Extreme Ultra-Violet Lithography
2005 International Symposium

CORNING
Discovering Beyond Imagination

Semiconductor Materials

Characterization of Striae in ULE®

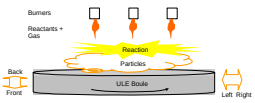
William Rosch,* Lorrie Beall, John Maxon, Robert Sabia, Robert Sell; Corning Inc, Corning, New York
roschwr@corning.com, beallf@corning.com, maxonje@corning.com, sabiar@corning.com, sellrd@corning.com

Introduction: Corning is characterizing the striae in ULE® glass as striae is likely to affect the roughness of polished EUVL photomasks. Polscope measurements have been used to better understand how striae varies through a boule. This characterization work is one element that has led to improved glass formation.

Details:

ULE Striae Formation

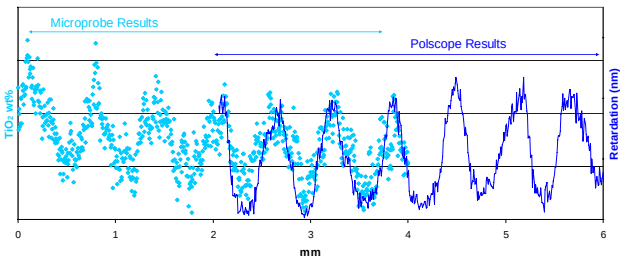
Corning's **U**ltra **L**ow **E**xpansion (**ULE®**) glass uses a flame hydrolysis process to form a mixture of SiO_2 and TiO_2. One side effect of this process is the creation of striations in the glass. These thin striae layers are due to small differences in the amount of TiO_2 incorporated into the glass. It is believed that polishing of EUVL photomask blanks is affected by the striae.



Striae Measurement Techniques

An electron **microprobe** can be used to measure the TiO_2 variation across the striations. Another method to characterize the striae is to use a **Polscope** to measure the material's internal stress created by the compositional variation.

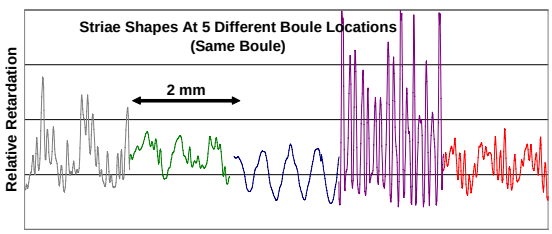
Polscope



Polscope Measurements

The Polscope uses monochromatic light (546 nm) to measure the optical retardation of the glass using a resolution of 8.6 µm/pixel.

A typical ULE® boule is measured from boule bottom to top at multiple radii to characterize the striae. Striae can vary in both **magnitude** and **frequency** depending on the location in the boule. These striae come from different locations in the same boule.

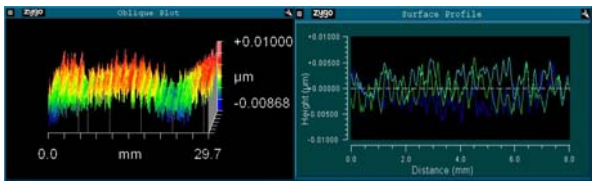


Conclusion: Striae can be characterized via optical retardation and data analysis.

Results:

Striae and Polishing

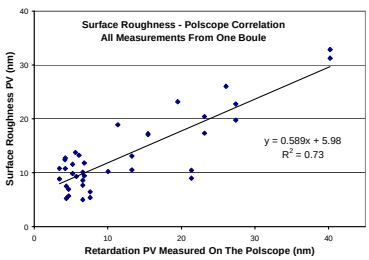
Since straie is wavy, striae will intersect the photomask surface regardless of best effort part extraction. Stress generates non-homogeneous material removal during chemical-mechanical polishing, resulting in mid-spatial frequency (MSF) roughness. These measurements were made using a NewView 5000™.



Example of Mid-Spatial Frequency Roughness on polished ULE, including line scans.

Striae and Surface Roughness Correlation

$R^2 = 0.73$ is the best correlation to date showing the relationship of Polscope data to surface roughness for polished blanks.

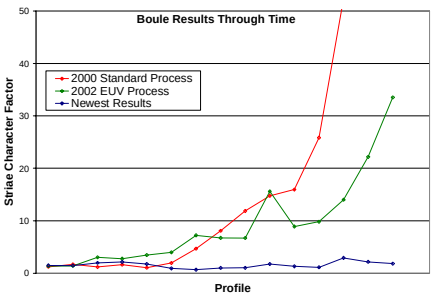


ULE Process Improvement: Striae Character Factor

Boule quality can be characterized using both striae magnitude and frequency via a Striae Character Factor (SCF), where low values indicate the least impact from both factors.

$$SCF = \int_{f_{min}}^{f_{max}} f \ \mathrm{PSD}(f)\,df$$

PSD=Power Spectral Density (include only when > 0.2)
f= striae per mm (1 to 30 mm^{-1})



Striae magnitude and frequency have improved due to continued process development efforts.

Future Work: Continue efforts to reduce striae in ULE® glass and the resulting impact on polishing.