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Environmental Transmission Electron Microscopy (ETEM)

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U.S. DEPARTMENT OF ENERGY
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FEI Titan ETEM G2

A state-of-the-art image-corrected and monochromated Titan Environmental Transmission Electron microscope (ETEM), 300 kV, provides the capability to resolve reactions between materials and gaseous environments with atomic-resolution imaging.

- Image corrector yields sub-Å resolution.
- TEM or STEM modes, with collection from a Ceta camera or bright-field and dark-field STEM detectors.
- Variety of in-situ TEM holders for cryo-EM, high-temperature, mechanical straining, and electrical biasing.
- Monochromator with various slit geometries.
- Low-dose mode for beam sensitive materials.
- Lorentz Microscopy mode.
- Piezo stage control.
- Heating up to 1200 ^{o}C is performed using a Protochips Aduro Heating Holder.

K2-IS Direct Electron Detection

Increasing resolution without increasing the e$^-$-dose-per-frame.

Camera capable of high-speed imaging, up to 1,600 frames per second, or low dose imaging, down to single electron sensitivity with direct electron counting.

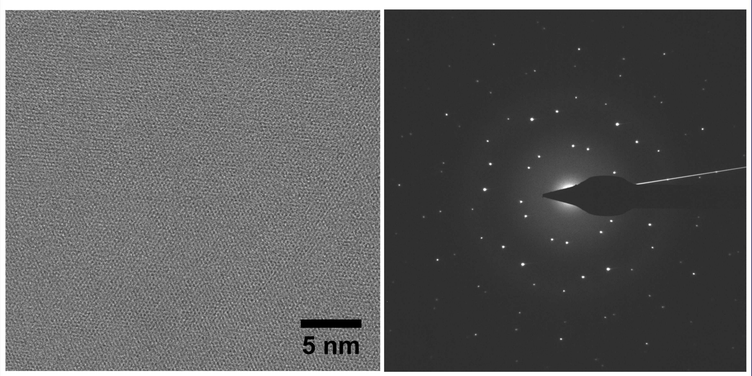
Gas Delivery System

For control over the gaseous environment in the ETEM column; including Flammable (H_2, CO, methane), Inert (N_2, Ar, He, CO_2), and Oxidizing (O_2) gases.

Three-dimensional, high cylinder density design to minimize laboratory flow space requirements. In only a 2 ft^2 area, the ETEM GC can support up to fifteen process gas cylinders. Virtually unlimited mixing combinations of all available process gasses can be delivered to the ETEM's column in a controlled and safe manner.

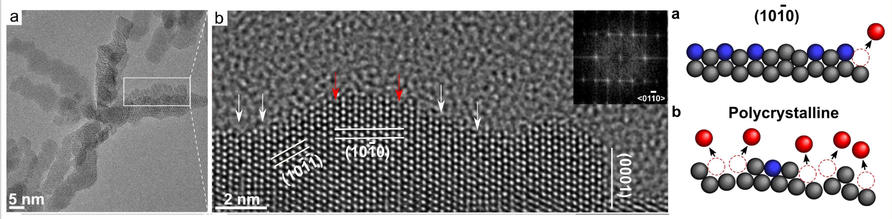
- Reactive Gases: 0-10 sccm +/-0.1 sccm up to 10 mbar.
- Diluent Gas (N_2): 0-1000 sccm +/-0.1 sccm up to 20 mbar.
- Delivery Pressure: 0-1000 Torr, +/-1 Torr
- Three isolated (Flammable, Oxidizer, Inert), differentially pumped, ultra-low volume (<10cc), process gas delivery circuits
- Dynamic or static flow control mode at any pressure level between 0-1000 Torr.
- Several pressure safety, hardware and software interlocks including a key switch and password protection to prevent unauthorized use.
- Expandable and easily reconfigured to meet future research demands.
- Portable to allow for routine maintenance on both the gas cart and ETEM.

MoS_2 Bilayer



- MoS_2 2D Bilayered Material.
- High resolution imaging of (0001) plane.
- Beam sensitive.
- Potential candidate for lithiation experiments.

Branched Ru Nanocatalysts



The Titan ETEM was used to characterize the surface of highly branched ruthenium (Ru) nanostructures, which display increased stability and a five-fold increase in activity for the oxygen evolution reaction (OER), when compared to polycrystalline Ru. It was shown that long, highly crystalline branches with low index crystal facets protect against Ru dissolution, a major factor reducing catalytic performance.

Poerwoprajitno, A. R., Gloag, L., Benedetti, T. M., Cheong, S., Watt, J., Huber, D. L., Gooding, J. J., Tilley, R. D., Formation of Branched Ruthenium Nanoparticles for Improved Electrocatalysis of Oxygen Evolution Reaction. *Small* **2019**, 1804577.

CINT User Proposal to Access the ETEM

CINT is a Department of Energy/Office of Science Nanoscale Science Research Center (NSRC) operating as a national user facility devoted to establishing the scientific principles that govern the design, performance, and integration of nanoscale materials. Through it's Core Facility in Albuquerque and Gateway to Los Alamos Facility, CINT provides open access to the tools and expertise needed to explore the continuum from scientific discovery to the integration of nanostructures into the micro- and macro world. User proposals are accepted in the months of March and September with active user proposals lasting a duration of 18 months. Proposals are 2 pages long and are evaluated by a team of external reviewers on the merit of the proposal in relation to nanoscience and potential impact on the community.

For more information on the ETEM, it's capability and availability, please contact;
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