Exploring the atomic world by aberration-corrected electron microscopy

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To be able to observe atoms in solids has been an old dream in materials science. Unfortunately all attempts undertaken between the invention of the electron microscope in the 1930s and the end of the 1980s, to find a way to correct lens aberrations in electron optics and to venture into atomic dimensions failed entirely. The reason for this lies in a fundamental law of physics: Gauss Law of Magnetism, one of Maxwell's equations, prohibiting the construction of diverging lenses which according to Abbe's principles of optics are indispensable for lens aberration correction. Between 1991 and 1997 Haider et al. [1] could show that this obstacle can be overcome employing magnetic multipole lenses, and on this basis they succeeded to construct the world's first aberration-corrected transmission electron microscope.

The new generation of commercial electron microscopes based on this invention brought about a change in paradigm in materials science. Atomic resolution investigations, by both conventional transmission (TEM) and by scanning transmission (STEM) electron microscopy are today part of most innovative materials studies. This includes not only structural investigations but also atomically resolved local elemental analysis by quantitative contrast analysis and by atomically resolved electron-energy loss spectroscopy (EELS).

The lecture will start with a historical overview and an introduction into the secrets, i.e. the principles of aberration correction in modern electron optics. In the second half typical examples of atomic-resolution electron microscopy of materials will be introduced. In fact it is intriguing that today by combination of modern electron optics with computer-based image analysis atomic positions can be measured at the precision of 1 picometer, i.e. one hundredth of the diameter of a hydrogen atom.

[1] M. Haider, S. Uhlemann, H. Rose, B. Kabius & K. Urban, Nature 392, 768 (1998).