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(19) **United States**(12) **Patent Application Publication****Liu et al.**(10) **Pub. No.: US 2009/0268139 A1**(43) **Pub. Date: Oct. 29, 2009**(54) **LIQUID CRYSTAL DISPLAY**

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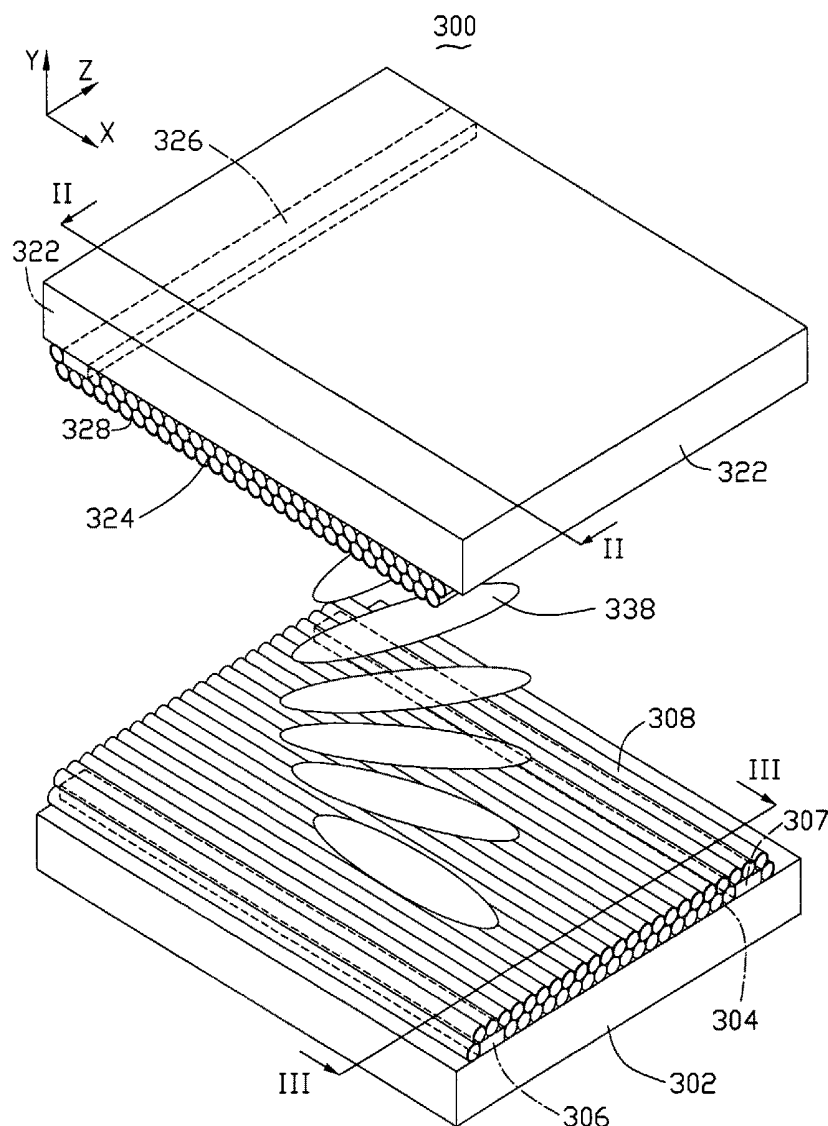
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G02F 1/1337 (2006.01)(52) **U.S. Cl.** **349/123; 977/742**(57) **ABSTRACT**

A liquid crystal display includes a first substrate, a first alignment layer, a liquid crystal layer, a second alignment layer, and a second substrate opposite to the first substrate, a first electrode and a second electrode. The liquid crystal layer is sandwiched between the first substrate and the second substrate. The first alignment layer is located on the first substrate and face the liquid crystal layer. The second alignment layer is located on the second substrate and face the liquid crystal layer. Furthermore, at least one of the first and second alignment layers comprises a carbon nanotube structure, and the carbon nanotube structure is electrically connected to the first electrode and the second electrode.



