Design and Construction of a Variable Temperature Atomic Force Microscope

Bethany Little and Brandon Hoffman. Department of Physics, Houghton College, One Willard Avenue, Houghton, New York 14744.

ABSTRACT

A variable temperature atomic force microscope is being constructed at Houghton College. The microscope will operate in a rough vacuum and will utilize spring vibration isolation and eddy current damping to minimize mechanical vibration. A modified "Johnny Walker" beetle is being constructed for the rough approach. The sample will be mounted onto the walker scanning head and scanned across a fixed cantilever tip and laser assembly. When completed, resolution should be on the order of nanometers. Liquid nitrogen and resistive heating will allow operation from ~100 K to 500 K.

THEORY

There are three modes of operation for the atomic force microscope:

Contact Mode

In this mode, the tip is dragged across the sample. The sample is moved up and down so that the laser beam reflected off the cantilever tip enters the sensor at a constant angle. This is accomplished by a feedback loop circuit which includes the up and down motion of the sample thus parallels the topography of the sample.

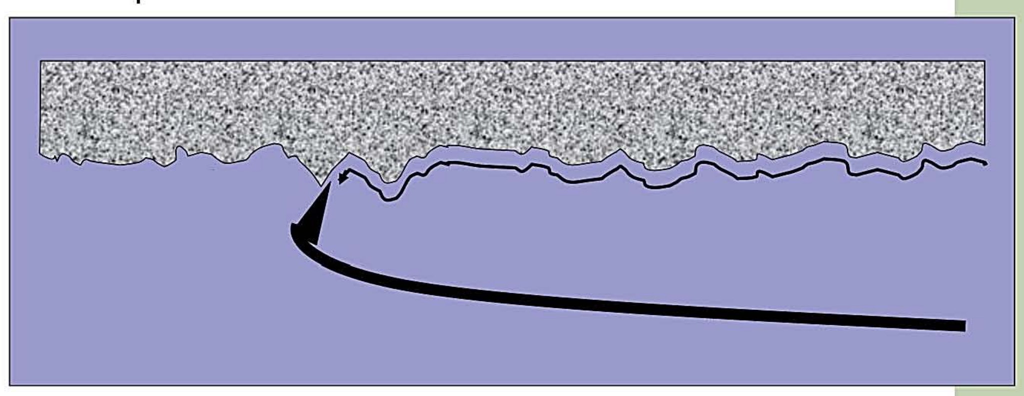

Figure 1: sample and Tip in Contact Mode

Tapping Mode

In this mode, the cantilever tip is set oscillating at its resonant frequency. As the sample is brought close to the tip, the tip touches the sample and the frequency of the oscillations change. The sample is then moved using the feedback setup so that the frequency of the oscillations remains constant. The movement of the sample corresponds to the topography of the sample.

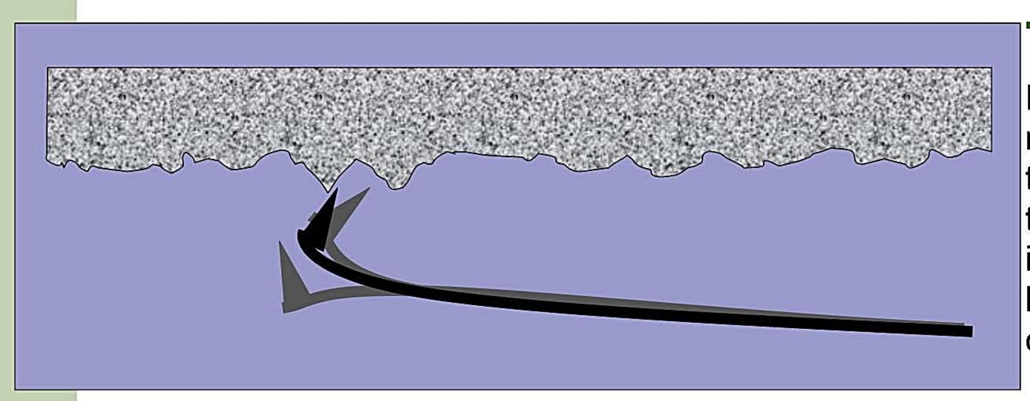

Figure 2: sample and Tip in Tapping Mode

Non-Contact Mode

This mode is very similar to Tapping Mode, except that the sample is not brought close enough to the tip to make contact. Instead, inter-molecular forces between the sample and the tip damp the oscillations. This allows mapping of the inter-molecular forces on the sample surface.

