Chemically Tailored 2D Materials for Electronic and Energy Technologies

Mark C. Hersam
Northwestern University, 2220 Campus Drive, Evanston, IL 60208-3108, USA
WWW: http://www.hersam-group.northwestern.edu/
E-mail: m-hersam@northwestern.edu

Layered two-dimensional (2D) materials interact primarily via van der Waals bonding, which has created new opportunities for heterostructures that are not constrained by epitaxial growth. However, it is important to acknowledge that van der Waals interactions are not limited to interplanar interactions in 2D materials. In principle, any passivated, dangling bond-free surface interacts with another via non-covalent forces. Consequently, layered 2D materials can be integrated with a diverse range of other materials, including those of different dimensionality, to form mixed-dimensional van der Waals heterostructures [1]. Furthermore, chemical functionalization provides additional opportunities for tailoring the properties of 2D materials [2] and the degree of coupling across heterointerfaces [3]. In order to efficiently explore the vast phase space for mixed-dimensional heterostructures, our laboratory employs solution-based additive assembly. In particular, constituent nanomaterials (e.g., carbon nanotubes, graphene, transition metal dichalcogenides, black phosphorus, boron nitride, and indium selenide) are isolated in solution, and then deposited into thin films with scalable additive manufacturing methods (e.g., inkjet, gravure, and screen printing) [4]. By achieving high levels of nanomaterial monodispersity and printing fidelity, a variety of electronic and energy applications can be enhanced including photodetectors, optical emitters, supercapacitors, and batteries [5-7]. Furthermore, by integrating multiple nanomaterials into heterostructures, unprecedented device function can be realized including anti-ambipolar transistors, gate-tunable Gaussian heterojunction transistors, and neuromorphic memtransistors [8-10]. In addition to technological implications for electronic and energy technologies, this talk will explore several fundamental issues including band alignment, doping, trap states, and charge/energy transfer across van der Waals heterointerfaces.

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