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(54) MATERIALS AND DEVICES FOR BLUE PHOSPHORESCENCE BASED ORGANIC LIGHT EMITTING DIODES

MATERIALIEN UND EINRICHTUNGEN FÜR ORGANISCHE LEUCHTDIODEN AUF BLAUPHOSPHORESZENZBASIS

MATERIAUX ET DISPOSITIFS POUR DIODES ORGANIQUES ELECTROLUMINESCENTES BASEES SUR UNE PHOSPHORESCENCE BLEUE

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(56) References cited:

EP-A1- 0 757 035	**EP-A2- 0 757 088**
WO-A-01/08230	**WO-A-01/41512**
WO-A1-98/55561	**DE-A1- 4 428 450**
US-A1- 2002 028 347	**US-A1- 2002 101 154**
US-A1- 2002 113 545	**US-B2- 6 365 270**

- **LYONS C H ET AL: "Solid-state light-emitting devices based on the trischelated Ruthenium(II) complex. 1. thin film blends with poly(ethylene oxide)" JOURNAL OF THE AMERICAN CHEMICAL SOCIETY, AMERICAN CHEMICAL SOCIETY, WASHINGTON, DC, US, vol. 120, 4 November 1998 (1998-11-04), pages 12100-12107, XP002190728 ISSN: 0002-7863**
- **BALDO M A ET AL: "Phosphorescent materials for application to organic light emitting devices", PURE & APPLIED CHEMISTRY, PERGAMON PRESS, OXFORD, GB, vol. 71, no. 11, 30 November 1999 (1999-11-30), pages 2095-2106, XP001182482, ISSN: 0033-4545, DOI: 10.1351/PAC199971112095 [retrieved on 2009-01-01]**

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Description

Field of the Invention

[0001] The present invention relates to highly efficient organic light emitting devices (OLEDs) that are, for example, capable of emitting blue light, and in particular to OLEDs that have an emitting layer comprising a phosphorescent dopant material and a charge carrying dopant material that are doped in an inert host material.

Background of the Invention

[0002] Organic light emitting devices (OLEDs), which make use of thin film materials that emit light when excited by electric current, are expected to become an increasingly popular form of flat panel display technology. This is because OLEDs have a wide variety of potential applications, including cell phones, personal digital assistants (PDAs), computer displays, informational displays in vehicles, television monitors, as well as light sources for general illumination. Due to their bright colors, wide viewing angle, compatibility with full motion video, broad temperature ranges, thin and conformable form factor, low power requirements and the potential for low cost manufacturing processes, OLEDs are seen as a future replacement technology for cathode ray tubes (CRTs) and liquid crystal displays (LCDs), which currently dominate the growing $40 billion annual electronic display market. Due to their high luminous efficiencies, electrophosphorescent OLEDs are seen as having the potential to replace incandescent, and perhaps even fluorescent, lamps for certain types of applications.

[0003] Successful utilization of phosphorescence holds enormous promise for organic electroluminescent devices. For example, an advantage of phosphorescence is that all excitons (formed by the recombination of holes and electrons in an EL), which are formed either as a singlet or triplet excited state, may participate in luminescence. This is because the lowest singlet excited state of an organic molecule is typically at a slightly higher energy than the lowest triplet excited state. This means that, for typical phosphorescent organometallic compounds, the lowest singlet excited state may rapidly decay to the lowest triplet excited state from which the phosphorescence is produced. In contrast, only a small percentage (about 25%) of excitons in fluorescent devices are believed to be capable of producing the fluorescent luminescence that is obtained from a singlet excited state. The remaining excitons in a fluorescent device, which are produced in the lowest triplet excited state of an organic molecule, are typically not capable of being converted into the energetically unfavorable higher singlet excited states from which the fluorescence is produced. This energy, thus, becomes lost to radiationless decay processes that only tend to heat-up the device.

[0004] As a consequence, since the discovery that phosphorescent materials can be used as the emissive material in highly efficient OLEDs, there is now much interest in finding still more efficient electrophosphorescent materials and OLED structures containing such materials.

[0005] High efficiency organic light emitting devices (OLEDs) using the phosphorescent dopant, *fac* tris(2-phenylpyridine)iridium ($Ir(ppy)_3$), have been demonstrated using several different conducting host materials. M. A. Baldo et al., Nature, vol. 395, 151 (1998); D. F. O'Brien et al., Appl. Phys. Lett., vol. 74, 442 (1999); M. A. Baldo et al., Appl. Phys. Lett., vol. 75, 4 (1999); T. Tsutsui et al., Japanese. J. Appl. Phys., Part 2, vol. 38, L1502 (1999); C. Adachi et al., Appl. Phys. Lett., vol. 77, 904 (2000); M. J. Yang et al., Japanese J. Appl. Phys., Part 2, vol. 39, L828 (2000); and C. L. Lee et al., Appl. Phys. Lett., vol. 77, 2280 (2000). Since the triplet level of the metal-ligand charge transfer state of the green-emitting $Ir(ppy)_3$ is between 2.5 eV and 3.0 eV, deep blue fluorophores with a peak wavelength at about 400 nm, such as 4,4'-*N*,*N'*-dicarbazole-biphenyl (CBP), are likely candidates as triplet energy transfer and exciton confining media. Using 6% to 10%-$Ir(ppy)_3$ in CBP leads to efficient $Ir(ppy)_3$ phosphorescence. In addition to the energetic resonance between the dopant and the host, the control of charge carrier injection and transport in the host layers is believed to be necessary for achieving efficient formation of radiative excitons. High electrophosphorescence efficiency has been achieved using $Ir(ppy)_3$ doped into CBP along with a 2,9-dimethyl-4,7-diphenyl- phenanthroline (BCP) electron transport and exciton blocking layer. M. A. Baldo et al., Appl. Phys. Lett., vol. 75, 4 (1999). In that device, the doped CBP layer was found to readily transport holes. Other light emitting devices are known from DE 44 28 450 A1, EP 757 088 A2, and Baldo et al. in Pure and Appl. Chem., vol. 71, no. 11, p. 2095.

[0006] Current materials used in phosphorescent OLEDs may be used to form devices with internal quantum efficiencies of near 100%. However, the materials used to form the hole transporting, recombination and blocking layers in these conventional devices tend to have triplet energies corresponding to emission in the green part of the visible spectrum. If a dopant capable of producing blue phosphorescence is inserted in such a device utilizing the existing materials and structures, the emission will only come, if at all, inefficiently from the matrix material, and not from the phosphorescent dopant material. Accordingly, there is great interest in finding efficient OLED structures that can emit in the blue region of the visible electro-magnetic spectrum.

Summary of the Invention

[0007] The present invention relates to OLED devices that efficiently emit light as defined in the claims, in particular that preferably emit light in the blue range of the visible spectrum. The OLEDs made according to the invention preferably include blue phosphorescent OLEDs with efficiency levels comparable to those of current green to red phosphorescent OLEDs.

[0008] The present invention is directed to an OLED, in which the emissive layer consists of a wide gap host material doped with both a charge carrying dopant material and a phosphorescent dopant material. The charge carrying dopant material is capable of transporting a hole or an electron, and the phosphorescent dopant material is capable of transporting a charge opposite to the charge carried by the charge carrying dopant material. Each dopant material, thus, carries charge, though of opposite polarity. The charge carrying phosphorescent material also performs the function of emitting the phosphorescent radiation. Thus, the term "charge carrying dopant material" is reserved herein to refer to the material that only carries charge, whereas the phosphorescent dopant material may be referred to, interchangeably herein, simply as the "phosphorescent dopant material" or, alternatively, as the "charge carrying phosphorescent dopant material".

[0009] For example, in one embodiment, the charge carrying dopant material is a hole transporting material and the phosphorescent dopant material is an electron transporting material. The phosphorescent dopant material is, in addition, the emissive material that produces phosphorescent radiation when a voltage is applied across the OLED. In another embodiment, the charge carrying dopant material is an electron transporting material and the phosphorescent dopant material is a hole transporting material, in addition to being the emissive material.

[0010] In each embodiment, the lowest triplet state energy level of the wide gap host material and the lowest triplet state energy level of the charge carrying dopant material are each higher than the lowest triplet state energy level of the phosphorescent dopant material. Preferably, the lowest triplet state energy level of the wide gap host material is also higher than the lowest triplet state energy level of the charge carrying dopant material. Typically, for those materials that are capable of producing phosphorescent radiation, such radiation is emitted almost exclusively only from the lowest triplet state energy level of that matertial.

[0011] The present invention is further directed to the emissive layer comprising the wide gap host material with the charge carrying dopant material and the phosphorescent dopant material that are each dispersed in the host material, wherein the lowest triplet state energy level of the wide gap host material and the lowest triplet state energy level of the dopant material are each higher than the lowest triplet state energy level of the phosphorescent dopant material. In this embodiment, the lowest triplet state energy level of the wide gap host material is also preferably higher than the lowest triplet state energy level of the charge carrying dopant material.

[0012] The present disclosure is further directed to a method of selecting the materials that may be used in an efficient OLED, in particular, selecting materials having the combination of relative properties as prescribed herein.

[0013] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

Brief Description of the Drawings

[0014] The accompanying drawings are included to provide a further understanding of the invention and are incorporated in an constituent part of this specification, illustrate several embodiments of the invention and together with a description serve to explain the present invention. In the drawings:

Figure 1 shows a schematic cross section of an OLED structure according to the present invention;

Figure 2 shows a schematic cross section of a second embodiment of an OLED structure according to the present invention, where the host material forms the electron injection layer;

Figure 3 shows a schematic cross section of a third embodiment of an OLED structure according to the present invention, including blocking layers;

Figure 4 is a diagram showing the energy levels in an OLED structure according to the invention; and

Figure 5 is a diagram showing the energy levels in another OLED structure according to the invention.

