

METHODS FOR PROCESSING A THIN FLEXIBLE GLASS SUBSTRATE WITH A GLASS CARRIER

[0001] This application claims the benefit of priority of U.S. Provisional Application Serial No. 61/826,181, filed on May 22, 2013, the content of which is relied upon and incorporated herein by reference in its entirety.

FIELD

[0002] The following description relates to methods for processing a thin flexible glass substrate with a glass carrier and, more particularly, to methods for processing a thin flexible glass substrate with a glass carrier having a textured surface.

BACKGROUND

[0003] The emergence of flexible substrates offers the promise of making thinner, lighter, more flexible, and more durable displays and lowering the cost of the devices incorporating such displays. Thus, there has been a focus on developing solutions enabling the manufacture of flexible substrates on existing toolsets designed to process large sheets of glass. One of these solutions includes the lamination of a flexible substrate to a glass carrier, thereby enabling the manufacture of display devices with flexible substrate using a sheet-to-sheet process on existing toolsets. In related examples of a glass-to-glass bonding process, a release area of a glass carrier, which is an area designed to have little or no bond with a thin flexible glass substrate, may be formed within a bonded periphery. The means for forming the release area of the glass carrier may be to increase a surface roughness of the release area. Thus, there is a need for a method by which the release area of the glass carrier may be textured to inhibit bonding thereof to an area of a thin flexible glass substrate, while simultaneously allowing a mount area of the glass carrier to bond to a mount area of a thin flexible glass substrate.

SUMMARY

[0004] In the examples described herein, glass carriers are subjected to wet chemical etching processes using an ammonium fluoride mixture as an etchant and are subsequently provided for the processing of thin flexible glass substrates. The process is suited to texture release areas of glass carriers used as rigid substrates to support thin flexible glass substrates during liquid crystal display (LCD) and organic light-emitting diode processing (OLED) for display devices including, but not limited to, cell phones, tablet computers, and televisions. A concentration of the ammonium fluoride mixture and a time of exposure to the ammonium

fluoride mixture can be varied to produce glass carriers with release areas having varying degrees of texture. The ammonium fluoride mixture may be soluble, thereby enabling a hermetic sealing of a mount area of the glass carrier to a mount area of the thin flexible glass substrate. In addition, the ammonium fluoride mixture is generally safer and easier to use as an etchant than the commonly used hydrofluoric acid.

[0005] In a first aspect, a method for processing a thin flexible glass substrate with a glass carrier includes the steps of: (I) providing the glass carrier including a release area and a mount area; then (II) providing the release area of the glass carrier with a textured surface by contacting an etchant including an ammonium fluoride mixture to the release area for a period; then (III) removing the etchant from the glass carrier; and then (IV) bonding a mount area of the thin flexible glass substrate to the mount area of the glass carrier. The textured surface prevents a target area of the thin flexible glass substrate from bonding to the release area of the glass carrier.

[0006] In one example of the first aspect, the period of step (II) is in a range of from about 1 minute to about 10 minutes.

[0007] In another example of the first aspect, step (II) provides the textured surface with a root-mean-squared surface roughness in a range from about 3 nm to about 232 nm.

[0008] In yet another example of the first aspect, step (II) provides the textured surface with a root-mean-squared surface roughness that is greater than about 2 nm and equal to or less than about 6 nm.

[0009] In still another example of the first aspect, the etchant of step (II) consists of the ammonium fluoride mixture, and the ammonium fluoride mixture consists of an ammonium fluoride solution in glacial acetic acid.

[0010] In a further example of the first aspect, a concentration of the ammonium fluoride solution is in a range from about 4 % to about 20 %.

[0011] In an additional example of the first aspect, the ammonium fluoride solution of step (II) is about 40 % ammonium fluoride in water.

[0012] In a still further example of the first aspect, after step (I) and prior to step (II), the method further includes the step of applying a mask to the mount area of the glass carrier. During step (II), the mask prevents the etchant from contacting the mount area of the glass carrier.

[0013] In another example of the first aspect, the mask includes an adhesive film.

[0014] In yet another example of the first aspect, step (II) includes printing the etchant on the release area of the glass carrier.

[0015] In still another example of the first aspect, step (II) includes screen-printing or stencil-printing the etchant on the release area of the glass carrier.

[0016] In a further example of the first aspect, step (II) applies the etchant as a gel etchant.

[0017] In a still further example of the first aspect, the gel etchant consists of the ammonium fluoride mixture and a thickener, and the ammonium fluoride mixture consists of an ammonium fluoride solution in glacial acetic acid.

[0018] In an additional example of the first aspect, a concentration of the ammonium fluoride solution is in a range from about 13 % to about 20 %.

