Influence of an Assist Beam on a Multilayer Mirror Filter

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Multilayer mirror filters of design $substrate|(HL)^6\ H|air$ were deposited using the Techne dual ion beam deposition system at various assist beam conditions. In particular, the assist beam current and ion energy were systematically varied to determine the influence on the filter performance. The reactively sputtered materials investigated were TiO_2 from a Ti target (H) and SiO_2 from a Si target (L). The filters were examined using a spectrophotometer and studied for potential changes to the index of refraction. Results are presented in this paper.

Introduction

Ion beam sputter deposition with an assist ion beam has been used in industry for years to produce dielectric coatings used for optical devices [1-3]. A dual ion beam system utilizes two sources as depicted in Figure 1. One ion beam source (deposition source) is directed at a target material to be sputtered. The system geometry is designed so the sputtered target material arrives at the substrates while ions from the second source (assist source) also arrive. Early investigations observed that when an assist source was used, the film stoichiometry improved for films deposited by evaporative type sources as well as films produced by ion beam sputtering [2,3]. Researchers examined assist ion energy, that is, the energy of the ion bombardment on the surface in the range of 30 to 500 eV. They also examined various ion doses (beam current) and different gas combinations.

The purpose of this investigation is to study changes to the optical performance of a multilayer mirror filter at various assist conditions. In particular, potential changes to the index of refraction of the deposited films will be examined.

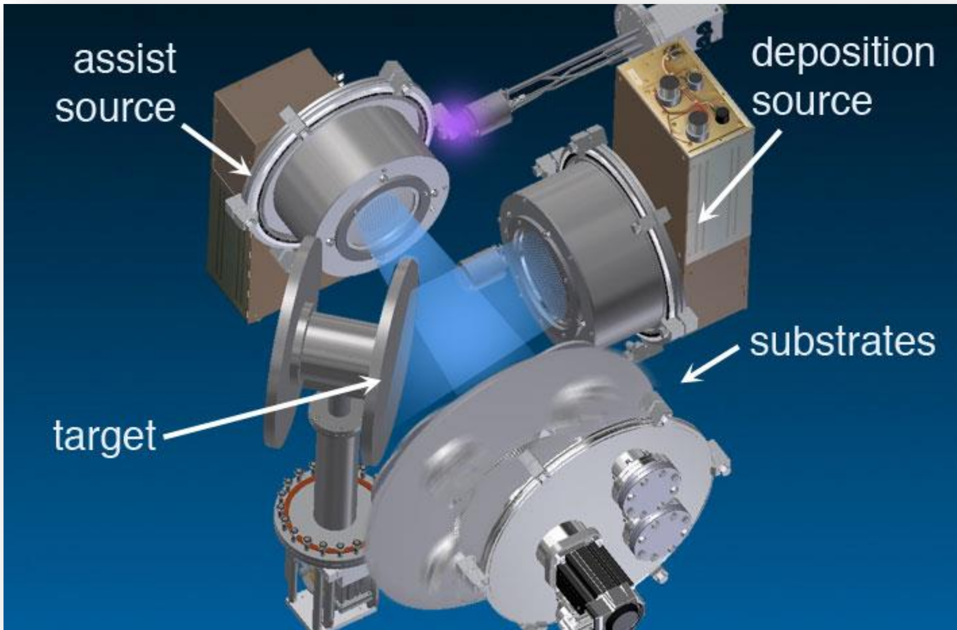

Figure 1. Dual ion beam deposition system layout.

This case study utilized a multilayer mirror fliter design centered at 650 nm. The design, *substrate|(HL)*^{6} *H|air*, uses TiO_2 for (H) and SiO_2 for (L). Typical index of refraction, n, for these materials at 650 nm is about 2.27 (H) and 1.47 (L) [5]. Using Concise Macleod software, the theoretical transmittance curve for this filter is plotted in Figure 2 for wavelengths 450 to 950 nm as the standard. The data in Figure 2 also show that for different phases of TiO_2 (anatase and rutile) the width of the rejection band changes. The anatase phase of TiO_2 has an index *n* near 2.15 at 650 nm and a wider rejection band, while the rutile phase of TiO_2 has an index *n* near 2.46.

