Van der Waals Heterostructures for Practical Electronic and Photonic Devices

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Abstract

The isolation of a growing number of two-dimensional (2D) materials has inspired worldwide efforts to integrate distinct 2D materials into van der Waals (vdW) heterostructures. While a tremendous amount of research activity has occurred in assembling disparate 2D materials into "all-2D" van der Waals heterostructures and making outstanding progress on fundamental studies, practical applications of 2D materials will require a broader integration strategy. Given that any passivated, dangling bond-free surface will interact with another via vdW forces, the vdW heterostructure concept can be extended to include the integration of 2D materials with non-2D electronic and photonic materials. In the first part of this talk I will present our work on emerging mixed-dimensional (2D + nD, where n is 0, 1 or 3) heterostructure devices. I will present our ongoing and recent work on integration of 2D materials with 3D semiconductors to realize novel, gate-tunable devices with novel functionality and record performances that can potentially augment the utility of Silicon based technology. I will present methods on scaling up and vertical integration.

The second part of talk will discuss my more recent work on photonic structures and photovoltaic devices from 2D semiconductors such as transition metal dichalcogenides (TMDCs). High efficiency inorganic photovoltaic materials (e.g., Si, GaAs and GaInP) can achieve maximum above-bandgap absorption as well as carrier-selective charge collection at the cell operating point. Similar opportunity exists for 2D chalcogenide semiconductors towards which we have made progress by light trapping in < 15 nm thick TMDC layers. I will present the fabrication and performance of our, broadband absorbing, heterostructure photovoltaic devices using sub-15 nm TMDCs as the active layers, with record high quantum efficiencies and open circuit voltages for high power conversion efficiences. I will then extend the concept of light trapping in TMDCs to explore fundamental light-matter interactions including observation of novel and tunable hybrid states. I will extend our concept of atomically-thin photonic meta-structures to large areas. I will conclude by giving a broad perspective of future work on 2D materials from fundamental science to applications.