Title: METHOD FOR MANUFACTURING SUBSTRATE WITH INSULATING LAYER AND DISPLAY HAVING THE SUBSTRATE

Abstract: A method for manufacturing a film substrate with an insulating layer of the present invention includes the steps of applying a polymerizable inorganic insulating material on the film substrate; and irradiating the insulating material with ultraviolet rays for polymerization thereof as the substrate is in contact with a table. The table has a pipeline for flowing a cooling agent in the vicinity of the supporting surface for the cooling of said supporting surface. The heat is transferred from the film substrate to the cooling agent in the pipeline. Accordingly, the rise in temperature of the film substrate can be restrained.
DESCRIPTION

METHOD FOR MANUFACTURING SUBSTRATE WITH INSULATING LAYER AND DISPLAY HAVING THE SUBSTRATE

TECHNICAL FIELD

The present invention relates to a method for coating a substrate with an insulating material. The present invention also relates to a method for manufacturing a display such as liquid crystal display (LCD) having the coated substrate.

BACKGROUND OF THE INVENTION

Conventionally, there has been known an LCD in which a pair of substrates (upper and lower substrates) is spaced apart from each other to form a predetermined gap therebetween to fill a liquid crystal (LC). A plurality of electrodes or column electrodes are formed on the lower surface of the upper substrate. Likewise, a plurality of electrodes or row electrodes are formed on the upper surface of the lower substrate. A matrix drive technique can be employed in which predetermined voltages are applied to a pair of electrodes on the upper and lower substrates, respectively, so that the displaying state of the LC therebetween is changed.
If necessary, an insulating layer and orientational control layer may be provided in this order on the electrodes. As is well known to those skilled in the art, a main reason for providing an insulating layer is to prevent electroconductive foreign matters from being mixed in the LCD during the manufacturing process thereof, which would otherwise cause a short-circuit between the electrodes, resulting in an inferior display quality.

Recently, there has been a high demand for reducing the weight of a display such as LCD. For this purpose, a plastic film, which is lighter and higher crack-resistant than a glass, is suitable for use as substrate of the LCD.

Since a plastic film has lower heat resistance than a glass, it is required that the insulating layer be formed on the film substrate at a relatively low temperature. For this purpose, it is known to those skilled in the art that metalalkoxide oligomer is used as a principal insulating material. Specifically, an insulating layer is formed on a film by application of the insulating material dissolved in a solvent, evaporation of the solvent, and then irradiation of the insulating material with ultraviolet rays for polymerization and curing thereof.

Since a relatively high amount of ultraviolet irradiation is required in order to polymerize such
insulating material, a device for irradiating with ultraviolet rays is generally provided with a high pressure mercury lamp or metal halide lamp as light source.

However, since such irradiation device irradiates infrared rays as well as ultraviolet rays, high intensity of illumination may cause the plastic film substrate to be heated, resulting in a deformation or degradation thereof. Also, since the plastic film substrate, which is made of polycarbonate for example, has a higher coefficient of thermal expansion than that of electrodes (which are typically made of indium tin oxide) on the substrate, the heating may cause a tension to be applied to the electrodes, so that cracks may occur in the electrodes. Further, the polymerization causes the insulating material to contract, which may result in a cracking of the electrodes. The cracks in the electrodes lead to an inferior display quality. In addition, the yield reduction increases the manufacturing cost of the display.

In view of above, in order to restrain the rise in temperature of the substrate during the irradiation process with ultraviolet rays, a filter may be used for cutting off infrared rays irradiated from the ultraviolet irradiating device to the substrate. However, it is in fact technically difficult to cut off infrared rays completely. Therefore, a higher intensity of illumination
inevitably raises the temperature of the substrate. Also, since the installation of the filter lowers the illuminance of ultraviolet rays, the irradiation time of ultraviolet rays required to polymerize the insulating material is increased, so that the productivity of the display is lowered.

