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(54) HOLE TRANSPORT MATERIALS CONTAINING TRIPHENYLENE

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H01L 51/54 (2006.01)

(52) **U.S. Cl.**
USPC **428/690**; 428/917; 313/504; 313/505; 313/506; 564/426; 564/434

(58) **Field of Classification Search** 428/690, 428/917; 313/504, 505, 506; 564/426, 434, 564/26
See application file for complete search history.

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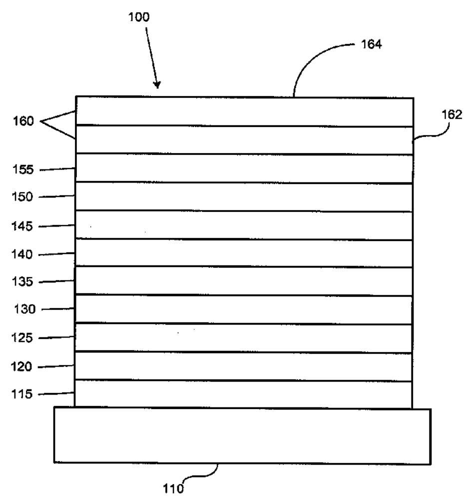
(57) **ABSTRACT**

Novel materials are provided, having a single phenyl or chain of phenyls where there is a nitrogen atom on each end of the single phenyl or chain of phenyls. The nitrogen atom may be further substituted with particular triphenylene groups. Organic light-emitting devices are also provided, where the novel materials are used as a hole transport material in the device. Combinations of the hole transport material with specific host materials are also provided.

20 Claims, 3 Drawing Sheets



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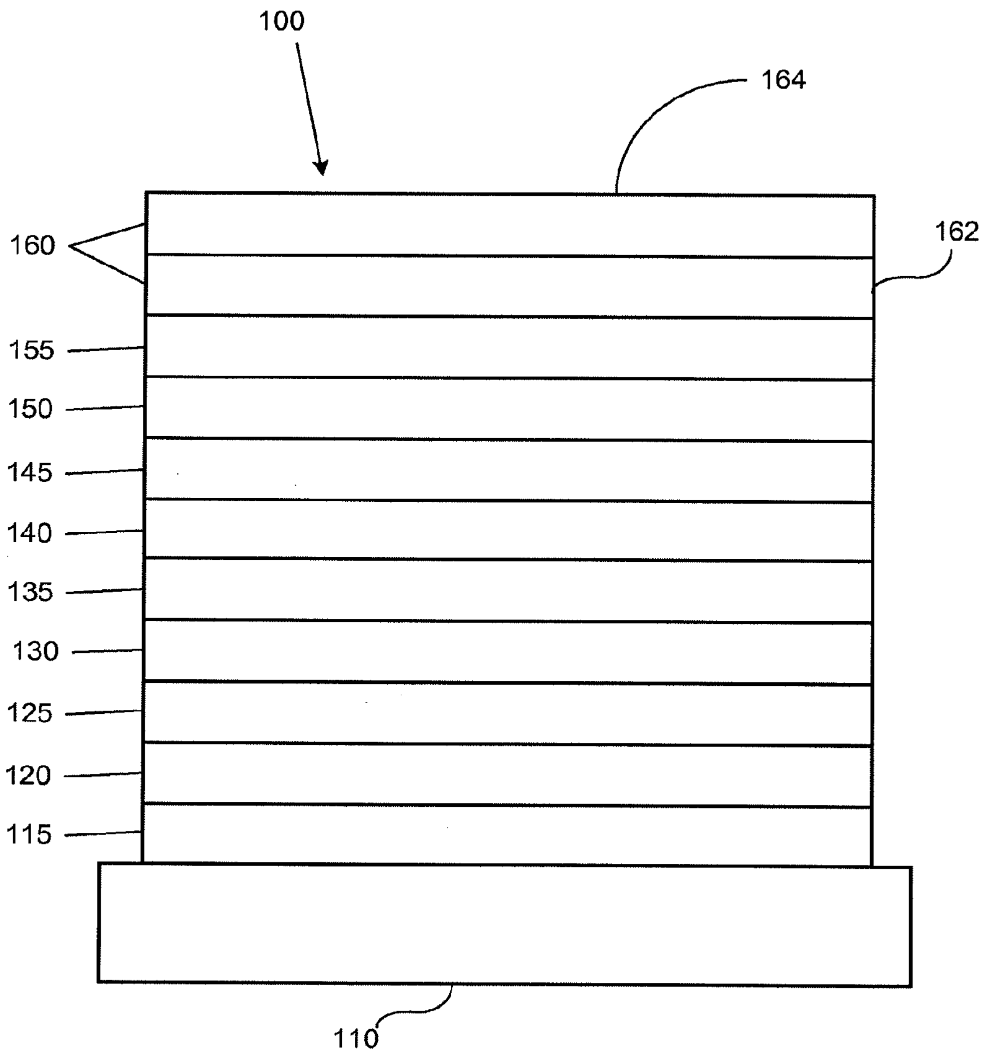


FIGURE 1

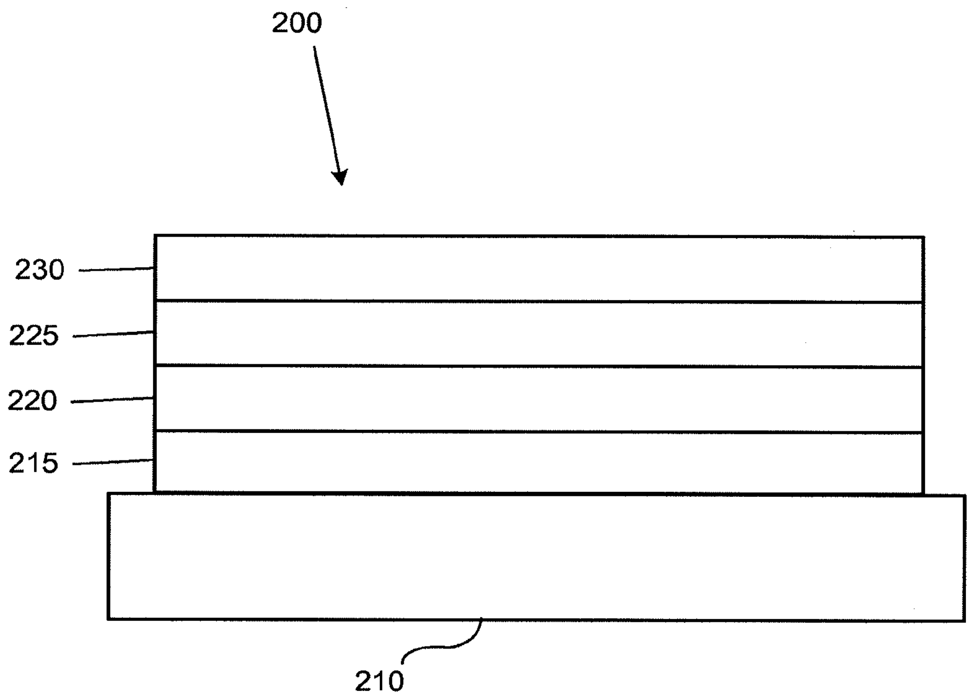
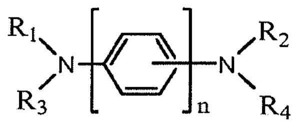
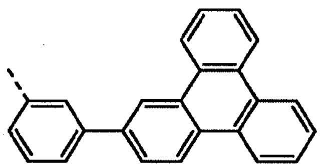


FIGURE 2



(Formula I)



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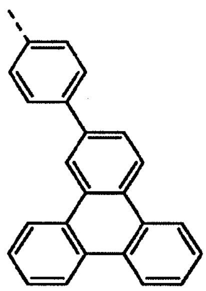

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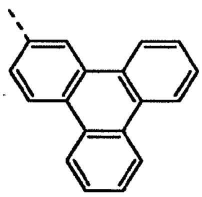

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FIGURE 3

HOLE TRANSPORT MATERIALS CONTAINING TRIPHENYLENE

This application is a National Stage of International Application No. PCT/US2009/049188, filed Jun. 30, 2009, which claims priority to U.S. Patent Application No. 61/077,095, filed on Jun. 30, 2008, the disclosures of which are incorporated herein by reference in their entirety.

This application claims priority to and benefit under 35 U.S.C. §119(e) to U.S. Provisional Application Ser. No. 61/077,095, filed Jun. 30, 2008, the disclosure of which is herein expressly incorporated by reference in its entirety.

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

The present invention relates to novel materials. More specifically, the present invention relates to novel materials useful in organic light emitting devices (OLEDs).

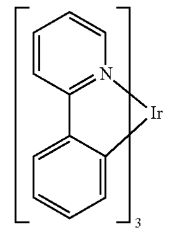
BACKGROUND

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

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



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

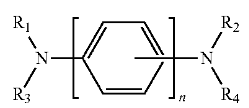
As used herein, "solution processible" means capable of being dissolved, dispersed, or transported in and/or deposited from a liquid medium, either in solution or suspension form.

A ligand is referred to as "photoactive" when it is believed that the ligand contributes to the photoactive properties of an emissive material.

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

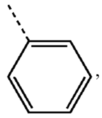
Novel materials are provided, having the chemical structure:



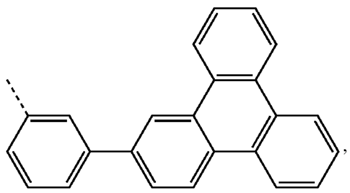
(Formula I)

n is 1, 2 or 3, and the phenyl rings between the nitrogen atoms may be attached to each other and to the nitrogen atoms in a para or meta configuration independently selected for each attachment. Each of R_1, R_2, R_3 and R_4 are independently selected from the group consisting of:

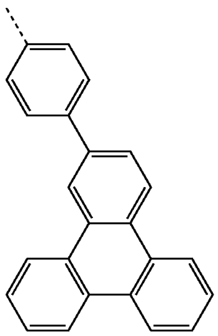
S-1



S-2

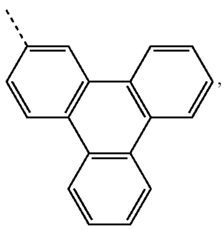


S-3



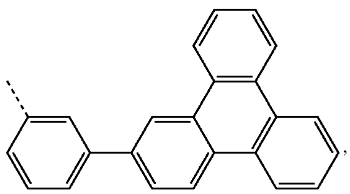
and

S-4



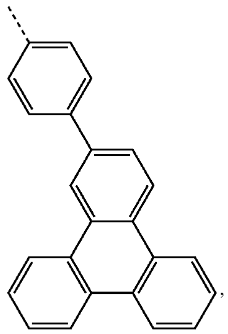
where the dotted line shows the point of attachment to a nitrogen atom of Formula I. At least one of R_1, R_2, R_3 and R_4 is selected from the group consisting of:

S-2



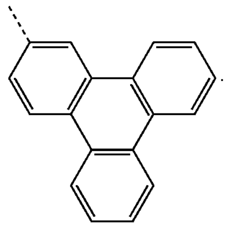
-continued

S-3



or

S-4



R_1, R_2, R_3 and R_4 are not all the same. Preferably, at least one of R_1, R_2, R_3 and R_4 is S-2. Preferably, at least one of R_1, R_2, R_3 and R_4 is S-3. Preferably, at least one of R_1, R_2, R_3 and R_4 is S-4. Each of R_1, R_2, R_3 and R_4 may be further substituted with substituents that are not fused to R_1, R_2, R_3 and R_4.

In one aspect, the compositions of matter provided having the structure of Formula I more specifically have the chemical structure of Formula II.

In another aspect, each of R_1, R_2, R_3 and R_4 is selected from the group consisting of S-1 though S-6.

Specific compositions of matter having Formula I are also provided, including compositions of matter having a structure selected from the group consisting of A-1 through A-6. Preferably, the composition of matter has the structure A-1 or A-5. Additionally, specific compositions of matter having Formula I are also provided, including compositions of matter having a structure selected from the group consisting of B-1 through B-6. Moreover, specific compositions of matter having Formula I are also provided, including compositions of matter having a structure selected from the group consisting of C-1 through C-6. Preferably, the composition of matter has the structure C-6.

Organic light-emitting devices and consumer products containing such devices are also provided, where the novel materials are used as a hole transport material in the device. Selections for the composition of matter having the structure of Formula I described as preferred for use in the materials having Formula I are also preferred for use in a device or consumer product that includes a composition of matter having the structure of Formula I. These selections include those for the substituents R_1, R_2, R_3, and R_4, Formula II, and structures A-1 though A-6, B-1 through B-6, and C-1 through C-6.

Combinations of the hole transport material with specific host materials are also provided. In one aspect, the host is a compound comprising a triphenylene containing benzo-fused thiophene. Preferably, the host is Compound 3. In another aspect, the host is an aryltriphenylene compound. Preferably, the host is Compound 2.

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.

FIG. **3** shows chemical structures.

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

FIG. **1** shows an organic light emitting device **100**. The figures are not necessarily drawn to scale. Device **100** may include a substrate **110**, an anode **115**, a hole injection layer **120**, a hole transport layer **125**, an electron blocking layer **130**, an emissive layer **135**, a hole blocking layer **140**, an electron transport layer **145**, an electron injection layer **150**, a protective layer **155**, 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 of 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 out-coupling, 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 ink-jet and OVJD. Other methods may also be used. The materials to be deposited may be modified to make them compatible with a particular deposition method. For example, substituents such as alkyl and aryl groups, branched or unbranched, and preferably containing at least 3 carbons, may be used in small molecules to enhance their ability to undergo solution processing. Substituents having 20 carbons or more may be used, and 3-20 carbons is a preferred range. Materials with asymmetric structures may have better solution processability than those having symmetric structures, because asymmetric materials may have a lower tendency to recrystallize. Dendrimer substituents may be used to enhance the ability of small molecules to undergo solution processing.

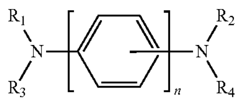
Devices fabricated in accordance with embodiments of the invention may be incorporated into a wide variety of consumer products, including flat panel displays, computer monitors, televisions, billboards, lights for interior or exterior illumination and/or signaling, heads up displays, fully transparent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

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.

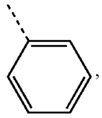
A novel composition of matter is provided. The novel composition of matter includes a "core" similar to that of naphthylphenylbiphenyl diamine (NPD). As used herein, the core of NPD has two nitrogen atoms connected to each other by two phenyl rings, all connected in the para position. Novel compositions of matter are provided having more possibilities for the core, including two nitrogen atoms connected by 1, 2 or 3 phenyl rings, where each connection may independently be para or meta. At least one group attached to a nitrogen atom of the core includes a triphenylene group. Thus, a novel composition of matter is provided having the structure:

(Formula I)

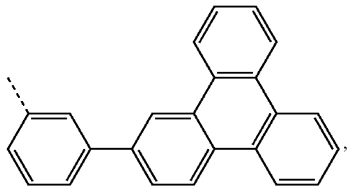


where n is 1, 2 or 3, and the phenyl rings between the nitrogen atoms may be attached to each other and to the nitrogen atoms in a para or meta configuration independently selected for each attachment. Each of R_1, R_2, R_3 and R_4 is independently selected from the group consisting of:

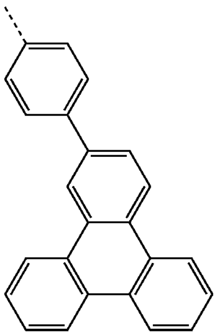
S-1



S-2

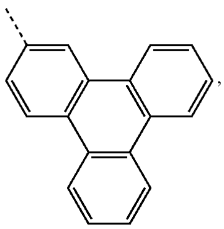


S-3



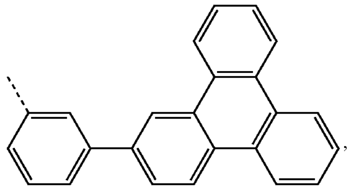
and

S-4



where the dotted line shows the point of attachment to a nitrogen atom of Formula I. At least one of R_1, R_2, R_3 and R_4 is selected from the group consisting of:

S-2



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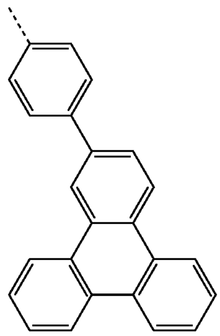
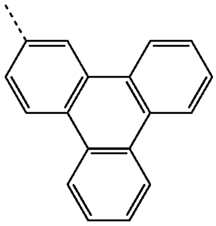
S-3



, or

S-4



.

