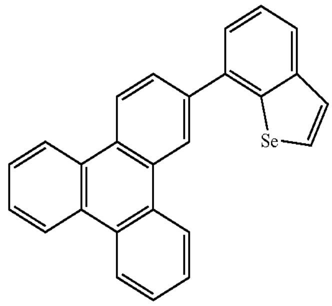

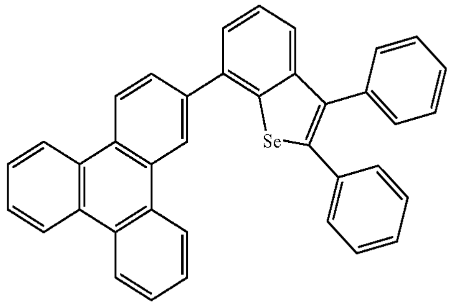

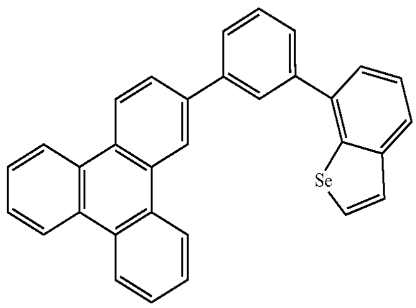

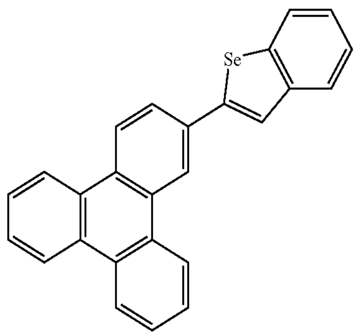

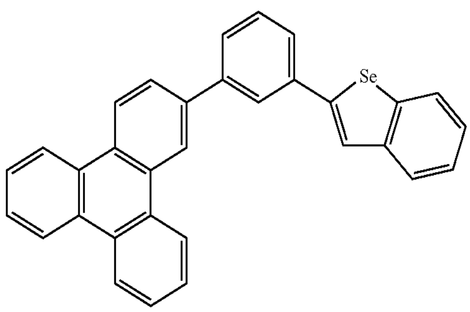

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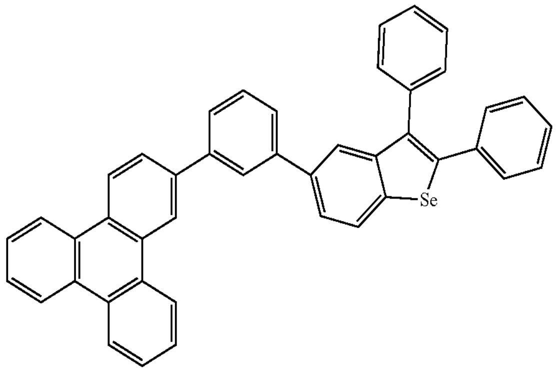


and derivative thereof. Derivatives, such compounds substituted by a substituent, including but not limited to halo, alkyl, heteroalkyl, cycloalkyl, alkenyl, alkynyl, arylkyl, heterocyclic group, aryl, and heteroaryl, are contemplated.

The organoselenium compounds of the present invention can be prepared by methods known in the art, including but not limited to method illustrated in the Examples below.

An organic light emitting device comprising the organoselenium compound of the invention is also provided. The device may include an anode, a cathode, and an organic emissive layer disposed between the anode and the cathode. The organic emissive layer may include a host and a phosphorescent dopant. In one embodiment, the device includes the organoselenium material of the invention as the host material in an emissive layer. Any of the dopants listed in Table 1 below may be used in the emissive layer in conjunction with an organoselenium material as the host material. In a preferred embodiment, the dopant is a red dopant selected from the list of red dopants in Table 1. In another preferred embodiment, the dopant is a green dopant selected from the list of green dopants in Table 1. In still another embodiment, the dopant is a blue dopant selected from the list of blue dopants in Table 1.

The concentration of the dopant in the emissive layer can be determined by a person skilled in the art based on the particular dopant used and the requirement of the device.

The organic light emitting device may comprise additionally a lack transporting layer (HTL) or an electron transporting layer (ETL). In preferred embodiments, the hole transporting layer or the electron transporting layer comprises an organoselenium material of the invention.

Combination with Other Materials

The organoselenium materials described herein as useful for a particular layer an organic light emitting device may be used in combination with a wide variety of other materials present in the device. For example, the organoselenium material of the invention can be used as a host of an emissive layer in conjunction with one or more emissive dopants disclosed in Table 1.

The organoselenium material may also be used in conjunction with a wide variety of other host materials disclosed Table 1 in transport layers, blocking layers, injection layers, electrodes and other layers that may be present in an OLED.

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.

In addition to and/or in combination with the materials disclosed herein, many hole injection materials, hole transporting materials, host materials, dopant materials, exciton/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 combination with materials disclosed herein are listed in Table 1 below. Table 1 lists non-limiting classes of materials, non-limiting examples of compounds for each class, and references that disclose the materials.

TABLE 1

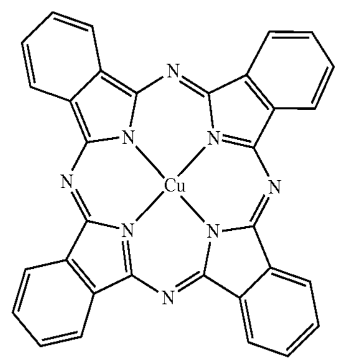
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Hole injection materials		
Phthalocyanine and porphyrin compounds		Appl Phys. Lett. 69, 2160 (1996)

TABLE 1-continued

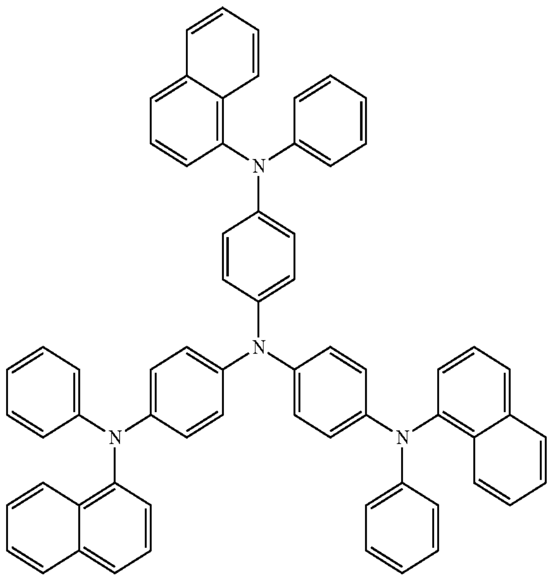
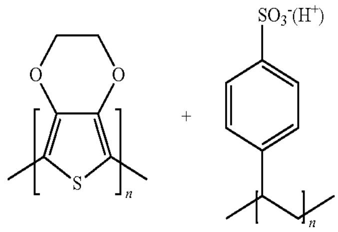
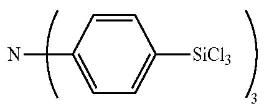
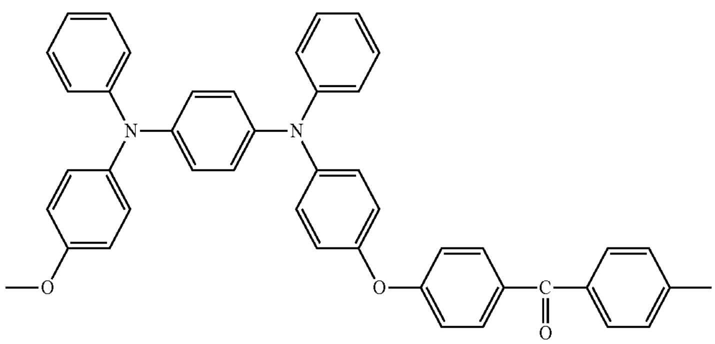
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Starburst triarylamines		J. Lumin. 72-74, 985 (1997)
CF_x Fluorohydrocarbon polymer	$-[CH_xF_y]_n-$	Appl. Phys. Lett. 78, 673 (2001)
Conducting polymers (e.g., PEDOT:PSS, polyaniline, polypthiophene)		Synth. Met. 87, 171 (1997) WO2007002683
Phosphonic acid and silane SAMs		US20030162053
Triarylamine or ploythiophene polymers with conductivity dopants	 and	EA01725079A1

TABLE 1-continued

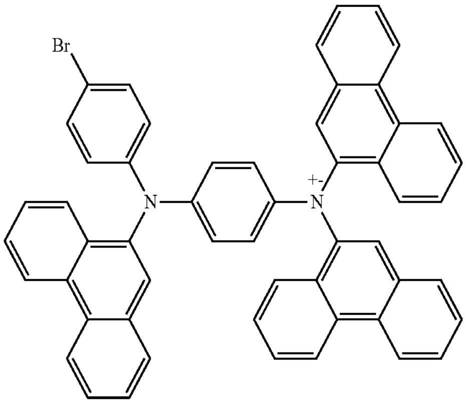
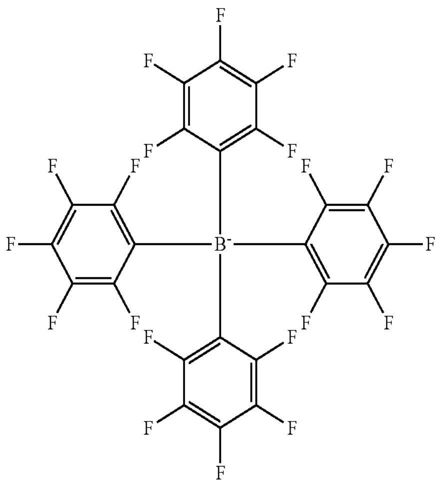
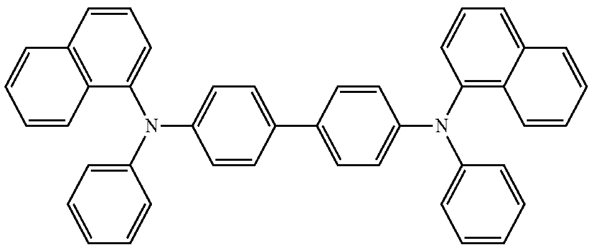
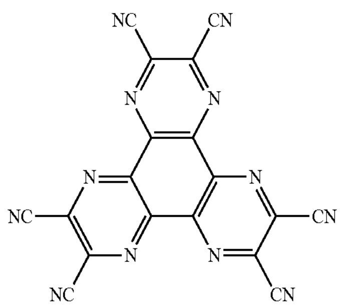
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	 	
Arylamines complexed with metal oxides such as molybdenum and tungsten oxides	 + MoO_x	SID Symposium Digest, 37, 923 (2006) WO2009018009
p-type semiconducting organic complexes		US20020158242

TABLE 1-continued

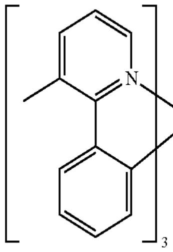
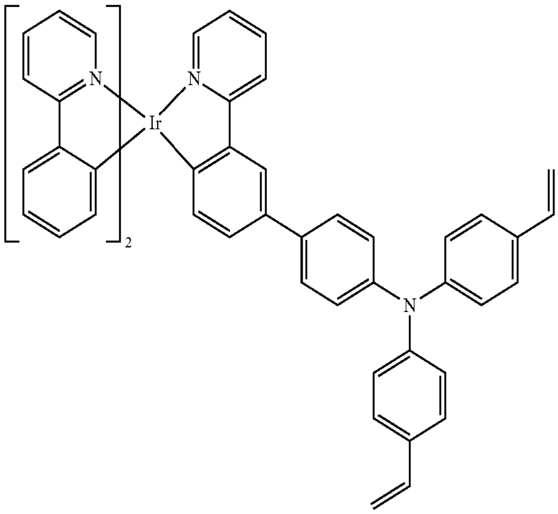
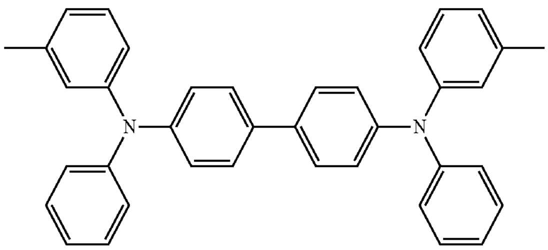
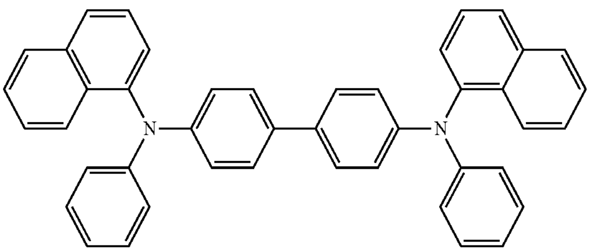
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Metal organometallic complexes		US20060240279
Cross-linkable compounds		US20080220265
	Hole transporting materials	
Triarylamines (e.g., TPD, α-NPD)		Appl. Phys. Lett. 51, 913 (1987)
		U.S. Pat. No. 5,061,569

TABLE 1-continued

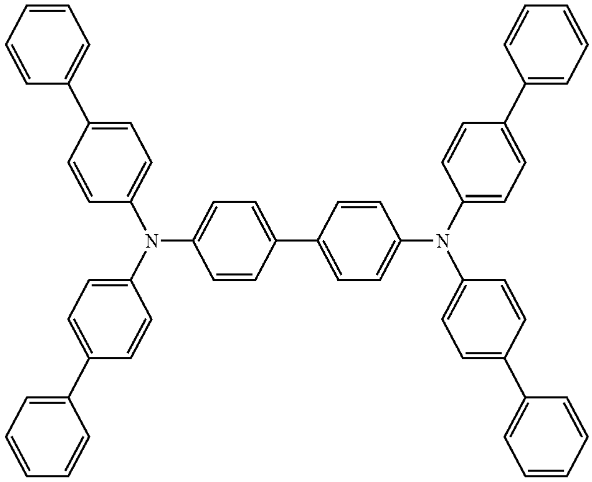
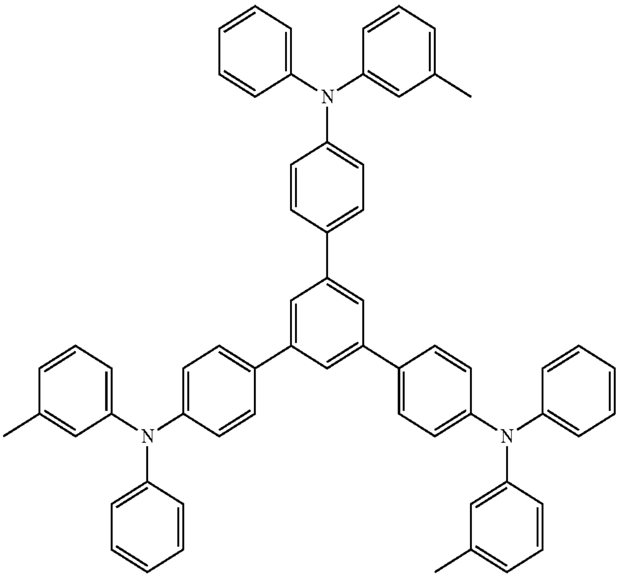
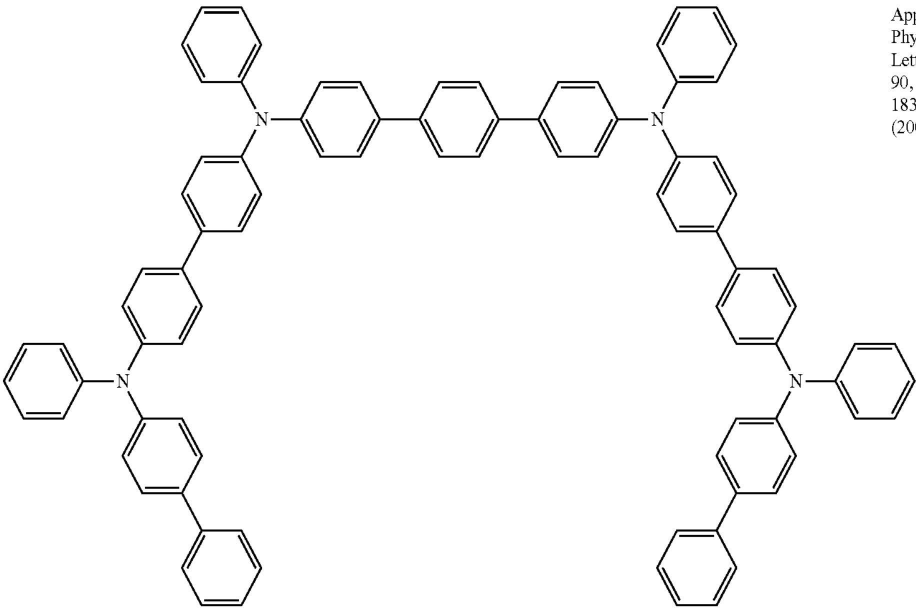
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		EP650955
		J. Mater. Chem. 3, 319 (1993)
		Appl. Phys. Lett. 90, 183503 (2007)

TABLE 1-continued

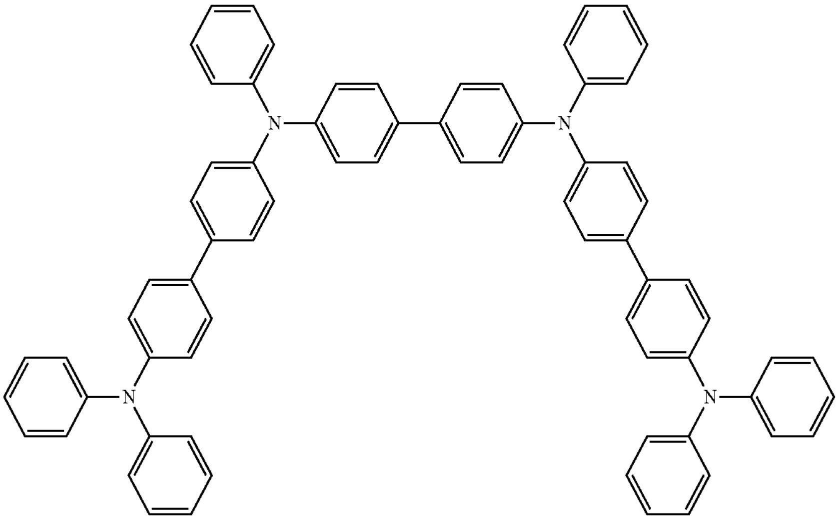
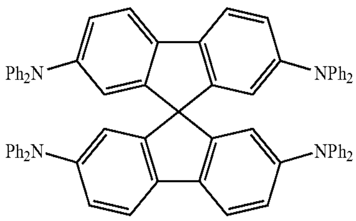
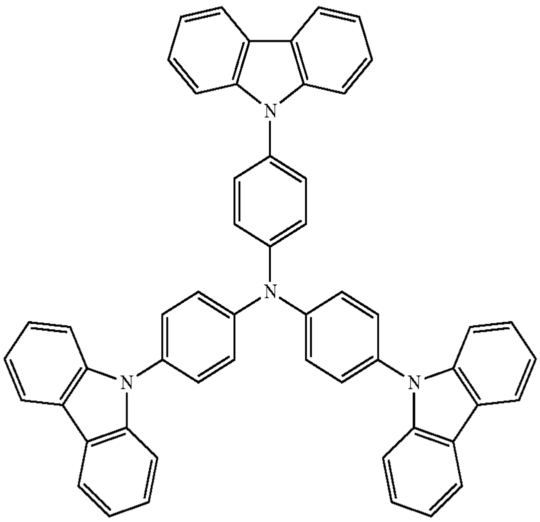
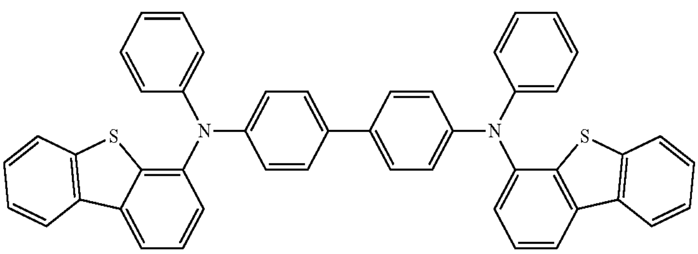
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Appl. Phys. Lett. 90, 183503 (2007)
Triarylamine on spirofluorene core		Synth. Met. 91, 209 (1997)
Arylamine carbazole compounds		Adv. Mater. 6, 677 (1994), US20080124572
Triarylamine with (di)-benzothiophene/(di)-benzofuran		US20070278938, US20080106190

TABLE 1-continued

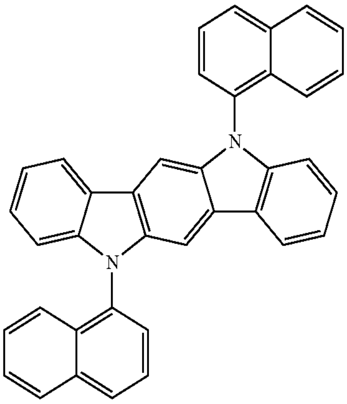
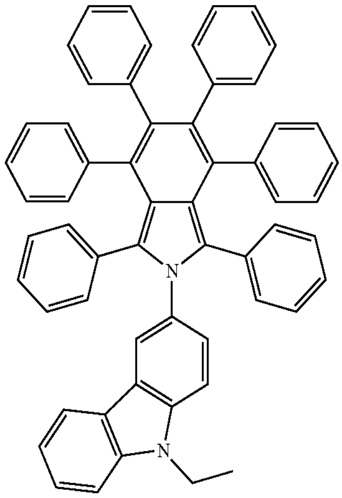
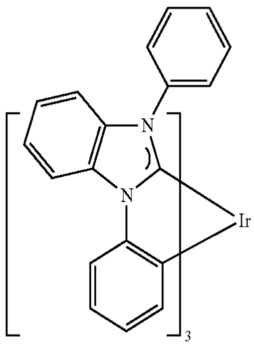
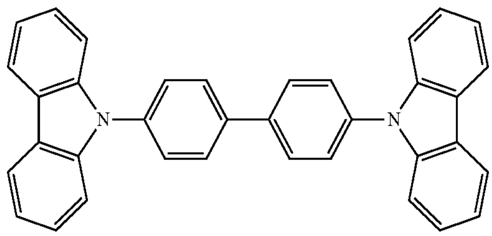
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Indolocarbazoles		Synth. Met. 111, 421 (2000)
Isoindole compounds		Chem. Mater. 15, 3148 (2003)
Metal carbene complexes		US20080018221
Phosphorescent OLED host materials Red hosts		
Arylcarbazoles		Appl. Phys. Lett. 78, 1622 (2001)

