

Tuesday, May 12

8:30 a.m. O-1 Monte Carlo Analysis of Random Thickness Errors in Infrared Optical Coatings

D. Fuller and W. Hasan, FLIR Systems, Inc., Wilsonville, OR

Infrared imaging systems commonly employ an assortment of lenses, mirrors, beam splitters, and filters. Each of these elements utilizes optical thin films to make them functional. As is the case with most optical coatings, layer thickness of infrared coatings is critical to spectral performance. Manufacturing errors result in non-optimum spectral performance and loss of product if errors are excessive. This paper utilizes Monte Carlo error analysis to predict production yields of infrared optical coatings. Statistical spectral data is presented based on repetitive calculations (eg. 100,000 iterations). Two case studies are presented: 1) a long-wave infrared band pass filter, and 2) a mid-wave infrared antireflective coating. Empirical results are compared to statistical predictions. The effects of coating design on error sensitivity are discussed. Comparative coating designs are presented which offer similar spectral performance, but different sensitivity to thickness errors.

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8:50 a.m. O-2 Modern State of Art in Design and Monitoring of Optical Coatings

A. Tikhonravov and M. Trubetskov, Research Computing Center, Moscow State University, Moscow, Russia

Invited 40 min. Talk

In recent years a tremendous progress in design of coatings of various types has been achieved. Non-local design techniques based on the needle optimization, Fourier-transform, inhomogeneous refinement enable an optical coating engineer to design two-component multilayers, rugate and quasi-rugate coatings with quite complicated spectral characteristics. In many situations multiple theoretical designs with excellent spectral properties can be obtained. These multiple designs can have different structural properties and thus more opportunities for choosing the most practical design are provided. For example it is possible to design hot mirrors having only thick layers at an expense of some increase of design total optical thickness. As it was shown at two last Optical Interference Coatings meetings in Tucson, new opportunities are provided by designing of multilayers containing very thin transparent metal layers. Modern optical coatings may have many dozens of layers and their successful practical implementation is very dependent on accuracy of monitoring of thicknesses of deposited layers. In recent years direct optical monitoring of coating production has gained more attention all over the world. This relates both to monochromatic and broadband monitoring techniques. In the case of direct optical monitoring layer thicknesses are monitored on one of the manufactured samples and this is an obvious advantage of direct techniques. However, a strong cumulative effect of errors in layer thickness is often observed when coatings with several dozens of layers are deposited using these techniques. In the last years several different monochromatic monitoring approaches aimed at reducing cumulative effect of thickness errors have been proposed. Recently presented theoretical results show that broadband optical monitoring is much less critical to measurement errors than monochromatic optical monitoring. This makes broadband monitoring especially attractive but more efforts are now required for developing broadband techniques with reduced cumulative effect of thickness errors.

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9:30 a.m. O-3 Designing Optical Coatings by Using Low-Index Equivalent Layers and Low-Index Effective Media

U. Schulz and N. Kaiser, Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Jena, Germany

The lowest refractive index material exhibited by a naturally available material is about 1.38 (magnesium fluoride). For some applications, especially broadband antireflective coatings for low-index substrates ($n=1.5$) it would be useful to have thin films with a lower index. The effect of a single layer with an equivalent refractive index below the index of natural materials can be achieved in a limited wavelength range by applying special designed layer sequences. On the other side, porous or structured layers can act as effective media with very low refractive index. This paper presents some designs showing the effect of both types of low-index replacements on examples.

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10:30 a.m. O-5 Using Different Thin-Film Design Software for Different Requirements

U. Schallenberg, mso jena Mikroschichtoptik GmbH, Jena, Germany

Invited 40 min. Talk

This presentation gives a brief overview on the use of commercial thin-film software for the design and the assistance of manufacturing thin-film optical coatings, particularly with regard to practical questions and special problems. With the means of well-known thin-film coating types, it is exemplified which performances optical coatings may bring into an optical system, which theoretical formalism is required to describe these performances, and which components for manufacturing and characterizing of these coatings are required. Packages are listed and briefly described that provide easy manageable program tools for design, manufacture assistance and characterization. It is shown which software packages have to be used necessarily to fulfill the different requirements given by high performance thin-film coatings for broadband antireflection, non-polarizing beam splitters, wide blocking band-pass filters, and steep-edge filters. In addition, software tools for the optical monitoring during the deposition and for some re-engineering problems after the deposition are demonstrated. Finally, some tools are discussed that can be recommended for an efficient serial production according to the state-of-the-art of thin-film deposition technologies.

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11:10 a.m. O-4 Broad Band Metal Dielectric Filters

D. Cushing, University of Arizona, Tucson, AZ

Filter designs with bandwidths greater than 30 nm for wavelengths in the visible spectrum will be described. Both reflective and transmissive types will be compared for use in optical systems with large fields of view. The filters will contain 7 to 45 layers consisting of two refractory oxides and a multiplicity of metal layers to provide the desired spectral results. The filters are designed for image quality applications. The pros and cons of reflective versus transmissive types will be discussed.

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11:30 a.m. O-7 Computer Simulation of Monitoring of Narrow Bandpass Filters at Non-Turning Points

R. Willey, Willey Optical Consultants, Charlevoix, MI; and A. Zoeller, Leybold Optics GmbH, Alzenau, Germany

The present work is the result of combining the work reported by Zoeller, et al. on the computer simulations of coating processes with monochromatic monitoring together with the work reported by Willey on the design and monitoring of narrow bandpass filters at non-turning points. A new software tool which simulates the coating process with monochromatic optical monitoring was introduced which can deal with systematic and random errors of thickness, deposition rate, refractive indices, etc. Narrow bandpass filters have historically been designs of quarter waves at the passband wavelength, and have been monitored at the turning points using the passband wavelength. By direct monitoring at the passband wavelength, errors have been shown to be primarily self compensated, and have allowed much better performance than could otherwise be expected. The turning points are difficult to detect precisely and accurately because the change in transmittance with thickness becomes zero at the desired termination point. The new simulation program is applied here to designs which have been adjusted to have all layer terminations at a distance from turning points in order to gain greater change in the reflectance or transmittance with thickness and thereby reduce layer termination errors. The simulation has allowed the assessment of the merits of the non-turning point monitoring and its limitations as compared to the conventional approach.

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11:50 a.m. O-8 *In Situ* Stress Measurement in Optical Coating Deposition System

M. Fang, J. Huang, K. Yi, Z. Fan, and J. Shao, Shanghai Institute of Optics and Fine Mechanics, Shanghai, China

Stress is a key factor causing deformation of coated optics. It is important to develop in-process observation technology in optical coating deposition system, and to control stress status more effectively and efficiently. In this paper, an instrument for *in situ* stress measurement in an optical coater based on optical deflection of two parallel light beams is introduced. The stress evolution of thin film can be observed in process. The instrument is applied to investigate the deposition of single-layer and multilayer coatings in different conditions. Results show that HfO₂ films have a stable tensile stress of 360MPa~660MPa for all deposition conditions. The tensile stress becomes larger when the vacuum is higher. SiO₂ films show a stable compressive stress of -350MPa.