cally useful organic optoelectronic device. The semiconductive organic layer of the cathode/organic layer interface is, therefore, alternatively referred to herein as the electron injecting interface layer.

[0044] For the purpose of specifying what is meant herein by a low-resistance electrical contact that may be used in a practically useful organic optoelectronic device, such a contact is one for which the voltage drop across the cathode/organic layer interface is not greater than the total voltage drop across the remainder of the device, that is, the voltage drop across the cathode/organic layer interface is less than about 50% of the total voltage drop across the overall device. Preferably, the voltage drop across the cathode/organic layer interface is less than about 30% of the total voltage drop.

[0045] The electrically conductive non-metallic layer may be selected from a wide range of non-metallic materials, wherein the term "non-metallic" is meant to embrace a wide range of materials provided that the material is free of metal in its chemically uncombined form. When a metal is present in its chemically uncombined form, either alone or in combination with one or more other metals as an alloy, the metal may alternatively be referred to as being present in its metallic form or as being a "free metal". Thus, the non-metallic cathodes of the present invention may sometimes be referred to by one or more of the inventors of the present invention as "metal-free cathodes" wherein the term "metal-free" is expressly meant to embrace a material free of metal in its chemically uncombined form. Such "non-metallic" or "metal-free" materials may also be referred to as "metal substitutes". As used herein, the term "metal substitute" refers to a material that is not a metal within the normal definition, but which has metal-like properties in appropriate contexts. Commonly used metal substitutes for electrodes would include wide band gap semiconductors, for example, transparent conducting oxides such as indium tin oxide (ITO), tin oxide (TO) and gallium indium tin oxide (GITO). In particular, ITO is a highly doped degenerate n+semiconductor with an optical band gap of approximately 3.2 eV rendering it transparent to wavelengths greater than approximately 320 nm. Another electrode material is the transparent conductive polymer polyanaline (PANI) and its chemical relatives.

[0046] It is to be understood that while the present invention relates to a non-metallic cathode material that is characterized as being free of a metal or metal alloy that is present in its metallic or chemically uncombined form, that is, free of free metal, the cathode material might include low levels of free metal in its metallic form while still falling within the scope and spirit of the present invention. Thus, while it is not presently intended or expected that the preferred cathode materials contain any free metal in metallic form, purposely adding low levels of a metal in an attempt solely to circumvent the scope of the present invention, or even to provide an as-yet-unknown benefit, would still fall fully within the scope and spirit of the present invention. The non-metallic cathode materials of the present invention may, thus, be characterized as embracing materials that are effectively free of free metal, wherein a material effectively free of free metal will correspondingly have a conductivity value which decreases as its temperature is lowered toward absolute zero. A concomitant property of non-metallic materials is that there is almost no practically detectable optical reflectivity due to the lack of partially occupied electronic conduction bands which are present in a free metal.

[0047] Another surprising aspect of the present invention is the fact that when representative embodiments of the claimed cathodes are used, for example, in an OLED, the cathode can efficiently inject electrons into the adjacent organic layer even though the non-metallic cathode material does not have the Fermi energy level that is typically provided by a low-work-function metal. Such efficient electron injection occurs in spite of the fact that a large barrier to electron injection would be expected at the cathode/organic layer interface between the electrically conductive non-metallic layer and the semiconductive organic layer. The present invention is, thus, further directed to a method for effectively reducing such barriers to electron injection.

[0048] More specifically, in the representative embodiment of the present invention as disclosed herein, the method of the present invention for producing a low-resistance electrical contact for electron flow across a cathode/organic-layer interface comprises providing a damage region at or near the surface of the semiconductive organic layer of the cathode/organic interface and, thus, between the non-metallic cathode material and the bulk of the semiconductive organic material. This damage region is prepared in such a manner that a high density of surface states or defect states for transport of electrons is produced. Though these surface states or defect states have not yet been detected directly, and may not in fact be readily observable directly, the presence of these surface states is believed to be necessary to account for the substantially reduced barrier to electron transport as evidenced indirectly by the low-resistance electrical contact across the cathode/organic layer interface.

[0049] In particular, it is believed that surface states are present at energy levels intermediate between the energy level of a conducting electron in the non-metallic cathode material and the energy level of a conducting electron in the bulk of the semiconductive organic layer of the cathode/organic interface. Furthermore, it is believed that the distribution of surface states is sufficiently dense in both energy and physical space that efficient electron transport can be effected across the cathode/organic layer interface region in spite of the large barrier to electron flow that would normally exist between a semiconductive organic material and a non-metallic material. Non-metallic cathodes having such an cathode/organic layer interface have been found, thus, to have a high efficiency, for example, for injecting electrons into the adjacent ETL of an OLED.

[0050] Furthermore, in the representative embodiment of the present invention in which ITO is used as the electrically conductive non-metallic layer and a phthalocyanine compound such as ZnPc or CuPc is used as the electron injecting interface layer, the low-resistance electrical contact is formed only when the ITO is deposited onto the organic layer and not when the organic layer is deposited onto the ITO layer. It is, thus, a further aspect of the present invention that when the preferred ITO and ZnPc or CuPc compounds are used to form the cathode/organic layer interface, the present invention is specifically directed to cathodes in which the non-metallic ITO layer is deposited onto the phthalocyanine layer using ITO deposition rates and phtha-