Under Pressure, Zirconium is a "Glass" Act

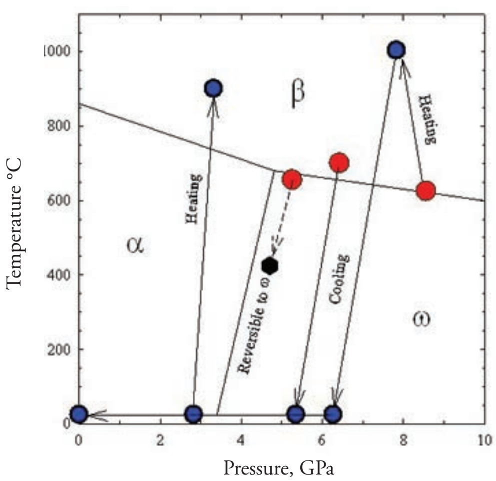
By working in part at the National Synchrotron Light Source (NSLS), scientists from Los Alamos National Laboratory have produced a new glass material by squeezing the metal zirconium under very high pressures. This glass may be stronger and more resilient than traditional glasses, and has the potential to be a better material for medical, sports, and electronics products. The research is published in the July 15, 2004, issue of *Nature*.

"This is the first time that this type of glass has been formed from a single element or pure metal," said Jianzhong Zhang, one of the two scientists who performed the research. "Moreover, because of its single-element nature and high stability at extreme temperatures, this zirconium glass has many exciting, potential applications."

Jianzhong Zhang (courtesy of Los Alamos National Laboratory)

Unlike conventional metals and metal alloys, which are made of tiny crystalline grains and are thus prone to breakage, metallic glasses made from a single element have a uniform, non-granular structure. These "bulk" glasses have many desirable properties, such as a high resistance to breaking, shattering, and distortion. In this way, bulk metallic glasses behave like a plastic yet are much stronger than other metal materials. These characteristics make them attractive engineering materials, for example.

At the NSLS and Argonne National Laboratory (ANL), Zhang and Zhao created the glass by placing a crystalline sample of pure zirconium in a device that subjected it to extreme conditions – up to 80,000 times atmospheric pressure and 1,300 degrees Fahrenheit. These factors caused the zirconium atoms in the crystal to change their positions and bond to each other differently, producing a material that is still made of zirconium, but takes on a different form: glass. As opposed to other pressure production methods, which produce microscopic samples, this method creates millimeter-sized samples of bulk glass and can even create inch-sized pieces large enough to be used in industry.



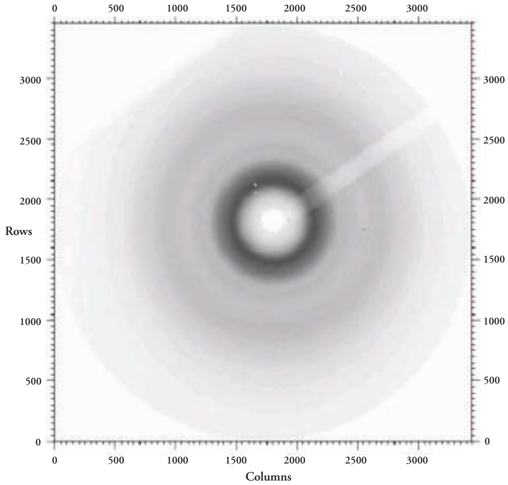
Glass-forming conditions and stability of amorphous zirconium. Circles in red refer to pressures and temperatures at which crystalline zirconium metal transformed into an amorphous phase upon heating. Arrows indicate the selected experimental P-T paths along which no precipitation of any crystalline phase was observed after the formation of amorphous zirconium. Circles in blue refer to a portion of data collected along the paths. The hexagon symbol corresponds to the conditions where the reversed transformation from glass to ω phase was observed upon cooling.

Bulk metallic glasses are being used in an increasing number of practical applications, such as to make electronics components, jewelry, and sports equipment. Scientists believed that bulk metallic glasses can only be alloys. But alloy glasses are not as stable as glasses made from pure metals, and are conventionally produced by melting the alloy metal and rapidly cooling it in water.

This research has dispelled these conventions. "We've broken new ground by showing that metallic glasses do not have to be alloys, and can be produced using an alternate method," said Yusheng Zhao, Zhang's colleague and the paper's co-author.

Zhang and Zhao used x-rays at NSLS beamline X17B2 and ANL to watch how the zirconium changed from a metal to a glass as the pressure and temperature increased. When shined at the sample, the x-rays acted like tiny probes. They bounced off the zirconium atoms and then exited the sample, forming a pattern recorded by a detector. When analyzed, the pattern yielded information about how the structure of the zirconium crystal changed as it was squeezed and heated.

In ongoing follow-up research, Zhang and Zhao will work with commercial-grade zirconium, which is not as pure and, therefore, is less expensive. They want to create a similar glass, but have found that even higher temperatures and pressures are required, and yield a glass



An x-ray scattering image recorded in a CCD detector for a zirconium specimen recovered at ambient conditions. The pattern is characteristic of an amorphous phase and does not reveal any diffraction lines of crystalline zirconium metal.

with lesser quality than that produced using pure zirconium. The researchers hope to remedy this with future experiments.

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—Laura Mgrdichian