R_1, R_2, R_3 and R_4 are not all the same. Each of R_1, R_2, R_3 and R_4 may be further substituted with substituents that are not fused to R_1, R_2, R_3 and R_4. FIG. **3** shows chemical structures relevant to some compositions of matter described herein.

Without being limited to any theory as to why the novel materials are desirable, it is believed that the benzidine (4,4'-diaminobiphenyl) core, along with the variations described herein, are particularly desirable. Benzidine with one phenyl and one 1-naphthyl attached to each of the nitrogens is α-NPD, which is a widely used hole transport layer in OLEDs, and it is believed that the core contributes to the desirability of NPD. However, NPD does not work well in certain devices, particularly blue and green devices, which have higher energy triplets and charge carriers. It is believed that the napthyl group of NPD, in connection with high energy charge carriers and triplets, may be responsible for this instability, and that a triphenylene group has superior stability in this context. In addition, it is believed that having some asymmetry to the molecule, i.e., R_1, R_2, R_3 and R_4 are not all the same, leads to the formation of better amorphous films.

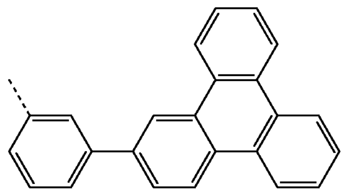
In OLED operation, some electrons may leak into the hole transport layer due to incomplete hole-electron charge recombination in the emissive layer. If the hole transport material is not stable to reduction, the device lifetime may be shortened. If the hole transport material is stable to reduction, the stability may be enhanced. Triphenylene is a polyaromatic compound which has extended π-conjugation and yet relatively high triplet energy. The benefits of triphenylene compounds, particularly in phosphorescent OLEDs, are further described in US20060280965, which is incorporated by reference in its entirety. For many of the triphenylene containing materials described herein, the hole transport materials retain the hole transporting properties by having the triarylamine moieties. In addition, the triphenylene moiety is believed to provide stabilization toward reduction of the hole transport materials when electrons leak into the hole transporting layer. The advantage of having triphenylene groups are demonstrated in the device examples compared to a hole transporting material α-NPD which contains a 1-naphthyl group as the most conjugated part. It is believed that a naphthyl group does not provide as much reduction stabilization as a triphenylene

group, and consequently, triphenylene containing hole transport materials described herein result in more stable OLEDs. Furthermore, such materials result in more efficient OLEDs compared to devices with α-NPD, which may be due to the higher triplet energy of triphenylene as compared to naphthalene.

Preferably, at least one of R_1 and R_3, and at least one of R_2 and R_4, is a group that includes a triphenylene group. While molecules having a group with a triphenylene attached to only one nitrogen of the core are useable, it is believed that molecules having at least one group containing a triphenylene attached to each nitrogen of the core, by providing more triphenylenes in more places, results in a more stable molecule. It is also believed that adding additional triphenylenes after there is at least one attached to each nitrogen may not result in much further improvement. While it is generally easier to have all of the triphenylene groups in a molecule be the same group, possible multiple times, different triphenylene groups may also be used in the same molecule.

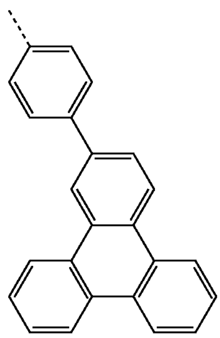
In addition, it is believed that the use of a phenyl "spacer" affects the triplet energy of the molecule. For example,

S-2



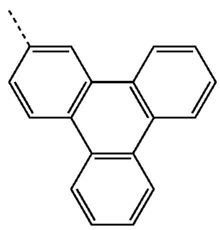
and

S-3



, but not

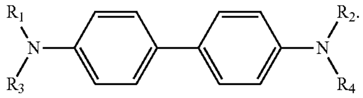
S-4



,

include a phenyl spacer. Different triplet energies are preferred for different device architectures, and the ability to insert or omit a phenyl spacer gives flexibility in designing devices.

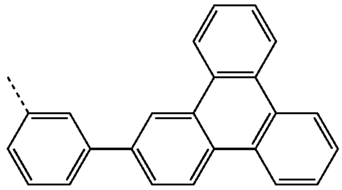
The benzidene core is preferred, i.e., the part of the composition represented by Formula I is more specifically:



(Formula II)

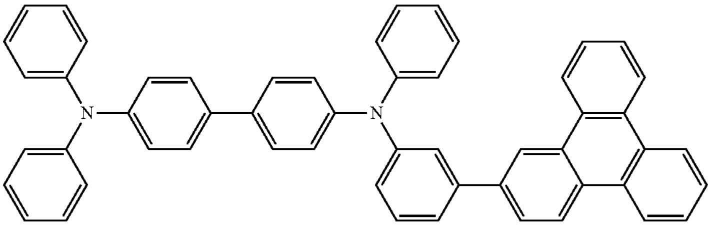
Molecules including each of the triphenylene-containing groups disclosed herein may be preferred, depending upon the context.

A composition of matter where at least one of R_1, R_2, R_3 and R_4 is

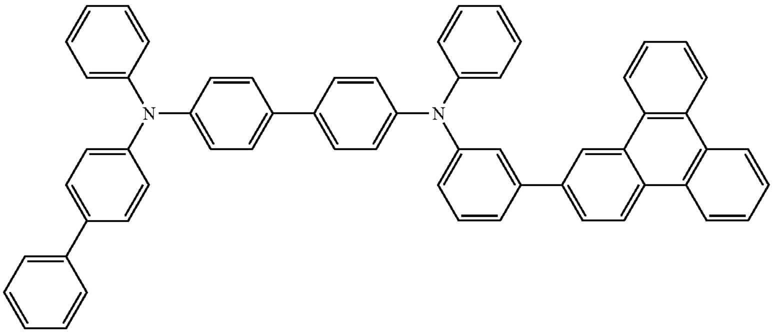


S-2

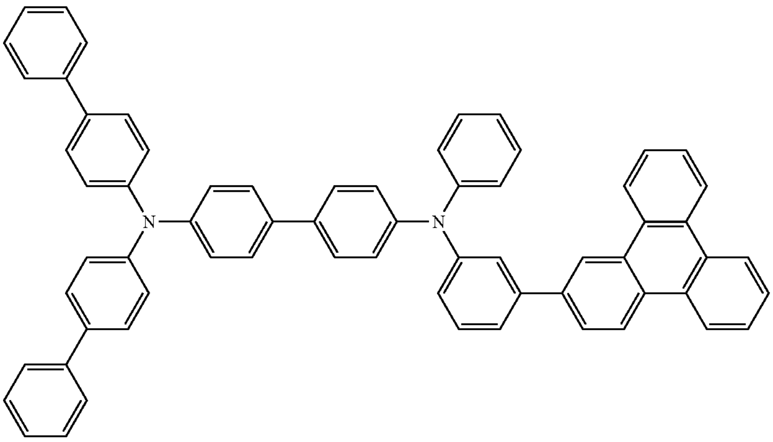
may be preferred. These compounds may be referred to as being in the A-group of compounds. Non-limiting examples of specific preferred molecules including this substituent include:



A-1



A-2



A-3

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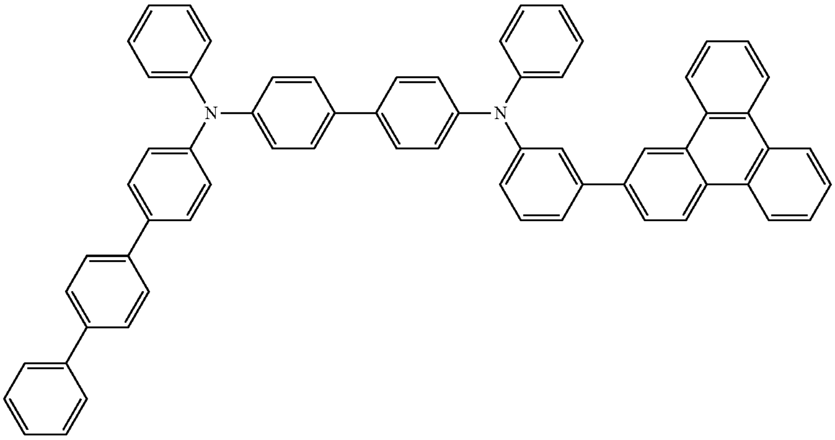
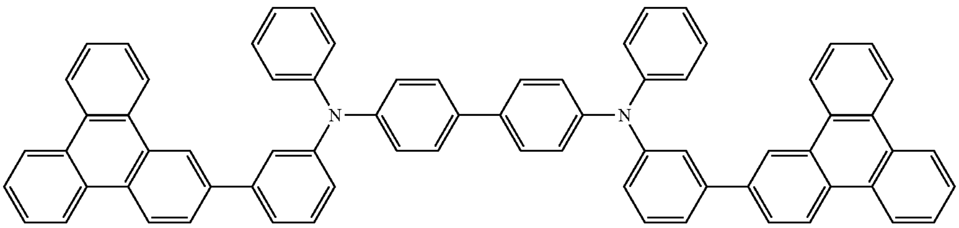
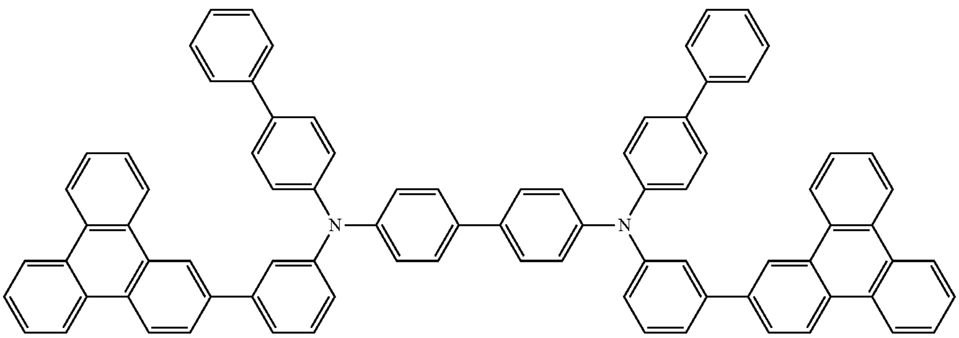
A-4



A-5

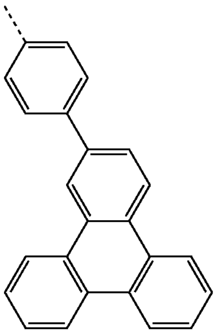


A-6



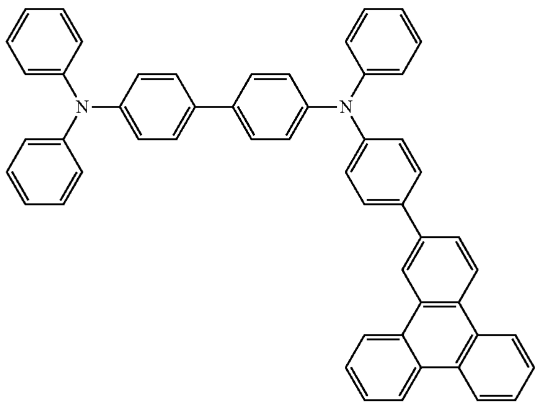
A composition of matter where at least one of R_1, R_2, R_3 and R_4 is

S-3

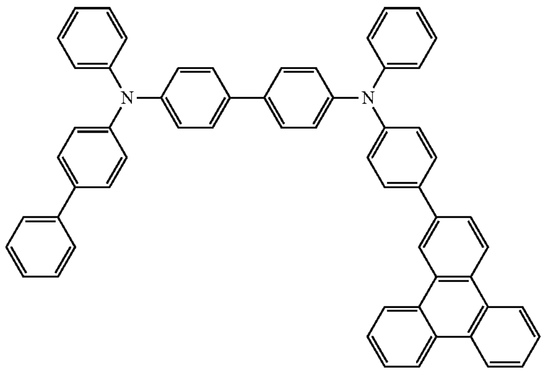


may be preferred. These compounds may be referred to as being in the B-group of compounds. Non-limiting examples of specific preferred molecules including this substituent include:

B-1



B-2



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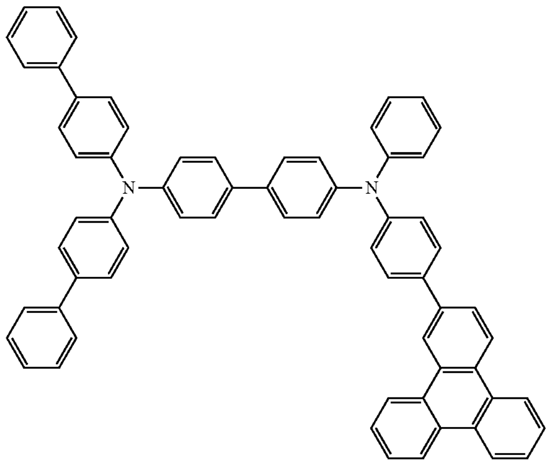
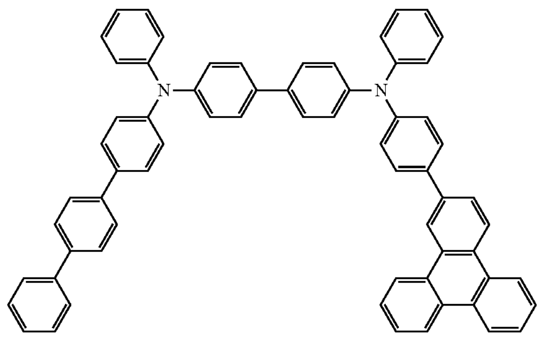
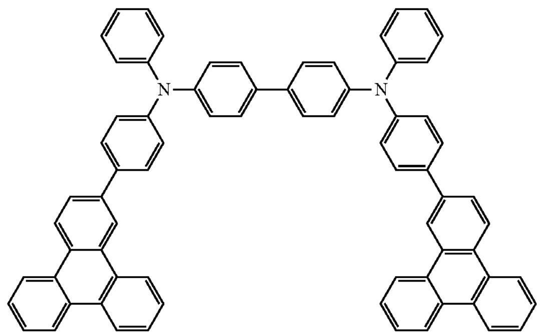
B-3



B-4



B-5



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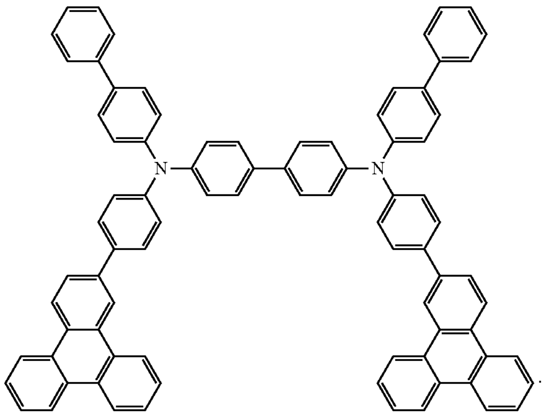
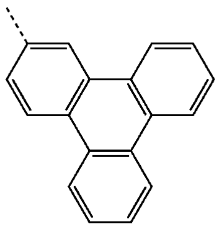
B-6



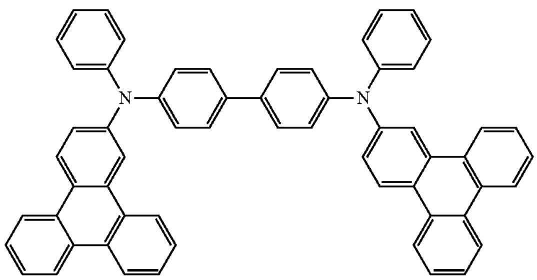
A composition of matter where at least one of R_1, R_2, R_3 and R_4 is

