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KIM et al.(10) **Pub. No.: US 2008/0122349 A1**(43) **Pub. Date: May 29, 2008**(54) **ORGANIC ELECTROLUMINESCENT
DISPLAY DEVICE AND METHOD OF
FABRICATING THE SAME****Publication Classification**(51) **Int. Cl.**
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H01L 51/56 (2006.01)(52) **U.S. Cl.** **313/504; 445/24**(57) **ABSTRACT**(76) **Inventors:** **Young-Mi KIM**, Incheon (KR);
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An organic electroluminescent display (OELD) device includes first and second substrates facing each other, a plurality of gate lines, a plurality of data lines and a plurality of power lines on the first substrate, the gate and data lines crossing each other to define a plurality of pixel regions, a switching element and a driving element connected to each other in each pixel region, a first electrode connected to the driving element, an organic luminescent layer on the first electrode, and a second electrode on the organic luminescent layer. The organic luminescent layer includes a hole injection layer, a hole transporting layer, an emission material layer, an electron transporting layer, and an electron injection layer in order. Further, the hole injection layer includes a crystallizable hole injection material and a hole transporting material, and the hole transporting layer includes the hole transporting material.

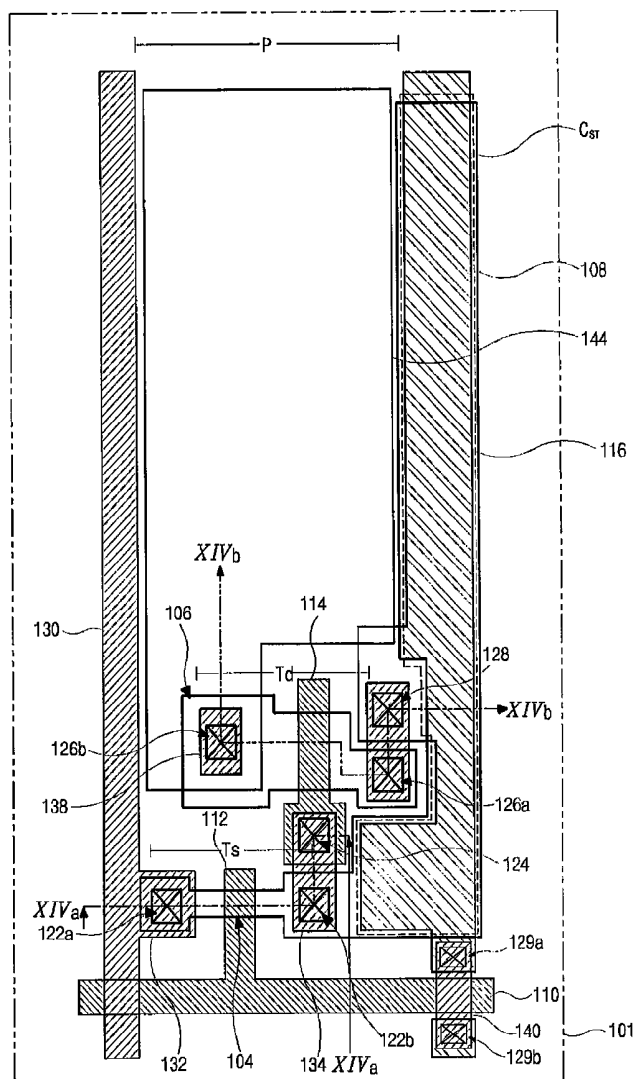


FIG. 1

Related Art

