

Tuesday Evening Poster Sessions

Electronic Materials and Processing

Room: Hall D - Session EM-TuP

Electronic Materials and Processing Poster Session

EM-TuP1 Growth of AlN Nanowires on Sapphire and Silicon using the Pulsed Electron Beam Deposition (PED) Process. *N. Arefin, P. Larson, University of Oklahoma, Matthew Kane, Texas A&M University, M.B. Johnson, P.J. McCann, University of Oklahoma*

This poster will describe results recently obtained with pulsed electron beam deposition (PED) of AlN on sapphire and silicon substrates. The PED technique is potentially useful for growth of III-nitrides at lower substrate temperatures, a capability that can allow use of new buffer layer materials, integration of chemically dissimilar materials, and help solve wafer bowing issues. In addition, PED has the advantage to deposit materials that are transparent to the Kr-F excimer lasers used in pulsed laser deposition and would thus be suitable for ultra-wide bandgap materials. Systematic studies are needed to explore the growth regimes for various materials as a function of processing conditions and sample preparation techniques. AlN was deposited on sapphire and silicon (111) at a substrate temperature of 500°C and 550°C, respectively, in a UHP N₂ (15 mTorr) environment (without any surface pre-treatment, i.e., pre-nitridation). A high power electron gun pulse was used to ablate the AlN target (1" dia. x 0.250" thick, 99.8% pure) stationed at 5 cm vertical distance from the substrate. The electron pulses were generated at 15KV, 0.3 J/pulse at 1 Hz for one hour. No post growth processing was performed following the growth. Scanning electron microscopy (SEM), Electron back scattered diffraction (EBSD), and X-ray diffraction (XRD), and various optical characterization techniques were performed on the as-grown material. SEM imaging confirms hexagonal faceted high aspect ratio AlN nanowires on both sapphire and silicon substrates. The nanowire lengths ranged from 10-100 μm with average diameter of 2.5 μm on the sapphire substrate, while on the silicon (111) substrate the nanowire dimensions ranged from 200 nm-10 μm in length, and the average diameter was 0.5 μm. EBSD scan over the nanowires identified the structures as c-plane oriented AlN. XRD θ-2θ scans from 20 = 30° to 2θ = 50° showed only one peak other than those from the sapphire substrate, at 2θ = 37.56°. We had insignificant contribution from the AlN NWs in the XRD scan due to limited quantity of the NWs on the sample. The obtained peak at 2θ = 37.56° represents Al (111) suggests that during the initial growth phases Al was accumulated as metal on the substrate which acted as a precursor in initiating the nanowire growth afterwards. This finding was also verified with EBSD scans, as it also detected presence of Al crystallites on the sample surface as well as highly c-axis oriented AlN nanowires.

EM-TuP2 Passivation of InSb(100) with 1-Eicosanethiol Self-Assembled Monolayers. *Y.D. Contreras, Pablo Mancheno, A.J. Muscat, University of Arizona*

III-V semiconductors have the potential to replace Si to make faster computer processors due to their higher charge mobility. In particular, the bandgap of InSb (0.17 eV, the smallest of the III-V group) makes this semiconductor an absorber and emitter in the infrared region, suitable for infrared detectors. III-V semiconductors oxidize rapidly when exposed to air after etching, and have complex oxide layers. It has been shown that sulfur-containing molecules can passivate and enhance the electrical properties of III-V semiconductors. In this study, InSb(100) was chemically passivated for 3 min after native oxide etching by liquid-phase deposition of an alkanethiol self-assembled monolayer (SAM) on the surface of the semiconductor. The SAM contained 1-eicosanethiol (ET, 20 C atoms). The passivated surface was characterized with atomic force microscopy (AFM), spectroscopic ellipsometry, X-ray photoelectron spectroscopy (XPS) and FTIR. Tapping Mode AFM images of InSb native oxide showed that the starting surface was rough (RMS 2.25 nm), which could limit the formation of a dense and ordered alkanethiol SAM. The thickness of the overlayer (both InSb oxides and ET) measured by spectroscopic ellipsometry was 35 Å immediately after passivation. XPS analysis showed that the passivation process with a 1.0 M HCl last step and 20 h passivation yielded no detectable oxygen in the Auger region for 3 min of air exposure, but the surface was completely oxidized after 4 h of exposure. As a comparison, passivation of GaAs(100) (bandgap of 1.4 eV) with an ET SAM maintained oxygen below detection limits after 30 min, but the surface still oxidized after 4 h. When the passivation of InSb(100) was performed with different preparation conditions (HCl and thiol concentrations, solvent type, and deposition time), the largest bulk InSb to Sb₂O₃ 3d + O 1s XPS peak area ratio (minimum Sb oxidation) was achieved by using 1.0 M HCl in the oxide etching steps, 0.1 mM ET in ethanol and long thiol deposition times

(~20 h). FTIR analysis of an InSb sample passivated for 20 h in 0.1 mM ET showed the presence of peaks characteristic of methyl and methylene stretches at 2963 cm⁻¹, 2925 cm⁻¹ and 2847 cm⁻¹. The position and width of these peaks indicates the presence of a partially ordered alkanethiol layer. These results demonstrate that physically blocking O₂ diffusion with alkyl chains is possible on the surface of a narrow band-gap semiconductor, even on a surface with a relatively high average roughness.

