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Characterization and Characteristics of a ULE®Glass Tailored for the EUVL Needs

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Abstract

Corning Incorporated is tailoring properties of ULE®Glass in order to meet the EUVL customer needs for mask substrates as well as optics. Improvements in ULE have been made in the areas of reduced inclusion levels [1], modeling predictions [2,3], reduced striae, and improved metrology capabilities [4]. Other properties inherent to ULE Glass that are conducive to optical applications include its thermal hysteresis [5,6], delayed elasticity [7,8], and temporal stability [9].

Inclusions

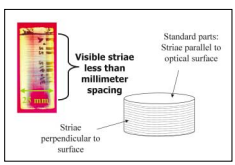
SEMI Draft 3148 currently require zero defects > 50 nm in size. Inclusions are not considered defects unless they manifest themselves on the surface of the substrate material. Predictions based on size and number of defects suggest only 1 defect expected in 300 substrates if the substrates were randomly selected. The observed inclusions were gaseous. The current technique is not capable of observing inclusions less than 1 µm in size.

Surface Defect Predictions…

Inclusion density	Predictions
0.002 inc/cm³	1 Defect in 300 Substrates

Striae

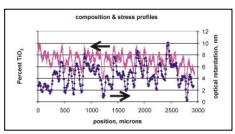
Striae present in ULE Glass is the result of small changes in the index of refraction that occurs as a result of small compositional difference in this binary glass. Standard parts have the optical surface parallel to the direction of the striae.



Developed Metrology

Microprobe

The microprobe technique has been refined to readily allow compositional variations to be measured that correlate to CTE variations of a few ppb/°C. This technique allows evaluation of CTE variations on a micron scale!

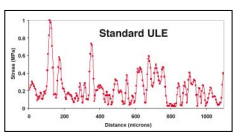


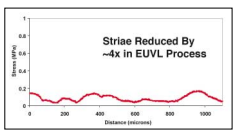
Polariscope

A polariscope was also used to evaluate striae within ULE Glass. Several metrology means are available for ready characterization of striae.

Striae Reduction

Process changes were made to reduce striae in ULE. The rms stress level between striae has been reduced by ~4x in this initial experiment. Development efforts are focusing on additional improvements.





Homogeneity

Measurement

The inherent properties of ULE enable the non-destructive assessment of CTE homogeneity over any part.

Mask Substrates

Glass is readily available today that meets SEMI Draft 3148 class A specifications for CTE homogeneity which is ±5ppb/K.

Optics

Although no homogeneity specification exists at the moment, improvements will likely be needed.

CTE Accuracy and Control

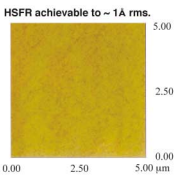
The current process is flexible and readily allows for targeting specific zero cross-over temperatures.

For Absolute CTE Measurements See:

4688-54: Vivek Badami and Michael Linder

Ability to Polish

Optics and photomask substrates require HSFR values to less than 0.15 nm rms. ULE Glass has been demonstrated to be polishable to levels below this specification by many [10,11,12].



Development Roadmap

	2000	2001	2002	2003	2004
Inclusion #/cm²	0.02	0.002	0.002	0.002	0.001
Predictions*	1 in 25	1 in 300	1 in 300	1 in 300	1 in 600
Striae (p-v Mpa)	±1.00	±0.20	±0.10	±0.05	±0.04 TBD
CTE Metrology: Precision (100 mm)	±0.4 ppb/K	Evaluate	Specify Equipment	±0.2 ppb/K	±0.1 ppb/K
CTE Metrology: Absolute		Evaluate	Design and Build	Debug and correlate	Quality control

Development Program

The development program underway at Corning Incorporated is designed to:

- Further reduce striae
- Improve CTE accuracy to < 1ppb/K
- Improve CTE precision in 100 mm glass from ±0.4 ppb/K to ±0.1 ppb/K
- Improve glass 3-D homogeneity
- Reduce birefringence levels

References

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(5) Shaffer and Bennett, "Effect of Thermal Cycling on Dimensional Stability of Zerodur and ULE," Applied Optics, 23 [17] 2852-2853, September 1, 1984.
(6) Jacobs, Johnston, Sasian,Watson, Targrove, and Bass, "Surface Figure Changes Due to Thermal Cycling Hysteresis," App. Opt., 26 [20] Oct. 15, 1987.
(7) Pepi and Golini, "Delayed Elastic Effects in the Glass Ceramic Zerodur and ULE at Room Temperature," Applied Opt., 30 [22], 3087-3088 Aug 1, 1991.
(8) Wilkins, Coon and Epstein, "Elastic Hysteresis Phenomena in ULE and Zerodur Optical Glasses at Elevated Temperatures," SPIE, 970, 40-46, (1988).
(9) Gulati and Edwards, "ULE-Zero Expansion, Low Density, and Dimensionally Stable Material for Lightweight Optical Systems, CR67 July 27-28, 1997.
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