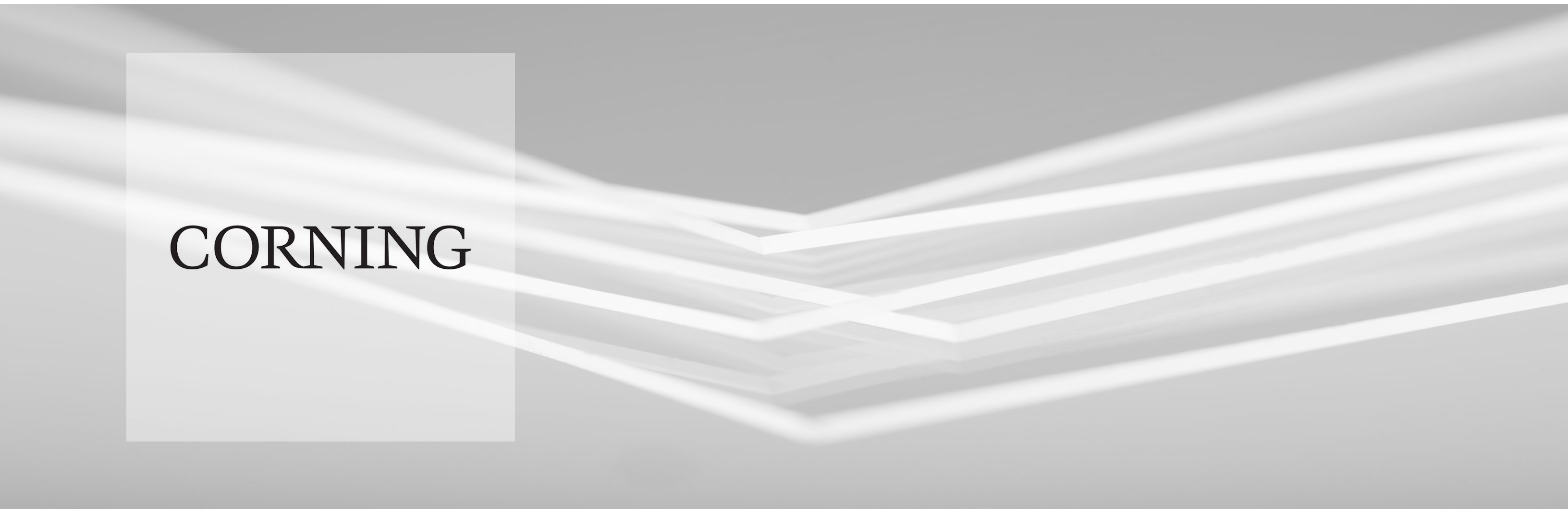
High Strength, Damage Resistant Display Panels



Issued: March 2021
Supercedes: May 2016

K. Hemanth Vepakomma*, G. Scott Glaesemann,
Donald A. Clark and Alicia M. Gallagher
Corning Incorporated, Corning, NY

This paper was first presented at SID Display Week 2016.

Abstract

Chemical etching can significantly increase the strength of surfaces and edges of display panels. This can be done in a selective fashion by targeting the desired region in need of increased strength. If done properly, the strength increase can be greater than ten times the original strength with values in excess of 1 GPa.

1. Introduction

As display devices become thinner, there is an expectation that the embedded display will experience more stress. For example, there are devices where the display panel is intentionally bent into a predetermined shape permanently. It is increasingly common for mobile devices that the underlying display be directly bonded to the cover glass and, consequently, flexing of the cover glass will be transferred directly to the display glass. The strength of the glass in an installed display panel may have to be increased above present levels. The need for damage resistant edges on display panels is on the horizon as well. The current industry trend is to minimize the width of the bezel and in some cases, even completely eliminate it. This means the edges will be exposed to in-service damage rather than being protected by the case and/or bezel.

Newly formed glass is exceptionally strong (around 6 GPa), ubt when glass is handled by various manufacturing steps, surfaces a and edges get newly formed glass is exceptionally strong (around 6 GPa), but when glass is handled by various manufacturing steps, surfaces and edges get damaged and the strength can drop to the range of 100 to 200 MPa for surfaces and lower levels for edges. Chemical etching can significantly, increase the strength of the surfaces and edges of display panels. This can be done in a selective fashion by targeting the desired surfaces and/or edges. Depending on the amount of etching, the strengths can be greater than 1 GPa (1000 MPa).

2. Fundamental Understanding

The concept of etching of glass to improve its strength has been known since, at least, the 1960s [1]. The purpose of this study was to engineer a methodology for applying this concept to display panels in order to improve their strength and mechanical reliability. This technology will primarily be applicable to thin, curved and flexible displays. Before engineering a solution, the first step was to understand and define the problem domain. The current problem was divided into two parts: (i) surface strength improvement and (ii) edge strength improvement. This was done because the flaws present on the surface are different from those found on the edges.

