Lateral and Chemical Force Microscopy
Mapping Surface Friction and Adhesion

By: M.G. Heaton, C.B. Prater, K.J. Kjoller

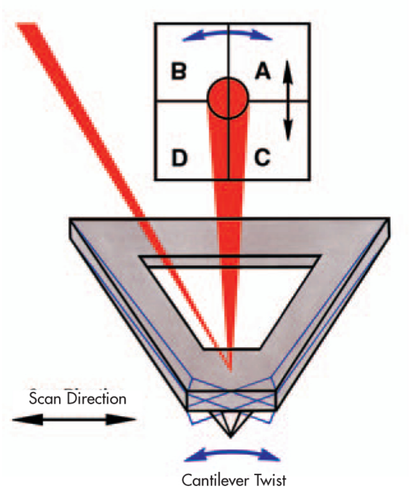

Figure 1. Scanning and detection with lateral force microscopy. For LFM, the probe is scanned sidewise and the friction signal is calculated as (A + C) - (B + D). The degree of torsion of the cantilever supporting the probe is a relative measure of surface friction caused by the lateral force exerted on the scanning probe. Note that for contact mode, the deflection signal is calculated as laser spot intensity for quadrants (A + B) - (C +D).

Lateral Force Microscopy (LFM) is a scanning probe microscopy (SPM) technique that identifies and maps relative differences in surface frictional characteristics. Applied with contact mode atomic force microscopy (AFM), LFM is particularly useful for differentiating components of heterogeneous surfaces. Applications include identifying transitions between different components in polymer blends, composites and other mixtures; identifying organic and other contaminants on surfaces; delineating coverage by coatings and other surface layers; and using functionalized tips for chemical force microscopy.

The Technique

In standard contact mode atomic force microscopy (AFM), the probe is scanned over the surface (or the sample is scanned under the probe) in an x-y raster pattern. A laser beam is focused on the cantilever and reflects onto a segmented photodiode detector to monitor the deflection of the cantilever during raster-scanning. A feedback loop maintains a constant force on the sample by adjusting the height of the cantilever to compensate for topographical features of the surface resulting in a three-dimensional map of the sample.

With the lateral force technique, the probe is scanned perpendicular to its length, meaning sideways on the fast axis and forward-back on the slow axis. The torsion, or twisting, of the cantilever supporting the probe will increase or decrease depending on the frictional characteristics of the surface (greater torsion results from increased friction). Since the laser detector has four quadrants (Figure 1), it can simultaneously measure and record topographic data and lateral force data. Both of these data sets may be viewed simultaneously in real time, and stored and processed independently.

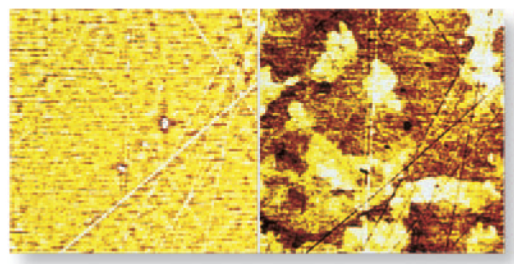

Figure 2. Topographic (left) and LFM (right) images of the surface of a polished poly-crystalline silicon carbide film. The polishing process obscures in the topography image the grain structure, which is clearly visible in the LFM image. 30µm scans.

Examples

LFM is extremely useful for identifying surface compositional differences where the materials have differing frictional characteristics and the topography is relatively flat. It should be noted, however, that these differences can be obscured by rough topography or by contamination on the sample surface.

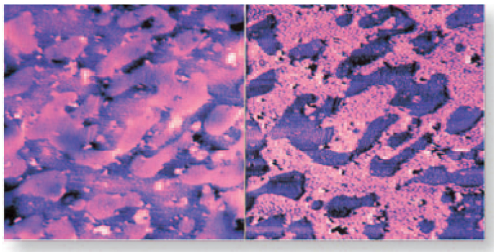

Figure 3. Topographic (left) and LFM (right) images of a natural rubber/EDPM blend. 12μm scans.

