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Environmental TEM in an Aberration Corrected Microscope

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The increasing use of environmental transmission electron microscopy (ETEM) in materials science provides exciting new possibilities for investigating chemical reactions and understanding both the interaction of fast electrons with gas molecules and the effect of the presence of gas on high-resolution imaging. A gaseous atmosphere in the pole-piece gap of the objective lens of the microscope alters both the incoming electron wave prior to interaction with the sample and the outgoing wave below the sample. Whereas conventional TEM samples are usually thin (below 10-20 nm), the gas in the environmental cell fills the entire gap between the pole pieces and is thus not spatially localized. By using an FEI Titan ETEM equipped with a monochromator and an aberration corrector on the objective lens, we have investigated the effects on imaging and spectroscopy caused by the presence of the gas.

State-of-the-art aberration corrected TEMs provide electron micrographs with high spatial resolution. The apparent interpretability of such images encourages microscopists to analyze data more quantitatively. Such an analysis requires a detailed knowledge of the entire path and propagation of the electrons along the microscope column. The effects of gas on the electron wave in the objective lens are not well understood and needs further attention. Imaging samples with a simple geometry, such as gold particles on a flat graphene substrate and analyzing the variations in contrast, provides a means for understanding the issues involved with imaging in the presence of a gas. Furthermore, electron energy-loss spectroscopy can tell us about the local chemical environment in the vicinity of the sample.

Using a differentially pumped FEI Titan 80-300 Titan ETEM, high-resolution TEM micrographs and electron energy-loss spectra were acquired from Au/graphene samples in vacuum and in a hydrogen atmosphere at pressures up to 700Pa. The gases were introduced into the environmental cell using digitally controlled mass flow controllers, providing accurate and stable control of the pressure in the cell. The loss of beam intensity when traversing the pole piece gap was measured by recording the signal outside the sample region on the pre-GIF CCD camera (see Figure 1 left). The effects on high resolution imaging were investigated by imaging gold nanoparticles below 5nm in diameter (see Figure 1 middle and right).

We will present results from imaging in various elemental as well as di-molecular gases and their effect on imaging and spectroscopy in the environmental transmission electron microscope.

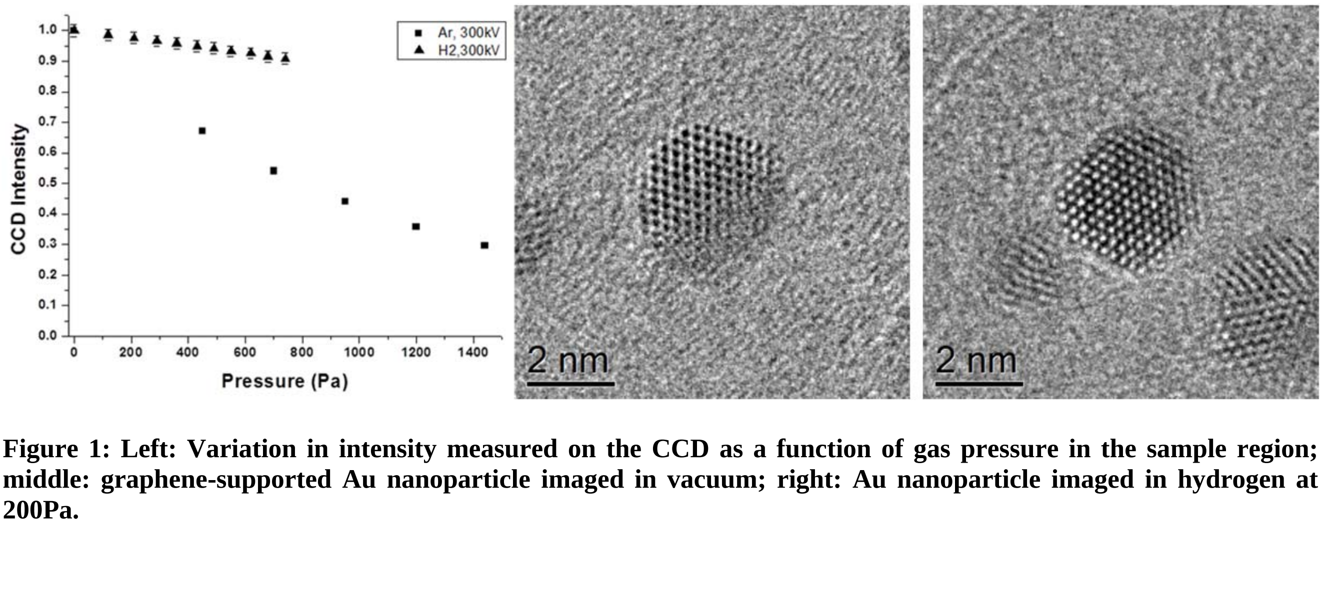

Figure 1: Left: Variation in intensity measured on the CCD as a function of gas pressure in the sample region; middle: graphene-supported Au nanoparticle imaged in vacuum; right: Au nanoparticle imaged in hydrogen at 200Pa.