10-25-2012

Electrostatic Discharge Properties of Fused Silica Coatings

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**Recommended Citation**

Andersen, Allen; Sim, Charles; and Dennison, JR, "Electrostatic Discharge Properties of Fused Silica Coatings" (2012). APS 4-Corners Section Regional Meeting; Socorro, NM; 2012. Graduate Student Posters. Paper 4.  
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Electrostatic Discharge Properties of Fused Silica Coatings

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Abstract

The electric field value at which electrostatic discharge (ESD) occurs was studied for thin coatings of fused silica (highly disordered SiO2/SiO3) on conductive substrates, such as those encountered as optical coatings and in Si microfabrication. The electrostatic breakdown field was determined using an increasing voltage, while monitoring the leakage current. A simple parallel-plate capacitor geometry was used, under medium vacuum and at temperatures down to ~150 K using a liquid N2 reservoir. The breakdown field, pre-breakdown arcing and I-V curves for fused silica samples were compared for ~60 nm and ~80 µm thick, room and low temperature, and untreated and irradiated samples. Unlike typical I-V results for polymeric insulators, the thin film silica samples did not exhibit pre-breakdown arcing, displayed transitional resistivity after initial breakdown, and in many cases showed evidence of a second discontinuity in the I-V curves. This diversity of observed discharge phenomena is discussed in terms of breakdown modes and defect generation on a microscopic scale.

Thin Films Fused Silica Test Results

ESD tests were performed on ~60 nm thin films of essentially the same material. The I-V curves were remarkably similar to those of the thicker ~60 µm, exhibiting few pre-breakdown discharges and transitional EBD. EBD for the thinner films is ~5 lower than for thicker films. This suggests that thickness-dependent, T-independent (Fowler-Nordheim like) tunneling transport mechanisms dominate for thinner films and T-dependent, thickness-independent (Schottky-like) transport mechanisms dominate thicker films.

Conclusions

The average breakdown field strength for each test configuration was determined as EBD = VESD/D, where D is the measured sample thickness.

<table>
<thead>
<tr>
<th>ESD Test Configuration</th>
<th>Breakdown Voltage (V)</th>
<th>Breakdown Electric Field (V/µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unirradiated @ 293 K</td>
<td>150 ± 50</td>
<td>2.6 ± 0.5</td>
</tr>
<tr>
<td>Unirradiated at Cryo</td>
<td>2230 ± 30</td>
<td>27.2</td>
</tr>
<tr>
<td>Irradiated @ 293 K</td>
<td>150 ± 5</td>
<td>19.0 ± 0.3</td>
</tr>
<tr>
<td>Irradiated at Cryo</td>
<td>1350 ± 15</td>
<td>18.8 ± 0.6</td>
</tr>
</tbody>
</table>

Based on these I-V curves, we conclude for fused silica that:
- Fused silica exhibits few partial discharge current spikes prior to breakdown, unlike LDPE and other polymers.
- Transitional ESD in fused silica usually results in a breakdown to an incomplete, finite, and variable resistance rather than a complete breakdown as occurs in polymers.
- EBD in untreated fused silica is ~35% higher at low T. EBD decreases as temperature increases.

References and Acknowledgements


We gratefully acknowledge contributions from the Materials Physics Groups including instrumentation and experimental efforts by Justin Dekany, help with thin film measurements by Matthew Stromo, and solid modeling by Bobby Johnson. "This work was supported through funding from NASA Goddard Space Flight Center."