Fundamentals and Technology of Multifunctional Materials and Devices

Room Sunrise - Session C2-1

Novel Oxide Films for Active Devices

Moderators: Marko Tadjer, Naval Research Laboratory, USA, Vanya Darakchieva, Linkoping University, Sweden

8:00am **C2-1-1 Characteristic of the bionic synapse on Lithium Aluminate Non-Volatile Resistive Random Access Memory**, ***Wan-Ching Su***, *T Chang, Y Hung, B Yan, S Huang, Y Tsao, T Tsai,* National Sun Yat-Sen University, Taiwan

This topic investigate the Characteristic of bionic synapse by non-voltage resistance random memory(RRAM). The material is aluminate lithium oxide as isolator. In operating process of RRAM the reset process reveals two reset stages. Moreover, The methods of measure it either DC voltage or Pulse have been applied to perform lithium aluminum oxide RRAM reveals the HRS resistance changing continuously. Applying the ionic diffusion and the titanium nitride attract is discussed ion model of lithium-ion, the phenomenon of the wide resistance value, and utilizing oxygen ions model. The redox reset resistance of lithium wire are explained for. Final, With Pulse voltage applied on lithium aluminum oxide RRAM can induce a bionic brain behavior: Spike-Timing-Dependent Plasticity.

8:20am **C2-1-2 Compared with the Different Thickness of Switch Layer on Resistive Random Access Memory**, ***Chih-Cheng Yang***, *T Chang, W Chen, C Lin, H Zheng, Y Chien,* National Sun Yat-Sen University, Taiwan

Resistive random acess memory(RRAM) is one of the next generated memory due to its low fabricated cost, structure simple, and high speed switch. In this work, the three HfO_2 thickness of Pt/HfO_2/TiN RRAM device was used to compared the IV curves. RRAM device was deposited by sputtering. After the device fabrication,the forming voltage and IV switch cycle was measured to compared with the different thickness. Moreover, IV curves was used to study the on/off ratio and the current fitting was used to identify the current conduction mechanism. Finally, the conduction model was proposal to explain the on off ratio and current conduction mechanism.

8:40am **C2-1-3 Investigating Abnormal Hump Under Positive Bias Temperature Stress for Hydrogenated a-InGaZnO Thin Film Transistors**, ***Yu-Chieh Chien***, *T Chang, T Tsai, H Chiang, Y Yang, Y Tsao, M Tai,* National Sun Yat-Sen University, Taiwan

Amorphous indium gallium zinc oxide (a-InGaZnO) is one of the most promising candidate for next generation electronics. A-InGaZnO is well known for its superior electrical characteristic, including high uniformity, high mobility (~10cm^2/Vs), low leakage current (~10^{-20}A). In addition, it can be fabricated by RF-sputtering at room temperature for application in transparent flexible displays. However, rapidly grown of display industry, including active-matrix liquid crystal display (AM-LCD) and active matrix organic light-emitted diode (AM-OLED), even 3D display technology, then enhance the requirement of carrier mobility. Thus, hydrogen were proposed to enhance device carrier mobility. However, reliability test after introducing hydrogen atoms need to be evaluated cautiously. In this investigation, a-InGaZnO TFTs after hydrogen plasma treatment (HPT) under positive bias temperature stress (PBTS) was compared to un-treated devices. An abnormal hump under PBTS condition was observed, in addition, the hump phenomenon only occurs in HPT devices. Hydrogen migrates to SiOx etching stop layer (ESL) induce positive fixed oxide charge was proposed and explained the degradation. Furthermore, different experiment conditions and COMSOL simulation were carried out to further verified the proposed model.

9:00am **C2-1-4 Optical and Electronic Properties of Monoclinic Ga_2O_3 Unravelled**, ***Mathias Schubert***, Linkoping University, Sweden, USA*; A Mock, R Korlacki, S Knight,* University of Nebraska-Lincoln, USA*; V Darakchieva,* Linköping University, Sweden*; B Monemar,* Linkoping University, Sweden*; Y Kumagai,* Tokyo University of Agriculture and Technology, Japan*; K Goto,* Tamura Corp., Japan*; M Higashiwaki,* National Institute of Information and Communications Technology, Japan

The stable monoclinic phase of Ga2O3 is currently at the forefront of research for high-power electronic and high-energy photonic applications due its large break down voltage and large band gap energy. Precise knowledge of its optical and electronic properties is crucial for further progress. Due to its monoclinic crystal symmetry, traditional techniques for measurement and calculation of solid state physics properties require careful reconsideration. In our presentation, we reveal how phonons [1], free carrier excitations [1], band-to-band transitions [2], optical constants [2], and exciton formation [2] differ fundamentally from previous front running semiconductors such as zincblende or wurtzite structure group-III group-V compounds. We demonstrate how traditional linear optical spectroscopy methods such as generalized ellipsometry and the optical Hall effect must be expanded to determine phonon, free carrier, and band-to-band transition characteristics from experiment, and we compare our findings with results from density functional theory calculations [2]. We discuss band ordering and polarization selection rules for band-to-band transitions, the peculiarities of valence and conduction band effective mass parameters, the breaking of phonon mode propagation degeneracies, the consequences for propagation of free charge carrier modes, and the need for the reformulation of the Lyddane-Sachs-Teller relationship [3]. We obtain a new description of dielectric function tensor properties from the Terahertz to the Deep Ultraviolet, and we revise previous incomplete phonon and band-to-band properties assignments [4,5]. [1] M. Schubert et al., Phys. Rev. B 93 (2016) 125209. [2] A. Mock et al., arXiv:1704.06711v1. [3] M. Schubert, Phys. Rev. Lett. 117 (2016) 215502. [4] C. Sturm et al., Phys. Rev. B 94 (2016) 035148. [5] C. Sturm et al., APL Materials 3 (2015) 106106.