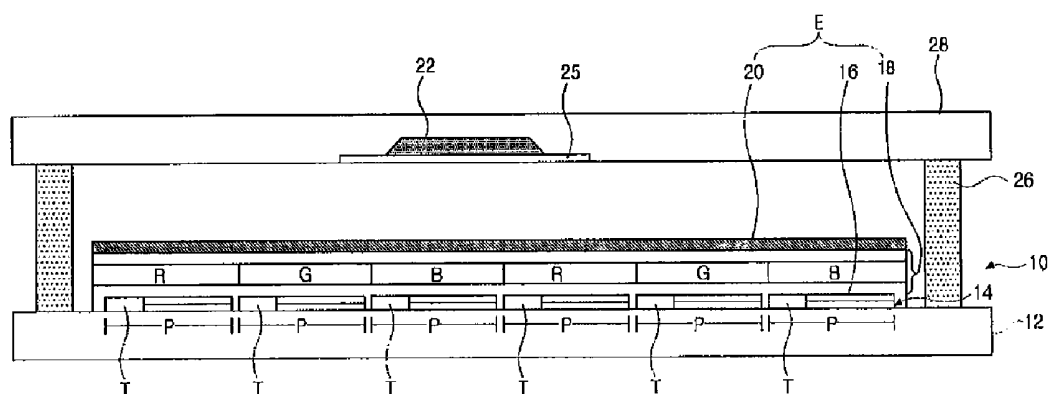


FIG. 2

Related Art

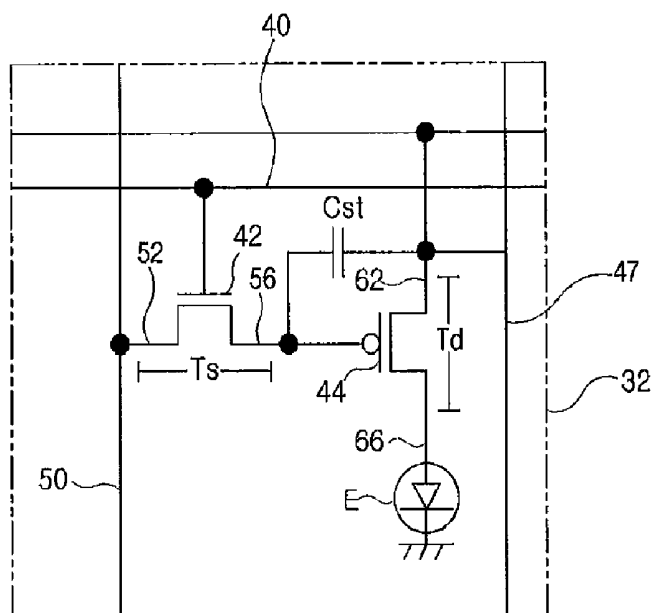


FIG. 3

Related Art

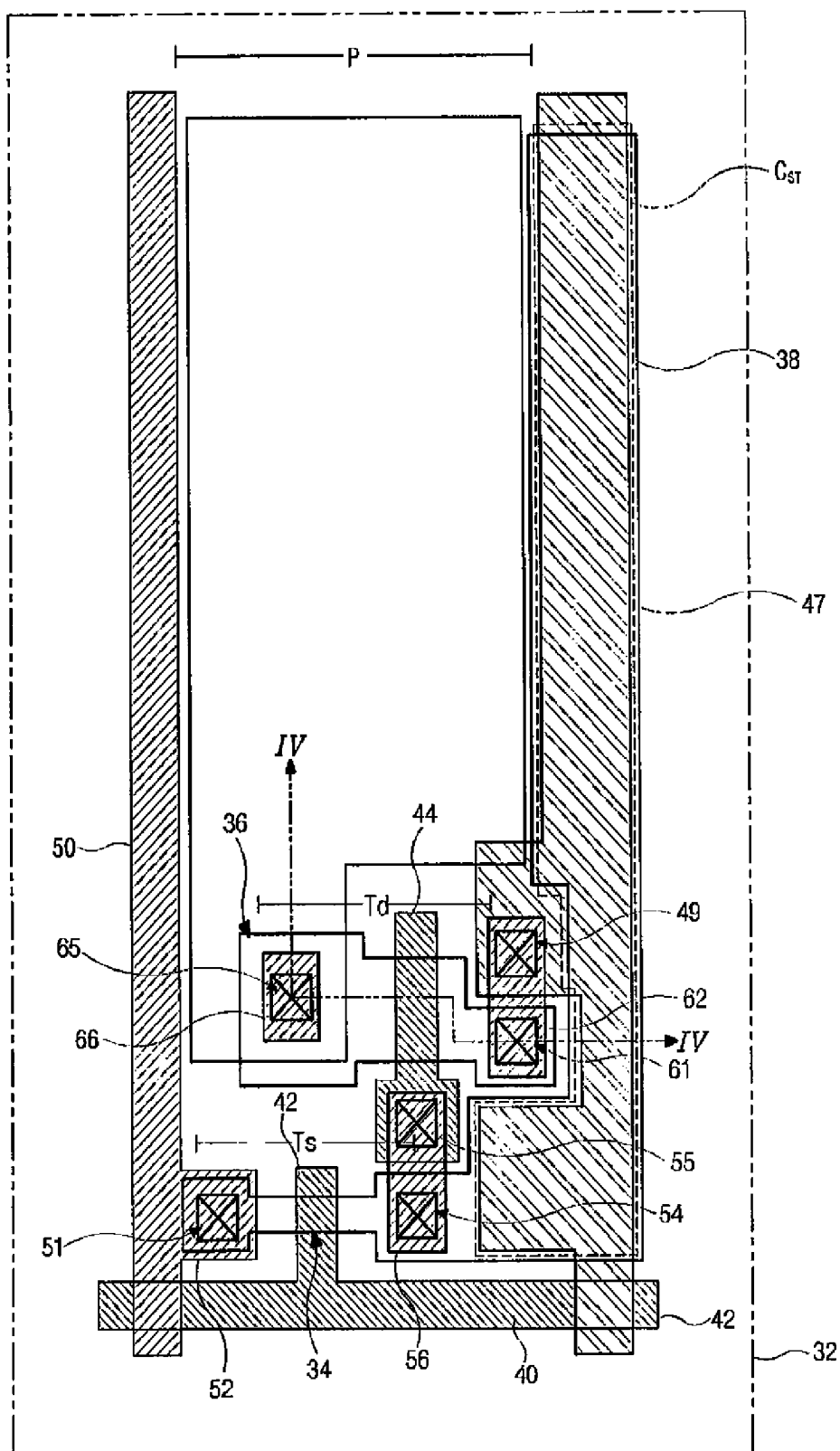


FIG. 4

Related Art

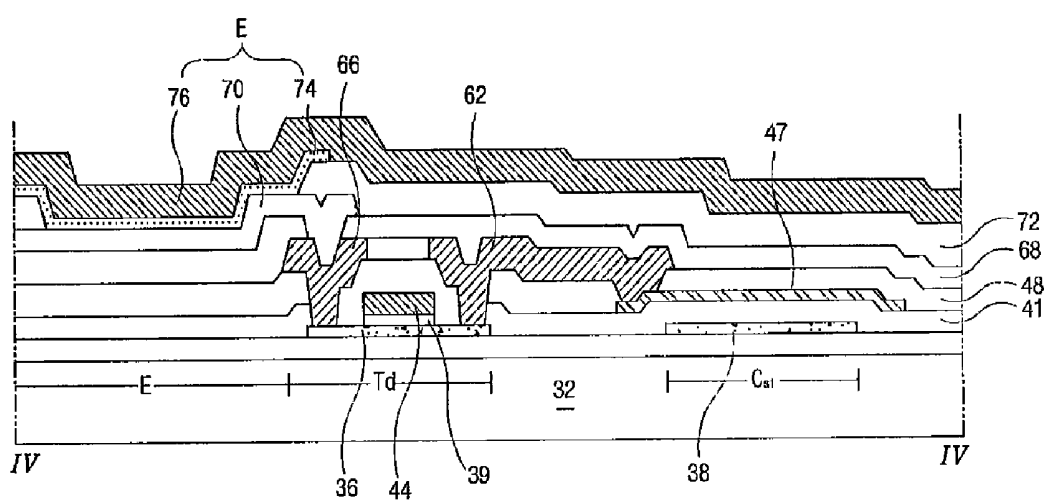


FIG. 5

Related Art

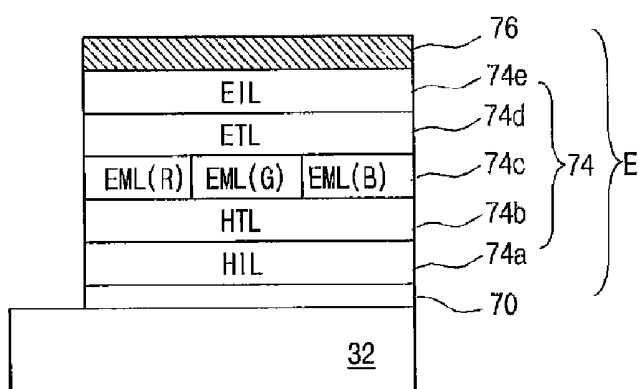


FIG. 6

Related Art

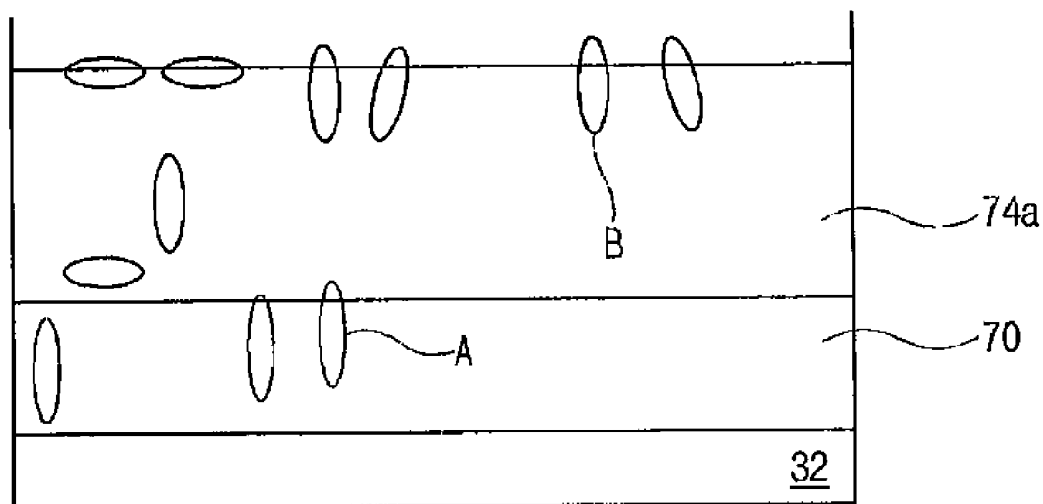


FIG. 7

Related Art

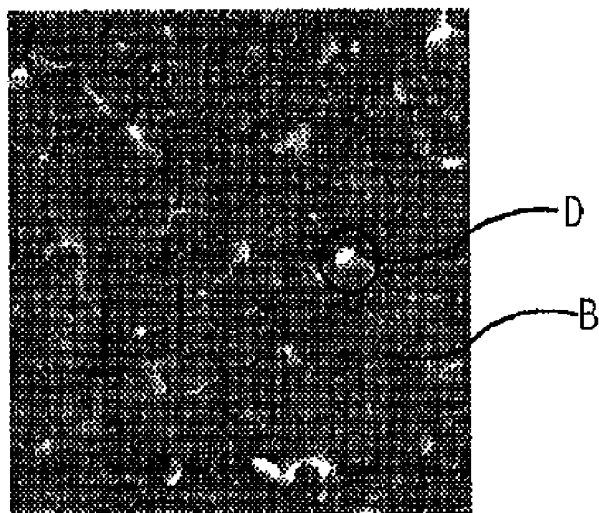


FIG. 8

Related Art

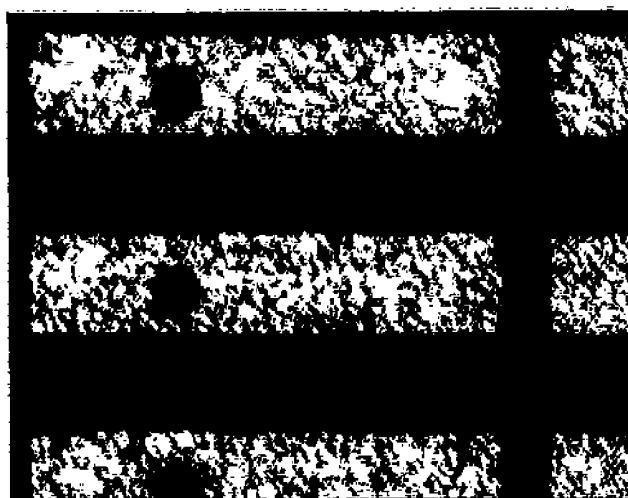


FIG. 9

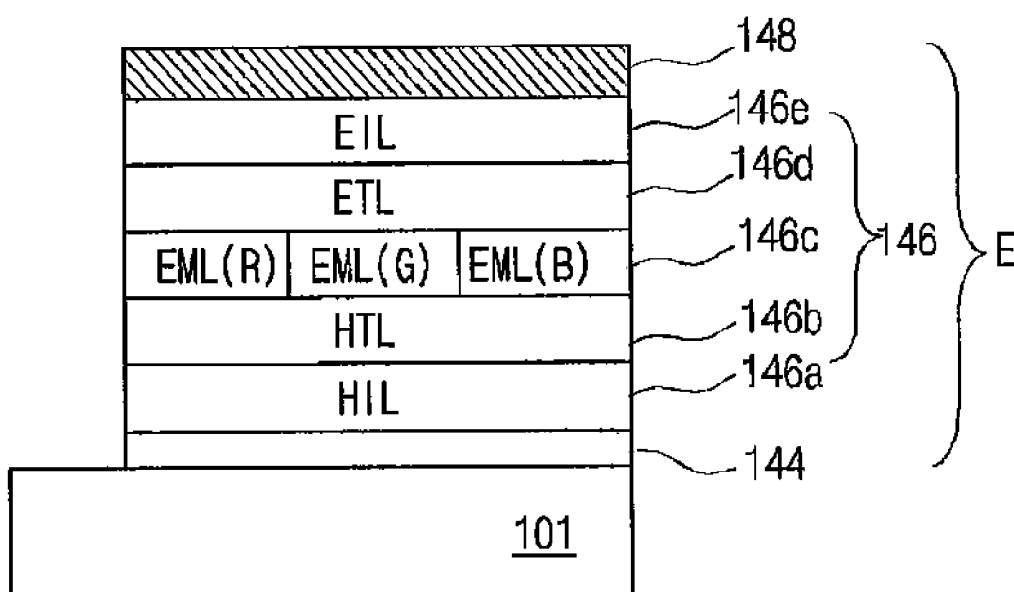


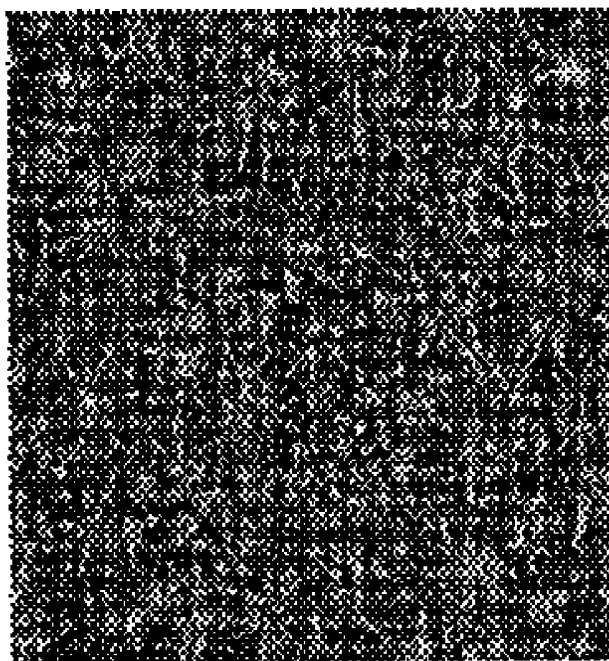
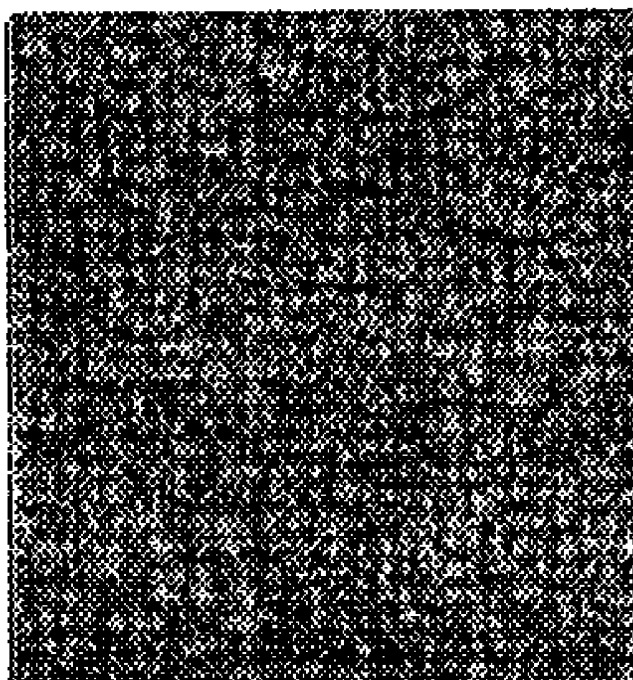
FIG. 10A***FIG. 10B***

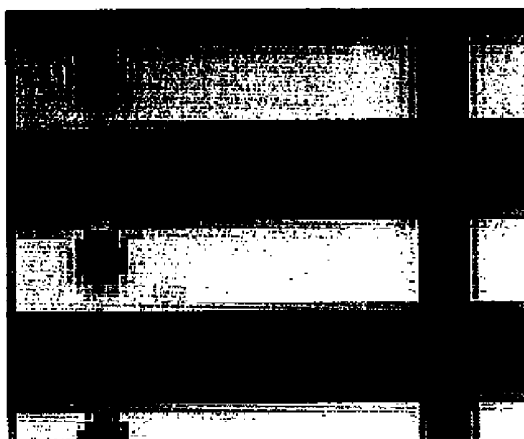
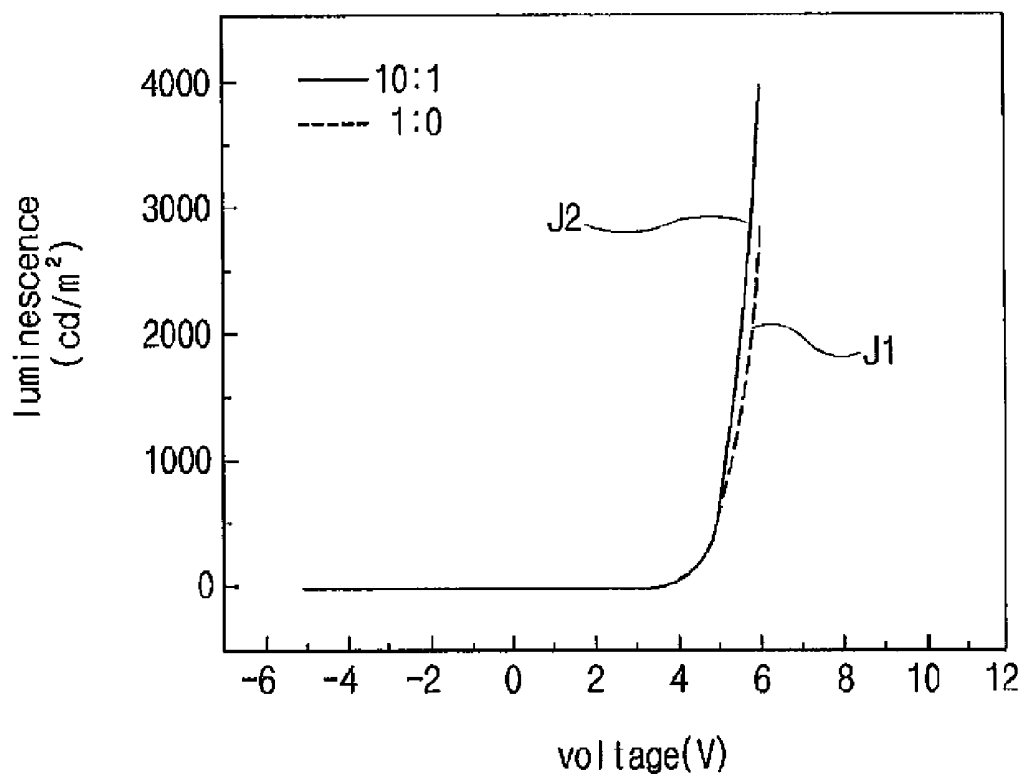
FIG. 11**FIG. 12A**

