NanOhmics™ Inc.

Empowering the next generation of electronic and opto-electronic devices

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

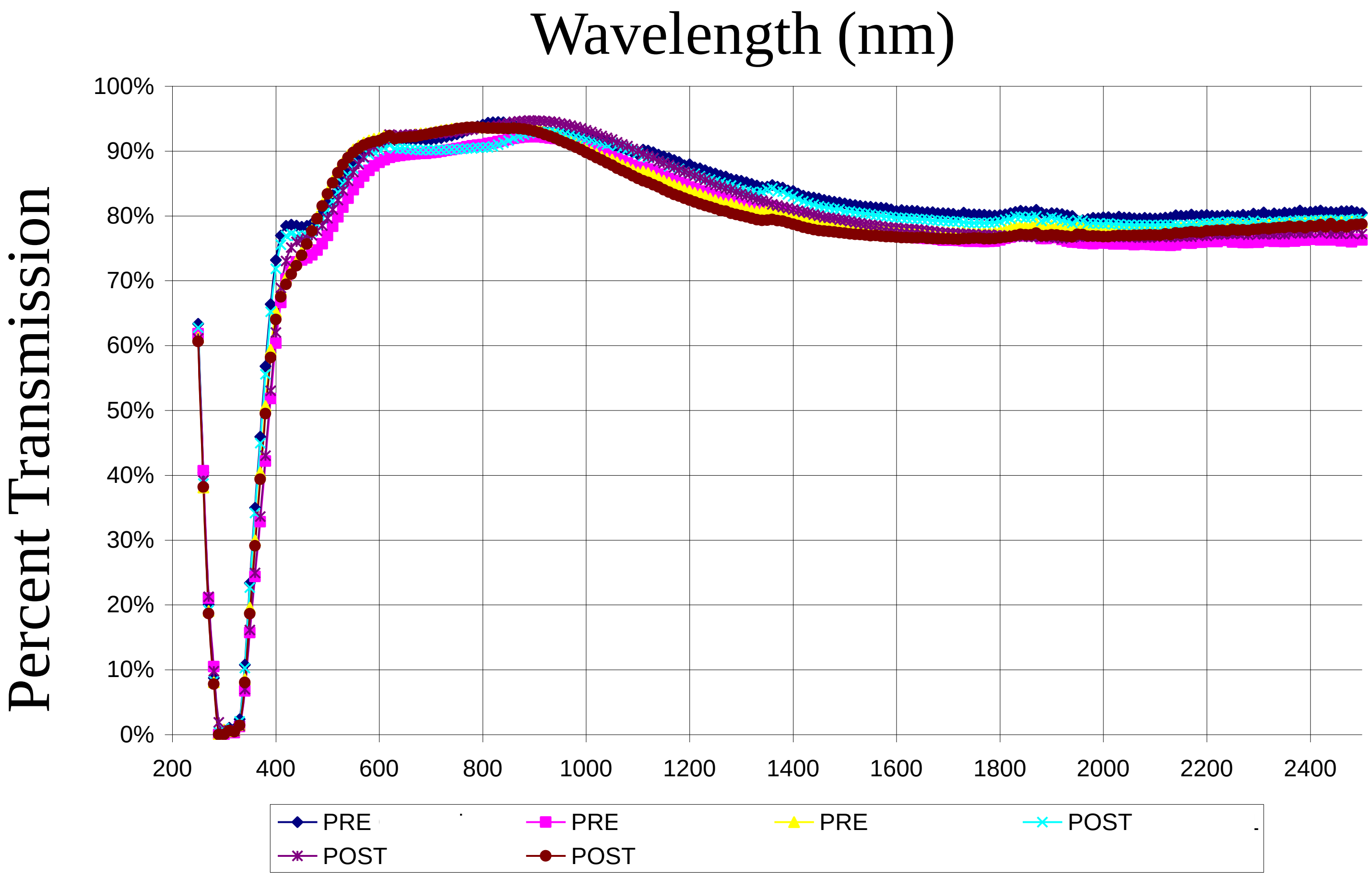
Phase I Goal: Demonstrate robust anti-reflective coating that can be applied to light weight optical materials such as PMMA (Plexiglas)

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 ~ 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.