TABLE 1-continued

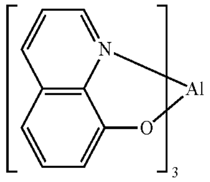
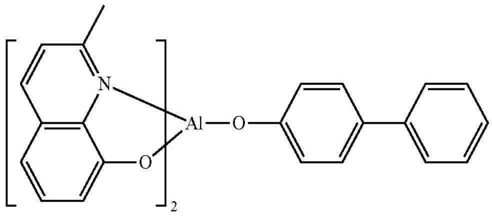
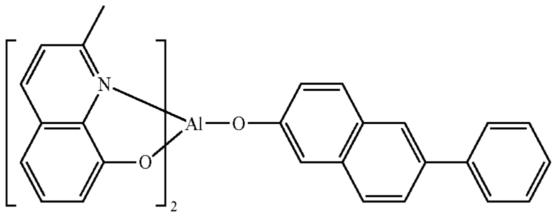
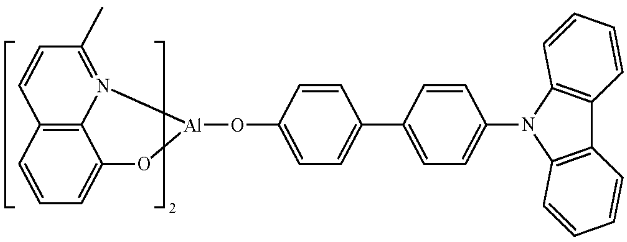
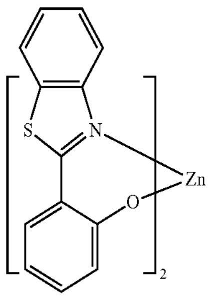
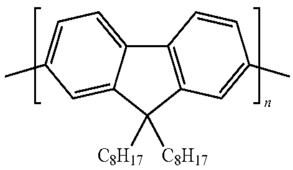
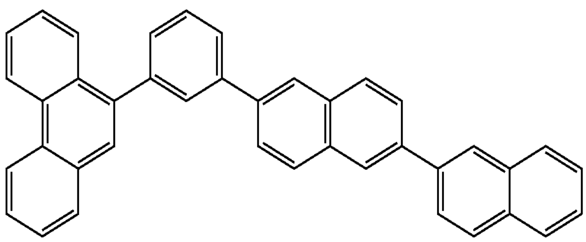
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Metal 8-hydroxyquinolates (e.g., Alq_3, BAlq)		Nature 395, 151 (1998)
		US20060202194
		WO2005014551
		WO2006072002
Metal phenoxy benzothiazole compounds		Appl. Phys. Lett. 90, 123509 (2007)
Conjugated oligomers and polymers (e.g., polyfluorene)		Org. Electron. 1, 15 (2000)
Aromatic fused rings		WO2009066779, WO2009066778, WO2009063833, US20090045731, US20090045730, WO2009008311, US20090008605, US20090009065

TABLE 1-continued

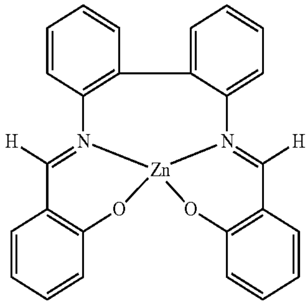
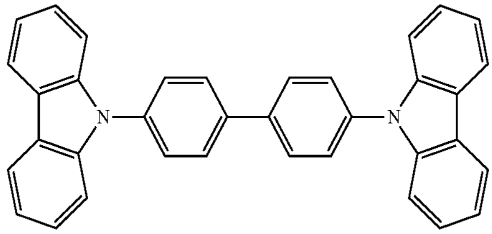
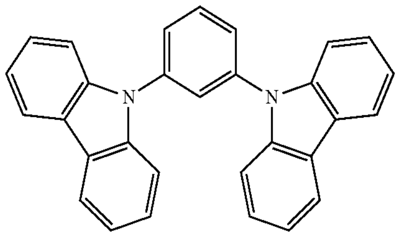
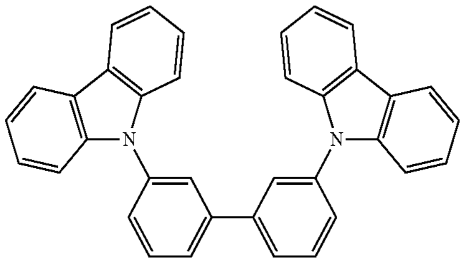
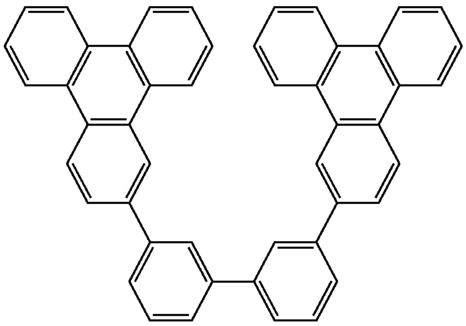
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Zinc complexes		WO2009062578
	Green hosts	
Arylcarbazoles		Appl. Phys. Lett. 78, 1622 (2001)
		US20030175553
		WO2001039234
Aryltriphenylene compounds		US20060280965

TABLE 1-continued

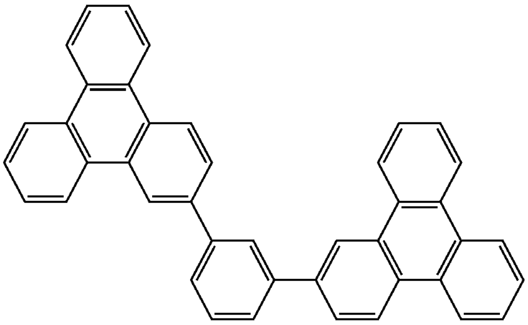
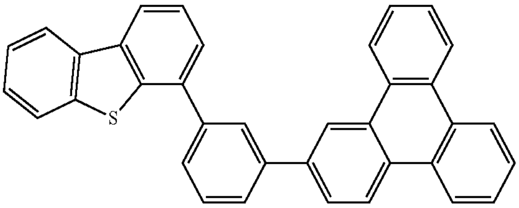
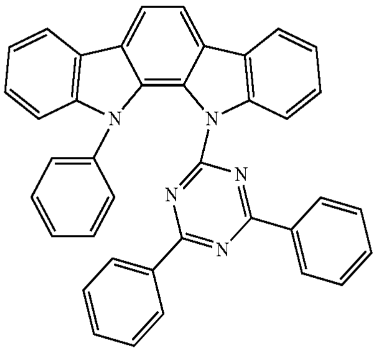
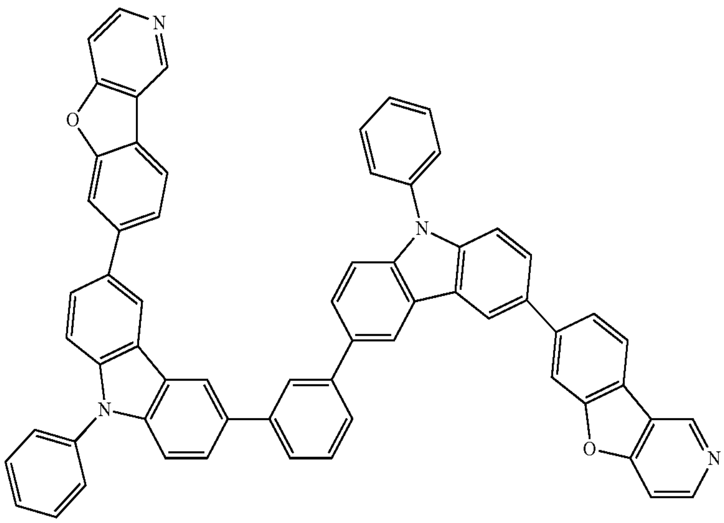
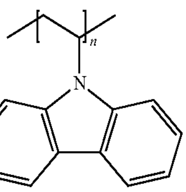
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20060280965
		WO2009021126
Donor acceptor type molecules		WO2008056746
Aza-carbazole/DBT/DBF		JP2008074939
Polymers (e.g., PVK)		Appl. Phys. Lett. 77, 2280 (2000)

TABLE 1-continued

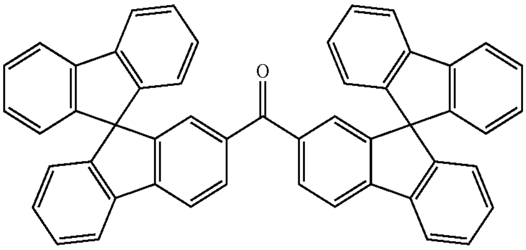
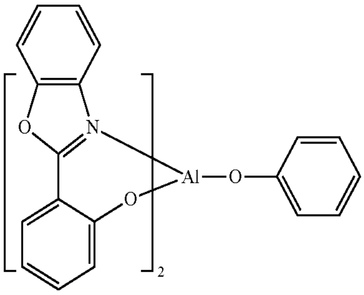
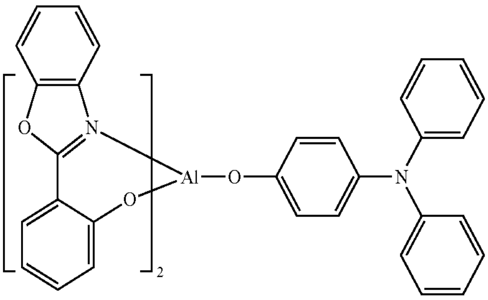
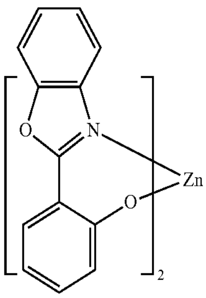
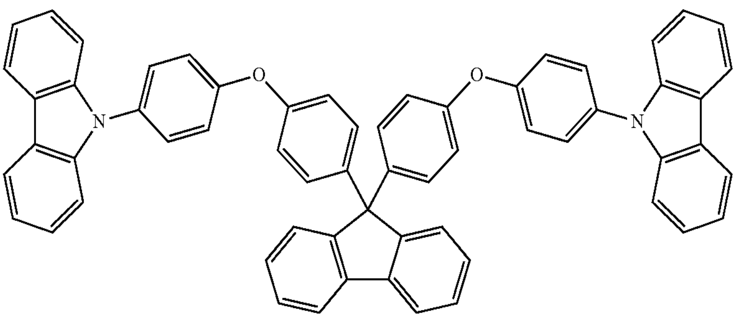
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Spirofluorene compounds		WO2004093207
Metal phenoxybenzooxazole compounds		WO2005089025
		WO2006132173
		JP200511610
Spirofluorene-carbazole compounds		JP2007254297

TABLE 1-continued

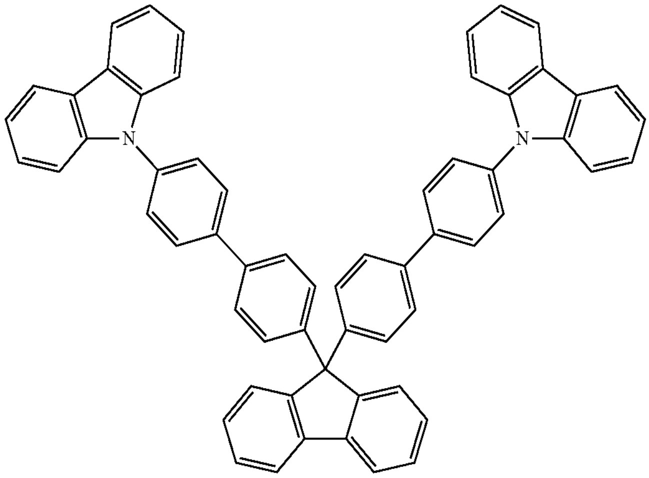
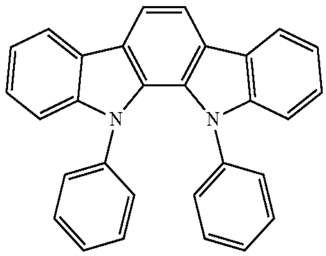
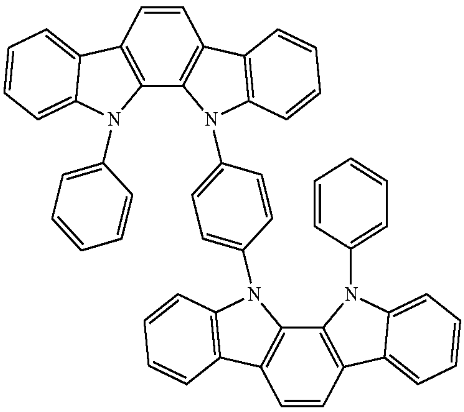
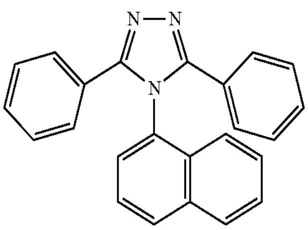
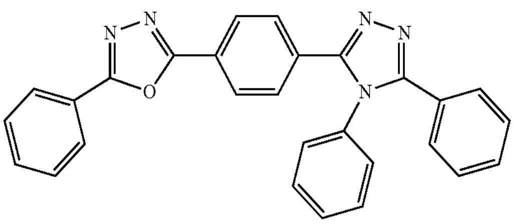
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		JP2007254297
Indolocarbazoles		WO2007063796
		WO2007063754
5-member ring electron deficient heterocycles (e.g., triazole, oxadiazole)		J. Appl. Phys. 90, 5048 (2001)
		WO2004107822

TABLE 1-continued

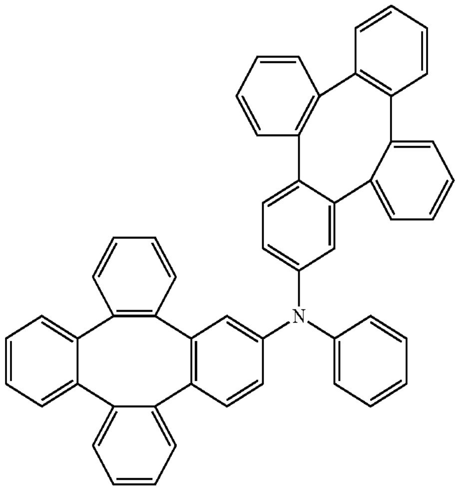
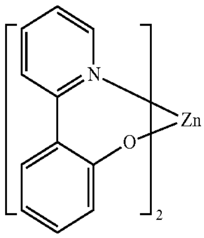
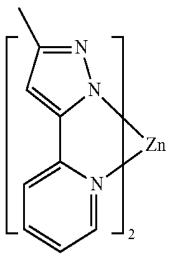
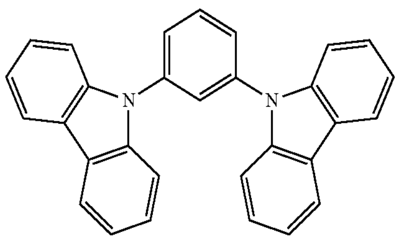
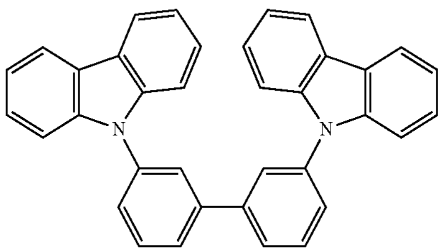
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Tetraphenylene complexes		US20050112407
Metal phenoxypyridine compounds		WO2005030900
Metal coordination complexes (e.g., Zn, Al with N^N ligands)		US20040137268, US20040137267
Blue hosts		
Arylcarbazoles		Appl. Phys. Lett, 82, 2422 (2003)
		US20070190359

TABLE 1-continued

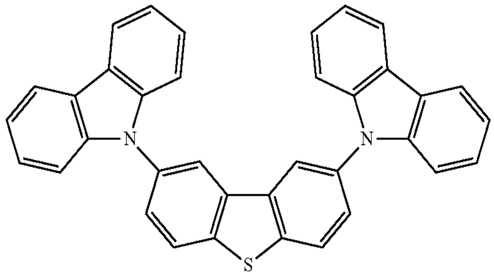
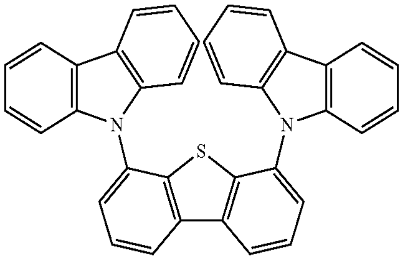
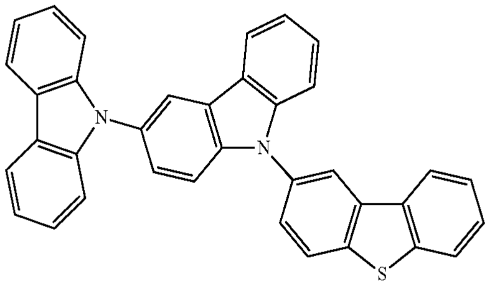
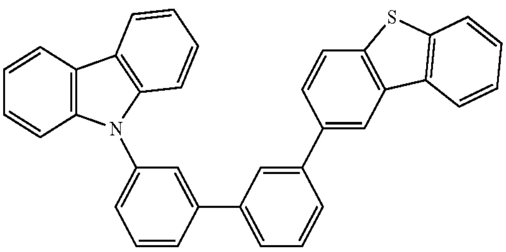
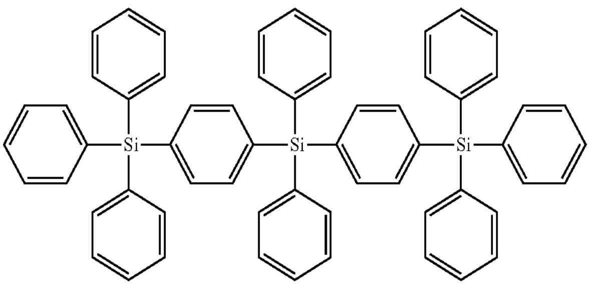
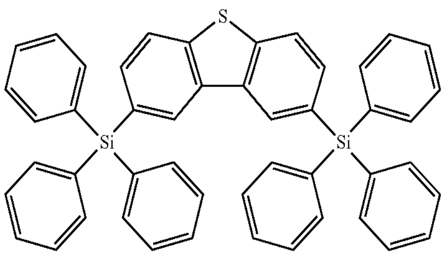
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Dibenzothiophene/Dibenzofuran-carbazole compounds		WO2006114966, US20090167162
		US20090167162
		WO2009086028
		US20090030202, US20090017330
Silicon aryl compounds		US20050238919
		WO2009003898

TABLE 1-continued

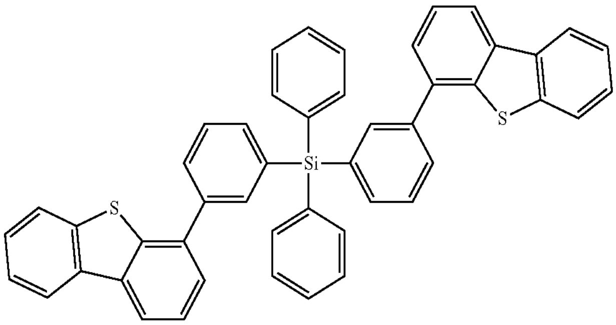
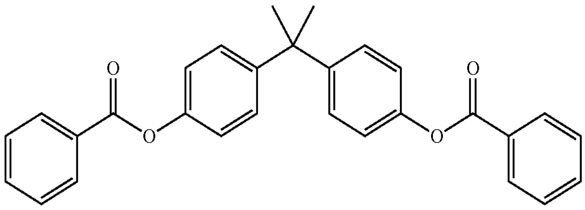
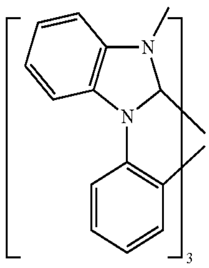
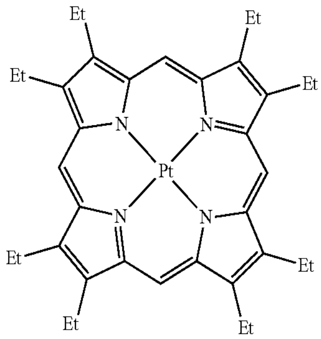
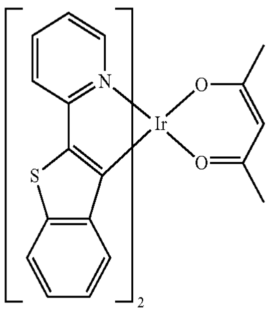
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Silicon/ Germanium aryl compounds		EP2034538A
Aryl benzoyl ester		WO2006100298
High triplet metal organometallic complex		U.S. Pat. No. 7,154,114
	Phosphorescent dopants Red dopants	
Heavy metal porphyrins (e.g., PtOEP)		Nature 395, 151 (1998)
Iridium (III) organometallic complexes		Appl. Phys. Lett. 78, 1622 (2001)

TABLE 1-continued

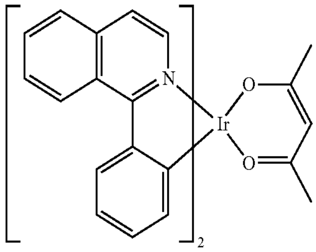
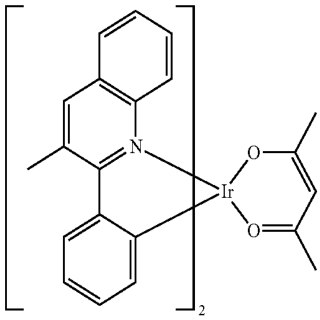
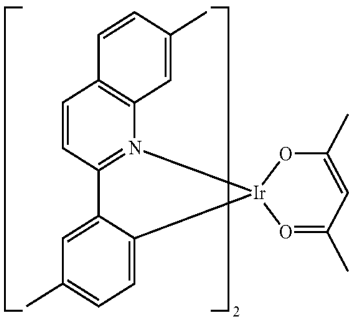
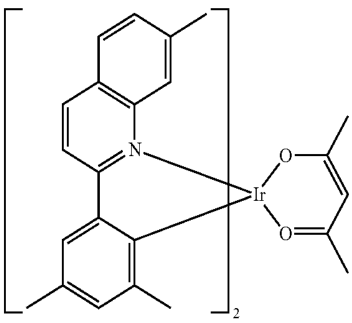
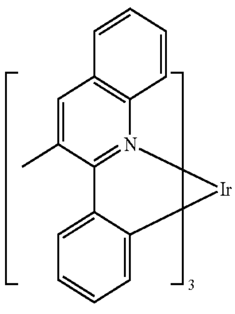
MATE-RIAL	EXAMPLES OF MATERIAL	PUBLI-CATIONS
		US2006835469
		US2006835469
		US20060202194
		US20060202194
		US20070087321

TABLE 1-continued

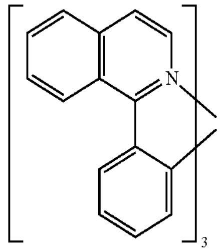
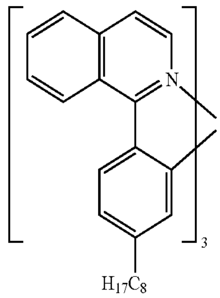
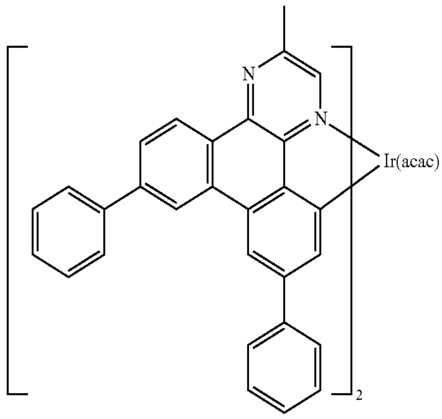
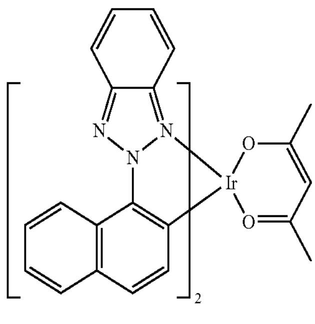
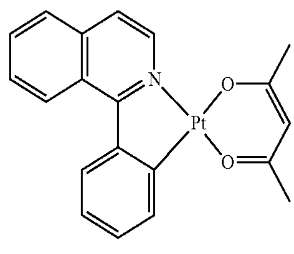
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20070087321
		Adv. Mater. 19, 739 (2007)
		WO2009100991
		WO2008101842
Platinum (II) organometallic complexes		WO2003040257

