Characterization of Bragg mirrors created with a single material (MoO_3) using the glancing angle deposition (GLAD) technique

Mathieu Boudreau, Gisia Beyaghyan, Serge Gauvin, P.V. Ashrit

Université de Moncton

Introduction

Glancing angle deposition (GLAD) is a technique allowing three dimensional control of the thin film structure, and has been used in creating exotic nanostructures such as two and three dimensional photonic crystals[1].

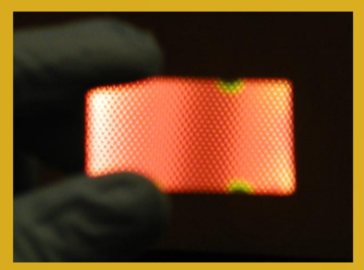

Figure 1

GLAD can also be used to control the porosity of the films, by fabricating vertical pillars with variable spacing. The controlled porosity allows very good control of the uniaxial indices of refraction. This property makes fabrication of multilayered films of different indices of refraction possible. Here, we present our results on fabrication of Bragg mirrors of an active material (MoO_3) with the GLAD technique. A typical mirror made of MoO_3, with a stopband centered at 630 nm is shown in Figure 1. The pattern on the sample is a projection of the screen covering the illuminating light.

Method

The index of refraction of the film layers was controlled by nanostructuring vertical pillars and controlling the porosity of the layers.

The GLAD technique (Figure2) consists of controlling the tilt angle and rotation of the substrate during deposition. The shadowing effect (Figure 3), i.e. the effect of pillars blocking an area from the incoming vapor, increases the porosity of the film. The higher the angle of vapor incidence, the greater will be the porosity. Rotating a substrate at an angle at a constant speed creates vertical pillars with controllable porosity around them.

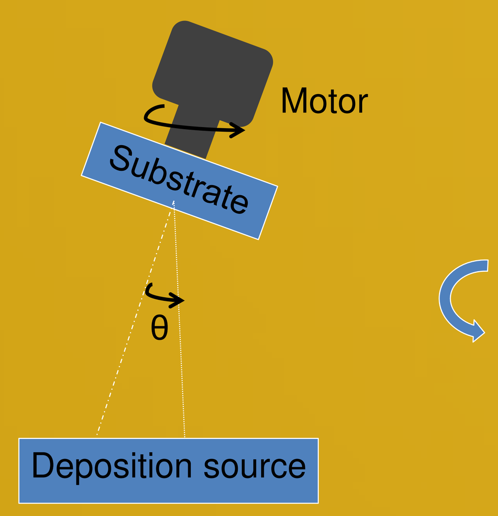

Figure 2

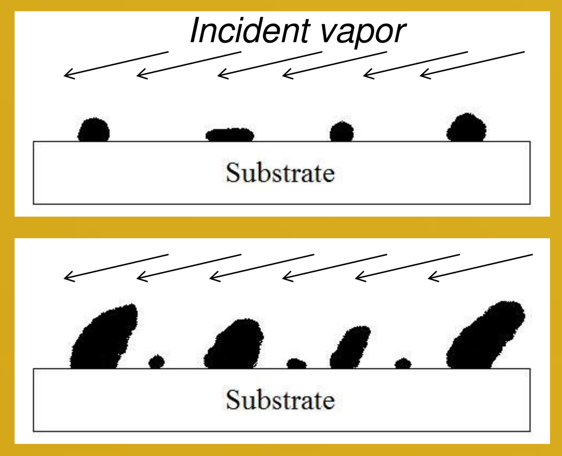

Figure 3

Our Bragg mirrors were created by depositing quarter wave stacks (for a stopband centered at 580 nm) of MoO_3 alternating between high index layers (0º tilt, 70.7 nm) and low index layers (70º tilt, 90.9 nm). Each single layer was generally uniaxial, with a plane-of-substrate index of refraction of 2.14 for 0º tilt, and 1.55 for 70º tilt. The mirrors were built in a $(HL)^4H$ configuration.

Optical Results

Experimental and modeled reflectivity curves are shown in Figure 4. The model was constructed using optical data, previously obtained from single layer films, using an in-house ellipsometer[2,3].

