Trieste and Lausanne — are carried out entirely in liquid and therefore involve two liquid/surface interfaces: the sample/liquid interface of the system under investigation and the tip/liquid interface, which can be considered to be independent of the tip position. The experimental key to obtaining atomic resolution is to operate the AFM dynamically with a cantilever that vibrates with small amplitude. Through a series of careful measurements, the authors establish the exact parameters necessary for high-resolution imaging[8]. They find that the optimal conditions for imaging occur when the tip oscillates as close as possible to the substrate without significantly interacting with it, and a simple theoretical model is used to describe this imaging mechanism.

The model assumes that, as the tip oscillates, the tip/liquid interface and the sample/liquid interface merge, coalescing into a single interfacial liquid layer, before returning to the original separate interfaces. This process is considered to be non-adiabatic — the liquid molecules do not have enough time to return to their equilibrium position during an oscillation — and the energy dissipated with every oscillation is directly related to the work of adhesion (which, in turn, is related to the interfacial energy) of both interfaces. The energy dissipated can be measured with the AFM, and work-of-adhesion maps can therefore be obtained with nanoscale resolution.

The work-of-adhesion values obtained using this approach were also compared to those calculated from macroscopic contact-angle measurements. Good agreement was found, yet with a systematic error between absolute values. This error is thought to arise primarily from different energy-dissipation mechanisms that were neglected in the tip-oscillation model. However, the authors develop a calibration procedure that limits the error to no more than 5%.

The technical developments of Voïtchovsky and colleagues provide a number of intriguing opportunities for application. Their approach could, for example, be used to help understand crystal growth, as it should allow the early stages of precipitation from the solution phase (including nucleation) to be visualized with high resolution, while simultaneously measuring variations in the interfacial energy. The relatively simple experimental requirements — a commercial AFM with a liquid-cell attachment — also mean that the technique could be readily used by a range of researchers to systematically study various combinations of interfaces and solvents.

To bridge the gap between nanoscale and macroscopic objects, the next step will be to consider topographic effects as opposed to atomically flat substrates. Resolution could also perhaps be improved by using nonlinear forces related to higher harmonics[9]. Finally, simultaneous scanning in the *z* direction should allow the whole three-dimensional interfacial space to be examined, as was recently demonstrated in the water/mica interface[10]. The dynamic lateral ordering in the first monolayer of water could then also be observed.

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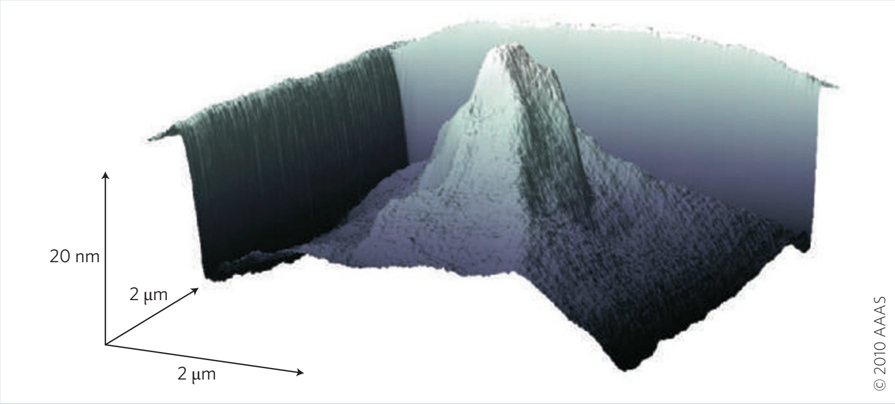
NANOFABRICATION

Hot tips for surface patterning



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The semiconductor industry uses masks to write patterns onto substrates at many stages during device fabrication. Masks are commonly made from organic resist materials because they are amenable to patterning. However, standard optical and electron beam lithography techniques struggle to produce mask feature sizes below 30 nm. Now, Armin Knoll and colleagues at IBM Research centres in Zurich, San Jose and Yorktown Heights have used a scanning probe to pattern resists to a resolution of 15 nm at high speeds and in three dimensions (*Science* **328,** 732–735; 2010).

The method involves applying a controlled amount of heat and pressure to a glassy organic resist through a scanning probe tip, overcoming the weak hydrogen bonds that bind the resist molecules and causing the resist to evaporate. Previous 'heated tip' methods involved breaking covalent bonds or causing chemical changes, which made them slow and also led to contamination of the tip. The new approach allows a resolution of 15 nm to be achieved at speeds comparable to electron beam lithography, which are sufficient for rapid prototyping. Higher speeds could be reached by using many scanning probes simultaneously.

The technique can also produce three-dimensional patterns by successively scanning over the same area of resist, removing varying depths with each scan. The IBM team used this approach to construct a 25-nm-high replica of the Swiss mountain, the Matterhorn. This shape (pictured) was subsequently etched into a silicon wafer.

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