S-4

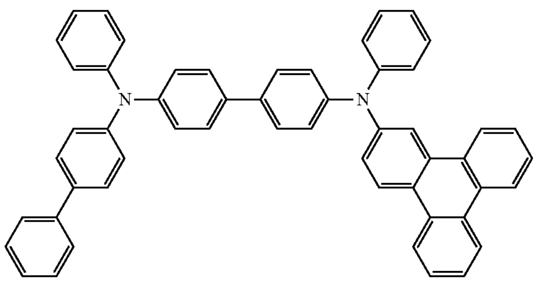


may be preferred. These compounds may be referred to as being in the C-group of compounds. Non-limiting examples of specific preferred molecules including this substituent include:

C-1

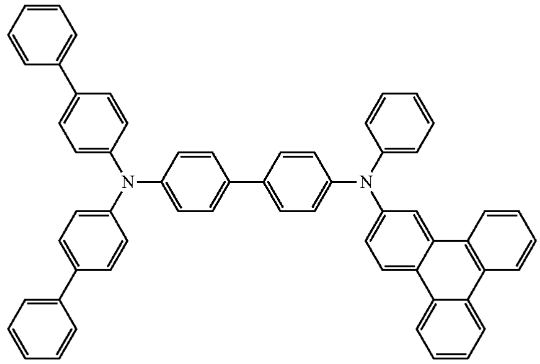


C-2

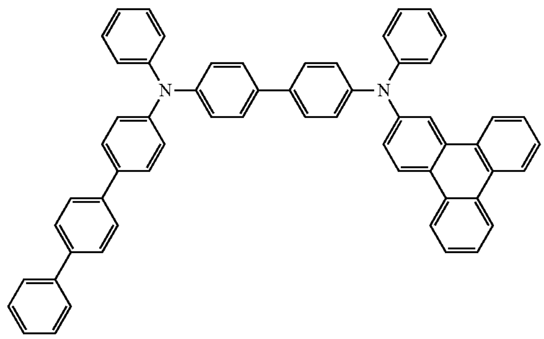


-continued

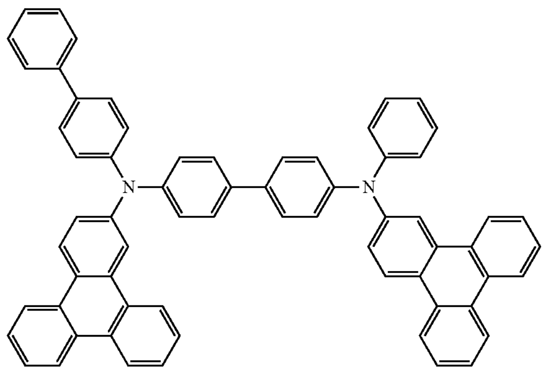
C-3



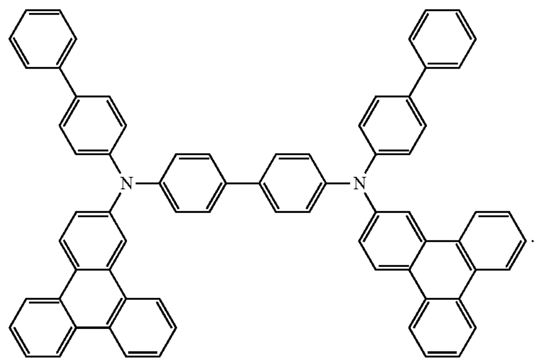
C-4



C-5

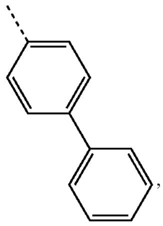


C-6

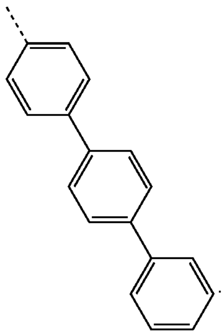


For the R groups that do not include a triphenylene, the following structures are preferred:

S-5

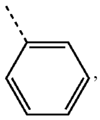


S-6

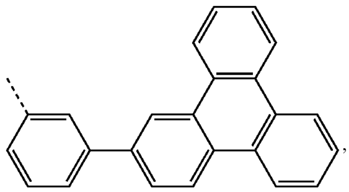


A composition of matter of Formula I is preferred where each of R_1, R_2, R_3 and R_4 is independently selected from the group consisting of:

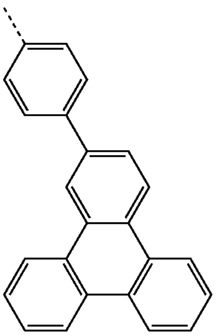
S-1



S-2

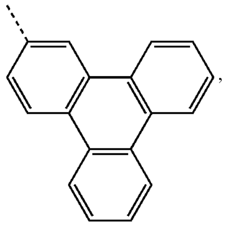


S-3

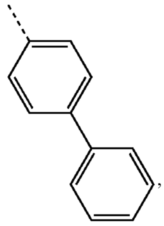


-continued

S-4

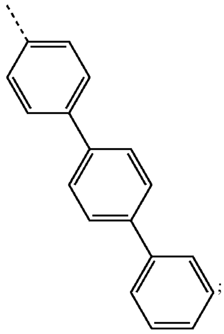


S-5



and

S-6



and there are no further substitutions to R_1, R_2, R_3 and R_4.

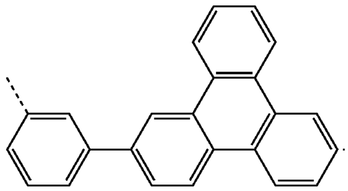
Molecules A-1, A-5 and C-1 have been synthesized, and a description of the synthesis is provided. The other molecules in the A, B and C groups of molecules, and the variations to those molecules described herein, can be readily fabricated using similar chemical synthesis.

An organic light emitting device 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 includes a host and a phosphorescent dopant. The device may also include an organic hole transport layer comprising a hole transport material, disposed between the organic emissive layer and the anode, and in direct contact with the organic emissive layer. The hole transport layer may have the structure of the novel compositions of matter disclosed herein, i.e., the structure of the novel materials having a core consistent with Formula I. The phosphorescent dopant is preferably an organometallic iridium material.

In addition, consumer products wherein the consumer product includes an organic light emitting device including a composition of matter having the structure of Formula I, as described, are provided. Selections for the substituents and structures described as preferred for the compositions of matter having the structure Formula I are also preferred for the devices and the consumer products including devices that comprise a composition of matter having the structure of Formula I. These selections include those described for substituents R_1, R_2, R_3, and R_4, Formula II, and structures A-1 through A-6, B-1 through B-6, and C-1 through C-6.

Organic light emitting devices having at least one of R_1, R_2, R_3 and R_4 being:

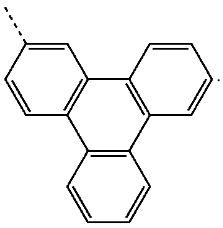
S-2



were fabricated. Specifically, molecule A-1 was used to fabricate devices, and it is believed that other molecules as disclosed herein having the same group would have similar performance. The devices had particularly good performance.

Organic light emitting devices having at least one of R_1, R_2, R_3 and R_4 being:

S-4



were fabricated. Specifically molecule C-1 was used to fabricate the device, and it is believed that other molecules as disclosed herein having the same group would have similar performance.

It is believed that the triphenylene-containing compounds disclosed herein, when used as a hole transport layer, work particularly well in devices where the host is a compound comprising a triphenylene containing benzo-fused thiophene. Devices fabricated with this combination showed particularly good performance. Such hosts are disclosed in U.S. Patent Application 61/013,391, filed Dec. 28, 2007, inventor Ma, Bin, which is incorporated herein by reference in its entirety and particularly for claimed subject matter. The C group of compounds are preferred hole transport materials for this combination. Compound 3 is a preferred example of such a host.

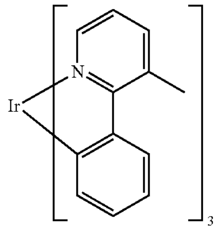
It is believed that the triphenylene-containing compounds disclosed herein, when used as a hole transport layer, work particularly well in devices where the host is an aryltriphenylene compound. Such hosts are disclosed in U.S. Patent Publication 2006-0280965, filed May 31, 2006, inventors Kwong et al., which is incorporated herein by reference in its entirety and particularly for claimed subject matter. The C group of compounds are preferred hole transport materials for this combination. Compound 2 is a preferred example of such a host.

It is believed that triphenylene containing hole transport materials described herein are desirable for use in fluorescent OLEDs in addition to phosphorescent OLEDs.

As used herein, the following compounds have the following structures:

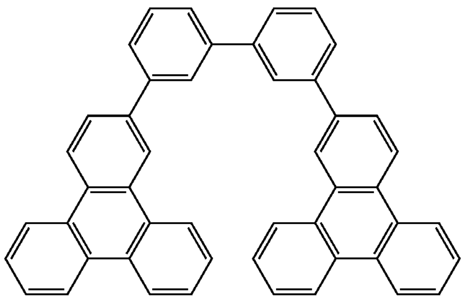
Compound 1—disclosed in JP 2000-299497:

Compound 1



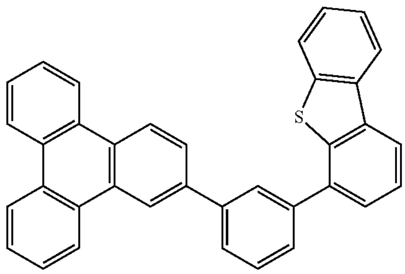
Compound 2—disclosed in U.S. Patent Publication 2006-0280965, inventors Kwong et. al, filed May 31, 2006:

Compound 2



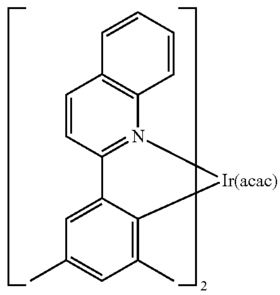
Compound 3—disclosed in U.S. Patent Application 61/013,391, filed Dec. 28, 2007, inventor Ma, Bin.

Compound 3



Compound 4—red phosphorescent emitter disclosed in U.S. patent application Ser. No. 12/044,234, filed Mar. 7, 2008, inventors Kwong et al.

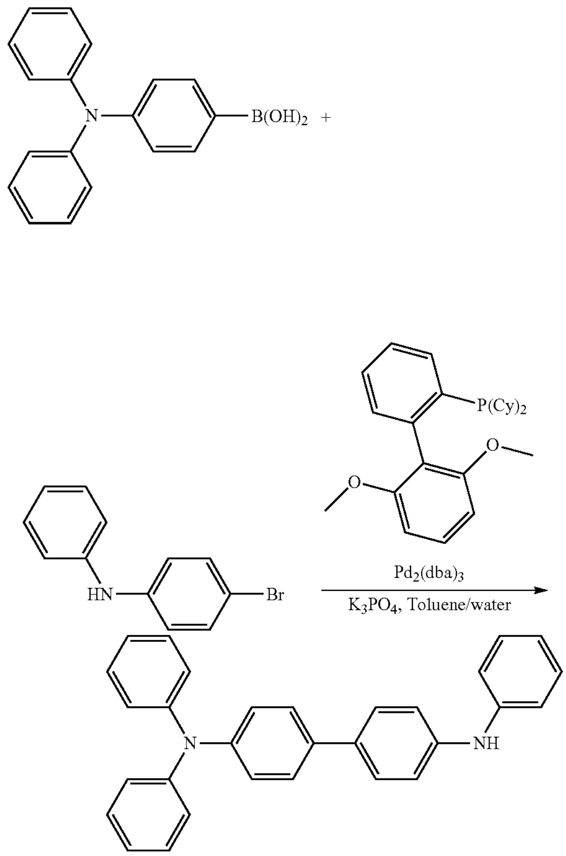
Compound 4



Bis(2-methyl-8-hydroxyquinolinolato) (4-phenylphenolato) aluminum (BAlq) and tris-(8-hydroxyquinolato) aluminum (Alq_3) are well known materials. LG-101 and LG-201 are proprietary materials available for purchase from LG Chem, Inc. of Korea.

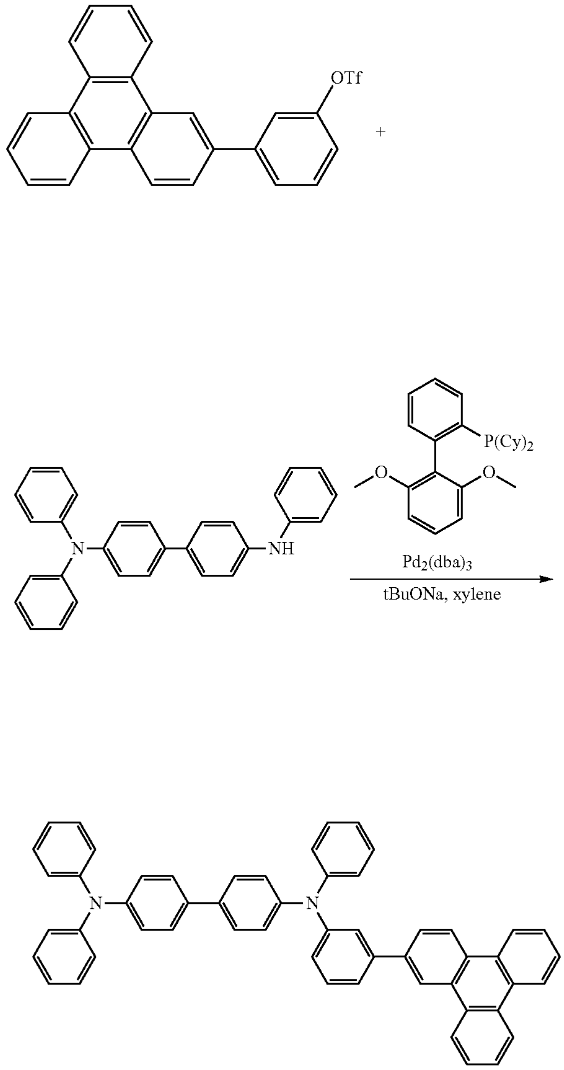
EXPERIMENTAL

Synthesis of A-1



Synthesis of N^4,N^4,$N^{4'}$-triphenylbiphenyl-4,4'-diamine

4-(diphenylamino)phenylboronic acid (4.87 g, 16.8 mmol), 4-bromo-N-phenylaniline (3.5 g, 14 mmol), potassium phosphate (9.2 g, 42 mmol), dicyclohexyl(2',6'-dimethoxybiphenyl-2-yl)phosphine (0.23 g, 0.56 mmol) were added to a three-neck flask under nitrogen. 200 mL of toluene and 20 mL of water was then added. The solution was degassed with nitrogen for 20 minutes. $Pd_2(dba)_3$ (0.13 g, 0.14 mmol) was added to the mixture. The mixture was then heated up to reflux overnight. After cooled to room temperature, the organic layer was separated and dried over magnesium sulfate. After evaporating solvent, the residue was purified by column chromatography using 1:2 dichloromethane and hexanes as eluent. 4.7 g of desired product was obtained. (81% yield)

