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Coherent Imaging with Inelastically Scattered Electrons: High Resolution Object Contrast for a Sample Thickness Exceeding Several Free Mean Paths

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The last few years have seen an increasing interest in using low electron energies for imaging, stimulated mainly by the observation that object contrast increases and at the same time certain object damaging effects decrease - in particular for objects consisting of light atoms such as carbon [1]. This allows ideal imaging e.g. of graphene and might as well be applicable to organic molecules, macromolecular complexes and biopolymers or even assemblies of organic materials e.g. of technical polymers in organic electronic devices. Combined with the obvious advantages of lower energy one observes, however, decreasing mean free paths, i.e. electrons interact with higher probability and thus the imaging of thick objects is largely affected by multiple scattering. In the case of low atomic number materials this multiple scattering is then highly dominated by inelastic scattering. For typical preparations of macromolecular complexes e.g. embedded in ice, electrons at e.g. 20 keV energy will all be inelastically scattered when tested after passing through the object. Thus image formation for thicker objects has to be reconsidered, since conventional image formation theory does not take into account inelastic scattering. For a long time inelastically scattered electrons would have been exclusively associated to analytical studies and spectroscopic imaging modalities. Recently work by Röder and Lichte [2] has shown, that electrons which have lost energy in an inelastic interaction process still possess high spatial and temporal coherence. With this result in mind it is illustrative to study the image formation for thick samples in an aberration corrected TEM, which corrects both, geometrical as well as chromatic aberrations [4]. In such a TEM elastically and inelastically scattered electrons are imaged in the same image plane. This property allows imaging with electrons of different "color" without the usual image deterioration in conventional microscopes. It has been shown that in such a highly corrected microscope inelastic images with very high SNR can be recorded and also that high resolution Bragg reflections can be obtained in Power spectra of inelastic images of crystalline material [3]. Here we demonstrate, that "coherent inelastic multiple-scattering imaging" can be used for imaging of very thick samples of low-Z materials at moderate electron energies (in our case we performed electron tomography on 1 µm thick samples at 300keV). This corresponds to samples in the tens of nm range for low electron energies such as e.g. 20-40 keV. [1] Kaiser, U.; et al.; Ultramicroscopy 2011, 111(8), 1239-1264. [2] Röder, F.; Lichte, H.; European Phys J Appl Phys 2011, 54(3) 33504 (11pages). [3] Kabius, B.; et al.; JEM 2009, 58(3), 147-155. [4] ACAT (ANL Chromatic Aberration-corrected TEM) research supported in part by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, Contract No. DE-AC02-06CH11357 at the ANL EM Center