Scientists use unique diamond anvils to view oxide glass structures under pressure

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Researchers at the U.S. Department of Energy's Argonne National Laboratory have used a uniquely-constructed perforated diamond cell to investigate oxide glass structures at high pressures in unprecedented detail.

Argonne physicist Chris Benmore and postdoctoral appointee Qiang Mei, along with colleagues at the University of Arizona, used microscopic laser-perforated diamond anvil cells to generate pressures of up to 32 gigapascals (GPa) – roughly one-tenth the pressure at the center of the Earth. By "squashing" vitreous (glassy) arsenic oxide samples between the anvils, the researchers were able to determine the mechanism behind the structure's atypical behavior under high-pressure.

This research may have far-reaching affects in the geophysical sciences, Benmore said, because oxide glasses and liquids represent a significant percentage of the materials that make up the Earth. For example, knowing the atomic structure of oxide materials at high pressures may give scientists a window on the behaviors of magma during the formation of the early Earth and moon. "We now have a technique where we can look a lot of different silicate glasses that are relevant to the Earth's process and at the complex behaviors of the melts that formed the Earth’s mantle," he said.

During their investigation, Benmore and Mei noticed that if arsenic oxide was subjected to high pressures the material underwent an unusual transformation at about 20 GPa, as the color of the compound changed from transparent to red. However, they did not know the atomic cause for this behavior.

By performing x-ray pair distribution function experiments at Argonne's Advanced Photon Source (APS), however, Benmore and Mei were able to see the atomic reconfiguration that produced the color change. Arsenic oxide, at normal pressures, typically exists in isolated molecular "cages" in which four arsenic atoms are surrounded by three oxygen atoms apiece – each of the six oxygen atoms is bounded to two arsenic atoms. When the pressure rose above 20 GPa, however, many of these molecular cages collapsed, creating new isomers in which each arsenic atom was bonded to six oxygen atoms.

Regular diamond anvils could not be used because they caused a great deal of background scattering that obscured the signal from the material. Previous experiments on vitreous materials had used mechanically drilled diamond anvil cells to create the high pressures, but these routinely failed at pressures above 15 GPa. This experiment involved one of the first-ever uses of laser-perforated diamond anvils combined with micro-focused high energy x-ray diffraction techniques, which have the ability to generate high pressures without also producing background noise.

Benmore hopes to extend his research to liquid oxides and silicates by heating them pass their melting points. By doing so, he expects to gain a better understanding of the structural transition, which is expected to occur more abruptly and be reversible in the liquid phases of these materials.

Source: Argonne National Laboratory