Abstract for an Invited Paper
for the MAR12 Meeting of
The American Physical Society

In-Situ Transmission Electron Microscopy with Nanosecond Temporal Resolution[1]

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The dynamic transmission electron microscope (DTEM) can obtain both high spatial ($\sim$1nm or better) and high temporal ($\sim 1\mu$s or faster) resolution. The high temporal resolution is achieved by using a short pulse laser to create the pulse of electrons through photoemission. This pulse of electrons is propagated down the microscope column in the same way as in a conventional high-resolution TEM. The only difference is that the spatial resolution is limited by the electron-electron interactions in the pulse (a typical 10ns pulse contains $\sim 10^9$ electrons). To synchronize this pulse of electrons with a particular dynamic event, a second laser is used to "drive" the sample a defined time interval prior to the arrival of the laser pulse. The important aspect of the DTEM is that one pulse of electrons is used to form the whole image, allowing irreversible transitions and cumulative phenomena such as nucleation and growth, to be studied directly in the microscope. The use of the drive laser for fast heating of the specimen presents differences and several advantages over conventional resistive heating *in-situ* TEM – such as the ability to drive the sample into non-equilibrium states. So far, the drive laser has been used for *in-situ* processing of nanoscale materials, rapid and high temperature phase transformations, and controlled thermal activation of materials. In this presentation, a summary of the development of the DTEM and in-situ stages to control the environment around the specimen will be described. Particular attention will be paid to the potential for gas stages to study catalytic processes and liquid stages to study biological specimens in their live hydrated states. The future potential improvements in spatial and temporal resolution that can be expected through the implementation of upgrades to the lasers, electron optics and detectors will also be discussed.

[1]Pacific Northwest National Laboratory is operated by Battelle Memorial Institute for the U.S. Department of Energy under Contract No. DE-AC05-76RL01830.