In-situ AFM measurements of $SrTiO_3$ and Co particles inside an electron microscope

atto**cube** systems offers a comprehensive line of products which are compatible with ultra high vacuum and cryogenic conditions. Recently, we have extended our product family by developing an Atomic Force Microscope (AFM) series designed for *in-situ* use inside Scanning Electron Microscopes (SEM) or environmental SEM (ESEM). This new series of ultra-compact AFMs allows scientists to perform high-resolution topographic, magnetic, or tensile strength measurements in material science, structural biology, solid state physics, and other fields of nanotechnology. Depending on the specific application, two different AFM versions are available: a cantilever based AFM with interferometric deflection detection and a tuning fork AFM.

Due to its typically soft cantilever, the AFM with interferometric deflection detection is perfectly suitable for experiments where very small interaction forces are measured, such as magnetic or electrostatic forces. In addition, tensile measurements form an intrinsic capability of this type of AFM thanks to its metrologically relevant cantilever deflection measurement. In contrast, the tuning fork based AFM shines due to its ultra-compact size, its ease of use, and its ultra-high spatial resolution.

In this application note, atto**cube**'s tuning fork based AFM was operated inside a LEO 1530 scanning electron microscope at the University of Bielefeld, Germany, see Fig. 1. While the tuning fork concept has already demonstrated to work reliably inside an SEM, it was yet to be determined whether this specific environment would also allow high resolution topographic measurements. Specifically the influence imposed by the electron beam (with currents typically one to three orders of magnitude larger than current induced by the tuning fork) and mechanical vibrations on the nanometer scale were expected to seriously constrain the achievable resolution. Despite these considerations, even atomic resolution topographic imaging was achieved with atto**cube**'s *in-situ* AFM, see Fig. 2a. It turns out, however, that AFM measurements with this high resolution can only be obtained on areas which have not been imaged by SEM beforehand. This can be explained by the electron beam induced dissociation of carbon molecules and subsequent adsorption of carbon on the surface.

In a second set of experiments, the attoAFM was used to image Co nanoparticles embedded in an organic matrix, see Fig. 3. Apart from its high resolution imaging capabilities, the tuning fork AFM also allows a more quantitative analysis of the imaged surface. For example, the local surface viscoelasticity can be determined from the dissipation of the tuning fork, a parameter inaccessible by SEM. By further using an Akiyama probe with reduced stiffness, other information such as surface magnetism or local electric charge becomes accessible.
In addition to all of these benefits, it is worth mentioning that the tuning fork AFM, measuring only in non-contact mode, is a true non-invasive instrument.

*Figure 1: atto**cube**'s tuning fork based attoAFM mounted inside a LEO 1530 Scanning Electron Microscope equipped with a laser interferometry table for electron lithography (Group of Prof. Reiss, University of Bielefeld, Germany).*

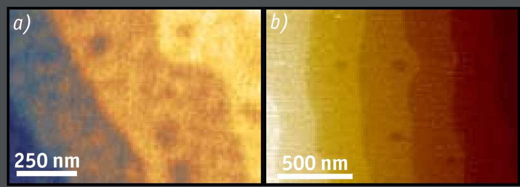

*Figure 2: Tuning fork AFM images of $SrTiO_3$ showing atomically resolved steps. In a), recorded inside the SEM, the surface is partially covered with carbon atoms. In contrast, b) was recorded in UHV conditions and shows a perfectly clean surface (Group of Prof. Reiss, University of Bielefeld, Germany & atto**cube** application labs, 2009).*

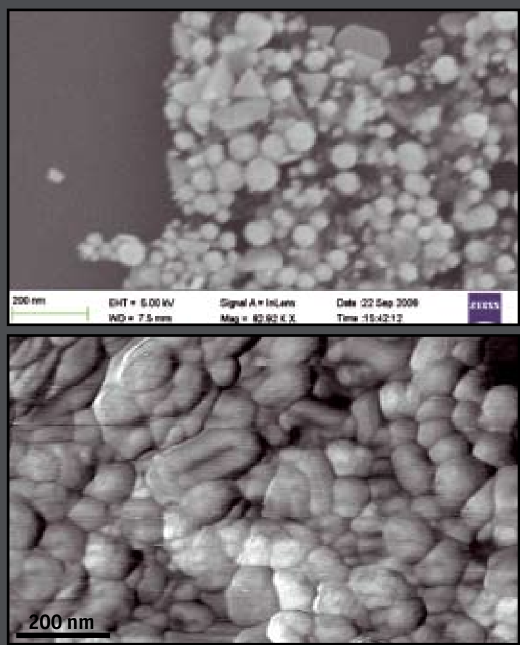

Figure 3: Scanning Electron Microscope (top) and tuning fork phase image (bottom) of magnetic Co particles confined in an organic matrix. The dark-white contrast in the AFM image corresponds to a phase-shift of 15 degrees (Group of Prof. Reiss, University of Bielefeld, Germany).

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