Detailed Description of Embodiments of the Invention

[0015] Embodiments of the present invention will be described with reference to the drawings. It is understood that these embodiments are intended as illustrative examples of the invention, and do not limit the invention.

[0016] The OLEDs made according to the present invention include phosphorescent dopants dispersed in the device's emissive layer, preferably capable of achieving internal quantum efficiencies approaching 100%. The emissive dopants in these devices typically contain heavy transition metal atoms, such as, for example, iridium or platinum, that induce efficient radiative relaxation of triplet excitons. Although iridium and platinum have provided high quantum efficiencies, other heavy metals such as osmium or gold may also be used. These phosphorescent dopants thus can take advantage of substantially all the excitons available within the emissive layer of the device, resulting in much higher efficiencies compared to devices using only singlet excitation to induce luminescence.

[0017] The luminescent emission from OLEDs is typically via fluorescence or phosphorescence. As used herein, the term "phosphorescence" refers to emission from a triplet excited state of an organic molecule and the term "fluorescence" refers to emission from a singlet excited state of an organic molecule.

[0018] The mechanism that was originally believed to be responsible for electroluminescence from dye-doped OLEDs involved exciton formation in the host matrix followed by energy transfer from the host to the dopant via a Forster or Dexter energy transfer process. While this process is still also believed to occur in phosphorescence-based OLEDs, there is a second process that is believed to be important for helping to increase the efficiency of these electrophosphorescent devices. The HOMO energy levels of the phosphorescent dopants are typically higher in energy than those of the matrix materials into which they are doped. This means that the dopants are capable of trapping holes and transporting them through the matrix if the doping level is high enough. The end result is that the dopant itself may act as the site of hole-electron recombination. This means that a Forster and/or a Dexter-type host-dopant energy transfer process may be unnecessary in an inert, non-charge-carrying host material, if the exciton can be preferentially formed at the dopant site.

[0019] A trapping/recombination process of this type may be beneficially used for the formation of the blue phosphorescent OLEDs of the present invention, since such a process does not require generation of excitons in the host matrix that are higher in energy than the blue phosphors (i.e., at the very high energy levels in the violet to ultraviolet regions of the spectrum). A simple structure is used in which the emissive region of the device is a wide gap host matrix, doped with a phosphorescent dopant that is capable of transporting holes and an electron transporter. Alternatively, the phosphor could carry electrons and the emissive layer would be co doped with a hole transporter. The present invention is directed toward OLEDs having such simple structures.

[0020] Thus, one of the distinctive features of the present invention is that the charge carrying materials that are typically used as the predominant component, if not sole component, for the hole transporting layer or the electron transporting layer in a conventional OLED, is used in the present invention as the charge carrying dopant material in an inert matrix. An additional feature of the present invention is the use of an emissive material capable of carrying a charge opposite to the charge carried by the charge carrying dopant material, wherein the emissive material is dispersed in the host matrix together with the charge carrying dopant material.

[0021] It is believed that selection of such charge carrying emissive materials permits electron/hole recombination to take place directly on the emissive material in the inert matrix. Furthermore, by selecting such a combination of materials as prescribed herein, it is believed that the electroluminescent radiation may be more readily obtained from materials that have emissive triplet state energy levels at much higher energies than are typically available for producing electrophosphorescent radiation. Typically, in a prior art OLED, energy transfer that tends to take place from these high triplet state energy levels to lower triplet state energy levels that are present in the other OLED materials would be expected to substantially prevent any radiative emission from being obtained from the higher-energy triplet states. Thus, the electrophosphorescent devices of the present invention are preferably capable of producing radiation in the higher energy regions of the visible spectrum, in particular, in the blue region of the visible spectrum.

[0022] It is further believed that by using an inert host matrix in combination with the prescribed charge carrying dopant material and the prescribed charge carrying phosphorescent dopant material, such a combination of materials permits selection from a much wider range of OLED materials. This is in contrast to a typical OLED that may have, in sequence, a hole injecting layer, a hole transporting layer, an electron transporting layer, an electron injecting layer, and a phosphorescent dopant material that is present in either the hole transporting layer or the electron transporting layer. The electron transporting layer, or still another electron transporting layer, may be used simply to function as a hole or exciton blocking layer. The materials used in each of these layers must be selected in combination so as to limit the radiationless energy transfer pathways that tend to reduce device efficiency.

[0023] The present invention is directed to OLEDs that are capable of containing a significantly smaller number of materials that need to be matched so as to limit the radiationless loss pathways. Only three organic OLED materials need to be used in the preferred embodiments of the present invention, an inert host material, a charge carrying dopant material and a charge carrying phosphorescent dopant material. The emissive layer includes an inert host material having such a large energy gap between the HOMO and LUMO levels of the material that the inert host matrix does not participate in hole or electron transport, since the hole and electrons that are created in the OLED do not have sufficient energy to be transported respectively through the HOMO or LUMO levels of the host material. In addition, since these inert host materials have such a wide energy gap between the HOMO and LUMO levels, such materials may be readily selected to have a lowest triplet excited state level that is higher than the lowest triplet state level of the emissive phosphorescent material and, optionally, also higher than the lowest triplet state level of the charge carrying dopant material.

[0024] This means that by selecting charge carrying dopant materials based on the relative location of their emissive triplet state energy levels and, in addition, based on their effectiveness in carrying charge through the inert host matrix, it is believed that one skilled in the art may choose from a much wider range of OLED materials than is possible if the host material is capable of participating in hole or electron transport. Thus, both the inert host and the charge carrying dopant materials may be more readily selected, in combination, so as to limit the radiationless energy relaxation pathways that can cause a loss in device efficiency.

[0025] Similarly, by selecting a charge carrying emissive material having the prescribed relative triplet state energy level, it is believed that one skilled in the art may also choose from a much wider range of charge carrying emissive materials since there are far fewer additional materials present in the OLED that must be properly matched with the charge carrying emissive material. In this case, one can select those charge carrying emissive materials that permit energy transfer to be channeled through a limited number of energy relaxation pathways so as to achieve a high electrophosphorescent efficiency.

[0026] In one of the preferred embodiments of the invention, the emissive material may be selected so as to produce radiation with an emission peak in the higher-energy, blue region of the visible spectrum. This corresponds to a range from about 430 nm to about 470 nm, more preferably with an emission peak at about 450 nm. It is to be understood that the materials and methods of the present invention may also be employed to produce radiation in other lower-energy regions, for example, in the green or red regions of the visible spectrum.

[0027] The preferred embodiments of the present invention are directed toward OLEDs containing a single, emissive, organic layer comprising only the host material doped with the charge carrying dopant material and the charge carrying phosphorescent dopant material, with one interface in direct contact with an anode and the opposite interface in direct contact with a cathode. However, the present invention also includes embodiments in which additional layers are present, for example, including a hole injecting layer, an electron injecting layer, and a hole blocking layer, and/or an exciton blocking layer. Thus, while it is preferred not to include these additional layers, it is believed that the single, emissive, organic layer may be used in combination with one or more of these additional layers.

[0028] An embodiment of an OLED structure according to the invention is described with reference to Figure 1. The device can be manufactured, for example, by forming the various layers on a substrate 10 by vacuum deposition or by organic vapor phase deposition (OVPD). Vacuum deposition typically requires a high vacuum of between about 10E-11 to 10E-5 torr. OVPD requires a weaker vacuum, for example of between about 10E-5 to 50 torr. Other manufacturing techniques may also be used to form the device. For example, polymeric layers may be formed by spin coating.

[0029] A substrate 10 is first formed, on which an anode layer 60 connected to a positive power supply is formed. Adjacent to anode layer 60 a hole injecting layer 50 may optionally be formed. For example, hole injecting layer 50 can be a coating formed on anode 60. A wide gap host material layer 40 is formed above the optional hole injecting layer 50, using conventional manufacturing methods. The wide gap host material layer 40 thus defines the emissive region of the OLED, which comprises a doped layer containing the charge carrying dopant material and the phosphorescent dopant material. An electron injecting layer 30 may optionally be formed next, and is followed by a conventional cathode layer 20 connected to a negative power supply. One or both of anode layer 60 and cathode layer 20 can be transparent to the electromagnetic radiation emitted by the device.

[0030] In one embodiment, the wide gap host material layer 40, also referred to as matrix material, has triplet state energy levels that are well above the energy levels of all the dopants used in the device. Wide gap host material layer 40 is preferably inert, that is, it preferably does not carry a charge within the structure of the OLED. Accordingly, charge is preferably carried only by the dopants, and not by the wide gap host material layer 40.

[0031] In a different embodiment shown in Figure 2, the OLED structure according to the invention includes electron and hole injection regions that are formed from portions of the inert host material, rather than being separate layers of different materials. Region 90 is an electron injection contact formed by an un-doped portion of the wide gap material layer 40. Region 95 is a hole injection contact also formed by an un-doped portion of wide gap material layer 40. These structures are used to prevent charge carriers or excitons from leaking out of the active region of the device, and from being quenched at the interfaces between the electrodes and the organic material layers. Figure 5 shows the energy levels associated with this embodiment.

[0032] The optional non-doped regions 90, 95 can be layers that are sufficiently thick to function as hole and/or exciton blocking layers, if necessary, but are also sufficiently thin to permit effective injection of electrons.

