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(54) **TOUCH-RESPONSIVE DISPLAY ASSEMBLY**

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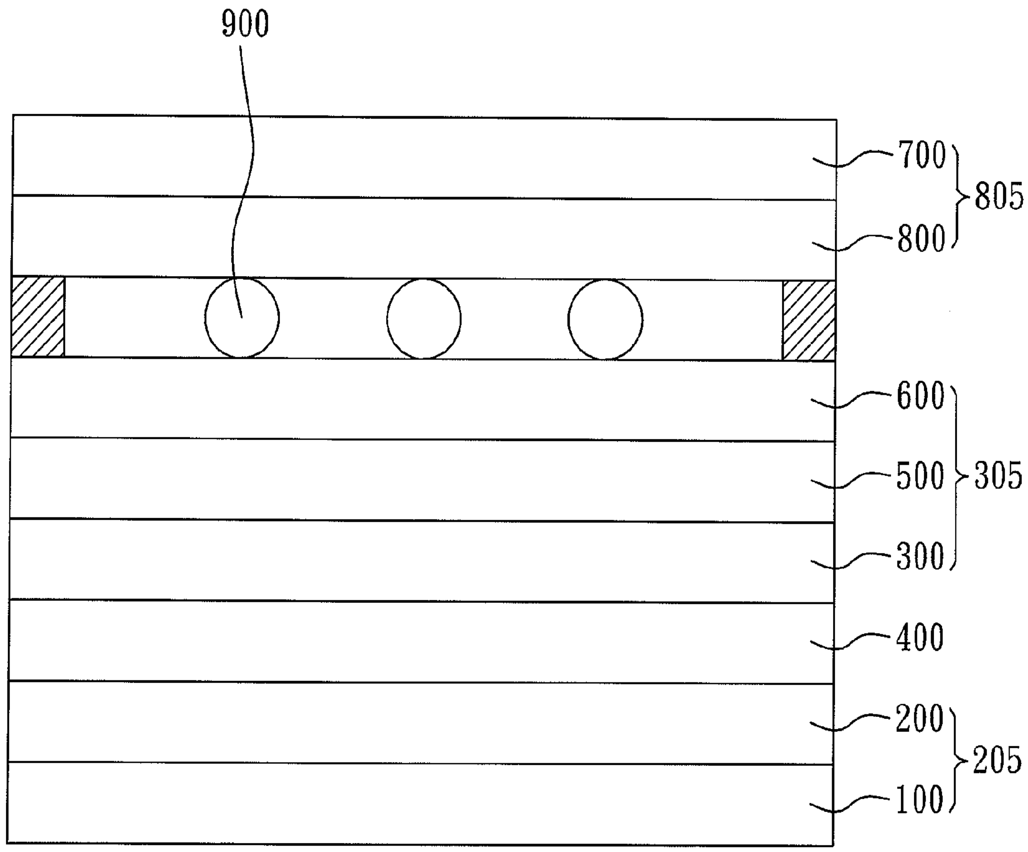
(57) **ABSTRACT**

A touch-responsive display assembly includes a touch panel. The touch panel includes: an anode, a cathode disposed over the anode, and an organic layered structure disposed between the anode and the cathode and including an organic electroluminescent layer that is emissive When a voltage is applied across the anode and the cathode. At least one of the anode and the cathode is made of a flexible film of a conductive nanomaterial that contains interconnected nanounits.



