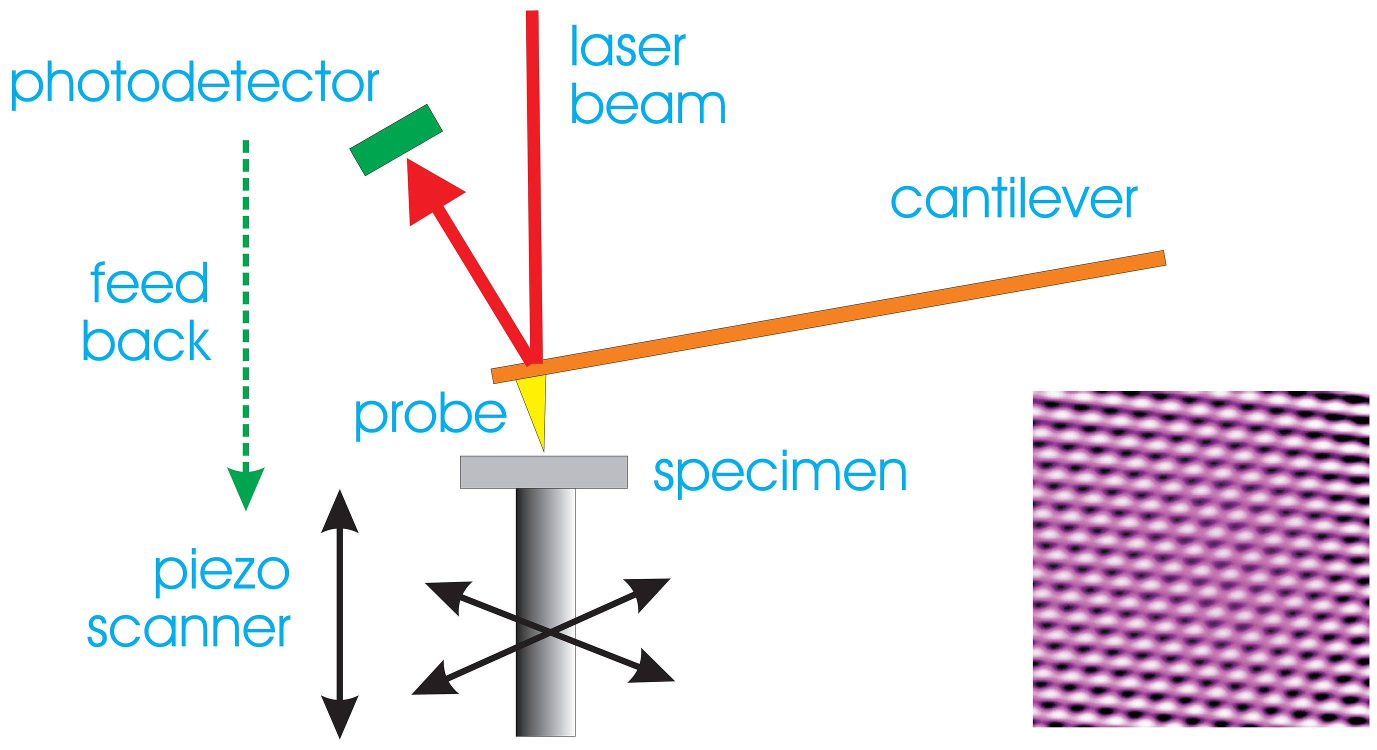
Nanofabrication on Si with AFM

Iwasaki Laboratory, ISIR, Osaka University

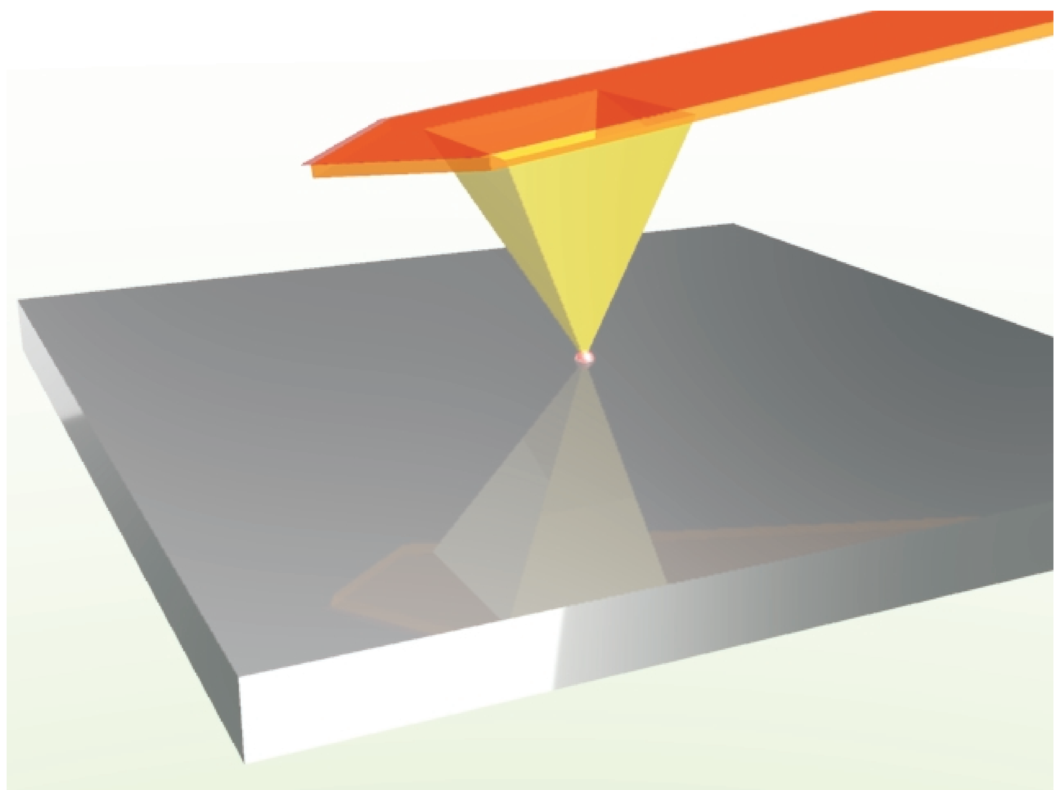
The atomic force microscope (AFM) is an instrument for investigating the geometry of the surface at a high spatial resolution.

In AFM, the sample is mounted on a piezo scanner, which enables positioning at an atomic resolution. A sharp tip mounted on a cantilever is in contact with the surface, and the atomic force between the tip and the surface is sensitively detected by the laser beam. During the scan, a feedback loop controls the length of the piezo scanner to maintain a constant force, and the height of the surface is recorded at each pixel to obtain the topography.

Thanks to its extremely high spatial resolution, wide applicability and easy operation, AFM has become a very popular tool for investigation of surfaces.



The schematic diagram of AFM and an example of atomically resolved image of mica.



