Quantitative atomic scale inelastic STEM imaging

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Z-contrast imaging in the scanning transmission electron microscope (STEM) has now become a routine technique for atomic scale imaging. Accompanied by developments like highbrightness guns and monochromators, improved electron energy-loss spectrometers or new Xray detector concepts, elemental-specific imaging at that scale has become feasible too. To date many examples of atomic resolution elemental maps have been published - mostly as color maps - often missing a profound explanation of the inelastic intensities and colors contained therein. As it turns out, the complex physics of scattering of the electron probe along aligned atomic columns produces a nonlinear relation between signal and composition and invalidates a simple relationship between the observed analytical intensities from the projected atomic positions.

Quantification of atomic resolution maps on an absolute scale (i.e. in units of atoms/nm3), is an even bigger challenge. First of all, the conversion of analytical intensities into concentration values for a particular quantification scheme often requires extra parameters that are not readily at hand. Secondly, to recover the true concentrations, approaches to compensate for channeling need to be taken into account. With the use of the so-called quantum excitation of phonons (QEP) model, for example, a calculation of the underlying elastic and thermal diffuse scattering is possible and quantitative comparisons between experiment and quantum mechanical calculations for both EDXS (energy-dispersive X-ray spectroscopy) and EELS (electron energy-loss spectroscopy) can be made. By implementing an inversion process, the correct numbers can be recovered approximately. Another possibility to reduce the effects of channeling is tilting or precessing the beam, with the drawback of losing resolution in the direction tilted. The signal obtained that way may serve, however, for normalizations of the channeled data set. Possibilities for a quantitative analysis on the atomic scale will be presented in this paper.