High accurate in-situ optical thickness monitoring

Alfons Zoeller, Michael Boos, Harro Hagedorn, Werner Klug, Christopher Schmitt

Leybold Optics GmbH, Siemensstrasse 88, D- 63755 Alzenau, Germany
Alfons.zoeller@LeyboldOptics.com

Abstract: The paper deals with single wavelength optical monitoring in batch type coating systems. Both indirect monitoring on stationary test slides and direct monitoring on a fast rotating substrate holder was investigated. Application results will be presented.

OCIS Codes: (310.1620) Coatings (310.1860) Deposition and fabrication

1. Introduction

The production capabilities for optical multilayer coatings were improved dramatically in the last decade. So called "shift free" coatings have become a standard in the coating production. Optical monitoring plays a key role to improve the layer thickness accuracy and therefore the production yield. Optical monitoring has been described and investigated by various workers [1-3]. A monitor system which is based on a grating monochromator and fiber optic light guiding was used. Advanced light chopping supports high accurate monitoring on stationary test slides as well as direct monitoring on rotating substrate holders. The useful wavelengths ranges from 200nm up to 2,2µm. Spectral photometric measurements are supported by a scanning function. The monitor system was investigated in plasma assisted evaporation and magnetron sputtering processes. Both indirect monitoring on stationary test slides and direct monitoring on a fast rotating substrate holder was applied. Application results of optical multilayer systems will be presented.

2. The optical monitor system

The emitted light from the light source is coupled into two fiber optic bundles – one for the measuring light and one for the reference light. The light is chopped mechanically. The chopper frequency is variable in the range from 10 to 80 Hz. The measuring fiber bundle transports the light from the chopper unit to the optical feed through of the deposition chamber while the reference bundle guides the light directly through the monochromator to the attached detector. The exit face of the measuring bundle is focused by an appropriate lens onto a test-glass or witness piece. The reflected or transmitted light from the test-glass or witness is then coupled by another lens into a fiber bundle which transports the measuring light to the entrance slit of the monochromator. The fiber bundles consist of a large number of single fibers. So the cross sections of the bundles can be shaped according to the actual needs. At the monochromator the measuring bundle and the reference bundle are combined to a rectangular cross section which fits to the entrance slit of the monochromator. Due to this arrangement the exit slit of the monochromator and the attached photodetector are illuminated sequentially by measuring and reference light followed by a dark phase.

The monochromator can be equipped with up to 3 gratings and 2 detectors. Depending on the wavelength range the useful grating and detector can be selected. The spectral resolution which is automatically controllable varies from 0,5 nm up to 10 nm depending on the widths of the monochromator slits. The following detector types are available: PMT, Silicon, Indium Gallium Arsenide, Lead sulfide. As the light source a quartz halogen lamp or a deuterium lamp can be selected. The total useful spectral ranges from 220nm up to 2200nm. The limitations on both sides are given by the transmittance of the fiber optics. Advanced light chopping supports high accurate monitoring on stationary test slides as well as direct monitoring on rotating substrate holders. Spectral photometric measurements are supported by a scanning function.

The monitoring software allows the monochromatic monitoring of even the most complicated optical layer systems. Turning point or trigger point monitoring can be applied. The online correction of trigger point is done by extensive software algorithms. The ability to vary the monitor wavelength in a broad range supports so called most sensitive wavelength monitoring strategies. This allows to monitor non quarter wave stacks on a stationary single test-glass or on a witness piece on the rotating substrate holder in case of direct monitoring.

3. Application results

Monitoring experiments were done in 2 different coating chambers. Figure 1 shows the spectral curve of a green filter which was deposited with plasma ion assisted deposition (PIAD) in an 1100mm box coating system. PIAD was described in reference [4]. The measured filter was placed on a dome shaped rotating substrate holder. In this case indirect monitoring with different stationary test glasses was applied. In the same chamber the reproducibility of an UV-IR cut filter coating was investigated. Figure 2 shows the performance of 6 consecutive production runs. The measured filters were placed on the inner ring of a dome shaped rotating substrate holder. In this case indirect monitoring with different stationary test glasses was applied too. For this 6 consecutive runs the wavelengths of the 50% transmittance point for the short wave and the long wave edges were in the range of 0,6% and 0,4% respectively. For both applications some calibration and test runs for determining the tooling factors were required.

Direct monitoring on the rotating substrate holder was applied in a magnetron sputtering system. The optical monitor was synchronized with the rotation of the substrate holder. One representive witness piece was measured intermittent app. 300mm out of center. Figure 3 shows the performance of a single cavity filter. No calibration or test run was required. Figure 4 shows the measured optical performance of a 5 cavity filter in comparison to the theoretical design. This filter was deposited in the same chamber with direct monitoring. As in the case above no calibration or test run was required.