EM-TuP3 Electric Measurements of RF SOI MOSFET using CMOS Technology. *William Mariano, UNICAMP, Brazil*

The aims of this work is the development of a 2 μm SOI CMOS process. The manufacturing of the devices was carried out using processes based on SOI CMOS technology. The characteristics of the fabricated devices in a SOI Silicon are compared in order to obtain its parameters, as well as with the results published in the literature. Besides is to present the electric measurements of n and p channel RF MOSFET fabricated on Silicon substrates of type SOI – Silicon On Insulator. The different structures of the devices had been fabricated and their physical and electrical characterizations performed. In addition, there will be a sequence of the process steps involved in building the CMOS chips. The devices are part of an academic chip, which will be used in disciplines of engineering courses and in research activities of the Microelectronics area.

EM-TuP5 Fabrication of Inverse Opal Structures by Langmuir-Blodgett Silica Microsphere Assembly and Germanium Back Filling by Molecular Beam Epitaxy. *M. Zhou, Sarun Atiganyanun, S. Ghosh, J. Chavez, S.E. Han, S.M. Han, University of New Mexico*

Photonic crystals give rise to a variety of applications such as absorbers, waveguides, and light filters. One of the common examples is an inverse opal structure made of semiconductors. This structure, unlike its counterpart opal structure, exhibits a complete photonic band gap. In this study, we investigate a low-cost and scalable fabrication of an inverse opal structure via self-assembly of colloidal silica microspheres and Ge molecular beam epitaxial (MBE) back filling, followed by buffered HF etching. First, silica microspheres are functionalized with allyltrimethoxysilane and dispersed in chloroform. Langmuir-Blodgett (LB) method is then used to self-assemble silica microspheres with a diameter of ~800 nm onto Si(100) substrates. By optimizing the pulling speed of the substrate and surface pressure within the trough, a hexagonally closed-packed opal structure is achieved. Scanning electron microscopy (SEM) images have shown domain size of the monolayer assembly to be approximately 10 μm by 10 μm. By repeating LB coating for *n* times, an *n*-multilayer assembly is formed, creating an opal template structure. After assembling silica microspheres on Si substrates, Ge MBE is used to back fill the voids between microspheres. The effusion cell temperature ranges from 1150 to 1000°C, which corresponds to the Ge flux of 6.44*10¹⁴ to 1.83*10¹³ Ge atoms/cm²-sec, respectively. When the substrate temperature is held constant at 580°C, the SEM characterization shows that the low Ge flux at 1000°C reduces random nucleation on top of the microspheres by approximately one order of magnitude compared to the high Ge flux at 1150°C. Following the backfill, the silica microspheres are removed by immersing the substrate in a buffered HF solution, creating a single-crystalline Ge inverse opal structure. In this presentation, we will further discuss the optimization of Ge flux and substrate temperature, examination of crystal quality of Ge by X-ray diffraction and Ge/Si interface by transmission electron microscopy, and the structure's optical properties with Fourier transform infrared spectroscopy.

EM-TuP7 Formation of AlN Thin Films by Direct Nitridation of Aluminum Thin Films and Their Visible Photoluminescence Property. *Shun Kajihara, M. Hamasaki, H. Katsumata, Meiji University, Japan*

AlN has the widest band-gap of 6.3 eV among the direct band-gap semiconductors and is therefore suitable for shorter wavelength light emitting devices and power devices. AlN thin films have been prepared by MOCVD and reactive sputtering with the deposition rate of about 0.1-10 nm/min. Meanwhile, AlN powders and AlN bulks have been prepared by reducing nitridation and direct nitridation methods. In this study, AlN thin films were formed by direct nitridation (DN) of Al thin films and their properties were compared with those formed by reactive sputtering (RS). For photoluminescence (PL) measurements, doping of Eu into AlN was performed to observe visible PL from Eu ions in AlN films.

Al thin films with a thickness of 150 nm were deposited on c-axis sapphire substrates by radio frequency (RF) magnetron sputtering using an Al target (φ4 inch, Koujundokagaku, Japan) in constant Ar (8.0 sccm) flow. Co-sputtering of Eu₂O₃ and Al was performed by placing 2 pieces of Eu₂O₃ tablets on the Al target for PL measurements. The films were subsequently annealed at 900°C for 15 sec in N₂ or NH₃ gas using a conventional electric quartz tube furnace, which can form AlN films with a theoretical thickness

of 300 nm. On the other hand, AlN thin films with a thickness of 500-700 nm were deposited on c-axis sapphire substrates by RS using an Al target in constant N₂ (5.6 sccm) and Ar (2.4 sccm) flow. Co-doping of Eu₂O₃ and Si during the formation of AlN films by RS was performed by placing several pieces of Eu₂O₃ and Si tablets on the Al target. Doping of Si was to observe the blue luminescence from Eu²⁺ in AlN by replacing Al atoms by Si atoms in AlN, which can prevent the formation of Eu³⁺. RF sputtering power was set at 200 W through this study. The films were subsequently annealed at 900°C for 30 min in N₂ with rapid thermal annealing system. Growth time of AlN films with a thickness of 300 nm by RS was approximately 30 times longer than that by DN. These samples were analyzed by X-ray diffraction (XRD), PL, optical transmittance and energy dispersive X-ray spectrometry. The wurtzite AlN (002) XRD peak appeared from the samples formed by DN. PL spectra of Eu₂O₃ doped AlN films formed by DN exhibited broad emissions at 400 nm and 530 nm, which were assigned to oxygen defect and Eu²⁺, respectively. The optical direct band-gap of AlN films doped with Eu₂O₃ was calculated to be 5.85 eV from their optical transmission spectra. These results were also obtained from the samples formed by RS. It is interesting to note that the PL spectral features of Eu₂O₃ doped AlN films formed by DN resembles those of Eu₂O₃ and Si co-doped AlN films formed by RS.