[0019] In another example of the first aspect, the ammonium fluoride solution is 40 % ammonium fluoride in water.

[0020] In yet another example of the first aspect, step (III) includes rinsing the etchant from the glass carrier and then drying the glass carrier.

[0021] In still another example of the first aspect, the etchant consists of soluble chemicals.

[0022] In a further example of the first aspect, after step (IV), the method further includes the step (V) of removing the mount area of the thin flexible glass substrate from the target area of the thin flexible glass substrate to release the target area of the thin flexible glass substrate from the glass carrier.

[0023] In a still further example of the first aspect, after step (IV), the method further includes the steps of: (V) providing the target area of the thin flexible glass substrate with functional features; and then (VI) removing the mount area of the thin flexible glass substrate from the target area of the thin flexible glass substrate to release the target area of the thin flexible glass substrate from the glass carrier.

[0024] The first aspect may be provided alone or in combination with any one or more of the examples of the first aspect discussed above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The above and other features, aspects and advantages of the present invention are better understood when the following detailed description of the invention is read with reference to the accompanying drawings, in which:

[0026] **FIG. 1** is a schematic top view illustrating an example of an article having a thin flexible glass substrate bonded to a glass carrier;

[0027] **FIG. 2** is a schematic end view illustrating an example of the article in **FIG. 1**;

[0028] FIG. 3 is a flow diagram illustrating a first example of a first aspect of a method for processing a thin flexible glass substrate with a glass carrier;

[0029] FIGS. 4-5 represents graphical diagrams illustrating examples of a surface texture profile of glass etched at two extremes of an etchant concentration and an exposure to the etchant using the first example of the first aspect of the method for processing a thin flexible glass substrate with a glass carrier;

[0030] FIG. 6 is a flow diagram illustrating a second example of the first aspect of the method for processing a thin flexible glass substrate with a glass carrier;

[0031] FIG. 7 is a graphical diagram illustrating a surface texture resulting from the etching of a glass carrier in accordance with the second example of the first aspect of the method for processing a thin flexible glass substrate with a glass carrier; and

[0032] FIG. 8 is a flow diagram illustrating an example of a second aspect of the method for processing a thin flexible glass substrate with a glass carrier.

DETAILED DESCRIPTION

[0033] The present invention will now be described more fully hereinafter with reference to the accompanying drawings in which example embodiments of the claimed invention are shown. Whenever possible, the same reference numerals are used throughout the drawings to refer to the same or like parts. However, the claimed invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. These example embodiments are provided so that this disclosure will be both thorough and complete, and will fully convey the scope of the claimed invention to those skilled in the art.

[0034] FIG. 1 is a schematic top view illustrating an example of an article having a thin flexible glass substrate 20 bonded to a glass carrier 10. FIG. 2 is a schematic end view illustrating an example of the article in FIG. 1.

[0035] With reference to FIGS. 1 and 2, the glass carrier 10, having a thickness 12, is bonded to the thin flexible glass substrate 20 so that the thin flexible glass substrate 20 can be utilized in existing device processing infrastructure. When the glass carrier 10 and the thin flexible glass substrate 20 are bonded to one another, their combined thickness 24 is the same as a thicker sheet for which the device processing equipment was designed. For example, if the processing equipment was designed for a 700-micron sheet, and the thin flexible glass substrate 20 had a thickness 22 of 300 microns, then the thickness 12 would be selected as 400 microns.

[0036] The glass carrier **10** and the thin flexible glass substrate **20** may be of any suitable composition including alumino-silicate, boro-silicate, alumino-boro-silicate, and soda-lime-silicate, and either alkali-containing or alkali-free, depending upon their ultimate application. Additionally, the glass carrier **10** may be made of one layer, as shown, or multiple layers (including multiple thin sheets) that are bonded together.

[0037] The thin flexible glass substrate **20** is bonded to the glass carrier **10** by a mount area **40**. At the mount area **40**, there is direct contact between the surface of the thin flexible glass substrate **20** and the surface of the glass carrier **10**, wherein these surfaces have an average surface roughness R_a sufficiently low enough to allow glass to glass bonding, for example, R_a of ≤ 2 nm. There is no bond, or a less strong bond, between the glass carrier **10** and the thin flexible glass substrate **20** in a release area **50** of the glass carrier **10**, wherein the release area is provided by roughening the surface of the glass substrate **20**, the glass carrier **10**, or both, so as to be of a value sufficiently high enough to prevent substantial direct glass to glass bonding, for example, $R_a > 2$ nm. The release area **50** of the glass carrier **10** has a perimeter **52**, outside of which the mount area **40** is disposed.

