



## **OIC**

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### **Optical Interference Coatings**

#### **Ninth Topical Meeting and Tabletop Exhibit**

**June 27-August 2, 2004**

[Loews Ventana Canyon Resort & Spa](#)  
[Tucson, Arizona](#)

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Markus K. Tilsch, *OCLI - A JDS Uniphase Co., USA*

## About OIC

**June 27-July 2, 2004**

This meeting serves as a focal point for global technical interchange in the field of optical interference coatings. It will include papers on research, development and applications of optical coatings, such as fundamental and theoretical contributions in the field as well as practical techniques and applications.

This conference, like its predecessors, meets every three years to survey and capture advancements in the broad area of optical coatings. The format of the meeting includes invited papers by leaders in the field, short oral presentations of papers, and poster sessions with ample discussion periods. There are no parallel sessions.

## Meeting Topics

Topics to be covered:

[Manufacturing Problem](#)

[Measurement Problem](#)

[Design Problem](#)

- Coating design
- Computer design
- Mathematical techniques
- Reverse engineering
- Depositions processes
- Sputtering technology
- Evaporation techniques
- Ion-assisted deposition
- Atomic layer deposition
- Chemical vapor deposition
- Plasma assisted deposition
- Novel deposition techniques
- Metrology
- Process monitoring and control
- Coating materials
- Fluorides/oxides/metals/composites
- Characterization of coatings
- Optical techniques

- Physical techniques
- Coating applications
- Aerospace
- Coatings for ultra-fast applications
- Coatings for displays
- Coatings for biological applications
- EUV/UV/VISIBLE/IR
- Electrochromic coatings
- High energy laser coatings
- Large area
- Medical optics
- Nanotechnologies
- Nonlinear coatings
- Photonic band gap materials
- Security coatings
- Tunable coatings
- Transparent conductive coatings
- Wavelength division multiplexing

## Invited Speakers

- MA1, **Future of optical coatings**, Angus Macleod, *Thin Film Ctr., USA*.
- MA2, **Some reflections on the history of optical coatings**, George Dobrowolski; *Natl. Res. Council of Canada, Canada*. [MA2.pdf](#)
- MB1, **Atomic Layer Deposition—An alternative to the deposition of optical coatings?** Mikko Ritala, Markku Leskelä; *Univ. of Helsinki, Finland*.
- MD1, **Manufacturing problem**, Steve Browning<sup>1</sup>, J. A. Dobrowolski<sup>2</sup>; <sup>1</sup>*Ball Aerospace Corp., USA*, <sup>2</sup>*Natl. Res. Council of Canada, Canada*. [MD1.pdf](#)
- ME1, **Coating machine concepts for precision optics**, Harro Hagedorn, *LEYBOLD OPTICS GmbH, Germany*. [ME1 Part I.pdf](#), [ME1 Part II.pdf](#), [ME1 Part III.pdf](#), [ME1 Part IV.pdf](#)
- MF1, **Optical coatings using the Filtered Cathodic Arc process**, Michael Fulton; *Ion Beam Optics, USA*. [MF1.pdf](#)
- TuA1, **An introduction to natural photonic systems**, Peter Vukusic, *Exeter Univ., UK*.
- TuA2, **Photoactive coatings for a photolytic artificial lung device**, Peter Martin, *PNL Batelle Northwest, USA*.
- TuB1, **New AR design concepts with equivalent layers**, Uwe Schallenger, *MSO Jena, Germany*. [TuB1.pdf](#)
- TuD1, **Design problem**, Markus Tilsch<sup>1</sup>, Karen Hendrix<sup>1</sup>, Pierre Verly<sup>2</sup>; <sup>1</sup>*OCLI/JDS Uniphase, USA*, <sup>2</sup>*Inst. for Microstructural Sciences, Natl. Res. Council, Canada*. [TuD1.pdf](#)
- TuE1, **Optical broadband monitoring of conventional and ion processes**, Detlev Ristau, Tobias Gross, Marc Lappschies; *Laser Zentrum Hannover (LZH), Germany*.
- TuF1, **Optical coatings for high power lasers**, Guillaume Ravel, *CEA-DRT-LETI/DOPT, France*.
- WA1, **Plasma-ion assisted deposition of optical coatings on thermoplastics polymers**, Ulrike Schulz, Peter Munzert, Norbert Kaiser; *Fraunhofer Inst. Angewandte Optik und Feinmechanik, Germany*. [WA1.pdf](#)
- WA2, **Plasma based processes for optical surface modifications in Germany**, Ralf Fellenberg, *VDI Technologiezentrum, Germany*.

- **WB1, Uncertainties in spectral reflectance caused by the measuring instrument**, Maria Nadal, *NIST, USA*. [WB1.pdf](#)
- **WD1, 2004 topical meeting on Optical Interference Coatings: Measurement problem**, Angela Duparré<sup>1</sup>, Detlev Ristau<sup>2</sup>; <sup>1</sup>*Fraunhofer IOF, Germany*, <sup>2</sup>*Laser Zentrum Hannover, Germany*. [WD1.pdf](#)
- **WE1, Light scattering in optical multilayers: review and progress**, Claude Amra, Carole Deumié; *Inst. Fresnel, France*. [WE1.pdf](#)
- **WF1, Status of the National Ignition Facility: An optics perspective**, Jack Campbell, *Lawrence Livermore Natl. Lab., USA*.
- **ThA1, Structure and density related properties of metal oxide films**, H.K. Pulker, Sr., Stephan Schlichtherle, *Univ. of Innsbruck, Austria*.
- **ThA2, Multilayer coatings for ultrafast lasers**, Günter Steinmeyer, Ursula Keller; *Max-Born-Inst. für Nichtlineare Optik und Ultrakurzzeitspektroskopie, Germany*. [ThA2.pdf](#)
- **ThB1, Tunable thin film filters**, Michel Lequime, *Inst. Fresnel, France*. [ThB1.pdf](#)
- **ThD1, The use of optical coatings in projection systems**, Toshikazu Hirasawa<sup>1</sup>, Yoshinori Chichibu<sup>1</sup>, Hiroshi Kawamura<sup>2</sup>; <sup>1</sup>*Nitto Thin Film Lab. Co., Japan*, <sup>2</sup>*Nitto Optical Co. Ltd., Japan*. [ThD1.pdf](#)
- **ThD2, Multilayer thin-film coatings for optical communication systems**, Martina Gerken, *Univ. Karlsruhe, Germany*. [ThD2](#)
- **ThE1, Mechanical properties of optical coatings**, Jolanta Klemberg-Sapieha, Ludvik Martinu; *École Polytechnique, Canada*.
- **FA1, Optical interference coatings and the growth of optoelectronic industry in Taiwan**, Fang C. Ho, IV, *Delta Electronics, Inc., Taiwan Republic of China*. [FA1.pdf](#)
- **FA2, Current issues in the science and technology of organic light-emitting devices**, Joseph Shinar; *Iowa State Univ., USA, Ames Lab.- USDOE, USA*.
- **FB1, Studies of Reststrahlen band materials in photonic crystals**, Carl Ribbing<sup>1</sup>, Herman Högstrom<sup>1</sup>, Andreas Rung<sup>1,2</sup>; <sup>1</sup>*Uppsala Univ., Sweden*, <sup>2</sup>*Div. of Sensor Technology, Swedish Defense Res. Agency, Sweden*. [FB1.ppt](#)

## Short Courses

With a strong commitment to continuing technical education, OSA offers OIC short courses designed to increase your knowledge of a specific subject while offering you the experience of expert teachers. Top-quality instructors stay current on the subject matter required to advance your research and career goals.

### Schedule

#### ▼ Sunday, June 27, 2004

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Time	Event
8:00 a.m. - 5:00 p.m.	<a href="#">SC224 Modern design and evaluation approaches aimed to raise coating production yields</a> Alexander Tikhonoravov, <i>Moscow State Univ., Russian Federation</i>
8:00 a.m. - 12:00 p.m.	<a href="#">SC225 Optical coating for the DUV-, VUV-, EUV-, and soft x-ray spectral region</a> Norbert Kaiser, <i>Fraunhofer Jena, Germany</i> <a href="#">SC226 Numerical methods for optical coatings</a> George Dobrowolski, <i>NRC Canada, Canada</i> <a href="#">SC227 Understanding the optical properties of optical coating materials</a> Olaf Stenzel, <i>Fraunhofer Jena, Germany</i>
1:00 p.m. - 5:00 p.m.	<a href="#">SC228 Mechanical properties of optical coatings</a> Ludvik Martinu, <i>Ecole Polytec Montreal, Canada</i> <a href="#">SC229 Optical coating design and monitoring</a> Ron Willey, <i>Consultant, USA</i> <a href="#">SC230 Spectrophotometry - instrumentation, traceability and best measurement practices</a> Joanne Zwinkles, <i>Natl. Res. Council, Canada</i>

### Continuing Education Units (CEUs)

Short Course attendees who successfully complete a course are eligible to receive continuing education units (CEUs). The CEU is a nationally recognized unit of measure for continuing education and training programs that meet established criteria. To earn CEUs, a participant must complete the CEU credit form and course evaluation and return it to the course instructor at the end of the course. CEUs will be calculated and certificates will be mailed to participants.

## **Course Descriptions**

### **SC224: Modern design and evaluation approaches aimed to raise coating production yields**

Alexander Tikhonravov, *Moscow State Univ., Russian Federation*

#### ***Course Description***

The course will start with a short discussion of those ideas of the thin film theory that are essential for the design and practical applications of optical thin film coatings. Widely used evaluation methods such as the matrix method will be briefly overviewed.

Modern techniques for optical coating design will be considered. The course will present the basic ideas of the needle optimization technique and its most recent modifications. Special attention will be paid to practical implementation of various design methods. Pro et contra of the entirely automatic design will be discussed. A detailed consideration will be given to the specification of design targets, indices selection, and starting design choice. Other important aspects will include the enhancement of design feasibility during the design procedure by removing thin layers and reducing the total number of layers, and the choice of the most manufacturable designs using an estimation of the production yield.

The course will cover various aspects of the pre-production error analysis of optical coatings. The effects caused by surface micro-roughness, bulk inhomogeneity and scattering, and how these effects may influence the spectral performance of the resulting coatings will be explained.

An important issue for the production of high-quality coatings is a reliable determination of the optical parameters of coating layers. Capabilities and limitations of thin film characterization based on spectral photometric and spectral ellipsometric data will be discussed. Effects of random and systematic errors will be considered in connection with the accuracy of the optical characterization of thin films.

The course will present the most recent results on the reverse engineering and post-production characterization of manufactured optical coatings. The calibration of monitoring devices and elimination of systematic manufacturing errors will be discussed. Raising coating production yields with the help of the on-line characterization and re-optimization of manufactured optical coatings will be considered.

#### ***Benefits and Learning Objectives***

This course should enable participants to:

- Select modern design techniques that are most suitable for solving their specific design problems;



- Correctly specify design targets and apply the most reasonable starting designs, in order to control the final design properties and meet various feasibility demands;
- Perform the pre-production error analysis of designed optical coatings and evaluate effects connected with inhomogeneity, scattering, and surface micro-roughness;
- Determine the optical parameters of thin films using spectral photometric and spectral ellipsometric data and estimate the accuracy of optical parameters determination;
- Investigate main reasons for the degradation of the spectral performance of manufactured coatings and find ways to improve the production yield; and
- Estimate the need for the on-line characterization and re-optimization in order to raise the production yield in a specific production environment.

### ***Intended Audience***

The intended audience includes designers of optical coatings, company staff responsible for measuring and testing optical coatings, production engineers and technicians. The background required is a general understanding of thin films and optical coatings. Any prior knowledge of design, evaluation and characterization methods is not essential because the course will cover basic ideas and practical aspects of modern design, evaluation and characterization approaches.

### ***Instructor Biography***

Alexander Tikhonravov is a Professor of Theoretical Physics and the Director of the Research at Computing Center at Moscow State University. He received his Ph.D. and Doctor of Sciences from Moscow State University. He has authored more than 220 publications, among them, the book Basics of Optics of Multilayer Systems. Alexander Tikhonravov is the inventor of the needle optimization technique, a universal technique for the design of optical coatings. He was a course instructor at the OIC 1995, OIC 1998, and OIC 2001 meetings.

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### **SC225: Optical coatings for the DUV-, VUV-, EUV-, and soft x-ray spectral region**

Robert Kaiser, *Fraunhofer Inst. Applied Optics and Precision Engineering, Jena, Germany*

### ***Course Description***

This is an introductory course for people who would like to become familiar with coatings for short and ultrashort wavelength. One of the main drivers toward the shortest possible wavelengths is semiconductor manufacturing with excimer lasers (248 nm, 193 nm, 157 nm), next generation lithography (13.5 nm), microscopy in the "water window" (2.3 – 4.4 nm), laser fusion, astronomy (5 – 31 nm), spectroscopy, plasma diagnostics and EUV/soft X-ray laser research.

### ***Benefits and Learning Objectives***

This course should enable you to:

- Discuss short wavelength, high energies, huge interaction cross-sections, optical resolution, and sources and applications of UV-radiation;
- Learn why optics needs coating, how coatings work and what is special about short wavelengths;
- Discover how to make a surface anti-reflective or high-reflective;
- Discover how to design and manufacture DUV/VUV-coatings and why laser damage is a serious problem; and
- Discuss reflective and absorbing XUV/EUV coatings.

### ***Intended Audience***

This course covers the area of optical interference coatings for short and ultra-short wavelengths. It is addressed to newcomers and experts. The course will provide a comprehensive view of the field while reflecting its dynamic and rapidly changing nature. The basic and most current results of the entire field are presented in logical order and completed by extensive bibliographic material. This course also is suitable and very interesting for people who (want to) apply or sell coatings on products or parts and want to know more about this technology and its possibilities.

### ***Instructor Biography***

Norbert Kaiser received his Diplom Physiker in 1974, his Dr. rer. nat. in 1983 and his Dr. habil in 1999 from the University of Jena, Germany. After nine years of research on nucleation and growth of thin films, he joined the Optical Thin Film Group of the Physikalisch Technisches Institut, Jena, and was responsible for R&D on coatings for the UV. Since 1992, he has headed the Optical Thin Film Department and is deputy director of the Fraunhofer Institute Applied Optics and Precision Engineering in Jena. He has authored a large number of papers and patents on nucleation, growth and structure-related properties of thin optical films. Kaiser is editor of Optical Interference Coatings in the Springer Series in Optical Sciences (2003), Program-Chair for the "9th Topical Meeting on Optical Interference Coatings" in Tucson, Arizona (2004), President of the technical committee "Thin Films for Optics and

Optoelectronics" for the European Society of Thin Films, and Chair of SPIE Conference Optical System Design – Advances in Optical Coatings in St. Etienne, France (2003). He has given short courses at various conferences and he is lecturer in Physics at the University and the Technical University of Jena, Germany.