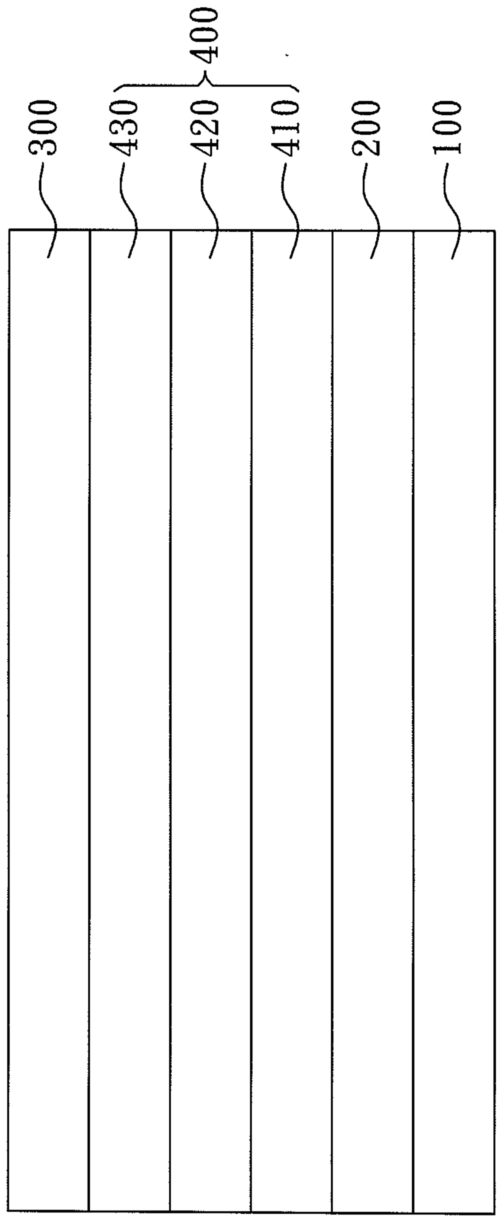


FIG. 1

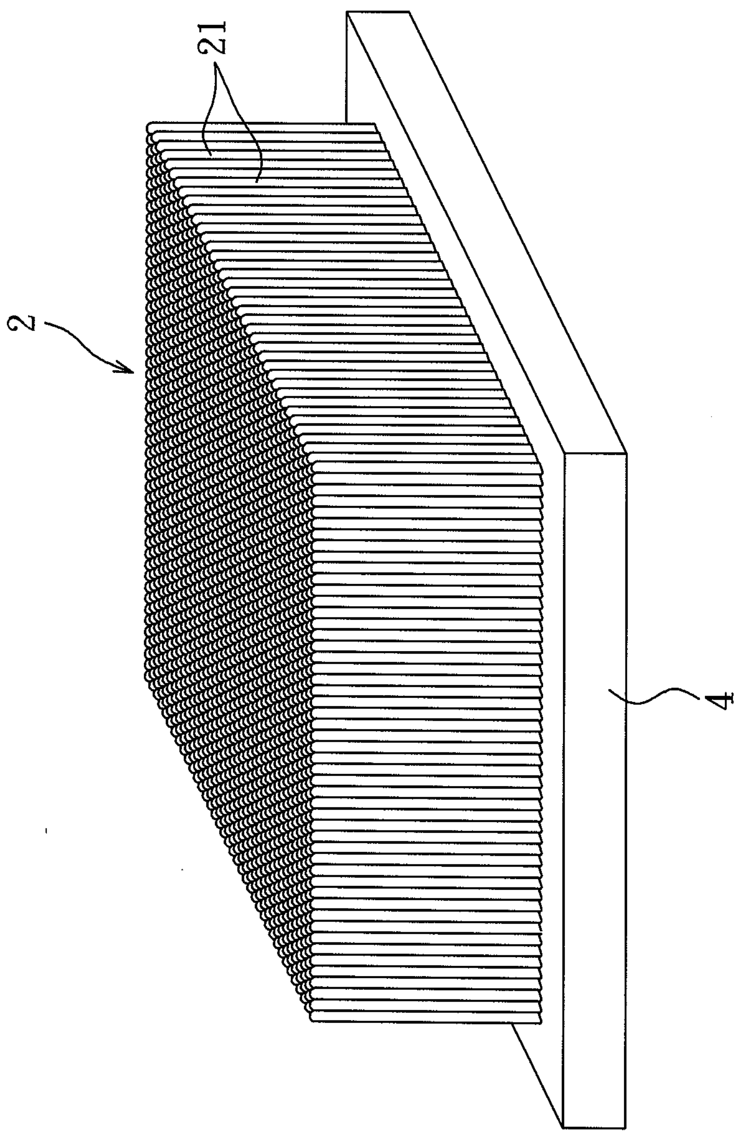


FIG. 2A

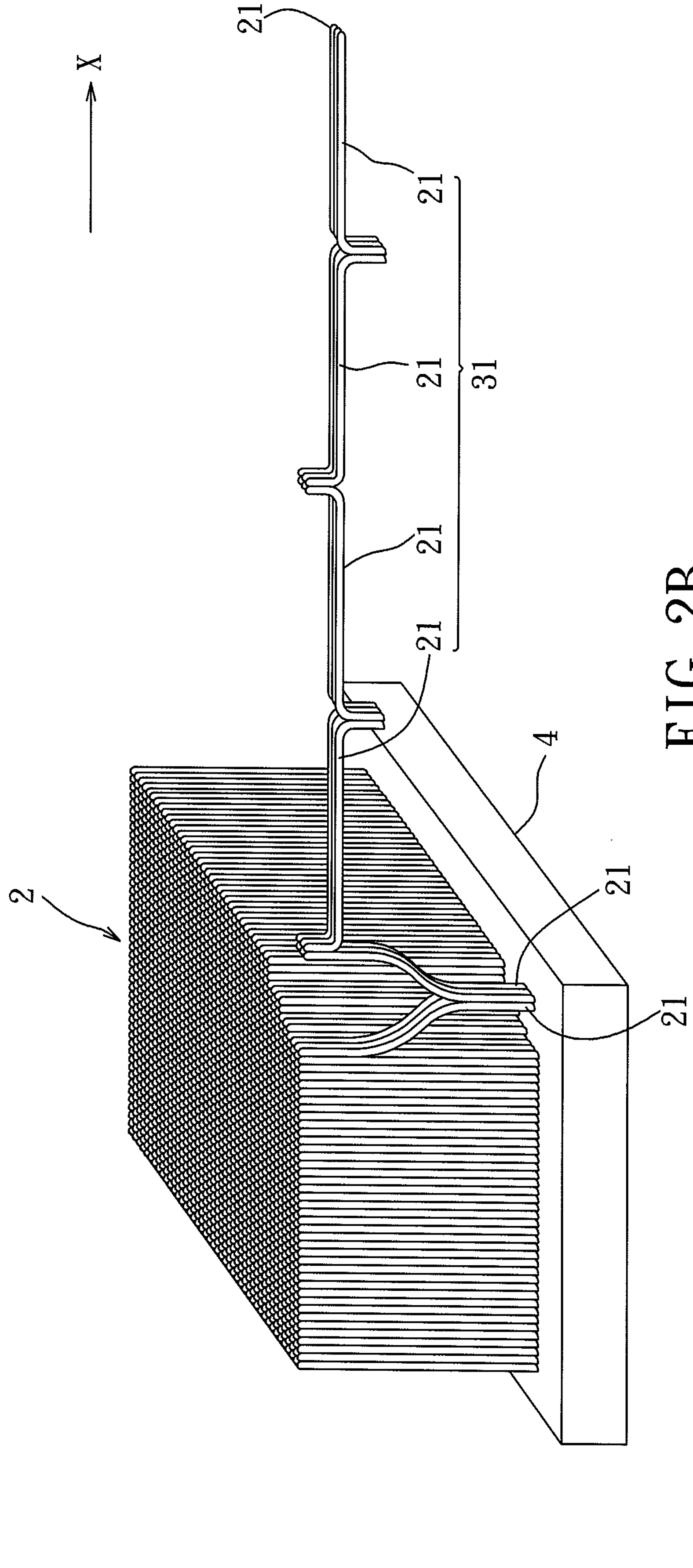


FIG. 2B

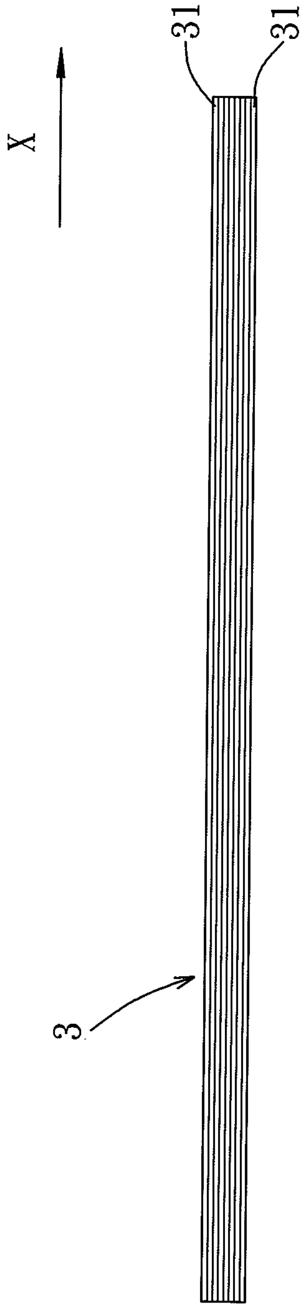


FIG. 2C

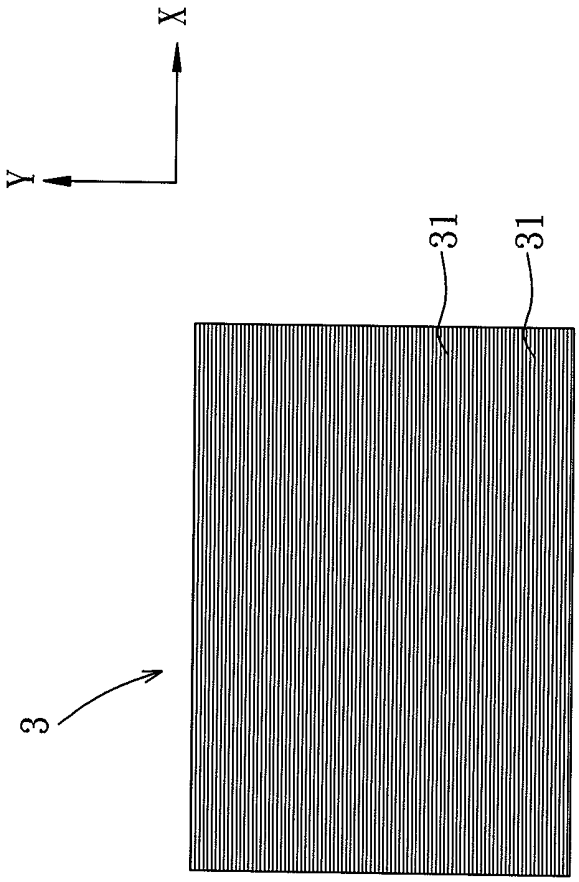


FIG. 2D

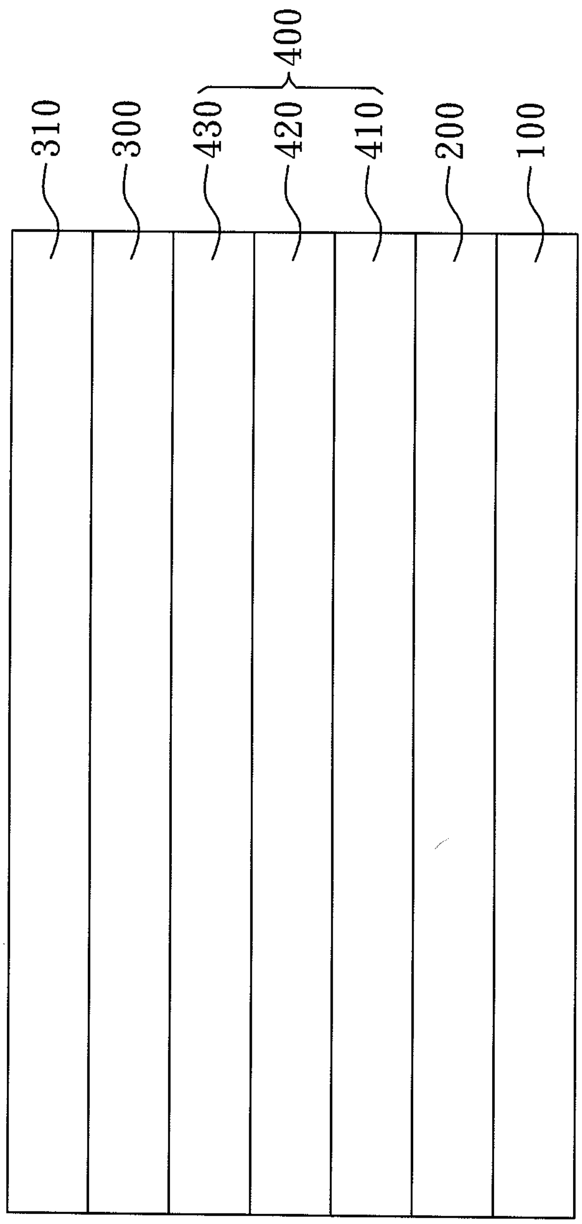


FIG. 3

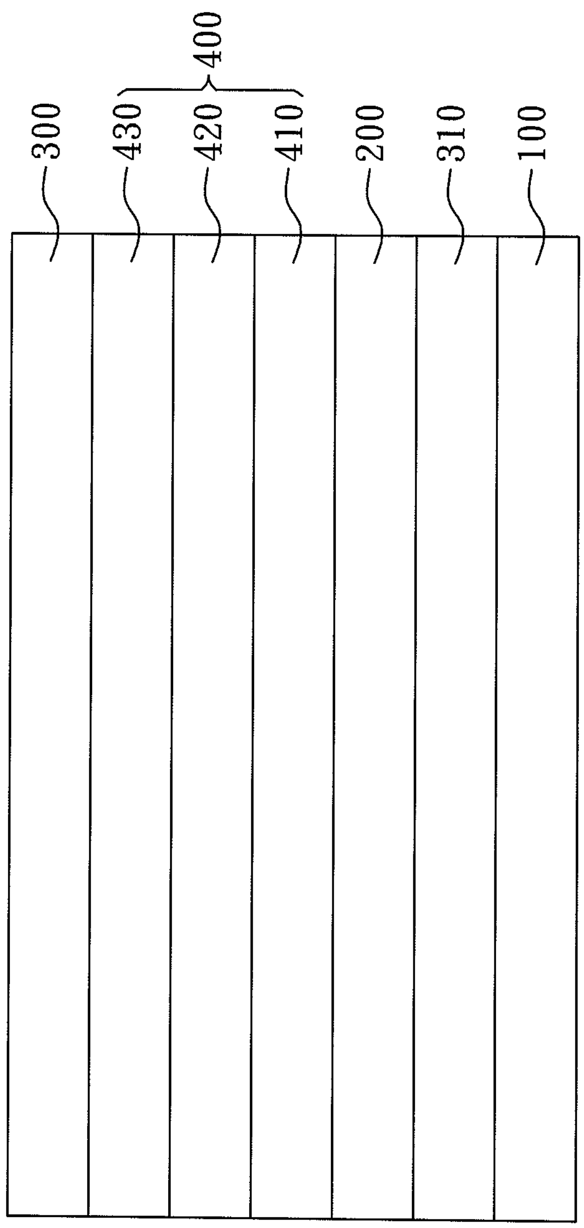


FIG. 4

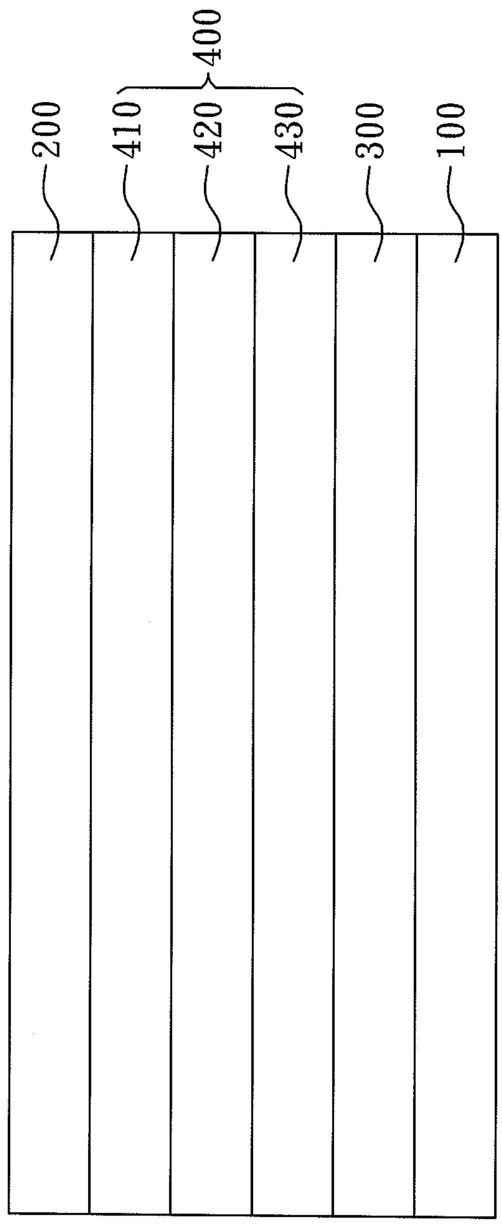


FIG. 5

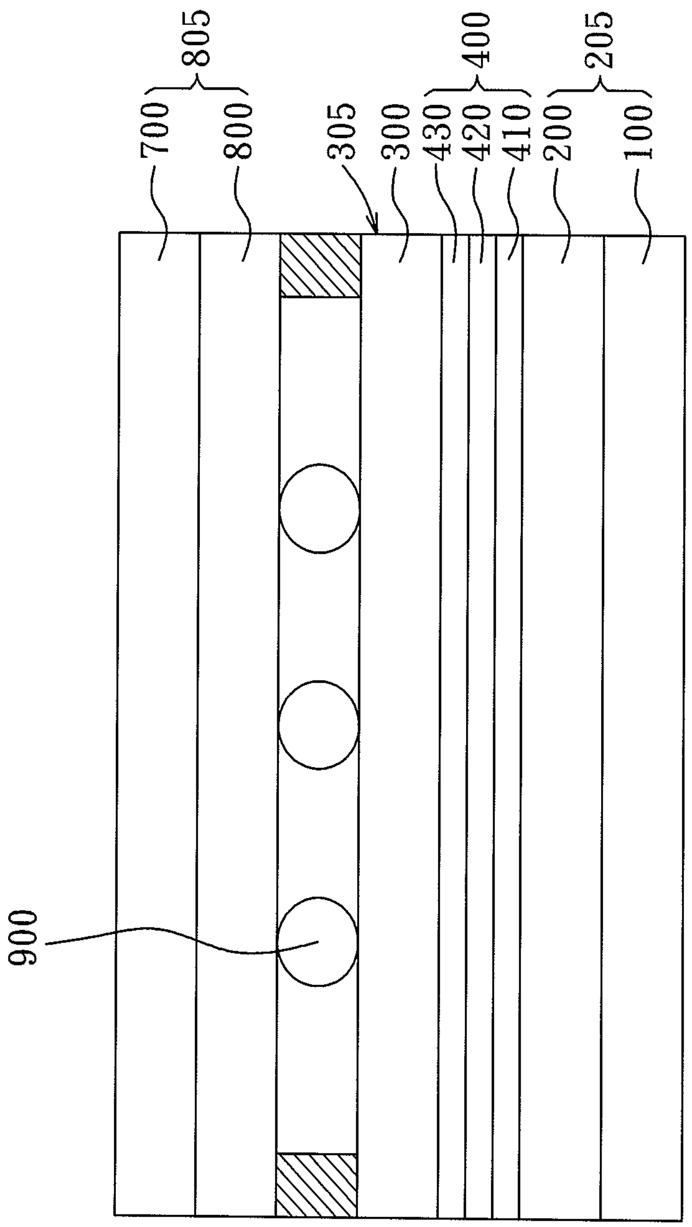


FIG. 6

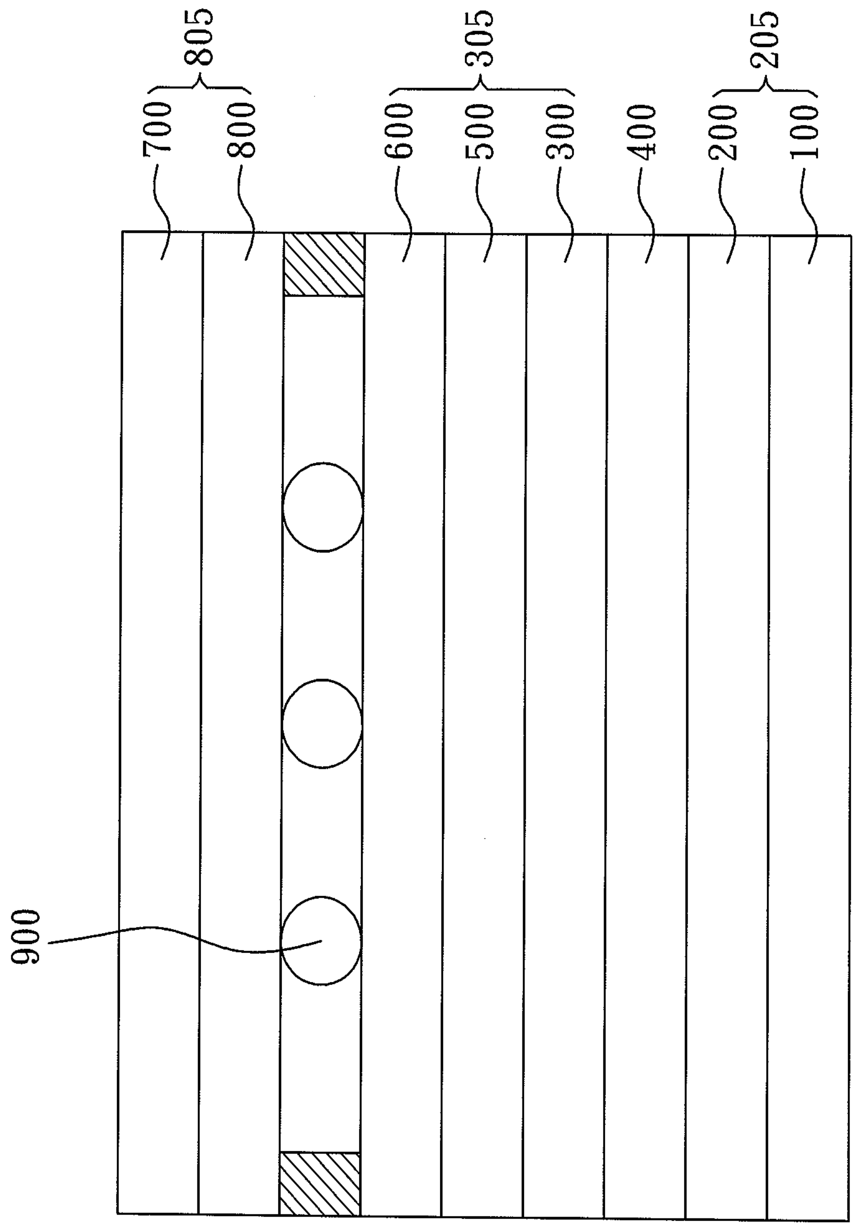


FIG. 7

TOUCH-RESPONSIVE DISPLAY ASSEMBLY