EM-TuP8 Improvement of Effective Work Function and Transmittance of ITO/Ultra-Thin In_{1-x}Ru_xO_y Stack Structure, Ippei Yamamoto, Shibaura Institute of Technology, Japan, *T. Kattareeya,* Chulalongkorn University, Thailand, *T. Chikyo, K. Tsukagoshi,* NIMS, Japan, *T. Ohishi,* Shibaura Institute of Technology, Japan, *T. Nabatame,* NIMS, Japan

The indium tin oxide (ITO), which is one of most attractive anode materials in organic electroluminescent, has a big issue of low work function (WF) of 4.7 eV. Several approaches have been proposed to improve the WF of ITO and/or develop new anode materials. We pay attention to RuO₂ material because of high WF (> 5 eV) and low resistivity. In this paper, we systematically investigate the characteristics of the In_{1-x}Ru_xO_y films. We also compare characteristics of ITO/ultra-thin RuO₂ (3 nm) and ITO/ultra-thin In_{1-x}Ru_xO_y (3 nm) stack structures.

The In_{1-x}Ru_xO_y films were prepared under Ar/O₂ (25 vol. %) by co-sputtering using Ru and In₂O₃ targets. The Ru composition ratio of the In_{1-x}Ru_xO_y films was varied from 0 to 1.0 by changing each sputtering power. A 150-nm-thick ITO film was deposited on RuO₂ (3 nm) or In_{1-x}Ru_xO_y (3 nm) film to fabricate ITO/RuO₂ or ITO/In_{1-x}Ru_xO_y stack structure by RF sputtering using an In_{0.9}Sn_{0.1}Ox target, respectively. The SiO₂ metal-oxide-semiconductor (MOS) capacitors with ITO/RuO₂ or ITO/In_{1-x}Ru_xO_y gate electrode were fabricated to obtain effective work function (EWF).

The In_{1-x}Ru_xO_y film consists of amorphous structure in x range from 0.3 to 0.83. The In_{0.38}Ru_{0.62}O_y film shows a lowest specific resistivity and smooth surface of small RMS (0.69 nm) value using atomic force microscopy. The maximum transmittance increased more than 80 % by reducing thickness less than 3 nm.

The ITO/RuO₂ (3 nm) stack structure shows a high EWF value (5.3 eV) and a slightly low transmittance (77 % in 600 nm) because the RuO₂ film has tetragonal crystal structure. On the other hand, the transmittance (80 % in 600 nm) of ITO/In_{0.38}Ru_{0.62}O_y (3 nm) is superior to that of ITO/RuO₂ stack structure. Furthermore, the ITO/In_{0.38}Ru_{0.62}O_y stack structure shows a high EWF (5.3 eV) and a low specific resistivity (9.2 × 10⁻⁵ Ω·cm). This suggests that the interface between ITO and In_{0.38}Ru_{0.62}O_y is kept to be clear because of same dominant element of indium and amorphous structure of In_{0.38}Ru_{0.62}O_y film.

EM-TuP9 Solid Phase Growth of Mg₂Si Thin Films on Poly-Si/Glass Substrates Prepared by Aluminum Induced Crystallization, Satoru Kawaguchi, A. Kusunoki, S. Yoshida, H. Katsumata, Meiji University, Japan

Aluminum induced crystallization (AIC) is a method of crystallizing amorphous Si (a-Si) by the interaction of Al and Si during the heat treatment. Polycrystalline Si (poly-Si) can be formed at lower temperature by AIC compared to solid phase growth techniques, since AIC can crystallize amorphous Si below the eutectic temperature of Al and Si at 577 °C. Poly-Si formed by AIC usually exhibits p-type conductivity with a high carrier concentration due to existence of residual Al. On the other hand, it has been difficult to form n-type poly-Si by metal induced crystallization using n-type doping materials as Sb. The purpose of this study is to fabricate a pn junction for light-receiving device consisting of AIC p-type poly-Si and n-type Mg₂Si. Mg₂Si (Eg: 0.6-0.7 eV) was selected as a candidate of n-type layers because Al atoms are considered to act as an n-type dopant in Mg₂Si.

The substrates used in this study were glass or p-Si (100) substrates. Al films with a thickness of 500 nm were deposited on the glass substrate by resistive evaporation. After deposition, they were exposed in the air for

more than 2 hours to form native Al oxide films. Subsequently, a-Si films with a thickness of 500 nm were deposited on the Al films by radio frequency (RF) magnetron sputtering. These samples were annealed at 450-500 °C for 3-12 hours in N₂ for AIC. After the AIC, Al top layer was removed with diluted HCl. Then, Mg films with a thickness of 100-300 nm were deposited either on AIC poly-Si films or p-type Si (100) substrates by resistive evaporation. These samples were annealed at 400 °C for 5 hours in Ar for solid phase growth of Mg₂Si.

Optical microscope images of surface of AIC poly-Si showed that the grain size of poly-Si increased with increasing AIC temperature. All sample showed Si (111) XRD peaks at 2θ = 28 degrees and Si Raman peaks at 520 cm⁻¹, which can be an evidence of formation of (111) preferentially oriented poly-Si by AIC. We investigated the correlation between grain size of poly-Si observed with optical microscope and FWHM of Raman peak at 520 cm⁻¹. As a result, it was found that the AIC at higher temperature decreased grain size and increased FWHM, while the AIC for longer time increased grain size and decreased FWHM. Optical band-gap of AIC poly-Si formed at 500 °C for 12 hours was determined to be 1.1 eV from optical transmittance spectra. Hall effect measurements of AIC poly-Si showed p-type conductivity with a hole concentration of 4.0 × 10¹⁷ cm⁻³ and a hole mobility value of 1.56 cm² · V⁻¹ · s⁻¹. Mg₂Si films formed both on AIC poly-Si/glass and p-Si (100) substrates showed Raman peaks at around 256 cm⁻¹, which originate from Mg₂Si.

