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Multi-dimensional Scanning Probe Microscopy

HANS J. HUG, Empa, Materials Science and Technology, CH-8600 Duebendorf, Switzerland and Institute of Physics, University of Basel, CH-4056 Basel, Switzerland

Since the first demonstration of true atomic resolution with a scanning force microscope in 1995 a large variety of samples have been imaged with atomic resolution. In 2000 Giessibl obtained atomic resolution with a (macroscopic) tuning fork operated with small oscillation amplitudes that correspond to the length of the inter-atomic interaction potentials. However, tuning fork sensors have a series of disadvantages that can all be overcome by optimized micro-fabricated cantilevers operated at similarly small or even smaller oscillation amplitudes. With their small mass and high mechanical quality factor, particularly after appropriate annealing in UHV force sensitivities that are orders of magnitude better than that of tuning forks and also far better than that of the best NEMS sensors is obtained. Recently Kawai et al and Sugimoto et al obtained atomic resolution with cantilevers with a operated in higher oscillation modes with sub-nanometer amplitudes. In order to make use of the excellent force sensitivity we developed a Fabry-Perot type interferometer optical sensor that maps flexural and torsional cantilever oscillations with fm/sqrt(Hz) deflection sensitivity. This deflection sensor allows the use of sub-Å cantilever oscillation amplitudes and thus the direct measurement of atomic interaction force gradients and, – in principle, the use of advanced tunnelling spectroscopy techniques that are well-established in the field of scanning tunnelling microscopy. The simultaneous mapping of flexural and torsional oscillation modes further allows the measurement of vertical and lateral tip-sample interaction forces and corresponding atomic scale energy loss processes.