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White Paper

Capturing the Robustness of Glass Panels in Touch-Screen Displays

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Introduction

The strength of glass panels is critical for the performance of touch-screen displays, especially in regards to how it responds to impact or drop. Insufficient drop testing performance can be related to two parameters: fracture strength and flaw size. The fracture strength of touch screen panels, everything else being equal, is primarily driven by the degree of strengthening performed on the surface of the glass. Glass of less than 1/8th inch thickness for touch screen panel applications tends to require a chemical strengthening process as thermal quenching can induce warpage in these thinner glass sheets. Chemical strengthening is performed through an ion-exchange mechanism, typically in a potassium-based solution. The larger potassium ion (r+ = 0.133 nm) substitutes for the smaller sodium ion (r+ = 0.098 nm), inducing a volumetric increase and creating residual compressive stresses at the outer layer of the glass (see Figure 1).

The degree of chemical strengthening can thus be characterized through depth profiling of the exchanged ions and stress measurement. While the degree of ion exchange will provide important information on the manufacturing processes, stress measurement is also an important measurement as post-exchange anneals can results in substantial changes in compressive stress values (see Figure 2).

Identification or characterization of flaw size is a slightly more difficult process as flaws that may drive different behaviors may be unobservable, either due to size or being located subsurface (or both). However, it is well known that the degree of beveling can influence drop behavior and overall mechanical strength as the corner and edges are known stress risers.

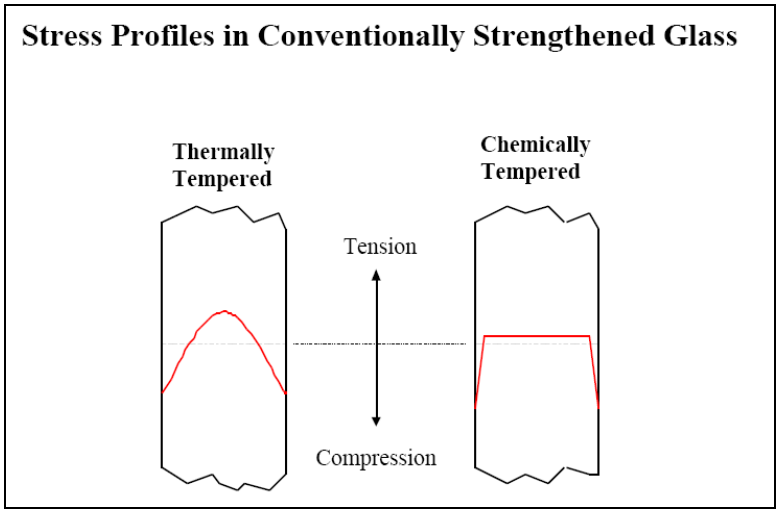

Figure 1: Cross Sections Showing Residual Stress Profiles Due to Thermal and Chemical Strengthening

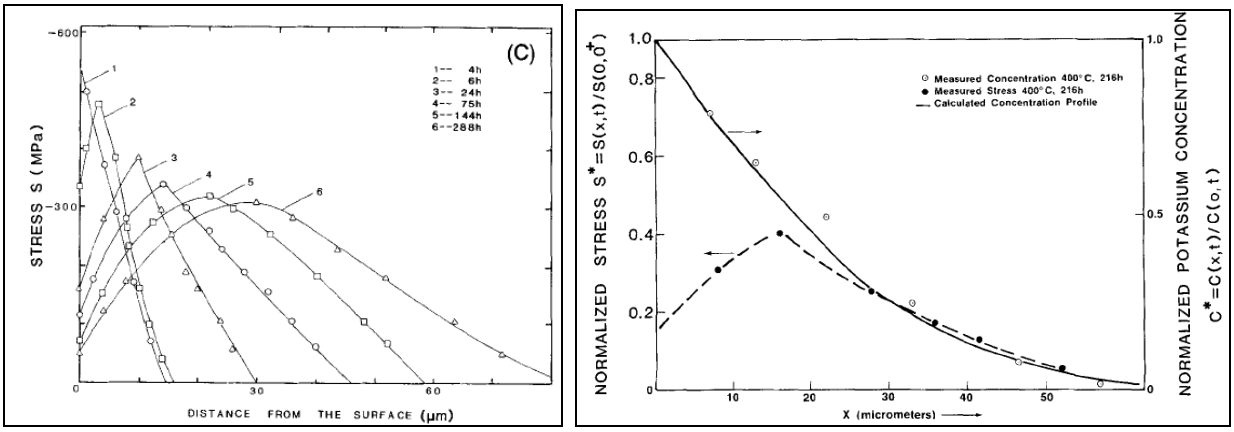

Figure 2: Change in residual stress as a function of time of exposure (left) and in comparison to potassium depth profile (right)[Sane, et. al., Stress Buildup and Relaxation During Ion Exchange Strengthening of Glass, JACerS, 70 [2] 86-89 (1987)]