[0033] In another embodiment of the OLED according to the invention, separate blocking layers are used between the emissive layer and the electrodes, wherein the blocking layers comprise a charge carrying material rather than an inert, non-charge-carrying material. As shown in Figure 3, first and second blocking layers 100, 110 are formed adjacent to the wide gap host material layer 40, between the doped layer and the electrodes. The materials forming these layers are selected to confine carrier recombination and emission to the doped layer of the wide gap host material layer 40. Blocking layers 100,110 can be used, for example, when un-doped regions of wide gap host material layer 40, such as injection regions 90,95 shown in Figure 2, do not provide sufficient confinement and carrier injection. In some cases, only one blocking layer may be used, for example, a hole and/or exciton blocking layer between the emission layer and the cathode layer.

[0034] Figure 4 shows the energy levels of the materials forming an OLED device according to the invention, and including an electron injection layer 75 and a hole injection layer 50. In the case where the phosphorescent dopant material dispersed in the wide gap host material layer 40 is an electron transporter, then $T_{HT} > T_{ET}$, and

$T_W > T_{ET}$, where T indicates triplet energy, and the subscripts indicate the wide gap material (W), the electron transporter (ET) and hole transporter (HT). In the case where the phosphorescent dopant material is a hole transporter, then $T_{ET} > T_{HT}$ and

$T_W > T_{HT}$.

[0035] From these relations it follows that the triplet state energy level of the host material layer 40 is greater than the triplet state energy level of the emitter dopant, but does not have to be greater than that of the non-emitting dopant. The HOMO-LUMO energy gap of the inert host material layer 40, in contrast to the triplet level, is greater than the energy gap of both the hole and electron transporters. The HOMO level of the inert host material is lower than the HOMO level of any of the dopant materials as well as any adjacent layers that are in direct physical contact with the inert host material. In addition, the LUMO level of the inert host material is higher than the LUMO level of any of the dopant materials as well as any adjacent layers that are in direct physical contact with the inert host material. As would be understood by one skilled in the art, a material that has a lower HOMO level as compared with another material is one that has a higher ionization potential (IP) as compared with the IP of the other material. Similarly, also as would be understood by one skilled in the art, a material that has a higher LUMO level as compared with another material is one that has a lower electron affinity as compared with the electron affinity of the other material.

[0036] When the above requirements and preferences are applied to the materials used according to the invention, the constraints on the HOMO and LUMO levels of the inert host material layer 40 relative to the levels of the electron and hole transporter dopants typically result in an inert host material layer having a wide energy gap between the HOMO and the LUMO energy levels. To ensure that the host material layer 40 is inert, the host material may be selected to have an energy gap of at least about 3.5 eV, and a triplet energy level well above the energy levels of both dopant materials forming the phosphorescent doped layer. This is especially important when the phosphorescent doped layer includes phosphors that emit blue light.

[0037] It is to be understood that while this 3.5 eV energy requirement may be used for convenience in selecting host materials that hold the greatest promise of functioning as effective inert hosts, there may be certain combinations of OLED materials that permit use of a host material with a slightly smaller energy gap and yet still provide highly efficient blue phosphorescence, provided that the other constraints as described herein are met. Thus, while the term "wide gap" material may typically refer to materials having a HOMO-LUMO energy gap of at least 3.5 eV, the term "wide gap" material, as used herein, may refer to any material that has a HOMO-LUMO energy gap large enough that it does not function as a charge carrying material when used as a host matrix in an OLED. Since a so-called non-charge-carrying material may be able to carry charge at least to some small degree, a non-charge-carrying material may be characterized herein as one which carries at least ten times less current than either of the charge carrying dopants.

[0038] According to the invention, the wide gap host material layer 40 is doped with two different materials, a charge carrying dopant material and a charge carrying phosphorescent dopant material, that are dispersed within the host material to form the emissive layer. The two dopant materials are typically dispersed uniformly throughout the host matrix, with the concentrations of each being independently selected to produce the desired results.

[0039] The charge carrying dopant material can be, for example, a hole transporting material, in which case the phosphorescent dopant material is also capable of transporting electrons. In an alternate embodiment, the roles are reversed, and the charge carrying dopant material transports electrons while the phosphorescent dopant material transports holes.

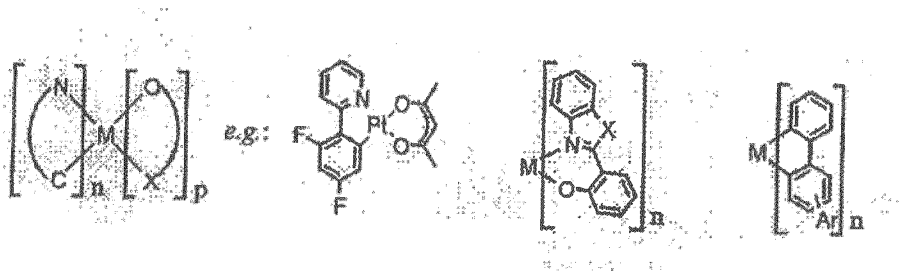
[0040] In one embodiment, the wide gap host material layer 40 can be formed, for example, by di-phenylenes, triphenylenes, napthalenes, tetraphenylbutadienes, which may, in each case, be substituted or unsubstituted, and other organic and metal organic materials. In another exemplary embodiment in which the phosphorescent dopant material is a hole transporter, the charge carrying dopant material can include electron transporting materials such as oxidiazoles, traizoles, cyclooctatetraenes and other wide gap electron transporters. When the electron transporting is carried out by the phosphorescent dopant material, the charge carrying dopant material can include hole transporting materials such as triarylamines, metal coordination complexes, donor substituted napthalenes and other wide gap materials with suitably high energy HOMO levels.

[0041] The charge carrying dopant material must have triplet energy levels above those of the phosphorescent dopant material. This is in addition to the requirement described above that the wide gap host material layer 40 must also have triplet energy levels above those of the phosphorescent dopant material. The same materials that are used as the charge carrying dopant material can also be used as the hole and/or exciton blocking layers that may be included in the structure of the OLED.

[0042] In general, these materials must have triplet energy levels corresponding to the UV-blue region of the visible spectrum so as to result in OLEDs that produce blue emission from the lower triplet state levels of the phosphorescent dopant.

[0043] The phosphorescent dopant material has a dual function of providing a phosphor that emits electromagnetic radiation in the desired wavelength range, and also providing a charge transporting material. As described above, when the charge carrying dopant material is an electron transporter, the phosphorescent dopant material must be a hole transporter, and vice versa.

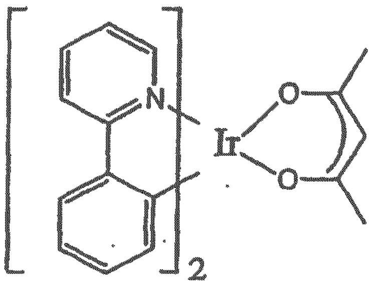
[0044] For example, the phosphorescent dopant material can contain a heavy metal atom, and can have a structure as shown below.



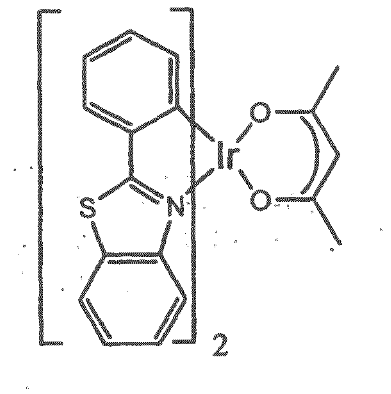
In the diagram, M represents a heavy transition metal, C--N a cyclometallated ligand and O--X a coordination ligand wherein X can be O, N or S, and wherein n= 1 or 2, and p= 0 or 1. These materials may be selected to form the doping phosphors because of their ability to tune the energies of the metal to ligand charge transfer and of the intraligand (3π-π*) excited states. In one example, the heavy metals forming the described compounds are preferably Ir or Pt atoms.

EXAMPLE OF THE INVENTION

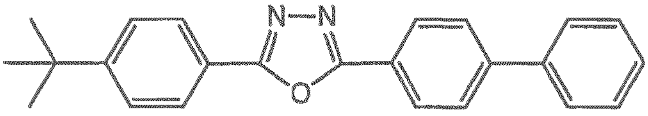
[0045] Using materials and methods known In the art for fabricating OLED's, In one exemplary embodiment, an OLED according to the invention was produced using a film of polystyrene as the inert host material. The dopant layers were formed by doping the inert host material with 15% of a hole transporting phosphorescent dopant and 40% of an electron transporting oxidiazole. More specifically, the phosphorescent dopants were bis(phenylpyridine) iridium acetylacetonate (PPIr), having the chemical structure:



and bis(2-phenylbenzothiazole) iridium acetylacetonate (BTIr), having the chemical structure:



and the oxidiazole was (4-biphenyl)(4-tertbutylphenyl)oxidiazole (PDB), having the chemical structure:



The device emitted light solely from the dopant with turn-on voltages of between about 7 and 9 Volts. The polystyrene acted as an inert matrix in which the dopants were supported. Although this device produced light in the green region of the visible spectrum, a different phosphor dopant in the same configuration may be used to produce light in the blue region of the spectrum.

[0046] It should be noted that additional layers can be used in the construction of OLEDs according to the present invention. These additional layers are known in the art, and thus will not be discussed in detail.

