

Thursday Afternoon Poster Sessions, November 10, 2016

Electronic Materials and Photonics

Room Hall D - Session EM-ThP

EMPD Poster Session

EM-ThP1 The Effects of VUV Radiation on Low-k Organosilicate Glass (SiCOH) as Measured with Electron-Spin Resonance, Panpan Xue, W. Li, University of Wisconsin-Madison; J. de Marneffe, M. Baklanov, IMEC, KU Leuven Belgium; V. Afanas'ev, Catholic University of Leuven, Belgium; Y. Nishi, Stanford University; J.L. Shohet, University of Wisconsin-Madison

The effects of VUV radiation on defect concentrations in SiCOH are investigated. Electron-spin resonance (ESR) spectroscopy is a very effective tool to detect defects in dielectrics. ESR has been used on various high-k dielectrics, such as HfO₂. Here, in order to obtain a clear spectroscopic signal, 60-nm thick SiCOH ($k=2.4$) was deposited on high-resistivity (3000 Ω -cm) wafers. There are at least two kinds of detectable defects in SiCOH: Si dangling bonds ($g=2.0054$) and Oxygen vacancies ($g=2.0020$). In this work, we concentrate on the silicon dangling-bond defects. In order to eliminate dangling bonds from the silicon substrate as well as its edges, CP4 and HF treatments were used. To investigate the influence of VUV radiation, the samples were exposed to synchrotron radiation with a range of photon energies from 7.3 to 21 eV. The ESR measurements showed that the defect concentration of the silicon dangling bonds increased after VUV exposure with photon energies higher than 8eV. In addition, when the photon energy was less than 15 eV, the defect concentration increased with higher photon energy, but did not increase further for VUV exposures with higher photon energies. This is likely caused by electron depletion by photoemission from defects during VUV irradiation. That is, before VUV irradiation, the silicon dangling bonds are filled with electrons. The electrons are then depleted by photoemission during irradiation. Since the band gap for SiCOH is approximately 8 eV, this is also consistent with the fact that the energy threshold for Si-H bond photolysis at the surface of H-passivated Si is ~ 7.9 eV. Moreover, VUV exposure can cause a loss of methylated species. It is possible that the loss of $-CH_3$ groups results in additional Si dangling bonds near the surface of the SiCOH films. The ESR signals have a Lorentzian shape and the Bloch model fits these well. We conclude that silicon dangling bond defects in SiCOH and its interface with silicon can be detected using ESR and that VUV exposure increases the defect concentration.

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EM-ThP2 Effect of Initial Substrate Conditioning on Structural and Optoelectronic Properties of In_{1-x}Ga_xN Grown by MEPA-MOCVD, Indika Senevirathna, D. Seidlitz, A. Fali, Y. Abate, N. Dietz, Georgia State University
Fabrication of high quality Indium rich- In_{1-x}Ga_xN layers is still a challenge due to the immiscibility between the binaries InN and GaN. The lack of lattice-matched substrate is an additional challenge for the growth of In_{1-x}Ga_xN layers. The lattice mismatch between the substrate template and the In_{1-x}Ga_xN layer generate residual strains and threading dislocations at the interface that propagate into the In_{1-x}Ga_xN layers, and consequently, degrade the quality of the In_{1-x}Ga_xN epilayer. To mitigate these effects, different approaches such as the use of buffer layers (e.g. GaN, InN, AlN) between the In_{1-x}Ga_xN layers are explored.

In this contribution, we present our findings on the effects of substrate treatments on the structural and optoelectronic properties of In_{1-x}Ga_xN layers grown by Migration-Enhanced, Plasma-Assisted MOCVD (MEPA-MOCVD). Furthermore, the analysis consist the data for In_{1-x}Ga_xN layers grown on different nitrided sapphire substrates as well as layers grown on sapphire substrates templates, containing InN, GaN or AlN interlayers.

The optoelectronic properties – e.g. free carrier concentration, the mobility of the carriers, high-frequency dielectric constant ϵ_{∞} , and layer thickness in the In_{1-x}Ga_xN layers have been analyzed by simulating the reflectance spectra, obtained via Fourier Transform Infra-red (FTIR) spectroscopy, using

a multilayer stack model and a dielectric function based on Lorentz-Drude model. AFM topography has been used to study the surface morphology of the layers. Raman spectroscopy has been utilized to analyze the local crystallinity ($E_2(\text{high})$ mode) of the In_{1-x}Ga_xN layers as well as the composition via the shift of the $A_1(\text{LO})$ mode and its broadening with In_{1-x}Ga_xN target composition.

