Electronic Materials and Photonics Division
Room Union Station B - Session EM-ThP

Electronic Materials and Photonics Poster Session

EM-ThP4 Characterization of Textile Yarn Coated with Polypyrrole/Carbon Black Electronic Material*, R. Villaneuva, **Deepak Ganta**, C. Guzman,* TAMIU

Electronic textiles combine the advantages of flexibility in textiles and the performance of electronics in a wearable form for sensing applications. We report an inexpensive and straightforward coating method of pre-treatment, dipping, and drying the cotton yarn, combining the advantages of polypyrrole/carbon black, while investigating the mechanical, in situ electrical properties, and thermal conductivity of polypyrrole/carbon black composite coated cellulose (cotton) yarn. The coated yarn is mechanically stable with the tensile strength of~11.6 N. The resistivity and conductivity properties of the yarn are measured from the linear response of the I–V curve, showing an ohmic behavior. Further, the coated surface was tested using scanning electron microscopy for uniformity in the surface coating. Thermal conductivity for the coated fabric was measured using Transient-hot-bridge method and measured to be 0.12 Wm−1 K−1 at ambient temperature.

EM-ThP5 Optical and Nonlinear Optical Properties of (1-x)Pb($Mg_{1/3}Nb_{2/3}$)O_3-x$PbTiO_3$ Thin Films Grown by Pulsed Laser Deposition*, **Da-Ren Liu**,* Taiwan Instrument Research Institute, Taiwan, Republic of Korea

Thin film optical devices have been especially attractive because of their potential for the integration with electronic and optoelectronic systems. Owing to its ferroelectricity, pyroelectricity, high dielectric constant and large electro-optic coefficients, lead magnesium niobate-lead titanate (PMN-PT) can be used in many applications that include pyroelectric detectors, actuators, integrated capacitors, and nonlinear optical devices. In this study, highly textured thin films of lead magnesium niobate-lead titanate were grown by pulsed laser deposition (PLD). The measurement of glancing-angle x-ray powder diffraction (GAXRD) was used to determine the structure of the PMN-PT films. The thickness and roughness of the films were characterized by grazing-incidence x-ray reflectivity (GIXR), and the complex refractive indices were measured in the range from 1.5 to 4.1 eV by spectroscopic ellipsometry (SE). The average oscillator strength and its associated wavelength were estimated by using a Sellmeier-type dispersion equation. Z-scan measurements were performed to study the third-order optical nonlinearity. It was found that the PMN-PT films exhibited strong nonlinear optical effect. The results show that PMN-PT thin films are promising materials for nonlinear optics.

EM-ThP6 Toward Selective Deposition of Boron Carbide Layers*, **Raja Sekhar Bale**, R. Thapa, L. Dorsett, S. Wagner, D. Bailey, A.N. Caruso,* University of Missouri-Kansas City*; J.D. Bielefeld, S.W. King,* Intel Corporation*; M.M. Paquette,* University of Missouri-Kansas City

The semiconductor industry is pushing its boundaries in device scaling technology by way of novel processing methods and increasingly complex patterning schemes. This requires a variety of functional and patterning-assist materials as well as advanced deposition techniques. For years, Si-based materials have been used to meet these needs; however, these alone cannot fulfill the range of material requirements moving forward. Boron carbide has shown promise due to compelling dielectric, thermal, mechanical, chemical, and etch properties. Toward applying this material to next-generation integration schemes, we have been exploring the potential of going beyond traditional growth processes (e.g., plasma-enhanced chemical vapor deposition) and investigating innovative area-selective atomic layer deposition (AS-ALD) strategies. Herein we explore schemes for the selective metal/dielectric deposition of boron carbide using layer-by-layer methods. X-ray photoemission spectroscopy (XPS) and atomic force microscopy (AFM) techniques are employed for characterization and imaging of the resulting surfaces.

EM-ThP7 The Effect of Processing Conditions on the Growth of Transition Metal Dichalcogenides by Molecular Beam Epitaxy*, **Peter Litwin**, S. McDonnell,* University of Virginia

The synthesis of high-quality transition metal dichalcogenides films is of significant interest for potential applications in nanoelectronic and thermoelectric devices. Molecular beam epitaxy is a promising route towards this aim, providing fine control over growth conditions. To further the present understanding of growth conditions on the quality of transition metal dichalcogenide thin films, we study the effect of growth temperature, chalcogen to metal flux ratio, and the use of a ripening step on the stoichiometry and surface morphology of grown WSe_2 thin films. In-situ X-ray photoelectron spectroscopy is performed to analyze the intrinsic chemical composition of the grown material prior to atmospheric exposure, and ex-situ atomic force microscopy is employed to study the surface morphology of grown, sub-monolayer films. We find that both low and high growth temperature ranges can be detrimental to the chemical makeup of the grown material and that these results are echoed in the resulting grain morphology. An intermediate growth temperature produced chemically superior films over a wide range of chalcogen to metal flux ratios. The chalcogen to metal flux ratio was seen to provide some control of the film morphology, with high fluxes producing films with cleaner grain boundaries. Lastly, we show that the use of a ripening step in the early stages of growth results in a chemically superior material. This ripening step has the added benefit of producing films which are chemically more consistent than those grown in the absence of this step. There is also evidence to suggest that utilizing a ripening step may expand the processing window for film growth, allowing the use of higher processing temperatures and consequently better control over film quality.