SUMMARY OF THE INVENTION

Hence, it is an object of the present invention to provide a method for manufacturing a film substrate with an insulating layer in which an insulating material is polymerized by irradiation with ultraviolet rays while the rise in temperature of the film substrate is restrained.

It is another object of the present invention to provide a method for manufacturing a display having a film substrate with an insulating layer.

To achieve the above object, a method for manufacturing a film substrate with an insulating layer of the present invention includes the steps of applying a polymerizable inorganic insulating material on the film substrate; and irradiating the insulating material with light for polymerization thereof as the substrate is in contact with a heat radiating support. Preferably, the light is ultraviolet light.

The supporting surface of the support for
supporting the film substrate may be smooth so that the film substrate can be in closer contact with the support.

The supporting surface of the support may be maintained in a predetermined range of temperature in the irradiation. For this purpose, a pipeline for flowing a cooling agent may be provided in the vicinity of the supporting surface of the support for the cooling of said supporting surface.

In order that the heat is transferred from the film substrate to the cooling agent in the pipeline efficiently, at least a portion of the support between the supporting surface and the pipeline may be made of metal.

A method according to the present invention for manufacturing a display which has a display layer between a pair of film substrates includes the steps of applying a polymerizable inorganic insulating material on the film substrate; and irradiating said insulating material with light for polymerization thereof as the substrate is in contact with a heat radiating support.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross sectional view of an LCD having a pair of film substrates;

Figs. 2A-2H are schematic diagrams showing steps of manufacturing the LCD of Fig. 1;
Fig. 3A is a schematic cross sectional view of a device for forming an insulating layer on the film substrate;

Fig. 3B is a top view of the table of Fig. 3A on which the film substrate is positioned, showing partially in perspective a plurality of suction holes and a pipeline for flowing a cooling agent;

Fig. 4 is a schematic cross sectional view of a device for forming an insulating layer in which a film substrate is irradiated with ultraviolet rays as it is held in the air;

Fig. 5 is a schematic cross sectional view of the device of Fig. 4 that is provided with a cooling fan for supplying a cooling air to the film substrate;

Fig. 6 is a schematic side view of a device for forming an insulating layer in which another means is provided for setting a film substrate in close contact to a heat radiating support; and

Fig. 7 is a schematic side view of a device for forming an insulating layer in which yet another means is provided for setting a film substrate in close contact to a heat radiating support.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, and particularly
to Fig. 1 thereof, there is shown an LCD 10 that includes a pair of transparent film substrates, i.e., lower and upper substrates 12 and 14, spaced apart from each other to form a predetermined gap therebetween. A plurality of transparent electrodes, i.e., column electrodes 16 arranged parallel to the direction extending across the front and rear surfaces of the drawing of Fig.1 are formed on the upper surface of the lower substrate 12. Likewise, a plurality of transparent electrodes, i.e., row electrodes 18 arranged laterally in Fig. 1 (i.e. perpendicular to the longitudinal direction of the column electrodes 16) are formed on the lower surface of the upper substrate 14. The column and row electrodes 16 and 18 cross each other at right angles to define a matrix of pixels. The film substrates 12 and 14 may be made of polycarbonate, polyethersulfone, or polyethylene terephthalate. As transparent electrodes 16 and 18, indium tin oxide (ITO) may be preferably used.

A seal 22 is formed around the outer boundaries of the lower and upper substrates 12 and 14 to contain liquid crystal 20 in the gap formed therebetween. As liquid crystal materials, nematic LC, smectic LC, discotic LC and cholesteric LC are exemplified. Preferably, thermosetting resin, ultraviolet curing resin or thermoplastic resin that has a relatively high softening point is used as seal 22.
In order to maintain an even gap, spherical particulate spacers 24 of the same diameter (e.g. 5 μm) are provided between the substrates 12 and 14. As spacers 24, a hard material such as silica, divinylbenzene resin, or acrylic resin is preferable, which is not deformed when it is pressurized or heated. Insulating layers 26 and 28 are formed on the lower and upper electrodes 16 and 18, respectively. If necessary, orientational control layers not shown may be provided on the insulating layers 26 and 28. The substrates 12 and 14 may be securely held by columns (not shown), which are preferably made of suitable resin, extending in the thickness direction of the LCD 10 at least in the region surrounded by the seal 22.