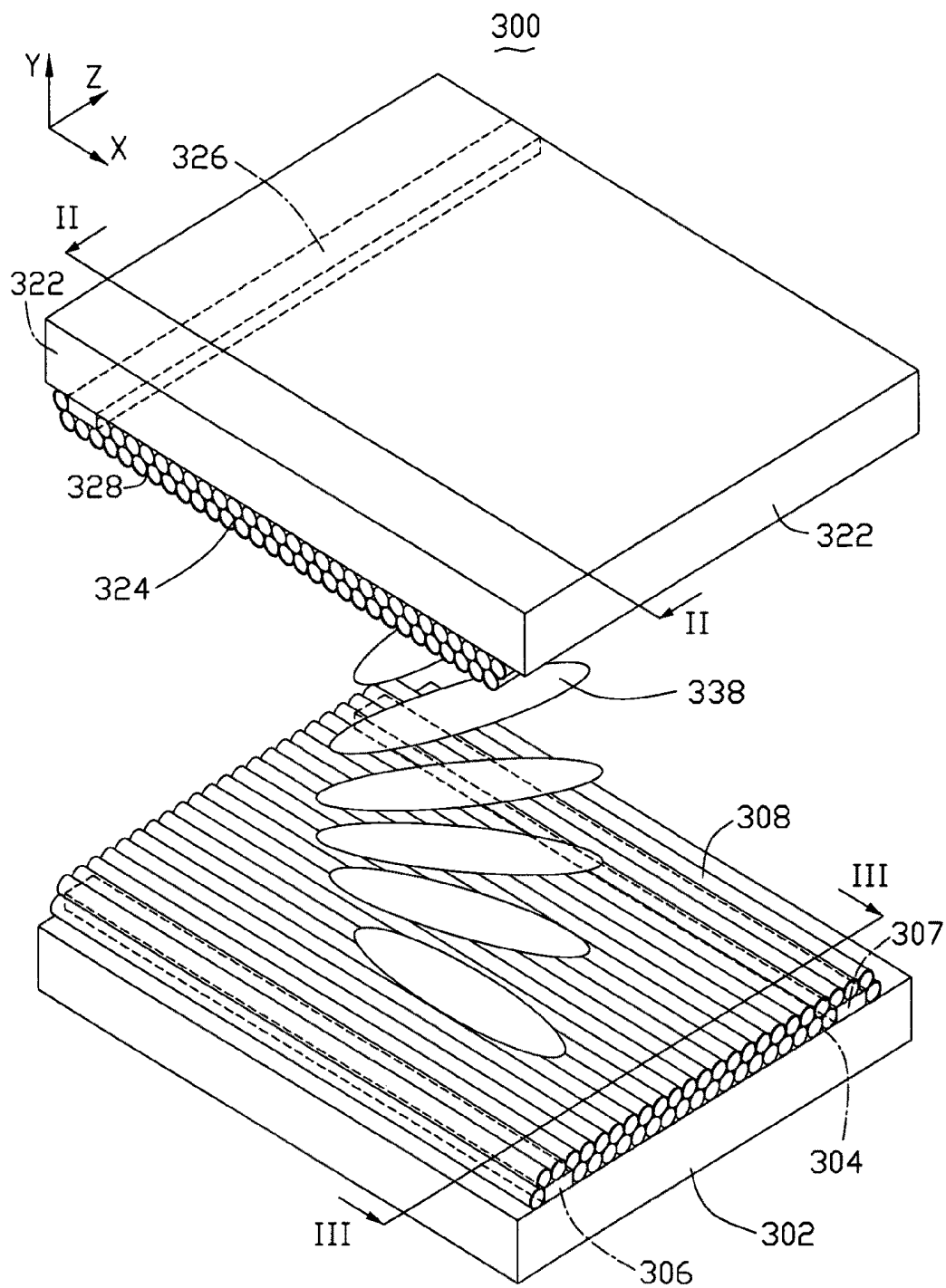


FIG. 1

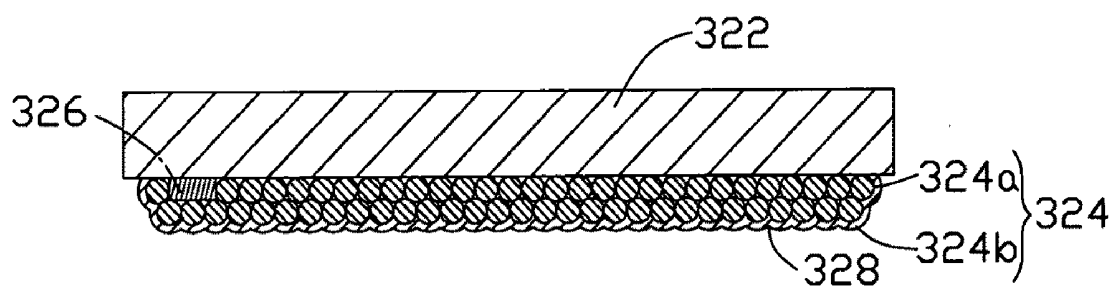


FIG. 2

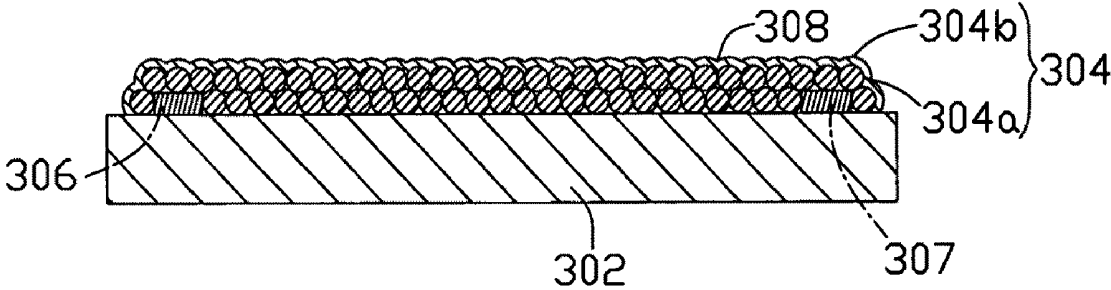


FIG. 3

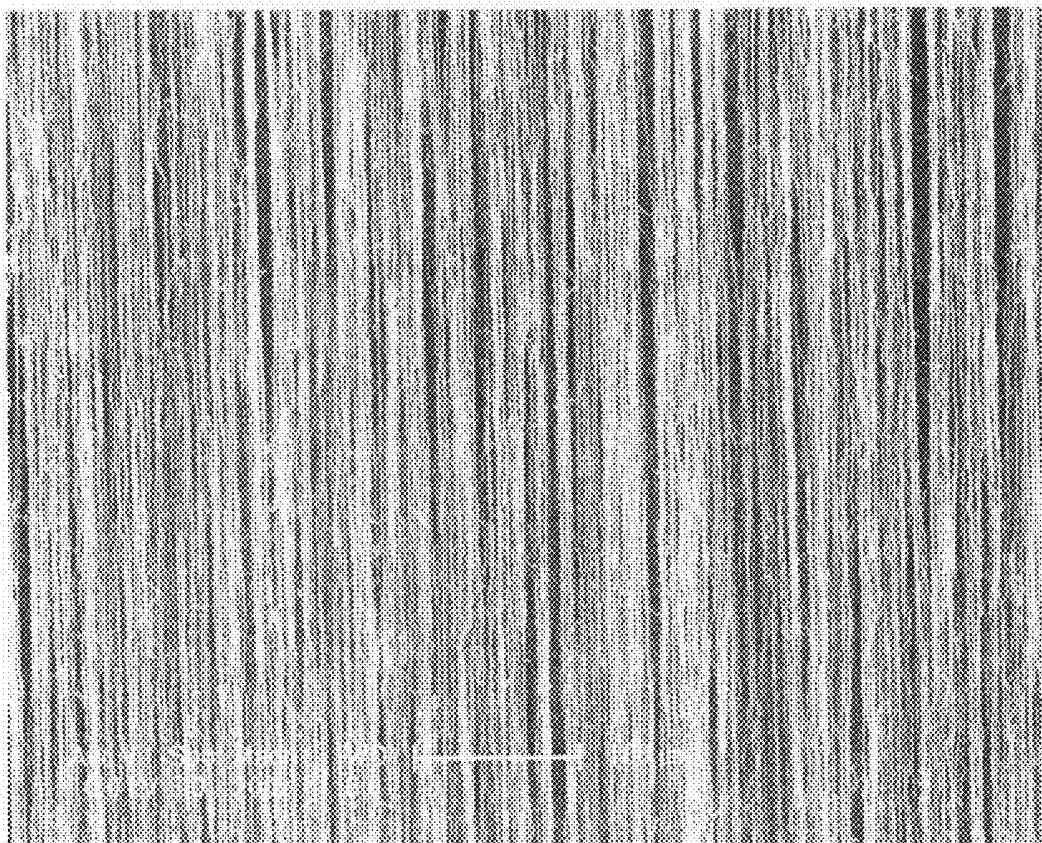


FIG. 4

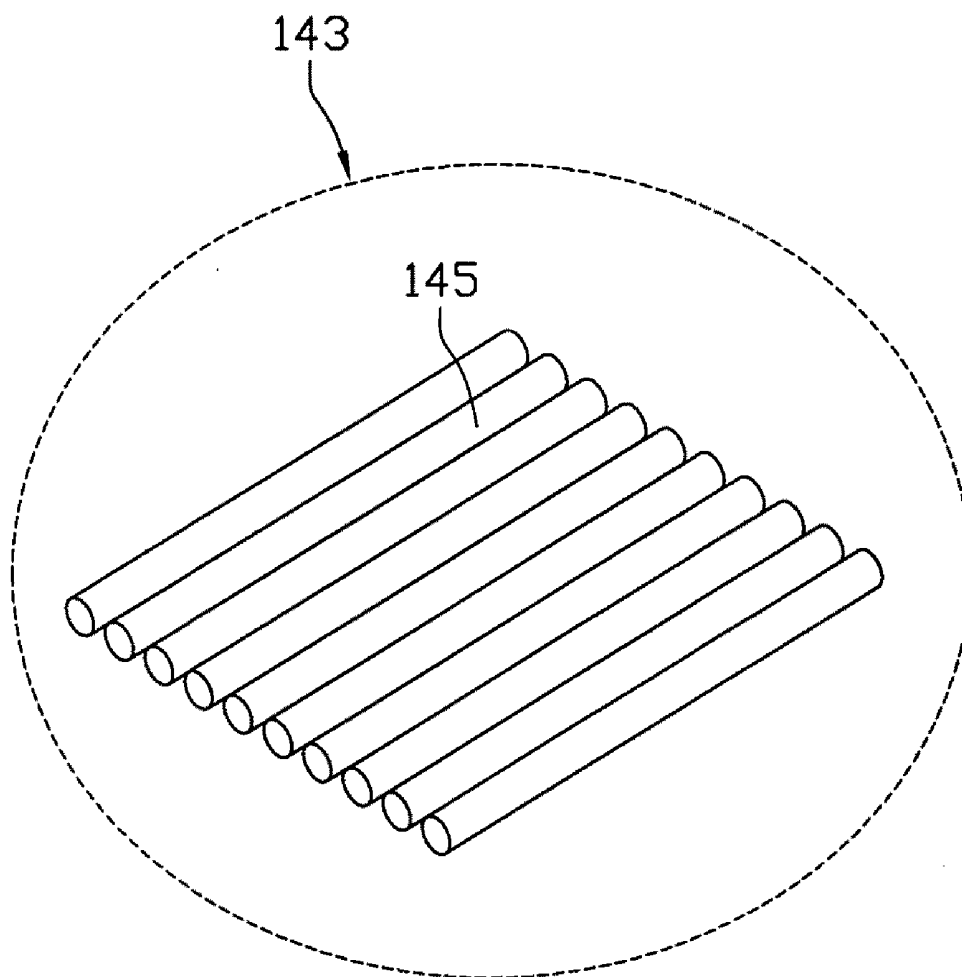


FIG. 5

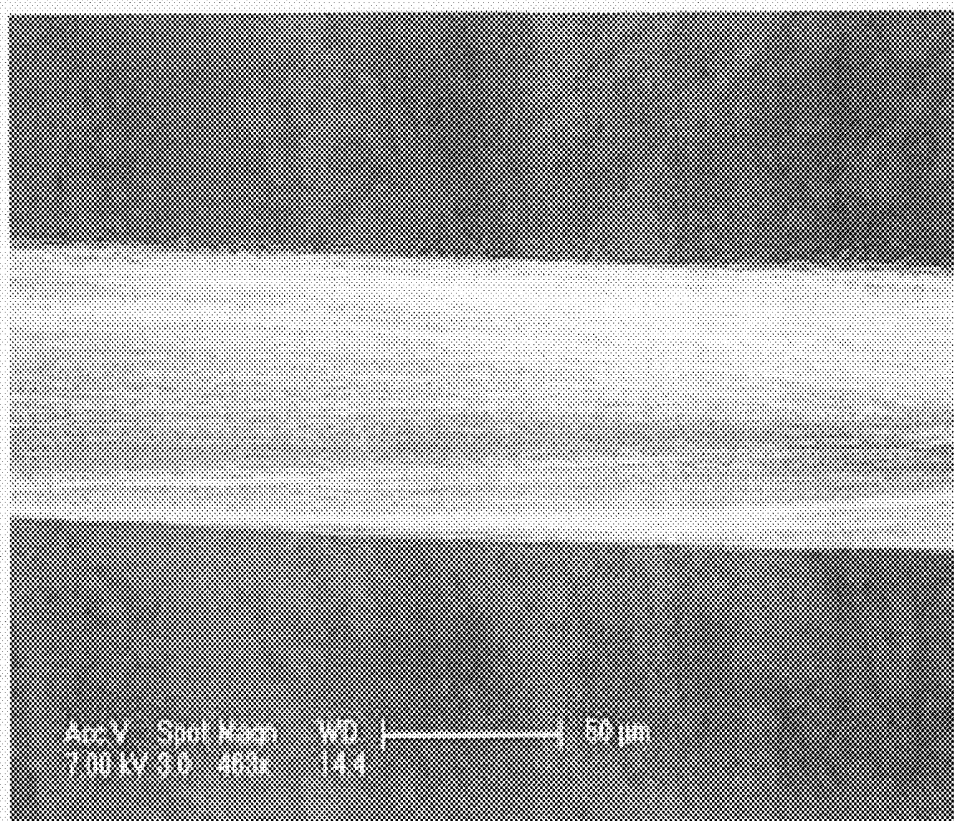


FIG. 6

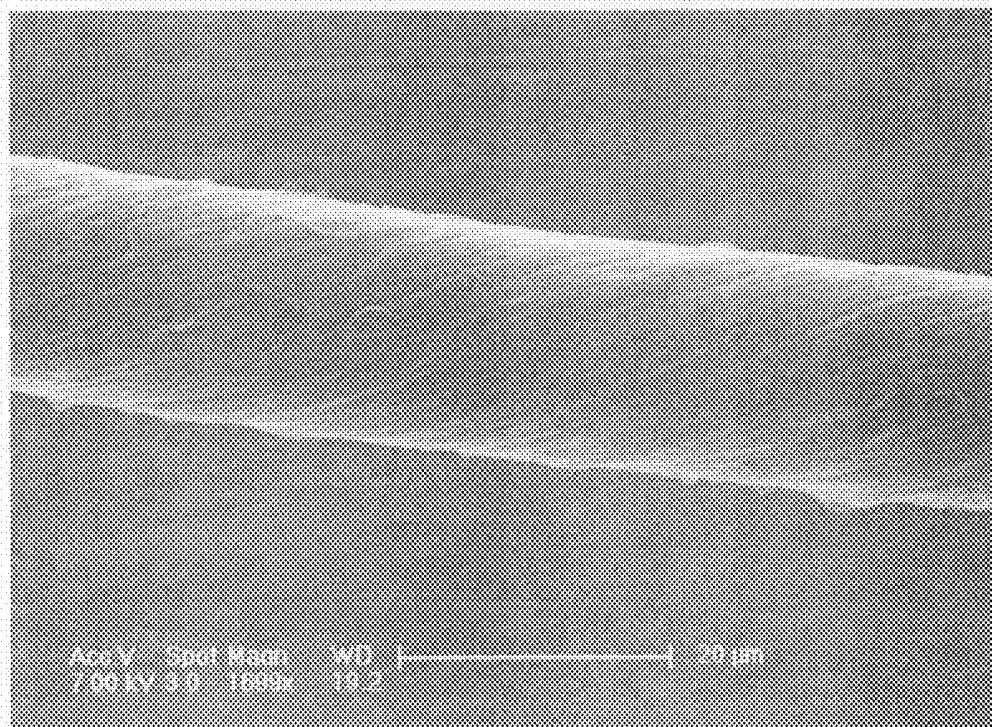


FIG. 7

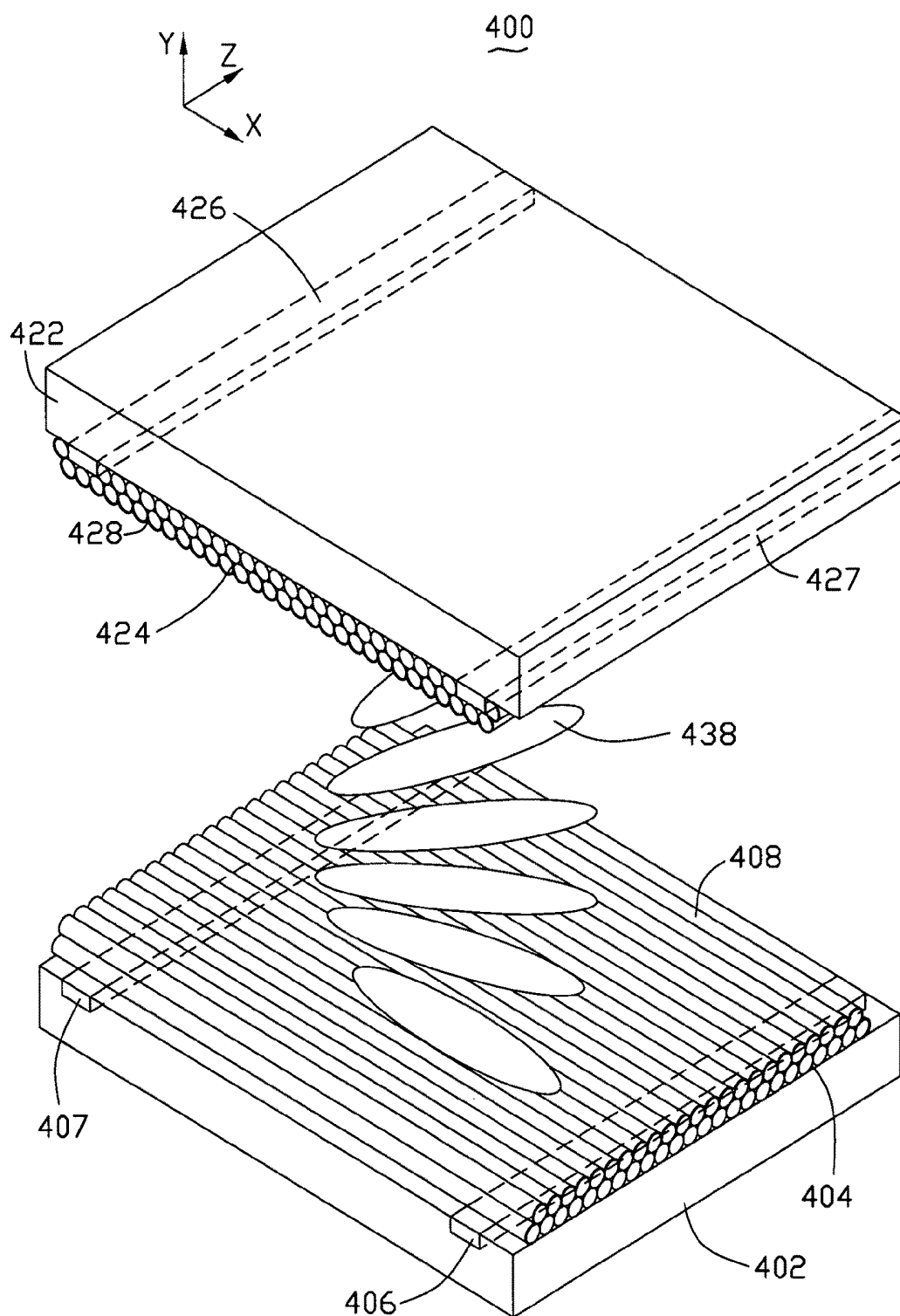


FIG. 8

LIQUID CRYSTAL DISPLAY

RELATED APPLICATIONS

