

METHOD FOR MANUFACTURING GLASS SUBSTRATE FOR DISPLAY AND GLASS SUBSTRATE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method for manufacturing a glass substrate for a flat panel display, and more particularly to a method for manufacturing a high-quality glass substrate at a high yield rate.

2. Description of the Prior Art

The term "flat panel display" (hereinafter, abbreviated as "FPD") is used in contrast with a display having a curved display panel, such as a cathode-ray tube (CRT) display. The major features of FPDs include thin depth, small footprint, and flat display panels. Such FPDs are practically used as liquid crystal displays, plasma displays, organic EL displays, and the like. Among these FPDs, liquid crystal displays are particularly widely used not only for TV sets but also as displays for cellular phones or computer devices.

Fig. 2 is a cross-sectional view of a typical display panel PN of a liquid crystal display. As shown in Fig. 2, the display panel PN has a structure in which a liquid crystal LC is interposed between a pair of first and second glass substrates 1 and 2 laminated together.

On the inner surface of the first glass substrate 1, color filters 4 divided by a black matrix 3, an overcoat layer 5 for coating the black matrix

3 and the color filters 4, transparent electrodes 6A, and an oriented film 7A are stacked in this order. On the inner surface of the second glass substrate 2, thin film transistors 8 and transparent electrodes 6B are provided, and an oriented film 7B is further provided thereon.

Generally, such a display panel PN having a structure shown in Fig. 2 is manufactured in the following manner. The first glass substrate 1 and the second glass substrate 2 are laminated together in such a manner that a plurality of spacers 9 are arranged between the oriented films 7A and 7B opposite to each other to make a space having a thickness of about 3 to 6 μm for a liquid crystal. Then, a liquid crystal LC is injected into the space between the glass substrates 1 and 2 by vacuum aspiration. Finally, polarizing films 10A and 10B are respectively attached to the outer surfaces of the glass substrates 1 and 2.

Recently, there is a case where the thickness of each of the glass substrates 1 and 2 is reduced to its lower limit. Specifically, first and second glass substrates GL1 and GL2 having a plurality of display panel regions PN – PN are laminated together to obtain a laminated glass substrate GL, and the outer periphery of the laminated glass substrate GL is tightly sealed. Then, the laminated glass substrate GL is immersed in an aqueous solution containing hydrofluoric acid to reduce the thickness of the laminated glass substrate GL by chemical polishing (see Fig. 3). By using a chemical polishing method, it is possible not only to manufacture a plurality of display panels PNs at a time but also to improve productivity because the polishing speed of chemical polishing is higher than that of mechanical

polishing. In addition, it is also possible to reduce the thickness of the laminated glass substrate GL to its lower limit, which makes it possible to respond to the demand of reducing the thickness and weight of a display panel PN.

After the completion of chemical polishing, the laminated glass substrate GL is cut to separate display panels PNs from each other. Then, each of the display panels PNs is subjected to the process of injecting a liquid crystal and the process of attaching polarizing films. It is to be noted that there are also display panels having no polarizing films.

As described above, by subjecting the laminated glass substrate GL to chemical polishing, it is possible to effectively reduce the thickness of the laminated glass substrate GL to its lower limit. However, such a method involves some issues that should be further addressed.

For example, when the glass substrate is chemically polished to reduce the thickness thereof, there is a case where a very minute flaw or an altered portion latently existing in the glass substrate becomes apparent as a flaw due to chemical polishing (hereinafter, referred to as an “etching flaw”). Such an etching flaw can be eliminated by further chemically polishing the glass substrate. However, in a case where the glass substrate cannot be further chemically polished to the extent that permits elimination of an etching flaw, the etching flaw remains as a visible flaw. More specifically, there is a possibility that an etching flaw having a maximum diameter of about 50 to 2,000 μm measured in plan view as viewed from the front of the glass substrate remains. Such an etching flaw is a recessed

flaw that is relatively smooth and that has a substantially circular or oval shape because it has been subjected to etching.

Further, even if the glass substrate has no recessed flaws after the completion of chemical polishing, there is a possibility that another recessed flaw such as a crack (hereinafter, referred to as a “non-etching flaw”) appears due to cutting or the like carried out after chemical polishing. Such a non-etching flaw is not smooth and does not have a round shape because it has not been subjected to etching. Therefore, the inner surface of a non-etching flaw has fine irregularities.

