

TITLE OF THE INVENTION

Method of producing flat panel display

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method of producing FPD (flat display panel) having a chemical polishing step using a hot-melt sealing material.

2. Description of the Prior Art

The term flat panel display (abbreviated as "FPD" in this description) is used in contrast with display devices having swell profile such as Braun tube of CRT display. Outstanding features of FPD are small depth and space saving and having no swell in the display panel, and as such, liquid crystal display, plasma display, organic EL display and the like have been brought into practical use. Among FPDs, liquid crystal displays, in particular, have become widespread, not only as a TV receiver set, but also as a display device for mobile phone set, computer device or the like.

By the way, for responding to the demands of reducing weight and thickness of liquid crystal display, a method of chemical polishing a laminated glass substrate constituting a liquid crystal display as thin as possible has been favorably employed in recent years. To be more specific, a first and a

second glass substrates 60, 60 provided with a plurality of display panel regions PN . . . PN are laminated, and the resultant laminated glass substrate GL is dipped in an aqueous solution containing hydrogen fluoride HF while the periphery thereof is firmly sealed, to effect chemical polishing for thinning the substrate (see Figs. 4 (a) and (b)).

Advantageously, such a chemical polishing method realizes good productivity because not only a plurality of display panels PN . . . PN can be produced collectively, but also a higher processing speed is realized than by mechanical polishing. Further, since the laminated glass substrate GL can be made as thin as possible, additional demands of smaller thickness and lighter weight of display panel PN can be satisfied.

In the above production method, sealing material SE having resistance to hydrofluoric acid, for sealing the periphery of the laminated glass substrate GL is required, and conventionally, UV curable resin is used as sealing material SE (Japanese Patent Application No. 2005-349714).

Disadvantageously, such sealing material SE made of UV curable resin is expensive, and once it has cured, it is impossible to repair a sealing defective part, if found thereafter. Therefore, thickness of a laminated glass substrate having just one sealing defective part could no longer be reduced, and all of the plurality of display panels PN . . .

PN could be wasted.

On the other hand, for avoiding the problem of sealing defective part, an applying amount tends to be large, and in this respect use of UV curable resin greatly raises the production cost. Further, the resin that is excessively applied will remain as a sharp edge after thinning of the glass substrate (see Fig. 4(d)), and the treatment thereof is also troublesome.

From these circumstances, there is strong demand for a sealing material which can reduce production cost and allows repair of a sealing defect part when it is detected. In order to improve the working efficiency, it is desired (1) to develop a sealing material which does not require ultraviolet ray irradiation, (b) to exert sealing performance by secure penetration into gap of laminated glass substrate with a minimum essential amount of application; and (c) to facilitate inspection after application.

In particular, since a gap of the laminated glass substrate GL is as small as about 5 μm , it is necessary to consider characteristics and an applying method of sealing material while taking this point into account.

The present invention was devised based on the above ideas, and it is an object of the invention to provide a method of producing FPD (flat panel display) which is improved to securely exert sealing performance, by using a minimum essential amount

of sealing material.

SUMMARY OF THE INVENTION

In order to achieve the above object, the present inventors accomplished a method of producing a flat panel display which includes the steps of: sealing a gap formed in a peripheral lateral face of a laminated glass substrate which is made up of two glass substrates and a display device interposed therebetween, with a hot-melt sealing material; and polishing an outer surface of the laminated glass substrate having the gap sealed with the sealing material, by bringing it into contact with a chemical polishing liquid containing hydrofluoric acid and thinning the laminated glass substrate to a predetermined thickness. Entire plate thickness of the laminated glass substrate which is subjected to the sealing step is preferably about 1.0 mm to 1.4 mm, and may become 0.5 mm or less after the polishing step.

As the hot-melt sealing material, adhesives are typically used, and of adhesives classified into ambient temperature curable, thermosetting, pressure sensitive, rewettable curable, and hot-melt (heat sensitive) adhesives, for example, hot-melt adhesives are preferably used. Such adhesives should not be interpreted in the narrow meaning, and any materials having such adhesivity that exerts a predetermined sealing effect are included.