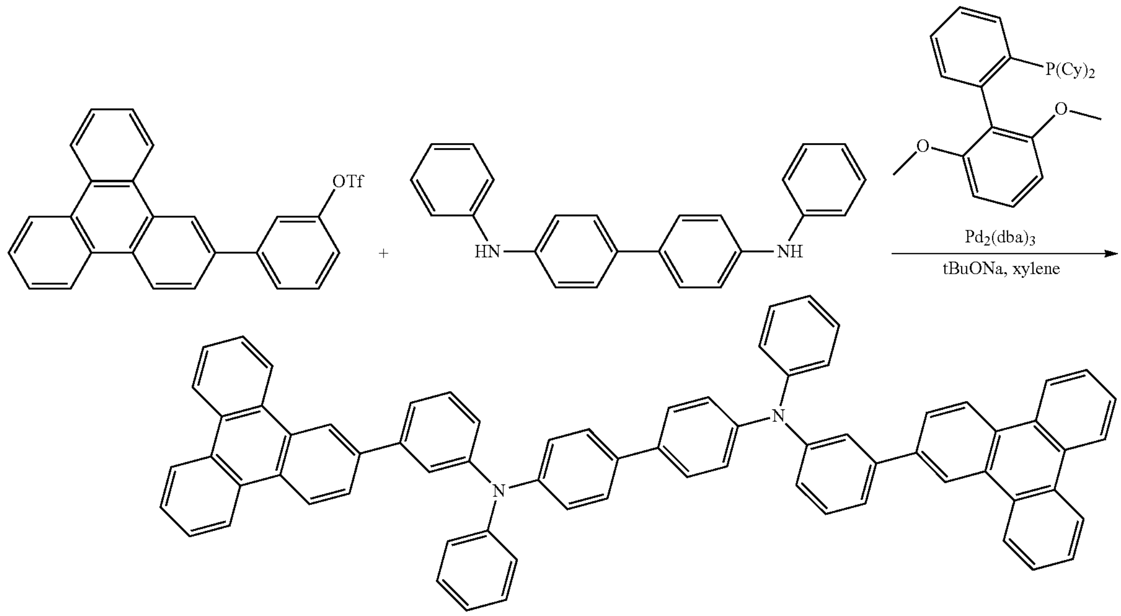


A-1

Synthesis of A-1

N^4,N^4,$N^{4'}$-triphenyl-$N^{4'}$-(3-(triphenylen-2-yl)phenyl)biphenyl-4,4'-diamine $Pd_2(dba)_3$ (0.07 g, 0.07 mmol) and dicyclohexyl(2',6'-dimethoxybiphenyl-2-yl)phosphine (0.13 g, 0.3 mmol) were added to a three-neck flask under nitrogen. 150 mL of xylene was then added. The solution was stirred under nitrogen for 20 minutes. To the solution was added 3-(triphenylen-2-yl)phenyl trifluoromethanesulfonate (3.87 g, 8.5 mmol), sodium tert-butoxide (1.1 g, 11.6 mmol), and N^4,N^4,$N^{4'}$-triphenylbiphenyl-4,4'-diamine (3.2 g, 7.7 mmol) in sequence. The mixture was then heated up to reflux overnight. After cooled to room temperature, 300 mL of dichloromethane was added to the solution. The solution was then filtered through a celite bed. After evaporating solvent, the residue was purified by column chromatography using 1:3 dichloromethane and hexanes as eluent. 3.5 g of desired product was obtained after purification. The product was further purified by high vacuum sublimation. (64% yield)

Synthesis of A-5

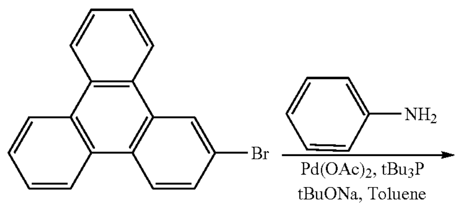


A-5

Synthesis of A-5

N^4,$N^{4'}$-diphenyl-N^4,$N^{4'}$-bis(3-(triphenylen-2-yl)phenyl)biphenyl-4,4'-diamine $Pd_2(dba)_3$ (0.1 g, 0.1 mmol) and dicyclohexyl(2',6'-dimethoxybiphenyl-2-yl)phosphine (0.17 g, 0.4 mmol) were added to a three-neck flask under nitrogen. 150 mL of xylene was then added. The solution was stirred under nitrogen for 20 minutes. To the solution was added 3-(triphenylen-2-yl)phenyl trifluoromethanesulfonate (5.0 g, 11.1 mmol), sodium tert-butoxide (1.5 g, 15 mmol), and N^4,$N^{4'}$-diphenylbiphenyl-4,4'-diamine (1.7 g, 5 mmol) in sequence. The mixture was then heated up to reflux overnight. After cooled to room temperature, the mixture precipitated from 300 mL of methanol. Solid was collected by filtration. The solid was then redissolved in dichloromethane and dried over magnesium sulfate. After evaporating solvent, 4.4 g of desired product was obtained. The compound was further purified by high vacuum sublimation.

Synthesis of C-1



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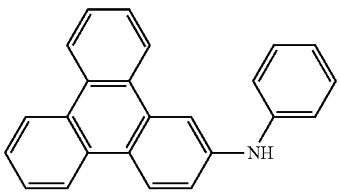
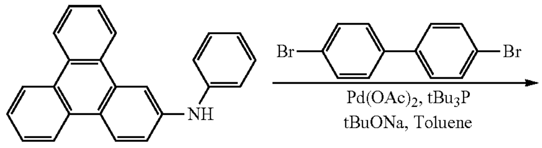


Synthesis of N-phenyltriphenylen-2-amine

Palladium acetate (0.01 g, 0.06 mmol) and 1.0 M tri(t-butyl)phosphine solution in toluene (0.02 mL, 0.02 mmol) were added to a three-neck flask under nitrogen. 100 mL of toluene was then added. The solution was stirred under nitrogen until the color disappeared. To the solution was added 2-bromotriphenylene (2 g, 6.5 mmol), sodium tert-butoxide (0.94 g, 9.8 mmol), and aniline (1.8 g, 20 mmol) in sequence. The mixture was then heated up to reflux overnight. After cooled to room temperature, the mixture was filtered through a celite bed and washed thoroughly with dichloromethane. The product was purified by column chromatography using 1:7 dichloromethane and hexanes as eluent. 0.8 g of desired product was obtained after purification.



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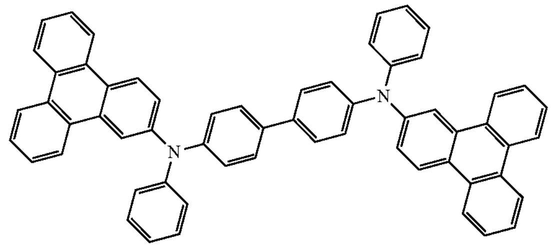


C-1

Synthesis of C-1

N^4,$N^{4'}$-diphenyl-N^4,$N^{4'}$-di(triphenylen-2-yl)biphenyl-4,4'-diamine palladium acetate (0.2 mg, 0.03 mmol) and 1.0 M tri(t-butyl)phosphine solution in toluene (0.1 mL, 0.1 mmol) were added to a three-neck flask under nitrogen. 60 mL of xylene was then added. The solution was stirred under nitro-

gen until the color disappeared. To the solution was added 4,4'-dibrombiphenyl (0.33 g, 1 mmol), sodium tert-butoxide (0.3 g, 3 mmol), and N-phenyltriphenylen-2-amine (0.7 g, 2.2 mmol) in sequence. The mixture was then heated up to reflux overnight. After cooled to room temperature, the mixture was filtered through a celite bed and washed thoroughly with dichloromethane. The product was purified by column chromatography using 1:2 dichloromethane and hexanes as eluent. 0.4 g of desired product was obtained after purification. The product was further purified by high vacuum sublimation.

Devices

Devices were fabricated using standard techniques. The devices have structures similar to that shown in FIG. **1**, but including the specific layers and materials described in the tables. Cmpd. is an abbreviation of compound. Ex. is an abbreviation of Example.

TABLE 1

Structures of green PHOLEDs with novel HTL materials and novel host/HTL combinations vs. comparative examples.

Ex.	HIL	HTL	Host	Cmpd. 1, %	BL	ETL
1	Cmpd 1 100 Å	-NPD 300 Å	Cmpd 2	10%	Cmpd 2 100 Å	Alq_3 400 Å
2	Cmpd 1 100 Å	C-1 300 Å	Cmpd 2	10%	Cmpd 2 100 Å	Alq_3 400 Å
3	LG-101 300 Å	-NPD 100 Å	Cmpd 3	10%	Cmpd 3 100 Å	LG-201 300 Å
4	LG-101 300 Å	C-1 100 Å	Cm[d 3	10%	Cmpd 3 100 Å	LG-201 300 Å
5	LG-101 300 Å	-NPD 100 Å	Cmpd 3	10%	Cmpd 3 100 Å	Alq_3 400 Å
6	LG-101 300 Å	C-1 100 Å	Cmpd 3	10%	Cmpd 3 100 Å	Alq_3 400 Å

TABLE 2

Performance of green PHOLEDs with novel HTL materials and novel host/HTL combinations vs comparative examples.

			At 1,000 nits					At 40 mA/cm^2 LT$_{80\%}$ [h]		
	CIE		Voltage	LE	EQE	PE	LT$_{50\%}$	Lo		
Ex.	x	y	[V]	[cd/A]	[%]	[lm/W]	[h]	[cd/m^2]	RT	70° C.
1	0.364	0.603	6.4	58.4	16.0	28.7		16,450	233	19
2	0.367	0.601	6.1	62.9	17.3	32.4		18,100	359	29
3	0.351	0.608	5.6	49.1	13.5	27.5	204,995	14,624	349	65
4	0.356	0.605	5.5	53.5	14.7	30.5	428,521	17,280	359	76
5	0.351	0.612	5.8	53.5	14.7	29.0	213,955	16,084	372	
6	0.355	0.609	5.7	59.1	16.3	32.6	434,086	18,875	350	

3 groups of experiments are shown in tables 1 and 2. The superior performance of green PHOLED devices with novel HTL material C-1 is shown relative to devices having an NPD HTL. The desirability of combining HTL materials similar to C-1 with hosts similar to Compounds 2 and 3 is also shown.

Group 1

Examples 1 and 2

The difference between Example 1 (comparative) and Example 2 is that Example 1 has an α-NPD HTL, whereas Example 2 has an HTL of compound C-1. The combination of HTL C-1 with Compound 2 as a host gives results superior to a similar device using an α-NPD HTL. Example 2 shows superior performance in device voltage, luminous efficiency and the lifetime. Moreover, the results for Example 2 are particularly good for a green-emitting device in general, showing the desirability of combining HTLs with compounds similar to C-1 with hosts similar to Compound 2.

Group 2

Examples 3 and 4

The difference between Example 3 (comparative) and Example 4 is that Example 3 has an α-NPD HTL, whereas Example 4 has an HTL of Compound C-1. There is also a difference in the hole injection layer (HIL). The combination of HTL C-1 with Compound 3 as a host gives results superior to a similar device using an α-NPD HTL. Example 4 shows superior performance in efficiency and the lifetime. Moreover, the results for Example 4 are particularly good for a green-emitting device in general, showing the desirability of combining HTLs with compounds similar to C-1 with hosts similar to Compound 3.

Group 3

Examples 5 and 6

Group 3 makes a similar comparison to that made in Group 2, except using an ETL of Alq_3 instead of LG-201. The same conclusions can be drawn from Group 3 as from Group 2.

TABLE 3

Structures of red PHOLEDs with novel HTL materials

Ex.	HIL	HTL	Host	Cmpd 4, %	BL	ETL
7	Cmpd 1 100 Å	NPD 400 Å	BAlq	9%	none	Alq_3 550 Å
8	Cmpd 1 100 Å	C-1 400 Å	BAlq	9%	none	Alq_3 550 Å
9	Cmpd 1 100 Å	A-1 400 Å	BAlq	9%	none	Alq_3 550 Å
10	LG-101 400 Å	NPD 100 Å	BAlq	9%	none	Alq_3 550 Å
11	LG-101 400 Å	C-1 100 Å	BAlq	9%	none	Alq_3 550 Å
12	LG-101 400 Å	A-1 100 Å	BAlq	9%	none	Alq_3 550 Å

TABLE 4

Performance of red PHOLEDs with novel HTL materials

			At 1,000 nits				At 40 mA/cm² $LT_{80\%}$ [h]		
	CIE		Voltage	LE	EQE	PE	Lo		
Ex.	x	y	[V]	[cd/A]	[%]	[lm/W]	[cd/m²]	RT	70° C.
7	0.667	0.331	8.2	20.0	18.9	7.7	6,439	850	90
8	0.667	0.331	8.0	18.5	17.8	7.3	6,086	600	83
9	0.666	0.332	8.9	19.9	18.7	7.0	6,220	297	
10	0.666	0.332	7.0	14.4	13.4	6.5	4,420	1,000	
11	0.666	0.332	7.1	14.9	14.0	6.6	4,643	860	
12	0.666	0.332	7.2	16.5	15.4	7.2	5,273	540	

2 groups of experiments are shown in tables 3 and 4. The performance of red PHOLED devices with novel HTL materials C-1 and A-1 is shown relative to devices having an α-NPD HTL. A BAlq host is used for all devices.

Group 4

Examples 7, 8 and 9

The difference between Example 7 (comparative) and Examples 8 and 9 is that Example 7 has an NPD HTL, whereas Examples 8 and 9 have an HTLs of compound C-1 and A-1, respectively. All HTLs are shown in combination with BAlq host. Examples 8 and 9 reveal performance lower in terms of efficiency and lifetime vs. α-NPD HTL comparative example 7. However, the performance of the devices of Examples 8 and 9 are still well above what is needed for a commercial device.

Group 5

Examples 10, 11 and 12

Group 5 makes a similar comparison to that made in Group 4, except using an HIL of LG-101 instead of Compound 1. The same conclusions can be drawn from Group 5 as from Group 4.

For red devices, the results for the devices using C-1 and A-1 as an HTL are not necessarily superior to those using NPD. But, all of the devices in tables 3 and 4 show performance well above that needed for a commercial display.

As a result, the suitability of HTL materials similar to C-1 and A-1 for a common device architecture is shown. It is desirable in many manufacturing scenarios to use the same materials in different devices as much as possible. For devices emitting different colors, such as red and green, the emissive molecule may be different. But it is still desirable that the red and green devices use the same non-emissive materials, such as the HTL, to as large an extent as possible.

In addition, green PHOLED lifetime is more of a limiting factor for commercialization than red PHOLED lifetime. Red PHOLEDs with any HTL have typically good performance (lifetime), enough for the mass production. Thus, an HTL material that exhibits superior performance in a green device is highly desirable, even if the material has lower performance in a red device.

A comparison of Groups 1, 2 and 3 with Groups 4 and 5 also shows that, while compounds similar to A-1 and C-1 can be used in different device architectures, those architectures having a combination of compounds similar to A-1 and C-1 in the HTL with certain hosts, such as those similar to Compound 2 and Compound 3, are particularly desirable and lead to unexpectedly good device performance.

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

In addition to and/or in combination with the materials disclosed herein, many hole injection materials, hole transporting materials, host materials, dopant materials, exiton/hole blocking layer materials, electron transporting and electron injecting materials may be used in an OLED. Non-limiting examples of the materials that may be used in an OLED in combination with materials disclosed herein are listed in Table 5 below. Table 5 lists non-limiting classes of materials, non-limiting examples of compounds for each class, and references that disclose the materials.

