Electronic Materials and Processing
Room: Southwest Exhibit Hall - Session EM-TuP

Electronic Materials and Processing Poster Session

EM-TuP1 Indium Nitride Epilayer Prepared by UHV- Plasma-Assisted Metalorganic Molecule Beam Epitaxy, ***W.-C. Chen***, National Applied Research Laboratories, Taiwan, *S.-Y. Kuo,* Chang Gung University, Taiwan, *F.-I. Lai, H.-Y. Wang, W.-T. Lin,* Yuan-Ze University, Taiwan, *C.N. Hsiao*, National Applied Research Laboratories, Taiwan

Indium nitride films grown at various growth temperatures were prepared on GaN buffer layer using self-designed plasma-assisted metal-organic molecule beam epitaxy. The influence of substrate temperature on film crystal structure, surface morphology, optical and electrical properties is studied using x-ray diffraction (XRD), field emission scanning electron microscopy (FE-SEM), transmission electron microscopy (TEM), X-ray diffraction, Hall effect, and photoluminescence (PL) measurements. The results show that all InN films grown on the GaN template have good quality and the full width at half maximum is around 1000 arcsec. At 500ºC, the optical measurements on the films revealed a luminescence feature in the vicinity of 0.7 eV. Also, TEM images of the films exhibit better structural properties indicated by a sharper InN/GaN interface. SEM images determine the growth rate of about 14 nm/min. These results indicate that the optoelectronic properties and crystalline quality can be improved significantly by increasing the growth temperature.

EM-TuP2 The Relationship between Surface Termination and Crystal Structure for HPCVD-grown InN Layers, ***A.R. Acharya***, *M. Buegler, S. Gamage,* Georgia State University, *J.S. Tweedie, R. Collazo,* North Carolina State University, *N. Dietz, B.D. Thoms*, Georgia State University

The surface structure and termination of semiconductor thin films are important factors during epitaxial growth and may affect the interfacial properties of devices. The structure and surface bonding configuration of indium nitride layers grown by high pressure chemical vapor deposition (HPCVD) have been studied using high resolution electron energy loss spectroscopy (HREELS) and X-ray diffraction (XRD). HREELS analysis of InN layers suggests that the surface is primarily terminated with NH2 species. This result is consistent with XRD, which shows the co-existence of different surface orientations. The observed termination by NH2 is in contrast to previous HREELS work on HPCVD-grown InN layers, which showed only NH species on the nitrogen-terminated surface.

EM-TuP3 Rapid Thermal Ex-Situ Activation and Effect on Contacts to p-type GaN, ***J.H. Melby***, *L. Huang, R.F. Davis, L.M. Porter*, Carnegie Mellon University

The difficulty of achieving ohmic contacts to p-type GaN is associated with the inherent difficulties involved in acceptor doping with Mg. Poor doping efficiency results in high contact resistance and high semiconductor sheet resistance. In GaN based devices, these issues lead to parasitic voltage drops and associated Joule heating. When grown via CVD methods a significant amount of Mg forms a complex with hydrogen. This complex prevents Mg from participating in active doping. The challenge is to achieve large concentrations of free Mg in the films. In-situ post-growth annealing has been found to enhance p-type conductivity, but there is a large disparity in activated Mg acceptors versus incorporated Mg atoms. Furthermore, we know of no reports in the literature regarding optimization of the annealing conditions. In this study we have conducted I-V, C-V, Hall, and contact resistance measurements of Ni/Au contacts on Mg-doped GaN films grown on AlN/SiC (0001) substrates as a function of annealing temperature and time, and nitrogen or oxygen concentration for in-situ and ex-situ anneals. We found that in-situ cooling in nitrogen after growth is important for initial activation of Mg dopants; however, additional in-situ annealing in nitrogen after growth had little effect on the electrical properties. We also found that the electrical characteristics are particularly sensitive to the presence of oxygen and temperature during ex-situ annealing; > 200% improvements in hole concentration were observed for annealing in 1:1 N_2:O_2 at 800°C. The electrical data will be correlated with SIMS data of the hydrogen concentration as a function of annealing conditions.