EM-ThP3 An In-Depth Study of Cu₂ZnSnS₄ Films Synthesized by Sulfurization of Stacked Metallic Layers, A. Alvarez Barragan, S.A. Exarhos, Lorenzo Mangolini, University of California Riverside

The quaternary chalcogenide Cu₂ZnSnS₄ (CZTS) is composed of earth-abundant elements and has interesting optoelectronic properties that project it as an important candidate for thin-film photovoltaics. Among several synthesis methods, sulfurization of metallic stacked layers has been heavily used because it does not rely on toxic compounds and provides good control over the final stoichiometry of the sample [1-3]. We present an in-depth structural and compositional analysis of CZTS synthesized by this technique. A first study exhibits preferential segregation of hexagonal SnS₂ when increasing the sulfurization pressure in a closed annealing chamber. Variations in film morphology suggest that different reaction pathways take place as the pressure is raised. Formation of gaseous SnS is favored at lower pressure, while nucleation of solid SnS₂ preferentially occurs at higher pressure. In addition to this investigation, an individual grain study sheds light on the complexity of this material system. Elemental analysis shows significant grain-to-grain variations in composition despite dealing with an overall close-to-ideal stoichiometry. High resolution Raman spectroscopy indicates that this is accompanied by grain-to-grain structural variations as well. The intensity from the 337 cm⁻¹ Raman peak, generally assigned to the kesterite phase of CZTS, remains constant over a large area of the sample. On the other hand, signals from secondary phases at 376 cm⁻¹ (copper-tin-sulfide) and 351 cm⁻¹ (zinc-sulfide) show significant variation over the same area. These results demonstrate how a seemingly homogeneous CZTS thin film can actually have considerable structural and compositional variations that are often overlooked.

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EM-ThP4 Optical and Magneto-Optical Properties of ZnO/Zn_{1-x}Co_xO Thin Films Grown by Pulsed Laser Deposition, Da-Ren Liu, C.J. Weng, Instrument Technology Research Center, National Applied Research Laboratories

Diluted magnetic semiconductors (DMS) have recently attracted considerable attention due to their potential applications for spintronic devices, such as spin-valve transistors, nonvolatile memory, and magneto-optical switches. ZnCoO is one of the most promising DMS materials due to its predicted above room temperature ferromagnetism. In this study, ZnO layer was conformally deposited on the Si substrates by atomic layer deposition (ALD). Then the Zn_{1-x}Co_xO (0.01 < x < 0.10) coatings were grown on ZnO layer by Nd:YAG pulsed laser deposition (PLD). The thickness and roughness of the films were characterized by grazing-incidence x-ray reflectivity (GIXR). According to the results of high-resolution x-ray diffraction, the ZnO/ Zn_{1-x}Co_xO thin films are polycrystalline with a preferential growth direction of (002). Photoluminescence spectra demonstrate ultraviolet emission peaks which have shift with the increase of Co ion concentration. The temperature-dependent magnetization (M-T) curves of the ZnO/ Zn_{1-x}Co_xO thin films were measured by a superconducting quantum interference device (SQUID) magnetometer and the magneto-optical properties were measured by micro-MOKE spectroscopy. The results show the room temperature ferromagnetism of the ZnO/ Zn_{1-x}Co_xO thin films suggested that the possibility for the application to diluted magnetic semiconductors.

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EM-ThP5 A bi-functional Bolometer with Sensitivity to IR Radiation and Hot Air Induced Temperature Variation, Evgenia Vaganova, The Hebrew University of Jerusalem, Israel

ABSTRACT We have shown previously that doping a poly(4-vinyl pyridine)/pyridine gel with an ester group-containing polymer (e.g. poly(butyl methacrylate)) (polymer acids as additives) expands the wavelength range of the gel photoelectrical sensitivity from the uv into the infra-red. Here we characterize the temporal response of the gel resistivity and demonstrate its ability to operate as a bi-functional bolometer. At constant room temperature, the bolometer can function as a rapidly responding IR detector. It can also respond to temperature variation produced by hot air, but with a much longer time constant. Measurements are shown in the figure below.

b)

Figure. a) Time dependence of the resistance changes of the polymer gel due to IR irradiation at 1 μm . The down pointing arrows indicate switch-on of the radiation source while the up pointing arrows indicate switch-off. b) Time dependence of the resistance changes of the polymer gel in response to temperature variation produced by hot air. The maximum temperature change was 4C (26C - 30C).

