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(54) STACKED ORGANIC LIGHT-EMITTING DIODE AND PREPARATION METHOD THEREFOR, AND DISPLAY DEVICE

(57) A stacked organic light-emitting diode (100), a display device and a manufacturing method of a stacked organic light-emitting diode (100) are disclosed. A stacked organic light-emitting diode (100) includes at least two light-emitting units (103) in a stacked arrangement and a charge generation layer (107) disposed between the adjacent light-emitting units (103), wherein the charge generation layer (107) includes a first material layer (1071), an electron injection layer (1072) disposed on the first material layer (1071) and a second material layer (1073) disposed on the electron injection layer (1072). By means of said stacked organic light-emitting diode (100) and manufacturing method thereof, it can achieve excellent electron injection effect, even in the case of manufacturing an inverted-type stacked organic light-emitting diode (the lower electrode is a cathode).

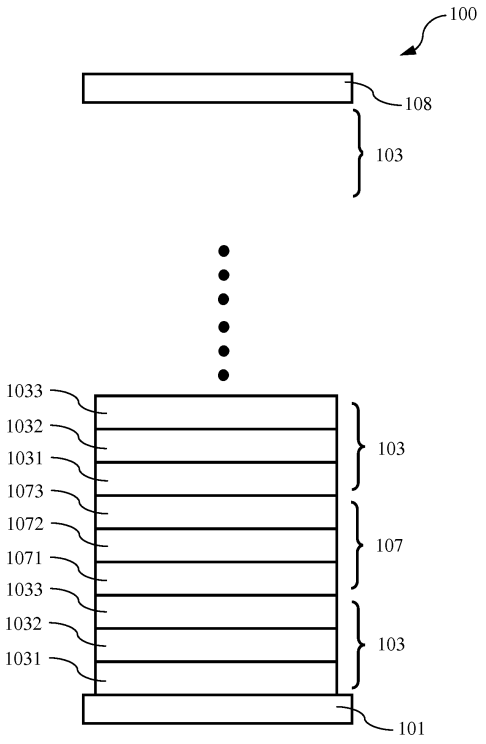

Fig. 1

EP 3 070 759 A1

Description

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of Chinese Patent Application No. 201410815361.1 filed on December 24, 2014 in the State Intellectual Property Office of China, the whole disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] Embodiments of the present disclosure relate to a stacked organic light-emitting diode, a display device and a manufacturing method of a stacked organic light-emitting diode.

Description of the Related Art

[0003] It is necessary for a plurality of light-emitting units of a stacked organic light-emitting diode to be connected to each other by a charge generation layer, which may be provided with various material layers, such as a metal layer, a metallic oxide layer, an organic compound layer, or an inorganic compound layer, and the like, in order to generate charge and successfully inject the generated charge into various light-emitting units.

SUMMARY OF THE INVENTION

[0004] The embodiments of the present disclosure aim to provide a stacked organic light-emitting diode, a display device and a manufacturing method of a stacked organic light-emitting diode, so as to enable the stacked organic light-emitting diode to achieve excellent electron injection effect.

[0005] According to one aspect of the present disclosure, there is provided a stacked organic light-emitting diode, comprising: at least two light-emitting units in a stacked arrangement; and a charge generation layer disposed between the adjacent light-emitting units, wherein the charge generation layer comprises a first material layer, an electron injection layer disposed on the first material layer and a second material layer disposed on the electron injection layer.

[0006] By means of such charge generation layer comprising the first material layer, the electron injection layer and the second material layer, it can achieve excellent electron injection effect. Furthermore, based on the stacked organic light-emitting diode according to embodiments of the present disclosure, it can enable the second material layer (for example, a metal layer or a mixed material layer) to react with the electron injection layer when manufacturing the stacked organic light-emitting diode, even in the case of manufacturing an inverted-type stacked organic light-emitting diode (the lower electrode is a cathode), thereby achieving excellent electron injection effect.

[0007] According to one aspect of the present disclosure, the first material layer is made of metal material.

[0008] According to one aspect of the present disclosure, the second material layer is made of metal material.

[0009] According to one aspect of the present disclosure, the first material layer is made of metal material and the second material layer is made of metal material.

[0010] Based on the stacked organic light-emitting diode according to embodiments of the present disclosure, since the second material layer is made of metal material, it can enable the second material layer to react with the electron injection layer when manufacturing the stacked organic light-emitting diode, even in the case of manufacturing an inverted-type stacked organic light-emitting diode (the lower electrode is a cathode), thereby achieving excellent electron injection effect.

[0011] According to one aspect of the present disclosure, the first material layer is made of a first mixed material, which is formed by mixing at least one first material having a first electrical conductivity and at least one second material having a second electrical conductivity, the first electrical conductivity being greater than the second electrical conductivity.

[0012] According to one aspect of the present disclosure, the second material layer is made of a second mixed material, which is formed by mixing at least one third material having a third electrical conductivity and at least one fourth material having a fourth electrical conductivity, the third electrical conductivity being greater than the fourth electrical conductivity.

[0013] According to one aspect of the present disclosure, the first material layer is made of a first mixed material, which is formed by mixing at least one first material having a first electrical conductivity and at least one second material having a second electrical conductivity, the first electrical conductivity being greater than the second electrical conductivity, and the second material layer is made of a second mixed material, which is formed by mixing at least one third material having a third electrical conductivity and at least one fourth material having a fourth electrical conductivity, the third electrical conductivity being greater than the fourth electrical conductivity.

[0014] According to one aspect of the present disclosure, the first electrical conductivity is greater than 10^3 S/cm, and the second electrical conductivity is less than 10^{-6} S/cm.

[0015] According to one aspect of the present disclosure, the third electrical conductivity is greater than 10^3 S/cm, and the fourth electrical conductivity is less than 10^{-6} S/cm.

[0016] According to one aspect of the present disclosure, the first electrical conductivity is greater than 10^3 S/cm, and the second electrical conductivity is less than 10^{-6} S/cm, and the third electrical conductivity is greater than 10^3 S/cm, and the fourth electrical conductivity is less than 10^{-6} S/cm.

[0017] According to one aspect of the present disclosure, the first material is a metal material and the second material is an organic material.

[0018] According to one aspect of the present disclosure, the third material is a metal material and the fourth material is an organic material.

[0019] According to one aspect of the present disclosure, the first material is a metal material and the second material is an organic material, and the third material is a metal material and the fourth material is an organic material.

