

Thursday Afternoon Poster Sessions

Electronic Materials and Processing Division

Room: East Exhibit Hall - Session EM-ThP

Electronic Materials and Processing Poster Session

EM-ThP1 Novel Quantized Edge States on Ag(111), A.R. DiLullo, Ohio University, *D. Acharya*, Pacific Northwest National Laboratory, *N. Takeuchi*, Universidad Nacional Autonoma de Mexico, *S. Ulloa*, *S.-W. Hla*, Ohio University

A one-dimensional electronic edge state has previously been observed using ultra-high-vacuum low-temperature scanning tunneling microscopy (UHV-LT-STM) methods at a sample tunneling bias of approximately 4V on Cu(111) and explained in terms of an image state at the step with energy modified by a dipolar potential[1]. Presented here are new measurements using sample bias dependent UHV-LT-STM imaging techniques of step edges on a Ag(111) surface which show numerous higher order states with correlated energy spacing. Measurements are additionally made at tip induced vacancy locations (holes in the surface) to examine effects of confinement on the newly observed one dimensional states. Experimental results are supported by density functional theory (DFT) calculations, and a framework for explanation of the newly observed energy correlated one dimensional and confined states is explored.

Supporting funding is supplied in part by the grants DOE DE-FG02-02ER46012 and NSF OSIE 0730257.

[1] L. Bartels, S. Hla, A. Kühnle, G. Meyer, K.-H. Rieder, and J. Manson, *Physical Review B* **67**, 1-5 (2003).

EM-ThP2 Fabrication of Multilayered Bi₂Te₃/Sb₂Te₃ and Bi₂Te₃/Bi₂Te_{3-x}Se_x Thin Film Cooling Devices, M. Hines, J. Lenhardt, Alabama A&M University, *M. Lu*, Brookhaven National Laboratory, *Z. Xiao*, Alabama A&M University

In this paper, we report to fabricate multilayered Bi₂Te₃/Sb₂Te₃ and Bi₂Te₃/Bi₂Te_{3-x}Se_x thin film cooling devices using the microfabrication techniques. The multilayered Bi₂Te₃/Sb₂Te₃ and Bi₂Te₃/Bi₂Te_{3-x}Se_x thin films will be grown using the e-beam evaporation. The in-plane and cross-plane micro cooling devices will be fabricated using the standard integrated circuit (IC) fabrication process; pn junction diodes will be fabricated as thermometers for the measurement of temperature in the devices. The electrical and thermal properties of the e-beam-grown Bi₂Te₃/Sb₂Te₃ and Bi₂Te₃/Bi₂Te_{3-x}Se_x thin films and the cooling efficiency of the fabricated cooling devices will be measured, and the measurement results will be reported in the conference. The developed devices could be a good candidate for the application of high-efficiency solid-state micro-cooling.

EM-ThP3 Solution-Based High Performance and Fully Patterned Chalcogenide Thin Film Transistors, J.I. Mejia, A. Salas-Villasenor, A. Carrillo-Castillo, B.E. Gnade, M.A. Quevedo-Lopez, University of Texas at Dallas

In recent years, the development of novel processes for inexpensive and flexible electronics has become an increasing research area where low-cost and low temperature deposition techniques are key point to fabricate large area and flexible circuits. Here, we demonstrate fully photolithography defined thin film transistors using cadmium sulfide (CdS) and lead sulfide (PbS) as n-type and p-type semiconductors, respectively. These chalcogenides materials are deposited using chemical bath deposition (CBD) which is a low cost solution-based process that requires temperatures below 70° C. Extracted mobility for CdS was 25 cm²/V-s and 0.14 cm²/V-s for PbS. These mobilities are among the highest reported for a fully patterned TFT made with either CdS or PbS as semiconductor. The maximum temperature used in the complete fabrication process was kept below 100° C. In addition, we studied how the device performance (mobility, threshold voltage and contact resistance) is affected depending on the semiconductor thickness, thermal annealing and the metal used as drain-source electrodes. Our fabrication approach can be integrated in complex designs such as CMOS logic gates, pixel arrays, etc., complying with all the requirements for a flexible electronics technology.

EM-ThP4 Novel Materials and Device Structures for Solid-State Charged Particle Detectors, J.W. Murphy, J.I. Mejia, B.E. Gnade, M.A. Quevedo-Lopez, University of Texas at Dallas

Detectors for charged particle spectroscopy are typically fabricated from crystalline silicon, germanium, or gallium arsenide, which are high-cost materials. However, if the purpose of the device is particle detection rather than spectroscopy, then it is possible to use less expensive materials and

deposition techniques to fabricate electrically-sensing, solid-state particle detectors. Particularly, we are interested in detecting alpha particles emitted from a 210-Polonium source. In this work we investigate ZnO nanostructures in combination with poly(3-hexylthiophene) (P3HT) to form hybrid inorganic/organic p-n diodes which are as charged particle sensors. The ZnO nanostructures are grown from solution on a Cr electrode, and the P3HT is subsequently deposited via the drop-casting technique to achieve bi-layer film thicknesses on the order of microns. We evaluate the devices' performance in terms of leakage current, capacitance, and alpha particle detection efficiency as a function of thickness, DC bias, and annealing treatment. The structures are investigated using x-ray diffraction and cross-sectional electron microscopy. We also study the materials degradation upon exposure to radiation by monitoring the leakage current.

