

Thin Film

Room: Hall 3 - Session TF-ThP

Thin Films Poster Session

TF-ThP2 The Nano-power Generator Fabricated with Thin Atomic Layer Deposited Films, *Giovanna Scarel*, James Madison University

The energy of low power infrared (IR) radiation can be transferred to a power generator (PG) device and transformed into usable power [1, 2]. This process, called IR power generation, is demonstrated with commercially available PG devices [1, 2]. However, active media, such as Nb-doped TiO₂ films, can be fabricated in the form of thin films [3]. Voltage production through IR power generation was recently realized using atomic layer deposited (ALD) films [4], but not optimized. This poster outlines the strategies in terms of film architecture and fabrication method that can be employed to increase the efficiency of nano-PG devices fabricated via ALD.

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TF-ThP3 Influence of Deposition Time on the Microstructure of Electrodeposited ZnO Films and p-Si/n-ZnO Heterojunction Diode Fabrication, *Saliha Ilican, Y. Caglar, S.A. Aksoy, M. Caglar*, Anadolu University, Turkey

ZnO is one of the widely studied materials for its number of exciting properties. It is a wide band gap semiconductor material with $E_g \sim 3.3$ eV. Electrodeposition is well known for depositing metals and metallic alloys at the industrial level, with a wide range of applications from large area surface treatments to most advanced electronic industries. Electrodeposition of semiconducting materials thus represents a new challenge, not only from the academic point of view, but also from the economic point of view, since this method presents interesting characteristics for large area, low cost and generally low temperature and soft processing of materials. ZnO nanorod array films were grown by electrochemical deposition onto p-Si substrates from an aqueous route. Aqueous solution of Zn(NO₃)₂·6H₂O and hexamethylenetetramine (HMT) was prepared using triple distilled water. The bath temperature is maintained at 90 °C during the electrodeposition of the ZnO films. The effect of deposition time on the crystallinity and nanorod arrays were investigated. The crystalline structure and orientation of the ZnO films were investigated using XRD method. The lattice parameters and texture coefficient values of the films were determined. Microstructure was analyzed by a field emission scanning electron microscope (FESEM), and the effects of the deposition time in the microstructure of the films were investigated. The film was determined the most appropriate structural properties and the p-n heterojunction diode was fabricated by using this film. The diode parameters were determined from the analysis of the measured dark I-V curves. Rectifying behavior was observed from I-V characteristics of these heterojunction diodes.

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TF-ThP7 The Effect of Nickel Content on Structural and Optical Properties of ZnO Films by Sol Gel Process, *Seval Aksoy, Y. Caglar, M. Caglar, S. Ilican*, Anadolu University, Turkey

Semiconductor materials have received much attention because of their novel properties. Zinc oxide (ZnO) has been attracting attention because of the commercial demand. It is well known that the addition of impurities into a wide band gap semiconductor. A selective doping element into ZnO has become an important route for enhancing and controlling its structural, morphological, electrical, and magnetic performance. The magnetic property in III–V semiconductors do not attract much attention for device fabrication. Ni is an important dopant in the magnetic materials. Additionally, Ni²⁺ (0.69 Å) has the same valence compared to Zn²⁺ and its radius is close to Zn²⁺ (0.74 Å), so it is possible for Ni²⁺ to replace Zn²⁺ in ZnO lattice.

In this work, undoped ZnO and Ni doped ZnO (ZnO:Ni) films have been deposited by sol–gel method using spin coating technique. As a starting

material, zinc acetate dihydrate was used. 2-methoxyethanol and monoethanolamine were used as a solvent and stabilizer, respectively. The dopant source of Ni was nickel (II) acetate tetrahydrate. The effects of Ni concentration on the crystal structure and orientation of the ZnO films have been investigated using X-ray diffraction (XRD) study. The crystal structure and orientation of the ZnO film were determined to be a hexagonal wurtzite structure and a preferred orientation of (002). The average crystallite size, texture coefficient, dislocation density and lattice constants of the ZnO:Ni films were calculated. The average crystallite size values for the films was found to be in the range of 33–42 nm. The highest grain size value was obtained for the undoped ZnO film. Surface morphology of the films has been also studied by a field emission scanning electron microscope (SEM). The transmittance spectra of the films were measured to investigate their optical properties. All the films are highly transparent with average transmission (>81%) in the visible range. The optical constants of these films were determined using transmittance and reflectance spectra.

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TF-ThP8 Effect of Applied Voltage on the Structural and Morphological Properties of Electrodeposited ZnO Films, *Pinar Bilgic Ozden, Y. Caglar*, Anadolu University, Turkey

ZnO is a widely used and produced n-type semiconductor material which can be obtained by several deposition techniques. Among them electrochemical deposition technique is one of the most promising technique for depositing ZnO because of the simplicity of the experiments and lower cost. It is possible to obtain high quality films by changing deposition parameters.