EM-TuP4 Investigation of Crystal Structure and Optical Properties of $Cd_{1-x}Mn_xS$ Epilayers, ***D.J. Kim***, *Y.D. Choi,* Mokwon University, Republic of Korea, *J.W. Lee*, Hanbat University, Republic of Korea

High quality $Cd_{1-x}Mn_xS$ epilayers were grown with changing source temperature on GaAs (111) substrates by the hot-wall epitaxy method. The crystal structure of the grown $Cd_{1-x}Mn_xS$ epilayers was confirmed to be the hexagonal structure by X-ray diffraction pattern (XRD) and scanning electron microscopy (SEM) image. To explore binding states and their potential applications, the hexagonal structured $Cd_{1-x}Mn_xS$ epilayers have been characterized using x-ray photoelectron spectroscopy (XPS). The optical properties of the $Cd_{1-x}Mn_xS$ epilayers were investigated in a wide photon energy range between 2.0-8.5 eV using spectroscopic ellipsometry (SE) at room temperature. The data obtained by SE were analyzed to find the critical points of the pseudodielectric function spectra, $< \varepsilon (E)>=< \varepsilon_1(E)>+i< \varepsilon_2(E)>$, such as E_0, E_{1A}, E_{1B}, E_0', F_1, and E_2 structures. In addition, the second derivative spectra, $d^2\varepsilon(E)/dE^2$, of the pseudodielectric function of $Cd_{1-x}Mn_xS$ epilayers were numerically calculated to determine the critical structures. Four structures, such as E_0', F_1, and two E_2 structures, from 6.0 eV to 8.0 eV were observed with changing Mn composition, for the first time, at 300 K by ellipsometric measurements for the $Cd_{1-x}Mn_xS$ epilayers.

EM-TuP5 Photovoltaic Characteristics of Sputtering-Deposited CdTe Thin Film Solar Cell by Hydrogen Doping Treatment, ***C.-H. Lim***, *S.-H. Ryu, J.-S. Park,* Chosun University, Republic of Korea, *N.-H. Kim,* Chonnam National University, Republic of Korea, *G.-B. Cho, W.-S. Lee*, Chosun University, Republic of Korea

CdTe thin film has the near ideal band gap energy of 1.45 eV for the achievement of the theoretical maximum photovoltaic conversion efficiency of 31%. CdTe thin film also has a high optical absorption coefficient of over 99% of the incident sunlight with only about 2 µm of active thickness. However, the highest conversion efficiency of 16.5% was recorded in the CdTe/CdS heterostructured thin film solar cell . Therefore, the investigations would be strongly required to improve the conversion efficiency with the sufficiently absorbed light. In this study, hydrogen doping treatment was performed with the various hydrogen gas levels and doping temperature in the vacuum desiccator at the fixed doping time in order to improve the efficiency of CdTe/CdS heterostructured cell because the hydrogen affects the electrical properties of CdTe through the fast diffusion of the interstitial hydrogen. The effects of hydrogen doping treatment on the electrical and optical properties of CdTe thin film were investigated by UV-Visible spectrophotometer and Hall effect measurement. The role of hydrogen was examined by some analytical methods including photoluminescence (PL) spectra. The improved cell parameters of CdTe/CdS thin film solar cell were successfully obtained at the optimum condition including short-circuit current density (J_{sc}), open-circuit voltage (V_{oc}), fill factor (FF), and efficiency. Acknowledgement: This work was supported by National Research Foundation of Korea(NRF) grant funded by the Korean Government(MEST) (20 10-0016048).

EM-TuP6 Crystal Structure Analyses of Bis(triisopropylsilylethynyl)-Pentacene Nanofilms Deposited on OTS-SAM and Poly(3,4-ethylenedioxythiophene) Surfaces, ***S. Kim***, *S. Choi,* Paichai University, Republic of Korea, *C. Yu,* Pohang Accelerator Laboratory, Republic of Korea, *T. Kim,* Paichai University, Republic of Korea, *J.-H. Boo*, Sungkyunkwan University, Republic of Korea

Highly pure 6,13-bis(triisopropylsilylethynyl)pentacene (TIPS-PEN) nanofilms were deposited on a very high quality OTS-SAM surface at two different substrate temperatures (70°C and 90°C) via the vacuum thermal evaporation (VTE) method. X-ray reflectivity (XRR) and grazing angle incidence x-ray diffraction (GID) measurements over a wide temperature range (30°C-284°C) revealed that out-of-plane crystallinity of the film (~10 nm) remains intact but in-plane crystallinity starts to become poor from ~100°C, and to become much worser from 260°C. Atomic force microscope images showed that TIPS-PEN films (~55 nm) prepared at the substrate temperature of 90°C or above commonly have a number of huge cracks between enormous crystal domains (up to 3mm) whereas the films didn't form such morphology below Ts=90°C. These results clearly suggest that an optimum substrate temperature of TIPS-PEN nanofilms on OTS-SAM surface must be somewhere between 70°C and 90°C, and the process temperature must be kept below 90°C in order to form and maintain a highly crystalline film for an organic thin film transistor device since in-plane crystallinity of a semiconductor channel deeply affects the performance of a transistor.

