Determining the Structure and Composition of Block Copolymer Microphases by Electron Microscopy

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We use electron microscopy to determine the morphology and composition of nanoscale phases in soft polymeric materials. We note in passing that while the polymer science literature is filled with morphological characterization data, chemical composition of within the morphological features is usually not determined. At first glance, this may seem strange, especially in light of the fact that Angstrom-scale features are routinely imaged in aberration-corrected microscopes. The main issue that prevents high-resolution study of nanoscale soft materials is beam damage and sample-preparation-related artifacts. We demonstrate the use of angle-resolved and energy-filtered electron microscopy to image the location of light elements like sulfur and oxygen in polymers. We demonstrate the need for tomographic reconstruction to avoid issues related to loss of information due to averaging across the entire thin section. We also demonstrate the use of modeling to compute the theoretical limits on resolution in soft materials. We also demonstrate how electron microscopy must be augmented by other techniques if the morphological feature of interest has a “needle-in-a-haystack” character. The examples we will discuss are ion-containing polymers for applications such as batteries and fuel cells.

Biographical Summary of Nitash P. Balsara
Nitash P. Balsara is a chemical engineer with a bachelor's degree from the Indian Institute of Technology in Kanpur, India in 1982, a master's degree from Clarkson University in Potsdam, New York in 1984, and a PhD from Rensselaer Polytechnic Institute in Troy, New York in 1988. From 1989-1991, he was a post-doctoral researcher, first at the Department of Chemical Engineering and Materials Science at the University of Minnesota, and then at Exxon Research and Engineering Company in Annandale, New Jersey. In 1992 he joined the faculty of Department of Chemical Engineering at Polytechnic University in Brooklyn, New York. He was promoted to associate professor in 1996 and professor in 1998. In 2000 he accepted the jobs that he currently holds: a joint appointment as professor of Chemical Engineering at the University of California, Berkeley, and faculty scientist at Lawrence Berkeley National Laboratory. He co-founded two start-ups in the battery space: Seeo, Inc. (currently a wholly-owned subsidiary of Robert Bosch LLC), and Blue Current.