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## **SC226: Numerical methods for optical coatings**

George Dobrowolski, *Natl. Res. Council of Canada (NRCC), Canada*

### ***Course Description***

The aim of this course is to describe the ways in which numerical methods are used at the various stages of the design and manufacture of optical coatings. First, it is necessary to establish, from experimental data, the actual optical constants of thin films of the coating materials to be used, as produced by the processes that are proposed for the construction of the multilayer. During the design stage, the construction parameters are sought of a layer system whose calculated performance matches the required performance of the coating. Sometimes it is sufficient to fine-tune with one of the many existing refinement procedures, the construction parameters of a known design having a performance that is close to a required one. Thin film synthesis methods are used to generate the solution from the start whenever there are no such reasonable starting designs. The synthesis methods that will be discussed are the comprehensive search, gradual evolution, minus filter, flip-flop inverse Fourier transform and needle methods. Commercially available optical thin film design programs will be listed. Before the construction of a multilayer system commences, a study should be performed on the sensitivity of the performance to probable production process errors. In extreme cases it may be necessary to find a less sensitive solution. Optical monitoring methods are frequently used during the manufacturing process to control the thicknesses of the individual layers. Numerical calculations can point to the optimum monitoring strategy. In the most advanced deposition processes the construction parameters of the partially deposited multilayers are determined in real-time and the thicknesses of the remaining layers are re-optimized to compensate for the errors made thus far. This is done automatically and without human intervention, and results in a much higher yield of the process. There is little doubt that in the future thicknesses of layers that exceed the required values will be adjusted in situ by ion beam etching, yielding further improvements in the manufacturing accuracy.

### ***Benefits and Learning Objectives***

This course should enable the participants to:

- Specify the required performance of an optical multilayer system;
- Choose an appropriate set of coating materials;

- Compare the properties of solutions found by different design methods;
- Select appropriate thin film design software and, in time, use same to design solutions to coating problems;
- Discuss with vendors or coating technicians possible monitoring methods;
- Compare calculated and measured performances of a multilayer coating and explain discrepancies between the two; and
- Identify more advanced deposition processes, should the required tolerances for the performance of the coating be very difficult to meet.

### ***Intended Audience***

The course should be of interest to students from industry and academia with various levels of prior experience in optical thin films. Technical as well as scientific and engineering staff should find the course useful. The presentation will be largely non-mathematical with an emphasis on understanding the processes involved, but the many examples presented will point students to sources in which a deeper knowledge of specific topics can be gained.

### ***Instructor Biography***

J.A. (George) Dobrowolski is a Researcher Emeritus at the NRCC. His main interests are the development of theoretical methods for the design and experimental methods for the construction of optical multilayers. He is interested in new technological and consumer-oriented applications of optical filters. Dobrowski is author or co-author of about 150 publications, 8 handbook articles, and 28 patents. He received the 1987 Joseph Fraunhofer Award and the 1996 David Richardson Medal from the OSA. He regularly teaches courses on optical thin films at the University of Rochester and at the SVC.

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## **SC227: Understanding the optical properties of optical coating materials**

Olaf Stenzel, *Fraunhofer Inst. of Applied Optics and Precision Engineering, Jena, Germany*

### ***Course Description***

The course provides attendees with theoretical knowledge on the basic properties of linear optical constants. It consists of two main parts. In the first (more formal) part, both normal and anomalous dispersion of the optical

constants will be extensively discussed based on general principles of the interaction of light with matter, including causality and Kramers-Kronig-relations. The specifics of the optical properties in different spectral regions, ranging from the infrared up to the X-ray spectrum, will be derived. The second (and more applicative) part of the course concentrates on the derivation and application of classical and semi-classical dispersion models to describe the optical behaviour of isotropic thin film optical materials. Examples include dielectrics as well as semiconductors and metals.

### ***Benefits and Learning Objectives***

This course should enable you to:

- Discuss the optical constants of any material basing on fundamental physical principles;
- Identify the correct dispersion model applicable to the material under investigation in practice;
- Calculate the optical constants of material mixtures, among them systems with metal island films;
- Discover the complicated relation between mass density and optical constants; and
- Simulate linear optical constants at both classical and semi-classical levels.

### ***Intended Audience***

This is an intermediate level course for people who would like to become familiar with the fundamentals of optical properties of optical materials with emphasis on typical coating materials.

This course is of use to anyone who needs to compute thin film optical constants for either design or characterization tasks. It is addressed to newcomers and experts. Some basic knowledge of higher mathematics (differential and integral calculus as well as vector algebra) is presumed, as well as basic knowledge of classical electrodynamics. Some knowledge on solid-state physics and quantum mechanics is of use, but not necessary to benefit from the course.

### ***Instructor Biography***

Olaf Stenzel received his Diplom Physiker in 1986 from Moscow State University, his Dr. rer. nat. in 1990 and his Dr. habil in 1999, both from the University of Technology in Chemnitz, Germany. He has over six years teaching experience as a university lecturer and has authored a textbook on thin film optics. Stenzel has authored and co-authored more than 50 scientific papers, mainly in the field of thin film spectroscopy. In 2001, he came to the Optical Coating Department at the Fraunhofer Institute of

Applied Optics and Precision Engineering in Jena, Germany. At present he is the Group Manager for NIR- and VIS-Coatings this department. The combination of university teaching with more applicative research at the Fraunhofer Institute defines the individual content and style of his short course.

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## **SC228: Mechanical properties of optical coatings**

Ludvik Martinu, *Ecole Polytechnique, Canada*

### ***Course Description***

Control of mechanical properties is essential for assuring good performance of optical thin film systems such as optical filters, optical waveguides, optical MEMS, optical films on plastic substrates and others. In this respect, mechanical characteristics of the individual layers and their relationship with the film microstructure and the film fabrication parameters represent an important issue in many advanced applications; this includes telecommunications, displays, and systems for their use in space, architecture, automobiles, and in consumer products. The required mechanical properties include adhesion, stress, scratch-, abrasion- and wear resistance, hardness and elastic modulus, and other functional characteristics, such as hydrophobicity/hydrophilicity, surface friction, thermal and environmental stability, etc. This course will particularly focus on the methodology of mechanical testing, on the relationship between the mechanical properties and the film microstructure, and on the approaches considered in different areas of optical film applications.

- Importance of mechanical properties in different optical film systems
- Origin of mechanical strength
- Mechanical properties – basic definitions
- Testing methods:
- Adhesion
- Stress
- Elasto-plastic properties
- Tribological properties
- Related film functional properties
- Relationship between the mechanical properties and the film microstructure
- Materials compatibility and role of interfaces
- Effect of film fabrication conditions on the mechanical properties:
- Physical vapor deposition

- Chemical vapor deposition
- Plasma-assisted processes
- Non-vacuum methods
- Examples of specific applications

### ***Benefits and Learning Objectives***

This course should enable you to:

- Explain the origin of the mechanical characteristics of optical films;
- Choose, describe and specify appropriate methods for mechanical testing;
- Determine and interpret mechanical behavior from the raw test data and predict their accuracy;
- Identify approaches to optimize the mechanical properties in optical film systems; and
- Evaluate the role of mechanical properties in specific optical applications.

### ***Intended Audience***

The interested participants are assumed to possess a graduate or an undergraduate level of experience in the area of materials science and thin film physics and technology. This course is particularly suited for graduate students, process engineers, junior and senior research scientists from both industrial and academic environments, and for managers of characterization facilities.

### ***Instructor Biography***

Ludvik Martinu is Full Professor at Ecole Polytechnique in Montreal, Chairman of the Department of Engineering Physics and Associate Director of the Thin Film Research Center (GCM) on the Université de Montréal Campus. His main research interest is the physics and technology of thin films, in particular new plasma-based fabrication processes, new materials and characterization techniques for optical and functional coatings, hard films, and thin film systems for photonic devices, especially optical filters and optical waveguides.

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### **SC229: Optical coating design and monitoring**

Ron Willey, *Consultant, USA*

### ***Course Description***

This course covers a review of optical coating design principles and techniques from both classical approaches and different viewpoints. Methods for the design and execution of monitoring strategies to produce desired coating results are described. The sensitivities, possibilities, and limitations of most control techniques are described.

- Fundamentals of thin film optics from various points of view
- The use of graphical methods to aid understanding of thin film design
- Estimating what can be done before designing
- A Fourier viewpoint of optical coatings
- Practical monitoring and control of thin film growth
- Error compensation and degree of control
- Sensitivity to errors and monitoring strategies

### ***Benefits and Learning Objectives***

This course should enable you to:

- Firmly grasp the fundamentals of thin film optics;
- Use graphical methods in thin film design, such as: reflectance, admittance, triangle, and prism diagrams;
- Create and choose appropriate starting designs for optimization;
- Understand rugate, discrete layer designs, and Fourier thin film synthesis and its current limitations;
- Estimate what can be achieved before starting a design;
- Understand various monitoring strategies and their advantages and limitations; and
- Use error compensation effects for better control of results and optimize the sensitivity of monitoring approaches.

### ***Intended Audience***

Engineers, scientists, and managers involved in design, development, and production of optical thin films. Extensive mathematical background is not required, but some exposure to optical coatings would be helpful. Limited prior knowledge should not be a handicap.

### ***Instructor Biography***

Ron Willey is a consultant with over 35 years experience in the fields of thin film and optical systems design, development and production. He has led groups in optical coating, instrumentation development and production at Martin Marietta, Raytheon, Opto Mechanik and LexaLite International. Willey



is experienced in practical thin films design, process development and the application of industrial Design Of Experiment methodology (DOE). He has published many papers on optical coating, optical design and the economics of optical tolerances, and the book, Practical Design and Production of Optical Thin Films. He is a Fellow of SPIE and OSA, and a past director of the SVC.

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## **SC230: Spectrophotometry – instrumentation, traceability and best measurement practices**

Joanne Zwinkels, *Natl. Res. Council of Canada (NRCC), Canada*

### ***Course Description***

This short-course will provide practical information on how to perform reliable spectrophotometric measurements. It will begin with an overview of the basic principles of spectrophotometry, the importance of accurate measurements, and the terminology used in precision spectrophotometric measurements and calibrations. The course will then describe the concepts of uncertainty estimation and the key components of uncertainty in spectrophotometric measurements of reflectance and transmittance. The basic components of spectrophotometric instrumentation will be discussed and advice will be given on how to select design options and instrument configurations to minimize measurement errors. The course will then cover the fundamental procedures involved in the calibration of a spectrophotometer. The traceability of spectrophotometric measurements will be explained and information will be provided on the choice of transfer and working material standards that are available for calibrating and validating instrument performance. Finally, the course will recommend best measurement practices for spectrophotometric measurements of transmittance and reflectance for a variety of applications widely used in industry. These applications include the design of optical coatings and other optical materials, and the color and appearance specification of manufactured colored goods, such as textiles, plastics and paper.

### ***Benefits and Learning Objectives***

This course should enable you to:

- Compare spectrophotometer designs and select the optimum type and operating parameters for a given measurement application;
- Define terms used to describe the technical performance of spectrophotometric instrumentation and the results of spectrophotometric measurements;
- Select and use appropriate methods and material standards for calibrating and validating spectrophotometer performance;

- Describe and estimate the key uncertainty components in spectrophotometric measurements;
- Determine the overall measurement uncertainty;
- Identify the best measurement practice to obtain the highest measurement precision for different applications; and
- Perform reliable measurements of spectral transmittance and reflectance.

### ***Intended Audience***

This course is designed for scientists, engineers and technicians who are concerned with precise and accurate spectrophotometric and colorimetric measurements for a wide variety of measurement applications, including design of optical coatings and filters, formulation of paints and dyes, and quality control of various manufactured colored goods, such as textiles, plastics, and paper. Proper traceability of spectrophotometric measurements is particularly relevant to those individuals working under quality systems where measurement traceability is a requirement.

### ***Instructor Biography***

Joanne Zwinkels is the Head of the Photometry and Radiometry Group at the National Research Council of Canada (NRCC). Her primary research is in the fields of spectrophotometry, gloss and fluorescence measurements. In the past 20 years, she has developed new primary calibration facilities and standards for the measurement of regular spectral transmittance, specular reflectance, color of fluorescent reflecting materials, and is currently developing a reference instrument for the calibration of specular gloss and for accurately characterizing the angle-dependent properties of gonioapparent materials such as special effect coatings. Dr. Zwinkels received her Ph.D. in Physical Chemistry from the University of Alberta in 1983.

## **Publications**

### **Conference Program**

The *Conference Program* will be available on the web in late April 2004. Authors submitting papers, past meeting participants and current committee members will automatically be notified by email when the *Conference Program* goes live.

### **Technical Digests**

The OIC *Technical Digest* will contain the camera-ready summaries of papers presented during the meeting. At the meeting, each registrant will receive a copy of the *Technical Digest* on CD-ROM. Extra CD-ROM copies can be purchased at the meeting for a special price of US\$ 45.

## Agenda

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### Sunday, June 27, 2004

<b>Time</b>	<b>Event/Location</b>
7:00 a.m. – 5:00 p.m.	Registration <i>Grand Ballroom Foyer</i>
8:00 a.m. – 5:00 p.m.	SC224: Modern design and evaluation approaches aimed to raise coating production yields <i>Salon J</i>
8:00 a.m. – Noon	SC225: Optical coatings for the DUV-, VUV-, EUV-, and soft e-ray spectral region <i>Salon K</i>
8:00 a.m. – Noon	SC226: Numerical methods for optical coatings <i>Salon L</i>
8:00 a.m. – Noon	SC227: Understanding the optical properties of optical coating materials <i>Parlor 2205</i>
1:00 p.m. – 5:00 p.m.	SC228: Mechanical properties of optical coatings <i>Salon K</i>
1:00 p. m. – 5:00 p.m.	SC229: Optical coating design and monitoring <i>Salon L</i>
1:00 p.m. – 5:00 p.m.	SC230: Spectrophotometry – instrumentation, traceability and best measurement practices <i>Parlor 2205</i>
5:00 pm - 6:00 p.m.	Welcome Reception <i>Ventana Dining Room</i>

### Monday, June 28, 2004

<b>Time</b>	<b>Event/Location</b>
7:30 a.m. – 5:30 p.m.	Registration <i>Grand Ballroom Foyer</i>
7:00 a.m. – 8:15 a.m.	Continental Breakfast <i>Kiva Ballroom</i>
8:15 a.m. – 8:30 a.m.	Opening Remarks <i>Salon B &amp; C</i>
8:30 a.m. – 9:30 a.m.	MA, Deposition of Optical Coatings I <i>Salon B &amp; C</i>
9:30 a.m. – 10:00 a.m.	Coffee Break <i>Salon A</i>
10:00 a.m. – 11:05 a.m.	MB, Deposition of Optical Coatings II <i>Salon B &amp; C</i>
11:05 a.m. – 12:05 p.m.	MC, Poster Session I (MA & MB Posters) <i>Salon A</i>
12:05 p.m. – 1:15 p.m.	Lunch <i>Kiva Ballroom</i>
1:15 p.m. – 1:45 p.m.	MD, Manufacturing Problem <i>Salon B &amp; C</i>
1:45 p.m. – 3:00 p.m.	ME, Deposition of Optical Coatings III <i>Salon B &amp; C</i>
3:00 p.m. – 3:30 p.m.	Coffee Break <i>Salon A</i>
3:30 p.m. – 4:40 p.m.	MF, Deposition of Optical Coatings IV <i>Salon B &amp; C</i>
4:40 p.m. – 5:40 p.m.	MG, Poster Session II (MD, ME & MF Posters) <i>Salon A</i>