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a division of U.S. patent application Ser. No. **12/825,341** filed on Jun. **29**, **2010**, which claims priority of Chinese Patent application No. **200910304235.9**, filed on Jul. **10**, **2009**. The disclosures of both are incorporated herein by reference.

BACKGROUND

[0002] 1. Technical Field

[0003] The present disclosure relates to a display panel and a touch-responsive display assembly, and more particularly to a display panel and a touch-responsive display assembly including the display panel having at least one electrode that is includes a nanomaterial.

[0004] 2. Description of Related Art

[0005] A conventional organic electroluminescence display, which is also called organic light emitting diode (OLED) display, includes a substrate, an anode disposed on the substrate, a hole transport layer, an organic emitting layer, an electron transport layer, an electron injection layer, and a cathode. In operation, when a voltage is applied across the anode and the cathode, the anode gives electron holes to the organic emitting layer through the hole transport layer and the cathode gives electrons to the organic emitting layer through the electron injection layer and the electron transport layer. The electrons and the holes recombine in the organic emitting layer, thereby resulting in emission of light. The anode includes a conductive material with a high working function, such as indium tin oxide (ITO), tin oxide, or zinc oxide. Hence, the conventional OLED normally involves the use of a transparent substrate formed with an ITO film which serves as the anode. One advantage of the conventional OLED over other types of displays is that it can be flexible when using a flexible substrate. However, the ITO film serving as the anode of the conventional OLED tends to be severely deformed and damaged when the conventional OLED is bent.