TABLE 1-continued

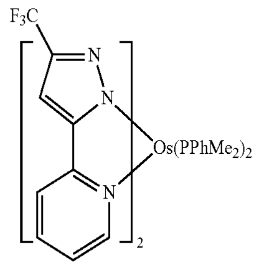
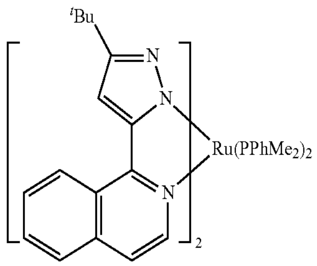
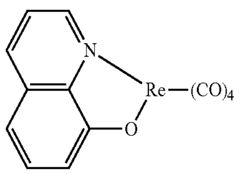
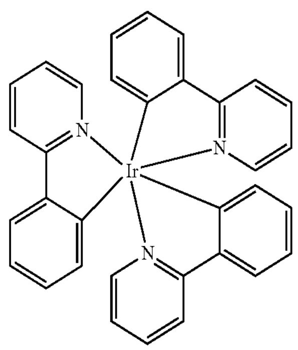
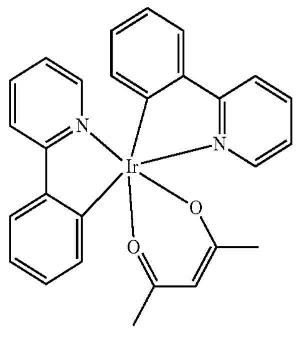
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Osmium (III) complexes		Chem. Mater. 17, 3532 (2005)
Ruthenium (II) complexes		Adv. Mater. 17, 1059 (2005)
Rhenium (I), (II), and (III) complexes		US20050244673
Green dopants		
Iridium (III) organometallic complexes	 and its derivatives	Inorg. Chem. 40, 1704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

TABLE 1-continued

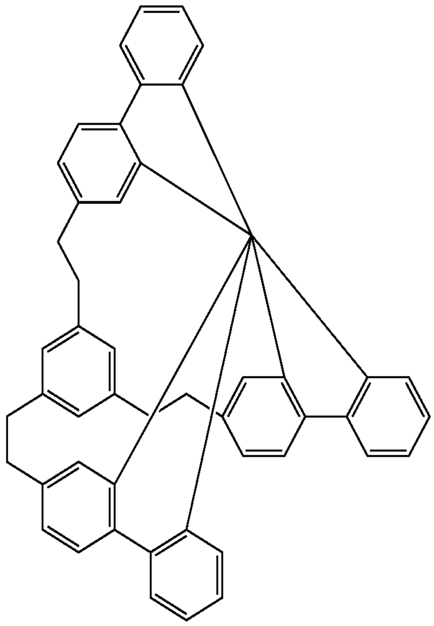
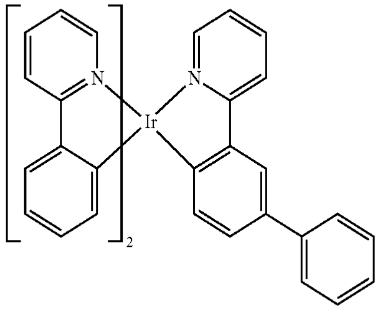
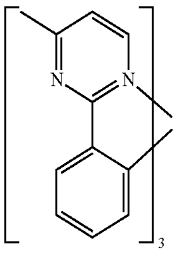
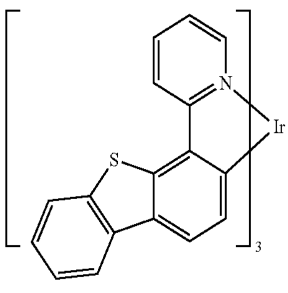
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		U.S. Pat. No. 7,332,232
		US20090108737
		US20090039776
		U.S. Pat. No. 6,921,915

TABLE 1-continued

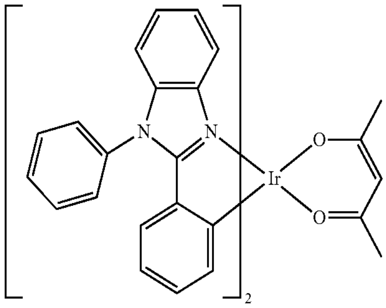
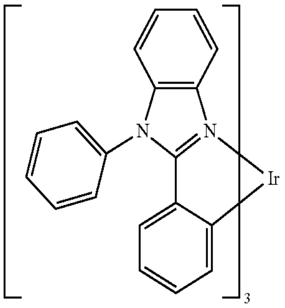
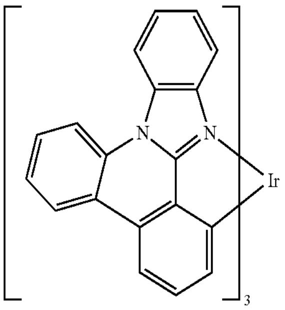
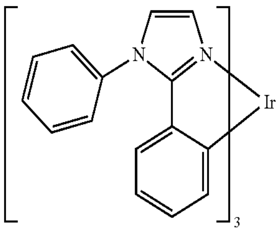
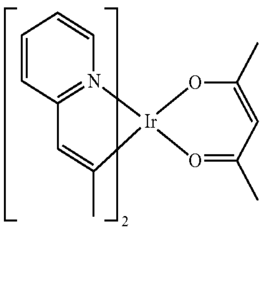
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		U.S. Pat. No. 6,687,266
		Chem. Mater. 16, 2480 (2004)
		US20070190359
		US 20060008670 JP2007123392
		Adv. Mater. 16, 2003 (2004)

TABLE 1-continued

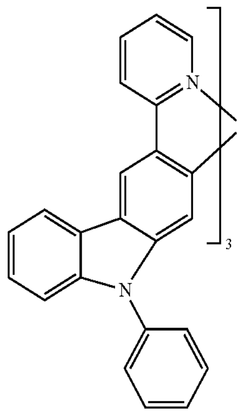
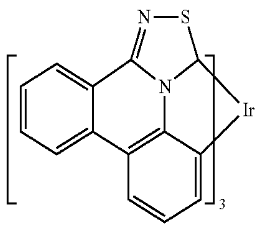
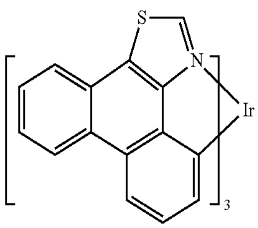
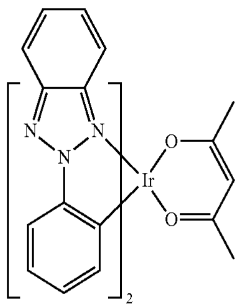
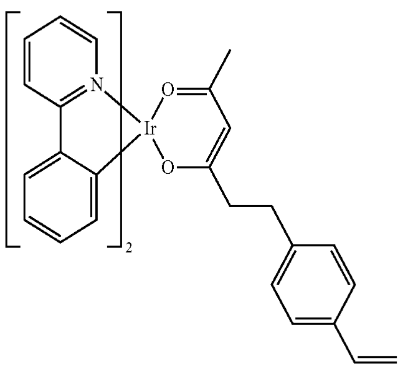
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Angew. Chem. Int. Ed. 2006, 45, 7800
		WO2009050290
		US20090165846
		US20080015355
Monomer for polymeric metal organometallic compounds		U.S. Pat. No. 7,250,226, U.S. Pat. No. 7,396,598

TABLE 1-continued

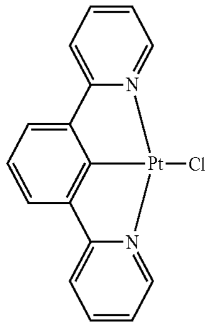
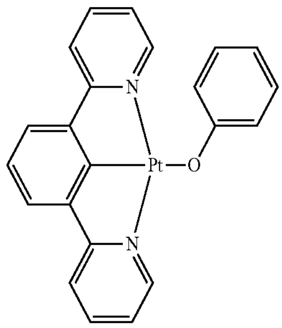
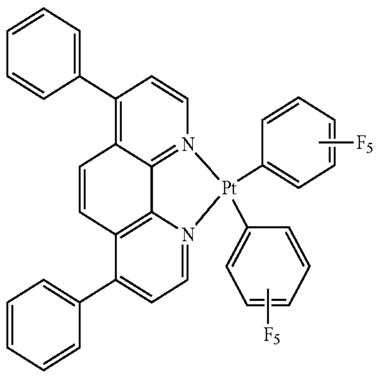
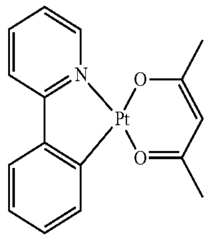
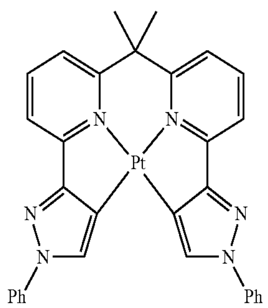
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Pt(II) organometallic complexes, including polydentated ligands		Appl. Phys. Lett. 86, 153505 (2005)
		Appl. Phys. Lett. 86, 153505 (2005)
		Chem. Lett. 34, 592 (2005)
		WO2002015645
		US20060263635

TABLE 1-continued

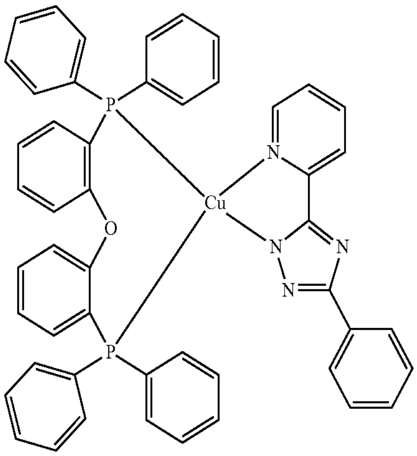
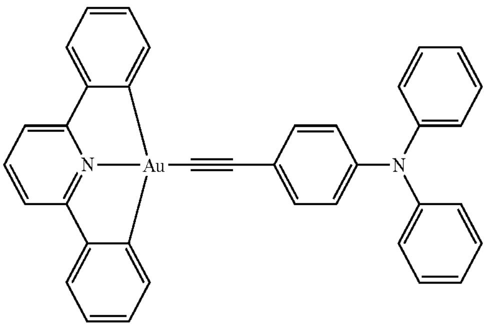
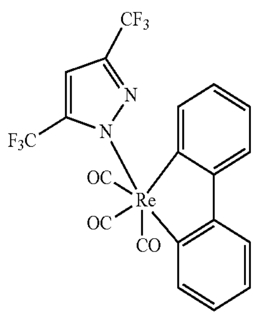
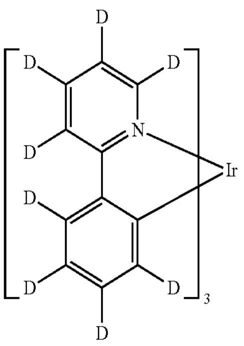
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Cu complexes		WO2009000673
Gold complexes		Chem. Commun. 2906 (2005)
Rhenium (III) complexes		Inorg. Chem. 42, 1248 (2003)
Deuterated organometallic complexes		US20030138657

TABLE 1-continued

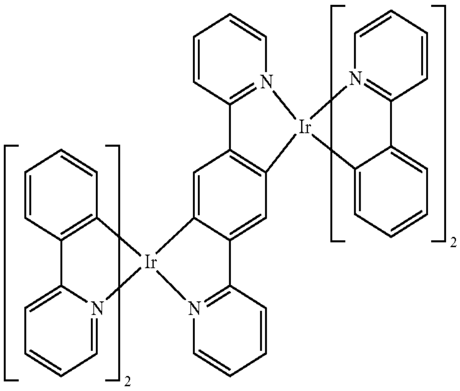
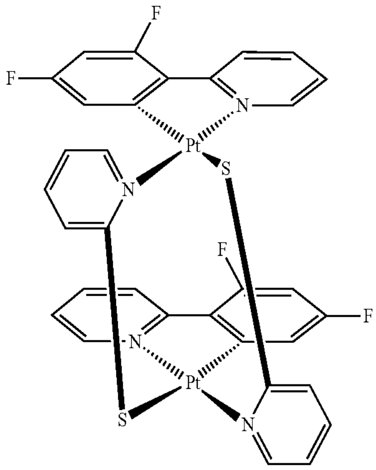
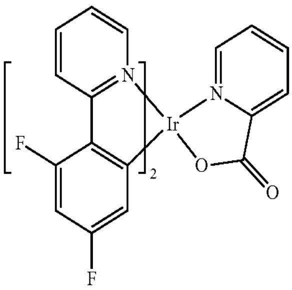
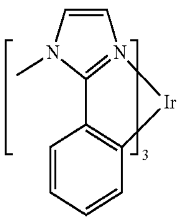
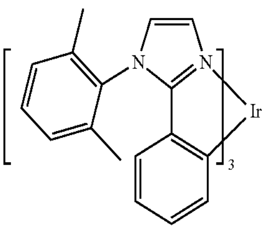
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Organometallic complexes with two or more metal centers		US20030152802
		U.S. Pat. No. 7,090,928
Blue dopants		
Iridium (III) organometallic complexes		WO2002002714
		WO2006009024
		US20060251923

TABLE 1-continued

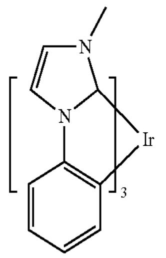
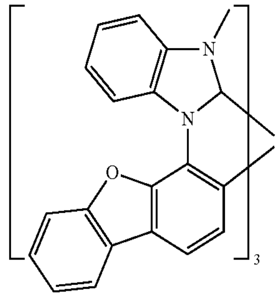
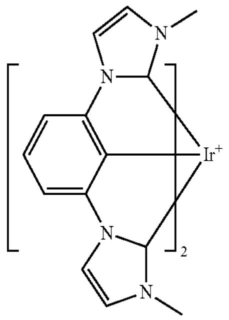
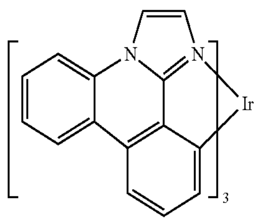
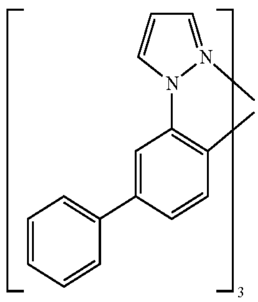
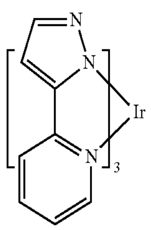
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		U.S. Pat. No. 7,393,599, WO2006056418, US20050260441, WO2005019373
		U.S. Pat. No. 7,534,505
		U.S. Pat. No. 7,445,855
		US20070190359, US20080297033
		U.S. Pat. No. 7,338,722
		US20020134984

TABLE 1-continued

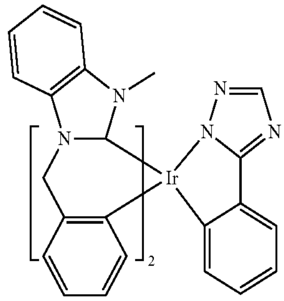
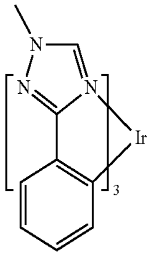
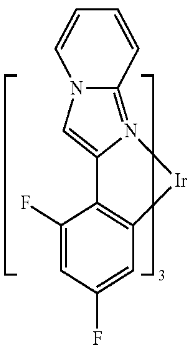
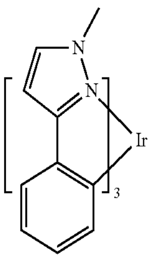
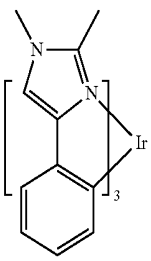
MATE-RIAL	EXAMPLES OF MATERIAL	PUBLI-CATIONS
		Angew. Chem. Int. Ed. 47, 1 (2008)
		Chem. Mater. 18, 5119 (2006)
		Inorg. Chem. 46, 4308 (2007)
		WO2005123873
		WO2005123873

TABLE 1-continued

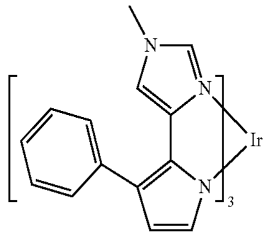
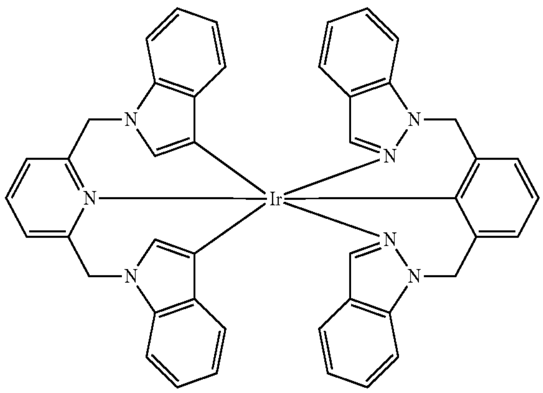
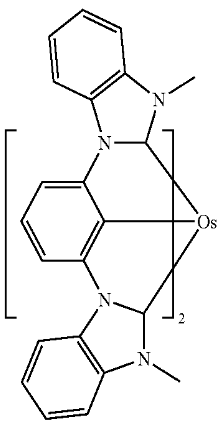
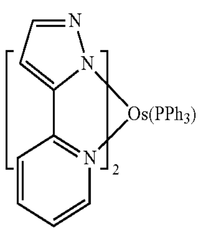
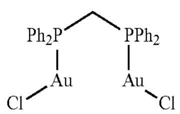
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2007004380
		WO2006082742
Osmium (II) complexes		U.S. Pat. No. 7,279,704
		Organometallics 23, 3745 (2004)
Gold complexes		Appl. Phys. Lett. 74, 1361 (1999)

TABLE 1-continued

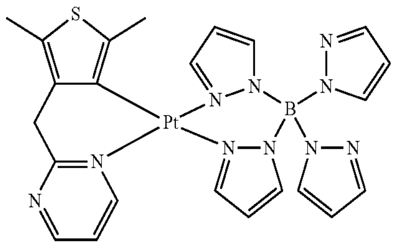
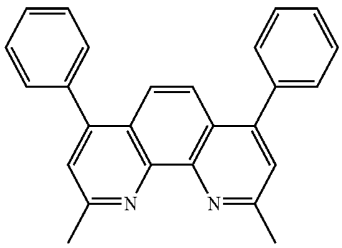
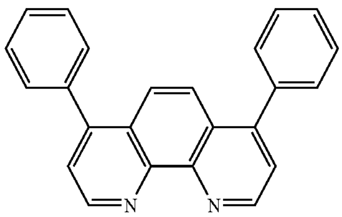
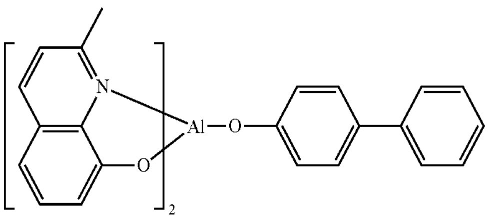
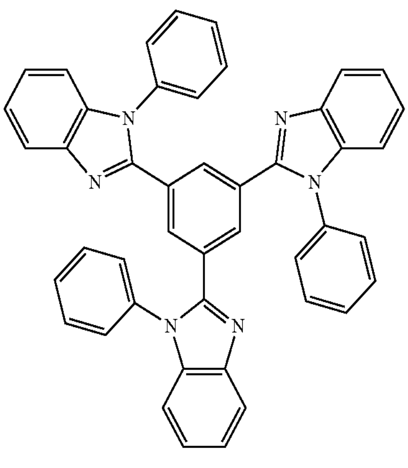
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Platinum (II) complexes		WO2006098120, WO2006103874
	Exciton/hole blocking layer materials	
Bathocuprine compounds (e.g., BCP, BPhen)		Appl. Phys. Lett. 75, 4 (1999)
		Appl. Phys. Lett. 79, 449 (2001)
Metal 8-hydroxyquinolates (e.g., BAlq)		Appl. Phys. Lett. 81, 162 (2002)
5-member ring electron deficient heterocycles such as triazole, oxadiazole, imidazole, benzoimidazole		Appl. Phys. Lett. 81, 162 (2002)

TABLE 1-continued

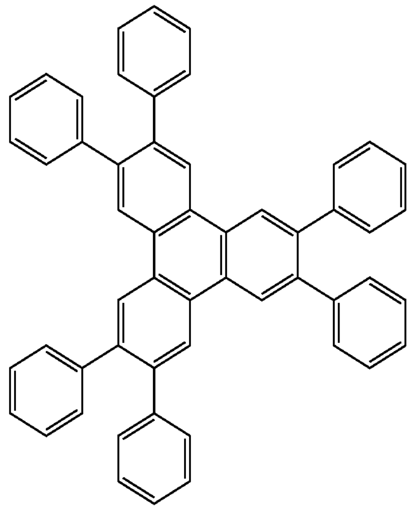
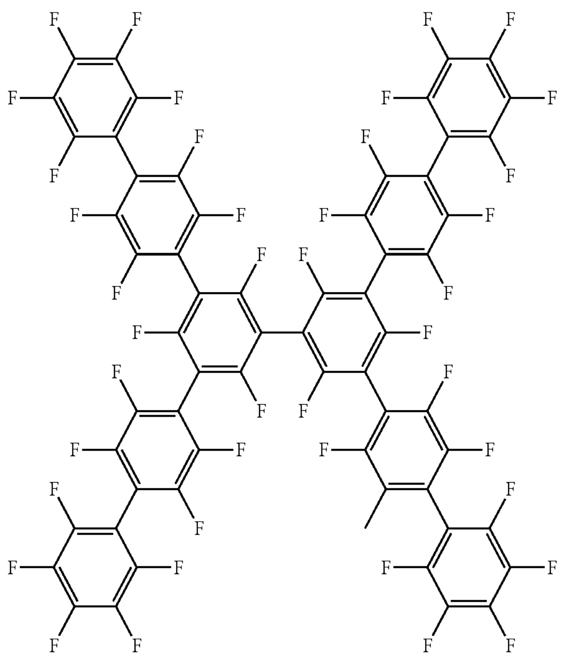
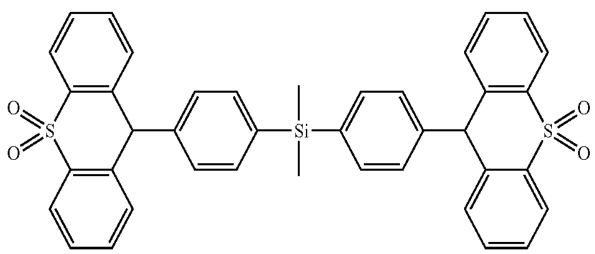
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Triphenylene compounds		US20050025993
Fluorinated aromatic compounds		Appl. Phys. Lett. 79, 156 (2001)
Phenothiazine-S-oxide		WO2008132085