FIG. 12B

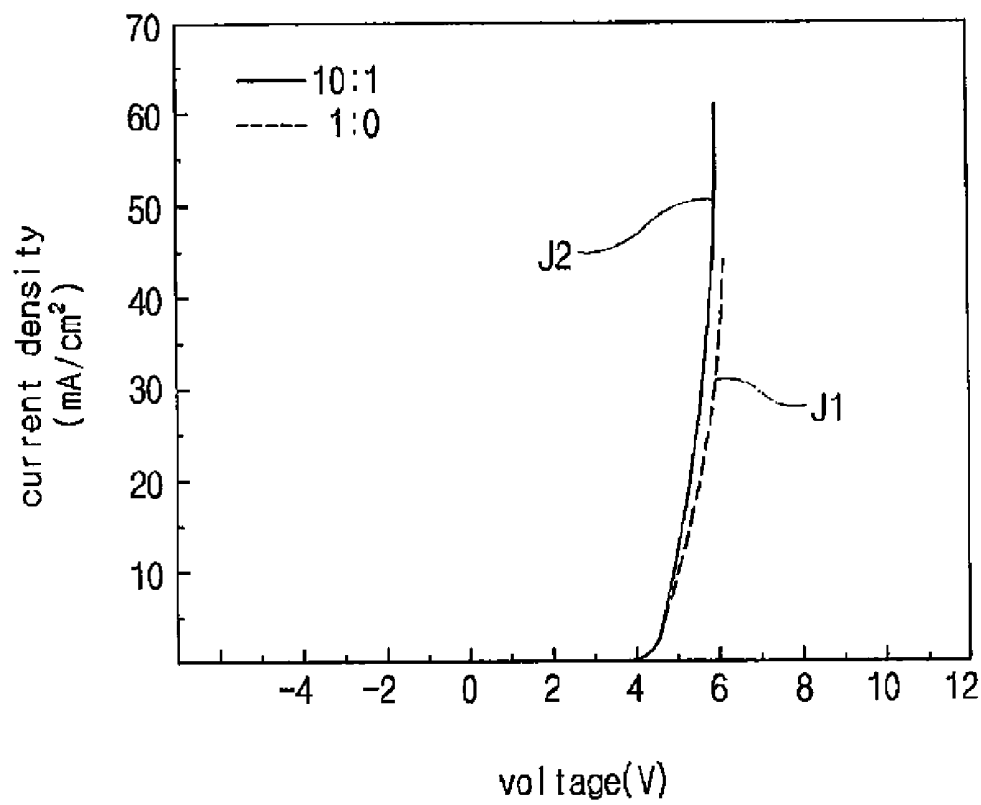


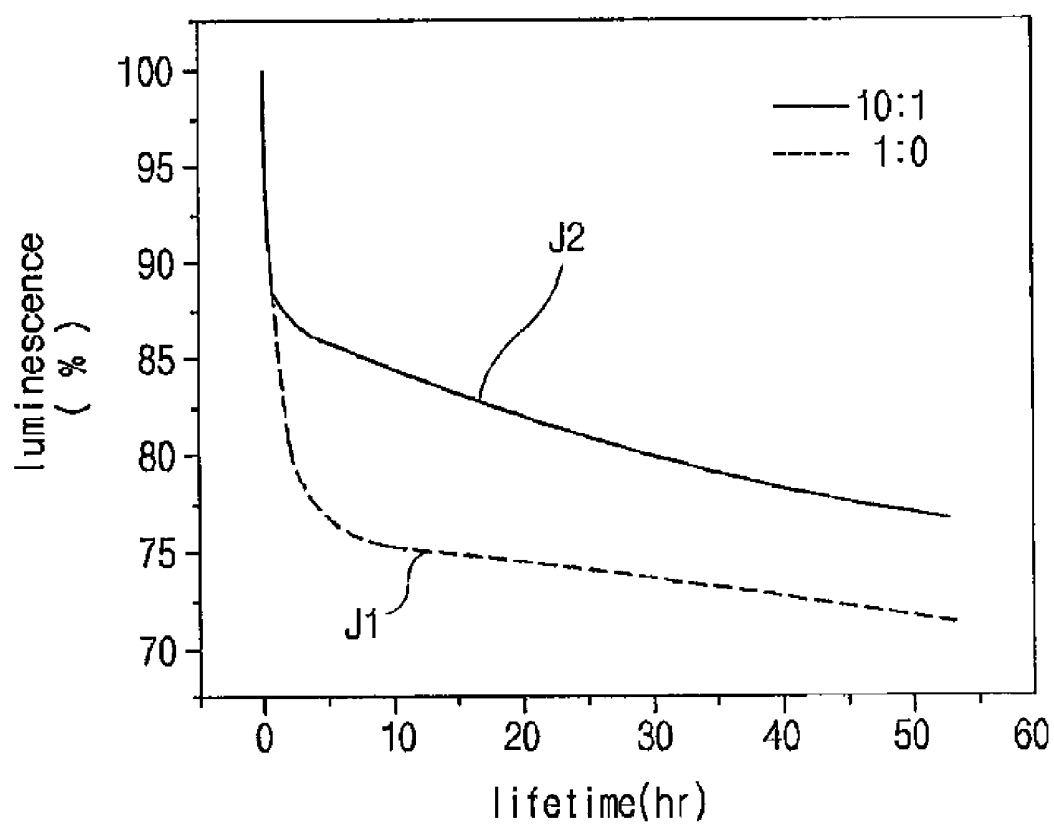
FIG. 12C

FIG. 13

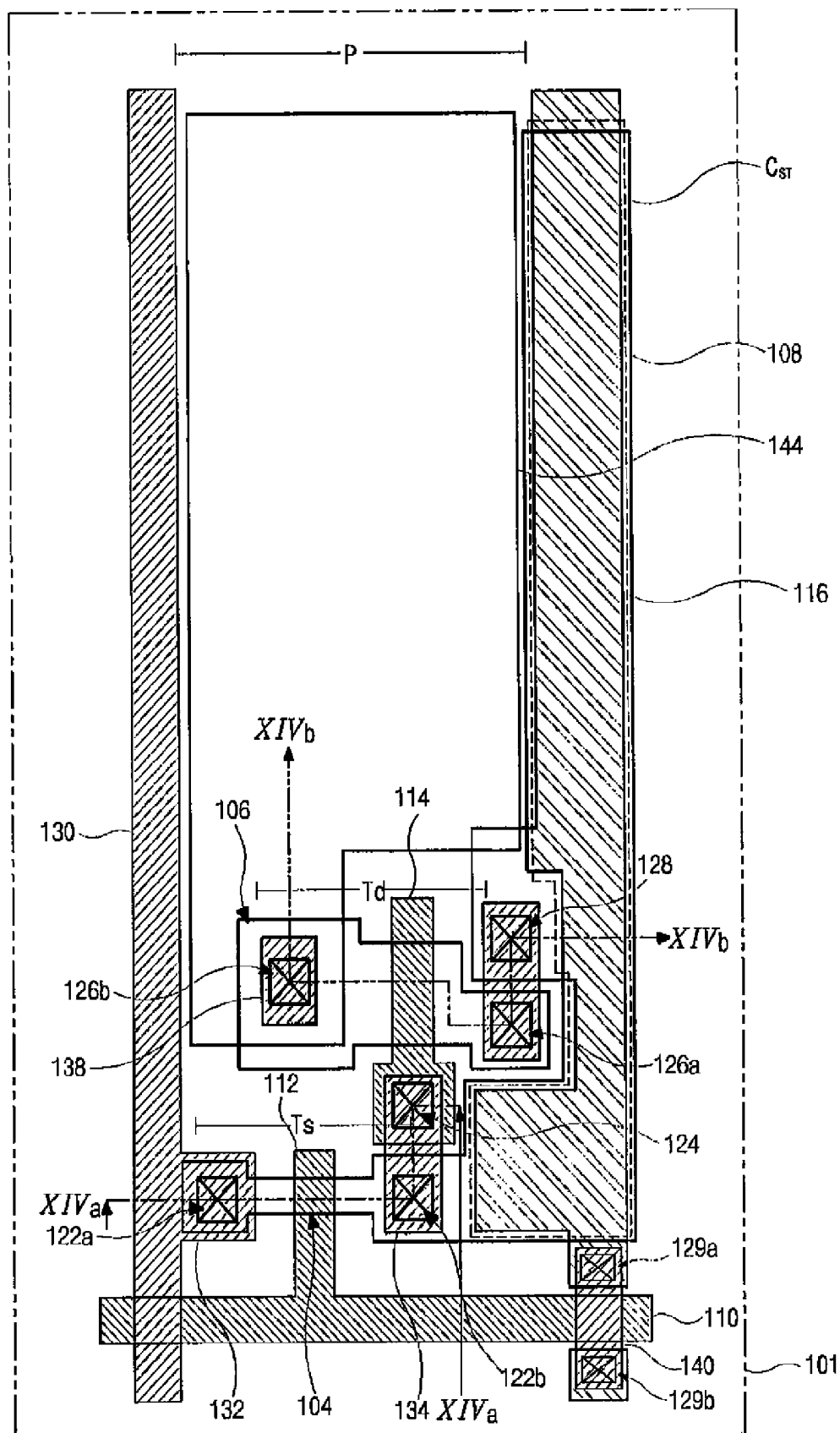


FIG. 14D

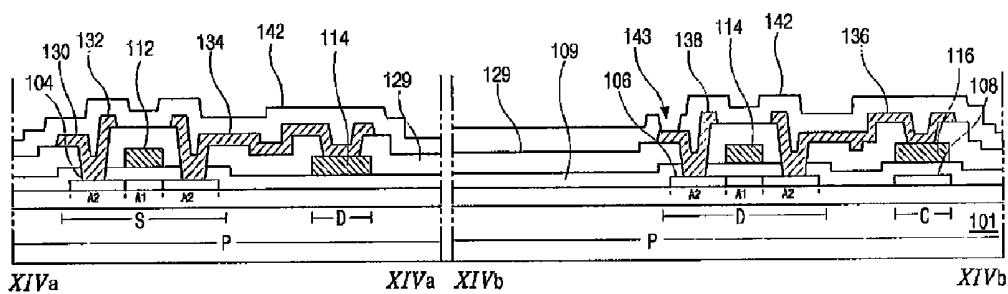


FIG. 14E

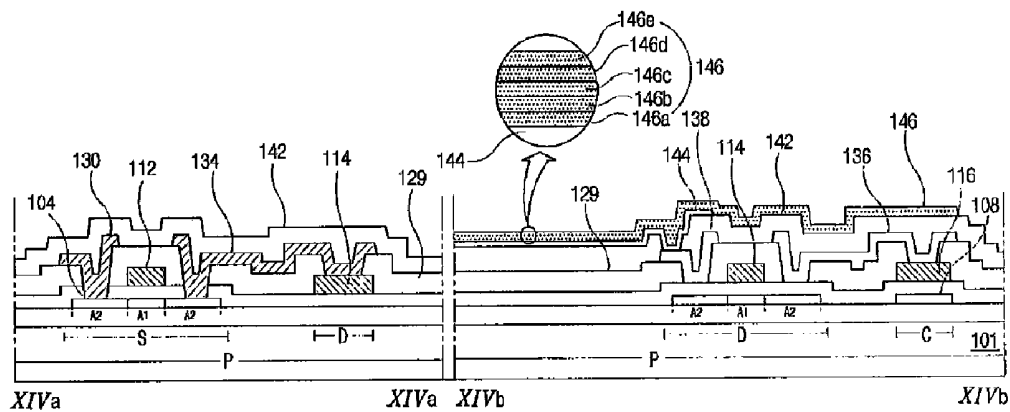
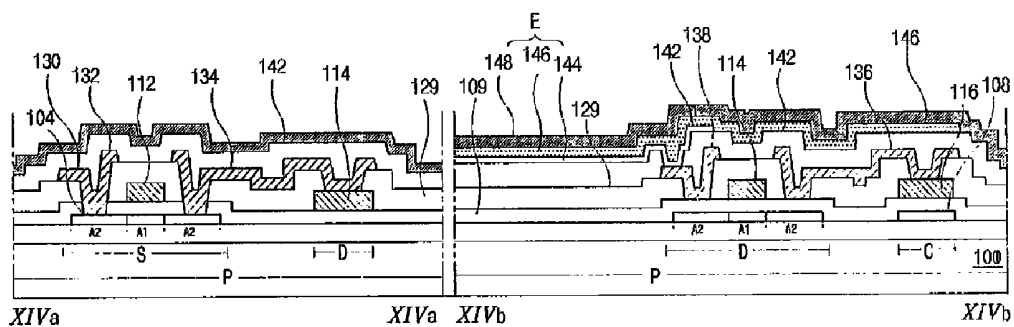


FIG. 14F



ORGANIC ELECTROLUMINESCENT DISPLAY DEVICE AND METHOD OF FABRICATING THE SAME

[0001] The present application claims the benefit of Korean Patent Application No. 2006-0118600 filed in Korea on Nov. 28, 2006, which is hereby incorporated by reference for all purposes as if fully set forth herein.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to an organic electroluminescent display (OELD) device, and more particularly, to an OELD device including a hole injection layer having an improved properties and method for fabricating the same.

[0004] 2. Discussion of the Related Art

[0005] In general, organic electroluminescent display (OELD) devices emit light by injecting electrons from a cathode and holes from an anode into an emission material layer, combining the electrons with the holes, generating excitons, and transforming the excitons of an excited state to a ground state. Unlike liquid crystal display (LCD) devices, OELD devices do not require an additional light source and therefore have the advantages of slimness and lightweight.

[0006] Because OELD devices have excellent characteristics, such as low power consumption, high luminance, fast response time, lightweight and so on, OELD devices can be applied to various electronic products, such as mobile phones, car navigation system (CNS), PDAs, camcorders, palm PCs, and so on. Moreover, due to their simple fabricating process, the fabrication costs of OELD devices are low when compared with those of LCD devices.

[0007] The OELD devices are divided into a passive matrix type and an active matrix type according to the driving method thereof. The passive matrix type OELD devices have a simple structure and a simple fabricating process. However, the passive matrix type OELD devices have disadvantages of high power consumption and low quality images. Moreover, the more lines are disposed, the less aperture ratio does the passive matrix type OELD device have. On the other hand, the active matrix type OELD devices have advantages of high emission efficiency and high quality images.