In Figure 2, the LFM image of a polished polycrystalline silicon carbide film identifies individual grains not seen in the topographical image. Figures 3, 4, and 5 show the improvement in image detail with LFM (relative to topography) for a rubber blend, a Langmuir-Blodgett film, and a magnetic recording head ceramic.

Chemical Force Microscopy

A specialized use of LFM is Chemical Force Microscopy (CFM), where the tip is functionalized with a chemical species, and scanned over a sample to detect adhesion differences between the species on the tip and those on the surface of the sample. Using both a Digital Instruments NanoScope® III controller and MultiMode® atomic force microscope, Frisbie et al.[1] changed the chemical species on the tip between scans of the same surface, causing the lateral force image of the surface to invert (Figure 6). This groundbreaking study helped open an entirely new area for lateral force measurements of functional group microstructure in polymers and other materials, as well as binding/recognition interactions in biological systems.

1. Frisbie C.D., Rozsnyai A., Noy A., Wrighton M.S., and Lieber C.M., 1994. Functional group imaging by chemical force microscopy. Science 265:2071-2074.

Summary

Lateral Force Microscopy is a very useful SPM technique that differentiates surface compositional variations by discovering relative differences in surface frictional characteristics. Applied with contact mode atomic force microscopy, LFM enables advanced research in semiconductor materials, polymers, deposited films, data storage devices, investigative studies of surface contamination, chemical speciation and frictional characteristics, and a growing list of new applications.

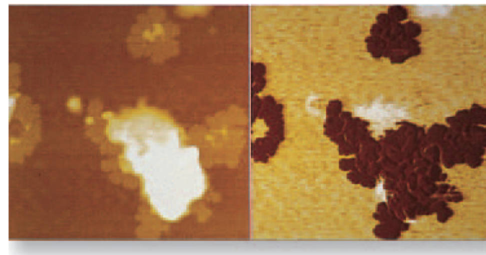

Figure 4. Topographic (left) and LFM (right) images of a Langmuir-Blodgett film. 1μm scans.

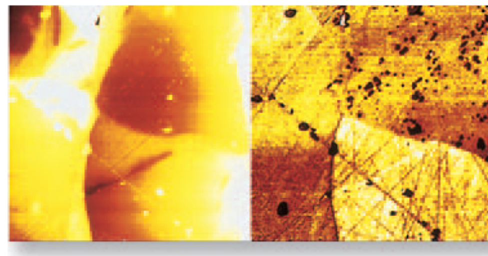

Figure 5. Air bearing surface of a magnetic recording head showing topographic (left) and LFM (right) of Al oxide grains and contamination. 800nm scans.

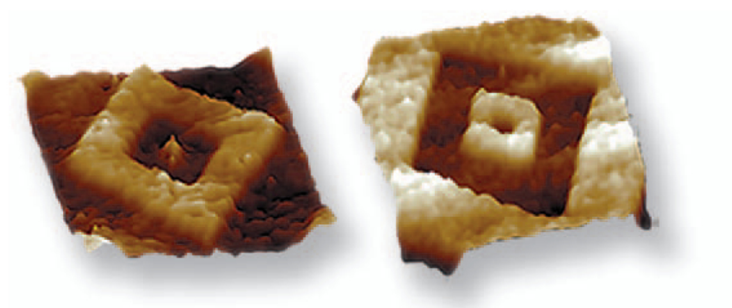

Figure 6. CFM scan of well-defined regions that terminate in either methyl or carboxylic acid groups. When a carboxylic acid-terminated tip is used for imaging (left), the carboxylic acid-terminated regions exhibit greater frictional force (lighter color) than the methyl-terminated regions. When a methylterminated tip is used (right), the friction contrast is reversed. No differences are revealed by the topographic AFM scan (not shown) since the functional groups are structurally quite similar. 50μm images acquired using the Digital Instruments MultiMode AFM system. Image courtesy of Dr. C. Lieber, Harvard University.