more of the sequential pairs of these layers. For example, for a double heterostructure, a separate emissive layer is included between the hole transporting layer and the electron transporting layer. This separate emissive layer may be characterized as being a "thin luminescent layer." Alternatively, or in addition, a hole injection enhancement layer may be present between the anode layer and the hole transporting layer.

[0080] The hole injecting enhancement layer may in some cases be comprised of the same material, CuPc, as is used in the electron injecting interface layer. In each case, the CuPc layer may be in direct contact with an ITO electrode, with the distinction between the two CuPc layers being that in one case the CuPc layer is in contact with an ITO layer that functions as an anode and in the other case the ITO layer functions as a cathode. In each case, the CuPc layer functions as a charge carrier and interface layer. On the one hand when in contact with the ITO anode, the CuPc layer assists in injecting and transporting holes from the anode to a hole transporting layer, and on the other hand when in contact with the ITO cathode, the CuPc layer assists in injecting and transporting electrons from the cathode to an electron transporting layer. The CuPc layer, in each case, may also function as a layer that protects any underlying organic layers, if present, from damage during the ITO deposition process. Whenever the ITO layer is present as the electrode in a SOLED structure, opposite faces of the ITO may function as an anode and cathode, respectively.

[0081] Either the anode layer or the cathode layer may be in contact with a substrate and each electrode is connected to electrical contacts which are capable of delivering a voltage across the device causing it to produce electroluminescence from either an electron transporting layer or a hole transporting layer. If the cathode layer is deposited on the substrate, the device may be referred to as having an inverted or IOLED structure. If the heterostructure for producing electroluminescence is included as part of a stacked OLED (SOLED), one or both of the electrodes of an individual heterostructure may be in contact with an electrode of an adjacent heterostructure. Alternatively, dependent on the circuitry used to drive the SOLED, an insulating layer may be provided between adjacent electrodes of two of the OLEDs in the stack.

[0082] While the present invention is directed to OLEDs comprised of non-metallic cathode layers rather than metallic cathode layers, the OLEDs of the present invention may, under certain circumstances, be used in combination with an OLED that does contain a metallic layer, for example, as the top or bottom OLED of a SOLED. In such cases, if the cathode layer is a metal cathode layer of Mg:Ag, a metal protective layer, for example, made of a layer of Ag for protecting the Mg:Ag cathode layer from atmospheric oxidation, may also be present. The single or double heterostructures as referred to herein are intended solely as examples for showing how an OLED embodying the present invention may be fabricated without in any way intending the invention to be limited to the particular materials or sequence for making the layers shown. For example, the heterostructure typically includes a substrate which may be opaque or transparent, rigid or flexible, and/or plastic, metal or glass, in particular, a transparent polymer such as polyester, glass, sapphire or quartz, or substantially any other material that may be used as the substrate of an OLED.

[0083] Representative materials that may be used as the hole-injecting anode layer in a representative embodiment of the present invention include, in particular, ITO, Zn—In—SnO_2 or SbO_2, or substantially any other material that may be used as the hole-injecting anode layer of an OLED.

[0084] Representative materials that are present as a glass are desirable for use in the HTL of an OLED, rather than as a crystalline or polycrystalline material, since glasses are capable of providing higher transparency as well as producing superior overall charge carrier characteristics as compared with the polycrystalline materials that are typically produced when thin films of the crystalline form of the materials are prepared. Representative materials that may be used in the hole transporting layer in a representative embodiment of the present invention include, in particular, N,N'-diphenyl-N,N'-bis(3-methylpheny)1-1'biphenyl-**4**, **4**'diamine (TPD), **4**,**4**'-bis[N-(1-naphthyl)-N-phenyl-amino] biphenyl (α-NPD) or **4**,**4**'-bis[N-(2-naphthyl)-N-phenyl-amino]biphenyl (β-NPD).

[0085] Representative materials that may be used as the electron transporting layer include, in particular, tris-(8-hydroxyquinoline)-aluminum (Alq_3) or **4**,**4**'-di(N-carbazolo) diphenyl (CBP).

[0086] Representative materials that may be used as the separate emissive layer, if present, include, in particular, dye-doped Alq_3, or substantially any other material that may be used as the separate emissive layer of an OLED.

[0087] In those cases wherein the OLEDs of the present invention are used in combination with another OLED to form a SOLED structure that contains a metallic cathode layer, the materials that may be used as the electron-injecting, metallic cathode layer may include, in particular, Mg—Ag, Li—Ag or Ca, or substantially any other material that may be used as the metallic cathode layer of an OLED.

[0088] The insulating layer, if present, may be comprised of an insulating material such as SiO_2, SiN_x or Al_2, or substantially any other material that may be used as the insulating material of an OLED, which may be deposited by a variety of processes such as plasma enhanced chemical vapor deposition (PECVD), electron beam, etc.

[0089] The OLEDs of the present invention have the advantage that they can be fabricated entirely from vacuum-deposited molecular organic materials. A vacuum-deposited material is one which can be deposited in a vacuum typically having a background pressure less than one atmosphere, preferably about 10^{-5} to about 10^{-11} torr for vacuum deposition, or about 50 torr to about 10^{-5} torr for vapor deposition.

[0090] Although not limited to the thickness ranges recited herein, the substrate may be as thin as 10 μ, if present as a flexible plastic or metal foil substrate, such as aluminum foil, or substantially thicker if present as a rigid, transparent or opaque, substrate or if the substrate is comprised of a silicon-based display driver; the ITO anode layer may be from about 500 Å (1 Å=10^{-8} cm) to greater than about 4000 Å thick; the hole transporting layer from about 50 Å to greater than about 1000 Å thick; the separate emissive layer of a double heterostructure, if present, from about 50 Å to about 200 Å thick; the electron transporting layer from about 50 Å to about 1000 Å thick; and the non-metallic cathode