In this study, ZnO films were electrodeposited onto 100nm thick tin doped indium oxide (ITO) coated glass substrate via electrochemical deposition technique. Hexamethylenetetramine (C₆H₁₂N₄) and zinc nitrate hexahydrate Zn(NO₃)₂·6H₂O salts were used as precursors in a 90°C aqueous solution. In our experimental setup, potassium chloride saturated silver/silver chloride (Ag/AgCl) electrode, a platinum (Pt) wire and ITO substrate were used as reference, counter and working electrodes, respectively. Experiments were carried out at -0.8, -0.9, -1.0, -1.1 and -1.2V for 90min of deposition time. After the depositions process, Structural and morphological properties of the ZnO films were investigated using Bruker D8 Advance XRD and Zeiss Ultra Plus FESEM.

From FESEM images, it is observed that as the applied voltage increase, the amount of the deposited film increase as well, but lower voltage values lead to insufficient coatings. XRD patterns reveal that films which deposited up to -1.0V applied voltage were grown along (002) orientation. Higher applied voltage values caused films to lost some part of their layers, it is probably the main reason of the weak diffraction peaks. As a result -1.0V applied voltage is found to be the best voltage value for this technique with using the parameters and materials mentioned above.

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TF-ThP10 Self-Assembled ZnO Nanoparticles Embedded in a Silicon Oxide Matrix Produced by Reactive RF Sputtering*, *A. Lara-Sanchez, Facultad de Ingenieria, Universidad Autonoma de Chihuahua, Mexico, A. Hernandez-Hernandez, Escuela Superior de Apan, Universidad Autonoma del Estado de Hidalgo, Mexico, A. Garcia-Sotelo, E. Campos, S. Gallardo-Hernandez, Departamento de Fisica-Cinvestav-IPN, Mexico, M. Zapata-Torres, J.L. Fernandez-Muñoz, CICATA-IPN, Legaria, E. Valaguez-Velazquez, UPIITA-IPN, MiguelAngel Melendez-Lira, Departamento de Fisica-Cinvestav-IPN, Mexico*

Self-assembled silicon and germanium nanoparticles embedded within a SiO₂ matrix taking advantage of surface roughness have been successfully produced taking advantage of the roughness associated with the sputtering deposition process[1,2]. The aforementioned approach has been employed to explore the possibility to produce ZnO nanoparticle les embedded within a silicon oxide matrix on soda-lime glass and p-silicon substrates. Silicon dioxide and metallic Zn films were deposited employing silicon and zinc targets. Oxygen content of the working plasma was modulated through argon partial pressure. X-ray diffraction characterization do not shown the presence of metallic zinc. Secondary ion mass spectroscopy shown an interdiffusion of zinc throughout the SiO₂ matrix. TEM micrographs indicated the presence of nanoparticles. XPS shown ZnO formation under specific growth parameters. Photoluminescence emission at room temperature for samples grown on silicon substrates was not observed. Transport properties were studied measuring the IvsV characteristics of the films. For samples grown on silicon rectifying behavior and spectral response are observed . The observed results of photoluminescence and

transport properties are discussed in terms of the crystalline structure of the ZnO nanoparticles and its interaction with SiO₂ matrix.

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TF-ThP11 Development of Dispersed C₆₀/TiAlN Nano-Composite Thin Films with Superior Mechanical Properties, Yuki Ishiyama, A. Matsumuro, Aichi Institute of Technology, Japan

We have succeeded in the development of innovative dispersed C₆₀ molecule nano-composite Al and TiN thin films with great high hardness and excellent tribological properties. Fabrication method of their composite films has been used by our original unique vacuum evaporation method with both RF magnetron sputtering source and heat evaporator source. Nano-indentation hardness of 1.0 wt.%C₆₀/Al nano-composite thin film showed increased up to 3 times larger than that of Al film. And 2.0 wt.%C₆₀/TiN nano-composite thin film, both nano-indentation hardness and tribological properties increased up to 30 % larger than those of a conventional TiN thin film. These results clearly indicated that dispersion of C₆₀ molecules in the conventional films contributed improvement in mechanical properties.

