appeared on 2nd March 2007

Feeling for bumps atom by atom

Microscopy is reaching incredible fineness in what it can see, says S.Ananthanaryanan.

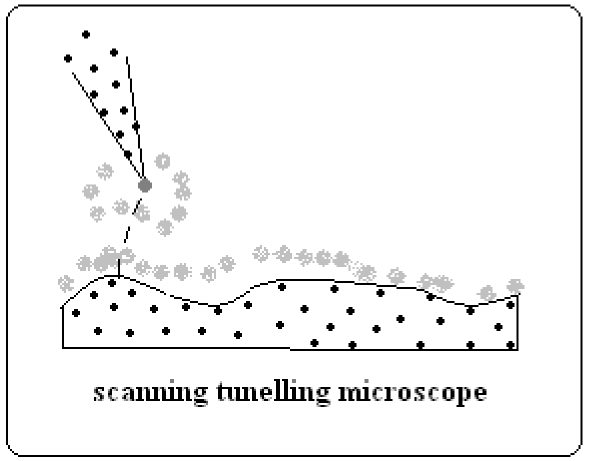
It was first thought that microscopes should imitate the eye, but do it better, to see small things. The simple optical microscope was an arrangement of glass lenses that brought a universe of bacteria and microbes into view.

Better quality lenses led to better microscopes, But the next was the electron microscope, which did better than improving the lenses, it used a different kind of light – the electron wave – which could act as a light beam with a really fine wavelength! The electron microscope enabled viewing of viruses and objects at almost the atomic level.

The STM and the AFM

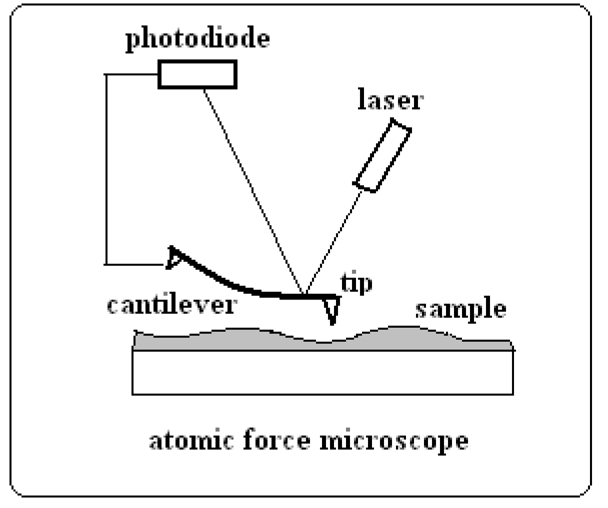
When the limits of optical type microscopy were almost reached, mechanical methods o greater sensitivity got developed. The scanning tunneling microscope (STM) is now a routine method of obtaining atom scale images of metal surfaces.

The free electron cloud associated with metal atoms extends just above the metal surface. If a sharp, metallic tip – in fact a needle that has been treated so that its tip is a single atom(!) – is brought really close to the surface, electrical forces start acting between the atom and the electron cloud at the surface..



If a small voltage is now applied, an electron can ‘tunnel’ through the repulsive barrier at the surface and this can be measured. As the current rises sharply if the tip moves even an atomic diameter closer, the current as the tip scan the surface yields a measure of the unevenness of the surface

The atomic force microscope (AFM) is a curved sliver of silicon whose size is in nanometers. As the sliver moves over the surface to be studied, forces between the tip



and the surface make the sliver bend. The bending can be magnified by a laser beam and this shows deformities in the surface. The AFM is purely mechanical and the surface need not be a metal.

Limitation

But still, the STM and the AFM can only ‘feel’ the surface for physical roughness, but cannot make out the chemical composition of the atoms on the surface. The AFM has even been refined to give a true 3-D image of the surface. As only scanning the surface has problems of the selecting the stiffness of the silicon cantilever and calibration, this was overcome by setting the cantilever vibrating as the surface is scanned. As the cantilever-surface distance varies, the frequency of vibration changes and this results in a clearer image of the surface. But the method still cannot tell the chemical identity of the atoms at the surface.

Now, Yoshiati Sugimoto at Osaka and others at Saitama in Japan, Madrid and Prague worked on just this and have announced in Nature this week that they have found a way out.

Refining the scans

It is apparent that the surface atomic distribution would be different for tin deposited on silicon, for instance, or for lead deposited on silicon. But this difference could not be used to identify the elements because even with a sample of a single metal, the scanning pattern did show variations – mostly because of the structure of the tip itself is not entirely in control. Hence, differences in the scanning results could not be reliably taken to indicate a difference in the atoms at the surface

The scientists worked around this by noticing that of all the attractive forces, it is the silicon atom at the surface that has the strongest. So they ‘normalised’ the forces measured with lead or tin by dividing the measured forces by the force with silicon. This brought the different forces into a kind of ***‘similar scale’*** and a ***‘fingerprint’*** for lead or tin could be worked out.

The next step was to theoretically model the surface for different metals and obtain a theoretical picture of what the fingerprints should be. Repeated trials showed that the theroretical model did correspond to the results of scans. The scientists then scanned the surface of an alloy of lead, tin and silicon and were able to label all the individual atoms.

The work that has been carried out is a major step – to show that tunneling methods and a statistical approach can reveal the atom scale chemical composition of semiconductor surfaces.