Glass Semiconductor Softens With Low-Power Laser, Then Re-Hardens

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Scientists at Ohio State University have found that a special type of glass that is finding use in the electronics industry softens when exposed to very low-level laser light, and hardens back into its original condition when the light is switched off. The discovery -- made by accident as physicists were trying to study properties of the material -- may one day enable new uses for the glass.

Ratnasingham Sooryakumar said that he and former doctoral student Jared Gump thought they were working with a bad batch of germanium-selenium glass when Gump was testing the material's hardness in the laboratory and couldn't reproduce his results.

"Every day he got a different result," recalled Sooryakumar, a professor of physics at Ohio State. "It took us a while to realize that the material was fine, it was just very sensitive to light."

They finally traced their strange results to the very low-power laser light that they were shining on the glass. Whether the laser was set to exactly the same power every time shouldn't have affected the experiment, but it did. The higher the laser power, the softer the glass. In fact, with the laser set to a mere 6 milliwatts –- six thousandths of a Watt -- the material became 50 percent softer than usual.

"Normally, you'd have to almost melt the glass to get it that soft, but here we were doing it with a light source that was essentially a laser pointer, and with no heat at all," said Sooryakumar. "And what's really important is that the whole effect is reversible."

In the journal Physical Review Letters, the physicists reported that the glass always hardened back into its original condition. Even the latticework of atoms that made up its structure appeared unchanged afterward.

Sooryakumar and Gump co-authored the paper with Ilya Finkler, a former undergraduate student majoring in physics and mathematics, and Hua Xia, a former postdoctoral associate, both of Ohio State; Wayne Bresser, an assistant professor of physics at Northern Kentucky University; and Punit Boolchand, professor of electrical and computer engineering and computer science at the University of Cincinnati. Gump is now a scientist at the Naval Surface Warfare Center in Indian Head, MD, Finkler is a graduate student studying physics at Harvard University, and Xia is an engineer at General Electric Corp.

The glass is part of a family of glass semiconductors that are often used in electronics for DVDs and information storage technologies.

Germanium is hard and selenium soft. A combination of 80 percent selenium and 20 percent germanium is the "magic formula" where the material is neither too hard nor too soft, and well suited for forming a glass. Scientists call this point the rigidity transition.

Scientists are very interested in studying why the 80-20 ratio works, and what happens to the mechanical strength of the glass during the rigidity transition. To answer those questions, Sooryakumar and his colleagues tried to examine the hardness of the material in a range of selenium-germanium combinations around the transition point.

One way to determine the hardness of a material is to measure the speed of sound waves traveling through it; sound waves travel faster through harder materials. The physicists bounced a low-powered red laser beam off the sound waves to measure the speed –- a technique similar to how radar detects the speed of a moving car. The laser beam was only about as wide as a human hair, and used about as much power as a laser pointer.

That's when they noticed the softening effect.

"It was as if the radar beam was influencing the speed of the car," Sooryakumar said.

For compositions closest to the transition point, the effect was greatest: the material softened by 50 percent, from a hardness of 26 to 13 gigapascals as the laser power increased from 2 to 6 milliwatts. Hardness is a measure of how much pressure a material can withstand, and diamond rates at 100 gigapascals.(A gigapascal is roughly 10,000 times the pressure of earth's atmosphere at sea level.)

Though the physicists don't yet have a complete picture of why the material softened, Sooryakumar suspects that the answer has to do with the nature of the rigidity transition itself. Stiff materials normally carry a certain amount of stress in them, because the stacked molecules support each other like steel girders in a building. The transition point is special, Sooryakumar noted, because the molecules are arranged in just the right way to lower stress on the structure to a minimum.

Here's why the physicists think the glass softened: When particles of light, called photons, hit the glass, they knocked some of the electrons that connect molecules in the latticework out of place. Such a change in bonding occurs most easily under conditions of minimum stress. With fewer supports holding up the structure, the glass became less stiff. Then, when the light was switched off, the electrons swung back into position, and the glass became stiff again.

Sooryakumar speculated that these types of glasses could have potential applications in re-writable computer memory. But right now, he and his colleagues are probing further to understand the rigidity transition and the remarkable response to light at this composition. They want to study what happens if the material is exposed to laser light of different color and higher power, and test different glasses besides selenium-germanium.

Source: Ohio State University

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