Amorphous Nitride Anti-Reflective Coatings on PMMA Optics

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Technology Days

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Radiation hard multi-layer optical coatings

SBIR Phase I Contract
NNX08CC81P
Nanohmics, Inc.
Space ready multi-layer optical coatings

**Problem**: New optical coatings need to be developed for next generation light weight space base optics for use in programs such as NASA’s EUSO observatory.

**Phase I Goal**: Demonstrate robust anti-reflective coating that can be applied to light weight optical materials such as PMMA (Plexiglas).

**Nanohmics’ approach**: Multi-layer amorphous nitrides / oxides as optical coating.
Advantages of Amorphous Nitrides

• Proven radiation resistance to darkening
• Multi-layers of amorphous nitrides and oxides can be used to design anti-reflection, reflective, and band pass coatings
• Deposit on room temperature substrates
• Adhere well to most materials
• Robust coating
Demonstration of Radiation Hardness

Multi-layer nitride / oxide coating exposed to $\sim 10^{15}$ protons/cc flux at 20 keV, 50 keV, 100 keV and 300 keV
Advantages of sputter deposition

• Able to deposit optical quality films
• Reactive growth of nitrides and oxides results in relatively fast deposition rates
• Sputter process results in higher density, better adhesion coatings compared to e-beam deposition
  – Bias sample if increased density desired
• Deposit on cooled substrates
• Large established infrastructure
• Relatively inexpensive process that can handle large substrates
CVD 601 Sputter Deposition System
Amorphous Nitride / Oxide Growth

- Initial work used AlN (n=2.1), ZrO$_2$ (n=2.3) and SiO$_2$ (n=1.56)
- All materials grown using reactive sputtering
  - Solid target (Al, Zr, Si, etc)
- RF power between 200 and 500 W RF
- Growth rates ~0.2-0.5 microns / hr
- All depositions on Glass and PMMA
- Measured thickness using SEM cross sections to determine growth rate
- Used 400 W RF power for initial depositions
  - Deposited on water cooled substrate holder
- No delamination noted after thermal cycling (-55 C to 75 C)
Growth Rate and Adhesion Strength

Growth rate of SiO$_2$, AlN, and ZrO$_2$ at 400 W RF power.

<table>
<thead>
<tr>
<th>Material</th>
<th>Growth Rate</th>
</tr>
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<tbody>
<tr>
<td>SiO$_2$</td>
<td>6.4 nm/min</td>
</tr>
<tr>
<td>AlN</td>
<td>2.1 nm/min</td>
</tr>
<tr>
<td>ZrO$_2$</td>
<td>1.15 nm/min</td>
</tr>
</tbody>
</table>

Adhesion strength to PMMA

<table>
<thead>
<tr>
<th></th>
<th>AlN Cooled</th>
<th>SiO$_2$ Cooled</th>
<th>ZrO$_2$ Cooled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Adhesion Force (Kg)</td>
<td>4.7</td>
<td>3.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Max Adhesion Strength (Kg/cm$^2$)</td>
<td>83</td>
<td>52</td>
<td>18</td>
</tr>
</tbody>
</table>
“typical” films

SiO$_2$  
ZrO$_2$
Bi-layer Reflector

- Initial design composition: AlN and SiO$_2$
- Optimization for single wavelength reflection to compare model with experimental results
- Reflector consisted of 6 alternating layers of 85nm of SiO$_2$ and 4nm of AlN
Reflection of Bi-layer Film

Reflection (AU)

Wavelength (nm)

10-Jul-08
Anti-reflective coating

SiO$_2$, AlN, and ZrO$_2$
Multi-layer (AlN, ZrO$_2$, SiO$_2$) film

Transmission spectra compared to uncoated coverglass
Issues

Stress in Film

Deposition Uniformity
Current Status / Results

- Designed a number of multi-layer coatings
  - Reflective coating in visible wavelength
  - Anti-reflective coating at visible wavelengths
  - Model used AlN, ZrO$_2$, and SiO$_2$ films
- Grew amorphous ZrO$_2$, AlN, SiO$_2$ films using reactive sputtering
- Demonstrated good adhesion of films to PMMA substrates
  - No delamination upon thermal cycling
- Fabricated and tested multi-layer coatings
  - Good comparison between theory and experiment
- Issues remain with film stress and uniformity
  - Modify pressure and power to minimize stress
  - Use uniformity shields and sample rotation to improve uniformity
Future Work

• Outlook for use of amorphous nitrides is good
• Deposition of AlN / ZrO$_2$ / SiO$_2$ or similar structure should work well
  – Examine other materials
    • e.g. HfO$_2$ (n=2)
  – Improve uniformity
    • Uniformity shields
    • sample rotation
  – Deposit on curved surfaces
  – Work to minimize stress in films
    • Power
    • pressure