EM-ThP8 Co-sputtered and Rapid Thermal Annealed ZnS:Cu Thin Films for Photovoltaic Applications*, Y.-K. Jun,* EM Co., Inc., Republic of Korea*; **Sakal Pech**, M.H. Yoo, G.-B. Cho, N.-H. Kim,* Chosun University, Republic of Korea

ZnS is one of the attractive II-VI semiconductors because of their potential applications in the novel electronics and optoelectronics devices. ZnS is an n-type semiconductor with relatively high transparency, large Bohr exciton radius (2.5 nm), large exciton binding energy (40 meV), high index of refraction (2.27) [1], and wide bandgap showing different bandgaps of 3.68 eV and 3.91 eV for cubic zinc blende (ZB) phase and hexagonal wurtzite (WZ) phase, respectively [2]. ZnS is considered one of the prospective candidates for the CIGS photovoltaic (PV) applications, compared to CdS, it has non-toxic handling, wide bandgap, and better lattice matching to CIGS absorber with bandgaps of 1.3–1.5 eV [2]. Some dopant metals, such as Al, Cu, Ag, Mn, and Tb, are widely doped into ZnS lattice. Some researchers have studied the effect of Cu doping on the emission of light in ZnS, in this study, ZnS:Cu thin films were deposited by using a co-puttering method for photovoltaic applications. Effect of doping content on morphological, optical and electrical properties of ZnS thin films after rapid thermal annealing (RTA) treatment was investigated with the structural properties of the different phases of ZB, WZ, and the mixture of them in X-ray diffraction studies . Optical and electrical characteristics of the thin films were analyzed by using an UV-Visible spectrophotometer and a Hall effect measurement system for optical transmittance, bandgap, resistivity, and carrier concentration. Acknowledgement: This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the Ministry of Trade, Industry & Energy (MOTIE) of the Republic of Korea (No. 20184010201650). [1] Sanjeev Kumar, C.L. Chen, C.L. Dong, Y.K. Ho, J.F. Lee, T.S. Chan, R. Thangavel, T.K. Chen, B.H. Mok, S.M. Rao, M.K. Wub, Room temperature ferromagnetism in Ni doped ZnS nanoparticles, J. Alloy Compd. 554, 357 (2013). [2] Md. Anisuzzaman Shakil, Sangita Das, Md. Ashiqur Rahman, Umma Salma Akther, Md. Kamrul Hassan Majumdar, Md. Khalilur Rahman, A Review on Zinc Sulphide Thin Film Fabrication for Various Applications Based on Doping Elements, Mater. Sci. Appl. 9, 751 (2018).

EM-ThP9 Biomimetic Electrospun Polyethylene Fabrics for Effective Radiative Cooling Under Sunlight*, **Bokyung Park**, S.M. Han, S.E. Han,* University of New Mexico

Clothing fabrics normally show high absorptivity for the mid-infrared radiation from human body. This high absorptivity, compared to transparency in the same spectral region, makes heat removal from the body relatively inefficient in hot weather conditions. In addition, the microstructures of typical fabrics are far from optimum for effective light scattering in the visible range, and the absorbed sunlight can significantly heat up the skin under the fabric. In this work, we borrow our inspiration from nature to optimize the fabric design. Biological species, such as white beetles, ingeniously regulate their body temperature using their scales. These scales consist of anisotropic fibrillar network structures to achieve extraordinary light scattering that is far superior to man-made optical diffusers. Based on the random photonic structures found in beetle scales, we have electrospun biomimetic fabrics using polyethylene, which is minimally absorptive in the mid-infrared range. By manipulating the fabric microstructures (e.g., anisotropy, porosity, and fibril diameter), we were able to increase the sunlight scattering strength. Optical scattering strength of our fabrics was characterized, using the optical diffusion model where the minimum photon transport mean free path – a length over which light propagation is no longer correlated to its original direction – represents the maximum scattering strength . We have discovered that the scattering strength can be enhanced by almost a factor of two by increasing the anisotropy of threads in the fabric. Our results suggest that fabrics for efficient heat removal from human body can be fabricated by simple electrospinning techniques that are low-cost, scalable, and high-throughput.