Such a recessed flaw formed on the surface of the glass substrate is detected in the step of quality checking. In this step, if a glass substrate having a recessed flaw is disposed of, productivity is significantly deteriorated because disposal of a glass substrate having a recessed flaw means disposal of an expensive display panel. However, if a glass substrate having a recessed flaw is used as it is, the quality of an image displayed on a screen is deteriorated. Particularly, deterioration of image quality is a fatal defect for display panels of cellular phones or personal computers that are watched closely. Most flaws that become apparent after the completion of chemical polishing are latent before chemical polishing. Therefore, it is not possible to effectively deal with the problem of latent flaws by only carrying out quality checking before chemical polishing, and it is highly desired that a defective glass substrate be turned into a non-defective glass substrate by repairing a recessed flaw in some way.

Some approaches can be taken to repair a recessed flaw. One

approach is to subject a defective glass substrate to mechanical polishing. However, there is a problem that it is impossible to polish the glass substrate at a high speed because the thickness of the glass substrate has already been reduced to its lower limit and a plurality of spacers are arranged between the pair of glass substrates laminated together, thereby significantly deteriorating productivity. In fact, it usually takes about 60 minutes to further mechanically polish one surface of the glass substrate to reduce the thickness thereof by 30 μm . In addition, even when glass substrates are polished at such a low speed, about 20 % of the glass substrates are broken during polishing. Therefore, the rate of turning defective glass substrates into non-defective glass substrates is not so high.

Another approach is to fill a recessed flaw with an appropriate filler (adhesive). In the case of a non-etching flaw, it is relatively easy to allow a filler to firmly attach to the glass substrate. However, in the case of an etching flaw having a wide opening due to chemical polishing, adhesion between a filler and the glass substrate is poor, when the filler is one usually used. For example, in a case where the necessity to detach and reattach a polarizing film to the glass substrate arises, there is a fear that a filler filled in an etching flaw is easily peeled off from the glass substrate because the etching flaw has a wide opening. Further, there is also a fear that the filler is peeled off from the glass substrate during finishing operation such as grinding. This is because it is necessary to make the surface of the filler filled in a recessed flaw smooth to the extent that it can be identified with the surface of the glass substrate around the recessed flaw.

These problems described above are not inherent in liquid crystal displays, but are common to other FPDs.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a method for manufacturing a high-quality glass substrate for a flat panel display at a high yield rate and a high-quality glass substrate. In order to achieve the above object, the present invention is directed to a method for manufacturing a glass substrate for a flat panel display comprising the steps of: chemically polishing a glass substrate for a flat panel display with an aqueous solution containing hydrofluoric acid; checking the glass substrate chemically polished to see whether or not a recessed flaw having a maximum diameter of 50 to 2,000 μm exists in order to detect a defective glass substrate having such a recessed flaw; applying a first coating agent to the recessed flaw of the defective glass substrate; applying a second coating agent to the recessed flaw to which the first coating agent has been applied so that the second coating agent overflows the recessed flaw; curing the second coating agent; and planarizing the surface of the glass substrate by removing only the cured second coating agent that bulges out from the surface of the glass substrate.

In the present invention, when the second coating agent is cured, it functions as a filler for filling a recessed flaw. Therefore, the amount of the first coating agent to be applied to a recessed flaw is limited to a minimum, but the second coating agent is applied to the recessed flaw so as to overflow

the recessed flaw. Specifically, the second coating agent is applied to a recessed flaw in an amount sufficient to bulge out from the surface of the glass substrate even after the second coating agent is shrunk due to curing. It is to be noted that the first and second coating agents are selected so that their refractive indexes and transmittances become substantially the same as those of the glass substrate when they are cured.

In the planarizing step, the cured second coating agent that bulges out from the surface of the glass substrate is removed to planarize the glass substrate. Therefore, the second coating agent applied to the recessed flaw can have a mirror finished surface similar to that of the glass substrate. As a result, the defective laminated glass substrate is turned into a non-defective laminated glass substrate. Further, planarization is preferably carried out by artificially scraping the unnecessary portion of the second coating agent off the glass substrate with a scraper or the like, or by cutting only the second coating agent with an electric cutting blade. It is to be noted that the latter method is more excellent in obtaining a flat finished surface than the former method.