## **Tuesday, June 29, 2004**

<b>Time</b>	<b>Event/Location</b>
7:30 a.m. – 5:30 p.m.	Registration <i>Grand Ballroom Foyer</i>
7:30 a.m. – 8:30 a.m.	Continental Breakfast <i>Kiva Ballroom</i>
8:30 a.m. – 9:45 a.m.	TuA, Nature/Catalysis <i>Salon B &amp; C</i>
9:30 a.m. – 6:15 p.m.	Exhibit Open <i>Grand Ballroom Foyer</i>
9:45 a.m. – 10:15	Coffee Break/Exhibit Time

a.m.	<i>Grand Ballroom Foyer</i>
10:15 a.m. – 11:25 a.m.	TuB, Design of Optical Coatings <i>Salon B &amp; C</i>
11:25 a.m. – 12:25 p.m.	TuC Poster Session III (TuA & TuB Posters) <i>Salon A</i>
12:25 p.m. – 1:35 p.m.	Lunch <i>Kiva Ballroom</i>
1:35 p.m. – 2:05 p.m.	TuD, Design Problem <i>Salon B &amp; C</i>
2:05 p.m. – 3:20 p.m.	TuE, Monitoring <i>Salon B &amp; C</i>
3:20 p.m. – 3:50 p.m.	Coffee Break/Exhibit Time <i>Grand Ballroom Foyer</i>
3:50 p.m. – 5:15 p.m.	TuF Stability of Coatings <i>Salon B &amp; C</i>
5:15 p.m. – 6:15 p.m.	TuG Poster Session IV (TuD, TuE & TuF Posters) <i>Salon A</i>

### **Wednesday, June 30, 2004**

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<b>Time</b>	<b>Event/Location</b>
8:00 a.m. – 5:30 p.m.	Registration <i>Grand Ballroom Foyer</i>
7:30 a.m. – 8:30 a.m.	Continental Breakfast <i>Kiva Ballroom</i>
8:30 a.m. – 9:45 a.m.	WA, Plasma Processes/Antireflection <i>Salon B &amp; C</i>
9:30 a.m. – 6:00 p.m.	Exhibit Open <i>Grand Ballroom Foyer</i>
9:45 a.m. – 10:15 a.m.	Coffee Break/Exhibit Time <i>Grand Ballroom Foyer</i>
10:15 a.m. – 11:20 a.m.	WB, Characterization of Optical Coatings I <i>Salon B &amp; C</i>
11:20 a.m. – 12:20 p.m.	WC, Poster Session V (WA & WB Posters) <i>Salon A</i>
12:20 p.m. – 1:30 p.m.	Lunch <i>Kiva Ballroom</i>
1:30 p.m. – 2:00 p.m.	WD, Measuring Problem <i>Salon B &amp; C</i>
2:00 p.m. – 3:15 p.m.	WE, Characterization of Optical Coatings II <i>Salon B &amp; C</i>

3:15 p.m. – 3:45 p.m.	Coffee Break/Exhibit Time <i>Grand Ballroom Foyer</i>
3:45 p.m. – 5:00 p.m.	WF, Short and Intense Wavelength Coatings <i>Salon B &amp; C</i>
5:00 p.m. – 6:00 p.m.	WG, Poster Session VI (WD, WE & WF Posters) <i>Salon A</i>
6:00 p.m. – 8:00 p.m.	Conference Reception <i>Bill's Grill and Croquet Court</i>

### **Thursday, July 01, 2004**

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<b>Time</b>	<b>Event/Location</b>
8:00 a.m. – 5:30 p.m.	Registration <i>Grand Ballroom Foyer</i>
7:30 a.m. – 8:30 a.m.	Continental Breakfast <i>Kiva Ballroom</i>
8:30 a.m. – 9:50 a.m.	ThA, Structure and Fast Coatings <i>Salon B &amp; C</i>
9:30 a.m. – 5:30 p.m.	Exhibit Open <i>Grand Ballroom Foyer</i>
9:50 a.m. – 10:20 a.m.	Coffee Break/Exhibit Time <i>Grand Ballroom Foyer</i>
10:20 a.m. – 11:25 a.m.	ThB, Filter I <i>Salon B &amp; C</i>
11:25 a.m. – 12:25 p.m.	ThC, Poster Session VII (ThA & ThB Posters) <i>Salon A</i>
12:25 p.m. – 1:35 p.m.	Lunch <i>Kiva Ballroom</i>
1:35 p.m. – 3:15 p.m.	ThD, Filter II <i>Salon B &amp; C</i>
3:15 p.m. – 3:45 p.m.	Coffee Break/Exhibit Time <i>Grand Ballroom Foyer</i>
3:45 p.m. – 5:00 p.m.	ThE, Filter III/Stress <i>Salon B &amp; C</i>
5:00 p.m. – 6:00 p.m.	ThF, Poster Session VIII (ThD & ThE Posters) <i>Salon A</i>

## Friday, July 02, 2004

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<b>Time</b>	<b>Event/Location</b>
8:00 a.m. – Noon	Registration <i>Grand Ballroom Foyer</i>
7:30 a.m. – 8:30 a.m.	Continental Breakfast <i>Kiva Ballroom</i>
8:30 a.m. – 9:45 a.m.	FA, Applications I <i>Salon B &amp; C</i>
9:45 a.m. – 10:15 a.m.	Coffee Break <i>Grand Ballroom Foyer</i>
10:15 a.m. – 11:20 a.m.	FB, Applications II <i>Salon B &amp; C</i>
11:10 a.m. – 12:10 p.m.	FC, Poster Session IX (FA & FB Posters) <i>Salon A</i>
12:10p.m. – 1:10 p.m.	Lunch <i>Grand Ballroom Foyer</i>

**Sunday, June 27, 2004**

*Grand Ballroom Foyer*

**7:00 a.m. – 5:00 p.m.**

**Registration**

*Salon J*

**8:00 a.m. – 5:00 p.m.**

**SC224: Modern design and evaluation approaches aimed to raise coating production yields**

*Salon K*

**8:00 a.m. – Noon**

**SC225: Optical coatings for the DUV-, VUV-, EUV-, and soft e-ray spectral region**

*Salon L*

**8:00 a.m. – Noon**

**SC226: Numerical methods for optical coatings**

*Parlor 2205*

**8:00 a.m. – Noon**

**SC227: Understanding the optical properties of optical coating materials**

*Salon K*

**1:00 p.m. – 5:00 p.m.**

**SC228: Mechanical properties of optical coatings**

*Salon L*

**1:00 p.m. – 5:00 p.m.**

**SC229: Optical coating design and monitoring**

*Parlor 2205*

**1:00 p.m. – 5:00 p.m.**

**SC230: Spectrophotometry – instrumentation, traceability and best measurement practices**

*Ventana Dining Room*

**5:00 p.m. – 6:00 p.m.**

**Welcome Reception**

**Monday, June 28, 2004**

*Grand Ballroom Foyer*

**7:30 a.m. – 5:30 p.m.**

**Registration**

*Kiva Ballroom*

**7:00 a.m. – 8:15 a.m.**

**Continental Breakfast**

*Salon B and C*

**8:15 a.m. – 9:30 a.m.**

**MA • Deposition of Optical Coatings I**

*Norbert Kaiser; Fraunhofer Inst. Applied Optics and Precision Engineering, Germany, Presider*

*Jennifer Kruschwitz; USA, Presider*

**MA • 8:15 a.m.**

**Opening Remarks**



*Ric Shimshock; MLD Technologies, USA*

**MA1 • 8:30 a.m. (Invited)**

**Future of optical coatings**

*Angus Macleod; Thin Film Ctr., USA.*

Optical coatings are essential components of virtually all optical systems but their development is largely in response to new requirements. We examine some current applications, consider trends and think what they mean for the future.

**MA2 • 9:00 (Invited)**

**Some reflections on the history of optical coatings**

*J. A. Dobrowolski; Natl. Res. Council of Canada, Canada,*

Abstract not available at this time.

*Salon A*

**9:30 a.m. – 10:00 a.m.**

**Coffee Break**

*Salon B and C*

**10:00 a.m. – 11:05 a.m.**

**MB • Deposition of Optical Coatings II**

*Angus Macleod; Thin Film Ctr., USA, Presider*

*J. A. Dobrowolski; Natl. Res. Council of Canada, Canada, Presider*

**MB1 • 10:00 a.m. (Invited)**

**Atomic Layer Deposition—An alternative to the deposition of optical coatings?**

*Mikko Ritala, Markku Leskelä; Univ. of Helsinki, Finland.*

Atomic Layer Deposition technique is introduced and its potential for optical coatings is discussed. The ALD technique has several advantages: simple and accurate thickness control, large-area uniformity, conformality, good reproducibility and straightforward scale-up.

**MB2 • 10:30 a.m.**

**A futuristic view of space-based deposition processes**

*Michael L. Fulton; Ion Beam Optics, USA.*

Space-based thin-film depositions enable the future development of flexible large-area space antennae and fixed telescope mirrors for lunar-station observatories. Deployable solar-propulsion concentrator arrays, coated in space, will accelerate the feasibility of human flights to Mars.

**MB3 • 10:35 a.m.**

**The properties of IAD oxide optical coatings**

*Shengming Xiong, Wei Huang, Yundong Zhang; Inst. of Optics & Electronics, Chinese Acad. of Sciences, China.*

The properties of oxide thin films deposited by ion assisted deposition (IAD) were studied. The refractives of oxide layers and the results of multi-layer AR coatings on sapphire for COIL laser window were reported.

**MB4 • 10:40 a.m.**

**Optimization of electron-beam deposition uniformity for large aperture NIF substrates in a planetary rotation system**

*James B. Oliver, David M. Talbot; Univ. of Rochester, USA.*

Optical-thin-film uniformity for 0.9-m-aperture optics in a 72-in. coating chamber is optimized for planetary rotation by analyzing source placement, planetary gearing, and mask design. Source efficiency is considered in achieving deposition nonuniformity of approximately 0.5%.

**MB5 • 10:45 a.m.**

**High quality optical thin film deposition with gas cluster ion beam assisted deposition**

Noriaki Toyoda<sup>1</sup>, Isao Yamada<sup>1</sup>, Shunsuke Niisaka<sup>2</sup>, Masatoshi Sato<sup>2</sup>; <sup>1</sup>Himeji Inst. of Technology, Japan, <sup>2</sup>Nikon Corp., Japan.

Gas cluster ion beam assisted depositions realize ultra-low energy (several eV/atom) ion irradiations and is able to deposit high-density films without damages by energetic ions. Surface smoothing effects are fascinating characteristics of this technique.

**MB6 • 10:50 a.m.**

**High throughput deposition of precision optical coatings using closed field magnetron sputtering**

Desmond R. Gibson<sup>1</sup>, J. M. Walls<sup>1</sup>, Ian Brinkley<sup>1</sup>, Joanne Hampshire<sup>2</sup>, Paul Teer<sup>2</sup>, Dennis G. Teer<sup>2</sup>; <sup>1</sup>Applied Multilayers, Ltd., UK, <sup>2</sup>Teer Coatings, Ltd., UK.

Closed field magnetron sputtering provides high ion current density and low bias voltage, enabling film deposition at high rate with excellent optical properties. Application to visible and near infra-red precision multilayer optical coatings is described.

**MB7 • 10:55 a.m.**

**I.B.S. coatings on large substrates: Towards an improvement of the mechanical and optical performances**

Danièle Forest, Patrick Ganau, Bernard Lagrange, Jean-Marie Mackowski, Christophe Michel, Jean-Luc Montorio, N. Morgado, Renée Pignard, Laurent Pinard, Alban Remillieux; SMA-VIRGO Univ. Lyon I, France.

Large mirrors (350 mm diameter), having extremely low optical loss (absorption, scattering, wavefront) were coated for the VIRGO interferometer. The new mirror generation needs better wavefront and lower mechanical loss. The first results are discussed.

**MB8 • 11:00am**

**Plasma ion-assisted deposition of TiO<sub>2</sub> and MgF<sub>2</sub> thin films**

Seouk Hoon Woo<sup>1</sup>, Chang Kwon Hwangbo<sup>1</sup>, Young Bae Son<sup>2</sup>, Il Choon Moon<sup>2</sup>, Geon Mo Kang<sup>2</sup>; <sup>1</sup>Inha Univ., Republic of Korea, <sup>2</sup>Samsung Techwin, Republic of Korea.

Optical and structural properties of TiO<sub>2</sub> and MgF<sub>2</sub> thin films deposited by plasma ion-assisted deposition were investigated and the effects of plasma ion-assistance and substrate heating were studied to deposit the stable TiO<sub>2</sub>/MgF<sub>2</sub> multilayers.

Salon A

**11:05 a.m. – 12:05 p.m.**

**MC • Poster Session I**

Kiva Ballroom

**12:05 p.m. – 1:15 p.m.**

**Lunch**

Salon B and C

**1:15 p.m. – 1:45 p.m.**

**MD • Manufacturing Problem**

Hisahi

Ohsaki, Univ. of Tokyo, Japan, Presider

Fang C. Ho, IV; Delta Electronics, Inc., Taiwan Republic of China, Presider

**MD1 • 1:15 p.m.**

**(Invited)**

**Manufacturing Problem**

Steve Browning<sup>1</sup>, J. A. Dobrowolski<sup>2</sup>; <sup>1</sup>Ball Aerospace Corp., USA, <sup>2</sup>Natl. Res. Council of Canada, Canada.

Measurements of the experimental filters, submitted to the second optical-thin film manufacturing problem, where the object was to produce multilayers with a spectral performance that's as close as possible to the specified target, are presented.

Salon B and C

**1:45 p.m. – 3:00 p.m.**

### **ME • Deposition of Optical Coatings III**

*Hans Pulker, Univ. of Innsbruck, Austria, Presider*

*Fang C. Ho, IV; Delta Electronics, Inc., Taiwan Republic of China, Presider*

#### **ME1 • 1:45 p.m. (Invited)**

##### **Coating machine concepts for precision optics**

*Harro Hagedorn; Leybold Optics GmbH, Germany.*

The performance of a tandem plasma source solution for large box coaters is investigated for layer performance and achievable growth rates. A new fully automated sputter coating system for producing complex interference filters is presented.

#### **ME2 • 2:15 p.m.**

##### **Inline sputter systems versus cluster or batch tools: Sputter coaters for optical multilayers**

*Christoph Köckert, M. List, K. Gehm, J. Hartung, J. Strümpfel; Von Ardenne Anlagentechnik, Germany.*

Optical multilayer coatings are successfully deposited by reactive magnetron sputtering. Inline systems are compared to newly designed cluster tools for both configurations horizontal and vertical setup. Excellent film properties and layer homogeneities are performed.

#### **ME3 • 2:20 p.m.**

##### **Relation of cathode voltage to stress for DC magnetron sputtered SiO<sub>2</sub> films**

*David W. Reicher, Catherine C. Sobczak; S. Systems Corp., USA.*

This investigation explored the relation of cathode voltage to stress of magnetron sputtered SiO<sub>2</sub> films. Films deposited at potentials from 320 to 500 volts had corresponding film stresses of 195 MPa to 272 MPa.

#### **ME4 • 2:25 p.m.**

##### **Structural and optical properties of titanium dioxide films produced by RAS (Radical Assisted Sputtering) coater**

*Yousong Jiang<sup>1</sup>, Yizhou Song<sup>1</sup>, Ming L.<sup>2</sup>, Haiqian Wang<sup>2</sup>, J. G. Hou<sup>2</sup>; <sup>1</sup>R & D Dept., Shincron Co., Ltd., Japan, <sup>2</sup>Structure Res. Lab., Univ. of Science and Technology of China, China.*

Titanium dioxide films were prepared by a previously described RAS (radical assisted sputtering) coater. Structural and optical properties of the films were investigated. Absorption-less multilayered optical filters were reached through 410nm to 700nm wavelength range.

