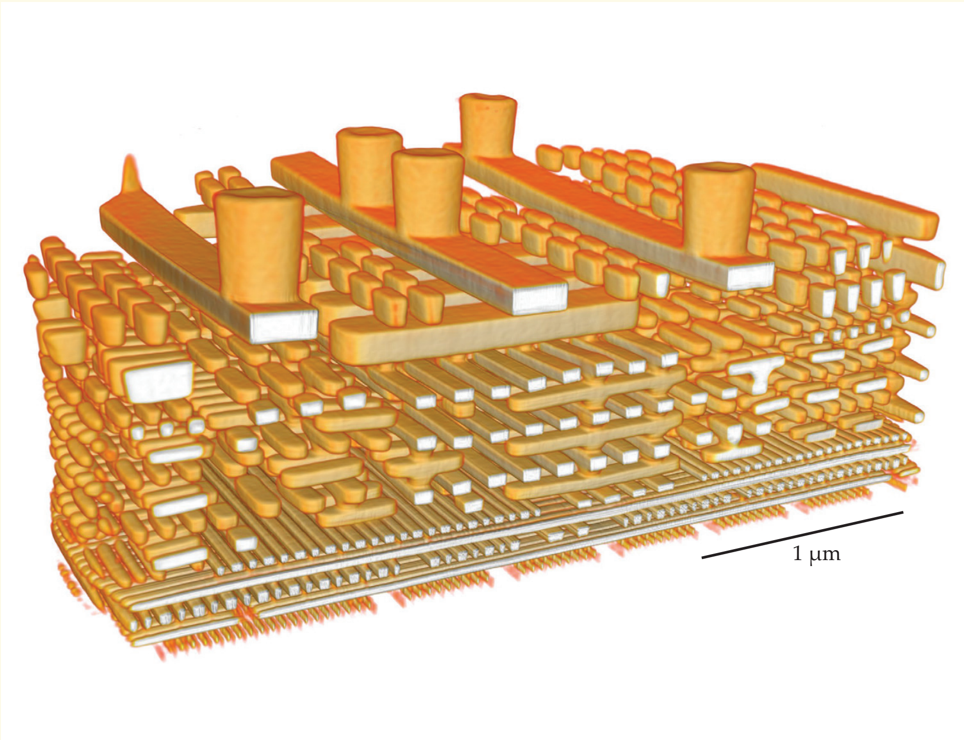
UPDATES

Imaging advance enables 3D maps of the smallest microchips

With improved x-ray tomography algorithms, researchers can analyze nanometer-scale features inside microchips and improve resolution in other imaging applications.

Today's microchips contain features nearing atomic length scales. The ability to see inside them is valuable for manufacturing, quality control, and security inspection, but as they continue to shrink, the techniques available to image them can't always keep up. Fine-scale features can be imaged with electron microscopy, but that requires the analysis and then removal of one thin slice of the chip at a time.

X-ray diffraction patterns can be used to visualize the 3D structure, in a method known as ptychographic tomography, without the need to destroy the chip. But until recently, ptychography could only provide a resolution of about 15 nm, not precise enough to capture the tiny transistors in modern microchips. Now, an advancement to that method by Tomas Aidukas, at the Paul Scherrer Institute in Switzerland, and colleagues has pushed the lensless imaging technique to a record 4 nm resolution.



A 3D MAP OF A MICROCHIP'S INNER WORKINGS highlights the metallic interconnections and tiny transistors that make up the integrated circuit. (Adapted from Aidukas et al., *Nature* **632**, 81, 2024.)

Much like how taking a good photograph requires sufficient light, reconstructing the interior of an object from the diffraction patterns it creates requires a high-enough dose of x rays over a long-enough span of time. But the longer an image is collected, the more opportunity there is for blur. For the new approach, instead of using one long x-ray dose to capture an image with the necessary flux, the researchers used short bursts of x rays to collect several less-blurry images that still captured enough flux when added together. Those snapshots provided the time-resolved data necessary to identify the primary source of resolution-limiting blur—in this case, a slight wobble of the x-ray beam. Combined with the burst snapshots, improvements to the back-projection algorithm enabled more-precise calculations of the relative positions of the sample and the beam, which in turn led to the resolution enhancement.

Though Aidukas and colleagues used the algorithm to correct for a wobble in the beam, the same approach could be used to correct for other sources of inaccuracies in a ptychographic measurement, such as a less stable microscope setup. "As long as you have the computational resources, this could essentially improve resolution at any existing beamline that is doing ptychography around the world," says Mirko Holler, a senior scientist on the research team. That may prove helpful for labs that have implemented ptychography at smaller facilities by taking advantage of recent advancements to lab-scale x-ray sources.

The high-flux x rays used by Aidukas and colleagues came from the Swiss Light Source, a third-generation synchrotron that is currently in the process of an upgrade scheduled for completion next year. With those improvements to the beam flux, ptychographic imaging at 4 nm resolution could be done much faster. The 40 hours of data collection that went into the latest 3D image could, in theory, be shrunk down to an hour. The researchers are also exploring the technique's other potential applications, such as imaging brain tissue. (T. Aidukas et al., *Nature* **632**, 81, 2024.)

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