

Thursday Afternoon Poster Sessions

Electronic Materials and Processing

Room: Hall B - Session EM-ThP

Electronic Materials and Processing Poster Session

EM-ThP1 Hot Fire Chemical Vapor Deposited Silicon-rich Oxides: Its Optical and Compositional Properties, A. Benítez, J.A.L. Luna, G. García, D. Vázquez, J. Carrillo, K. Monfil, Benemérita Universidad Autónoma de Puebla, Mexico, A. Morales, Centro de Investigación en Materiales Avanzados, Mexico

Silicon Rich oxides have been considered as a material to overcome the drawbacks of silicon to achieve optical functions. Various techniques can be used to produce it, including Hot-fire Chemical Vapor Deposition (HFCVD). Obtain silicon compatible material with an optimal photoluminescence response is important for to have optoelectronic functions. The SiOx has shown to have a very good photoluminescence response and is also compatible with silicon technology. In this works, SiO_x Films were obtained by hot fire chemical vapor deposition (HF-CVD) with different deposit conditions. The hydrogen flows were changing of: 50, 75, 100, and 125 and 150 sccm, and the range of deposit temperature were from 800 to 1000°C. The compositional and optical properties of the SiOx films were obtained using fourier transformed infrared spectroscopy (FTIR), photoluminescence (PL), Transmittance and perfilometer. The IR absorption spectrum shows the presence of three typical Si–O–Si vibrations modes in SiO₂ also the change of the morphology. At 75 and 100sccm showed the most intense PL. Transmittance spectra showed a wavelength shift of the absorption border from 350 to 450nm. We have analyzed the dependence of PL on the composition of non-stoichiometric SiOx films.

EM-ThP2 Effect of Co-implantation of Nitrogen and Fluorine on the Total Dose Radiation Response of the Buried Oxide Layer of SOI Materials, Z.S. Zheng, Institute of Microelectronics of Chinese Academy of Sciences, China

In order to suppress the total dose radiation response of the buried oxide layer of silicon-on-insulator (SOI) materials, the method of co-implantation of nitrogen and fluorine into the buried oxide is used by fluorine implantation into the nitrogen-implanted buried oxide. The total dose radiation response of the modified buried oxide layer is characterized by the capacitance–voltage ($C-V$) technique after irradiation using a Co-60 source. The results show the radiation hardness differences between the co-implanted buried oxide layers and the nitrogen-implanted ones, and the improved radiation tolerance for the modified buried oxide layer under some conditions, compared to the unmodified one. It is also found that there is a negligible annealing effect for the co-implanted buried oxide at a temperature of 150°C after irradiation. All the results have been discussed and analyzed.

EM-ThP3 The Effects of Water Uptake on the Mechanical Properties of Low-k Organosilicate Glass, X. Guo, University of Wisconsin-Madison, J. Jakes, USDA Forest Service Forest Products Laboratory, M. Nichols, University of Wisconsin-Madison, S. Banna, Applied Materials Inc., Y. Nishi, Stanford University, J.L. Shohet, University of Wisconsin-Madison

Water uptake in porous low-k dielectrics has become a significant challenge for both back-end-of-the-line integration and circuit reliability. The influence of absorbed water on the mechanical properties of PECVD organosilicate glasses (SiCOH) was investigated with nanoindentation. The roles of physisorbed (α -bonded) and chemisorbed (β -bonded) water were examined separately through annealing at different temperatures. Nanoindentation measurements were made on dehydrated organosilicate glass (SiCOH) during exposure to different humidity conditions. The indentation results at shallow depth show that for as-deposited SiCOH, the elastic modulus and hardness were all intimately linked to the concentration of the absorbed water in the dielectric bulk and qualitatively held the same evolution mechanism with in-diffused water concentration. After annealing, the water-concentration-related film mechanical property changes were shown to be reversible. UV curing of SiCOH was shown to lower water-induced mechanical property variation effectively by depopulating the hydrophilic chemical groups in SiCOH. A high-load indentation test shows that in-diffusion of water at the film/substrate interface can degrade the hardness of a SiCOH/Si film stack significantly, while showing less effect on the elastic modulus.