The material used for the insulating layers 26 and 28 is a polymerizable inorganic insulating material such as metalalkoxide oligomer. It should be noted that such insulating material satisfies following fundamental requirements with regard to the insulating layer used in an LCD:

1. Where electroconductive foreign matters are mixed during the manufacturing process of the LCD, a short circuit between the column and row electrodes 16 and 18 does not occur.

2. The insulating layer is capable of being in full contact with its neighboring elements (i.e., electrodes 16
or 18 and, if necessary, orientational control layer) so that substantial no clearance may be left therebetween.

(3) The insulating layer has a lower surface roughness so that the thickness of the layer is substantially even.

(4) The difference in refractive index between the insulating layer and its neighboring elements is small so that light can be refrained from reflecting at the boundary therebetween.

(5) The insulating layer has a high dielectric constant so that power loss due to the layer is small when a voltage is applied between the electrodes 16 and 18.

Hereinafter, an exemplary method for manufacturing an LCD 10 will be described with reference to Figs. 2A-2H. First, as shown in Fig. 2A, a plurality of parallel transparent electrodes 18 each having a predetermined width are formed at equal distances on the upper substrate 14. As shown in Fig. 2B, an insulating layer 28 is formed on the transparent electrodes 18 as will be described in greater detail. If necessary, an orientational control layer not shown, which is made of polyimide resin for example, may be formed on the insulating layer 28 using flexography. Next, as shown in Fig. 2C, spacers 24 are spread on the substrate 14 using a spreading unit (not shown). Likewise, as shown in Fig. 2D, a plurality of parallel transparent electrodes 16 each
having a predetermined width are formed at equal distances on the lower substrate 12. As shown in Fig. 2E, an insulating layer 26 is formed on the transparent electrodes 16 as will be described in greater detail. If necessary, an orientational control layer not shown may be formed on the insulating layer 26. As shown in Fig. 2F, a seal 22 is formed along the outer boundary of the lower substrate 12 except for a portion that will serve to be an opening for injection of liquid crystal material, using screen printing for example. Then, as shown in Fig. 2G, the lower and upper substrates 12 and 14 are superimposed one on top the other so that the electrodes 16 and 18 formed on the substrates 12 and 14, respectively, cross each other at right angle to form empty cells therebetween. The liquid crystal material 20 is supplied into the empty cells by a vacuum injection through the opening not shown in the seal 22. Afterwards, the opening is closed by the same material as or a material different from the seal material. Where the seal 22 is made of an ultraviolet curing resin, the irradiation with ultraviolet rays enables the seal 22 to be cured so that the lower and upper substrates 12 and 14 are securely held to form an LCD 10, as shown in Fig. 2H.

The insulating layers 26 and 28 are coated on the lower and upper substrates 12 and 14 using a coating device shown in Figs. 3A and 3B. Hereinafter, for simplicity
of description, a method for forming the insulating layer 28 on the upper substrate 28 will be described, although the insulating layer 26 can be formed on the lower substrate 12 in a similar manner.

As shown in Fig. 3A, the coating device 30 includes a table 32 that is configured so that a negative pressure can be applied to the upper substrate 14 to fix it on the flat supporting surface of the table 32. As described below, the table 32 also serves as a heat radiating support for dissipating heat. The table 32 has a plurality of suction holes 34 that are connected with a cavity 35 in the table 32. The cavity 35 is connected via a solenoid valve 36 to a vacuum pump 38 so that the opening of the valve 36 permits the entire surface of the substrate 14 to be brought into contact with the flat surface of the table 32.