In a case where a scraper is used, the entire edge of the scraper is pressed against the glass substrate at an angle of about 25 to 35° with respect to the glass substrate to apply a load of about 0.7 to 1.0 kg to the glass substrate, and is then pushed forward to scrape the unnecessary portion of the second coating agent off the glass substrate. On the other hand, in a case where an electric apparatus is used, the electric apparatus is pressed against the glass substrate at an angle of 30 to 40° with respect to

the glass substrate to apply a cutting load of 0.2 kg or less to the glass substrate, and is then pulled to cut only the second coating agent without causing damage to the glass substrate.

If a recessed flaw produced on the surface of the glass substrate during chemical polishing is too large, the effect of the present invention is reduced by half. Therefore, it is preferred that the maximum diameter of the recessed flaw is controlled to be 2,000 μm or less. Specifically, control of the maximum diameter of the recessed flaw can be effectively carried out by a method (a) in which a latent flaw is removed by mechanically polishing the glass substrate by a predetermined thickness prior to chemical polishing and/or a method (b) in which the chemical polishing amount of the glass substrate is limited. On the other hand, a recessed flaw having a maximum diameter of less than 50 μm can be left as it is because it does not have a harmful effect from a practical standpoint. In the present invention, recessed flaws to be considered as problems include not only etching flaws that are derived from minute flaws which have already existed in the glass substrate before chemical polishing and that are enlarged by chemical polishing but also non-etching flaws that are produced by operation carried out after chemical polishing.

Further, in the present invention, chemical polishing can be carried out by using two polishing solutions different in composition. In this case, for example, a glass substrate is polished with a first polishing solution at a high rate of 1 $\mu\text{m}/\text{sec}$ or more, and is then polished with a second polishing solution at a low rate of 0.5 to 20 $\mu\text{m}/\text{min}$. By doing so, it is possible to

effectively suppress the maximum diameter of a recessed flaw (an etching flaw) produced by chemical polishing to 100 μm or more but less than 300 μm (most preferably 100 μm or more but less than 200 μm).

The first polishing solution is an aqueous solution containing hydrofluoric acid and sulfuric acid. The concentration of the hydrofluoric acid in the first polishing solution is preferably 10 to 30 wt%, more preferably 15 to 28 wt%, even more preferably 17 to 25 wt%. The concentration of the sulfuric acid in the first polishing solution is preferably 20 to 50 wt%, more preferably 30 to 45 wt%, even more preferably 35 to 42 wt%. The time for bringing the surface of the glass substrate in contact with the first polishing solution is preferably one minute or less. As described above, the rate of polishing with the first polishing solution is 1 $\mu\text{m}/\text{sec}$ or more, but is preferably 3 to 10 $\mu\text{m}/\text{sec}$, more preferably 5 to 8 $\mu\text{m}/\text{sec}$.

On the other hand, the second polishing solution is an aqueous solution containing hydrofluoric acid in an amount of 10 wt% or less. The second polishing solution preferably contains one kind or two or more kinds of inorganic acids and surfactants in addition to the hydrofluoric acid. Examples of such inorganic acids include hydrochloric acid, nitric acid, sulfuric acid, and phosphoric acid. Examples of such surfactants include ester-based surfactants, phenol-based surfactants, amide-based surfactants, ether-based surfactants, nonionic surfactants, and amine-based surfactants. As described above, the rate of polishing with the second polishing solution is 0.5 to 20 $\mu\text{m}/\text{min}$, but is preferably 0.5 to 10 $\mu\text{m}/\text{min}$.

The first coating agent is not particularly limited, but is preferably a primer for improving adhesion between the glass substrate and the second coating agent. The opening of an etching flaw has been enlarged by chemical polishing, and therefore a filler for filling such a recessed flaw is likely to be peeled off from the glass substrate. For this reason, a primer is particularly effective as the first coating agent. As such a primer, a silane-based primer containing a silane coupling agent as a main ingredient is preferably used.

As the second coating agent, a curable resin is used. In order to prevent the distortion of an image on a display screen, a methacrylic resin or an acrylic resin having substantially the same refractive index and transmittance as those of glass when it is cured is preferably used. Such a curable resin may be of, for example, a thermosetting type or a photocurable type, but a photocurable type is preferably used. Particularly, a UV curing adhesive is preferably used. Among UV curing adhesives, an anaerobic curing type that requires the absence of air is particularly preferably used, but a UV curing type that can be cured by only irradiation with ultraviolet rays may also be used.