This work was supported by the Semiconductor Research Corporation under Contract 2012-KJ-2359 and by the National Science Foundation under Grant CBET-1066231.

EM-ThP4 Study of Phosphorus-doped Polysilicon Films using Si₃H₈ by Ultra-high Vacuum Chemical Vapor Deposition, B. Kim, H. Jang, D.-S. Byeon, S. Koo, D.-H. Ko, Yonsei University, Republic of Korea

In situ phosphorus-doped polysilicon films grown on silicon oxide layers using trisilane (Si₃H₈) and phosphine (PH₃) as precursors were investigated as a function of Si₃H₈/PH₃ gas flow ratio and growth temperature. At high flow rate of Si₃H₈ the deposition process was controlled by the rate of desorption of hydrogen molecules on the surface, which has an activation energy of 1.13 eV, in the temperature range of 600 ~ 700 °C. In comparison, the deposition was limited by the diffusion of Si₃H₈ gas to the surface in the case of low Si₃H₈ flow rate for growth temperatures of > 650 °C. The presence of phosphorus decreased the crystallization temperature of polysilicon layers during growth. In addition, the ratio of phosphorus incorporated into the polysilicon at the same Si₃H₈/PH₃ ratio decreased with increasing growth temperature. The results of sheet resistance measurements suggest that the resistivity of phosphorus-doped polysilicon films decreased with increasing deposition temperature at the same phosphorus concentration, indicating that the use of a high growth temperature results in an enhancement in the activation of phosphorus in the polysilicon films during growth.

EM-ThP5 Electrical Properties of Atomic-Layer-Deposited Al-doped TiO₂ Films on p-type GaAs, Y. An, Y.-C. Byun, S. Choi, H. Kim, Sungkyunkwan University, Republic of Korea

For the development of high speed III-V-based metal-oxide-semiconductor field-effect transistors (MOSFETs) in replacement of current Si-based devices, high- k gate dielectric is the most crucial component and, especially, atomic layer deposition (ALD) technique has been acknowledged to be the ultimate solution in acquiring high electrical quality such as low leakage current and equivalent oxide thickness (EOT). In order to achieve a sub-1nm EOT value, many researchers have tried to introduce TiO₂ film due to its much higher k value than Al₂O₃ and HfO₂ [1, 2]. However, one major drawback in adopting TiO₂ is relatively high leakage current due to its small band gap (~3.1 eV) [1]. As an effort to reduce the leakage current, recently, Kim *et al.* employed Al-doped TiO₂ (ATO) films for memory capacitor application and demonstrated promising electrical performance [1]. More recently, Mahata *et al.* tried (TiO₂)_x(Al₂O₃)_{1-x} alloy film on In_{0.53}Ga_{0.47}As as a gate insulator [2].

In this study, we deposited various ATO films on S-passivated p-type GaAs substrates and characterized their electrical properties, while varying the Al₂O₃ doping concentration and film thickness. The nanolaminating ALD process for the formation of ATO films utilized trimethylaluminum, titanium tetrakis-isopropoxide, and H₂O precursors at a deposition temperature of 250 °C. After MOS capacitor fabrication, various electrical properties including capacitance-voltage, interface state density, and leakage current were evaluated. The dependency of these electrical properties on the ATO film composition will be discussed and correlated with various interface and film characterization results.

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EM-ThP6 Surface Deactivation of SiO₂ using Octadecyltrichlorosilane Based Self-Assembled Monolayers, A. Hinckley, A.J. Muscat, University of Arizona