With reference also to Fig. 3B, a pipeline 40 is provided in the upper portion (i.e., in the vicinity of the flat surface) of the table 32 for flowing a cooling water as cooling agent. A cooling air may be flowed in the pipeline 40 instead of the cooling water. The cooling water in the pipeline 40 is circulated through the table 32 and a heat exchanger not shown so that the cooling water supplied to the upper portion of the table 32 can be maintained at a substantially constant temperature.
Accordingly, the heat can escape from the substrate 14 via the supporting surface, which is in close contact with the substrate 14, to the table 32. That can restrain the rise in temperature of the upper substrate 14.

5 To allow the heat to escape from the upper substrate 14 efficiently, the upper portion of the table 32 that surrounds the pipeline 40 are preferably made of a metal having a high thermal conductivity such as aluminum, copper or silver. However, any other metals such as stainless steel that have a lower thermal conductivity than the above-exemplified metals may be employed instead as long as the heat can be transferred from the substrate 14 to the cooling water flowing in the pipeline 40.

10 In addition to the cooling method mentioned above, a cooling air may be supplied onto the substrate 14. That enhances the effect to prevent the rise in temperature of the substrate 14.

15 As shown in Fig. 3A, a unit 50 for irradiating with ultraviolet rays is provided above the table 32. The irradiation unit 50 includes a lamp 52, a reflector 54 provided on the opposite side of the lamp 52 with respect to the table 32, and a guide 56 extending from the reflector 54 to the region in the vicinity of the table 32. The surface of the guide 56 facing the lamp 52 is made of the same material capable of reflecting ultraviolet rays as
that of the reflector 54. As light source 52 of the irradiation unit 50, high pressure mercury lamp, low pressure mercury lamp, metal halide lamp or Xenon lamp may be used. The components 52, 54 and 56 of the unit 50 are extended in the direction extending across the front and rear surfaces of the drawing of Fig. 3A. A filter 58 for cutting off infrared rays may be provided between the lamp 52 and table 32 to reduce the amount of infrared rays irradiated toward the upper substrate 14 located on the table 32, so that the rise in temperature of the substrate 14 can be restrained more effectively.

An exemplary process for coating an insulating layer on the substrate is performed as follows:

First, a solution of insulating material in a solvent is applied on the electrodes 18 (see Fig. 2A) formed on the upper substrate 14, using an application method such as flexography, roll coating, spin coating, or spray coating. Next, the substrate 14 is held in an oven of, for example, about 80°C to evaporate the solvent so that the insulating material is dried.

Then, the substrate 14 is positioned in full contact with the table 32 with no substantial clearance being left therebetween. The substrate is irradiated with ultraviolet rays by the lamp 52, so that the insulating material is polymerized to form the insulating layer 28.
Afterwards, the substrate 14 is held in an oven of, for example, about 140°C to bake the insulating layer 28 to prepare for the next step. The next step may be for forming an orientational control layer on the insulating layer 28 if the orientational control layer is necessary.

Discussions will be made to examples prepared by the inventor of the present invention. In each of examples 1 and 2, and comparative examples 1-3, a hundred of substrates coated with an insulating layer were manufactured using the process described below. The polymerization of the insulating material was performed successively on the same table for all of the hundred substrates.

Example 1

A substrate made of polycarbonate with an ITO film was prepared. The substrate had a thickness of 100µm. The ITO film had a thickness of 100nm. Using photolithography, a hundred of electrodes in a form of strip each having a width of 140µm were formed at an equal distance of 10µm. Next, the electrical continuity of each electrode was checked using a circuit tester. There was no disconnection and short circuit. Then, using flexography, an insulating material (under the tradename of TA-606
manufactured by Catalysts & Chemicals Ind. Co., Ltd.) in which metalalkoxide oligomer was dispersed in a solvent of hexylene glycol was applied on the substrate. Afterwards, the substrate was held in an oven of 80°C so that the solvent was evaporated. The coating of the insulating material had a thickness of about 130nm.