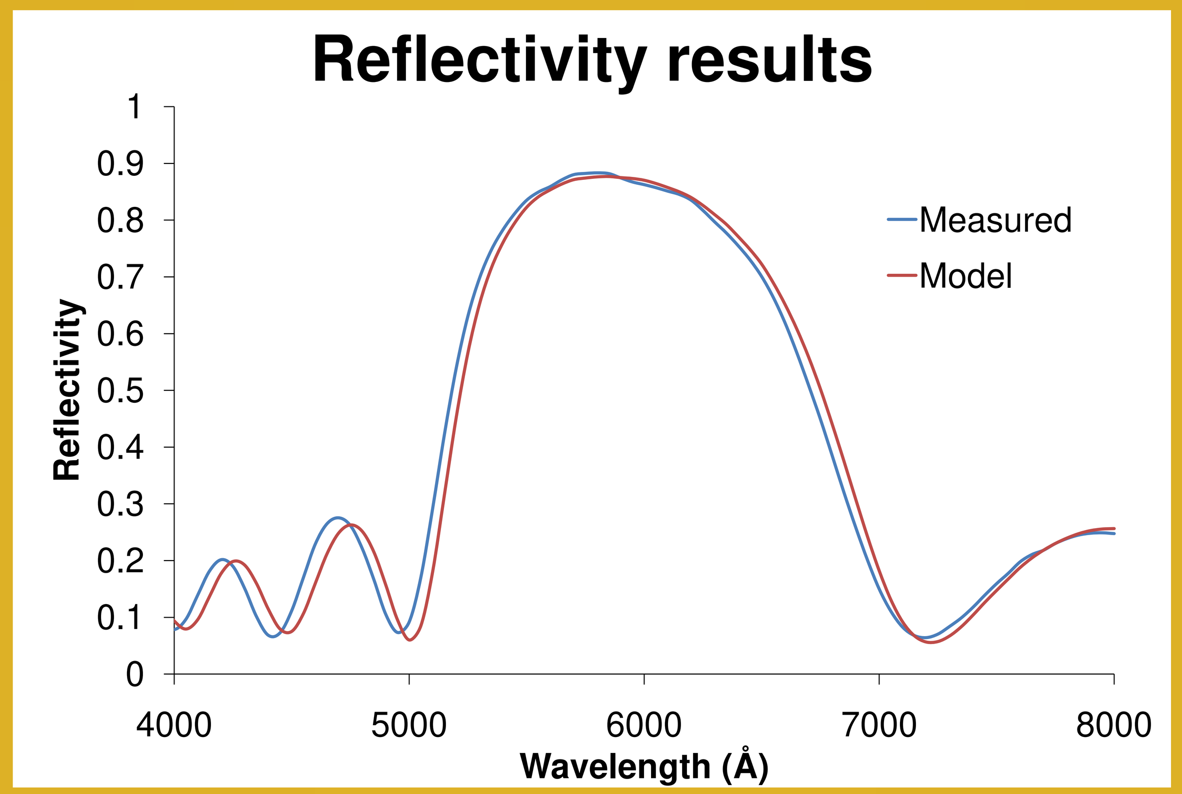

Figure 4

The measured spectrum is in agreement with the prediction of our model (see Figure 4). Minor fluctuations in temperature and pressure during deposition, as well as the rate of deposition and thickness of films may have caused the shift to lower wavelength of the stopband of this mirror. The reproducibility of theses types of mirrors are therefore dependent on the ability to control the deposition parameters, and the extent of this dependence has not yet been studied.

