UV- and VIS Filter Coatings by Plasma Assisted Reactive Magnetron Sputtering (PARMS)

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Abstract: The advantage of PARMS for the manufacturing of high performance low loss coatings is demonstrated with UV- and VIS band pass filter based on HfO2 respectively Nb2O5 and SiO2.

1. Introduction

Reactive sputtering with MF dual magnetron is a highly developed technique and successfully used for many thin film applications. For high performance low loss optical filter coatings based on oxides the reactive process has to avoid any kind of arcing, hard arcs as well as µ-arcs. This requirement is solved by PARMS as well as a high deposition rate for an economic production of high end optical filter coatings.

The principle of PARMS is based on a two step process, the reactive deposition of a thin oxide layer with a controlled deficit of oxygen followed by a RF plasma assist process with reactive oxygen for the transformation to a stoichiometric oxide layer. This sequence is repeated until the final layer thickness is stopped by time control or by an optical monitoring system. Details of the PARMS technology are given in references [1-3].

The advantage of PARMS is to avoid non conducting areas on the target surface which results in a fully stable sputtering process free of any arcing and a high sputter yield compared to classical reactive sputtering without a plasma assist process. Two band pass filter coatings, one UV filter based on HfO2/SiO2 and one VIS filter with a high blocking based on Nb2O5/SiO2, demonstrate the capability of PARMS for the economic production of high performance filter coatings.

2. Sputtering equipment

The investigations are done in a HELIOS sputtering tool. Figure 1a shows an overview of the tool.

