Scanning Transmission Electron Microscopy: Towards Atom-by-Atom Imaging in Three Dimensions

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Abstract

In Feynman's famous 1959 lecture "There's Plenty of Room at the Bottom," he challenged us to improve the electron microscope 100 times, so we could "just look at the thing." With the spectacular advances in aberration correction of the last decade, we have improved image resolution to well below 1 Å and gained a new level of sensitivity to structure, bonding, elemental valence and even spin state. We are able to image atomic diffusion within a solid, identify active sites in a catalyst andexplain the unexpected ferromagnetism in ultrathin, insulating $LaCoO_{3-x}$ (LCO) films. We can understand the surprisingimpact of interface termination on ferroelectricity in $BiFeO_3$ (BFO) films grown on $La_{0.5}Sr_{0.5}MnO_{3-x}$ (LSMO), and how grain boundaries in CdTe solar cells improve cell efficiency.We ca watch the dynamics of nanoclusters and nanowires. But today's microscope is only 20 times better than in Feynman's time.If we were to achieve another factor of two in lateral resolution we would achieve a depth resolution at the atomic level, opening the door to microscopic studies of whole new classes of materials by optical sectioning [1-3]. Finally we may be able to see the atomic structure of glasses, nanophase materials and those so-called "random" grain boundaries.

[1] S. J. Pennycook and S. V. Kalinin, Nature, **515**, 487-488 (2014)

[2] S. J. Pennycook, *MRS Bull*, **40**, 71–78 (2015).

[3] R. Ishikawa, A. R. Lupini, Y. Hinuma and S. J. Pennycook, Ultramicroscopy, **151**, 122–129 (2015).

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