Claims

1. An emissive layer of an organic light emitting device, said emissive layer consisting of
a wide gap host material,
a charge carrying dopant material, present as a dopant in the wide gap host material, and a phosphorescent dopant material, present as a dopant in the wide gap host material, wherein the charge carrying dopant material is a hole transporting material and the phosphorescent dopant material is an electron transporting material,
wherein said phosphorescent dopant material emits from a triplet excited state of an organic molecule in said phosphorescent dopant material, and
wherein the lowest triplet state energy level of the wide gap host material (T_W) is higher than the lowest triplet state energy level of the electron transporting material (T_{ET}) ($T_W > T_{ET}$), and the lowest triplet state energy level of the hole transporting material (T_{HT}) is higher than the lowest triplet state energy level of the electron transporting material (T_{ET}) ($T_{HT} > T_{ET}$),
wherein the HOMO-LUMO energy gap of the wide gap host material is greater than the HOMO-LUMO energy gap of both the hole and electron transporting materials,
the HOMO level of the wide gap host material is lower than the HOMO level of any of the dopant materials as well as any adjacent layers that are in direct physical contact with the wide gap host material, and
the LUMO level of the wide gap host material is higher than the LUMO level of any of the dopant materials, as well as any adjacent layers that are in direct physical contact with the wide gap host material.

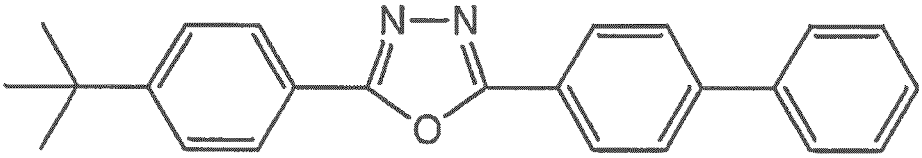
2. An emissive layer of an organic light emitting device, said emissive layer consisting of
a wide gap host material,
a charge carrying dopant material, present as a dopant in the wide gap host material, and a phosphorescent dopant material, present as a dopant in the wide gap host material, wherein the charge carrying dopant material is an electron transporting material and the phosphorescent dopant material is a hole transporting material,
wherein said phosphorescent dopant material emits from a triplet excited state of an organic molecule in said phosphorescent dopant material, and
wherein the lowest triplet state energy level of the wide gap host material (T_W) is higher than the lowest triplet state energy level of the hole transporting material (T_{HT}) ($T_W > T_{HT}$), and the lowest triplet state energy level of the electron

transporting material (T_{ET}) is higher than the lowest triplet state energy level of the hole transporting material (T_{HT}) ($T_{ET} > T_{HT}$),
wherein the HOMO-LUMO energy gap of the wide gap host material is greater than the HOMO-LUMO energy gap of both the hole and electron transporting materials,
the HOMO level of the wide gap host material is lower than the HOMO level of any of the dopant materials as well as any adjacent layers that are in direct physical contact with the wide gap host material, and
the LUMO level of the wide gap host material is higher than the LUMO level of any of the dopant materials, as well as any adjacent layers that are in direct physical contact with the wide gap host material.

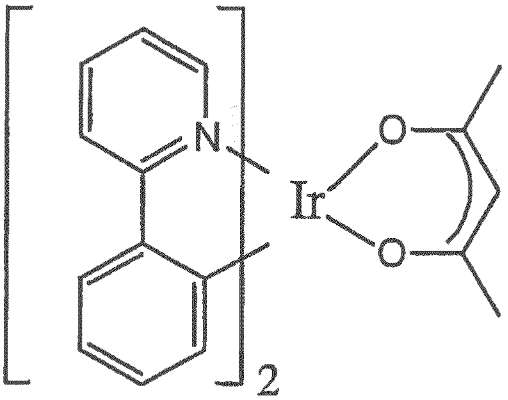
3. The emissive layer of claim 1, wherein the charge carrying dopant material comprises a material selected from the group consisting of a triarylamine, a metal coordination complex, and a donor substituted naphthalene.

4. The emissive layer of claim 2, wherein the charge carrying dopant material comprises a material selected from the group consisting of an oxadiazole, a triazole, and a cyclooctatetraene.

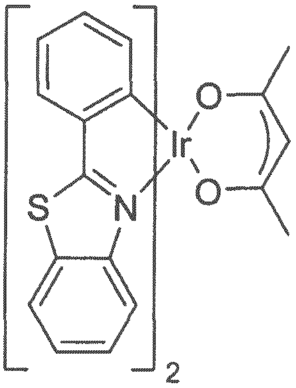
5. The emissive layer of claim 2, wherein the wide gap host material comprises polystyrene, the charge carrying dopant material comprises (4-biphenyl)(4-tertbutylphenyl)oxadiazole (PDB), having the chemical structure



and the phosphorescent dopant material comprises bis(phenylpyridine) iridium acetylacetonate (PPIr), having the chemical structure

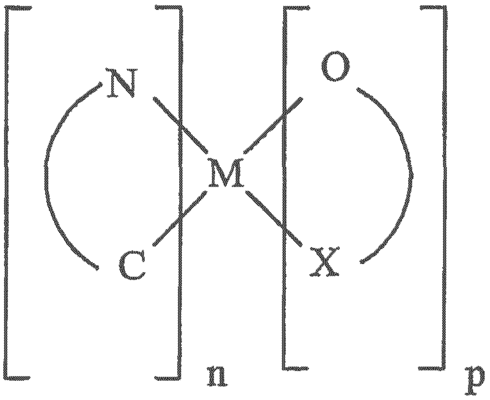


and bis(2-phenylbenzothiazole) iridium acetylacetonate (BTIr), having the chemical structure



6. The emissive layer of any one of claims 1 to 4, wherein the wide gap host material comprises a material selected from the group consisting of a di-phenylene, a substituted di-phenylene, a substituted tri-phenylene, a naphthalene, a substituted naphthalene, a tetraphenylbutadiene, and a substituted tetraphenylbutadiene.

7. The emissive layer of any one of claims 1 to 4 and 6, wherein the phosphorescent dopant material comprises a compound having a structure of general formula:



wherein M is a heavy transition metal, C--N is a cyclometallated ligand, O--X is a coordination ligand wherein X is selected from the group consisting of oxygen, nitrogen, and sulphur, and wherein n equals 1 or 2, and p equals 0 or 1.

8. The emissive layer of claim 7, wherein M is selected from the group consisting of iridium, platinum, osmium, and gold.

9. The emissive layer of any one of claims 1 to 8, wherein the lowest triplet state energy level of the wide gap host material is higher than the lowest triplet state energy level of the charge carrying dopant material.

10. The emissive layer of any preceding claim, wherein the wide gap host material has an energy gap between the HOMO and the LUMO energy levels of at least about 3.5 eV.

11. The emissive layer of any of claims 1 to 4, 6 to 8, and claims 9 and 10 when not dependent on claim 5, wherein the emissive layer emits radiation in the blue region of the visible spectrum.

12. The emissive layer of claim 11, wherein the radiation has an emission peak in the range of from about 430 nm to about 470 nm.

13. The emissive layer of claim 12, wherein the emission peak is at about 450 nm.

14. An organic light emitting device comprising an anode layer, an emissive layer as claimed in any one of the preceding claims over the anode layer, and a cathode layer over the emissive layer.

15. The device of claim 14, further comprising a hole injecting layer between the anode layer and the emissive layer.

16. The device of claim 15, further comprising an electron injecting layer between the emissive layer and the cathode layer.

17. The device of claim 16, further comprising a hole blocking layer between the emission layer and the electron injecting layer.

18. The device of claim 17, further comprising an exciton blocking layer between the emission layer and the electron injecting layer.

19. The device of claim 18, further comprising an electron blocking layer between the emission layer and the hole injecting layer.

20. The device of claim 18, further comprising an exciton blocking layer between the emission layer and the hole injecting layer.

21. The device of claim 14, wherein the wide gap host material includes an electron injection region comprising an un-doped region of the wide gap host material which is in contact with the anode layer, and a hole injection region comprising an un-doped region of the wide gap host material which is in contact with the cathode layer.

Patentansprüche

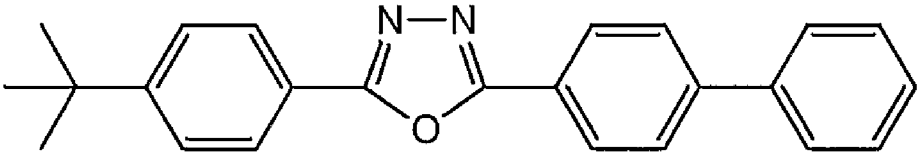
1. Eine Emissionsschicht einer organischen lichtemittierenden Vorrichtung, wobei die Emissionsschicht besteht aus einem Wirtsmaterial mit großem Abstand,
einem ladungstragenden Dotiermaterial, das als Dotierstoff im Wirtsmaterial mit großem Abstand vorhanden ist, und einem phosphoreszierenden Dotiermaterial, das als Dotierstoff im Wirtsmaterial mit großem Abstand vorhanden ist, wobei das ladungstragende Dotiermaterial ein lochleitendes Material und das phosphoreszierende Dotiermaterial ein elektronenleitendes Material ist,
wobei das phosphoreszierende Dotiermaterial aus einem Triplett-angeregten Zustand eines organischen Moleküls in dem phosphoreszierenden Dotiermaterial emittiert, und
wobei das niedrigste Triplett-Zustands-Energieniveau des Wirtsmaterial mit großem Abstand (TW) höher ist als das niedrigste Triplett-Zustands-Energieniveau des elektronenleitenden Materials (T_{ET}) ($TW > T_{ET}$), und das niedrigste Triplett-Zustands-Energieniveau des lochleitenden Materials (T_{HT}) höher ist als das niedrigste Triplett-Zustands-Energieniveau des elektronenleitenden Materials (T_{ET}) ($T_{HT} > T_{ET}$),
wobei die HOMO-LUMO-Energielücke des Wirtsmaterial mit großem Abstand größer ist als die HOMO-LUMO-Energielücke sowohl des Loch- als auch des Elektronentransportmaterials,
das HOMO-Niveau des Wirtsmaterial mit großem Abstand niedriger ist als das HOMO-Niveau eines der Dotiermaterialien sowie aller angrenzenden Schichten, die in direktem physischen Kontakt mit dem Wirtsmaterial mit großem Abstand stehen, und
das LUMO-Niveau des Wirtsmaterial mit großem Abstand höher ist als das LUMO-Niveau eines der Dotiermaterialien sowie aller angrenzenden Schichten, die in direktem physischen Kontakt mit dem Wirtsmaterial mit großem Abstand stehen.

