Precision Filter Manufacture Using Direct Optical Monitoring

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Abstract: The performance of a box coater with double rotating substrate holders in combination with direct optical monitoring was investigated. The reproducibility and uniformity results of a multilayer system with tight specifications will be presented.

1. Introduction

Substantial progress with direct optical monitoring in intermittent mode on single rotating substrate holders was described in reference 1. The monitoring technique was applied in large box coaters on dome shaped calottes up to 1500mm in diameter. The present paper describes intermittent monitoring in combination with a planetary substrate holder.

2. Optical monitoring set-up

Figure 1a shows the schematic of a PIAD box coater with intermittent monitoring on a dome as described in reference 1. A dome shaped substrate holder rotates with single rotation. A substrate or a witness, which is located far out of center, acts as the monitor glass. The control electronics of the optical monitor is synchronized with the substrate drive. At each rotation, the transmittance is measured for some milliseconds while the monitor glass is crossing the light beam. Then the measured transmittance value is stored and refreshed at each rotation. The transmittance is measured close to normal incidence. The transmitted light is guided into the entrance slit of a grating monochromator by use of a fiber optic. A photo detector is attached to the exit slit of the monochromator.

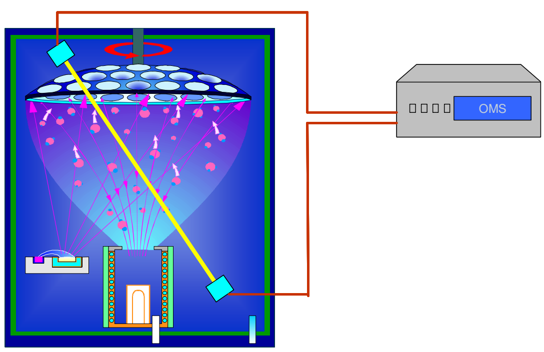

Fig. 1a: Schematic of a PIAD box coater with intermittent monitoring on dome.

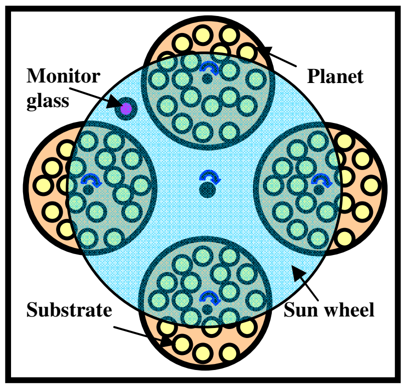

Fig. 1b: Top view of a box coater with planetary substrate holders.

Fig. 1b shows the top view of a box coater with planetary substrate holders. The planets are moved with the sun wheel in single rotation with app. 20 rpm. In addition, each planet is rotating round its own axis driven by the sun wheel with a special gear system. The double rotation is used to improve the thickness uniformity on the substrate holders. The monitor glass located in a holder, which is fixed on the sun wheel, moves in single rotation. The radial position of the monitor glass is close to the radial position of the planet axis, which is app. 300mm out of the centre. The transmittance measurement on the monitor glass is organized in the same way as for the dome shaped calotte described in figure 1a.

3. Application

Reproducibility and uniformity were investigated with a dichroic multilayer coating system. The coatings were produced in a Leybold Optics box coater, type Syruspro 1104. The system was equipped with two electron beam evaporators and APSpro plasma source. The deposition rates where controlled by quartz crystal measurement. The thicknesses were controlled by an optical monitor, type OMS5000 in intermittent mode. The monitoring arrangement was described above. Large BK7 substrates (210mm x 160mm x 60mm) were located on planetary substrate holders with four planets (Ø=345mm).

Coating Specification

The coating is specified in the wavelength range 540nm – 550nm. High transmittance is required over an AOI range from 0° - 30°. High reflectance is specified over 52° - 80° AOI. Table 1 shows the detailed specification. The small AOI space between high transmittance and high reflectance requires a very accurate and stable coating over the substrate area (diagonal 265mm). In addition to the optical performance 7 environmental test criteria were specified.

	AOI	Absolute	Average
Transmittance	0 – 16°	> 90%	> 95%
Transmittance	17° - 30°	> 85%	> 90%
Reflectance	52° - 80°	> 95%	

Table 1: Specification of the optical performance

Layer design and monitoring strategy

The layer system consists of 32 alternating layers with TiO_2 as H-index and SiO_2 as L-index material. The individual layer thickness ranges between 9nm and 180nm. The total layer thickness equals app. 2.8µm.

Figure 2a shows the theoretical transmittance under normal incidence. A simulation tool, which was described in reference 2, was used to investigate the monitoring strategy and to optimize the parameterization of the optical monitor. Six different monitor wavelengths between 430nm and 590nm were used. The last two layers were controlled by quartz crystal measurement. Figure 2b shows the theoretical monitoring curves. The deposition rates were app. 0.4 nm/s for both materials. The layers were deposited with plasma assistance from the APS [3].

