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Application of the spectral control systems for deposition of IR interference filters

1. Introduction

In the multilayer optical coating technology special attention has always been given to methods of controlling the deposition of thin films. Optical monitoring methods are based on interference phenomena in thin films. Currently, with the development and improvement of optical engineering, new spectral monitoring systems (BBOM - broad band optical monitors) based on spectrometers are used for supervision of vacuum deposition of the coatings. In contrast to the single-wavelength monitoring systems, which are designed around monochromators and provide transmission or reflection values just on the one controlled wavelength, spectral control system (SCS) display spectral characteristics along the whole spectral range at any given time. This significantly improves the detection accuracy of the end of the layer as well overall coating performance.

2. Control of the deposition process, using the spectral system

In the spectral control systems the following requirements shall be ensured for spectrometers to guarantee an effective broad-band optical monitoring of the deposition process.

- Separation of orders;
- Minimum stray light;
- High signal to noise ratio in the whole spectral range (see Fig.1 for example of the signal in the range 380-1100 nm)

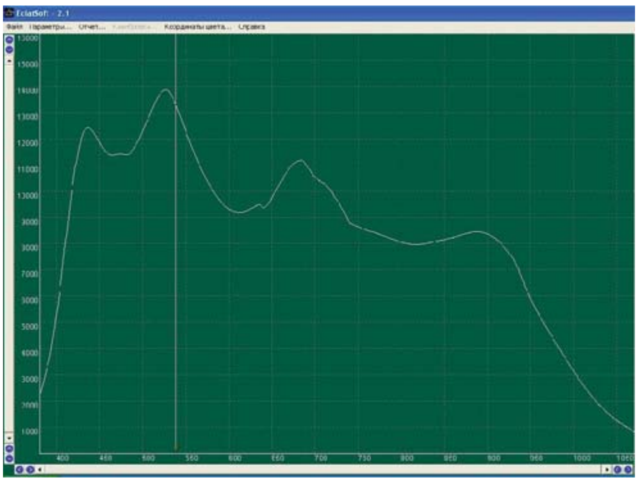

Fig. 1. View of the signal in 380-1700 nm range.

The spectral control system shall be designed to compensate the intrinsic noise of diode arrays and simultaneously provide high baseline stability. With SCS, satisfying these requirements in a complex, one can obtain reliable spectral data on the growing thin film.

3. Initial requirements for coatings

One of the prospective customer's objectives was to develop a sustainable manufacturing technology of various IR optical filters in the region of 15 - 20 microns using a typical 700 mm e-beam coater configured with two-e-beam guns, resistive evaporation source and ion assist source. The customer chose IRIS 1017 spectral control system from EssentOptics for process design and thin film deposition.

The following requirements were developed for the spectral characteristics of filters:

Band-pass filter :

T ≤ 1% @ 1.5 - 7,0 mkm
T ≥ 80% @ 8.5 - 12,5 mkm
T ≤ 1% @ 14.5 - 20,0 mkm

The design of the band-pass filter consists of two separate coatings with 28 and 13 non-quarter wavelength layers deposited on both sides of the germanium substrate. The physical thickness of individual layers reaches 2000 nm and more.

Cut-off filter:

T ≤ 0.2% @ 1,0 - 5,2 mkm
T ≥ 80% @ 5.8 - 15,0 mkm

The design of cut-off filter also consists of two separate coatings with 15 and 11 non-quarter wavelength layers deposited on both sides of the silicon substrate.

4. Application results of the spectral monitoring system for the manufacture of cut-off and band-pass filters

Short time spectrum measurements (20 - 40 ms) allows for controlling either the reference glass or parts located on the calotte. At the same time, the possibilities of modern SCS provide an efficient support for supervision of coatings with an effective operation range to be considerably far in the IR than the direct control capabilities of the SCS. Figure 2 shows the band-pass filter covering the region of 8,5-12,5 mm, obtained by SCS having a direct control range in 950-1700nm.

The MultiSpectrum thin film calculation software was used together with SCS to calculate the spectral characteristics of interference coating. MultiSpectrum software allows to calculate transmission and reflection of the coatings. Additionally, it calculates intermediate spectra within each layer (up to 7 intermediate spectra of single layer), as well as overcoating with a given limit in %. For the purposes of study, two intermediate spectra were used, apart from the start and end spectra of the layer.

The interface of SCS allows to upload the intermediate spectra – this capability significantly reduces the time for testing of the deposition of such coatings, as well as the time for analysis of coatings. In the present study, the preparation time was about 5 minutes. Application of the intermediate spectra gives the thin film engineer wide opportunities to analyze the deposition control procedure and select an appropriate strategy for successful deposition. As a result, the subsequent practical implementation no longer requires high qualifications of the operator of the vacuum coater. Maximum combined efficiency of the SCS and MultiSpectrum is reached during the deposition of cut-off and band-pass filters, which was confirmed by the presented results (Figs. 2 and 3).

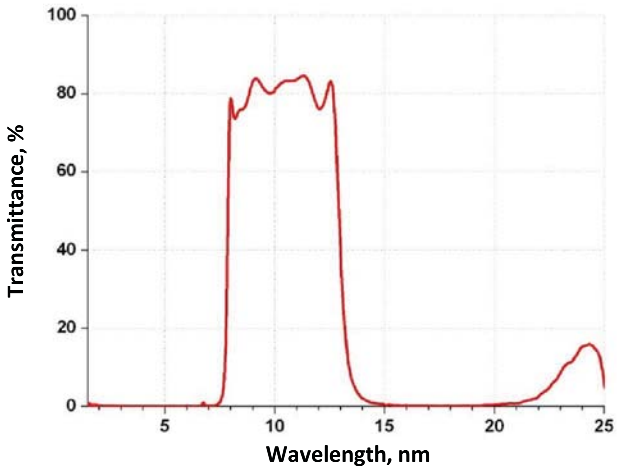

Fig. 2. Bandpass filter, 8,5-12,5 mkm range

In order to test the reproducibility of the deposition processes with SCS several coating runs were performed to deposit cut-off filters. Figure 3 shows the measured spectra of the filters from several different processes. The interval between batches for some deposition was up to 2 hours, for others - a day, without any noticeable effect on the reproducibility of the deposition. Relatively low transmission of the filters is due to absorption in the film and substrate.

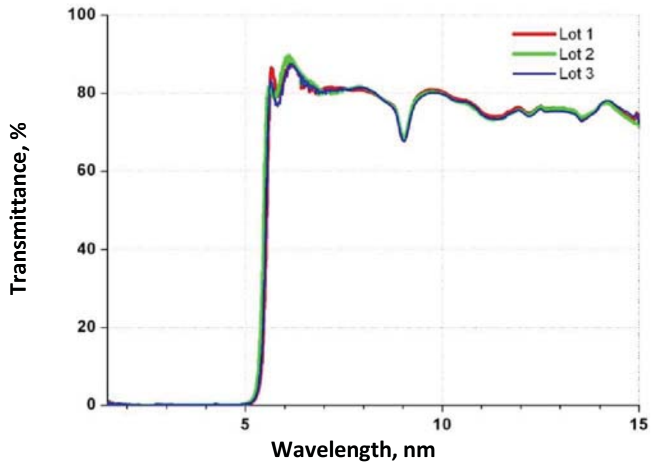

Fig. 3. Spectra of cut-off filters on the 5.5 mkm from different coating runs