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(54) **OLEDs DOPED WITH PHOSPHORESCENT COMPOUNDS**

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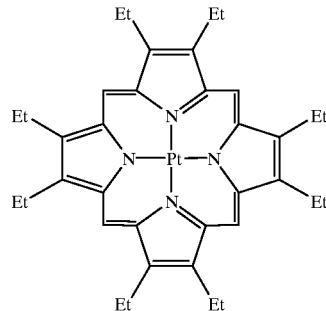
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(57) **ABSTRACT**

Organic light emitting devices are disclosed which are comprised of a heterostructure for producing electroluminescence wherein the heterostructure is comprised of an emissive layer containing a phosphorescent dopant compound. For example, the phosphorescent dopant compound may be comprised of platinum octaethylporphine (PtOEP), which is a compound having the chemical structure with the formula:



**63 Claims, 3 Drawing Sheets**

"Method for Deposition and Patterning of Organic Thin Film", (filed Nov. 24, 1997) now U.S. Pat. No. 6,013,538; (Ser. No. 08/976,666), now U.S. Pat. No. 5,953,587; each co-pending application being incorporated herein by reference in its entirety. The subject invention may also be used in conjunction with the subject matter of each of co-pending U.S. patent application Ser. No. 08/354,674 (U.S. Pat. No. 5,707,745), U.S. Ser. No. 08/613,207 (U.S. Pat. No. 5,703,436), U.S. Ser. No. 08/632,322 (U.S. Pat. No. 5,757,026) and U.S. Ser. No. 08/693,359 and provisional patent application Serial No. 60/010,013 (U.S. Ser. No. 08/779,141, filed Jan. 6, 1997, Allowed) U.S. Ser. No. 60/024,001 (U.S. Ser. No. 08/789,319, filed Jan. 23, 1997, U.S. Pat. No. 5,844,363) U.S. Ser. No. 60/025,501 (U.S. Ser. No. 08/844,353, filed Apr. 18, 1997), U.S. Ser. No. 60/046,061 (U.S. Ser. No. 09/010,594, filed Jan. 22, 1998) and U.S. Ser. No. 60/053,176, each of which is also incorporated herein by reference in its entirety.

The materials that may be used as the substrate, the hole-injecting anode layer, the hole transporting layer, the electron transporting layer, the electron-injecting, metal cathode layer or the electron-injecting, non-metallic cathode layer, the protection layer, if present, the separate emissive layer, if present, or the insulating layer, if present, include the materials as disclosed in these co-pending applications.

The OLED of the present invention may be used in substantially any type of device which is comprised of an OLED, for example, in OLEDs that are incorporated into a larger display, a vehicle, a computer, a television, a printer, a large area wall, theater or stadium screen, a billboard or a sign.

This invention will now be described in detail with respect to showing how certain specific representative embodiments thereof can be made, the materials, apparatus and process steps being understood as examples that are intended to be illustrative only. In particular, the invention is not intended to be limited to the methods, materials, conditions, process parameters, apparatus and the like specifically recited herein.

#### AN EXAMPLE OF THE INVENTION

The procedures that were used for fabrication of Organic Light-Emitting Devices (OLEDs) were as follows:

The hole transporting material TPD and the electron transporting material Alq<sub>3</sub> were synthesized according to literature procedures, and were sublimed before use. The dopant PtOEP was purchased from Porphyrin Products, Inc., Logan, UT, and was used as received.

OLEDs were prepared using the following procedures: The ITO/Borosilicate substrates (100Ω/square) were cleaned by sonicating with detergent for five minutes followed by rinsing with deionized water. They were then treated twice in boiling 1,1,1-trichloroethane for two minutes. The substrates were then sonicated twice with acetone for two minutes and twice with methanol for two minutes.

The background pressure prior to deposition was normally  $7 \times 10^{-7}$  torr or lower and the pressure during the deposition was around  $5 \times 10^{-7}$  to  $1.1 \times 10^{-6}$  torr.

All the chemicals were resistively heated in various tantalum boats. TPD was first deposited at a rate from one to four Å/s. The thickness was typically controlled at 300 Å.

The electron transporting layer Alq<sub>3</sub> was doped with PtOEP.

Typically, the dopant was first vaporized with the substrates covered. After the rate of the dopant was stabilized, the host material was vaporized to the certain rate. The cover

over the substrates was then opened and the host and guest were deposited at the desired concentration. The rate of dopant was normally 0.1–0.2 Å/s. The total thickness of this layer was controlled at about 450 Å.

The substrates were removed from the deposition system and masks were put directly on the substrates. The masks were made of stainless steel sheet and contain holes with diameters of 0.25, 0.5, 0.75 and 1.0 mm. The substrates were then put back into vacuum for further coating.

Magnesium and silver were co-deposited at a rate normally of 2.6 Å/s. The ratio of Mg:Ag varied from 7:1 to 12:1. The thickness of this layer was typically 500 Å. Finally, 1000 Å Ag was deposited at the rate between one to four Å/s.

The devices were characterized within five hours of fabrication. Typically electroluminescent spectra, I–V curves, and quantum yields were measured from direct front.

What is claimed is:

**1.** An organic electroluminescent emissive layer comprising a charge carrying, host material and a phosphorescent material, wherein the phosphorescent material is present in a lower concentration than the charge carrying, host material and the phosphorescent material emits phosphorescent radiation from a triplet molecular excited state when a voltage is applied across the electroluminescent emissive layer.

**2.** The organic electroluminescent layer of claim 1 wherein the phosphorescent material is present at a concentration from about 0.01 to 10.0 mol % based on the electroluminescent layer.

**3.** The organic electroluminescent layer of claim 1 wherein the charge carrying, host material is a hole transporting material.

**4.** The organic electroluminescent layer of claim 1 wherein the charge carrying, host material is an electron transporting material.

**5.** The organic electroluminescent layer of claim 1 wherein the phosphorescent material has a phosphorescent lifetime not longer than about 10 microseconds.

**6.** The organic electroluminescent layer of claim 1 wherein the phosphorescent lifetime from about 10 to about 100 microseconds.

**7.** A device for producing electroluminescence comprising an organic light emitting device including a phosphorescent material and a charge carrying host material, wherein the phosphorescent material emits phosphorescent radiation from a triplet molecular excited state when a voltage is applied across the organic light emitting device.

**8.** The device of claim 7 wherein the phosphorescent material has a phosphorescent lifetime not longer than about 10 microseconds.

**9.** The device of claim 7 wherein the phosphorescent material has a phosphorescent lifetime from about 10 to about 100 microseconds.

**10.** The device of claim 7 wherein the phosphorescent radiation produces a primary color.

**11.** The device of claim 10 wherein the primary color is red.

**12.** The device of claim 10 wherein the primary color is green.

**13.** The device of claim 10 wherein the primary color is blue.

**14.** A device for producing electroluminescence comprising an organic light emitting device including an emissive layer that emits phosphorescent radiation from a triplet molecular excited state when a voltage is applied across the device, wherein the emissive layer includes a host material