In our study, we challenged to apply the established techniques to fabricate nano-composite materials using C₆₀ to TiAlN, which is harder than TiN. Development of the synthesis method of C₆₀/TiAlN nano-composite thin films with the excellent mechanical properties more than those of TiN nano-composite must give effective industrial contributions. C₆₀/TiAlN nano-composite thin films with constant thickness 200 nm were deposited on Si(100) water-cooled substrates using by the same method with both Ti and Al sputtering targets for 30 minutes. The concentrations C₆₀ molecule powder were changed in the range from 0.5 to 40 wt.%, and the evaporation temperature was controlled in the range of 523-723 K. The structure analyses of all nano-composite thin films showed that XRD patterns indicated only TiAlN crystalline structure and absorption peaks estimated by FT-IR also corresponded to those of C₆₀ molecule. From these results, the microstructures of C₆₀/TiAlN nano-composite thin films were confirmed to consist of both C₆₀ molecule and TiAlN crystalline metallic compound. Nano-indentation hardness made clear that the hardness of the composite films of 2.0 wt.%C₆₀/TiAlN showed the maximum hardness of 20 GPa and this value was increased up to 20 % larger than that of TiAlN thin film. Furthermore, tribological properties were also increased up to 20 % larger than that of TiAlN.

On the basis of remarkable results of the previous researches and the present results, it clearly indicates that C₆₀ nano-composite is extremely effective in great mechanical properties improvement to dispersed C₆₀ uniformly in matrix conventional thin films. Therefore, this study let us know one of bright future view of development of the innovative great hard composite thin films using by C₆₀ molecules.

TF-ThP12 Interface of Mo/Si Multilayer formed by Magnetron Sputtering for Extreme Ultraviolet Lithography, Chao-Te Lee, D. Chiang, P.-K. Chiu, H.P. Chen, C.N. Hsiao, National Applied Research Laboratories, Taiwan, Republic of China, H.-B. Zhang, C.-C. Jaing, Minghsin University of Science and Technology, Taiwan, Republic of China

The periodic Mo/Si bilayers with Ru capping layer were deposited on Si (100) substrate by RF magnetron sputtering with Mo, Si, and Ru targets. The multilayers were designed for reflectivity at the wavelength of 13.5 nm. The effects of Ru capping layer on the microstructure, surface roughness and reflectance of multilayers were investigated by atomic force microscopy (AFM), high resolution transmission electron microscopy (HRTEM), X-ray photoelectron spectroscopy (XPS), and a spectrometer. The surface roughness of Ru thin film was decreased from 0.35 nm to 0.15 nm when the RF power was increased from 50 W to 200 W. The AFM measurements showed the uniform morphology with a very low surface roughness value under 0.15 nm with 50V dc-bias assisting. It was found that the Mo-on-Si, Si-on-Mo, and Ru/Si interface layers were discriminated by HRTEM, and XPS. The Mo-on-Si interface layer was 0.45 nm. However, the Si-on-Mo interface layer was increased with thickness increased from 0.9 nm to 1.35 nm. The cause of Mo/Si and Ru/Si interfaces form was attributed to the substrate temperature was increased during sputtering. In this work, the reflectivity of the multilayers was 60 ~ 65 % which was attributed to form the Mo/Si and Si/Ru interfaces.

TF-ThP13 Influence of Cu Doping on the Electrical Transport Properties of Transparent ZnO Nanocrystalline Films Prepared by Sol-Gel Spin Coating Process, Chung-Yuan Kung, Department of Electrical Engineering, National Chung Hsing University, Taichung, Taiwan, Taiwan, Republic of China, S.L. Young, H.H. Lin, Department of Electronic Engineering, Hsiuping University of Science and Technology, Taichung, Taiwan, Taiwan, Republic of China

ZnO and Zn_{0.98}Cu_{0.02}O nanocrystalline films were separately deposited on the glass substrates by sol-gel spin-coating technique for the exploration of Cu doping effect. X-ray diffraction patterns of the films show the same wurtzite hexagonal structure and preferential orientation along the *c*-axis. The grain size of ZnO and Zn_{0.98}Cu_{0.02}O films are 52.3 and 126.4 nm calculated by Scherrer Formula, respectively. The increase of grain size induced by Cu doping result can be also observed by SEM images. Hall mobility and carrier concentration of the *p*-type Zn_{0.98}Cu_{0.02}O films decrease and resistivity increase as Cu doping due to the increase of defects examined by photoluminescence spectra. Temperature dependence resistivity reveals a semiconductor transport behavior for both nanocrystalline films. Exponent relationship $\sigma(T) = \sigma_{00} \exp[-(T_0/T)^{1/4}]$ at low temperature region and Arrhenius equation $\sigma(T) = \sigma_0 \exp[-(E_a/KT)]$ at high temperature region are both fitted well, which separately reveals Mott variable range hopping behavior and thermal activation conduction. Activation energy *E_a* increases from 46 meV for ZnO to 124 meV for Zn_{0.98}Cu_{0.02}O calculated by Arrhenius equation, respectively. The results demonstrate that the crystallization and the corresponding carrier transport behavior of the Zn_{0.98}Cu_{0.02}O films are affected by Cu doping.