In any cases, the sealing material of the present invention is a thermoplastic adhesive which melts under heating, and solidifies and adheres under cooling. Preferably, the sealing material of the present invention is in a colored state at normal temperature. In this case, it is particularly easy to detect a defective part by inspection after sealing step.

In the present invention, since the sealing material may be applied again on a defective part, and the sealing material has thermo-plasticity, it may be melted again by reheating after solidification, and the sealing defective part can be repaired. Therefore, only a minimum essential amount of sealing material is sufficient for use, and the production cost is reduced.

As a coloring agent, the one that is visible even in a thickness of about 5 μm in correspondence with a gap of the laminated glass substrate GL is selected. As the coloring agent, for example, green, red or black pigment may be used, however, according to the examination of the present inventors, white pigment was proved to be effective from the viewpoint of visibility. It is particularly preferred to add green or red pigment on the base of white pigment. White-base color generated by mixing white and green or red in a ratio of 5 to 3: 1 is most effective in terms of visibility.

As the white pigment, Chinese white (zinc oxide), lithopone, titanium dioxide, lead white (lead carbonate) and the like are preferred. Titanium dioxide is particularly

preferably used. Here, as a blending amount with regard to the hot-melt adhesive, a minimum amount whereby a part where an adhesive is applied can be visually observed even when the adhesive is applied in a gap of 5 μm thick glass substrate is selected.

As described above, the adhesive of the present invention contains pigment and other ingredient, and softening point of the adhesive is preferably from 60°C or higher and less than 100°C, and more preferably from 65°C or higher and less than 90°C, and most preferably from 65°C or higher to less than 85°C. When the softening point is less than 60°C, sufficient sealing effect is not necessarily achieved by chemical polishing step. Further, when the softening point is too high, workability of sealing process is impaired. The term softening point used herein refers to a value measured by a ring and ball method under the conditions according to description of JAI (Japan Adhesive Industry Association)-7. Preferably, it is measured by using an automatic softening point measuring machine.

In the adhesive of the present invention, melt viscosity at melt temperature of 180°C is preferably 650 $\text{mPa}\cdot\text{s}$ or less (more preferably 400 $\text{mPa}\cdot\text{s}$ or less), and melt viscosity at melt temperature of 80°C is preferably 300 $\text{mPa}\cdot\text{s}$ or more (more preferably 400 $\text{mPa}\cdot\text{s}$ or more). The manner of measurement follows JAI-7 and melt viscosity is measured by using a Brook Field-type automatic viscometer (spindle No. 27, a rotation

speed 10 rpm). The sealing material of the present invention is adhered to the periphery of glass substrate in melt state, however, when the melt viscosity at a melt temperature of 180°C exceeds 650 mPa·s, an internal display device may be broken when heat is applied so as to obtain desired melt viscosity. On the other hand, when the melt viscosity at a melt temperature of 80°C is less than 300 mPa·s, required sealing performance may not be achieved in a process temperature range of e.g., chemical polishing step.

From the view points of workability of sealing process and penetrability of sealing material, the sealing material of the present invention has a viscosity in melt state ranging from 200 to 1000 mPa·s, preferably from 300 to 800 mPa·s, and more preferably from 350 to 650 mPa·s. If the viscosity is too low, the sealing material deeply penetrates into the glass plate, so that the periphery of the glass substrate cannot be suitably sealed.

As the adhesive used as the sealing material of the present invention, those containing paraffinic substances such as paraffin wax, or synthetic resins such as thermoplastic resin are preferably exemplified. Examples of the paraffinic substances used herein include petroleum wax or natural wax separated and purified from distilled oil or residue oil of distillation under reduced pressure, or heavy distilled oil, as well as blended products of thereof with resin, in particular,

thermoplastic resin or the like. As the thermoplastic resin, synthetic resin such as a copolymer of ethylene and vinyl acetate, petroleum resin and modified substances thereof can be exemplified.

As the chemical polishing liquid, hydrofluoric acid water containing hydrofluoric acid as an essential etching component can be exemplified, and it is used in a concentration ranging preferably from 1 to 45% by weight, more preferably from 1 to 35% by weight, and further preferably from 1 to 25% by weight. When concentration of hydrofluoric acid is more than 45% by weight, an etching speed is too large, and an adverse effect arises that planarity of etched glass part is impaired. On the other hand, when the concentration of hydrofluoric acid is less than 1% by weight, an etching speed is too small and the time required for etching is elongated.