EM-ThP5 Structural and Electrical Characteristics of TaN Film Deposited by DC Sputtering for MOS Capacitor and Schottky Diode Upper Electrodes, L.P.B. Lima, J.A. Diniz, State University of Campinas, Brazil, *C. Radtke*, Federal University of Rio Grande do Sul, Brazil, *I. Doi*, *J. Miyoshi*, *A.R. Silva*, *J. Godoy Fo*, State University of Campinas, Brazil

Tantalum nitride (TaN) films have been obtained by DC sputtering deposition in a nitrogen/argon ambient on Si substrates. TaN film have been used as gate electrodes in MOS capacitors and in Schottky diodes on Si substrates. 20nm and 100nm thick TaN layers were deposited by DC sputtering in N₂:Ar (20:60 sccm) ambient, with a sputtering power of 1000 W. These films presented electrical resistivity of 327 Ω.cm and polycrystalline structure. XPS analysis evidence TaN and Ta₂O₅ formation in both 20 nm (Fig. 1) and 100 nm (Fig. 2) thick films. Ta₂O₅ formation could be related with the exposure the metal electrode to air. To get MOS capacitors with TaN/SiO₂/Si/Al and Al/TaN/SiO₂/Si/Al structures, the Si substrates were used and were cleaned with a standard RCA method. After, dry thermal oxidation at 1000°C for 2 min was carried out and a 8 nm thick SiO₂ layer on Si was obtained. 20 nm and 100nm thick TaN layer was deposited on SiO₂/Si by DC sputtering. Finally, in some devices a 200nm thick aluminium (Al) layer was deposited on TaN layer by DC sputtering, in order to reduce these contamination of the metal electrode. MOS capacitor pattern was defined by a mask composed of an array of 200 μm diameter dots. These devices were sintered in conventional furnace in forming gas at 450 °C for 30 minutes and were electrical characterized by capacitance-voltage (C-V) measurements. Figure 3 and 4 presents MOS capacitor C-V characteristics. TaN work function values and flat-band voltage were extracted from all C-V measurements using CVC software and 1/C² method. The extracted TaN work function values and flat-band voltage were between 4.3 and 4.4 eV (Fig. 3-4), 0.1 and 0.2 V (Fig. 3-4), respectively. The variations on work function values are related with the dipole variations due the interface between metal and dielectric. To investigate the TaN work function, Schottky diodes were fabricated in the same substrate of MOS capacitors. TaN layer were deposited by DC sputtering in a N₂:Ar (20:60 sccm) ambient, with a sputtering power of 1000 W. TaN/Si/Al and Al/TaN/Si/Al diodes were formed with TaN (20nm and 100nm) gate electrodes and Al layer (200nm) were deposited by DC sputtering process. These diodes were sintered in conventional furnace in forming gas at 450 °C for 30 minutes. The electrodes were patterned with a mask composed of an array of 200 μm diameter dots. These diodes were electrical characterized by current-voltage (I-V) measurements, and the ideality factor between 1.1 and 1.5, and work function values between 4.4 and 4.5 eV were extracted, which is near the work function values for mid-gap electrode application.

EM-ThP6 TiAlO and TiAlON Obtained by e-Beam Evaporation with Additional Electron Cyclotron Resonance (ECR) Plasma Oxidation and Oxynitridation on Si for MOS Gate Dielectric, J. Miyoshi, A.R. Silva, F.A. Cavarsan, J.A. Diniz, L.P.B. Lima, State University of Campinas, Brazil

Titanium-Aluminum Oxide (TiAlO) and Titanium-Aluminum Oxynitride (TiAlON) high *k* films have received considerable attention due to their electrical and physical properties, which are from the composition of Titanium Oxide and Aluminum Oxide properties, such as higher permittivity (*k*~80) and higher band gap (E_g~8.8 eV), respectively, than others high *k* (such as HfO₂ and ZrO₂) films [1,2]. Furthermore, this composition can reduce the undesirable effects on sub-32 nm MOS devices, which are high leakage current, due to the value of band offset of 2.8 eV to Al₂O₃, and EOT higher than 2 nm, due to relatively low *k* between 8 and 10, respectively. In this work, Titanium-Aluminum Oxide (TiAlO) and Titanium-Aluminum Oxynitride (TiAlON) were obtained on Si wafers as follow: 0.75 nm Titanium (Ti) and 0.25 nm Aluminum (Al) were sequentially deposited by vacuum e-beam evaporation, without any substrate heating. The evaporation pressure was 3x10⁻⁸ Torr, and the Ti and

Al evaporation rates were of 0.1 nm/min, resulting in Al/Ti/Si structures. ECR (electron cyclotron resonance) plasma oxidation and oxynitridation process were carried out on these structures using O₂/Ar and O₂/N₂/Ar gases, respectively, to get the TiAlO and TiAlON films on Si. Physical thickness values between 6.3 and 6.9 nm were determined by ellipsometry. XPS (X-Ray Photoelectron Spectroscopy) analysis was performed and the formation of TiAlO and TiAlON films was confirmed. These films were used as gate insulators in MOS capacitors fabricated with TiN (20nm)/Al (180 nm) electrodes, and they were used to obtain capacitance–voltage (C–V) measurements. A relative dielectric constant of 3.9 was adopted to extract the equivalent oxide thickness (EOT) of films from C–V curves under strong accumulation condition, resulting in values between 0.5 and 1.4 nm, and effective charge densities of about 10¹¹ cm⁻². Because of these results, nMOSFETs with TiN/Al gate electrode and TAON gate dielectric were fabricated and characterized by current–voltage (I–V) curves. These results indicate that the obtained TiAlON and TiAlO films are suitable gate insulator for the next generation (MOS) devices.