The coated substrate was positioned on a table as shown in Fig. 3. A cooling water of 23°C was flowed in the pipeline. The ultraviolet irradiation device (under the tradename of UV Projector UNICURE manufactured by Ushio Inc.) having a high pressure mercury lamp as a light source was used to irradiate the insulating material with ultraviolet rays to form the insulating layer on the substrate. The intensity of illumination was 50 mJ/cm²/sec. The irradiation time was 80 seconds. Accordingly, the total irradiation energy was 4000 mJ/cm². The substrate was held in an oven of about 150°C for an hour for baking to cure the insulating layer completely. The baked insulating layer had a thickness of about 75nm.

In the irradiation, the substrate was kept in contact with the table and therefore no waviness of the substrate due to heating occurred. Before the irradiation, the table and the substrate had a surface temperature of 25°C. Immediately before the irradiation process for each substrate has been completed, the table and the substrate
had a surface temperature of 27°C and 33°C, respectively.

As described above, the hundred of substrates were successively irradiated from the high pressure mercury lamp with ultraviolet rays to manufacture the hundred of substrates coated with the insulating layer. The electrical continuity of the electrodes was checked using a circuit tester to find out there was no disconnection. An orientational control layer was coated on each of the hundred of the substrates. For each of the fifty substrates, spacers were spread (on a region corresponding to the display region of the LCD). For each of the remaining fifty substrates, a seal was formed (at the periphery of a region corresponding to the display region of the LCD). Each of the fifty substrates on which the spacers had been spread and each of the fifty substrates on which the seal had been formed were superimposed one on top the other so that the opposed electrodes on the substrates cross each other at right angle to form empty cells therebetween. The liquid crystal material was supplied into the empty cells by a vacuum injection to manufacture an LCD device. All of the fifty LCD devices so manufactured provided a display of high quality without any disconnection in the electrodes and display nonuniformity.
A hundred of substrates coated with the insulating layer were manufactured in a similar manner to example 1 except that a cooling water was not flowed in the table during the irradiation process. The first seventy substrates could be coated with the insulating layer without any disconnection in the electrodes. A disconnection was found in some of the remaining thirty substrates. The surface temperature of the table reached 90°C when the hundredth substrate was irradiated with ultraviolet rays.

Comparative Example 1

A hundred of substrates coated with the insulating layer were manufactured in a similar manner to example 1 except that, as shown in Fig. 4, each substrate 60 was irradiated with ultraviolet rays as it was held in the air and supported at its both ends by the holding strips 62 which attach to and extend beyond the sides of the surface of the table 63. In the irradiation, the waviness of the substrate 60 due to the heating was observed. Immediately before the irradiation process for each substrate 60 has been completed, some surface regions of the substrate 60 reached 170°C. After the insulating layer 64 was formed, there was a disconnection in the electrodes 66 on all of the hundred substrates.
Note that the reduction of the illuminance of ultraviolet rays allowed a possibility of the waviness or disconnection to be lowered. However, in order to lower the possibility of disconnection sufficiently, it was required that the illuminance of ultraviolet rays be greatly lowered, which resulted in a lower productivity due to a drastically and impractically longer irradiation time. For example, when the illuminance is reduced to 10 mJ/cm²/sec, it was required that the irradiation time be five times as long as in case of an illuminance of 50 mJ/cm²/sec. Therefore, the time required to complete the irradiation of a hundred of substrates was about nine hours longer.