2. Eine Emissionsschicht einer organischen lichtemittierenden Vorrichtung, wobei die Emissionsschicht besteht aus einem Wirtsmaterial mit großem Abstand,
einem ladungstragenden Dotiermaterial, das als Dotierstoff im Wirtsmaterial mit großem Abstand vorhanden ist, und einem phosphoreszierenden Dotiermaterial, das als Dotierstoff im Wirtsmaterial mit großem Abstand vorhanden ist, wobei das ladungstragende Dotiermaterial ein elektronenleitendes Material und das phosphoreszierende Dotiermaterial ein lochleitendes Material ist,
wobei das phosphoreszierende Dotiermaterial aus einem Triplett-angeregten Zustand eines organischen Moleküls in dem phosphoreszierenden Dotiermaterial emittiert, und
wobei das niedrigste Triplett-Zustands-Energieniveau des Wirtsmaterial mit großem Abstand (TW) höher ist als das niedrigste Triplett-Zustands-Energieniveau des lochleitenden Materials (T_{HT}) ($TW > T_{HT}$), und das niedrigste Triplett-Zustands-Energieniveau des elektronenleitenden Materials (T_{ET}) höher ist als das niedrigste Triplett-Zustands-Energieniveau des lochleitenden Materials (T_{HT}) ($T_{ET} > T_{HT}$),
wobei die HOMO-LUMO-Energielücke des Wirtsmaterial mit großem Abstand größer ist als die HOMO-LUMO-Energielücke sowohl des Loch- als auch des Elektronentransportmaterials,
das HOMO-Niveau des Wirtsmaterial mit großem Abstand niedriger ist als das HOMO-Niveau eines der Dotiermaterialien sowie aller angrenzenden Schichten, die in direktem physischen Kontakt mit dem Wirtsmaterial mit großem Abstand stehen, und
das LUMO-Niveau des Wirtsmaterial mit großem Abstand höher ist als das LUMO-Niveau eines der Dotiermaterialien sowie aller angrenzenden Schichten, die in direktem physischen Kontakt mit dem Wirtsmaterial mit großem Abstand stehen.

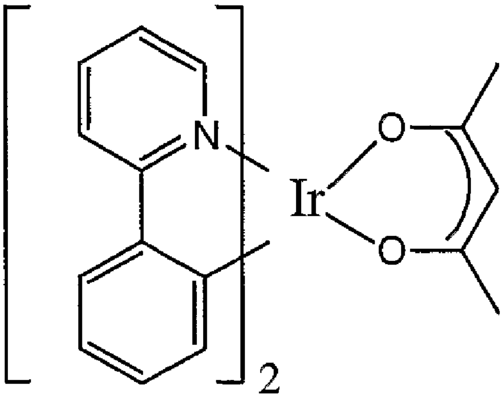
3. Emissionsschicht nach Anspruch 1, wobei das ladungstragende Dotiermaterial ein Material umfasst, das aus der Gruppe ausgewählt ist, die aus einem Triarylamin, einem Metallkoordinationskomplex und einem Donor-substituierten Naphthalin besteht.

4. Emissionsschicht nach Anspruch 2, wobei das ladungstragende Dotiermaterial ein Material umfasst, das aus der Gruppe ausgewählt ist, die aus einem Oxadiazol, einem Triazol und einem Cyclooctatetraen besteht.

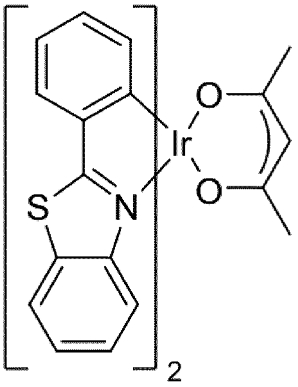
5. Emissionsschicht nach Anspruch 2, wobei das Wirtsmaterial mit großem Abstand Polystyrol umfasst, das ladungstragende Dotiermaterial (4-Biphenyl)(4-tertbutylphenyl)oxadiazol (PDB) mit der chemischen Struktur



und das phosphoreszierende Dotiermaterial Bis(phenylpyridin)-iridiumacetylacetonat (PPIr) mit der chemischen Struktur



und Bis(2-phenylbenzothiazol)-iridiumacetylacetonat (BTIr) mit der chemischen Struktur



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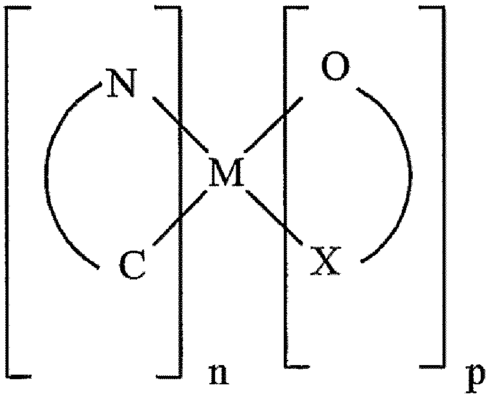
6. Emissionsschicht nach einem der Ansprüche 1 bis 4, wobei das Wirtsmaterial mit großem Abstand ein Material umfasst, das aus der Gruppe ausgewählt ist, die aus einem Diphenylen, einem substituierten Diphenylen, einem substituierten Triphenylen, einem Naphthalin, einem substituierten Naphthalin, einem Tetraphenylbutadien und einem substituierten Tetraphenylbutadien besteht.

7. Emissionsschicht nach einem der Ansprüche 1 bis 4 und 6, wobei das phosphoreszierende Dotiermaterial eine Verbindung mit einer Struktur der allgemeinen Formel umfasst:



worin M ein schweres Übergangsmetall ist, C--N ein cyclometallierter Ligand ist, O--X ein Koordinationsligand ist, worin X aus der Gruppe ausgewählt ist, die aus Sauerstoff, Stickstoff und Schwefel besteht, und worin n gleich 1 oder 2 ist und p gleich 0 oder 1 ist.

8. Emissionsschicht nach Anspruch 7, wobei M aus der Gruppe bestehend aus Iridium, Platin, Osmium und Gold ausgewählt ist.

9. Emissionsschicht nach einem der Ansprüche 1 bis 8, wobei das niedrigste Triplett-Zustands-Energieniveau des Wirtsmaterial mit großem Abstand höher ist als das niedrigste Triplett-Zustands-Energieniveau des ladungstragenden Dotiermaterials.

10. Emissionsschicht nach einem der vorhergehenden Ansprüche, wobei das Wirtsmaterial mit großem Abstand eine Energielücke zwischen dem HOMO- und dem LUMO-Energieniveau von mindestens etwa 3,5 eV aufweist.

11. Emissionsschicht nach einem der Ansprüche 1 bis 4, 6 bis 8 und 9 und 10, wenn sie nicht von Anspruch 5 abhängig ist, wobei die Emissionsschicht Strahlung im blauen Bereich des sichtbaren Spektrums emittiert.

12. Emissionsschicht nach Anspruch 11, wobei die Strahlung einen Emissionspeak im Bereich von etwa 430 nm bis etwa 470 nm aufweist.

13. Emissionsschicht nach Anspruch 12, wobei der Emissionspeak bei etwa 450 nm liegt.

14. Eine organische lichtemittierende Vorrichtung, die eine Anodenschicht, eine Emissionsschicht nach einem der vorhergehenden Ansprüche über der Anodenschicht und eine Kathodenschicht über der Emissionsschicht umfasst.

15. Vorrichtung nach Anspruch 14, die ferner eine Lochinjektionsschicht zwischen der Anodenschicht und der Emissionsschicht umfasst.

16. Vorrichtung nach Anspruch 15, die ferner eine Elektroneninjektionsschicht zwischen der Emissionsschicht und der Kathodenschicht umfasst.

17. Vorrichtung nach Anspruch 16, die ferner eine Lochsperrschicht zwischen der Emissionsschicht und der Elektroneninjektionsschicht aufweist.

18. Vorrichtung nach Anspruch 17, die ferner eine Excitonensperrschicht zwischen der Emissionsschicht und der Elektroneninjektionsschicht aufweist.

19. Vorrichtung nach Anspruch 18, die ferner eine Elektronensperrschicht zwischen der Emissionsschicht und der Lochinjektionsschicht aufweist.

20. Vorrichtung nach Anspruch 18, die ferner eine Excitonensperrschicht zwischen der Emissionsschicht und der Lochinjektionsschicht aufweist.

21. Vorrichtung nach Anspruch 14, wobei das Wirtsmaterial mit großem Abstand einen Elektroneninjektionsbereich mit einem undotierten Bereich des Wirtsmaterial mit großem Abstand, der mit der Anodenschicht in Kontakt steht, und einen Lochinjektionsbereich mit einem undotierten Bereich des Wirtsmaterial mit großem Abstand, der mit der Kathodenschicht in Kontakt steht, aufweist.