[0020] By means of the first material layer made of the first mixed material and/or the second material layer made of the second mixed material, especially when the mixed material consists of metal and organic material, a material layer with good uniformity may be formed, while an affection of a relatively thick material layer on the penetrance and a sideward electrically conducting problem may be avoided.

[0021] According to one aspect of the present disclosure, the stacked organic light-emitting diode further comprises an organic layer disposed between the electron injection layer and the second material layer.

[0022] According to embodiments of the present disclosure, by means of the organic layer disposed between the electron injection layer and the second material layer, the material of the electron injection layer may be reacted with the material of the organic layer when manufacturing the stacked organic light-emitting diode, thereby generating more excellent electron injection effect.

[0023] According to one aspect of the present disclosure, the organic layer is provided with a plurality of through-holes in a thickness direction, such that the second material layer and the electron injection layer are locally directly contacted with each other.

[0024] According to one aspect of the present disclosure, the organic layer is made of one chosen from Alq, MADN, TPBi, BCP and BPhen.

[0025] According to one aspect of the present disclosure, each of the first material layer and the second material layer has a thickness of less than 3nm.

[0026] According to one aspect of the present disclosure, each of the first material layer and the second material layer has a thickness of approximately 0.5nm.

[0027] According to one aspect of the present disclosure, the first material layer and the second material layer are made of the same material.

[0028] According to one aspect of the present disclosure, the first material layer and the second material layer are made of one chosen from Al, Ag, Mg, Au and Li.

[0029] According to one aspect of the present disclosure, the electron injection layer has a thickness of approximately 1nm.

[0030] According to one aspect of the present disclosure, the electron injection layer is made of organometallic complex compound or inorganic material.

[0031] According to one aspect of the present disclosure, the electron injection layer is made of alkali metal compound.

[0032] According to one aspect of the present disclosure, the electron injection layer is made of one chosen from LiF, LiQ, NaF, CsF and Cs_2CO_3.

[0033] According to one aspect of the present disclosure, the fourth material is an electron transport material.

[0034] According to one aspect of the present disclosure, the stacked organic light-emitting diode further comprises: a substrate; a first electrode disposed on the substrate, the at least two light-emitting units in a stacked arrangement being disposed on the first electrode, and the first electrode being a cathode.

[0035] According to one aspect of the present disclosure, there is provided a display device, comprising the stacked organic light-emitting diode described above.

[0036] By means of such charge generation layer comprising the first material layer, the electron injection layer and the second material layer, it can achieve excellent electron injection effect. Furthermore, based on the stacked organic light-emitting diode according to embodiments of the present disclosure, it can enable the second material layer (for example, a metal layer or a mixed material layer) to react with the electron injection layer when manufacturing the stacked organic light-emitting diode, even in the case of manufacturing an inverted-type stacked organic light-emitting diode (the lower electrode is a cathode), thereby achieving excellent electron injection effect. Thereby, the quality of the display device may be improved.

[0037] According to one aspect of the present disclosure, there is provided a manufacturing method of a stacked organic light-emitting diode, comprising steps of: forming a first light-emitting unit; forming a first material layer on the first light-emitting unit; forming an electron injection layer on the first material layer; forming a second material layer on the electron injection layer, the first material layer, the electron injection layer and the second material layer composing a charge generation layer; and forming a second light-emitting unit on the second material layer.

[0038] By means of such charge generation layer comprising the first material layer, the electron injection layer and the second material layer, it can achieve excellent electron injection effect. Furthermore, based on the manufacturing method of the stacked organic light-emitting diode according to embodiments of the present disclosure, it can enable the second material layer (for example, a metal layer or a mixed material layer) to react with the electron injection layer when manufacturing the stacked organic light-emitting diode, even in the case of manufacturing an inverted-type stacked organic light-emitting diode (the lower electrode is a cathode), thereby achieving excellent electron injection effect.

[0039] According to one aspect of the present disclosure, the first material layer is made of metal material.

[0040] According to one aspect of the present disclosure, the second material layer is made of metal material.

[0041] According to one aspect of the present disclo-

sure, the first material layer is made of metal material and the second material layer is made of metal material.

[0042] According to one aspect of the present disclosure, the manufacturing method of the stacked organic light-emitting diode further comprises a step of: forming an organic layer, on which the second material layer is formed, on the electron injection layer after forming the electron injection layer.

[0043] According to embodiments of the present disclosure, by means of forming the organic layer, on which the second material layer is formed, on the electron injection layer after forming the electron injection layer, the material of the electron injection layer may be reacted with the material of the organic layer when manufacturing the stacked organic light-emitting diode, thereby generating more excellent electron injection effect.

[0044] According to one aspect of the present disclosure, the first material layer is made of a first mixed material, which is formed by mixing at least one first material having a first electrical conductivity and at least one second material having a second electrical conductivity, the first electrical conductivity being greater than the second electrical conductivity.

[0045] According to one aspect of the present disclosure, the second material layer is made of a second mixed material, which is formed by mixing at least one third material having a third electrical conductivity and at least one fourth material having a fourth electrical conductivity, the third electrical conductivity being greater than the fourth electrical conductivity.

[0046] According to one aspect of the present disclosure, the first material layer is made of a first mixed material, which is formed by mixing at least one first material having a first electrical conductivity and at least one second material having a second electrical conductivity, the first electrical conductivity being greater than the second electrical conductivity, and the second material layer is made of a second mixed material, which is formed by mixing at least one third material having a third electrical conductivity and at least one fourth material having a fourth electrical conductivity, the third electrical conductivity being greater than the fourth electrical conductivity.

[0047] According to one aspect of the present disclosure, the first electrical conductivity is greater than 10^3 S/cm, and the second electrical conductivity is less than 10^{-6} S/cm.

[0048] According to one aspect of the present disclosure, the third electrical conductivity is greater than 10^3 S/cm, and the fourth electrical conductivity is less than 10^{-6} S/cm.

[0049] According to one aspect of the present disclosure, the first electrical conductivity is greater than 10^3 S/cm, and the second electrical conductivity is less than 10^{-6} S/cm, and the third electrical conductivity is greater than 10^3 S/cm, and the fourth electrical conductivity is less than 10^{-6} S/cm.

[0050] According to one aspect of the present disclosure, the first material is a metal material and the second material is an organic material.

[0051] According to one aspect of the present disclosure, the third material is a metal material and the fourth material is an organic material.