EM-TuP11 The Effect of Vacuum-Ultraviolet Irradiation on Copper Diffusion into Low-k Dielectrics, Xiangyu Guo, University of Wisconsin-Madison, *Y. Nishi,* Stanford University, *J.L. Shohet,* University of Wisconsin-Madison

Cu diffusion into low-k dielectrics can cause serious reliability issues in on-chip interconnect systems. A considerable attention in the research community had been devoted to understanding the effect of Cu diffusion in the electrical breakdown properties of low-k dielectrics, while Cu-induced diffusion from vacuum-ultraviolet (VUV) irradiated low-k dielectrics has received only minimal attention. This work is aimed at determining the nature of copper interactions with VUV irradiated low-k dielectrics in integrated circuits. The effects of VUV irradiation on the Cu diffusion into low-k organosilicate glass (SiCOH) dielectric films were investigated. X-ray photoelectron spectroscopy depth profiling was used to assess Cu diffusion in the dielectric in the presence of a bias-temperature stress. After 12-eV photon irradiation under bias-temperature stressing at 3.5 MV/cm and 225°C respectively, Cu penetrates farther into the SiCOH, compared to that of an unirradiated sample. Further examination of the VUV photon-exposed SiCOH shows that the Cu distribution profile in the dielectric after bias-temperature stressing is different from the profile after the same temperature annealing but without electrical bias. In addition, no such enhanced phenomenon was observed in unexposed dielectrics, suggesting that Cu ion drift can occur in VUV-irradiated SiCOH. The implication of these findings on time-dependent dielectric breakdown in Cu/VUV irradiated low-k dielectrics is discussed.

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EM-TuP12 Electronic and Vibrational Structures in Photoemission Spectra for Dibenzopentacene on Au(111), Masaru Aoki, A. Suzuki, H. Sato, The University of Tokyo, Japan, *K. Shudo,* Yokohama National University, Japan, *S. Masuda,* The University of Tokyo, Japan

Electronic properties of dibenzopentacene (DBP) thin films on Au(111) were examined by ultraviolet photoemission spectroscopy (UPS), metastable atom electron spectroscopy (MAES),^{1,2} and first-principles DFT calculation. The UPS and MAES spectra for DBP multilayer show four bands near the Fermi level (E_F) due to π-derived 8b_g(HOMO), 7b_g+7a_u, 6a_u, and 6b_g states, in agreement with an earlier study.³ The corresponding bands emerge in the monolayer region, but the bandwidth of the HOMO band is much narrower than that in the multilayer. Furthermore, the HOMO band consists of three peaks with interval of ~160 meV, which is attributed to the vibrational structure of the CC stretching modes of DBP⁺ ion produced by photoionization. A similar vibronic coupling has been reported for organic molecules on inert surfaces such as phthalocyanine on graphite⁴ and pentacene on graphite,⁵ but to our knowledge there is no report in the organic-metal system. In the conference, we will introduce the weak interactions between DBP and Au(111) based on our DFT calculation, temperature-dependent (50-273 K) vibronic structure, and lifetime of photohole in organic-metal system.

References

- [1] Y. Harada, S. Masuda, H. Ozaki, *Chem. Rev.* **97**, 1897 (1997).
- [2] S. Masuda, *Appl. Surf. Sci.* **256**, 4054 (2010).

[3] B. Mahns, F. Roth, A. König, M. Grobosch, M. Knupfer, T. Hahn, *Phys. Rev. B* **86**, 035209 (2012).

[4] S. Kera, H. Yamane, I. Sakuragi, K. K. Okudaira, N. Ueno, *Chem. Phys. Lett.* **364**, 93 (2002).

[5] H. Yamane, S. Nagamatsu, H. Fukagawa, S. Kera, R. Friedlein, K. K. Okudaira, N. Ueno, *Phys. Rev. B* **72**, 153412 (2005).

EM-TuP13 Evolution of Gap States in Potassium-Doped Dibenzopentacene, *Hirofumi Sato, S. Mihara, M. Aoki*, The University of Tokyo, Japan, *K. Shudo*, Yokohama National University, Japan, *K. Akimoto*, University of Tsukuba, Japan, *S. Masuda*, The University of Tokyo, Japan

Electronic properties of potassium-doped dibenzopentacene (DBP) thin films on Au(111) were studied by ultraviolet photoemission spectroscopy (UPS), metastable atom electron spectroscopy (MAES),^{1,2} and first-principles DFT calculation. The UPS and MAES spectra for K₃DBP (0 ≤ x ≤ 3.5) films show three types of gap state (GS1~GS3) in the HOMO-LUMO gap of pristine DBP. The GS1 and GS2 emerge at the initial stage of deposition and are attributed to the modified HOMO state and partially-filled LUMO state, respectively. The threshold of electron emission for K₁DBP is located ~0.1 eV below the Fermi level (E_F) with no metallic feature, suggesting that K₁DBP is a Mott-Hubbard insulator. At the formation of K₂DBP, the GS1 and GS2 saturate in intensity and shift to the higher binding energy. This indicates that the native LUMO state is fully occupied by electron transfer, resulting in a wide-gap insulator. Upon further deposition, the GS3 appears near E_F and is attributed to partial electron filling in the LUMO+1~LUMO+3 states. For K_{3.5}DBP, the leading edge of GS3 is located ~0.1 eV below E_F without a metallic feature. Therefore, the heavily doped species transfers to a Mott-Hubbard insulator again. The GS3 plays a key role in superconductivity of K₃DBP at low temperature.³

The interaction of alkaline-metal atoms with aromatic hydrocarbons could be classified into three categories, i.e., weak interaction,⁴ simple charge transfer,⁵ and heavy mixing of mutual wave functions. The K-doped DBP belongs to third category, and the detail will be discussed in the conference.

