LINEAR AND NONLINEAR CONTACT RESONANCE SPECTROSCOPY IN ATOMIC FORCE MICROSCOPY

S. Hirsekorn, U. Rabe, D. Rupp* and **W. Arnold**
Fraunhofer Institute for Non-destructive Testing (IZFP), Bldg. E 3.1, University,
D-66123 Saarbrücken, Germany
*Present address: Institut für Angewandte Physik, Universität Karlsruhe, Wolfgang-Gaede-Straße 1, 76131 Karlsruhe, Germany

Several techniques combine atomic force microscopy with ultrasonics. In atomic force acoustic microscopy the cantilever is forced to ultrasonic vibrations while the tip is in contact with a sample surface. The various physical forces acting between the tip and the surface depend nonlinearly on the distance. Linear approximations are restricted to tip-sample displacements covering small parts of the interaction force curve, which is realized for example at high static loads and small amplitudes of the cantilever and the sample surface vibrations. In this case, the tip-sample contact can be modelled as a system of linear springs and dashpots. The quantitative evaluation of contact resonance frequencies of an AFM cantilever yields the contact stiffness, and eventually the local indentation modulus of the sample if the material properties and the geometry of the cantilever and the sensor tip are known. With increasing vibration amplitudes the nonlinearity of the forces becomes noticeable by generation of higher harmonics in the spectrum of the cantilever vibration. A frequency dependent transfer function can be derived from the model of the cantilever as a beam with constant cross-section using the differential equation for flexural vibrations. By multiplying the transfer function with experimental spectra the nonlinear contact and adhesion forces were calculated as a function of time. In-situ measurements of the cantilever and the sample vibrations acquired with the combination of a commercially available atomic force microscope (AFM) and a calibrated heterodyne Mach-Zehnder-interferometer are presented. This allowed us to reconstruct the tip-sample interaction forces as a function of tip-sample distance.