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(54) **LIQUID CRYSTAL DISPLAY WITH
 TRANSPARENT HEATING LAYER
 COMPRISING CARBON NANOTUBE
 STRUCTURE**

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(51) **Int. Cl.**
G02F 1/1333 (2006.01)
G02F 1/1345 (2006.01)
G02F 1/1337 (2006.01)
 (52) **U.S. Cl.** **349/161**; 349/149; 349/158; 349/123
 (58) **Field of Classification Search** 349/161,
 349/149, 158, 123; 977/742
 See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS
 7,045,108 B2 5/2006 Jiang et al.
 2004/0053780 A1 3/2004 Jiang et al.

2005/0007648 A1 1/2005 Wu et al.
 2006/0113510 A1 6/2006 Luo et al.
 2007/0115413 A1* 5/2007 Liu et al. 349/123
 2007/0296897 A1 12/2007 Liu et al.
 2009/0102810 A1* 4/2009 Jiang et al. 345/173
 2011/0025645 A1* 2/2011 Mata et al. 345/174
 2011/0149373 A1* 6/2011 Liu et al. 359/288

FOREIGN PATENT DOCUMENTS

CN 1483667 A 3/2004
 CN 1955819 A 5/2007
 CN 1979948 6/2007
 JP 2004-107196 4/2004
 JP 2004-348121 12/2004
 JP 2007-122057 5/2007
 JP 2007-314776 12/2007
 JP 2008-3606 1/2008

OTHER PUBLICATIONS

Fan et al., Explorations on growth mechanism, controlled synthesis
 and applications of carbon nanotubes, Physics, vol. 35, No. 5, pp.
 376-381, (2006).

Atomic-beam alignment of inorganic materials for liquid-crystal dis-
 plays? P. Chaudhari, et al., Nature, vol. 411, p. 56 (2001).

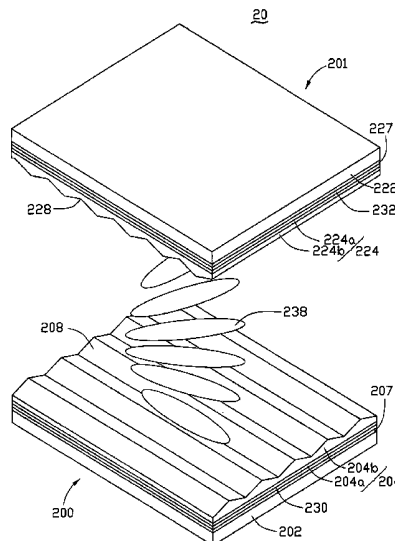
* cited by examiner

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(57) **ABSTRACT**

A liquid crystal display includes a first substrate and a second
 substrate. A liquid crystal layer is located between the first
 and the second substrates. A first transparent heating layer is
 attached on the first substrate. A second transparent heating
 layer is attached on the second substrate. Each of the first and
 second transparent heating layers includes a plurality of car-
 bon nanotubes.