References

[1] Y. Harada, S. Masuda, H. Ozaki, *Chem. Rev.* **97**, 1897 (1997).

[2] S. Masuda, *Appl. Surf. Sci.* **256**, 4054 (2010).

[3] M. Xue, T. Cao, D. Wang, Y. Wu, H. Yan X. Dong, J. He, F. Li, G. F. Chen, *Sci. Rep.* **2**, 1 (2012).

[4] M. Sogo, Y. Sakamoto, M. Aoki, S. Masuda, *J. Chem. Phys.* **133**, 134704 (2010).

[5] F. Bussolotti, S. Kera, N. Ueno, *Phys. Rev. B* **86**, 155120 (2012).

EM-TuP15 In Situ Metrology during GaN and InGaN Growth by Remote Plasma-assisted MOCVD, *Daniel Seidlitz, R.L. Samaraweera*, Georgia State University, *I.T. Ferguson*, University of North Carolina at Charlotte, *A. Hoffman*, Technical University Berlin, Germany, *N. Dietz*, Georgia State University

Using real-time optical diagnostics during the GaN and InGaN growth progress in a remote plasma-assisted Metal Organic Chemical Vapor Deposition (RPA-MOCVD) reactor provides details in the precursors' decomposition processes and epitaxial layer growth mechanisms. Growth process control provisions in the RPA-MOCVD reactor enable a temporal and spatial controlled injection of metal organics (MO) as well as ammonia (N₂) plasma activated hydride precursors such as hydrogen (H₂) or ammonia (NH₃). Remote activated hydride precursor fragments (e.g. N*/NH*/NH₂*) are generated using a hollow cathode driven by a tunable radio frequency (rf) power source up to 600W. The radicals are directed to the substrate surface by the remote plasma afterglow regime. Plasma Emission Spectroscopy (PES) and UV-Absorption spectroscopy (UV-AS) are used to identify the active species in the plasma and determine their concentrations in dependence of the injected precursors N₂, H₂ and NH₃. Plasma emission spectroscopy during the growth run allows also a time dependent recording of the quantitative behavior of the reactive particles inside the plasma. In addition, real-time measurements and analysis of reflection spectroscopy at normal incidence on the growth surface contribute sub-monolayer growth rates for GaN and InGaN. In this report we will present and discuss results of in-situ Plasma emission spectroscopy, UV-Absorption spectroscopy and Normal incidence reflection spectroscopy (NI-RS). The combination of these real-time characterization methods provides qualitative and quantitative identification of active species in the gas phase and determination of growth rates at the growth surface. The in-situ obtained growth rates are compared with ex-situ thickness measurements (e.g. Transmission and reflection spectroscopy) and results of layer structural characterization methods (Raman spectroscopy, PL). These studies will aid our understanding of how process growth parameter such as substrate

temperature, plasma-assisted precursor generation/defragmentation, or the quantity of active species concentrations influence the growth and properties of binary and ternary group III-nitride alloys.

EM-TuP16 AFM Study on the Structural Properties of Gold Thin Films by RF Magnetron Sputtering, *Moniruzzaman Syed*, Lemoyne-Owen College, *C. Glaser, M. Schell, I. Senevirathne*, Lock Haven University

Gold (Au) thin films offer a wide range of applications in many fields such as memory storage, energy harvesting and storage, nanosensors, optics, biosensing devices and catalysis. Au film is paying more attention in many critical applications as it is highly conductive and is not easily oxidized. Therefore, it is necessary to understand the growth mechanism of film on various substrates. The structural properties of gold thin films are also playing very important role on the film quality which may affect optical properties as well as the sensing capabilities of the devices. In this study, Gold (Au) thin films were deposited on both glass and Si (100) substrates at room temperature (RT) with Ar gas atmosphere as a function of deposition time. The structural properties and surface morphology of Au thin film has been studied using Atomic Force Microscope (AFM). The deposition rate was found to be increased with increasing time of those films deposited on glass substrate. The effect of annealing temperature on the structural properties of Au film deposited on various substrates will also be discussed.

EM-TuP17 Influence of Plasma-Activated Nitrogen Species in MOCVD Grown GaN/GaN Epilayers, *Rasanga Samaraweera, D. Seidlitz*, Georgia State University, *B. Hussain*, University of North Carolina at Charlotte, *M.K.I. Senevirathna*, Georgia State University, *I.T. Ferguson*, University of North Carolina at Charlotte, *N. Dietz*, Georgia State University

This contribution will present results on the influence of remote plasma activated nitrogen containing precursor species on the physical properties of GaN and ternary GaInN layers grown by plasma-assisted metal organic chemical vapor deposition (PA-MOCVD). A hollow cathode rf-plasma source (13.65 MHz, 50-500 W) was used to generate reactive nitrogen plasma species in which hydrogen (H₂) and ammonia (NH₃) are added downstreams to tailor the reactive nitrogen species (N*/NH* etc.) interacting at the growth sites.

Growth parameters such as: H₂, N₂, NH₃ flows, metalorganic (MO) flows, plasma power, reactor pressure, and/or substrate temperature have been varied to assess their influence on the physical layer properties. The plasma species and its compositions have been analyzed using plasma emission spectra and absorption spectra. The structural and optoelectronic properties of the epilayers have been studied by x-ray diffraction (XRD), Raman spectroscopy, Fourier transform infrared reflectance (FTIR) and Photoluminescence (PL) spectroscopy. The optical analysis of the GaN layers by Infrared (IR) reflectance reveals the optical dielectric function around ε_∞= 5.35, which is comparable with the reported bulk values. The growth rates vary up to 200 nm/hour for GaN.