In addition to hydrofluoric acid, at least one or more kind of inorganic acid selected from the group consisting of hydrochloric acid, sulfuric acid, nitric acid and phosphoric acid may be included. From a viewpoint of preventing the reaction product such as silicofluoride generated by etching from adhering on the glass substrate, at least one or more kind of surfactant selected from the group consisting of carboxylic acid-based, phenolic acid-based, amidic, fatty acid ester-based, phosphoric acid ester-based, sulfuric acid ester-based, sulfonic acid-based, amine-based, ether-based

and polymeric alcohol surfactants may be included in addition to hydrofluoric acid. A polishing speed is typically, but is not limited to, about 0.5 to 10 $\mu\text{m}/\text{min}$.

In the sealing step of the present invention, a gap formed on the peripheral lateral face of a laminated glass substrate which is made up of two glass substrates and a display device interposed therebetween is sealed with a hot-melt sealing material. Here, the position where the sealing material is used is preferably a lateral face not containing outer surfaces of back and front sides of the laminated glass substrate, and the sealing material is preferably arranged in the form of a thin strip. Smaller width of sealing material is preferred, however, sufficient sealing effect is difficult to be obtained when the width is too small. Therefore, the width is appropriately selected in accordance with the balance of these factors.

As a method of arranging a sealing material in the form of a thin strip on the peripheral lateral face of the laminated glass substrate, such a method can be exemplified that includes dipping a laminated glass substrate in a predetermined depth of melt sealing material that is melted by heating, to allow the melt sealing material to penetrate into the gap of the glass substrate and solidify therein. When the dipping technique is employed, it is preferred to mask the outer surfaces of front and back sides other than lateral sides of laminated glass substrate and to provide the sealing material only on lateral

faces of the laminated glass substrate.

As an alternative method of providing a sealing material in the form of a thin strip, also preferred is to apply a melt sealing material on the peripheral lateral face on the upper part of a laminated glass substrate which is upstanding. In this case, it is preferred to gently discharge the melt sealing material toward the gap of peripheral lateral face in the applying operation. Following the applying step of sealing material, a step of reheating the sealing material is preferably provided. In this case, a similar process is repeated on four sides of the laminated glass substrate, and the applying process and the reheating process may be successively conducted for each side, or reheating process may be executed for the four sides after completion of the applying operation on the four sides.

As a method of providing the sealing material in the form of a thin strip, a sealing material formed in the form of a narrow strip, or filament of a certain thickness (circular or angular section) may be placed on the peripheral lateral face of the laminated glass substrate, and the sealing material may be heated to melt and caused to penetrate into the gap of the glass substrate, and then caused to solidify.

In any cases employing any of the above methods, an ablation step for ablating the sealing material remaining in the peripheral lateral face of the removing step of the laminated glass substrate may be provided prior to polishing

step. In this case, the remaining sealing material will not form an edge regardless of how thin the thickness of the glass substrate is made by a chemical polishing process. However, an excess sealing material may be prevented from being left on the peripheral lateral face of the laminated glass substrate by using a sealing material in the form of a thin strip, or by providing a reheating step without instead of providing such a removing step.

After sealing the periphery of the laminated glass substrate with the sealing material in this manner, an outer surface of the glass substrate is brought into contact with a chemical polishing liquid to polish the outer surface of the glass substrate, and reduce the thickness of the glass substrate to a predetermined thickness. As a method of bringing into contact with the chemical polishing liquid, dipping the glass substrate into the chemical polishing liquid, or applying the chemical polishing liquid to the outer surface of the glass substrate, and the like can be exemplified.

According to the present invention, not only an UV radiation step becomes unnecessary, but also a gap of laminated glass substrate can be securely sealed with a minimum essential applying amount. Further, even when a sealing defective part occurs, it can be readily repaired by reheating. When the sealing material is colored, a part where application and penetration amount is insufficient can be detected particularly

easily.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an explanatory view of sealing step;

Fig. 2 is a plan explanatory view showing one step of sealing operation;

Fig. 3 is a perspective view for explaining adhesiveness comparing experiment; and

Fig. 4 is an explanatory view of production method of FPD.