TF-ThP14 Design and Fabrication of MgF₂ Protected Aluminum Mirrors for the DUV Spectral Range, Hung-Pin Chen, W.H. Cho, C.N. Hsiao, National Applied Research Laboratories, Taiwan, Republic of China, C.C. Lee, National Central University, Taiwan

Protected or enhanced aluminum is widely used for the preparation of highly reflective coatings in the DUV spectral range. The obvious choice for a coating with high reflectance above DUV Spectral Range is Al protected with MgF₂. This article presents our preliminary experimental studies on processes to produce MgF₂ protected aluminum mirror, the focus is placed on high reflective coatings for the DUV wavelength range above 125nm to 325nm. Aluminum layers protected with fluoride coatings have been deposited by ion beam-assisted deposition, all the samples were deposited on fine polished fused silica substrate. The optical parameters of optical interference coatings were optimized using admittance loci analysis by the Essential MacLeod software. The corresponding properties of the films were investigated by in situ optical monitoring, surface quality of the layers has been judged by means scanning electron microscopy, and atomic force microscopy scanning. The reflectance results were measured at the BL04B Beamline of National Synchrotron Radiation Research Center (Taiwan) in DUV spectral region. The highest average reflectance of the DUV reflector (with protect coating) is about 80%. Interference coatings were added to the basic protected Al design to enhance the reflectance.

TF-ThP15 Reliability Analysis of Zinc Tin Oxide Thin Film Transistor under Mechanical Stress and NBIS (Negative Biased Illuminated Stress) Condition, Sungmin Kim, H.J. kim, Seoul National University, South Korea

Amorphous zinc tin oxide (ZTO) attracts attention as a new channel material of switching thin film transistor (TFT). It has remarkable properties like high field effect mobility (>10 cm²/Vs) as well as high uniformity and low processing temperature. In this study, electrical properties like threshold voltage (*V_{th}*), mobility, and subthreshold swing of ZTO TFTs with/without mechanical stress were investigated to find the effects of the photo-bias instability of ZTO TFTs on their mechanical stress.

The fabricated ZTO TFTs have a bottom gate and top contact configuration. Thinned Si wafers of 50μm thickness were used as substrates to allow ZTO TFTs to be flexible. To measure the effects of mechanical stress to electrical properties and photo-bias instability, the negative biased illuminated stress (NBIS) tests were performed in three illumination conditions with the photo-wavelengths of 400, 450 and 500 nm as well as in two mechanical bending directions, parallel and perpendicular to a channel width of TFTs, with a bending curvature of 40mm.

Under a mechanical strain, a mobility and a subthreshold swing of ZTO TFTs remained unchanged, but a *V_{th}* showed noticeable changes. Tensile strain under the bending parallel to a channel width caused more severe photo-instability with more *V_{th}* shift. *V_{th}* of ZTO TFTs remained unchanged under the 500nm NBIS condition, while for 400 and 450 nm NBIS conditions *V_{th}* shifted with a mechanical strain. Particularly, parallel bending of ZTO TFTs under the 400nm NBIS condition showed severe instability, a large and negative *V_{th}* shift of -11.6V compared to -7.2V of a non-bended sample. And for the 450 nm NBIS condition, relatively small *V_{th}* shift of -6.1V and -4.4 V for bended and non-bended samples,

respectively, was observed, showing similar tendency to the 400nm case. But in case of the bending perpendicular to a channel width showed less V_{th} shift from non-bending condition; -15.8 V to -15.2 V and -5.5 V to -4.0 V for the 400nm and 450 nm NBIS conditions, respectively.

The exact mechanism of this phenomenon is not clear at this point, but the strain in film might change the distance between metal atoms, causing the variation of an orbital overlap in the bandgap and an activation energy for V_{th} shift. G. Zhang et al. reported that a strain in a channel layer makes difference of ZnO band structure like midgap states from the first principle simulation. The tensile strain can cause more midgap levels in bandgap, and vice versa. It is in a good agreement well with our result. The more reasonable mechanisms of strain to affect the band structure is under investigation.

TF-ThP17 Laser Surface Modification of AZ31B-H24 for Improved Corrosion Resistance, Michael Melia, University of Virginia, N. Birbilis, Monash University, Australia, J.R. Scully, J.M. Fitz-Gerald, University of Virginia

The development of Mg alloys has been accelerated over the last decade due to the need for significant weight reduction of structural components. One long-standing obstacle regarding the use of Mg alloys for widespread field application is their intrinsically poor corrosion resistance and lack of surface films or oxides. Micro-galvanic induced "self-corrosion" due to alloy heterogeneity is a key concern. Therefore, chemical and structural homogenization is of long standing and great interest. Furthermore, there is a need to exploit possible benefits of low fluence LSM, local composition variations and LSM processing gas environments on corrosion behavior. Here we report on the effect of laser surface modification (LSM) on the corrosion resistance of an Mg alloy (AZ31B-H24).