Experimental Procedure

In this study, DfR examined four touch screen panels. Two of the panels, samples 2 and 4, were from a lot displaying insufficient robustness when exposed to drop and impact testing. This report presents the results of depth profiling using energy dispersive X-ray spectroscopy (EDS) and observation of beveling.

Elemental Analysis

For the depth profiling using SEM/EDS, the glass panels were cut and the cross-sections were polished using diamond cloth and SiC cloth. Subsequently, the glass panels were covered with a thin gold layer to avoid charging of the insulating glass in the scanning electron microscope (SEM).

The material characterization was carried out performing a line scan of about 45 um length with a stepping distance of about 0.6 um. The data for silicon, potassium, sodium, magnesium and calcium were recorded simultaneously. The integration time for each data point was 3000 ms. For each sample up to six linescans were taken.

Data processing was performed with the assumption of the silicon content in the glass being constant. The line scans for each sample were aligned to the edge. The data for the dopants were calibrated against the silicon to remove any unwanted surface effects. Then the line scan data for each sample and dopant were averaged. To remove any artifacts due to differences in mounting of the samples and differences in beam size of the electron beam size during the measurements, all dopant data points were calibrated against the mean value of the silicon averaged along the linescan.

Optical Observations

The degree of beveling was photographed using a stereoscope at various magnifications.

Results: Elemental Analysis

In the following graphs, the dopant distribution is presented for all four samples as a function of the distance from the surface of the glass (x = 0 um). The data was prepared as outlined in section 0 (a count to atom conversion was not performed, not allowing for a direct comparison of the values between the different dopants.) The data are presented in a scale, where 100 is the benchmark average value of the silicon along the lines.

Figure 3 shows the potassium distribution for the four measured samples. Sample 1 and sample 3 have higher potassium values at the surface with a steeper decline, compared to samples 2 and 4. This could be due to a higher concentration of potassium in the exchange solution and a shorter exposure time.

Figure 4 shows the distribution of magnesium. Magnesium must be present in the ion exchange solution and diffuses into the glass during the exchange process. As with potassium, the magnesium distribution also shows a declining concentration starting from the surface of the glass. Within measurement accuracy, a difference between the samples cannot be detected.

Figure 5 shows the sodium distribution in the four samples. Potassium is expected to replace the sodium, strengthening the glass. The measurement of the sodium shows a high variability, making it difficult to reliably detect a difference between the samples. Sample 1 shows the lowest variability, and also exhibits the smallest sodium concentration close to the glass surface.

As seen in Figure 6 the calcium distribution close to the glass surface is reduced. Calcium as present in the glass originally is being replaced by magnesium or potassium. A difference between all four samples cannot be detected.