[0008] FIG. 1 is a cross-sectional view illustrating an active matrix type OELD device according to the related art.

[0009] Referring to FIG. 1, the OELD device 10 includes first and second substrates 12 and 28 facing each other. The first substrate 12 is transparent and flexible. The first substrate 12 has an array element 14 including a plurality of thin film transistors (TFTs) T and an organic electroluminescent diode E including a first electrode 16, an organic luminescent layer 18 and a second electrode 20. The organic luminescent layer 18 in each pixel region P includes one of red, green and blue color materials.

[0010] The second substrate 28 includes a moisture absorbent 22 of a powder type. The moisture absorbent 22 removes moisture inside the OELD device 10. The moisture absorbent 22 is in a concave portion of the second substrate 28 and is sealed by a taping 25. The first and second substrates 12 and 28 are attached to each other with a seal pattern 26.

[0011] In the OELD device 10, because the first electrode 16 is formed of a transparent material, the light emitted from

the organic luminescent layer 18 travels toward the first substrate 12. Accordingly, it is referred to as a bottom emission type OELD device.

[0012] FIG. 2 is a circuit diagram of an OELD device according to the related art.

[0013] Referring to FIG. 2, gate and data lines 40 and 50 are formed on a substrate 32. The gate and data lines 40 and 50 cross each other and a switching element Ts is formed near the crossing portion of the gate and data lines 40 and 50. The switching element Ts includes a gate electrode 42, a source electrode 52 and a drain electrode 56. The gate electrode 42 is connected to the gate line 40. The source electrode 52 separated from the drain electrode 56 is connected to the data line 50.

[0014] A driving element Td is electrically connected to the switching element Ts. The driving element Td of a p-type TFT includes a gate electrode 44, a source electrode 62 and a drain electrode 66. The gate electrode 44 of the driving element Td is connected to the switching element Ts. A storage capacitor Cst is formed between the source and gate electrodes 62 and 44 of the driving element Td. The drain electrode 66 of the driving element Td is connected to the first electrode 16 (of FIG. 1) of the organic electroluminescent diode E. The source electrode 62 of the driving element Td is connected to a power line 47.

[0015] When a gate signal from the gate line 40 is supplied to the gate electrode 42 of the switching element Ts, a data signal from the data line 50 is supplied to the gate electrode 44 of the driving element Td through the switching element Ts. Then, the organic electroluminescent diode E is driven by the driving element Td such that the organic electroluminescent diode E emits light. Because the storage capacitor Cst maintains a voltage level of the gate electrode 44 of the driving element Td, even if the switching element Ts is turned off, the organic electroluminescent diode E can continuously emit light for a predetermined period of time.

[0016] FIG. 3 is a plan view illustrating a pixel region in an array substrate of an active matrix type OELD device according to the related art and FIG. 4 is a cross-sectional view taken along the line IV-IV of FIG. 3.

[0017] Referring to FIGS. 3 and 4, the active matrix type OELD device includes a switching element Ts, a driving element Td and a storage capacitor Cst on a substrate 32. Each pixel P of the OELD device may include more than one pair of the switching element Ts and the driving element Td. The substrate 32 is formed of a transparent and insulating material, such as glass and plastic.

[0018] A gate line 40 and a data line 50 are formed on the substrate 32 with an insulating layer interposed therebetween. A power line 47 is formed along the data line 50. A pixel region P is defined by the crossing between the gate and data lines 40 and 50.

[0019] The switching element Ts may be a thin film transistor including a first active layer 34, a gate insulating layer 39, a gate electrode 42, a first interlayer insulating layer 41, a second interlayer insulating layer 48, source and drain electrodes 52 and 56. The gate electrode 42 of the switching element Ts corresponds to the first active layer 34 and is connected to the gate line 40. The first interlayer insulating layer 41 is formed on the gate electrode 42 and has a first contact hole 51 and a second contact hole 54. The source electrode 52 of the switching element Ts is connected to the data line 50 and is spaced apart from the drain electrode 56 of the switching element Ts. The source and drain electrodes 52

and 56 are insulated from each other due to the second interlayer insulating layer 48. The drain electrode 56 of the switching element Ts is connected to a gate electrode 44 of the driving element Td through a third contact hole 55.

[0020] The driving element Td may be also a thin film transistor including a second active layer 36, a gate insulating layer 39, a gate electrode 44, a first interlayer insulating layer 41, a second interlayer insulating layer 48, source and drain electrodes 62 and 66. The gate electrode 44 of the driving element Td corresponds to the second active layer 36 and is connected to the drain electrode 56 of the switching element Ts through the third contact hole 55. The first interlayer insulating layer 41 is also formed on the gate electrode 44 of the switching element Td and has a fourth contact hole 61 and a fifth contact hole 65. The source electrode 62 of the driving element Td is connected to the power line 47 through a sixth contact hole 49 and is spaced apart from the drain electrode 66 of the driving element Td. The source and drain electrodes 62 and 66 of the driving element Td are insulated from each other due to the second interlayer insulating layer 48.

[0021] A first passivation layer 68 is formed on the switching and driving elements Ts and Td and exposes a portion of the driving electrode 66 of the driving element Td. An organic electroluminescent diode E having a first electrode 70, an organic luminescent layer 74 and a second electrode 76 is formed over the substrate including the switching and driving elements Ts and Td. The first electrode 70 is connected to the drain electrode 66 of the driving element Td, and the organic luminescent layer 74 is interposed between the first and second electrodes 70 and 76. In addition, a second passivation layer 72 is formed on the first electrode 70 to insulate from the second electrode 76.

[0022] Moreover, an impurity-doped silicon layer 38 is formed on the substrate 32 and under the power line 47. The impurity-doped silicon layer 38 and the power line 47 respectively function as first and second capacitor electrodes, and the first interlayer insulating layer 41 therebetween functions as a dielectric material. The first capacitor electrode, the second capacitor electrode, and the dielectric material constitute a storage capacitor Cst.

[0023] FIG. 5 is a schematic cross-sectional view of an organic electroluminescent diode of a conventional OLED device.

[0024] Referring to FIG. 5, the OLED device includes the organic electroluminescent diode E over the substrate 32. The organic electroluminescent diode E includes the first electrode 70, the organic luminescent layer 74 and the second electrode 76. The first and second electrodes 70 and 76 may be referred to as an anode and a cathode, respectively. When voltages are applied to the first and second electrodes 70 and 76, the first and second electrodes 70 and 76 respectively output holes and electrons. The organic luminescent layer 74 includes a hole injection layer (HIL) 74a, a hole transporting layer (HTL) 74b, an emission material layer 74c including a red emission material layer EML(R), a green emission material layer EML(G) and a blue emission material layer EML(B), an electron transporting layer (ETL) 74d and an electron injection layer (EIL) 74e. Because an organic material has very different mobilities with respect to the hole and the electron, the organic electroluminescent diode E includes the hole transporting layer 74a and the electron transporting layer 74d to effectively transport the holes and electron from the first and second electrodes 70 and 76 into the emission material layer 74c. It is possible to obtain a balance between the

holes and the electrons such that emission efficiency is improved. The organic electroluminescent diode E includes the hole injection layer 74a between the first electrode 70 and the hole transporting layer 74b and the electron injection layer 74e between the second electrode 76 and the electron transporting layer 74d. The hole injection layer 74a decreases a barrier energy for injecting the hole into the emission material layer 74c, and the electron injection layer 74e decreases a barrier energy for injecting the electron into the emission material layer 74c. As a result, there are advantages that emission efficiency is improved and driving voltage is reduced. In generally, when the hole injection layer 74a is formed of a crystallizable material such as perylene, tri-phenylene, it is much effective to reduce the driving voltage. However, the crystallizable material has an un-uniform arrangement of grains. It causes deterioration in the organic electroluminescent diode E and decrease of lifetime of the OLED device.

[0025] FIG. 6 shows an arrangement of grains in a hole injection layer according to the related art, FIG. 7 is a picture showing a surface of hole injection layer according to the related art, and FIG. 8 is a picture showing an emission state of an organic electroluminescent diode according to the related art.

[0026] As shown in FIG. 6, a first electrode 70 of a transparent conductive material, such as indium-tin-oxide (ITO), and a hole injection layer 74a of a crystallizable material are laminated over a substrate 32. The transparent conductive material of the first electrode 70 may have one of amorphous phase and crystallized phase. The amorphous phase is changed into the crystallized phase by heating. FIG. 6 shows the first electrode 70 of the crystallized phase. Because the ITO material having the crystallized phase has a uniformly arranged grains A, the first electrode 70 has an even surface to have an excellent interface with the hole injection layer 74a. However, grains B of the hole injection layer 74a of the crystallizable material are un-uniformly arranged. Some grains protrude from the upper surface of the hole injection layer 74a. Accordingly, the hole injection layer has a uneven upper surface.

[0027] Referring to FIG. 7, the grains B has different sizes. Because light emitted from the organic luminescent layer 74c passes through the hole injection layer 74a, the protruding grains from the upper surface of the hole injection layer 74a cause defect sites D. When the OLED device having the above mentioned hole injection layer 74a is driven, currents are concentrated into the defect sites D to have brightness much than other sites. Namely, the defect site D becomes a bright site. Moreover, as the concentration of the currents is progressed, the defect sites D have brightness less than the other sites. Namely, the defect site D becomes a dark site. It causes a deterioration problem in the emission material layer 74c (of FIG. 6).

[0028] Referring to FIG. 8, the OLED device can not produce a uniform brightness due to the defect sites D (of FIG. 7) of the hole injection layer 74a (of FIG. 6). Accordingly, the OLED device does not display high quality images. Moreover, lifetime of the OLED device decreases because of the deterioration problem in the emission material layer 74c (of FIG. 6).