TABLE 1-continued

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
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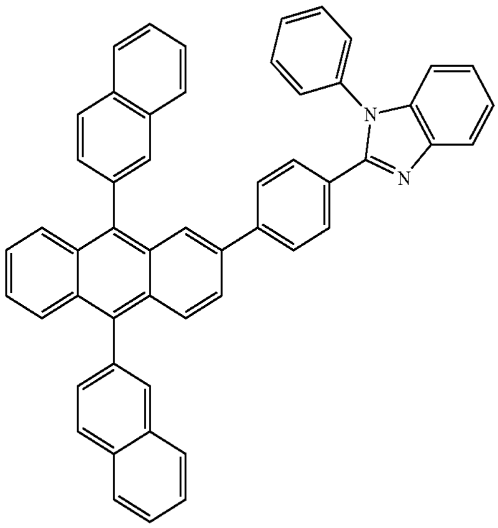
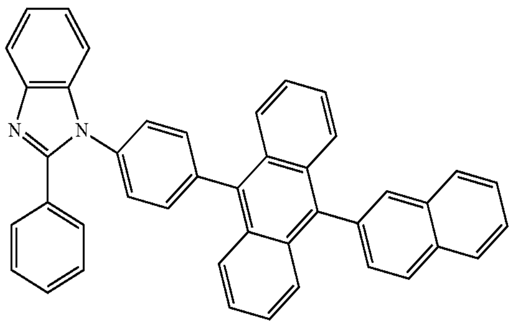
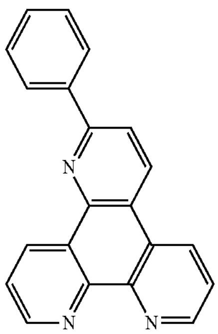
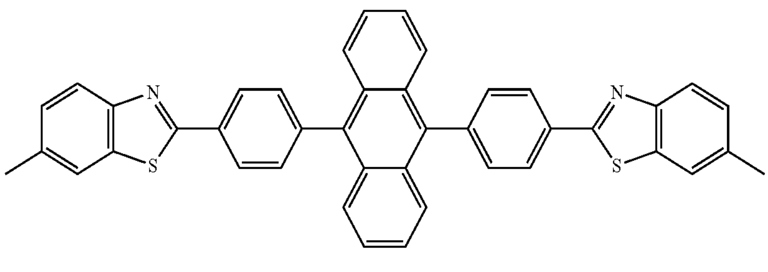
Anthracene-benzoimidazole compounds		WO2003060956
		US20090179554
Aza triphenylene derivatives		US20090115316
Anthracene-benzothiazole compounds		Appl. Phys. Lett. 89, 063504 (2006)

TABLE 1-continued

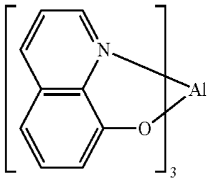
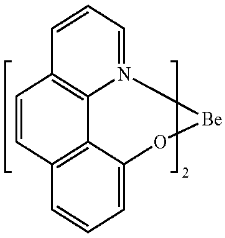
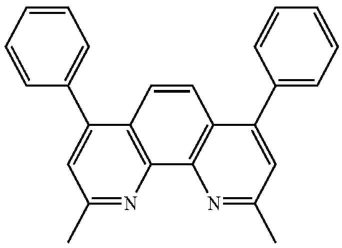
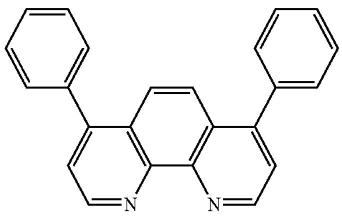
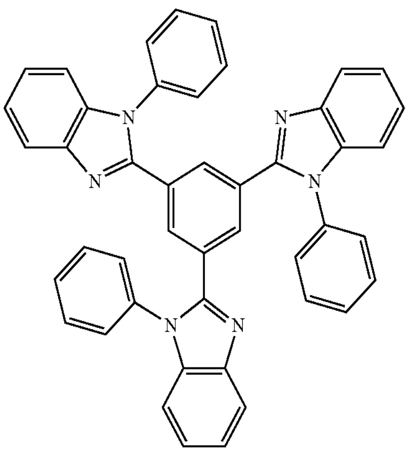
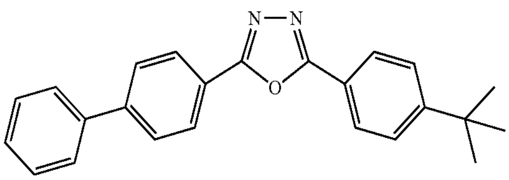
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Metal 8-hydroxyquinolates (e.g., Alq_3, Zrq_4)		Appl. Phys. Lett. 51, 913 (1987) US7230107
Metal hydroxybenoquinolates		Chem. Lett. 5, 905 (1993)
Bathocuprine compounds such as BCP, BPhen, etc		Appl. Phys. Lett. 91, 263503 (2007)
		Appl. Phys. Lett. 79, 449 (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)

TABLE 1-continued

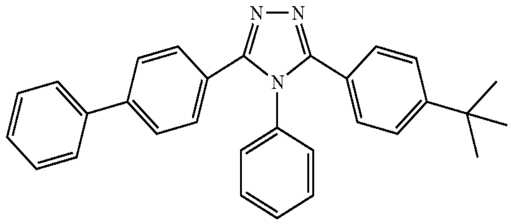
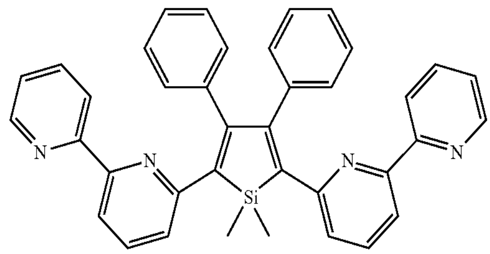
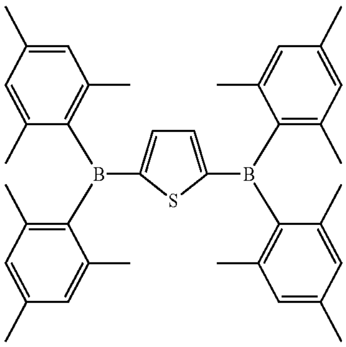
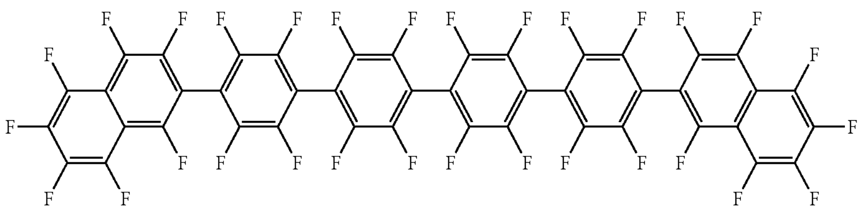
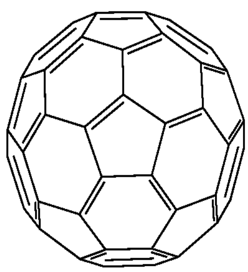
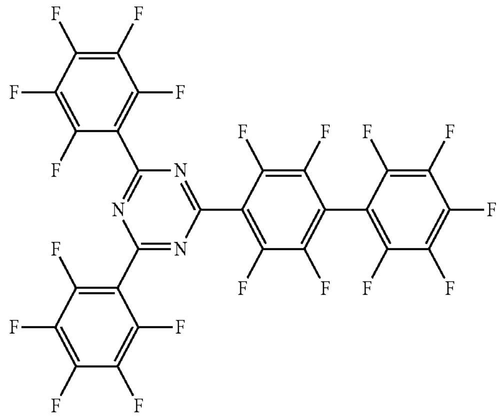
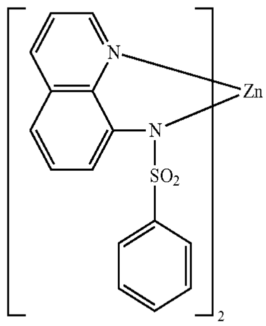
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Jpn. J. Apply. Phys. 32, L917 (1993)
Silole compounds		Org. Electron. 4, 113 (2003)
Arylborane compounds		J. Am. Chem. Soc. 120, 9714 (1998)
Fluorinated aromatic compounds		J. Am. Chem. Soc. 122, 1832 (2000)
Fullerene (e.g., C60)		US20090101870

TABLE 1-continued

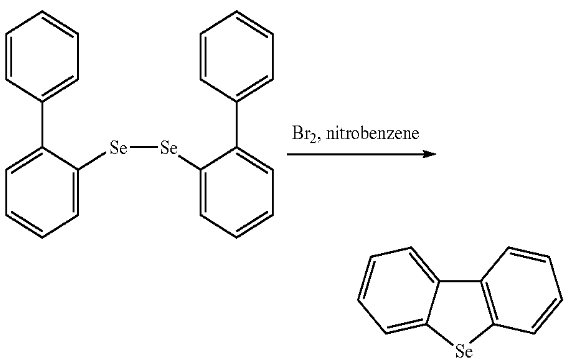
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Triazine complexes		US20040036077
Zn (N^N) complexes		U.S. Pat. No. 6,528,187

EXAMPLES

Example 1

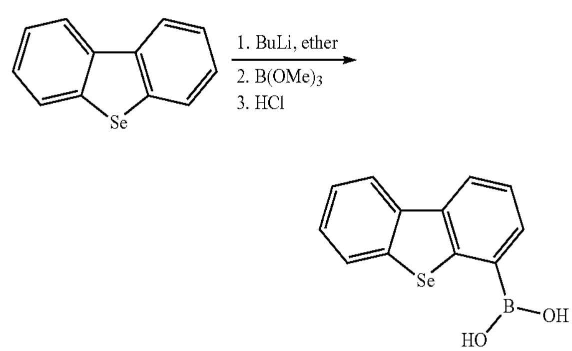
Compound H-1

1. Synthesis of dibenzoselenophene



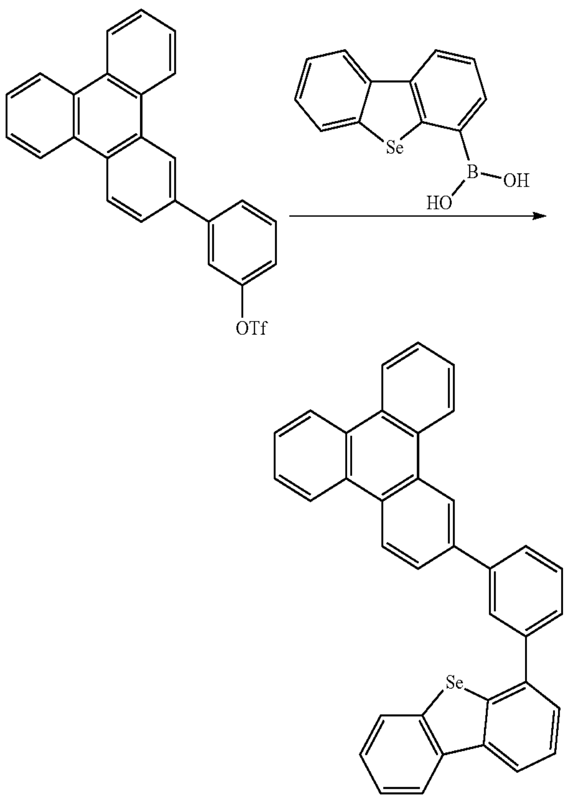
A mixture of 10 g (21.5 mmol) of 1,2-di(biphenyl-2-yl) disilane (synthesized according to J. Am. Chem. Soc. 1950, 72, 5753-5754), 3.45 g, (21.5 mmol) of bromine and 30 mL nitrobenzene was heated at 110° C. for 3.5 hours. Then the reaction mixture was cooled and nitrobenzene was removed by vacuum distillation. The residue was purified by silica gel column chromatography using 10% methylene chloride in hexane as the ehttetit 9.8 g of white solids were obtained as the product which was confirmed by MS.

2. dibenzoselenophen-4-ylboronic acid



4.0 g (17.3 mmol) of dibenzoselenophen and 150 mL of dry ether were added in a 250 mL three necked flask under nitrogen. To the mixture, 11.5 mL of BuLi (1.6 M in hexane) was added slowly at room temperature. The reaction mixture was then heated to reflux for 5 hours. The reaction mixture was cooled to −78° C. and 5 mL of trimethylborate was added. It was the left to stir at room temperature for overnight. About 50 mL of 1 M HCl was added to the reaction mixture. The organic phase was extracted with ethyl acetate and dried with sodium sulfate. The combined organic phase was evaporated to dryness and 100 mL 30% ethyl acetate in hexane was added to the solid with stirring at room temperature for 8 hours. The suspension was filtered, the solids were washed with hexane and dried, yielding 2 of white solids as the product which was confirmed by NMR

3. Synthesis of Compound H-1



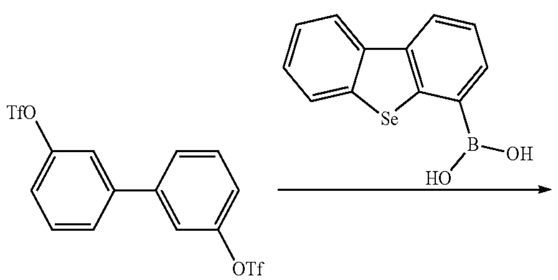
H-1

1.0 g (3.6 mmol) of dibenzoselenophen-4-ylboronic acid, 1.51 g (3.3 mmol) of triphenylenephenyl triflate (synthesized according to the method disclosed in Example 3 below), 0.15 g (0.16 mmol) of $Pd_2(dba)_3$, 0.27 g (0.66 mmol) of dicyclohexylphosphino-2',6'-dimethoxybiphenyl, 4.2 g of K_3PO_4, 90 mL of toluene and 10 mL of water were added in a 250 mL three necked flask. The reaction mixture was bubbled with nitrogen for 20 mins and heated to reflux for overnight under nitrogen. The reaction mixture was dried and purified by silica gel column chromatography with 15% methylene chloride in hexane as elutent, ~1.35 g of white solids were obtained as the product which was confirmed by NMR.

Example 2

Compound II-2

1. Synthesis of Compound H-2



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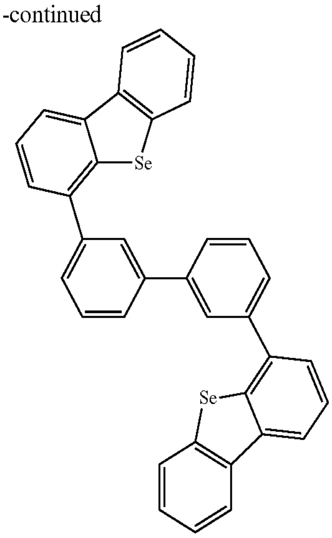
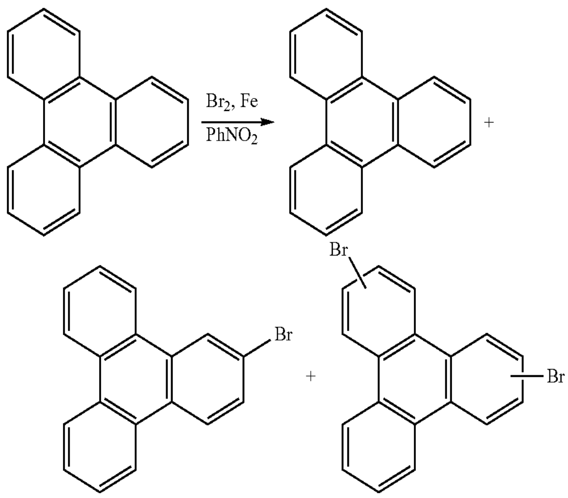


H-2

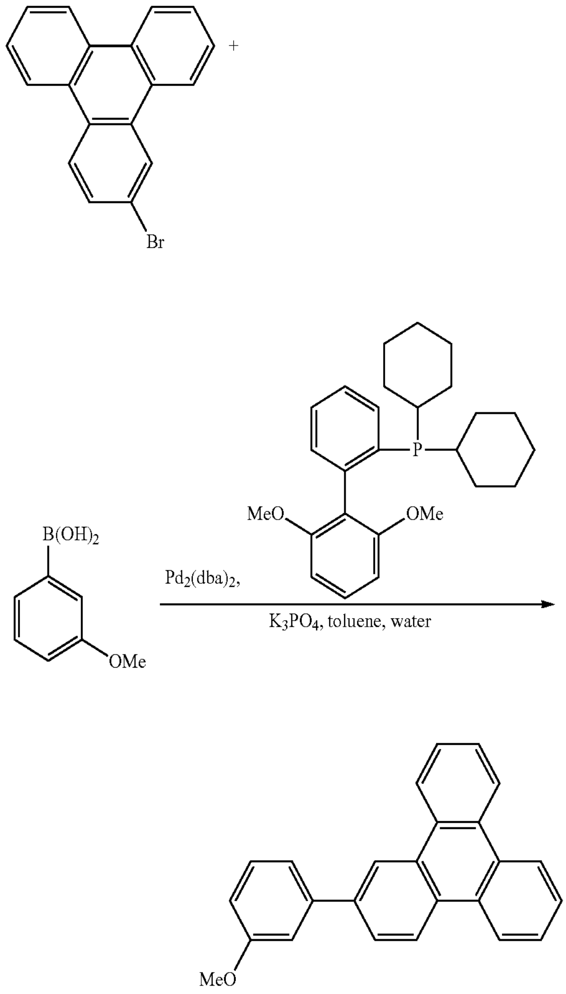
1.67 g (6.0 mmol) of dibenzoselenophen-4-ylboronic acid, 1.20 g (2.6 mmol) of biphenyl-4,4'-diyl bis(trifluoromethanesulfonate), 0.025 g (0.027 mmol) of $Pd_2(dba)_3$, 0.045 mg (0.11 mmol) of dicyclohexylphosphino-2',6'-dimethoxybiphenyl, 1.7 g of K_3PO_4, 90 mL of toluene and 10 mL of water were added in a 250 mL three necked flask. The reaction mixture was bubbled nitrogen for 20 mins and then heated to reflux for overnight under nitrogen. The reaction mixture was dried and the residue was purified by silica gel column chromatography with 10% methylene chloride in hexane as elutent. ~1.31 g of white solids was obtained as the product which was confirmed by NMR.

Example 3

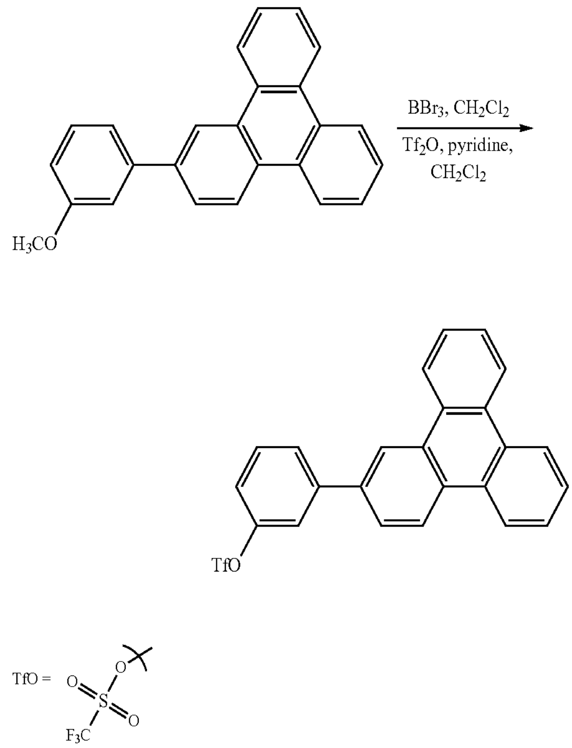
Method of Preparing 3-(triphenylen-2-yl)phenyl trifluoromethanesulfonate (triphenylenephyenyl triflate)



Triphenylene (19.0 g, 83 mmol) was added to and 600 mL of nitrobenzene. After all the triphenylene had dissolved, iron powder (0.07 g, 1.25 mmol) was added. The reaction flask was put in an ice bath. Bromine (20.0 g, 125 mmol) in 50 mL of nitrobenzene was slowly added via addition funnel. After that, the reaction was stirred in an ice bath for 5 hours. HPLC was performed to monitor the reaction (TLC did not show separation of triphenylene and bromotriphenylenes). When the ratio of triphenylene:2-bromotriphenylene:dibromotriphenylenes reached approximately 2:7:1 (at 254 nm), the reaction was quenched by adding Na_2SO_3 solution. The mixture was then extracted with CH_2Cl_2. The combined organic extract was dried over $MgSO_4$ and the CH_2Cl_2 was removed by rotovap. The remaining nitrobenzene was removed by vacuum distillation to yield the crude bromotriphenylene product which was used without further purification.



12 g (39 mmol) bromotriphenylene mixture containing a 2:7:1 mixture of unreacted triphenylene, monobromo and dibromo triphenylene, 13 g (86 mmol) 3-phenylboronic acid, 0.6 g (1.56 mmol) 2-dicyclohexylphosphino-2',6'-dimethoxybiphenyl and 25 g (117 mmol) potassium phosphate tribasic (K_3PO_4) are weighed in a round bottom flask. 150 mL toluene and 80 mL water were added to the flask as solvent. The solution was purged with nitrogen and 0.4 g (0.39 mmol) of tris(dibenzylideneacetone)dipalladium (0) [$Pd_2(dba)_3$] was added. The solution was heated to reflux for twelve hours. Upon cooling, the organic layer was separated, and dried with $MgSO_4$. The product was readily separated by column chromatography from triphenylene di-(3-methoxyphenyl) substituted triphenylene using Hexane/dichloromethane as eluent (1/0 gradient to 3/2). The solvent was removed by rotary evaporation, and the product, 2-(3-methoxyphenyl)triphenylene, was dried overnight under vacuum.



In a round bottom flask under nitrogen, 1.8 g (5.4 mmol) 2-(3-methoxyphenyl)triphenylene was dissolved in 25 mL anhydrous dichloromethane. The solution was cooled to −78° C. and 4 g (1.5 mL, 16 mmol) boron tribromide was added slowly via syringe. The solution was warmed to room temperature and stirred overnight. Ice was carefully added to quench unreacted BBr_3. The 3-(triphenylen-2-yl)phenol intermediate precipitated upon addition of ice, and dichloromethane was added to dissolve. The organic layer was separated and dried with $MgSO_4$, the dichloromethane was removed by rotary evaporation and the product was dried under vacuum.

1.7 g (5.3 mmol) of 3-(triphenylen-2-yl)phenol was added to a flask under nitrogen with 0.84 g (10.5 mmol) anhydrous pyridine and 100 mL anhydrous dichloromethane. The solution was cooled in an ice bath and 2.97 g (10.5 mmol) trifluoromethanesulfonic anhydride (Tf_2O) was added slowly via syringe. The solution was warmed to room temperature and stirred overnight. The solution was washed with water, dried with $MgSO_4$ and the solvent was removed by rotary evaporation. The product, 3-(triphenylen-2-yl)phenyl trifluoromethanesulfonate, was purified by column chromatography using hexane/dichloromethane as eluent (1/0 to 1/1 gradient).

Description of the method of synthesis can also be found in U.S. provisional application No. 60/963,944 corresponding to International Application No: PCT/US08/72452, filed Aug. 7, 2008, which is incorporated herein by reference in its entirety.

