Non-contact atomic force microscopy - an introduction

Michael Reichling
Fachbereich Physik, Universität Osnabrück, Barbarastr. 7, 49076 Osnabrück, Germany
reichling@uos.de

Non-contact atomic force microscopy (NC-AFM) is a dynamic technique for exploring the field of forces by a sharp tip oscillating above a surface. Although, the forces measured are always of electromagnetic nature, the details of the tip-surface interaction may be very different and allow the measurement of many properties like the surface atomic structure, nanostructure, charge and polarisation, chemical affinity and magnetic interactions. A clear identification and quantitative description of the measured quantities, however, always requires a combination of experimental results with rigorous modelling of the forces acting between the tip and the surface as well as a precise characterisation of the force probe. Meaningful and accurate results are obtained in experiments with a tip well suited for the respective task and a measurement and control system optimised in its transfer functions for the pre-set experimental parameters, the probe dynamics and the tip-surface interaction.

The basic idea of NC-AFM is to keep the tip mounted on an elastic probe system in constant oscillation and to periodically probe the tip-sample interaction over a certain range of tip-surface distances. For a probe system of sufficient stiffness, the restoring force will always be larger than any adhesive force and the tip will not snap into contact to the surface. This allows the experimentalist to precisely position the tip by the proper choice of cantilever-surface distance and oscillation amplitude and to probe the tip-sample interaction either over a large range of the tip-sample interaction curve or differentially at a certain point above the surface. For high resolution imaging, it is advantageous to choose a working point close to the minimum of the tip-sample force where short range interactions between tip and surface atoms can best be separated from the background of longer range tip-surface interactions. The interaction between tip and sample introduces a slight anharmonicity in the otherwise harmonically oscillating probe system. This anharmonicity can be measured by various methods. The most common method is to stabilise the oscillation amplitude by a feedback control loop and measuring the cantilever resonance frequency f_{int} as a function of the tip-sample interaction while alternatively the interaction-induced change in amplitude of the probe system excited to oscillation at a fixed frequency close to the resonance frequency can be measured.

The basic principles, components and parameters relevant in NC-AFM are introduced and a rational approach towards "best practice" NC-AFM imaging and force mapping is discussed.