The fractional change in resistance caused by IR irradiation at 1mm is $\Delta R/R_0 = 0.13$; the fractional change caused by hot air induced temperature variation - $\Delta R/R_0 = 0.06/1^\circ\text{C}$. The relaxation rate of the IR response following switch-off is 260%/s. The temperature-induced relaxation curve could be fit to an exponential function with two time constants - $\tau_1=0.148\text{s}$ and $\tau_2=17.11\text{s}$. Analysis of the relaxation of the photo-response was limited by the time resolution of the resistance measurements, i.e. 0.02s.

Polymer/liquid pyridine interactions² are considered to be responsible for this interesting functionality of the polymer blend and they will be discussed.

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EM-ThP6 Proton-Induced Effects on HfOx-Based Resistive Random Access Memory, K. Hsu, T. Chang, University of Wisconsin-Madison; **L. Zhao, Z. Wang,** Stanford University; **R. Agasie, T. Betthausser, J. Nickles, J. Chang,** University of Wisconsin-Madison; **Y. Nishi,** Stanford University; **Z. Ma, J. Leon Shohet,** University of Wisconsin-Madison

Resistive Random Access Memory (RRAM) [1], is considered to be a very promising memory technology. As RRAM technology matures and electronic devices using RRAM are likely to be built soon, malfunctions of RRAM caused by radiation will become an important problem in industry since the size of these devices will continue to decrease. The goal of this work is the measurement of proton-induced effects on HfOx RRAM cells. Proton irradiation in the MeV range of energies were initially chosen since most cosmic-ray protons are in this range. However, protons lose energy when they pass through matter and thus, lower-energy protons were also investigated. According to TRIM code calculations, there is more interaction between protons and HfOx films when the proton energy decreased to several keV.

Two proton fluences were chosen ($\sim 2 \times 10^{15}\text{cm}^{-2}$ and $\sim 2 \times 10^{14}\text{cm}^{-2}$). The proton-induced effects on HfOx RR AM cell include forming rate, modification to forming voltage, resistance of high resistance state (HRS) and shifts in set/reset voltage. After proton irradiation, no RRAM cells were formed and ended up in the low resistance state (LRS) and no changes were observed in the forming voltage of irradiated RRAM cells even when exposed to very high fluence ($\sim 2 \times 10^{15}\text{cm}^{-2}$).

An increase in the resistance of HRS was observed in proton-irradiated RRAM cells. RRAM cells irradiated with 60 keV protons have a higher increase in their HRS state than RRAM cells irradiated with 5 MeV protons. The shift in values of the set voltage can be seen on the I-V characteristic of the proton-irradiated RRAM cell. It is very likely that there is an annealing process occurs and it might be a result of defect reordering after proton irradiation.

The shift in set voltage after 5 MeV proton irradiation (fluence $\sim 2 \times 10^{15}\text{cm}^{-2}$) is from 3.5 V to 7 V. The shift in set voltage after 60 keV proton irradiation (fluence $\sim 2 \times 10^{15}\text{cm}^{-2}$) is from 3.5 to 11 V. Such shifts of set voltages may create problems in real device applications. These shifts are likely to be attributed to atomic-structure changes in HfOx caused by proton irradiation.

This work was supported by the Semiconductor Research Corporation under Contract No. 2012-KJ-2359, by the National Science Foundation under Grant No. CBET-1066231.