[0052] According to one aspect of the present disclosure, the first material is a metal material and the second material is an organic material, and the third material is a metal material and the fourth material is an organic material.

[0053] By means of the first material layer made of the first mixed material and/or the second material layer made of the second mixed material, especially when the mixed material consists of metal and organic material, a material layer with good uniformity may be formed, while an affection of a relatively thick material layer on the penetrance and a sideward electrically conducting problem may be avoided.

[0054] According to one aspect of the present disclosure, the organic layer is provided with a plurality of through-holes in a thickness direction, such that the second material layer and the electron injection layer are locally directly contacted with each other.

[0055] According to one aspect of the present disclosure, the organic layer is made of one chosen from Alq, MADN, TPBi, BCP and BPhen.

[0056] According to one aspect of the present disclosure, each of the first material layer and the second material layer has a thickness of less than 3nm.

[0057] According to one aspect of the present disclosure, each of the first material layer and the second material layer has a thickness of approximately 0.5nm.

[0058] According to one aspect of the present disclosure, the first material layer and the second material layer are made of the same material.

[0059] According to one aspect of the present disclosure, the first material layer and the second material layer are made of one chosen from Al, Ag, Mg, Au and Li.

[0060] According to one aspect of the present disclosure, the electron injection layer has a thickness of approximately 1nm.

[0061] According to one aspect of the present disclosure, the electron injection layer is made of organometallic complex compound or inorganic material.

[0062] According to one aspect of the present disclosure, the electron injection layer is made of alkali metal compound.

[0063] According to one aspect of the present disclosure, the electron injection layer is made of one chosen from LiF, LiQ, NaF, CsF and Cs_2CO_3.

[0064] According to one aspect of the present disclosure, the fourth material is an electron transport material.

[0065] According to one aspect of the present disclosure, the stacked organic light-emitting diode further comprises: a substrate; a first electrode disposed on the substrate, the at least two light-emitting units in a stacked arrangement being disposed on the first electrode, and the first electrode being a cathode.

BRIEF DESCRIPTION OF THE DRAWINGS

[0066]

Fig. 1 is a schematic view of a stacked organic light-emitting diode according to an embodiment of the present disclosure;

Fig. 2 is a schematic view of a stacked organic light-emitting diode according to another embodiment of the present disclosure; and

Fig. 3 is a flow chart of a manufacturing method of a stacked organic light-emitting diode according to an embodiment of the present disclosure.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0067] The embodiments of the present disclosure will be further described in detail below, in combination with the accompanying figures. Furthermore, for the purpose of explanation, many specific details are set forth in the detailed description below to provide a comprehensive understanding for the embodiments. However, obviously, one or more embodiments may be implemented without theses specific details. In other cases, well-known structures and devices are embodied in an illustration manner to simplify the accompanying figures.

[0068] Fig. 1 shows a stacked organic light-emitting diode according to an embodiment of the present disclosure. As shown in Fig. 1, the stacked organic light-emitting diode 100 according to the embodiment of the present disclosure comprises: at least two light-emitting units 103 in a stacked arrangement; and a charge generation layer 107 disposed between the adjacent light-emitting units 103. The charge generation layer 107 comprises a first material layer 1071, an electron injection layer 1072 disposed on the first material layer 1071 and a second material layer 1073 disposed on the electron injection layer 1072. The first material layer 1071 and the second material layer 1073 may be made of the same or different materials. By means of such charge generation layer 107 comprising the first material layer 1071, the electron injection layer 1072 and the second material layer 1073, it can achieve excellent electron injection effect. As shown in Fig. 1, the stacked organic light-emitting diode 100 according to the embodiment of the present disclosure may further comprise: a substrate (not shown); and a first electrode 101 disposed on the substrate, wherein the at least two light-emitting units 103 are disposed on the first electrode 101. The stacked organic light-emitting diode 100 further comprises a second electrode 108 disposed on the uppermost light-emitting unit 103. The first electrode 101 may be one of a cathode and an anode, while the second electrode 108 may be the other of the cathode and the anode.

[0069] According to some embodiments of the present disclosure, at least one of the first material layer 1071 and the second material layer 1073 is made of metal material. For example, the first material layer 1071 and the second material layer 1073 may be made of one chosen from Al, Ag, Mg, Au and Li, or any other suitable material. Based on the stacked organic light-emitting diode according to the embodiment of the present disclosure, since the second material layer 1073 is made of metal material, it can enable the material layer to react with the electron injection layer when manufacturing the stacked organic light-emitting diode, even in the case of manufacturing an inverted-type stacked organic light-emitting diode (the lower electrode is a cathode), thereby achieving excellent electron injection effect.

[0070] Optionally, according to other embodiments of the present disclosure, the first material layer 1071 is made of a first mixed material, which is formed by mixing at least one first material having a first electrical conductivity and at least one second material having a second electrical conductivity, wherein the first electrical conductivity is greater than the second electrical conductivity, and/or the second material layer 1073 is made of a second mixed material, which is formed by mixing at least one third material having a third electrical conductivity and at least one fourth material having a fourth electrical conductivity, wherein the third electrical conductivity is greater than the fourth electrical conductivity. The first electrical conductivity may be greater than 10^3 S/cm or 10^5 S/cm, and the second electrical conductivity may be less than 10^{-6} S/cm, and the third electrical conductivity may be greater than 10^3 S/cm or 10^5 S/cm, and the fourth electrical conductivity may be less than 10^{-6} S/cm. The first material layer 1071 and the second material layer 1073 form an electrically conductive layer. According to an example of the present disclosure, the weight percentage of the first material in the first mixed material is in a range of 5~95 or 45~75, while the weight percentage of the second material is in a range of 95~5 or 55~25, and the weight percentage of the third material in the second mixed material is in a range of 5~95 or 45~75, while the weight percentage of the fourth material is in a range of 95~5 or 55~25. Each of the first material and the third material is chosen from AlQ_3, ITO, IZO, AZO, FTO, ZnO, ZITO and GITO; or chosen from metallic oxides composed of at least two of In, Sn, Zn, Al, Fe and Ga; or chosen from Cs, Li, Na, K, Al, Ag, Ca, Li and Mg. Each of the second material and the fourth material is chosen from organic material or metallic oxide. For example, each of the second material and the fourth material may be chosen from Alq_3, Alq, MADN, TPBi, BCP, BPhen. The fourth material may be an electron transport material. By means of the first material layer 1071 made of the first mixed material and/or the second material layer 1073 made of the second mixed material, especially when the mixed material consists of metal and organic material, a material layer with good uniformity may be formed, while an affection of a relatively thick material layer on the penetrance and a sideward electrically con-

ducting problem may be avoided.

