Plasma-Enhanced Chemical Vapour Deposition of Flexible Dielectric Mirrors Designed for Energy-Efficient Window

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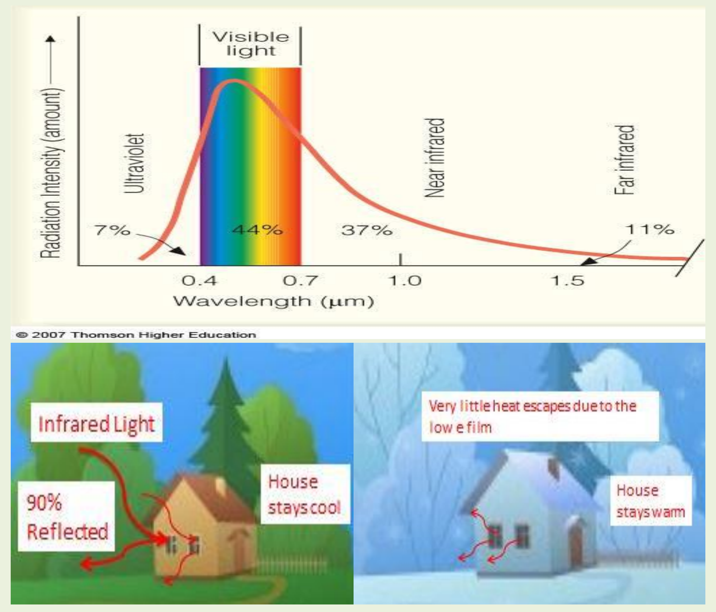
Motivation

Buildings consume ~40% of the energy used in the US through lighting, heating, and cooling. Much of this energy is lost through windows. Roughly half of the energy arriving from the sun is in the form of infrared (IR) light - wavelengths between 700 nm and 1mm. Ideally windows would transmit visible light and reflect the IR, reducing air conditioning loads. Likewise, in the winter the windows would retain IR radiation generated inside the house, reducing heating costs.



Images from http://www.123rf.com/

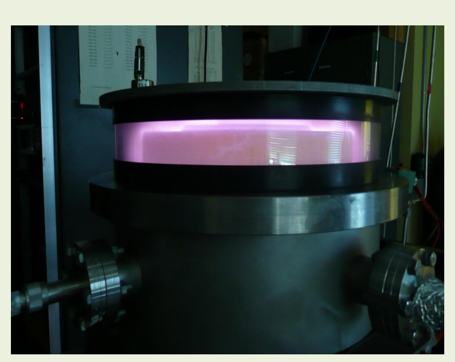
Goals of this Work

The objective of this research was to design and demonstrate transparent, flexible films that could be retrofitted into existing windows to reduce cooling and heating costs. Requirements for this application include:

- 90% transmission of visible light
- 90% reflection of Infrared light
- Low cost/mechanical flexibility

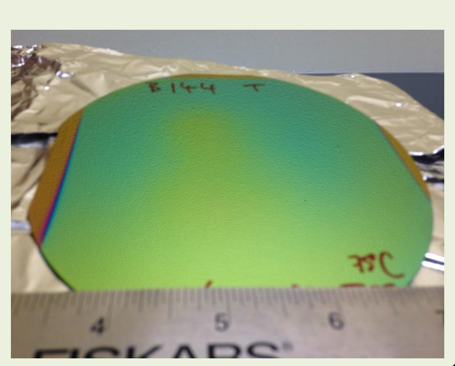
In this work we designed dielectric reflectors based on hybrid nanolaminates comprised of inorganic TiO_2 and polymeric silicone. These structures were fabricated using **plasma-enhanced chemical vapour deposition (PECVD)** at low temperature on low cost polyethylene (PET) foils and their optical properties were assessed.

Fabrication Technique: PECVD



- Low temperature, good uniformity
- High rate, good thickness control
- High index layer: TiO_2 (n~2.4) using $TiCl_4/O_2$
- Low index layer: Silicone (n~1.5) using HMDSO

Characterisation



- Spectroscopic Ellipsometry
- UV-Vis-NIR Spectrophotometry

Principle of Optical Interference Coatings

- At an interface light can be both reflected and transmitted
- If the second medium has a higher refractive index (n) the reflected waves are 180° out of phase
- Coatings can be added to the glass to increase/decrease reflection at certain wavelengths by constructive/destructive interference

