Los Alamos pressure process makes pure zirconium glass

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Zirconium may not be a girl's best friend, but by squeezing the metal with roughly the same pressure needed to make diamonds, scientists at the University of California's Los Alamos National Laboratory made a pure glass that may prove nearly as valuable as real diamonds.
The pure metallic glass formed by their high-pressure method holds promise for stronger, more stable materials for medical, sports and electronic products.

Yusheng Zhao and Jianzhong Zhang, both from Los Alamos' Lujan Neutron Scattering Center, have found that pure zirconium metal forms glass at temperatures roughly one-third of zirconium's melting temperature and static pressures around five billion pascals, or more than 50,000 times atmospheric pressure. They published their findings in the July 15 edition of Nature.

"This is the first time that bulk metallic glass has been formed from a single element or pure metal," Zhao said. "By using industrial pressure processes to make pure samples without the defects that appear in metallic glasses made the conventional way, we've identified a method with potentially important commercial applications."

Bulk metallic glasses have found more and more uses in the past 15 years or so, and have begun replacing some conventional materials such as crystalline metals, metal alloys and high-tech ceramics. Among current applications are structural engineering materials, consumer electronic components, jewelry, replacement joints and skis, tennis rackets, golf club heads and other gear that requires lots of rebound.

Although novel, bulk metallic glasses are highly desirable. They resist breaking when stretched, they keep their shape and they are hard to shatter. In scientific terms, they possess high elastic strain limit, high yield strength and fracture toughness. They behave elastically like polymers but are much stronger than metal alloys, characteristics that make them ideal for structural engineering materials and many other applications.

But all the bulk metallic glasses contain three or more component elements, which means they have lower thermal stability and phase separation at high temperatures, Zhao said.

"We've broken with the conventional wisdom that BMGs can only be produced from multicomponent alloys and only with the conventional approach of melting and fast quench," he explained.

Zhao said one of the most remarkable characteristics of the amorphous or glass zirconium they produced is its thermal stability. The Los Alamos samples remain as glass at temperatures above 1,600 degrees Fahrenheit - more than 400 degrees higher than the temperatures at which they were formed - and pressures of 2.8 billion pascals. Traditional BMGs turn to crystals, and thus lose many important properties, at temperatures as low as 800 degrees F.

Zhao and Zhang used a large-volume press to produce samples of millimeter size, but the relatively low pressure and temperature range allows them to make samples of up to an inch, so their process could be scaled up to industrial conditions. Some previous high-pressure experiments used diamond-anvil cells to form amorphous phases from other crystalline materials, with much smaller sample sizes of a few thousandths of a millimeter.

"One of the key reasons for the success of our experimental method was the high purity of the polycrystalline zirconium metal that we were given by our colleagues Paulo Rigg and Rusty Gray," Zhao said. "We worked with them on zirconium equation of state studies at high pressures and temperatures, as well as phase diagram studies."

Much remains to be learned about the new class of pure glass. Zhao and Zhang have tried to duplicate their experiments with commercial-grade zirconium, but found that higher temperatures and pressures were needed to make the glass, and it didn't retain its characteristics when pressures and temperatures returned to normal. They plan follow-up experiments to try to solve this dilemma.

All the experimental work took place at Los Alamos Neutron Science Center's HIPPO flight path, and the synchrotron X-ray beam lines at Argonne and Brookhaven national labs. The Lujan Center is supported by the U.S. Department of Energy's Basic Energy Sciences program. Funding of early work on pressure forming of bulk glass alloys came from the internal Laboratory Directed Research and Development program.

Source: [Los Alamos National Laboratory]