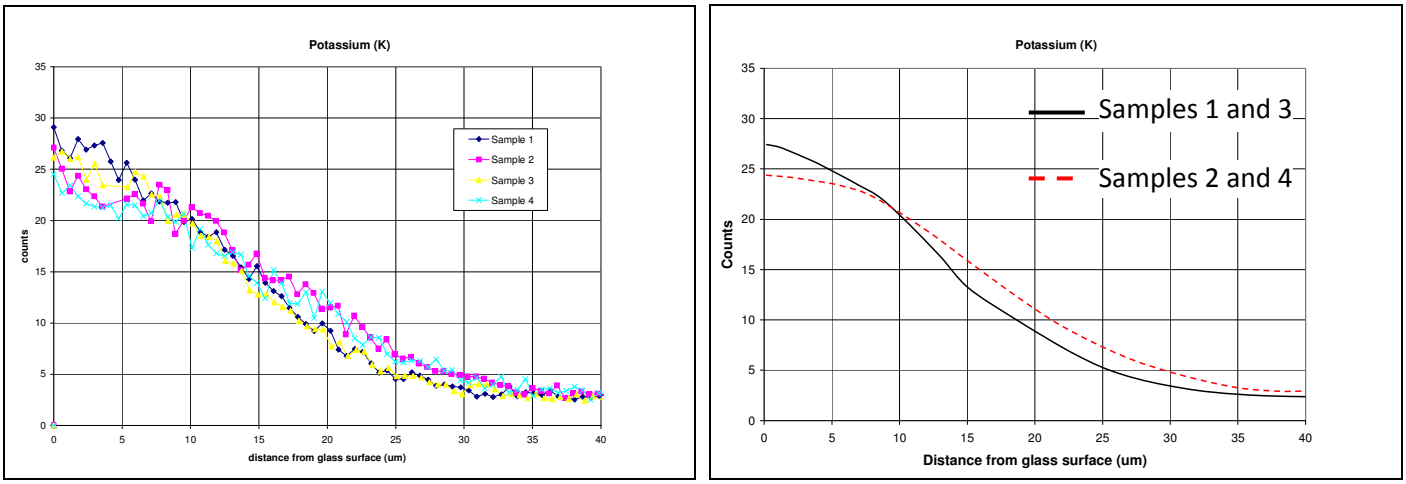

Figure 3: Measured (left) and average (right) potassium concentration distribution in Samples 1/3 and 2/4