Reference:

[1] Miyoshi J., Diniz J.A., Barros A.D., Doi I., Von Zuben A.A.G., (2010) *Microelectronic Engineering*, 87 (3), pp. 267-270.

[2] A. P. Alekhin, A. A. Choupruk, S. A. Gudkova, and A. M. Markeep, Yu. Yu. Lebedinskii, Yu. A. Matveyev, and A. V. Zenkevich, 01A302-1 J. Vac. Sci. Technol. B 29(1), Jan/Feb 2011.

EM-ThP7 Exploring Thermal Reduction Efficiency of Reduced Graphene Oxide with Alcohols Studied by First - Principles Calculations and Infrared Spectroscopy. R.M. Abolfath, C.G. Gong, M. Acik, Y.J. Chabal, K. Cho, The University of Texas at Dallas

Graphite oxide (GO) is convenient to be used as a precursor for functionalization studies and explore the chemistry in solution. Since GO is solution-processable and hygroscopic, tuning the chemical properties by reduction therefore tailors the electronic and electric properties of thermally/chemically reduced GO. The reduction processes of GO sheets have gained much interest since improvement and systematic investigation of the graphitic structure–electrical property relationship is particularly required for graphene nanoelectronics applications. The excellent electrical conductivity of the reduced GO sheets therefore promises potential electronic applications.

It was reported by Su *et al.* in (ACS Nano, 4, 5285-5292, 2010) that the use of high-temperature alcohol vapor for reducing GO increases the conductivity dramatically which improves the graphitic domains. However, details of understanding reduction mechanisms behind the interactions of alcohol molecules within the reduced defective sites of reduced GO still remains elusive.

One of our recent study in (ACS Nano 4, 5861-5868, 2010) shows that trapped water molecules intercalate in the interlayers of as-synthesized GO and interacts with the carbon dangling bonds of the etch holes upon reduction. In this study, formation of carbonyl groups and production of CO₂ from the structural decomposition is a key experimental observation. Replacing intercalated water with methanol and ethanol and performing thermal reduction of GO at 60-300°C, *in-situ* infrared spectroscopy measurements in transmission demonstrate that the thermal reduction efficiency of reduced GO changes dramatically within two different alcohol environment. In the presence of methanol in the interlayers of reduced GO, an increase of infrared absorption could be observed which is attributed to a stable carbonyl concentration during annealing. In contrast, compared with methanol, carbonyl formation at ~1750-1850 cm⁻¹ is absent when there is ethanol in the interlayers of reduced GO. To understand differences in these experimental observations, we simulate the reduction mechanisms by both MD and DFT calculations which show a faster diffusion of methanol in the interlayer of GO that facilitate its reaction with etch holes, inducing a competing mechanism. In the case of ethanol intercalation, simulations confirm that the carbonyl formation which tends to enlarge the etch hole upon annealing can be blocked.

EM-ThP8 Characterization of Ion Implantation-Induced Vacancy Defects and Graphitization in Diamond Lattices by Coherent Acoustic Phonon Spectroscopy. J.M. Gregory, A.D. Steigerwald, Vanderbilt University, H. Takahashi, Japan Advanced Institute of Science and Technology, Japan, N.H. Tolk, Vanderbilt University

We describe implantation damage experiments on single-crystal diamond samples and subsequent characterization using optical pump-probe techniques. Samples are irradiated using He⁺ ions with energies on the order of 1 MeV, generating lattice defects and buried layers of graphitic carbon under high pressure. Using the time-resolved optical technique known as coherent acoustic phonon spectroscopy, these samples are characterized in a

depth-dependent manner. The resulting oscillation patterns reveal clues about the optical and electronic structure of the defects and the graphitic layers.

EM-ThP9 New Reconstruction Mechanism of Dense SiC(111) on Sparse Si(110) Interface. E. Abavare, University of Tokyo, Japan, J.-I. Iwata, University of Tsukuba, Japan, A. Oshiyama, University of Tokyo, Japan

SiC grown on Si substrates is a promising candidate for mass production of Graphene, an emerging material in technology. SiC(111) on Si (110) with particular alignments of the two planes offers almost perfect matching of the lattice periodicity, albeit dense SiC and sparse Si. We here report the total-energy electronic-structure calculations based on the Real-Space Density Functional Theory (RSDFT), that elucidate new reconstruction mechanism of the dense 3C-SiC(111) on the sparse Si(110) interface with the relaxed superstructures displaying undulating structures near the interface. We have explored a variety of candidate interface structures and reached two distinctive types called type I and II which shows bistability at the interface. In type I, the silicon-silicon interface energy is calculated as 9.57 eV whereas that of silicon-carbon is 10.41 eV. Similarly, in type II, silicon-silicon interface energy is 9.89 eV and that of silicon-carbon is 10.84 eV. We argue that in both types, the silicon-silicon interface is energetically favorable compared with the silicon-carbon interface.