#### **ME5 • 2:30 p.m.**

##### **Surface morphology and microstructure of zirconia thin films prepared at different deposition rates**

*Dongping Zhang, Jianda Shao, Meiqiong Zhan, Ming Fang, Jianbing Huang, Ruiying Fan, Zhengxiu Fan; Shanghai Inst. of Optics and Fine Mechanics, China.*

ZrO<sub>2</sub> films were prepared by electron beam thermal evaporation at different rate of deposition. And the variation of the surface morphology, rms roughness, crystal structure, and internal stress with the deposition rate were studied.

#### **ME6 • 2:35 p.m.**

##### **Effects of substrate and deposition method onto the mirror scattering**

*Hyun-Ju Cho, Myung-Jin Shin, Jae-Cheul Lee; Inst. for Advanced Engineering, Republic of Korea.*

Dielectric mirrors were deposited on the different substrate roughness by either IBS or EB. The mirrors by IBS showed lower scattering than EB's. Over ~2Å in substrate roughness, scattering strongly depended on the substrate roughness.

#### **ME7 • 2:40 p.m.**

##### **Deposition dependence of zirconium tungstate (ZrW<sub>2</sub>O<sub>8</sub>) based negative thermal expansion films for optical coatings**

*Michael S. Sutton, Joseph J. Talghader; Univ. of Minnesota, USA.*

Zirconium tungstate-based thin films have been deposited with positive and negative thermal expansion coefficients, where the type of expansion appears to be critically dependent on the film density. Film deposition and characterization is presented.

**ME8 • 2:45 p.m.**

**Optimal control on optical properties of inhomogeneous films processed by RPLD**

*Enrique Samano<sup>1</sup>, Javier Camacho<sup>1</sup>, Roberto Machorro<sup>2</sup>; <sup>1</sup>CCMC-UNAM, Mexico, <sup>2</sup>CCMC, Mexico.*

We report the growth of SiO<sub>x</sub>N<sub>y</sub> films by RPLD using two different solid targets, Si<sub>3</sub>N<sub>4</sub> and Si, in the ambient of N<sub>2</sub> and O<sub>2</sub>, as the film is monitored by real time ellipsometry.

**ME9 • 2:50 p.m.**

**Improved rate control for E-beam evaporation and evaluation of optical performance improvements**

*Michael Gevelber<sup>1</sup>, Bing Xu<sup>1</sup>, Douglas Smith<sup>2</sup>; <sup>1</sup>Manufacturing Engineering, Boston Univ., USA, <sup>2</sup>Vacuum Process Technology, Inc., USA.*

A new deposition rate control and E-gun strategy has been developed which significantly reduces the growth rate variations for E-beam deposited SiO<sub>2</sub> coatings. The reduced growth variations are shown to greatly improve the optical performances of two multilayered bandpass filters.

**ME10 • 2:55 p.m.**

**Temperature dependence of optical and structural properties of TiO<sub>2</sub> / Nb<sub>2</sub>O<sub>5</sub> laminated layers**

*Hans A. van Sprang, Margot van Grootel, Roy Verbeek, Monja Kaiser; Philips Res. Lab., Netherlands.*

Nano-laminates of TiO<sub>2</sub> with Nb<sub>2</sub>O<sub>5</sub> initially delay the growth of rutile TiO<sub>2</sub> crystallites. In-situ TEM reveals that at 900C the Nb is redistributed and a rutile lattice is observed with increased lattice distances.

*Salon A*

**3:00 p.m. – 3:30 p.m.**

**Coffee Break**

*Salon B and C*

**3:30 p.m. – 4:40 p.m.**

**MF • Deposition of Optical Coatings IV**

*Mikko Ritala; Univ. of Helsinki, Finland, Presider*

*Harro Hagedorn; Leybold Optics GmbH, Germany, Presider*

**MF1 • 3:30 p.m.**

**(Invited)**

**Optical coatings using the Filtered Cathodic Arc process**

*Michael Fulton; Ion Beam Optics, USA.*

No abstract provided.

**MF2 • 4:00 p.m.**

**Room-temperature crystallization of amorphous thin films by RF plasma treatment**

*Hisashi Ohsaki<sup>1</sup>, Y. Shibayama<sup>1</sup>, A. Kinbara<sup>1</sup>, T. Watanabe<sup>1</sup>, K. Fukuhisa<sup>2</sup>, K. Shinohara<sup>2</sup>, A. Nakajima<sup>3</sup>; <sup>1</sup>Univ. of Tokyo, Japan, <sup>2</sup>Advanced Systems of Technology Incubation, Japan, <sup>3</sup>Graduate School of Science and Engineering, Tokyo Inst. of Technology, Japan.*

The crystallization of amorphous thin films was achieved by plasma treatment without heating. The gas pressure on the plasma treatment was found to be the key parameter on the crystallization.

**MF3 • 4:05 p.m.**

**Study of the growth and interface engineering of dense/porous SiN<sub>x</sub> optical coatings by real-time spectroscopic ellipsometry**

*Aram Amassian, Richard Vernhes, Jolanta Klemberg-Sapieha, Patrick Desjardins, Ludvik Martinu; Ecole Polytechnique de Montréal, Canada.*

We study the growth of dense and porous SiN<sub>x</sub>:H films deposited in radiofrequency and microwave plasmas. Ion bombardment is used to densify and flatten the surface of porous films, thus improving the quality of interfaces.

**MF4 • 4:10 p.m.**

**Growth study of ultra-porous silicon for photonic interference filters**

*Kate Kaminska<sup>1</sup>, Aram Amassian<sup>2,3</sup>, Ludvik Martinu<sup>2,3</sup>, Kevin Robbie<sup>1</sup>; <sup>1</sup>Queen's Univ., Canada, <sup>2</sup>Ecole*

*Polytechnique de Montréal, Canada, <sup>3</sup>Regroupement Québécois sur les Matériaux de Pointe (RQMP), Canada.*

We study the growth of glancing angle deposited films using in situ spectroscopic ellipsometry for the first time. Our results should improve our future ability to control the fabrication of photonic interference filters.

**MF5 • 4:15 p.m.**

**Effects of different thermal histories on the residual stress of ZrO<sub>2</sub> thin films**

*Shao Shuying, Shao Jianda, Fan Zhengxiu; Chinese Acad. of Science, China.*

The influences of the deposition temperature and post-deposition annealing on the residual stress of ZrO<sub>2</sub> films were studied. The variation of residual stress may be attributed to the evolution of the microstructure.

**MF6 • 4:20 p.m.**

**Growth of highly c-axis oriented SBN thin films on Si(100) by the sol-gel method**

*Zhiru Shen, Xiao Yan Cao, Hui Ye, Nian Hui Deng, Bing Guo; Zhejiang Univ., China*

Strontium barium niobate thin films on Si(001) substrates were obtained by sol-gel method. Highly c-axis oriented films were obtained by using the NbCl<sub>5</sub> precursor instead of Nb(OC<sub>2</sub>H<sub>5</sub>)<sub>5</sub>-precursor, appropriate annealing temperature and introduction of buffer layer.

**MF7 • 4:25 p.m.**

**Large area sol-gel optical coatings for french high power laser drivers**

*Eric Lavastre, Philippe Prené, Philippe Belleville; CEA, France.*

Performances of sol-gel coatings provided for the Laser MegaJoule prototype are presented. Sol-gel technology is proved to be a very convenient process to coat large optics requiring high laser damage threshold and outstanding antireflective coatings.

**MF8 • 4:30 p.m.**

**Micro-structured thin-film based photonic crystal for directive thermal sources**

*Ziyad Elalamy, Julien Fièrè, Stéfan Enoch, Ludovic Escoubas, Jean-Jacques Simon, François Flory, Frédéric Lemarquis; Inst. Fresnel, France.*

A photonic crystal composed of a stack of grid-patterned gold evaporated films and ZnSe films is presented. This structure acting as an infrared light thermal source is simulated, fabricated, and experimentally characterized.

**MF9 • 4:35 p.m.**

**Multidielectric quarter-wave coatings on microspheres**

*Philippe Voarino, Carole Deumié, Claude Amra; Inst. Fresnel, France.*

Quarter-wave coatings are deposited on microspheres and their spectral properties are compared to those of planar multilayers, in regard to the sphere diameter. Specific functions are studied to create coloured powders.

**MF10 • 4:40 p.m.**

**Ion assisted deposition of TiO<sub>2</sub>/SiO<sub>2</sub> multilayer for mass-production, Bin Fan, Masahiro Suzuki, Ken**

*Tang; Optorun Co., Ltd., Japan.* Optical and micro-structural properties of TiO<sub>2</sub> and SiO<sub>2</sub> multi-layers deposited by different IAD parameters were investigated. The proper IAD coating conditions for mass-product environmental stable, low scattering and low absorption TiO<sub>2</sub>/SiO<sub>2</sub> multi-layers were gotten after comparison with these filters

**k • 4:45 p.m.**

**Optical properties of fluoride thin films deposited by RF magnetron sputtering, Koichiro Iwahori,**

*Masahiro Furuta, Yusuke Taki, Tomoyuki Yamamura, Akira Tanaka; Nikon Corp., Japan.* Fluoride thin films for 193nm lithography were deposited by three different types of RF magnetron sputtering.

Systematic analysis of relationship between optical properties and deposition conditions of these thin films were discussed.

**MF12 • 4:50 p.m.**

**Preparation of high performance optical coatings with fluoride-nano-particle films made from**

**autoclaved sols**, *Tsuyoshi Murata; Nikon Corp., Japan*. An ultra-low refractive index is very advantageous when one designs antireflection coating. We have successfully obtained high quality  $\text{MgF}_2$  thin films with ultra-low refractive indices from autoclaved sols prepared from magnesium acetate and hydrofluoric acid.

*Salon A*

**4:55 p.m. – 5:55 p.m.**

**MG • Poster Session II**

**Tuesday, June 29, 2004**

*Grand Ballroom Foyer*

**7:30 a.m. – 5:30 p.m.**

**Registration**

*Kiva Ballroom*

**7:30 a.m. – 8:30 a.m.**

**Continental Ballroom**

*Salon B and C*

**8:30 a.m. – 9:45 a.m.**

**TuA • Nature/Catalysis**

*Charles K. Carniglia; JDS Uniphase, USA, Presider*

*Brian Sullivan; Iridian Spectral Technologies, Canada, Presider*

**TuA1 • 8:30 a.m.**

**(Invited)**

**An introduction to natural photonic systems**

*Peter Vukusic; Exeter Univ., UK.*

Diverse designs of naturally evolved nano-scale periodicity generate optical functionality in the living world. While these systems have clearly evolved for biological purposes, they are increasingly offering inspiration and design protocols for applied optical technologies.

**TuA2 • 9:00 a.m.**

**(Invited)**

**Photoactive coatings for a photolytic artificial lung device**

*Peter Martin; PNL Batelle Northwest, USA.*

Photoactive anatase  $\text{TiO}_2$  films developed for use in photolytic artificial lung. PAL capable of facilitating gas exchange in blood, thereby bypassing alveolar-capillary interfaces. Device will eventually be used in ex-vitro and in-vitro devices.

**TuA3 • 9:30 a.m.**

**The structural color of rainbow ammonite**

*Masashi Oyabu<sup>1</sup>, Shigetaro Ogura<sup>2</sup>; <sup>1</sup> Ph.D. Course, Kobe Design Univ., Japan, <sup>2</sup> Faculty of Graduate School, Kobe Design Univ.; Japan.*

*Placenticerias meeki* (rainbow ammonite) which generates iridescence and has microstructure on the surface or cross-section of its' shell was observed in order to investigate the mechanisms of the structural color.

**TuA4 • 9:35 a.m.**

**Enhancement of photocatalyticity using an optical interference effects**

*T. Nuida, N. Kanai, T. Watanabe, K. Hashimoto, Hisashi Ohsaki; Univ. of Tokyo, Japan.*

Self-cleaning Al mirror system with a photocatalytic titania thin film as the outermost layer was designed realizing a higher ultra-violet (UV) light absorption by the titania layer and a neutral reflectance spectrum in visible region.

**TuA5 • 9:40 a.m.**

### **Photocatalytic properties of SnO<sub>2</sub>/TiO<sub>2</sub>/glass multilayers**

*N. Kanai, Y. Fukunaga, M. Suzuki, T. Watanabe, K. Hashimoto, Hisashi Ohsaki; Univ. of Tokyo, Japan.*  
Photocatalytic activities of SnO<sub>2</sub>/TiO<sub>2</sub>/Glass were realized by controlling the SnO<sub>2</sub>/TiO<sub>2</sub> interface and SnO<sub>2</sub> film properties. The results removed the restriction on the layer design for optical coatings with photocatalicity.

*Grand Ballroom Foyer*

**9:30 a.m. – 5:30 p.m.**

**Exhibit Open**

*Grand Ballroom Foyer*

**9:45 a.m. – 10:15 a.m.**

**Coffee Break**

*Salon B and C*

**10:15 a.m. – 11:25 a.m.**

**TuB • Design of Optical Coatings**

*Alexander V. Tikhonravov; Res. Computing Ctr. of Moscow State Univ., Russian Federation, Presider*  
*Markus Tilsch; OCLI/JDSU, USA, Presider*

**TuB1 • 10:15 a.m.**

**(Invited)**

**New AR design concepts with equivalent layers**

*Uwe Schallenberg; MSO-Jena, Germany.*

Some new concepts to design AR coatings with equivalent layers are discussed including an approach to use the theory of stopband suppression as one of the basics of broadband AR coatings.

**TuB2 • 10:45 a.m.**

**AR–hard broadband antireflective coatings generated by a controlled needle–optimization technique**

*Ulrike Schulz<sup>1</sup>, Norbert Kaiser<sup>1</sup>, Uwe B. Schallenberg<sup>2</sup>; <sup>1</sup>Fraunhofer Inst. für Angewandte Optik und Feinmechanik, Germany, <sup>2</sup>MSO-Jena Mikroschichtoptik GmbH, Germany.*

AR–hard designs can be understood as step–down designs composed of layer stacks with low equivalent index. The AR bandwidth can be adjusted in accordance with the optical thickness used for each step.

**TuB3 • 10:50 a.m.**

**Practical layer designs for polarizing beam splitter cubes**

*Bernhard von Blanckenhagen; Carl Zeiss, Germany.*

LCoS based digital projection systems require high performance polarizing beam splitters. The classical beam splitter cube with immersed interference coating can fulfil these requirements. Practical layer stacks can be generated by computer optimisation.

**TuB4 • 10:55 a.m.**

**New optical coating optimization algorithm based on the equivalent layers theory**

*Tatiana V. Amotchkina<sup>1</sup>, Alexander V. Tikhonravov<sup>1</sup>, Michael K. Trubetskov<sup>1</sup>, Alfred Thelen<sup>2</sup>; <sup>1</sup>Res. Computing Ctr. of Moscow State Univ., Russian Federation, <sup>2</sup>Prof. Dr.–Ing. Alfred Thelen & Partner, Germany.*

A new optical coating design algorithm using the equivalent layers theory is presented. The algorithm is based on the merit function constrained optimization in the accessible domain of equivalent phase thicknesses and equivalent refractive indices.

**TuB5 • 11:00 a.m.**

**Design of minus filters using arbitrary refractive index films**

*Yorio Wada, Nobuyoshi Toyohara, Yoshiki Shinta, Shigemi Iura, Kenji Takahashi, Ken Kawamata; Olympus Corp., Japan.*

Newly designed minus filters using arbitrary refractive index films are presented. The filters show no ripples in the transmittance and have sharp rejection–band edges.