Example 4

Device Examples

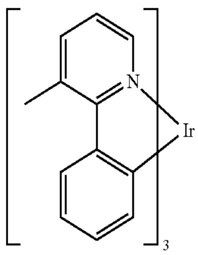
All example devices were fabricated by high vacuum ($<10^{-7}$ Torr) thermal evaporation. The anode electrode is 1200 Å of indium tin oxide (ITO). The cathode consisted of 10 Å of LiF followed by 1,000 Å of Al. All devices are encapsulated with a glass lid sealed with an epoxy rosin in a nitrogen glove box (<1 ppm of H_2O and O_2) immediately after fabrication, and a moisture getter was incorporated inside the package.

The organic stack of the device examples consisted of sequentially, from the ITO surface, 100 Å of Compound A as the hole injection layer (HIL), 300 Å of 4,4'-bis[N-(1-naphthyl)-N-phenylamino]biphenyl (α-NPD) as the hole transporting layer (HTL). 300 Å of the invention compound doped with 10 or 15 wt % of an Ir phosphorescent compound as the emissive layer (EML). 50 Å of HTP or 100 Å of the invention compound as the ETL2 and 450 or 400 Å of Alq_3 (tris-8-hydroxyquinoline aluminum) as the ETL1.

Comparative Examples 1 and 2 were fabricated similarly to the Device Examples except that the CBP is used as the host.

The device structures and data are summarized in Tables 2 and 3, where Table 2 shows device structure and Table 3 shows corresponding measured results for those devices. As used herein, Compounds A and B and HPT, have the following structures:

Compound A



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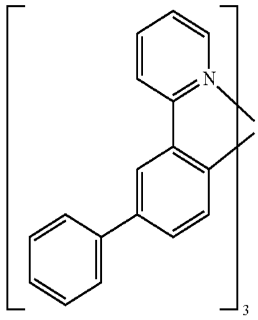
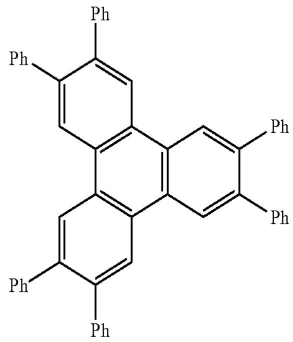
Compound B





HPT

TABLE 2

Device Example	Host	Dopant %	ETL2 (Å)	ETL1 (Å)
Comparative 1	CBP	B 10%	HPT (50)	Alq_3 (450)
Comparative 2	CBP	A 10%	HPT (50)	Alq_3 (450)
1	H-1	A 10%	HPT (50)	Alq_3 (450)
2	H-1	A 10%	H-1 (100)	Alq_3 (400)
3	H-1	A 15%	HPT (50)	Alq_3 (450)
4	H-1	A 15%	H-1 (100)	Alq_3 (400)
5	H-2	A 10%	HPT (50)	Alq_3 (450)
6	H-2	A 10%	H-2 (100)	Alq_3 (400)
7	H-2	A 15%	HPT (50)	Alq_3 (450)
8	H-2	A 15%	H-2 (100)	Alq_3 (400)

TABLE 3

Device	CIE		At L = 1000 cd/m^2				At J = 40 mA/cm^2	
Example	X	Y	V (V)	LE (cd/A)	EQE (%)	PE (lm/W)	L_o (cd/m^2)	LT_{max} (hr)
Comparative 1	0.331	0.627	6.1	61.0	17	31.4	18,935	87
Comparative 2	0.346	0.613	6.2	57.0	16	28.9	13,304	105
1	0.357	0.605	6.1	62.6	17.3	33.2	15,561	140
2	0.358	6.605	6.7	56.9	15.7	26.7	15,421	150
3	0.362	0.604	5.8	63.3	17.4	34.3	17,977	130
4	0.363	0.603	6.3	56.8	15.4	27.8	16,436	175
5	0.352	0.611	6.2	61.1	16.8	30.9	16,102	126
6	0.351	0.610	7.3	45.6	12.6	19.6	14,364	148
7	0.354	0.610	6.3	59.2	16.3	29.5	16,255	73
8	0.354	0.610	7.5	36.5	10	15.3	11,882	185

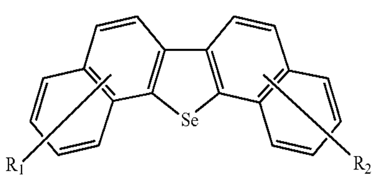
From Device Examples 1-8, it can be seen that Compounds H-1 and H-2 as hosts in green phosphorescent OLEDs give high device efficiency (LE>40 cd/A at 1000 cd/m^2), indicating the dienzoselenophene linked with aryl building blocks such as biphenyls or triphenylene, have triplet energy high enough for efficient green electrophosphorescence. The high stability of devices incorporating Compounds H-1 and H-2 as the host is notable. Device Example 1 and Comparative Example 2 are only different in the host. Device Example 1 uses Compound H-1 as the host whereas Comparative Example 2 uses the commonly used host CBP. The lifetime, $T_{80\%}$ (defined as the time required for the initial luminance, L_0, to decay to 80% of its value, at a constant current density of 40 mA/cm^2 at room temperature) are 140 hours and 105 hours respectively, with Device Example 1 having a slightly higher L_0. Similarly, Device Example 5 using Compound H-2 as the host, is more stable than Comparative example 2. It is also notable that the compounds may function well as an enhancement layer material (ETL2). For example, Device Example 8 and Device Example 4 both have Compound H-1 and H-2 as the host and ETL2 layer, respectively. They have $T_{0.8}$ of 185 and 175 hours respectively, indicating the good performance of Compounds H-1 and H-2 as the enhancement layer material.

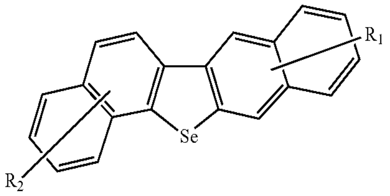
The data suggest that hosts containing dibenzoselenophenes are excellent host and enhancement layer materials for phosphorescent OLEDs, providing as least the same efficiency and improvement in stability compared to the commonly used CBP as the host. More conjugated versions of triphenylene containing benzoselenophenes, for example triphenylene and dibenzoselenophene units linked via p-phenylene (such as 4,4'-biphenyl) may be very suitable for lower energy (yellow to red) phosphorescent OLEDs. The triphenylene containing group may be attached to any position of benzoselenophenes.

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 includes 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.

What is claimed is:

1. An organic light emitting device, comprising an organic layer positioned between an anode layer and a cathode layer, said organic layer comprising an organoselenium material, wherein said organoselenium material is selected from the group consisting of





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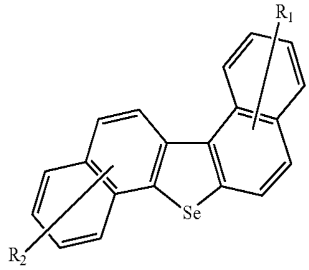

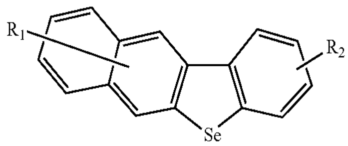

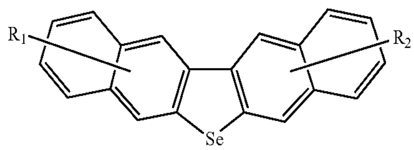

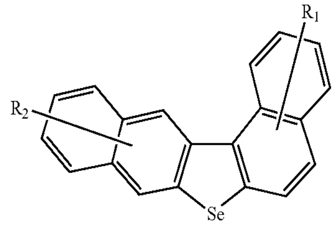

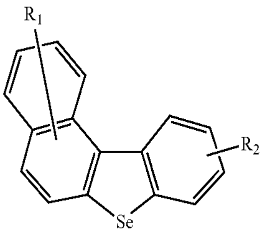

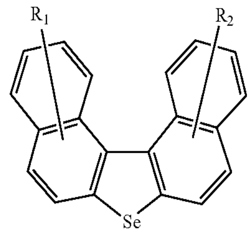

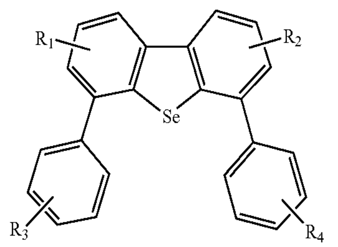

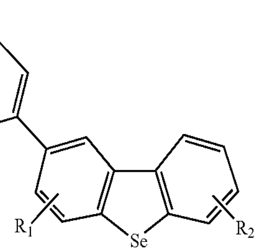

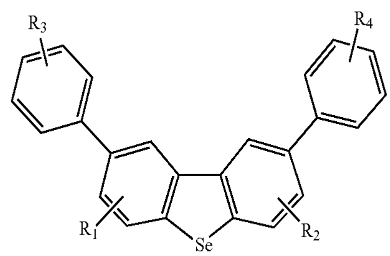

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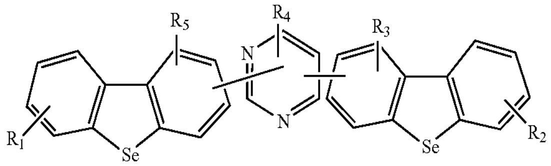

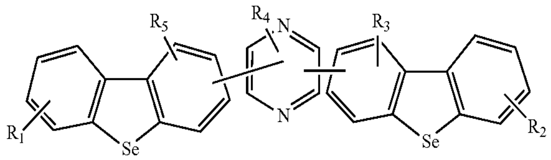

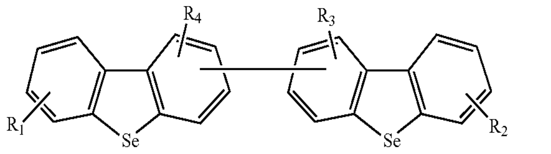

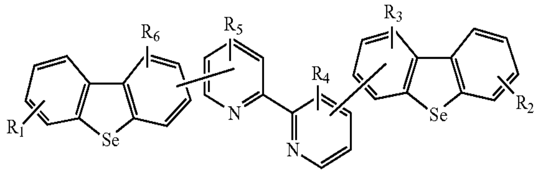

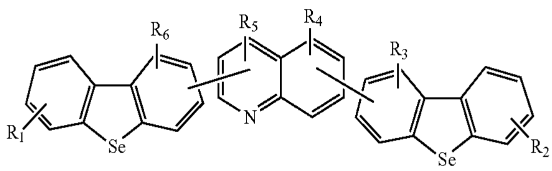

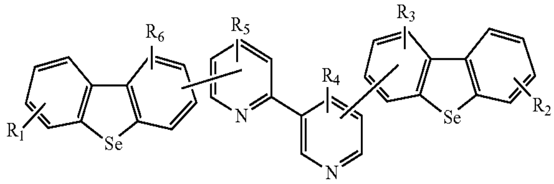

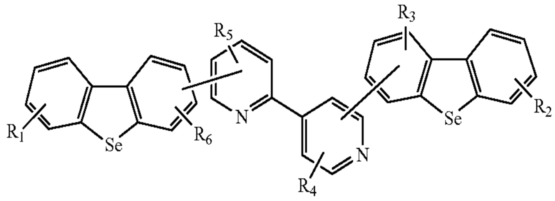

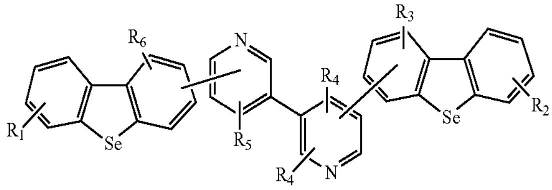

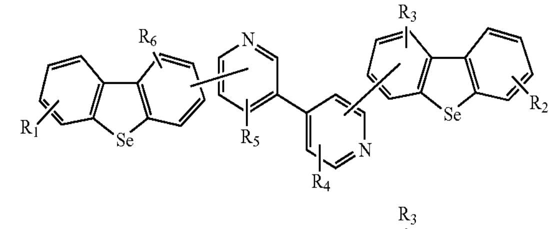

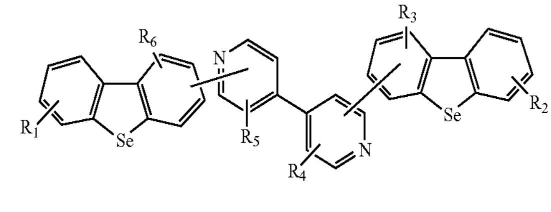

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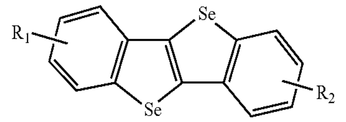

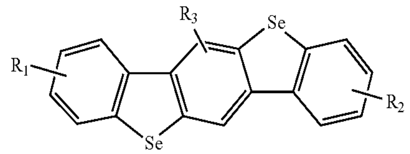

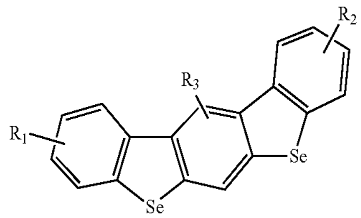

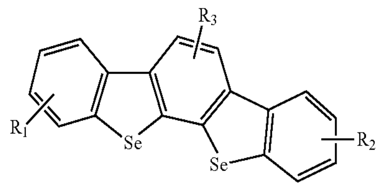

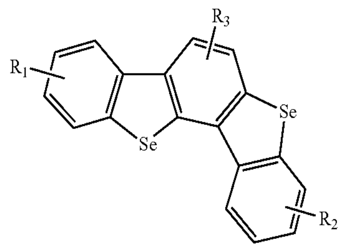

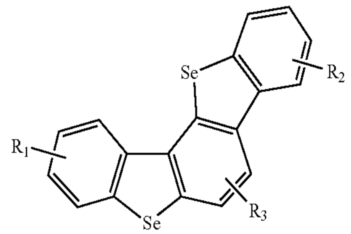

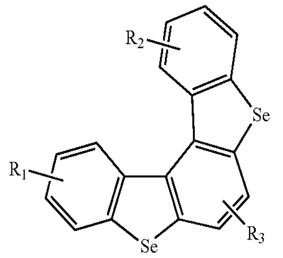

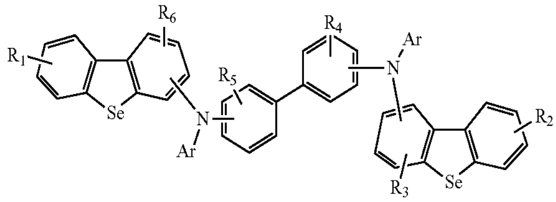

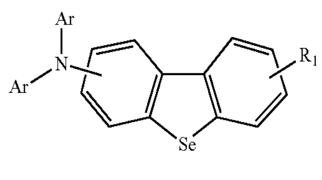

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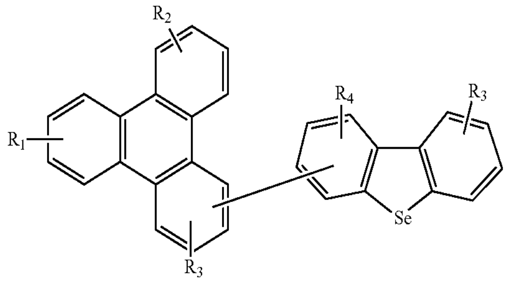

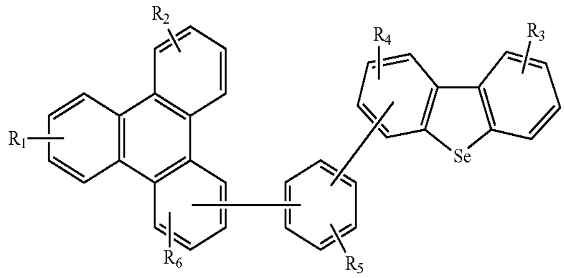

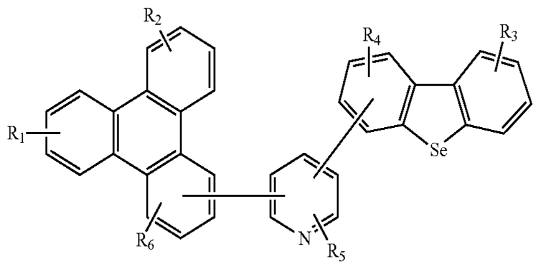

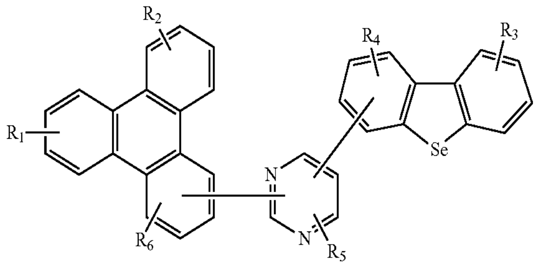

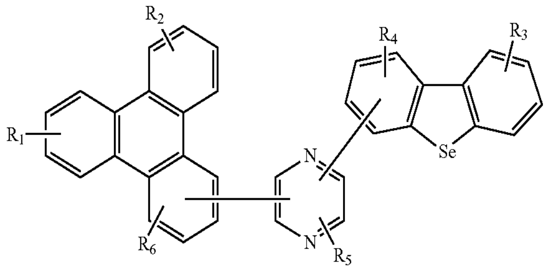

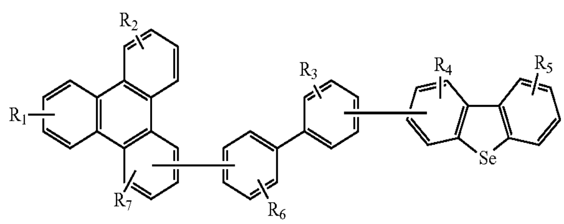

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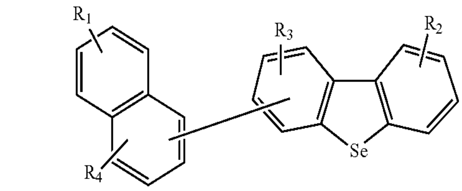

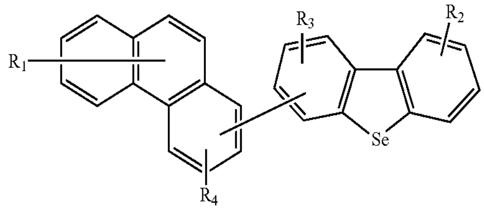

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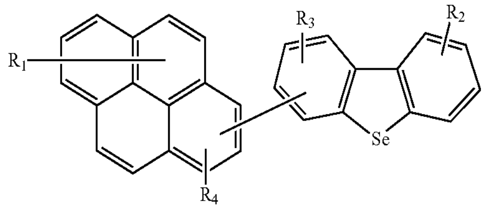

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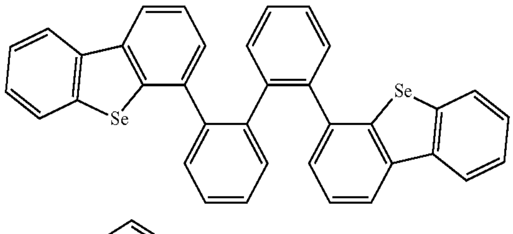
wherein each of R_1, R_2, R_3, R_4, R_5, R_6, and R_7 indicates an optional substituent to any possible position in the relevant moiety and are independently selected from the group consisting of halo, alkyl, heteroalkyl, cycloalkyl, alkenyl, alkynel, arylalkyl, heterocyclic group, aryl, and heteroaryl,

Ar indicates an aromatic group, and each line linking two molecular moieties indicates attachment between the two moieties at any possible positions on the respective moieties.

2. An organic light emitting device, comprising an organic layer positioned between an anode layer and a cathode layer, said organic layer comprising an organoselenium material, wherein said organoselenium material is selected from the group consisting of



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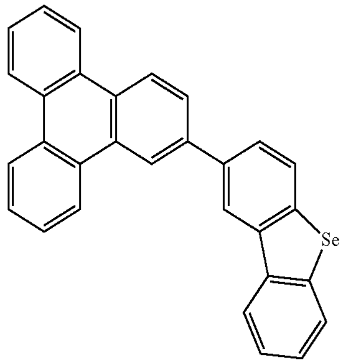

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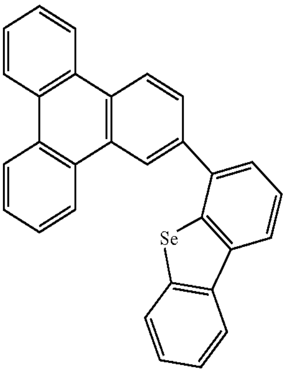

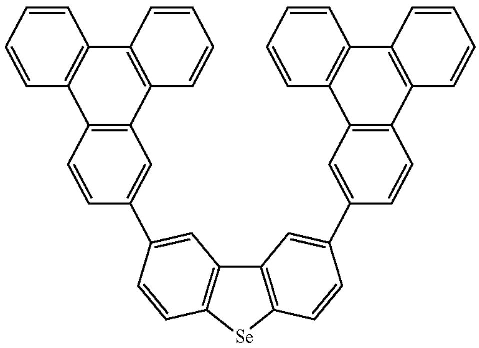

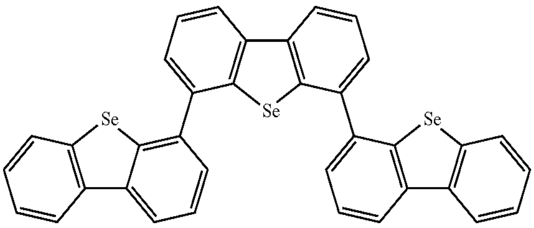

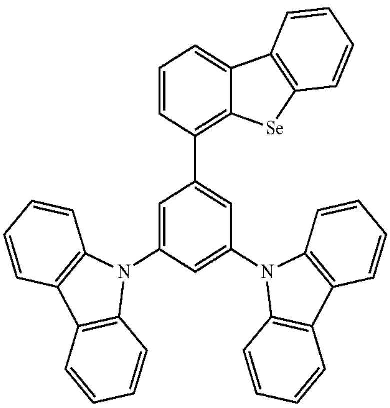

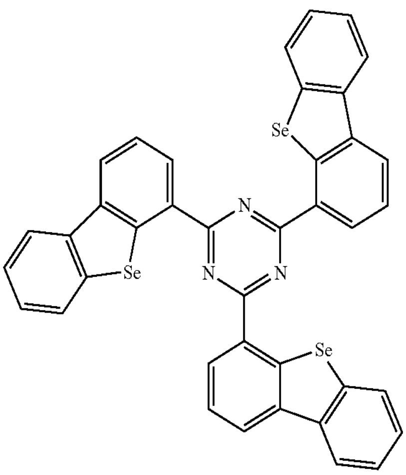

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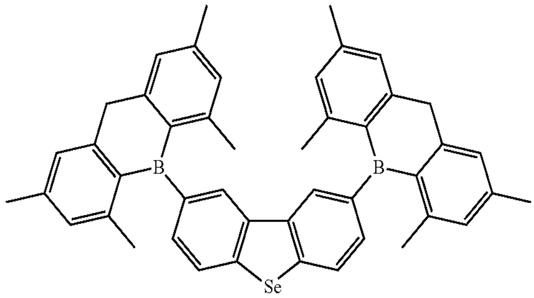

