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An approach to Young's modulus determination for atomic-force microscope with interferometric cantilever-deflection system

N.V. Andreeva

Peter the Great St. Petersburg Polytechnic University, 195251, Saint-Petersburg, Russia
nvandr@gmail.com

Interferometric optical deflection system is used in atomic-force microscopes with a closed cycle cryostat for low temperature measurements. A conventional interpretation of force-distance curve for Young's modulus determination could not be applied in this case. For this purpose another approach for Young's modulus determination was developed.

A common method of Young's modulus determination by means of atomic-force microscopy is based on a registration of force-distance curves. These curves represent a displacement of the cantilever while it approaches or withdraws the sample surface. To measure the beam displacement a beam-deflection method is conventionally used. In this method a laser beam reflected off the back of the cantilever is registered with a position-sensitive photodetector. The intensity of the collected by the detector light is proportional to the cantilever displacement and could be recalculated to the force acting from the sample surface on the cantilever. For this purpose a well-developed calibration methods are used.

In some application, there is a necessity to modify a design of an optical cantilever deflection system of atomic-force microscopes due to geometrical reasons. For example, for low temperature measurements an atomic-force microscope is sometimes combined with a two stage closed-cycle cryostat. In this setup, the lack of space in the cryostat led to the modification of the cantilever deflection system. An optical interferometric method is implemented to measure the cantilever displacement. In this method a laser beam is delivered to the cantilever with an optical fiber, reflected off its back and collected again with a polished end of the same fiber, so, an optical interferometer Fabry-Perot is composed by the polished end of the optical fiber and the back of the cantilever. An intensity of the signal from this interferometer is proportional to the cantilever displacement. Thus, for force-distance curve interpretation, an interferograms are used. The problems should be solved in this case, are 1) finding a tip-surface contact point on the base of registered interferograms; 2) determination the part of the force-distance curve corresponding to the indentation regime correctly; 3) measurements the value of the tip-surface indentation. Moreover, as a combination of atomic-force microscope with a cryostat is used for low temperature measurements, it is necessary to take into account the dependence of the cantilever force constant on temperature.

In this work an approach for force-distance curve interpretation in case of interferometric cantilever-deflection system was developed based on the measured interferograms. The comparison of the results of Young's modulus determination with a common beam-deflection optical system with position sensitive photodetector and interferometer-based optical system was performed for room temperature. The temperature dependence of the cantilever's spring constant was measured in the temperature range of 30 – 295 K. Sader method [1] was used for the cantilever spring constant determination at each temperature point. A model experiment for the determination of the Young's modulus temperature dependence of the polylysine with the developed approach was conducted. The results show the nonlinear increase of the polylysine Young's modulus with temperature decrease. The nonlinear dependence is supposed could be conditioned by the structural modification of the polylysine caused by low temperatures.

1. J.E. Sader, J.W.M. Chon, P. Mulvaney, *Rev. Sci. Instrum* **70** (1999).