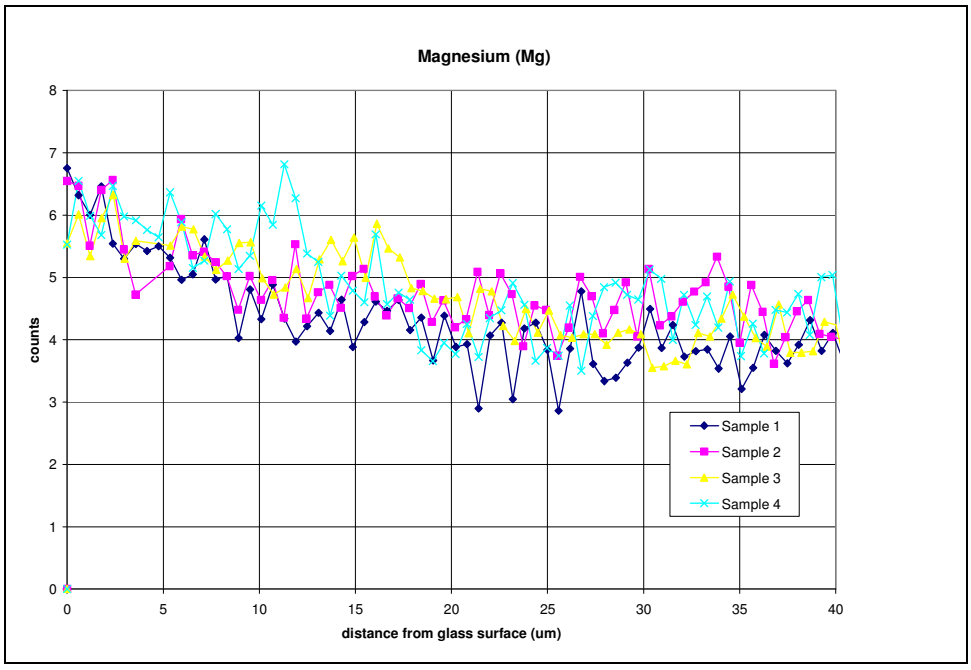

Figure 4: Magnesium distribution for ion-exchange strengthened glass

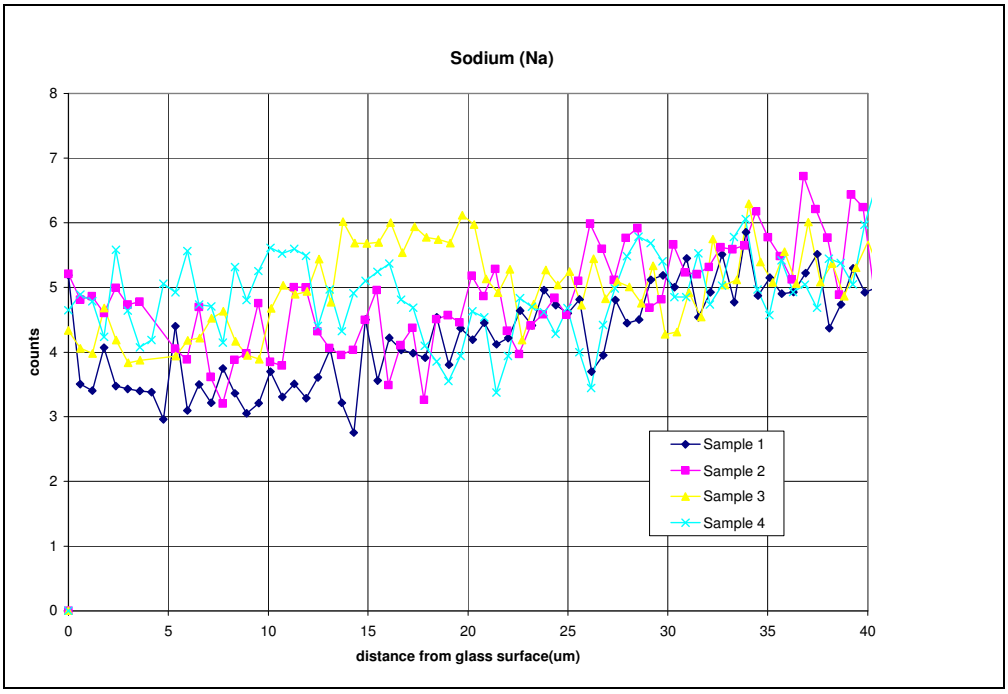

Figure 5: Sodium distribution for the ion-exchange strengthened glass samples.

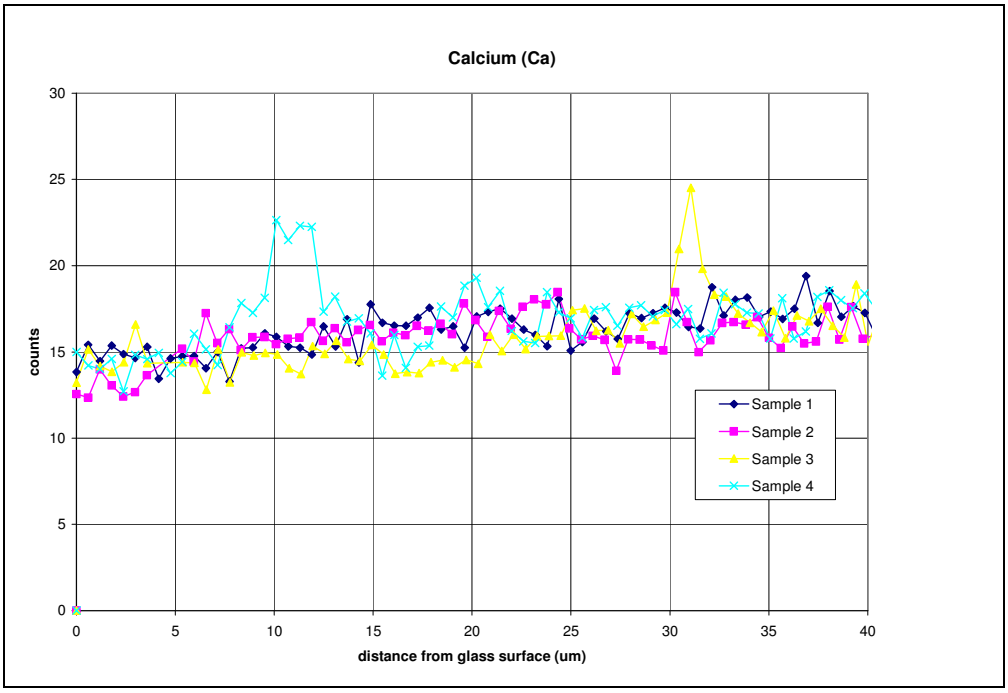

Figure 6: Calcium distribution for the ion-exchange strengthened glass samples.

Results: Optical Observations

The degree of bevel on the four samples is displayed in Figure 7 and Figure 8. Two definitive differences were noted. In samples 1 and 3, the bevel is relatively severe, extending to the mid-plane of the glass panel. In samples 2 and 4, the bevel is much less severe, with only a minimal degree of rounding at the corners.

In addition, samples 2 and 4 displayed relatively large chip outs in comparison to samples 1 and 3. These chip outs are well known to induce failures during drop testing, but should have no influence on crack initiation during ball drop testing.