**TuB6 • 11:05 a.m.**

**A simple way to include dispersion in the design of graded-index optical filters by the Fourier transform method**

*Stéphane Larouche, Ludvik Martinu; Ecole Polytechnique de Montréal, Canada.*

We propose to include dispersion in the Fourier transform method by applying a multiplicative correction factor and a wavelength scaling of the Q function. Results show good agreement with the target.

**TuB7 • 11:10 a.m.**

**Three layer equivalent theory for a layer having  $n$  and  $k$**

*William H. Southwell; Table Mountain Optics, USA.*

Any layer with arbitrary refractive index  $n$  and extinction coefficient  $k$  is equivalent to three layers with fixed  $n$  and  $k$ .

**TuB8 • 11:15 a.m.**

**The optical properties of periodic multilayer thin films of negative and positive refractive index medium**

*Xu Liu, Xiang Dong Liu, Peifu Gu, Jinfa Tang; Zhejiang Univ., China.*

The interference effect of periodic negative and positive refractive index multilayer thin films is investigated. The ultra-wide reflective band and rippleless in transition region are presented great different from the normal multilayer thin film coatings.

**TuB9 • 11:20 a.m.**

**Estimation for the maximum of electric field in multilayer high-reflectors**

*Alexander V. Tikhonravov, M. K. Trubetskov; Res. Computing Ctr. of Moscow State Univ., Russian Federation.*

We present theoretical estimation predicting: maximum value of electric field inside multilayer-high-reflector cannot be reduced below value specified by refractive index of ambient medium and highest-layer refractive index. Estimation valid for high-reflecting-coating of arbitrary type.

**TuB10 • 11:25 a.m.**

**Chirped-cavity dispersive compensation filter design, Ya-Ping Lee, Cheng-Chung Lee; Inst. of Optical Sciences, Taiwan Republic of China.** A new structure of dispersive compensation filter including the advantages of GTI filter and CM was designed. The chirped-cavity dispersion compensator (CCDC) filter provides a negative GDD of  $-50 \text{ fs}^2$  with bandwidth of 56THz.

*Salon A*

**11:30 a.m. – 12:25 p.m.**

**TuC • Poster Session III**

*Kiva Ballroom*

**12:25 p.m. – 1:35 p.m.**

**Lunch**

*Salon B and C*

**1:35 p.m. – 2:05 p.m.**

**TuD • Design Problem**

*Christopher Stolz; Lawrence Livermore Natl. Lab., USA, Presider*

*Uwe Schallenberg; MSO-Jena, Germany, Presider*

**TuD1 • 1:35 p.m.**

**(Invited)**

**Design problem**

*Markus Tilsch<sup>1</sup>, Karen Hendrix<sup>1</sup>, Pierre Verly<sup>2</sup>; <sup>1</sup>OCLI/JDS Uniphase, USA, <sup>2</sup>Inst. for Microstructural Sciences, Natl. Res. Council, Canada.*

2 thin-film design-problems proposed: broadband, broad-angle antireflection (AR) coating for visible (Problem A), and 'minimum-shift' immersed-short-pass filter (Problem B). 25 submissions received: 13-Problem A, 12-Problem B. Winners announced at conference, in-depth analysis of designs presented.



Salon B and C

**2:05 p.m. – 3:20 p.m.**

**TuE • Monitoring**

*Christopher Stolz; Lawrence Livermore Natl. Lab., USA, Presider*

*Uwe Schallenberg; MSO–Jena, Germany, Presdier*

**TuE1 • 2:05 p.m. (Invited)**

**Optical broadband monitoring of conventional and ion processes**

*Detlev Ristau, Tobias Groß, Marc Lappschies; Laser Zentrum Hannover e.V., Germany.*

This contribution is focussed on applications of spectroscopic methods for the precise control of deposition processes. Different approaches for online spectroscopy on the growing layer systems will be evaluated for conventional and ion processes.

**TuE2 • 2:35 p.m.**

**Optical monitoring of dip coating**

*Alexandre F. Michels, Thiago Menegotto, Hans P. Grieneisen, Flavio Horowitz; Inst. de Fisica, UFRGS, Brazil.*

Interferometric monitoring is applied to dip coating with Newtonian, non-volatile oils and compared to a simple model. For more complex films, a new polarimetric approach is introduced for direct measurement of a varying refractive index.

**TuE3 • 2:40 p.m.**

**Fast scanning ellipsometer: Second generation**

*Kopel Rabinovitch<sup>1</sup>, Gregory Toker<sup>2</sup>, Andrei Brunfeld<sup>2</sup>; <sup>1</sup>ELOP – Electrooptics Industries, Ltd. (retired), Israel, <sup>2</sup>Amsys, Ltd., Israel.*

A scanning multi-angle ellipsometer equivalent to the null configuration is described. It is free from any mechanical motion, has data acquisition rate of 10 – 100 kHz, and is suitable for real-time surface inspection applications.

**TuE4 • 2:45 p.m.**

**Application of optical broad band monitoring to quasi-rugate filters by ion beam sputtering**

*Marc Lappschies, Björn Görtz, Detlev Ristau; Laser Zentrum Hannover e.V., Germany.*

An example for a fabricated quasi-rugate-filter is presented, which demonstrates the potential of broad-band-optical-monitoring in conjunction with the ion-beam-sputter-process. This method allows for comparing basic theory of interference-coatings containing very thin layers to practical results.

**TuE5 • 2:50 p.m.**

**Real time process control and monitoring in multi-layer filter deposition**

*Svetlana Dligatch, Roger P. Netterfield; CSIRO, Australia.*

We report on the progress in real-time deposition control in the fabrication of non-quarter-wave multi-layer optical designs with demanding specifications. A combination of real-time ellipsometric and spectrophotometric monitoring was used to achieve sub-nanometer accuracy.

**TuE6 • 2:55 p.m.**

**In-situ broadband monitoring and characterization of optical coatings**

*Steffen Wilbrandt, Robert Leitel, Dieter Gäbler, Olaf Stenzel, Norbert Kaiser; Fraunhofer Inst. für Angewandte Optik und Feinmechanik, Germany.*

An in-situ broadband monitoring system to measure reflectance or transmittance of optical coatings deposited with IAD was developed. First results on the deposition of metal island layers and gradient refractive index layers are presented.

**TuE7 • 3:00 p.m.**

**On-line control of the deposition of optical coatings by magnetron sputtering**

*Matthias List<sup>1</sup>, Christian Melde<sup>1</sup>, Christoph Köckert<sup>1</sup>, Claus Illgen<sup>2</sup>; <sup>1</sup>Von Ardenne, Germany, <sup>2</sup>Berliner Glas, Germany.*

Reactive sputtering processes become more relevant for the deposition of complex optical coatings. Using an in situ transmittance measurement the thickness growing of low (SiO<sub>2</sub>) and high (Nb<sub>2</sub>O<sub>5</sub>) index layers can be measured and controlled.

**TuE8 • 3:05 p.m.**

**Turning–point monitoring is not simply optical thickness compensation**

*Stéphane Larouche, Aram Amassian, Bill Baloukas, Ludvik Martinu; Ecole Polytechnique de Montréal, Canada.*

Contrarily to widespread belief, turning–point monitoring entails more than simply optical thickness compensation. In fact, we demonstrate that optical thickness compensation is barely better than no correction at all for the fabrication of narrow–band filters.

**TuE9 • 3:10 p.m.**

**Dynamics of surface modifications during optical coating deposition in plasma–assisted processes**

*Aram Amassian, Patrick Desjardins, Ludvik Martinu; Ecole Polytechnique de Montréal, Canada.*

We analyze substrate surface modifications in initial moments of optical coating deposition under intense ion bombardment using in situ spectroscopic ellipsometry. This is followed by a study of the initial growth of TiO<sub>2</sub> thin films.

**TuE10 • 3:15 p.m.**

**High accurate in–situ optical thickness monitoring**

*Alfons Zoeller, Michael Boos, Harro Hagedorn, Werner Klug, Christopher Schmitt; Leybold Optics GmbH, Germany.*

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

*Grand Ballroom Foyer*

**3:20 p.m. – 3:50 p.m.**

**Coffee Break**

*Salon B and C*

**3:50 p.m. – 5:15 p.m.**

**TuF • Stability of Coatings**

*Steve Browning; Ball Aerospace Corp., USA, Presider*

*Detlev Ristau; Laser Zentrum Hannover e.V., Germany, Presider*

**TuF1 • 3:50 p.m.**

**(Invited)**

**Optical coatings for high power lasers**

*Guillaume Ravel; CEA–DRT–LETI/DOPT, France.*

This paper reviews steps of experimental progress towards very high Laser–Induced Damage Thresholds for hafnia/silica coatings. Extensive laser damage testing and deposition capabilities provide opportunities to display a few case studies.

**TuF2 • 4:20 p.m.**

**Laser damage testing of small optics for the Natl. Ignition Facility**

*Robert Chow, Mike Runkel, John R. Taylor; Univ. of California, USA.*

A damage test procedure was established for optical components that have large incident beam footprints. The procedure was applied on coated samples for a high powered 1053 nm, 3–ns pulse length laser system.

**TuF3 • 4:25 p.m.**

**Polarizers coatings for the Laser MegaJoule prototype**

*Eric Lavastre<sup>1</sup>, Jérôme Néauport<sup>1</sup>, Jacky Duchesne<sup>1</sup>, Hervé Leplan<sup>2</sup>, François Houbre<sup>2</sup>; <sup>1</sup>CEA, France, <sup>2</sup>SAGEM, France.*

Optical coatings performances of polarizers provided for the Laser MegaJoule prototype are presented. These large silica optics are used in dry environment and have to meet stringent spectral and laser induced

damage threshold requirements.

**TuF4 • 4:30 p.m.**

**Pulsed laser induced damage model of optical coatings with a spherical absorbing inclusion**

*Yuanan Zhao, Jianda Shao, Tao Wang, Dongping Zhang, Hongbo He, Zhengxiu Fan; Shanghai Inst. of Optics and Fine Mechanics, Chinese Acad. of Sciences, China.*

Laser damage model of optical coatings with a spherical inclusion was improved. The absorption cross section of the inclusion was simplified. The numerical result was found to agree well with experimental data.

**TuF5 • 4:35 p.m.**

**The effects of ion cleaning on the roughness of substrates and laser induced damage thresholds of films**

*Dawei Zhang, Jianda Shao, Shuhai Fan, Yuana Zhao, Ruiying Fan, Yingjian Wang, Zhengxiu Fan; Shanghai Inst. of Optics and Fine Mechanics, Chinese Acad. of Sciences, China.*

Ion cleaning has different effects on the roughness of substrates with the different ion cleaning time, and it improves the laser induced damage thresholds of films greatly.

**TuF6 • 4:40 p.m.**

**Optical properties and thermal stability of niobium–pentoxide single layers**

*Nils Beermann, Henrik Ehlers, Detlev Ristau; Laser Zentrum Hannover e.V., Germany.*

This contribution is focussed on the optical properties and thermal stability of Niobium–pentoxide single layers produced by different coating techniques. The evaluation is based upon Laser calorimetry according to ISO 11551, transmission and reflexion measurements.

**TuF7 • 4:45 p.m.**

**High temperature stable coatings for use on short arc lamps**

*Arnd Ritz, Holger Moench; Philips GmbH, Germany.*

Dichroic coatings are prepared on short arc lamps by magnetron sputtering. Their optical properties and long–term temperature stability up to 1000°C are examined. The influence on lamp characteristics and application in projection systems are discussed.

**TuF8 • 4:50 p.m.**

**Coatings for the next–generation micro mechanical mirrors**

*Alexandre Gatto<sup>1</sup>, Minghong Yang<sup>1</sup>, Norbert Kaiser<sup>1</sup>, Jörg Heber<sup>2</sup>, Jan Uwe Schmidt<sup>2</sup>, Thilo Sandner<sup>2</sup>, Harald Schenk<sup>2</sup>, Hubert Lakner<sup>2</sup>; <sup>1</sup>Fraunhofer Inst. für Angewandte Optik und Feinmechanik, Germany, <sup>2</sup>Fraunhofer Inst. Photonische Mikrosysteme, Germany.*

High performance coatings for the next–generation micro–mechanical mirrors have been developed. The high reflective metal systems are applicable in MOEMS from the NIR down to the VUV spectral region.

**TuF9 • 4:55 p.m.**

**Light intensification by nodular defects in multilayer coatings**

*Christopher Stolz<sup>1</sup>, François Y. Génin<sup>1</sup>, Thomas V. Pistor<sup>2</sup>; <sup>1</sup>Lawrence Livermore Natl. Lab., USA, <sup>2</sup>Panoramic Technology Inc., USA.*

The laser damage threshold of defects within optical coatings is inversely proportional to defect height. Electric-field modeling shows light intensification as large as 11.8× at normal incidence and as large as 20.4× at oblique incidence.

**TuF10 • 5:00 p.m.**

**All–dielectric front–surface non–polarizing beam splitter operating between 500 and 600 nm**

*Penghui Ma, P. G. Verly, J. A. Dobrowolski, F. Lin; Natl. Res. Council of Canada, Canada.*

Design and experimental realization of all–dielectric front–surface non–polarizing beam splitters is described. The challenge was to find designs with good performance in this configuration that were practical enough to be made with current technology.

**TuF11 • 5:05 p.m.**

**Optical & Environmental Performance of Durable Silver Mirror Coatings fabricated at LLNL**

*Jess Wolfe, Dave Sanders; Lawrence Livermore Natl. Lab., USA.*

Family of Durable Silver Mirror Designs fabricated at LLNL. We report on optical–environmental performance of basic design, which can be cleaned with standard glass cleaner and cloth after months of exposure to outside atmosphere.

**TuF12 • 5:10 p.m.**

**An electrochemical impedance spectroscopy study of durable silver coatings**

*Chung–Tse Chu, Peter D. Fuqua, James D. Barrie; The Aerospace Corp., USA.*

Corrosion protection behavior of SiN<sub>x</sub> coated silver–mirror investigated with electrochemical impedance spectroscopy and compared with results from humidity testing. A 3 Å NiCrN<sub>x</sub> interlayer between SiN<sub>x</sub> and Ag afforded denser SiN<sub>x</sub> film and enhanced mirror–durability.

*Salon A*

**5:15 p.m. – 6:15 p.m.**

**TuG • Poster Session IV**

**Wednesday, June 30, 2004**

*Grand Ballroom Foyer*

**8:00 a.m. – 5:30 p.m.**

**Registration**

*Kiva Ballroom*

**7:30 a.m. – 8:30 a.m.**

**Continental Breakfast**

*Salon B and C*

**8:30 a.m. – 9:45 a.m.**

**WA • Plasma Processes/Antireflection**

*Peter Martin; PNL Batelle Northwest, USA, Presider*

*Michael L. Fulton; Ion Beam Optics, USA, Presider*

**WA1 • 8:30 a.m.**

**(Invited)**

**Plasma–ion assisted deposition of optical coatings on thermoplastics polymers**

*Ulrike Schulz, Peter Munzert, Norbert Kaiser; Fraunhofer Inst. Angewandte Optiik und Feinmechanik, Germany.*

Coating of plastics requires substrate specific technologies to achieve sufficient coating adhesion and long–term stability in use. Plasma–Ion Assisted Deposition is applied to produce multifunctional coatings on different thermoplastic polymers.