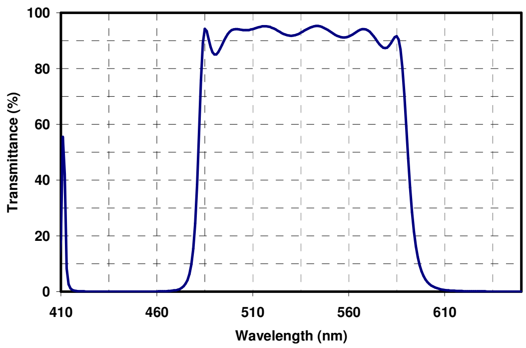

Fig. 2a: Theoretical transmittance (AOI 0°)

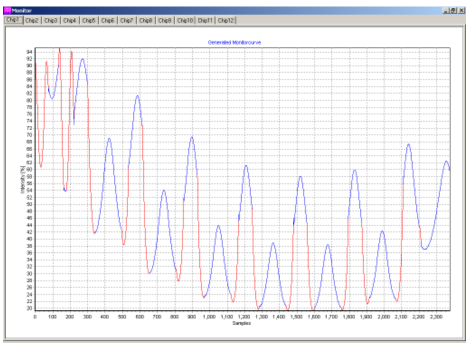

Fig. 2b:Theoretical monitor run sheet

4. Results

The performance of the coating system was investigated with the layer system described above. The thickness uniformity over the planets was optimized by stationary masks. Six substrates (Ø 25mm), which represent the area of the large substrate (diagonal 265mm), were used to qualify the chamber. Since the motion of the monitor glass is not identical to that of the planetary substrate holder there is a slight difference of the performance. There is a tooling factor of some nanometers between the monitor glass and the substrates on the planet.

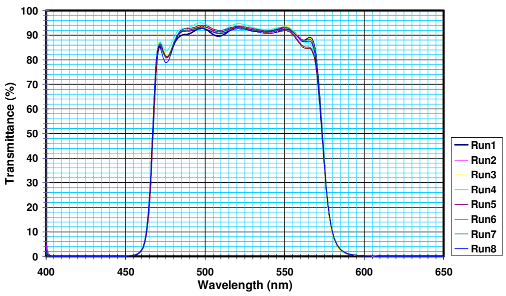

Fig. 4a: Performance of the monitor glasses of 9 consecutive runs (AOI=0°)

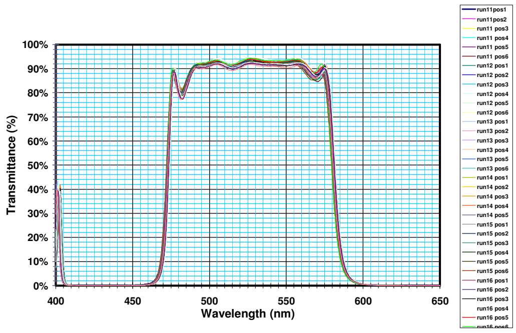

Fig. 4b: Performance of 6 substatrate positions over 9 consecutive runs (AOI=0°)

The reproducibility was tested with nine consecutive coating runs. Figure 4a shows the reproducibility of the monitor glasses of the nine runs. The maximum deviation of the 50% transmission point at 573 nm is 0.33 nm which is less than 0.06 %. The nine runs with six substrates on a planet results in 54 transmittance measured curves, which are shown in figure 4b. It represents the reproducibility and uniformity over the large substrate area. The maximum deviation of the edge at 580 nm is 2.6nm that is app. 0.45%. The standard deviation of the edge is 0.7 nm, which is app. 0.12 %. All substrates passed the transmittance and reflectance specification under the specified AOI ranges described above.

A humidity test (MIL-C-675B 4,5,8) and a heavy steamer test (1 hour in hot steam >= 100°C) confirmed the shift free properties of the layer stack. Abrasion according to MIL-C-675B 4,5,10 passed 100 rubs with no degradation.

5. Conclusions

A Syruspro 1104 coating chamber with double rotating substrate holders and a single rotating monitor glass was investigated regarding the optical performance and durability of a dichroic filter. Six small substrates, which represent the area of the large substrate (210mm x 160mm) , were distributed over a planetary plate. Excellent reproducibility and uniformity were demonstrated over nine consecutive coating runs. The standard deviation over all was app. 0.12 %. All substrates passed the specification of the optical performance in the specified AOI range. In addition, the environmental tests were passed for all runs.

5. References

[1] K. Matl, R. Goetzelmann, A. Zoeller, "Ion assisted deposition with a new plasma source", Mat. Sci. Eng. A140, pp 523-537 (1991)

[2] A. Zoeller, M. Boos, R. Goetzelmann, H. Hagedorn, W. Klug, " Substantial progress in optical monitoring by intermittent measurement technique", SPIE Vol. 5963-13, 2005

[3] A. Zoeller, M. Boos, H. Hagedorn, B. Romanov, "Computer simulation of coating processes with monochromatic monitoring", SPIE Vol. 7101-16, 2008