SUMMARY

[0006] According to one aspect of the present disclosure, there is provided a display panel that comprises: an anode; a cathode disposed over the anode; and an organic layered structure disposed between the anode and the cathode and including an organic electroluminescent layer that is emissive when a voltage is applied across the anode and the cathode. At least one of the anode and the cathode is made of a flexible film of a conductive nanomaterial that contains interconnected nanounits.

[0007] According to another aspect of the present disclosure, there is provided a touch-responsive display assembly that comprises: a first electrode unit; a second electrode unit disposed over the first electrode unit; a third electrode unit disposed between the first and second electrode units; and an organic layered structure disposed between the first and third electrode units and having an organic electroluminescent layer that is emissive when a voltage is applied across the first and third electrode units. The second electrode unit is electrically coupled to the third electrode unit and cooperates with the third electrode unit to form a touch panel that is touch-responsive. At least one of the first, second and third electrode units includes a flexible film of a conductive nanomaterial that contains interconnected nanounits.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The components in the drawings are not necessarily drawn to scale, the emphasis instead being placed upon clearly illustrating the principles of at least one embodiment. In the drawings, like reference numerals designate corresponding parts throughout the various views.

[0009] FIG. **1** is a schematic side view of the first exemplary embodiment of a display panel of the present disclosure.

[0010] FIGS. **2**A and **2**B are perspective views to illustrate consecutive steps of how a material for an anode of the first exemplary embodiment can be prepared.

[0011] FIG. **2**C is a schematic side view of the material for the anode of the first exemplary embodiment.

[0012] FIG. **2**D is a schematic top view of the material for the anode of the first exemplary embodiment.

[0013] FIG. **3** is a schematic side view of the second exemplary embodiment of a display panel of the present disclosure.

[0014] FIG. **4** is a schematic side view of the third exemplary embodiment of a display panel of the present disclosure.

[0015] FIG. **5** is a schematic side view of the fourth exemplary embodiment of a display panel of the present disclosure.

[0016] FIG. **6** is a schematic side view of the first exemplary embodiment of a touch-responsive display assembly of the present disclosure.

[0017] FIG. **7** is a schematic side view of the second exemplary embodiment of a touch-responsive display assembly of the present disclosure.

DETAILED DESCRIPTION

[0018] Reference will now be made to the drawings to describe various embodiments in detail.

[0019] Referring to FIG. **1**, in combination with FIGS. **2**A to **2**D, the first exemplary embodiment of a display panel of the present disclosure includes: a lower substrate **100**; an anode **200** disposed on the lower substrate **100**; a cathode **300** disposed over the anode **200**; and an organic layered structure **400** disposed between the anode **200** and the cathode **300** and including a hole transport layer **410**, an electron transport layer **430**, and an organic electroluminescent layer **420** that is sandwiched between the hole transport layer **410** and the electron transport layer **430** and that is emissive when a voltage is applied across the anode **200** and the cathode **300**. The anode **200** is sandwiched between the lower substrate **100** and the hole transport layer **410**.

[0020] The lower substrate **100** can be a flexible transparent substrate of a polymeric material. Examples of the polymeric material include but are not limited to polymethylmethacrylate (PMMA) board, polyethylene terephthalate (PET) board, and polycarbonate (PC) board.

[0021] In the first exemplary embodiment, the anode **200** is transparent and is made of a flexible film **3** (see FIGS. **2**C and **2**D) of a conductive nanomaterial that contains strings **31** of interconnected nanounits **21** (see FIG. **2**B). The flexible film **3** exhibits electric anisotropy, (i.e., the flexible film **3** exhibits different resistivities in different directions). The interconnected nanounits **21** may be nanotube bundles, nanotubes or nanoparticles. In the embodiment, the interconnected nanounits **21** are carbon nanotube bundles. The carbon nanotube bundles extend along a stretching direction (X) (see FIG. **2**B). The strings **31** of the interconnected nanounits **21** are substantially parallel to each other, and are distributed and aligned along a second direction (Y) transverse to the first direction (X). The flexible film **3** has a much higher conductivity or a much lower resistance in the first direction (X) than that in the second direction (Y). For example, the resistance of the flexible film **3** in the second direction(Y) to the first direction (X) is about 50~350 times. The resistance of the flexible film **3** is between 1 Kilo-ohm per square and 800 Kilo-ohm per square based on the positions and the direction of the measurement. As illustrated in FIGS. **2**A and **2**B, the conductive nanomaterial of the conductive film **3** is prepared by forming a cluster **2** of the nanounits **21** on a supporting substrate **4** through deposition techniques, followed by pulling the nanounits **21** along the first direction (X) to make the nanounits **21** interconnected through Van der Waals' interaction to form the strings **31** and then stretching the strings **31** of the interconnected nanounits **21** to form the conductive nanomaterial.

[0022] The cathode **300** is includes a conductive material having a low working function for enhancing injection rate of electrons given by the cathode **300** to the organic electroluminescent layer **420**. The conductive material is made from metal or an alloy. Examples of metal suitable for the cathode **300** include but are not limited to Ag, Al, Li, Mg, Ca, In, for example. The alloy can be prepared, for instance, by vapor deposition of a chemically active metal with a low working function and a chemically stable metal with a high working function such that the chemically active metal and the chemically stable metal are mixed together in one single layer or are separated in different layers. Examples of the alloy include but are not limited to Mg/Ag, Li/Al, for example. In addition, the alloy can also includes an outer layer of aluminum and an inner layer of an ultra thin film of a metal oxide, such as LiF, Li2O, MgO, Al2O3, for example. The alloy thus formed can enhance the light emitting efficiency of the display panel and improves the I-V characteristics curve of the display panel.