As described above, according to the present invention, it is possible to manufacture a high-quality glass substrate for a flat panel display at a high yield rate. Further, the glass substrate is not mechanically polished when it is repaired, thereby reducing the time and cost for repair. Furthermore, such a repairing method does not cause damage to the glass substrate, thereby achieving a non-defective ratio of substantially 100 %.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A is a flow chart which shows a method for manufacturing a liquid crystal display;

Fig. 1B is a detailed flow chart of the step of repairing a glass substrate;

Fig. 2 is a cross-sectional view of a display panel of a liquid crystal display;

Fig. 3 is a schematic view of a laminated glass substrate;

Figs. 4A and 4B are illustrations for explaining the step of planarizing a glass substrate; and

Fig. 5 is a flow chart of a modified step of repairing a glass substrate.

DETAILED DESCRIPTION OF THE INVENTION

Hereinbelow, the present invention will be described in detail with reference to preferred embodiments. Fig. 1A is a flow chart which shows a method for manufacturing a liquid crystal display, and Fig. 1B is a detailed flow chart of the step of repairing a glass substrate.

A finally obtained display panel PN has the same structure as that shown in Fig. 2. However, in the step of laminating glass substrates (ST1) shown in Fig. 1, a plurality of semi-finished display panels PN - - - PN are arranged in a matrix in a laminated glass substrate GL having a size of, for example, 730 mm × 920 mm (see Fig. 3).

Specifically, in this state, each of the display panels PN_s is a semi-finished display panel which does not have a liquid crystal LC to be interposed between a glass substrate GL 1 and a glass substrate GL 2 in the step ST6 and polarizing films 10A and 10B to be respectively attached to the glass substrates GL1 and GL 2 in the step ST7. After the glass substrates GL1 and GL2 are laminated together to obtain a laminated glass substrate GL, the outer periphery of the laminated glass substrate GL is sealed with an acid-resistant sealant.

Then, the laminated glass substrate GL is immersed in an aqueous solution containing hydrofluoric acid to chemically polish the outer surfaces of the glass substrates GL1 and GL2 (ST2). The entire thickness of the laminated glass substrate GL is about 0.6 mm, 0.8 mm or 1.0 mm. Each of the glass substrates GL1 and GL2 is polished to reduce the thickness thereof by about 50 to 300 μm (the entire thickness of the laminated glass substrate GL is reduced by 100 to 600 μm). At this time, the above-described first and second polishing solutions are preferably used in this order.

In the step of chemical polishing, it is necessary to reduce the thickness of each of the glass substrates GL1 and GL2 while maintaining the flatness of these glass substrates. Therefore, it is preferred that air bubbles are continuously formed at the bottom of a polishing bath to produce an upward flow of the polishing solution. Further, it is also preferred that the polishing solution continuously overflows the polishing bath to remove a reaction product by filtration, or the polishing solution is entirely or partly renewed at the right time.

However, even in a case where chemical polishing is carried out in such a manner described above, latent flaws originally existing in the glass substrates GL1 and GL2 tend to enlarge due to chemical polishing of the glass substrates. Therefore, depending on the depth of such a latent flaw, there is a case where the latent flaw becomes apparent as a recessed flaw having a maximum diameter of 50 to 2,000 μm after the completion of chemical polishing.

Such a recessed flaw has a substantially circular or oval shape in plan view, and they are separated individually or connected to each other. In either case, by carrying out chemical polishing using such a preferred method described above, the maximum diameter of a recessed flaw is made less than 2,000 μm . It is to be noted that the maximum diameter of a recessed flaw is measured in plan view as seen from the front of the glass substrate, and that in a case where recessed flaws are connected together, the maximum diameter of a recessed flaw means a hypothetical maximum diameter of each of the recessed flaws.

