Two-dimensional Atomic Crystals: It Is All About the Surface

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Two-dimensional (2D) atomic crystals are recently discovered materials that are only atoms thick, and yet can span laterally over millimeters. The diverse family of such materials includes graphene: a semimetal with massless relativistic charge carriers, and monolayer transition metal dichalcogenides (TMDCs), such as molybdenum disulfide (MoS_2): direct band gap semiconductors with strong spin-orbit interaction. Since every atom in these materials belongs to the surface, their physical properties are greatly affected by the immediate environment. In my talk, I will demonstrate that ultra-high electronic and optical quality of 2D atomic crystals can be obtained by tuning the local microenvironment, and I will discuss device applications.

In the first part of the talk, I will demonstrate that the electronic quality of graphene is enhanced when placed into a high dielectric stationary liquid environment, through suppression of Columbic scattering strength. I will demonstrate the use of graphene field effect transistors (FETs) in sensing different physical parameters of *nanometer-thick* interfacial liquid volumes, both stationery and moving. By embedding graphene FETs in a microfluidic channel, I will demonstrate sensing of flow velocity – with sensitivity 70nL/min, and ion concentration with sensitivity as low as 40 nM. Overall, our results highlight the usefulness of graphene FETs for applications in ultra-precise fluidic sensing and as a potential replacement for silicon in next generation transistors.

In the second part of my talk, I will focus on mononalyer TMDCs and explore the formation, binding energies, and dissociation mechanisms of various excitons in monolayer TMDCs through photocurrent spectroscopy and photoluminescence measurements. I will also demonstrate that their optical properties, fluorescence quantum yield, and transparency can be tuned via electrical gating. Our findings suggest the possibility of TMDCs for diverse applications ranging from nanoscale electro-optical modulators to novel energy harvesting devices.