Spectroscopic Imaging of (Solvated) Soft Materials in the Cryo-Scanning Transmission Electron Microscope

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Traditional methods for studying the morphology of soft materials – both synthetic polymers and biological structures - in the transmission electron microscope (TEM) principally rely on differential heavy-element staining (e.g. Os/Ru tetroxide among others) to induce amplitude contrast based on elastic electron scattering. This imaging approach has had substantial impact on the electron-optical imaging of soft-materials morphology over many decades of practice, but it is increasingly unsuited for the quantitative mapping of composition with the necessary near-nanometer spatial resolution demanded by a broad range of technologically forward-looking applications. Our work concentrates on an alternate method based on quantitative maps of composition in unstained soft materials using electron energy-loss spectroscopy to study the inelastically scattered electrons. Soft materials offer rich electronic structure with which to spectroscopically differentiate between specimen components. Here we use two examples – synthetic polymer nanoparticles and frozen-hydrated tissue – to illustrate some of the problem-solving possibilities afforded by this imaging approach. More generally, we have achieved 1 nm resolution studying interfaces in poly(styrene)-poly(2 vinyl pyridine) homopolymer blends, 5 nm resolution studying epoxy-alumina composite interphases, and 8-15 nm resolution studying hydrated polymers and tissue where cryo-TEM/STEM techniques are needed. In contrast to traditional imaging of radiation resistant hard materials where the resolution is ultimately limited by the quality of the electron optics, the achievable spatial resolution associated with imaging of unstained soft materials is instead determined by the radiation sensitivity of the specimen. Improving the so-called dose-constrained resolution thus concentrates on enhanced data acquisition and spectral-analysis techniques rather than on minimizing the spherical aberration of the objective lens.

Matthew Libera is a Professor of Materials Science at the Stevens Institute of Technology located in northern New Jersey on the western shore of the Hudson River overlooking New York City. Libera's interests center on the development and understanding of polymers and polymeric biomaterials. Much of his current research is focused on nanostructured hydrogel-based materials with applications to problems involving infection control of biomedical devices. He is the Executive Director of the Stevens Laboratory for Multiscale Imaging, a multiuser facility with advanced capabilities for TEM, SEM, AFM, and confocal imaging. He earned his Sc.D. in Materials Science from MIT in 1987. After a post-doc experience at the IBM Almaden Research Center in San Jose, California, he joined the Stevens faculty in 1989.