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Quantitative ADF-STEM and STEM-EELS at the atomic level

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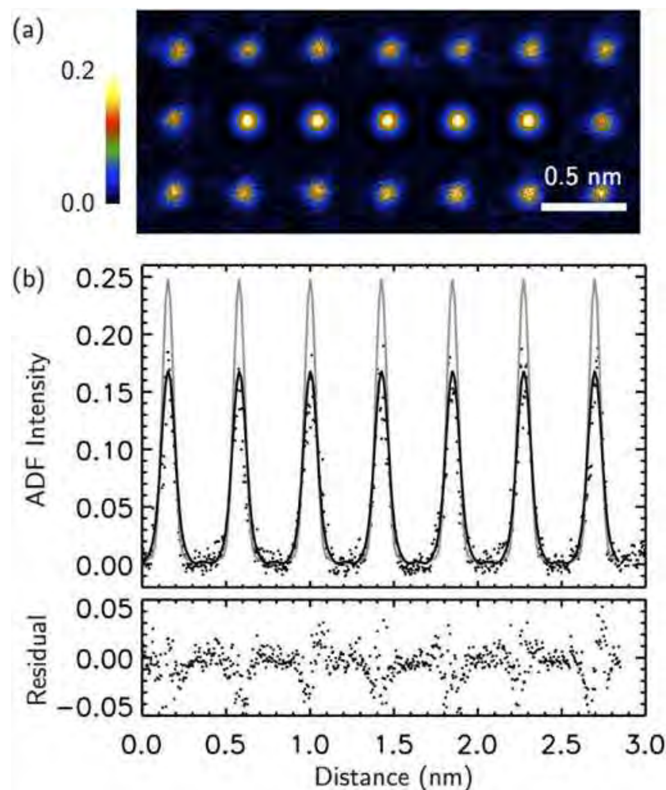
The ability to count, locate and distinguish the atoms in a material is one of the ultimate pursuits of nanomaterials characterization. In recent decades, significant advances toward this goal have occurred in the field of scanning transmission electron microscopy (STEM), with the establishment of a class of imaging modes capable of ~0.1 nm spatial resolution and high chemical sensitivity. High-angle annular dark-field (ADF) imaging and chemical mapping via core-level spectroscopy are prominent techniques in this class, with applicability to a wide variety of nanostructured materials, such as nanoparticles, interfaces, and embedded phases. With such advances comes the ability to perform fully quantitative imaging for unprecedented accuracy in nanostructure characterization. However, full realization of this goal requires that we must be able to isolate and quantify all of the experimental parameters pertinent to imaging at 0.1 nm resolution, so that the only remaining unknown is the nanostructure itself. This is demonstrated in the present work. We present a systematic study of the influence of experimental factors pertinent to 0.1 nm ADF-STEM. We demonstrate that ADF-STEM images can be interpreted on a quantitative basis, in terms of the number, positions and species of atoms in the material, *without* recourse to adjustable parameters [1]. The figure presents a demonstration for [001]-oriented LaB6. A similar demonstration will be shown for atomic-resolution chemical mapping based on core-level electron energy-loss spectroscopy (EELS) [2]. The approach demonstrated here improves on previous works by removing instrumental unknowns from the analysis. Applications of this approach will be presented.

***[1]** C. Dwyer, C. Maunders, C.L. Zheng, et al. Appl. Phys. Lett. 2012, 100, 191915.,* ***[2]** H.L. Xin, C. Dwyer, D.A. Muller. "Is there a Stobbs factor in atomic-resolution STEM-EELS mapping?", Ultramicroscopy 2014, in press.*



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