Revendications

1. Couche émissive d'un dispositif électroluminescent organique, ladite couche émissive étant constituée par
un matériau hôte à bande interdite importante,
un matériau dopant porteur de charge, présent sous forme de dopant dans le matériau hôte à bande interdite importante, et
un matériau dopant phosphorescent, présent sous forme de dopant dans le matériau hôte à bande interdite importante,
où le matériau dopant porteur de charge est un matériau transporteur de trou et le matériau dopant phosphorescent est un matériau transporteur d'électron,
où ledit matériau dopant phosphorescent émet à partir d'un état excité triplet d'une molécule organique dans ledit matériau dopant phosphorescent, et
où le niveau d'énergie d'état triplet le plus bas du matériau hôte à bande interdite importante (T_W) est plus élevé que le niveau d'énergie d'état triplet le plus bas du matériau transporteur d'électron (T_{ET}) ($T_W > T_{ET}$), et le niveau d'énergie d'état triplet le plus bas du matériau transporteur de trou (T_{HT}) est plus élevé que le niveau d'énergie d'état triplet le plus bas du matériau transporteur d'électron (T_{ET}) ($T_{HT} > T_{ET}$),
où la bande interdite d'énergie HOMO-LUMO du matériau hôte à bande interdite importante est supérieure à la bande interdite d'énergie HOMO-LUMO des matériaux à la fois transporteurs de trou et d'électron,
le niveau de l'HOMO du matériau hôte à bande interdite importante est plus bas que le niveau de l'HOMO de l'un quelconque des matériaux dopants, ainsi que de toutes couches adjacentes qui sont en contact physique direct avec le matériau hôte à bande interdite importante, et
le niveau de la LUMO du matériau hôte à bande interdite importante est plus élevé que le niveau de la LUMO de l'un quelconque des matériaux dopants, ainsi que de toutes couches adjacentes qui sont en contact physique direct avec le matériau hôte à bande interdite importante.

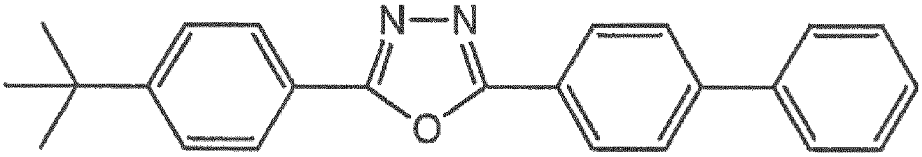
2. Couche émissive d'un dispositif électroluminescent organique, ladite couche émissive étant constituée par
un matériau hôte à bande interdite importante,
un matériau dopant porteur de charge, présent sous forme de dopant dans le matériau hôte à bande interdite importante, et
un matériau dopant phosphorescent, présent sous forme de dopant dans le matériau hôte à bande interdite importante,
où le matériau dopant porteur de charge est un matériau transporteur d'électron et le matériau dopant phosphorescent est un matériau transporteur de trou,
où ledit matériau dopant phosphorescent émet à partir d'un état excité triplet d'une molécule organique dans ledit matériau dopant phosphorescent, et
où le niveau d'énergie d'état triplet le plus bas du matériau hôte à bande interdite importante (Tw) est plus élevé que le niveau d'énergie d'état triplet le plus bas du matériau transporteur de trou (T_{HT}) ($Tw > T_{HT}$), et le niveau d'énergie d'état triplet le plus bas du matériau transporteur d'électron (T_{ET}) est plus élevé que le niveau d'énergie d'état triplet le plus bas du matériau transporteur de trou (T_{HT}) ($T_{ET} > T_{HT}$),
où la bande interdite d'énergie HOMO-LUMO du matériau hôte à bande interdite importante est supérieure à la bande interdite d'énergie HOMO-LUMO des matériaux à la fois transporteurs de trou et d'électron,
le niveau de l'HOMO du matériau hôte à bande interdite importante est plus bas que le niveau de l'HOMO de l'un quelconque des matériaux dopants, ainsi que de toutes couches adjacentes qui sont en contact physique direct avec le matériau hôte à bande interdite importante, et
le niveau de la LUMO du matériau hôte à bande interdite importante est supérieur au niveau de la LUMO de l'un quelconque des matériaux dopants, ainsi que de toutes couches adjacentes qui sont en contact physique direct avec le matériau hôte à bande interdite importante.

3. Couche émissive selon la revendication 1, où le matériau dopant porteur de charge comprend un matériau choisi dans le groupe constitué par une triarylamine, un complexe de coordination de métal et un naphtalène substitué par un donneur.

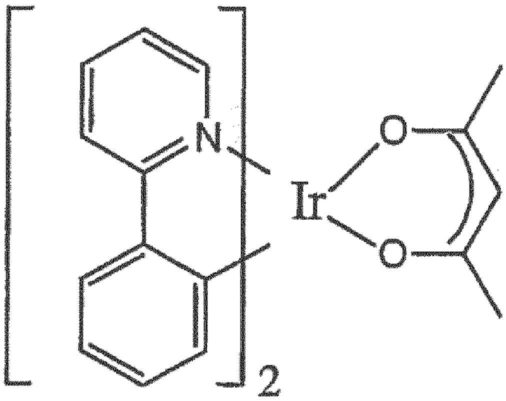
4. Couche émissive selon la revendication 2, où le matériau dopant porteur de charge comprend un matériau choisi

dans le groupe constitué par un oxadiazole, un triazole et un cyclooctatétraène.

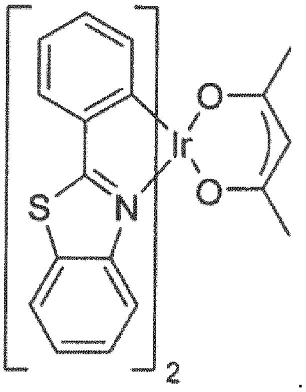
5. Couche émissive selon la revendication 2, où le matériau hôte à bande interdite importante comprend du polystyrène, le matériau dopant porteur de charge comprend du (4-biphényl)(4-tertbutylphényl)oxadiazole (PDB), ayant la structure chimique



et le matériau dopant phosphorescent comprend de l'acétylacétonate de bis(phénylpyridine) iridium (PPIr), ayant la structure chimique

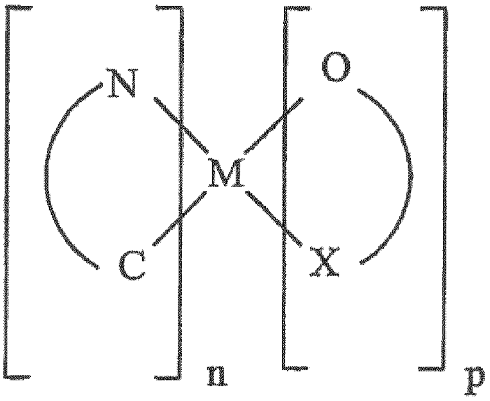


et de l'acétylacétonate de bis(2-phénylbenzothiazole) iridium (BTIr), ayant la structure chimique



6. Couche émissive selon l'une quelconque des revendications 1 à 4, où le matériau hôte à bande interdite importante comprend un matériau choisi dans le groupe constitué par un diphénylène, un diphénylène substitué, un triphénylène substitué, un naphtalène, un naphtalène substitué, un tétraphénylbutadiène et un tétraphénylbutadiène substitué.

7. Couche émissive selon l'une quelconque des revendications 1 à 4 et 6, où le matériau dopant phosphorescent comprend un composé ayant une structure de formule générale :



où M est un métal de transition lourd, C--N est un ligand cyclométallé, O--X est un ligand de coordination où X est choisi dans le groupe constitué par l'oxygène, l'azote et le soufre, et où n est égal à 1 ou 2, et p est égal à 0 ou 1.

8. Couche émissive selon la revendication 7, où M est choisi dans le groupe constitué par l'iridium, le platine, l'osmium et l'or.

9. Couche émissive selon l'une des revendications 1 à 8, où le niveau d'énergie d'état triplet le plus bas du matériau hôte à bande interdite importante est plus élevé que le niveau d'énergie d'état triplet le plus bas du matériau dopant porteur de charge.

10. Couche émissive selon une quelconque revendication précédente, où le matériau hôte à bande interdite importante a une bande interdite d'énergie entre les niveaux d'énergie de l'HOMO et de la LUMO d'au moins environ 3,5 eV.

11. Couche émissive selon l'une quelconque des revendications 1 à 4, 6 à 8, et des revendications 9 et 10 lorsqu'elles ne dépendent pas de la revendication 5, où la couche émissive émet un rayonnement dans la région bleue du spectre visible.

12. Couche émissive selon la revendication 11, où le rayonnement a un pic d'émission compris dans la plage allant d'environ 430 nm à environ 470 nm.

13. Couche émissive selon la revendication 12, où le pic d'émission se situe à environ 450 nm.

14. Dispositif électroluminescent organique comprenant une couche d'anode, une couche émissive telle que revendiquée dans l'une quelconque des revendications précédentes par-dessus la couche d'anode, et une couche de cathode par-dessus la couche émissive.

15. Dispositif selon la revendication 14, comprenant en outre une couche d'injection de trou entre la couche d'anode et la couche émissive.

16. Dispositif selon la revendication 15, comprenant en outre une couche d'injection d'électron entre la couche émissive et la couche de cathode.

17. Dispositif selon la revendication 16, comprenant en outre une couche de blocage de trou entre la couche d'émission et la couche d'injection d'électron.

