"Colocalized nanoscale mechanical, electrical and infrared mapping of Graphene"

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Abstract
We provide an overview of unique scanning probe technologies for nondestructive measurement of Graphene's mechanical, electrical and infrared properties. The data shown are acquired on a MultiMode AFM system using the methods of PeakForce Quantitative Nanomechanical Mapping (PFQNM), PeakForce Kelvin Probe Force Microscopy (PF-KPFM), and infrared scattering Scanning Nearfield Optical Microscopy (IR-sSNOM) respectively. Together these modes of nanoscale characterization allow the user to quantitatively map properties such as adhesion, stiffness, work function, and carrier density - all with a spatial resolution below 20nm. We present two case studies as examples of applying these modalities to Graphene. In the first example, a multilayer exfoliated Graphene sample is characterized using co-localized PFQNM, PF-KPFM and IR-sSNOM. The methods are used in a complementary fashion to find and confirm defect rich regions, characterize the number of layers and estimate the nanoscale carrier density. In the second example, a single exfoliated layer of Graphene on a suspended Silicon Nitride window is characterized using the PFQNM and PF-KPFM techniques in ambient as well as Argon atmosphere environments. The combined methodology allows us to quantify Graphene's work function and study its spatial inhomogeneity. The demonstrated spatial resolution is below 20nm while the potential resolution is better than 10mV. We find that regions of high adhesion contrast appear to greatly influence the measured work function. Through the removal of water and oxygen, the controlled environment of the Glovebox is also shown to greatly reduce both the work function and the presence of inhomogeneities in Graphene.

Figures

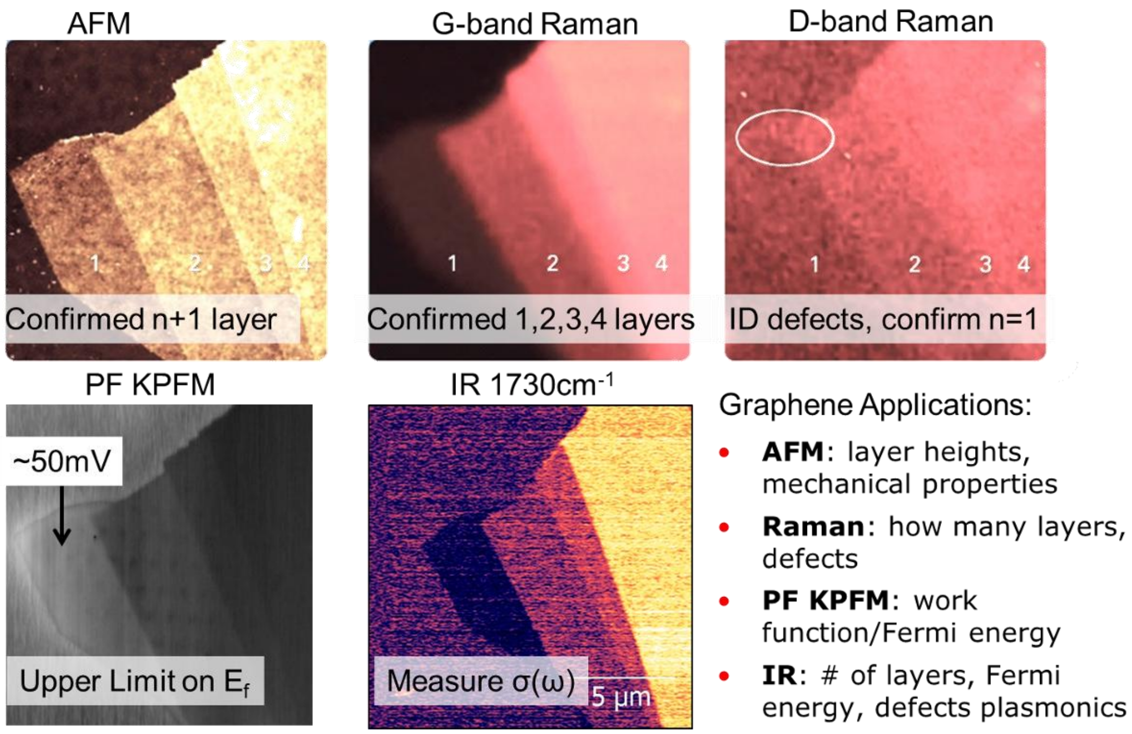

Figure1. Colocalized imaging of an exfoliated Graphene sample highlighting the possible applications for Graphene characterization of each modality.

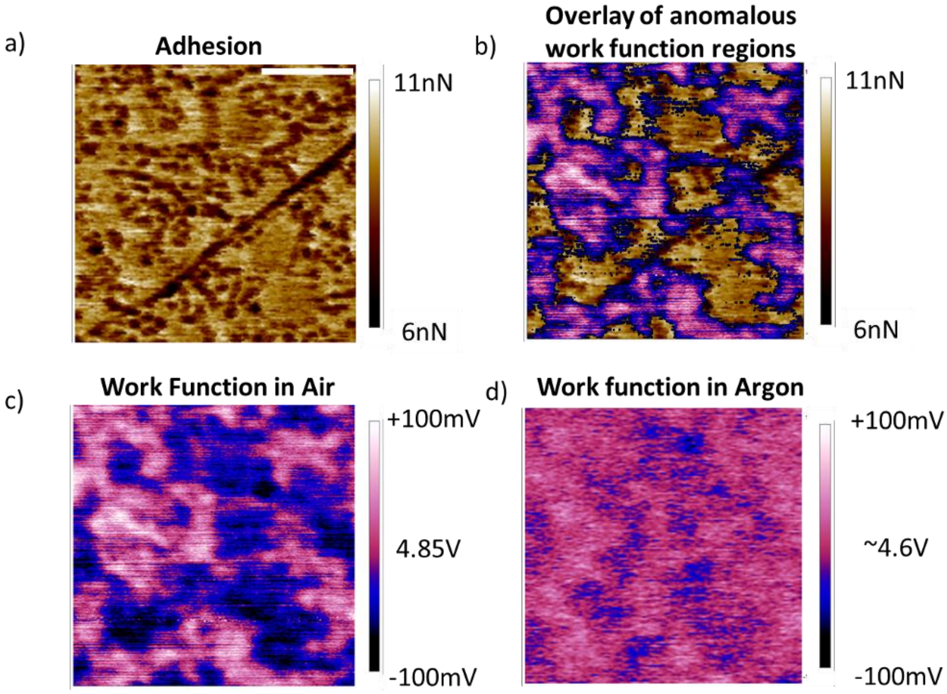

Figure2. Colocalized imaging of a contaminant rich region on an exfoliated Graphene sample. Regions of low adhesion are shown to correlate with larger work functions/charge density. The overall work function and the degree of inhomogeneity are greatly reduced in Argon.