EM-ThP10 The Influence of the Layer Thickness on the Optoelectronic Properties of InN. M.K.I. Senevirathna, S. Gamage, R. Atalay, Georgia State University, J. Hong, Georgia Institute of Technology, N. Dietz, A.G.U. Perera, Georgia State University

Indium nitride (InN) and indium-rich group III-nitride alloys may have great potential for high efficient energy conversion devices such as solar cells, high speed optoelectronic devices, and various types of light emitting device structures. Scientists are exploring several different growth methods and various characterization methods to improve the material quality and to understand the optical, structural, and electronic properties of these epilayers. However, till today, the growth of high quality InN alloys and epilayers is still a challenge, mainly due to low InN dissociation temperature and due to stoichiometry instabilities at optimum growth conditions. InN epilayers exhibit significant different physical properties depending on the growth techniques (PAMBE, MBE, MOCVD, etc.) and the substrate material used. At present, low-pressure CVD based growth methods are limited to InN growth temperatures at or below 600°C, which creates problems related to a suited nitrogen precursor, since the ammonia decomposition at these growth temperatures is insufficient. To stabilize InN at higher growth temperature, we explored the growth of InN by high-pressure chemical vapor deposition (HPCVD) at 10 bar and 15 bar reactor pressures. Under these growth conditions the growth temperature can be increased to around 800 °C, resulting in improved ammonia decomposition and smaller group III/N precursor ratio.

This contribution presents results on the effect of the layer thickness on the physical properties of epitaxial InN layers. All InN layers were grown on GaN/sapphire (0001) templates under identical growth conditions, only the growth time was varied. Fourier transform IR reflectance (FTIR) spectroscopy was used to analyze the film thickness and the optoelectronic layer properties. We will present results on the free carrier concentration and mobility as a function of layer thickness. The reflectance spectra were simulated using a Lorentz-Drude model and a multilayer stack model, which allows determining the phonon frequencies, dielectric function, plasma frequency, and damping parameters. From these, the free carrier concentration and mobility for each layer can be calculated. The crystalline quality of the epilayers has been characterized by XRD 2theta- omega scans and by Raman spectroscopy analysis.

EM-ThP11 The Effect of Reactor Pressure on the Optoelectronic Properties of InN Epilayers Grown by HPCVD. M.K.I. Senevirathna, S. Gamage, M. Buegler, R. Atalay, Georgia State University, J. Hong, Georgia Institute of Technology, N. Dietz, A.G.U. Perera, Georgia State University

The dependency of the optoelectronic and structural properties of InN epilayers on the reactor pressure is presented. The InN epilayers were grown by high-pressure chemical vapor deposition (HPCVD) varying the reactor pressure from atmospheric pressure to 18.5 bar. The optoelectronic properties such as free carrier concentration and mobility have been studied using Fourier transform IR reflection spectroscopy. The film thickness, growth rate, free carrier concentration and carrier mobility of the InN layer are obtained by simulating the IR reflectance spectra, using a multilayer stack layer model and a Lorentz-Drude model. XRD 2theta- omega scans and Raman spectroscopy were used to evaluate the structural properties of the epilayers.

EM-ThP12 Effect of Buffer Layers on Structural and Optical Properties of InN Films by RF-MOMBE. W.C. Chen, National Applied Research Laboratories, Taiwan, Republic of China, S.Y. Kuo, Chang Gung University, Taiwan, Republic of China, F.-I. Lai, Yuan-Ze University, Taiwan, Republic of China, C.-T. Lee, C.N. Hsiao, D.P. Tsai, National Applied Research Laboratories, Taiwan, Republic of China

Hexagonal InN films were prepared on sapphire by RF-MOMBE using AlN, GaN and ZnO buffer layers. Also, we have investigated the effect of buffer layers on optical, structural and electrical properties of InN films. The crystalline quality of the InN film is sensitive to the underlying buffer layer when the film is grown under the high effect V/III ratio condition. The structural, optical and electrical properties of InN films were investigated by X-ray diffraction (XRD), Field emission scanning electron microscopy (FE-SEM), transmission electron microscopy (TEM), UV/VIS/IR spectrum measurements, and Hall effect, respectively. The XRD pattern indicated all InN films along c-axis growth. Optical absorption edge by spectrophotometer confirms that the band gap of wurtzite InN films were 1 to 1.2 eV. A Hall mobility of more than 170 cm²/V-s with a carrier concentration of 9.2×10^{19} cm⁻³ at room temperature can be routinely obtained on InN/GaN film. Also, the average later thicknesses range measured about 800 to 1000 nm, and high growth rate about 1.6 mm/hr at InN/GaN, 2 mm/hr at InN/ZnO and 1 mm/hr at InN/AlN, respectively. We suggest that the reduced lattice mismatch between the InN epilayer and top buffer layer is responsible for improvement of sample quality using the buffer-layer technique.

