

Prototype Cantilevers for AFM Nanomechanical Property Measurement

CNF Project # 1273-04

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National Institute of Standards and Technology

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Category:

Mechanical Devices

Abstract:

Atomic Force Microscopy (AFM) is a widely used technique for imaging surfaces and measuring properties at the micro and nano-scales; however, the accuracy and precision of these measurements is hampered by the lack of suitable traceable standards and precision measurement methods. The purpose of this project is to explore potential cantilever designs as calibration reference artifacts and probes for making precise nanomechanical property measurements.

Summary of Research:

This project utilizes microfabrication using silicon-on-insulator (SOI) materials to create cantilever devices for calibration and nanomechanical property measurement. Our first device, a reference cantilever array [1] was first successfully prototyped in 2006 as a means of providing a Systeme International (SI)-traceable pathway for calibration of AFM test cantilevers in the field. It is now in the final stages of production and certification. The second device, the "Hammerhead" cantilever [2], was more recently developed to overcome difficulties in torsional optical lever sensitivity measurement in an AFM and it enables accurate friction measurements on surfaces. During the past year we have been refining the design for optimal performance and adding integrated tips to simplify the measurement process for users.

Hammerhead Cantilever Prototypes:

The Hammerhead cantilever is essentially a rectangular cantilever modified with distinctive lateral appendages which make it easier to calibrate for friction measurements (Figure 1). The appendages are pressed down onto surface features (edges or points) to allow calibration of the torsional optical lever sensitivity from which friction can be determined. Early prototypes of this cantilever design were tipless and could only be used after a sphere was attached to the end of the device. The small hole near the end of the cantilever seen in figure 1 was used as an alignment feature for placement of the sphere which usually ranged from 10 μm to 50 μm in diameter. More recently, we have been investigating the use of reactive

ion etching (RIE) and combinations of RIE and deep reactive ion etching(DRIE) to fabricate tips that might be integrated into the Hammerhead design to enable friction measurement without requiring the addition of spheres to the end of the cantilever.

Two types of tips (regular and rocket) were prepared. First, a thermal oxide was grown on top of silicon. Optical lithography was used to pattern a circular disk on the oxide and RIE was used to anisotropically etch away the oxide layer outside the disk. RIE was then used to isotropically etch away the underlying Si in a manner that would undercut the oxide mask and produce the regular tip shown in figure 2. The oxide was removed using HF, leaving a sharp tip protruding from the surface. The rocket tip design followed the same process with a DRIE step between the isotropic Si RIE etch and the HF wet etch which created a longer shaft as shown in figure 3. The advantage of this design is that it provides a longer lever arm for torque during sliding, making the cantilever more sensitive to this lateral force.

Versions of these prototype tips will be incorporated into the final Hammerhead cantilever design.

References:

- [1] Gates, R.S. and Pratt, J.R. , “Prototype cantilevers for SI-traceable nanonewton force calibration,” Meas. Sci. Technol. 17 No 10 2852-2860 (2006).
- [2] Reitsma, M.G., "Lateral force microscope calibration using a modified atomic force microscope cantilever," Rev. Sci. Instrum. 78, 106102 (2007).

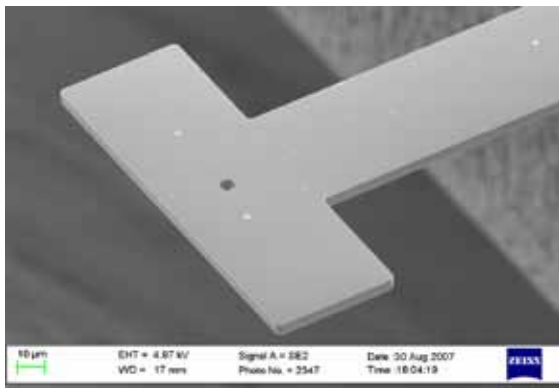


Figure 1. End of prototype Hammerhead cantilever.

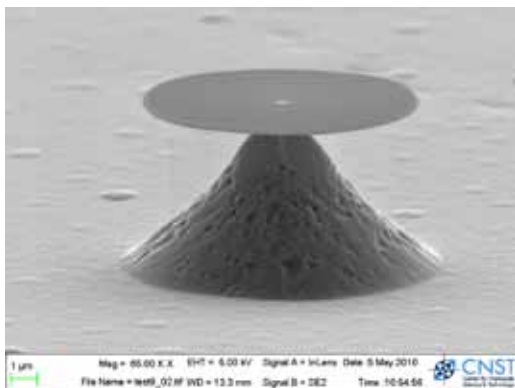


Figure 2. Regular tip prototype made with RIE.

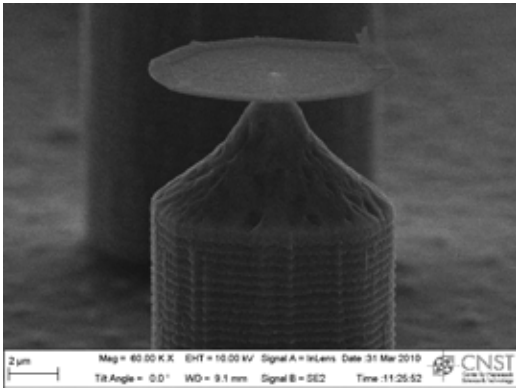


Figure 3. Rocket tip prototype made with RIE and DRIE.