TABLE 5

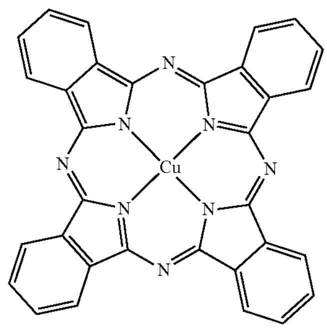
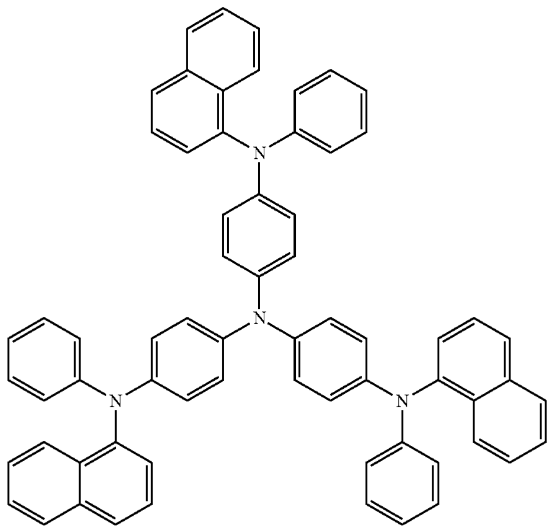
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Phthalocyanine and porphryin compounds		Appl. Phys. Lett. 69, 2160 (1996)
Starburst triarylamines		J. Lumin. 72-74, 985 (1997)

TABLE 5-continued

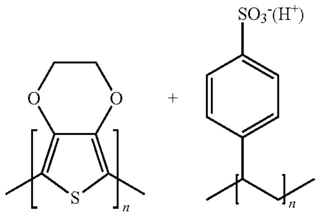
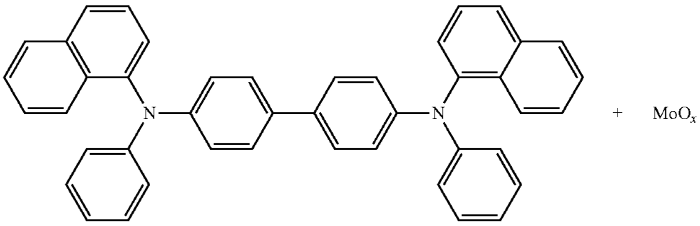
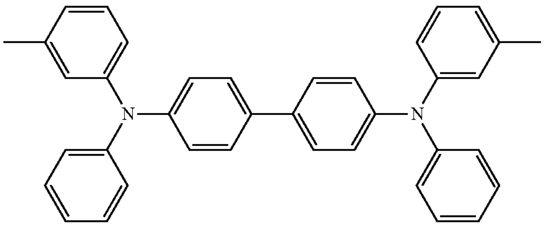
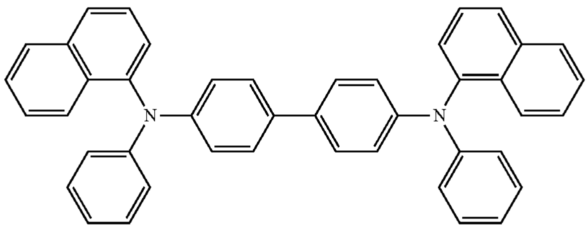
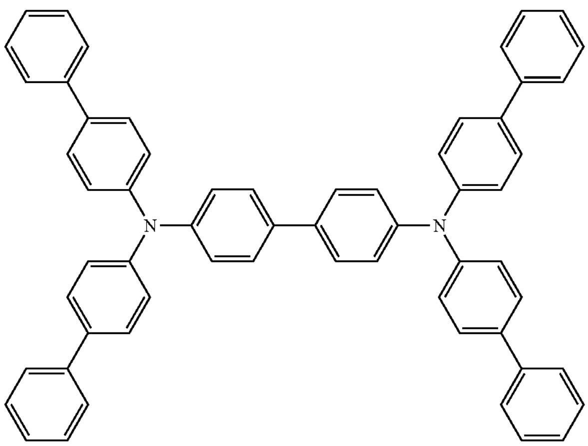
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
CF_x Fluorohydrocarbon polymer	$-[CH_xF_y]_n-$	Appl. Phys. Lett. 78, 673 (2001)
Conducting polymers (e.g., PEDOT:PSS, polyaniline, polypthiophene)		Synth. Met. 87, 171 (1997)
Arylamines complexed with metal oxides such as molybdenum and tungsten oxides		SID Symposium Digest, 37, 923 (2006)
	Hole transporting materials	
Triarylamines (e.g., TPD, α-NPD)		Appl. Phys. Lett. 51, 913 (1987)
		US5061569
		EP650955

TABLE 5-continued

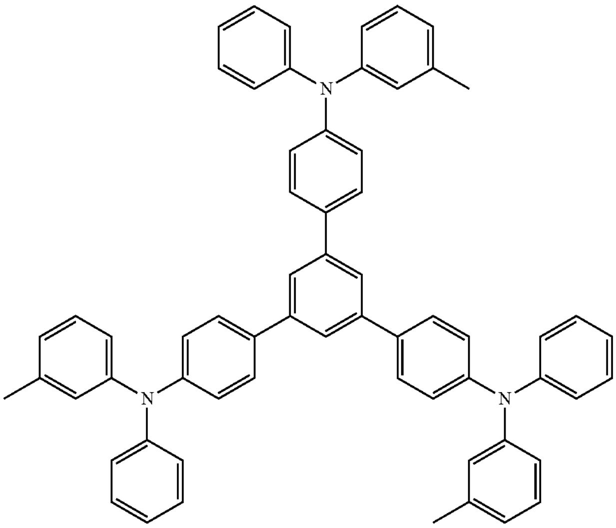
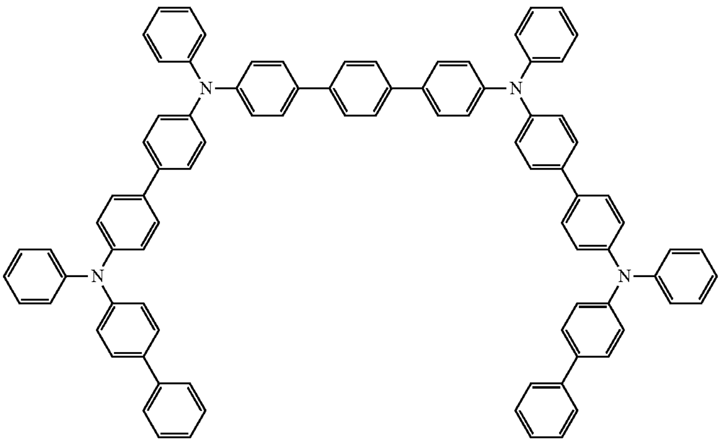
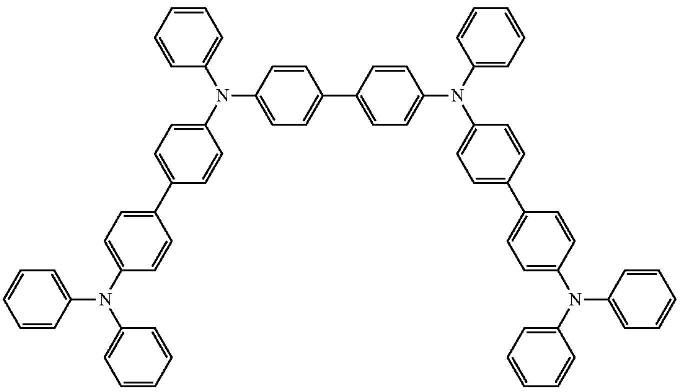
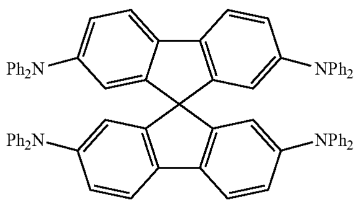
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		J. Mater. Chem. 3, 319 (1993)
		Appl. Phys. Lett. 90, 183503 (2007)
		Appl. Phys. Lett. 90, 183503 (2007)
Triaylamine on spirofluorene core		Synth. Met. 91, 209 (1997)

TABLE 5-continued

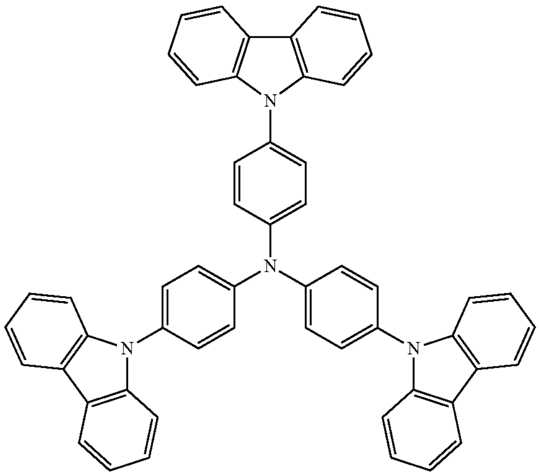
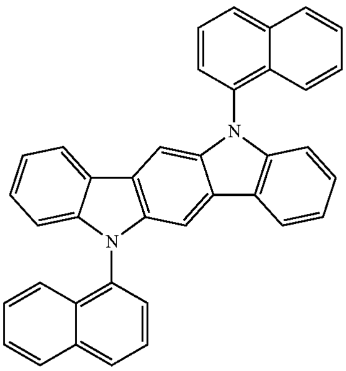
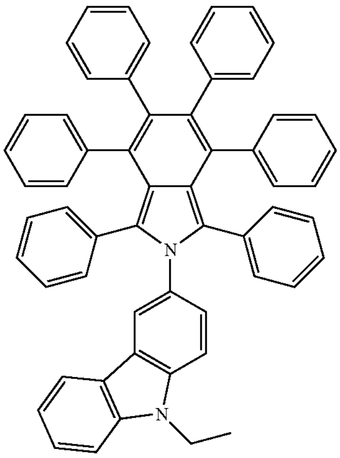
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Arylamine carbazole compounds		Adv. Mater. 6, 677 (1994)
Indolocarbazoles		Synth. Met. 111, 421 (2000)
Isoindole compounds		Chem. Mater. 15, 3148 (2003)
	Phosphorescent OLED host materials Red hosts	

TABLE 5-continued

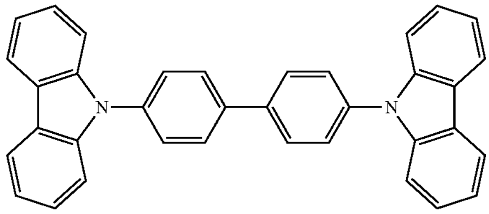
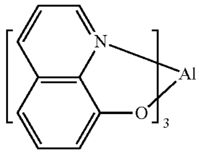
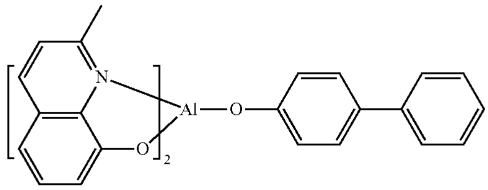
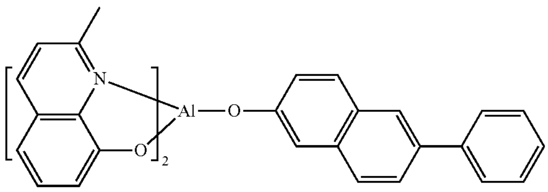
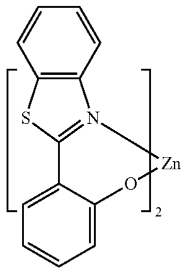
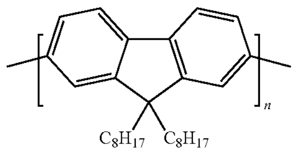
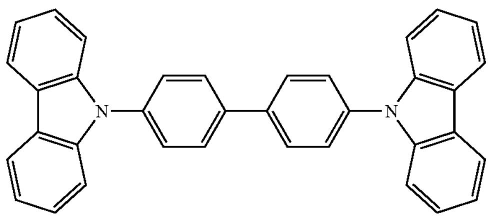
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Arylcarbazoles		Appl. Phys. Lett. 78, 1622 (2001)
Metal 8-hydroxyquinolates (e.g., Alq_3, BAlq)		Nature 395, 151 (1998)
		US20060202194
		WO2005014551
Metal phenoxy-benzothiazole compounds		Appl. Phys. Lett. 90, 123509 (2007)
Conjugated oligomers and polymers (e.g., polyfluorene)		Org. Electron. 1, 15 (2000)
	Green hosts	
Arylcarbazoles		Appl. Phys. Lett. 78, 1622 (2001)

TABLE 5-continued

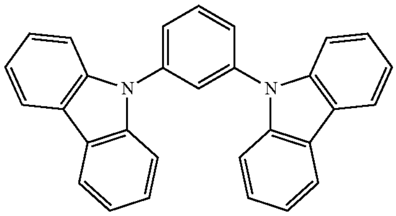
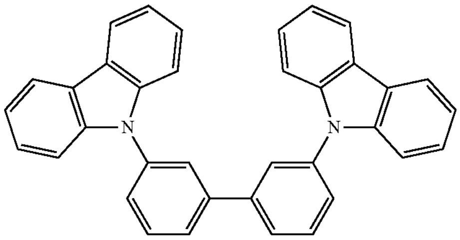
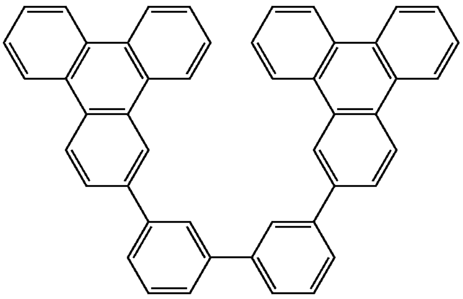
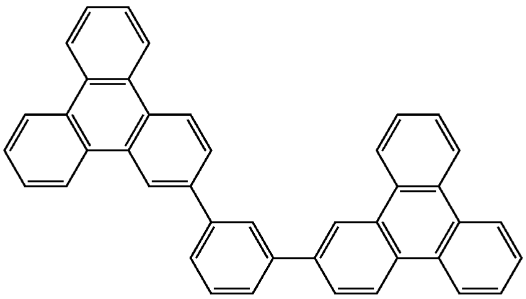
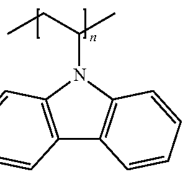
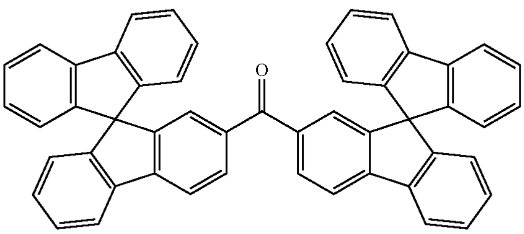
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US2003175553
		WO2001039234
Aryltriphenylene compounds		US20060280965
		US20060280965
Polymers (e.g., PVK)		Appl. Phys. Lett. 77, 2280 (2000)
Spirofluorene compounds		WO2004093207

TABLE 5-continued

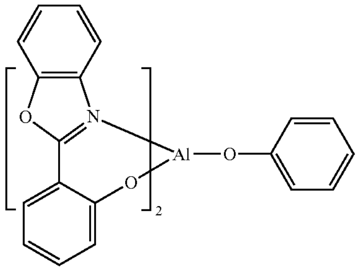
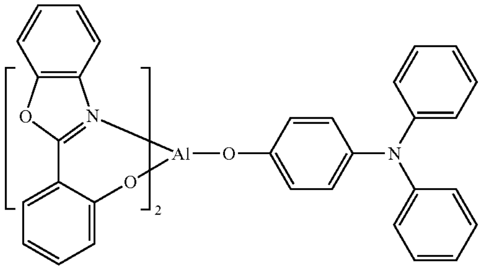
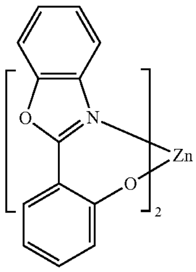
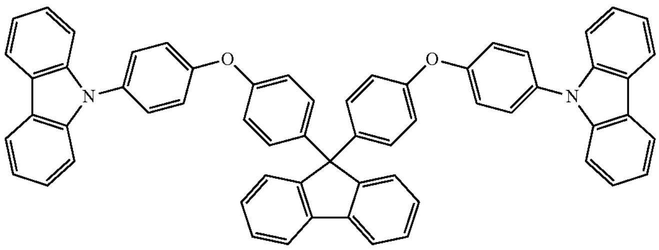
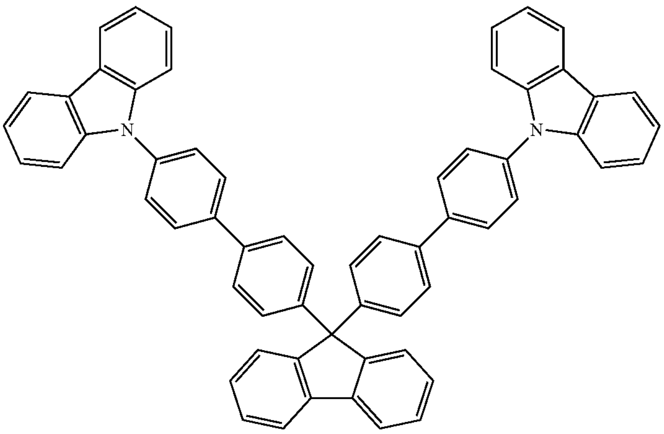
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Metal phenoxy-benzooxazole compounds		WO05089025
		WO06132173
		JP200511610
Spirofluorene-carbazole compounds		JP2007254297
		JP2007254297