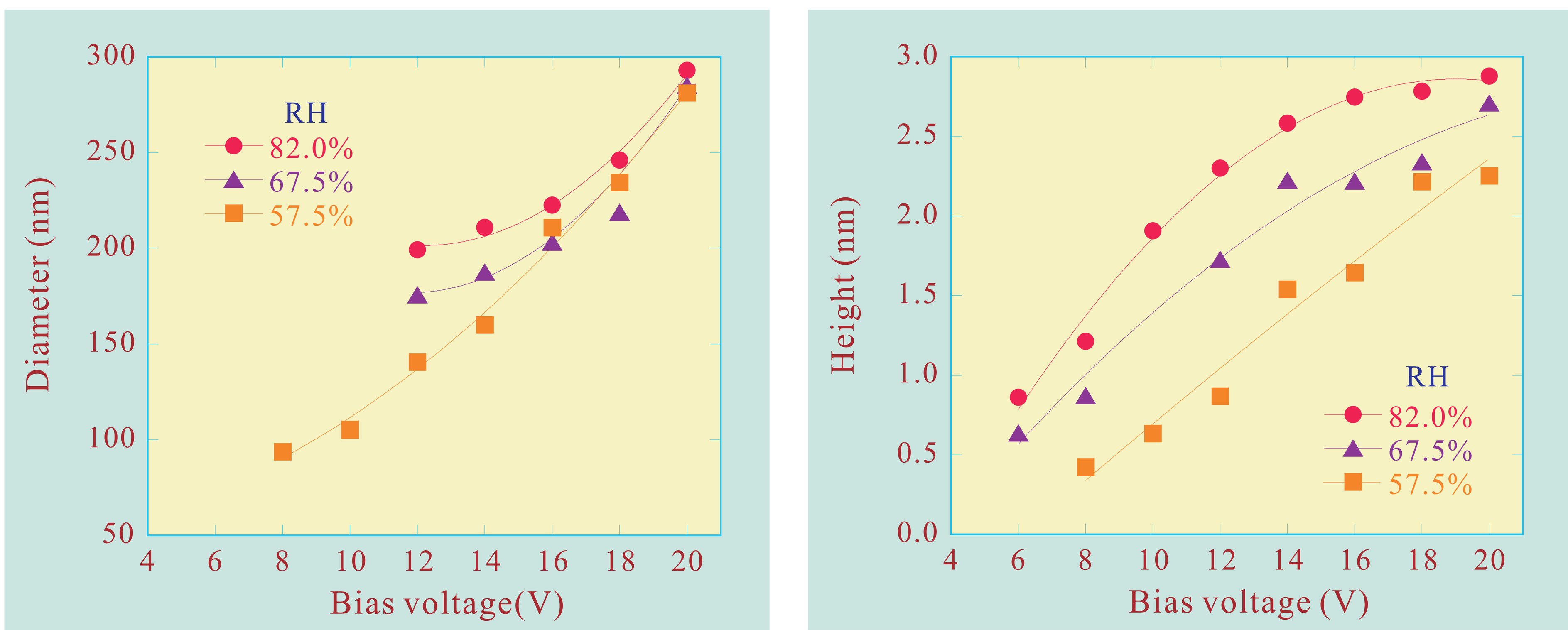
Formation of an oxide dot on Si by application of bias voltage between the tip and the surface.

It has been recognized, however, that AFM can be used not only for measurement, but also for modification of the surface with a high spatial resolution. Examples include mechanical scratching of the surface and transfer of materials from the tip.