DETAILED DESCRIPTION OF THE INVENTION

In the following, the present invention will be explained more specifically based on exemplary embodiments. A production method according to an exemplary embodiment includes a step of applying a sealing material, a step of reheating the sealing material, and an inspecting step of applied condition. Fig. 1(a) is an explanatory view of the applying step.

<Applying step of sealing material>

In the applying step of sealing material, an automatic applicator (dispenser) in which a front rotation roller 1, a rear rotation roller 2 and a discharge nozzle 3 are integrated is used. To be more specific, the automatic applicator moves horizontally in the direction of the arrow over the laminated glass substrate GL kept in a vertical position, and in the course of this horizontal movement, a sealing material is

automatically applied into an upper periphery ED of the glass substrate GL.

In each of two rotation rollers 1, 2, a rotor 4 having a substantially U shaped notch is rotatably held by a rotation axis 5. The rotation axis 4 is held at its both ends by a coupling arm 6. Each of the rotation rollers 1, 2 does not roll on the periphery ED of the laminated glass substrate, but is used for positioning a laminated glass substrate relative to the discharge nozzle 3 by loosely holding the periphery ED of the laminated glass substrate GL.

The discharge nozzle 3 is a part provided for discharging sealing material in melt state, and is in communication with a tank (not shown) which stores sealing material under heating. The discharge nozzle 3 includes a cylindrical body 30 and a conical tip part 31 connected with each other, and on the outer circumference of the cylindrical body 30, fluorine sponge rubber and silicon rubber sheet are wound in this order. This serves to suppress heat radiation from the discharge nozzle 3 and discharge the sealing material at a predetermined viscosity.

The sealing material of the present embodiment contains a hot-melt adhesive having softening point of 65°C or higher and less than 90°C (most preferably, 65°C or higher and less than 85°C) and titanium dioxide which is white pigment. In the present embodiment, the sealing material is discharged while

it is heated so that the viscosity is about 350 to 650 mPa·s in the condition that it is applied to the periphery ED of the laminated glass substrate GL. Here, the lower the viscosity, the more excellent the penetrability into the gap of glass substrate, and hence the subsequent reheating step of sealing material can be omitted. However, if the viscosity falls within the above range, penetrability of sealing material can be secured in the subsequent reheating step even if the viscosity is relatively high.

<Reheating step>

Next, a plurality of the glass substrates GL ··· GL having experienced the applying step are accommodated in a single heating chamber, and a reheating operation of sealing material is conducted. In the reheating step, only four sides of periphery of laminated glass substrate are selectively heated. Therefore, adverse effect will not be exerted on electric devices and other components in the laminated glass substrate.

Further, since softening point of the sealing material of the present invention is 65°C or higher and less than 90°C (most preferably, 65°C or higher and less than 85°C), and reheating step may be completed rapidly, better operation efficiency is achieved compared to a conventional process which requires UV radiation time of several tens minutes. Reheating operation is executed on each side currently in upper position, but not executed simultaneously on four sides of the periphery,

however, operation time is shorter than the case where UV curable resin is used.

<Inspecting step>

In the inspecting step, penetration condition of the sealing material is visually checked. The sealing material applied in melt state is naturally cooled and solidified in the course of penetration into a gap of the glass substrate. And a leading end of penetration of sealing material usually forms a gentle wave line.

In the inspecting step, this wavy leading end line is visually checked. If a part where application amount is insufficient is detected, manual repair operation is conducted with a dispenser. This inspecting operation may be executed prior to the reheating step.

In the above, the first exemplary embodiment of the present invention has been explained, however the specific content of description will not limit the present invention. For example, in the embodiment of Fig. 1(a), two rotation rollers 1, 2 are used, however, only one rotation roller may be used. In this case, preferably, only the front rotation roller 1 is provided. A rotation roller is not necessarily used insofar as proper positioning of laminated the glass substrate GL with respect to the discharge nozzle 3 is achieved, and for example, a planar holder having U-shaped notch may be traveled previous to the discharge nozzle 3.