Samples were processed with a pulsed excimer laser operating at 248 nm and a fluence = 1.5 J/cm². Microstructure and composition were characterized with scanning electron microscopy (SEM), grazing incidence X-ray diffraction (GIXRD), and energy dispersive spectroscopy (EDS). Corrosion analysis was performed in a standard three electrode corrosion cell in quiescent 0.6 M NaCl solution. Electrochemical Impedance Spectroscopy (EIS) and potentiodynamic polarization measurements were used to determine corrosion resistance, anodic/cathodic behavior, pitting potential and open circuit potential (OCP). Corrosion experiments were imaged by optical video microscopy during testing to draw conclusions regarding the breakdown of the irradiated surface.

Layered structures of nanoscale MgO, Mg₃N₂, and AlN constituents formed in the irradiated region as a function of process gas and proximity to the Al₃Mn₅ intermetallic particles (IMPs). Partial homogenization of IMPs was observed, reducing the initial particle size by 40-60% and creating large areas of Al/Mn enrichment, irrespective of process gas used (Ar, N₂). The results show that a reduction in the H₂ evolution reaction rate was achieved correlated with an order of magnitude decrease in the cathodic current density, as well as a 100 mV to 200 mV reduction in the open circuit potential over short immersion times of up to 4 hours, irrespective of processing gas. In addition, Impedance results support these findings with a 4 and 25 fold increase in the polarization resistance after processing in both N₂ and Ar atmospheres respectively. The behavior in full immersion has not been extrapolated to long term field testing.

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TF-ThP18 Enhanced Mechanical Properties of Boron Doped Amorphous Carbon Films by UV Laser Annealing, ChulMin Yoon, T. Choi, Sejong University, Republic of Korea, J.Y. Yang, TES Co. Ltd., Republic of Korea, K.P. Park, G.H. Hur, TES Co., Ltd., Republic of Korea
The hard forms of amorphous carbon (a-C, diamond like carbon) include hydrogenated amorphous carbon (a-C:H) and tetrahedral amorphous carbon have raised interest as coating materials. Recently, boron doped amorphous carbon films have been studied as hard mask materials of 3D vertical NAND flash memory. Hard mask was demanded to enhance critical dimension (CD) uniformity, anti-etching and lifting while decreasing thickness. Boron has been widely known efficient dopant for passivating the oxidation of various carbon materials. We have prepared boron doped amorphous carbon film deposited with the fixed B₂H₆ flow rate as a function of the process temperature using plasma enhanced chemical vapor deposition (PECVD). We investigated the physical and optical properties of film with the refractive index, hardness and chemical bonding configuration. Especially, the effect of ultraviolet (UV) laser annealing on the hardness was studied. UV annealing caused a change of chemical bonding configuration, i.e., sp²/sp³ bonding ratio and C-H bonds, through analysis of the Fourier transform-infrared (FT-IR) and RAMAN spectrum. It is found that a significant enhancement of hardness could be attributed to

surface confined graphitization and increase of the sizes of sp² and sp³ clusters, which occur without any damage of surface and delamination of films. In addition, the influence of laser annealing on the stress relief behavior and electronic properties of boron doped amorphous carbon layers will be discussed. Our approach can offer easy control of surface properties of amorphous carbon materials.

TF-ThP19 Influence of Zn(O,S) Buffer Layers on the Performance of Cu₂ZnSn(S,Se)₄ Earth-abundant Thin Film Solar Cells, H. Hong, Jaeyeong Heo, Chonnam National University, Republic of Korea

A solar cell is an electrical device that converts light energy into electricity. One of the crucial parts of realizing high-performance thin-film-based solar cells is an *n*-type buffer layer. Instead of the widely used, but toxic CdS buffer layer, we investigated the possibility of using Zn(O,S) as an alternative material grown by atomic layer deposition (ALD). First of all, structural, electrical, chemical, and optical properties of Zn(O,S) thin films were studied. In addition, this new buffer layer was applied for earth-abundant Cu₂ZnSn(S,Se)₄ solar cells and the highest power-conversion efficiency (PCE) of ~2.7% was achieved by optimizing oxygen-to-sulfur (O/S) ratio. Detailed device analysis which includes current-voltage (J-V), external quantum efficiency (EQE), dark current-voltage, transmission electron microscopy (TEM) and energy dispersive X-ray analysis (EDX) will be presented.