[0001] This application is related to applications entitled “LIQUID CRYSTAL DISPLAY”, filed _____ (Atty. Docket No. US19075); “LIQUID CRYSTAL DISPLAY”, filed _____ (Atty. Docket No. US21521). The disclosures of the above-identified applications are incorporated herein by reference. The application is also related to co-pending applications entitled “LIQUID CRYSTAL DISPLAY SCREEN”, filed Nov. 20, 2008 (Atty. Docket No. US18573); “LIQUID CRYSTAL DISPLAY SCREEN”, filed Nov. 20, 2008 (Atty. Docket No. US18574); “METHOD FOR MAKING LIQUID CRYSTAL DISPLAY SCREEN”, filed Nov. 20, 2008 (Atty. Docket No. US18575); “LIQUID CRYSTAL DISPLAY SCREEN”, filed Nov. 20, 2008 (Atty. Docket No. US19048); “LIQUID CRYSTAL DISPLAY SCREEN”, filed Nov. 20, 2008 (Atty. Docket No. US19049); and “LIQUID CRYSTAL DISPLAY SCREEN”, filed Nov. 20, 2008 (Atty. Docket No. US19050); “METHOD FOR MAKING LIQUID CRYSTAL DISPLAY SCREEN”, filed Nov. 20, 2008 (Atty. Docket No. US19051).

