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Black phosphorus for future devices

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Black phosphorus (or phosphorene at the monolayer limit) has attracted significant attention as an emerging 2D material due to its unique properties compared with well-explored graphene and transition metal dichalcogenides such as MoS_2 and WSe_2. In bulk form, this monoelemental layered structure is a highly anisotropic semiconductor with a bandgap of 0.3 eV which presents marked distinctions in optical and electronic properties depending on crystalline directions. In addition, black phosphorus possesses a high carrier mobility, making it promising for applications in high frequency electronics. A large number of characterization studies have been performed to understand the intrinsic properties of BP. Here I wil present a number of investigations where first-principles modelling was combined with scanning tunneling microscopy (STM) [1], Raman spectroscopy [2], and transmission electron microscopy (TEM) [3] to assist in the design of phosphorene-based devices. [1]. I will provide an overview of these studies and position them in the context of the very active research devoted to this material. In particular, I will show how low-frequency Raman spectra provide a unique handle on the physics of multilayered systems and how BP's structural anisotropy weaves its way to its unusual polarization dependent Raman signature. Finally, I will show recent progress where nanopores, nanobridges, and nanogaps have been sculpted directly from a few-layer BP sample using a TEM, and indicate the potential use of these results on the creation of phosphorene-based nanoelectronics. I wil conclude this talk with a critical look at the issues of phosphorene stability under ambient conditions.
References: [1] Nano Lett. 14, 6400-6406 (2014); [2] ACS Nano, 2015, 9 (6), pp 63336342 (2015); [3] unpublished

[1]Collaborators on this research include: Liangbo Liang, Bobby G. Sumpter, Alex Puretzky, Minghu Pan, (Oak Ridge National Laboratory), Marija Drndic (University of Pennsylvania), Mildred Dresselhaus, Xi-Ling, Shengxi Huang (Massachusetts Institute of Technology)