Material	**Growth Rate**
SiO_2	6.4 nm/min
AlN	2.1 nm/min
ZrO_2	1.15 nm/min

Adhesion strength to PMMA

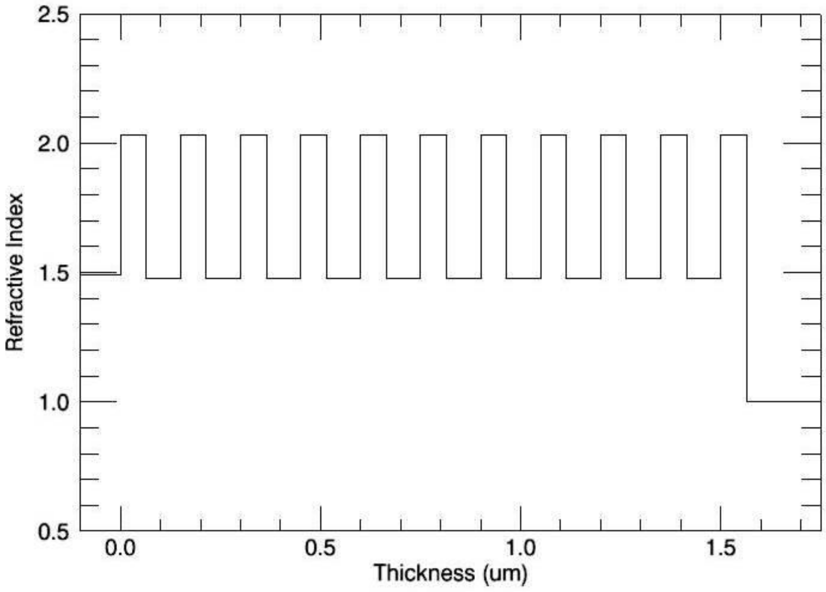
	AlN Cooled	SiO_2 Cooled	ZrO_2 Cooled
Max Adhesion Force (Kg)	4.7	3.0	1.0
Max Adhesion Strength (Kg/cm^2)	83	52	18

