## Electronic Materials and Devices
## Room Hall A-C - Session EM+SC-TuP
## Poster Session

**EM+SC-TuP2 A New Method to Produce Silicon-on-Insulator Wafer- Ar@super +@ Implantation with H@super +@-plasma Processing**, ***B. Chen,*** New Jersey Institute of Technology; *A. Usenko,* New Jersey Silicon Wafer Tech; *W. Carr,* New Jersey Institute of Technology

In this paper, we describe a new method to fabricate SOI wafer. Ar+ ions were implanted into Si(100) at energy ranging from 30 KeV to 200 KeV and dose from 1*10@super 15@ to 1*10@super 16@ cm@super -2@. To avoid amorphization, the samples were thermally insulated and the beam current was maintained high enough (about 3mA/cm2). After implantation, pieces of these samples were subjected to thermal annealing at temperature ranging from 200°C to 800°C. The evolution of microstructure of these samples were investigated by TEM. In the annealed samples, Argon clusters are found in either 2-D cavities (Nano-cracks) or 3D cavities (bubbles). Then, these samples were processed by H+ plasma. Nano-cracks and bubbles will help trapping H diffused from the surface. Then this hydrogenated wafer was bonded with the other oxidized wafer. After annealed at 600 °C, a thin layer will be transferred from the hydrogenated wafer to the oxidized one. In this way, we can get the thin layer SOI wafer.

**EM+SC-TuP3 Effects of Remasking Materials and Dimensions on Sidewall Roughness of Deep Etched Waveguide**, ***J.W. Bae,*** *W. Zhao, J.H. Jang, I. Adesida,* University of Illinois at Urbana Champaign; *A. Lepore, M. Kwakernaak, J.H. Abeles,* Sarnoff Corporation

Photonic devices and circuits based on InP/InGaAsP materials require optical waveguides with highly anisotropic and smooth sidewall profile to achieve good optical mode quality and low loss performance. In the fabrication of optical waveguides, critical factors include lithography, masking, and etching. Each factor introduces various degrees of sidewall roughness (SWR). The rough sidewall of waveguides causes scattering loss, which is one of the major sources of optical loss in deep etched waveguides. Therefore, the characterization of sidewall roughness for the various processes is required. In this study, the SWR of InP/InGaAsP heterostructures fabricated using inductively-coupled-plasma etching (ICP) was investigated as a function of the remasking materials and the dimensions of masks. Among the factors introducing SWR, lithography and etching conditions were fixed at optimum condition that was previously determined. Remasking materials including silicon dioxide and silicon nitride were deposited on NiCr (40 nm)/SiO@sub 2@ (600 nm) mask using plasma enhanced chemical vapor deposition. Also, the effects of thicknesses of NiCr mask layer and remasking materials on the SWR were investigated in the range from 40 to 100 nm and 25 to 100 nm, respectively. Atomic force microscopy (AFM) was utilized to directly measure the SWR of waveguides. Electron beam lithography was used to delineate specially designed line patterns that permitted AFM tips to be directly utilized to measure SWR. Results on SWR from various sources will be presented and discussed with relation to optical losses.

**EM+SC-TuP4 Sub 100 nm Radius of Curvature Wide-Bandgap III-Nitride Vacuum Microelectronic Field Emitter Structures Sharpened by ICP Etching**, ***P.B. Shah,*** *M.D. Derenge, B.M. Nichols, T.S. Zheleva, K.A. Jones,* US Army Research Laboratory