[0038] The thin flexible glass substrate **20** may be bonded to the glass carrier **10** initially by van der Waals forces. Then, the bond strength may be increased in certain regions while retaining the ability to remove the thin flexible glass substrate **20** after processing the thin sheet/carrier article to form devices thereon. At least a portion of the thin flexible glass substrate **20** may be bonded to the glass carrier **10** such that device process fluids are prevented from entering between the thin flexible glass substrate **20** and the glass carrier **10**, thereby reducing the chance that contamination may occur in downstream processes. In other words, the mount area **40** between the thin flexible glass substrate **20** and the glass carrier **10** may be hermetic. The glass carrier **10** and the thin flexible glass substrate **20** may be cleaned and have surfaces thereof prepared to facilitate bonding. The initial bond between the thin flexible glass substrate **20** and the glass carrier **10** may be strengthened at the mount area **40**. Releasability of the thin flexible glass substrate **20** from the glass carrier **10** may be provided by the release area **50** of the glass carrier, thereby allowing desired parts **56**, having perimeter **58**, of the thin flexible glass substrate **20** to be extracted.

[0039] FIG. 3 is a flow diagram illustrating a first example of a first aspect of a method (300) for processing a thin flexible glass substrate **20** with a glass carrier **10**. Referring to the example illustrated in FIG. 3, a glass carrier **10** including the release area **50** and the mount area **40** may be provided (301).

[0040] After the glass carrier **10** is provided (**301**), the release area **50** of the glass carrier **10** may be provided (**302**) with a textured surface by contacting an etchant including an ammonium fluoride mixture to the release area **50** for a period. The period during which the release area **50** is contacted by the etchant including the ammonium fluoride mixture may be in a range from about 1 minute to about 10 minutes. The textured surface may be provided with a root-mean-squared surface roughness (hereinafter referred to as “Rq”) in a range from about 4 nm to about 232 nm.

[0041] The etchant may consist of soluble chemicals. In addition, the etchant may consist of the ammonium fluoride mixture. The ammonium fluoride mixture may consist of an ammonium fluoride solution in glacial acetic acid. A concentration of the ammonium fluoride solution may be in a range from about 4 % to about 20 %. The ammonium fluoride solution may be about 40 % ammonium fluoride in water.

[0042] After the providing (**301**) of the glass carrier **10** and before the providing (**302**) of the release area **50** of the glass carrier **10**, a mask may be applied (**305**) to the mount area **40** of the glass carrier **10**. During the providing (**302**) of the release area **50** of the glass carrier **10**, the mask may prevent the etchant from contacting the mount area **40** of the glass carrier **10**. The mask may include an adhesive film.

[0043] After the providing (**302**) of the release area **50** of the glass carrier **10**, the etchant may be removed (**303**) from the glass carrier **10**. The removing (**303**) of the etchant may include a rinsing (**306**) of the etchant and then a subsequent drying (**307**) of the glass carrier **10**.

[0044] After the removing (**303**) of the etchant, a mount area of the thin flexible glass substrate **20** may be bonded (**304**) to the mount area **40** of the glass carrier **10**. As such, the textured surface provided (**302**) to the release area **50** of the glass carrier **10** may prevent a target area of the thin flexible glass substrate **20** from bonding to the release area **50** of the glass carrier **10**.

[0045] After the bonding (**304**) of the mount area of the thin flexible glass substrate **20** to the mount area **40** of the glass carrier **10**, the mount area of the thin flexible glass substrate **20** may be separated (**308**) from the target area **56** of the thin flexible glass substrate **20** to release the target area of the thin flexible glass substrate **20** from the glass carrier **10**.

[0046] After the bonding (**304**) of the mount area of the thin flexible glass substrate **20** to the mount area **40** of the glass carrier **10**, the target area **56** of the thin flexible glass substrate **20** may be provided (**309**) with functional features. After the providing (**309**) of the target area of the thin flexible glass substrate **20** with functional features, the removing (**308**)

of the mount area of the thin flexible glass substrate **20** from the target area of the thin flexible glass substrate **20** may be performed to release the target area **56**, having perimeter **58**, of the thin flexible glass substrate **20** from the glass carrier **10**.

[0047] The method (300) of FIG. 3 may represent a wet chemical etching process for texturing glass that will enable a surface of a release area **50** of a glass carrier **10** to be textured. The texturing of the surface of the release area **50** may be performed to enable the glass carrier **10** to be used as a rigid substrate to support thin flexible glass substrates **20** during liquid crystal display (LCD) or organic light-emitting diode (OLED) processing for display devices including, but not limited to, cell phones, tablet computers, and televisions.