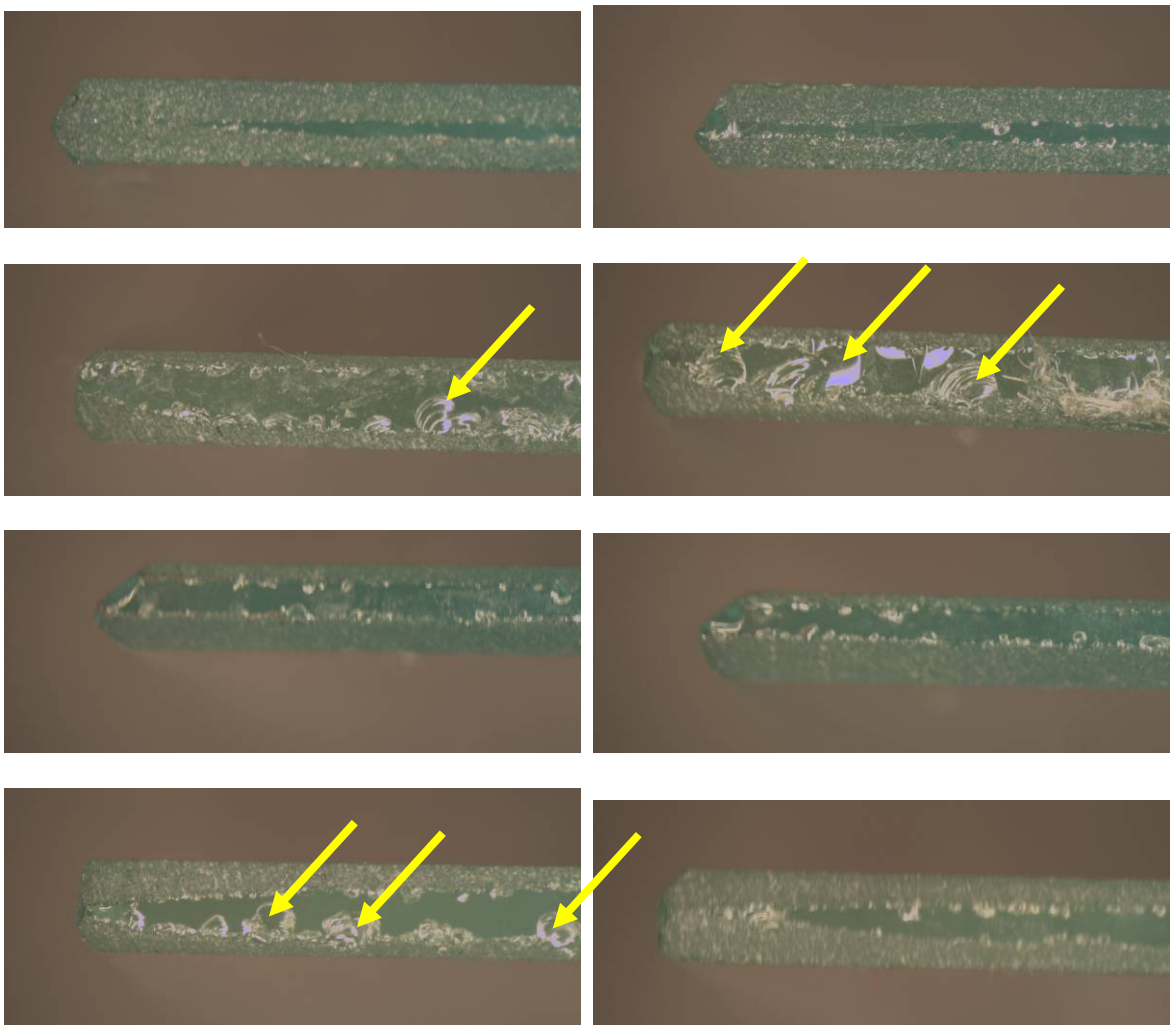

Figure 7: Edge-on view of glass panel showing the degree of beveling in Samples 1 through 4 (top to bottom). Yellow arrows mark relatively large chip outs at the edge of the glass panel.