EM-ThP13 The Influence of Ammonia - MO Precursors Pulse Separation on the Gallium Incorporation in Indium-Rich In_xGa_{1-x}N Epilayers. S. Gamage, R. Atalay, M.K.I. Senevirathna, Georgia State University, J. Hong, Georgia Institute of Technology, J.S. Tweedie, R. Collazo, North Carolina State University, N. Dietz, Georgia State University Ternary In_xGa_{1-x}N alloys and embedded epilayers are of great interest due to their large band gap tenability, which enables new applications in the fields of advanced optoelectronic devices. Here, the growth of ternary In_xGa_{1-x}N epilayers is explored by high-pressure chemical vapor deposition (HPCVD) and pulsed precursor injection in order to reduce the temperature gap between the binary alloys GaN and InN and to improve the phase stability on the ternary alloys. In the pulsed precursor injection approach, the precursor separation times between the metal organic (MO) sources (TMI and TMG) and ammonia (S₁), and ammonia and MO (S₂) are two critical process parameters. Previous studies on InN growth showed that the precursors separation critically influences the surface chemistry and the resulting structural and physical layer properties.

In this contribution, we present results on indium-rich InGaN epilayers grown by simultaneous MO injection and with different S₂ timings, with the aim to find the optimum S₂ separation for high quality, single-phase InGaN epilayers. We will show that the S₂ separation is critical for the incorporation of gallium into the epilayers. In order to maintain single-phase epilayers, the S₂ separation has to be increased from S₂=400 ms for InN to over 1200 ms for In_xGa_{1-x}N with x=0.2. Raman spectroscopy and X-ray diffraction (XRD) are used to study the structural properties and the Fourier Transform Infra-red (FTIR) and transmission spectroscopy are used to study the electrical and optical properties of the epilayers.

EM-ThP14 Thermal Stability of HPCVD Grown InN Epilayers. A.R. Acharya, S. Gamage, N. Dietz, B.D. Thoms, Georgia State University

The thermal stability of InN layers grown on sapphire by high-pressure chemical vapor deposition (HPCVD) was studied using isothermal desorption measurements and Auger electron spectroscopy (AES). The desorption of hydrogen-, carbon-, and nitrogen-containing species was analyzed using a differentially-pumped mass spectrometer while the sample temperature was ramped from room temperature to a target value, where it was held constant for ten minutes before cooling back to room temperature. Experiments were performed with increasing target temperatures from 500 °C and 700 °C. No significant evaporation of nitrogen and other species was observed until the samples were annealed to 600 °C. However, during isothermal heating to 650 °C or above, the evaporation of molecular nitrogen commenced around 450 °C and an abrupt increase occurred above 600 °C indicating serious degradation of the film. The stability of InN layers was found to be dependent on V/III ratio, being more stable for the film grown in higher V/III ratio growth conditions. After annealing to 700 °C, the AES spectra showed carbon, oxygen, and traces of indium but no nitrogen indicating the complete desorption of nitrogen from the InN film.

EM-ThP15 Substrate Template and V/III-Ratio Effects on the Surface and Structural Properties of HPCVD Grown InN Films. A.R. Acharya, M. Buegler, R. Atalay, S. Gamage, Georgia State University, J.S. Tweedie, R. Collazo, North Carolina State University, N. Dietz, B.D. Thoms, Georgia State University

Nucleation and growth processes in chemical vapor deposition determine the crystalline quality and orientation which also affect the surface configuration. The bulk and surface structural properties of InN layers grown by high-pressure chemical vapor deposition (HPCVD) were investigated by Raman spectroscopy, x-ray diffraction (XRD), and high resolution electron energy loss spectroscopy (HREELS). HREEL spectra of InN grown on GaN/sapphire with a group V/III precursor ratio of 630 showed surface NH species and nitrogen-termination. For this layer Raman spectroscopy and x-ray diffraction (XRD) showed c-axis film orientation. In contrast, HREEL spectra of InN grown directly on sapphire with a higher group V/III precursor ratio of 3000 revealed that the dominant surface species is NH₂. For this sample, the Raman and XRD analysis indicate the existence of micro-crystallites oriented in the (01-11) direction. Two factors suggested to account for the appearance of these tilted planes are slower surface diffusion under more nitrogen-rich conditions and strain due to the larger lattice mismatch when growing on sapphire substrates.

EM-ThP16 P-Si / N-type GaN Heterojunction. J. Kim, J. Ahn, Korea University, Republic of Korea

P-N heterojunction from P-Si thin film / N-GaN microstructures have been demonstrated. To control the position of GaN microstructures, a mechanical method or electric-field assisted method was employed. Firstly, thermally-grown SiO₂(300nm) on top of p-Si substrate was wet-etched to define the mesa structures. Then, the metal was deposited on both front (on top of the SiO₂) and backside. Finally, GaN microstructures were moved to form p-n heterojunction. When P-Si thin film / N-GaN microstructures were forward-biased, the electroluminescence from p-n heterojunction was observed. The details of the fabrication and the characterizations of P-Si thin film / N-GaN microstructures will be presented.

EM-ThP17 CIGS Thin Film Prepared by One-Step Sputtering Process by Using a Powder Target. S. Oh, G. Cho, N. Kim, Chosun University, Republic of Korea

CIGS thin film with cells reported the highest efficiency up to 20% in the thin film solar cells, which is generally considered as the most promising thin film solar cell. It has been fabricated by using the three stage process in evaporation process with four sources of Cu, In, Ga, and Se pure elements. This preparation method requires very strict controls during the deposition process of CIGS thin film. Recently, there are two widely used methods for CIGS thin film fabrication: selenization with H₂Se or Se after sputtering and thermal co-evaporation. Although the sputtering process was the most suitable method for the deposition of CIGS thin film over the large area with a good uniformity, the two-step selenization shows the critical drawbacks including the additional manufacturing steps, higher materials costs, and the less efficiency. The co-evaporation for CIGS thin film is hard to manage the sources in sequence and to deposit over the large area. For this reason, the novel method for CIGS preparation was demonstrated by using the sputtering process with the powder target. This method has the advantages of the production of target, change of stoichiometry, and easy doping of impurities. The composition of the powder-sputtered CIGS thin film with 1 μm-thickness were analyzed and compared to that of the starting powder target with a composition of Cu, In, Ga, and Se at 25, 15, 10, and 50 at% by electron probe microanalysis (EPMA). The crystal structure, surface morphology, optical properties, and electrical characteristics of CIGS thin film were analyzed by using X-ray diffraction (XRD), atomic force microscope (AFM), UV-Visible spectrophotometer, and a Hall effect measurement system.

