Multilayer Anti-Reflective Coating Development for PMMA Fresnel Lenses

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Mirror Technology SBIR/STTR Workshop

Boulder, CO
June 7, 2009
Radiation Hard Multilayer Optical Coatings

SBIR Phase II Contract
NNX09CB36C
COTR: Bill Jones
Marshall Space Flight Center
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 II Goal**: Develop a robust anti-reflective coating that can be applied to UVT-PMMA Fresnel lenses

**Nanohmics’ Approach**: Multi-layer amorphous nitrides / oxides as optical coating
Why PMMA?

- Light weight
- UV Resistant
- UV Transparent
- Inexpensive
Advantages of Amorphous Oxides and Nitrides

- Proven radiation resistance to darkening
- Can be used to design anti-reflection, reflective, and band pass coatings
- Room temperature deposition
- Adhere well to most materials
- Robust coating
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 (12” dia. in our system)
New Deposition System
Sputter Deposition System
Amorphous Nitride / Oxide Growth

• Coating materials: AlN, ZrO$_2$, and SiO$_2$
• All materials grown using reactive sputtering
  • Solid target (Al, Zr, Si)
  • Background gas (Ar:O$_2$ or Ar:N$_2$)
• RF power = 200 W
• Growth rates $\sim$1.7-7.7 nm/min
• Thickness measured using optical methods (Filmetrics F20) and profilometry (Dektak)
• No delamination noted after thermal cycling (-55 C to 75 C)
Growth Rate and Adhesion Strength

Growth rate of SiO₂, AlN, and ZrO₂ at 200 W RF power.

<table>
<thead>
<tr>
<th>Material</th>
<th>Growth Rate</th>
</tr>
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<tbody>
<tr>
<td>SiO₂</td>
<td>7.7 nm/min</td>
</tr>
<tr>
<td>AlN</td>
<td>2.4 nm/min</td>
</tr>
<tr>
<td>ZrO₂</td>
<td>1.7 nm/min</td>
</tr>
</tbody>
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Adhesion strength to PMMA

<table>
<thead>
<tr>
<th></th>
<th>AlN</th>
<th>SiO₂</th>
<th>ZrO₂</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/cm²)</td>
<td>83</td>
<td>52</td>
<td>18</td>
</tr>
</tbody>
</table>
Optical Constant Data

At 500 nm:
- AlN (n=1.973, k=0.0004)
- ZrO$_2$ (n=2.10, k=0.0002)
- SiO$_2$ (n=1.47, k=0.0007)
Stress

AR Coatings at 200 W; 500x magnification

Old System

New System
Amorphous Films

Old System

New System
Anti-Reflective Coating Model

SiO₂, AlN, and ZrO₂

Prescription

Anticipated Spectrum
AR Coated UVT PMMA

Uncoated  Coated
AR Coated UVT PMMA

![Graph showing the transmission of light for uncoated and AR coated materials. The graph plots %Transmission against Wavelength (nm) for wavelengths ranging from 200 to 800 nm and from 300 to 450 nm. The graph shows a significant increase in transmission for AR coated materials compared to uncoated ones.]
Current Status / Results

- Designed and implemented new deposition
- Measured $n$ and $k$ for amorphous materials
- Stress eliminated in the films
- Initial AR coatings look promising
Future Work

• Improve models with new data
• Qualify new deposition tool
  • Deposition parameters
  • Coating uniformity (now at 90% uniformity)
• Deposition on Fresnel lenses
• Environmental Testing
  • Humidity
  • Temperature cycling
  • UV exposure
Multilayer Anti-Reflective Coating Development
For PMMA Fresnel Lenses

Nanohmics, Inc.
Austin, TX

INNOVATION
Nanohmics is developing a robust, radiation-hard, anti-reflective coating for use on polymeric Fresnel lenses.

ACCOMPLISHMENTS
◆ Novel deposition system designed, fabricated, and implemented
◆ Low stress, high quality dielectric materials deposited on a variety of substrates including polymethylmethacrylate (PMMA)
◆ Highly amorphous films achieved
◆ Excellent adhesion to most materials
◆ 90% uniformity achieved

COMMERCIALIZATION
◆ Primary markets for the coatings include optics, tooling, and ceramics.
◆ Presently using the technology to increase the strength of ceramic drilling materials.
◆ Sales from the technology have reached $12,500. If successful, a revenue stream of 2% gross is expected from our partner.
◆ Exploring partnerships with optics manufacturers.

GOVERNMENT/SCIENCE APPLICATIONS
◆ Technology being developed for use in the Extreme Universe Space Observatory (EUSO).
◆ Coatings still must be fully tested.
◆ Technology can be used for any number of robust, hard coatings especially for optical materials.
◆ Polymeric lenses will result in a lower launch weight and enhanced savings over using glass lenses.

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2009 SBIR Phase II: NNX09CB36C