

# MSE 520: SEMINAR SERIES

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## Mixed-Dimensional van der Waals Heterostructures for Electronic and Energy Applications

Layered two-dimensional (2D) nanomaterials 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, the emerging layered 2D nanomaterials can be integrated with a diverse range of other materials, including those of different dimensionality, to form van der Waals heterostructures. This talk will explore mixed-dimensional combinations of 2D + n-D ( $n = 0, 1$  and 3) materials, thus significantly expanding the van der Waals heterostructure concept [1]. In order to efficiently explore the vast phase space for mixed-dimensional heterostructures, our laboratory employs solution-based additive assembly [2]. In particular, constituent nanomaterials (e.g., carbon nanotubes, graphene, transition metal dichalcogenides, black phosphorus, and boron nitride) are isolated in solution, and then deposited into thin films with scalable additive manufacturing methods (e.g., inkjet, gravure, and screen printing) [3]. By achieving high levels of nanomaterial monodispersity and printing fidelity [4], a variety of electronic and energy applications can be enhanced including digital logic circuits [5] and lithium-ion batteries [6]. Furthermore, by integrating multiple nanomaterial inks into heterostructures, unprecedented device function is realized including anti-ambipolar transistors [7], gate-tunable photovoltaics [8], and neuromorphic memristors [9]. 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 previously unexplored mixed-dimensional heterointerfaces [10].



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Mark C. Hersam is the Walter P. Murphy Professor of Materials Science and Engineering and Director of the Materials Research Center at Northwestern University. He also holds faculty appointments in the Departments of Chemistry, Applied Physics, Medicine, and Electrical Engineering and Computer Science. He earned a B.S. in Electrical Engineering from the University of Illinois at Urbana-Champaign (UIUC) in 1996, M.Phil. in Physics from the University of Cambridge (UK) in 1997, and a Ph.D. in Electrical Engineering from UIUC in 2000.

His research interests include nanofabrication, scanning probe microscopy, semiconductor surfaces, and nanoelectronic materials. Dr. Hersam has received several honors including the Presidential Early Career Award for Scientists and Engineers, TMS Robert Lansing Hardy Award, AVS Peter Mark Award, MRS Outstanding Young Investigator, U.S. Science Envoy, MacArthur Fellowship, and seven Teacher of the Year Awards. Dr. Hersam is the co-founder of NanoIntegris, which is a commercial supplier of nanoelectronic materials, and an elected member of the National Academy of Inventors. Dr. Hersam is a Fellow of MRS, AVS, APS, AAAS, SPIE, and IEEE, and also serves as an Associate Editor of ACS Nano.



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