Probing Structural Dynamics with High Spatial and Temporal Resolution

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Pacific Northwest NATIONAL LABORATORY
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Project 2.5; October 2011 – September 2014

Purpose

- Develop an understanding of the structural dynamics that occur on the µs-ns timescale
- We will make use of a unique aberration-corrected dynamic TEM (DTEM), where a photoemission source will enable these time-resolved images to be obtained at/near atomic resolution

Expected Outcomes

- Single-shot imaging with atomic spatial resolution for in situ gas/liquid stages
- Detection schemes for "movie-mode" acquisition
- Pulse compression for temporal lenses

Key Successes in FY13

- Base instrument installed
- Laser installed
- 10 invited presentations at conferences and research institutions
- 8 papers published

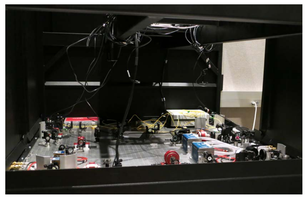
Research Accomplishments

Advances in the DTEM installation

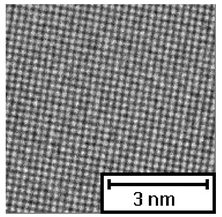
Laser installation

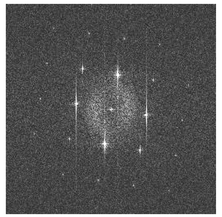
Beginning FY13

Current

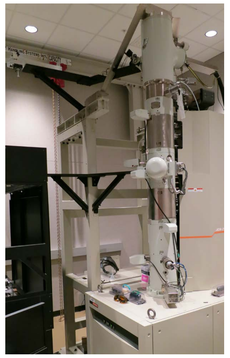


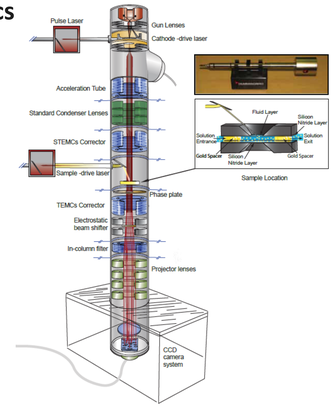
Performance of base instrument





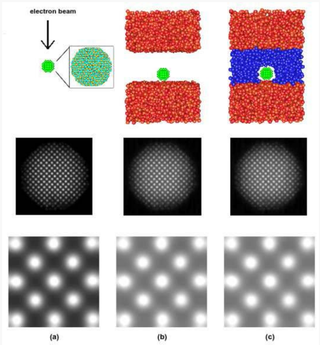
Breadboards and optics





Performance tests of base microscope yield sub-angstrom nominal resolution. Laser system is currently installed on the optical table and first laser energy tests have been realized. Construction of the UV radiation delivery system to the EM column has started.

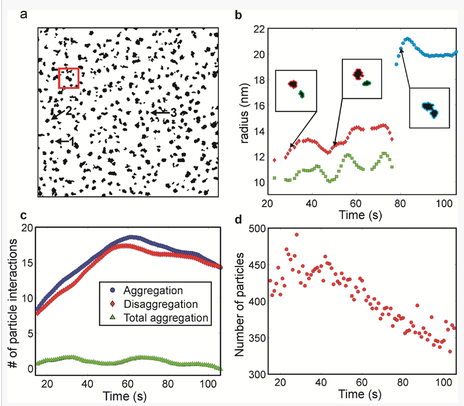
Imaging conditions for in situ liquid microscopy



Welch DA et al. 2013 *Ultramicroscopy,* in press.

Designing experiments in the DTEM will benefit from image simulation techniques able to predict the obtainable resolution depending on in situ holder design, microscope parameters, and sample. We developed a technique for virtual imaging of model environmental stage systems. Applying this technique to STEM, Z contrast images of PbS in vacuum (a), in the in situ stage in vacuum (b), and in water (c) are simulated.

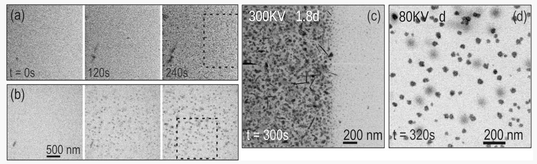
Mesoscale growth dynamics in nanoparticle synthesis



The DTEM will provide better kinetics to direct imaging of growth mechanisms occurring across different length scales. Quantitative analysis of nanoparticles synthesis in solution demonstrates that nanoscale as well as mesoscale effects, such as aggregation, are involved in nanoparticle growth mechanisms. Growth dynamics of silver nanoparticles by monomer attachment and aggregation can be tracked (a) and quantified (b)-(d).

Woehl TJ et al., submitted.

Beam interaction with liquids



Initial stages of a reaction can be observed in the DTEM by controlling the electron dose. To reproduce similar experimental conditions in a different instrument, the specific electron optical settings must be considered. The effect of electron energy on the growth of particles in solution for 80-KeV electrons (b) and (d) and 300-KeV (a)-(c) is illustrated.

Next Steps

- Develop DOE-BES proposal, connect with NIH opportunities
- Gun modification in June and first pulses by end of July. DTEM fully operational 10/13
- Application of in situ methods in the DTEM and development of new capabilities for battery research

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