Fabrication, characterization and modelling of force sensors and tips

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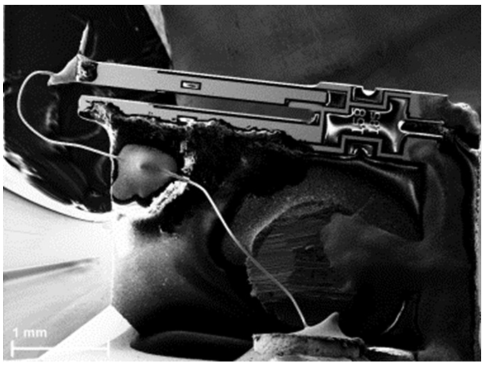
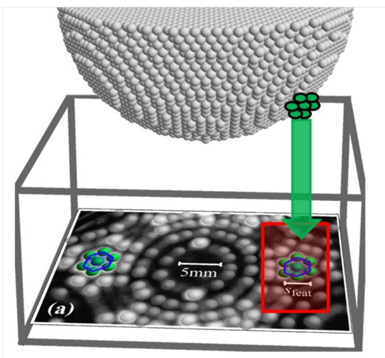
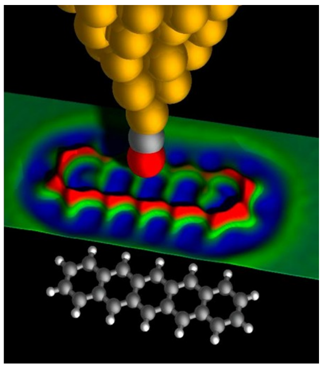
Non-contact atomic force microscopy allows measurement of the force interaction between a sharp tip and a sample surface with atomic scale precision. Usually, the surface atom identities as well as their positions are known from the high resolution surface scan. Further, the exact force interaction curves can be obtained by force spectroscopy techniques, i.e. measuring the frequency shift as a function of tip sample distance. However, interpretation of those force curves depends critically not only on the surface atoms, but equally on the exact tip structure and tip atom termination. This information is usually unknown making image contrast interpretation ambiguous. Secondly, quantitative force curves rely on force sensor calibration, which is a recurring issue in the nc-AFM community.

In this lecture I will review the current state of force spectroscopy techniques, from point spectroscopy to full 3D force field acquisition [1]. Force curve interpretation with respect to different force contributions from dispersion forces, electrostatic forces and chemical forces is discussed. The two mainly used force sensors, i.e. cantilever beams and quartz crystal tuning forks, are introduced, as well as the corresponding force calibration methods with recent modelling approaches. In the last part, I will focus on current strategies to resolve the unknown tip atom problem from the experimental point of view. One possibility is to use field ion microscopy, which allows atomic scale tip imaging and interpretation of sharp metal tips [2]. A further approach is to pick-up surface atoms or molecules of known identity, and use those functionalized tips for imaging and force curve acquisition. In particular the latter method has revolutionized imaging of surface molecules, making nc-AFM a powerful tool for studying surface confined chemical reactions mechanisms.







[1] A. Schirmeisen, H. Hölscher, and U.D. Schwarz "Force Field Spectroscopy in Three Dimensions" in: Noncontact Atomic Force Microscopy II, ISBN 3642014941, Edts. Morita, Wiesendanger, Meyer, Springer (2009), pp.95
[2] J. Falter, G. Langewisch, H. Hölscher, H. Fuchs and A. Schirmeisen, "Field ion microscopy characterized tips in noncontact atomic force microscopy…", Physical Review B 87 (2013) 115412
[3] L. Gross, F. Mohn, N. Moll, P. Liljeroth, G. Meyer, "The Chemical Structure of a Molecule Resolved by Atomic Force Microscopy, Science 325 (2009) 1110