Solution-Based Nanoengineering of Multifunctional Coatings through Self-Assembly Techniques

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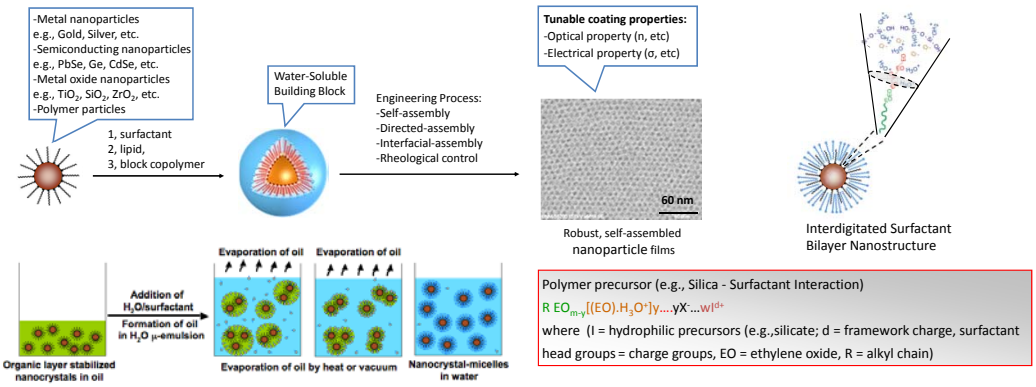
Introduction

Optical films are widely used in consumer electronics, semiconductor devices, and high-performance glass and ceramic materials. Presently most of these films are manufactured using complicated and costly processes like sputter deposition and chemical vapor deposition (CVD), which requires high temperature and/or high vacuum. A simpler and less expensive process is needed, and we have developed such a process—a rapid and versatile self-assembling process that employs nanotechnology as an alternative to conventional CVD and sputter-deposited optical films. Using these techniques and their combination with top-down fabrication processes such as lithography, coatings with hierarchical features can be produced with form and function in multiple length scales. Our technology involves an interfacial self-assembly of polymers and nanoparticles to synthesize multifunctional nanoparticles and to assemble them into ordered, three-dimensional films. Quarter wave stacking of self-assembled films are developed for near infrared reflectors, which overcomes the harsh conditions from conventional processing (CVD, sputtering, etc) with improved functionality. Theory modeling shows very good consistency with experimental results, which addresses key manufacturing issues.

Interfacial Self-Assembly of Polymers and Nanoparticles to Synthesize Multifunctional Films



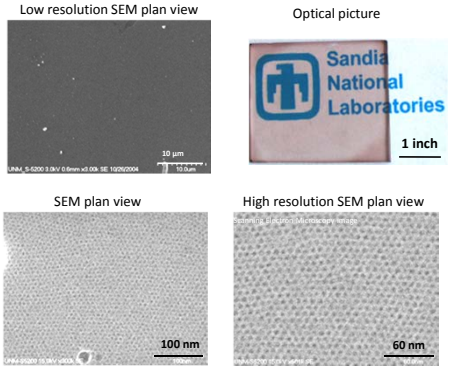
Polymer precursor (e.g., Silica - Surfactant Interaction)

$R\ EO_{m-y}[(EO).H_3O^+]y....yX^-...wI^{d+}$

where (I = hydrophilic precursors (e.g.,silicate; d = framework charge, surfactant head groups = charge groups, EO = ethylene oxide, R = alkyl chain)

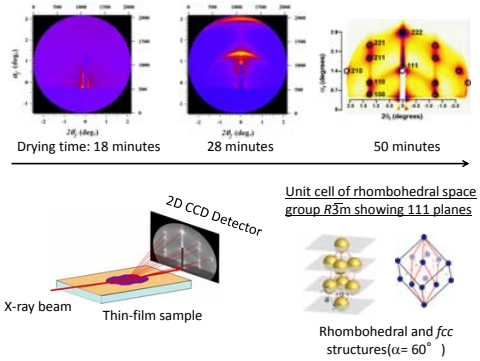
Fan, H. *et al.* Patent No.: US 8,092,595 B1, issued on Jan. 10, 2012. Fan, H. *et al*. Patent No.: US 8,288,001 B1, issued on Oct. 16, 2012.