EM-ThP18 Effects of Ta Addition on the Characteristics of ITO Thin Film Transistors by Sputtering. S.M. Chung, J.H. Shin, C.H. Hong, W.S. Cheong, ETRI, Republic of Korea

Thin-film transistors (TFTs) using amorphous oxide semiconductors (AOSs) as an active layer have shown remarkable performances including low-temperature processing, high transparency, environmental stability, and high mobility for alternative display backplanes of active-matrix organic light emitting displays (AM-OLEDs), thin-film-transistor liquid crystal displays (TFT-LCDs) and opto-electronic components. Oxide material combinations such as InZnO (IZO), InGaZnO (IGZO), ZnSnO (ZTO), and GaZnSnO (GZTO) have been vastly studied for enhancing the mobility and stability. Though the mobility of the amorphous oxide TFTs has been much improved for several years, the instability under prolonged on-current status is still critical issue to substitute for Si-based technology. Recently, other elements of high oxygen affinity such as Al, Zr, Si, and Hf were added to oxide based TFTs for improving the stability characteristics, which, however, results in a mobility reduction problem. In order to overcome the

problem, we used Ta dopant. This work reports on the characteristics of bottom-gate Ta-doped InSnO (ITO) TFTs. An amorphous ITO:Ta channel layer was deposited at room temperature by sputtering. The devices were annealed at 50 ~ 200°C in oxygen condition for 1 hours. Optical transmittance data in the visible range reveal average transmittance higher than 80% including the glass substrate. The field-effect mobility of 15.9 cm²/V-s, the ON/OFF ratio of >10⁸, and the sub-threshold slope of 0.81 V/decade are achieved in the n-channel ITO:Ta TFTs. Effects of ITO:Ta preparation conditions on the resulting TFT performances were discussed. Stability experiments and further device optimizations through processes are under investigation. The detailed results will be revealed in this presentation.

EM-ThP19 Infrared Absorption Enhancement in Silicon via Silicidation and Nanoparticle Incorporation, C.M. Gonzalez, R. Sachan, G. Duscher, R. Kalyanaraman, P.D. Rack, University of Tennessee, Knoxville

Conventional silicon photovoltaics lack the ability to absorb the full electromagnetic spectrum arriving from the sun. Nickel silicides are small band-gap semiconductors that effectively engage the near-infrared region, whereas bare silicon does not. Ultra-thin (<100nm) silicon structures incorporated with nickel silicides have been synthesized and characterized and have shown enhanced absorption from 750-3000nm wavelengths. Four different structures were constructed via a combination of sputtering, co-sputtering and laser irradiation and their optical and electrical characteristics were compared. In one case, the nickel is deposited and reacted between the p and the n+ silicon regions; in another, nickel is co-sputtered along with p-Si and co-sputtered with n+ silicon; and finally nickel is co-sputtered with silicon followed by laser irradiation to form nickel silicide nanoparticles via pulsed laser induced dewetting. This last structure contains non-patterned nanoparticles (<50nm) in close proximity to a pn junction after capping the former with the p and n+ silicon. In this presentation we will correlate the material composition and micro and nanostructure by STEM and EELS to the observed optical and photovoltaic responses and demonstrate effective media approximations for the observed optical properties.

EM-ThP20 Fabrication of Shape-Controlled Metal Nanodot Array by Electrostatically-Driven Self-Assembly as well as their Charge Injection Properties, R. Sumi, Nagoya University, Japan, T. Hosoi, H. Watanabe, Osaka University, Japan, X. Hu, O. Takai, N. Saito, N. Zetsu, Nagoya University, Japan

Nanometer-sized inorganic particles play an important role in modern nanotechnology owing to their superior characteristics that can lead to fascinating function that are difficult to be realized using conventional used bulk materials. Recently the development of shape-controlled synthesis techniques make possible to obtain various well-defined shapes of nanoparticles with high yield. To determine their surface-to-volume ratio and crystal structure are expected to lead to improvement in performance in given application.

In this paper, we demonstrated fabrication of various metal nanodots MOS capacitors for floating nanodot gate memory using an evaporation-based colloidal self-assembly in order to attain a tight control over the size, shape, and density of metal nanodots, as well as the study of their effects on the charge injection characteristics of the nanodot arrays.

We synthesized Au nanoparticles with 2nm diameter by solution plasma processing in aqueous solution. The surface was modified with organic surfactants which tuned their zeta-potential to be approximately -40mV. We have recently proposed a versatile method for the fabrication of self-assembled metallic nanodot arrays onto a SiO₂/Si substrate with dimension of 50 x 100mm² by using a newly developed electrostatically-driven self-assembly. The substrate surface was modified with amino-silane agents prior to use assembly. In order to make MOS capacitor containing Au nanodot array as a charge trapping layer, the Au nanodot array was embedded in a gate oxide.