Nanometer scale tips make possible cold cathodes that when used in vacuum microelectronic (VME) devices bring together the advantages of high power that vacuum tubes provide with the advantages of instantaneous turn-on (no need for tedious warm up), miniaturization and long device lifetime. The advantage of gallium nitride (GaN) in these applications is it's very small electron affinity (energy necessary to remove the electron from the material surface into vacuum.) Aluminum nitride (AlN) is even better because it may exhibit a negative electron affinity. For vacuum microelectronic devices we are developing field emitters using inductively coupled plasma (ICP) etching. This technique involves two steps, first, a fast deep etch to define columns of a given aspect ratio followed by etches to sharpen the columns. We investigate and optimized gas flow rates, etch times, gas pressures, ICP coil RF power, chuck RF power, and masking material. Advantages of this technique over other demonstrated techniques for producing GaN based field emitters such as selective area deposition are that it can be easily transferred to existing fabrication lines and that it allows for easy definition of complex VME device structures. Using an ICP etch high aspect ratio field emitters were fabricated from MOCVD grown GaN exhibiting a tip radius of 80 nm and height of 900 nm. Currently we are optimizing the technique to achieve a smaller GaN tip radius. In parallel an etch process is being optimized to produce field emitter tips from AlN. Our presentation will discuss optimized etch chemistries and preliminary electrical performance along with surface passivation and cleanup techniques.

**EM+SC-TuP5 A Study of Silicon Carbide (SiC) Etching Characteristics using Magnetized Inductively Coupled Plasmas (MICP)**, ***H.Y. Lee,*** *D.W. Kim,* Sungkyunkwan University, South Korea; *Y.J. Sung,* Samsung Advanced Institute of Technology, South Korea; *G.Y. Yeom,* Sungkyunkwan University, South Korea

SiC is an attractive material for electronic devices operating at high power levels and high temperatures. In addition, the large Si-C bonding energy makes the components made of SiC resistant to chemical attack and radiation, and thus attractive for the applications in harsh environments. SiC is also used as a substrate for microelectromechanical system(MEMS) and GaN epitaxial devices due to its excellent electrical, thermal, and mechanical properties. However, due to its stability and inertness of SiC in conventional acid or base solutions at normal temperatures, plasma-based etching plays a important role in patterning SiC for the fabrication of electronic devices. Optimum etch strategies for the fabrication of these devices demand excellent profile control, low ion-induced etch damage, smooth etch surfaces, and high etch rates. In this article we report on the SiC etching in SF6 based discharges and the etch selectivity of SiC over various mask materials to obtain high etch rates and low surface damages. The etch characteristics such as etch rates, etch selectivities, and etch profiles in addition to the plasma characteristics were investigated as functions of source power, and dc bias voltage to the substrate, gas mixtures and applied external magnetic field strength.

**EM+SC-TuP6 Electroless Copper Deposition as a Seed Layer on TiSiN Barrier**, ***Y.C. EE,*** *Z. Chen, S. Xu,* Nanyang Technological University, Singapore; *L. Chan, K.H. See, S.B. Law,* Chartered Semiconductor Manufacturing Ltd., Singapore

Electroless deposition of copper as a seeding technology has received considerable attention in back-end-of-line device fabrication. This work explores the effects of plasmas processing parameters such as argon gas flow rate and nitrogen plasmas treatment time on the properties of electrolessly plated Cu on TiSiN barrier layers formed by a low-frequency inductively coupled plasma process. TiSiN films have emerged as a promising candidate for the future generation barrier material because of its good adhesion to Cu. The properties of deposited electroless copper were characterized by X-ray diffraction (XRD), four-point resistivity probe, atomic force microscopy (AFM) and field emission secondary electron microscope (FESEM). Comparison is made with the Cu seed layer on TiN. It is found that the required palladium activation time is greatly reduced on TiSiN. The results also show that there is a preferred crystal orientation of Cu in (111) plane. Cu grain size is within the range of 24-33 nm. The sheet resistance of the Cu seed layer is less than 1.2 @ohm@ per square area. The roughness of plated Cu layer largely follows the one of the underlying TiSiN. Good surface coverage of electroless Cu seed layer on TiSiN is obtained in our experiments.