[0023] Alternatively, the cathode **300** can include a conductive material, such as the aforesaid nanomaterial of the flexible film **3**, instead of the metal or alloy.

[0024] The hole transport layer **410** is made of a thermally stable transparent film that permits formation of a small energy barrier at an interface between the hole transport layer **410** and the anode **200** and that can achieve a structure free of pin holes when deposited through vacuum vapor deposition techniques. Examples of the hole transport layer **410** include but are not limited to aromatic tertiary amines.

[0025] The electron transport layer **430** is made of a transparent material that permits high electron transport rate and that exhibits good film forming ability and thermal stability. Examples of the electron transport layer **430** include but are not limited to aromatics with a large conjugated plane, such as Alq, PBD, Beq2, and DPVBi (the chemical names of the compounds can be referred to U.S. Pat. No. 6,433,355)

[0026] The organic electroluminescent layer **420** is made of a light-transmissible semiconductor material with a good film-forming property and a good thermal stability, and contains a fluorescent material with a high quantum efficiency. The semiconductor material can be polymers or low molecular weight organic compounds. The polymers are conductive or semi-conductive conjugated polymers with a molecular weight ranging from 10000 to 100000.

[0027] The polymers can be formed into a film using spin coating techniques, which is easy to conduct and which is cost effective. However, the purity of the polymers is required to be very high, which is difficult to be obtained. In addition, the resistance to degradation, the brightness and the color of the polymers are not competitive as compared to the low molecular weight organic compounds.

[0028] The low molecular weight organic compounds have a molecular weight ranging from 500 to 2000, can be formed into film by using vacuum vapor deposition techniques, and are organic dyes. The organic dyes are easy to be chemically modified, can be produced in a very high purity, and have a broad selectivity and a high quantum efficiency. Moreover, the organic dyes have various colors, including red, green and blue ,for example. However, the organic dyes tend to suffer from degradation when used in a solid state, which can result in widening of the emission peak and red shift of the emission peak. Hence, the organic dyes are required to be blended in a matrix containing charges. The matrix is normally made of a material the same as that of the hole transport layer **410** or the electron transport layer **430**.

[0029] Examples of the red dyes include but are not limited to Rhodamine, DCM, 2,4-dimethoxy-6-chloro-s-triazine (DCT), DCJT, DCJTB, DCJTI, and 1,1,4,4-tetrapheneyl-1,3-butadiene (TPBD) (the chemical names for the compounds DCM, DCJT and DCJTB and for the compound DCJTI can be referred to U.S. Pat. No. 5,935,720 and U.S. Pat. No. 7,582,508, respectively).

[0030] Examples of the green dyes include but are not limited to coumarin 6, quinacridone (qA), coronene, and naphthalimides.

[0031] Examples of the blue dyes include but are not limited to N-aryl-benzinidazole derivatives, 1,2,4-triazole (also used for electron transport layer **430**), and distyrylarylene.

[0032] In use, when a forward bias voltage is applied to the display panel, holes from the anode **200** are injected into the organic electroluminescent layer **420** through the hole transport layer **410**, and electrons are injected into the organic electroluminescent layer **420** through the electron transport layer **430**, and recombination of the holes and the electrons in the organic electroluminescent layer **420** subsequently takes place to generate sufficient energy for exciting the fluorescent material of the organic electroluminescent layer **420**, thereby resulting in emission of light.

[0033] By replacing the ITO film used in the conventional display panel with the flexible film of the nanomaterial for the anode **200**, the display panel thus formed can be bent without the problem as encountered in the prior art that causes damage to the flexible film and the manufacturing costs can be reduced.

[0034] FIG. **3** illustrates the second exemplary embodiment of a display panel of the present disclosure. The display panel of the second exemplary embodiment differs from the previous exemplary embodiment in that the display panel further includes a reflective layer **310** disposed on the cathode **300** for reflecting light emitted from the organic electroluminescent layer **420**. The cathode **300** is sandwiched between the reflective layer **310** and the electron transport layer **430**, and can include the transparent nanomaterial. Hence, the light emitted from the organic electroluminescent layer **420** toward the reflective layer **310** can be reflected by the reflective layer **310** and be directed toward the lower substrate **100** so as to exit from the lower substrate **100**.

[0035] FIG. **4** illustrates the third exemplary embodiment of a display panel of the present disclosure. The display panel of the third exemplary embodiment differs from the second exemplary embodiment in that the reflective layer **310** is sandwiched between the lower substrate **100** and the organic electroluminescent layer **420**. In this exemplary embodiment, the lower substrate **100** can be opaque. Moreover, the lower substrate **100** can be a colored opaque substrate or a colored transparent substrate. Hence, the light emitted from the organic electroluminescent layer **420** toward the reflective layer **310** can be reflected by the reflective layer **310** and be directed toward the cathode **300** so as to exit from the cathode **300**.

[0036] FIG. **5** illustrates the fourth exemplary embodiment of a display panel of the present disclosure. The display panel of the fourth exemplary embodiment differs from the first exemplary embodiment in that the cathode **300** is disposed on the lower substrate **100** instead of the anode **200**. In this exemplary embodiment, the cathode **300** is sandwiched between the lower substrate **100** and the electron transport layer **430**.

