

# Radiation damage bigger problem in microelectronics than previously thought

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The amount of structural damage that radiation causes in electronic materials at the atomic level may be at least ten times greater than previously thought.

That is the surprising result of a new characterization method that uses a combination of lasers and [acoustic waves](#) to provide scientists with a capability tantamount to X-ray vision: It allows them to peer through [solid materials](#) to pinpoint the size and location of defects buried deep inside with unprecedented precision.

The research, which was conducted by post-doctoral fellow Andrew Steigerwald under the supervision of Physics Professor Norman Tolk, was published online on July 19 in the [Journal of Applied Physics](#).

"The ability to accurately measure the defects in [electronic materials](#) becomes increasingly important as the size of [microelectronic devices](#) continues to shrink," Tolk explained. "When an individual transistor contains millions of atoms, it can absorb quite a bit of damage before it fails. But when a transistor contains a few thousand atoms, a single defect can cause it to stop working."

Previous methods used to study damage in electronic materials have been limited to looking at defects and [deformations](#) in the atomic [lattice](#). The new method is the first that is capable of detecting disruption in the positions of the [electrons](#) that are attached to the atoms. This is particularly important because it is the behavior of the electrons that

determine a material's electrical and [optical properties](#).

"An analogy is a thousand people floating in a [swimming pool](#). The people represent the atoms and the water represents the electrons," said Steigerwald. "If another person – representing an energetic particle – jumps into the pool, the people in his vicinity change their positions slightly to make room for him. However, these shifts can be fairly subtle and difficult to measure. But the jumper will also cause quite a splash and cause the level of the water in the pool to rise. Much like the water in the pool, the electrons in a material are more sensitive to defects than the atoms."

To detect the electron dislocations, the physicists upgraded a 15-year-old method called coherent acoustic phonon spectroscopy (CAPS).

"CAPS is similar to the seismic techniques that energy companies use to search for underground oil deposits, only on a much smaller scale," said Steigerwald.

Oil explorers set off a series of small explosions on the surface and measure the sound waves that are reflected back to the surface. That allows them to identify and map the layers of different types of rock thousands of feet underground.

Similarly, CAPS generates a pressure wave that passes through a chunk of semiconductor by blasting its surface with an ultrafast pulse of laser light. As this happens, the researchers bounce a second laser off the pressure wave and measure the strength of the reflection. As the pressure wave encounters defects and deformities in the material, its reflectivity changes and this alters the strength of the reflected laser light. By measuring these variations, the physicists can detect individual defects and measure the effect that they have on the material's electrical and optical properties.

The physicists tested their technique on a layer of gallium arsenide semiconductor that they had irradiated with high-energy neon atoms. They found that the structural damage caused by an embedded neon atom spread over a volume containing 1,000 atoms – considerably more extensive than that shown by other techniques.

"This is significant because today people are creating nanodevices that contain thousands of atoms," said Steigerwald. One of these devices is a solar collector made from quantum dots, tiny semiconductor beads that each contains a few thousand atoms. "Our results may explain recent studies that have found that these quantum-dot solar collectors are less efficient than predicted," he said.

"The fact is that we really don't understand how any atomic-scale defect affects the performance on an optoelectronic device," said Tolk. "Techniques like the one that we have developed will give us the detailed information we need to figure this out and so help people make nanodevices that work properly."

Provided by Vanderbilt University

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