2-nm narrow band pass filter in standard configuration evaporate coating machine

Jingwei Li (李景薇)[1*], R. Goetzelmann[1], Xiaoyi Wang (王笑夷)[2], Jiangfan Wu (邬江帆)[1], and Chang Xiao (肖 畅)[1]

[1]*Leybold Optics (Beijing) Co.,Ltd., Beijing 101102, China*

[2]*Key Laboratory of Optical System Advanced Manufacturing Technology, Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, Changchun 130000, China*

[*]*Corresponding author: karida.li@leyboldoptics.com*

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High sophisticated optical monitoring systems like the OMS 5000 from Leyboldoptics are commonly used in vacuum coating system to improve the capabilities and reliability of production processes concerning optical performance and repeatability optics. This letter describes a method to perform high end optical filters with additional backside blocking over a wide spectral range. The direct monitoring with intermittent measurement on a large area rotating substrate holder is used to facilitate a narrow band pass filter of 2-nm half bandwidth at 532 nm and high transmittance together with a complex blocking filter to retard disturbing radiation from the ultraviolet (UV) range to the near infrared range. The machine is an ARES 1 350 coating system with basically standard configuration.

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Thickness monitoring system is widely used in high vacuum coating plants. As high accuracy thickness monitoring system, optical monitoring system becomes more and more essential in coating processes. There are various optical monitoring methods[1,2]. The standard method is indirect monitoring, which uses witness glasses in the center of the substrate holder. Both thickness monitoring error and witness glass inhomogeneity have effect on optical thickness monitoring, and the inhomogeneity of witness glass will increase along with the increasing of coating layers[3]. So for high accurate ultra-narrow band pass filters with good transmittance, normally dense wavelength division multiplexing (DWDM) coating machines with special configuration[4] are used.

This letter introduces 2-nm narrow band pass filter at 532 nm and broad band blocking filter coating process together with the results in standard configuration evaporate coating machine of Leyboldoptics ARES 1 350 coating system. This machine is equipped with OMS 5000 optical monitoring system, two HPE12 electron beam guns and APSpro plasma source, etc.

OMS 5000 optical monitoring system monitors and controls the layer thickness on substrate automatically. There are two different monitoring methods.

Firstly, indirect optical monitoring method is traditional optical monitoring method. In this way, there is difference between witness glass and substrates, which needs optical tooling to be compensated. It is not conducive to accurately measure and analysis on substrates. And it is also difficult to ensure the high repeatability of some sensible filters such as narrow band pass filter.

Secondly, direct optical monitoring method is a new monitoring method developed in recent years. In this way, the substrate is monitored directly by OMS 5000, which eliminates the error of monitoring position displacement, to get very good coating result. OMS 5000 direct optical monitoring method can monitor from wavelength from 350 to 2 400 nm, which covers visible and near-infrared range. It can be used to monitor many kinds of high accurate optical film, such as band pass filter, blocking filter, and splitter filter, etc[5].

Figure 1 shows the principle of direct optical monitoring method working in standard configuration coating system.

Take Fabry-Perot multi-cavity narrow-band filter design as film design. Coating materials are Ta_2O_5 and SiO_2, film design: SUB/$(HL)^5$H2L$(HL)^5(HL)^5$H 2L$(HL)^4$H/AIR, and substrate is K9 glass.

Figure 2 shows the theoretical spectral curve of 2-nm narrow band pass filter at 532 nm.

The coating process was monitored by OMS 5000 direct optical monitoring method in monitoring wavelength 532 nm, and the signal-to-noise ratio (SNR) of the measured intensity was kept below 0.03% which provided accurate turning-point and trigger-point detections. And with this monitoring method, the thickness errors are compensated with automatic thickness correction in the next layer. So it ensures very good coating result. Figure 3 shows measured curve.

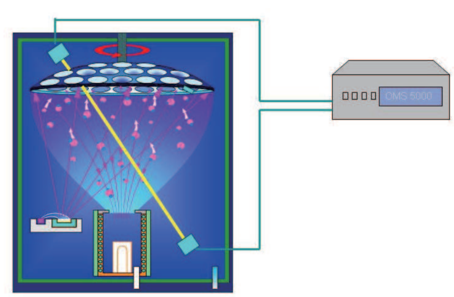

Fig. 1. Principle of direct optical monitoring method working in standard configuration coating system.