Self-assembled monolayers (SAMs) of octadecyltrichlorosilane (OTS) were investigated as a deactivation technique for SiO₂ surfaces. Liquid phase chemisorption of OTS has been previously described as a surface modification technique for prevention of atomic layer deposition in selective areas. However, the development of an OTS monolayer with the appropriate density required to fully deactivate the SiO₂ surface is extremely sensitive to multiple experimental parameters, including the ambient humidity. This study presents a liquid phase chemisorption method of forming deactivating SAMs in the absence of humidity control. SAMs were deposited both using OTS alone as well as co-adsorbed with trimethylchlorosilane (TMCS) monomers to repair defects in the OTS SAM which might have formed. Monolayers were deposited as a function of solution concentration, solvent, substrate temperature prior to deposition, and hydroxylating solution. Ellipsometric and goniometric results showed that the ideal OTS SAM thickness (26 Å) and water contact angle (110°) were achieved. X-ray photoelectron spectroscopy was used to probe monolayers for defects in conjunction with TiO₂ atomic layer deposition. High resolution Ti 2p XPS spectra showed that no titanium was bonded to

oxygen for up to 100 ALD deposition cycles. In addition, monolayers which initially showed evidence for titanium deposition were passivated via another exposure to the SAM process. This evidence suggests that a fully-deactivated SiO₂ surface can be achieved via the use of a secondary TMCS deposition step without the necessary humidity control. Future work includes the use of SAMs in patterned structures and the deposition of an OTS SAM from the vapor phase.

EM-ThP7 Investigation of Dual-Active-Layered Zinc-Tin-Oxide/Indium-Gallium-Zinc-Oxide Thin-Film Transistors with the Durability of the Chemical Damage, C.H. Kim, H.J. Kim, Yonsei University, Republic of Korea

Amorphous-indium-gallium-zinc-oxide (a-IGZO) as channel materials of thin-film transistors (TFTs) has attracted attention as alternative of amorphous silicon (a-Si) for the backplanes of next-generation active-matrix organic light-emitting diode (AMOLED) displays and active-matrix liquid-crystal displays (AMLCDs) due to advantages such as high field-effect mobility, flexibility, good uniformity, transparency in visible light, and low temperature process. However, IGZO thin film has an activated chemical reaction in the bulk of wet etchants for patterning source/drain (S/D) electrodes. Therefore, the process using IGZO film as a channel layer should adopt the protection layer (mainly insulator), that is high cost process due to accessional lithography process and causes a large parasitic capacitance due to the misalignment margin among the gate, the protection layer, and the S/D. So as to improve the above disadvantages, we applied Zn-Sn-O (ZTO) to the protection layer. ZTO has higher chemical stability than IGZO owing to its SnO₂ content, and provides very lower contact resistance compared to that of insulator due to the semiconductor property. The dual-active-layered IGZO/ZTO (DALZI) has the IGZO layer under ZTO layer, which is the protection layer that shield IGZO layer from damage by the aluminum etchant. The DALZI TFT was successfully shielded by ZTO layer during soaking in aluminum etchant, whereas the IGZO TFT was readily damaged or removed. As the above reason, the electrical performance of the DALZI TFT could be preserved after exposure to aluminum etchant compared with that of the IGZO TFT. Hence, the DALZI structure could grant IGZO-based oxide semiconductor the first option for next-generation active-matrix switch device due to low cost.

EM-ThP9 Comparison of Properties of FTO and ITO Films with Different Concentrations, J.A.L. Luna, M. Meneses, J. Carrillo, F. Flores, A. Morales, J. Martínez, J. Sosa, E. Gómez, K. Monfil, A. Benítez, Benemérita Universidad Autónoma de Puebla, Mexico