[0048] The chemical etch of the wet chemical etching process of the method (300) of FIG. 3 may include exposing the glass carrier **10** to an etchant composed of a mixture of glacial acetic acid and a 40 % aqueous mixture of ammonium fluoride. The chemical etch may be applied selectively to the glass carrier **10** to generate one or more release areas **50** on one surface of the glass carrier **10**, the release areas **50** being textured by the chemical etch. The texture of the release areas **50** is determined through the control of the composition, concentration, and temperature of the etchant and the duration of an exposure of the glass carrier **10** to the etchant.

[0049] The exposure of the glass carrier **10** to the etchant may be via vertically dipping the glass carrier **10** into the etchant. For example, a cleaned glass carrier **10** may be laminated on one side with an adhesive film. The adhesive film may have an opening on the glass carrier **10** that is equivalent to a desired size of a release area **50** to be patterned by the etchant. The glass carrier **10** may then be dipped into a bath of the etchant for a period ranging from 1 to 10 minutes. After the glass carrier **10** is dipped into the etchant bath, the glass carrier **10** may be rinsed, for example, rinsed three times in three separate rinse tanks, and dried. The laminated adhesive film may then be removed, after which the glass carrier **10** may be washed with isopropyl alcohol and dried with an air knife.

[0050] The glass carrier **10** may be various types of glass, including, but not limited to, Gorilla[®] glass, Eagle XG[®] glass, Lotus[™] glass, all of the foregoing glass codes available from Corning Incorporated, having headquarters in Corning NY, and soda-lime glass. The glass carrier **10** can be used to support various types of thin flexible glass substrates **20**, including, but not limited to, glass having a thickness ≤ 300 microns, for example, 300, 290, 280, 270, 260, 250, 240, 230, 220, 210, 200, 190, 180, 170, 160, 150, 140, 130, 120, 110, 100, 90, 80, 70, 60, 50, 40, 30, 20, 10 microns, for example, Willow[™] glass, a glass code available from Corning Incorporated, with headquarters in Corning NY.

[0051] In an example, 2" × 2" samples of Gorilla® glass (Corning glass code 2318) were etched using various mixtures of ammonium fluoride (NH₄F) and glacial acetic acid (GAA) in a wide concentration range. The NH₄F concentration was varied from 2 % to 20 %. The duration of etchant exposure was varied from 30 seconds to 15 minutes. The samples were then rinsed in deionized water and blown dry. The surface texture of the samples was then measured using a Zygo NewView™ model 7300 white light optical profilometer.

[0052] FIGS. 4-5 includes graphical diagrams illustrating examples of a surface texture profile of Gorilla® glass etched at two extremes of an etchant concentration and an exposure to the etchant using the first example of the method of processing the thin flexible glass substrate with the glass carrier. The graphical diagrams illustrate that 15 minutes of etch time for Gorilla® glass in a 20 % NH₄F concentration etch bath produce deeper, coarser features in the surface texture profile, whereas 30 seconds of etch time for Gorilla® glass in a 4 % NH₄F concentration etch bath produce shallower, finer features in the surface texture profile.

[0053] In other words, the surface texture of a glass carrier 10 can be tuned by varying the etch bath concentration and varying the duration in which the glass carrier 10 is exposed to the etch bath concentration. Table 1, provided herebelow, summarizes the surface texture attributes of Gorilla® glass generated by this process. Measurements were carried out using a Zygo NewView™ 7300 optical profilometer. The microscope settings were a 20X lens with a 2X zoom. The low and high filter wavelengths were 0.5 μm and 50 μm, respectively. Roughness average Ra, root-mean-squared (RMS) roughness Rq, along with skewness (R sk) and kurtosis (R ku), constitute the fingerprint of a surface.

Table 1

Fluoride concentration % w/v	Etch Time	R a nm	R q nm	R sk	R ku
20	30s	22	32	2	8
20	45s	56	73	2	5
20	1min	101	114	1	2
20	2min	144	178	-1	3
20	3min	113	152	-2	7
20	4min	92	115	-1	4
20	5min	91	114	-1	4
20	6min	97	122	-1	4
20	7min	113	159	1	28
20	8min	141	176	-1	3
20	9min	165	203	-1	3
20	10min	193	232	0	3
20	15min	239	289	0	2
4	30s	4	5	-1	4
4	45s	3	4	-1	5
4	1min	3	4	-1	4
4	2min	3	4	-1	4
4	3min	3	4	-1	5
4	4min	3	4	0	4
4	5min	3	4	0	4
4	6min	3	4	0	4
4	7min	3	4	0	4
4	8min	3	3	0	4
4	9min	3	4	0	4
4	10min	4	5	0	4
4	15min	4	6	-1	5

[0054] Ra is a mean height of the surface profile. Rq is more sensitive to peaks and valleys than Ra, because the amplitudes of Rq are squared.