After the completion of the step of chemical polishing (ST2), the laminated glass substrate GL (see Fig. 3) is then subjected to the step of cutting and separation (ST3). In the step of cutting and separation, the semi-finished display panels PN - PN arranged in a matrix are separated from each other by cutting. In connection with this, it is preferred that scribe lines are mechanically provided on the laminated glass substrate GL along demarcation lines (represented by broken lines in Fig. 3) between the display panels prior to chemical polishing. By doing so, it becomes easy to

separate the display panels from each other by cutting. In this case, portions where the scribe lines have been mechanically provided are etched deeper than other portions by chemical polishing in the step ST2 so that grooves are formed. Therefore, in the step of cutting and separation (ST3), by only mechanically applying a moderate load to the laminated glass substrate GL, each of the display panels PNs is accurately cut from the laminated glass substrate GL along the grooves. In addition, the cutting surfaces of each of the display panels PNs are smooth because the cutting surfaces have been subjected to etching.

After the completion of the step of cutting and separation (ST3), the display panels are then subjected to the step of quality checking (ST4). In this step, in addition to a typical quality checking, each of the semi-finished display panels PNs is checked to see whether or not a recessed flaw having a maximum diameter of 50 to 2,000 μm exists. If there is a display panel PN having such a recessed flaw, the display panel PN is subjected to the step of repairing a glass substrate (ST5).

As shown in Fig. 1B, in the step of repairing a glass substrate, the surface of the glass substrate is first cleaned with, for example, ethanol (ST10). Next, a cotton swab is impregnated with a primer that is a first coating agent, and the cotton swab is pressed and rubbed against a recessed flaw to apply the primer to the recessed flaw (ST11). It is to be noted that the time for pressing the cotton swab against the recessed flaw is about 30 seconds, which does not impair workability at all.

Then, an anaerobic UV curing resin that is a second coating agent is

applied to the recessed flaw (ST12). Specifically, an anaerobic UV curing resin is applied to the recessed flaw with a micropipet or the like so as to overflow the recessed flaw. It is to be noted that the UV curing resin is applied to the recessed flaw in an amount sufficient to bulge out from the surface of the glass substrate even after the UV curing resin is shrunk due to curing.

As described above, since an anaerobic UV curing resin is used in this embodiment, a shielding mask is laminated on the second coating agent for deaeration after the completion of the step ST12. At this time, the shielding mask is laminated on the second coating agent in such a manner that air bubbles are not trapped in the second coating agent. As a shielding mask to be used, a UV permeable PP (polypropylene) film is preferably used.

After the completion of such preparations described above, the second coating agent is irradiated with ultraviolet rays emitted from a hand-held UV curing unit through the shielding mask (ST14). It is to be noted that the dose and time of ultraviolet irradiation vary depending on the size and depth of a recessed flaw to be repaired, but the second coating agent can be cured by irradiation with ultraviolet rays at an intensity of 200 to 450 mJ for about 3 to 4 minutes. Therefore, it is possible to smoothly cure the second coating agent without taking so much time.

Thereafter, the shielding mask is removed from the second coating agent (ST15), and then the step of planarization (ST16) is carried out. Since the cured second coating agent bulges out from the surface of the glass substrate, the glass substrate is planarized using a scraper 20 or an electric

shaver 30 in this step.

In a case where the scraper 20 is used, the entire edge of the scraper 20 is pressed against the glass substrate GL at an angle of about 25 to 35° with respect to the glass substrate GL to apply a load of about 0.7 to 1.0 kg to the glass substrate GL, and is then pushed forward to remove a bulge 40 (see Fig. 4A). On the other hand, in a case where the shaver 30 is used, the shaver 30 is pressed against the glass substrate GL at an angle of 30 to 40° with respect to the glass substrate GL to apply a cutting load of 0.2 kg or less to the glass substrate GL, and is then pulled to cut only a bulge 40 (see Fig. 4B).

After the completion of planarization, the surface of the glass substrate GL around the repaired area is cleaned with ethanol or the like (ST17) to complete the step of repairing a glass substrate. Thereafter, a liquid crystal LC is injected into the repaired display panel PN (ST6), and then polarizing films 10A and 10B are respectively attached to the front and rear surfaces of the display panel PN (ST7). By attaching the polarizing films to the display panel PN, it is possible to completely cover the repaired area. Even in a case where the need for detaching the polarizing film from the display panel arises for some reason, there is no fear that the second coating agent will be peeled off from the glass substrate because the first coating agent and the second coating agent are layered in the recessed flaw so that adhesion between the glass substrate and the second coating agent is improved.