15 Claims, 11 Drawing Sheets



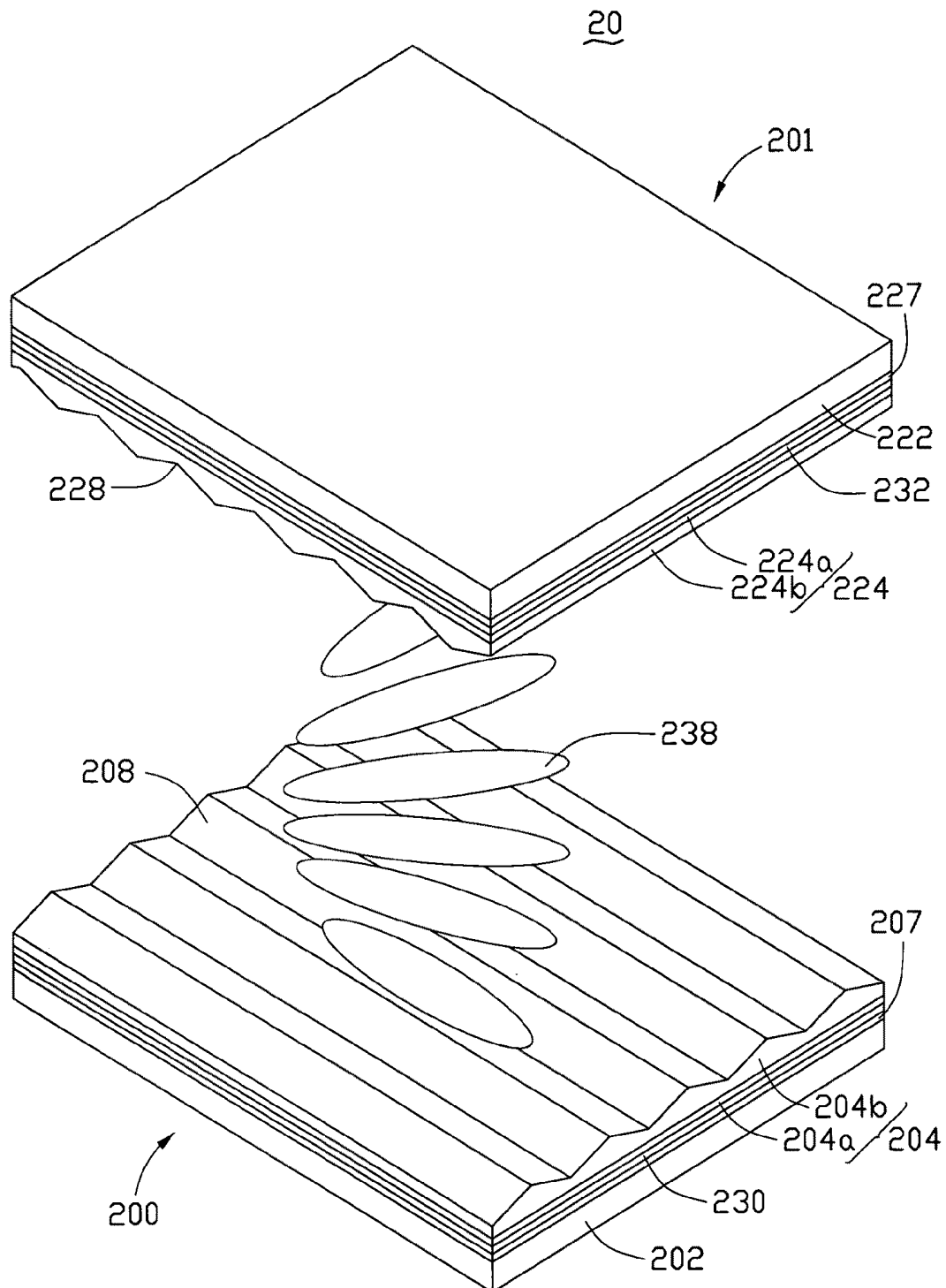


FIG. 1

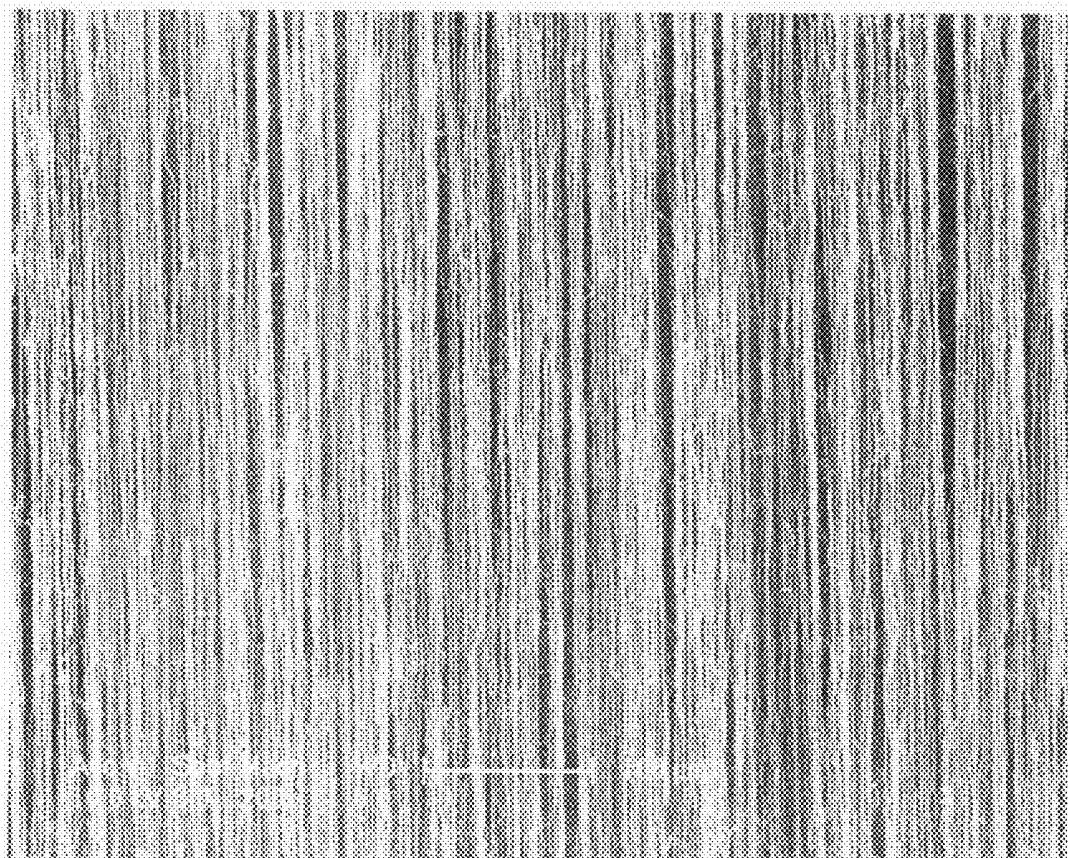


FIG. 2

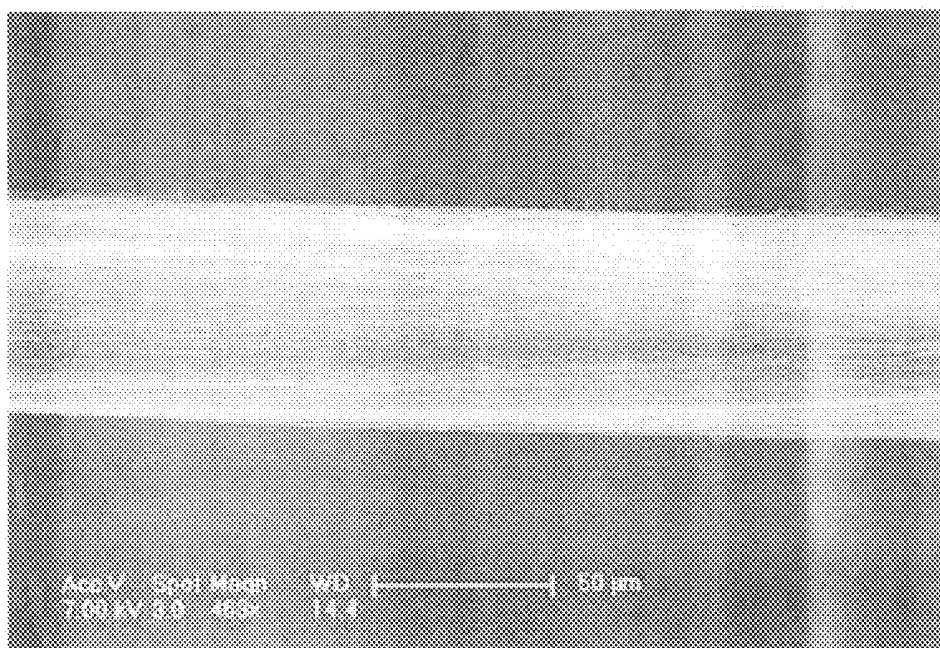


FIG. 3

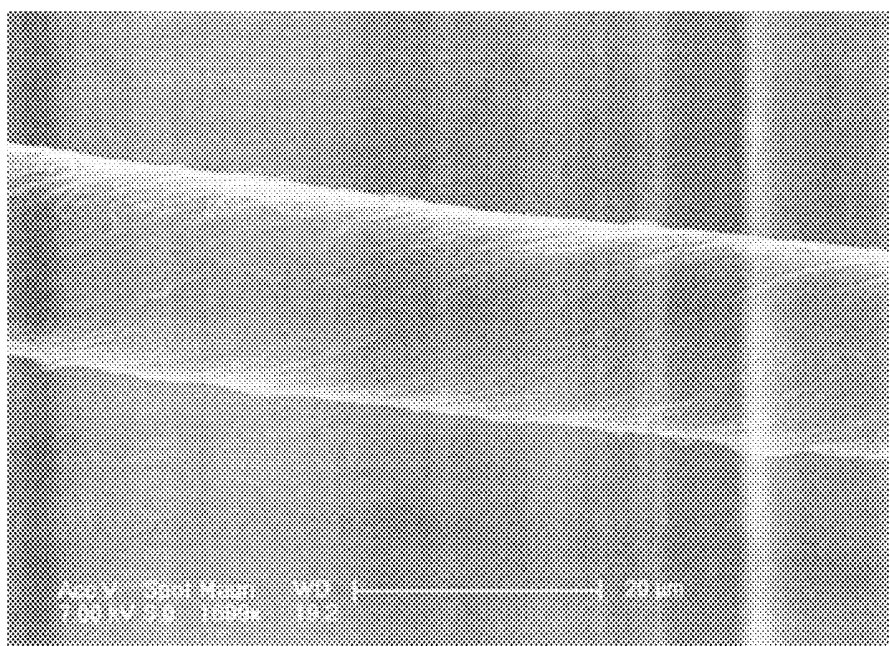


FIG. 4

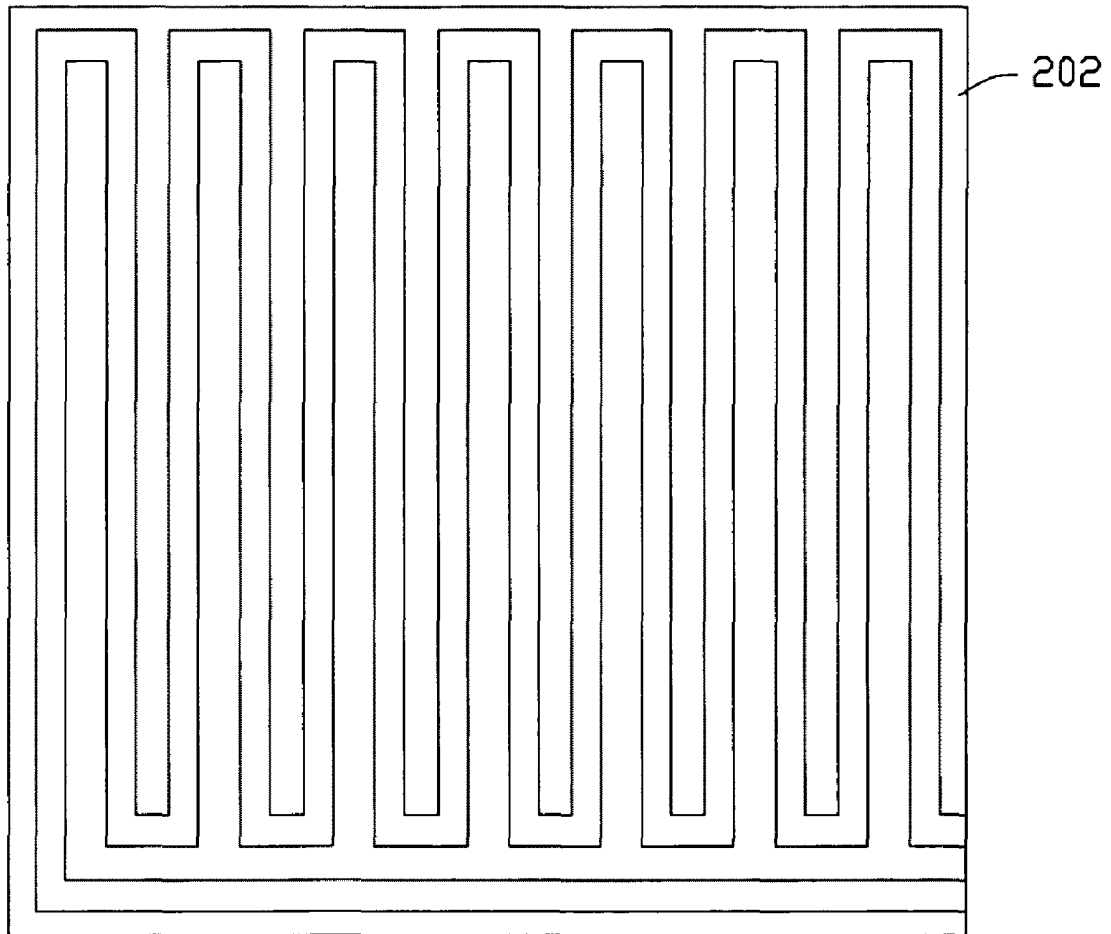


FIG. 5

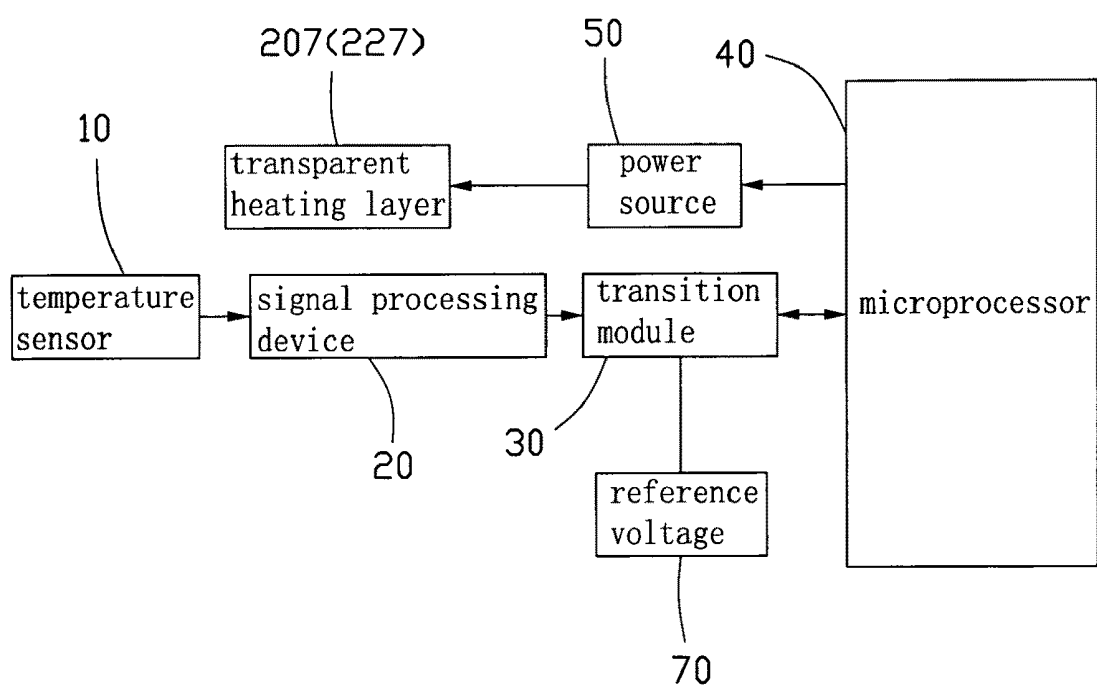


FIG. 6

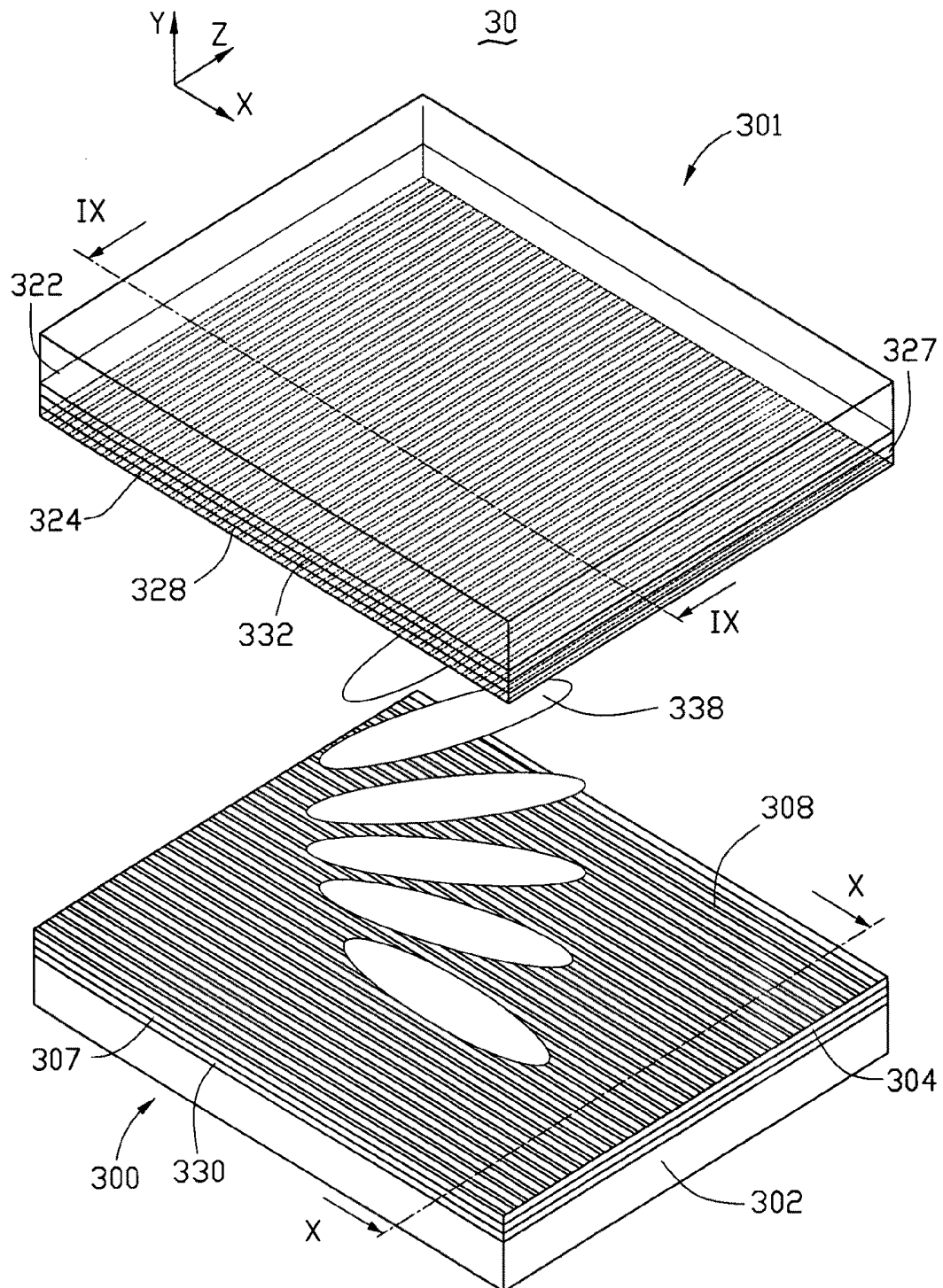


FIG. 7

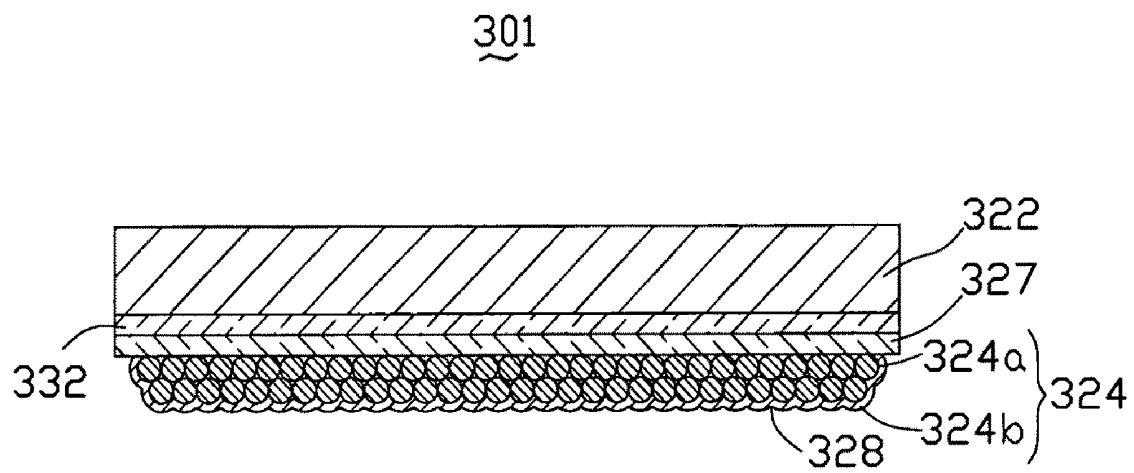


FIG. 8

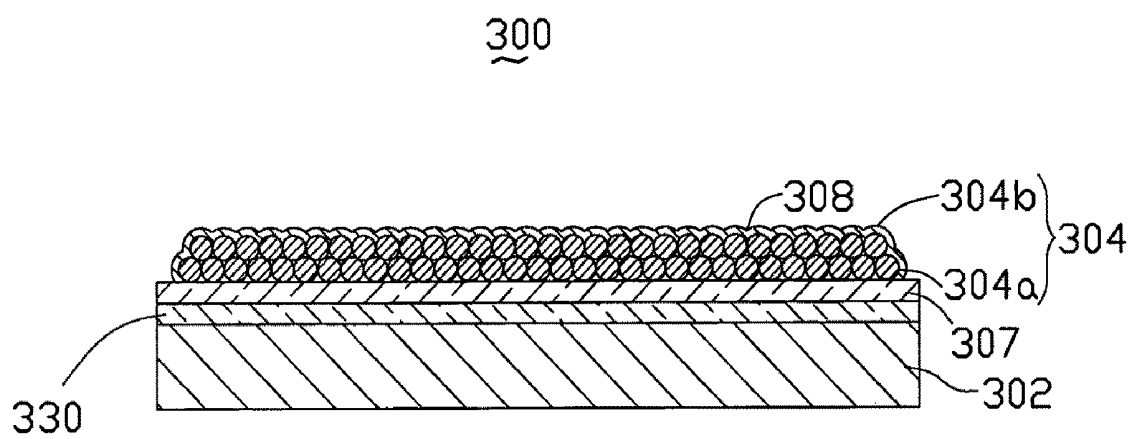


FIG. 9

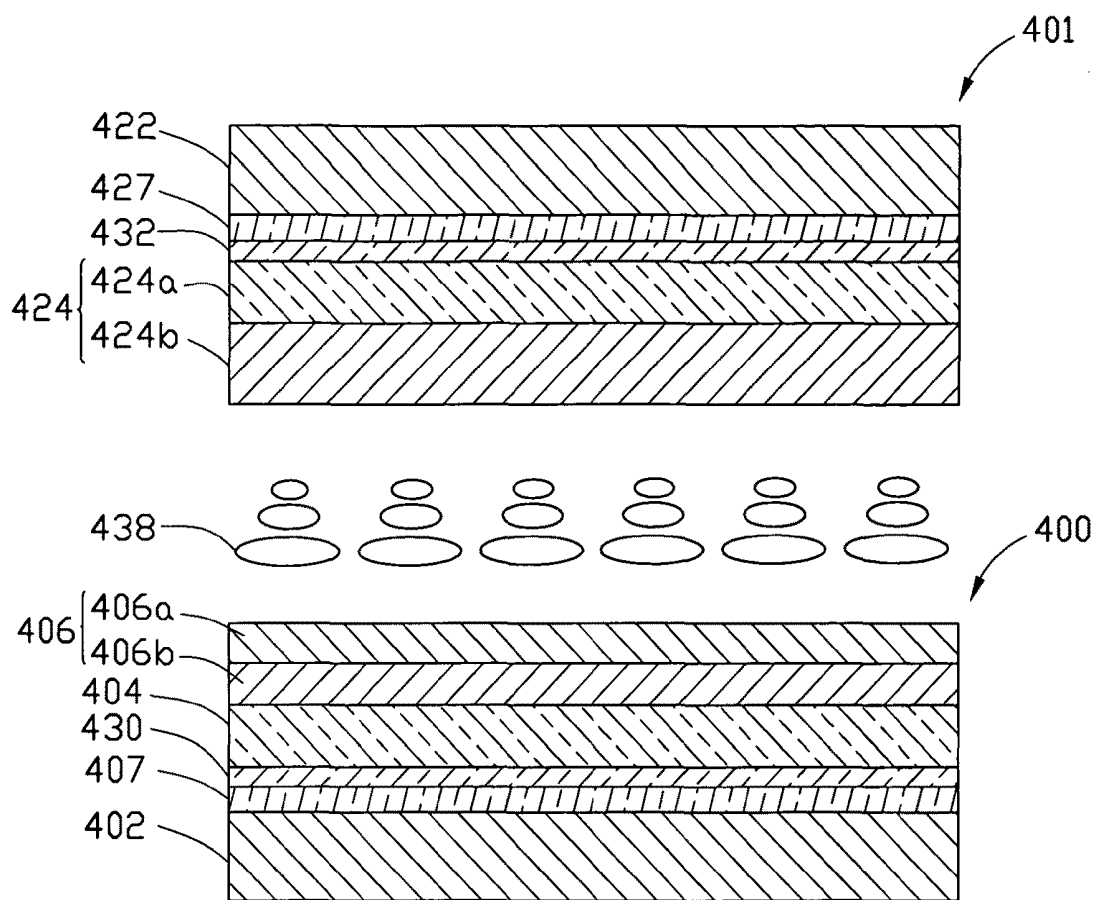


FIG. 10

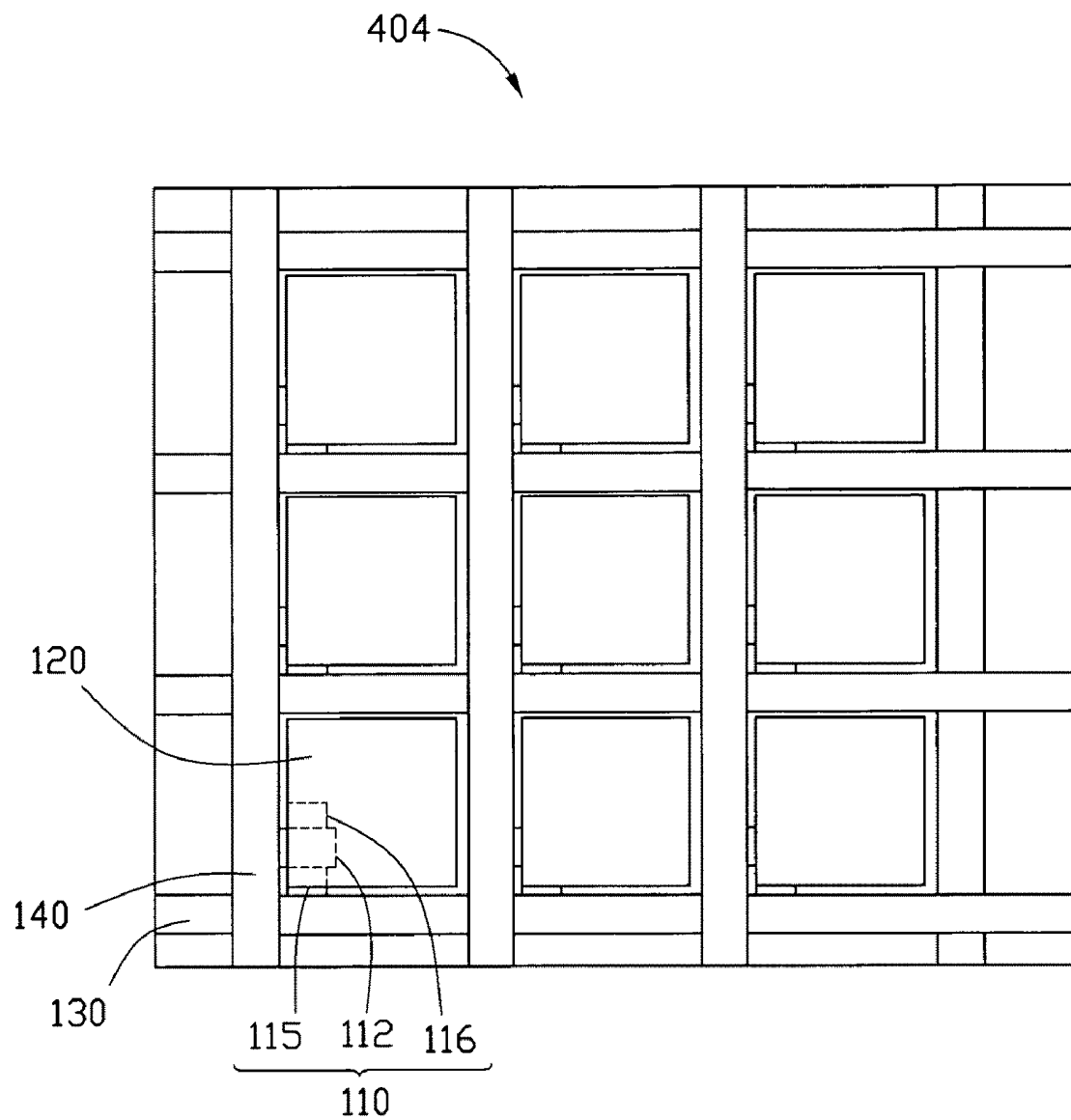


FIG. 11

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LIQUID CRYSTAL DISPLAY WITH TRANSPARENT HEATING LAYER COMPRISING CARBON NANOTUBE STRUCTURE

RELATED APPLICATIONS

This application is related to applications entitled "LIQUID CRYSTAL DISPLAY", filed Apr. 16, 2009 Ser. No. 12/386,407; "LIQUID CRYSTAL DISPLAY", filed Apr. 16, 2009 Ser. No. 12/386,408. 