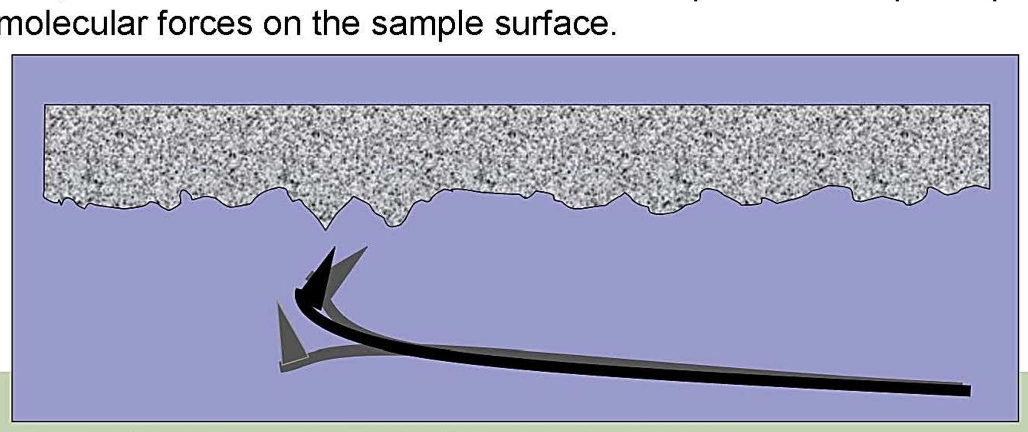

Figure 3: sample and Tip in Non-Contact Mode

MOTIVATION

A Variable Temperature Atomic Force Microscope will be of great use to not only the physics department, but all of the science departments at Houghton College. It will provide topographical scans of many different surfaces, and will allow further study of surfaces such as thin metal films.

DESIGN

(See Figure 6)

Movement of the Sample

The sample mount rests on three piezo-electric legs (1) which "walk" down a ramped platform, bringing the sample (2) closer to the cantilever tip (3). The legs, which expand and contract according to the voltage put across them (figure 4), are connected to a circuit. By controlling the voltage applied to different parts of each leg, the legs can bend and twist, moving the sample mount up and down the ramp. The sapphire balls at the end of the legs enable stick-slip motion. The legs also enable the sample to scan back and forth across the cantilever tip.

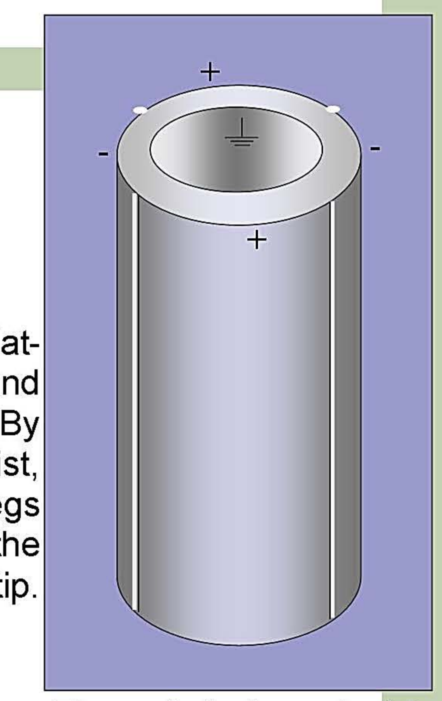

Figure 4: A piezo-electric leg, with four electrodes on the outside and the inside tied to ground, as shown. The ceramic of the tube expands according to the voltage gradient across the electrodes

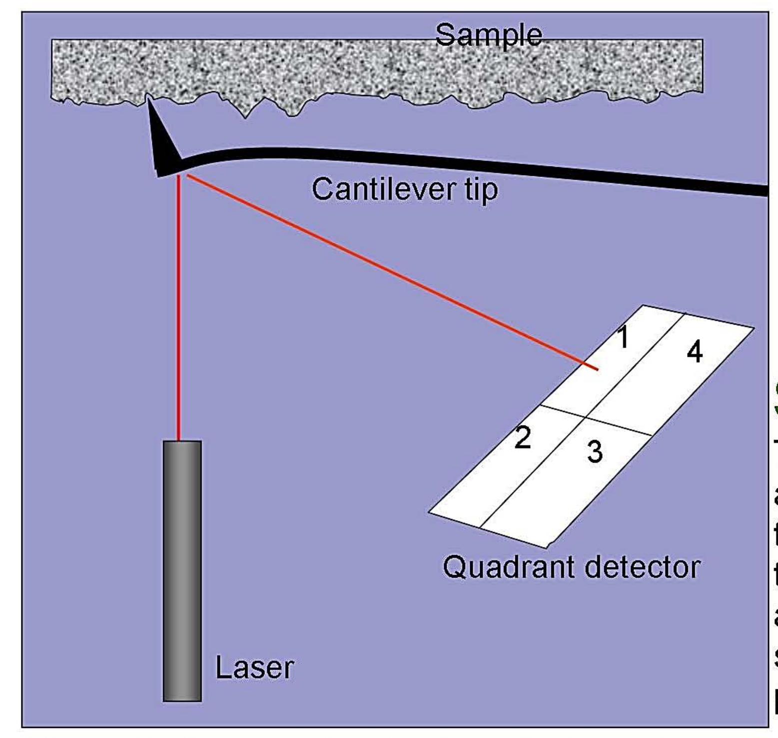

Figure 5: diagram showing how the laser is reflected off the cantilever tip and into the quadrant detector. In the instance shown, movement into cell 2 would show a change in topography and movement into cell 4 would show that the tip is experiencing torsion due to frictional forces.