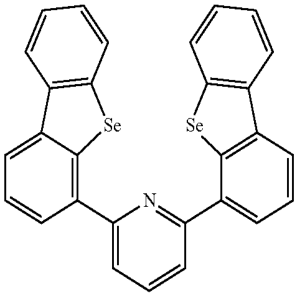

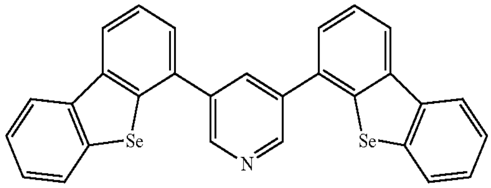

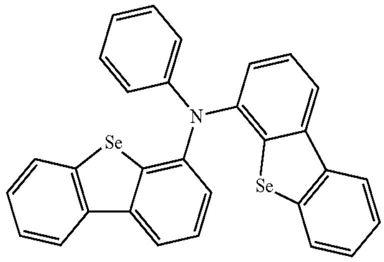

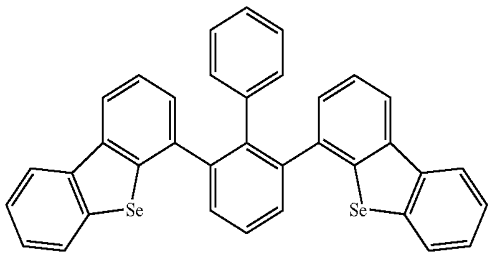

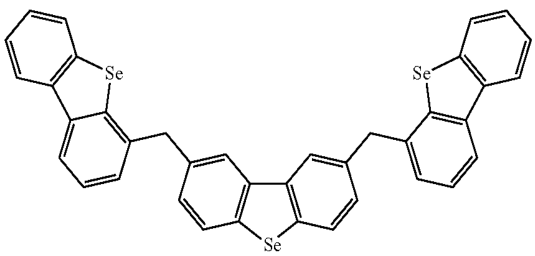

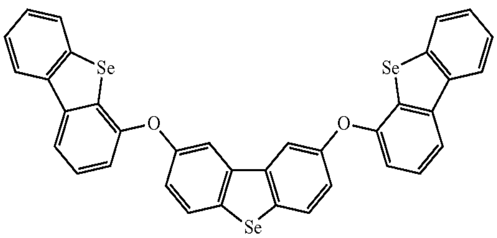

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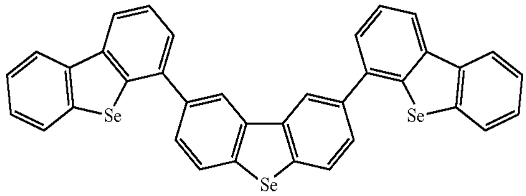

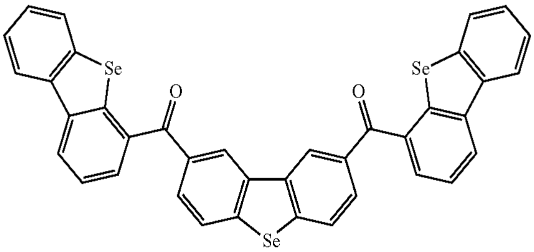

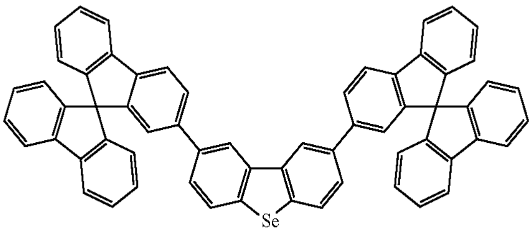

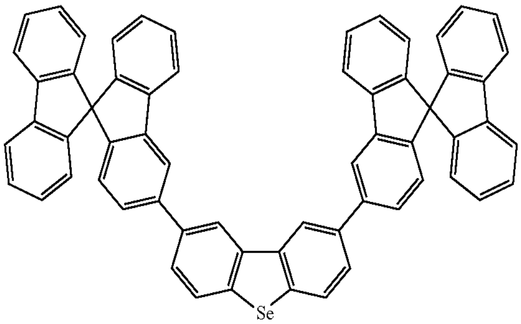

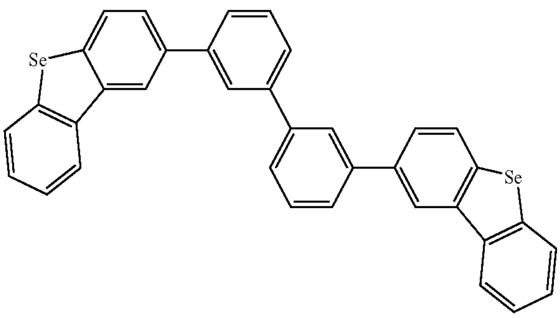

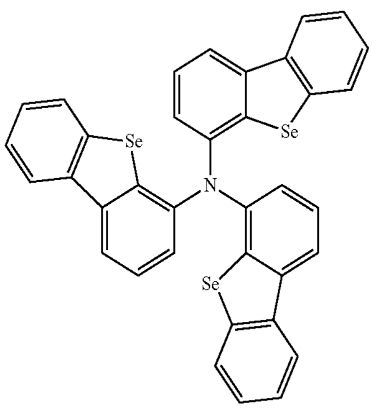

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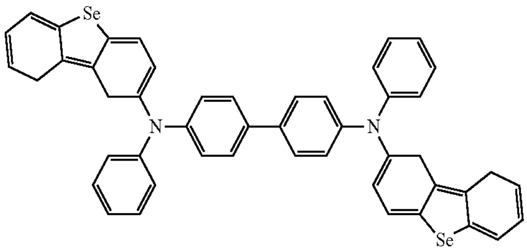

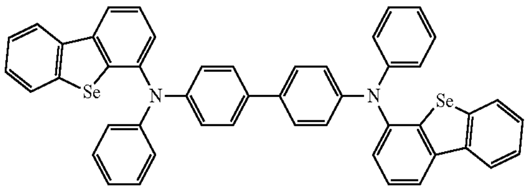

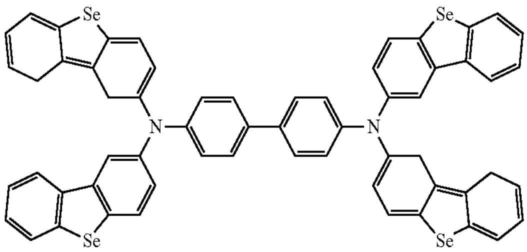

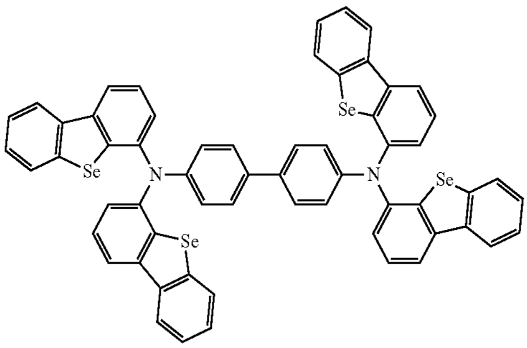

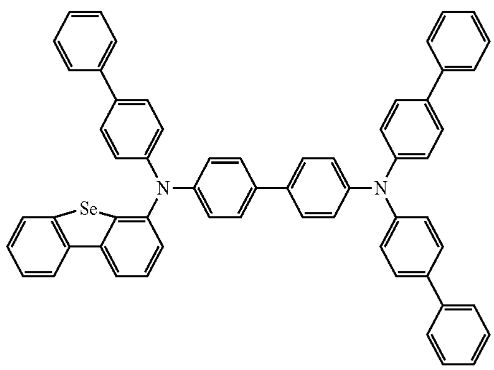

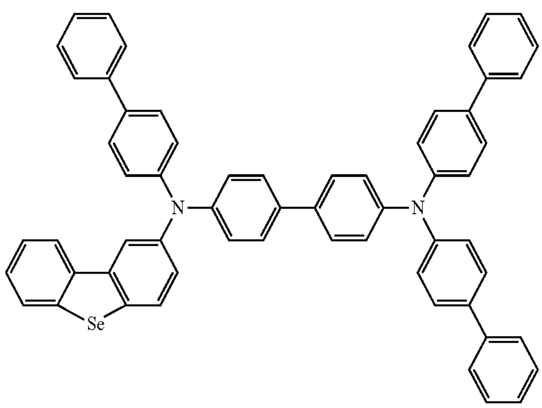

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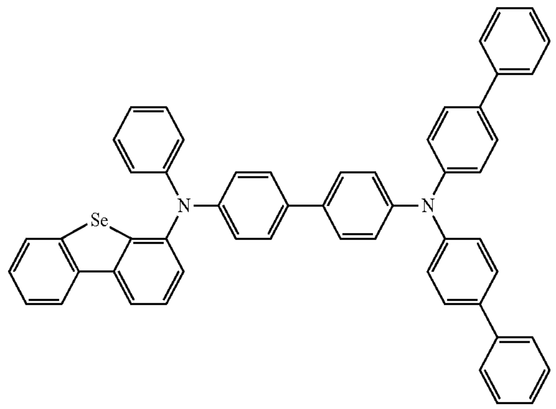

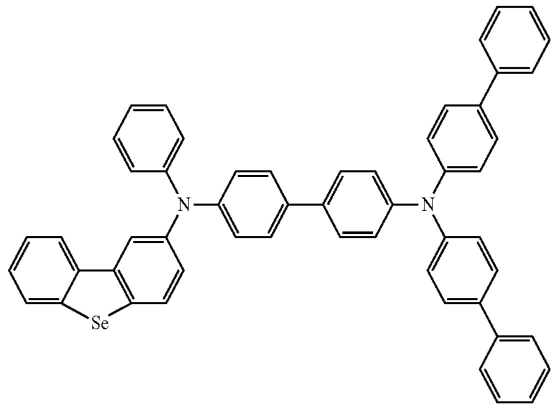

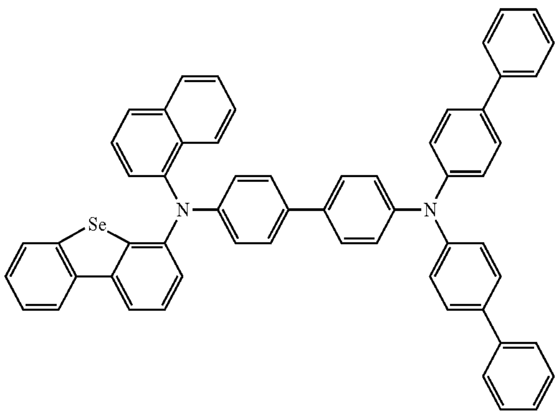

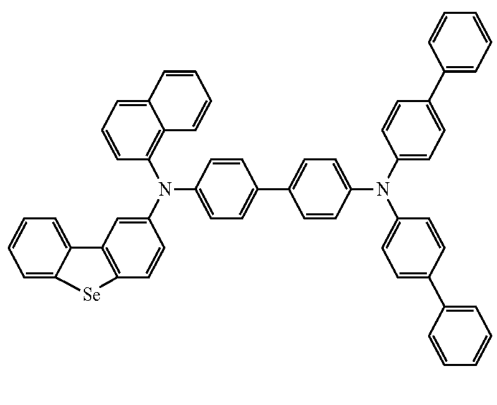

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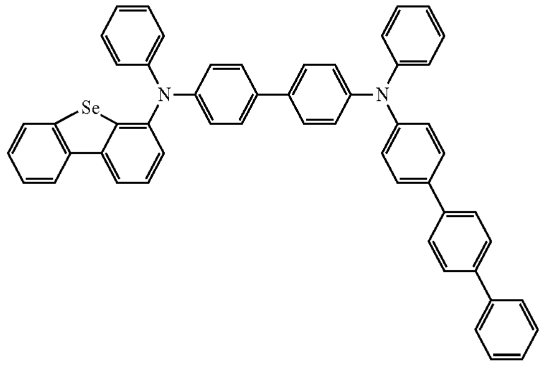

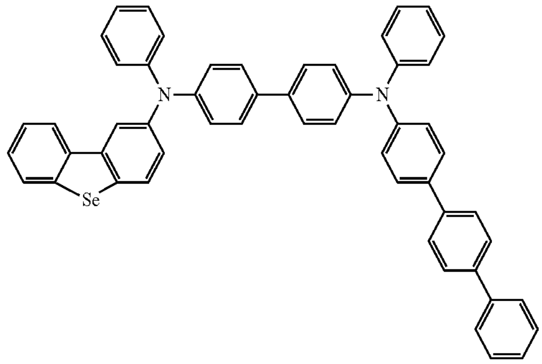

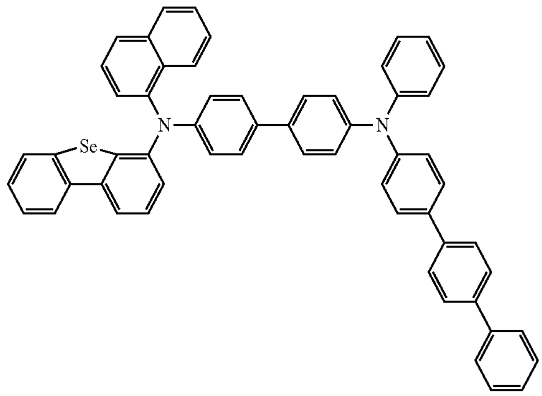

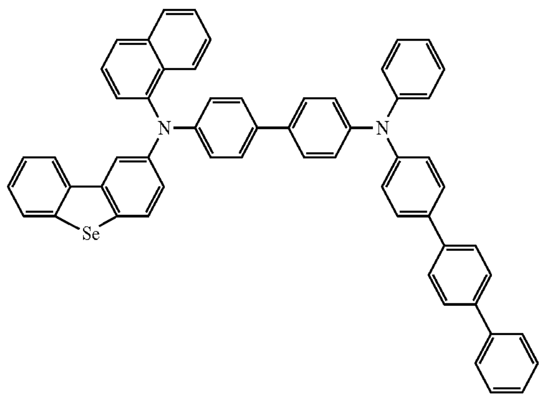

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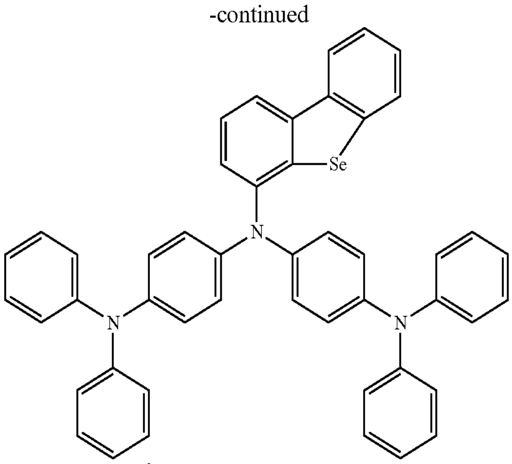

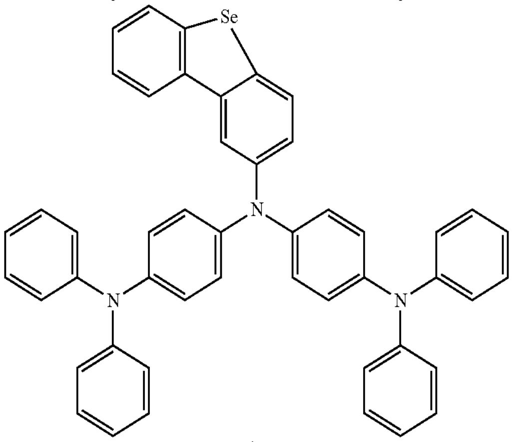

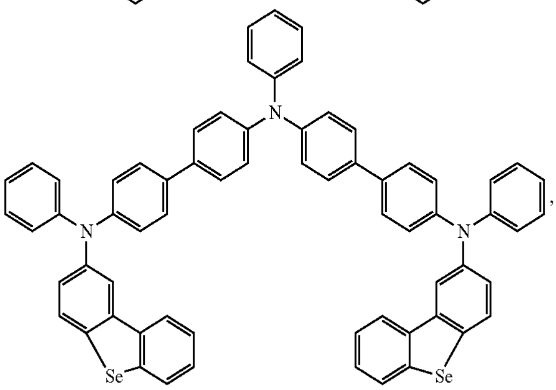

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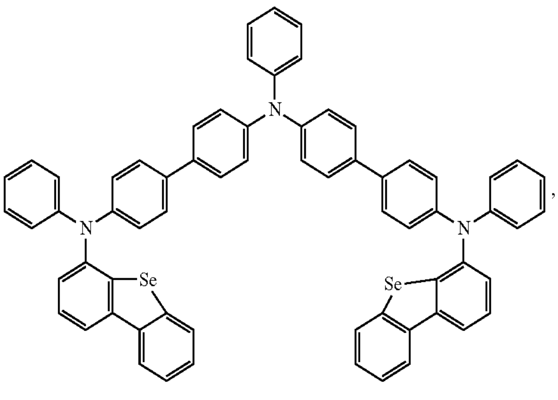


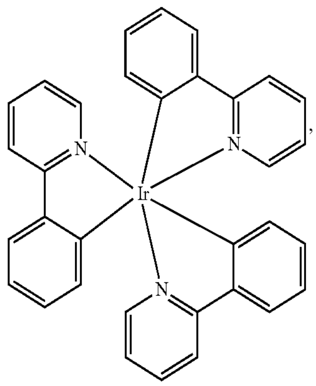
and derivatives thereof.

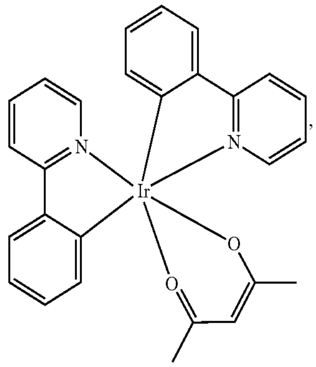
3. The organic light emitting device of any of claims **1** to **2**, wherein said organoselenium material is a host material, and wherein said organic layer further comprises a dopant material.

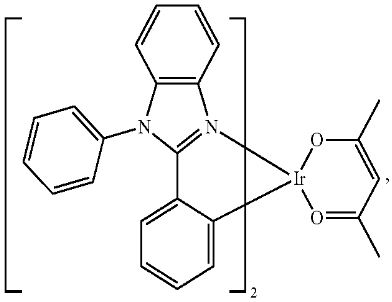
4. The organic light emitting device of claim **3**, wherein said organic layer is an emissive layer, and wherein said dopant material is a phosphorescent or fluorescent dopant material.

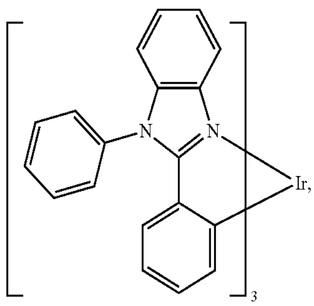
5. The organic light emitting device of claim **4**, wherein said dopant material is a phosphorescent dopant material.

6. The organic light emitting device of claim **5**, wherein said dopant material is a phosphorescent dopant material selected from the group consisting of









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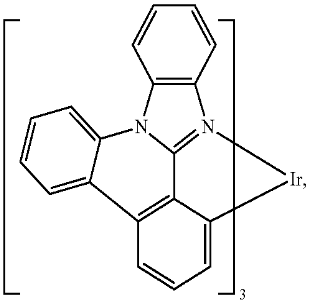

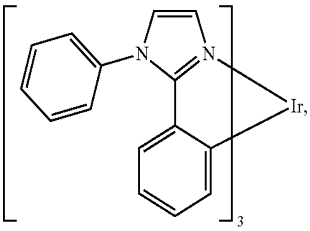

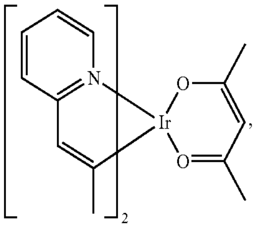

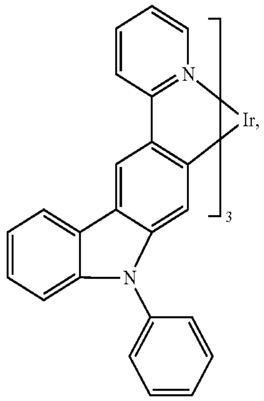

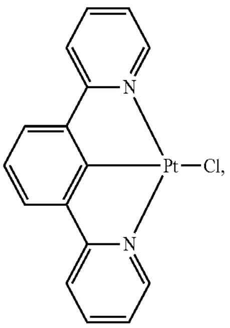

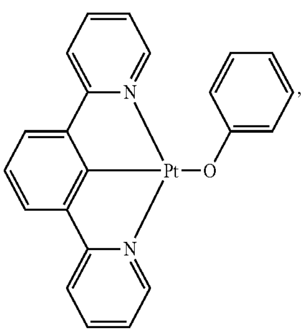

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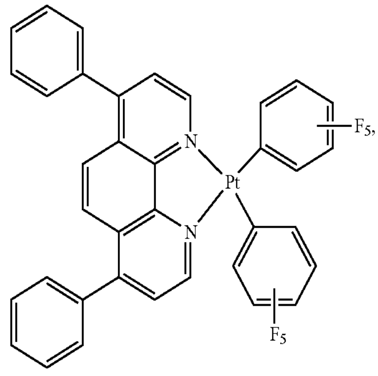
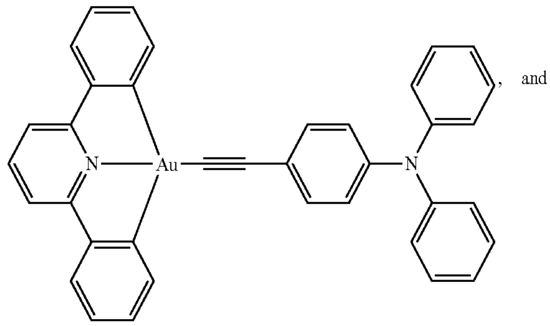
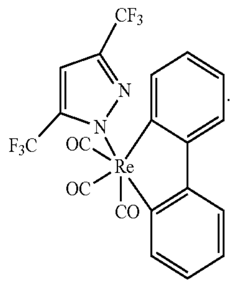
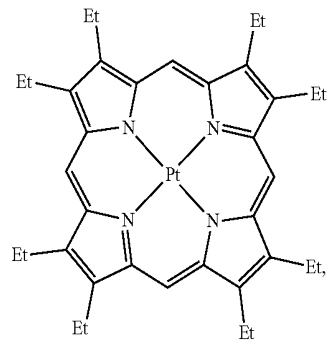
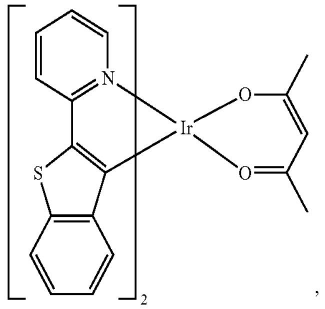






7. The organic light emitting device of claim 5, wherein said dopant material is a phosphorescent dopant material selected from the group consisting of





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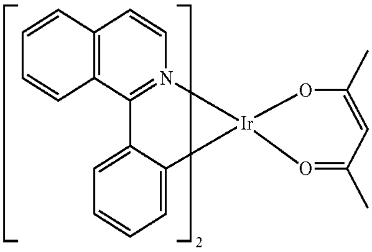

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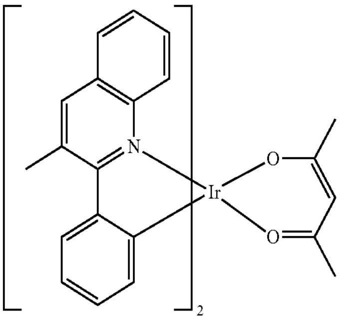