A held part of laminated glass substrate may not be necessarily traveled in correspondence with the discharge nozzle. Fig. 1(b) is a view exemplarily showing an arrangement in which a laminated glass substrate is held by a holding plate 10 having truncated V-shaped section. The holding plate 10 is allowed to freely move up and down, and after receiving the laminated glass substrate GL in the position of applicator, the holding plate 10 moves down to gently hold the laminated glass substrate. Then sealing material is applied while the discharge nozzle 3 travels in the horizontal direction on the top surface of the holding plate 10.

The holding plate 10 has a heater incorporated therein. Therefore, the applied sealing material can be kept being reheated for a predetermined time, so that complete penetration state of the sealing material is achieved. Therefore, according to the embodiment of Fig. 1(b), applying operation and reheating operation may be successively conducted for individual substrate.

Next, explanation will be made on performance test for checking performance of sealing material used in the above production method. It is to be noted that the following explanation will not limit the scope of the present invention.

Examples

1. Bonding of glass substrates

Two glass substrates (size: 50 mm × 50 mm, thickness: 0.7 mm) were bonded with tape glue so that a gap of about 10 μm was generated between the glass substrates (hereinafter, referred to as "laminated substrate").

2. Sealing operation

Masking tape was cut into a width of about 1 cm, and as shown in Fig. 2, the tape was stuck on each face of one side of outer periphery of the laminated substrate while ends of the masking tapes were aligned with position of end faces (On both faces, about 1 cm of the masking tape protrudes. The protruding parts of tape are adhered to each other, however, for convenience of drawing, they are illustrated as if they are not adhered to each other in Fig. 2.).

The sealing material listed below is heated to melt on a hot plate so that melt viscosity is as shown in Table 1, and in the sealing material, the one side on which masking tapes are stuck is dipped in the condition (time) shown in Table 1. After solidifying the sealing material by air cooling to room temperature, the protruding parts on both sides by about 1 cm are cut, and the masking tapes stuck on the substrate are removed.

The above operation was similarly conducted for the remaining three sides, and four sides of the laminated substrate were sealed to give a sealed glass substrate. Then, whether there was a sealing defective part was examined by visual check.

The results are shown in Table 1.

[Sealing materials]

1) Sealing material A

Softening point 80°C

2) Sealing material B

Softening point 65°C

Table 1

Sealing material A	Melt viscosity	650 mPa·s
	Dipping time	About 9 seconds × 4 sides
	Sealing defective part	Not observed in 4 sides
Sealing material B	Melt viscosity	350 mPa·s
	Dipping time	About 6 seconds × 4 sides
	Sealing defective part	Not observed in 4 sides

Temperature was measured by using an alcohol thermometer and an infrared radiation thermometer. As is apparent from the results shown in Table 1, when sealing material A was used, it was possible to seal the periphery of the glass substrate without any problems in the condition of melt viscosity of 650 mPa·s, and dipping time of about 9 seconds. On the other hand, when sealing material B was used, it was possible to seal the periphery of the glass substrate without causing any problems in the condition of melt viscosity of 350 mPa·s, and dipping time of about 6 seconds.

3. Polishing step

The sealed and peeled glass substrate (total glass thickness: 0.7 mm × 2=1.4 mm) was set in a carrier, and polished

until total thickness was 0.3 mm in the condition described below. Thereafter, condition of sealing material and occurrence of liquid flooding were examined by visual check. The results and time required for polishing (polishing time) are shown in Table 2.

[Table 2]

Sealing material A	Polishing time	2 hours and 53 minutes
	Condition of sealing material	No change observed
	Liquid flooding	Not observed in 4 sides
Sealing material B	Polishing time	2 hours and 53 minutes
	Condition of sealing material	No change observed
	Liquid flooding	Not observed in 4 sides

In the polishing condition of experiment, polishing was executed over 2 hours and 53 minutes to reduce the substrate thickness from a total thickness of 1.4 mm to a total thickness of 0.3 mm. Change recognizable by visual check and liquid flooding were not observed in any cases using sealing material A and sealing material B.