EM-TuP18 The Electrical Properties of a Bimodal Nb Nanocluster Distribution Formed Through Plasma Gas Condensation, *Kevin Bray, C.Q. Jiao*, UES, Inc., *J.N. DeCervo, J.N. Merrett*, Air Force Research Laboratory

Nanocluster growth and characterization is an expanding field of research due to the promising catalytic, electrical, magnetic, mechanical, and optical properties exhibited by these materials. The properties of nanoclusters vary from the bulk material and can be tuned by varying the nanocluster size. The ability to obtain desired nanocluster sizes and distribution is an important step in effectively utilizing these materials. Transition metal clusters have received considerable interest due to their wide range of applications. Niobium has attracted attention due to observations of ferroelectric properties at low temperature. In this work, Nb nanoclusters are deposited using a plasma gas condensation process which involves the sputtering of a Nb target to create a dense metallic vapor where clusters are formed. Changes in the nanocluster nucleation and growth are influenced through modifications of the process parameters such as carrier gas composition and flow rate, sputter source ion current, and aggregation length. The formation of a bimodal cluster distribution under select process conditions has been observed, with the smaller cluster diameter near 1 nm and the larger cluster diameter varying from 2 to 10 nm. The larger cluster forms as a simple condensation product while the smaller cluster appears to arise from a different nucleation and growth mechanism. The effects of differing argon and helium carrier gas ratios on cluster formation in conjunction with varying sputter source currents and aggregation lengths will be discussed. The effect of the cluster size on the electrical properties will be examined.

EM-TuP20 Electron-Hole Exchange Energy in PbS and PbSe Nanocrystals, Joseph G. Tischler, E.E. Foos, D. Placencia, W. Yoon, J.E. Boercker, Naval Research Laboratory

Lead chalcogenides (PbS, PbSe and PbTe) nanocrystals (NC) possess outstanding optical properties such as broad optical absorption from the ultraviolet to the near infrared (NIR), bandgap tunability in the NIR, efficient multiple exciton generation and relatively high quantum yield luminescence. Such properties can be exploited in a variety of optoelectronic applications including biological tags, lasers, photodetectors, LEDs and photovoltaics. Thus, the electron-hole pair (or exciton) ground state electronic structure and dynamics is of particular interest. In particular, it has been reported that the luminescence of PbS nanocrystals is produced by two electronic states. A higher energy state with a lifetime of the order of tens of nanoseconds and a lower energy state with a lifetime of a few microseconds. Competition between these two levels have been reported in dynamics as a function of temperature and nanocrystal size. Furthermore, these two states have been invoked to explain the seemingly large Stokes shift dependence with nanocrystal size. Although there has been a lot of consensus on these observations, the origin of these states has been highly controversial. Some of the explanations utilized to explain the observed structure and dynamics include: a dark-exciton state, a hybrid state consisting of a trapped electron and hole in the conduction band, a trapped exciton state, an exciton state split-off due to the intervalley interaction, and shallow trap surface states.

In this work, we show that both the Stokes shift and splitting between the two energy states scale as d^{-3} , where d is the diameter of the NC. These findings imply that these two states correspond to the singlet "bright" state and the triplet "dark" state respectively. Furthermore we demonstrate that the Stokes shift is mainly given by the electron-hole exchange energy, and that opposite to what it was previously believed, the exchange energy is determined by the short-range interaction instead of the long-range interaction. Also, from these measurements we determined for the first time the bulk exchange interaction strength constant (J) for both PbSe and PbS.

EM-TuP22 Ultrasound Treatment Influence on the Si-SiO₂ interface defects structure, Daniel Kropman, Tallinn University of Technology, Estonia, T. Laas, Tallinn University, Estonia

The effect of ultrasonic treatment (UST) on the defect structure of the Si-SiO₂ system by means of electron spin resonance (ESR), selective etching, MOS capacitance technique and secondary ions mass spectroscopy is presented. The non-monotonous dependence of the defect densities on the US wave intensity has been observed. The influence of the UST frequency on the ESR signal intensity of the defect centres depended on the defects type and may be caused by vibration energy dissipation, which are a function of defect centres type. In the ESR spectra of Si samples a signal with $g=1.9996$ (P a centers) connected with vacancy complexes is observed. After UST appears another signal with $g=2.0055$ (broken bonds of Si atoms). The influence of the US frequency and sample orientation on the ESR signal intensity varies for different centres. The frequency and orientation dependence of the ESR signal with $g=1.9996$ and the lack of this dependence for the centres with $g=2.0055$ show that vibration energy dissipation depends on the type of defect centers. Defect density at the interface grows with an increase of US wave intensity or changes non-monotonously depending on the oxide thickness and crystallographic orientation. In the samples with thick oxide there is a maximum in the dependence of the charge carriers lifetime on the US wave amplitude and in the samples with thin oxides there is a minimum. This shows that the structural defects form electrically active centers and their density can be varied by US. The density of point defects and absorbed impurities at the Si-SiO₂ interface can be reduced and its electrical parameters improved by an appropriate choice of the UST and oxidation condition. US is widely used not only for materials treatment but in medicine as well (cancer treatment).

References:

[1] D.Kropman, V.Poll, L.Tambek, T.Karner, U.Abru. Ultrasonics 36(1998)1021-1025.