Comparative Example 2

A hundred of substrates coated with the insulating layer were manufactured in a similar manner to comparative example 1 except that, as shown in Fig. 5, each substrate 60 was irradiated with ultraviolet rays as it was supplied with a cooling air from a fan 70. In the irradiation, the substrate 60 had a surface temperature of 140°C. There was a disconnection in the electrodes on twenty of the hundred substrates each coated with the insulating layer.
As is seen from the results of the examples, it is advantageous to set a substrate in close contact to a supporting surface of the table and maintain the temperature of the table at a substantial constant for example by flowing a cooling water in the table, in order to restrain the rise in temperature of the substrate during the coating process of an insulating layer on the substrate. This provides a substrate having the insulating layer without any disconnection of electrodes. This also results in a relatively short irradiation time of ultraviolet rays and therefore an improved productivity.

Although the present invention has been described by way of examples with reference to the accompanying drawings, further changes and modifications can be made without departing from the spirit and scope of the inventions. For example, although in the previous embodiment a film substrate is irradiated with ultraviolet rays as it is applied with a vacuum force through the suction holes and is in contact with the table, which serves as a heat radiating support, the film substrate may be in electrostatic contact with the table. Alternatively, as shown in Fig. 6, a pressure-sensitive adhesive coating may be applied on a table 82 in order that a film substrate 86 having a coating 84 including an insulating
material is brought into contact with the table 82. Note that electrodes on the film substrate 86 are not shown in Fig. 6.

The supporting surface of the table may not be flat as long as it is smooth. For example, as shown in Fig. 7, a table 90 may have a convex supporting surface 92. In this case, a substrate 96 having a coating 94 including an insulating material is set in contact to the convex supporting surface 92 as it is applied with an adequate tension at its both ends held by a pair of holding members 98. Again, electrodes on the film substrate 96 are not shown in Fig. 7.

According to the present invention, during the coating process of the insulating layer, cracks can be restrained from occurring in the electrodes on a film substrate, which allows a film substrate of high quality that is coated with an insulating layer. Also, in a display having such film substrate as a display substrate, display defects can be restrained from occurring.
CLAIMS

1. A method for manufacturing a film substrate coated with an insulating layer, comprising the steps of:
   applying a polymerizable inorganic insulating material on the film substrate; and
   irradiating said insulating material with light for polymerization thereof as the substrate is in contact with a heat radiating support.

2. A method in accordance with claim 1 wherein the supporting surface of said support for supporting the film substrate is smooth.

3. A method in accordance with claim 1 wherein said light is ultraviolet light.

4. A method in accordance with claim 1 wherein said light has an illuminance of more than 10 mJ/cm²/sec.

5. A method in accordance with claim 1 wherein said insulating material includes metalalkoxide oligomer.

6. A method in accordance with claim 1 wherein the supporting surface of said support is maintained in a predetermined range of temperature in said irradiating step.
7. A method in accordance with claim 6 wherein a pipeline for flowing a cooling agent is provided in the vicinity of the supporting surface of said support for the cooling of said supporting surface in said irradiation step.

8. A method in accordance with claim 7 wherein at least a portion of the support between said supporting surface and the pipeline is made of metal.

9. A method in accordance with claim 1 wherein a plurality of suction holes are provided in said support for applying a suction to the film substrate so that it is brought into contact with the supporting surface of the support.

10. A method in accordance with claim 1 wherein said insulating material is irradiated with said light through a filter capable of cutting off infrared rays.

11. A method in accordance with claim 1 wherein said film substrate is a substrate on which electrodes are formed.

12. A method for manufacturing a display which has a
display layer between a pair of film substrates, comprising
the steps of:

applying a polymerizable inorganic insulating material
on the film substrate; and

irradiating said insulating material with light for
polymerization thereof as the substrate is in contact with
a heat radiating support.
Fig. 1
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C09D1/00 G02F1/1333 H01L21/314 H01L21/316

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G02F H01L C09D B05D C08F

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Patent family members are listed in annex.

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Date of the actual completion of the international search

18 October 2002

Date of mailing of the international search report

30/10/2002

Name and mailing address of the ISA

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