TF-ThP22 Low-Temperature Atomic Layer Deposition of Platinum Using (Methylcyclopentadienyl)trimethylplatinum and Ozone, Huazhi Li, N. Sullivan, P. Chinoy, Arradiance

Because of the excellent electric and catalytic properties of Pt, ALD of Pt has attracted considerable attention for applications in nanoelectronics, electrochemistry, catalysis, and sensing. The most commonly applied ALD process for Pt uses (methylcyclopentadienyl)trimethylplatinum (MeCpPtMe₃) and O₂ as precursors. It was found that the optimum process window of this process is 250 - 300 °C. Below 250 °C, very low growth rates and poor Pt nucleation on some substrates such as Si or SiO₂, are observed. These limitations rule out applications on heat sensitive polymer substrates.

To address the need for low temperature ALD Pt, processes based on ozone² and oxygen plasma with a subsequent reduction by H₂³ have been reported. O₃ is being used in a growing number of atomic layer deposition (ALD) processes because O₃ is a powerful oxidizer and is easier to purge than H₂O, particularly at lower growth temperatures (≤ 100 °C). The development low temperature ALD processes using O₃ process⁴ and low temperature plasma processes will be reported. In this work, growth kinetics, crystalline structure, resistivity, and purity of Pt thin films grown using O₃ as reactant gas in combination with the MeCpPtMe₃ precursor are studied. Additionally, the conformality of the MeCpPtMe₃/O₃ process and its nucleation behavior on a SiO₂ surface will be discussed. The results reported describe a process that is highly suited for Pt deposition on thermally fragile substrates.

Literature:

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TF-ThP25 Flash Networking Poster: Surface Characterization and Luminescent Properties of Pulsed Laser Deposited Dysprosium-Doped Rare-Earth Oxyorthosilicates Thin Films, Martin Nwaeeborwa, S.N. Ogugua, H.C. Swart, University of the Free State, South Africa

Luminescent materials or phosphors have a wide range of technological applications in electronic information displays, solid state lighting, solar cells, advertising, medical imaging, etc. Although phosphors are usually used as powders, thin films have more advantages in many practical applications. We report luminescent properties and surface states of dysprosium (Dy³⁺)-doped lanthanum gadolinium oxyorthosilicate (La_{2-x}Gd_xSiO₅:Dy³⁺; where x = 0, 0.5, 1.0, 1.5, 2) that were ablation deposited onto Si (111) substrates using the pulsed laser deposition (PLD) technique. Several deposition parameters were varied, including vacuum versus partial

pressure of gas (O_2 or Ar), and substrate temperature using the 266 nm Nd:YAG excimer laser. The ablated targets were prepared from powders which were synthesized by combustion method. The films exhibited tunable and white photoluminescence emission when excited by either a monochromatized xenon lamp or a 325 nm HeCd laser in air at room temperature. The PL emission colour and the peak intensity were dependent on the ratio of La to Gd, concentration of Dy^{3+} , and deposition conditions. Data from scanning electron microscopy (SEM) and atomic force microscopy (AFM) show that the major influence of the deposition conditions on the PL peak intensity was through changes in the morphology and topography of the films, which affects light scattering and out-coupling. The time-of-flight secondary ion mass spectroscopy (ToF-SIMS) was used to study the distribution of atomic and molecular ionic species on the surface of the films, while X-ray photoelectron spectroscopy (XPS) was used to analyse the chemical composition and electronic states of our samples.

TF-ThP28 Effect of a Substrate Temperature on the Properties of the RF-sputtered Indium Selenide Thin Films as a Buffer Layer for CIGS Photovoltaics, MyoungHan Yoo, N.H. Kim, Chosun University, Republic of Korea

CIGS, which has suitable optical absorption, tunable band gap, good electrothermal stability, and no toxic/hazardous pollutant, has been used in thin film solar cells with the conventional structure of glass/Mo/CIGS/buffer layer/TCO. Instead of the very noxious and polluting CdS buffer layer, Cd-free materials have been attracted great interest in the buffer layer for CIGS photovoltaic applications. The Cd-free buffer layers require some qualifications, such as a band gap energy between CIGS and TCO (typically zinc oxide, $E_g \sim 3.4$ eV), an optical transmittance $\geq 80\%$, and a resistivity $\leq 10^4 \Omega\text{-cm}$ [1] to replace the conventional CdS buffer layer. Indium selenides are III-VI semiconducting compounds with the wide deviation from stoichiometry, which were proposed for the Cd-free buffer layer in CIGS photovoltaics with several advantages including better heterointerface of the same elemental effusion with CIGS absorber layer. In the prior studies, indium selenides were prepared by using RF-magnetron sputtering method with $InSe_2$ target and rapid thermal annealing. The variations in film thickness, stoichiometry, annealing duration, and annealing temperature did not affect the crystallization of indium selenide precursors in amorphous nature. Subsequently, the substrate temperature, which induces significant changes in the properties of indium selenide, was varied in the RF sputtering process. Rapid thermal annealing process was performed to transform the 50-nm-thickness indium selenide into the γ -phase In_2Se_3 at 700°C for 1 min. Some analyses were examined in the structural, optical and electrical properties of the RF-sputtered indium selenide thin films with the different substrate temperatures for the optimal buffer layer in CIGS photovoltaics. [1] J. H. Yoon, W. M. Kim, J. K. Park, Y. J. Baik, T. Y. Seong and J. Jeong, Prog. Photovolt: Res. Appl. 22, 69 (2014).

