NT-MDT
Molecular Devices and Tools for NanoTechnology

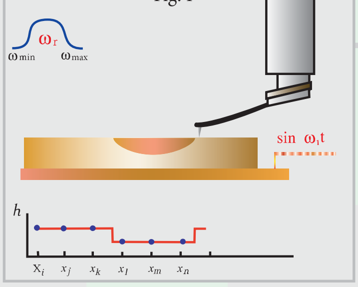
Atomic Force Acoustic Microscopy - the unique tool for qualitative and quantitative analysis of elastic properties of different materials

AFAM UNIT

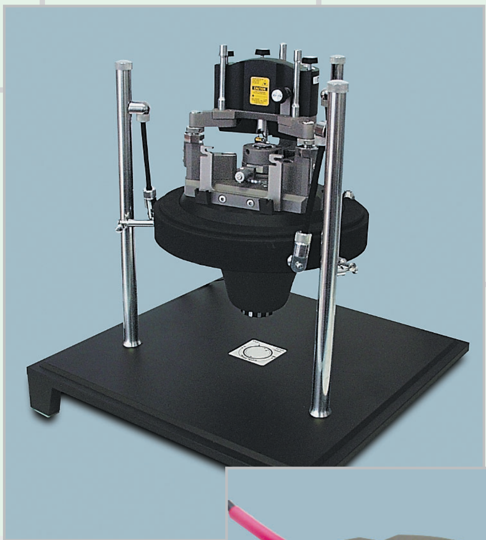
Atomic Force Acoustic Microscopy is a new SPM measuring mode developed at the Fraunhofer Institute of Nondestructive Testing, Saarbruecken, Germany [1, 2]. This technique, licensed to NT-MDT, allows the measurement of qualitative and quantitative local elastic properties of different materials.

The basic idea is to excite the cantilever of an atomic force microscope into flexural vibrations when the tip is in contact with the sample (Fig. 1). The frequency of the eigenmodes of the cantilever depends, amongst other parameters, on the stiffness of the tip-sample contact and on the contact radius, which in turn are both a function of the Young's modulus of the sample and the tip, the tip radius, the load exerted by the tip, and the geometry of the surface. Such a technique allows one to determine the Young's modulus from the contact stiffness with a resolution of a few tens of nanometers, mode sensitivity is about 5%.

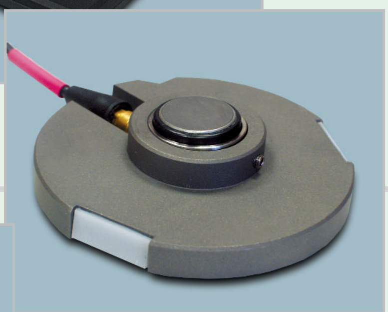
Fig. 1



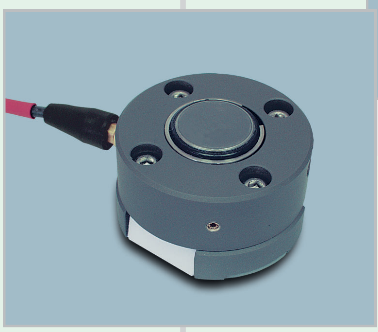
In the AFAM setup the sample is coupled to a piezoelectric transducer. It emits longitudinal acoustic waves into the sample, which cause out-of-plane vibrations of the sample surface. The surface vibrations are transmitted into the cantilever via the sensor tip. The cantilever vibrations are measured by a 4-sectioned photo-diode and evaluated by a lock-in amplifier. This setup can be used either to acquire cantilever vibration spectra or to take acoustic images. The latter are maps of cantilever amplitudes on a fixed excitation frequency near the resonance. The contact-mode topography image is acquired simultaneously with the acoustic one. The frequency range employed covers the flexural modes of the cantilever from 10 kHz up to 2 MHz.



Solver P47H with AFAM set up



Ultrasonic transduser



Technical specification

Lock-in amplifier:

Operation frequency:	up to 2 MHz (step - 0.01 Hz)
Input amplification:	1-1000
Output LP filters:	DC to 0.1-50 kHz
Output signals:	I, Q rectangular components; Module signal
Detection of up to	9 harmonics

Acoustic transducer:

Frequency:	10 kHz - 3 MHz (2.25MHz central frequency)
Element size:	0.5 in diameter

Highlights

1. AFAM is a state-of-the-art SPM technique that can be used to map variations in surface elastic properties of soft as well as very hard samples where other techniques, such as Phase Imaging or Force Modulation, fail.

2. AFAM enables to measure elastic properties of thin films, that can not be measured with the use of other techniques.

3. With AFAM it is possible to perform numerical calculations of hardness and Young's modulus. This unique opportunity is included in the software as an option based on the theory of Prof. Walter Arnold.