BACKGROUND

[0002] 1. Technical Field

[0003] The present disclosure relates to liquid crystal displays and, particularly, to a carbon-nanotube-based liquid crystal display.

[0004] 2. Discussion of Related Art

[0005] A liquid crystal display (LCD) generally includes a first substrate, a second substrate, and a liquid crystal layer. The first substrate is located parallel to the second substrate. The liquid crystal layer including a plurality of liquid crystal molecules is located between the first substrate and the second substrate. A first transparent electrode layer and a first alignment layer are formed on a surface of the first substrate facing toward the liquid crystal layer. A first polarizer is formed on an opposite surface of the first substrate that faces away from the liquid crystal layer. A second transparent electrode layer and a second alignment layer are formed on a surface of the second substrate that faces toward the liquid crystal layer. A second polarizer is formed on an opposite surface of the second substrate that faces away from the liquid crystal layer.

[0006] When no voltage is supplied to the liquid crystal display, light can pass through the liquid crystal display. When voltage is supplied, light cannot pass through the liquid crystal display. Thus, when a predetermined voltage is selectively applied to different pixels defined in the liquid crystal display, a picture can be shown.

[0007] However, for many reasons, the liquid crystal display cannot perform at low temperature environment. Firstly, since the threshold voltage of the liquid crystal display is related to the temperature, the threshold voltage of the liquid crystal display will increase as the external temperature decreases. A change in the threshold voltage will deteriorate the contrast of the liquid crystal display. Secondly, the viscosity of the liquid crystal molecules in the liquid crystal layer will increase as the external temperature decreases. The liquid crystal molecules become hard to transit its phases and then the response of the liquid crystal display becomes slow.

[0008] Conventionally, in order to overcome the above problems, a heating layer can be located on the substrate to

increase an operating temperature of the liquid crystal display. The heating layer is usually an indium-tin oxide transparent conductive layer. However, the indium-tin oxide transparent conductive layer is not very efficient for heating and consumes space, which requires that the liquid crystal display be thicker.

[0009] What is needed, therefore, is to provide a thin liquid crystal display that can perform at low temperatures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Many aspects of the present liquid crystal display can be better understood with reference to the following drawings. The components in the drawings are not necessarily drawn to scale, the emphasis instead being placed upon clearly illustrating the principles of the present liquid crystal display.

[0011] FIG. 1 is a schematic, isometric view of a liquid crystal display in accordance with a first embodiment.

[0012] FIG. 2 is a cross-sectional schematic view of the liquid crystal display of FIG. 1, taken along a line II-II.

[0013] FIG. 3 is a cross-sectional schematic view of the liquid crystal display of FIG. 1, taken along a line III-III.

[0014] FIG. 4 is a Scanning Electron Microscope (SEM) image of a carbon nanotube film in accordance with the first embodiment.

[0015] FIG. 5 is a structural schematic view of a carbon nanotube segment of the carbon nanotube film of FIG. 4.

[0016] FIG. 6 is a Scanning Electron Microscope (SEM) image of an untwisted carbon nanotube wire in accordance with the first embodiment.

[0017] FIG. 7 is a Scanning Electron Microscope (SEM) image of a twisted carbon nanotube wire in accordance with the first embodiment.

[0018] FIG. 8 is a schematic, isometric view of a liquid crystal display in accordance with a second embodiment.

[0019] Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate at least one embodiment of the present liquid crystal display, in at least one form, and such exemplifications are not to be construed as limiting the scope of the disclosure in any manner.

DETAILED DESCRIPTION

[0020] References will now be made to the drawings to describe, in detail, various embodiments of the present liquid crystal display.

[0021] Referring to FIGS. 1, 2, and 3, a liquid crystal display 300 in the first embodiment includes a first substrate 302, a first alignment layer 304, a liquid crystal layer 338, a second alignment layer 324, and a second substrate 322. The liquid crystal layer 338 is sandwiched between the first substrate 302 and the second substrate 322. The first alignment layer 304 is located on the first substrate 302 adjacent to the liquid crystal layer 338. A plurality of parallel first grooves 308 is defined in a surface of the first alignment layer 304 facing the liquid crystal layer 338. The second alignment layer 324 is located on the second substrate 322 adjacent to the liquid crystal layer 338. A plurality of parallel second grooves 328 is defined in a surface of the second alignment layer 324 facing the liquid crystal layer 338. An alignment direction of the first grooves 308 is perpendicular to an alignment direction of the second grooves 328.

[0022] At least one of the first alignment layer 304 and second alignment layer 324 includes a carbon nanotube structure. In the present embodiment, both the first alignment layer 304 and second alignment layer 324 include a carbon nanotube structure.

[0023] The carbon nanotube structure in first alignment layer 304 is electrically connected to at least two electrodes. The electrodes are used to supply voltage to the carbon nanotube structure. Furthermore, the carbon nanotube structure in the second alignment layer 324 is electrically connected to at least one electrode. In the present embodiment, the liquid crystal display 300 includes a first electrode 306, a second electrode 307 and a third electrode 326. The first electrode 306 and the second electrode 307 are located separately and electrically connected to the carbon nanotube structure in the first alignment layer 304. The third electrode 326 is electrically connected to the carbon nanotube structure in the second alignment layer 324.

[0024] The carbon nanotube structure includes a plurality of carbon nanotubes arranged along the same direction. The carbon nanotubes can be single-walled carbon nanotubes, double-walled carbon nanotubes, multi-walled carbon nanotubes or any combination thereof. Diameters of the single-walled carbon nanotubes range from about 0.5 to about 10 nanometers. Diameters of the double-walled carbon nanotubes range from about 1 to about 50 nanometers. Diameters of the multi-walled carbon nanotubes range from about 1.5 to about 50 nanometers. Each carbon nanotube structures can include one or more carbon nanotube films, or a plurality of carbon nanotube wires.

[0025] In one embodiment, the carbon nanotube structure includes one carbon nanotube film. Referring to FIGS. 4 and FIG. 5, the carbon nanotube film includes a plurality of successively oriented carbon nanotube segments 143 joined end-to-end by van der Waals attractive force therebetween. Each carbon nanotube segment 143 includes a plurality of carbon nanotubes 145 parallel to each other, and combined by van der Waals attractive force therebetween. The carbon nanotube segments 143 can vary in width, thickness, uniformity and shape. The carbon nanotubes 145 in the carbon nanotube film 143 are oriented along a preferred orientation.