By precise control of the velocity of the leading edge of a liquid slug, the volume ratio of the particles, and the deposition rate, we were able to reproducibly form an array consisting of a single layer of Au nanodot array with density of 1012particles/cm². We further demonstrated the charge injection characteristics of the Au nanodot array, embedded in the ultra-thin SiO₂ layer consisting of both thermally grown tunnel oxide and RF-driven sputtered control oxide layer. Counterclockwise hysteresis was observed reproducibly, whereas there was no hysteresis in the C-V curve of the MOS capacitor without Au nanodots. This hysteresis indicates the charging and discharging of the embedded Au nanodots. This electron confinement caused the flat-band voltage shift observed as the capacitance hysteresis.

EM-ThP21 Small-Molecule Scaffolds for Directed Self-Assembly, P. Mancheno-Posso, A.J. Muscat, University of Arizona

Self-assembled monolayers (SAMs) are often used as scaffolds for the deposition of a subsequent layer. This process allows the surface properties to be tailored to a specific application and facilitates the construction of functional nanostructures. For instance, copper electrodes and graphene have been deposited on carboxyl-terminated and on 3-aminopropyltriethoxysilane (APTES) monolayers, to create metallic electrodes for electronic devices and a lubricating layer for nanoelectromechanical systems, respectively. Small silane molecules in particular could be used to direct the self-assembly of another layer and keep it in close proximity to a silicon surface. Vinyltrichlorosilane (VTCS, CH₂=CH-SiCl₃) is a candidate and contains a carbon-carbon double bond. A vinyl C=C bond is a versatile functional group because it can be reacted in situ to generate a variety of terminations, including -COOH, -SH, and -NH₂, and could also direct the assembly of new molecules on the surface. While VTCS SAMs have been studied previously, a reproducible and self-limiting process to form a single monolayer from solution has not yet been achieved. In this work we adsorbed VTCS from solution on a Si(100) substrate and characterized the layer with ellipsometry, X-ray photoelectron spectroscopy (XPS), and atomic force microscopy (AFM). Silicon wafers were cleaned and hydroxylated in a piranha solution. After drying, the samples were dipped for different times into a 1:1000 solution of VTCS in toluene, hexane, chloroform and acetone. The thickness of the monolayer was monitored ex situ using ellipsometry. Toluene and hexane yielded multilayers with a thickness greater than 10 Å, whereas chloroform and acetone produced more consistent monolayers with a thickness of about 6 Å. A bromination was performed to demonstrate the presence of the unsaturated bond. We are in the process of making XPS and AFM measurements to determine whether VTCS is covalently attached to the Si substrate and to assess whether the vinyl group is suitable to graft molecules to the substrate.

EM-ThP22 Deposition of Organic and Inorganic Hybrid Laminates using Ozone Based ALD (Atomic Layer Deposition), S. Lee, NCD Technology, J. Huang, M. Lee, University of Texas at Dallas, P.-R. Cha, University of Texas at Dallas and Kookmin Univ., Korea, J. Kim, University of Texas at Dallas

Recently, organic materials have been attracting attention due to the large area, low cost, and flexibility. On the other hand, inorganic conducting materials have several benefits such as high conductivity, functional properties, and rigid characteristics, etc. A novel technique for building an organic and inorganic hybrid stack has been introduced by M. M. Sung et al. using a modified ALD method.¹ It has advantages to minimize the defects during growth of organic and inorganic films because hybrid films are deposited by an in-situ process through the sequential self-limiting surface reaction like atomic layer deposition (ALD), while maintaining their flexibility and functionality.

In this study, we investigate the growth characteristics of organic/inorganic conducting material, ZnO, and 7-octenyltrichlorosilane (7-OTS) thin film using an ozone based ALD. 7-OTS is grown by exchange reaction between functional group and water and then the terminal vinyl group of 7-OTS is converted into a carboxylic group through ozone activation.¹ The deposition rate and the contact angle of the organic films are about 7Å/cycle and 60°, respectively. In case of the ZnO, it is deposited using diethylzinc (DEZ) source and H₂O oxidant under the temperature of 120°C. The deposition rate is about 2 Å/cycle. The organic/inorganic hybrid laminate films will be analyzed by TEM, AFM, Ellipsometer and FTIR. The electrical characteristics of laminate structure will be discussed.

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EM-ThP23 Simple Methods to High Quality Self-Assembled Monolayers of Alkylsilanes on Oxides, B.D. Gates, Y. Gong, A. Liu, H.W. Ng, M. Wang, Simon Fraser University, Canada