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EM-ThP7 SiGe_x (100) (x=0.25, 0.5, 0.75) and Ge (100) MOSCaps with Aqueous Ammonium Sulfide Passivation, Lauren Peckler, S.L. Heslop, A.J. Muscat, University of Arizona

SiGe_x is a potential semiconductor for next generation transistors because it could be incorporated into current, silicon-based semiconductor manufacturing processes and it would improve transistor performance due to the high carrier mobility of Ge. Despite these advantages, one major challenge is to reduce the number of Ge defects at the SiGe/dielectric interface because they degrade electrical performance of the transistor. While a relatively stable SiO₂ layer can be grown on Si with relatively few defects, the same is not true for Ge. One approach to forming a high quality interface is to remove Ge oxides by passivating the Ge atoms on the surface. SiGe and Ge metal oxide semiconductor capacitors (MOSCaps) were fabricated (10 nm Al₂O₃) and tested to evaluate the effect of sulfur-based chemical passivation on electrical performance. The (100) faces of three SiGe_x substrates - x = 0.25, 0.5, 0.75 - and one Ge substrate were cleaned and treated with one of two ammonium sulfide, (NH₄)₂S, wet chemistries: (NH₄)₂S/H₂O (1:100 v/v) or (NH₄)₂S/HCl/HF/H₂O (1:0.15:0.15:100 v/v). The surfaces of control MOSCaps were cleaned only. The contact area on each device was 12.6 μm^2 .

Average capacitance in accumulation for SiGe_x MOSCaps (x = 0.25, 0.5) was 199 ± 5.4 and 205 ± 22 pF, with a DC bias sweep from -2 to +2 V at 1 MHz. The same capacitance was 42 ± 1.3 pF for SiGe_x (x = 0.75) and 457 ± 12 pF for the Ge MOSCaps. Both (NH₄)₂S treatments increased the accumulation capacitance by 6% and 34%, on average, for SiGe_x (x = 0.25, 0.5), 8% for SiGe_x (x = 0.75), and 8% for Ge MOSCaps. Similarly, V_{FB} shifted -2 V (SiGe_x (x = 0.25, 0.5)) and -14 V (SiGe_x (x = 0.75) and Ge) with respect to the controls. While flatband shifting is at least due to reduction of oxide defects in the Al₂O₃ layer, the low magnitude of accumulation capacitance (according to oxide thickness calculations) suggests that there are other oxide layers present.

Half of the SiGe_x MOSCaps (x = 0.25, 0.75) were annealed in forming gas. V_{FB} shifted +3 V for SiGe_x MOSCaps (x = 0.25) with respect to non-annealed results, which is indicative of a reduction in negatively charged bulk oxide defects. SiGe_x (x = 0.75), and Ge MOSCaps possibly had less bulk oxide defects because their V_{FB} were within ± 0.5 V before and after annealing. Less bulk oxide defects in these MOSCaps suggest that nucleation and growth of the Al₂O₃ layer on these surfaces may differ from that of the SiGe_x (x = 0.25) surface. Among all three SiGe_x (x = 0.25) MOSCaps, the one treated with (NH₄)₂S and acid and annealed resulted in the flatband voltage closest to 0 V, as well as the lowest capacitance.

EM-ThP8 Investigating U₃O₈ for Solid-State Direct-Conversion Neutron Detection Applications, Shailesh Dhungana, G. Bhattarai, University of Missouri-Kansas City; **B.C. Shaver, S. Lawson, B. Musicó, T. Meek,** The University of Tennessee Knoxville; **M.M. Paquette, A.N. Caruso,** University of Missouri-Kansas City

Solid-state direct-conversion neutron detectors, wherein a semiconductor detector heterostructure is made up of a neutron absorbing material, are capable in principle of very high neutron detection efficiencies. High-efficiency direct-conversion detectors have not yet been achieved in practice, however, because of challenges in finding suitable materials that simultaneously meet the necessary criteria, including high neutron absorption, high mobility-lifetime product, and low leakage current. Uranium-oxide-based semiconductors make up a promising class of neutron detection materials as uranium undergoes neutron-induced fission

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to yield very high energy primary reaction products, which can in turn create a large number of electron-hole pairs—two-to-four orders of magnitude higher than in the case of boron and lithium, the materials commonly studied for direct-conversion detectors. This additional charge can help to overcome limitations in charge transport properties, such as high leakage current and low charge carrier mobility, typically seen in candidate neutron-absorbing semiconductor materials. Of the uranium oxides, UO_2 has been studied the most, and literature reports show that its resistivity and charge carrier mobility vary widely with stoichiometry and microstructure. Very few studies on the electrical transport properties of U_3O_8 exist, with one reporting values of $10^4 \text{ } \Omega \text{ cm}$ for resistivity and $1 \text{ cm}^2/\text{V s}$ for mobility (George & Karkhanavala, 1963). Like for UO_2 and other semiconductors, however, these properties would be expected to vary widely. To determine the range of the possible charge transport properties in U_3O_8 , as well as how they vary with material composition and microstructure, a rigorous study is necessary. We report the results of charge transport measurements using a range of techniques, including four-point van der Pauw resistivity and DC Hall, on sintered U_3O_8 pellets of varying stoichiometry and grain size. Additionally, we report results from ultraviolet and x-ray photoelectron spectroscopy toward probing the electronic structure of the U_3O_8 surface toward the development of suitable electrical contacts for this material.