18. Dispositif selon la revendication 17, comprenant en outre une couche de blocage d'exciton entre la couche d'émission et la couche d'injection d'électron.

19. Dispositif selon la revendication 18, comprenant en outre une couche de blocage d'électron entre la couche d'émission et la couche d'injection de trou.

20. Dispositif selon la revendication 18, comprenant en outre une couche de blocage d'exciton entre la couche d'émission et la couche d'injection de trou.

21. Dispositif selon la revendication 14, où le matériau hôte à bande interdite importante inclut une région d'injection d'électron comprenant une région non dopée du matériau hôte à bande interdite importante qui est en contact avec la couche d'anode, et une région d'injection de trou comprenant une région non dopée du matériau hôte à bande interdite importante qui est en contact avec la couche de cathode.

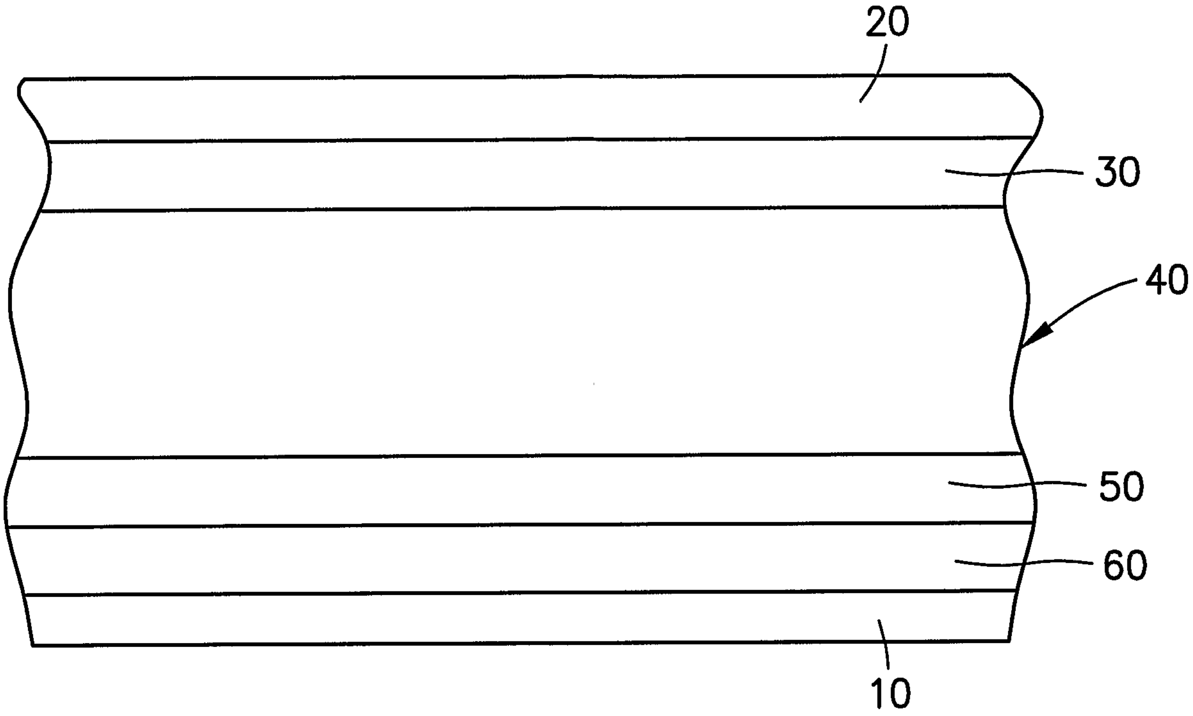


Fig. 1

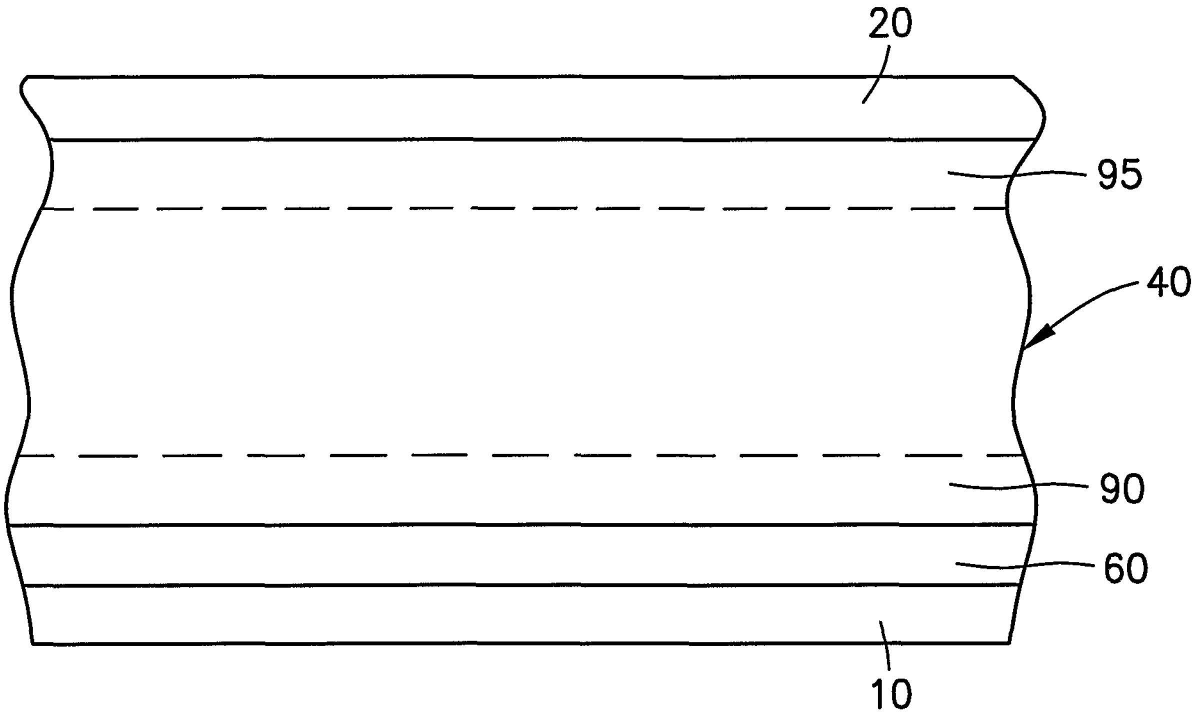


Fig. 2

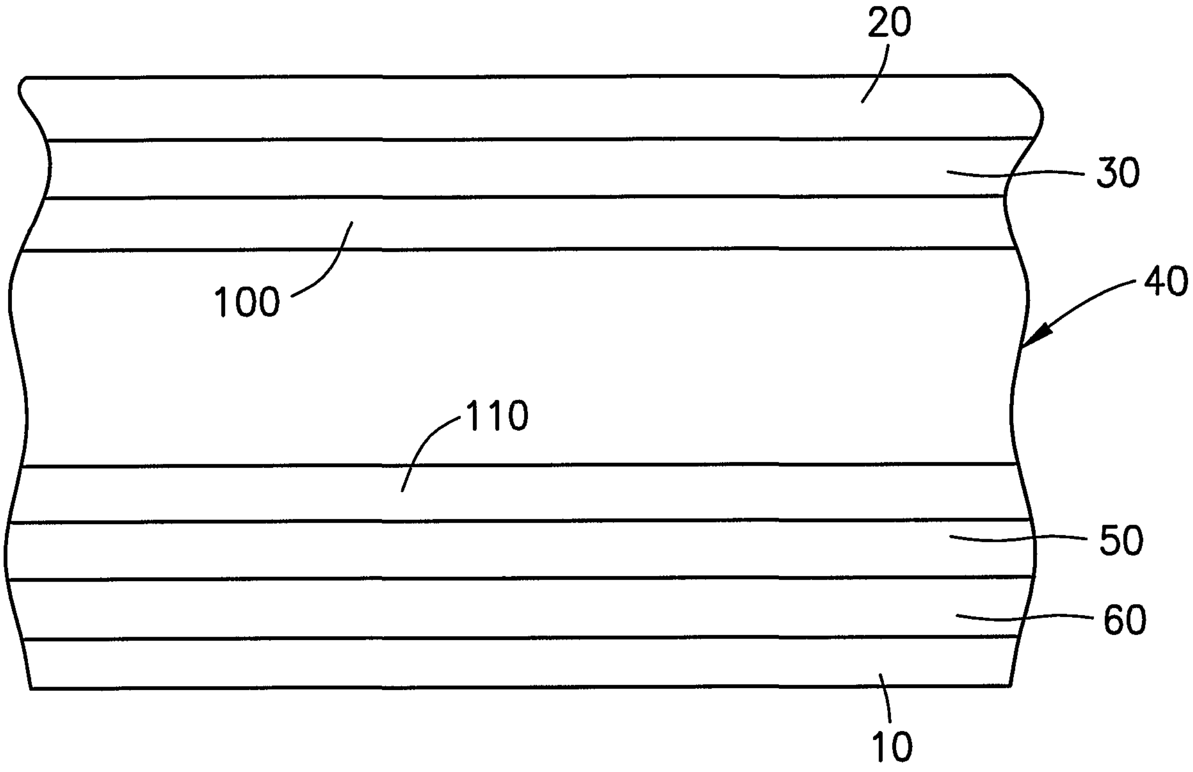


Fig. 3

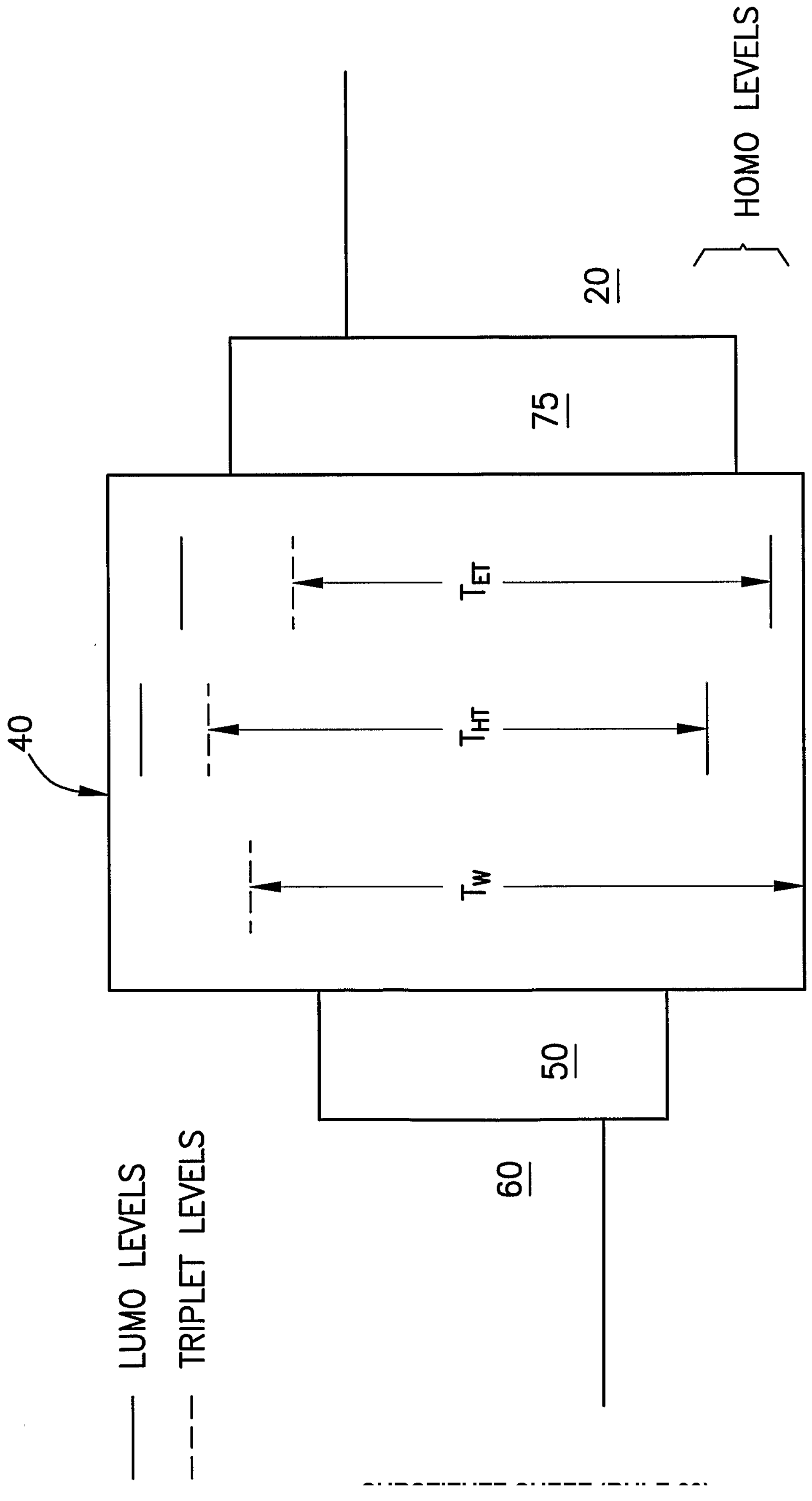

HOMO LEVELS
20
75
40
T_{ET}
T_{HT}
T_W
50
60
LUMO LEVELS
TRIPLET LEVELS

Fig. 4

