X-rays scratch below the surface

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A new X-ray microscope sees clearer and deeper than ever before.

Scientists have made an important step towards developing a camera that takes atomic-scale snapshots. They have created a microscope that forms three-dimensional images using X-rays.

At present, the new microscope can reveal structures no more than eight nanometres (millionths of a millimetre) across. Atoms are typically just a few tenths of a nanometre across. But using brighter X-ray beams or longer exposure times should give atomic-scale resolution, say Jianwei Miao of Stanford University, California, and his colleagues, who developed the new device.

Scientists have long dreamed of the X-ray microscope. Such a device could show any arrangement of atoms in three dimensions, because X-rays have a wavelength similar to the size of atoms.

There are already several ways of seeing atoms, but each has limitations. Transmission electron microscopy can resolve individual atoms only for samples about 50 nanometres thick. Scanning probe microscopes can reveal individual atoms, but only at a material's surface.

Crystallography reveals atoms' three-dimensional patterns by bouncing waves off a sample and looking at how they interfere with each other, a phenomenon called diffraction. But this only...
works for crystals, which have a regular arrangement of atoms. Many structures aren't like this, including living cells, polymers and glasses.

First sight

Miao and his colleagues' technique is a kind of hybrid of diffraction and microscopy. It involves firing a beam of coherent X-rays, in which all the waves rise and fall in step, at a sample and looking at the diffraction pattern in the reflected beam.

The pattern forms from X-rays bouncing off only a very small region of the sample. So the image shows local structure, as in a microscope, rather than some average structure, as is the case in crystallography.

Miao's team first reported this sort of X-ray microscopy\(^2\) in 1999. But at the time it revealed only two-dimensional structures, with a resolution of about 70 nm.

Now the researchers can see two-dimensional structures about ten times smaller than this. And they can map out three-dimensional structures with a resolution of around 50 nm. For example, they could see two different, complex patterns in nickel films stacked 1,000 nm apart.

One way of improving the resolution would be to use longer X-ray exposures. This would work for robust substances such as semiconductors, but it would fry cells. Deep-freezing samples would help, say the researchers. Or using the much brighter beams of X-ray lasers, which are currently in development.

References