**EM+SC-TuP8 Thermal Conductivity Analysis of Highly-Oriented Diamond Films for Silicon on Diamond Electronic Applications**, ***N. Govindaraju,*** North Carolina State University; *A. Aleksov,* North Carolina State Univeristy; *F. Okuzumi, G.N. Yushin,* North Carolina State University; *S.D. Wolter, J.T. Prater,* Army Research Office / AMSRL- RO-PM; *Z. Sitar,* North Carolina State University

The extremely high thermal conductivity of diamond (~ 22 W/cmK) along with its wide bandgap (5.3 eV) and high specific resistance (~10@super 12@ @ohm@cm) make it an alluring material for incorporation as a dielectric in Silicon On Diamond (SOD) technology. SOD offers enhanced thermal transport properties in addition to the speed and power enhancing properties offered by the traditional Silicon On Insulator (SOI) technology. As the single crystal growth of diamond on silicon proves elusive, the pragmatic approach would entail the use of Highly Oriented Diamond (HOD) films. It is imperative, for the proposed SOD technology, that the thermal properties be well characterized. The current study seeks to fulfill this requirement by measuring all aspects of thermal conductivity of HOD films. Commercially available thin wire thermocouples (Type K) were used in conjunction with a thin film heater to carry out steady state measurements using the traditional heated bar technique. Preliminary results indicated an average value of ~ 8 W/cmK for measurements done on free standing HOD films. To further refine the accuracy of the measured thermal conductivity, measurements using a thin film heater and thin film thermocouples were implemented. Studies by Graebner@footnote 1@ have shown that grain size has a great impact on the thermal conductivity of randomly oriented polycrystalline diamond. Since it is known that the size of the columnar grains varies as a function of diamond film thickness, we studied thermal conductivity as a function of thickness. This was achieved by etching away the diamond using an argon-oxygen plasma and implementing the thermal measurements recursively. All thermal conductivity data has been measured as a function of temperature. @FootnoteText@@footnote 1@J.E. Graebner, et. al., Diamond and Related Materials, 2 (1993), 1059-1063.

**EM+SC-TuP9 Deposition and Field-Emission Characterization of Electrically Conductive Diamond-Like Amorphous Carbon Films***, **H. Kinoshita**, R. Ikuta, K. Sakurai, S. Murakami,* Shizuoka University, Japan

Diamond-like amorphous carbon films doped with nitrogen (DAC:N) were formed using intermittent supermagnetron plasma chemical vapor deposition (CVD) technique,@footnote 1@ for the fabrication of high performance field emitters. DAC:N films were deposited on Si and glass wafers using i-C@sub 4@H@sub 10@/N@sub 2@ plasma to investigate the influence of discharge-off time, at lower-electrode temperature of 100°C, upper- and lower-electrode rf powers (UPRF/LORF) of 800W/100W, and electrode spacing of 40mm. Discharge-on time was 1min, and off time (cooling time) was controlled to 15sec-10min. With decrease of cooling time, resistivity was decreased. At cooling time of 15sec, however, DAC:N film was peeled off from a wafer by its plasma heating. By reducing the electrode spacing from 40mm to 20mm, resistivity and optical band gap of DAC:N film deposited at 800W/800W rf powers and 5min cooling time decreased to 0.11@ohm@cm and 0eV, respectively. A DAC:N film of 500Å thickness was deposited on a n-Si wafer at 850W/100W, and was patterned in many island shapes of 1µm x 1µm sizes. Using it, a threshold emission current density of 0.01mA/cm@super 2@ was observed at the electric field of 12V/µm. At the electric field of 21V/µm, maximum field-emission current density (IMAX) of 3mA/cm@super 2@ was observed at the electric field of 21V/µm. A flat DAC:N film of 700Å thickness was deposited on a n-Si wafer at 800W/800W. Using the flat DAC:N film, a threshold electric field of 18V/µm, and IMAX of 2.2mA/cm@super 2@ was observed at the electric field of 32V/µm. @FootnoteText@ @footnote 1@H.Kinoshita and T.Murakami, J.Vac.Sci.Tecnol.A 20, (2002) 403.