TF-ThP33 Stress-curvature Relationship for Configurations with Thin and Anisotropic Substrates undergoing Large Deformations, SaiSharan Injeti, R. Annabattula, Indian Institute of Technology Madras, India

In a thin film configuration, the film is often stressed to conform to the surface of the substrate, commonly due to epitaxial effects, difference in thermal expansion coefficients between the film and the substrate materials, or phase transformations accompanied with volume changes. This stress causes the film-substrate system to assume a curvature. The relation that relates this curvature to the stress in the film is referred to as the Stoney equation. One of the major assumptions of the Stoney equation is that the substrate is orders of magnitude thicker than the film, leading to small and purely elastic deformation of the substrate. Moreover, the well known equation also assumes that the substrate material is isotropic in nature.

At the moment, the traditional Stoney equation is being used to relate the film stress to the system curvature. However, in majority of the cases where the film stress is measured from the system curvature, Si wafers are used as substrates. Si wafers are anisotropic in nature as they are obtained by slicing single crystals. In this paper, a more generalized version of the Stoney equation is presented.

This form of the equation is derived by first relaxing the constraints that the film is very thin compared to the substrate and that the deformations are small. Next, this formula is modified specifically for the cases of Si(001) and Si(111) wafers. Ultimately, a modified version of the Stoney equation is presented which can be used for configurations with anisotropic substrates where the thicknesses of the film and substrate are comparable, and the deformations are large. Extension of this expression to systems assuming asymmetric elliptical configurations rather than symmetric spherical deformations, is also discussed.

Keywords: Thin film, Large deformation, Stoney, Silicon, Wafer curvature

TF-ThP34 Doping of High-aspect Ratio Silicon Structures using Thin Film Dopant Sources Grown by Plasma-assisted Atomic Layer Deposition, Bodo Kalkofen, Otto von Guericke University Magdeburg, Germany, A.A. Amusan, Otto von Guericke University, Magdeburg, Germany, M. Lisker, IHP, Frankfurt (Oder), Germany, Y.S. Kim, Lam Research Corporation, E.P. Bulte, Otto von Guericke University, Magdeburg, Germany

Plasma-assisted atomic layer deposition (PALD) was carried out for growing thin oxide films of silicon dopants onto flat and high-aspect ratio silicon substrates. The applicability of these films as dopant sources for shallow doping of silicon using various rapid thermal annealing methods, such as RTP, flash lamp anneal, and laser anneal, was investigated. Remote CCP and ICP sources were applied for generating oxygen radicals in the PALD processes. Tris(dimethylamido)borane was used as boron containing precursor for p type silicon doping, source layers for n type doping were grown using triethylphosphite and triethylantimony as phosphorus and antimony containing oxides, respectively.

The as-deposited films of boron oxide were highly unstable in ambient air and could be protected by capping with in-situ PALD grown antimony oxide films. Phosphorus containing films were stabilized by incorporating them into a silicon dioxide matrix by carrying out ALD processes with supercycles of phosphorus and silicon precursor reactions with oxygen radicals. Also capping of the phosphorus containing films was applied. Antimony oxide films were stable at ambient air conditions. Conformal growth of such films could be obtained on silicon trench structures of 6:1 to 10:1 aspect ratio with pitch below 50 nm.

Boron and phosphorus doping of silicon could be obtained using the respective oxide films as dopant sources. This was confirmed by SIMS and sheet resistance measurements. Diffusion of antimony into silicon from antimony oxide needs to be further improved by optimizing the annealing conditions. The influence of source layer thickness and different annealing conditions during rapid thermal annealing processes on the doping results was investigated. Controlled doping of 3-D nanostructured devices by pre-deposition with ALD source layers should be feasible by this method.

TF-ThP36 Kurt J. Lesker- TORUS "Mag Keeper" Sputtering Sources- "Enabling Thin Film Coating Technology for a Better World", Jason Hrebik, Kurt J. Lesker Company

The thin film coating industry, particularly in magnetron sputtering, is a critical means for our current and future advancements in technology. There are a wide range of applications, which have many critical performance requirements to make them successful. The main component driving these applications is the magnetron sputtering cathode or "magnetron".