TABLE 5-continued

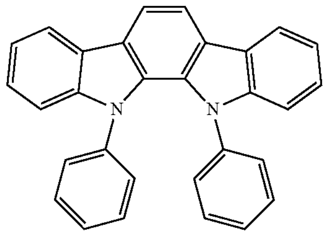
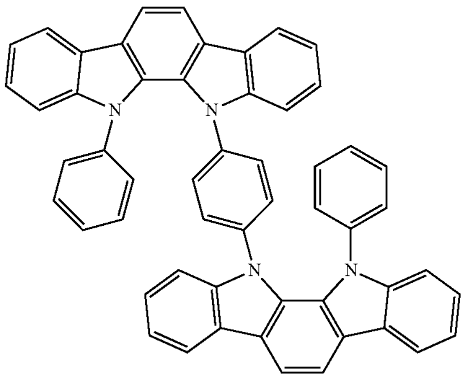
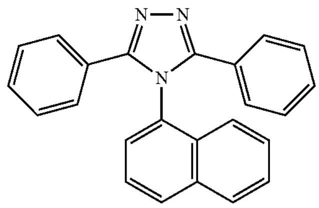
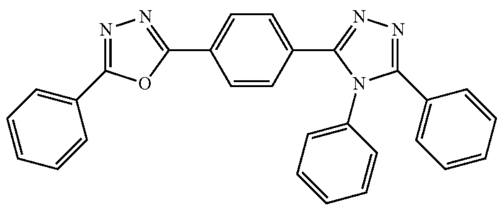
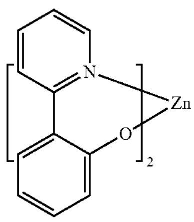
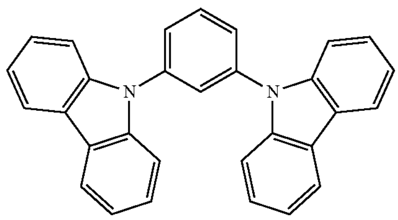
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Indolocabazoles		WO07063796
		WO07063754
5-member ring electron deficient heterocycles (e.g., triazole, oxadiazole)		J. Appl. Phys. 90, 5048 (2001)
		WO04107822
Metal phenoxypyridine compounds		WO05030900
	Blue hosts	
Arylcarbazoles		Appl. Phys. Lett, 82, 2422 (2003)

TABLE 5-continued

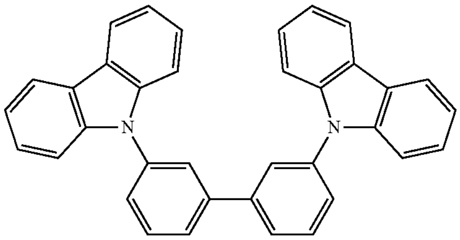
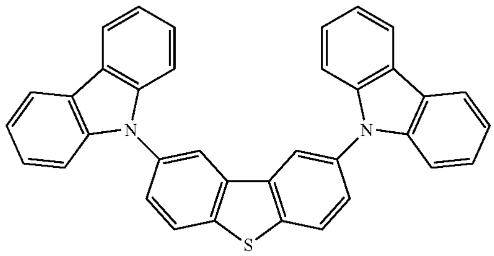
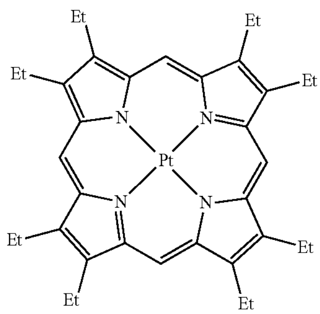
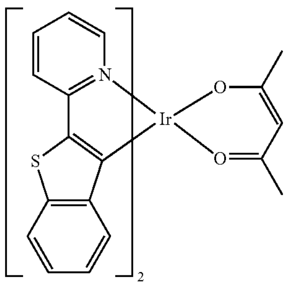
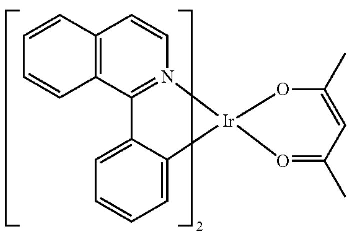
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20070190359
Dibenzothiophene-carbazole compounds		WO2006114966
	Phosphorescent dopants Red dopants	
Heavy metal porphyrins (e.g., PtOEP)		Nature 395, 151 (1998)
Iridium(III) organometallic complexes		Appl. Phys. Lett. 78, 1622 (2001)
		US06835469

TABLE 5-continued

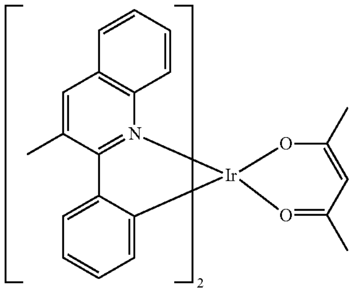
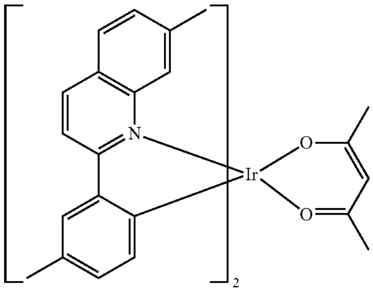
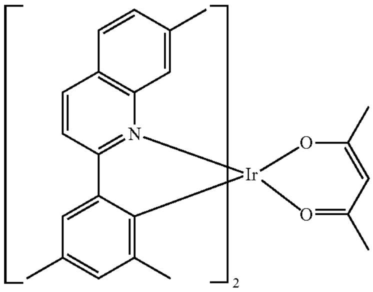
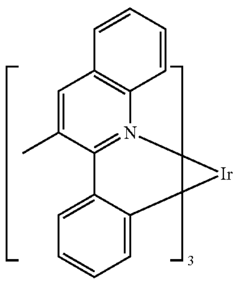
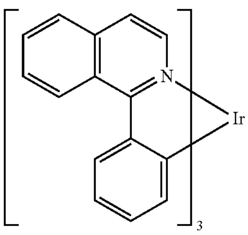
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US06835469
		US20060202194
		US20060202194
		US07087321
		US07087321

TABLE 5-continued

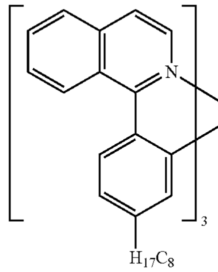
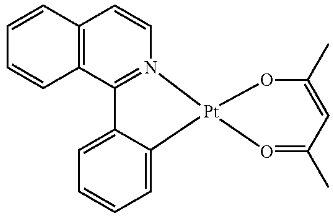
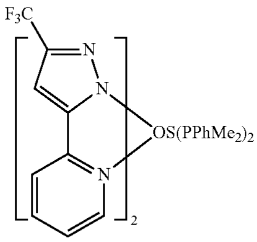
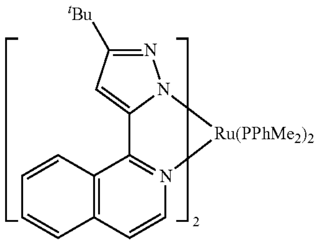
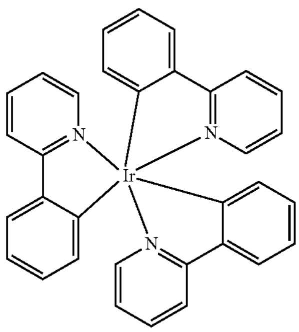
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Adv. Mater. 19, 739 (2007)
Platinum(II) organometallic complexes		WO2003040257
Osminum(III) complexes		Chem. Mater. 17, 3532 (2005)
Ruthenium(II) complexes		Adv. Mater. 17, 1059 (2005)
	Green dopants	
Iridium(III) organometallic complexes	 and its derivatives	Inorg. Chem. 40, 1704 (2001)

TABLE 5-continued

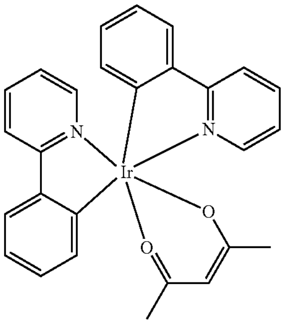
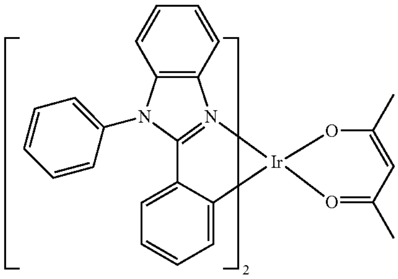
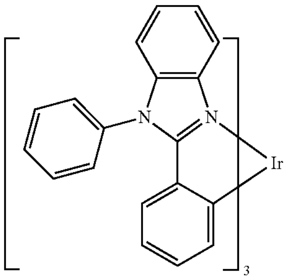
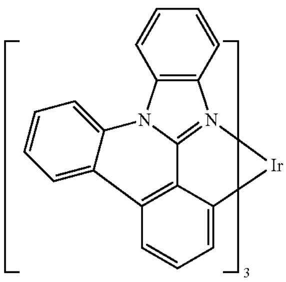
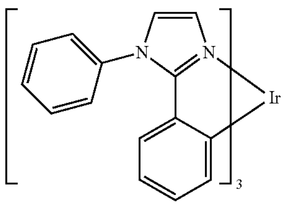
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US2002034656
		US06687266
		Chem. Mater. 16, 2480 (2004)
		US2007190359
		US 2006008670 JP2007123392

TABLE 5-continued

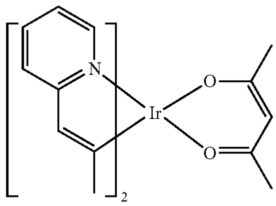
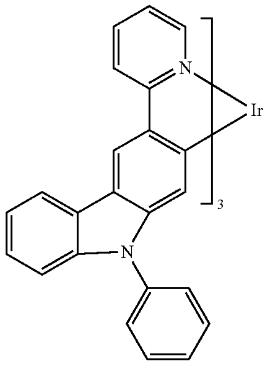
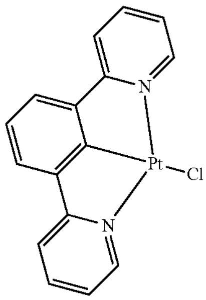
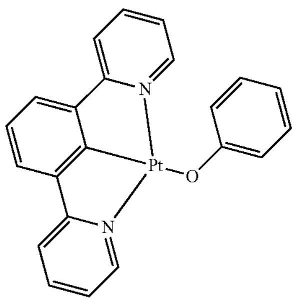
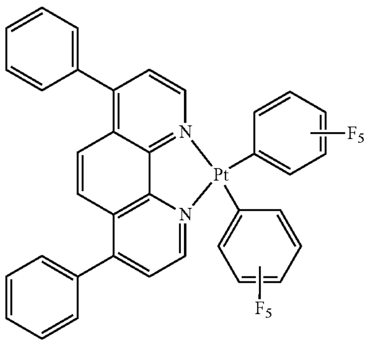
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Adv. Mater. 16, 2003 (2004)
		Angew. Chem. Int. Ed. 2006, 45, 7800
Pt(II) organometallic complexes		Appl. Phys. Lett. 86, 153505 (2005)
		Appl. Phys. Lett. 86, 153505 (2005)
		Chem. Lett. 34, 592 (2005)

TABLE 5-continued

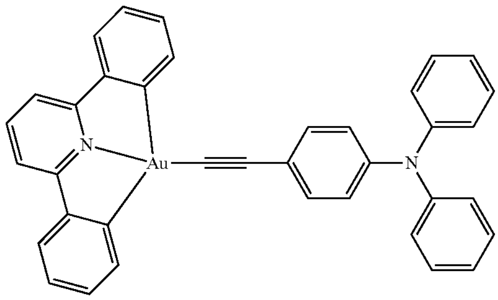
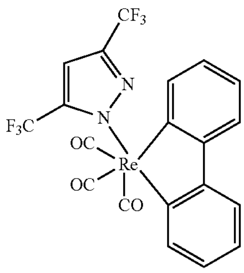
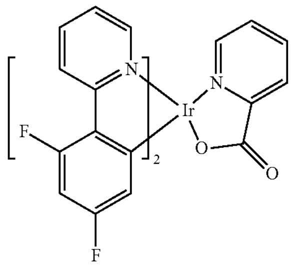
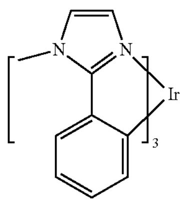
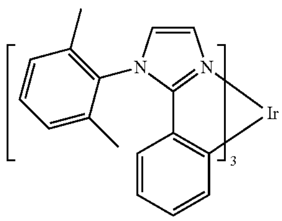
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Gold complexes		Chem. Commun. 2906 (2005)
Rhenium(III) complexes		Inorg. Chem. 42, 1248 (2003)
	Blue dopants	
Iridium(III) organometallic complexes		WO2002002714
		WO2006009024
		US2006251923

TABLE 5-continued

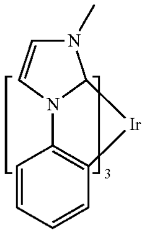
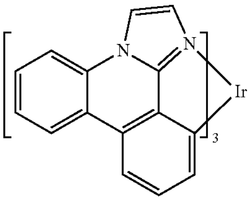
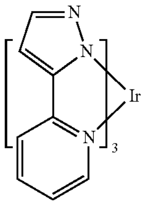
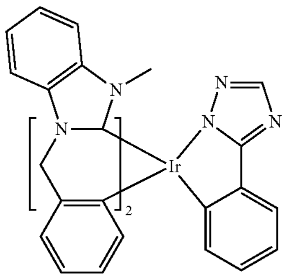
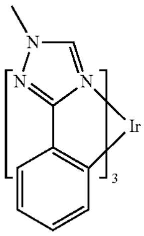
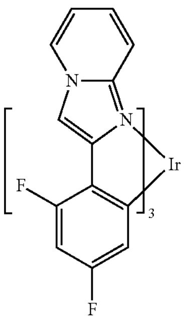
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2006056418, US2005260441
		US2007190359
		US2002134984
		Angew. Chem. Int. Ed. 47, 1 (2008)
		Chem. Mater. 18, 5119 (2006)
		Inorg. Chem. 46, 4308 (2007)

TABLE 5-continued

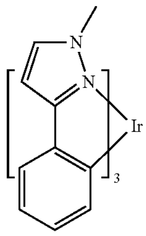
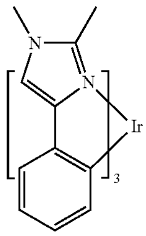
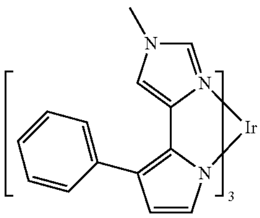
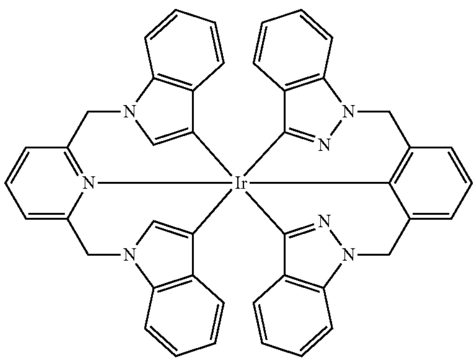
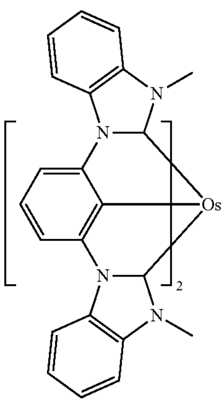
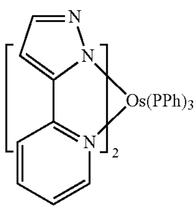
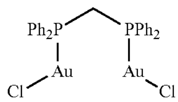
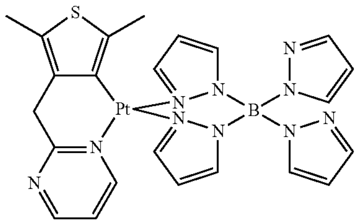
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO05123873
		WO05123873
		WO07004380
		WO06082742
Osmium(II) complexes		US2005260449

TABLE 5-continued

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Organometallics 23, 3745 (2004)
Gold complexes		Appl. Phys. Lett.74, 1361 (1999)
Platinum(II) complexes		WO06098120, WO06103874