SUMMARY OF THE INVENTION

[0029] Accordingly, the present invention is directed to an organic electroluminescent display (OLED) device and

method for fabricating the same that substantially obviate one or more of the problems due to limitations and disadvantages of the related art.

[0030] An advantage of the present invention is to provide an OLED device with a uniform luminance and prevent decreasing of lifetime of the OLED device.

[0031] Additional features and advantages of the invention will be set forth in the description which follows, and in part will be apparent from the description, or may be learned by practice of the invention. These and other advantages of the invention will be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

[0032] To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described herein, an organic electroluminescent display (OLED) device includes first and second substrates facing each other; a plurality of gate lines, a plurality of data lines and a plurality of power lines on the first substrate, the gate and data lines crossing each other to define a plurality of pixel regions, a switching element and a driving element connected to each other in each pixel region, a first electrode connected to the driving element, an organic luminescent layer on the first electrode, and a second electrode on the organic luminescent layer. The organic luminescent layer includes a hole injection layer, a hole transporting layer, an emission material layer, an electron transporting layer, and an electron injection layer in order. Further, the hole injection layer includes a crystallizable hole injection material and a hole transporting material, and the hole transporting layer includes the hole transporting material.

[0033] In another aspect of the present invention, a method of fabricating an organic electroluminescent diode for an organic electroluminescent display (OLED) device includes forming a first electrode having a first work function, forming a hole injection layer on the first electrode, the hole injection layer including a crystallizable hole injection material and a hole transporting material, forming a hole transporting layer on the hole injection layer, the hole transporting layer including the hole transporting material, forming an emission material layer on the hole transporting layer, forming an electron transporting layer on the emission material layer, forming an electron injection layer on the electron transporting layer; and forming a second electrode on the electron injection layer, the second electrode having a second work function smaller than the first work function.

[0034] In another aspect of the present invention, a method of fabricating an organic electroluminescent diode for an organic electroluminescent display (OLED) device includes forming a first electrode having a first work function, forming an electron injection layer on the first electrode, forming an electron transporting layer on the electron injection layer, forming an emission material layer on the electron transporting layer, forming a hole transporting layer on the emission material layer, the hole transporting layer including a hole transporting material, forming a hole injection layer on the hole transporting layer, the hole injection layer including a crystallizable hole injection material and the hole transporting material, and forming a second electrode on the hole injection layer, the second electrode having a second work function larger than the first work function.

[0035] It is to be understood that both the foregoing general description and the following detailed description are exem-

plary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0036] The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description serve to explain the principles of the invention.

[0037] In the drawings:

[0038] FIG. 1 is a cross-sectional view illustrating an active matrix type OLED device according to the related art;

[0039] FIG. 2 is a circuit diagram of an OLED device according to the related art;

[0040] FIG. 3 is a plan view illustrating a pixel region in an array substrate of an active matrix type OLED device according to the related art;

[0041] FIG. 4 is a cross-sectional view taken along the line IV-IV of FIG. 3;

[0042] FIG. 5 is a schematic cross-sectional view of an organic electroluminescent diode of a conventional OLED device;

[0043] FIG. 6 shows an arrangement of grains in a hole injection layer according to the related art;

[0044] FIG. 7 is a picture showing a surface of hole injection layer according to the related art;

[0045] FIG. 8 is a picture showing an emission state of an organic electroluminescent diode according to the related art;

[0046] FIG. 9 is a schematic cross-sectional view of an organic electroluminescent diode of an OLED device according to the present invention;

[0047] FIGS. 10A and 10B are pictures respectively showing a surface of a hole injection layer having different composition of an OLED device according to the present invention;

[0048] FIG. 11 is a picture showing an emission state of an organic electroluminescent diode of an OLED device according to the present invention;

[0049] FIGS. 12A to 12C are graphs respectively showing properties between luminance and voltage, between current and voltage, and between luminance and lifetime in a hole injection layer of an OLED device according to the present invention;

[0050] FIG. 13 is a plan view illustrating a pixel region in an array substrate of an active matrix type OLED device according to the present invention;

[0051] FIGS. 14A to 14F are cross-sectional views showing a process of fabricating a portion taken along the lines XIVa-XIVa and XIVb-XIVb of FIG. 13; and

[0052] FIG. 15 is a cross-sectional view showing a dual-panel type OLED device having a hole injection layer according to the present invention.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

[0053] Reference will now be made in detail to embodiments of the present invention, examples of which are illustrated in the accompanying drawings. The same reference numbers may be used throughout the drawings to refer to the same or like parts.

[0054] As the present invention may be embodied in several forms without departing from the spirit or essential characteristics thereof, it should also be understood that the above-

described embodiments are not limited by any of the details of the foregoing description, unless otherwise specified, but rather should be construed broadly within its spirit and scope as defined in the appended claims, and therefore all changes and modifications that fall within the metes and bounds of the claims, or equivalence of such metes and bounds are therefore intended to be embraced by the appended claims.

[0055] In an OLED device of the present invention, a hole injection layer includes a first material forming the hole injection layer in a conventional OLED device and a second material forming the hole transporting layer in a conventional OLED device to improve properties of the hole injection layer.

[0056] FIG. 9 is a schematic cross-sectional view of an organic electroluminescent diode of an OLED device according to the present invention. Referring to FIG. 9, an OLED device according to the present invention includes an organic electroluminescent diode E over a substrate 101. The organic luminescent diode E includes a first electrode 144, a second electrode 148 and an organic luminescent layer 146 interposed therebetween. The first electrode 144 may be formed of a transparent conductive material, such as indium-tin-oxide (ITO) and indium-zinc-oxide (IZO) and function as an anode. The second electrode 148 may be formed of an opaque conductive material and function as a cathode. The second electrode 148 has either a single layer including one of calcium (Ca), aluminum (Al), magnesium (Mg), silver (Ag) and lithium (Li) or a double layer including fluorolithium and aluminum (LiF/Al).

[0057] The organic luminescent layer 146 has laminated layers of a hole injection layer (HIL) 146a, a hole transporting layer (HTL) 146b, an emission material layer 146c including a red emission material layer EML(R), a green emission material layer EML(G) and a blue emission material layer EML(B), an electron transporting layer 146d and an electron injection layer 146e. The hole injection layer 146a and the electron injection layer 146e respectively facing the first and second electrodes 144 and 148. The hole injection layer 146a includes a crystallizable hole injection material and a hole transporting material. A volumetric ratio of the crystallizable hole injection material and the hole transporting material in the hole injection layer 146a ranges from approximately about 5:1 to about 30:1. The crystallizable hole injection material and the hole transporting material are deposited on the first electrode 144 at the same time to form the hole injection layer 146a. The hole transporting material prevents over-crystallizing of the crystallizable hole injection layer such that the hole injection layer 146a has more even surface than the hole injection layer according to the related art which does not have the hole transporting material. The crystallizable hole injection material includes one of triphenylene, triphenylamine derivatives, perylene, pyrene, tetracene and anthracene, and the hole transporting material includes an amine group material such as triphenylamine and triphenylamine derivatives.

[0058] The two materials in different crucibles are heated to be evaporated and deposited on the first electrode 144. The ratio of the crystallizable hole injection material and the hole transporting material in the hole injection layer 146a is controlled by differing heating temperatures. For example, the ratio of the crystallizable hole injection material and the hole transporting material in the hole injection layer 146a is desired to be 10:1, the heating temperatures are set to have deposition rates of the crystallizable hole injection material

and the hole transporting material may be 3 angstrom per second and 0.3 angstrom per second, respectively.

[0059] FIGS. 10A and 10B are pictures respectively showing a surface of a hole injection layer having different composition of an OLED device according to the present invention. Surfaces of the hole injection layer respectively having a volumetric ratio of the crystallizable hole injection material and the hole transporting material in 7:1 and 10:1 are shown in FIGS. 10A and 10B. The hole injection layer in FIG. 10B has a more uniform surface than the hole injection layer in FIG. 10A. Namely, the less hole transporting material the hole injection layer includes, the more uniform the surface of the hole injection layer is. In this instance, when the hole injection layer includes the hole transporting material less than the ratio of 30:1, the hole transporting material does not have a desired function such that the problems discussed in the related art are not resolved. On the other hand, when the hole injection layer includes the hole transporting material such that the ratio is greater than 5:1, the hole injection layer does not have a desired hole injecting function.

[0060] When the OLED device including the above mentioned organic electroluminescent diode is driven, the OLED device has a uniform brightness as shown in FIG. 11.

[0061] FIGS. 12A to 12C are graphs respectively showing properties between luminance and voltage, between current and voltage, and between luminance and lifetime in a hole injection layer of an OLED device according to the present invention. In FIGS. 12A to 12C, dotted line J1 illustrates properties of the hole injection layer including the crystallizable hole injection material without the hole transporting material, while solid line J2 illustrates properties of the hole injection layer including the crystallizable hole injection material as well as the hole transporting material according to the present invention. Namely, the dotted line J1 shows the properties of the hole injection layer where a volumetric ratio of the crystallizable hole injection material to the hole transporting material is 1:0, and the solid line J2 shows the properties of the hole injection layer where a volumetric ratio of the crystallizable hole injection material to the hole transporting material is 10:1.

[0062] In FIG. 12A, when the same voltage is supplied to the first and second electrodes of the organic luminescent diode, the solid line J2 has luminescence greater than the dotted line J1. Thus, the OLED device according to the present invention has luminescence greater than the conventional OLED device. The solid line J2 has luminescence 1000 nit as much as the dotted line J1 in maximum at the same voltage. That is, a difference in luminescence between the solid line J2 and the dotted line J3 may be about 1000 nits at 6V, for example. Similarly, as shown in FIG. 12B, the solid line J2 has current density greater than the dotted line J1 at the same voltage.

