Towards the Goal of Half-Ångstrom Resolution: From OÅM to TEAM

Michael A. O'Keefe
Materials Science Division, LBNL 2R200, 1 Cyclotron Road, Berkeley, CA 94720, USA

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Abstract

Sub-Ångstrom resolution is important for nanotechnology. As researchers design and build artificially-structured nanomaterials such as semiconductor devices, ceramic coatings, and nanomachines that operate at the atomic level, the requirement for "seeing" what has been built becomes more crucial. Whereas metal atoms can be routinely imaged in TEM specimens at resolutions from 2Å to 1.5Å, better resolutions (nearer to 1Å) are required to "see" lighter atoms such as carbon [1], nitrogen [2] and lithium [3].

Once its spherical aberration has been corrected, a microscope's resolution is controlled by its information limit. The one-Ångstrom microscope (OÅM) at LBNL provides C_S-corrected images by using focal-series reconstruction software [4,5] in combination of a field-emission high-resolution electron microscope (CM300FEG/UT) modified to extend its information limit. With excellent lens current stability, the OÅM has demonstrated the capability for 0.78Å resolution at 300keV [6]. The Transmission Electron Achromatic Microscope (TEAM) was proposed [7] to reach resolutions of 0.5Å using hardware correction of C_S [8] in combination with a monochromator (to reduce electron-beam energy spread and improve the TEAM's information limit beyond that of the OÅM's 0.78Å). In addition, the TEAM proposal called for chromatic aberration correction so as to extend the information limit even further by allowing a range of electron energies to be focussed at the same image plane.

Methods employed in the design and implementation of the successful OÅM project [1] have been used to determine appropriate parameters for the TEAM [9]. Calculations show that a C_C corrector is not required for the TEAM to reach 0.5Å at 300keV or 200keV, provided that energy spreads can be reduced to 0.4eV and 0.2eV respectively. These values allow more substantial beam current than the usually-quoted 100meV. However, at lower voltages, the TEAM would require stricter limits on energy spread to reach the targeted 0.5Å resolution.

Because the monochromator determines the energy spread in the beam, no improvement in HT stability is required to improve the information limit *per se*. However, improved HT stability has the effect of producing improved beam current statistics (the number of electrons passing through the monochromator) by placing more of the electrons closer to the center of the energy-spread distribution [10].

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[10] Work supported by the Director, Office of Science through the Office of Basic Energy Sciences, Material Sciences Division, U.S. Department of Energy, under contract No. DE-AC03-76SF00098.