Physicists Find a World of Motion In the Mystery of Aging Glass

September 19 2009

(PhysOrg.com) -- Physicists super-cooled a liquid into glass in order to observe the slowing of particles. It's a material that still perplexes researchers despite thousands of years of household and industrial use.

Physicists working with glasses, a material that still perplexes researchers despite thousands of years of household and industrial use, have found new clues about how glasses age.

The University of Pennsylvania-led study set out to determine why glasses become more viscous and rigid over time without major changes to their molecular structure, a phenomenon known as aging. The researchers introduced a new technique to permit observation of particle rearrangements in an aging glass just after its formation. The findings provide experimental input for modern theories of glasses and provide insight about dynamic arrest in systems ranging from traditional molecular glasses to traffic jams.

The physicists created soft colloidal glasses by suspending microgel spheres in water. The microgel particles were special in that their diameters vary with changes in temperature. Using a mercury lamp to focus energy into the colloidal suspension, the team rapidly heated the spheres, causing them to shrink, move freely and rearrange in an experimentally-induced liquid state. The team then removed the light, thus quenching the entire system using a rapid temperature drop and returning the liquid to a glass state in about a tenth of a second.

In the following tens of seconds, the team used a microscope to observe what they believe to be the reason why the dynamics of glass get slower and more sluggish as they age. Researchers observed a special class of rearrangement event in which the particles composing the glass dramatically change their local environments, losing neighboring particles never to regain them. The number of these so-called irreversible rearrangement events decreased as the glass continued to age, and the number of particles required to move as part of these irreversible rearrangements increased. Initially, rearrangement of particles would occur in groups of 10 to 20. As time passed and the glass continued to relax, a real concerted effort was required. In this case, some 50 to 100 particles were required to move to gain a better particle configuration, slowing the process even further.

Thus, as glass ages, the motion of more and more particles is required to accompany irreversible arrangements, thereby slowing glass dynamics.

“The nature of the glass phase is a deep and long-standing unsolved problem in science, and insights about how these materials age hold potential for applications ranging from improved vehicles for drug delivery to novel coatings based on polymer, ceramic, and metallic glasses,” said Peter Yunker, a doctoral student in the Department of Physics and Astronomy at Penn.

The Penn researchers employed state-of-the-art digital imaging technology and computer image analysis for their microscopy experiments. “We used microscopy to visualize the structure and dynamics of ‘big slow-moving atoms’ in the colloidal glass,” said Arjun Yodh, professor in the Department of Physics and Astronomy at Penn. “ We discovered that only a very select class of fast-moving clusters of particles play a role in helping the glass to find its low energy configurations.”

The study, “Irreversible Rearrangements, Correlated Domains, and Local Structure in Aging Glasses,” was published in the Sept. 11 issue of the journal *Physical Review Letters*.

Provided by University of Pennsylvania (news : web)