3-Dimensional Mapping of Electrostatic Interactions

Kristen M. Burson[1,2], Pavel Nagornykh[2,3], Cory R. Dean[4,5], Philip Kim[6], K. Watanabe[7], T. Taniguchi[7], William G. Cullen[1,2]

[1]*Materials Research Science and Engineering Center,* [2]*Department of Physics,* [3]*Laboratory for Physical Sciences, University of Maryland, College Park, MD 20742-4111 USA*

[4]*Departments of Electrical Engineering USA* [5]*Mechanical Engineering, and* [6]*Physics, Columbia University, New York, New York, 10027, USA,* [7]*Advanced Materials Laboratory, National Institute for Materials Science, 1-1 Namiki, Tsukuba, 305-0044, Japan*

E-mail: wcullen@physics.umd.edu

Graphene has attracted a great deal of attention due, in part, to the high carrier mobility. However, graphene carrier mobility is substrate-limited, showing approximately an order of magnitude improvement on boron nitride (BN) over silicon dioxide (SiO_2) which may be described by reduced charged impurity density [1]. This implies that the mobility should be dependent on BN layer thickness, as the BN flakes are located on top of SiO_2, which has yet to be verified by transport. Employing simultaneous UHV Kelvin probe force microscopy (KPFM) and atomic force microscopy (AFM), we obtain potential maps for BN and SiO_2. The surface potential of the SiO_2 is well described by a 2D random charge distribution with a charge density of 2.5×10^{11} cm^{-2}. KPFM data taken with the 40 nm BN flake could be expected to show improvement consistent with moving the SiO_2 charges 40 nm farther away from the graphene device. However, the distribution on BN is significantly attenuated with respect to the expected potential distribution at 40 nm for the surface charge determined from the SiO_2 measurements. Models which account for the full electrostatics of the conducting tip/dielectric/substrate system may be required to quantify our SiO_2 and BN KPFM data.

Here we analyze our measurements using a model for KPFM which considers tip/substrate electrostatics and discuss its limitations. We calculate the force between the tip and the sample for a single point charge located on the sample surface. We determine the tip potential which minimizes the force and discuss how this potential compares to the expected potential when neglecting the influence of this tip. This work is supported by the University of Maryland MRSEC under Grant No. DMR 05-20471 and the U.S. ONR MURI. MRSEC Shared Experimental Facilities were used in this work, and additional infrastructure support was provided by the UMD CNAM and NanoCenter.

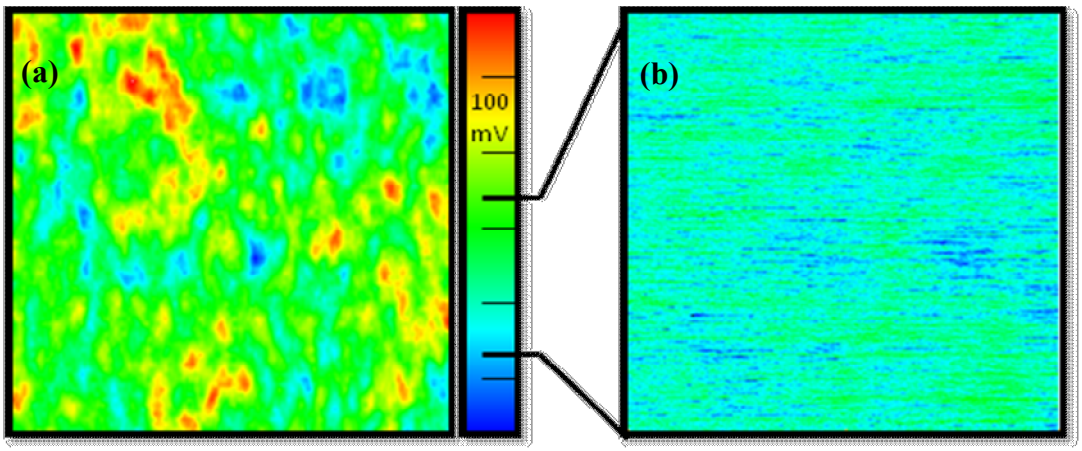

Figure 1: KPFM potential map of (a) SiO_2 surface and (b) BN surface. Images are 1μm x 1μm in size.

[1] C. Dean et al Nature Nanotechnology 5, 722-726 (2010)