The operating procedure described above in detail with reference to

Fig. 1 is merely illustrative and is not intended to limit the scope of the invention. For example, in a case where there is no necessity to create anaerobic conditions, the steps ST13 and ST 15 are naturally omitted.

Further, the second coating agent is not necessarily applied to a recessed flaw at one time. For example, in the case of a relatively large recessed flaw having a maximum diameter of 200 to 300 μm or more, the second coating agent is preferably applied to such a recessed flaw over two times.

Fig. 5 is a flow chart which shows an operating procedure in which the second coating agent is applied over two times. Specifically, after the first coating agent is applied to a recessed flaw, the second coating agent is applied to the recessed flaw so that the recessed flaw is substantially filled with the second coating agent (ST20). If necessary, the second coating agent is covered with a shielding mask. Then, the second coating agent is irradiated with ultraviolet rays. In this case, the dose and time of ultraviolet irradiation are set so that the second coating agent is cured to a gel state. Thereafter, in a case where the second coating agent is covered with a shielding mask, the shielding mask is removed. Further, in a case where the second coating agent exists around the recessed flaw, it is removed with a scraper or the like.

Then, the second coating agent is further applied to the recessed flaw so as to overflow the recessed flaw (ST22). If necessary, the second coating agent is covered with a shielding mask. Then, the second coating agent is irradiated with ultraviolet rays. In this case, the dose and time of

ultraviolet irradiation are set so that the second coating agent finally applied to the recessed flaw is completely cured. As a result, the second coating agent applied to the recessed flaw for the first time is further cured so that adhesion between the second coating agent and the glass substrate is further improved. Thereafter, planarization is carried out as shown in Fig. 1B.

As described above, in a case where the second coating agent is applied to a recessed flaw over two times, adhesion between the second coating agent and the glass substrate is further improved as compared to a case where the step ST5 is carried out according to the flow chart shown in Fig. 1B. Therefore, even in a case where a polarizing film is not attached to the surface of the glass substrate, the recessed flaw is completely covered.

What is claimed is:

1. A method for manufacturing a glass substrate for a flat panel display, the method comprising the steps of:

chemically polishing a glass substrate for a flat panel display with an aqueous solution containing hydrofluoric acid for reducing the thickness of the glass substrate;

checking the glass substrate chemically polished to see whether or not a recessed flaw having a maximum diameter of 50 to 2,000 μm exists in order to detect a defective glass substrate having such a recessed flaw;

applying a first coating agent namely a primer for improving adhesion between the primer and the glass to the recessed flaw of the defective glass substrate;

applying a second coating agent namely a photocurable adhesive to the recessed flaw to which the first coating agent has been applied so that the second coating agent overflows the recessed flaw;

curing the second coating agent; and

planarizing the surface of the glass substrate by removing only the second coating agent that bulges out from the surface of the glass substrate.

2. The manufacturing method according to claim 1, further comprising the step of attaching a polarizing film to the glass substrate that has been subjected to the polarizing step.

3. The manufacturing method according to claim 1 or 2, wherein the glass substrate is a laminated glass substrate in which a plurality of

display panel regions are arranged in a matrix, and wherein the step of cutting the laminated glass substrate to separate the display panel regions from each other is carried out prior to the step of checking the glass substrate.

4. The manufacturing method according to any one of claims 1 to 3, wherein only the second coating agent is mechanically ground in the step of planarizing the glass substrate.

5. The manufacturing method according to any one of claims 1 to 4, wherein the first coating agent is a primer for improving adhesion between the glass substrate and the second coating agent and the second coating agent is a photocurable adhesive.

6. The manufacturing method according to any one of claims 1 to 5, wherein the second coating agent is covered with a light-transmittable covering material when cured in the curing step.

7. The manufacturing method according to any one of claims 1 to 6, wherein the step of applying a second coating agent further comprises the steps of:

pre-applying a second coating agent to the recessed flaw to which the first coating agent has been applied so that the second coating agent does not overflow the recessed flaw; and

finally applying the second coating agent to the recessed flaw so that the second coating agent overflows the recessed flaw before the second coating agent that has been pre-applied to the recessed flaw is completely cured.

8. A glass substrate manufactured by the method according to any one of claims 1 to 7.

9. A flat panel display manufactured using the glass substrate according to claim 8.