**WA2 • 9:00 a.m.**

**(Invited)**

**Plasma based processes for optical surface modifications in Germany**

*Ralf Fellenberg; VDI Technologiezentrum GmbH, Germany.*

Optical coatings have a long history in Germany. New Res. developments of plasma based processes were done by Inst.s and companies during the past two decades. This technologies were used to create innovative optical products.

**WA3 • 9:30 a.m.**

**Gradient antireflection coatings with complex refractive index**

*Peep Adamson; Inst. of Physics, Univ. of Tartu, Estonia.*

Antireflection coatings for absorbing materials, based on films with an inhomogeneous complex refractive index, are considered. It is shown that properly selected absorbing materials can be used to obtain surfaces with extremely low reflection coefficients.

**WA4 • 9:35 a.m.**

**Design and fabrication of infrared anti-reflective Germanium gratings**

*Jean-Jacques Simon<sup>1</sup>, Ludovic Escoubas<sup>1</sup>, Marisa Lo Monaco<sup>1</sup>, Ron Willey<sup>2</sup>, Ziyad Elalamy<sup>1</sup>, Stéfan Enoch<sup>1</sup>, Hugues Giovannini<sup>1</sup>; <sup>1</sup>Inst. Fresnel, France, <sup>2</sup>Willey Optical Consultants, USA.*

A germanium grating, working in the infrared at high angles of incidence, has been designed and fabricated using wet anisotropic etching. The reflectance properties are calculated using a modal method and compared with experimental results.

**WA5 • 9:40 a.m.**

**Super antireflection coating at 1.5µm**

*Noboru Uehara, Ryousuke Okuda, Toshitaka Shidara; Santec Corp., Japan.*

We describe the super antireflection (AR) coatings of less than -60 dB ( $R < 0.0001\%$ ) of two layer V-coating and of less than -50 dB ( $R < 0.001\%$ ) of four layer at 1.5 µm.

*Grand Ballroom Foyer*

**9:30 a.m. – 5:30 p.m.**

**Exhibit Open**

*Grand Ballroom Foyer*

**9:45 a.m. – 10:15 a.m.**

**Coffee Break**

*Salon B and C*

**10:15 a.m. – 11:20 a.m.**

**WB • Characterization of Optical Coatings I**

*Angela Duparré; Fraunhofer Inst. für Angewandte Optik und Feinmechanik, Germany, Presider  
Jin Fa-Tang; Zhejiang Univ., China, Presider*

**WB1 • 10:15 a.m.**

**(Invited)**

**Uncertainties in spectral reflectance caused by the measuring instrument**

*Maria Nadal; NIST, USA.*

The existence of many variables in instrument design has made the need for standardized measurements increasingly important in order to achieve accurate reflectance. This paper describes the uncertainties in reflectance caused by the instrument.

**WB2 • 10:45 a.m.**

**Non-optical and optical characterization of gradient index layers and rugate filters**

*Olaf Stenzel, Steffen Wilbrandt, Robert Leitel, Dieter Gäbler, Norbert Kaiser; Fraunhofer Intitut für Angewandte Optik und Feinmechanik, Germany.*

Gradient index films and rugate filters built of niobium pentoxide and silicon dioxide have been produced by IAD. The coatings have been characterized by cross-sectional electron microscopy and EELS, as well as optical spectroscopy.

**WB3 • 10:50 a.m.**

**Determination of optical constants and thickness of crystalline  $\text{Sr}_x\text{Ba}_{1-x}\text{Nb}_2\text{O}_6$  thin films by single transmission measurement**

*Weidong Shen, Xu Liu, Zhiru Shen, Hui Ye, Peifu Gu, Jinfa Tang; Zhejiang Univ., China.*

Using Forouhi-Bloomer model and modified 'Downhill' simplex method, optical constants and film thickness of crystalline SBN60 films with different potassium ion doping ratio are obtained by fitting the measured transmission curve.

**WB4 • 10:55 a.m.**

**Absorptivity measurement for thin films based on surface thermal lensing**

*Shuhai Fan, Hongbo He, Jianda Shao, Zhengxiu Fan, Dongqing Zhang; Shanghai Inst. of Optics and Fine Mechanics, China.*

Two absorptivity measuring methods by a measurement system based on Surface Thermal Lensing theory

are given. The measuring results indicate a deviation of 5ppm and the sensitivity is better than 10ppm.

**WB5 • 11:00 a.m.**

**Dedicated spectrophotometer for localized transmittance and reflectance measurements**

*Laetitia Abel–Tiberini, Frédéric Lemarquis, Michel Lequime; Inst. Fresnel, France.*

A dedicated spectrophotometer is developed for localized transmittance and reflectance measurements with a spatial resolution from 50  $\mu\text{m}$  to 2 mm. Typical applications are related to thickness uniformity characterization and measurements of variable filters.

**WB6 • 11:05 a.m.**

**The algebra of envelopes and the optical characterization of films and interfaces**

*Juan Carlos M. Anton; Univ. Complutense Madrid, Spain.*

Interference films are frequently characterized by the spectrophotometric envelopes. We set a more solid analytical base for the envelope algebra and extend it to cover ellipsometry and more model parameters: absorption, inhomogeneity, roughness, anisotropy, etc...

**WB7 • 11:10 a.m.**

**SiO<sub>2</sub> film aging: Spectral shift on a mirror over a 3 years period**

*Bernard André, Guillaume Ravel, Carole Lediraison; CEA / LETI, France.*

When submitted to air SiO<sub>2</sub> films undergoes chemical reactions with water, which induce physical and chemical changes. The spectral shift of a SiO<sub>2</sub>/HfO<sub>2</sub> Bragg mirror on a 3 years period is discussed.

**WB8 • 11:15 a.m.**

**Interaction between a guided mode and a surface nano defect**

*Javier Durán–Favela<sup>1</sup>, Jorge Gaspar–Armenta<sup>1</sup>, Raúl García–Llamas<sup>1</sup>, José Valenzuela–Benavides<sup>2</sup>;*  
*<sup>1</sup>Univ. de Sonora, Mexico, <sup>2</sup>CCMC-UNAM, Mexico.*

The electromagnetic near–field produced by the interaction between a transverse electric guided mode and a surface nano–defect in a planar structure is studied. A Fourier Transform technique is used to obtain the surface defect profile.

**WB9 • 11:20 a.m.**

**Design of solar energy control windows with thick titanium dioxide layer,** *Masato Tazawa, Masato Tazawa, Ping Jin, Gang Xu, Masahisa Okada, Kazuki Yoshimura; AIST, Japan.* Vanadium dioxide based thermochromic solar energy control window with photo-catalytic effect is proposed. This window consisting of multi-layered thin film on glass has thick titanium dioxide layer exposed to the air.

**WB10 • 11:25 a.m.**

**Characterization of thin films based on reflectance and transmittance measurements at oblique angles of incidence,** *Saulius Nevas, Antti Lamminpää, Farshid Manoocheri, Erkki Ikonen; Helsinki*

*University of Technology, Finland.* The optical parameters of a SiO<sub>2</sub> coating determined from the reflectance data at various incidence angles and those from the normal and oblique-incidence transmittance measurements are compared and the effect of systematic factors is discussed

*Salon A*

**11:30 a.m. – 12:20 p.m.**

**WC • Poster Session V**

*Kiva Ballroom*

**12:20 p.m. – 1:30 p.m.**

**Lunch**

*Salon B and C*

**1:30 p.m. – 2:00 p.m.**

**WD • Measuring Problem**

*Li Li; Natl. Res. Council of Canada, Canada, Presider*

*Robert Schaffer; Evaporated Coatings, Inc., USA, Presider*

**WD1 • 1:30 p.m. (Invited)**

**2004 topical meeting on optical interference coatings: Measurement problem**

*Angela Duparre<sup>1</sup>, Detlev Ristau<sup>2</sup>; <sup>1</sup>Fraunhofer IOF, Germany, <sup>2</sup>Laser Zentrum Hannover, Germany.*

The measurement problem at the OIC'04 concerns two tasks, the determination of the optical parameters and the surface roughness of a single layer oxide coating.

*Salon B and C*

**2:00 p.m. – 3:15 p.m.**

**WE • Characterization of Optical Coatings II**

*Li Li; Natl. Res. Council of Canada, Canada, Presider*

*Robert Schaffer; Evaporated Coatings, Inc., USA, Presider*

**WE1 • 2:00 p.m. (Invited)**

**Light scattering in optical multilayers: review and progress**

*Claude Amra, Carole Deumie; Inst. Fresnel Marseille, France.*

Angle-resolved light scattering has been used for several decades to probe heterogeneities in optical multilayers and substrates. We present a summary of results reached in Marseilles since the 80's, and address promising techniques for future.

**WE2 • 2:30 p.m.**

**High-sensitivity light scattering measurement of optical coating components**

*Stefan Gliech, Sven Schröder, Angela Duparré; Fraunhofer IOF, Germany.*

We report on our recent achievements of the development of measurement systems to determine the light scattering of optical coatings and substrates in a wavelength range from the VUV to the IR spectral region.

**WE3 • 2:35 p.m.**

**Light scattering characterization of superpolished transparent substrates**

*Carole Deumie<sup>1</sup>, Myriam Zerrad<sup>1</sup>, Michel Lequime<sup>1</sup>, Claude Amra<sup>1</sup>, Mike Ewart<sup>2</sup>; <sup>1</sup>Inst. Fresnel, France, <sup>2</sup>WZW, Switzerland.*

Light scattering characterization of surface roughness is used from numerous years. However this technique presents difficulties when the substrates are transparent, because of simultaneous scattering from both faces of the sample.

**WE4 • 2:40 p.m.**

**Accurate formulas for estimating the effect of surface micro-roughness on ellipsometric angles of dielectric thin films**

*Andrei A. Tikhonravov<sup>1</sup>, Alexander V. Tikhonravov<sup>2</sup>, Michael K. Trubetskov<sup>2</sup>; <sup>1</sup>Physics Faculty of Moscow State Univ., Russian Federation, <sup>2</sup>Res. Computing Ctr. of Moscow State Univ., Russian Federation.*

Accurate formulas for the variations of ellipsometric angles caused by the surface micro-roughness are derived. These formulas are used for estimating sensitivities of the ellipsometric angles to the thickness of surface overlayer presenting surface micro-roughness.

**WE5 • 2:45 p.m.**

**Design and characterization of ultra-hydrophobic coatings**

*Marcel Flemming, Kristina Roder, Angela Duparré; Fraunhofer IOF, Germany.*

Films with specific nanoroughness are designed by "virtual coating" to yield ultra-hydrophobicity while the light scatter remained below an application-relevant threshold. Examples of "real coating" experiments demonstrate the realization of predicted properties.

**WE6 • 2:50 p.m.**

**High-resolution photothermal microscope: A very sensitive tool for the detection of nano-scale isolated absorbing defects in optical coatings**

*Bertrand Bertussi, Mireille Commandré, Jean-Yves Natoli; Inst. Fresnel, France.*

Photothermal deflection technique permits to highlight the presence of absorbing defects in optical components. The detection of nano-sized isolated inclusions requires to develop a very sensitive

photothermal setup.

**WE7 • 2:55 p.m.**

**Angular phase measurements of polarized scattering from arbitrary surfaces and bulks**

*Carole Deumié, Olivier Gilbert, Claude Amra; Inst. Fresnel, France.*

Angular polarimetric phase measurements are recorded from scattering samples in the far field. The data allow to separate surface and bulk effects, and provide new information to reconstruct the topography of random samples.

**WE8 • 3:00 p.m.**

**Simultaneous absorption, scattering and fluorescence mappings for defect characterization on UV optical coatings and substrates**

*Laurent Gallais, Mireille Commandré; Inst. Fresnel, France.*

We present an experimental set-up, based on the laser-induced deflection technique, to measure simultaneously the 244nm laser absorption, scattering and fluorescence with a high sensitivity and resolution. Application are given on UV coatings and substrates.

**WE9 • 3:05 p.m.**

**Optical characterizations of thin films for gas sensors**

*Thomas Mazingue<sup>1</sup>, Christian Forestier<sup>1</sup>, Ludovic Escoubas<sup>2</sup>, François Flory<sup>2</sup>, Miroslav Jelinek<sup>3</sup>, Khalifa Aguir<sup>4</sup>; <sup>1</sup>Cybernetix, France, <sup>2</sup>Inst. Fresnel, France, <sup>3</sup>Inst. of Physics, Czech Republic, <sup>4</sup>L2MP, France.*

The opto-geometrical properties of various sensitive thin films involved in gas sensing applications are investigated using m-line technique and Atomic Force Microscopy. Variations of these optical properties under gas exposure are studied.

**WE10 • 3:10 p.m.**

**Crystallographic evaluation of ion-assisted SiO<sub>2</sub> thin film with EELS in TEM and AES**

*Tomonori Aoki<sup>1</sup>, Shigetaro Ogura<sup>2</sup>, Kouichi Muro<sup>1</sup>, Takashi Watanabe<sup>3</sup>; <sup>1</sup>Optron Inc., Japan, <sup>2</sup>Kobe Design Univ., Japan, <sup>3</sup>Kobelco Res. Inst., Inc., Japan.*

We tried evaluation for an amorphous silica film with EELS in atomic scale. In film deposition, ion assist in evaporation change the amorphous to crystalline film was found.

*Grand Ballroom Foyer*

**3:15 p.m. – 3:45 p.m.**

**Coffee Break**

*Salon B and C*

**3:45 p.m. – 5:00 p.m.**

**WF • Short and Intense Wavelength Coatings**

*Ludvik Martinu; Ecole Polytechnique de Montréal, Canada, Presider*

*Angela Duparré; Fraunhofer Inst. für Angewandte Optik und Feinmechanik, Germany, Presider*

**WF1 • 3:45 p.m.**

**(Invited)**

**Status of the Natl. Ignition Facility: An optics perspective**

*Jack Campbell; Lawrence Livermore Natl. Lab., USA.*

The NIF is now operating the first four of its 192 independent laser beamlines. The design of the laser system is discussed from an optics perspective and the status of the optics manufacturing effort reviewed.

**WF2 • 4:15 p.m.**

**Physical vapor deposition of fluoride coatings using a pulsed ion source**

*Hansjoerg Niederwald<sup>1</sup>, Henrik Ehlers<sup>2</sup>, Stefan Günster<sup>2</sup>, Detlev Ristau<sup>2</sup>; <sup>1</sup>Carl Zeiss, Germany, <sup>2</sup>Laser Zentrum Hannover e.V., Germany.*

An ST 2000 Pulsed Ion Source was applied to produce optical thin films of MgF<sub>2</sub> and LaF<sub>3</sub> for the VIS and NUV. In situ film growth studies, contamination, optical parameters and environmental stability are discussed.



**WF3 • 4:20 p.m.**

**Microstructure related properties at 193nm of MgF<sub>2</sub> and GdF<sub>3</sub> films deposited by resistive heating boat**

*Ming-Chung Liu<sup>1</sup>, Cheng-Chung Lee<sup>1</sup>, Masaaki Kaneko<sup>2</sup>, Kazuhide Nakahira<sup>2</sup>, Yuuichi Takano<sup>2</sup>; <sup>1</sup>Inst. of Optical Sciences, Natl. Central Univ., Taiwan Republic of China, <sup>2</sup>Tochigi Nikon Corp., Japan.*

MgF<sub>2</sub> and GdF<sub>3</sub> are used for the coating at 193nm. Single layer and multi-layer coatings were deposited by resistive heating boat. Optical characteristics, microstructure and stress of the films have been investigated.