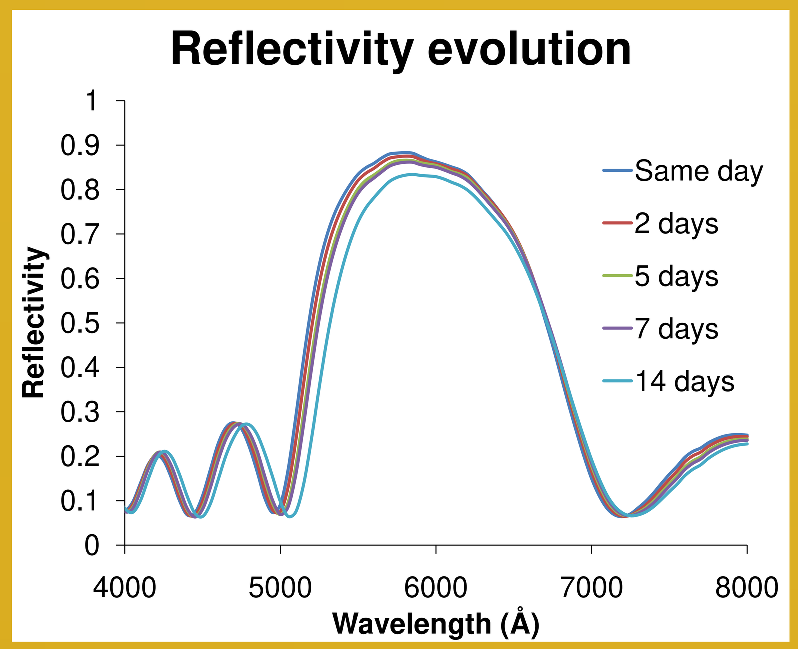

Figure 5

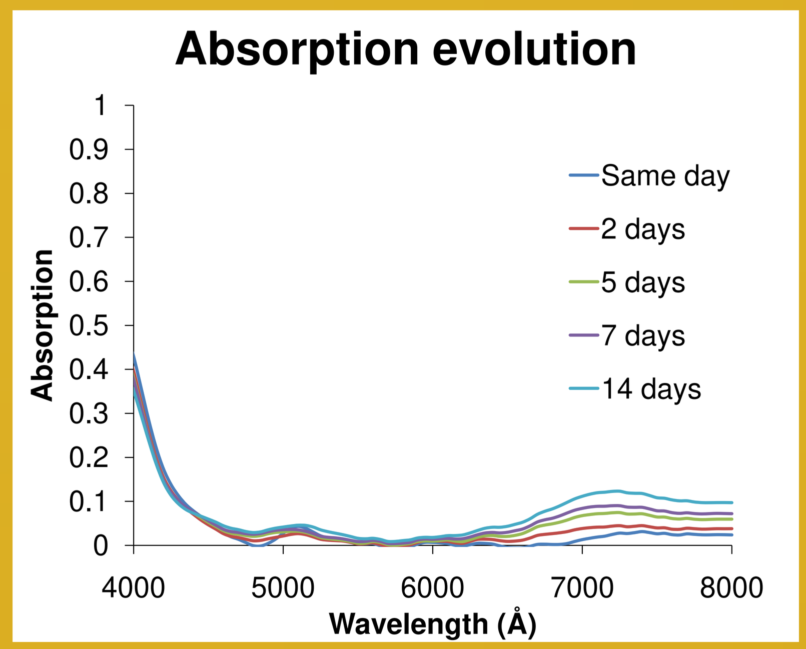

Figure 6

Figures 5 and 6 show the change in reflectivity and absorption of our Bragg mirror with time. The increase in absorption seems to be the underlying cause of the spectrum change, most notably the shifting of the stopband position to higher wavelengths. Assuming the structural change to be negligible, we believe the spectral changes are due to an electrochromic reaction in our sample with the hydrogen ions present in humidity, as MoO_3 is well known for its electrochromic properties[2]. Preliminary results have supported this hypothesis.

Structural Results

Figure 7 shows a typical atomic force microscope (AFM) image of the mirror surface. The surface height profile along the line shown (blue arrows, Figure 7) is seen in Figure 8. The root-mean-squared roughness of this profile is 2.1 nm.

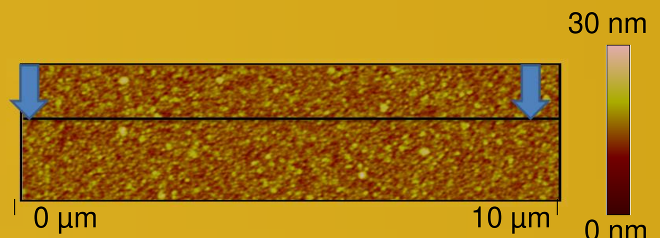

Figure 7

Even though the mirror includes many porous layers, its surface is smooth, homogenous, and exhibits very little roughness.

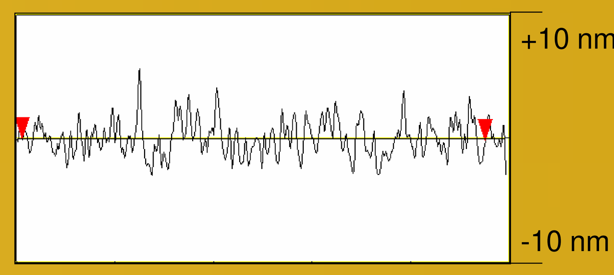

Figure 8

Discussion

We have successfully created Bragg mirrors from a single active material (MoO_3) with GLAD. The optical spectra of the films are in agreement with our models. Previous studies of a similar nature include the fabrication of omnidirectional mirrors[5]. Another study included creation of Bragg mirrors with a single material (ITO)[4]. The latter study produced biaxial films, with tilted columns, while ours are generally uniaxial and have very little anisotropy in the plane of the substrate. Our future work includes studying the cross-sectional structure of our mirrors using SEM, as well as looking more closely at the effect of humidity on sample characteristics.

Acknowledgments

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