Wednesday Afternoon, November 9, 2022

Electronic Materials and Photonics Division
Room 330 - Session EM-WeA

Compound Semiconductors
Moderator: Erica Douglas, Sandia National Laboratories

5:20pm **EM-WeA-10 Strain-Induced Semiconducting to Metallic Phase Transition in Suspended Mote$_2$ using a Single-Ion Conductor***, **Shubham Awate**,* University of Pittsburgh*; K. Xu,* Rochester Institute of Technology*; J. Liang, B. Mostek,* University of Pittsburgh*; B. Katz,* Pennsylvania State University*; R. Muzzio,* Carnegie Mellon University*; V. Crespi,* Pennsylvania State University*; J. Katoch,* Carnegie Mellon University*; E. Backman, S. Fullerton-Shirey,* University of Pittsburgh

Commonly studied transition metal dichalcogenide (TMD) crystals exhibit polymorphism, where the electronic structure of the material changes significantly with a change in the crystal structure. $MoTe_2$ has gained particular interest because the potential energy difference between the semiconducting 2H and semi-metallic 1T' phase is the lowest (40 meV) among TMD polymorphs, making it promising for low voltage phase change memory and transistors. Although the 2H phase is the most stable form, it can be transformed to 1T' by 0.3 - 3% by tensile strain thereby causing a large change in the electronic conductivity. Recent studies have experimentally shown this phase transition by mechanically stretching the entire substrate or applying local mechanical strain using atomic force microscopy (AFM) tip, but both strain methods would be difficult to implement in CMOS. What is needed is a straining mechanism driven by field-effect, where a single device can be controlled electrically by a nearby gate.

Here, we employ an ‘ionomer’ or single-ion conductor to impart strain. An ionomer contains mobile cations but has anions that are covalently bonded to a polymer backbone. Under an applied electric field, the cations accumulate at the $MoTe_2$ surface, effectively controlling electron transport in the material, while anions maintain their position in the polymer backbone creating a charge imbalance. The imbalance causes the ionomer to bend, which then induces strain in the $MoTe_2$.

In this work, the electrical and structural properties of a suspended $MoTe_2$ FET are measured simultaneously using a home-built set-up combining electrical measurements with Raman spectroscopy. With no gate voltage (V_G) applied, the insulating 2H phase is confirmed. For V_G > 2.5 V, the 1T’ phase is detected by a significant decrease in the electrical resistance accompanied by a characteristic 1T’ peak in the Raman spectra. Mapping the 2H and 1T’ peaks across the entire flake reveals that the phase transition is reversible (i.e., the flake reverts to the semiconducting 2H phase when the voltage is removed), which is an essential feature of memory. The output characteristic of the FET shows a large change in the I_D-V_G slope for V_G >1.5 V. Further, metallic conduction is confirmed by the positive temperature coefficient of resistance for V_G = +2 and +3 V. Lastly, time-dependent Raman spectroscopy is performed to study the phase change dynamics. The demonstrated gate-controlled reversible straining method can be easily extended to strain other types of two-dimensional materials to explore fundamental properties as well as discover new device mechanisms.

5:40pm **EM-WeA-11 Investigation of Thermal Stability of Pure-Metal Schottky Contacts to β-Ga_2O_3***, **Elizabeth Favela**, K. Zhang, A. Ho, S. Kim,* Carnegie Mellon University*; K. Das,* North Carolina State University*; L. Porter ,* Carnegie Mellon University