EM-TuP7 Atomic Imaging of Monolayer Nucleation of Atomic Layer Deposition Precursors, *W. Melitz,* ***J. Shen***, *J. Clemens, E. Chagarov, A.C. Kummel*, University of California at San Diego

For highly scaled atomic layer deposition (ALD) of gate oxides (EOT < 1nm) on III-V semiconductors, the general requirements for an unpinned, high mobility oxide/III-V interface are as follows: (a) The metal precursor cannot disrupt the substrate during deposition; (b) The metal precursor must form a monolayer of nucleation sites in order for aggressive scaling of the

equivalent oxide thickness (EOT); (c) The oxide has to be resistant to atom donation to/from the substrate; (d) The oxide needs to bond weakly to the interface or to form nearly covalent bonds to the interface to balance polarity. The nucleation/passivation layer has to enable all four requirements. Half cycle room temperature ALD of trimethylaluminum (TMA) and dimethylaluminium ethoxide (DEAE) have been performed on InAs and InGaAs surface to compare two precursors for the same oxide one of which is oxygen-free and one which contains oxygen. The electronic properties of the clean and deposited surfaces are probed via scanning tunneling spectroscopy and microscopy (STS and STM), and Kelvin probe force microscopy (KPFM). Previous STS and KPFM studies for both clean InAs and InGaAs (4×2) surfaces determined the Fermi level is pinned 0.3eV above the valance band; DFT studies show that the surface are pinned by homodimers in the trough. STM and STS show that TMA forms an ordered monolayer of absorbates which unpin the Fermi level suggesting that an ordered monolayer layer might be a requirement for unpinning. However, STM of DEAE reacted InGaAs(001)-(4x2) shows a nearly amorphous monolayer layer while STS shows even this amorphous layer unpins the interface. The influence of larger ligands on the DEAE might account for more degeneracy in bonding configurations making order structures less probable. The results are consistent with a multitude of bonding configuration being able to unpin the Fermi level as long as the pining sites are removed and the presence of oxygen in the precursor not being an impediment to passivation as long as there is still attractive interactions between the absorbates which promote monolayer formation.

EM-TuP8 Synthesis and Magnetic Properties of $Zn_{1-x}Mn_xO$ Hollow Nanospheres, ***D.R. Liu**, T.C. Wu, Y.C. Yeh, W.H. Cho*, National Applied Research Laboratories, Taiwan

EM-TuP9 Fringing Field effects of Different Size Indium Gallium Zinc Oxide (IGZO) Active Layers Thin Film Transistors, ***J. Noh**, S. Kwon, J.H. Noh,* University of Tennessee, *P.D. Rack*, University of Tennessee at Knoxville; Oak Ridge National Laboratory

To realize the high performance-thin film transistors (TFTs) using amorphous indium gallium zinc oxide (a-IGZO) as the semiconducting active layer, we will present the how the a-IGZO with different active sizes affects the electrical characteristics of TFTs. The TFTs are fabricated with a bottom-gate staggered structure and the a-IGZO active size is photolithgraphically patterned to different lateral dimensions. A Cr gate is deposited on buffered silicon dioxide on a silicon substrate and SiN_x is thegate dielectric which is deposited via plasma enhanced chemical vapor deposition (PECVD). The a-IGZO semiconducting active layers are deposited using rf magnetron sputtering in a reactive Ar-O2 atmosphere which controls the carrier concentration which can be metallic at low oxygen flow rates and insulating at high (>20% O2) flow rates. The a-IGZO layer is patterned with different size by wet etch process with diluted HF. Finally, source and drain electrodes are formed and the device is annealed for activation. We will discuss the TFT characteristics based on fringing electric field effects in which the fringing electric field around the periphery of the patterned source and drain electrodes can induce electrical conduction as current paths in the semiconductor layer, changing electrical properties in the device, especially increasing the leakage current through the backchannel on IGZO. Furthermore, we will correlate the different pattern size of IGZO to the electrical properties of the TFT devices . Finally, we will present a new application for our a-IGZO TFTs: an addressable microfluidic electrowetting channel device.