[0037] FIG. **6** illustrates the first exemplary embodiment of a touch-responsive display assembly of the present disclosure. The display assembly is an application of the display panel of the first exemplary embodiment. The display assembly includes: a first electrode unit **205**, a second electrode unit **805** disposed over the first electrode unit **205**, a third electrode unit **305** disposed between the first and second electrode units **205**, **805**, a spacer unit **900** of an insulator disposed between the second and third electrode units **805**, **305**, and the organic layered structure **400** disposed between the first and third electrode units **205**, **305**. At least one of the first and second electrode units **205**, **805** is transparent. The second electrode unit **805** is electrically coupled to the third electrode unit **305** and cooperates with the third electrode unit **305** to form a touch panel that is touch-responsive. At least one of the first, second and third electrode units **205**, **800**, **305** includes a flexible film of the aforesaid conductive nanomaterial that contains the interconnected nanounits.

[0038] In this exemplary embodiment, the first electrode unit **205** includes the lower substrate **100** and the anode **200** of the display panel of the first exemplary embodiment, the third electrode unit **305** includes the cathode **300** of the display panel of the first exemplary embodiment, and the second electrode unit **805** includes an upper electrode **800** disposed on the spacer unit **900**, and an upper substrate **700** disposed on the upper electrode **800**.

[0039] In this exemplary embodiment, the upper electrode **800** includes the aforesaid nanomaterial so as to exhibit electric anisotropy, the upper substrate **700** is flexible, and the touch panel thus formed is resistive touch-responsive. As such, when the upper substrate **700** of the touch panel is touched to permit electrical connection between the upper electrode **800** and the cathode **300**, which results in generation of a potential difference between two opposite detecting points on the touch panel attributed to the electric anisotropy property of the upper electrode **800**, the location of the touch point can be determined based on the measured potential difference and the positions of the two detecting points.

[0040] FIG. **7** illustrates the second exemplary embodiment of a touch-responsive display assembly of the present disclosure. The display assembly of the second exemplary embodiment differs from the display assembly of the first exemplary embodiment in that the third electrode unit **305** includes the cathode **300** disposed on the organic layered structure **400**, a middle substrate **500**, and a middle electrode **600** disposed on the middle substrate **500**. The middle substrate **500** is sandwiched between the cathode **300** and the middle electrode **600**.

[0041] For example, at least one of the upper electrode **800** and the middle electrode **600** is transparent and includes the nanomaterial. In the embodiment, the upper substrate **700** and the middle substrate **500** are flexible.

[0042] In sum, by using the conductive nanomaterial instead of the ITO as the material for the anode **200** or the cathode **300** of the flexible display panel of this disclosure, the aforesaid drawback associated with the prior art can be eliminated.

[0043] It is to be understood that even though numerous characteristics and advantages of the present embodiments have been set forth in the foregoing description, together with details of the structures and functions of the embodiments, the disclosure is illustrative only; and that changes may be made in detail, especially in matters of shape, size, and arrangement of parts, within the principles of the embodiments, to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

What is claimed is:

1. A touch-responsive display assembly, comprising:

a first electrode unit;

a second electrode unit disposed over said first electrode unit;

a third electrode unit disposed between said first and second electrode units; and

an organic layered structure disposed between said first and third electrode units and having an organic electroluminescent layer that is emissive when a voltage is applied across said first and third electrode units;

wherein said second electrode unit is electrically coupled to said third electrode unit and cooperates with said third electrode unit to form a touch panel that is touch-responsive; and

wherein at least one of said first, second and third electrode units includes a flexible film of a conductive nanomaterial that contains interconnected nanounits.

2. The touch-responsive display assembly of claim **1**, wherein said first electrode unit includes a lower substrate and an anode disposed on said lower substrate, said third electrode unit includes a cathode, and said organic layered structure is sandwiched between said cathode and said anode.

3. The touch-responsive display assembly of claim **2**, wherein said anode is transparent and includes the conductive nanomaterial.

4. The touch-responsive display assembly of claim **1**, wherein said flexible film exhibits electric anisotropy.

5. The touch-responsive display assembly of claim **1**, wherein said interconnected nanounits of said conductive nanomaterial are carbon nanotube bundles.

6. The touch-responsive display assembly of claim **1**, wherein said interconnected nanounits of said conductive nanomaterial extend along a direction.

7. The touch-responsive display assembly of claim **1**, further comprising a spacer unit of an insulator disposed between said second and third electrode units.

8. The touch-responsive display assembly of claim **7**, wherein said third electrode unit further includes a middle substrate disposed on said cathode and a middle electrode sandwiched between said middle substrate and said spacer unit.

9. The touch-responsive display assembly of claim **8**, wherein said second electrode unit includes an upper substrate and an upper electrode sandwiched between said spacer unit and said upper substrate, said spacer unit separating said upper and middle electrodes apart from each other.

10. The touch-responsive display assembly of claim **9**, wherein at least one of said upper and middle electrodes includes the conductive nanomaterial.

11. The touch-responsive display assembly of claim **10**, wherein said flexible film exhibits electric anisotropy.

12. The touch-responsive display assembly of claim **10**, wherein said interconnected nanounits of said conductive nanomaterial are carbon nanotube bundles.

13. The touch-responsive display assembly of claim **10**, wherein said interconnected nanounits of said conductive nanomaterial extend along a direction.

* * * * *

专利名称(译)	触摸响应显示组件		
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[标]申请(专利权)人(译)	群创光电股份有限公司		
申请(专利权)人(译)	奇美群创光电		
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外部链接	Espacenet USPTO		

摘要(译)

触摸响应显示组件包括触摸板。触摸面板包括：阳极，设置在阳极上的阴极，以及设置在阳极和阴极之间的有机层状结构，并且包括当在阳极和阴极之间施加电压时发射的有机电致发光层。阳极和阴极中的至少一个由导电纳米材料的柔性膜制成，该导电纳米材料包含互连的纳米材料。