Due to its ultra-wide band gap (E_G ~ 4.8 eV) and the availability of melt-grown single-crystal substrates, gallium oxide (Ga_2O_3) has attracted intense interest for (opto)electronic devices that can operate under extreme conditions. However, for these devices to operate reliably, electrical contacts to Ga_2O_3 that are chemically and electrically stable at elevated temperatures must be demonstrated. In this study we investigated the electrical properties, interfacial chemistry and surface morphology of Co/Au and Ni/Au Schottky contacts on Sn-doped (N_D =10^{18} cm^{-3}) (-201) β-Ga_2O_3 substrates through two different annealing series. Current-voltage and capacitance-voltage measurements were conducted at room temperature after sequential annealing treatments totaling >400 h at 300 °C and >150 h at 500 °C in air. Schottky barrier heights were relatively stable through the annealing series at 300 °C. However, gradual degradation in the electrical behavior was observed through the annealing series at 500 °C. Whereas the contacts were relatively stable after 300 °C anneals, characterizations using scanning transmission electron microscopy, energy dispersive x-ray spectroscopy, and scanning electron microscopy of samples annealed at 500 °C showed substantial changes in morphology, multi-element diffusion, and phase segregation within the contacts. The results suggest that these pure-metal contacts could be useful in Ga_2O_3 Schottky diodes at temperatures below, or possibly up to, 300°C. However, alternative contact compositions, possibly incorporating metal-oxides [1], will be required for Ga_2O_3-based device operation at or above the 300 °C temperature range. The results of this work in context of other Ga_2O_3 contact studies and the implications for future research directions will also be presented.

[1]C. Hou, R. M. Gazoni, R. J. Reeves, and M. W. Allen, Direct Comparison of Plain and Oxidized Metal Schottky Contacts on β-Ga_2O_3, Appl. Phys. Lett. 114, 033502 (2019).

6:00pm **EM-WeA-12 Electrical and Chemical Effects of Metal Contacts to β-Ga_2O_3 Surfaces***, **Luke Lyle**,* Pennsylvania State University

Over the last decade significant progress has been demonstrated for -Ga2O3, with its ultrawide bandgap of 4.6-4.8 eV, controllable range of n-type, shallow dopants (Sn, Si, Ge), and a scalable melt-growth process allowing the production of large-area, native substrates this material has garnered strong interest for applications as UV photodetectors and high-power electronics. A critical piece of development for ultrawide bandgap materials is the optimization of the metal-semiconductor interface for high-power applications. This talk focuses on the electrical properties of various metallizations to differently oriented β-Ga2O3 crystals and focuses on the resulting chemistry of certain metal-semiconductor interfaces. The Schottky barriers of Ti/Au, Mo, Co, Ni, Pd, and Au on (100) β-Ga2O3 substrates were analyzed using a combination of current-voltage (J-V), capacitance-voltage (C-V), and current-voltage-temperature (J-VT) measurements. The ideality factors and Schottky barrier heights from J-V and C-V methods are documented and discussed. J-V-T measurements of Ti/Au, Co, and Pd diodes reveal inhomogeneity of the Schottky energy barrier. These combined results reveal a strong positive correlation between the calculated Schottky barrier heights and the metal work functions: the index of interface behavior, S, for J-V and C-V data. Additionally, Ti and Au metallizations reveal peculiar electrical properties (higher ideality factors, different J-V and C-V Schottky barrier heights, etc) and further characterizations are pursued. Au contacts to (100) β-Ga2O3 were subsequently examined with transmission electron microscopy (TEM) due to the electrical properties exhibited via J-V and C-V measurements. The contacts exhibited a chemical reaction with void formation 5-20 nm below the Au/β-Ga2O3 interface, a reacted region at the interface that is structurally dissimilar to the bulk β-Ga2O3 structure, the presence of Ga interstitials diffusing to the metalsemiconductor interface, and EDS mapping reveals Ga diffusion into the Au overlayer. Chemical measurements of Ti/(010) and Ti/(001) β-Ga2O3 contacts were examined with x-ray photoelectron spectroscopy (XPS). XPS revealed partial Ti oxidation at both interfaces in the as-deposited condition, with more Ti oxidation on the (001) β-Ga2O3 epilayer surface than the (010) β-Ga2O3 substrate surface. The amount of oxidized Ti increased with annealing temperature. J-V and C-V measurements of contacts made from these devices reveal a strong orientation dependence of the electrical properties of Ti/β- Ga2O3 diodes.

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