Prism: a new aberration-corrected scanning transmission electron microscope facility for planetary materials research.

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Introduction: Transmission electron microscopy is an established, valuable method for structural and elemental analysis of planetary materials. However, recent advances in instrument design, including incorporation of aberration-correcting electron optics, have dramatically improved the spatial resolution and sensitivity of electron microscope imaging and spectroscopy. Measurements are now possible across a range of scales from micrometers to picometers, with a sensitivity extending down to the imaging and spectroscopy of single atoms. These advances have the potential to significantly enhance mineralogy and petrology studies of planetary materials in general, and returned sample analysis in particular.

PRISM (Picometer-Resolution Imaging and Spectroscopy Microscope) is a new scanning transmission electron microscopy (STEM) facility at the Naval Research Laboratory (NRL), established in 2014. PRISM was funded jointly by the NASA LARS program and NRL. After final commissioning in early 2015, PRISM will be available as a resource to the planetary materials community.

Instrument Features: PRISM is a custom configuration of the Nion UltraSTEM200, dedicated scanning transmission electron microscope, equipped with Gatan Enfinium ER Dual EELS™ and Bruker X-flash™ windowless (~0.6 sr) SDD EDS spectrometers. The electron source is a cold field emission gun, operable at voltages of 40, 60, 100 and 200 kV. The nominal energy resolution at 60kV and 1 nA probe current and 1 msec collection times is 0.3 eV, with 0.25 eV achievable. The aberration-correction optics enable an information limit of 80 pm at 60 kV as determined from observation of lattice spacings of gold nanoparticles on amorphous carbon, and resolution of individual C atoms in single layers of graphene.

The vacuum system is UHV, with a base pressure of < 2 nTorr in the sample area of the column, and < 0.02 nTorr in the gun chamber. The improved vacuum compared to a conventional side-entry TEM, enables longer useful measurements times, due to reduced sample contamination from redeposition of volatilized hydrocarbons, and reduced beam etching of the sample due to reduced level of residual water vapor in the column. In order to maintain UHV cleanliness in the column, the sample cartridges, held in a magazine that accommodates five cartridges, are fully enclosed in the instrument through a load lock mechanism. Prior to loading the samples, they are typically baked at 140°C for 6 hours in a freestanding vacuum chamber.

The pm-scale spatial resolution results from a combination of the electrical and mechanical stability of the microscope, and the stability of the room environment. PRISM is installed in the NRL Institute for Nanoscience, in a suite of two rooms that separate the main instrument from the operator and control electronics. The instrument room has an independent floating concrete pad, distributed airflow across the entire ceiling through HEPA filters, and temperature control to < 0.1°C per hour.

Figure 1. PRISM during installation with front enclosure removed (top) and after completed installation with open enclosure (left).

Example Data: As submission of this abstract, specifications testing of PRISM is in the final stages. A wide variety of samples have been tested, including graphene, C60, meteoritic IOM and nanodiamonds, and synthetic silicate glasses for Fe oxidation state analysis.

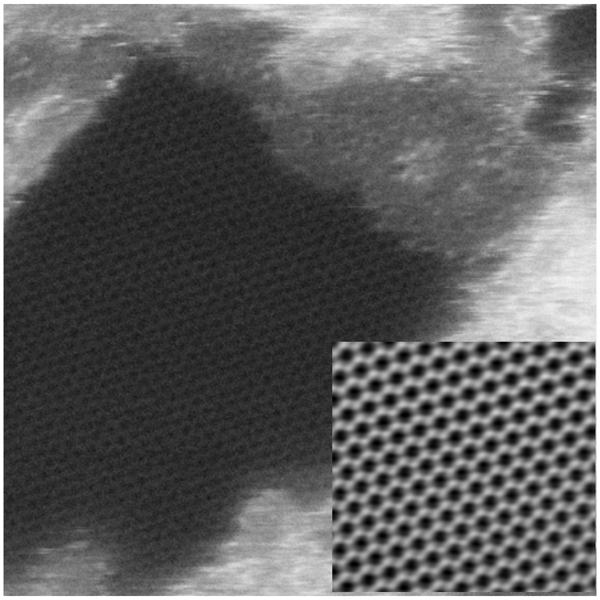

Figure 2. Raw STEM dark field image of graphene with a large single layer region. (inset) FFT-filtered image from the single layer region showing individual carbon atoms.