EM-TuP10 Optical Constant Measurements and Relation to Substrate Currents of Dielectric Layers under Vacuum Ultraviolet Irradiation, *D.B. Straight, H. Sinha, J. Lauer,* University of Wisconsin-Madison, *N.C. Fuller, S.U. Engelmann, Y. Zhang,* IBM Research, *G.A. Antonelli,* Novellus Systems, Inc., *Y. Nishi,* Stanford University, ***J.L. Shohet***, University of Wisconsin-Madison

We report an inexpensive and rapid method to measure the reflectance of dielectrics in the vacuum ultraviolet (VUV) range of the spectrum using synchrotron radiation. Porous low-*k* organosilicate (SiCOH) dielectrics deposited on silicon were irradiated with VUV photons of various energies. Reflectance is calculated from ratio of the measured reflected photon flux to the measured incident photon flux. A 90% transmitting nickel mesh connected to a picoammeter was used to measure the incident and reflected photon flux. When the sample is absent from the path of the VUV photons, a photon dump is used to minimize any possible reflectance. Thus, the net photon flux incident on the nickel mesh is the synchrotron flux. Under these circumstances the reading from the picoammeter is proportional to the synchrotron flux. When the sample is present some of the photons are reflected from the sample. Since the sample is placed normal to the VUV photon flux, the reflected photons can travel back to the nickel mesh. Thus, under these conditions, the nickel mesh current is sum of the incident synchrotron photon flux and the reflected photon flux. The reflectance is calculated from the two current measurements. The reflectances of SiCOH of different porosities were compared. By using the Kramers-Kronig algorithm, [1] the index of refraction and the extinction coefficient as a function of energy can be obtained from the reflectance. We also find that during VUV irradiation, the reflectance of a dielectric and the substrate current are inversely correlated. Thus, the reflectance can be obtained from the substrate current and vice versa. We conclude that reflectance or substrate current measurements can determine which photon energies are more likely to be absorbed and can therefore cause dielectric damage during processing. [2] Reducing the flux of deleterious photon energies in processing systems can minimize dielectric damage.

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EM-TuP11 Resistive Switching in Big Band Gap Material- beta - Ga_2O_3, ***S.X. Zheng**, T.C. Lovejoy,* University of Washington, *V. Garcia, S. Ueda,* NIMS, Japan, *A. Pakhomov, M.A. Olmstead, F.S. Ohuchi*, University of Washington

Gallium oxide has a unique combination of properties that hold significant promise for variety applications. Pure beta-Ga2O3 has band gap of 4.8 eV which has potentials as UV-transparant optics material. Recent findings suggest its n-type semiconducting behavior after treating it in reducing atmospheres, which place it in the group of new generation transparent conductive oxides. On the other hand, its conductivity change after gases like CO and NO2 makes it a potential gas sensing material. Despite its unique optic/optoelectronic properties, incomplete mechanistic understanding of the origins of conductivity becomes a barrier to device development. According to recent findings, oxygen vacancy contribution to the conductivity is widely accepted due to inverse correlation of conductivity and oxygen partial pressure during material growth. However, other models were also proposed, e.g, experimental results show trace amount of impurities can enhance the conductivity of Ga2O3 without changing its crystal structure. On the other hand, formation energy calculation suggests possible vacancy alignment along conducting direction can also improve the electron hopping, thus enhance the conductivity. Unfortunately, most of the conclusions were either lack of experimental support, or based on samples prepared from different synthesizing techniques, whose properties can be substantially changed.

In this report, Single crystal beta-Ga2O3 prepared by float zone technique was used to investigate the electrical property change after heating under different atmospheres. It is discovered that by passing direct current through the material in the ultra high vacuum, resistivity of beta-Ga2O3 along [010] direction can have significant increase, which contradicts to the oxygen vacancies model. A detailed investigation using X-ray Photoemission Spectroscopy (XPS), Scanning Tunneling Microscopy (STM), Physical Property Measurement System(PPMS) reveals the change in stoichiometry, work function, surface morphology and polaron hopping dimensions, which bring insight to the origins of conductivity in Ga2O3 along different crystal orientations. Based on the understanding on the single crystal conductivity, epitaxial Ga2O3 thin film with designated resistive switching properties using Pulse laser deposition can also be prepared.

EM-TuP12 Mass Fabrication of TiO_2-based Resistive Switching Arrays by Step and Flash Imprint Lithography, ***K.D. Kim**, D.K. Yun,* Korea Institute of Machinery and Materials, Republic of Korea, *H.Y. Jeong,* ETRI, Republic of Korea, *J.H. Lee, J.H. Jeong,* Korea Institute of Machinery and Materials, Republic of Korea, *S.Y. Choi,* ETRI, Republic of Korea, *H.H. Park,* KANC, Republic of Korea, *J.H. Choi*, Korea Institute of Machinery and Materials, Republic of Korea

Nanoimprint lithography is a low-cost method of fabricating nanoscale patterns as small as 6 nm. It has been emerged as a key technology for the fabrication of devices with nanoscale patterns, such as polarizer, optical devices, bio devices, and patterned media. The ultraviolet nanoimprint lithography (UV-NIL) process is also a promising alternative to the expensive conventional optical lithographic process for producing non-volatile memory. Resistive random access memory (RRAM), which utilizes the resistance change effect of oxide material, has attracted considerable attention and been widely investigated due to its potential application in memory devices.