[0055] Rsk is the skewness of the height distribution of the surface features. If $Rsk < 0$, the surface can includes valleys. If $Rsk > 0$, the surface can be flat and have peaks. Values numerically greater or less than 1 may indicate extreme valleys or peaks on the surface.

[0056] Rku is the kurtosis of the height distribution. Kurtosis is a measure of the randomness of heights, and of the sharpness of a surface. Surfaces with a kurtosis of 3 have a perfectly random surface. Surfaces having a kurtosis of less than or greater than 3 are less random and more repetitive as the kurtosis value becomes further removed from 3. Surfaces with spikes generally have higher kurtosis values, while bumpy surfaces generally have lower kurtosis values.

[0057] For example, according to **Table 1**, a first etching of one of the above-referenced samples for 10 minutes using an NH_4F mixture having 20 % NH_4F solution in GAA produces a sample surface having a R_q of 232 nm, skewness of -0.5, and a kurtosis of 3. This indicates that, after the etching, the sample surface that is subject to the first etching is made of randomly spaced valleys. On the other hand, a second etching of one of the above-referenced samples for 10 minutes using an NH_4F mixture having 4 % NH_4F in GAA produces a sample surface having a R_q of 4 nm, a skewness of -0.3, and a kurtosis of 4. This indicates that, after the etching, while the sample surface subject to the second etching is still made of randomly spaced valleys, the second etching produces the randomly spaced valleys with lower amplitudes than produced by the first etching.

[0058] **FIG. 6** is a flow diagram illustrating a second example of the first aspect of the method (500) for processing the thin flexible glass substrate 20 with the glass carrier 10. Referring to the example illustrated in **FIG. 6**, a glass carrier 10 including the release area 50 and the mount area 40 may be provided (501).

[0059] After the glass carrier 10 is provided (501), the release area 50 of the glass carrier 10 may be provided (502) with a textured surface by contacting an etchant including an ammonium fluoride mixture to the release area 50 for a period. The period during which the release area 50 is contacted by the etchant including the ammonium fluoride mixture may be in a range from about 1 minute to about 10 minutes. The textured surface may be provided with a R_q that is greater than about 2 nm and equal to or less than about 6 nm.

[0060] The etchant may consist of soluble chemicals. The etchant may be printed on the release area 50 of the glass carrier 10. The printing of the etchant may include, but is not limited to, screen-printing or stencil printing the etchant on the release area 50 of the glass carrier 10. The etchant may be applied as a gel etchant. The gel etchant may consist of the ammonium fluoride mixture and a thickener. The ammonium fluoride mixture may consist of an ammonium fluoride solution in glacial acetic acid. A concentration of the ammonium fluoride solution may be in a range from about 13 % to about 20 %. The ammonium fluoride solution may be 40 % ammonium fluoride in water.

[0061] After the providing (502) of the release area 50 of the glass carrier 10, the etchant may be removed (503) from the glass carrier 10. The removing (503) of the etchant may include a rinsing (505) of the etchant and then a subsequent drying (506) of the glass carrier 10.

[0062] After the removing (503) of the etchant, a mount area of the thin flexible glass substrate 20 may be bonded (504) to the mount area 40 of the glass carrier 10. As such, the

textured surface provided at (502) to the release area 50 of the glass carrier 10 may prevent a target area of the thin flexible glass substrate 20 from bonding to the release area 50 of the glass carrier 10.

[0063] After the bonding (504) of the mount area of the thin flexible glass substrate 20 to the mount area 40 of the glass carrier 10, the mount area of the thin flexible glass substrate 20 may be removed (507) from the target area of the thin flexible glass substrate 20 to release the target area of the thin flexible glass substrate 20 from the glass carrier 10.

[0064] After the bonding (504) of the mount area of the thin flexible glass substrate 20 to the mount area 40 of the glass carrier 10, the target area of the thin flexible glass substrate 20 may be provided (508) with functional features. After the providing (508) of the target area of the thin flexible glass substrate 20 with functional features, the removing (507) of the mount area of the thin flexible glass substrate 20 from the target area of the thin flexible glass substrate 20 may be performed to release the target area of the thin flexible glass substrate 20 from the glass carrier 10.

[0065] Similarly to the method (300) of FIG. 3, the method (500) of FIG. 6 may represent a wet chemical etching process for texturing glass that will enable a surface of a release area 50 of a glass carrier 10 to be textured. The texturing of the surface of the release area 50 may be performed to enable the glass carrier 10 to be used as a rigid substrate to support thin flexible glass substrates 20 during liquid crystal display (LCD) or organic light-emitting diode (OLED) processing for display devices including, but not limited to, cell phones, tablet computers, and televisions.