9:20am **C2-1-5 Ga_2O_3 for Ultra-High Power Rectifiers and MOSFETs**, ***Stephen Pearton***, *F Ren, J Yang, P Carey,* University of Florida, USA*; M Tadjer, M Mastro,* Naval Research Laboratory, USA **INVITED**

Gallium Oxide (Ga_2O_3) is emerging as a viable candidate for certain classes of power electronics, solar blind UV photodetectors, solar cells and sensors with capabilities beyond existing technologies due to its large bandgap. The performance of technologically important high voltage rectifiers and enhancement-mode Metal-Oxide Field Effect Transistors benefit from the larger critical electric field of β-Ga_2O_3 relative to either SiC or GaN.Reverse breakdown voltages of over 1kV for β-Ga_2O_3 have been reported by several groups, either with or without edge termination.The on-of ratios ranged from $3x10^7$ to $2.5x10^6$ for this range of biases and showed only a small dependence on temperature in the range 25-100°C.The metal-oxide-semiconductor field-effect transistors (MOSFETs) fabricated on Ga_2O_3 to date have predominantly been depletion (d-mode) devices, with a few demonstrations of enhancement (e-mode) operation. The channels have been undoped, Si , Sn or Ge -doped and HfO_2, Al_2O_3 and SiO_2 have been the most widely used dielectrics.Si ion implantation has been employed to improve source/drain resistance in some cases.

10:00am **C2-1-7 Fabrication and Characterization of Pulsed-Laser Deposited $Ba_{0.8}Ca_{0.2}Ce_xTi_{1-x}O_3$ (BCCT) Thin Films**, ***Cristian Grijalva***, The University of Texas at El Paso, USA*; J Jones,* Air Force Research Laboratory, Materials and Manufacturing Directorate, USA*; R Chintalapalle,* The University of Texas at El Paso, USA

Intrinsic and doped barium titanate ($BaTiO_3$) thin films have drawn considerable recent interest due to their second order nonlinear response, ferroelectric properties, and electro-optic properties. Co-doping approach, which proved to be quite successful with many of the multifunctional materials, has been attractive to tailor the structural, optical, electrical and mechanical properties of barium titanate ceramic thin films. Therefore, in the present work, the Ca,Ce co-doped barium titanate materials were considered to obtain tunable optical properties. $Ba_{0.8}Ca_{0.2}Ce_xTi_{1-x}O_3$ (BCCT) thin films with fixed Ca content and variable Ce content were fabricated using pulsed-laser deposition (PLD). While such BCCT thin films are anticipated to have applications in electro-optic and memory devices, a detailed characterization has been performed to understand the effect of Ce on the structural and optical properties of resulting BCCT films. BCCT films with a nominal thickness of 90 nm were deposited onto quartz and low-impedance Silicon wafers heated to 250 ºC. X-ray diffraction (XRD), spectroscopic ellipsometry (SE) and nano-mechanical were performed to understand the effect Ce on the structure and properties. The results indicate that the BCCT films were amorphous. All the BCCT films were optically transparent. The band gap decreases with increasing Ce content. The results and analyses will be presented and discussed in the context of utilizing these films in contemporary electronic and optical device application.

10:20am **C2-1-8 Thermo-Chemical Stability Evaluation of Titanium Doped β-Ga_2O_3 Thin Films**, *S Manandhar, A Battu,* ***Ramana Chintalapalle***, University of Texas at El Paso, USA

Gallium oxide (Ga_2O_3), one among the wide band gap oxides, has drawn the attention of scientific and research community for its fascinating physical,

chemical and electronic properties, which can be readily utilized in numerous technological applications. Ga_2O_3 with a band gap (E_g) of ~5 eV is an ideal candidate for utilization in the field of electronics, optoelectronics, spintronics, gas sensing, and ultraviolet photo detectors. Specifically, β-Ga_2O_3 is stable at very high temperatures and has shown to function as oxygen sensor at high temperatures (>700°C). We recently demonstrated improvement of response characteristics time and sensitivity towards oxygen sensing at high temperature using metal doped β-Ga_2O_3. However, a fundamental study of thermo-chemical stability of metal doped β-Ga_2O_3 is quite important to predict the thermodynamic stability and performance of such materials in extreme environments. In this work, we performed a detailed thermal study to understand the effect of extreme environment on titanium (Ti) doped β-Ga_2O_3 (GTO). The GTO films with variable Ti content were deposited by co-sputtering. The real environment condition for sensor (>700°C) application was simulated to understand the effect of temperature on the crystal structure, electronic properties and oxidation states of Ti doped β-Ga_2O_3.

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