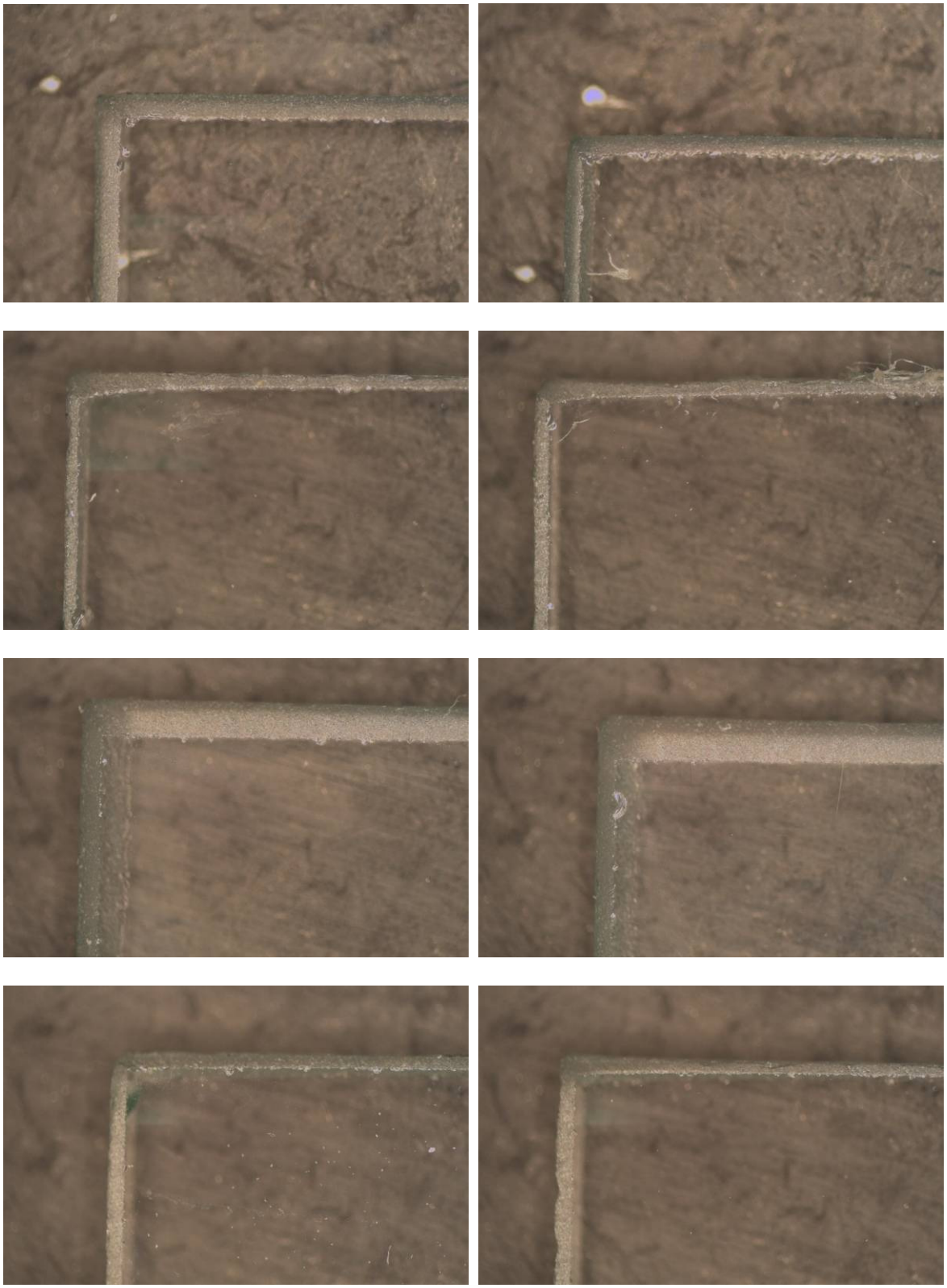

Figure 8: Top-down view of glass panel showing degree of beveling in Samples 1 through 4 (top to bottom)

Discussion

Definitive differences in potassium concentration profiles and degree of beveling were observed between Samples 1 and 3 and Samples 2 and 4. Based on these results, it is speculated that Samples 2 and 4 will demonstrate insufficient performance when subjected to ball drop testing and product drop testing. To ensure better performance, the following recommendations are suggested

- Modify bath parameters. This could include increasing potassium salt concentration or decreasing bath temperature or exposure time
- Improve beveling process and perform periodic visual inspection of bevel to ensure limited chip out (size and frequency)

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