Improvements Made to Corning ULE® Glass to Meet P-37 Specifications

CORNING
Discovering Beyond Imagination

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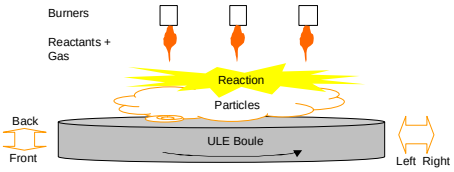
Introduction:

Corning ULE® glass is a binary SiO_2 + TiO_2 composition that is formed directly using a flame hydrolysis process. It possesses a very low thermal expansion range that can be adjusted to accommodate different uses, including mask blanks for EUV photolithography. For this particular application, it is necessary to produce a material that can be polished to meet stringent flatness and roughness specifications. However, small compositional striations formed in the glass during hydrolysis affect the surface roughness when the mask blank is polished. Recently, predictive models of furnace burner coverage and furnace oscillation patterns utilized during glass formation have been developed and experimentally verified. These models have been employed to enhance the fundamental understanding of the glass forming process. This understanding has led to process adjustments that have produced glass with improved striae characteristics. It has also been shown that the striae can be improved by applying additional thermal treatments to the glass. Effective use of these treatments depends on the striae characteristics of the glass. These thermal treatments and the aforementioned process adjustments via modeling have resulted in significant improvements in striae characteristics critical to polishing performance.

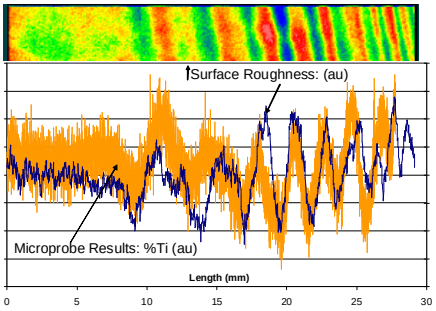
Details:

Ultra Low Expansion (ULE®) Glass Formation

Corning uses flame hydrolysis to form a mixture of SiO_2 and TiO_2. One consequence of this process is the creation of striations in the glass. These thin striae layers are due to small differences in the amount of TiO_2 incorporated into the glass.



Striae Correlates to Surface Roughness and Ti%

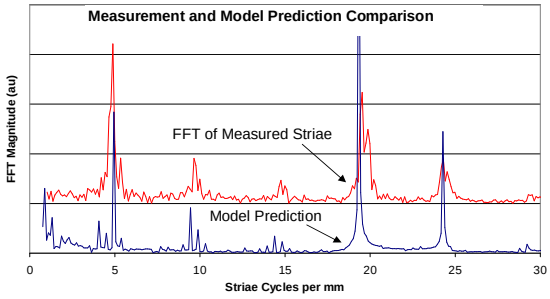


Here, striae layers in ULE are shown to correlate with the surface roughness of polished material. A pattern similar to the surface roughness is also seen in the Ti composition measurements made by an electron microprobe.

Predictive Striae Modeling and Model Verification

Recently, predictive models of furnace burner coverage and furnace oscillation patterns used while forming the glass have been developed. These models look at parameters including: burner coverage, impingement velocity, point velocity range, dwell time profile, and temperature range in order to predict striae formation. Comparison versus the measured striae have verified the model predictions.

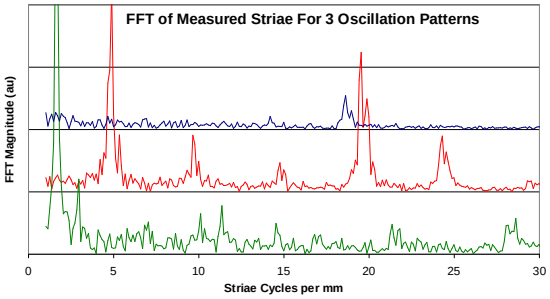
Below are Fast Fourier Transforms (FFT's) of the striae for one furnace oscillation pattern. There is excellent agreement between the measured (red) and predicted (blue) results.



Results:

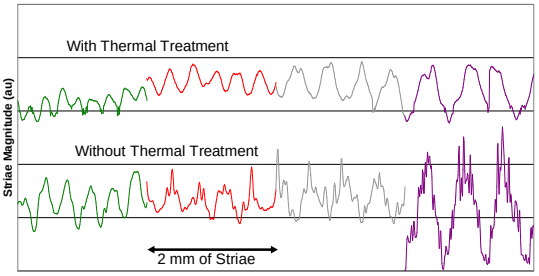
Predictive Modeling Used to Modify Striae Pattern

Below are FFT's of striae measurements obtained for three different furnace oscillation patterns. Using the verified models now allows Corning to optimize the striae pattern that will be obtained in the glass. The FFT's have been offset vertically for clarity.



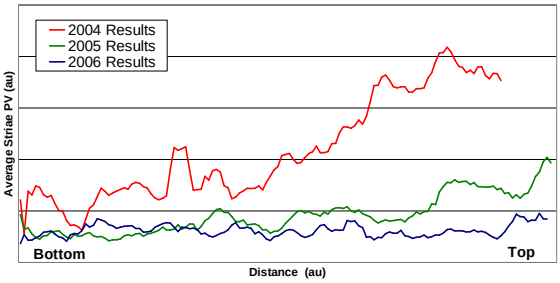
Thermal Treatments Used to Improve Striae

Another way to fundamentally change the striae in ULE is to apply thermal treatments to the glass. The graph below shows four, 2-mm sections from one boule, with and without thermal treatments. The treatment changes certain aspects of the striae.



Recent Striae Improvement

The combination of predictive modeling coupled with thermal treatments has resulted in greatly reduced straie, with current straie levels uniform across the boule.



Conclusions:

Through the combination of modeling and experimentation, Corning has significantly reduced the striae in ULE. Corning is ready to supply this low striae glass to the market for use in EUVL development programs.