2.1 Surface Strength Improvement

From our prior knowledge of testing display panels, a surface strength around 100 MPa represents the lower end of possible strengths. The test strategy here employed the use of surrogate flaws with a strength of approximately 100 MPa. If the strength of these flaws were improved by chemical etching, all other surface flaws would be strengthened as well. In order to create flaws with strengths of 100 MPa, a cube corner diamond incident was chosen with an indentation load of 3 grams. A cube corner diamond creates well-defined crack systems at low loads and 3 grams places the strength in the region of interest. The experiment was conducted on 0.7 mm EAGLE XG® glass specimens.

An AFM image of a typical incident is shown in Figure 1. Half of the specimens were used as reference and the other half were subjected to a chemical etching process typical for glass. Figure 2 compares images of an indent before and after etching. After etching only a few microns of glass, the flaw shape changed, and the sharp flaw was converted to a blunt flaw. This effectively converts a fracture mechanics problem to a stress concentration problem, thereby increasing the strength. These specimens were tested using a ring-on-ring (ROR) fixture creating a biaxial flexure (Figure 3). Testing was done in a controlled environment of 50% RH and 22 °C. The specimens were taped on the compression side and the indents were then tested in tension. The non-etched specimens all failed from the flaw created by the indenter in the range of 100 to 150 MPa. The etched specimens were sufficiently strong that the ROR setup reached its limit of 800 MPa before most of the specimens could break. Figure 4 shows the ROR strength comparison between both the sets. The actual strength of the etched specimens is greater than the reported values on the Weibull plot.

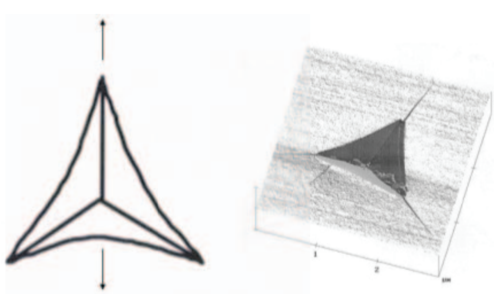
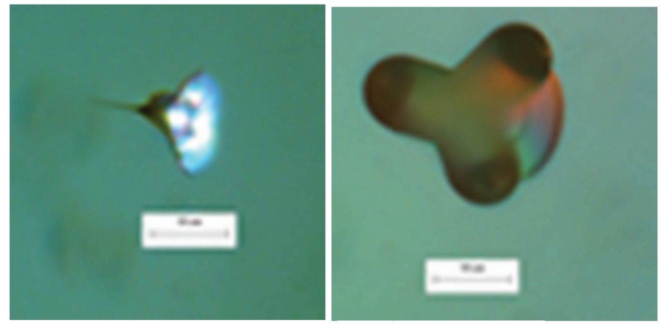


Figure 1. Atomic force microscopy of a 1 gram indent from a cube corner indenter. [2]



(a) Before Etch (b) After Etch

Figure 2. Three gram indents before (a) and after (b) etching.

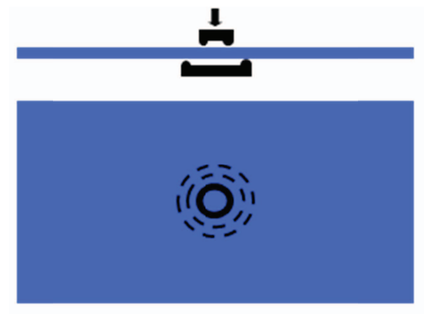


Figure 3. Ring-on-ring test setup and schematic.

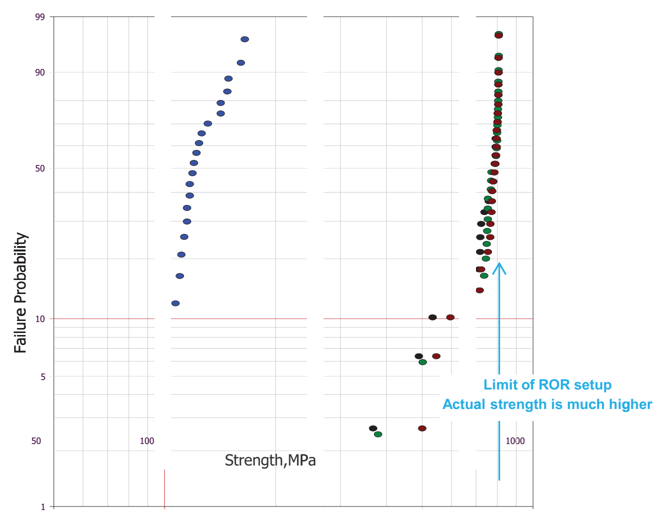


Figure 4. Surface strength of specimens using ring-on-ring test. 800 MPa was the limit of the test setup and so the actual strength is much higher.

2.2. Edge Strength Improvement

To demonstrate the effect of chemical etching on glass edges, we chose scored/broken edges because they have the lowest strength when compared to other edge finishing methods. Because high edge strengths were anticipated after chemical etching, the two point bending test was used for testing these specimens. The scored side was tested in tension, while the compression side was taped with 0.0762 mm (3 mil) thick tape to preserve the pieces for failure mode analysis.

