Physicists crack another piece of the glass puzzle (w/ Video)

October 16 2012, by Carol Clark

Shattering myths: For all practical purposes, glass is a solid. But physicists are still struggling to explain how, and when, a liquid transitions into a glassy material.

(Phys.org)—When it comes to physics, glass lacks transparency. No one has been able to see what's happening at the molecular level as a super-cooled liquid approaches the glass state – until now. Emory University physicists have made a movie of particle motion during this mysterious transition.

Their findings, showing how the rotation of the particles becomes decoupled from their movement through space, are being published in the Proceedings of the National Academy of Sciences.

"Cooling a glass from a liquid into a highly viscous state fundamentally changes the nature of particle diffusion," says Emory physicist Eric Weeks, whose lab conducted the research. "We have provided the first direct observation of how the particles move and tumble through space during this transition, a key piece to a major puzzle in condensed matter physics."

Weeks specializes in "soft condensed materials," substances that cannot be pinned down on the molecular level as a solid or liquid, including everyday substances such as toothpaste, peanut butter, shaving cream,the plastic and glass.

Scientists fully understand the process of water turning to ice. As the temperature cools, the movement of the water molecules slows. At 32 F, the molecules lock into crystal lattices, solidifying into ice.

In contrast, the molecules of glasses do not crystallize. The movement of the glass molecules slows as the temperature cools, but they never lock into crystal patterns. Instead, they jumble up and gradually become glassier, or more viscous. No one understands exactly why.

The phenomenon leaves physicists to ponder the molecular question of whether glass is a solid, or merely an extremely slow-moving liquid.

This purely technical physics question has stoked a popular misconception: That the glass in the windowpanes of some centuries-old buildings is thicker at the bottom because the glass flowed downward over time. "The real reason the bottom is thicker is because they hadn't yet learned how to make perfectly flat panes of glass," Weeks says. "For practical purposes, glass is a solid and it will not flow, even over centuries. But there is a kernel of truth in this urban legend: Glasses are different than other solid materials. "

To explore what makes glasses different, the Weeks lab uses mixtures of water and tiny plastic balls, each about the size of the nucleus of a cell. This model system acts like a glass when the particle concentration is increased.

A major drawback to this model system is that actual glass molecules are not spherical, but irregularly shaped.

"When the hot molten liquid that forms a glass cools down, it's not just that the viscosity becomes enormous, growing by a factor of a billion, there is something different about how the molecules are moving," Weeks says. "We wanted to set up an experiment that would allow us to see that movement, but spheres move differently than irregular shapes."

In 2011, however, the physics lab of David Pine, at New York University, developed a way to join clusters of these tiny plastic balls together to form tetrahedrons.

Kazem Edmond, while a graduate student at Emory, added these tetrahedral particles to the glass model system and led the experiments. Using a confocal microscope, he digitally scanned the samples as the viscosity increased, creating up to 100 images per second. The result was three-dimensional movies that showed the movement and the behavior of the tetrahedrons as the system reached a glassy state.

The movie and data from the experiment provide the first clear picture of the particle dynamics for glass formation. As the liquid grows slightly more viscous, both rotational and directional particle motion slows. The amount of rotation and the directional movements of the particles remain correlated.

"Normally, these two types of motion are highly coupled," Weeks says. "This remains true until the system reaches a viscosity on the verge of being glass. Then the rotation and directional movements become decoupled: The rotation starts slowing down more."

He uses a gridlocked parking lot as an analogy for how the particles are behaving. "You can't turn your car around, because it's not a sphere shape and you would bump into your neighbors. You have to wait until a car in front of you moves, and then you can drive a bit in that direction. This is directional movement, and if you can make a bunch of these, you may eventually be able to turn your car. But turning in a crowded parking lot is still much harder than moving in a straight line."

Previous research has inferred this decoupling of movement by experimenting with actual molecular glasses. The Weeks lab used a simple model system to scale up glassy material so that you can actually watch the decoupling process happening.

"Glass is important in everyday life," Weeks says. "The more we understand its fundamental nature, the more we may be able to improve it and use it in different ways. One reason that smart phones are getting smaller and better, for example, is that stronger and thinner glass is being developed."

More information: www.pnas.org/content/early/201 … /1203328109.abstract

Provided by Emory University