[0066] The chemical etch of the wet chemical etching process of the method (500) of FIG. 6 may include exposing the glass carrier 10 to an etchant composed of a mixture of glacial acetic acid and a 40 % aqueous mixture of ammonium fluoride. The chemical etch may be applied selectively to the glass carrier 10 to generate one or more release areas 50 on one surface of the glass carrier 10, the release areas 50 being textured by the chemical etch. The texture of the release areas 50 is determined through the control of the composition, concentration, and temperature of the etchant and the duration of an exposure of the glass carrier 10 to the etchant.

[0067] In contrast to the method (300) of FIG. 3, with respect to the method (500) of FIG. 6, the exposure of the glass carrier 10 to the etchant may be via screen-printing or stencil-printing the etchant onto the glass carrier 10. For example, where a cleaned glass carrier 10 may have been laminated on one side with an adhesive film in the method (300) of FIG. 3, with respect to the method (500) of FIG. 6, the etchant may be selectively screen-

printed or stencil-printed on the glass carrier **10** according to a desired size of a release area **50** to be patterned by the application of the etchant.

[0068] Screen-printing or stencil-printing the etchant onto the glass carrier **10** may require the addition of a thickener resulting in a thixotropic gel that is compatible with the screen-printing or stencil-printing process. For example, water-soluble polymers may be added from the polyethylene oxide family available from Dow Wolff CellulosicsTM under the trade name PolyoxTM. The resultant gel etchant may remain on the glass carrier **10** for a period ranging from 1 to 10 minutes, after which the glass carrier **10** may be rinsed three times and dried.

[0069] Again, the glass carrier **10** may be various types of glass, including, but not limited to, Gorilla[®] glass, Eagle XG[®] glass, LotusTM glass, and soda-lime glass. The glass carrier **10** can be used to support various types of thin flexible glass substrates **20**, including, but not limited to, WillowTM glass.

[0070] In an example, 2” squares of Eagle XG[®] glass were screen printed with two different etching gels. One of the gels included an NH₄F mixture of a 20 % NH₄F solution in GAA and 20 % PolyoxTM N80. The other gel included an NH₄F mixture of a 16 % NH₄F solution in GAA and 20 % PolyoxTM N80. The duration of etchant exposure was varied from 1 minute to 10 minutes. The samples were then rinsed in deionized water and blown dry. The surface texture of the samples was then measured using a Zygo NewViewTM model 7300 white light optical profilometer. The microscope settings were a 20X lens with a 2X zoom. The resulting surface texture parameters are summarized in **Table 2**.

Table 2

Fluoride conc. % w/v	Etch time min	PV nm	Rq nm	Rsk	Rku
16	1	30	3	-1	112
	3	41	3	2	10
	5	52	5	2	4
	10	61	4	3	1
20	1	35	2	6	82
	3	46	3	4	35
	5	64	4	3	36
	10	61	6	1	5

[0071] PV stands for “peak-to-valley” and represents the distance between the highest peak and the lowest valley.

[0072] Based on the range of textures seen in **Table 2**, Eagle XG[®] glass carriers were etched with a 310 mm × 410 mm screen-printed etchant gel pattern using a 16 % NH₄F/GAA mixture thickened with Polyox[™] N80 for 3 minutes. **FIG. 7** represents the texture parameters of the carrier surface resulting from the etching conditions described above.

[0073] After this, the patterned carriers were pre-bonded to 360 mm × 460 mm × 0.13 mm Willow[™] glass and thermally bonded at 400 °C for 10 minutes. The bonded assembly of patterned Eagle XG[®] glass carriers and Willow[™] glass was then scored and broken. The area in which the mount area of the glass carriers and the Willow[™] glass were bonded broke monolithically. The release area of the glass carriers and the corresponding areas of the Willow[™] glass broke with clear separation of the glass carriers and the Willow[™] glass.

[0074] While the method (500) provides a method of varying a Rq of a release area 50 of a glass carrier 10 over a wide range for bonding Willow[™] glass to the glass carrier and subsequently enabling release of a portion of the Willow[™] glass from the glass carrier, an example of a desired Rq is about 2 nm. While it is possible to produce a desired Rq through various combination of etching times and etchant concentrations, an example of a desired ammonium fluoride solution concentration is about 13 % and a desired etching time is about 3 minutes.

[0075] **FIG. 8** is a flow diagram illustrating an example of a second aspect of the method (700) for processing a thin flexible glass substrate 20 with a glass carrier 10. This method (700) is directed to roughening a glass surface using an etching cream, which contains a mixture of fluorine salts, insoluble salts, soluble salts, and mineral acid, and may be particularly useful when the glass to be roughened (either the flexible glass substrate 20 or the glass carrier 10) is a low ion soda lime glass, although it may be used on Eagle XG[®] type glass as well.

