Abstract

Anti-reflective (AR) coatings comprised of several layers of oxide and nitride dielectric materials have successfully been sputter deposited on UV transparent polymethylmethacrylate (UVT-PMMA) windows. The amorphous coatings are deposited using reactive sputtering in a custom-designed magnetron sputtering tool. The AR coatings are adherent, radiation hard, and improve the transmission of UVT-PMMA windows by approximately 5% in the 300-450 nm range. The coatings will be applied and tested on UVT-PMMA Fresnel lenses for use in space-borne telescopes.
Multilayer Anti-Reflective Coating Development for PMMA Fresnel Lenses

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**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
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
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 ~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 SiO$_2$, AlN, and ZrO$_2$ at 200 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>7.7 nm/min</td>
</tr>
<tr>
<td>AlN</td>
<td>2.4 nm/min</td>
</tr>
<tr>
<td>ZrO$_2$</td>
<td>1.7 nm/min</td>
</tr>
</tbody>
</table>

Adhesion strength to PMMA

<table>
<thead>
<tr>
<th>Max Adhesion Force (Kg)</th>
<th>AlN</th>
<th>SiO$_2$</th>
<th>ZrO$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></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>
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

SiO$_2$, AlN, and ZrO$_2$

Prescription

Anticipated Spectrum
AR Coated UVT PMMA
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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