Precision measurements of atomic positions and displacements in aberration-corrected conventional transmission electron microscopy (CTEM)

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With the introduction of aberration-corrected electron optics, transmission electron microscopy has achieved single-atom resolution. Moreover, atomic structures can now be measured, atom by atom, with picometer-level precision. This is of outstanding importance, since atomic displacements in these dimensions are responsible for corresponding local changes in physical properties. This access to locally varying properties, e.g. at the unit cell level or at an internal interface or at a surface make transmission electron microscopy a unique tool in the study of materials.

The objective of this paper is to provide an overview of ultra-high precision measurements in the aberration-corrected conventional transmission electron microscope (CTEM) [1]. The starting point of such measurements is the fact that the high precision can only be achieved indirectly, by proper refinement of the experimental data. A central element is the calculation of the image by iterative solution of the Schrödinger equation, where the unknown sample parameters as well as the only imprecisely known optical parameters enter as variables. The model, both of the specimen and of the imaging process itself, obtained on the basis of an optimal fit (at absolute value of the image contrast) to the intensity distribution in the experimental image, represents the actual result of the investigation.

The value of atomic resolution electron microscopy as a quantitative measuring technique for physical investigations depends crucially on the extent to which it is possible to quantify the measurement errors [2,3,4,5]. The key measure here is the precision, expressed by the standard deviation, which refers to the closeness of agreement between the individual measurement results.

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