VACUUM DEPOSITED NON POLYMERIC FLEXIBLE ORGANIC LIGHT EMITTING DEVICES

RELATED APPLICATION

[0001] This invention is related to provisional Application No. 60/024,001 dated Aug. 12, 1996.

FIELD OF THE INVENTION

[0002] The subject invention is directed to flexible organic light emitting devices (OLED's) including a hole transporting layer and/or an electron transporting layer comprised of a vacuum-deposited, non-polymeric material.

BACKGROUND OF THE INVENTION

[0003] In one type of electrically controlled light emitting device, organic material is placed between a layer of conductive material that can inject electrons and a layer of conductive material that can inject holes. When a voltage of proper polarity is applied between the outer layers of conductive material, electrons from one layer combine with holes from the other so as to release energy as light that is, to produce electroluminescence (EL). These devices are referred to as organic light emitting devices, OLED's.

[0004] OLED's have been constructed from polymers so as to have a highly advantageous flexibility that enables them to be used for light weight, portable, roll-up displays or to be used for conformable displays which can be readily attached to windows, windshields or instrument panels that may have curved surfaces; "The Plastic LED: A Flexible Light-Emitting Device Using a Polyaniline Transparent Electrode" by G. Gustafsson et al in "Synthetic Metals", 55-57 4123-4227 (1993). Even though there is a widespread application of vacuum-deposited, small-molecule-based heterostructural OLED's, which have been constructed on inflexible glass substrates and use ITO as the hole emitting layer, the devices of Gustafsson were fabricated using a polymer, that is, soluble semiconducting polymer poly(2-methoxy, 5-(2'-ethyl-hexoxy)-1,4-phenylene-vinylene) (MEH-PPV) as the emissive layer, since the mechanical properties of polymers were deemed to be unique with respect to making such devices.

[0005] It would be desirable if flexible OLED's could be fabricated having improved electroluminescent properties as well as the advantage of being readily fabricated using the vacuum deposition techniques typically used for preparing OLED's.

SUMMARY OF THE INVENTION

[0006] In accordance with this invention, a flexible OLED using small molecule based heterostructure of organic material is provided in which the hole transporting layer, the electron transporting layer, and/or the emissive layer, if separately present, includes a non-polymeric material, that is, a layer comprised of small molecules.

[0007] The term "small molecules" is used herein to refer to molecules which are small in the sense that such molecules are not made up of a plurality of repeating molecular units such as are present in a polymeric material. Thus, for purposes of this invention, the term "small molecule" is intended to be used interchangeably with the term "non-polymeric." In fact, the term "small molecules" may embrace relatively large molecules such as are typically used in the hole transporting layer, the electron transporting layer and/or the emissive layer that is present in an OLED.

[0008] The subject invention is further directed to a method of fabricating flexible OLED's wherein the hole transporting layer, the electron transporting layer and/or the emissive layer, if present, may be prepared using vacuum deposition techniques, rather than using the less convenient fabrication technique such as employed by Gustafsson et al, that is, rather than spin coating a layer of polymer, such as polyaniline onto the flexible substrate. Such vacuum deposition methods are particularly suitable for use in fabricating the OLED's of the subject invention since the other layers of the OLED are also typically prepared using vacuum deposition techniques. Integration of all the vacuum deposition steps into a single overall sequence of steps for fabricating the OLED, without requiring the use of solvents or removing the air sensitive layers from a vacuum chamber and exposing them to ambient conditions provides an additional especially beneficial advantage. Thus, the subject invention is directed to a method, wherein the hole transporting, electron transporting, and/or separate emissive layer, if present, may be prepared using vacuum deposition steps.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] **FIG. 1** is a cross section of one embodiment of a flexible OLED constructed in accordance with this invention;

[0010] **FIG. 2** contains graphs illustrating the current vs. voltage characteristic of an OLED such as shown in **FIG. 1** before and after repeated bending and the current vs. voltage characteristic of a prior art OLED having a glass substrate in place of the flexible polyester substrate; and

[0011] **FIG. 3** contains graphs illustrating the optical power vs. current characteristics of an OLED such as shown in **FIG. 1** before and after repeated bending and the current vs. voltage characteristic of a prior art OLED used in a glass substrate in place of the flexible polyester substrate.

[0012] **FIG. 4** shows atomic force microscope (AFM) images of a typical ITO-coated polyester substrate film wherein (a) shows the ITO (top) substrate and (b) shows the polyester (bottom) substrate surface. The height range of the images was −50 nm (nanometers).

[0013] **FIG. 5** shows a photograph of an array of nine unpackaged 1 cM^2 vacuum-deposited, non-polymeric flexible OLED's. One device in contact with the probe arm is shown operating in air in a well-illuminated room at normal video display brightness (−100 cd/m^2)

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0014] The subject invention will now be described in detail for specific preferred embodiments of the invention, it being understood that these embodiments are intended only as illustrative examples and the invention is not to be limited thereto.

[0015] As illustrative embodiments of the subject invention, the subject OLED's may be incorporated into a single heterostructure or in a double heterostructure. The materials,