Improved Characteristics of ULE® Glass for Meeting EUVL Needs

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Introduction:

ULE® Glass is a low expansion silicate glass that has been historically used for ground and space based telescope mirrors. Industry experts have now identified ULE Glass as a material of choice for EUVL, with some property improvement required. Striae and homogeneity are two properties which require improvement for optics applications. Striae in standard ULE glass has been found to impact mid spatial frequency roughness of optics. EUVL grade ULE Glass has been tailored to eliminate this issue. Metrology tools are being developed to meet homogeneity needs.

Inclusion Reduction ... Results from 1999–2002

<table>
<thead>
<tr>
<th>Year</th>
<th>Inclusion Density (in/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1 2000</td>
<td>0.05</td>
</tr>
<tr>
<td>Q3 2000</td>
<td>0.04</td>
</tr>
<tr>
<td>Q1 2002</td>
<td>0.03</td>
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</tbody>
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Metrology Improvement:
Laser system increases detection limit from 80 µm to 1 µm.

Material Improvement:
Shows inclusions reduced 10 to 25x.

Evaluatin Striae with: Sandwich Seal® Test

\[ \Delta t = 2\Delta t_{\text{sample}} - \Delta t_{\text{reactant}} \]

Smoothness of surface suggests primarily chemical removal during super-polishing (lack of fracture surfaces).

Stress stats in silica glass known to impact diffusion and solubility of water into glass*.
Summary and Conclusions:
EUVL grade ULE Glass is an appropriate material for EUV applications. A roadmap for glass quality and metrology improvements is being pursued.
Striae effect on surface roughness has been investigated and the impact reduced. This was accomplished by characterizing the striae, developing the proper metrology tools and improving the forming process. Future work will focus on improving the low frequency CTE homogeneity within ULE and the development of appropriate metrology tools.