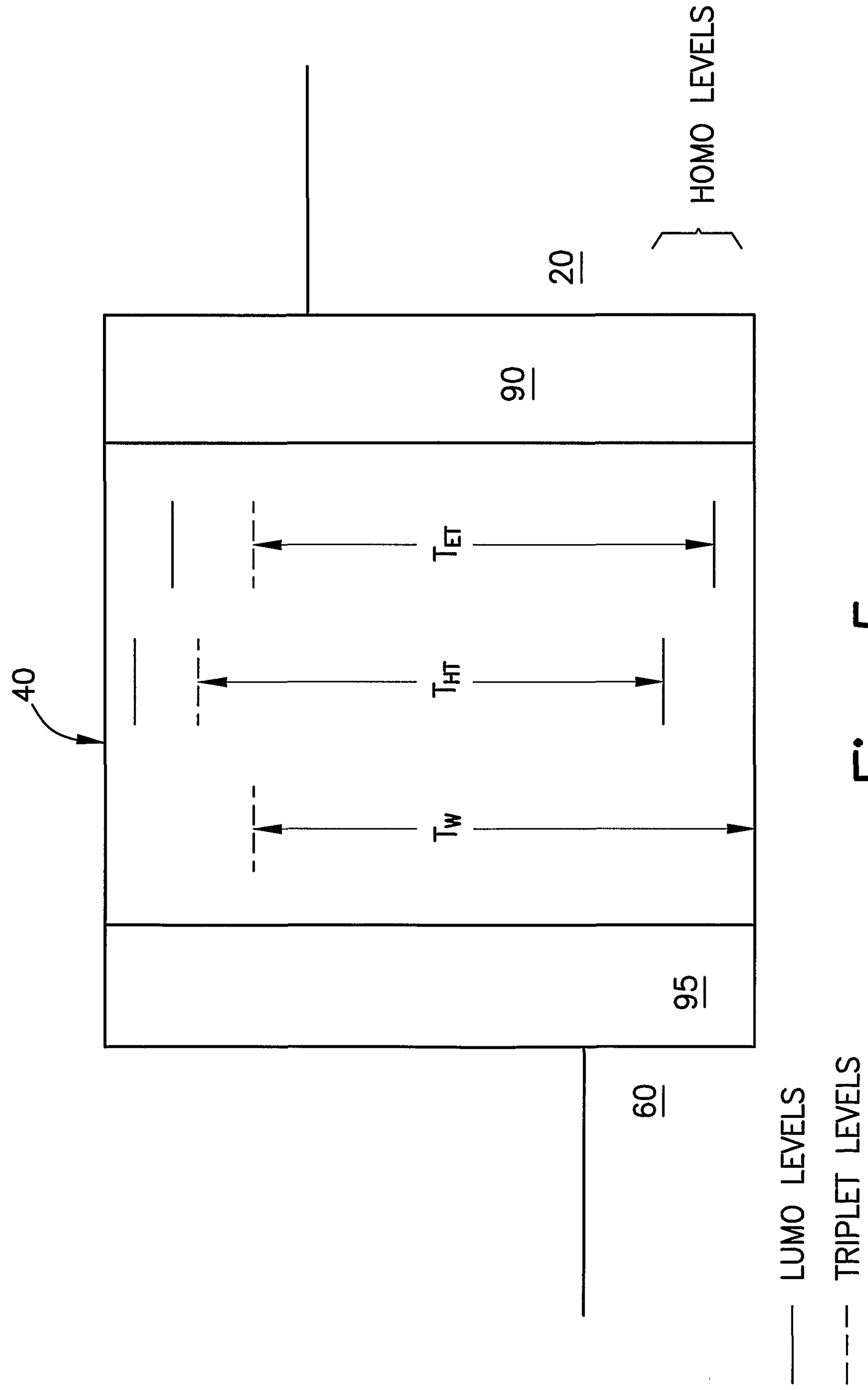

40
90
20
HOMO LEVELS
T_{ET}
T_{HT}
T_W
95
60
LUMO LEVELS
TRIPLET LEVELS

Fig. 5

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- DE 4428450 A1 **[0005]**
- EP 757088 A2 **[0005]**

Non-patent literature cited in the description

- **M. A. BALDO et al.** *Nature,* 1998, vol. 395, 151 **[0005]**
- **D. F. O'BRIEN et al.** *Appl. Phys. Lett.,* 1999, vol. 74, 442 **[0005]**
- **M. A. BALDO et al.** *Appl. Phys. Lett.,* 1999, vol. 75, 4 **[0005]**
- **T. TSUTSUI et al.** Japanese. J. Appl. Phys. 1999, vol. 38, L1502 **[0005]**
- **C. ADACHI et al.** *Appl. Phys. Lett.,* 2000, vol. 77, 904 **[0005]**
- **M. J. YANG et al.** Japanese J. Appl. Phys. 2000, vol. 39, L828 **[0005]**
- **C. L. LEE et al.** *Appl. Phys. Lett.,* 2000, vol. 77, 2280 **[0005]**
- **BALDO et al.** *Pure and Appl. Chem.,* 2095, vol. 71 (11 **[0005]**

专利名称(译)	荧光基上的有机发光二极管的材料和设施		
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外部链接	Espacenet		

摘要(译)

OLED包括掺杂有两种掺杂剂的宽间隙惰性主体材料（40）。 掺杂剂之一是可以传输电子或空穴的发光磷光材料。 另一种掺杂剂是电荷传输材料，其可以传输未被磷光掺杂剂传输的任何电子和空穴。 选择材料，使得主体材料的最低三重态能级和携带电荷的掺杂剂材料的最低三重态能级分别处于比磷光掺杂剂材料的最低三重态能级更高的能级。 该装置尤其能够有效地发射可见光谱的蓝色区域中的光。