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 Ser. No. 12/313,452; "LIQUID CRYSTAL DISPLAY SCREEN", filed Nov. 20, 2008 Ser. No. 12/313,394; "METHOD FOR MAKING LIQUID CRYSTAL DISPLAY SCREEN", filed Nov. 20, 2008 Ser. No. 12/313,450; "LIQUID CRYSTAL DISPLAY SCREEN", filed Nov. 20, 2008 Ser. No. 12/313,393; "LIQUID CRYSTAL DISPLAY SCREEN", filed Nov. 20, 2008 Ser. No. 12/313,415; and "LIQUID CRYSTAL DISPLAY SCREEN", filed Nov. 20, 2008 Ser. No. 12/313,440; "METHOD FOR MAKING LIQUID CRYSTAL DISPLAY SCREEN", filed Nov. 20, 2008 Ser. No. 12/313,414.

BACKGROUND

1. Technical Field

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

2. Description of Related Art

Liquid crystal displays (LCD) are been widely used in applications for displaying information, for example, mobile telephones, electronic notebooks, computers, because it can be operated with extremely low power consumption and provide a flat screen. The most common LCD types are Twisted Nematic (TN), In-Plane Switching (IPS) and Vertical Alignment (VA). These three types of LCD control the twist angle and movements of liquid crystal molecules to allow light to pass through them in their twisted phase.

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.

However, for many reasons, the liquid crystal display cannot perform at low temperature environments. The threshold voltage of the liquid crystal display is related to the temperature, increasing as the temperature decreases. The high threshold voltage will deteriorate the color contrast of the liquid crystal display. In addition, the viscosity of the liquid crystal molecules in the liquid crystal layer will increase as the temperature decreases. When the liquid crystal molecules become hard move, the response time of the liquid crystal display becomes slow.

Conventionally, in order to overcome the above problems, a heating layer is provided on the surface away from the liquid crystal molecules to increase an operating temperature of the liquid crystal display. The heating layer is usually made of indium-tin oxide transparent conductive layer. However, the indium-tin oxide transparent conductive layer is inefficient heater. The process of heating with an indium-tin oxide transparent conductive layer consumes a lot of energy and requires a preheating process.

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What is needed, therefore, is to provide a liquid crystal display that can perform in low external temperature environments.

BRIEF DESCRIPTION OF THE DRAWINGS

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.

FIG. 1 is a schematic, isometric view of a liquid crystal display in accordance with a first embodiment of the present disclosure.

FIG. 2 is a Scanning Electron Microscope (SEM) image of a carbon nanotube film that can be used in the embodiment shown by FIG. 1.

FIG. 3 is a Scanning Electron Microscope (SEM) image of an untwisted carbon nanotube wire.