**EM+SC-TuP10 Avalanche Ballistic Electron Emission Microscopy (BEEM) Studies of Subthreshold BEEM Current and STM Induced Photocurrent***, **C. Tivarus**, E.R. Heller, J.P. Pelz,* The Ohio State University

We present Ballistic Electron Emission Microscopy (BEEM) studies where the metal is deposited directly over an avalanche pn diode. Because the avalanche diode provides a hot electron gain of up to many millions, intrinsic BEEM current noise levels as low as 20 aA are possible. Hence, this technique can be very useful in nm-resolution studies of electronic transport in structures that otherwise show very low ballistic current for traditional BEEM measurements. Using this technique we were able to accurately study the shape of the subthreshold regions of the BEEM current-voltage curves where all the BEEM current is due to thermally excited electrons above the Fermi level in the STM tip. One of the problems encountered when interpreting the measurements for this avalanche BEEM technique is the presence of the Scanning Tunneling Microscopy induced photo current (STM-PC). Since this STM-PC resembles a normal BEEM current, [E.R. Heller and J.P. Pelz, Appl. Phys. Lett. to be published] it can interfere with BEEM measurements of structures with low signal and/or intrinsic BEEM threshold voltage larger than the substrate bandgap. We have characterized this low signal STM-PC effect using the high photon sensitivity and large collector solid angle of the underlying avalanche diode and will discuss methods to distinguish true BEEM current from STM-PC.

**EM+SC-TuP11 Submicron MTJ Cell Selectivity and Switching Field Analysis using Scanning Probe Microcopy Technique***, **D.S. Kim**, J. Heo, I.S. Chung,* SungKyunKwan University, Korea

It has been reported that in a Synthetic Anti Ferromagnet (SyAF) deposited MTJ bit, the demagnetizing magneto static domain will be diminished regardless of its size with a very low aspect ratio. Thus, the anisotropy ratio and the size of the MTJ (Magnetoresistance Tunneling Junction) cell can be reduced more. Scanning Probe Microscopy (SPM) analysis has great advantage in submicron MTJ bit characterization, since it does not need to make a MTJ contact. We have successfully attained the H-R curve using SPM under controlling external magnetic field for submicron scaled MTJ bits. Therefore, We made to investigate the issues in selectivity characteristics and switching field characteristics in terms of various anisotropy ratio and sizes. We can attain the asteroid curve by applying both hard axis and easy axis magnetic field simultaneously either by rotating sample in diagonal or by applying current through write line. We found the newly introduced SPM diagonal field appliance method would be more efficient than conventional ones, in investigating a MTJ bit switching field characterization.

**EM+SC-TuP12 The Analysis on the Origin of High Resistivity in Polycrystalline CdZnTe Thick Films***, **K.H. Kim**, S.Y. Ahn, M.H. Kim, Y.J. Park, K.N. Oh,* Korea University*; S.U. Kim,* Korea University, Korea

The CdZnTe have an inherently high stoping power, an excellent carrier transport property, and relatively wide band gap energy. Therefore detectors using this materials have the potential for sufficient X-ray sensitivity and DQE at a sufficiently low leakage current.@footnote 1@ Although research results have been presented on single crystal CdTe and CdZnTe detectors with small sized silicon readout devices, it would be difficult to apply these results to large area flat-panel detectors. Alternatives of single crystal, we have grown large area ( 10 x 10 cm @super 2@ ) polycrystalline CdZnTe films by thermal evaporation method. The thickness, average grain size and Zn composition was 150 µm , 3 µm and 4%. Resisitivity of CdZnTe films is in the order of 2 x 10@super 9@ @Omega@cm which is comparable that of CdZnTe single crystal samples. In X-ray detectors, high leakage current limits the maximum integration time of the a-Si array for X-ray imaging applications so that high resistivity receptor material is required. Recent reports have identified deep level defects which are likely to be associated with semi-insulating property.@footnote 2@ Based on multiple trapping model, the localized state distributions of high resistivity polycrystalline CdZnTe from TOF (time of flight) transient current are examined using Laplace transform and Tikhonov reularization methods.@footnote 3@ We found 3 different deep localized states above valence band related to the resistivity. In TOF measurements, indium was used as top electrode to form Schottky type cotact to prevent carrier injection. @FootnoteText@@footnote 1@ S. Tokuda, H. Kishihara, S. Adachi, T. Sato, Y. Izumi, O. Teranuma, Y. Yamane, and S. Yamada, Proceedings of SPIE Vol. 4682 , 30 (2002)@footnote 2@ A. Zumbiehl, S. Mergui, M. Ayoub, M. Hage-Ali, A. Zerrai, K. Cherkaoui, G. Marrakchi, Y. Daricim, Material Science and Engineering B 71, 297 (2000)@footnote 3@ J. Weese , Comput. Phys. Commun. 69, 99 (1992).