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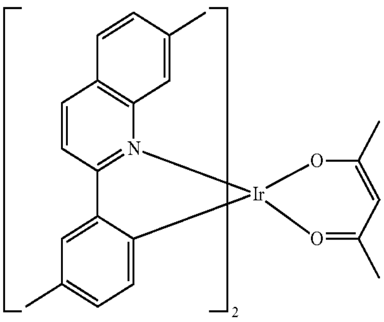

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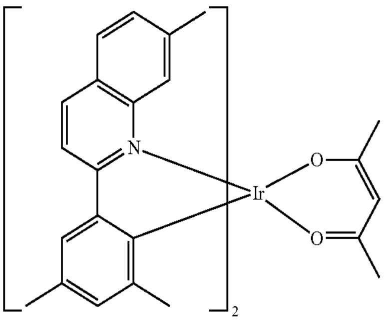

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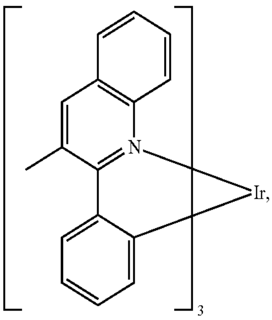

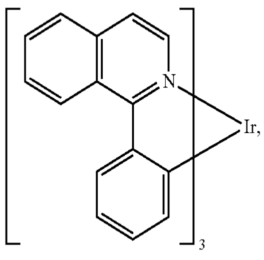

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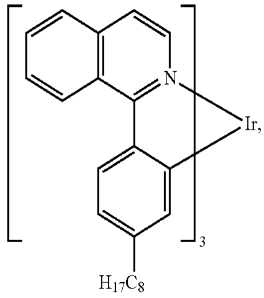

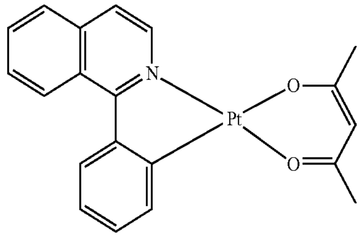

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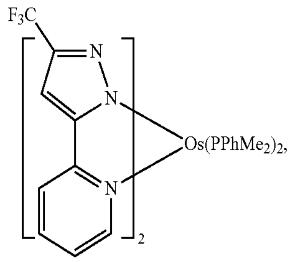

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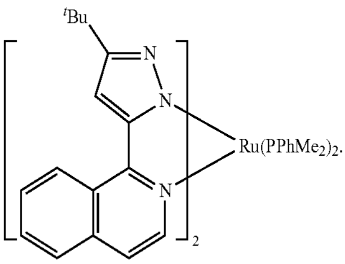
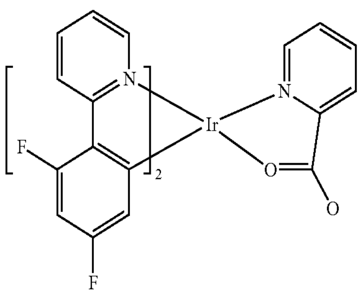


8. The organic light emitting device of claim **5**, wherein said dopant material is a phosphorescent dopant material selected from the group consisting of



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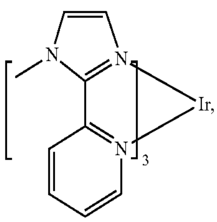

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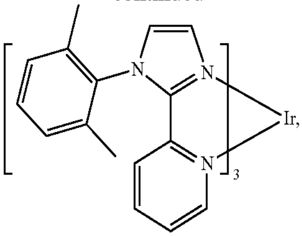

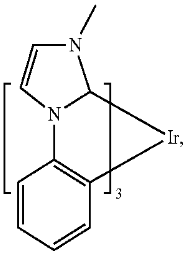

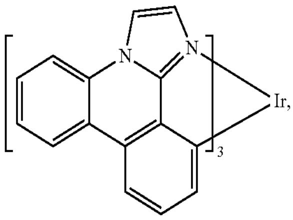

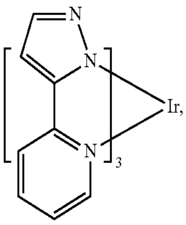

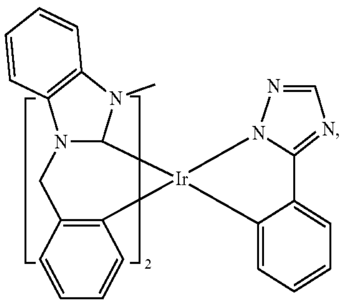

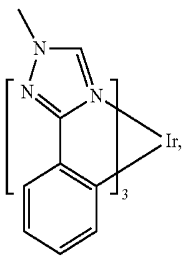

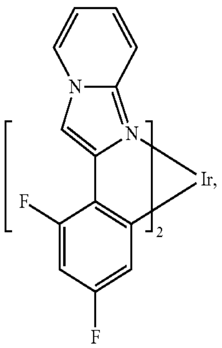

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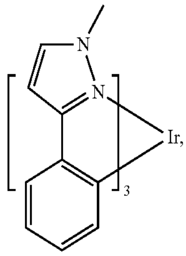

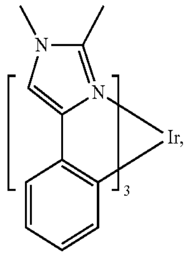

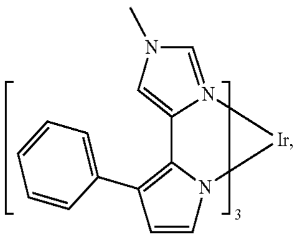

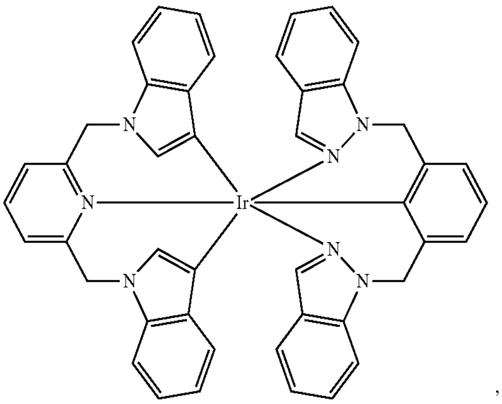

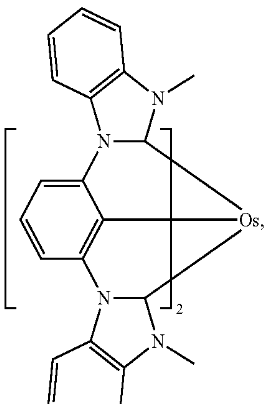

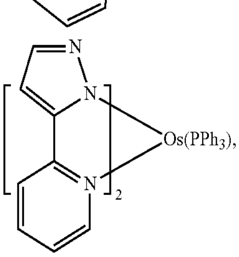

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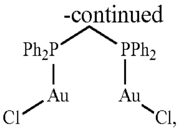

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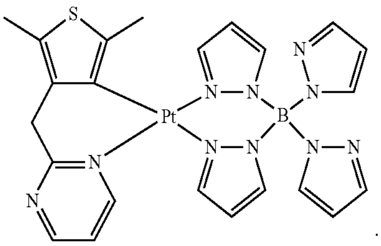


9. The organic light emitting device of claim 5, further comprising one or more organic layers selected from the group consisting of a hole injecting layer, an electron injecting layer, a hole transporting layer, an electron transporting layer, a hole blocking layer, an exciton blocking layer, and an electron blocking layer.

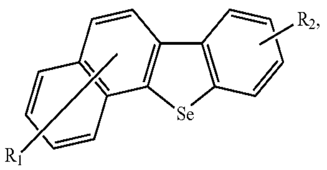
10. The organic light emitting device of claim 9, wherein said hole transporting layer comprises an organoselenium material.

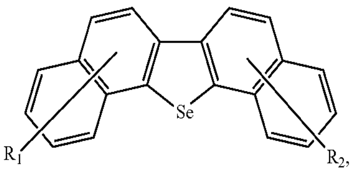
11. The organic light emitting device of claim 9, wherein said electron transporting layer comprises an organoselenium material.

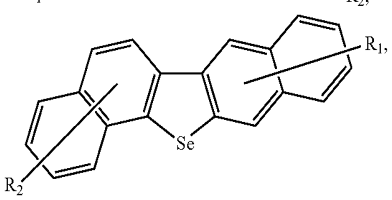
12. The organic light emitting device of any of claim 1, wherein said organic layer is a hole transporting layer or an electron transporting layer.

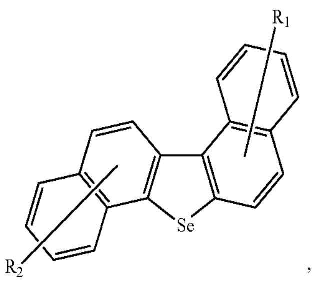
13. The organic light emitting device of any of claim 2, wherein said organic layer is a hole transporting layer or an electron transporting layer.

14. An organoselenium compound selected from the group consisting of









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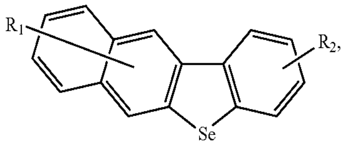

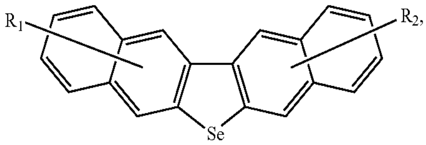

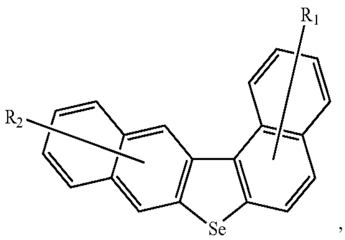

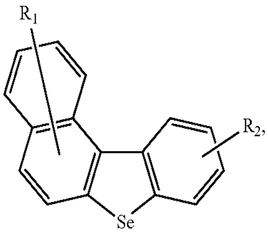

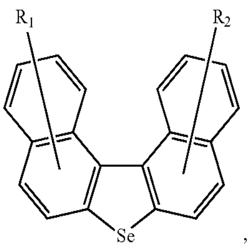

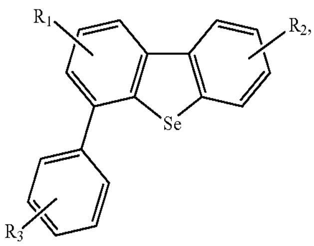

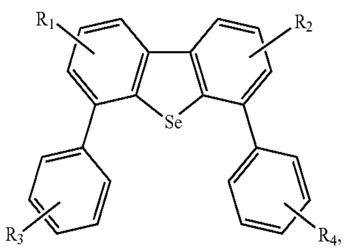

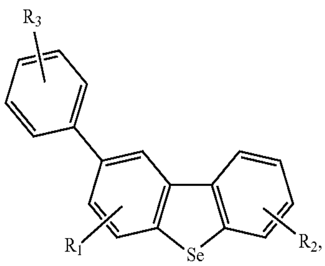

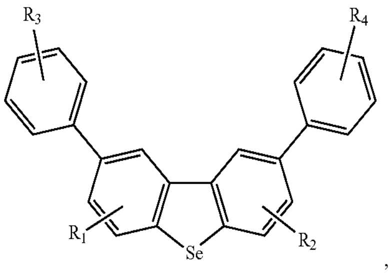

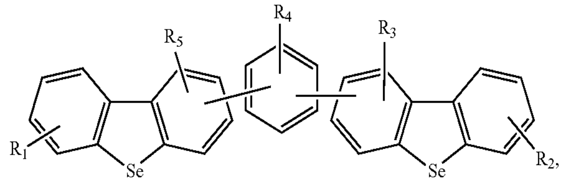

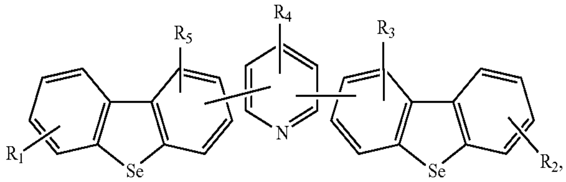

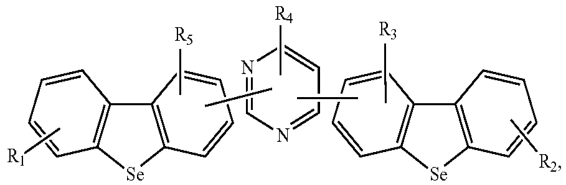

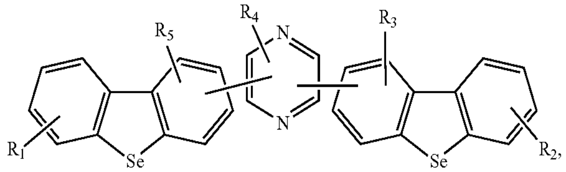

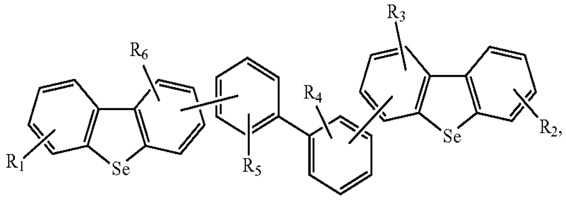

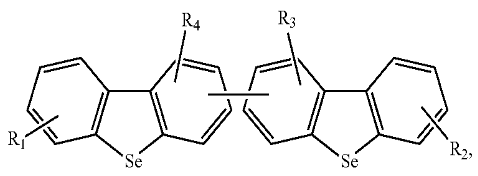

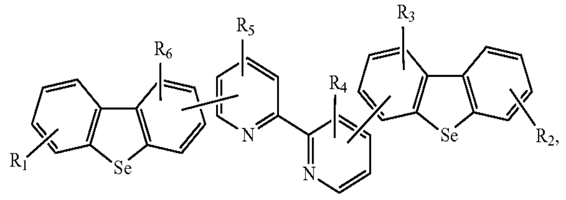

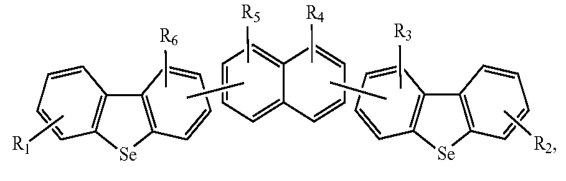

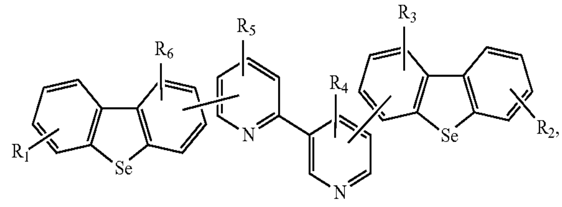

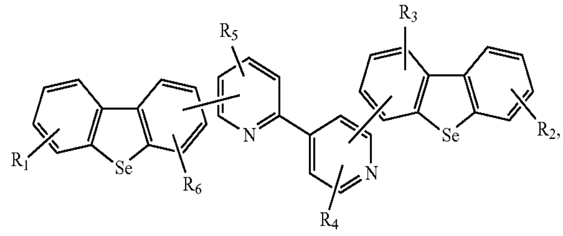

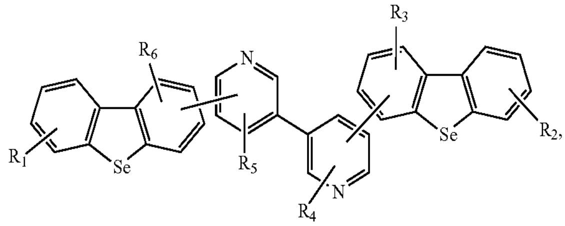

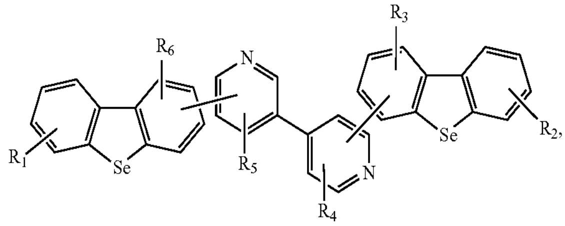

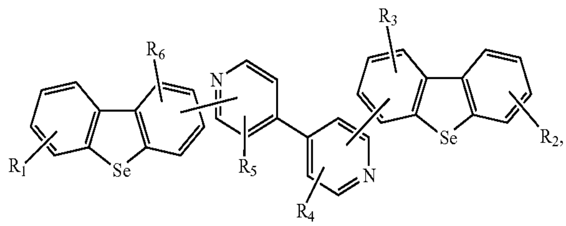

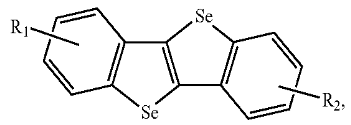

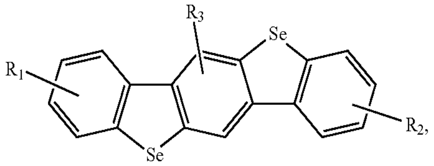

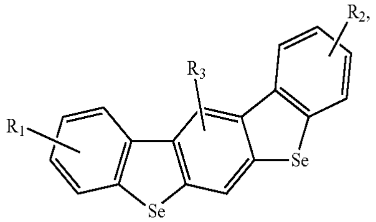

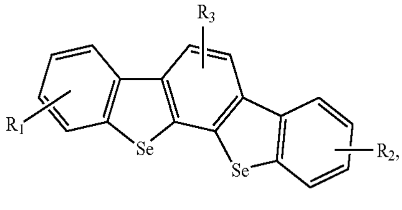

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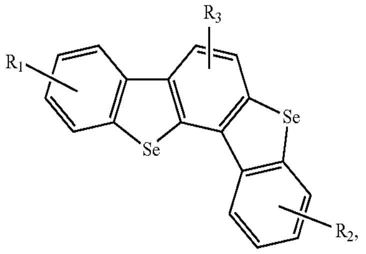

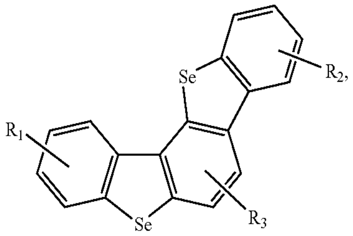

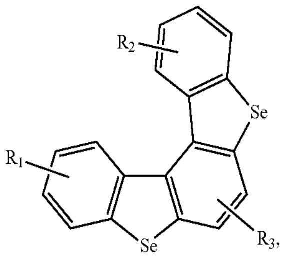

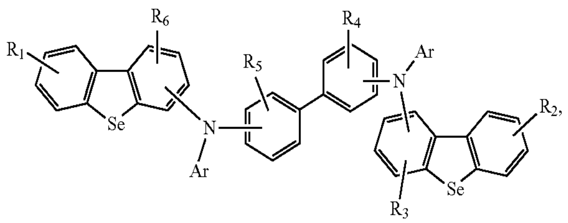

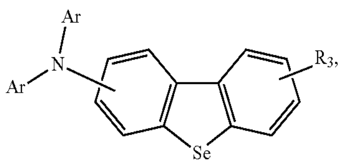

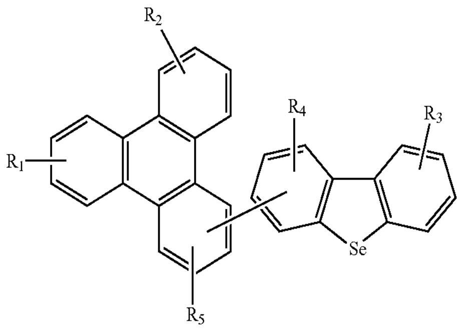

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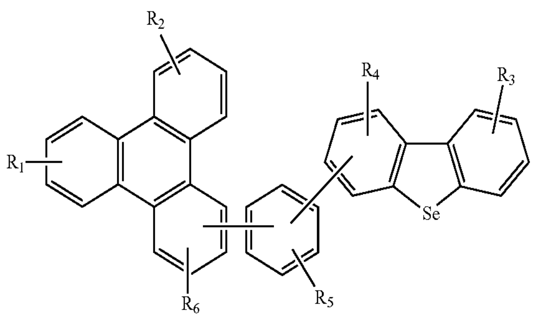

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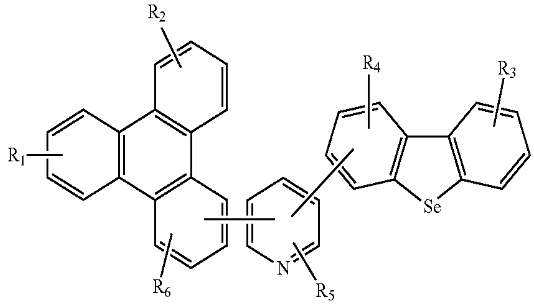

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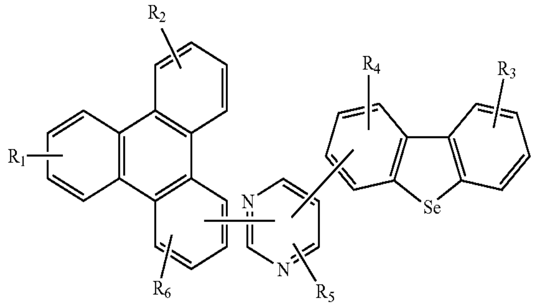

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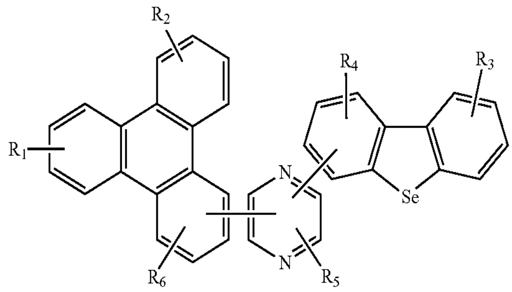

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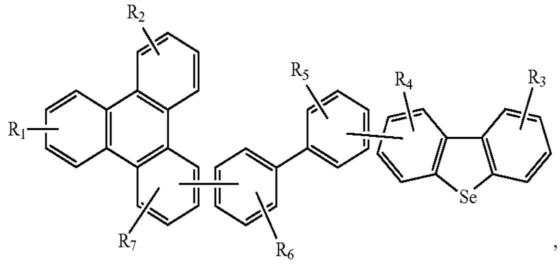

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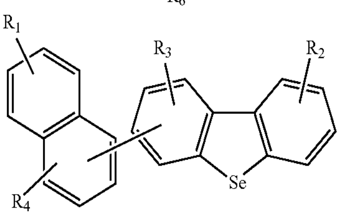

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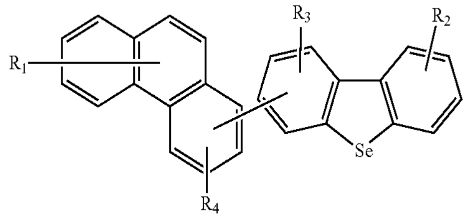

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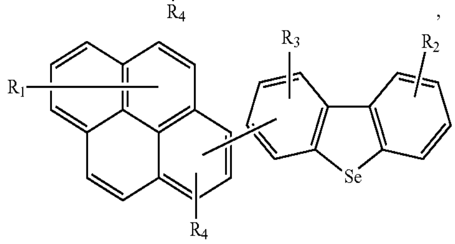
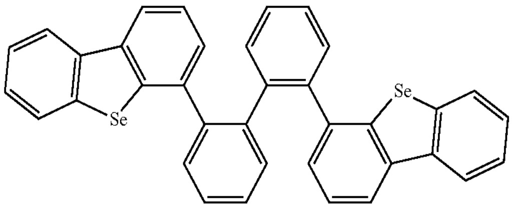


wherein each of R_1, R_2, R_3, R_4, R_5, R_6, and R_7 indicates an optional substituent to any possible position in the relevant moiety and are independently selected from the group consisting of halo, alkyl, heteroalkyl, cycloalkyl, alkenyl, aklynel, arylalkyl, heterocyclic group, aryl, and heteroaryl, Ar indicates an aromatic group, and each line linking two molecular moieties indicates attachment between the two moieties at any possible positions on the respective moieties.