[0071] According to some embodiments of the present disclosure, each of the first material layer 1071 and the second material layer 1073 has a thickness of less than 3nm, for example, each of the first material layer 1071 and the second material layer 1073 has a thickness of approximately 0.5nm. The electron injection layer 1072 may have a thickness of approximately 1nm or of any other suitable values. By means of choosing suitable thickness of the various layers, a material layer with good uniformity may be formed, while an affection of a relatively thick material layer on the penetrance and a sideward electrically conducting problem may be avoided.

[0072] According to some embodiments of the present disclosure, as shown in Fig. 1, the light-emitting unit 103 may comprise an electron transport layer 1031, a light-emitting layer 1032 and a hole transport layer 1033, or comprise an electron injection layer, an electron transport layer 1031, a light-emitting layer 1032, a hole transport layer 1033 and a hole injection layer. The light-emitting unit 103 may be any suitable conventional light-emitting unit. The first electrode 101 and the second electrode 108 may be any suitable electrically conductive layer, including metal, metallic oxide or conductive polymer. One of the first electrode 101 and the second electrode 108 may be made of transparent conductive material, for example, the first electrode 101 is made of transparent conductive material.

[0073] According to some embodiments of the present disclosure, the electron injection layer 1072 is made of organometallic complex compound or inorganic material. According to other embodiments of the present disclosure, the electron injection layer 1072 is made of alkali metal compound. For example, the electron injection layer 1072 is made of one chosen from LiF, LiQ, NaF, CsF and Cs_2CO_3, or any other suitable materials.

[0074] According to the stacked organic light-emitting diode 100 of the embodiment of the present disclosure, the charge generation layer 107 comprises the electron injection layer 1072 disposed on the first material layer 1071 and the second material layer 1073 disposed on the electron injection layer 1072, therefore, the second material layer 1073 is manufactured after manufacturing the electron injection layer 1072. The heat energy generated during manufacturing of the second material layer 1073 enables the electron injection layer 1072 and the second material layer 1073 to produce chemical change, thereby causing the entire charge generation layer 107 to have more excellent electron injection effect. Therefore, it can enable the second material layer 1073 (for example, a metal layer or a mixed material layer) to react with the electron injection layer when manufacturing the stacked organic light-emitting diode, even in the case of manufacturing an inverted-type stacked organic light-emitting diode (the lower electrode is a cathode), thereby achieving excellent electron injection effect.

[0075] Fig. 2 shows a schematic view of a stacked organic light-emitting diode according to another embodiment of the present disclosure. This embodiment differs from the above described embodiment in that: the stacked organic light-emitting diode 100 further comprises an organic layer 1075 disposed between the electron injection layer 1072 and the second material layer 1073 in the case that the second material layer 1073 is made of metal. According to some embodiments of the present disclosure, the organic layer 1075 is provided with a plurality of through-holes in a thickness direction, such that the second material layer 1073 and the electron injection layer 1072 may be locally directly contacted with each other. Thereby, the metal layer may react with the electron injection layer when manufacturing the stacked organic light-emitting diode. The organic layer 1075 may be made of one chosen from Alq, MADN, TPBi, BCP and BPhen, or any other suitable materials.

[0076] Based on the stacked organic light-emitting diode 100 according to the embodiment of the present disclosure, it can enable the second material layer 1073 to react with the electron injection layer when manufacturing the stacked organic light-emitting diode, even in the case of manufacturing an inverted-type stacked organic light-emitting diode (the lower electrode is a cathode), thereby achieving excellent electron injection effect. In addition, by means of the organic layer 1075 disposed between the electron injection layer 1072 and the second material layer 1073, the electron injection effect is further improved.

[0077] According to an embodiment of the present disclosure, there is provided a display device, comprising the stacked organic light-emitting diode 100 described above, for example, an organic light-emitting diode (OLED) display device.

[0078] As mentioned above, based on the stacked organic light-emitting diode 100 according to the embodiment of the present disclosure, it can enable the second material layer 1073 (for example, a metal layer of a mixed material layer) to react with the electron injection layer when manufacturing the stacked organic light-emitting diode, even in the case of manufacturing an inverted-type stacked organic light-emitting diode (the lower electrode is a cathode), thereby achieving excellent electron injection effect. Therefore, it may achieve a high-quality display device.

[0079] Next, a manufacturing method of a stacked organic light-emitting diode according to an embodiment of the present disclosure will be described.

[0080] Fig. 3 shows a flow chart of a manufacturing method of a stacked organic light-emitting diode according to an embodiment of the present disclosure. Referring to Fig.

3 in combination with Figs. 1 and 2, the manufacturing method of the stacked organic light-emitting diode according to an embodiment of the present disclosure comprises steps of:

step S100: forming a first light-emitting unit 103;

step S200: forming a first material layer 1071 on the first light-emitting unit 103;
step S300: forming an electron injection layer 1072 on the first material layer 1071;
step S400: forming a second material layer 1073 on the electron injection layer 1072; and
step S500: forming a second light-emitting unit 103 on the second material layer 1073.

[0081] The first material layer 1071, the electron injection layer 1072 and the second material layer 1073 compose a charge generation layer 107. The first material layer 1071 and the second material layer 1073 may be made of the same or different materials.

[0082] Referring to Figs. 1 and 2, the manufacturing method of the stacked organic light-emitting diode according to the embodiment of the present disclosure may further comprise steps of: providing a substrate before forming the first light-emitting unit 103; and forming a first electrode 101 on the substrate. The step S100 of forming the first light-emitting unit 103 comprises forming the first light-emitting unit 103 on the first electrode 101.

[0083] According to some embodiments of the present disclosure, in the case that the second material layer 1073 is made of metal, the manufacturing method of the stacked organic light-emitting diode 100 further comprises a step of: forming an organic layer 1075, on which the second material layer 1073 is formed, on the electron injection layer 1072 after forming the electron injection layer 1072. The organic layer 1075 is provided with a plurality of through-holes in a thickness direction, such that the second material layer 1073 and the electron injection layer 1072 may be locally directly contacted with each other.

[0084] According to some embodiments of the present disclosure, the manufacturing method of the stacked organic light-emitting diode 100 further comprises a step of: forming a second electrode 108 on the uppermost light-emitting unit 103.