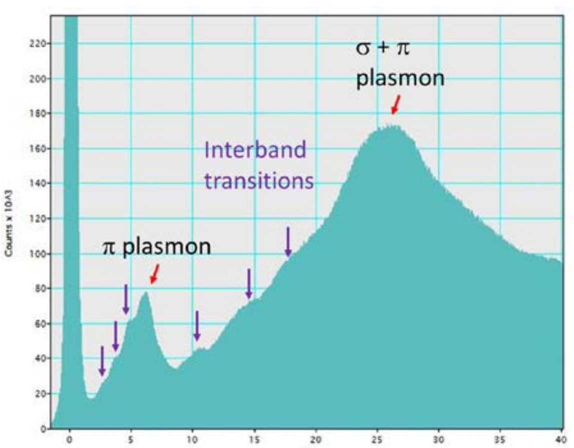

Figure 3. Low loss EELS measurement of a C60 solid.

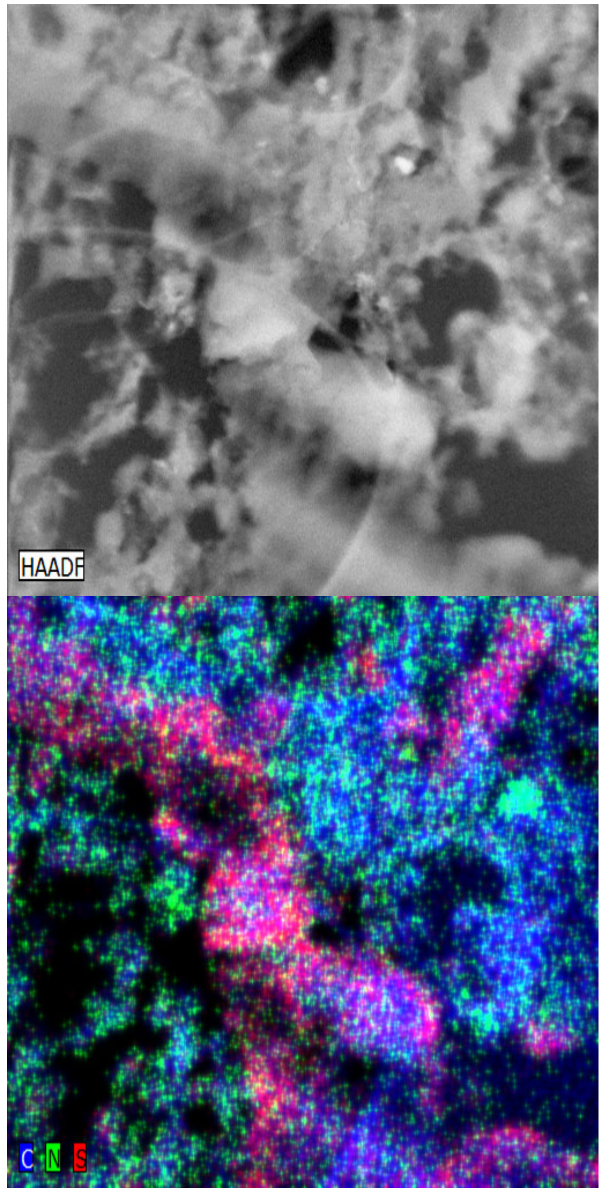

Figure 4. STEM dark field (top) and EDS elemental RGB map (bottom) of meteoritic organic matter, The field of view is approximately 1 μm.