NANO 703/703L

Lab: Atomic Force Microscopy

Due: Following Lab Session

BACKGROUND

Atomic force microscopy (AFM) measures the changes in force exerted by a surface on a nanoscopic tip. The force change may result from surface topography, elastic stiffness variations, or other tip-surface interactions. AFM belongs to a family of proximal-probe microscopy techniques, by which material properties are mapped by slowly rastering a precision tip across a nominally 2-D surface. In the case of AFM, the tip extends from a cantilever, usually formed on a Si or SiN wafer by lithographic processes. In the most basic mode of operation, the tip is placed in light contact with the surface of interest. A laser is directed onto the back of the cantilever, opposite the tip, at an oblique angle, forming an optical lever. The laser spot reflects onto a pair of vertically displaced photodiodes. A mirror is used to split the signal precisely between the two photodiodes. Any small deflection of the tip changes the angles of incidence and reflection off the cantilever, moving the laser spot vertically by a proportional, but greatly magnified, distance.

Experimentally, the deflection of the laser spot is kept minimal throughout a scan, by mounting the sample on a piezoelectric tube that not only imparts lateral motion of the sample with respect to the tip, permitting the rasterized scan, but also adjusts the sample height in response to negative feedback to offset any change in tip deflection.

The feedback signal invokes an anticipated correction in sample height to zero the difference signal. Additional cantilever deflection, given by the residual difference signal between the photodetectors, constitutes “error”, which should be minimized. In constant-force (contact) mode, the sum of the feedback and “error” gives the true topographic signal.

The cantilever behaves like a damped harmonic oscillator; the displacement of the tip is proportional to the applied force. Measurement of the tip deflection corresponds to the net force on the tip, and also to height, for a hard surface, The force exerted on the tip is not, however, in all cases attributable to sample topography, because the sample may exhibit variations in elastic compliance across the scanned area, in which case the interactions between the tip and the specimen become important. This is especially true for soft materials, such as polymers, for which it is more revealing to use intermittent contact, or “tapping mode” AFM, in which the cantilever is driven into oscillation by a piezoelectric transducer. Non-contact AFM is also possible, in which the cantilever is driven by a sinusoidal oscillation near its resonance frequency. The response of the cantilever to this drive signal varies depending on the forces experienced locally by the tip.

Once an AFM scan is acquired, numerous possibilities exist to analyze the data and present the topographic map in graphical form. One computationally simple means to highlight topography is to evaluate the spatial derivative (gradient) of the data. This gives a shaded appearance, similar to that produced by directional illumination (Fig.).

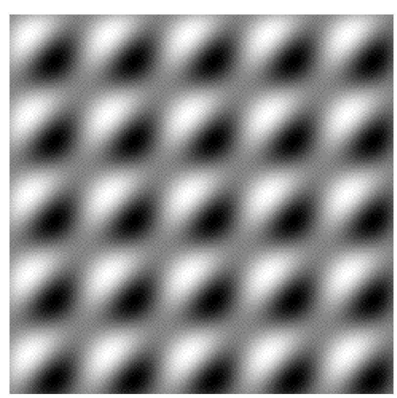

Fig.: Simulation showing the use of the derivative to highlight topography.

GOAL

Acquire AFM scans from various structures. Learn the basics of operating the instrument and analyzing the data.

REPORT

Write a procedure for loading a sample in the AFM, performing a scan, and acquiring and displaying the data. Include an image generated from an AFM scan, with descriptive annotations.