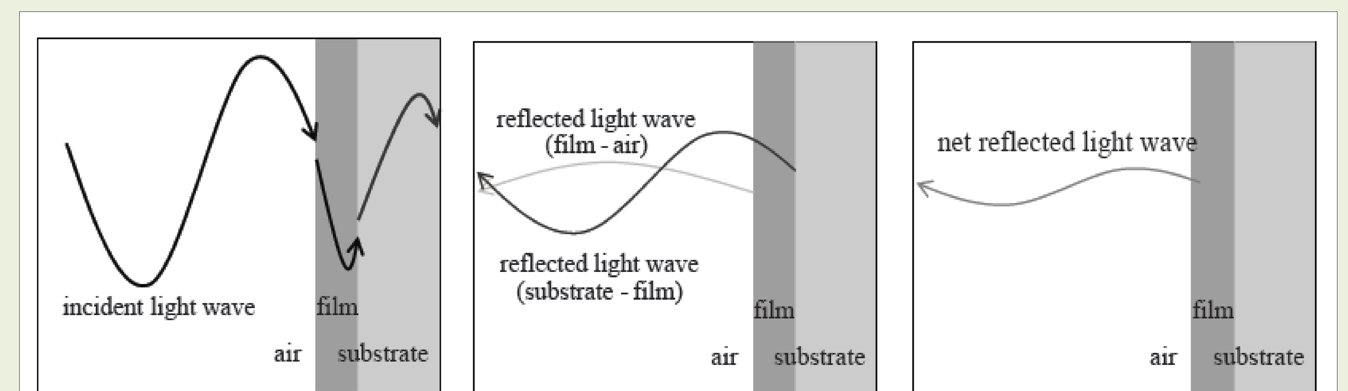
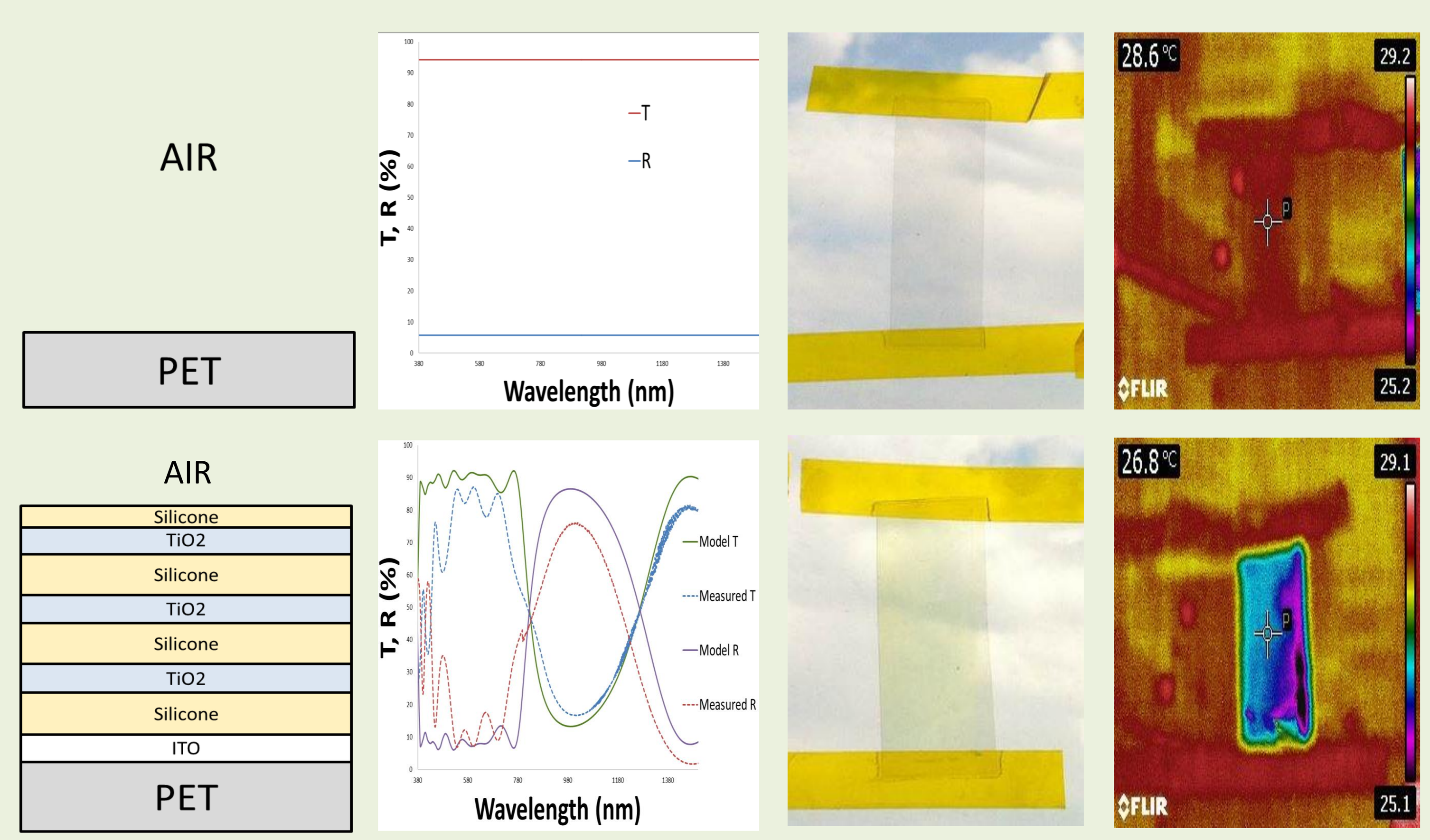