EM-ThP10 Suppression of the Spectral Weight ofTopological Surface States on the Nanoscale via Local Symmetry BreakingviaLocal Symmetry Breaking*, **Omur E. Dagdeviren**, S. Mandal, K. Zou, C. Zhou, S. Simon, S. Albright, X. Zhu, S. Ismail-Beigi, F.J. Walker, C. Ahn, U.D. Schwarz, E.I. Altman,* Yale University

In topological crystalline insulators, the topological conducting surface states are protected by crystal symmetry. Here, we show using scanning tunneling microscopy/spectroscopy that defects that break local mirror symmetry of SnTe suppress electron tunneling over an energy range as large as the bulk band gap, an order of magnitude larger than that produced globally via magnetic fields or uniform structural perturbations [1]. The results reveal the influence of various defects on the electronic properties, including screw dislocations, point defects, and tilt boundaries that lead to dislocation arrays that serve as periodic nucleation sites for pits grown on SrTiOinsulators the topological conducting surface states are protected by crystal symmetry. Here, we show using scanning tunneling microscopy/spectroscopy that defects that break local mirror symmetry of SnTe suppress electron tunneling over an energy range as large as the bulk band gap, an order of magnitude larger than that produced globally via magnetic fields or uniform structural perturbations [1]. The results reveal the influence of various defects on the electronic properties, including screw dislocations, point defects, and tilt boundaries that lead to dislocation arrays that serve as periodic nucleation sites for pits grown on $SrTiO_3$ [2,3]. Complementary ab initio calculations show how local symmetry breaking obstructs topological surface states as shown by a threefold reduction of the spectral weight of the topological surface states. The findings highlight the potential benefits of manipulating the surface morphology to create devices that take advantage of the unique properties of surface states and can operate at practical temperatures.

[1] O.E. Dagdeviren et al., Physical Review Materials **2**, 114205 (2018).

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EM-ThP11 Optical and Electrical Properties of Layer-by-layered and Mixed ZnS/CdS Structures with a Decrease in Cd-content by Co-sputtering Method*, S. Pech,* Chosun University, Republic of Korea*; Y.-K. Jun,* EM Co., Inc., Republic of Korea*; **Geum-Bae Cho**, N.H. Kim,* Chosun University, Republic of Korea

CdS is one of the most attractive n-type II–VI semiconductor materials for window layers or buffer layer in heterojunction thin film solar cells because of its high transmitivity, low resistivity, and excellent permeability with a bandgap of 2.42 eV [1]. However, the use of cadmium would be deleterious for the environment because of carcinogenic and toxic nature. To reduce the use of cadmium ZnS/CdS structures were investigated in this study. ZnS is an n-type semiconductor with relatively high transparency, large Bohr exciton radius (2.5 nm), large exciton binding energy (40 meV), high index of refraction (2.27) [2]. Two types of structure were fabricated with the same thickness: layer-by-layered and mixed structures were fabricated by co-sputtering method with each ZnS and CdS target as a function of Cd-content. Cd-content was adjusted by a sputtering time for CdS target. All samples were annealed in a rapid thermal annealing system at 400°C for 10 min. Structural properties of two-types of structure with the different Cd-content by X-ray diffraction studies. Optical and electrical properties of them were analyzed by using an UV-Visible spectrophotometer and a Hall effect measurement system for optical transmittance, bandgap, resistivity, carrier mobility, and carrier concentration. Acknowledgement: This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the Ministry of Trade, Industry & Energy (MOTIE) of the Republic of Korea (No. 20184010201650). [1] Nam-Hoon Kim, Seung-Han Ryu, Hyo-Sup Noh, Woo-Sun Lee, Electrical and optical properties of sputter-deposited cadmium sulfide thin films optimized by annealing temperature, Mater. Sci. Semicond. Process. 15, 125 (2012). [2] Sanjeev Kumar, C.L. Chen, C.L. Dong, Y.K. Ho, J.F. Lee, T.S. Chan, R. Thangavel, T.K. Chen, B.H. Mok, S.M. Rao, M.K. Wub, Room temperature ferromagnetism in Ni doped ZnS nanoparticles, J. Alloy Compd. 554, 357 (2013).

EM-ThP12 Design and Simulation of a Leaf-like Antenna on Thin Kapton Sustrate for the 915MHz Frequency*, **Felipe Frazatto**, L.T. Manera, L.S. Perissinotto,* UNICAMP, Brazil

When launching a satellite into orbit, every gram reduced from its total weight counts toward cheaper missions, with this in mind and inspired by the wide range of applications allowed by flexible electronics, this work presents the study and simulation of a leaf-like coplanar microstrip antenna on an one mil thick Kapton substrate centered in the 915MHz frequency to be used with a LoRa communication module in Low Earth Orbit (LEO) CubeSats.