**EM+SC-TuP13 Electrical, Thermal, and Elastic Properties of MAX Phase Materials***, S.E. Lofland, P. Finkel, **J.D. Hettinger**,* Rowan University*; M.W. Barsoum, A. Ganguly, S. Gupta,* Drexel University*; K. Harrell, J. Palma, B. Seaman,* Rowan University

We have characterized physical properties of several materials in the MAX phase family.@footnote 1@ These materials derive their name from the basic chemical formula M@sub n@AX@sub n-1@, where M is an early transition metal, A is an A-group element, and X is either N or C. These highly conductive ceramics are readily machinable and possess very desirable structural properties.@footnote 1@ From a systematic study of the transport properties, we find most of these materials require two conduction bands, one consisting of holes and the other of electrons, to explain the electrical conductivity, Hall coefficient, and magnetoresistance. A Wiedemann-Franz analysis of the thermal conductivity suggests that, in most of the materials investigated, the mean-free-path of the entropy carriers is the same as that for the charge carriers. The Lorenz number at room temperature indicates that the thermal conductivity is mostly electronic in nature. We have also performed heat capacity and speed of sound measurements on many of the MAX phase materials allowing the extraction of the elastic moduli and Debye temperatures. We find very good agreement between the Debye temperature as determined from specific heat and that determined from elastic measurements. We find that the electronic term in the specific heat depends strongly on the transition metal element and very weakly on the A-group element. In general we find that the transition metal element impacts the electrical properties more dramatically than the A-group element. In contrast, the A-group element seems to more strongly impact the elastic properties of the materials. The justification for these statements will be presented. This work was supported by the New Jersey Commission on Higher Education, the NSF under grants DMR-0072067 and DMR-0114073 and Rowan University. @FootnoteText@@footnote 1@M. W. Barsoum, Prog. Solid State Chem. 28, 201(2000).

**EM+SC-TuP14 Photo-electronic Properties of n-ZnO:Al/p-Si Heterojunctions***, **F. Mohammed**, A. Pontarelli, S. Bokhari, J.R. Doyle,* Macalester College

We present a study of the photo-electronic properties of n-ZnO:Al/p-Si heterojunctions. Transparent conducting ZnO:Al layers having resistivities < 1 x 10@super -3@ ohm-cm and transparencies of about 80% are deposited on p-Si using reactive dc magnetron sputtering. In some devices a higher resistance ZnO:Al buffer layer was inserted between the highly conducting ZnO:Al and silicon. The junctions are characterized by dark current-voltage measurements as a function of temperature (IVT), capacitance-voltage measurements (CV), spectral response measurements, and conversion efficiency. Excellent rectification is obtained, with soft breakdown voltages typically in the range of 3-5 V reverse bias. Analysis of the IVT characteristics imply that the carrier transport is mainly tunneling limited, and the CV measurements imply a barrier height of about 1 eV. The presence of the buffer layer has no systematic effect on the dark junction characteristics. However, the buffer layer devices exhibited a significantly enhanced spectral response and efficiency, with the best devices resulting in a 3 % conversion effeciency under 100 mW/cm@super 2@ white light illumination. Possible roles of the buffer layer in enhancing the photoresponse will be discussed, as well as the potential application of these devices as photodetectors and solar cells.