[0085] According to the embodiment of the present disclosure, the first electrode 101 is firstly formed, the light-emitting units 103 and the charge generation layers 107 are then formed alternately, a final light-emitting units 103 is then formed, and the second electrode 108 is formed on the uppermost light-emitting unit 103, as a result, the stacked organic light-emitting diode 100 is formed. The first electrode 101 may be one of a cathode and an anode, while the second electrode 108 may be the other of the cathode and the anode. By means of such charge generation layer 107 comprising the first material layer 1071, the electron injection layer 1072 and the second material layer 1073, it can achieve excellent electron injection effect.

[0086] According to some embodiments of the present disclosure, at least one of the first material layer 1071 and the second material layer 1073 is made of metal material. For example, the first material layer 1071 and the second material layer 1073 may be made of one chosen from Al, Ag, Mg, Au and Li, or any other suitable material. Based on the stacked organic light-emitting diode according to the embodiment of the present disclosure, since the second material layer 1073 is made of metal material, it can enable the material layer to react with the electron injection layer when manufacturing the stacked organic light-emitting diode, even in the case of manufacturing an inverted-type stacked organic light-emitting diode (the lower electrode is a cathode), thereby achieving excellent electron injection effect.

[0087] As an option, according to other embodiments of the present disclosure, the first material layer 1071 is made of a first mixed material, which is formed by mixing at least one first material having a first electrical conductivity and at least one second material having a second electrical conductivity, wherein the first electrical conductivity is greater than the second electrical conductivity, and/or the second material layer 1073 is made of a second mixed material, which is formed by mixing at least one third material having a third electrical conductivity and at least one fourth material having a fourth electrical conductivity, wherein the third electrical conductivity is greater than the fourth electrical conductivity. The first electrical conductivity may be greater than 10^3 S/cm or 10^5 S/cm, and the second electrical conductivity may be less than 10^{-6} S/cm, and the third electrical conductivity may be greater than 10^3 S/cm or 10^5 S/cm, and the fourth electrical conductivity may be less than 10^{-6} S/cm. The first material layer 1071 and the second material layer 1073 form an electrically conductive layer. According to an example of the present disclosure, the weight percentage of the first material in the first mixed material is in a range of 5~95 or 45~75, while the weight percentage of the second material is in a range of 95~5 or 55~25, and the weight percentage of the third material in the second mixed material is in a range of 5~95 or 45~75, while the weight percentage of the fourth material is in a range of 95~5 or 55~25. Each of the first material and the third material is chosen from AlQ_3, ITO, IZO, AZO, FTO, ZnO, ZITO and GITO; or chosen from metallic oxides composed of at least two of In, Sn, Zn, Al, Fe and Ga; or chosen from Cs, Li, Na, K, Al, Ag, Ca, Li and Mg. Each of the second material and the fourth material is chosen from organic material or metallic oxide. Each of the second material and the fourth material may be chosen from Alq_3, Alq, MADN, TPBi, BCP, BPhen. The fourth material may be an electron transport material. By means of the first material layer 1071 made of the first mixed material and/or the second material layer 1073 made of the second mixed material, especially when the mixed material consists of metal and organic material, a material layer with good uniformity may be formed, while an affection of a relatively thick material layer on the penetrance and a sideward electrically conductiing problem may be avoided.

[0088] According to some embodiments of the present disclosure, the organic layer 1075 is made of one chosen from Alq, MADN, TPBi, BCP and BPhen, or any other

suitable materials. The electron injection layer 1072 may be made of organometallic complex compound or inorganic material, or the electron injection layer 1072 is made of alkali metal compound. For example, the electron injection layer 1072 is made of one chosen from LiF, LiQ, NaF, CsF and Cs_2CO_3, or any other suitable materials.

[0089] Each of the first material layer 1071 and the second material layer 1073 may have a thickness of less than 3nm, for example, each of the first material layer 1071 and the second material layer 1073 has a thickness of approximately 0.5nm. The electron injection layer 1072 may have a thickness of approximately 1nm or any other suitable thicknesses. By means of choosing suitable thickness of the various layers, a material layer with good uniformity may be formed, while an affection of a relatively thick material layer on the penetrance and a sideward electrically conducting problem may be avoided.

[0090] In an example of the present disclosure, referring to Figs. 1 and 2, the stacked organic light-emitting diode 100 comprises: a substrate (not shown); a first electrode 101 disposed on the substrate, a light-emitting unit 103 (including an electron injection layer, an electron transport layer 1031, a light-emitting layer 1032, a hole transport layer 1033, a hole injection layer) disposed on the first electrode 101, a charge generation layer 107 (including a first material layer1071(Al, 0.5nm thickness), an electron injection layer 1072 (LiQ, 1nm thickness) disposed on the first material layer 1071 and a second material layer 1073 (Al, 0.5nm thickness) disposed on the electron injection layer 1072) disposed on the light-emitting unit 103, a light-emitting unit 103, a charge generation layer 107, ..., a light-emitting unit 103, a second electrode 108.

[0091] In an example of the present disclosure, referring to Fig. 1, the stacked organic light-emitting diode 100 comprises: a substrate (not shown); a first electrode 101 disposed on the substrate, a light-emitting unit 103 (including an electron injection layer, an electron transport layer 1031, a light-emitting layer 1032, a hole transport layer 1033, a hole injection layer) disposed on the first electrode 101, a charge generation layer 107 (including a first material layer1071(a mixture of MADN and Ag, 0.5nm thickness), an electron injection layer 1072 (LiQ, 1nm thickness) disposed on the first material layer 1071 and a second material layer 1073 (a mixture of Alq_3 and Al, 0.5nm thickness) disposed on the electron injection layer 1072) disposed on the light-emitting unit 103, a light-emitting unit 103, a charge generation layer 107, ..., a light-emitting unit 103, a second electrode 108.

