Mesoscale Priority Research Direction

(Rapid Evolution of Mesoscale Material Structure by DTEM)

Opportunity

Engineering performance of virtually all materials depends on mesoscale structure (e.g. defects, inclusions, morphology)

Especially today, this structure is deliberately (though often statistically) introduced via material processing and/or direct nanoscale patterning

With Materials Genome and other initiatives, the time has come to go beyond purely empirical "black box" approaches to the structure/property/processing relationships that are the heart of materials science

Meso Challenge

Under typical processing conditions, mesoscale structures can evolve over a huge range of time scales. This evolution is typically irreversible.

Much of the most important action is on the ns to µs scale. To open up the black box, we need *direct real-space imaging of irreversibly evolving materials on the scale of nanometers and nanoseconds*.

References: J. S. Kim et al., *Science* **321**, 1472 (2008); T. LaGrange et al., *Ultramicroscopy* **108**, 1441 (2008); B. W. Reed et al., *Microsc. Microanal.* **15**, 272 (2009); G. H. Campbell et al., *J. Elect. Microsc.* **1-8**, 1 (2010)

Approach

Dynamic Transmission Electron Microscopy (DTEM) records nm/ns-scale snapshots and movies of unique material events

Coupled with DTEM diffraction and post-mortem analysis, this lets us unravel and quantify previously mysterious sequences of events

Interaction of pre-existing microstructure, fast-evolving temperature and phase fields, and defect motion under extreme driving forces creates enormous microstructural complexity even from simple initial states

Complements optical, X-ray, and stroboscopic techniques

Impact

No amount of static before-and-after processing studies can match the insights gained from directly watching material processes in detail. Through direct visualization, we enhance our understanding of phase transformations, defect motion, chemical reactions, catalysis, etc.

We anticipate DTEM becoming a standard tool for mesoscale material dynamics in coming years, in much the same way that aberration correction became a standard technology

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