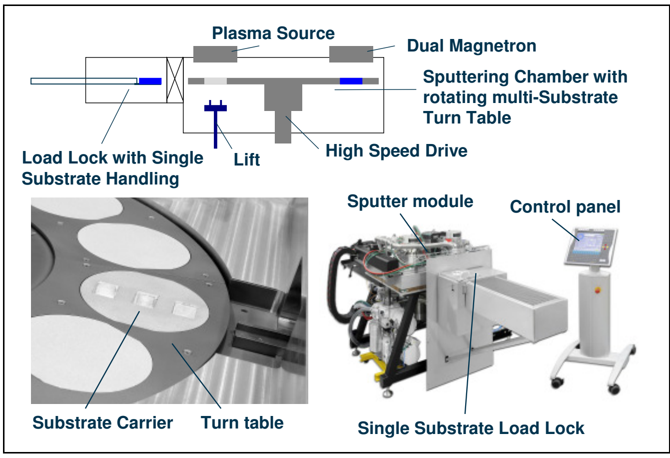


Figure 1a: Overview of the HELIOS sputtering tool

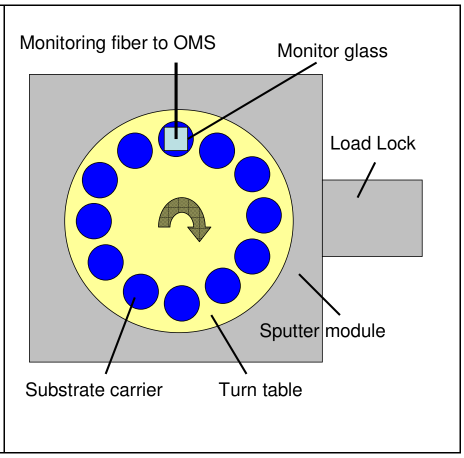


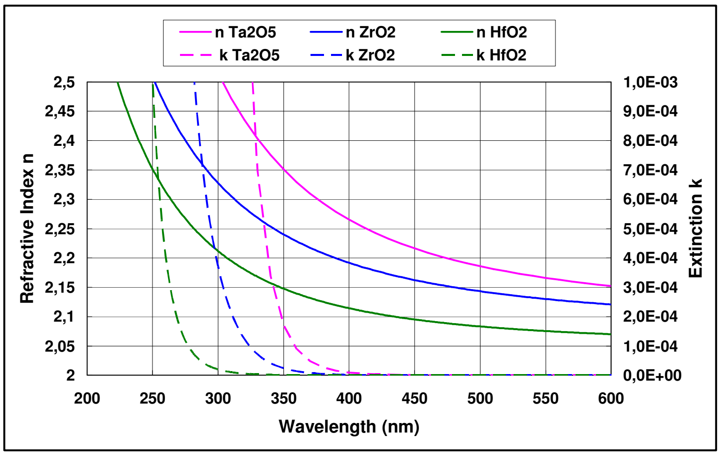
Figure 1b: Direct optical monitoring

The tool is equipped with two dual magnetrons, one with Hf respectively Nb for the high index material and one with Si for the low index material. For plasma cleaning and the plasma assist process a RF plasma source is used. Quartz respectively D263 glass substrates are loaded on substrate carriers and transferred via a load lock into the turn table. One substrate is used as monitoring substrate for the optical thickness control in intermittent mode shown in figure 1b. Optical thickness was measured in transmittance. The used deposition rate is in the range of 0.5nm/s.

3. UV band pass filter

For the production of UV band pass filter coatings down to a wavelength of 250nm we investigated and optimized ZrO2 and HfO2. Hafnium oxide and zirconium oxide are well known candidates with pretty high refractive indices but sometimes difficult to optimize all relevant film properties like losses by absorption and scattering or stress and maintain a high deposition rate [3, 4].

With modified sputtering conditions we could improve at a high deposition rate the micro-structure and surface smoothness of hafnium oxide and zirconium oxide leading to low absorption, low scattering losses and low film stress. Fig. 2 shows the dispersion n & k of HfO2 and ZrO2 in comparison with Ta2O5. Depending on the application Ta2O5 can be used in the UV till 325nm, ZrO2 till 280nm and HfO2 till 250nm. The compressive stress of HfO2 and ZrO2 could be remarkably reduced to -170MPa respectively -70MPa while a high deposition rate of 0,5nm/s could be maintained.

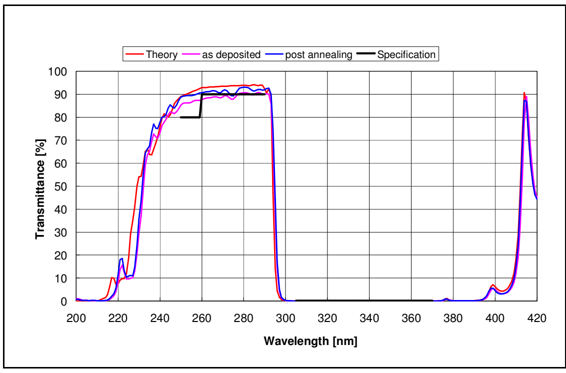


Specification	Wavelength
Tavg > 80%	250 – 260nm
Tavg > 90%	260 – 290nm
Tavg < 0.1%	305 – 370nm

Figure 2: Dispersion n & k of optimized HfO2, ZrO2, and Ta2O5

Table 1: UV BP filter specification

The specification with backside AR of the UV band pass filter based on HfO2 and SiO2 is given in table 1. The corresponding filter design consists of 60 layer with a total thickness of 2.98µm, 2.2µm SiO2 and 0.78µm HfO2. Figure 3a shows a comparison of the theoretical design based on n&k values obtained from single layer results with the as deposited and post annealed band pass filter coating without backside AR.



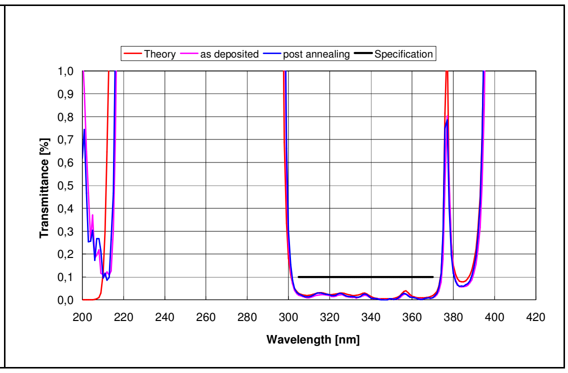


Figure 3a: Filter performance of a 60 layer HfO2/SiO2 BP

Figure 3b: Performance of the blocking band

Even without backside AR the as deposited filter is in the pass band very close to the specification while a post annealing step at 350°C improved the pass band transmittance at 260nm by 3%. Figure 3b shows the low transmittance within the blocking band which is clearly below the specified value of 0.1%. There is a very good spectral correlation between the theory and the experimental filter coating.