[0026] The carbon nanotube film can be formed by the substeps of: (a) providing a super-aligned carbon nanotube array on a substrate; (b) selecting two or more carbon nanotubes having a predetermined width from the super-aligned array of carbon nanotubes; and (c) pulling the carbon nanotubes to form carbon nanotube segments that are joined end to end. The carbon nanotube segments can be pulled at a uniform speed to achieve a uniform carbon nanotube film. The width and length of the carbon nanotube film is dependent on the size of the carbon nanotube array. In one embodiment, when the substrate is a 4-inch P-type silicon wafer as in the present embodiment, the width of the carbon nanotube film is in a range from about 0.5 nanometers to about 10 centimeters, and the thickness of the carbon nanotube film is in a range from about 0.5 nanometers to about 100 microns. The length of the carbon nanotube film can be larger than about 10 meters.

[0027] In other embodiments, the carbon nanotube structures may include at least two stacked carbon nanotube films. Adjacent carbon nanotube films are held in contact with each other by van der Waals attractive force therebetween. An

angle α between the preferred orientations of the carbon nanotubes in two adjacent carbon nanotube films is equal to approximately 0 degrees.

[0028] In another embodiment, the carbon nanotube structure may include a plurality of carbon nanotube wires. The carbon nanotube wires are located parallel to each other. The carbon nanotube wire can be in twisted form or in untwisted form. The untwisted carbon nanotube wire is formed by treating the carbon nanotube film with an organic solvent. Specifically, the entire surface of the carbon nanotube film is soaked in volatile organic solvent. After being soaked in the organic solvent, the adjacent parallel carbon nanotubes in the carbon nanotube film will be bundled together because the surface tension of the organic solvent. This causes the carbon nanotube film to shrink into untwisted carbon nanotube wire when the organic solvent vaporizes. Referring to FIG. 6, an untwisted carbon nanotube wire includes a plurality of carbon nanotubes substantially oriented along the same direction (i.e., a direction along the length of the untwisted carbon nanotube wire). Specifically, the carbon nanotubes are substantially parallel to the axis of the untwisted carbon nanotube wire. Length of the untwisted carbon nanotube wire can be arbitrarily set as desired. A diameter of the untwisted carbon nanotube wire is in a range from about 0.5 nanometers to about 100 micrometers.

[0029] The twisted carbon nanotube wire is formed by twisting a carbon nanotube film. In the exemplary embodiment, the twisted carbon nanotube wire is formed by using a mechanical force to turn the two ends of the carbon nanotube film in opposite directions. Referring to FIG. 7, a twisted carbon nanotube wire includes a plurality of carbon nanotubes oriented around an axial direction of the twisted carbon nanotube wire in a helix pattern.

[0030] Further, the twisted carbon nanotube wire can be treated with a volatile organic solvent. After being soaked in the organic solvent, the adjacent parallel carbon nanotubes in the twisted carbon nanotube wire will be bundled together, due to the surface tension of the organic solvent when the organic solvent vaporizes. As a result, the specific surface area of the twisted carbon nanotube wire will decrease. The density and the strength of the twisted carbon nanotube wire will be increased.

[0031] Referring to FIGS. 2, 3, the liquid crystal display 300 further includes a fixing layer. The fixing layer is located on the carbon nanotube structure and faces the liquid crystal layer. In the present embodiment, the first alignment layer 304 includes a first carbon nanotube structure 304a and a first fixing layer 304b; and the second alignment layer 324 includes a second carbon nanotube structure 324a and a second fixing layer 324b. Due to the first carbon nanotube structure 304a having a plurality of parallel and uniform gaps, when the first fixing layer 304b is formed on the first carbon nanotube structure 304a, the first grooves 308 are formed on surfaces of the first fixing layer 304b. Due to the second carbon nanotube structure 324a having a plurality of parallel and uniform gaps, when the second fixing layer 324b is formed on the second carbon nanotube structure 324a, the second grooves 328 are formed on surfaces of the second fixing layer 324b.

[0032] In order to fabricate first grooves 308 that are perpendicular to the second grooves 328, the arranged direction of the carbon nanotubes in the first alignment layer 304 are perpendicular to the arranged direction of the carbon nanotubes in the second alignment layer 324. For example, the

carbon nanotubes in the first alignment layer **304** are each aligned parallel to an X-axis, and the carbon nanotubes in the second alignment layer **324** are each aligned parallel to a Z-axis. A thickness of each of the first alignment layer **304** and the second alignment layer **324** is in a range from about 1 micrometer to about 50 micrometers.

[0033] The fixing layers **304b**, **324b** can be made of the materials selected from the group consisting of diamond, silicon nitrogen, hydride of random silicon, silicon carbon, silicon dioxide, aluminum oxide, tin oxide, cerium oxide, zinc titanate, and indium titanate. The fixing layers **304b**, **324b** can be fabricated by evaporating, sputtering, or plasma enhanced chemical vapor deposition. Alternatively, the fixing layers **304b**, **324b** can be made of the materials selected from the group consisting of polyethylene ethanol, polyamide, polymethyl methacrylate, and polycarbonate. The fixing layers **304b**, **324b** are sprayed on the first carbon nanotube structure **304a** and the second carbon nanotube structure **324a**. A thickness of the fixing layers is in a range from about 20 nanometers to about 2 micrometers.

[0034] The first substrate **302** and the second substrate **322** can be made of materials selected from the group comprising of glass, quartz, diamond, and plastics. In the present embodiment, the first substrate **302** and the second substrate **322** are made of flexible materials, such as cellulose triacetate (CTA). According to user-specific needs, the first substrate **302** and the second substrate **322** can be made of different suitable.

[0035] The liquid crystal layer **338** includes a plurality of cigar-shaped liquid crystal molecules. The liquid crystal layer **338** can also be made of other liquid crystal materials, which are generally used in the present technology. Furthermore, a plurality of supporters (not shown) can be located between the first alignment layer **304** and the second alignment layer **324**. The supporter can be a small ball made of polyethylene. A diameter of the ball ranges from about 1 to about 10 micrometers. In the present embodiment, the diameter of the ball is 5 micrometers.