4. Comparative experiment of adhesiveness of sealing material

In order to compare adhesiveness between UV curable resin and the sealing material of the present invention, an experiment was conducted in the experimental condition and procedure as shown below. The results are shown in Table 3.

1) Experimental condition

Glass substrate: 50×50×0.7 mmt

Sealing material: (1) Sealing material A

(2) UV curable resin (conventional)

Measuring machine: push-pull scale

2) Experimental procedure

[Measurement of adhesiveness of sealing material A]

- a. Place 0.05 g of sealing material A on a glass substrate and cause it to melt on a hot plate.
- b. Place a clip having a bottom area of about 0.9 cm² on the melt sealing material, as shown in Fig. 3.
- c. Leave for about five minutes after returning to room temperature, to completely cure the sealing material.
- d. Connect a push-pull scale to a hook of clip.
- e. Fix the glass substrate and pull up manually, and record measurement at the time of peeling of the sealing material.

Similar operation was repeated and the average was determined.

[Measurement of adhesiveness of UV curable resin]

- a. Place 0.05 g of UV curable resin on a glass substrate and causing it to melt on a hot plate, and place a clip having a bottom area of about 0.9 cm² on the melt sealing material, as shown in Fig. 3.
- b. Conduct UV irradiation for about 15 minutes to completely cure the sealing material.

- c. Connect a push-pull scale to a hook of clip.
- d. Fix the glass substrate and pull up manually, and record measurement at the time of peeling of the sealing material.

Similar operation was repeated five times and the average was determined.

[Table 3]

	1st	2nd	3rd	Average
Sealing material A	71N	67N	72N	70N
UV curable resin	Measurments of five times: 69±11 N			69N

Adhesiveness realized by using sealing material A which is a hot-melt adhesive of the present invention was about 70N which was substantially comparable to adhesiveness obtained by using UV curable resin which is a conventional sealing material. As to the sealing material B, the result was inferior to the case of sealing material A but was fairly satisfactory.

Similar experiments were conducted while melt viscosity was changed to about 500 to 800 mPa·s through variation of dipping temperature for sealing material A, and while melt viscosity was changed to about 300 to 500 mPa·s through variation of dipping temperature for sealing material B, and the results which were comparable to these obtained above in every performance were obtained.

What is claimed is:

1. A method of producing a flat panel display comprising the steps of:

sealing a gap formed in a peripheral lateral face of a laminated glass substrate made up of two glass substrates and a display device interposed therebetween, with a hot-melt sealing material; and

polishing an outer surface of the laminated glass substrate having the gap sealed with the sealing material through contact with a chemical polishing liquid containing hydrofluoric acid and thinning the laminated glass substrate to a predetermined thickness.

2. The production method according to claim 1, wherein prior to the sealing step, the sealing material is melted by heating at 60°C or higher.

3. The production method according to claim 1, wherein prior to the polishing step, the sealing material applied or placed on the peripheral lateral face is reheated so that melt viscosity thereof is from 300 to 800 mPa·s.

4. The production method according to claim 1, wherein in the sealing step, a process of dipping the laminated glass substrate in the chemical polishing liquid and making the

sealing material penetrate into the gap, or a process of discharging and applying the sealing material on upper peripheral lateral face of the laminated glass substrate which is in an upright position is executed.

5. The production method according to claim 1, wherein the sealing material is discharged in melt state from a nozzle toward the gap.

6. The production method according to claim 5, wherein the nozzle discharges the sealing material while moving in correspondence with a movable body which travels while carrying a peripheral lateral face of the laminated glass substrate.

7. The production method according to claim 1, wherein the peripheral lateral face of the laminated glass substrate is applied with the sealing material while being held by a plate member having a heater incorporated therein.

8. The production method according to claim 1, wherein the sealing material comprises a paraffinic substance or a thermoplastic resin, and has a melt viscosity of 650 mPa·s or less at melt temperature of 180°C and a melt viscosity of 300 mPa·s or more at melt temperature of 80°C.

9. The production method according to claim 1, wherein the sealing material is in colored state at normal temperature.

10. The production method according to claim 9, wherein the sealing material is an adhesive which is colored by containment of white pigment.