Thin Films
Room 306 - Session TF-ThM

Optical Thin Films
Moderator: C. Stoessel, Consultant

8:20am **TF-ThM1 Refractive Index Control of Sputtered Multicomponent Bismuthate Glass Films for Bi-EDWA**, ***J. Kageyama***, *Y. Kondo, M. Ono, N. Sugimoto,* Asahi Glass Co., Ltd., Japan

Multicomponent bismuthate glass films were deposited from a glass target by radio frequency planar magnetron sputtering for fabricating bismuthate erbium doped waveguide amplifier (Bi-EDWA).@footnote 1, 2@ It is essential to control the refractive index of the film, because it affects the beam propagation in optical waveguide structure. The appropriate refractive index difference between the core and the cladding of Bi-EDWA is about 0.03. Thus it is desired that the batch-to-batch reproducibility of refractive index is less than 0.001. The refractive index of the film is mostly stable during the beginning of target life, however it decreases as the total sputtering time increases. In this work, it was revealed that the main reason why the refractive index varies is not the change of cationic composition in the film, but the increase of oxygen concentration in the film as the deposition rate decreases. It was also found that the decrease of deposition rate is caused by the decrease of sputtering rate. Additionally it was considered that the decrease of sputtering rate is linked with the decrease of self bias voltage at the target as the target becomes thinner. We also examined the effect of new magnetic circuit having an improved magnetic alignment and a lower magnetic flux density to make the above-mentioned film properties stable. As a result, we succeeded in obtaining good reproducibilities of refractive index and deposition rate dramatically. It is expected that this method is widely applied in sputtering of insulating films and effective for suppressing the decrease of deposition rates and the variation of film properties. @FootnoteText@ @footnote 1@ Y. Kondo, M. Ono, J. Kageyama, M. Reyes, H. Hayashi, N. Sugimoto, Proc. OFC/NFOEC 2005, Anaheim, CA, USA, PDP2. @footnote 2@ Y. Kondo, M. Ono, J. Kageyama, H. Hayashi, M. Reyes, N. Sugimoto, Electron. Lett. 41, 317 (2005).

8:40am **TF-ThM2 Controlled Doping and Photoluminescence Properties of Er-doped Yttrium Oxide Thin Films**, ***T.T. Van***[1], University of California, Los Angeles*; J. Bargar,* Stanford Synchrotron Radiation Laboratory*; R. Ostroumov, K. Wang, J.P. Chang,* University of California, Los Angeles

Though silica has traditionally been used as the Er host in fiber amplifiers, it is an unsuitable host in small, compact amplifiers due to its low solubility for Er. One potential host is Y@sub 2@O@sub 3@. Its high refractive index allows for a compact geometry and large signal admittance angle, thus higher pumping efficiency. Due to the similarities in crystal structure and lattice constant between Y@sub 2@O@sub 3@ and Er@sub 2@O@sub 3@, a much higher Er concentration can be incorporated Y@sub 2@O@sub 3@, compared to that in silica. Er-doped Y@sub 2@O@sub 3@ thin films were synthesized by radical-enhanced atomic layer deposition (RE-ALD) at 350°C, using metal beta-diketonates as the metal precursors and O radicals as the oxidant. The deposition of Y@sub 2@O@sub 3@ was alternated with Er@sub 2@O@sub 3@ and the Er doping level was effectively controlled by varying the ratio of Y@sub 2@O@sub 3@:Er@sub 2@O@sub 3@ cycles. The films were polycrystalline with a preferential growth in the (111) plane. Room-temperature PL at 1.54 μm was observed in a 500-Å Er-doped (6.6 at.%) Y@sub 2@O@sub 3@ film, showing well-resolved Stark features indicating the proper incorporation of Er in Y@sub 2@O@sub 3@. The result is very promising, since the film is fairly thin and no annealing at high temperature is needed to activate the Er ions. Extended X-ray absorption fine structure (EXAFS) analysis showed an identical Er local environment for samples with 6-14 at.% Er, suggesting the PL quenching at high Er concentration (>12 at.%) is likely dominated by ion-ion interaction and not by clustering. The effective absorption cross section for Er in Y@sub 2@O@sub 3@ was estimated to be on the order of 10@super -18@ cm@super 2@, about three orders of magnitude larger than that in the silica host. These results validate Y@sub 2@O@sub 3@ as a promising Er host and demonstrate that RE-ALD is a viable technique for synthesizing thin films with well-controlled dopant incorporation.

9:00am **TF-ThM3 Alternating Current Thin Film Electroluminescence (ACTFEL) from Zinc Sulfide Doped with Rare Earth Fluorides**, ***D.M. DeVito***, *A.A. Argun, M.R. Davidson, P.H. Holloway,* University of Florida