[0063] On the other hand, as shown in FIG. 12C, the solid line J2 illustrates that the luminescence decreases at a lower rate than the dotted line J1 as the lifetime increases. This is because the hole transporting material in the hole injection layer prevents the grains of the hole injection material from protruding from the surface of the hole injection layer 146a. As mentioned above, the protruding grains cause the deterioration problems. Accordingly, the OLED device according to the present invention has an improved lifetime.

[0064] FIG. 13 is a plan view illustrating a pixel region in an array substrate of an active matrix type OLED device according to the present invention, and FIGS. 14A to 14E are cross-

sectional views showing a process of fabricating a portion taken along the lines XIVa-XIVa and XIVb-XIVb of FIG. 13. Referring to FIG. 13, the active matrix type OLED device includes a switching element Ts, a driving element Td and a storage capacitor Cst on a substrate 101. Each pixel P of the OLED device may include more than one pair of the switching element Ts and the driving element Td. The substrate 101 is formed of a transparent and insulating material, such as glass or plastic. Further, a gate line 110 and a data line 130 are formed on the substrate 101 with an insulating layer interposed therebetween. A power line 116 is formed along the data line 130. A pixel region P is defined by the crossing between the gate and data lines 110 and 130.

[0065] The switching element Ts may be a thin film transistor including a first active layer 104, a gate insulating layer (not shown), a first gate electrode 112, a first source electrode 132 and a first drain electrode 134. The first gate electrode 112 of the switching element Ts corresponds to the first active layer 104 and is connected to the gate line 110. The first source electrode 132 and the first drain electrode 134 of the switching element Ts are respectively connected to the first active layer 104 through first and second contact holes 122a and 122b. The first source electrode 132 of the switching element Ts is connected to the data line 130 and is spaced apart from the first drain electrode 134 of the switching element Ts.

[0066] The driving element Td may be also a thin film transistor including a second active layer 106, a gate insulating layer (not shown), a second gate electrode 114, a second source electrode 136 and a second drain electrode 138. The second gate electrode 114 of the driving element Td corresponds to the second active layer 106 and is connected to the first drain electrode 134 of the switching element Ts through a third contact hole 124. The second source electrode and the second drain electrode 138 of the driving element Td are respectively connected to the second active layer 106 through fourth and fifth contact holes 126a and 126b. The second source electrode 136 of the driving element Td is connected to the power line 116 through a sixth contact hole 128 and is spaced apart from the second drain electrode 138 of the driving element Td. The second drain electrode 138 of the driving element Td is connected to a first electrode 144 of an organic electroluminescent diode (not shown). In FIG. 13, because the power line 116 is formed of the same layer as the gate line 110, the power line 116 is disconnected at crossing portion with the gate line 110 to avoid electrical short. A power line connection pattern 140, which may be formed of the same layer as the data line 130, connects the disconnected portion of the power line 116 through the seventh and eighth contact holes 129a and 129b.

[0067] Moreover, an impurity-doped silicon layer 108 is formed on the substrate 101 and under the power line 116. The impurity-doped silicon layer 108 and the power line 116 respectively function as first and second capacitor electrodes, and the gate insulating layer (not shown) therebetween functions as a dielectric material. The first capacitor electrode, the second capacitor electrode, and the dielectric material constitute a storage capacitor Cst.

[0068] Although not shown, an emission material layer and a second electrode of the organic electroluminescent diode are laminated on the first electrode. As mentioned above, the emission material layer includes a hole injection layer formed of a crystallizable hole injection material and a hole transporting material.

[0069] Referring to FIGS. 14A to 14F, methods of fabricating an organic electroluminescent diode and an OLED device having the same according to the present invention are explained. In FIG. 14A, a buffer layer 102 is formed on the substrate 101 where a pixel region P, a switching region S, a driving region D and a capacitor region C are defined. The pixel region P is defined by crossing between the gate and data lines 110 and 130. The switching and driving elements Ts and Td are respectively formed in the switching and driving regions S and D, and the storage capacitor Cst is formed in the capacitor region C. The buffer layer 102 functions as a blocking layer for preventing an alkali ion from diffusing into the first and second active layers 104 and 106. The alkali ion causes damages on properties of the first and second active layers 104 and 106. However, if not necessary, the buffer layer 102 can be omitted.

[0070] Next, a polycrystalline silicon layer (not shown) is formed on the substrate 101 by depositing, dehydrating and crystallizing intrinsic amorphous silicon (a-Si:H). The polycrystalline silicon layer (not shown) is patterned to form a first polycrystalline silicon pattern 104 in the switching region S, a second polycrystalline silicon pattern 106 in the driving region D, and a third polycrystalline silicon pattern 108 in the capacitor region C. Ions are doped onto the third polycrystalline silicon pattern 108 to form the impurity-doped amorphous silicon layer 108. As mentioned above, it functions as the first capacitor electrode of the storage capacitor Cst.

[0071] Next, the gate insulating layer 109 is formed on the first and second polycrystalline silicon patterns 104 and 106, and the first capacitor electrode 108. A first metal layer (not shown) is formed on the gate insulating layer 109 and patterned to form a first gate electrode 112 in the switching region S, a second gate electrode 114 in the driving region D, and the power line 116 in the capacitor region C. Namely, the first gate electrode 112, the second gate electrode 114 and the power line 116 correspond to a center portion of the first polycrystalline silicon pattern 104, a center portion of the second polycrystalline silicon pattern 106 and the first capacitor electrode 108, respectively. The center portions of the first polycrystalline silicon pattern 104 and the second polycrystalline silicon pattern 106 are defined as a first active region A1, and both side portions of the first polycrystalline silicon pattern 104 and both side portions of the first polycrystalline silicon pattern 106 are defined as a second active region A2. The power line 116 overlaps the first capacitor electrode 108 to function as a second capacitor electrode. The first capacitor electrode 108, the second storage capacitor electrode 116 and the gate insulating layer 109 therebetween constitute the storage capacitor Cst. Because the power line 116 crosses and is formed of the same material as the gate line, the power line 116 is disconnected at crossing portion with the gate line to avoid electrical short. At the same time, the gate line (not shown) is formed along widthwise direction. The first gate electrode 112 of the switching element Ts is connected to the gate line (not shown).

[0072] In FIG. 14B, an interlayer insulating layer 129 is formed on the first and second gate electrodes 112 and 114, the power line 116 and the gate line (not shown) and patterned to form the first to sixth contact holes 122a, 122b, 124, 126a, 126b and 128. The first and second contact holes 122a and 122b respectively expose the second active regions A2 of the first active layer 104, and the third contact hole 124 exposes a portion of the second gate electrode 114. The fourth and fifth contact holes 126a and 126b respectively expose the second

active regions A2 of the first active layer 106, and the sixth contact hole 128 exposes a portion of the power line 116. Although not shown, the seventh and eighth contact holes 129a and 129b are formed to respectively expose disconnected portions of the power line 116. Further, impurities are doped onto the second active regions A2 of the first and second active layers 104 and 106 through the first, second, fourth and fifth contact holes 122a, 122b, 126a and 126b.

[0073] In FIG. 14C, a second metal layer (not shown) is formed on the interlayer insulating layer 129 and patterned to form the data line 130, the first source electrode 132, the first drain electrode 134, the second source electrode 136 and the second drain electrode 138. The data line 130 crosses the gate line 110 to define the pixel region P and is connected to the first source electrode 132 of the switching element Ts. The first source electrode 132 and the first drain electrode 134 are respectively connected to the second active regions A2 of the first active layer 104 through the first and second contact holes 122a and 122b (of FIG. 14B), and the second source electrode 136 and the second drain electrode 138 are respectively connected to the second active regions A2 of the second active layer 106 through the fourth and fifth contact holes 126a and 126b (of FIG. 14B). Moreover, the first drain electrode 134 is connected to the second gate electrode 114 of the driving element Td through the third contact hole 124 (of FIG. 14B), and the second source electrode 136 is connected to the power line 116 through the sixth contact hole 128. Although not shown, the power line connection pattern is formed at the disconnected portion of the power line 116. The power line connection pattern is connected to the power line 116 through the seventh and eighth contact holes 129a and 129b.

[0074] Next, in FIG. 14D, a passivation layer 142 is formed on the first and second source electrodes 132 and 136, the first and second drain electrodes 134 and 138, and the data line 130 and patterned to form a ninth contact hole 143 exposing the second drain electrode 138 of the driving element Td.

[0075] In FIG. 14E, a transparent conductive material layer (not shown) including one of indium-tin-oxide (ITO) and indium-zinc-oxide (IZO) is formed on the passivation layer 142 and patterned to form the first electrode 144. The first electrode 144 is connected to the second drain electrode 138 of the driving element Td through the ninth contact hole 143. And then, the organic luminescent layer 146 including a hole injection layer 146a, a hole transporting layer 146b, an emission material layer 146c, an electron transporting layer 146d and an electron injection layer 146e is formed on the first electrode 144. The hole injection layer 146a is formed by evaporating and depositing a crystallizable hole injection material and a hole transporting material at the same time. A volumetric ratio of the crystallizable hole injection material to the hole transporting material ranges from approximately 5:1 to 30:1. The crystallizable hole injection material and the hole transporting material are evaporated under different temperature to control the ratio. The hole injection layer 146a has a uniform surface due to the hole transporting material. The crystallizable hole injection material includes one of triphenylene, triphenylamine derivatives, perylene, pyrene, tetracene and anthracene, and the hole transporting material includes an amine group material such as triphenylamine and triphenylamine derivatives.

[0076] Next, in FIG. 14F, the second electrode 148 is formed on the organic luminescent layer 146. The second electrode 148 may be either a single layer including one of

calcium (Ca), aluminum (Al), magnesium (Mg), silver (Ag) and lithium (Li) or a double layer including fluorolithium and aluminum (LiF/Al).