**WF4 • 4:25 p.m.**

**Optical coatings for the 157 nm full-field exposure tool FS1**

*Minoru Otani, T. Itho, S. Kuwabara, R. Biro, H. Fukushima, G. S. Jung, K. Sone; Canon Inc. Optics R&D Ctr., Japan.*

Canon's 157 nm full-field exposure tool FS1 is in the stage of the total evaluation on the actual production tool. The optical performance of the coatings used for the FS1 is presented.

**WF5 • 4:30 p.m.**

**Fluoride coatings for DUV/VUV optics fabricated by Ion Beam Sputtering method**

*Toshiya Yoshida, Keiji Nishimoto, Keiichi Sekine, Kazuyuki Etoh; Central Res. Lab., Japan.*

We have been developing optical coatings of fluoride materials fabricated by Ion Beam Sputtering method, especially for excimer laser lithography. An anti-reflection coating with a transmittance of 99.6% at wavelength of 193.4nm is achieved.

**WF6 • 4:35 p.m.**

**Assessment of AR coated CaF<sub>2</sub> DUV optical components**

*Jue Wang, Robert L. Maier; Corning Tropol Corp., USA.*

A two-step process including standard ellipsometric and quasi-Brewster angle measurements has been employed to identify the process variations originating from coating and/or polished substrates of AR coated CaF<sub>2</sub> deep-ultraviolet (DUV) fluoride components.

**WF7 • 4:40 p.m.**

**Post-fluorination of fluoride films for VUV lithography in order to improve their optical properties**

*Yusuke Taki<sup>1</sup>, Shunji Watanabe<sup>1</sup>, Akira Tanaka<sup>2</sup>; <sup>1</sup>1st R&D Section, Lens Engineering Development Dept., Nikon Corp., Japan, <sup>2</sup>3rd R&D Section, Lens Engineering Development Dept., Nikon Corp. Japan.*

Post-fluorination process that consists of 'fluorination of F-poor areas' and 'modification to denser structure' has been developed. This process reduces the optical losses of fluoride films and prevents the losses from increasing with elapsed time.

**WF8 • 4:45 p.m.**

**Dielectric mirror development for VUV free electron laser**

*Stefan Günster<sup>1</sup>, Detlev Ristau<sup>1</sup>, Alexandre Gatto<sup>2</sup>, Norbert Kaiser<sup>2</sup>, Mauro Trovo<sup>3</sup>, Miltcho Danailov<sup>3</sup>; <sup>1</sup>Laser Zentrum Hannover, Germany, <sup>2</sup>Fraunhofer-Inst. für Angewandte Optik und Feinmechanik, Germany, <sup>3</sup>Sincrotrone Trieste, Italy.*

Mirrors for storage ring free electron lasers in the VUV must provide adequate reflectivity and resistance against synchrotron radiation. The strategy for the dielectric mirror development running between 155 and 190 is presented.

**WF9 • 4:50 p.m.**

**Towards resistant VUV coatings for free electron laser down to 150 nm**

*Alexandre Gatto<sup>1</sup>, Norbert Kaiser<sup>1</sup>, Stefan Günster<sup>2</sup>, Detlev Ristau<sup>2</sup>, Mauro Trovo<sup>3</sup>, Miltcho Danailov<sup>3</sup>; <sup>1</sup>Fraunhofer Inst. für Angewandte Optik und Feinmechanik, Germany, <sup>2</sup>Laser Zentrum Hannover, Germany, <sup>3</sup>Sincrotrone Trieste, Italy.*

Res. and development are currently trying to run storage ring FEL down to 150 nm with robust optics. VUV fluoride optics with protected oxide layers and enhanced metallic mirrors are investigated.

**WF10 • 4:55 p.m.**

### **EUV and soft X-ray multilayer coatings**

*Norbert Kaiser, Sergiy Yulin, Torsten Feigl; Fraunhofer–Inst. für Angewandte Optik und Feinmechanik, Germany.*

Mo/Si multilayers for Extreme Ultraviolet Lithography related applications, Cr/Sc multilayers for the water window and Sc/Si multilayers for the 35 ... 50 nm wavelength range were realized and optimized in terms of reflectivity and stability.

*Salon A*

**5:00 p.m. – 6:00 p.m.**

**WG • Poster Session VI**

*Bill's Grill and Croquet Court*

**6:00 p.m. – 8:00 p.m.**

**Conference Reception**

### **Thursday, July 1, 2004**

*Grand Ballroom Foyer*

**8:00 a.m. – 5:30 p.m.**

**Registration**

*Kiva Ballroom*

**7:30 a.m. – 8:30 a.m.**

**Continental Breakfast**

*Salon B and C*

**8:30 a.m. – 9:50 a.m.**

**ThA • Structure and Fast Coatings**

*Keith Lewis; QinetiQ, UK, Presider*

*Ian J. Hodgkinson; Dept. of Physics, New Zealand, Presider*

**ThA1 • 8:30 a.m. (Invited)**

**Structure and density related properties of metal oxide films**

*Hans Pulker, Stefan Schlichtherle; Univ. of Innsbruck, Austria.*

Structure and density of the material in a deposited film determine many important film characteristics. Energetic coating conditions, strongly influence both and the resulting environmental stable, constrained amorphous films offer interesting optical and mechanical properties.

**ThA2 • 9:00 a.m. (Invited)**

**Multilayer coatings for ultrafast lasers**

*Günter Steinmeyer, Ursula Keller; Max–Born–Inst. für Nichtlineare Optik und Ultrakurzzeitspektroskopie, Germany.*

Chirped mirrors have significantly advanced femtosecond pulse generation. We provide an overview on the design of such mirrors and describe novel approaches towards the compression of octave–spanning spectra to a duration of few optical cycles.

**ThA3 • 9:30 a.m.**

**Time–domain analysis of multilayer mirrors for ultrafast optics**

*Gabriel Tempea, Vladislav Yakovlev; Vienna Univ. of Technology, Austria.*

A merit function that quantifies the capability of dispersive multilayers to control the temporal shape of reflected pulses enables the design of mirrors having air as medium of incidence and supporting the generation of 4–fs–pulses.

**ThA4 • 9:35 a.m.**

**Design of negative–dispersion mirrors for use in Ti:Sapphire femtosecond mode–locked lasers**

*Chunyan Liao, Jianda Shao, Zhengxiu Fan; Res. and Development Ctr. for Optical Thin Film Coatings, Shanghai Inst. of Optical and Fine Mechanics, Chinese Acad. of Sciences, China.*

A new negative-dispersion mirror design is reported. It exhibits high reflectivity (>99.5%) from 720 to 870 nm, high transmittance (>90%) from 510 to 550 nm and smooth group delay dispersion from 740 to 850 nm.

**ThA5 • 9:40 a.m.**

**Ultra-broadband beam splitter with matched group delay dispersion**

*Jung-Won Kim<sup>1</sup>, Franz X. Kaertner<sup>1</sup>, Volker Scheuer<sup>2</sup>, Gregor Angelow<sup>2</sup>; <sup>1</sup>MIT, USA, <sup>2</sup>NanoLayers, Germany.*

We present the design for an ultra-broadband beam splitter from 600 to 1500 nm for femtosecond laser applications. The splitter shows the same dispersion in reflection and transmission equal to a thin fused silica plate.

**ThA6 • 9:45 a.m.**

**Efficient analytic computation of group delay dispersion from optical interference coatings**

*Jonathan R. Birge, Christian Jirauschek, Franz X. Kaertner; MIT, USA.*

An inductive analytic method is presented for computing exact derivatives of phase with respect to frequency for arbitrary dielectric multilayer coatings. This algorithm is useful for the optimization of broadband dispersion compensating femtosecond laser optics.

*Grand Ballroom Foyer*

**9:30 a.m. – 5:30 p.m.**

**Exhibit Open**

*Grand Ballroom Foyer*

**9:50 a.m. – 10:20 a.m.**

**Coffee Break**

*Salon B and C*

**10:20 a.m. – 11:25 a.m.**

**ThB • Filter I**

*Claude Amra; Inst. Fresnel Marseille, France, President*

*Ulrike Schulz; Fraunhofer IOF, Germany, President*

**ThB1 • 10:20 a.m.**

**(Invited)**

**Tunable thin films filters**

*Michel Lequime; Inst. Fresnel, France.*

A comparative analysis of the performances and use constraints of three promising concepts of tunable thin-film filters will be done and completed by a description of a possible design evolution towards configurable items.

**ThB2 • 10:50 a.m.**

**Tunable thin film filters using thermo-optic silicon**

*Lawrence Domash; Aegis Semiconductor Inc., USA.*

Thin film tunable filters without moving parts use thermo-optic effects in PECVD amorphous silicon. Demonstrations include single and multiple cavity tunable filters, and fixed wavelength switchable WDM add/drop filters using hybrid dielectric / semiconductor cavities.

**ThB3 • 10:55 a.m.**

**Broadband tunable Fabry-Perot filters**

*Li Li, Daniel Poitras, Xiaoshu Tong; Natl. Res. Council of Canada, Canada.*

Air-spaced tunable Fabry-Perot filters with low phase dispersion reflecting coatings are designed for 1.2–2.5 $\mu\text{m}$  and 2.0–5.0 $\mu\text{m}$  spectral regions. Calculated performances are presented for two tunable filters with high index materials of amorphous silicon and germanium.

**ThB4 • 11:00 a.m.**

**Variable transmission filters with wide rejection band for space applications**

*Angela M. Piegari<sup>1</sup>, Enrico Masetti<sup>1</sup>, Jiri Bulir<sup>2</sup>; <sup>1</sup>ENEA, Italy, <sup>2</sup>Acad. of Sciences, Czech Republic.*

Variable transmission filters are useful for compact spectrometers. The peak wavelength is required to change over few mm length and the extreme operation–wavelengths ratio to be larger than 2:1. Metal–dielectric filters can satisfy both conditions.

**ThB5 • 11:05 a.m.**

**Solid spaced filters: An alternative for narrow bandpass applications**

*Johan Floriot, Fabien Lemarchand, Gérard Albrand, Michel Lequime; Inst. Fresnel, France.*

Solid–spaced filters are composed of thin transparent wafers acting as Fabry–Perot spacer layers. We study the different steps of the design and the manufacture of a narrow bandpass SSF following the 50Ghz specifications.

**ThB6 • 11: 10 a.m.**

**A simple formula for thermal shift of the center–wavelength of Fabry–Perot type narrow–bandpass filters**

*Sung–Hwa Kim, Chang Kwon Hwangbo; Inha Univ., Republic of Korea.*

We have developed a simple formula to calculate the center–wavelength shift of a Fabry–Perot type narrow–bandpass filter as the temperature varies, which is in good agreement with Takashashi’s experimental results.

**ThB7 • 11:15 a.m.**

**Narrow bandpass hybrid filter with wide rejection band**

*Julien Lumeau, Michel Cathelinaud, Jean Bittebierre, Michel Lequime; Inst. Fresnel, France.*

We present the theoretical simulations and the experimental realization of an ultra–narrow bandpass filter, joining a Fiber Bragg Grating and a dielectric mirror directly deposited at the extremity of the fiber tip.

**ThB8 • 11:20 a.m.**

**Automated optical filter measurement, inspection and mapping system**

*Kevin Mackrodt, M. Hall, J. Howes, P. Girow, I. Toop, S. T. Allan; Thales Optical Coatings, Ltd., UK.*

This paper describes an automated optical filter measuring, inspection and mapping system developed using a spectrophotometer, scanners, ink jet printing system and robot arm. The system provides a fully automated solution for checking product compliance

*Salon A*

**11:25 a.m. – 12:25 p.m.**

**ThC • Poster Session VII**

*Kiva Ballroom*

**12:25 p.m. – 1:35 p.m.**

**Lunch**

*Salon B and C*

**1:35 p.m. – 3:15 p.m.**

**ThD • Filter II**

*Michel Lequime; Inst. Fresnel, France, Presider*

*Douglas Smith; Vacuum Process Technology, Inc., USA, Presider*

**ThD1 • 1:35 p.m.**

**(Invited)**

**The use of optical coatings in projection systems**

*Toshikazu Hirasawa<sup>1</sup>, Yoshinori Chichibu<sup>1</sup>, Hiroshi Kawamura<sup>2</sup>; <sup>1</sup>Nitto Thin Film Lab. Co., Ltd., Japan, <sup>2</sup>Nitto Optical Co., Ltd., Japan.*

Thin film optical coatings are used inside projection display and mainly used for liquid crystal display (LCD) system. The actual use of optical coatings in LCD projector will be presented.

**ThD2 • 2:05 p.m.**

**(Invited)**

**Multilayer thin-film coatings for optical communication systems**

*Martina Gerken; Univ. Karlsruhe, Germany.*

Recent developments in thin-film coatings for optical communication systems reviewed. Emphasis on thin-film designs with dispersion related to photonic-crystal-superprism effect. Single-dispersive coating may be used for multiplexing or demultiplexing several wavelength channels by spatial-beam shifting.

**ThD3 • 2:35 p.m.**

**Non-polarizing thin film interference filters with FTIR**

*Li Li, Penghui Ma, Pierre G. Verly; Natl. Res. Council of Canada, Canada.*

The theory of non-polarizing thin film interference filters operating at angles greater than the critical is described. Examples are given for a beam-splitter, a bandpass filter, a shortwave cut-off filter and a longwave cut-off filter.

**ThD4 • 2:40 p.m.**

**Fabrication of Fabry-Perot filters using porous-dense silicon nitride stacks with optimized interfaces**

*Richard Vernhes, Aram Amassian, Jolanta E. Klemberg-Sapieha, Ludvik Martinu; Ecole Polytechnique de Montréal, Canada.*

We fabricated Fabry-Perot filters using PECVD of porous/dense silicon nitride multilayers. The surface of porous layers was systematically treated by ion bombardement in order to control the properties of interfaces and enhance the filter performance.

**ThD5 • 2:45 p.m.**

**Influence of scatter on out-of-band blocking of multilayer dielectric optical filters**

*James D. Barrie, Peter D. Fuqua, Brandon L. Jones, Kelsey A. Folgner, Chung-Tse Chu; The Aerospace Corp., USA.*

Optical bandpass filters were deposited on substrates seeded with polystyrene microspheres. The resultant scatter caused decreased out-of-band blocking and a dependence of optical density on filter-to-detector distance.

**ThD6 • 2:50 p.m.**

**Temperature stability of thin film interleaver with solid cavity**

*Haixing Chen, Peifu Gu, Xu Liu, Weige Lu, Xiaoyun Qin; Zhejiang Univ., China.*

Analysis shows that the shift of Ctr. wavelength of interleaver is mainly caused by the temperature coefficient of the refractive index of cavity material, not the stress mismatch between solid cavity and thin film stack.

**ThD7 • 2:55 p.m.**

**Demonstration of a novel low-dispersion thin-film DWDM filter for high datarate applications**

*Charles A. Hulse<sup>1</sup>, Karen D. Hendrix<sup>1</sup>, Fred K. Zernik<sup>1</sup>, Markus Tilsch<sup>1</sup>, Georg Ockenfuss<sup>1</sup>, Robert B. Sargent<sup>1</sup>, Andrew Zhao<sup>2</sup>, Heidi Pinkney<sup>2</sup>, Steven Moffat<sup>2</sup>; <sup>1</sup>JDS Uniphase, USA, <sup>2</sup>JDS Uniphase, Canada.*

Conventional thin-film filters introduce chromatic dispersion, which impairs high datarate systems. A 50 GHz filter that imparts <1 ps/nm dispersion over a 30 GHz passband was designed, built and compared to conventional filters.