[2] D.Kropman, S.Dolgov. Physica status Solidi (c) v.9, issue 10-11, pp.2173-2176, 2012.

EM-TuP24 Low Temperature Growth of High-Quality SiO₂ Gate Dielectric by Atomic Layer Deposition, Sangram Pradhan, E. Tyani, A.K. Pradhan, Norfolk State University

A novel as well as simple method preparation of atomic layer deposited high quality SiO₂ gate dielectrics were fabricated using highly reactive ozone and tris (dimethylamino) silane. Small frequency dispersion and hysteresis behavior of SiO₂ MOS capacitor shows an ideal C-V behavior, suggesting excellent interfacial quality as well as purity of SiO₂ film. The flat-band voltage of the samples shifted from negative to positive sweep voltage region with increase in TDMAS pulse from 0.2 to 2 seconds. Based

on EOT point-of-view, the ALD SiO₂ has gate leakage current density as well as electrical fields of all ALD SiO₂ samples are nearly very good and more than (~ 10 MV/m) which is better comparable to that of thermal silicon oxide grown at temperatures above 800°C. The appealing electrical properties of thin ALD SiO₂ enable its potential applications as high-quality gate insulators for thin-film MOS transistors, and insulators for sensor structures and nanostructures on non-silicon substrates.

EM-TuP25 Surface Temperature and Kinetic Energy Dependence of SiGe Growth, Sang Choi, NASA Langley Research Center, H.J.K. Kim, National Institute of Aerospace

Silicon-germanium (SiGe) is an important semiconductor alloy for high-speed field effect transistors (FETs), high-temperature thermoelectric devices, photovoltaic solar cells, and photon detectors.[1] Semiconductor chipsets and devices require a single-crystalline phase of material without defects, while thermoelectric materials need granulated domains of poly crystalline structure with an interfacing boundary electrically connected but causing phonon scattering.[2] The structural formation between SiGe and substrate can be tailored for either single crystal or twin lattice structure.

Highly ordered single crystals with rhombohedral epitaxy using an atomic alignment of the [111] direction in cubic SiGe with the [0001] direction in the sapphire basal plane (c-plane) have been successfully grown at the NASA Langley Research Center. The changes in the growth temperature (from 820°C to 890°C) strongly influence the shape, size and density of the SiGe nuclei in the early growth stage and eventually the film morphology and defect density in the final growth stage. Annular bright field (ABF) and high angular dark field (HAADF) scanning transmission electron microscopy (STEM) were used to investigate the atomic structure and chemistry of SiGe and sapphire (Al₂O₃) interfaces, sapphire substrate reconstruction, and defects for studying the film growth mechanism. The best growth condition can be achieved by choosing the suitable substrate temperature and kinetic energy of impinging Si and Ge atomic flux. By controlling the kinetic energy of the surface atoms, either a dominant twin crystal or dominant single crystal was steadily formed. The kinetic energy of surface atoms is determined at the growth temperature between 820°C and 890°C.

[1] D. L. Hareme and B. S. Meyerson, IEEE Transactions on Electron Device, 48 (11), 2555 (2001).

[2] C. Gui, M. Elwenspoek, N. Tas, and J. G. E. Gardeniers, J. Appl. Phys. 85 (10), 7448 (1999).

EM-TuP26 TiN/Ag Multilayers made by dc Magnetron Sputtering for Patch Antennas Applications, José Ampuero, A.F. Talledo, V. Peña, C. Benndorf, Universidad Nacional de Ingeniería, Peru, M. Yarlequé, R. Cerna, Pontificia Universidad Católica del Peru

Titanium nitride has excellent physical properties such as high hardness, high abrasion wear resistance, as well as, high corrosion resistance, however, its electrical conductivity is poor compared to that of noble metals such as copper, silver or gold. On the other hand, silver films show excellent conductivity but in contact with normal atmosphere they are spoiled rapidly.

We have found that multilayers of silver and titanium nitride show high conductivity, high hardness and high corrosion resistance which make them useful for electrical and electronic applications.

In this paper we report (i) the production of silver-titanium nitride multilayers made by dc magnetron sputtering, (ii) structural and stoichiometry characterization made by X-ray diffraction and Auger electron spectroscopy. We also report the performance of patch antennas made of TiN/Ag multilayers deposited by dc magnetron sputtering on alumina plates. The analysis was made by using a Vector Network Analyzer. Typical bandwidth was in the range 3.3-3.4 GHz.

EM-TuP28 Quantum Effects Produced by Silicon Nanoparticles Embedded in Stacks of Silicon Rich Oxide Obtained by Low Pressure Chemical Vapor Deposition, Karim Monfil-Leyva, Benemerita Universidad Autónoma de Puebla, Mexico, M. Aceves-Mijares, Instituto Nacional de Astrofísica Óptica y Electrónica, A.L. Muñoz-Zurita, Universidad Autónoma de Coahuila, J.A. Luna-López, Benemerita Universidad Autónoma de Puebla, R.C. Ambrosio-Lázaro, Universidad Autónoma de Ciudad Juárez

Currently, new electronic and optoelectronic applications are using stacked arrays of different films, like superlattices, multilayers, tandem solar cells, etc. This work shows results and discussion of the structural and electrical properties from stacks of silicon rich oxide (SRO) films with different silicon excess. SRO films were deposited on *n*-type silicon (Si) substrate with low resistivity ($2\sim 3 \Omega\cdot\text{cm}$) using the low pressure chemical vapor deposition (LPCVD) technique. Two different stacks of SRO (SSRO) were formed varying the flow ratio (Ro) between N₂O and SiH₄ with Ro=10

