High Performance Optical Coatings Utilizing Tailored Refractive Index Nanoporous Thin Films

by

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ABSTRACT

Refractive index is perhaps the most important quantity in optics. It is particularly relevant in the field of optical coatings, where the refractive index appears in virtually every optics equation as a figure of merit. Recently it has been demonstrated through control of the deposition angle during oblique-angle electron-beam deposition, nanoporous films of virtually *any* desired porosity may be accurately deposited. As the porosity of a nanoporous film directly relates to its effective refractive index, the refractive index value of a film may be tailored to *any* value between that of the bulk material and close to that of air. These two characteristics, namely; (i) tailored-refractive index and (ii) very low-refractive index values close to that of air, offer significant advantages in the design and optical performance in *all* optical coating applications. In this dissertation we explore optical coating applications whose performance can be greatly enhanced by utilization of a tailored- and low-refractive index nanoporous material system.

One such important application is in the design and fabrication of broadband, omnidirectional antireflection (AR) coatings on solar cell devices. To harness the full spectrum of solar energy, Fresnel reflections at the surface of a photovoltaic cell must be reduced as much as possible over the relevant solar wavelength range and over a wide range of incident angles. However, the development of AR coatings embodying omni-directionality over a wide range of wavelengths is challenging. By utilizing the tailored- and low-refractive index properties of the nanoporous material system, in conjunction with a computational genetic algorithm and a predictive quantitative model for the porosity of such nanoporous films, truly optimized AR coatings can be designed and fabricated on solar cells. Here we show that these optimized AR structures demonstrate significant improvement to overall device efficiency.

Traditionally, nanoporous films fabricated by oblique-angle deposition techniques have been restricted to rigid and planar substrates such as silicon and glass. This limitation greatly constrains the applicability, tailorability, functionality and even the economic viability of such nanoporous films. As another avenue into extending the applicability of such films, here we demonstrate a novel nanoporous film / polymer substrate composite system fabricated by utilizing oblique-angle electron-beam

methodology. This unique composite system exhibits several favorable characteristics, namely i) fine-tuned control over film nano-porosity and thickness, ii) excellent adhesion between the nanoporous film and polymer substrate, iii) and ability to withstand significant and repeated bending as well as three dimensional molding, all the while closely retaining the composite system's designed nanostructure and optical properties. These newly available characteristics show promise to greatly extend the range of applications and functionalities of such nanoporous films.