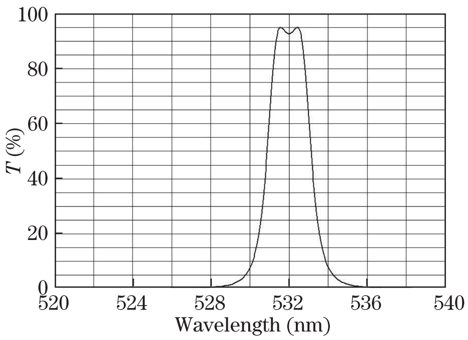

Fig. 2. Theoretial spectral curve of 2-nm narrow band pass filter at 532 nm.

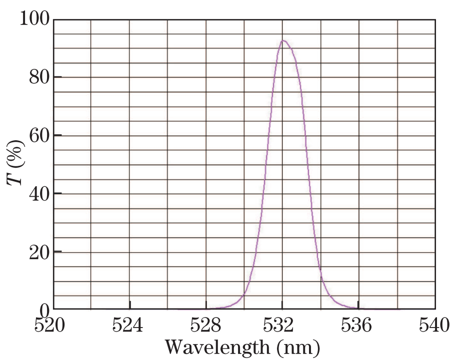

Fig. 3. Measured curve.

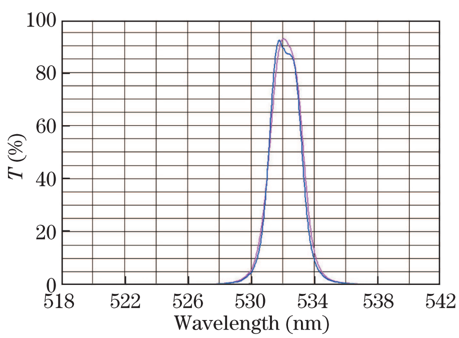

Fig. 4. (Color online) Measured curve of two-run narrow band pass filter.

The plasma-assisted coating ensures the stability of the coating process. Figure 4 shows measured curves of two-run narrow band pass filter. The excellent repeatability of the filter wavelength is due to the direct monitoring on the substrate.

Broad band blocking filter was coated on the back-side of 2-nm narrow band pass filter at 532 nm, and coating materials are Nb_2O_5 and SiO_2. Figure 5 shows the theoretical spectral curve of the broad band blocking filter. The final requirement is with both side coating, 2-nm half bandwidth and high transmission at 532 nm, and

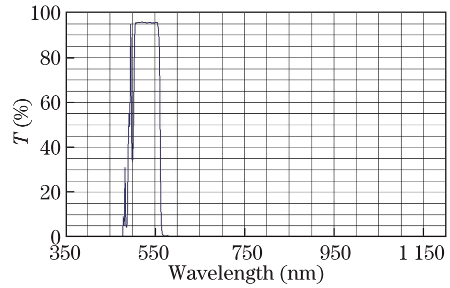

Fig. 5. Theoretical spectral curve of the broad band blocking fiter.

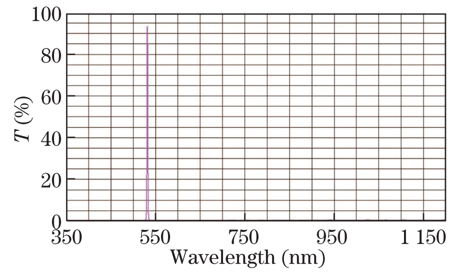

Fig. 6. Measured curve of both side coated fiter.

low transmission from 350 to 1 200 nm, $T_{\rm avg} < 0.5\%$ and $T_{\rm max} < 1.5\%$ in blocking band.

The coating process was deposited with APSpro plasma source, and monitored by OMS 5000 direct optical monitoring method in few different monitoring wavelengths. Figure 6 shows the measured curve of both side coated filter. It met the requirement in blocking band, and maximum transmission at 532 nm , $T_{532\ \rm nm} > 90\%$.

In conclusion, direct optical monitoring method of OMS 5000 with a wide range of wavelength monitoring, stability of the optical signal and low SNR greatly reduces the error of optical thickness monitoring in coating process. A standard configuration coating machine which is not DWDM special coating machine with OMS 5000 optical monitoring system, can be used either in indirect monitoring method or direct monitoring method. For various types of precision optical coating, both high control accuracy and repeatability can be achieved.

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