NANOSCIENCE COLLOQUIUM

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Novel attributes of non-planar heterojunctions in low-dimensional materials

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Precise 1-D and 2-D nanomaterials and growth methods enable the creation of low dimensional heterojunctions with novel properties arising from their geometries (e.g. 1-D nanowire core-shell heterostructures) and unique materials combinations (e.g. 2-D van de Waals heterostructures). While the distinctive attributes of semiconductor nanowires in applications including information processing, energy generation, and energy storage have now been demonstrated, 2-D materials beyond graphene are much less mature. Furthermore, there remain significant gaps in understanding of the properties of nanoscale heterojunctions in both 1-D and 2-D materials. Correlated characterization of nanoscale structure and properties is needed to understand intrinsic and extrinsic influences on the behavior of electrons, photons, and phonons at heterojunctions in the low dimensional limit. I will first describe the analysis of semiconductor nanowires using atom probe tomography with an emphasis on III-As core-shell heterostructures heterostructures. Three-dimensional analyses of dopant distribution and composition fluctuations are used to model and understand the electrical and optical properties of the nanowires and associated devices. I will then discuss recent investigations of novel properties and device behaviors in 2-D MoS_2, a semiconducting transition metal dichalchogenide whose bandgap undergoes an indirect to direct transition upon going from a bilayer to a single layer. We find that devices formed across single-layer/multi-layer junctions in exfoliated material are rectifying, raising fundamental questions about the electronic structure of this unusual junction. Scanning photocurrent microscopy (SPCM) of devices and semi-classical simulations were used to probe how charge carriers respond to the potential landscape and thereby establish the nature of the junction. SPCM and device characteristics were reproduced in simulations assuming a type II band alignment, and hot electrons were found to dominate the zero-bias junction photocurrent. In chemical vapor deposition grown MoS_2, the stoichiometry was found to strongly influence device characteristics. Specifically, intentional introduction of sulfur vacancies facilitated ohmic contact formation and improvements in mobility, providing a route to optimization of materials properties for given application. Furthermore, a novel gate-tunable memristive behavior was discovered to be mediated by grain boundary migration in sub-stoichiometric single layer films, providing an example of unique opportunities that may arise from defect engineering in the low dimensional limit.

Host: Kimberly Dick Thelander (Solid State Physics)

This is one in a regular series of Nanoscience Colloquia, aimed at all researchers and students with an interest in nanoscience. The series is arranged by the Strategic Research Environment "The Nanometer Structure Consortium at Lund University" (nmC@LU) and by the Linnaeus environment "Nanoscience and Quantum Engineering", funded by the Swedish Research Council (VR).