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EM-ThP9 Investigation of Electro-Optical and Chemical properties InN epilayer grown on Ga-face GaN by RF-MOMBE, W.-C. Chen, Chien-Nan Hsiao, Instrument Technology Research Center, National Applied Research Laboratories, Taiwan, Republic of China

Epitaxial indium nitride layers were grown on gallium nitride/c-sapphire by radio frequency metal-organic molecular beam epitaxy. We discussed the effect of V/III flow ratios on the Electro-Optical and Chemical properties of epitaxial indium nitride. The chemical properties of the indium nitride films were characterized in detail using Secondary ion mass spectrometry and X-ray photoelectron spectroscopy, and the electrical and optical properties were studied by Hall Effect and photoluminescence measurements. Secondary ion mass spectrometry and X-ray photoelectron spectroscopy results showed that carbon and hydrogen of average concentration were measured about 10^{20} cm^{-3} in InN films and O concentration in the InN film is about 10^{19} cm^{-3} . Also, the C and O concentrations decrease with increasing trimethylindium flow rate. A relatively high C, H and O concentration exists near the surface of the InN film. After etching, the etched InN film exhibited a decreased carrier concentration of $3.31 \times 10^{19} \text{ cm}^{-3}$, increased electron mobility of $335 \text{ cm}^2/\text{V-s}$. Optical properties showed that the PL spectra exhibited NBE peak in the range of $0.692 \sim 0.735 \text{ eV}$. Also, the peaks showed blue-shift with increasing V/III flow ratio.

EM-ThP12 Temperature-Resistance Effect of Carbon Black / Polydimethylsiloxane Composite, Jing Xu, L.Z. Ouyang, Tennessee State University

In the present work, temperature-resistance effect is found in carbon black/Polydimethylsiloxane composites. The composites were made by mixing the carbon black, aluminium oxide powder and polydimethylsiloxane (PDMS). Interdigitated copper electrodes were obtained using chemical etching method on the flexible polyimide substrate in order to determine the resistance change of the composites at different temperatures. The resistances of as-fabricated composites at different temperatures are measured using multimeter. From the results, we found out that the resistance increases dramatically with temperature increasing, and the fitting result shows that it's an exponential increase. This composite has the potential to fabricate the flexible and high-precision temperature sensor.

EM-ThP13 Dependence of Electrical Conductivity on Observed Microstructure of Sintered U_3O_8 , Seth Lawson, B.C. Shaver, B. Musicó, The University of Tennessee Knoxville; S. Dhungana, G. Bhattarai, M.M. Paquette, A.N. Caruso, University of Missouri-Kansas City; T. Meek, The University of Tennessee Knoxville

Actinide compounds, such as uranium oxides, have been shown to have band gaps similar to conventional semiconducting materials such as Si, Ge, and GaAs but with significantly higher operating temperatures as well as higher resistance to radiation damage, allowing for possible use as a detector material in environments and conditions that would otherwise be impractical. Under standard atmosphere and pressure, U_3O_8 is the most stable form of uranium oxide. This work will focus on the stoichiometric

composition and will detail the methods used to develop green pellets of U_3O_8 from natural uranium in the form of uranyl acetate. Understanding the microstructure morphology of these pellets as a function of sintering conditions is an important step toward elucidating the activation energy of sintering and grain growth kinetics of this material. The morphology and grain size can then be correlated to changes of measured electrical properties. Optical microscopy was used to determine the grain characteristics for each sintering condition in order to evaluate the influence on sintering on grain growth. Electrical property studies were conducted with measurements including four-point van der Pauw resistivity and DC Hall measurements. These studies will contribute to a larger effort aimed at exploring the electrical properties of uranium oxides to determine whether the properties of U_3O_8 can be optimized to fabricate a competitive direct conversion solid-state neutron detector.

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