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Image Calculation for Low-voltage Microscopy Based on Mutual Coherence Approach
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The aim of the SALVE (Sub-Angstrom Low-Voltage Electron microscope) project is to visualize low-Z materials with atomic resolution and minimum radiation damage by employing voltages in the range between 20 and 80kV. To understand the image contrast, it is necessary to perform image calculations. The conventional image simulations consider only elastic scattering, which suffices at medium voltages for most objects. However, because at 20kV all atoms are strong scatters, we must incorporate the effect of inelastic scattering in the image calculation. For inelastic scattering, the sample states and the incident wave are coupled. Therefore, we cannot ignore anymore excitations of the object as in the elastic case. Our approach is based on the mixed dynamic form factor and the light-optical concept of mutual coherence. However, this procedure still poses a big challenge for the computer since it involves 4D Fourier transforms. In order to reduce the computing time, it is necessary to look for suitable approximations to transform the 4D Fourier transform into 2D Fourier transforms. In this work we will present a new approximation which has the maximum similarity with the original function; and calculated EFTEM images based on it for voltages as low as 20kV and 40kV. We employed the experimental EELS spectra for the simulation of the EFTEM images. For mono-atomic layered structures, our approach takes one elastic scattering and one inelastic scattering into account; for multi-layered structures, our method can take two inelastic scattering and multiple elastic scattering into account. Our calculation shows convincingly the effect of inelastic and elastic double scattering within a mono-layered structure at 20kV, exemplified by graphene, as well as two inelastic scattering and multiple elastic scattering within multi-layered structure at 40kV, exemplified by Si<110> with the thickness of 54nm. The smaller the energy loss, the more delocalized is the inelastic process and the lower is the blurring of the image formed by the doubly (elastically and inelastic) scattered electrons. Energy filtered inelastic images are only visible when Cc is corrected. However, in order to obtain the same S/N ratio as for the elastic image, the dose must be 10^6 times higher.