Ring resonators and coplanar transmission lines (CPW) were also simulated to be used in the substrate's material characterization and help understand the various challenges poused by the thin thickness. Comparing the simulations of the CPW and characteristic impedance equations found in the literature, it was possible to notice divergences between the simulated model impedance and the theoretical calculated value when dealing with the thin substrate, witch indicates that the equation's models may not consider effects that appear with the reduced thickness, making it difficult to obtain a good impedance matching.

The designed antenna is presented alongside a impedance matching semi flexible circuit, a coplanar waveguide, ring resonator and the study of the impedance matching hardships when using thin substrates for radio frequency applications.

EM-ThP13 Examining the Compositional Uniformity of GaAsNBi Alloys using Atom Probe Tomography*, **Jared W. Mitchell**, C.M. Greenhill, T.Y. Jen, R.S. Goldman,* University of Michigan, Ann Arbor

Due to the significant bandgap narrowing and complementary strain induced by dilute fractions of N and Bi in III-V semiconductors, dilute nitride-bismide alloys are of significant interest for near- and mid-infrared applications ranging from temperature-insensitive laser diodes to ultra-high efficiency multi-junction photovoltaic cells. However, to date, few dilute nitride-bismide compositions have been accessed experimentally, and determinations of alloy compositions have typically not accounted for the presence of interstitial N. Using direct measurements of N and Bi mole fractions, via ion beam analysis, in conjunction with direct measurements of the out-of-plane misfit via x-ray rocking curves, we recently determined the "magic ratio" for lattice-matching of GaAsNBi alloys with GaAs substrates.[1] In addition, using photoreflectance and photoluminescence (PL) spectroscopy, we mapped the composition- and misfit-dependence of the bandgap energies. However, the PL emission from the layers displays an extended low-energy tail, likely due to emission from a distribution of localized states. To explore the origins of the localized states, we are examining alloy non-uniformities in GaAsNBi epilayers using local-electrode atom-probe (LEAP) tomography. In particular, we are exploring the role of N interstitial complexes and metallic cluster formation on the isovalent co-alloying of GaAs with Bi and N. We will present LEAP analysis of a series of nearly-lattice-matched GaAsNBi layers with various N and Bi fractions. We will also discuss correlations between alloy non-uniformities and local electronic states in GaAsNBi epilayers and heterostructures.

1. J. Occena, T. Jen, J.W. Mitchell, W.M. Linhart, E.-M. Pavelescu, R. Kudrawiec, Y.Q. Wang, and R.S. Goldman, Appl. Phys. Lett. in press (2019).

EM-ThP14 Silicon Nanowire P-N Junction Photovoltaic Device*, **Michael Small**, S.D. Collins, R.L. Smith,* University of Maine

This paper presents the fabrication and testing of a low cost, silicon nanowire photovoltaic device. The silicon nanowires are etched into the surface of a silicon wafer, via metal assisted chemical etching (MACE). This method of nanowire fabrication does not require photolithographic patterning, thereby reducing manufacturing complexity and related costs. Vertically aligned nanowire p-n junctions have the potential to increase the optical bandwidth of a silicon photovoltaic device by allowing a greater amount of short wavelength light to reach the depletion region near the junction, resulting in improved conversion efficiency. When compared to a planar analog, the nanowire device produced an order of magnitude higher power in response to blue light (405 nm), attributed to increased collection at the exposed p-n junctions. Power conversion efficiency is eight times better than previously reported with a similar construct.

EM-ThP18 Incredibly Simple Synthesis of a Zinc Oxide / Graphene Hybrid Nano Material*, **Daniel Little,*** Ohio Dominican University*; J. Pfund, A. McLain, S. Lantvit, S.T. King,* University of Wisconsin - La Crosse

Hybrid materials of zinc (II) oxide (ZnO) nanocrystals and graphene are of current interest due to their cheap, Earth-abundant composition, low toxicity, and varied applications in photocatalysis, sensing, and electronics among others. We have developed a novel methodology for the synthesis of such materials utilizing the thermal decomposition of zinc (II) oxalate in solid-state solution with graphene nanoplatelets. Although the procedure involves simply precursor mixing and heating, electronic interaction between the ZnO and graphitic phases is spectroscopically observed in the hybrid material – beyond that of a homogeneous mixture of ZnO and graphene – via powder XRD, XPS, and ATR-IR spectroscopy. The synthetic method employed can be easily tuned for the desired hybrid product stoichiometry, and is easily industrially scalable with minimal chemical waste products. The method can also be adapted for the creation of thin film composite materials.

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