[0092] As mentioned above, based on the manufacturing method of the stacked organic light-emitting diode 100 according to the embodiment of the present disclosure, by means of such charge generation layer comprising the first material layer, the electron injection layer and the second material layer, it can achieve excellent electron injection effect. Furthermore, based on the manufacturing method of the stacked organic light-emitting diode 100 according to the embodiment of the present disclosure, the second material layer 1073 is manufactured after manufacturing the electron injection layer 1072. The heat energy generated during manufacturing the second material layer 1073 enables the electron injection layer 1072 and the second material layer 1073 (a metal layer or a mixed material layer) to produce chemical change, thereby causing the entire charge generation layer 107 to have more excellent electron injection effect. Therefore, it can enable the second material layer 1073 (for example, a metal layer or a mixed material layer) to react with the electron injection layer when manufacturing the stacked organic light-emitting diode, even in the case of manufacturing an inverted-type stacked organic light-emitting diode (the lower electrode is a cathode), thereby achieving excellent electron injection effect. The manufacturing method of the stacked organic light-emitting diode 100 according to the embodiment of the present disclosure may be used in the manufacture of a usual stacked organic light-emitting diode (the lower electrode is an anode), furthermore, it may also be used in the manufacture of an inverted-type stacked organic light-emitting diode (the lower electrode is a cathode).

[0093] According to the embodiment of the present disclosure, in the case that the second material layer 1073 is made of metal, an organic layer 1075, on which the second material layer 1073 is formed, is formed on the electron injection layer 1072 after forming the electron injection layer 1072. As a result, the material of the electron injection layer may be reacted with the material of the organic layer, thereby generating more excellent electron injection effect.

[0094] The above embodiments are merely intended to describe the present disclosure, rather than limiting the present disclosure. Various changes and modifications may be made to the present disclosure by the person skilled in the art without departing from the spirit and scope of the present disclosure. Therefore, all equivalent technical solutions fall into the scope of the present disclosure, and the protection scope of the present disclosure is defined by the accompanying claims.

Claims

1. A stacked organic light-emitting diode, comprising:

   at least two light-emitting units in a stacked arrangement; and
   a charge generation layer disposed between the adjacent light-emitting units,

   wherein the charge generation layer comprises a first material layer, an electron injection layer disposed on the first material layer and a second material layer disposed on the electron injection layer.

2. The stacked organic light-emitting diode according

to claim 1, wherein the first material layer is made of metal material.

3. The stacked organic light-emitting diode according to claim 1, wherein the second material layer is made of metal material.

4. The stacked organic light-emitting diode according to claim 1, wherein the first material layer is made of metal material and the second material layer is made of metal material.

5. The stacked organic light-emitting diode according to claim 1, wherein the first material layer is made of a first mixed material, which is formed by mixing at least one first material having a first electrical conductivity and at least one second material having a second electrical conductivity, the first electrical conductivity being greater than the second electrical conductivity.

6. The stacked organic light-emitting diode according to claim 1, wherein the second material layer is made of a second mixed material, which is formed by mixing at least one third material having a third electrical conductivity and at least one fourth material having a fourth electrical conductivity, the third electrical conductivity being greater than the fourth electrical conductivity.

7. The stacked organic light-emitting diode according to claim 1, wherein the first material layer is made of a first mixed material, which is formed by mixing at least one first material having a first electrical conductivity and at least one second material having a second electrical conductivity, the first electrical conductivity being greater than the second electrical conductivity, and
wherein the second material layer is made of a second mixed material, which is formed by mixing at least one third material having a third electrical conductivity and at least one fourth material having a fourth electrical conductivity, the third electrical conductivity being greater than the fourth electrical conductivity.

8. The stacked organic light-emitting diode according to claim 5, wherein the first electrical conductivity is greater than 10^3 S/cm, and the second electrical conductivity is less than 10^{-6} S/cm.

9. The stacked organic light-emitting diode according to claim 6, wherein the third electrical conductivity is greater than 10^3 S/cm, and the fourth electrical conductivity is less than 10^{-6} S/cm.

10. The stacked organic light-emitting diode according to claim 7, wherein the first electrical conductivity is greater than 10^3 S/cm, and the second electrical conductivity is less than 10^{-6} S/cm, and
wherein the third electrical conductivity is greater than 10^3 S/cm, and the fourth electrical conductivity is less than 10^{-6} S/cm.

11. The stacked organic light-emitting diode according to claim 5, wherein the first material is a metal material and the second material is an organic material.

12. The stacked organic light-emitting diode according to claim 6, wherein the third material is a metal material and the fourth material is an organic material.

13. The stacked organic light-emitting diode according to claim 7, wherein the first material is a metal material and the second material is an organic material, and
wherein the third material is a metal material and the fourth material is an organic material.

14. The stacked organic light-emitting diode according to claim 3 or 4, further comprising an organic layer disposed between the electron injection layer and the second material layer.

15. The stacked organic light-emitting diode according to claim 14, wherein the organic layer is provided with a plurality of through-holes in a thickness direction, such that the second material layer and the electron injection layer are locally directly contacted with each other.

16. The stacked organic light-emitting diode according to claim 14, wherein the organic layer is made of one chosen from Alq, MADN, TPBi, BCP and BPhen.

17. The stacked organic light-emitting diode according to any one of claims 1-16, wherein each of the first material layer and the second material layer has a thickness of less than 3nm.

18. The stacked organic light-emitting diode according to any one of claims 1-17, wherein each of the first material layer and the second material layer has a thickness of approximately 0.5nm.

19. The stacked organic light-emitting diode according to any one of claims 1-10, wherein the first material layer and the second material layer are made of the same material.

20. The stacked organic light-emitting diode according to claim 4, wherein the first material layer and the second material layer are made of one chosen from Al, Ag, Mg, Au and Li.

21. The stacked organic light-emitting diode according

to any one of claims 1-20, wherein the electron injection layer has a thickness of approximately 1nm.

22. The stacked organic light-emitting diode according to any one of claims 1-21, wherein the electron injection layer is made of organometallic complex compound or inorganic material.

23. The stacked organic light-emitting diode according to any one of claims 1-22, wherein the electron injection layer is made of alkali metal compound.

24. The stacked organic light-emitting diode according to any one of claims 1-20, wherein the electron injection layer is made of one chosen from LiF, LiQ, NaF, CsF and Cs_2CO_3.

25. The stacked organic light-emitting diode according to any one of claims 6, 7, 9, 10, 12 and 13, wherein the fourth material is an electron transport material.

26. The stacked organic light-emitting diode according to any one of claims 1-25, further comprising:

a substrate;
a first electrode disposed on the substrate, the at least two light-emitting units in a stacked arrangement being disposed on the first electrode, and the first electrode being a cathode.

27. A display device, comprising the stacked organic light-emitting diode according to any one of claims 1-26.

28. A manufacturing method of a stacked organic light-emitting diode, comprising steps of:

forming a first light-emitting unit;
forming a first material layer on the first light-emitting unit;
forming an electron injection layer on the first material layer;
forming a second material layer on the electron injection layer, the first material layer, the electron injection layer and the second material layer composing a charge generation layer; and
forming a second light-emitting unit on the second material layer.