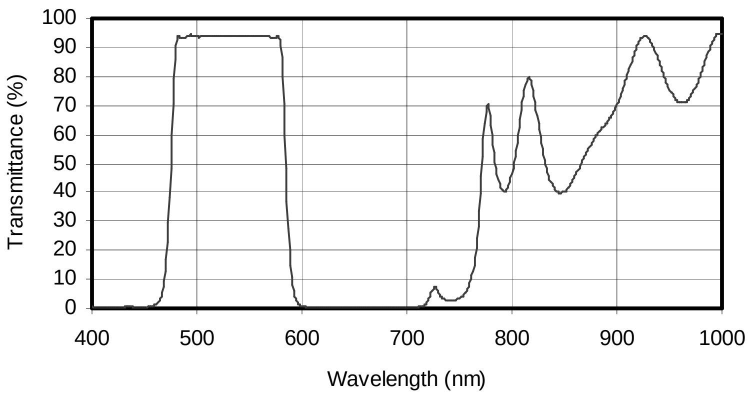

Fig. 1 Measured performance of a green filter monitored with stationary test-glasses

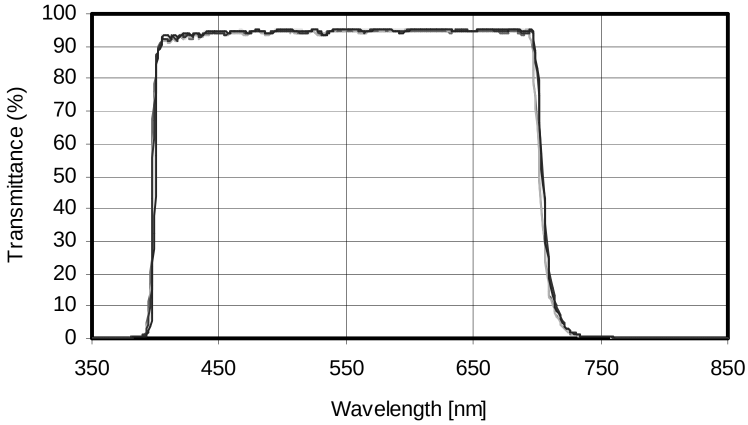

Fig. 2 Measured performance of 6 consecutive runs of a UV-IR cut filter monitored with stationary test-glasses

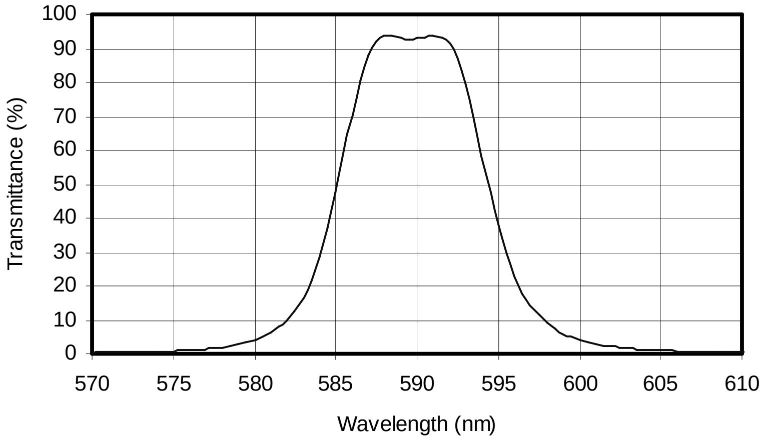

Fig. 3 Measured performance of a 2-cavity filter monitored intermittent on the rotating substrate holder

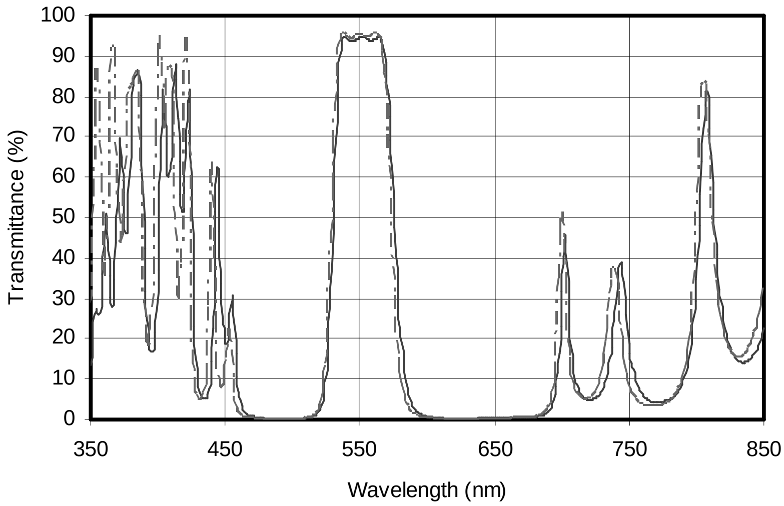

Fig. 4 Measured Performance of a 5 cavity filter monitored intermittent on the rotating substrate holder in comparison to the theory.

4. Summary

A single wavelength optical monitor was used with indirect monitoring on stationary test glasses in a box coating evaporation system. Direct monitoring in intermittent mode was applied in a magnetron sputtering system. In both cases excellent results were achieved. With direct monitoring calibration runs can be avoided. A variation in the tooling factor doesn't play a role at least on the substrates which are placed on the same radius as the witness piece. Therefore a significant increase in the production yield is expected with direct monitoring.

5. References

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