Variable Reflectivity Coatings for Optical Propulsion Applications

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Solar Sailing

Facts
• Uses solar radiation pressure
  • Microscale propulsion
  • Attitude control

Advantages
• No need to bring fuel
  • Long lasting
Utilizing pressure difference

Absorption radiation pressure = \( \frac{1}{2} \) Reflectance radiation pressure

- Off State = Absorption
  - Perfectly black service
  - No reflection

- On State = Reflectance
  - Appears like a mirror
  - Reflects all wavelengths
  - No absorption

Differences in pressure causes torque
- Attitude control
Radiation Pressure Equation

\[ P = \frac{1}{C} \int_{0.5 \mu m}^{4 \mu m} I(2R + A) d\lambda \]

\[ I = \text{Solar extraterrestrial AM 1.5 Spectrum} \]
\[ R = \text{Reflectance} \]
\[ A = \text{Absorption} \]
\[ C = \text{Speed of light} \]
\[ T = \text{Transmittance} \]

\[ A + R + T = 1 \]
\[ A = 1 - R \]
Results

Top mirror metals

- Aluminum
- Gold
- Tungsten

Bottom mirror metal

- Gold
- Tungsten
- Aluminum
Results
Anti-Reflective coating SiO$_2$

\[ n_i = 1 \]

Anti-Reflective coating SiO$_2$

Anti-Reflective coating VO$_2$

Au film mirror

Phase change spacer VO$_2$

Tungsten W mirror

Silica wafer

Reflection

\[ R = \left| \frac{n_1 - n_2}{n_1 + n_2} \right|^2 \]
Fabrication

1) Starts with a Silica Wafer
2) Tungsten added via Sputtering
3) VO₂
   - Electron Beam Evaporation
   - Furnace annealing to oxidize
4) Au Gold via Electron Beam
5) VO₂ Using that same method
   - Electron Beam Evaporation
   - Furnace annealing to oxidize
6) Anti-Reflective coating SiO₂ using Chemical Vapor Depositions
Future plans

• Characterize the interaction between thermochromic and electrochromic responses

• Verify model experimentally

• Redesigns for electrical measurements
Acknowledgments

- ASU / NASA Space Grant
- Liping. Wang Ph.D (Mentor)
- Sydney Taylor
- Desiree Crawl
- Hassan Alshehri
- My Audience for listening

References