Thin Films Division
Room 316 - Session TF2+2D-TuA

Low Dimension Material Application

Moderator: Mark Losego, Georgia Institute of Technology

2:20pm **TF2+2D-TuA-1 Operando and High-throughput Approaches to Advance Integrated Process Technology of Atomically Thin Device Materials**, ***Stephan Hofmann,*** University of Cambridge, UK **INVITED**

For the ever increasing family of layered 2D materials many exciting properties and device concepts have been reported, yet the understanding of fundamental mechanisms that can underpin scalable process technology for these materials is lagging far behind. We developed cross-correlative operando probing capability to "unblind" the underlying mechanisms, including open and closed cell approaches for XPS, optical spectroscopy, and scanning and transmission electron microscopy. While the previous focus has been to sample select process conditions, this talk will focus on our efforts to access and fast screen the entirety of the vast, interconnected parameter space. We report on an approach to bring together substrate preparation, specifically single crystal metal catalysts, and 2D growth in a combined process flow using a standard cold-wall CVD reactor.[1] This enables large scale data acquisition and new optimisation approaches for holistic end-to-end process development, comprising growth, handling, transfer, and heterogeneous device integration for atomically thin films, particularly for emerging (opto)electronic devices where clean interfacing is crucial. We adapted a SEM to allow operando reaction monitoring for the formation and etch reactions of atomically thin WS_2 layers. This allows us to unlock a data-driven approach to understanding the underlying complex kinetics across scales. We also explored new characterization approaches for accessing pertinent device interfaces, such as TMD heterostructures,[2] and functional defects, such as emissive defects hosted in h-BN for nanophotonics, sensors, and quantum metrology and technology.[3]

[1] Burton et al., ACS Nano 14, 13593 (2020), Burton et al., submitted (2022)

[2] Schmitt et al., Nature, Accepted (2022)

[3] Stern et al, ACS Nano 13, 4538 (2019); Stewart et al., ACS Nano 15, 13591 (2021).

3:00pm **TF2+2D-TuA-3 Versatile Synthesis of 2D Superlattices from Conversion of Sequentially Layered Sub-nanomater Metal Films**, ***Nicholas Glavin***[1], Air Force Research Laboratory, Materials and Manufacturing Directorate, USA

Manipulation of bulk material properties by controlling layer-by-layer chemistry and structure of nanomaterials has remained an overarching goal of nanoscience and nanoengineering. In the case of 2D materials, heterostructures consisting of different compositions, stacking and orientation have been demonstrated leading to possibilities of artificially stacked van der Waals materials. To date, structure tunability, scalability and control of synthesis has remained a challenge. Most attempts to overcome this limitation have relied on layer-by-layer growth or transfer of grown single layers or multi-precursor growth of few-layer structures but none of these methods have the potential of scalable synthesis of controlled, periodic 2D superlattice structures.In this talk, we discuss a method to directly convert easily fabricated sub-nm metal multi-layer heterostructures on both sapphire and SiO_2 substrates followed by conversion to scalable 2D van der Waals superlattices that exhibit novel properties compared to individual 2D layers themselves including reduced bandgap, enhanced light-matter coupling, and improved catalytic performance. By annealing wafer-scale layered molybdenum/tungsten heterostructures in chalcogen vapors between temperatures of 400-800 °C, formation of mixed and horizontally-oriented superlattices as well as horizontal and vertically oriented alloys are realized. This versatility enables tunable orientation, layer structure, and chemistry in an exciting class of 2D nanomaterials and provides an opportunity to generate a wide range of artificially stacked multi-compositional 2D superlattices in controlled morphologies.

3:20pm **TF2+2D-TuA-4 Study of the Functionality of Spin Crossover Thin Films on the Ti_3C_2 Mxene Substrates**, ***Saeed Yazdani,*** *J. Phillips,* Department of Physics, Indiana University-Purdue University Indianapolis*; B. Wyatt,* Department of Mechanical and Energy Engineering, and Integrated Nanosystems Development*; P. Wang, M. Shatruk,* Department of Chemistry and Biochemistry, Florida State University*; B. Anasori,* Department of Mechanical and Energy Engineering, and Integrated Nanosystems Development*; P. Dowben,* Department of Physics and Astronomy, Jorgensen Hall, University of Nebraska*; R. Cheng,* Department of Physics, Indiana University-Purdue University Indianapolis

Spin crossover (SCO) molecules are a class of complexes promising for use in molecular-based devices due to the change in conductance that accompanies the change in spin state by an external stimulus. Different substrates can drastically interact with SCO molecular thin films at the interface. Although metallic substrates due to their high conductance and other unique properties are points of interest to be used as substrates for many devices, they tend to lock the spin state of SCO molecular thin films near the interface due to the strong coupling between SCO complexes and high electron density on metallic surfaces. Both experimental measurements and theoretical studies demonstrated that two-dimensional (2D) surfaces have minimum interaction with SCO complexes. In this work, for the first time, the properties of SCO molecular thin films on conductive 2D Ti_3C_2 MXene are studied. Various techniques including atomic force microscopy (AFM), UV-Vis spectroscopy, and electronic transport studies are utilized to study the functionality of [Co (SQ)(Cat)(3-tpp)$_2$] SCO molecules. Conductive 2D MXene with outstanding electronic, optical and mechanical properties can be considered as an alternative substrate.

4:40pm **TF2+2D-TuA-8 AVS Thin Film Division/Graduate Student Harper Award TED-Talk Competition**,

[1] **TFD Paul Holloway Award Winner**

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