[0076] Referring to the example illustrated in **FIG. 8**, the glass carrier 10 may be cleaned (701) to remove contaminations. Then, the glass carrier 10 may be placed (702) into an ultrasonic bath with deionized water for further cleaning. After drying (703), the glass carrier 10 may be laminated (704) with an anti-acid polyethylene to protect a mount area 40 of the glass carrier 10. Then, the glass carrier 10 may be immersed (705) in a diluted hydrofluoric acid and hydrochloric acid solution for a short period to remove a very thin surface layer of the glass carrier 10 and to clean and activate the surface. This period may be within a range of 5 seconds to 10 seconds.

[0077] After rinsing (706), for example, in deionized water for 10 seconds, the glass carrier 10 is exposed (707) to etching cream between 30 and 120 seconds while being moved

slightly up and down. For this application, the etching powder used for the etching cream may be composed of 10-40 wt% of KF as a fluorine source, 10-40 wt% of KCl or KNO_3 as an additional salt, 5-20 wt% of BaSO_4 as filler, 1-10 wt% of starch, and 1-10 wt% of polyacrylamide. This powder may be dissolved in 20-50 wt% of concentrated HCl acid or a mixture of HCl acid and acetic acid to form the etching cream. Up to 20 wt% of water can be added if the slurry created by the dissolved powder is too thick. After dissolving, the etching cream can be kept at ambient conditions for 12 hours prior to use with manual agitation every 2-4 hours to reach chemical equilibrium.

[0078] After the exposure (707) to the etching cream for the required amount of time, the glass carrier 10 may be quickly rinsed (708), for example, in deionized water for 10 seconds. Afterwards, the lamination may be removed (709) and the glass carrier 10 may be thoroughly rinsed (710) to remove the remaining acid and etching cream on the surface. The Ra of the resulting release area 50 of the glass carrier 10 may be about 25 nm.

[0079] The uniformity of the release area 50 may be controlled by the physical properties of the etching cream, which include, but are not limited to, viscosity, sedimentation, and insoluble particle size distribution. A certain range of viscosity and sedimentation time may be required to reach the desired texture uniformity of the release area 50. These parameters can be adjusted by adjusting the content of the salts of the etching powder, the mineral acid, and the water. Insoluble large particles may be preferably removed to reach the desired slurry viscosity and sedimentation time.

[0080] The roughness of the release area 50 can be controlled by the concentration of the etching cream and the time for which the glass carrier 10 is exposed to the etching cream. Higher etching cream concentrations and longer etching cream processing times may lead to greater surface roughness. An increase in acid concentration or processing time also may lead to a rougher surface texture.

[0081] The etching chemistry described above in connection with this second aspect of the method (700) may also be used in connection with roughening low ion soda lime glass for silicon tandem photovoltaic cell applications. In silicon tandem thin film photovoltaic cells, rough glass substrates can increase the light trapping and thus increase the conversion efficiency.

[0082] In a third aspect of the method (700) for processing a thin flexible glass substrate 20 with a glass carrier 10, an etching cream containing NH_4HF_2 , NH_4F , KCl, BaSO_4 , and HCl can be used. This etching cream may be particularly useful when Gorilla® Glass is used as either one of the substrate 20 or the glass carrier 10, and includes the surface

to be roughened to provide the release area. For this application, the method (700) may include a second acid exposure (711) for 2 minutes containing 15 wt% of H_2SO_4 and 5 wt% HCl after the exposure (707) to the etching cream for the required amount of time. Further, after the second acid exposure (711) and a 10 second deionized water rinse (712) and before the quick rinse (708), a third acid exposure (713) containing 24 wt% HF and 45.5 wt% HCl may be conducted for 90 seconds.

[0083] Further, an etching cream composed of 10-20 wt% of NH_4F , 10-20 wt% of NH_4HF_2 , 0-10 wt% of KNO_3 as additional salt, 5-20 wt% of BaSO_4 as filler, 1-10 wt% of soluble starch, and 0-5 wt% of polyacrylamide can be used. The solids mentioned above can be combined with 36-38 % concentrated HCl acid and prepared as stated above with respect to the etching cream being used for texturing the carrier glass 10. A method of applying the etching cream may include performing steps (701) - (710) as referenced above with respect to the etching cream being used for texturing the carrier glass 10. In some applications, following the exposure (707) to the etching cream, the Gorilla[®] glass can be further polished by the second acid exposure (711) for a certain period, followed by the quick rinse (708).