FIG. 4 is a Scanning Electron Microscope (SEM) image of a twisted carbon nanotube wire.

FIG. 5 is a schematic top view of a transparent heating layer that can be used in the embodiment shown by FIG. 1.

FIG. 6 is a schematic view of a temperature control system that can be used in the embodiment shown by FIG. 1.

FIG. 7 is a schematic, isometric view of a liquid crystal display in accordance with another embodiment of the present disclosure.

FIG. 8 is a cross-sectional schematic view of the liquid crystal display of FIG. 8 taken along a line IX-IX.

FIG. 9 is a cross-sectional schematic view of the liquid crystal display of FIG. 8 taken along a line X-X.

FIG. 10 is a cross-sectional schematic view of the liquid crystal display in accordance with a one embodiment of the present disclosure.

FIG. 11 is a schematic top view of a thin-film transistor array that can be used in the embodiment shown by FIG. 10.

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

DETAILED DESCRIPTION

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

Referring to FIG. 1, a single-pixel liquid crystal display 20 in one embodiment includes a bottom portion 200, an upper portion 201 facing the bottom portion 200, and a liquid crystal layer 238 sandwiched between the bottom portion 200 and the upper portion 201.

The bottom portion 200 includes a first substrate 202, a first transparent heating layer 207, a first insulating layer 230, and a first conductive alignment layer 204 in that order from bottom to top. The first transparent heating layer 207 is configured to heat the liquid crystal molecules of the liquid crystal display 20. The first insulating layer 230 is configured to insulate the first conductive alignment layer 204 from the first transparent heating layer 207. The first conductive alignment layer 204 is adjacent to the liquid crystal layer 238 and is configured to arrange and orient the liquid crystal molecules of the liquid crystal layer 238.

The upper portion 201 includes a second substrate 222, a second transparent heating layer 227, a second insulating

layer **232**, and a second conductive alignment layer **224**. The second transparent heating layer **227** is also configured to heat the liquid crystal molecules of the liquid crystal display **20**. The second insulating layer **232** is configured to insulate the second conductive alignment layer **224** from the second transparent heating layer **227**. The second conductive alignment layer **224** is adjacent to the liquid crystal layer **238** and configured to arrange and orient the liquid crystal molecules of the liquid crystal layer **238**. The liquid crystal layer **238** is sandwiched between the first conductive alignment layer **204** and the second conductive alignment layer **224**.

The first substrate **202** and the second substrate **222** can be made of hard materials selected from the group consisting of glass, quartz, diamond, or flexible transparent materials, such as plastics. In the one embodiment, the first substrate **202** and the second substrate **222** are made of cellulose triacetate (CTA). According to actual needs, the first substrate **202** and the second substrate **222** can be made of different suitable materials.

The first transparent heating layer **207** and the second transparent heating layer **227** each include a carbon nanotube structure. The carbon nanotube structure can be a carbon nanotube layer.

The carbon nanotube layer can include a plurality of ordered or disordered carbon nanotubes distributed uniformly therein. The ordered carbon nanotubes are primarily oriented along the same direction. Alternatively, the ordered carbon nanotubes can be arranged to be oriented along the same direction.

The carbon nanotube layer can include at least one carbon nanotube film. The carbon nanotube film can be formed by pulling the carbon nanotubes from the carbon nanotube array to achieve a uniform carbon nanotube film. The width and length of the drawn carbon nanotube film is dependent on the size of the carbon nanotube array. Many films can be used, and the adjacent carbon nanotube films can be held in contact with each other by van der Waals attractive force therebetween. An angle α between the carbon nanotubes in two adjacent carbon nanotube films, with the preferred orientations, is in the range of 0 up to and including 90 degrees. The carbon nanotubes in the carbon nanotube layer can be single-walled carbon nanotubes, double-walled carbon nanotubes, multi-walled carbon nanotubes or any combination thereof.

Referring to FIG. 2, a carbon nanotube layer is shown. It includes one drawn carbon nanotube film comprising a plurality of successively oriented carbon nanotubes joined end-to-end by van der Waals attractive force therebetween. The carbon nanotubes are parallel to each other, and combined by van der Waals attractive force therebetween. The carbon nanotubes in the carbon nanotube film are oriented along a preferred orientation. It is understood that there will be some variation in the film.

The carbon nanotube film can be formed by the substeps of: (a) providing a carbon nanotube array on a substrate that can be drawn; (b) selecting two or more carbon nanotubes having a predetermined width from the 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, 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.

The carbon nanotube layer can include a plurality of carbon nanotube wires. The carbon nanotube wires are parallel to each other. The carbon nanotube wires can be in twisted form or in untwisted form. Referring to FIG. 3, 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). The untwisted carbon nanotube wire can be 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 of 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. 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 can be in a range from about 20 nanometers to about 100 micrometers.

The twisted carbon nanotube wires can be formed by twisting a carbon nanotube film. The twisted carbon nanotube wires can be formed by using a mechanical force to turn the two ends of the carbon nanotube film in opposite directions. Referring to FIG. 4, the twisted carbon nanotube wire shown includes a plurality of carbon nanotubes oriented around an axial direction of the twisted carbon nanotube wire, resulting in a helix pattern. 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 as 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.

The carbon nanotube layer can include a carbon nanotube film and a plurality of carbon nanotube wires located on the carbon nanotube film. The adjacent carbon nanotube wires can be parallel to each other.

The first transparent heating layer **207** can be a layer covering the entire surface of the first substrate **202**. Alternatively, the first transparent heating layer **207** can be in a square-wave fashion (as seen in FIG. 5) or in a saw-tooth wave fashion. The fashion of the first transparent heating layer **207** can be formed by irradiating a laser beam along a predetermined path on the carbon nanotube layer thereby cutting a predetermined pattern within the path. The pattern of the first transparent heating layer **207** can be arbitrarily set as desired. The plurality of carbon nanotube wires can directly applied in the desired fashion on the first transparent heating layer **207**. Referring to the embodiment shown in FIG. 5, the first heating layer **207** is the square-wave fashion located on the surface of the first substrate **202**.

Further, the liquid crystal display **20** can include a second transparent heating layer **227**. The second transparent heating layer **227** is located on the surface of the second substrate **222**. The material and the structure of the second transparent heating layer **227** can be the same as the first transparent heating layer **207**. It is to be understood that the first transparent heating layer **207** and/or the second transparent heating layer **227** can be used to heat the liquid crystal display **20**.

The first insulating layer **230** and the second insulating layer **232** can be made of a material selected from the group consisting of silicon dioxide, polymethyl methacrylate (PMMA), spin-on-glass (SOG), and silicon nitride. The thickness of the first insulating layer **230** and the second insulating layer **232** can be in a range from about 5 nanometers to about 10 microns.

The first and the second conductive alignment layers **204**, **224** are conductive and transparent. The first conductive alignment layer **204** includes a first conductive layer **204a** and a first alignment layer **204b** attached on the first conductive layer **204a**. The second conductive alignment layer **224** includes a second conductive layer **224a** and a second alignment layer **224b** attached on the second conductive layer **224a**. The first conductive layer **204a** and the second conductive layer **224a** can be indium-tin oxide transparent conductive films. The first alignment layer **204b** and the second alignment layer **224b** can be made of a material typically selected from the group consisting of polyimide, polystyrene, polystyrene derivative, polyimide, polyvinyl alcohol, epoxy resin, polyamine resin, and polysiloxane. In the one embodiment, the first alignment layer **204b** and the second alignment layer **224b** are made of polyimide. A plurality of first grooves **208** is defined in the top surface of the first alignment layer **204b**. A plurality of second grooves **228** is defined in the bottom surface of the second alignment layer **224b**. The first and second grooves **208**, **228** are configured to arrange and orient the liquid crystal molecules of the liquid crystal layer **238** in a particular direction. The alignment orientation of the first grooves **208** is perpendicular to the alignment orientation of the second grooves **228**.