Image from The University of Arizona

- By using large multi-layered stacks (with alternating high/low index materials) we control the transmission & reflection over a wider wavelength range
- These stacks were modeled and optimized using the thin-film coating software TFCalc

IR Reflecting Film for Energy Efficient Windows

- Good agreement between optical design and experimental
- Vis and IR photography verify the efficacy of the coating

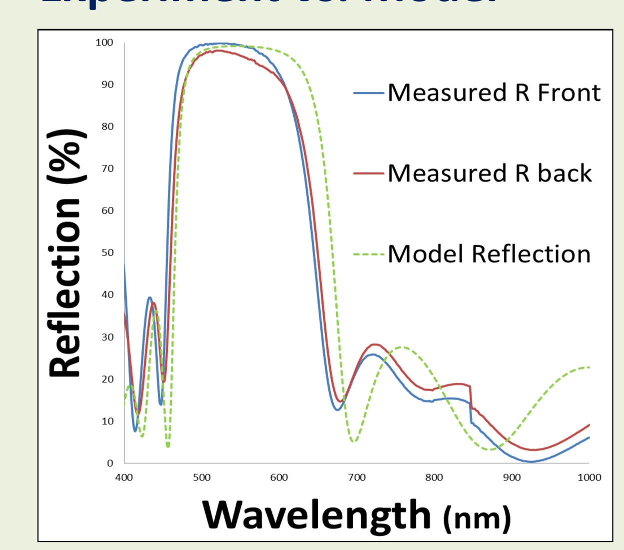


Physical Stack Employed | Transmission & Reflection | Visible Photography | Infrared Photography

Flexible Dielectric Mirror

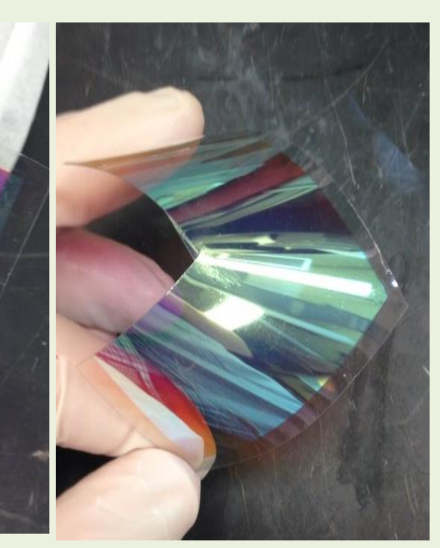
- Demonstrate mechanical integrity and high visible reflection
- Use 2 transparent materials (Silicone and TiO_2) to make a reflective coating
- 11 repeating layers of TiO_2 (57nm) and Silicone (92nm) on PET
- Narrow reflection band means mirror results in red/purple hue
- Flexible, robust: No cracking or de-lamination observed

Experiment vs. Model



Flat

Flexed



Conclusions

- Flexible dielectric mirrors were designed and constructed by depositing TiO_2/silicone nanolaminates on PET using PECVD
- The reflection was tuned from the IR for efficient windows to the visible for mirror applications, validating model predictions
- Coatings deposited on low cost PET substrates displayed robust performance under flexure
- Provides proof-of-concept for future scale up of this technology
- For better results more control of the Silicone is needed

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