Transparent conductive oxides (TCO) have become increasingly important in a large variety of applications due to demands as transparent and conductive materials. Applications of these devices include thin-film solar cells, display devices, optoelectronic devices, polymer-inorganic composite solar cells, gas sensors, and frost-resistant surfaces [1-4]. ITO is an n-type semiconductor where indium oxide (In₂O₃) has been doped with tin oxide in order to improve many of the material's properties, including its electrical conductivity [5]. Also, FTO is an ideal candidate for applications requiring TCO due to its ability to adhere strongly to glass, resistance to physical abrasion, chemical stability, high optical visible transparency, and electrical conductivity. FTO is frequently used as an alternative to ITO when chemical and electrical stability at elevated temperatures is required for device fabrication or application. FTO is more thermally stable because it does not depend on oxygen vacancies to provide charge carriers. As a result, when exposed to elevated temperatures, FTO does not experience the characteristic decrease in conductivity seen in the ITO system. Therefore, as device size continues to decrease, the potential use of nanoscaled structures of these TCOs grows, and a study for these TCO's is necessary. In this work, Spray pyrolysis automatized technique was used to deposit FTO and ITO films on glass coming. This technique allows us to obtain a better control on thin FTO and ITO films, with different properties just by varying the concentration of the fluorine. The structural and optical properties of the FTO and ITO films were obtained using X-ray Diffraction and scanning electronic microscopy, photoluminescence (PL), Transmittance and perfolometer. The diffractograms shows the presence of preferential planes of the FTO and ITO. SEM images showed the formation of different agglomerates. All films showed different intensities PL and transmittance spectra showed a wavelength shift of the absorption border. With Hall Effect we obtain some electrical properties.

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EM-ThP10 Optical Monitoring of Vapor Induced Phase Separation During Spin Coating of PVDF, N. Dawson, K. Malloy, University of New Mexico

Poly(vinylidene fluoride) has been studied extensively owing to both its ferroelectric properties and its usefulness as a porous membrane. Its large

polarization response makes PVDF a promising material for electrical applications in digital memory, super capacitors, and electrocaloric coolers. These and other applications of PVDF require high quality thin films. While there are different ways to deposit thin polymer films, spin coating is particularly attractive due to its affordability and ubiquitous use in industry. Understanding the processes occurring under varying conditions during spin coating of PVDF is therefore important. Humid environments have been shown to affect the morphology and crystallinity of spin coated PVDF films. In this presentation we use *in situ* optical reflectance to present evidence that film formation during spin coating in a humid environment is controlled by liquid-liquid and solid-liquid phase separation similar to the demixing seen in the vapor induced phase separation and immersion techniques used to create PVDF membranes. This enables real-time identification of the film formation processes, suggesting that monitoring of optical reflectivity is a basis for process control during spin coating and hence tailoring of film morphology for specific applications.

EM-ThP12 High-efficiency Semipolar GaN-based Light Emitting Diodes Fabricated by Wet Chemical Etching, S. Jung, Chonbuk National University, Republic of Korea, S.-N. Lee, Korea Polytechnique University, Republic of Korea, H. Kim, Chonbuk National University, Republic of Korea

Semipolar GaN semiconductors have become significantly important owing to their potential applications to high-efficiency optoelectronic and electronic devices, especially for the light-emitting diodes (LEDs) with a quantum-confined Stark effect free by eliminating the polarization-induced internal electric fields in the active regions. Another feature of semipolar GaN planes is weaker chemical inertness against chemical solutions compared to the polar (0001) c-plane, indicating that wet etching can be practically used. Indeed, several previous studies have revealed that the wet etching of semipolar GaN planes can form peculiar surface textures such as striated trigonal prisms by exposing specific crystallographic planes. These features are quite interesting in terms of the fabrication of more energy-efficient and cost-competitive LEDs. For example, first, the mesa of LEDs having semipolar orientations can be made using a wet etching process instead of conventional dry etching. Second, the crystallographic surface textures formed after wet etching can act as excellent light scatterers or exits for the guided mode caused by the large mismatch of the refractive indices of GaN and the environment (air), implying that the extraction efficiency can be significantly improved. Furthermore, wet etched surfaces were found to be much more efficient in making ohmic contacts, as will be discussed in our study for the first time. These findings suggest that wet etching can be practically used in the fabrication of LEDs. In this regard, we demonstrate the first semipolar GaN-based LEDs fabricated by a wet etching process, which led to better device performance than reference LEDs.

