Type of presentation: Invited

IT-12-IN-3176 Towards 1.5λ resolution with low energy electrons

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The highest resolution aberration-corrected electron microscopes today, operating at 300 keV, achieve a spatial resolution of 50 pm, or about 25 times the wavelength of the electron, l. With the third-order spherical aberration of the objective lens compensated, this resolution is limited by chromatic aberration, fifth-order spherical aberration, parasitic aberrations, and various microscope instabilities. On the other end of the spectrum, Low Energy Electron Microscopy (LEEM) without aberration correction has achieved a spatial resolution of 4 nm at 3.5 eV, or about 6l. The resolution in such instruments is primarily limited by the spherical and chromatic aberrations of the uniform electrostatic field between sample and cathode objective lens. This uniform field is the first (virtual) image-forming element of the microscope. When used as a Photo Electron Emission Microscope (PEEM) resolution is usually limited to the range of 10-20 nm, depending on the details of the imaging conditions. In LEEM/PEEM aberration coefficients are strongly energy-dependent, and must be readily adjustable even in a single experiment, so as to track the aberrations as they change with electron energy.

Over the last several years we have developed an aberration-corrected LEEM/PEEM instrument[1], using a relatively simple catadioptric (i.e. electrostatic lens + mirror) correction system which provides independent control over the lowest order spherical and chromatic aberration coefficients, and the focal length of the correction optics. We have demonstrated the practical feasibility of aberration correction in LEEM/PEEM, achieving spatial resolution below 2 nm for the first time [2]. Detailed studies of the wave-optical image formation process show that resolution well below 1 nm is possible in principle [3].
In this talk I will review challenges and recent progress towards reaching the goal of a spatial resolution of just 1.5 times the wavelength of the electron in LEEM.

1. A new aberration-corrected, energy-filtered LEEM/PEEM instrument. I. Principles and design, R.M. Tromp, J.B. Hannon, A.W. Ellis, W. Wan, A. Berghaus, O. Schaff; Ultramicroscopy 110 (2010) 852

2. A new aberration-corrected, energy-filtered LEEM/PEEM instrument. II. Operation and results; R.M. Tromp, J.B. Hannon, W. Wan, A. Berghaus, O. Schaff; Ultramicroscopy 127 (2013) 25-39

3. A Contrast Transfer Function approach for image calculations in standard and aberration-corrected LEEM and PEEM, S.M. Schramm, A.B. Pang, M.S. Altman, R.M. Tromp; Ultramicroscopy 115 (2012) 88-108