[0077] The first electrode 144, the second electrode 148 and the organic luminescent layer 146 therebetween constitute the organic electroluminescent diode E. The first electrode 144 functions as an anode to emit holes, and the second electrode 148 functions as a cathode to emit electrons. Light emitted from the organic luminescent layer 146 passes through the first electrode 144.

[0078] A lower substrate of the OLED device is fabricated by the above processes. Although not shown, the OLED device is fabricated by attaching an upper substrate including a moisture absorbent to the lower substrate.

[0079] Even though a bottom emission type OLED is explained, in which the first electrode is formed of ITO, the first embodiment could be applied to a top emission type OLED in which the second electrode is formed of ITO. In the top emission type OLED, the order of the hole injection layer, the hole transporting layer, the emission material layer, the electron transporting layer and the electron injection layer should be reversed in comparison with the bottom emission type OLED.

[0080] FIG. 15 is a cross-sectional view showing a dual-panel type OLED device having a hole injection layer according to the present invention. In FIG. 15, the dual-panel type OLED device includes first and second substrates 201 and 241 facing each other. A gate line (not shown) and a data line (not shown) are formed on the first substrate 201 and cross each other to define a pixel region P. Moreover, a power line to supply a voltage to an organic electroluminescent diode E is formed on the first substrate 201. A switching element (not shown) and a driving element Td are formed in each pixel region P. The driving element Td includes a gate electrode 212 on the first substrate 201, a gate insulating layer 214 on the gate electrode 212, a semiconductor layer 216 including an active layer 216a and an ohmic contact layer 216b, a source electrode 218 and a drain electrode 220. The gate electrode 212 is connected to a drain electrode of the switching element (not shown). When the switching element (not shown) is opened, a signal voltage is supplied to the gate electrode 212 of the driving element Td through the switching element (not shown).

[0081] A passivation layer 230 having a contact hole 232, which exposes a portion of the drain electrode 220 of the driving element Td, is formed on the driving element Td. Although not shown, the source electrode 218 of the driving element Td is connected to the power line (not shown). A connection electrode 234 is formed on the passivation layer 230 to be connected to the drain electrode 220 of the driving element Td through the contact hole 232.

[0082] On the other hand, an organic electroluminescent diode E is formed on an inner surface of the second substrate 241, which faces the first substrate 201. The organic electroluminescent diode E includes a first electrode 244, an organic luminescent layer 246 and a second electrode 248. The second electrode 248 is formed on an entire surface of the second substrate 241. The second electrode 248 is formed of a transparent conductive material, such as indium-tin-oxide (ITO) and indium-zinc-oxide (IZO). An organic luminescent layer 246 including a hole injection layer 246a, a hole transporting layer 246b, an emission material layer 246c, an electron transporting layer 246d and an electron injection layer 246e is formed on the second electrode 248 in each pixel

region P. The hole injection layer **246a** is formed by evaporating and depositing a crystallizable hole injection material and a hole transporting material at the same time. A volumetric ratio of the crystallizable hole injection material to the hole transporting material ranges from approximately 5:1 to 30:1. The crystallizable hole injection material and the hole transporting material are evaporated under different temperature to control the ratio. The hole injection layer **246a** has a uniform surface due to the hole transporting material. The crystallizable hole injection material includes one of triphenylene, triphenylamine derivatives, perylene, pyrene, tetracene and anthracene, and the hole transporting material includes an amine group material such as triphenylamine and triphenylamine derivatives. The first electrode **244** is formed on the organic luminescent layer **246** at each pixel region P. The first electrode **244** may be either a single layer including one of calcium (Ca), aluminum (Al), magnesium (Mg), silver (Ag) and lithium (Li) or a double layer including fluorolithium and aluminum (LiF/Al). The first electrode **244** functions as a cathode to emit electrons, and the second electrode **248** functions as an anode to emit holes. Light emitted from the organic luminescent layer **246** passes through the second electrode **248** and the second substrate **241**.

[0083] A connection pattern **236** to electrically connect the connection electrode **234** of the first substrate **201** and the first electrode **244** of the second substrate **241** is formed on one of the connection electrode **234** of the first substrate **201** and the first electrode **244** of the second substrate **241**. When the driving element Td is opened, a voltage of the power line (not shown) is supplied to the first electrode **244** through the driving element Td, the connection electrode **234** and the connection pattern **236** to drive the OLED device.

[0084] In the OLED device according to the present invention, a hole injection layer includes not only a crystallizable hole injection material but also a hole transporting material to have a uniform surface. Because light emitted from an organic luminescent layer passes through the hole injection layer having a uniform surface, the OLED device has a uniform brightness. Moreover, because there is no deterioration problem resulted from protruding grains of the conventional hole injection layer, the OLED device according to the present invention has an improved lifetime.

[0085] It will be apparent to those skilled in the art that various modifications and variation can be made in the present invention without departing from the spirit or scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. An organic electroluminescent display device, comprising:

- first and second substrates facing each other;
- a plurality of gate lines, a plurality of data lines and a plurality of power lines on the first substrate, the gate and data lines crossing each other to define a plurality of pixel regions;
- a switching element and a driving element connected to each other in each pixel region;
- a first electrode connected to the driving element;
- an organic luminescent layer on the first electrode, the organic luminescent layer including,
 - a hole injection layer,
 - a hole transporting layer,

- an emission material layer,
 - an electron transporting layer, and
 - an electron injection layer in order,
- wherein the hole injection layer includes a crystallizable hole injection material and a hole transporting material, and the hole transporting layer includes the hole transporting material; and
- a second electrode on the organic luminescent layer.

2. The device according to claim 1, wherein a volumetric ratio of the crystallizable hole injection material to the hole transporting material in the hole injection layer ranges from 5:1 to 30:1.

3. The device according to claim 1, wherein the crystallizable hole injection material includes one of triphenylene, triphenylamine derivatives, perylene, pyrene, tetracene and anthracene.

4. The device according to claim 1, wherein the hole transporting material includes triphenylamine and triphenylamine derivatives.

5. The device according to claim 1, wherein the hole injection layer contacts the first electrode.

6. The device according to claim 5, wherein the first electrode includes one of indium-tin-oxide and indium-zinc-oxide.

7. The device according to claim 5, wherein the second electrode is an opaque single layer including either one of calcium, aluminum, magnesium, silver and lithium or an opaque double layer having fluorolithium and aluminum.

8. The device according to claim 5, further comprising a moisture absorbent on the second substrate.

9. The device according to claim 1, wherein the electron injection layer contacts the first electrode.

10. The device according to claim 9, wherein the second electrode includes one of indium-tin-oxide and indium-zinc-oxide.

11. The device according to claim 9, wherein the first electrode is an opaque single layer including either one of calcium, aluminum, magnesium, silver and lithium or an opaque double layer having fluorolithium and aluminum.

12. The device according to claim 9, further comprising a connecting pattern between the driving element and the first electrode, wherein the first electrode is connected to the driving element through the connecting pattern.

13. A method of fabricating an organic electroluminescent diode for an organic electroluminescent display device, comprising:

- forming a first electrode having a first work function;
- forming a hole injection layer on the first electrode, the hole injection layer including a crystallizable hole injection material and a hole transporting material;
- forming a hole transporting layer on the hole injection layer, the hole transporting layer including transporting material;
- forming an emission material layer on the hole transporting layer;
- forming an electron transporting layer on the emission material layer;
- forming an electron injection layer on the electron transporting layer; and
- forming a second electrode on the electron injection layer, the second electrode having a second work function smaller than the first work function.

14. The method according to claim **13**, wherein a volumetric ratio of the crystallizable hole injection material to the hole transporting material in the hole injection layer ranges from 5:1 to 30:1.

15. The method according to claim **13**, wherein the step of forming the hole injection layer includes depositing the crystallizable hole injection material by heating a crystallizable hole injection material source at a first temperature and depositing the hole transporting material by heating a hole transporting material source at a second temperature.

16. The method according to claim **15**, wherein the first temperature is greater than the second temperature.

17. The method according to claim **15**, wherein a volumetric ratio of the crystallizable hole injection material to the hole transporting material in the hole injection layer is controlled by difference between the first and second temperatures.

18. A method of fabricating an organic electroluminescent diode for an organic electroluminescent display device, comprising:

- forming a first electrode having a first work function;
- forming an electron injection layer on the first electrode;
- forming an electron transporting layer on the electron injection layer;

forming an emission material layer on the electron transporting layer;

forming a hole transporting layer on the emission material layer, the hole transporting layer including a hole transporting material;

forming a hole injection layer on the hole transporting layer, the hole injection layer including a crystallizable hole injection material and the hole transporting material; and

forming a second electrode on the hole injection layer, the second electrode having a second work function larger than the first work function.

19. The method according to claim **18**, wherein a volumetric ratio of the crystallizable hole injection material to the hole transporting material in the hole injection layer ranges from 5:1 to 30:1.

20. The method according to claim **18**, wherein the step of forming the hole injection layer includes depositing the crystallizable hole injection material by heating a crystallizable hole injection material source at a first temperature and depositing the hole transporting material by heating a hole transporting material source at a second temperature, wherein the first temperature is greater than the second temperature.

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摘要(译)

有机电致发光显示 (OLED) 器件包括彼此面对的第一和第二基板，多条栅极线，多条数据线和在第一基板上的多条电源线，栅极线和数据线彼此交叉以限定多个像素区域，在每个像素区域中彼此连接的开关元件和驱动元件，连接到驱动元件的第一电极，第一电极上的有机发光层和有机发光层上的第二电极。有机发光层依次包括空穴注入层，空穴传输层，发光材料层，电子传输层和电子注入层。此外，空穴注入层包括可结晶空穴注入材料和空穴传输材料，空穴传输层包括空穴传输材料。