It was shown that the wet etching of semipolar GaN was a reaction-limited process with an E_a of 11.3 kcal mol⁻¹, exhibiting etching rates as high as 530 Å/min under 4M-KOH solution at 90°C. In particular, the wet etched surfaces exhibited the typical trigonal prism cell structure with a (0001) c-plane and [10-10] m-planes. Notably, the ohmic contact could be better formed on the wet etched surface, which could be attributed to the enhanced carrier transport through local shallow barriers associated with the exposed crystallographic structure. The LEDs fabricated by wet etching showed excellent output performance at 1.89 times higher than that of the reference LEDs. This could be due to the role of the textured surfaces. These findings suggest that wet chemical etching can be potentially important to semipolar or nonpolar-plane LEDs, which open new ways to achieve brighter and cost-competitive lighting engines for solid state lighting.

EM-ThP13 Characterization of Non-Stoichiometric Zinc Tungstate Thin Films, S.T. King, E.M. Dinauer, J.S. Krueger, B.R. Zink, Z.C. Koop, University of Wisconsin - La Crosse

Zinc tungstate (ZnWO₄) has recently gained much attention for its possible uses in photocatalysis and photovoltaic applications [1,2]. While many studies have focused on the fabrication and characterization of nanoscale structures of this material, few have investigated the properties of zinc tungstate thin films. Fewer have explored the properties of non-stoichiometric zinc tungstate materials.

The current study presents preliminary results on the structural, optical, and electronic properties of non-stoichiometric zinc tungstate thin-films fabricated using reactive DC sputter deposition. Such Zn_{1-x}W_xO₄ have been investigated in the parameter space from x = 0 to 0.5. The initial results of these studies suggest that the properties of zinc tungstate are strongly dependent on the quantity of W incorporated into the film. Therefore, the physical properties of zinc tungstate may be tailored for specific applications by employing such non-stoichiometric materials.

References:

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EM-ThP17 Development of Chalcogenide Materials for Inline Phase Change Switches (IPCS) for RF Applications, M.R. King, B.P. Wagner, E.B. Jones, N. El-Hinnawy, S.R. McLaughlin, P. Borodulin, J.S. Mason, Jr., R.S. Howell, R.M. Young, M.J. Lee, Northrop Grumman ES

Recently the digital memory industry has exploited chalcogenide materials for their distinct phase-dependent electrical properties, where the large resistivity difference between crystalline and amorphous states is used to create efficient memory platforms.

Digital applications primarily require large DC on/off ratios; RF switches on the other hand require very low on-resistance (R_{on}) and off-capacitance (C_{off}). These requirements are often mutually exclusive, where gains in one come at the expense of the other. Chalcogenide phase change materials represent a unique solution to this dilemma. With PCM devices, not only is it possible to obtain a very low R_{on} concomitant with very low C_{off} , but one can also achieve zero prime power consumption during steady state operation.

This presentation will detail the development of phase change materials that enable world class RF switch performance. Specifically a chalcogenide inline phase change switch (IPCS) utilizing GeTe has been fabricated for the first time utilizing a 3rd terminal for controlling an independent resistive heater to accomplish the thermal actuation of the phase change material. An on-state resistance of 6 Ω (0.06 Ω -mm), with an off-state capacitance and resistance of 33fF and 1 M Ω were measured, respectively, resulting in an RF switch figure-of-merit cut-off frequency (F_{co}) of 0.7 THz and a switching on/off ratio of 10^5 . The power required to change the GeTe from amorphous to crystalline was as low as 0.5W, with zero power consumption during steady state operation, making it a non-volatile RF switch. To the authors' knowledge, this is the first reported implementation of an RF phase change switch in a traditional, 3-terminal, in-line configuration.

In order to achieve such a high level of performance, significant material development efforts were undertaken. GeTe films were deposited using the DC magnetron sputtering technique and a power-pressure matrix was utilized to minimize sheet resistivity (R_s) and maximize the on-off ratio. Morphological features were evaluated using XRD, SEM and FIB-based cross sections. Electrical properties of as-deposited GeTe films were evaluated using 4-point probe measurements and a heated stage. The combined effect of sputtering power and pressure on film morphology and material properties will be presented.

In addition to wide ranging morphological and R_s variations with deposition parameters, it was found that the sputtering process significantly affects the chemical susceptibility of the films. An optimized fabrication scheme will be presented, in which high quality GeTe films were capable of being processed without a capping layer.

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