Self-Assembled Nanoparticle Films



- Near ambient coating conditions.
- More stable in inorganic framework. (>200˚C)
- Uniform and continuous without cracking.
- Compatible with standard semiconductor fabrication process.
- Robust material: metal, semiconducting, magnetic, etc

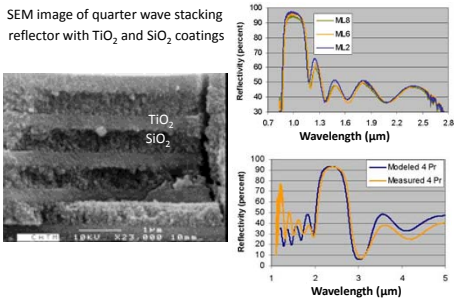
In-situ Grazing Incidence Small Angle X-ray Scattering Characterizations of Ordered Nanoparticle Films.



- GISAXS at a synchrotron source enables us to follow the development of long-range thin-film structure and monitor film defects in real time (high intensity beam) during self-assembly.

Dunphy, D. *et al. Langmuir.*, 24 (19) 10575-10578, 2008.

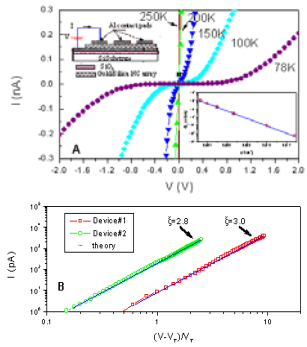
Application of Nanoparticle Coatings to Near Infrared Reflectors



- Quarter wave stacking of self-assembled nanoparticle films for near infrared reflectors, overcomes the harsh conditions from conventional processing (CVD, sputtering, etc) with improved functionality.
- Reflectivity studies show high and reproducible reflectivity over controlled wavelength windows (1-2μm, 2-3μm, 8-12μm, etc).
- Model design show 99.9% and address key manufacturing issues.

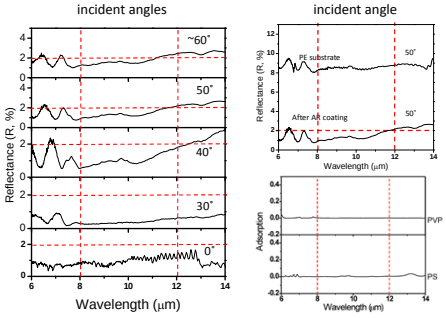
(2010 R&D 100 Award)

Current-Voltage Scaling



- Films exhibit non-linear current-voltage behavior at low temperatures.
- Linear Arrhenius plot testifies both to the uniformity of nanoparticle sizes and to the dominance of charge transport mechanism at room temperature.

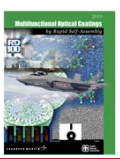
Reflectance of Self-Assembled Nanoparticle Coating at Infrared



- Reflectivity studies show high and reproducible reflectivity over controlled wavelength windows (1-12μm).
- Films show no absorption over 1-12 μm.

Conclusions

We developed a simple and economic coating process through interfacial self-assembly of polymers and nanoparticles as an alternative to conventional CVD and sputter-deposited optical films. Through control of structural parameters of assemblies, we were able to fabricate uniform reflective optical coatings. Quarter wave stacking of self-assembled nanoparticle films are developed for near infrared reflectors, which overcomes the harsh conditions from conventional processing (CVD, sputtering, etc) with improved functionality. Our technology involves an interfacial self-assembly of polymers and nanoparticles to synthesize multifunctional nanoparticles and to assemble them into ordered, three-dimensional films. Reflectivity studies show high and reproducible reflectivity over controlled wavelength windows (1-12μm). Theory modeling shows very good consistency with experimental results, which addresses key manufacturing issues.



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