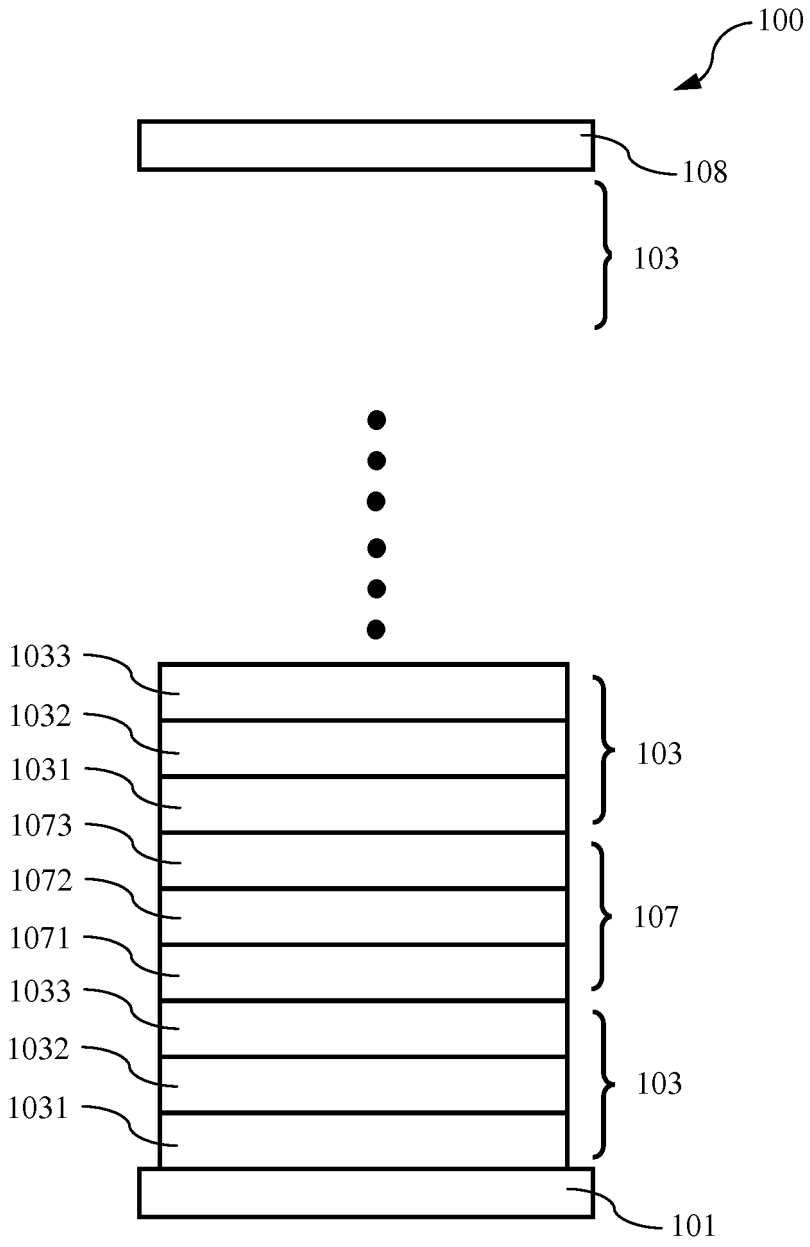
100
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Fig. 1

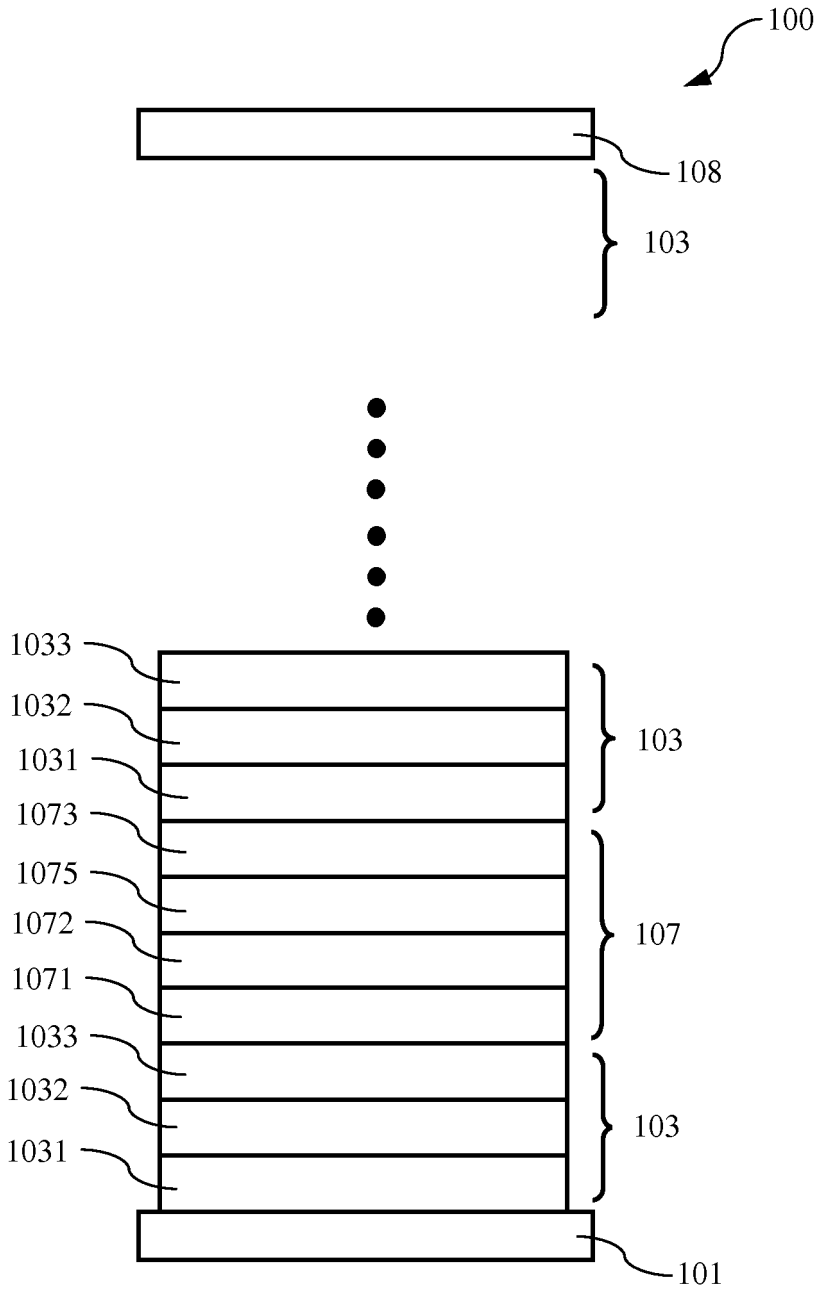
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Fig. 2