[0036] The shape of the first electrode **306**, the second electrode **307** and the third electrode **326** is arbitrary. In the present embodiment, each of the electrodes is strip-shaped. The first electrode **306** and the second electrode **307** are located in parallel and extend along a first direction. The first electrode **306** and the second electrode **307** are located on the surface of the first alignment layer **304** adjacent to the first substrate **302**. The first electrode **306** and the second electrode **307** are located on the two opposite ends of the first substrate **302**. The third electrode **326** is located on the surface of the second alignment layer **324** adjacent to the second substrate **322** and extends along a second direction. The first direction and the second direction intersect with each other. In present embodiment, the first direction is perpendicular with the second direction. Also, the electrodes **306**, **307**, **326** can be located on the surface of the alignment layer **304**, **324** far away from the substrate **302**, **322** or on the surface of the fixing layer **304b**, **324b** far away from the liquid crystal layer **338**.

[0037] The first alignment layer **304** of the liquid crystal display **300** can be heated if needed as described below.

[0038] When the liquid crystal display **300** does not need to be heated, the third electrodes **326** is kept at zero, and the first electrode **306** and the second electrode **307** are controlled by information source to allow the liquid crystal display **300** work. When the liquid crystal display **300** needs to be heated, the second electrode **307**, electrically connected to the first

carbon nanotube structure **304a**, is in any one of four states. In the first state the second electrode **307** pre-heats the liquid crystal display **300** before it operates, by applying a steady pre-determined amount of direct current to the first carbon nanotube structure **304a** to heat the liquid crystal display **300** up to a predetermined temperature. The second electrode **307** enters the second state to keep the liquid crystal display **300** heated while it is in an "off" state, by applying direct current pulses to the first carbon nanotube structure **304a**. In this state, a compensation voltage such as 2.5 V should be applied to the third electrode **326** to keep the liquid crystal display **300** in an "off" state. The second electrode **307** enters the third state when the liquid crystal display **300** is in transition between the "off" state and "on" state, and heats the display **300** by applying a high frequency alternating current to the first carbon nanotube structure **304a**. Because the relaxation time of the liquid crystal display **300** between the "off" state and "on" state is a matter of microseconds, the frequency of the high frequency current should be above 10 kilohertz. While the display **300** is in the "on" state the second electrode **307** enters the fourth state and does not apply current.

[0039] Referring to FIG. 8, the liquid crystal display **400** in the second embodiment includes a first substrate **402**, a first alignment layer **404**, a liquid crystal layer **438**, a second alignment layer **424**, a second substrate **422**, a first electrode **406**, a second electrode **407**, a third electrode **426**. The liquid crystal display **400** in the second embodiment has a similar structure with the liquid crystal display **300** in the first embodiment. The difference between the liquid crystal display **400** and the liquid crystal display **300** is that the liquid crystal display **400** includes a fourth electrode **427** used to supply voltage to the carbon nanotube structure in the second alignment layer **424**. The fourth electrode **427** and the third electrode **426** are located in parallel.

[0040] The alignment layer **404**, **424** of the liquid crystal display **400** can be heated if needed as described below. While the liquid crystal display **400** does not need to be heated, the first electrodes **426**, **427** are kept at zero, and the electrodes **406**, **407** are controlled by information source to allow the liquid crystal display **400** work. While the liquid crystal display **400** needs to be heated, the heating process is similar with the heating process of the liquid crystal display **300**. The difference is that a current is applied to the carbon nanotube structure in the both first alignment layer **404** and second alignment layer **424** at same time. In the present embodiment, because the voltage applied to the fourth electrode **427** can keep the liquid crystal display **400** in an "off" state, no additional compensation voltage should be applied to the third electrode **426**.

[0041] When the liquid crystal display **400** needs to be heated, the second electrode **407**, electrically connected to the first carbon nanotube structure, is in any one of four states. In the first state the second electrode **407** pre-heats the liquid crystal display **400** before it operates, by applying a steady pre-determined amount of direct current to the carbon nanotube structure in the first alignment layer **404** to heat the liquid crystal display **400** up to a predetermined temperature. In this state, a voltage, such as 5 V, is applied to the fourth electrode **427** to apply a steady pre-determined amount of direct current to the carbon nanotube structure in the second alignment layer **424** to heat the liquid crystal display **400**. The second electrode **407** enters the second state to keep the liquid crystal display **400** heated while it is in an "off" state, by applying direct current pulses to the carbon nanotube structure in the

first alignment layer **404**. In this state, a voltage such as 5 V is applied to the fourth electrode **427** to apply a steady pre-determined amount of direct current to the carbon nanotube structure in the second alignment layer **424** to heat the liquid crystal display **400** and no additional compensation voltage should be applied to the third electrode **426**. The second electrode **407** enters the third state when the liquid crystal display **400** is in transition between the “off” state and “on” state, and heats the display **400** by applying a high frequency current to the carbon nanotube structure in the alignment layer **404**, **424**. Because the relaxation time of the liquid crystal display **400** between the “off” state and “on” state is a matter of microseconds, the frequency of the high frequency current should be above 10 kilohertz. While the display **400** is in the “on” state the second electrode **407** enters the fourth state and does not apply current.

[0042] Due to the carbon nanotube having excellent conductive properties, thermal stability, high thermal radiation efficiency and large specific surface area, the carbon nanotube structure of the present embodiment can serve as a perfect black body. The thermal response speed of the carbon nanotube structure is high due to its small heat capacity of per unit area which less than $1.7 \times 10^{-6} \text{ J}/(\text{CM}^2 \cdot \text{K})$. A carbon nanotube film with a thickness of about 1 micrometer to about 1 millimeter can reach its highest surface temperature within 1 second. A drawing carbon nanotube film can reach its highest surface temperature within 0.1 milliseconds.

[0043] Because the carbon nanotubes provide each carbon nanotube structure with good electrical conductivity, each carbon nanotube structure can be used to conduct electricity and thereby replace a conventional transparent electrode layer. Specifically, the carbon nanotube structure can act as both an alignment layer and an electrode layer. This simplifies the structure and reduces the thickness of the liquid crystal display, thereby enhancing the efficiency of usage of an associated backlight while retaining all functionality. Additionally, it forms a plurality of parallel gaps in carbon nanotube structure without the use of mechanical treatments (such as rubbing the carbon nanotube film). Thus, the conventional art problem of electrostatic charge and dust contamination can be avoided, while the corresponding alignment layers have improved alignment quality.

[0044] Moreover, by covering a fixing layer on the carbon nanotube structure, this prevents the carbon nanotube structure of the alignment layer from falling off when the carbon nanotube structure is in contact with the liquid crystal layer. Therefore, the liquid crystal display has improved durability and an excellent arrangement of liquid crystal molecules.