[0084] Texture uniformity may be normally satisfied for square shaped samples of the Gorilla[®] glass after exposure to the above-referenced etching cream as a dip to achieve anti-glare properties. For rectangular or other irregular or 3D shaped samples, a spray of etching cream instead of a dip may show better texture uniformity. In the spray method, the etching cream can be allowed to spray onto the Gorilla[®] glass surface either manually or using a pump. In the spray method, the Gorilla[®] glass may be put in a rack with 30 degree of tilt from a horizontal plane. The Gorilla[®] glass can be sprayed homogeneously with the same flow rate. An anti-acid pump with a flow rate ranging from 20 L/min to 50 L/min may be used for spraying the etching cream onto the Gorilla[®] glass surface having a size of 120 mm $\times$ 60 mm. Larger glass surfaces may require a spray having a higher flow rate. Any size or shape of the glass may be applicable either using the spray method or dipping method.

[0085] The etching chemistry and processes described above in connection with this third aspect of the method (700) may also be used in connection with providing a roughened surface to a cover glass, for example Gorilla[®] Glass, to provide an anti-glare surface or to achieve anti-glare properties. More particularly, reduction of the specular reflection is often a desired property for the cover glass of touch sensitive electronic devices, electronic ink readers, interactive whiteboards, and other portable LCD panels, especially when used in certain light conditions. A cover glass having such properties can be realized by creating textures on the surface. The surface texture reduces the reflection light through the random

scattering of the reflected light and leads to a blurred reflective image, which is also referred to as anti-glare surface. These surface textures may be provided by the etching chemistry of this third aspect of the method (700). The etching cream formulation and process of this aspect can roughen the Gorilla® glass surface to achieve anti-glare properties. The textured surface properties, like haze, gloss, distinctiveness of image (DOI), and roughness, can be regulated in a broad range by controlling the etching cream formulation and the process parameters, thereby providing a low cost, scratch resistant, and flexible method for obtaining anti-glare Gorilla® glass surface. This technique is particularly useful on Corning code 2317 and 2318 type glasses before ion exchanging into Gorilla® Glass.

[0086] The methods (300) and (500) may use soluble ingredients and the method (700) may use insoluble ingredients. The use of soluble ingredients in the methods (300) and (500) may avoid deposition of particulates that may be left by the use of insoluble ingredients in the method (700). These particulates, if not adequately rinsed off in steps (708), (710), and (712), may serve to interfere with bond formation between the thin flexible glass substrate 20 and the glass carrier 10 at the respective mount areas.

[0087] It will be apparent to those skilled in the art that various modifications and variations can be made to the present invention without departing from the spirit and scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A method for processing a thin flexible glass substrate with a glass carrier, comprising the steps of:
 - (I) providing the glass carrier including a release area and a mount area; then
 - (II) providing the release area of the glass carrier with a textured surface by contacting an etchant including an ammonium fluoride mixture to the release area for a period; then
 - (III) removing the etchant from the glass carrier; and then
 - (IV) bonding a mount area of the thin flexible glass substrate to the mount area of the glass carrier, wherein the textured surface prevents a target area of the thin flexible glass substrate from bonding to the release area of the glass carrier.
2. The method of claim 1, wherein the period of step (II) is in a range of from 1 minute to 10 minutes.
3. The method of claim 1, wherein step (II) provides the textured surface with a root-mean-squared surface roughness in a range from 3 nm to 232 nm.
4. The method of claim 1, wherein step (II) provides the textured surface with a root-mean-squared surface roughness that is greater than 2 nm and equal to or less than 6 nm.
5. The method of claim 1, wherein the etchant of step (II) consists of the ammonium fluoride mixture, and
wherein the ammonium fluoride mixture consists of an ammonium fluoride solution in glacial acetic acid.
6. The method of claim 5, wherein a concentration of the ammonium fluoride solution is in a range from 4 % to 20 %.
7. The method of claim 5, wherein the ammonium fluoride solution of step (II) is 40 % ammonium fluoride in water.
8. The method of claim 1, wherein step (II) applies the etchant as a gel etchant.
9. The method of claim 8, wherein the gel etchant consists of the ammonium fluoride mixture and a thickener, and
wherein the ammonium fluoride mixture consists of an ammonium fluoride solution in glacial acetic acid.
10. The method of claim 9, wherein a concentration of the ammonium fluoride solution is in a range from 13 % to 20 %.
11. The method of claim 9, wherein the ammonium fluoride solution is 40 % ammonium fluoride in water.
12. The method of claim 1, wherein after step (IV), further comprising the steps of:

(V) providing the target area of the thin flexible glass substrate with functional features; and then

(VI) removing the mount area of the thin flexible glass substrate from the target area of the thin flexible glass substrate to release the target area of the thin flexible glass substrate from the glass carrier.