IBS CINAP Seminar

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Two-dimensional Multi-junction Heterostructures Based on Transition Metal Dichalcogenides

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Abstract

Atomically thin layers are known as two-dimensional (2D) materials and have attracted a growing attention due to their great potential as building blocks for a future generation of low-power and flexible 2D optoelectronic devices. Similar to the well-established 3D electronics, the development of functional 2D devices will depend on our ability to fabricate heterostructures and junctions where the optical and electronic properties of different compounds are brought together to create new functionalities. Vertical heterostructures can be produced by selective van der Waals stacking of different monolayers with distinct chemical composition. However, in-plane lateral heterostructures where different materials are combined within a single 2D layer, have proven to be more challenging. During the formation of the hetero-junction, it is important to minimize the incorporation of undesired impurities and the formation of crystal defects at the junction that will impact the functionality of the 2D device. When fabricating periodic structures it is equally important to develop the ability to control the domain size of each material. In this talk, we will review different techniques that have been used to create 2D lateral heterostructures of transition metal dichalcogenide compounds. Emphasis will be made in our recently reported one-pot synthesis approach, using a single heterogeneous solid source, for the continuous fabrication of lateral multi-junction heterostructures of TMD monolayers.[1] In this method, the heterojunctions are sequentially created by only changing the composition of the reactive gas environment in the presence of water vapor. This allows to selectively control the water-induced oxidation and volatilization of each transition metal precursors, as well as its nucleation on the substrate, leading to sequential edge-epitaxy of distinct TMDs. This simple method have proven to be effective for continuous growth of TMD-based multi-junction lateral heterostructures, including selenides, sulfides and ternary alloys. Basic devices with field effect transistor configuration were fabricated to study the electrical behavior of these heterojunctions, their diode-like response, photo-response as a function of laser power as well as photovoltaic behavior of the heterojunctions will be discussed.

1. P. K. Sahoo, S. Memaran, Y. Xin, L. Balicas and H. R. Gutiérrez. Nature 553, (7686), 63 (2018).

Brief Bio

Prof. Humberto Gutierrez received his Ph.D State University of Campinas (UNICAMP), São Paulo, Brazil in 2001 in the field of condensed matter physics. He worked as a postdoctoral research in the Pennsylvania State University in the US where he studied synthesis and characterization of nanomaterials including carbon nanotubes, graphene and semiconducting nanowires. Later he was hired as an assistant professor in department of physics and Astronom at university of Louisville from 2012 to 2015. Now, he is an assistant professor in department of physics at university of South Florida. His current research interest is understanding the mechanisms leading to the formation of nanostructures including transition metal dichalcogenides, as well as the study of their structural properties (via SEM, TEM, EDS, EELS, electron diffraction and XRD), the correlation with their optical, electrical and mechanical properties; as well as their technological applications are the main research topics. Particular attention is devoted to nanomaterials with novel physical properties that make them potential candidates for the generation and/or storage of renewable energy; including the development of new photovoltaic configurations. Dr. Gutierrez is Author/co-author of 77 scientific publications in peer-reviewed journals, 11 publications in conference proceedings, one book chapter and two U.S. patents. H-index: 32.

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