Going Beyond Graphene: Doped Graphene, Chalcogenide Monolayers and van der Waals Solids

Mauricio Terrones

Department of Physics, Department of Chemistry, Department of Materials Science and Engineering and Center for 2-Dimensional & Layered Materials. The Pennsylvania State University, University Park, Pennsylvania 16802, USA & Research Center for Exotic Nanocarbons (JST), Shinshu University, Nagano, Japan

e-mail: mut11@psu.edu & mtterrones@shinshu-u.ac.jp

Regarding other 2-Dimensional materials beyond graphene, we will describe various approaches to synthesize WS_2 and MoS_2 triangular monolayers, as well as large area films using a high temperature sulfurization of WO_x clusters deposited on insulating substrates. We will show that depending on the substrate and the sizes of the oxide clusters, various morphologies of layered WS_2 could be obtained. In addition, photocurrent measurements on these materials were performed using different laser photon wavelengths. Our results indicate that the electrical response strongly depends on the laser photon energy. The excellent response observed to detect different photon wavelengths in mono- and few-layers of WS_2, MoS_2, and WSe_2, suggest these materials could be used in the fabrication of photo sensors and optoelectronic devices. From the theoretical stand point, using first principles calculations, we found that by alternating individual layers of different metal chalcogenides (e.g. MoS_2, WS_2, WSe_2 and $MoSe_2$) with particular stackings, it is possible to generate direct band gap bi-layers ranging from 0.79 eV to 1.157 eV as well as other novel van der Waals solids with fascinating electronic characteristics. Interestingly, in this direct band gap, electrons and holes are physically separated and localized in different layers. We foresee that the alternation of different chalcogenide layers would result in the fabrication of materials with unprecedented optical and physico-chemical properties.

This talk will also discuss the synthesis of large-area, high-quality monolayers of nitrogen- and boron-doped graphene sheets on Cu foils using ambient-pressure chemical vapor deposition (AP-CVD). Scanning tunneling microscopy (STM) and spectroscopy (STS) reveal that the defects in the doped graphene samples arrange in different geometrical configurations exhibiting unique electronic properties. Interestingly, these doped layers could be used as efficient molecular sensors and in the fabrication of electronic devices. In addition, the synthesis of hybrid carbon materials consisting of sandwich layers of graphene layers and carbon nanotubes have been synthesized by a self assembly route. These films are novel, energetically stable and could well find important applications as field emission sources, catalytic supports, gas adsorption materials and super capacitors.