The interfacial properties of a material can be easily modified by modifying its surfaces with self-assembled monolayers. These single-molecule thick coatings can be used to prevent non-specific adsorption of biomolecules, protect the underlying material from chemical attack, serve as a masking layer to prevent or direct the deposition of a coating material, and reduce friction between two materials. Interest in the use of self-assembled monolayers continues to grow. The applications being pursued for these molecular coatings are increasingly interested in the robustness and uniformity of these films. An important aspect of their resilience is the density and size of defects within the monolayers, which can have a large role in their overall performance. One type of monolayer for which it is particularly challenging to achieve high quality coatings are those films

based on the assembly of alkylsilane molecules. Often these coatings are pursued for the modification of oxidized surfaces, but form either a sub-monolayer or a multilayered film. A primary goal of the work that will be presented is to further optimize the conditions in which monochloro alkylsilane-based molecules are assembled into monolayers. Considerations for the development of these refined methods include the ease of scaling the technique to cover larger areas and the ability to avoid stringent requirements for environmental control during growth of the monolayer. Additional work is being pursued to identify and repair defects within the silane-based films. One approach that will be discussed uses solvent extraction techniques to remove adsorbed molecules, followed by further assembly of alkylsilane molecules onto the unprotected regions of these surfaces. The 'repaired' surfaces exhibit improved resistance to chemical attack. A key aspect of this work has been the development of new analytical methods for determining the density and size of the defects. These methods are used to also monitor the success of repairing the defects. The talk will cover these and other aspects of our progress towards developing simple methods that will produce high quality monolayers of alkylsilane-based molecules.

EM-ThP24 Deposition and Characterization of Hydrophobic Coatings on Electronic Devices, V. Gupta, S.C. Kunzler, M.R. Linford, Brigham Young University

More cell phones are damaged by water than by any other means, and this damage often requires the devices to be discarded. The number of damaged phones is also increasing because these phones are now taken almost everywhere. Chemical vapor deposition may provide a solution to this problem, which is large (100.9 million Smartphones were shipped in Q4 2010). For example, the phones may be coated with a hydrophobic monolayer or multilayer of fluorosilanes. Bonding of the fluorosilane may be improved using of a primary adhesion layer, which may be a different silane monolayer, e.g., an isocyanatosilane, and/or by introduction of hydroxyl groups via plasma treatment. The latter process is typically rapid and economical and can take place both on oxide and polymeric materials. The presence of OH groups can be assayed by XPS, ToF-SIMS and ATR-FTIR. The density of surface hydroxyl groups can be varied by changing the proportions of etch gases, the time and intensity of the plasma treatment, and the system base pressure. The hydrophobicity of the surface can be characterized by contact angle goniometry and XPS and ToF-SIMS analysis of fluorine. Resistance to abrasion can be tested with a Martindale abrasion tester. This work can be further extended to touch screen panels in equipment used under water.

EM-ThP25 Impact of Substrate Type on the Formation of Si Nanocrystals in the Annealed SiO_x and SiO_x:Er,F Films, A.S. Nikolenko, M.V. Sopinsky, V.V. Strelchuk, L.I. Veligura, N.A. Vlasenko, V. Lashkaryov Institute of Semiconductor Physics, Ukraine

Erbium doped nc-Si/SiO₂ nanosystems are considered as possible candidates for the manufacturing of light emitting sources compatible with silicon technology [1]. Fluorine, like other halogens, has a tendency to enhance recrystallization processes. Therefore, one could hope that introduction of F will intensify the transformation of amorphous silicon nanoinclusions formed on initial stage of SiO_x thermal decomposition into Si nanocrystallines, and reduce the low-temperature threshold of this process. Lowering of the process temperature is the essential advantage of every technology. In case of SiO_x:ErF₃ films this is principally important because at $T_{ann} > 900^{\circ}\text{C}$ the segregation of erbium ions into metallic clusters takes place. Consequently, the final stage of forming the erbium-doped light-emitting system should not exceed 1000 °C.

In this work the silicon nanoparticle formation due to the structural-phase transformations in the SiO_x and SiO_x:Er,F films evaporated onto c-Si and sapphire substrates is studied. These transformations are induced by moderate temperatures annealing (650–1000°C). For this study the methods of Micro-Raman scattering and multi-angle ellipsometry are used. It was established that more intensive formation of a-Si nanoparticles takes place in the doped films as compared to undoped SiO_x films on both c-Si and sapphire substrates. Besides, it was found that the crystallization of a-Si nanoparticles is much more intensive and occurs at lower temperatures ($\geq 750^{\circ}\text{C}$) in the annealed SiO_x:Er,F films on sapphire substrate as compared to the annealed SiO_x:Er,F films on c-Si substrate.

Analysis of available literature data which deal with behaviour of Er and F in silicon, Si–O, and Al–O systems allows explaining the obtained results by the influence of F. In our opinion, the mechanism of F influence on the crystallization of a-Si nanoparticles is similar to the mechanism of hydrogen-induced crystallization of amorphous Si thin films [1]. Fluorine diffuses into Si–O and c-Si extremely fast. Therefore, during the annealing of SiO_x:Er,F films deposited on c-Si the significant part of mobile fluorine easily diffuses into c-Si substrate and its concentration in the film drops considerably. On the contrary, F very slowly diffuses into Al₂O₃ – even the thin native aluminum oxide layer provides very good protection against

fluorine diffusion. Accordingly, fluorine concentration in the film on sapphire substrate stays significant, and its crystallization action manifests itself stronger.

Conclusions.

1) It is shown that the formation of erbium doped nc-Si/SiO₂ nanosystems at the temperatures $\geq 750^{\circ}\text{C}$ is possible by annealing of SiO_x:Er,F films on sapphire substrate.

2) This work, together with the work [2], demonstrates the wide variety of mechanisms by which a substrate can impact upon the formation of nc-Si–SiO_x nanosystems.

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