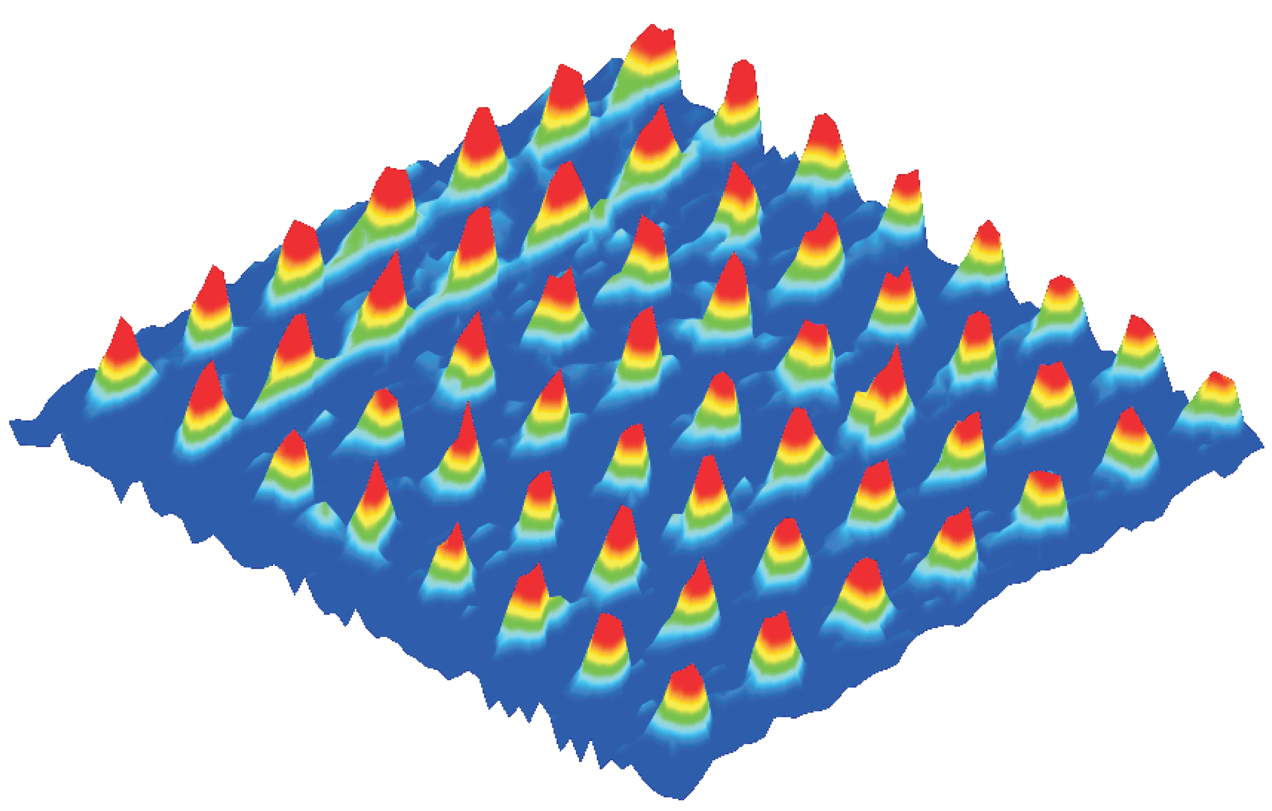
In the case of the Si surface, it is possible to form a small oxide dot by application of a bias voltage between a metal-coated tip and the surface. The mechanism of the oxide formation is believed to be "anodic oxidation", in which the tip and the surface work as a cathode and an anode, respectively, in the electrochemical reaction mediated by the adsorbed water between them.

The dimensions of the oxide dot are dependent on the applied bias voltage, the duration of the voltage pulse, the relative humidity (RH) of the ambience and the chemical treatment of the surface prior to the fabrication process.

The diameter of the dot is typically in the 100nm range, but it is controllable at least down to 80nm. The height is controllable in the sub-nm range. For higher voltages, the height saturates at 3nm, while the dot grows laterally in diameter.



The diameter and height of oxide dots formed at different values of bias voltage and relative humidity. The duration of the voltage pulse is 2.5 ms.

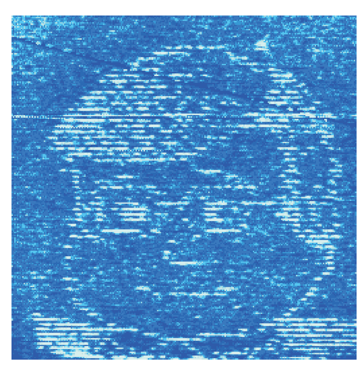


An array of oxide dots fabricated with AFM.

With this technique, an arbitrary pattern of oxide dots and lines can be fabricated. Possible applications include fabrication of quantum and molecular devices. Periodic structures such as an array of dots or lines can be used as gratings in optical or optoelectronic applications.

Since the oxide pattern is removable with HF, it can be used as a negative mask in a "lift-off" process for patterning of a deposited

Finally, we are also interested in application of the oxide pattern to immobilization and patterning of biomolecules such as proteins and DNA.



Written by Tatsuo Yoshinobu (nov@sanken.osaka-u.ac.jp)