**ThD8 • 3:00 p.m.**

**Thermal shift determination of DWDM filter from the monitoring curve**

*Sheng-Hui Chen<sup>1</sup>, Chien-Cheng Kuo<sup>1</sup>, Cheng-Chung Lee<sup>1</sup>, Douglas Lu<sup>2</sup>, Ching-Yi Wei<sup>2</sup>; <sup>1</sup>Thin Film Technology Ctr., Taiwan Republic of China, <sup>2</sup>Apogee Optocom Co., Ltd., Taiwan Republic of China.*

The optical monitoring curve behaves abnormally when the temperature does not reach at constant during the deposition. We utilize such an abnormal behavior to predict the thermal shift of a DWDM filter during the fabrication.

**ThD9 • 3:05 p.m.**

**Influence of monitor passband width to layer thickness determination during depositing a DWDM filter**

*Chien-Cheng Kuo<sup>1</sup>, Sheng-Hui Chen<sup>1</sup>, Cheng-Chung Lee<sup>1</sup>, Douglas Lu<sup>2</sup>, Ching-Yi Wei<sup>2</sup>; <sup>1</sup>Thin Film Technology Ctr., Taiwan Republic of China, <sup>2</sup>Apogee Optocom Co., Ltd., Taiwan Republic of China.* Both of monitor passband width and quartz monitor are considered to fabricate a DWDM filter. Peak insertion loss and transmittance were analyzed. Monitor passband width shall be less than half of the design bandwidth.

**ThD10 • 3:10 p.m.**

**Rugate filter made with composite thin film by ion beam sputtering**

*Cheng-Chung Lee<sup>1</sup>, Chien-Jen Tang<sup>1</sup>, Jin-Cherng Hsu<sup>2</sup>, Jean-Yee Wu<sup>1</sup>; <sup>1</sup>Natl. Central Univ., Taiwan Republic of China, <sup>2</sup>Fu-Jen Catholic Univ., Taiwan Republic of China.*

Composite film of Ta-Si oxide with refractive indices varied from 1.48 to 2.15 has been realized by using RF ion beam sputtering. Film surface roughness was less than 0.3nm and a rugate filter was fabricated.

**ThD11 • 3:15 p.m.**

**High performance super-PON thin-film filter**, *Okuda Ryosuke; santec co., Japan* . We describe the high reproducibility high performance super-PON (passive optical network) thin-film filter of 47dB reflection isolation at 1550 to 1560 nm by use of an ion-beam sputter deposition.

*Grand Ballroom Foyer*

**3:20 p.m. – 3:45 p.m.**

**Coffee Break**

*Salon B and C*

**3:45 p.m. – 5:00 p.m.**

**ThE • Filter III/Stress**

*Martina Gerken; Univ. Karlsruhe, Germany, Presider*

*Georg J. Ockenfuss; JDS Uniphase, USA, Presider*

**ThE1 • 3:45 p.m. (Invited)**

**Mechanical properties of optical coatings**

*Jolanta E. Klemberg-Sapieha, Ludvik Martinu; Ecole Polytechnique, Canada.*

This presentation reviews the most important mechanical testing methods and mechanical characteristics for different optical coating applications.

**ThE2 • 4:15 p.m.**

**Ultra-low stress thin film interference filters**

*Georg J. Ockenfuss, Robert E. Klinger; JDS Uniphase, USA.*

A method to reduce the optical-degrading effect of coating stress in a thin-film filter by releasing the filter from the substrate it was deposited on is described. An extremely challenging 8-skip-0-100GHz WDM bandsplitting-filter is demonstrated.

**ThE3 • 4:20 p.m.**

**Parameter-dependent angle effects in microcavities with dielectric Bragg reflectors**

*Ligong Yang, Xu Liu, Peifu Gu; Dept. of Optical Engineering, Zhejiang Univ., China.*

This paper presents an analytic approach to angle-dependent properties in active microcavities with dielectric Bragg reflectors. The analysis is based on the hard mirror (or penetration depth) approximation, and the penetration-length-dependent angle effects are investigated.

**ThE4 • 4:25 p.m.**

**Lateral shift and internal electric fields in multi-cavity narrow-band-pass-filters**

*C. K. Carniglia<sup>1</sup>, D. G. Jensen<sup>2</sup>, A. J. Fielding<sup>3</sup>; <sup>1</sup>JDS Uniphase, USA, <sup>2</sup>ITN Energy Systems, Inc., USA, <sup>3</sup>Applied Sciences, L.L.C., USA.*

The internal and transmitted fields, calculated for a collimated gaussian beam incident on a narrow-band-pass filter at angle, predict a lateral beam shift. For a focused incident beam, the transmitted beam is distorted.

**ThE5 • 4:30 p.m.**

**Beam displacement and distortion effects in narrowband optical thin film filters**

*R. E. Klinger, C. A. Hulse, R. B. Sargent; JDS Uniphase, USA.*

A three-dimensional model for beam propagation through optical interference filters is presented. Results demonstrate such effects as a lateral beam displacement and beam distortion. A measurement that substantiates the displacement effect is described.

**ThE6 • 4:35 p.m.**

**Stress, microstructure and thermal-elastic properties of evaporated thin MgF<sub>2</sub> – films**

*Roland Thielsch<sup>1</sup>, Jörg Heber<sup>2</sup>, Torsten Feigl<sup>2</sup>, Norbert Kaiser<sup>2</sup>; <sup>1</sup>Southwall Europe GmbH, Germany, <sup>2</sup>Fraunhofer Inst. für Angewandte Optik und Feinmechanik, Germany.*

Mechanical stress, microstructure and thermal-elastic properties of thin evaporated MgF<sub>2</sub> films were studied in dependence on substrate temperature. Data on biaxial modulus and coefficient of thermal expansion of 50nm thick films are presented.

**ThE7 • 4:40 p.m.**

**Narrow bandpass filters for the VUV spectral range**

*Minghong Yang, Alexandre Gatto, Norbert Kaiser; Fraunhofer Inst. IOF, Germany.*

VUV narrow bandpass filters are required in analytical chemistry for atomic emission spectrum separation. Design and manufacturing concerning VUV narrow bandpass filters are investigated. Deposition is realized with the required characterization.

**ThE8 • 4:45 p.m.**

**Contribution of Ag surface plasmons to the optical properties of Ag/dielectric-material multilayers**

*Yuko Tachibana<sup>1</sup>, Hisashi Ohsaki<sup>2</sup>; <sup>1</sup>Asahi Glass Co., Ltd., Japan, <sup>2</sup>Univ. of Tokyo, Japan.*

The optical properties and XPS spectra of silver/dielectric-material multilayers were investigated. It was found the surface plasmons of silver are generated in the silver/dielectric-material interface and largely contribute to the optical properties of these multilayers.

**ThE9 • 4:50 p.m.**

**Photonic crystal-photonic crystal surface modes: Narrow band-pass filters**

*Francisco V. Villa<sup>1</sup>, Jorge A. Gaspar-Armenta<sup>2</sup>; <sup>1</sup>Ctr. de Investigaciones en Optica, Mexico, <sup>2</sup>Ctr. de Investigación en Física de la Univ. de Sonora, Mexico.*

The study of properties and conditions of existence of electromagnetic surface modes in one-dimensional photonic crystals is considered by applying the ideas of equivalent multilayers. These modes can be used as multiple cavity filters.

**ThE10 • 4:55 p.m.**

**Optical coatings for thermophotovoltaic spectral control**

*Patrick M. Fourspring<sup>1</sup>, David M. DePoy<sup>1</sup>, Thomas D. Rahmlow, Jr.<sup>2</sup>, Jeanne E. Lazo-Wasem<sup>2</sup>, Edward J. Gratrix<sup>2</sup>; <sup>1</sup>Lockheed Martin Co./KAPL, USA, <sup>2</sup>Rugate Technologies, Inc., USA.*

The efficiency of thermophotovoltaic (TPV) energy conversion is dependent on efficient spectral control. An edge pass filter in series with a highly doped, epitaxially grown layer has achieved the highest performance of TPV spectral control.

*Salon A*

**5:00 p.m. – 6:00 p.m.**

**ThF • Poster Session VIII**

**Friday, July 2, 2004**

*Grand Ballroom Foyer*

**8:00 a.m. – Noon**

**Registration**

*Kiva Ballroom*

**7:30 a.m. – 8:30 a.m.**

**Continental Breakfast**

*Salon B and C*

**8:30 a.m. – 9:45 a.m.**

**FA • Applications I**

*Ian Stevenson, Presider*

*Shigetaro Ogura; Kobe Design Univ., Japan, Presider*

**FA1 • 8:30 a.m. (Invited)**

**Optical interference coatings and the growth of opto–electronic industry in Taiwan**

*Fang C. Ho, IV; Delta Electronics, Inc., Taiwan Republic of China.*

Optical interference coating technology plays a key role in the growth of Taiwan's opto–electronic industry. OIC–related research works in universities and research organizations and R/D programs of market–oriented technologies in industry are reported.

**FA2 • 9:00 a.m. (Invited)**

**Current issues in the science and technology of organic light–emitting devices**

*Joseph Shinar<sup>1,2</sup>; <sup>1</sup>Iowa State Univ., USA, <sup>2</sup>Ames Lab. – USDOE, USA.*

$\pi$ -conjugated materials have enabled the realization of numerous near-UV to red OLEDs. This technology may eventually dominate display, and perhaps even general lighting applications. I will review the outstanding scientific and technological issues in OLEDs.

**FA3 • 9:30 a.m.**

**Anticaloric and antireflective coating for blast shield used in the LMJ laser amplifier**

*Eric Monterrat, Corinne Marcel, Philippe Prené, Claude Bonnin, Philippe Belleville; CEA, France.*

The LMJ light amplifier medium is protected by a 9mm thick glass in case of flashlamp blast. To improve the visible transmission and IR reflection of this shield a coating has been designed and deposited.

**FA4 • 9:35 a.m.**

**Non–polarizing color separation and color re–combination prism for projection display systems**

*Fang C. Ho, IV<sup>1</sup>, Cheng–Wei Chu, IV<sup>2</sup>; <sup>1</sup>Delta Electronics, Inc., Taiwan Republic of China, <sup>2</sup>Industrial Technology Res. Inst., Taiwan Republic of China.*

Prism assembly designed to separate white light into three primary colors through a 2–stage mechanism characterizes in out–performed color management, short and equal optical paths for R,G,B color beams, and simplified physical layout.

**FA5 • 9:40 a.m.**

**Biaxial thin–film coated–plate polarizing beam splitters for use at 45–degrees**

*Ian J. Hodgkinson, Qi H. Wu, Matthew Arnold, Lakshman De Silva; Dept. of Physics, Univ. of Otago, New Zealand.*

We present a design for a thin film polarizing beam splitter that transmits the *p*–polarized component of a beam of light without change of direction and reflects the *s*–polarized component at right angles.

*Grand Ballroom Foyer*

**9:45 a.m. – 10:15 a.m.**

**Coffee Break**

*Salon B and C*

**10:15 a.m. – 11:20 a.m.**

**FB • Applications II**

*Angela M. Piegari; ENEA, Italy, Presider*

*Jolanta Klemberg–Sapieha; École Polytechnique, Canada, Presider*

**FB1 • 10:15 a.m. (Invited)**



**Studies of Reststrahlen band materials in photonics crystals**

*Carl Ribbing<sup>1,2</sup>, Herman Högstrom<sup>1</sup>, Andreas Rung<sup>1,2</sup>; <sup>1</sup>Uppsala Univ., Sweden, <sup>2</sup>Div. of Sensor Technology, Swedish Defence Res. Agency, Sweden.*

Polaritonic gaps are caused by lattice excitations in one of the components in a photonic crystal. The interaction with ordinary photonic gaps, caused by interference, is discussed in 1- and 2-D cases .

**FB2 • 10:45 a.m.****Wide-angle antireflection coatings based on the use of Reststrahlen materials**

*J. A. Dobrowolski<sup>1</sup>, Yanen Guo<sup>1</sup>, Daniel Poitras<sup>1</sup>, Penghui Ma<sup>1</sup>, Tom Tiwald<sup>2</sup>; <sup>1</sup>Natl. Res. Council of Canada, Canada, <sup>2</sup>Woollam Co. Inc., USA.*

The measured performance of the experimentally produced antireflection coatings will be presented. The optical constants of the thin films used in the construction were determined by spectrophotometric ellipsometry and will be compared to literature values.

**FB3 • 10:50 a.m.****Electromagnetic field optimization for enhancing photovoltaic efficiency of organic solar cells**

*Jean-Jacques Simon<sup>1</sup>, Philippe Torchio<sup>1</sup>, Ludovic Escoubas<sup>1</sup>, Michel Cathelinaud<sup>1</sup>, Salima Alem<sup>2</sup>, Jean-Michel Nunzi<sup>2</sup>; <sup>1</sup>Inst. Fresnel, France, <sup>2</sup>ERT Cellules Solaires Photovoltaïques Plastiques, France.*

The electromagnetic field distribution inside multilayer organic solar cells composed of interpenetrated networks of conjugated polymers is calculated. By enhancing the electromagnetic field in the photoactive region, an increase of the photovoltaic efficiency is expected.

**FB4 • 10:55 a.m.****Design study for a two colour avionic head up display**

*Stuart T. Allan, Kevin Mackrodt, S. Ashwell, P. Girow; Thales Optical Coatings, Ltd., UK.*

This paper reports on a design study showing that by using rugate techniques to reflect green and red wavelengths a neutral colour transmission of the outside world is maintained whilst giving high photopic transmission

**FB5 • 11:00 a.m.****Advanced LIGO coating research**

*G. M. Harry, H. Armandula, L. Zhang, G. Billingsley, D. Coyne, D. Shoemaker; LIGO Lab., USA.*

The optical coating R&D work for the Advanced LIGO (Laser Interferometer Gravitational-wave Observatory) is reported. Further reductions of the thermal noise from optical coating for the Advanced LIGO are discussed.

**FB6 • 11:05 a.m.****In-situ Ellipsometry and in-situ Raman thin film growth monitoring**

*Mathias Schubert<sup>1</sup>, Carsten Bundesmann<sup>1</sup>, Nurdin Ashkenov<sup>1</sup>, Eva Schubert<sup>2</sup>, Horst Neumann<sup>2</sup>, Gerd Lippold<sup>3</sup>; <sup>1</sup>Univ. Leipzig, Inst. für Experimentelle Physik II, Germany, <sup>2</sup>Inst. für Oberflächenmodifizierung e.V. Leipzig, Germany, <sup>3</sup>Solarion GmbH Leipzig, Germany.*

Fast and reliable optical in-situ process diagnostics by spectroscopic ellipsometry and Raman scattering spectroscopy demonstrated. Applications: design and control of dielectric multilayer mirrors for soft-x-ray applications and solar-cell absorber layers deposited within a roll-to-roll system.

**FB • 11:10 a.m.****Closing Remarks**

*Norbert Kaiser; Fraunhofer Inst. Applied Optics and Precision Engineering, Germany.*

**11:10 a.m. – 12:10 p.m.****FC • Poster Session IX**

*Grand Ballroom Foyer*

**12:10 p.m. – 1:10 p.m.****Lunch**