The concept for this investigation is to examine changes to the width of the rejection band (where the transmittance is the lowest) on filters that were deposited using different assist conditions. In this fashion, changes in this width will imply changes to the index of refraction have occurred.

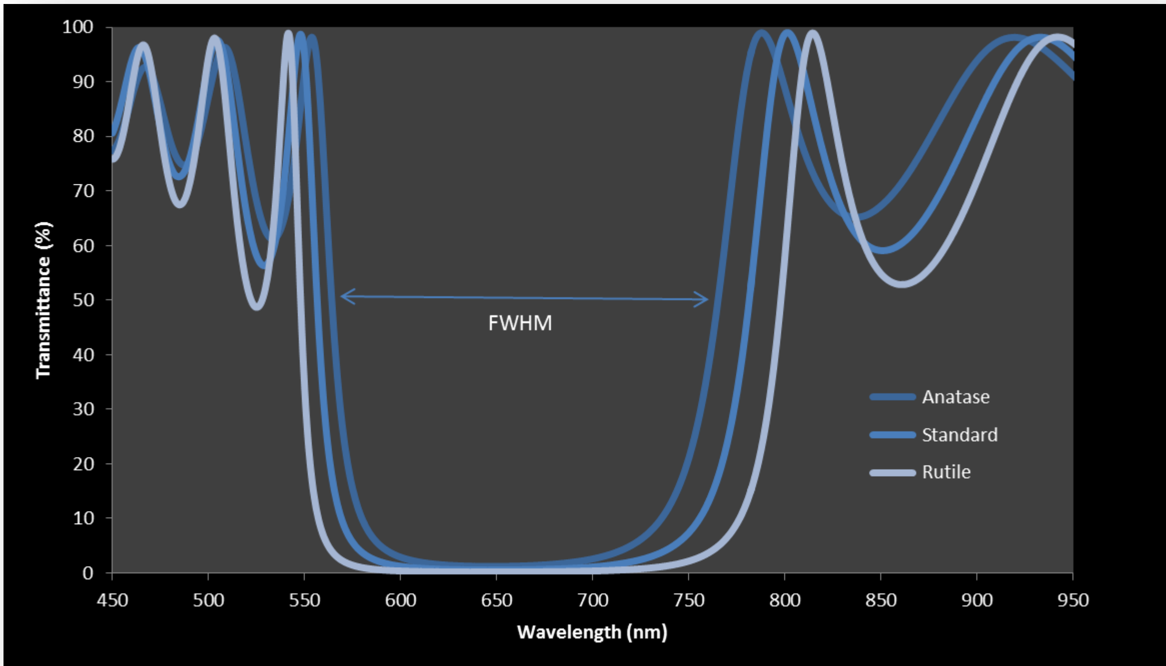

Figure 2. Transmittance curves for the multilayer mirror filter

Below are the full width half maximum values of the rejection band for a filter that contains different phases of TiO_2 for the data shown in Figure 2.

TiO_2 index	FWHM [nm]
2.15 - Anatase	201
2.27 - Standard	225
2.46 - Rutile	250

Table 1. Full width half maximum values for different index.

Experimental Apparatus and Procedure

The multilayer mirror filters were deposited on glass slides in the Techne dual ion beam deposition system. The high index (H) material TiO_2 was reactively deposited using a Ti target and similarly, the low index (L) material SiO2 was reactively deposited using a Si target. For both materials, oxygen was supplied to the target and the partial pressure was optimized for each material.

The 16 cm RF deposition source was operated on Argon and the beam conditions were optimized for this investigation. The 12 cm RF assist source was operated on oxygen and the conditions examined for this study are shown in Table 2. This investigation examined low energy and high dose conditions.

Assist Source	Beam voltage [V]	Beam current [mA]
On	OFF	OFF
On	50	300
On	100	300
On	200	300

Table 2. Assist source conditions for this investigation

The glass slide substrates were mounted to a planetary type fixture for improved uniformity. Calibration of the system produced a typical uniformity of about ±0.25% for H and ±0.38% for L over a 150 mm diameter planet. Typical process time was about 5 hours. The multilayer mirror filters were then measured in transmittance using a Semiconsoft MProbe equipped with an Ocean Optics USB4000 spectrophotometer.