Each specimen was loaded between an upper and lower platen and bent until failure as the platens moved together. A schematic is shown in Figure 5. The spacing of the platens at failure, along with thickness and initial platen displacement, were used to calculate the maximum stress in MPa [3].

The specimens used for the experiment were 200 x 20 mm. Two different thicknesses namely, 0.35 mm and 0.5 mm were tested. The non-etched specimens showed stresses around 100 MPa for both thicknesses. After etching, the strengths increased at least an order of magnitude, reaching values between 1000 and 3000 MPa (Figure 6).

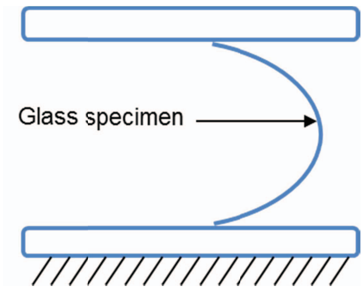


Figure 5. Schematic of two point bend test.

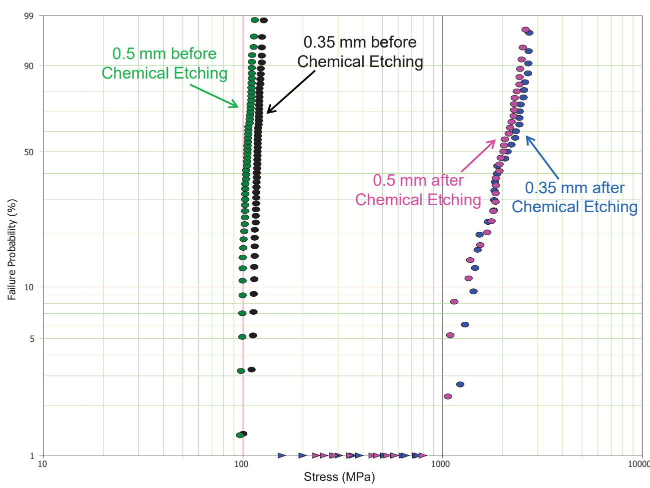


Figure 6. Two-point-bend testing of score/break specimens with score-side in tension.

3. Chemical Etching of Display Panels

This concept of chemical etching can be applied to display panels to make them strong and reliable. Chemical etching is more effective when conducted after singularization os that the cut edges on the device-sized panels can be strengthened. This requires that the "tab" region of panels be protected from the etchant. There may also be a need to protect additional regions of the panel. Figure 7 shows the steps involved in carrying out chemical etching on device-sized panels. Depending on the strength requirements, all surfaces and edges can be etched or it can be done in a selective fashion by targeting the desired surfaces and/or edges. Acid resistant films can be used to mask the surfaces and the "tab" portion of the panel that contains the electronics. The acid solution may comprise HF with HCI, H2SO4 or HNO3. The epoxy sealant used to seal the LCD panel is generally acid resistant and will prevent the acid from penetrating into the panel. If the outwardly facing major surfaces of the display panel comprise of additional layers of material on the glass substrates, such as ITO or polarization layers, a surface masking film is deposited on the outwardly facing major surfaces. After etching, the masks are removed and the panels are thoroughly rinsed. After etching, while the surfaces and edges are very strong, they are also vulnerable to new damage, which can reduce the strength. Polarizers help protected the surfaces from additional damage and for edges, it is possible to apply polymer coatings to preserve the strength. These polymer coatings act as bumpers and resist new damage introduction. The key is to apply the polarizers and the polymer coating without introducing new damage to the glass. At this point, the panels can be installed into a device.

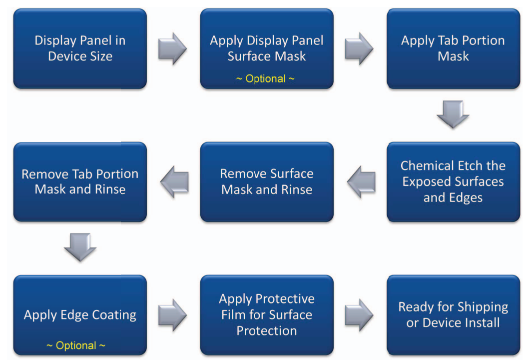


Figure 7. General process flow for strengthening a device level display panel.

4. Summary

Chemical etching can significantly increase the strength of display panels. Taking advantage of this process will enable the device manufacturers to push their design boundaries. This will also help in improving the mechanical realibility of curved and flexible displays.

5. References

1. Proctor, B, The effects of hydrofluoric acid etching on the strength of glasses. Phys. Chem, Glasses, 3 (1) 7-27 (1962).
2. Semjonov, S.> and Kurkjian, C.R., Strength of Silica Optical Fibers with Micron Size Flaws, J. Non-Cryst. Solids, 283 220-224 (2001).
3. Gulati, Suresh T., Westbrook, Jamie, Carley, Stephen, Vepakomma, Hemanth, and Ono, Toshihiko, Two Point Bending of Thin Glass Substrate. SID Symp Digest of Technical Papers, 42 (1) 652-654 (2011).

This paper was first presented at SID Display Week 2016.