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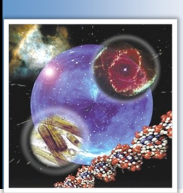
Seeing Small: Enabling New Discoveries Through Advanced Transmission Electron Microscopy

Aberration-Corrected TEM/STEM, In-situ TEM and D-STEM have emerged as powerful tools for the characterization of nanomaterials. Aberration-Corrected TEM/STEM enable atomic and structural imaging resolution below 0.1 nanometers while performing chemical analysis at the atomic level, in-situ TEM allows dynamic real-time imaging of nanomaterials behavior and D-STEM coupled with precession microscopy enables orientation and phase mapping information from nanostructures, as small as 3 nm, in a completely automated procedure. In this talk, a brief overview of D-STEM, Aberration-Corrected TEM/STEM and in-situ TEM will be presented and related to the quest for investigating nanomaterials. Subsequently, three examples showing the power of these techniques in providing scientific insight will be discussed.

First, a recently developed D-STEM technique, coupled with precession microscopy will be presented to obtain orientation information from nano copper interconnects. We find that the increasing influence of the trench sidewalls in narrow Cu lines results in dominant sidewall growth of {111} grains, as well as clusters of small grains in the vicinity of large grains. The presence of such small grain-clusters, mostly linked by high angle boundaries, adversely influence stress migration and electromigration reliability in copper interconnects.

Second, using aberration-corrected HAADF/STEM imaging and STEM simulations, as well as EDS analyses, the atomic structure and composition of lithium-rich layered oxides for lithium-ion batteries will be discussed. We find that the amount of excess lithium causes significant changes in the phases formed and the composition of each particle. Overall, the best electrochemical performance is found when the excess lithium content is sufficient to form homogenous particles containing nickel, with a C2/m monoclinic solid solution structure.

In the last part of the talk, aberration-corrected in-situ TEM nanoindentation experiments conducted on individual single-crystal silver nanoparticles will be presented. Evidence for nucleation of dislocations and dislocation motion was observed during in-situ TEM nanoindentation, but upon unloading dislocations were no longer visible. A new model for explaining dislocation instability is introduced.This is crucial for understanding the mechanical properties of nanoparticles.



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