Exciton/hole blocking layer materials

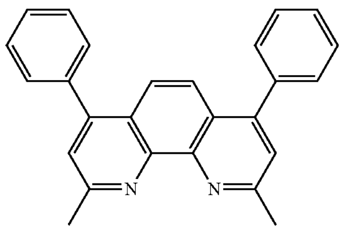
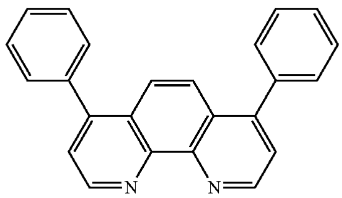
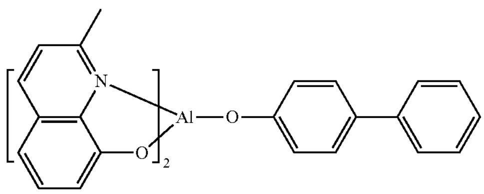
Bathocuprine compounds (e.g., BCP, BPhen)		Appl. Phys. Lett. 75, 4 (1999)
		Appl. Phys. Lett. 79, 449 (2001)
Metal 8-hydroxyquinolates (e.g., BAlq)		Appl. Phys. Lett. 81, 162 (2002)

TABLE 5-continued

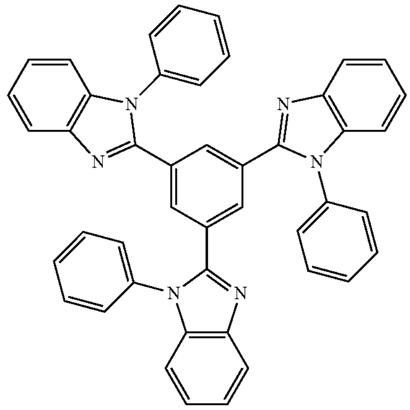
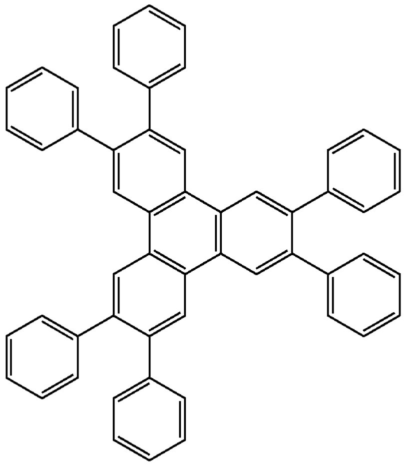
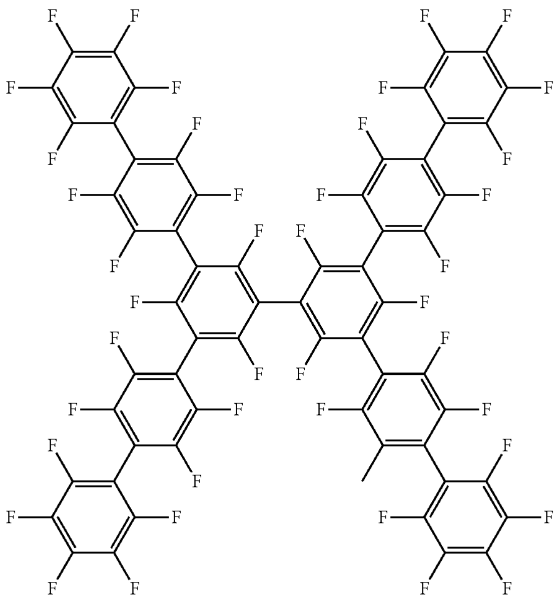
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
5-member ring electron deficient heterocycles such as triazole, oxadiazole, imidazole, benzoimidazole		Appl. Phys. Lett. 81, 162 (2002)
Triphenylene compounds		US20050025993
Fluorinated aromatic compounds		Appl. Phys. Lett. 79, 156 (2001)
	Electron transporting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

TABLE 5-continued

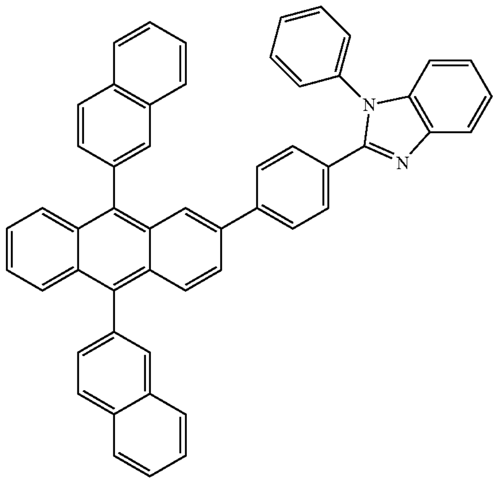
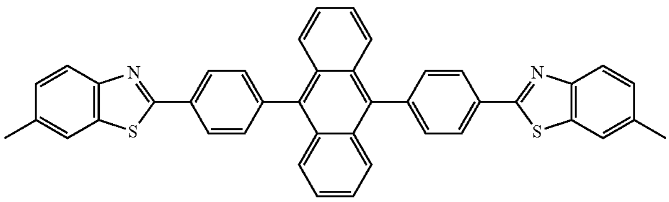
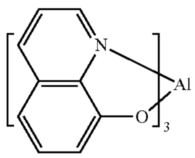
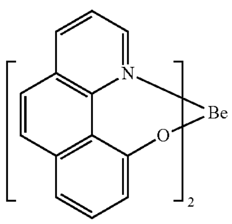
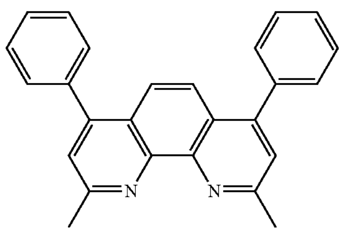
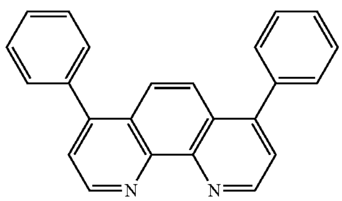
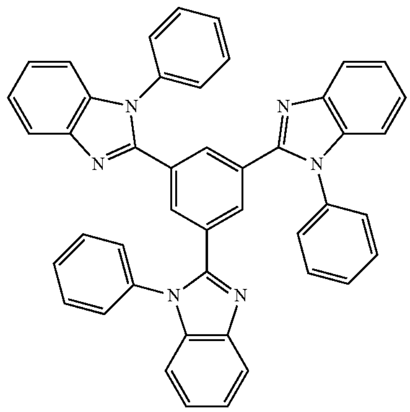
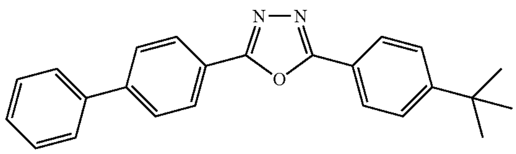
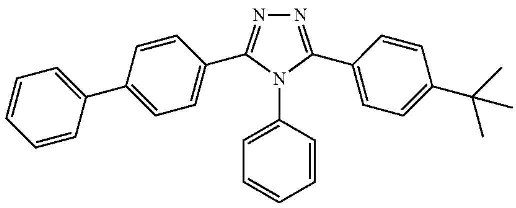
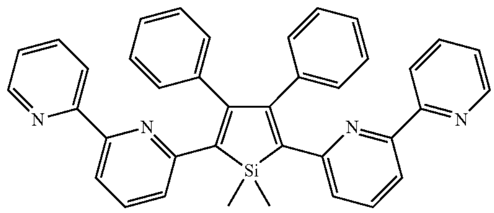
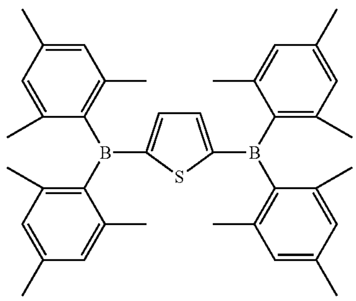
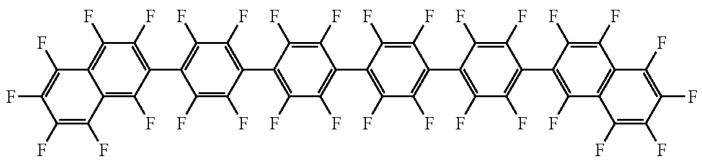
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Anthracene-benzoimidazole compounds		WO03060956
Anthracene-benzothiazole compounds		Appl. Phys. Lett. 89, 063504 (2006)
Metal 8-hydroxyquinolates (e.g., Alq_3)		Appl. Phys. Lett. 51, 913 (1987)
Metal hydroxy-benoquinolates		Chem. Lett. 5, 905 (1993)
Bathocuprine compounds such as BCP, BPhen, etc		Appl. Phys. Lett. 91, 263503 (2007)
		Appl. Phys. Lett. 79, 449 (2001)

TABLE 5-continued

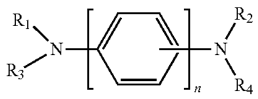
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
5-member ring electron deficient heterocycles (e.g., triazole, oxadiazole, imidazole, benzoimidazole)		Appl. Phys. Lett. 74, 865 (1999)
		Appl. Phys. Lett. 55, 1489 (1989)
		Jpn. J. Apply. Phys. 32, L917 (1993)
Silole compounds		Org. Electron. 4, 113 (2003)
Arylborane compounds		J. Am. Chem. Soc. 120, 9714 (1998)
Fluorinated aromatic compounds		J. Am. Chem. Soc. 122, 1832 (2000)

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.

The invention claimed is:

1. A composition of matter having the chemical structure:

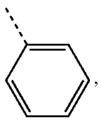
(Formula I)



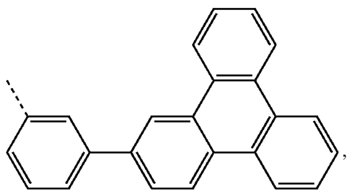
wherein n is 1, 2 or 3, and the phenyl rings between the nitrogen atoms may be attached to each other and to the nitrogen atoms in a para or meta configuration independently selected for each attachment;

wherein each of R_1, R_2, R_3 and R_4 are independently selected from the group consisting of:

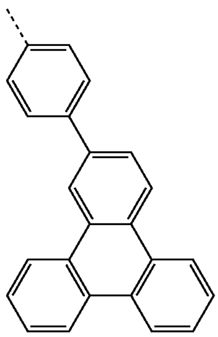
S-1



S-2

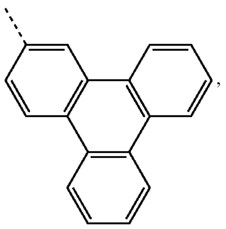


S-3



and

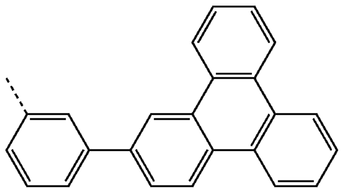
S-4



wherein the dotted line shows the point of attachment to a nitrogen atom of Formula I;

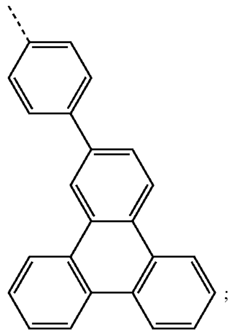
wherein at least one of R_1, R_2, R_3 and R_4 is selected from the group consisting of:

S-2



or

S-3



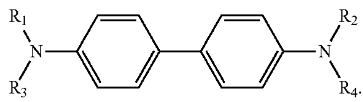
;

wherein R_1, R_2, R_3 and R_4 are not all the same; and

wherein each of R_1, R_2, R_3 and R_4 may be further substituted with substituents that are not fused to R_1, R_2, R_3 and R_4.

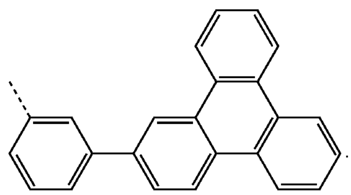
2. The composition of matter of claim **1**, wherein the part of the composition represented by Formula I is more specifically:

(Formula II)



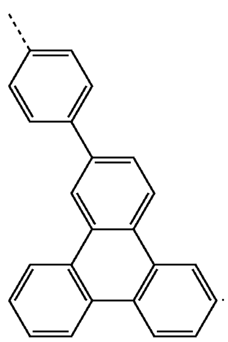
3. The composition of matter of claim **1**, wherein at least one of R_1, R_2, R_3 and R_4 is:

S-2



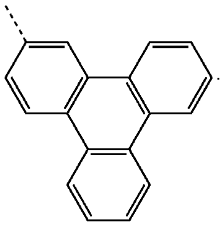
4. The composition of matter of claim **1**, wherein at least one of R_1, R_2, R_3 and R_4 is:

S-3



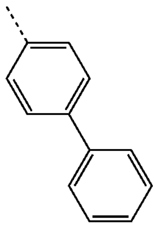
5. The composition of matter of claim 1, wherein at least one of R_1, R_2, R_3 and R_4 is:

S-4

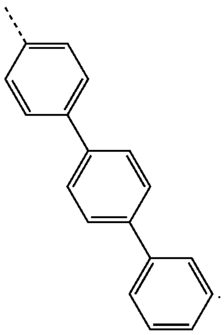


6. The composition of matter of claim 1, wherein at least one of R_1, R_2, R_3 and R_4 is selected from the group consisting of:

S-5

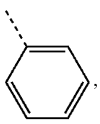


S-6

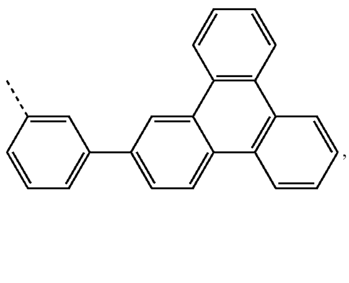


7. The composition of matter of claim 1, wherein each of R_1, R_2, R_3 and R_4 is independently selected from the group consisting of:

S-1



S-2



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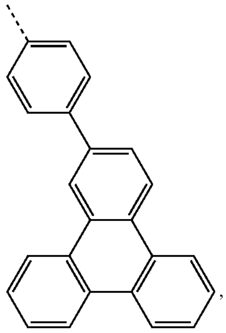
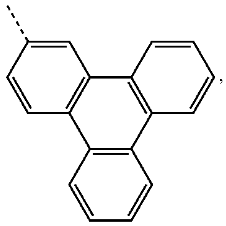
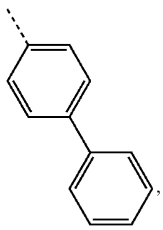
S-3



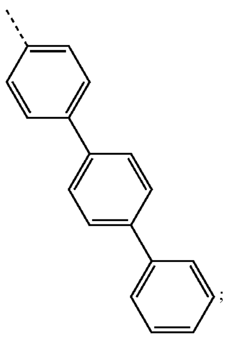
S-4



S-5

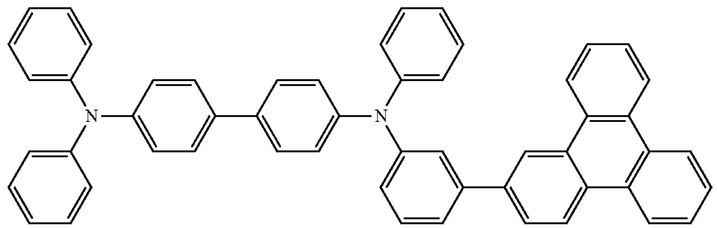


S-6

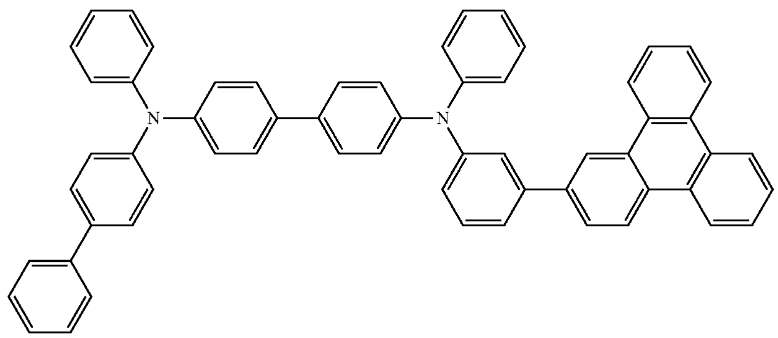


wherein there are no further substitutions to R_1, R_2, R_3 and R_4.

