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Graphene monofluoride: a wide bandgap material derived from graphene

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Fluorination provides an effective way of controlling the properties of carbon materials. In this talk, I will describe our experimental and theoretical work on the synthesis, structural, electrical and optical properties of fully fluorinated graphene and graphite, i. e., graphene monofluoride CF and graphite monofluoride $(CF)_n$. $(CF)_n$ is synthesized by reacting HOPG graphite with F_2 gas at high temperature. Transmission electron microscopy and electron diffraction measurements show crystalline few-layer CF with a lattice constant 4% larger than that of graphene, in good agreement with first principle calculations. We observe the E_g and A_{1g} Raman modes of graphene monofluoride using UV Raman spectroscopy. Photoluminescence measurements of $(CF)_n$ using variable excitation wavelength (244-514 nm) and temperature (5-295 K) show several emission modes in the visible spectrum, which likely originate from mid-gap defect states. The absence of the band edge emission suggests a large band gap of greater than 5 eV. Partially fluorinated graphene fluoride exhibits non-linear, strongly insulating transport with variable-range hopping temperature dependence, consistent with the presence of localized states due to missing fluorine atoms. Highly conductive graphene can be recovered by annealing CF in Ar/H_2 at high temperature, resulting in a conductance improvement of five orders of magnitude. As a transparent and atomically thin insulator, graphene monofluoride may find its use in graphene electronics and photonics. In collaboration with: Bei Wang, Shih-Ho Cheng, Justin Sparks, Humberto Gutierrez, Ke Zou, Ning Shen, Youjian Tang, Qingzhen Hao, Awnish Gupta, Peter Eklund, Vincent Crespi, Jorge Sofo and Fujio Okino (Shinshu University, Japan). References: Cheng et al, "Reversible fluorination of graphene: towards a two-dimensional wide band gap semiconductor," Phys. Rev. B 81, 205435 (2010) Wang et al, "Photoluminescence from nanocrystalline graphite monofluoride," Appl. Phys. Lett. 97, 141915 (2010)