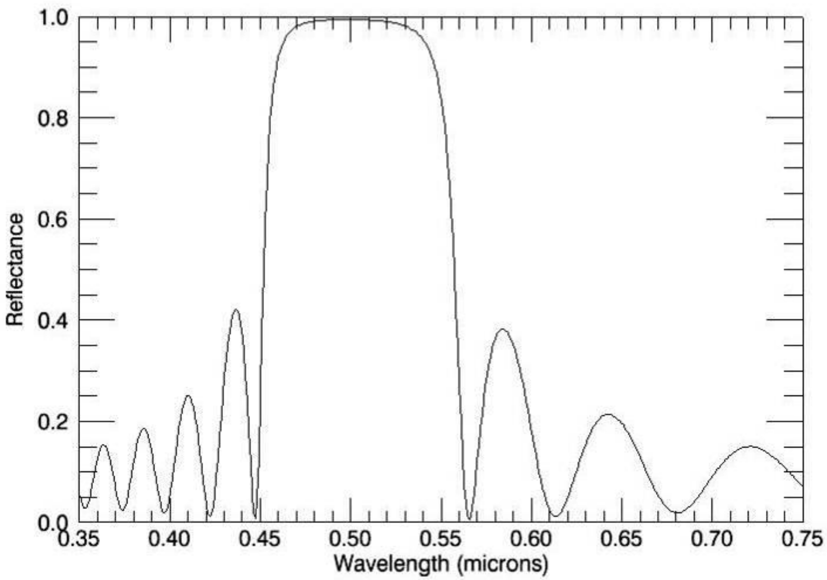
“typical” films

SiO_2 ZrO_2

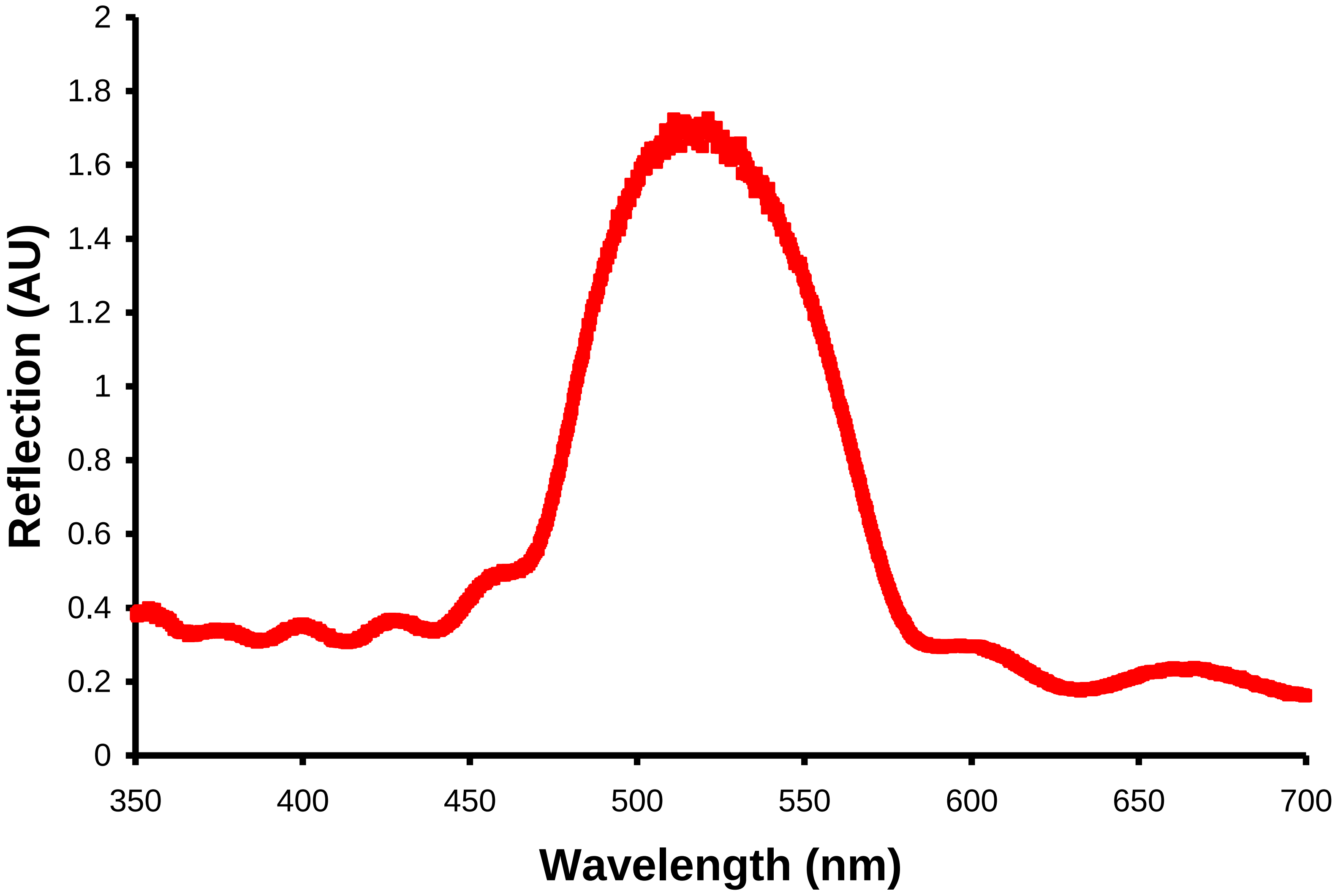
Bi-layer Reflector

- 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