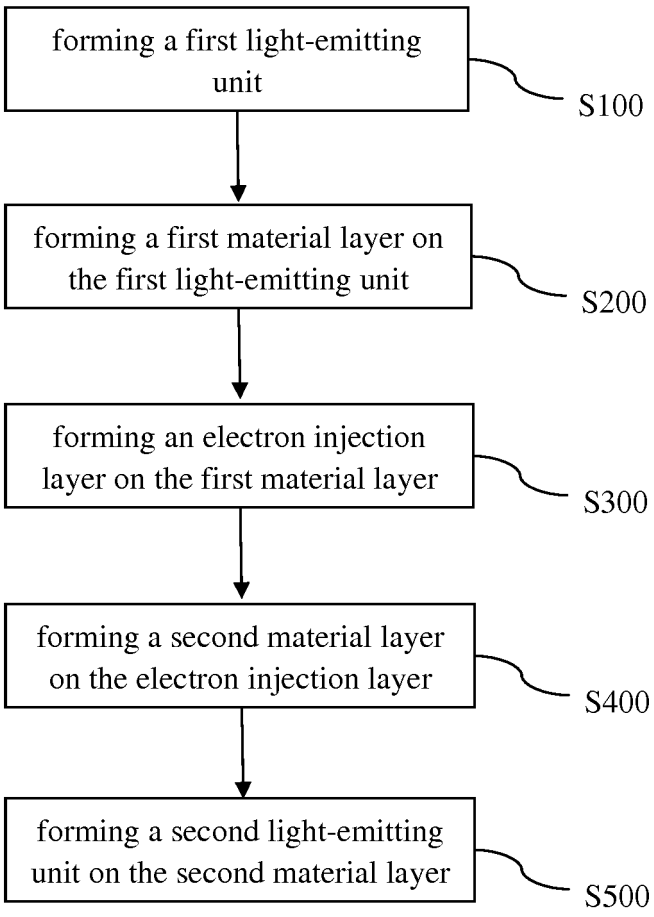
forming a first light-emitting unit
S100
forming a first material layer on the first light-emitting unit
S200
forming an electron injection layer on the first material layer
S300
forming a second material layer on the electron injection layer
S400
forming a second light-emitting unit on the second material layer
S500

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2015/091844

A. CLASSIFICATION OF SUBJECT MATTER

H01L 51/52 (2006.01) i; H01L 51/56 (2006.01) i
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L 51/

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
CPRS, CNTXT, VEN: electroluminescence, charge-generating layer, OLED, CGL, carrier, metal, organic

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 104051639 A (OCEAN'S KING LIGHTING SCIENCE & TECHNOLOGY CO., LTD. et al.), 17 September 2014 (17.09.2014), description, paragraphs 0002-0131, and figure 1	1, 5-13, 17-18, 21-28
Y	CN 104051639 A (OCEAN'S KING LIGHTING SCIENCE & TECHNOLOGY CO., LTD. et al.), 17 September 2014 (17.09.2014), description, paragraphs 0002-0131, and figure 1	2-4, 19-20
A	CN 104051639 A (OCEAN'S KING LIGHTING SCIENCE & TECHNOLOGY CO., LTD. et al.), 17 September 2014 (17.09.2014), description, paragraphs 0002-0131, and figure 1	14-16
Y	CN 104051661 A (OCEAN'S KING LIGHTING SCIENCE & TECHNOLOGY CO., LTD. et al.), 17 September 2014 (17.09.2014), claim 1, and description, paragraph 0127	2-4, 19-20
PX	CN 104466023 A (BOE TECHNOLOGY GROUP CO., LTD.), 25 March 2015 (25.03.2015), claims 1-28, and description, paragraphs 0003-0064	1-28

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 January 2016 (12.01.2016)	**27 January 2016 (27.01.2016)**
Name and mailing address of the ISA/CN: State Intellectual Property Office of the P. R. China No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088, China Facsimile No.: (86-10) 62019451	Authorized officer **ZHAO, Ying** Telephone No.: (86-10) **62089521**

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2015/091844

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 104051639 A	17 September 2014	None	
CN 104051661 A	17 September 2014	None	
CN 104466023 A	25 March 2015	None	

Form PCT/ISA/210 (patent family annex) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- CN 201410815361 **[0001]**

专利名称(译)	叠层有机发光二极管及其制备方法和显示装置		
公开(公告)号	EP3070759A4	公开(公告)日	2017-08-16
申请号	EP2015866399	申请日	2015-10-13
[标]申请(专利权)人(译)	京东方科技集团股份有限公司		
申请(专利权)人(译)	京东方科技集团股份有限公司.		
当前申请(专利权)人(译)	京东方科技集团有限公司		
[标]发明人	LIAO CHIN LUNG WU CHANG YEN		
发明人	LIAO, CHIN-LUNG WU, CHANG-YEN		
IPC分类号	H01L51/52 H01L51/56		
CPC分类号	H01L51/5221 H01L51/5012 H01L51/5072 H01L51/5092 H01L51/52 H01L51/5278 H01L51/56		
代理机构(译)	AWAPATENT AB		
优先权	201410815361.1 2014-12-24 CN		
其他公开文献	EP3070759A1		
外部链接	Espacenet		

摘要(译)

公开了堆叠有机发光二极管（100），显示装置和堆叠有机发光二极管（100）的制造方法。堆叠式有机发光二极管（100）包括堆叠排列的至少两个发光单元（103）和设置在相邻的发光单元（103）之间的电荷产生层（107），其中电荷产生层（107）包括第一材料层（1071），设置在第一材料层（1071）上的电子注入层（1072）和设置在电子注入层（1072）上的第二材料层（1073）。通过所述叠层有机发光二极管（100）及其制造方法，即使在制造倒置型叠层有机发光二极管（下电极为阴极）的情况下，也可以实现优异的电子注入效果。