Sensors

The topography of the sample is measured using a laser (5) and a photodiode sensor (6 and figure 5). The laser is directed so that it hits the cantilever tip (3) and is reflected into a quadrant detector sensor. When the tip comes into contact with the sample and is bent, the laser is reflected into a different part of the sensor. The sensor is connected to a feedback loop circuit with the piezo-electric legs, as explained in *Theory,* left.

Variable Temperature

The sample can be heated by resistive heating in the mount and cooled by liquid nitrogen, also in the mount. All major components of the microscope are symmetrical, and materials have been carefully chosen so that as they expand and contract, the scanning will not be affected.

Damping System

The microscope makes use of two damping systems to ensure that there is minimal vibration. A spring vibration isolation system (7) consisting of four spring and a heavy copper base attached to a solid frame, as shown, stops all vibration except in the vertical direction. These vertical vibrations are damped by eddy current damping, consisting of magnetic bars (8) which rest in grooves around the edge of the base.

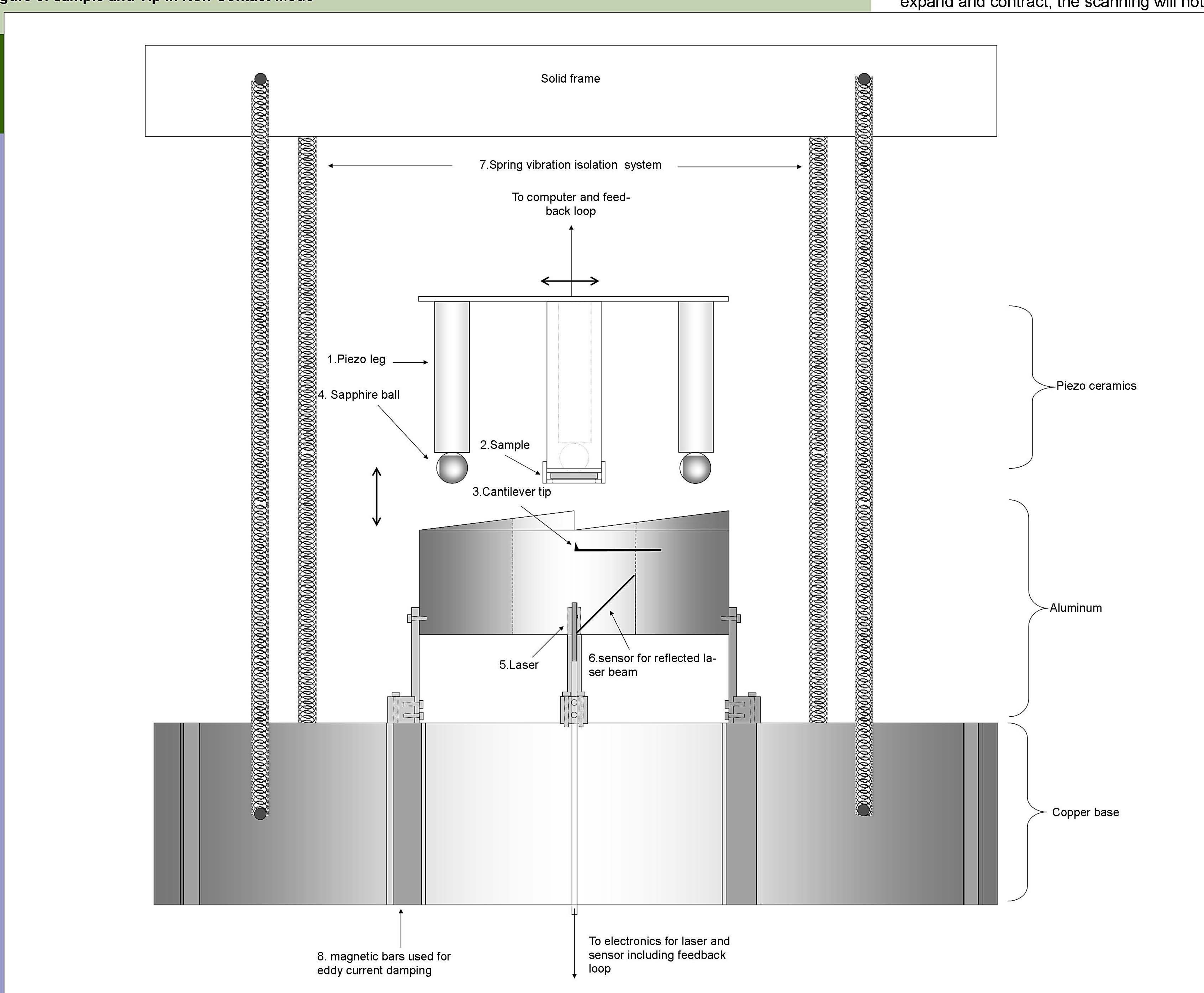

Figure 6: Design of the atomic force microscope showing the sample mount and approach mechanism, scanning cantilever tip, laser and sensor, and damping system.

CURRENT STATUS

We are in the early stages of construction, and look forward to the final outcome of this project.