The liquid crystal layer **238** includes a plurality of cigar-shaped liquid crystal molecules. The liquid crystal layer **238** can also be made of other liquid crystal materials. Furthermore, a plurality of supporters (not shown) can be located between the first conductive alignment layer **204** and the second conductive alignment layer **224** to support the liquid crystal molecules and prevent the liquid crystal molecules from being extruded by the first and the second conductive alignment layers **204**, **224**. The supporters can be small balls made of polyethylene. Diameters of the balls range from about 1 to 10 micrometers. In the present embodiment, the diameter of the balls is about 5 micrometers.

Additionally, the liquid crystal display **20** includes two elements that will act as polarizer (not shown). According to user-specific needs, the polarizer can be located on any surface of the first substrate **202** or the second substrate **222**.

The first transparent heating layer **207** and the second transparent heating layer **227** are controlled by a temperature controlling system. Referring to an embodiment shown in FIG. 6, the temperature controlling system includes a temperature sensor **10**, a signal processing device **20**, a transition module **30**, a microprocessor **40**, and a power source **50**. The temperature sensor **10** is located inside the liquid crystal display **20** and electrically connected to the signal processing device **20**. The signal processing device **20** is electrically connected to the transition module **30**. The transition module **30** is electrically connected to the microprocessor **40**. The microprocessor **40** is electrically connected to the power source **50**. The first transparent heating layer **207** and the second transparent heating layer **227** are electrically connected to the power source **50**. The transition module **30** is supplied with a reference voltage **70**. The microprocessor **40** is a single-chip microcomputer.

The process of heating the liquid crystal display **20** by the first transparent heating layer **207** and the second transparent heating layer **227** using the embodiment shown in FIG. 6 will

be indicated as following. The temperature sensor **10** collects the temperature signals and passes the temperature signals to the signal processing device **20**. The temperature signals are amplified and filtered by the signal processing device **20**, and then the signals will be passed to the transition module **30**. The transition module **30** converts the temperature signals to digital signals, and then outputs the digital signals to the microprocessor **40**. When the temperature in the liquid crystal display **20** is lower than the reference value, the power source **50** outputs a pulse voltage signal to the first and second heating layers **207**, **227**. The first and second heating layers **207**, **227** begin to heat the liquid crystal display **20**. When the temperature in the liquid crystal display **20** reaches the reference value, the power source **50** stops outputting the pulse voltage signal to the first and second heating layers **207**, **227**, and the first and second heating layers **207**, **227** stop heating.

Referring to FIGS. 7, 8 and 9, a single-pixel liquid crystal display **30** according to another embodiment includes a bottom portion **300**, an upper portion **301** facing, and a liquid crystal layer **338**. The liquid crystal layer **338** is sandwiched between the bottom portion **300** and the upper portion **301**.

The bottom portion **300** includes a first substrate **302**, a first transparent heating layer **330**, a first insulating layer **307**, and a first conductive alignment layer **304**. The first transparent heating layer **330** is configured to heat the liquid crystal molecules of the liquid crystal display **30**. The first insulating layer **307** is configured to insulate the first conductive alignment layer **304** from the first transparent heating layer **330**. The first conductive alignment layer **304** is capable of arranging and orienting the liquid crystal molecules of the liquid crystal layer **338**.

The upper portion **301** includes a second substrate **322**, a second transparent heating layer **332**, a second insulating layer **327**, and a second conductive alignment layer **324**. The second transparent heating layer **332** is configured to heat the liquid crystal molecules of the liquid crystal display **30**. The second insulating layer **327** is configured to insulate the second conductive alignment layer **324** and the second transparent heating layer **332**. The second conductive alignment layer **324** is capable of arranging and orienting the liquid crystal molecules of the liquid crystal layer **338**.

The liquid crystal display **30** in the embodiment shown in FIG. 7 has a structure similar to the liquid crystal display **20** in the embodiment shown in FIG. 1. The difference between the liquid crystal display **30** and the liquid crystal display **20** is that the first conductive alignment layer **304** and the second conductive alignment layer **324** of the liquid crystal display **30** include a carbon nanotube structure. The carbon nanotubes provide the carbon nanotube structure with good electrical conductivity. The carbon nanotube structure can be used to conduct electricity and thereby replace a conventional conductive layer. Specifically, the carbon nanotube structure can act as both an alignment layer and a conductive 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.

The carbon nanotube structure in the embodiment shown in FIG. 7 is the same as the carbon nanotube structure in the embodiment shown in FIG. 1. The carbon nanotube structure includes a plurality of ordered carbon nanotubes distributed uniformly therein. The carbon nanotubes define a plurality of parallel gaps in carbon nanotube structure without the use of mechanical treatments. The gaps can be used as the first and second grooves **308**, **328**, which are configured to arrange and orient the liquid crystal molecules of the liquid crystal layer **338** in a particular direction. The alignment orientation of the first grooves **308** is perpendicular to the alignment orientation

of the second grooves **328**. Thus, the conventional art problem of electrostatic charge and dust contamination can be avoided, while the corresponding alignment layers have improved alignment quality.

The carbon nanotube structure may include a plurality of carbon nanotube wires. The carbon nanotube wires are located parallel to each other and define a plurality of parallel gaps in carbon nanotube structure. The gaps can be used as the first and second grooves **308**, **328**, which are configured to arrange and orient the liquid crystal molecules of the liquid crystal layer **338** in a particular direction. The alignment orientation of the first grooves **308** is perpendicular to the alignment orientation of the second grooves **328**.

In the one embodiment, the first conductive alignment layer **304** includes a first transparent protective layer **304b** and a first carbon nanotube layer **304a**. The first transparent protective layer **304b** is configured to cover the carbon nanotube layer **304a**. The second conductive alignment layer **324** includes a second transparent protective layer **324b** and a second carbon nanotube layer **324a**. The second transparent protective layer **324b** is configured to cover the second carbon nanotube layer **324a**. The transparent protective layer prevents the carbon nanotube layer from being exposed to the environment. Due to the first carbon nanotube layer **304a** having a plurality of parallel and uniform gaps, when the first transparent protective layer **304b** is correspondingly formed on the first carbon nanotube layer **304a**, the first grooves **308** are defined on surface of the first transparent protective layer **304b**. Due to the second carbon nanotube structure **324a** having a plurality of parallel and uniform gaps, when the second transparent protective layer **324b** is correspondingly formed on the second carbon nanotube structure **324a**, the second grooves **328** are defined on surfaces of the second transparent protective layer **324b**.

The transparent protective layer **304b**, **324b** can be made of a materials selected from a group consisting of diamonds, silicon nitrogen, hydride of random silicon, silicon carbon, silicon dioxide, aluminum oxide, tin oxide, cerium oxide, zinc titanate, indium titanate, benzocyclobutane, and acrylic resin. The thickness of the transparent protective layer can be in a range from about 5 nanometers to about 2 microns.

The first conductive alignment layer **304** includes a plurality of parallel first grooves **308**. The second conductive alignment layer **324** includes a plurality of parallel second grooves **328**. The alignment orientation of the first grooves **308** is perpendicular to the alignment orientation of the second grooves **328**.