**EM+SC-TuP15 Effects of Threading Dislocations and In Composition on Structural and Optical Properties in InGaN/GaN Triangular-shaped Quantum Wells***, **R.J. Choi**, Y.B. Hahn, H.J. Lee,* Chonbuk National University, Korea

Structural and optical properties of InGaN/GaN multiple triangular quantum well (QW) structures have been studied with different threading dislocation (TD) densities and wavelengths (or In compositions). As the In composition increased, the extent of variation of the linewidth of photoluminescence (PL) measurements increased over a temperature range of 13 - 300 K. The structural quality of the quantum wells is not consistent with the PL intensity. More fluctuation of the local In composition and severer degradation of PL intensity at a higher TD density were observed, which were attributed to the stress field created by the dislocations. Observations by X-ray diffraction, transmission electron microscopy, and monochromated scanning cathodoluminescence imaging revealed that the optical property of the InGaN/GaN triangular-shaped MQWs is greatly affected by structural imperfections.

**EM+SC-TuP16 Electroluminescence in the Infrared Region from Thin Film Zinc Sulfide Doped with Rare Earth Fluorides***, **D. DeVito**, N. Shepherd, A.S. Kale, W. Glass, M.R. Davidson, P.H. Holloway,* University of Florida

While electroluminescent phosphors are routinely studied for flat panel display technology, infrared emission is often ignored. A variety of applications exist for infrared emitters, including chemical analysis, infrared displays, communications and therapeutic medical treatment. Thin film electroluminescent devices could serve as highly efficient, reliable, rugged infrared emitters. Electroluminescence in high-field devices is generated by impact excitation and subsequent radiative relaxation by electronic transitions located on the luminescent centers. Rare earth elements, including erbium, terbium and holmium, are good choices for luminescent centers as they exhibit many transitions ranging from visible (550 nm) to the mid-infrared wavelengths (5 micron), as will be documented with experimental data from ZnS films deposited by RF planar magnetron sputtering. Among these, holmium is particularly interesting because of transitions at 1210 nm, 1400 nm, 2.9 micron, 4.8 micron and 5 micron. Suppression of emission at visible wavelengths and enhanced infrared emission by selective processing of sputter deposited films is achieved through proper selection of annealing temperature. Optimum luminance at characteristic wavelengths was developed by the appropriate choice of luminescent center and activator concentration, deposition temperature and annealing conditions. Low temperature device measurements are presented to evaluate the effects of room temperature on the number of energy transitions and energy transfer mechanisms in thin film devices.

**EM+SC-TuP17 Visible and Near-infrared Electroluminescence from Er-doped GaN Thin Films Prepared by RF Planar Magnetron Sputter Deposition***, J.H. Kim, **M.R. Davidson**, N. Shepherd, P.H. Holloway,* University of Florida

Erbium (Er)-doped GaN thin films were prepared by radio frequency (RF) planar magnetron co-sputtering of a commercial GaN target and a metallic Er target in a pure nitrogen atmosphere. The alternating-current thin-film electroluminescent (ACTFEL) devices were fabricated using a standard half-stack configuration with an Al metal electrode, GaN:Er electroluminescent layer, ATO (Al@sub2@O@sub3@-TiO@sub2@) dielectric, and ITO (indium-tin-oxide) transparent conducting electrode. Visible and near-infrared (NIR) EL emission peaks were observed from the fabricated devices at 530, 550, 660, 1000, and 1550 nm. These emissions were attributed to the Er@super3+@ 4f - 4f intrashell transitions from the @super2@H@sub11/2@, @super4@S@sub3/2@, @super4@F@sub9/2@, @super4@I@sub11/2@, and @super4@I@sub13/2@ excited-state levels to the @super4@I@sub15/2@ ground-state, respectively. GaN host films had a wurtzite polycrystalline structure with a preferred orientation in the [0001] direction perpendicular to the film surface. Full width at half maximum (FWHM) of the (0002) wurtzite-GaN diffraction peak and the lattice constant, c both increased from 0.38° to 0.45° and from 5.18 Å to 5.205 Å, respectively, as the Er concentration in GaN host was varied from 0 to around 5 at.%, indicating that incorporation of larger Er atoms into GaN host expands the host lattice. The optimum concentration of Er was determined to be around 1 at.% for both of the green 530 nm and NIR 1550 nm emissions.

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