Photo-tuning acoustic resonances in glasses

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DMR-0205521

Glasses are complex materials whose molecules are disordered (like a liquid) but are rigidly bonded (like a solid). In this work we have discovered that specific germanium-selenium glasses can be reversibly softened (photo-melted) by illuminating with a *mere few thousandths of a Watt* of light! To place this work in context, similar magnitude of changes through thermal means would require heating the material close to its melting point (~900°C) or subjecting it to thousands of atmospheres of pressure. This discovery has opened new ground in the study of glasses providing information about the role of connectivity of their atoms and, remarkably, how chemical bonding can be tuned by very low level illumination.

Physical Review Letters 92, 245501 (2004).

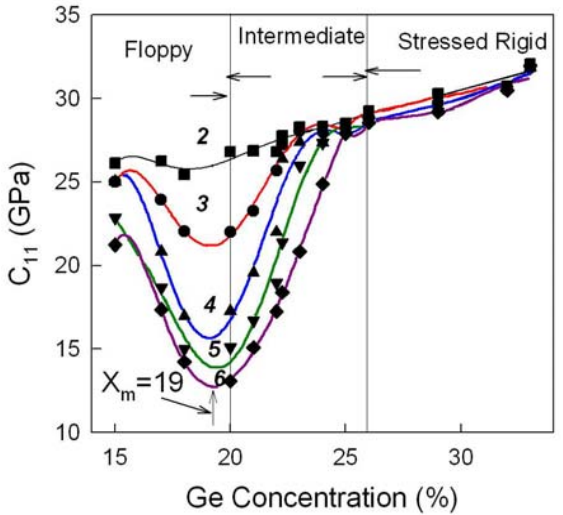

Figure: The elastic constant C_{11} pertains to a material deforming under a force and then recovering to its original shape after the force ceases. Here the "force" is provided by the laser light. Figure shows variations of C_{11} as a function of laser power increasing from 2 to 6 milli-Watts in Ge_xSe_{1-x} glasses. Note the deep minimum in C_{11} near the composition x = 19% illustrating the dramatic photo-softening.

Noble laureate P.W. Anderson has stated that "*"The deepest and most interesting unsolved problem in solid state theory is probably the theory of the nature of glass and the glass transition. This could be the next breakthrough in the coming decade."* - P.W. Anderson, Science **267**, 1615 (1995). This statement highlights one of the most significant issues in contemporary solid state physics. The underlying importance stems from the tremendously varied and complex material that constitute a glass. These random networks are an assembly of interconnected atomic or molecular units whose organization has been arrested to varying degrees, thereby making their theoretical understanding difficult and experiments challenging to interpret. Despite the complexity of glasses and the challenges in understanding their fundamental characteristics, these non-crystalline materials find wide usage in the high technology sector and will continue to make a major impact in the future.

In this study we have explored the photo-response of glasses in an effort to understand their mechanical properties and relationship to the connectivity between atomic units. We have discovered a previously unidentified, large scale, photo-reversible glass state whose chemical bonds can be manipulated by low level laser illumination. This discovery opens a new Research and Development avenue to pursue efforts to understand these complex technologically important materials. The results were published in the June 18, 2004 issue of Physical Review Letters.

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Education:

One undergraduate (Ilya Finkler), one graduate student (Jared Gump) and a postdoctoral associate (Hua Xia) contributed to this work. Ilya Finkler was an REU student and has since graduated and is presently pursing a Ph.D. in Physics at Harvard. He was awarded an NSF graduate fellowship and was a Goldwater fellow. Jared Gump received his Ph.D in 2003 and, after a postdoctoral position at the Naval Research Laboratory, recently joined their permanent staff. Hua Xia is presently at the General Electric Corporation as a Photonic Systems Engineer at its Global Research and Development Center.

Societal Impact:

The response of glasses to photo-illumination has a major impact in our lives. Applications of these photo-induced effects include communication/data transmission via glassy fibers (presently transmitting more information than copper wires) and in technologies such as optical/holographic recording and erasable compact discs, nano-scale read write memories and non-linear devices. As shown in this work, the ability to reversibly manipulate chemical bonds with light to tune the elastic behavior in glassy materials has the potential for new applications in information storage and recovery.