[0045] Because the carbon nanotubes in each carbon nanotube structure are arranged in parallel, the carbon nanotube structure has a light polarization characteristic, and as a result, can be used to replace a conventional polarizer. However, at least one polarizer can be located on a surface of the first substrate that faces away from the liquid crystal layer, and/or on a surface of the second substrate that faces away from the liquid crystal layer.

[0046] The liquid crystal display provided in the present embodiment is a single-pixel liquid crystal display. By arranging a number of the liquid crystal displays in a predetermined fashion, a multi-pixel liquid crystal display could be obtained. The multi-pixel liquid crystal display could have the same or different substrate.

[0047] The liquid crystal display in the present embodiment has the many advantages including the following.

Firstly, the carbon nanotube structure can be used as a heating layer, thus the liquid crystal display can perform at low external temperatures. Secondly, the carbon nanotube structure can be used as a heating layer and an alignment layer at the same time, thus simplify the structure of the liquid crystal display and reduce the thickness of the liquid crystal display. Thirdly, the carbon nanotube structure can act as both an alignment layer and an electrode layer, thus further simplify the structure of the liquid crystal display and reduce the thickness of the liquid crystal display. Therefore, the liquid crystal display has improved durability and improved arrangement of liquid crystal molecules.

[0048] Finally, it is to be understood that the above-described embodiments are intended to illustrate rather than limit the disclosure. Variations may be made to the embodiments without departing from the spirit of the disclosure as claimed. The above-described embodiments illustrate the scope of the disclosure but do not restrict the scope of the disclosure.

What is claimed is:

1. A liquid crystal display comprising:

a first substrate;

a second substrate;

a liquid crystal layer located between the first substrate and the second substrate;

a first alignment layer located on a surface of the first substrate, the first alignment layer comprising a first carbon nanotube structure;

a second alignment layer located on the second substrate; and

a first electrode and a second electrode, and the first electrode and the second electrode are electrically connected to the first carbon nanotube structure.

2. The liquid crystal display as claimed in claim 1, wherein the first carbon nanotube structure comprises a plurality of carbon nanotubes arranged along the same direction.

3. The liquid crystal display as claimed in claim 1, wherein the first carbon nanotube structure comprises at least one carbon nanotube film comprising a plurality of carbon nanotubes parallel to each other.

4. The liquid crystal display as claimed in claim 3, wherein the first carbon nanotube structure comprises at least two stacked carbon nanotube films, and an angle between the aligned directions of the carbon nanotubes in adjacent carbon nanotube layers is equal to approximately 0 degrees.

5. The liquid crystal display as claimed in claim 3, wherein the carbon nanotube film comprises a plurality of successively oriented carbon nanotube segments joined end-to-end by van der Waals attractive force therebetween.

6. The liquid crystal display as claimed in claim 5, wherein each carbon nanotube segment comprises of a plurality of carbon nanotubes, the carbon nanotubes have a substantial same length, and adjacent carbon nanotubes are attracted by van der Waals attractive force therebetween.

7. The liquid crystal display as claimed in claim 3, wherein a plurality of gaps are defined between the carbon nanotubes.

8. The liquid crystal display as claimed in claim 1, wherein the first carbon nanotube structure comprises a plurality of carbon nanotube wires, and the carbon nanotube wires are located in parallel to each other.

9. The liquid crystal display as claimed in claim 8, wherein each carbon nanotube wire comprises a plurality carbon nanotubes joined end-to-end by van der Waals attractive force.

10. The liquid crystal display as claimed in claim 8, wherein the carbon nanotube wire is twisted.

11. The liquid crystal display as claimed in claim 8, wherein a plurality of gaps are defined between the carbon nanotube wires.

12. The liquid crystal display as claimed in claim 1, wherein the first electrode and the second electrode are located on the surface of the first substrate, and the first electrode and the second electrode are located in parallel and extend along a first direction.

13. The liquid crystal display as claimed in claim 12, wherein the second alignment layer comprises a second carbon nanotube structure.

14. The liquid crystal display as claimed in claim 13, further comprising a third electrode, the third electrode is electrically connected to the second carbon nanotube structure, and the third electrode is located on the surface of the second substrate and extends along a second direction.

15. The liquid crystal display as claimed in claim 14, further comprising a fourth electrode, the fourth electrode is electrically connected to the second carbon nanotube structure, and the fourth electrode is located on the surface of the second substrate and parallel to the third electrode.

16. The liquid crystal display as claimed in claim 14, wherein the first direction crosses the second direction.

17. The liquid crystal display as claimed in claim 16, wherein the first direction is perpendicular to the second direction.

18. The liquid crystal display as claimed in claim 1, wherein the first alignment layer further comprises a fixing layer on the first carbon nanotube structure.

19. The liquid crystal display as claimed in claim 18, wherein the material of the fixing layer is comprises of a material that is selected from the group consisting of diamond, silicon nitrogen, hydride of random silicon, silicon carbon, silicon dioxide, aluminum oxide, tin oxide, cerium oxide, zinc titanate, and indium titanate, polyethylene ethanol, polyamide, polymethyl methacrylate, and polycarbonate.

20. The liquid crystal display as claimed in claim 1, further comprising at least one polarizer located on surface of the first substrate, at least one polarizer located the second substrate or at least one polarizer located on both the first and second substrate.

* * * * *

专利名称(译)	液晶显示器		
公开(公告)号	US20090268139A1	公开(公告)日	2009-10-29
申请号	US12/386407	申请日	2009-04-16
[标]申请(专利权)人(译)	清华大学 鸿海精密工业股份有限公司		
申请(专利权)人(译)	清华大学 鸿海精密工业股份有限公司.		
当前申请(专利权)人(译)	清华大学 鸿海精密工业股份有限公司		
[标]发明人	LIU LIANG JIANG KAI LI FU WEI QI FAN SHOU SHAN		
发明人	LIU, LIANG JIANG, KAI-LI FU, WEI-QI FAN, SHOU-SHAN		
IPC分类号	G02F1/1337		
CPC分类号	G02F2202/36 G02F1/1337		
优先权	200810066689.2 2008-04-25 CN		
其他公开文献	US8031311		
外部链接	Espacenet USPTO		

摘要(译)

液晶显示器包括第一基板，第一取向层，液晶层，第二取向层和与第一基板相对的第二基板，第一电极和第二电极。液晶层夹在第一基板和第二基板之间。第一取向层位于第一基板上并面向液晶层。第二取向层位于第二基板上并面向液晶层。此外，第一和第二取向层中的至少一个包括碳纳米管结构，并且碳纳米管结构电连接到第一电极和第二电极。

