Saturday Afternoon, September 16, 2023

Workshop on Quantum Materials Epitaxy
Room Ballroom A - Session QME-SaA1

2D and Heteroepitaxial Integration

Moderator: Dr. Roman Engel-Herbert, Paul Drude Institute

2:00pm **QME-SaA1-1 Invited Paper*, Grace Xing,*** Cornell University **INVITED**

2:30pm **QME-SaA1-3 Growth of Topological Materials by Molecular Beam Epitaxy*, Stephanie Law,*** Pennsylvania State University **INVITED**

Topological materials are those materials that have a topologically non-trivial band structure and include topological insulators (TIs), Dirac semimetals (DSMs), and Weyl semimetals (WSMs). TIs, in particular, have been of interest due to their ability to host two-dimensional surface states with spin-momentum locking. In order to take advantage of these states, we need to be able to grow TI thin films with controllable thickness, few to no grain boundaries, few defects, and as part of heterostructures. This has typically proven to be a challenge, since most TI materials are layered materials. The weak interaction between the film and the substrate results means that it is possible to grow TIs on a variety of substrates, but that the nucleation of the film is difficult to control. In this talk, I will describe our recent progress growing three classes of TI thin films: Bi_2Se_3, the prototypical TI; BiSb, a TI that can be made to be bulk insulating; and $MnBi_2Se_4$, an antiferromagnetic TI. I will describe commonalities in the growth of these materials as well as challenges unique to each material. Finally, I will give an outlook on the prospects for the growth of insulting layered TI thin films on technologically-relevant substrates.

3:00pm **QME-SaA1-5 Big Flat Quantum Crystals: Wafer-Scale Growth of 2D Materials by Metalorganic Chemical Vapour Deposition*, James A. Gupta,*** University of Ottawa, Canada **INVITED**

Following the successful development of monolayer graphene and the subsequent Nobel Prize, the field of 2D materials has exploded into a universe of exciting new materials and applications. To date, however, most samples have been produced by mechanical exfoliation, yielding single-crystal monolayer films with dimensions of only a few 10's of microns. Such samples have worked extremely well for proof-of-concept devices, but it is very clear that epitaxial growth is needed for large-scale device development, reproducibility and manufacturability. For the epitaxial growth of most compound semiconductors, the greatest challenges are in the requirements for the growth of many layers with precisely-controlled composition and thickness to satisfy the device requirements. In contrast, for 2D materials, the challenge is to controllably grow single-crystal monolayer films with low densities of defects and grain boundaries, and to grow heterostructures of different, weakly-bonded van der Waals materials . In this presentation I will discuss the requirements for epitaxial growth of 2D materials, particularly graphene, hexagonal boron nitride and transition metal dichalcogenides (e.g. MoS_2, WS_2, $MoSe_2$, WSe_2). As with any epitaxial growth process, the identification of suitable molecular sources and substrates is critical. At the University of Ottawa, we have established a 2D growth facility featuring an Aixtron 3X2" Close-Coupled Showerhead MOCVD system. I will discuss the specific materials, precursors and processes used at uO, as well as the challenges and opportunities for 2D epitaxial growth in general.

3:30pm **QME-SaA1-7 Advanced Heterogeneous Integration Enabled by Remote Epitaxy*, Jeehwan Kim,*** Massachusetts Institute of Technology **INVITED**

For future of electronics such as bioelectronics, 3D integrated electronics, and bendable electronics, needs for flexibility and stackability of electronic products have substantially grown up. However, conventional wafer-based single-crystalline semiconductors cannot catch up with such trends because they are bound to the thick rigid wafers such that they are neither flexible nor stackable. Although polymer-based organic electronic materials are more compatible as they are mechanically complaint and less costly than inorganic counterparts, their electronic/photonic performance is substantially inferior to that of single-crystalline inorganic materials. For the past half a decade, my research group at MIT has focused on mitigating such performance-mechanical compliance dilemma by developing methods to obtain cheap, flexible, stackable, single-crystalline inorganic systems. In today's talk, I will discuss about our strategies to realize such a dream electronic system and how these strategies unlock new ways of manufacturing advanced electronic systems. I will highlight our remote epitaxy technique that can produce single-crystalline freestanding membranes including III-nitrides, III-V and complex oxide system with their excellent semiconducting performance. In addition, I will present unprecedented artificial heterostructures enabled by stacking of those freestanding 3D material membranes, e.g., world's smallest vertically-stacked full color micro-LEDs, world's best multiferroic devices, battery-less wireless e-skin, and heat dissipating system GaN power devices.

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