Prototype Cantilevers for AFM Lateral Force Measurement

CNF Project # 1273-04

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Abstract

One of the major difficulties in calibrating the lateral forces measured with optical lever atomic force microscopy is in determining the lateral optical lever sensitivity. Novel cantilevers have been designed and fabricated to simplify this measurement and pave the way for accurate calibrated cantilevers in which normal and lateral forces (e.g. from friction) can be easily measured.

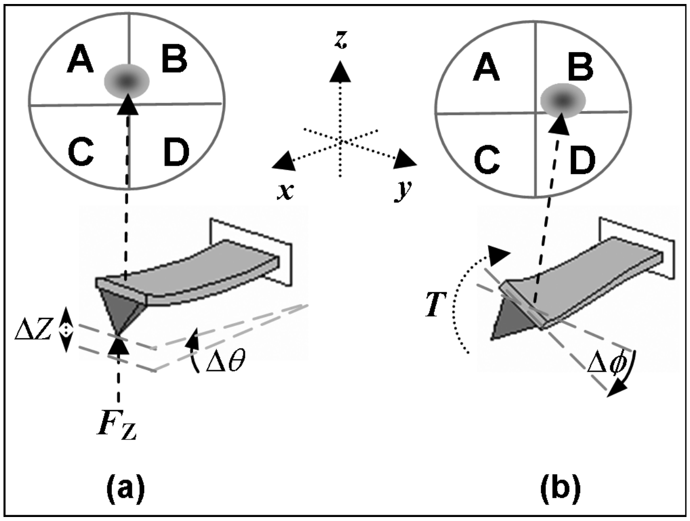

Figure 1: Normal (a) and torsional (b) deflection of an AFM cantilever.

Lateral (Friction) Force Microscopy

Atomic force microscopy (AFM) is widely used today to image surfaces and measure nanoscale forces. The most common form of AFM relies on a laser beam reflecting off the back of a cantilever to provide feedback on interaction of the cantilever tip with the surface of interest. The two most common deflections measured during surface interaction are normal and torsional, as depicted in Figure 1 (a) and (b), respectively. To accurately convert the observed AFM cantilever deflections to normal force and friction using contact AFM requires both accurate cantilever spring constant (stiffness) calibration for both normal and torsional deformation, as well as the determination of the normal and lateral sensitivity of the optical lever. Calibration of the normal spring constant and normal optical lever sensitivity is relatively straightforward using the reference cantilever technique and suitable SI traceable cantilever artifacts [1]. Calibration of the torsional spring constant and torsional optical lever sensitivity, needed for friction measurement, is more difficult.

Lateral Force Microscope Calibration Using a Modified Cantilever

One of the most straightforward methods of applying a known torsion to a cantilever involves fixing a lever to the cantilever and applying a force to the end of the lever arm as

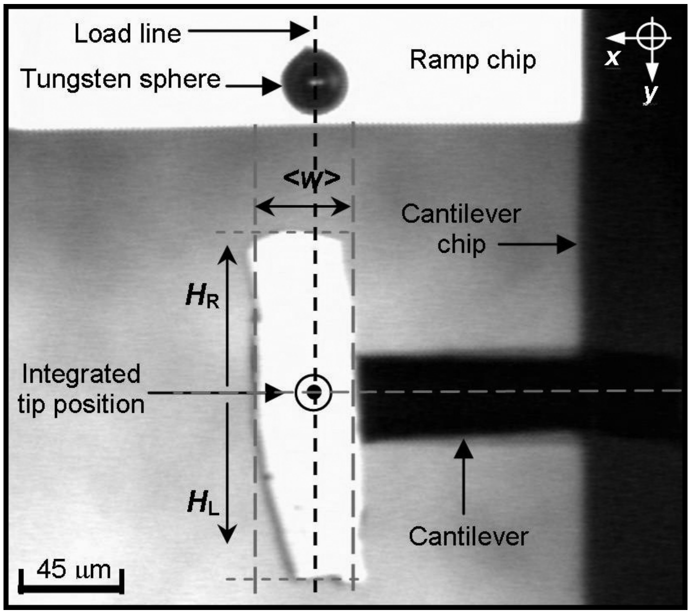

Figure 2: Cross piece attached to an AFM cantilever.

in the technique of Feiler, et al. [2]. More recently, a refined version of this technique was demonstrated by Reitsma [3] in which a cross piece was glued to a cantilever forming a double lever arm (Figure 2). Application of a series of forces at different lever arm distances were performed to more precisely determine the torsional optical lever sensitivity (by a factor of 5 over Feiler) and demonstrate the principles of the new method.

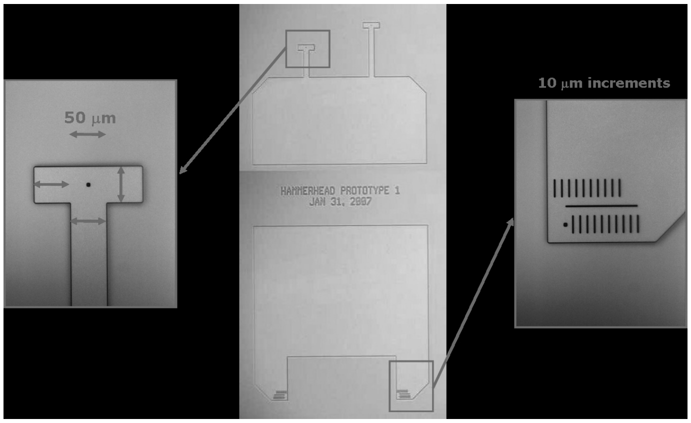

Figure 3: Microfabricated cantilever prototype incorporating cross piece.

Prototype Microfabricated Lateral Force Cantilever

A new cantilever has been designed that incorporates the cross piece into a microfabricated cantilever beam. The front side design pattern, shown in the white light interferometric microscope images in Figure 3, provides three important features. The basic handle die (central image) allows the device to be easily utilized in a commercial AFM. Two cantilevers with different normal and torsional spring constants extend over the front edge of the handle die. The cutout at the bottom of the handle die provides the means to calibrate the optical lever sensitivity using a different die. It incorporates a positioning mark and fiducial marks to aid in the placement of the cantilever during the critical torsional optical lever sensitivity measurement. Pressing the cantilever down on the edge of this feature while lined up with the fiducial marks allows known amounts of torque to be applied to the cantilever. A series of these measurements taken at different lever arm lengths then defines the torsional optical lever sensitivity in a precise way.

The device was patterned on silicon-on-insulator wafers using optical lithography and etched using deep reactive ion etching (DRIE). Back side alignment was used to match the handle chip to the front side pattern. Final release of the structure was accomplished with buffered oxide etch (HF).

The microfabricated prototypes are currently being evaluated for their ability to measure the torsional optical lever sensitivity precisely. Torsional spring constants, measured using a calibrated instrumented indenter, will also be compared to Euler-Bernoulli theoretical models based on dimensional measurements and material properties for these experimental cantilevers.

References

[1] Gates, R. and Pratt, J. , "Prototype cantilevers for SI-traceable nanonewton force calibration," Meas. Sci. Technol. 17 No 10 2852-2860 (2006).

[2] Feiler, A., Attard, P., Larson, I., "Calibration of the torsional spring constant and the lateral photodiode response of frictional force microscopes," Rev. Sci. Instrum. 71(7):2746-2750 (2000).

[3] Reitsma, M., "Lateral Force Microscope Calibration using a Modified AFM Cantilever" submitted to Exp.Mechanics (2007).