Low-Stress Silicon Cladding for Surface Finishing Large UVOIR Mirrors NASA

SBIR Phase II contract No. NNX14CP14
Technical Monitor: Dr. David Redding (JPL)

PI: David A. Sheikh
ZeCoat Corporation
11/20/2014
Introduction

• In this presentation, I will discuss the status of our Phase II silicon cladding development effort, which is based on ion-assisted, physical evaporation (PV)

• The coating area is currently 1.2-meter in diameter and we are considering options for demonstrating coating a larger area (2-meter+)

• Future large telescopes may be monolithic (4-meters or larger), or comprised of many smaller segments (~1.5-m).
What is Silicon Cladding?

• Silicon cladding is a material applied on the surface of a SiC mirror substrate, to provide a better surface to polish and to reduce figuring time
• A 10 to 100-micron silicon layer is typically applied on top of the SiC
• Why Silicon? Good material to diamond turn or polish, and the CTE is very close to SiC
Research Goals

• Create a viable cladding production process for large mirrors
• Create a process that is scalable to ANY size vacuum chamber
• Create a “turn-key” technology suitable for licensing to silicon carbide mirror manufacturers
  • ZeCoat 2nd source supplier
  • ZeCoat R&D
ZeCoat’s Si cladding process is based on periodically alternating the sign of the coating stress to yield a near-zero net coating stress. IAD silicon has compressive stress and non-IAD silicon has natural tensile stress.
Calculating Stress (goal is less than 85 MPa)

Profilometry measurement shows ~11 microns of Si

1 inch diameter, 20-mil fused silica disc bent 16-microns = ~60 MPa (tensile)
ZeCoat’s 1.2-m vacuum coating chamber was completed in March, 2013 and utilizes an ion-assisted e-beam evaporation system
Phase I & II Challenges

• Surface defects
  – A spitting event is when molten silicon explodes from the evaporation crucible potentially damaging the silicon clad surface.
    • Pre-conditioning
    • Excessive evaporation rates, e-beam “digging”
  – Dust; opening and closing the chamber many times during the process to replenish materials, etc.

• Arcing
  – Arcs associated with ebeam evaporation (high voltage discharges within the chamber) cause many problems
Overcoming Arcing Problems

• Designed and installed new shielding over the electron emitter assembly
• New shielding over ceramic insulators
• Ground wires far from high-voltage lines
• Installed relays between the computer system and process sensors within the chamber, to isolate the computer from arcing interference
• Wrote new motion control software to detect false signals due to arcing and reset the computer system seamlessly
Silicon Polishing Tests
## Polishing Results Phase I and Phase 2 (1<sup>st</sup> Q)

Scan length 1024 microns

<table>
<thead>
<tr>
<th>Project</th>
<th>ID</th>
<th>Substrate</th>
<th>Evap. Rate</th>
<th>Si Thickness (μ)</th>
<th>PTV (A)</th>
<th>RMS (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I</td>
<td>1a</td>
<td>SiC (rough)</td>
<td>3x</td>
<td>20</td>
<td>16</td>
<td>2.8</td>
</tr>
<tr>
<td>Phase I</td>
<td>1b</td>
<td>SiC (rough)</td>
<td>3x</td>
<td>20</td>
<td>236</td>
<td>21.5</td>
</tr>
<tr>
<td>Phase I</td>
<td>1c</td>
<td>SiC (rough)</td>
<td>3x</td>
<td>20</td>
<td>460</td>
<td>36.7</td>
</tr>
<tr>
<td>Phase I</td>
<td>2a</td>
<td>SiC (rough)</td>
<td>3x</td>
<td>20</td>
<td>137</td>
<td>21.4</td>
</tr>
<tr>
<td>Phase I</td>
<td>2b</td>
<td>SiC (rough)</td>
<td>3x</td>
<td>20</td>
<td>84.2</td>
<td>10.8</td>
</tr>
<tr>
<td>Phase I</td>
<td>2c</td>
<td>SiC (rough)</td>
<td>3x</td>
<td>20</td>
<td>314.1</td>
<td>24.4</td>
</tr>
<tr>
<td>Phase II</td>
<td>SN1</td>
<td>Fused Silica (polished)</td>
<td>1x</td>
<td>4</td>
<td>9.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Phase II</td>
<td>SN3</td>
<td>Fused Silica (polished)</td>
<td>1x</td>
<td>11</td>
<td>23.3</td>
<td>3.2</td>
</tr>
</tbody>
</table>
Surface Roughness Profile
Silicon Coated SiC Sub #1 B
Processed
RMS  21.53 angstroms
P-V  236.78 angstroms
Points 1024 microns

Coastline Optics, LLC
900 Via Alondra
Camarillo, CA 93012
(805) 384-0609
28 Oct 2013 14:17:34
Surface Roughness Profile

Silicon Coated Sic Sub #1 C

Processed

RMS 36.85 angstroms
P-V 459.52 angstroms
Points 1024 microns

Coastline Optics, LLC
906 Via Alondra
Camarillo, CA 93012
(805) 384-0609

Surface Roughness Profile

FS-01
Processed
RMS 1.36 angstroms
P-V 9.19 angstroms
Points 1024 microns

Coastline Optics, LLC
906 Via Alondra
Camarillo, CA 93012
(805) 384-2609

11 Nov 2014  14:43:41
Motorized Dust Cover Inside Vacuum Chamber
Alternatives to heating with an electron beam? Possible advantages (higher rates?, reduced surface defects?)

- Thermal resistive Ta source (1800°C)
- Inductive heating
- Resistive graphite heating (3000°C)
Other things to investigate?

• Cold-cathode neutralization of the ion gun?
  • Process duration is currently limited because of required ion gun maintenance (neutralization filament replacement)

• More automation
  • Rate control
  • Automate ion gun turning on off
  • Crucible changes (heat up and cool down)

• How to remove the silicon for re-work?
  • Chemical removal
  • Micro-gritblasting
Questions?