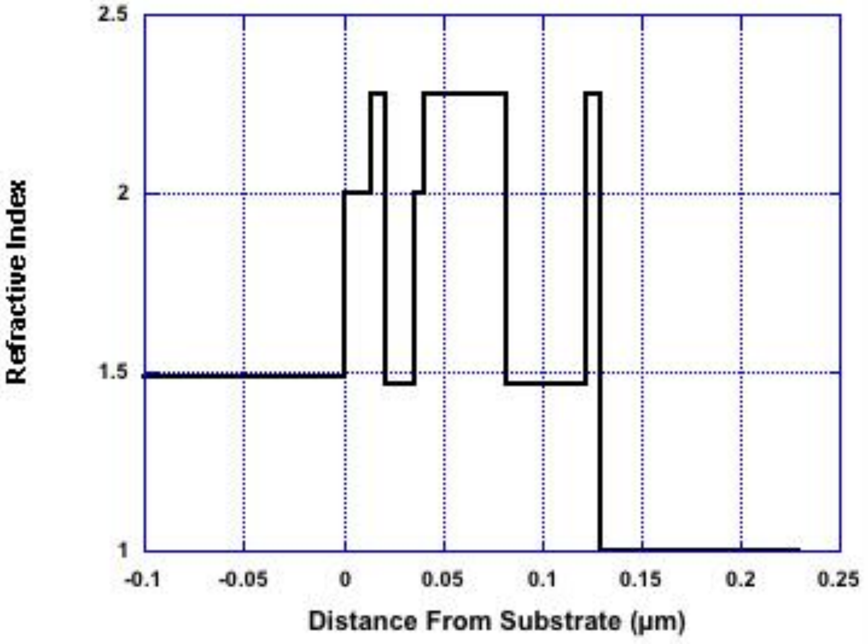


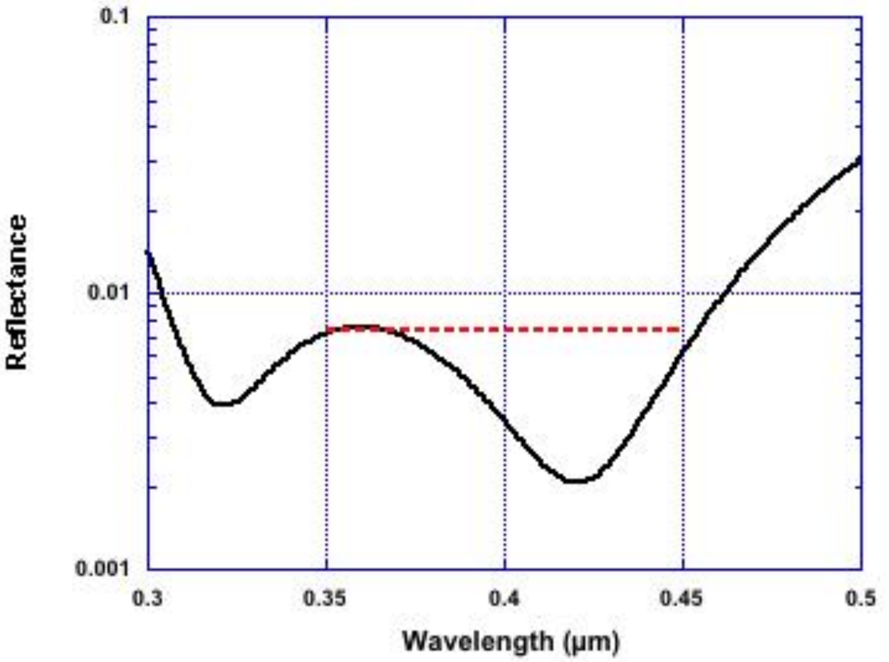
Reflection of Bi-layer Film



Anti-reflective coating

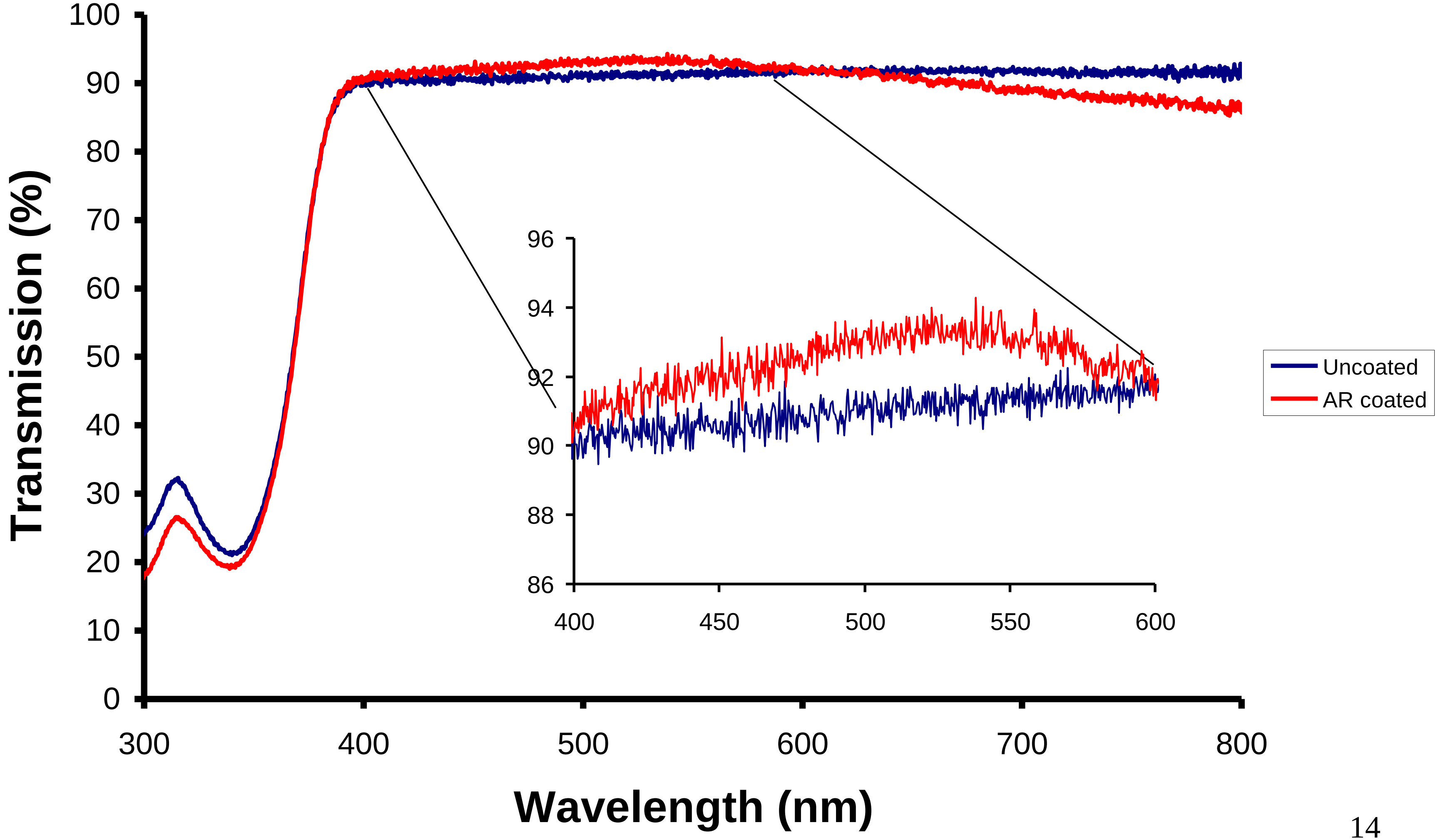
SiO_2, AlN, and ZrO_2