Results and discussion

The performance of a typical multilayer mirror filter deposited on the Techne dual ion beam deposition system is plotted in Figure 3. The results primarily agree with the theoretical curve and amplitude differences are mainly due to reflection error from the substrate backside. The full width half maximum values can readily be obtained from the scan.

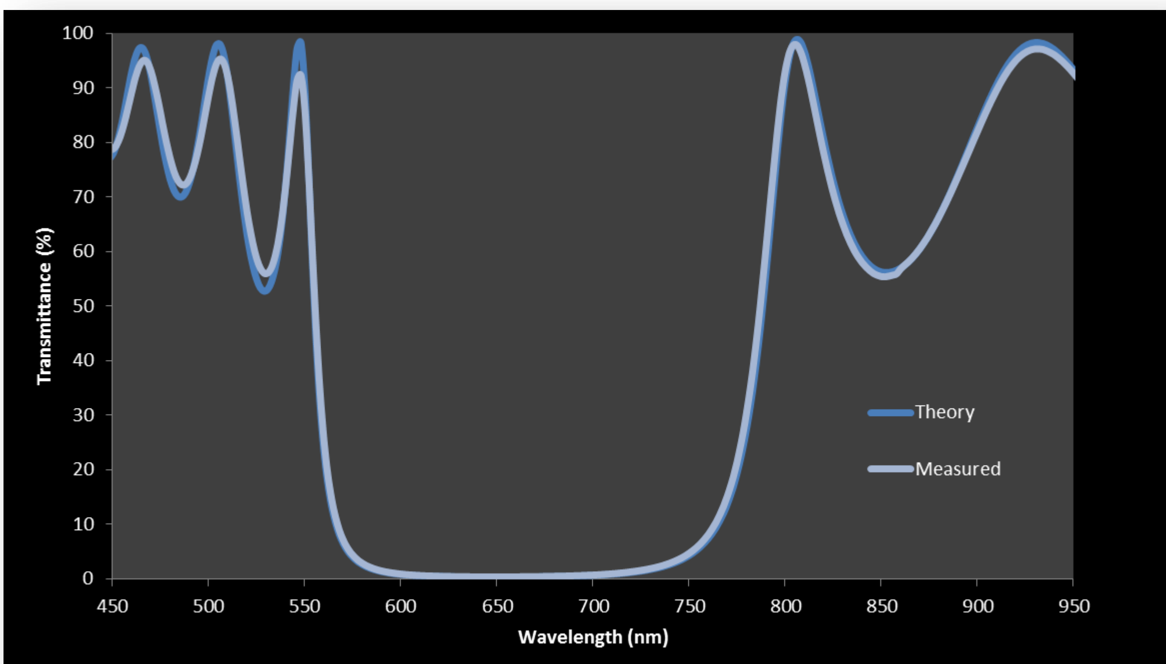

Figure 3. Measured transmittance of a typical multilayer mirror filter.

The results for this investigation are summarized in Table 3. These data indicate the filter performance is very close to the theoretical for most of the assist conditions investigated. The FWHM values are very close to the +/- 0.5 nm accuracy of the measurement setup. Any discernable trends are not present. Essentially, there is very limited change in the index contrast between these two materials with the assist conditions investigated. Further material composition studies are planned.

Conditions	**Comments**	**FWHM [nm]**
Theory	Standard index for H	225
Assist source on	Beam is off	224
50 eV / 300 mA assist	Assist for H and L materials	222
50 eV / 300 mA assist	Assist for H material only	223
50 eV / 300 mA assist	Assist for L material only	225
100 eV / 300 mA assist	Assist for H and L materials	223
200 eV / 300 mA assist	Assist for H and L materials	222

Conclusions

Various assist beam conditions were examined to determine their influence on the optical performance of a multilayer mirror filter. It appears the assist does not change the full width half maximum (FWHM) significantly at low energies. Further studies are planned.

References

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