In many cases, it is difficult to find an ideal "magnetron" that can meet all of the process requirements. In addition, there are a broad range of "magnetron" providers in the industry that all have advantages and disadvantages to their technology. This can make choosing the best option very difficult.

One of the most critical performance requirements in any magnetron design is target cooling. Good thermal conductivity between the target and the cathode is essential for maximum power density and sputtering rate. The new Mag Keeper sputtering source utilizes an enhanced target cooling design in which the cooling water flows through a brazed copper channel that is in direct contact with the backside of the sputtering target. This along with a magnetically enhanced clamping force provides an uncompromised cooling advantage.

In addition, the Mag Keeper design has only a single metal seal, contains no O-rings, and utilizes all ceramic insulators, making it both HV and UHV compatible.

Over the course of extensive performance testing campaign, the design showed several key advantages. Using a variety of target materials, it was found that the Mag Keeper's cooling efficiency is comparable to that of a direct-cooled magnetron providing the ability to run at power densities over 200 watts/ in² with thermally conductive materials such as copper and aluminum. A key advantage to the magnetic profile was the ability to operate a 0.375" thick non-magnetic target at 0.5mTorr pressure. In terms of target erosion, the Mag Keeper design has a very broad profile maximizing both utilization and uniformity. In addition, with the High Strength magnet configuration, a 3" source was able to sputter up to 3mm thick Fe.

From a mechanical standpoint, the Mag Keeper source does not use a target clamp or anode shield assembly resulting in a very quick target change averaging less than 5 minutes due to only having to loosen (2) bolts in order to access the target.

In conclusion, the Mag Keeper magnetron design offers the industry a design that is capable of meeting a very broad range of application

requirements with the conveniences needed for meeting production efficiencies!

TF-ThP39 Femtosecond X-Ray Magnetic Circular Dichroism Spectroscopy at an X-Ray Free Electron Laser, *Daniel Higley, K. Hirsch, E. Yuan, E. Jal, G.L. Dakovski, A.A. Lutman, J. MacArthur, A.H. Reid, T. Liu*, SLAC National Accelerator Laboratory, *J. Joseph*, Lawrence Berkeley National Laboratory, *A. Tsukamoto*, Nihon University, *H.A. Durr, W.F. Schlotter*, SLAC National Accelerator Laboratory

In the last twenty years, the field of ultrafast magnetization dynamics has seen tremendous growth and development. Ferromagnetic transition metals have been seen to demagnetize on a sub-picosecond time-scale when excited by ultrafast laser pulses, much faster than expected from dynamics close to equilibrium. The mechanism of this ultrafast magnetization quenching, almost twenty years after its discovery, is still a matter of active debate. Other materials exhibit ultrafast switching of the magnetization when excited similarly. The switching mechanism, however, is also still debated. To unravel the mysteries of these processes requires probes which can sensitively and reliably probe the transfer of angular momentum and energy between the electronic, electronic spin, and lattice systems.

X-ray magnetic circular dichroism spectroscopy (XMCD) directly and element-specifically probes the spin and orbital magnetic moments of electrons in matter and has proven invaluable in studies of static magnetism. This information is extracted from the difference in absorption of right- and left-circularly polarized x-rays at spin-orbit split resonances where core-level electrons are excited into unoccupied valence states.

XMCD with femtosecond time resolution is an ideal tool to investigate ultrafast magnetization dynamics. Femtoslicing beamlines at synchrotrons have been used to perform such measurements and make seminal contributions to the field of ultrafast magnetization dynamics. The low photon throughput of these sources, however, necessitates long integration times for measurements and restricts the possibility of systematic studies as well as measurement of small signals. X-Ray Free Electron Lasers (XFELs), which provide femtosecond pulses with a much increased flux compared to femtoslicing sources, give an important path to extending these results.

Here, we report on ultrafast XMCD spectroscopy measurements in the soft x-ray range at an XFEL utilizing a recently installed variable polarization undulator at the XFEL LCLS at the SLAC National Accelerator Laboratory. We are able to record static XMCD spectra of GdFeCo samples over the iron L-edges and gadolinium M5 edge which match those observed at synchrotrons. In addition, by monitoring the time-resolved XMCD at these edges we reproduce the classic observation of a transient ferromagnetic alignment of antiferromagnetically coupled spins in amorphous GdFeCo during ultrafast, laser-induced, switching. With the high-flux and intrinsically ultrafast pulses of XFELs, we are able to record this measurement in less than an hour, a fraction of the time required for the original measurement.

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