Multi-layer (AlN, ZrO_2, SiO_2) film

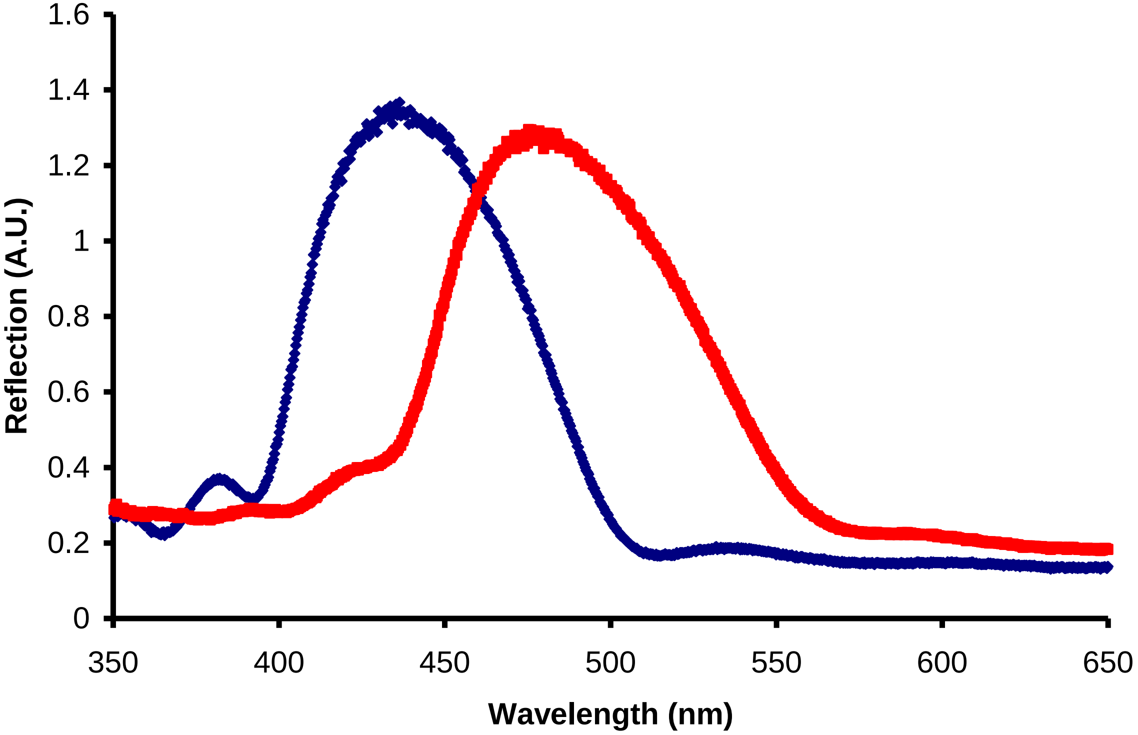
Transmission spectra compared to uncoated coverglass



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