Ultrafast Electron Microscopy: Principle and Demonstrations in Chemical and Materials Science

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With advances in spatial resolution reaching the atomic scale, 2 and 3 dimensional (D) imaging in transmission electron microscopy (TEM) has become an essential methodology in various fields of research providing *static* structural information. Now it has become possible to integrate the ultrahigh temporal resolution (fourth dimension) to the 3D spatial resolution of TEM.[1,2] Here, presented is the concept of time-resolved imaging in ultrafast electron microscopy (UEM). As it provides images with a spatiotemporal resolution, UEM, in principle, should enable the visualization of single-nanoparticle structural *dynamics* in real and reciprocal space.

Here, we demonstrate the selectivity and sensitivity of the technique by visualizing the spin-crossover dynamics of single, isolated metal–organic framework nanocrystals by introducing a small aperture in the microscope.[3] Its behavior was observed to be distinct from that imaged by averaging over ensembles of heterogeneous nanoparticles.

Another demonstration is the ultrafast metal–insulator phase transition of vanadium dioxide induced by laser excitation and followed by taking electron-pulsed, time-resolved images and diffraction patterns.[4] The single-particle selectivity is achieved by identifying the origin of all constituent Bragg spots on Debye–Scherrer rings from the ensemble. Orientation mapping and dynamic scattering simulation of the electron diffraction patterns in the monoclinic and tetragonal phase during the transition confirm the observed behavior of Bragg spots change with time. We found that the threshold temperature for phase recovery increases with increasing particle sizes and we quantified the observation through a theoretical model developed for single-particle phase transitions.

References

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