Multi-Dimensional Liquid Phase TEM for Directly Observing Colloidal Systems

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Liquid cell TEM (LTEM) has been introduced recently for in-situ study of chemical reactions occurring in liquid. Liquid cells allow an opportunity to utilize high spatial and temporal resolution of TEM in studying reactions of colloidal nanoparticles. Achieving sub-nm spatial resolution by adjusting the thicknesses of window materials and the encapsulated liquid, important steps in growth trajectories of different types of nanoparticles have been directly observed at high-resolution of TEM. Along with computational analysis, we also study growth trajectories of ensemble number of nanoparticles. We also observe the diffraction patterns from individual nanoparticles as they rotate in the liquid cell, and ultimately, we are able to align and invert those images to obtain the 3D atomic structure of individual particles freely moving in liquid. Obtained 3D density maps unveil structural features of nanoparticles that have been either underestimated or unattainable in conventional analysis. We present our efforts to augment a combination of above-mentioned analytical tools in directly observing chemical reactions of nanoparticles in reactive environments.