15. An organoselenium compound selected from the group consisting of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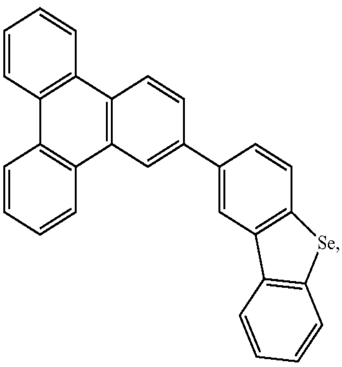
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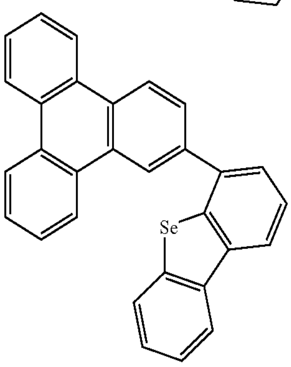
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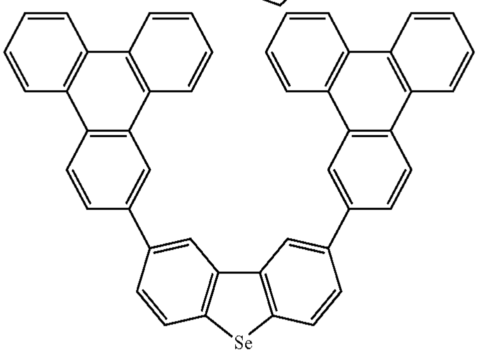
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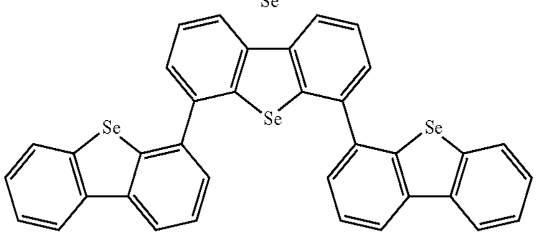
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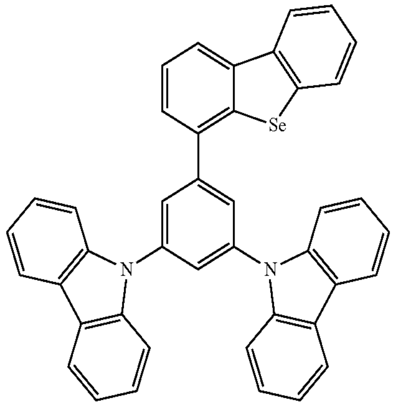
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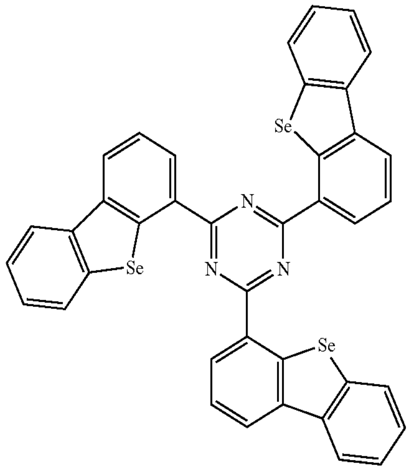
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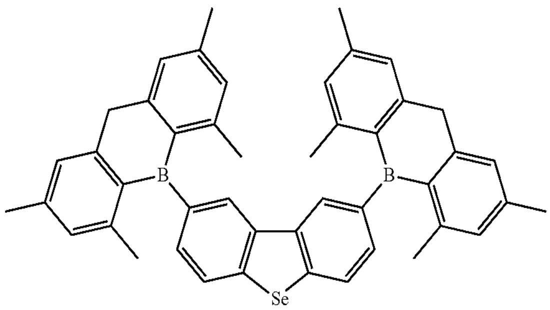
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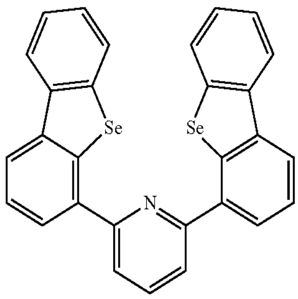
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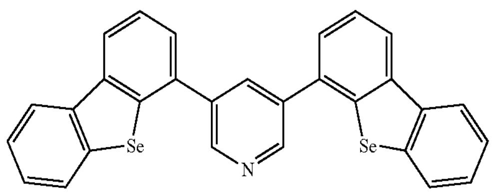
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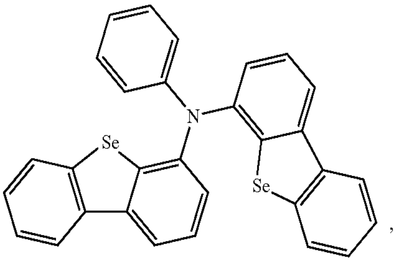

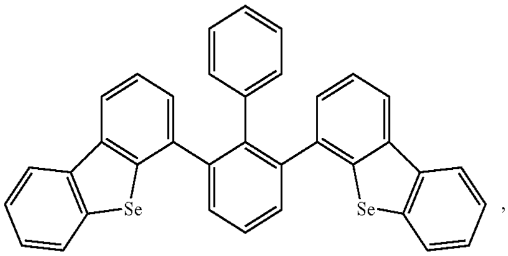

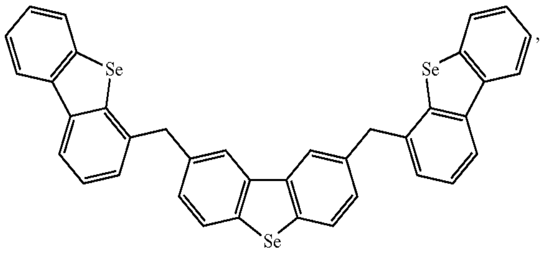

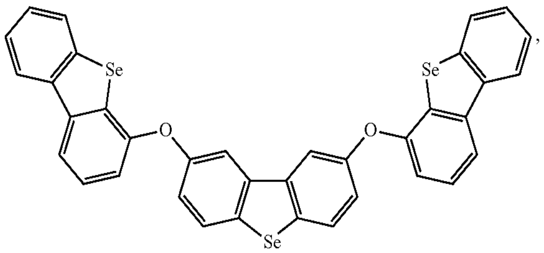

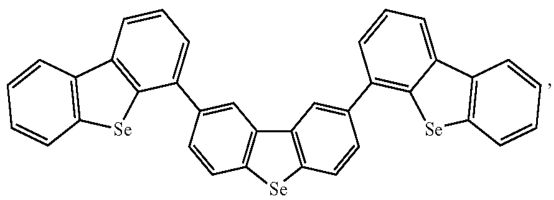

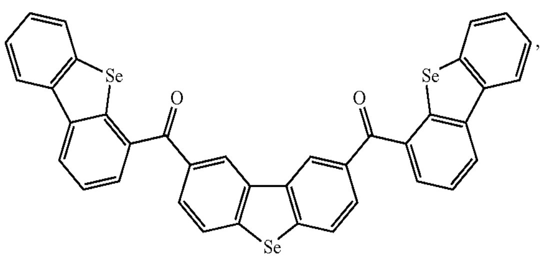

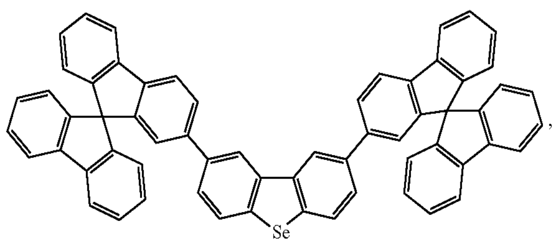

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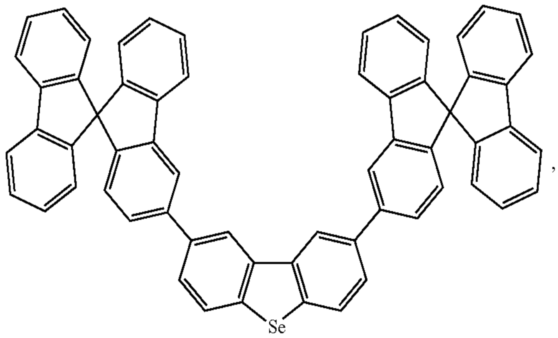

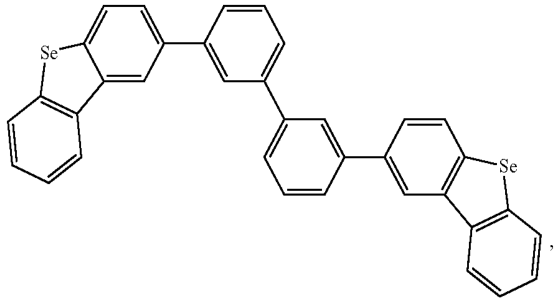

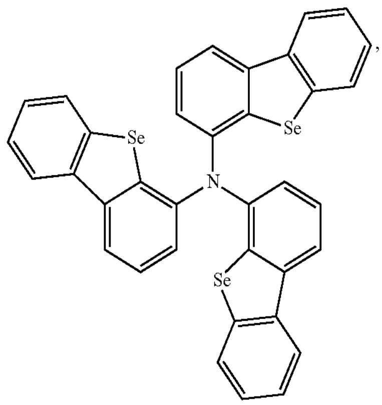

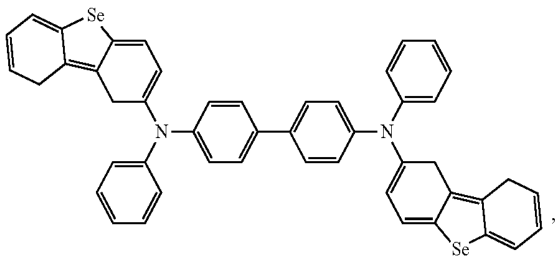

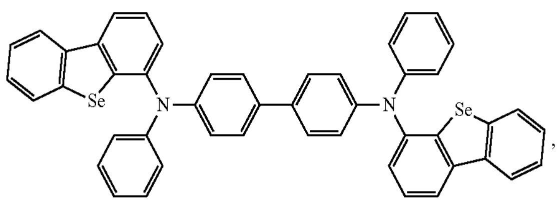

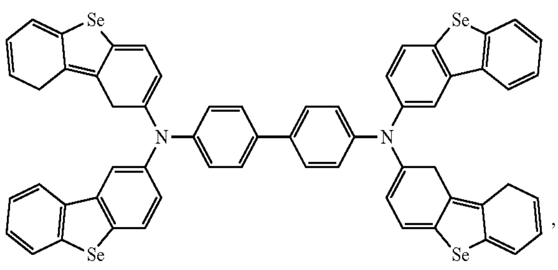

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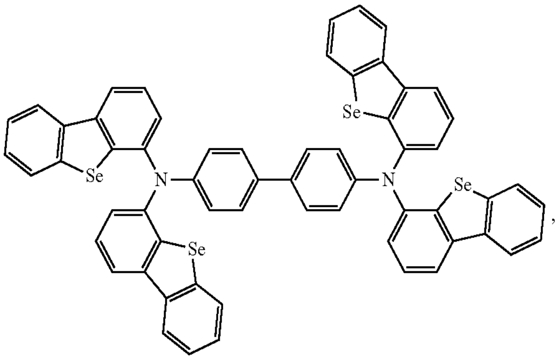

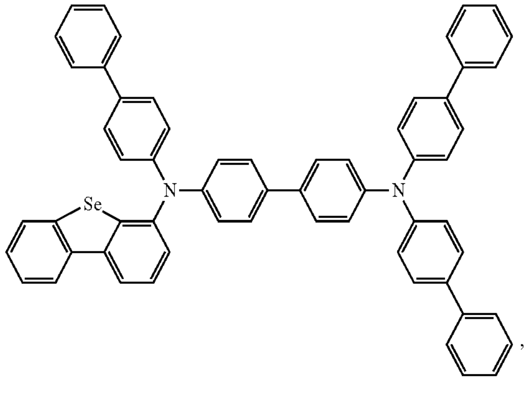

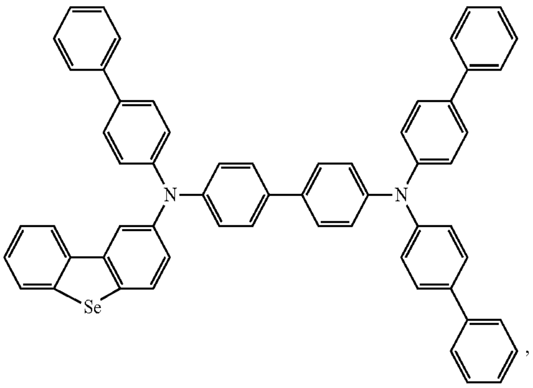

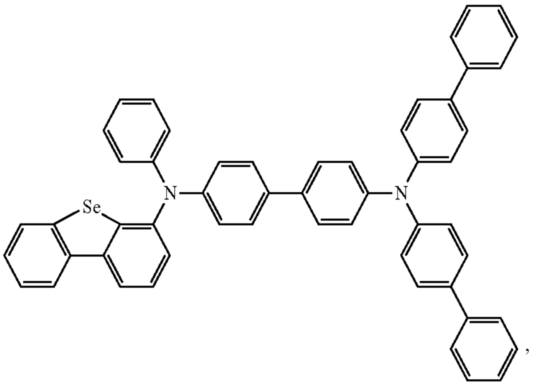

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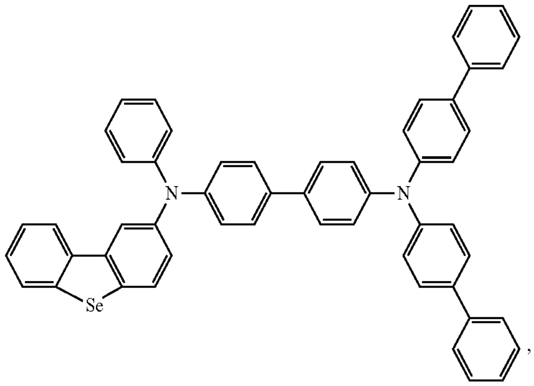

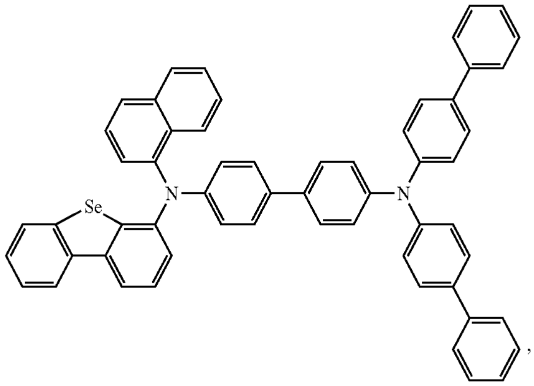

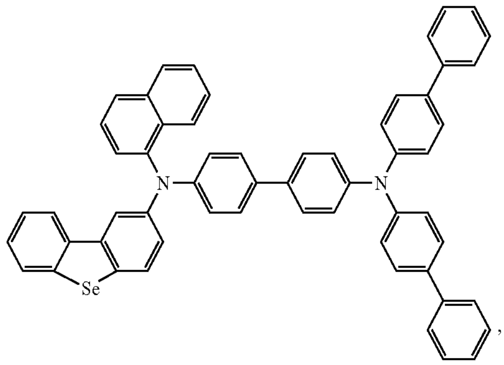

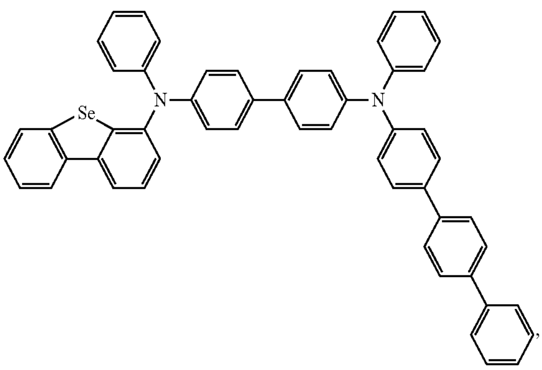

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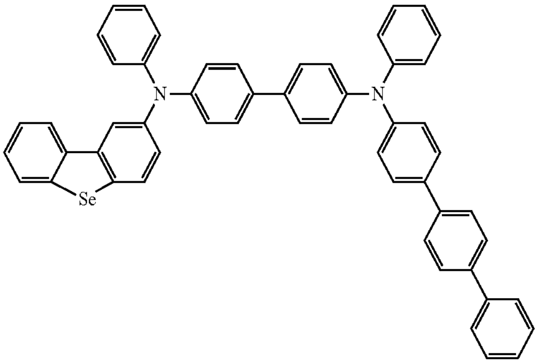
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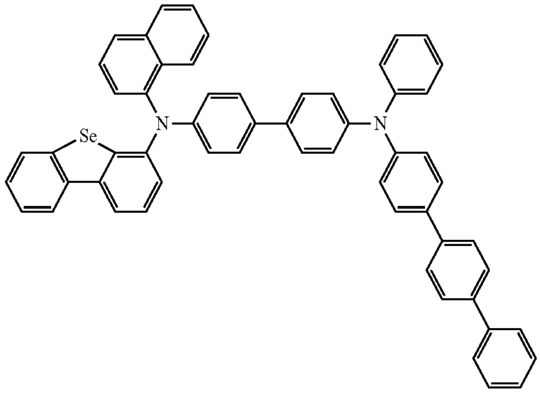
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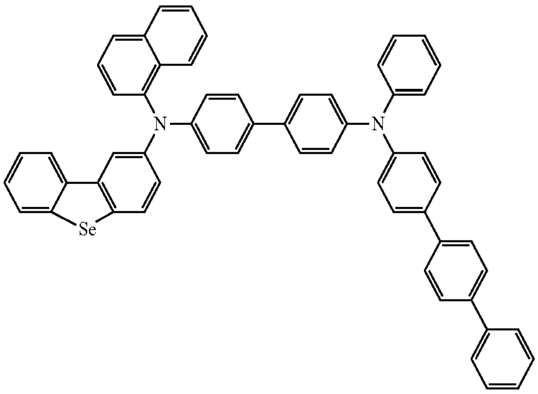
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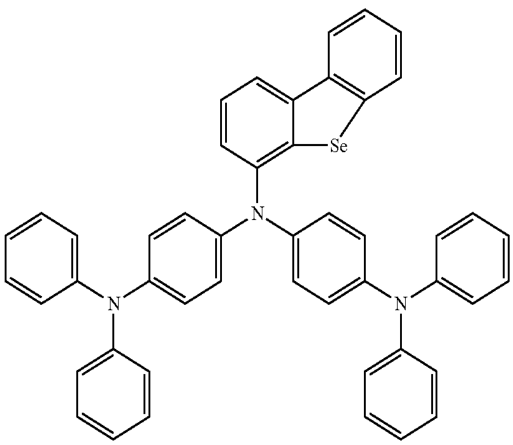
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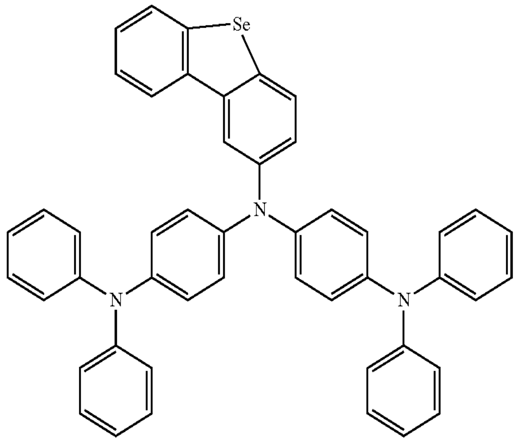
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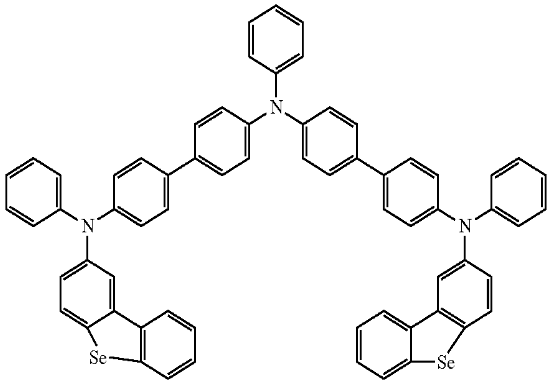
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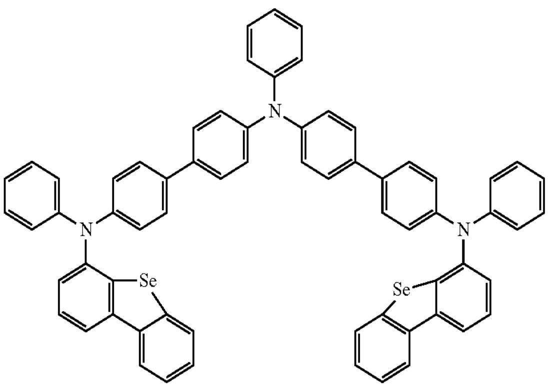
,

and derivatives thereof.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,455,411 B2
APPLICATION NO. : 14/611468
DATED : September 27, 2016
INVENTOR(S) : Raymond Kwong et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Specification

In Column 2, Line 51, please delete “omissive” and insert -- emissive --

In Column 2, Line 62, please delete “as” and insert -- a higher --

In Column 2, Line 64, please delete “loss” and insert -- less --

In Column 6, Line 11, please delete “bare” and insert -- have --

In Column 6, Line 23, please delete “mico-displays” and insert -- micro-displays --

In Column 6, Line 47, please delete “a mixture” and insert -- dibenzoselenophene --

In Column 14, Line 11, please delete “belicnes” and insert -- helicenes --

Signed and Sealed this
Twelfth Day of September, 2017

Joseph Matal

Joseph Matal
Performing the Functions and Duties of the
Under Secretary of Commerce for Intellectual Property and
Director of the United States Patent and Trademark Office

patsnap

专利名称(译)	有机电致发光材料和器件		
公开(公告)号	US9455411	公开(公告)日	2016-09-27
申请号	US14/611468	申请日	2015-02-02
[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	KWONG RAYMOND MA BIN XIA CHUANJUN LIN CHUN		
发明人	KWONG, RAYMOND MA, BIN XIA, CHUANJUN LIN, CHUN		
IPC分类号	H01L51/54 H01L51/00 C09K11/06 C07D345/00 C07F5/02 C07D421/14 H01L51/50		
CPC分类号	H01L51/0071 C07D345/00 C07D421/14 C07F5/027 H01L51/0061 H01L51/0067 H01L51/0069 H01L51/0072 H01L51/0085 H01L51/0087 H01L51/0088 H01L51/506 H01L51/5012 H01L51/5016 H01L51/5076 Y10S428/917		
代理机构(译)	DUANE MORRIS LLP		
优先权	61/100229 2008-09-25 US		
其他公开文献	US20150155499A1		
外部链接	Espacenet USPTO		

摘要(译)

本发明提供了包括二苯并硒酚有机硒化合物，苯并[b]硒酚或苯并[c]硒酚和它们在有机发光器件的用途。