4. VIS band pass filter with high blocking

The specification of the challenging BP with high blocking is given in table 2. The design consists of a front- and backside design based on Nb_2O_5 and SiO_2 with 93 layer respectively 104 layer and a total thickness of 19.8µm. The spectral performance shown in figure 4a is extremely close to the theory with a low loss of 1% in the BP. Figure 4b shows the optical density. Due to limitations of our measurement equipment we could not measure the obtained OD > 6 which was confirmed by external measurements.

Pass band	**Blocking**
Tavg >90% @ λ = 490 – 550nm	OD > 6 @ λ = 290 – 450nm and 610 – 800nm
Tmin >80% @ λ = 490 – 550nm	OD > 5 @ λ = 800 – 1100nm

Table 2: Specification of a VIS band pass filter with high blocking

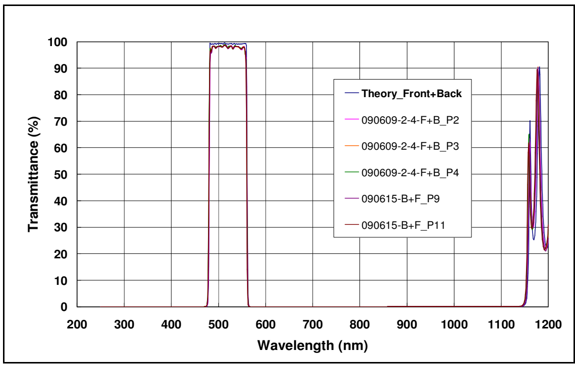


Figure 4a: Spectral performance of the VIS BP in transmittance

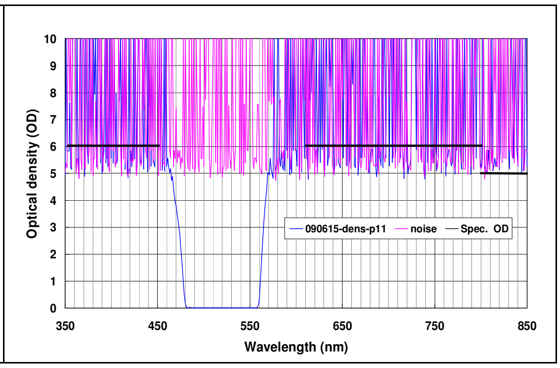


Figure 4b: Spectral performance of the optical density

5. Conclusions

With Plasma Assisted Reactive Magnetron Sputtering (PARMS) technology in a Helios puttering tool we could demonstrate high performance band pass filter coatings with low losses for the UV as well as for the VIS spectral range by use of HfO_2 respectively Nb_2O_5 as high index material and SiO_2 as low index material.

6. References

[1] M. Scherer, J. Pistner, W. Lehnert, "Innovative production of high quality optical coatings for applications in optics and optoelectronics", 47th Annual Technical Conference Proceedings of the Society of Vacuum Coaters, 179, 2004

[2] M. Scherer, H. Hagedorn, W. Lehnert , J. Pistner, "Innovative production of thin film laser components", Proc. of SPIE, Vol.5963-45, 2005

[3] M. Scherer, U. Schallenberg, H. Hagedorn, W. Lehnert, B. Romanov, A. Zoeller, "High performance notch filter coatings produced with PIAD and magnetron sputtering", Proc. of SPIE, Vol. 7101, 71010I, Glasgow 2008

[4] V. Pervak, F. Krausz, A. Apolonski, "Dispersion control over the ultraviolet-visible-near-infrared spectral range with HfO2/SiO2 chirped dielectric multilayers", Optics Letters, Vol. 32, No. 9, May 1, 2007