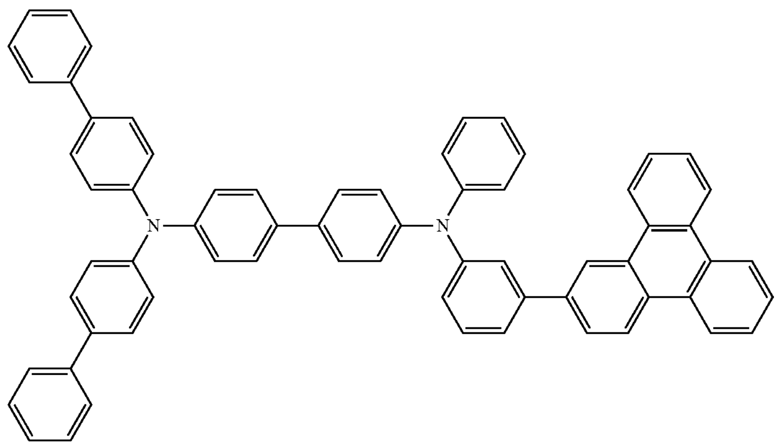
8. The composition of matter of claim **3**, wherein the composition of matter has a structure selected from the group consisting of:



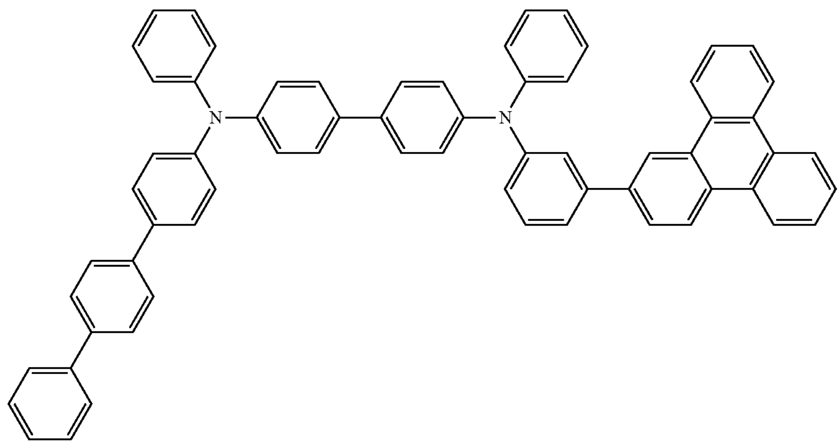
A-1



A-2



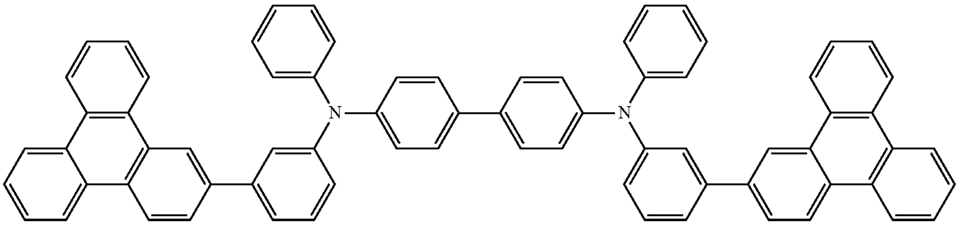
A-3



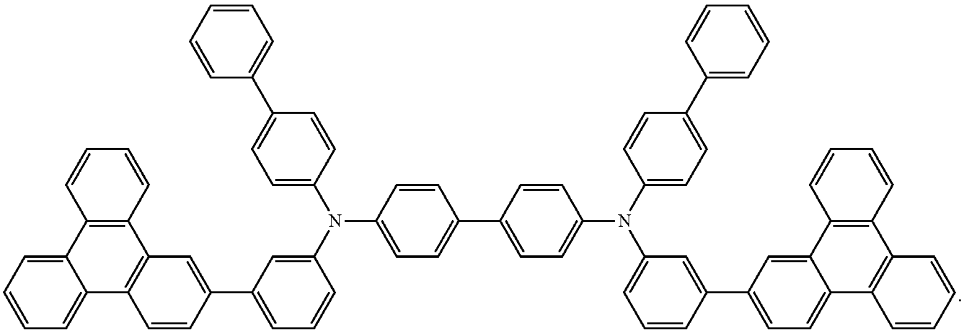
A-4

-continued

A-5

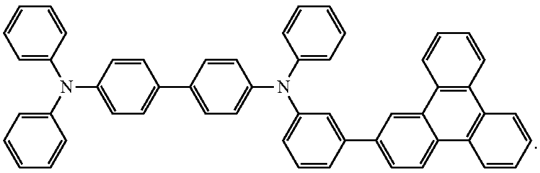


A-6



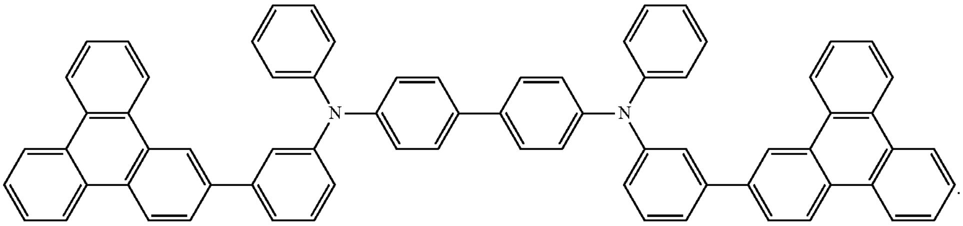
9. The composition of matter of claim **8**, wherein the composition of matter has the structure:

A-1



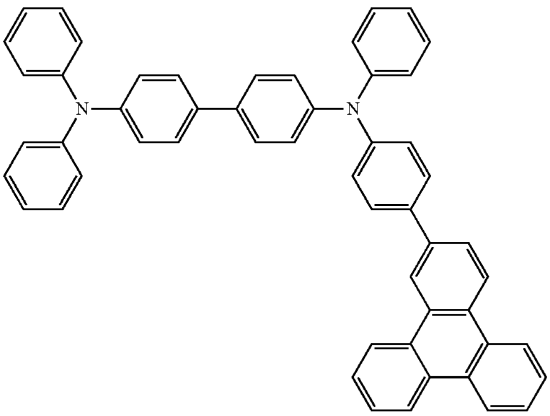
10. The composition of matter of claim **8**, wherein the composition of matter has the structure:

A-5

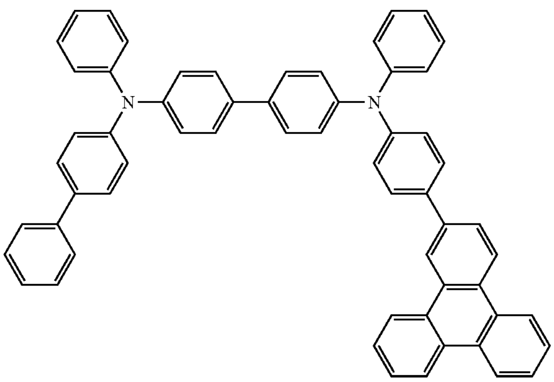


11. The composition of matter of claim 4, wherein the composition of matter has a structure selected from the group consisting of:

B-1



B-2



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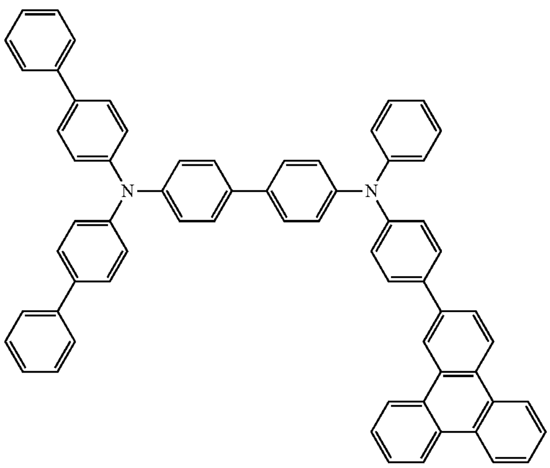

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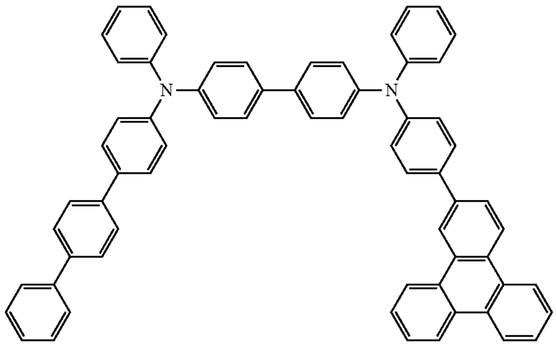
B-4



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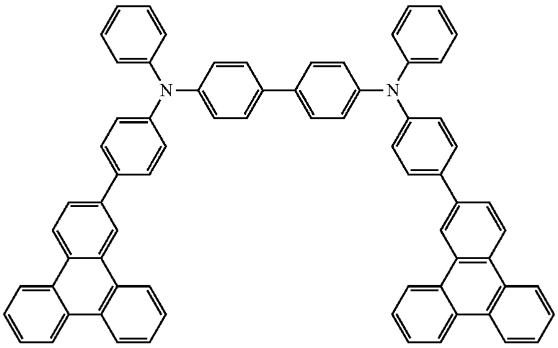
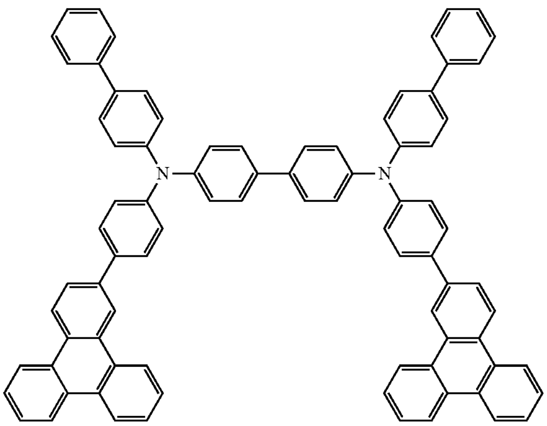


B-6



12. An organic light emitting device comprising:

an anode;

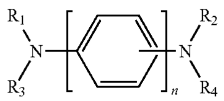
a cathode;

an organic emissive layer, disposed between the anode and the cathode, the organic emissive layer further comprising a host and a phosphorescent dopant,

an organic hole transport layer comprising a hole transport material, disposed between the organic emissive layer and the anode, and in direct contact with the organic emissive layer;

wherein the hole transport material has the structure:

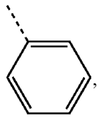
(Formula I)



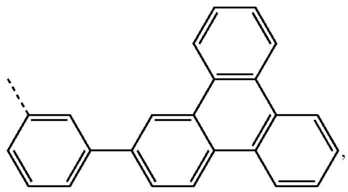
wherein n is 1, 2 or 3, and the phenyl rings between the nitrogen atoms may be attached to each other and to the nitrogen atoms in a para or meta configuration independently selected for each attachment;

wherein each of R_1, R_2, R_3 and R_4 are independently selected from the group consisting of:

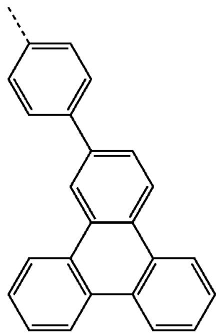
S-1



S-2

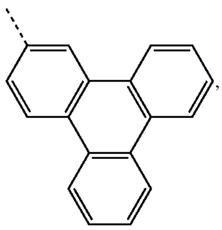


S-3



and

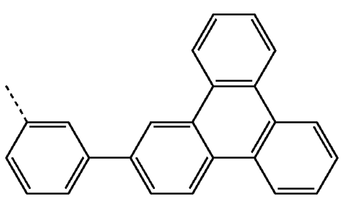
S-4



wherein the dotted line shows the point of attachment to a nitrogen atom of Formula I;

wherein at least one of R_1, R_2, R_3 and R_4 is selected from the group consisting of:

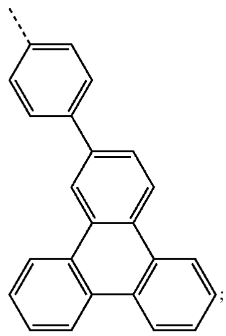
S-2



or

-continued

S-3



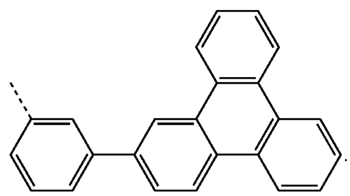
wherein R_1, R_2, R_3 and R_4 are not all the same; and

wherein each of R_1, R_2, R_3 and R_4 may be further substituted with substituents that are not fused to R_1, R_2, R_3 and R_4.

13. The device of claim **12**, wherein the dopant is an organo-metallic iridium material.

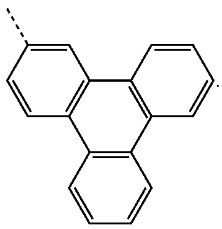
14. The device of claim **12**, wherein at least one of R_1, R_2, R_3 and R_4 is:

S-2



15. The device of claim **12**, wherein at least one of R_1, R_2, R_3 and R_4 is:

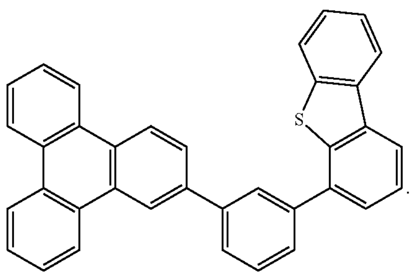
S-4



16. The device of claim **12**, wherein the host is a compound comprising a triphenylene containing benzo-fused thiophene.

17. The device of claim **16**, wherein the host is:

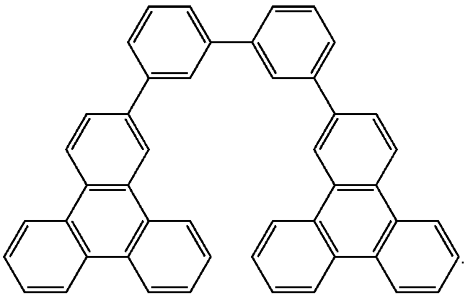
Compound 3



18. The device of claim **12**, wherein the host is an aryltriphenylene compound.

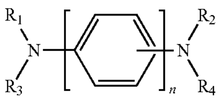
19. The device of claim **18**, wherein the host is:

Compound 2



20. A consumer product, wherein the consumer product includes an organic light emitting device that further includes a composition of matter having the chemical structure:

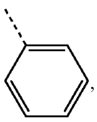
(Formula I)



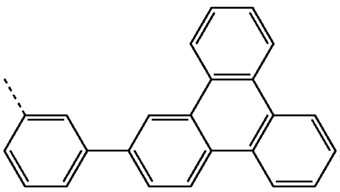
wherein n is 1, 2 or 3, and the phenyl rings between the nitrogen atoms may be attached to each other and to the nitrogen atoms in a para or meta configuration independently selected for each attachment;

wherein each of R_1, R_2, R_3 and R_4 are independently selected from the group consisting of:

S-1



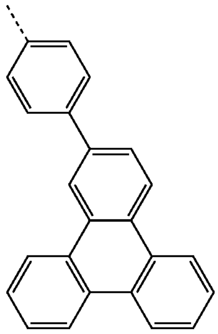
S-2



, and

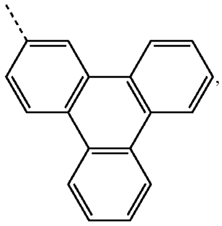
-continued

S-3



and

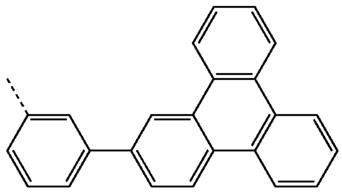
S-4



wherein the dotted line shows the point of attachment to a nitrogen atom of Formula I;

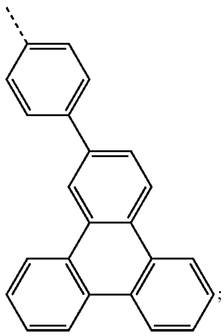
wherein at least one of R_1, R_2, R_3 and R_4 is selected from the group consisting of:

S-2



or

S-3



wherein R_1, R_2, R_3 and R_4 are not all the same; and

wherein each of R_1, R_2, R_3 and R_4 may be further substituted with substituents that are not fused to R_1, R_2, R_3 and R_4.

* * * * *

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申请号	US13/001949	申请日	2009-06-30
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[标]发明人	XIA CHUANJUN KWONG RAYMOND		
发明人	XIA, CHUANJUN KWONG, RAYMOND		
IPC分类号	H01L51/54		
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摘要(译)

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