Ellipsometric Modeling of Serially Bi-Deposited Glancing-Angle–Deposition Coatings

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Glancing-angle–deposition (GLAD) coatings have been in development at LLE for a variety of applications. When produced using serial bi-deposition,[1] a birefringence is created due to the difference in coating density along perpendicular axes in the coating plane, as shown in Fig. 1. The higher-density direction corresponds to the coating flip axis, while the lower-density region is created due to the self-shadowing nature of the GLAD coating process.

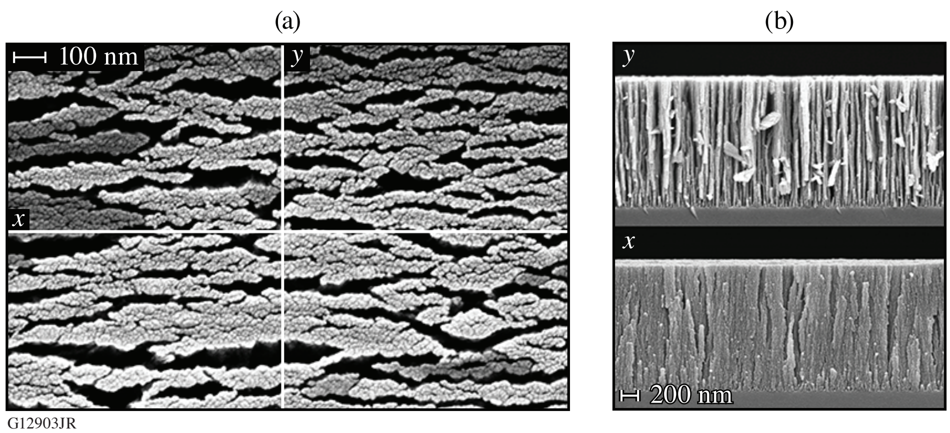

Figure 1
The birefringence of these coatings is achieved because of the microstructure produced in the GLAD serial bi-depostion process. The scanning electron micrograph of (a) the top view of the coating shows the directionality of the density difference, while (b) the side view shows the magnitude.

The birefringence created in this process makes ellipsometric modeling difficult due to the number of fit parameters, leaving unconstrained variables. Incorrect models produce unreliable dispersion curves, making coating design nearly impossible. In this work, a process was developed combining ellipsometric measurement techniques with well-established optical coating design methods to create precise index models. This enabled the development of complex optical coatings using only a single material.

In this experiment, a coating was designed using alternating GLAD and amorphous silica layers. To create these multilayer coatings, a methodical approach was taken. Short, single-layer GLAD coatings were created and measured on a Woollam VASE® ellipsometer in multiple orientations. This made precise characterization possible, resulting in high-quality dispersion curves. Due to the deposition process used in this experiment, the multilayer coating was presumed to have a slightly different density than the single-layer coatings. To correct for this, the single-layer dispersion curves were used to design a seven-layer calibration coating described by Baumeister.[2] This coating is highly sensitive to changes in optical thickness and is commonly used for material characterization or process corrections. When this coating was evaluated (Fig. 2) and optimized using the thin-film design software OptiRE, new dispersion curves were created that closely matched the measured performance.

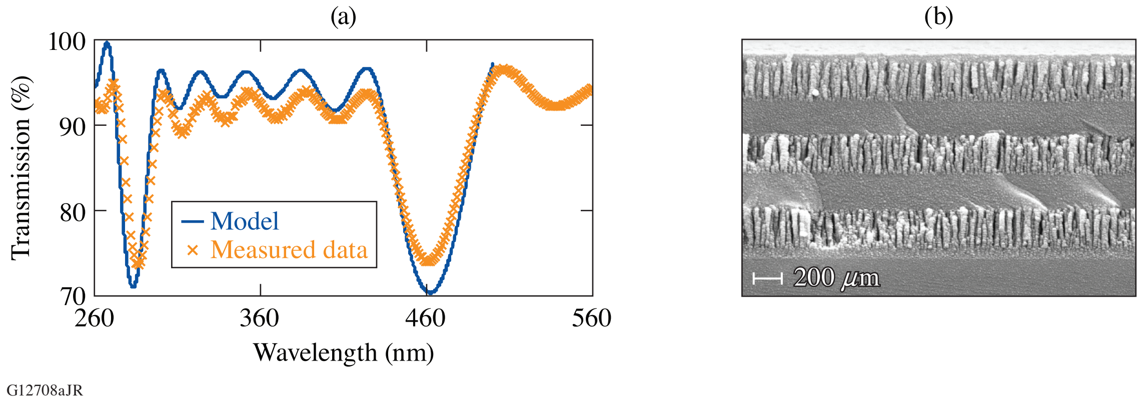

Figure 2
(a) Spectral design versus measured data used to create the seven-layer coating; (b) SEM micrograph of the calibration coating.

Additionally, this experiment required an antireflective (AR) overcoat. A three-layer coating was designed to mimic the density of the final three layers of the multilayer. This coating was evaluated using the same techniques described above, and a dispersion curve for the final layer was found. Using these data, along with the data from the seven-layer coating, a 31-layer wave plate was created (Fig. 3).

This experiment used only three different coating parameters to alter the index of the material and create a final product with only three indices, but the technique described is sufficient for the design and production of a limitless number of indices using a single material. Future work will focus on expanding these capabilities.

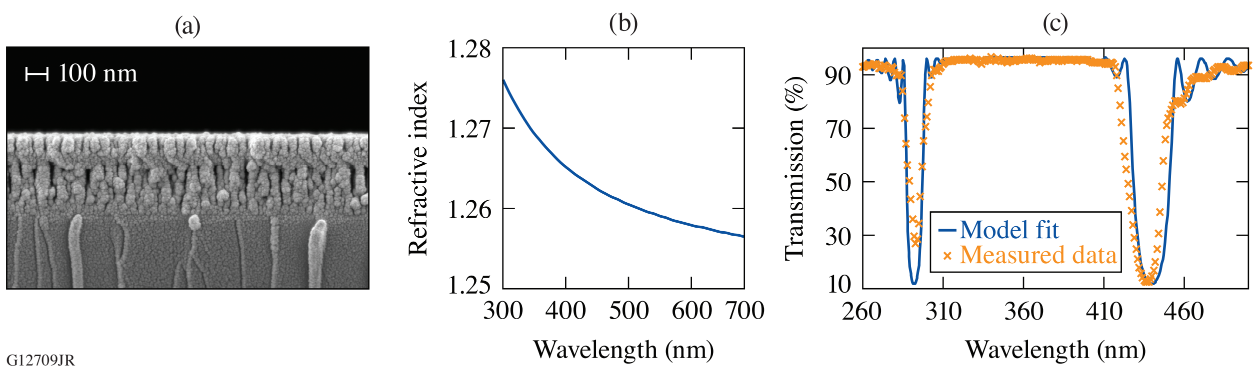

Figure 3
(a) A three-layer coating closely approximating the last three layers of the wave plate; (b) dispersion curve calculated for the final AR layer; (c) spectral measurement versus measured data used to create the 31-layer coating.

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1. S. MacNally *et al.*, in *Optical Interference Coatings Conference (OIC) 2019*, OSA Technical Digest (OIC) 2019 (Optical Society of America, 2019), Paper MD.2.

2. P. Baumeister, *Optical Coating Technology* (SPIE Optical Engineering Press, 2004), pp. 9-56–9-57.