(SRO₁₀) and Ro=30 (SRO₃₀). Also, low and high Si-implantation, 5×10^{15} and 2×10^{16} at/cm² doses respectively, were applied to SSRO. A thermal annealing was applied to all SSRO at 1100°C for 3 hours. Metal-oxide-semiconductor (MOS) structures were fabricated using the SSRO as dielectric layer with Aluminium (Al) on top and back contacts obtained by thermal evaporation. Cross section images of the Al/SSRO/Si structures were obtained by Transmission Electron Microscopy (TEM). The thickness of SSRO and diameters of embedded Si-nanoparticles (Si-Np's) were calculated from TEM images. The Si-implantation increases the size and density of Si-Np's in the SSRO. Current vs. Voltage (*I-V*) measurements of the Al/SSRO/Si structures showed current oscillations, staircases and bumps at room temperature. High frequency Capacitance vs. Voltage (*C-V*) measurements exhibited little jumps in the accumulation region due to charge trapping and de-trapping effect produced by the presence of Si-nPs. A group of SSRO structures showed a large hysteresis related to traps density in the SRO₁₀ films. The current oscillations and the other anomalies from electrical characterization were related with quantum effects like tunneling and Coulomb blockade between on and off states of the conductive paths as a result of Si-nPs embedded in the SSRO.

EM-TuP30 Tuning A Strong Photoluminescence Using Thin Silicon Rich Oxide And Silicon Rich Nitride Films Obtained By Low Pressure Chemical Vapor Deposition. *K. Monfil-Leyva*, Benemerita Universidad Autónoma de Puebla, Mexico, *A. Morales-Sánchez*, Centro de Investigación en Materiales Avanzados, S.C., *A.L. Muñoz-Zurita*, Universidad Autónoma de Coahuila, *F.J. Flores-Gracia*, Benemerita Universidad Autónoma de Puebla, *M. Moreno-Moreno*, Instituto Nacional de Astrofísica Óptica y Electrónica, *Esteban Ojeda-Durán*, Benemerita Universidad Autónoma de Puebla

Luminescent process in materials based on silicon nanostructures has attracted a great effort to overcome the intrinsic disadvantages of bulk-Si to develop optoelectronic devices. Nowadays, the Silicon Rich Oxide (SRO) and Silicon Rich Nitride (SRN) arise as a cheap and effective alternative to develop ultraviolet absorbers or silicon-based light emitters. SRO and SRN films can be deposited by several techniques but homogeneous layers can be easily obtained by low pressure chemical vapor deposition (LPCVD) using N₂O and NH₃ respectively mixed with SiH₄ as reactive gases. Silicon excess in SRO and SRN is well controlled by $R_o = N_2O/SiH_4$ and $R_{o_n} = NH_3/SiH_4$.

In this work, we report a wide study of the optical properties of thin SRO and SRN films obtained by LPCVD where silicon excess was changed by the pressure ratio Ro in the range of 15 and 45 (SRO15 to SRO45) and Ro_n in the range of 4 to 80 (SRN4 to SRN80). The effect of annealing at high temperature was studied at 1100 °C. Ellipsometry measurements were done on each sample to calculate the thickness and the refractive index. Fourier transform infrared (FTIR) measurements were applied on SRO and SRN films to confirm a change on stoichiometry. Absorbance spectra of SRO films showed the four characteristic peaks of non-stoichiometric silicon dioxide (SiO_x) after annealing. The as-deposited SRN films showed the characteristic peaks of a hydrogenated SiN_x matrix. However, the Si-H and N-H stretching peaks (2210 and 3315 cm⁻¹) disappeared after applying the annealing. SRN films showed a transmittance of 40 up to 90 % in the visible to near infrared region (400 to 900 nm). SRO films showed a strong photoluminescence (PL) at room temperature (RT) on two bands, a blue band from 400 to 550 nm or a red band from 575 nm to 875 nm depending on Ro. Blue and red emission bands were related to donor acceptor decays between traps promoted by defects. SRN films with high Si excess showed a wide PL from 450 to 850 nm. PL intensity from SRN was reduced when annealing temperature was increased, then the PL was also related to defects in the SiN_x matrix.

EM-TuP31 High Spatial Resolution Mass Spectrometry Imaging of Electronic Devices by Femtosecond Laser Desorption. *Yang Cui, M. Majeski, L. Hanley*, University of Illinois at Chicago

A variety of methods beyond secondary ion mass spectrometry are now available to molecularly image electronic devices and materials structures. Previous studies have shown the advantages of femtosecond laser desorption by removing sample without damaging remaining material, potentially allowing three dimensional imaging of molecular species [S. Milasinovic, et al., Anal. Chem. 84 (2012) 3945; Ibid, J. Phys. Chem. C (2014) <http://dx.doi.org/10.1021/jp504062u>]. Vacuum ultraviolet radiation has been added to femtosecond laser desorption to facilitate molecular detection [Y. Cui, ACS Appl. Mater. Interf. 5 (2013) 9269]. Nonlinear excitation by 800 nm, <100 fs laser pulses may also allow sampling of an analyte within a region smaller than the laser focus size. We explore this strategy to demonstrate mass spectrometry imaging by operating laser just above the ablation threshold. A USAF resolution test target and organic compound pattern were used for testing resolution. A simulated organic electronic device structure was then analyzed by depositing pentacene through a 1500 mesh electron microscopy grid onto a silicon wafer. The

sample was analyzed after the grid was removed, allowing collection of a mass spectrometric image of the pentacene grid as represented by signal from the intact pentacene ion. Overall, the method demonstrated a ~2-4 micron spatial resolution with the capability to maintain significant molecular information on an intact electronic device structure.

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