In this study, identical patterns and characteristics of sub-100nm TiO_2-based resistive switching systems on 4 inch silicon substrates are demonstrated using Step and flash imprint lithography (SFIL). SFIL is a nanoimprint lithography technique, offering the advantages of a high aspect-ratio, reliable nano-patterns and a transparent stamp that can be used to facilitate overlay techniques. The overlay process from the alignment system in IMPRIO 100 was appropriate for the fabrication of nanoscaled crossbar arrays in this work. Crossbar arrays consisting of TiO_2 resistive switching material sandwiched between Pt and Al electrodes with a width of 80 nm and a half-pitch of 100 nm are in turn replicated through successive imprinting and etching processes. Use of a direct metal etching process enhances the uniformity of the TiO_2/electrodes interface. The electrical property of the crossbar arrays showed the reproducible resistive switching behavior resulting in the application of the nonvolatile resistive memory.

EM-TuP13 Fabrication of Heavy Capacitive Organic Capacitor using All Ink Jet Process, ***I.J. Bae**, J.J. Han, I.S. Chung*, Sungkyunkwan University, Republic of Korea

We attempted to fabricate an organic capacitor on polyethersulphone (PES) substrate using ink jet printing. The capacitor cell was designed for the storage capacitor in E-paper backbone panel. Two different materials like Poly-4-vinylphenol (PVP) and Poly Methyl Methacrylate (PMMA) were examined by varying thickness and w%. The Area of the capacitor was 100 um x 100um. Silver was used as a metal electrode. All the processes were done using ink-jet printer. The dielectric properties were analyzed by measuring C-V, and the physical properties including the morphologies of the ink jet films were analyzed using optical microscope, SPM and SEM.

EM-TuP14 Copper-Electrochemical Mechanical Planarization (Cu-ECMP) Characteristics with a Change of Electrical Variables, ***K.D. Myung**, W.-S. Lee,* Chosun University, Republic of Korea*, N.-H. Kim*, Chonnam National University, Republic of Korea

Electrochemical mechanical planarization (ECMP) process for copper interconnects is an alternative process of the conventional chemical mechanical polishing (CMP) process due to its critical limitation in the recent industrial standards by the high pressure and abrasive. ECMP process dissolved the copper to copper ions for the generation of copper complex layer on the surface electrochemically by applying in an aqueous electrolyte with the electrical source, and then removed the copper complex layer by polishing with the lower pressure. In this study, ECMP was performed with changes of electrical variables including current, voltage, immersing time, size of electrodes, electrode materials, and distance between each electrode. ECMP characteristics such as removal rate, WIWNU%, RMS roughness, and peak-to-valley roughness were measured. The properties of electrolyte were examined as functions of the upper electrical variables in order to estimate the influences of the changed electrolyte on the ECMP characteristics in Cu-ECMP process. The surface of copper was also analyzed with various electrical variables by using XPS and nanoindentation to investigate the surface behaviors with chemical and mechanical properties. Acknowledgement: This work was supported by National Research Foundation of Korea(NRF) grant funded by the Korean Government(MEST) (2010-0016609).

EM-TuP15 Nanoparticle-enhanced Multilayered Thin Film Cooling Devices, ***M. Hines**, C. Cochran, Z. Xiao*, Alabama A&M University

We report the fabrication of solid-state cooling devices using the nanoparticle and Bi_2Te_3 and Sb_2Te_3 multilayered thermoelectric thin films. The multilayer thin films have a periodic structure consisting of alternating Bi_2Te_3 and nanoparticle layeres or Sb_2Te_3 and nanoparticle layers. The Bi_2Te_3 and Sb_2Te_3 thin films were deposited using e-beam evaporation. PbS Nanoparticle thin film was prepared to form the multilayered film using spin coating. The multilayer structure of films and the interface of layers were analyzed by X-ray diffraction and reflection. The multilayer thin films-based cooling devices were fabricated using the microfabrication process. The thermal and electrical properties of the nanoparticle-enhanced multilayered thin films and the cooling temperature difference of the fabricated devices were measured. The measurement results on the nanoparticle-enhanced material systems and the fabricated cooling devices will be reported in the conference.

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