In order to fabricate the first grooves **308** so that they are perpendicular to the second grooves **328**, the carbon nanotubes in the first conductive alignment layer **304** are arranged perpendicular to the carbon nanotubes in the second alignment layer **324**. A thickness of each of the first conductive alignment layer **304** and the second conductive alignment layer **324** can be in a range from about 10 nanometers to about 50 micrometers.

Because the carbon nanotubes in each carbon nanotube layer are arranged in parallel, the carbon nanotube layer has a light polarization characteristic, and thus, can be used to replace a conventional polarizer. This simplifies the structure and reduces the thickness of the liquid crystal display.

The liquid crystal displays **20** and the liquid crystal displays **30** provided in the present disclosure are single-pixel liquid crystal displays. By arranging a number of the single-pixel 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 substrates.

Referring to the embodiment shown in FIG. **10**, a multi-pixel liquid crystal display **40** includes a bottom portion **400**, an upper portion **401**, and a liquid crystal layer **438**. The liquid crystal layer **438** is sandwiched between the bottom portion **400** and the upper portion **401**.

The bottom portion **400** includes a first substrate **402**, a first transparent heating layer **407**, a first insulating layer **430**, a thin-film transistor array **404**, and a first conductive alignment layer **406**. The first conductive alignment layer **406** includes a first conducting layer **406a** and a second alignment layer **406b**.

The upper portion **401** includes a second substrate **422**, a second transparent heating layer **427**, a second insulating layer **432**, and a second conductive alignment layer **424**. The second conductive alignment layer **424** faces the liquid crystal layer **438**. The second transparent heating layer **427** and the second conductive alignment layer **424** are electrical insulated by the second insulating layer **432**. The second conductive alignment layer **424** includes a second conducting layer **424a** and a second alignment layer **424b**.

Referring to FIG. **11**, the thin-film transistor array **404** includes a plurality of parallel source electrodes **130**, a plurality of parallel gate electrodes **140**, a plurality of pixel electrodes **120**, and a plurality of thin-film transistors **110**. The source electrodes **130**, gate electrodes **140**, pixel electrodes **120**, and thin-film transistors **110** are in the same plane. The orientation of the gate electrode **140** is perpendicular to and extends across the source electrodes **130**. The gate electrodes **140** and the source electrodes **130** are insulated each other. Each area has a pixel electrode **120** and a thin-film transistor **110** mounted thereon. The thin-film transistor **110** includes a source **115**, a drain **116**, a semiconductor layer (not labeled), and a gate **112**. The source **115** is electrically connected to the source electrodes **130**. The drain **116** is electrically connected to the pixel electrodes **120**. The semiconductor layer is electrically to the source **115** and the drain **116**. The gate **112** is electrically connected to the gate electrodes **140**.

In one embodiment, the first conductive alignment layer **406** is conductive and transparent. The carbon nanotube layer divided into a number of carbon nanotube blocks. The carbon nanotube blocks are arranged in a matrix, each carbon nanotube block corresponds to a pixel electrode **120**. Each carbon nanotube block is electrically insulated with each other to prevent each pixel electrodes **120** from short circuiting. The second alignment layer **424b** has a number of blocks corresponding to the carbon nanotube blocks. The second alignment layer **424b** is made of polyimide. The grooves on the surface of the second alignment layer **424b** can be formed by rubbing, incline silicon oxide evaporation, and atomic beam alignment micro-treatment.

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 transparent heating layer, thus the liquid crystal display can perform at low external temperatures. Secondly, the same carbon nanotube structure can be used as a conducting 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. Therefore, the liquid crystal display has improved durability and improved arrangement of liquid crystal molecules.

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 sandwiched between the first substrate and the second substrate;
a first transparent heating layer located on the first substrate;
a second transparent heating layer located on the second substrate, at least one of the first the second transparent heating layers comprises a carbon nanotube structure.
2. The liquid crystal display as claimed in claim 1, wherein the carbon nanotube structure comprises a carbon nanotube layer, and the carbon nanotube layer comprises a plurality of carbon nanotubes.
3. The liquid crystal display as claimed in claim 2, wherein the carbon nanotube layer comprises at least one carbon nanotube film comprising a plurality of the carbon nanotubes joined end-to-end by van der Waals attractive force therebetween.
4. The liquid crystal display as claimed in claim 2, wherein the carbon nanotube layer comprises at least two stacked carbon nanotube films, an angle α between the preferred orientations of the carbon nanotubes in two adjacent carbon nanotube films is equal to 0 degrees to about 90 degrees.
5. The liquid crystal display as claimed in claim 2, wherein the carbon nanotube layer comprises a plurality of carbon nanotube wires.
6. The liquid crystal display as claimed in claim 1, wherein the first and the second transparent heating layers each are patterned carbon nanotube structures.
7. The liquid crystal display as claimed in claim 1, further comprises a first insulating layer attached to the first transparent heating layer, a second insulating layer attached to the second transparent heating layer, a first conducting alignment layer attached to the first insulating layer, and a second conducting alignment layer attached to the second insulating layer.
8. The liquid crystal display as claimed in claim 7, wherein the first conducting alignment layer and the second conducting alignment layer are configured to arrange and orient the liquid crystal molecules of the liquid crystal layer, the first and second transparent heating layers are configured to heat the liquid crystal molecules of the liquid crystal layer, the first

insulating layer is configured to insulate the first conducting alignment layer from the first transparent heating layer, and the second insulating layer is configured to insulate the second conducting alignment layer from the second transparent heating layer.

9. The liquid crystal display as claimed in claim 8, wherein the first and the second conducting alignment layers each further comprise a transparent protective layer.

10. The liquid crystal display as claimed in claim 7, wherein the first and the second conducting alignment layers each comprise a carbon nanotube structure, wherein the carbon nanotube structure comprises a plurality of ordered carbon nanotubes, a plurality of gaps is defined between adjacent carbon nanotubes.

11. The liquid crystal display as claimed in claim 7, wherein the alignment orientation of the first conducting alignment layer is perpendicular to the second conducting alignment layer.

12. The liquid crystal display as claimed in claim 1, further comprising a temperature controlling system, the temperature controlling system comprises:

- a temperature sensor;
- a signal processing device;
- a transition module;
- a microprocessor; and
- a power source;

wherein the power source electrically connected to the transparent heating layer.

13. The liquid crystal display as claimed in claim 1, wherein a thin-film transistor layer is located between the first conducting alignment layer and the first insulating layer.

14. The liquid crystal display as claimed in claim 13, wherein the thin-film transistor layer comprises:

- a plurality of parallel source electrodes;
- a plurality of parallel gate electrodes;
- a plurality of pixel electrodes; and
- a plurality of thin-film transistors;

wherein the orientation of the gate electrode is perpendicular to and extends across the source electrodes to define a plurality of areas therein, each area has a pixel electrode and a thin-film transistor mounted thereon.

15. The liquid crystal display as claimed in claim 1, wherein both the first and second transparent heating layers comprises the carbon nanotube structure.

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专利名称(译)	具有透明加热层的液晶显示器，包括碳纳米管结构		
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[标]申请(专利权)人(译)	清华大学 鸿海精密工业股份有限公司		
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摘要(译)

液晶显示器包括第一基板和第二基板。液晶层位于第一和第二基板之间。第一透明加热层附着在第一基板上。第二透明加热层附着在第二基板上。第一透明加热层和第二透明加热层中的每一个包括多个碳纳米管。