4. The contrast of AFAM images is much sharper compared to those obtained in Phase Imaging or Force Modulation mode.

5. AFAM can be operated in air as well as in a liquid environment (in a droplet).

6. AFAM is a non-destructive technique.

AFAM package

AFAM package includes:
- AFAM mode user license;
- AFAM software upgrade;
- Acoustic transducer;
- Cables;
- Description and application manual.

References

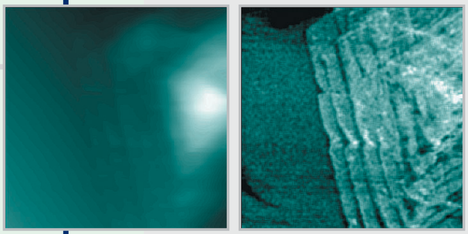
[1] U. Rabe, S. Amelio, E. Kester, V. Scherer, S. Hirsekorn, and W. Arnold, "Quantitative determination of contact stiffness using atomic force acoustic microscopy", Ultrasonics 38 (2000) 430-437.

[2] U. Rabe, S. Amelio, M. Kopycinska, S. Hirsekorn, M. Kempf, M. Goeken, and W. Arnold, "Imaging and measurements of local mechanical material properties by atomic force acoustic microscopy", Surf. Interface Anal. 2002; 33: 65-70.

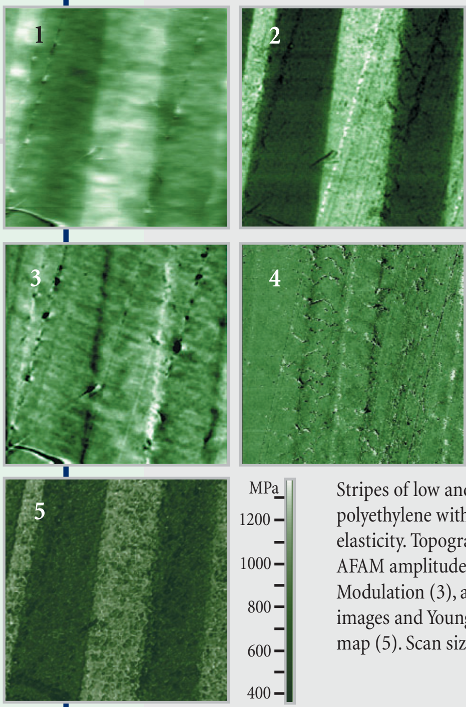
[3] . Rabe, E. Kester, and W. Arnold, "Probing Linear and Nonlinear Tip-Sample Interaction Forces by Atomic-Force Acoustic Microscopy", Surface and Interface Analysis 27, 386-391(1999)

[4] M. Muraoka and W. Arnold, "A Method to Evaluate Local Elasticity and Adhesion Energy Based on Nonlinear Response of AFM Cantilever Vibration", JSME International Journal, A44, 396-405, 2001.

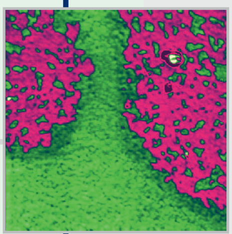
[5] U. Rabe, S. Amelio, S. Hirsekorn, and W. Arnold, "Imaging of Ferroelectric Domains by Atomic Force Acoustic Microscopy", Proc. 25th Acoustical Imaging, Halliwell, M. and Wells, P.N.T. (Eds.), Kluwer Academic Publishers, New York, 253-260 (2001).



Rhombic polyethylene crystal on mica substrate. Contact Mode Topography (left) and AFAM (right) images. Scan size: 7x7µm.

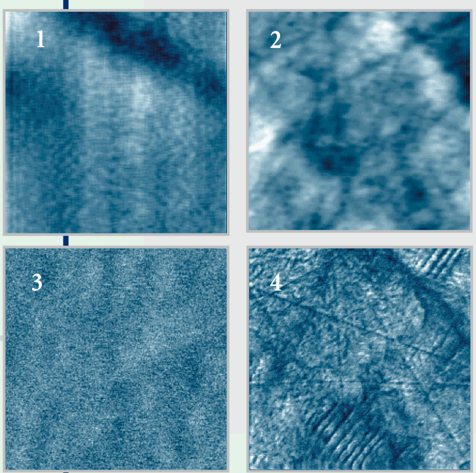


Stripes of low and high density polyethylene with different elasticity. Topography (1), AFAM amplitude (2), Force Modulation (3), and Phase (4) images and Young Modulus map (5). Scan size: 47x47µm.



Composite protein film. AFAM image of areas with different components. Scan size: 3x3µm.

Polished PZT sample of 1mm thickness. Contact Mode Topography (1), Force Modulation (2), Phase Imaging (3) and AFAM images (4) of stripe ferroelectric domains. Scan size: 4x4µm.



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