Thin film electroluminescent (EL) devices are an excellent source for efficient infrared emission. A wide variety of applications exist for infrared emitters, including therapeutic medical treatment, chemical analysis, infrared displays and telecommunications. Rare earth elements, such as erbium, thulium and holmium are ideal choices for dopants in phosphors because they possess a number of sharp transition in the infrared region from 850-2800nm. These rare earth dopants also emit in the visible region (400-700 nm) and have been used in a variety of visible display technologies. Zinc sulfide is a suitable semiconductor host material because it is chemically stable, possesses a bandgap of 3.6 eV at 300 K and is therefore transparent to visible and NIR photons, and provides a lattice in which electrons can be excited to ballistic energies in order to excite emission from rare earth dopants. Thin films, approximately 0.8 microns thick, of rare earth doped ZnS were RF magnetron sputter deposited at 120 W from dual targets of undoped ZnS and rare earth fluoride doped ZnS. Deposition temperature, duty cycle, sputter gas pressure and post-deposition annealing temperature were varied in a design-of-experiment to optimize the ratio of near-infrared to visible emission. Suppression of visible emission can result in energy transfer into the infrared transitions and higher NIR/visible intensity ratios. Post-deposition annealing is a key parameter for increasing this ratio, and temperatures between 350°C and 525°C for 1 hour in N@sub 2@ show good results. Maximum EL radiance for ZnS:ErF@sub 3@ at 1550 nm was increased from ~1 μW/cm@super 2@ before annealing to 28 μW/cm@super 2@ post-anneal. The optimum concentrations of both rare-earth ion and fluorine were determined by EDS and SIMS analysis.

9:20am **TF-ThM4 Custom-design of Optical Thin Films of Silicon Oxide by Direct Write Deposition**, ***H.D. Wanzenboeck***, *M. Fischer, E. Bertagnolli,* Vienna University of Technology, Austria

The fabrication of optical transparent thin films on specific areas has gained increased interest due to optical interconnect concepts. Robust, inorganic materials such as silicon oxide provide optical interconnects with a high bandwith and a fast, power-saving data transmission. Moreover, the fabrication of transparent thin flims is also desirable for the modification of optical photomasks. This work describes a rapid fabrication approach of thin silicon oxide films on confined areas by direct-write deposition. This maskless process utilizes the localized chemical vapor deposition on specific areas utilizing a focused electron beam. The deposition from siloxane vapor in presence of oxygen is initiated by the energy of the electron beam with a 5 nm diameter. By scanning the beam, thin films with arbitrary geometry and 3-dimensional structures were deposited. The process was optimized towards a high deposition rate and high material purity. The influence of process parameters on the deposition efficiency is discussed. A characterization of the chemical composition and of the surface roughness was performed with AES and AFM respectively. The optical properties were investigated by infrared and UV/Vis spectroscopy. The correlation to processing conditions and the growth mechanism is discussed. The electrical features of silicon oxide were tested with a metal-insulator-metal capacitor setup. This work illustrates the flexibility of this maskless method and the potential to control material properties via the process parameters. The fabrication of exemplary structures such as 3-dimensional silicon oxide rods, transparent films in trenches and networks of silicon oxide wires illustrate the application potential of this versatile direct-write method.

9:40am **TF-ThM5 Vacuum-Deposited Form-Birefringent Materials for Use as Retarders and Polarizers**, ***I.J. Hodgkinson***, University of Otago, New Zealand **INVITED**

Vacuum-deposited form-birefringent films are of special interest today due to their potential use as trim retarders for front and rear projection TV systems. The presentation reviews basic computational methods, deposition geometries, and experimental techniques for characterizing nanostructures, optical performance and physical properties. As well several related developments are discussed, including multilayered birefringent coatings, birefringent arrays and chiral coatings deposited as twisted stacks of birefringent layers.

10:20am **TF-ThM7 Birefringent Films for Contrast Enhancement of LCoS Projection Systems**, ***K.D. Hendrix***, *M. Duelli, D.M. Shemo, K.L. Tan,* JDS Uniphase **INVITED**

High performance projection displays based on LCoS panel technology have the potential to deliver very high contrast and performance at an attractive

[1] **TFD Student Award Winner**

price. These systems use polarization-based light engines that utilize wire grid polarizers (WGP) and vertical-aligned nematic (VAN) LCoS panels. To achieve high contrast, the linear polarization state created by the WGP must be maintained in the dark state to prevent light leakage to the screen. However, the LCoS panel has a residual retardance, and without compensation, this leakage degrades the system contrast. We describe the design and contrast measurement results of a birefringent contrast enhancing component that compensates this residual retardance and improves the overall system contrast to 4500:1. The component is comprised of birefringent films with individually controllable a-plate and c-plate compensation, accurate retardance targeting and excellent uniformity for both retardance magnitude and orientation. The component also has good environmental durability and low defects.

11:00am **TF-ThM9 New Imaging Ellipsometric Techniques for Thin Film Dielectric Tensor Measurement**, ***R.A. Chipman***, University of Arizona **INVITED**

NO ABSTRACT SUBMITTED.

11:40am **TF-ThM11 Thin Film Optical Constants in the EUV using Simultaneous Reflection and Transmission Measurements**, *D.D. Allred,* ***G.A. Acosta***, *R.S. Turley, J.E. Johnson,* Brigham Young University; *K.R. Adamson,* Harvard University; *N. Farnsworth,* Brigham Young University

We discuss the use of variable-angle transmission/reflection measurements for determination of optical constants of thin films from 50 to 600 eV. Such techniques have been widely used in the visible portion of the electromagnetic spectrum, but are relatively less well known in the EUV and beyond. For this range, depositing a thin film on a transparent substrate is impossible since partially transparent films must be less than ~50 nm and transparent substrates are unknown. Instead we deposited films directly on the surface of a diode detector. We expanded the technique by measuring simultaneously, both reflection from, and transmission at, the same position on the diode to minimize errors stemming from film nonuniformity. Two materials so studied at CXRO's beamline 6.3.2 at the Advanced Light Source at the Berkeley National Laboratory were reactively sputtered thorium oxide and scandium oxide. We will report the complex index of refraction obtained by fitting this data for a number of energies in this range.

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