single OLED of a monochromatic TOLED, a balance needs to be established between metallic layers that are thick enough to function as a cathode, but not so thick as to cause substantial light transmission or reflection losses. A conventional TOLED, therefore, uses 75-100 Å Mg:Ag capped with a thick layer of sputter-deposited ITO; the Mg:Ag layer serving both to inject electrons into Alq_3 and to protect it from the ITO sputtering. Thus, although a device with about 70% transmission may be obtained, there is still significant reflection from the compound cathode. In addition, in SOLED devices in which at least one of the color-producing layers is contained between the metallic cathodes of adjacent color-producing OLEDs, microcavity effects are present which can give rise to color tuning problems. Z Shen, P. E. Burrows, V. Bulovic, S. R. Forrest, and M. E. Thompson, *Science* 276, 2009 (1997). Such microcavity effects may also lead to an undesired angular dependence of the emitted light. Furthermore, thin Mg:Ag layers are sensitive to atmospheric degradation and, therefore, require special designs and processing steps to be undertaken so as to preserve their effectiveness in functioning as the cathode of an OLED.

[0009] Though solar cells have been disclosed in which a highly transparent ITO layer may have functioned as a cathode under certain circumstances, such ITO cathodes were disclosed as having been prepared by depositing the charge-carrying organic layer onto the ITO layer, N. Karl, A. Bauer, J. Holzäofel, J. Marktanner, M. Möbus, and F. Stölzle, "*Efficient Organic Photovoltaic Cells: The Role of Excitonic Light Collection, Exciton Diffusion to Interfaces, Internal Fields for Charge Separation, and High Charge Carrier Mobilities*", *Molecular Crystals and Liquid Crystals*, Vol. 252, pp 243-258, 1994 (Karl et al) and Whitlock, J. B., Panayotatos, P., Sharma, G. D., Cox, M. D., Savers, R. R., and Bird, G. R.; "*Investigations of Materials and Device Structures for Organic Semiconductor Solar Cells,*" *Optical Eng.*, Vol. 32, No. 8, 1921-1934 (August 1993), (Whitlock et al). ITO layers on which the organic layer had been deposited would not have been expected to form a low-resistance electrical contact with the adjacent organic layer and, thus, would not have been expected to function, as confirmed hereinafter for OLEDs, as an efficient cathode.

[0010] It would be desirable if optoelectronic devices could be made using cathodes that are as highly transparent as the highly transparent ITO anodes. It would be desirable, furthermore, that such highly transparent cathodes still have, for example, in OLEDs, electron-injection characteristics comparable to the thin, semi-transparent, low-work-function metallic layers, such as Mg:Ag, that are typically used as the cathode layer.

ADVANTAGES AND SUMMARY OF THE INVENTION

[0011] The present invention is directed to cathodes comprised of an electrically conductive non-metallic layer in low-resistance contact with a semiconductive organic layer.

[0012] The present invention is directed toward highly transparent non-metallic cathodes that may be used in substantially any type of optoelectronic device.

[0013] More specifically, the present invention is directed to highly transparent non-metallic cathodes that may be used, for example, in OLEDs that have electron-injection properties comparable to semi-transparent metallic cathodes but which, instead, have an optical transmission of up to at least about 85% or still higher.

[0014] Still more specifically, the present invention is directed to a highly transparent organic light emitting device (OLED) comprised of a non-metallic cathode.

[0015] In another embodiment, the present invention is directed to an OLED comprised of an inorganic semiconducting material, such as ITO, that functions as the non-metallic cathode.

[0016] In yet another embodiment, the present invention is directed to organic semiconducting lasers comprised of a non-metallic cathode.

[0017] In still another aspect of the present invention, the OLED is comprised of a non-metallic cathode which is in contact with an organic protection layer that is capable of assisting in the injection and transport of electrons from the cathode to the luminescent zone of the OLED and that is, furthermore, capable of protecting the underlying organic layers from damage during deposition of the cathode layer. This organic protection layer may be in direct contact with the electron transporting layer in the luminescent zone of the device or there may be an additional electron transporting layer between these two layers which further assists in transporting electrons to the luminescent zone of the OLED.

[0018] In still another aspect of the present invention, the present invention is directed to a method for fabricating a cathode comprising preparing a cathode comprised of an electrically conductive non-metallic layer and a semiconductive organic layer, wherein the preparation includes the step of forming a region between the electrically conductive non-metallic layer and the semiconductive organic layer that causes the electrically conductive non-metallic material to be in low-resistance electrical contact with the semiconductive organic layer.

[0019] In addition, the present invention is directed to a method of fabricating an organic light emitting device comprised of a non-metallic cathode.

[0020] Further objectives and advantages of the present invention will be apparent to those skilled in the art from the detailed description of the disclosed invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] **FIG. 1** shows a schematic illustration of a standard prior art OLED.

[0022] **FIG. 2*a*** shows a representative OLED of the present invention.

[0023] **FIG. 2*b*** shows an another representative OLED of the present invention.

[0024] **FIG. 3** shows the light output vs. current of an OLED as shown in **FIG. 2*a*** having an ITO cathode layer and a CuPc electron injecting interface layer. The lowest set of values shown in this figure was obtained at 180 hours.

[0025] **FIG. 4** shows the light output vs. current of a standard prior art TOLED device having an Mg:Ag cathode layer. The lower set of values in this figure was measured at 180 hours.

[0026] **FIG. 5** shows the I-V curves for a ZnPc electron injecting interface layer and a CuPc electron injecting interface layer.