Probing the mechanical response of colloidal glasses using confocal microscopy

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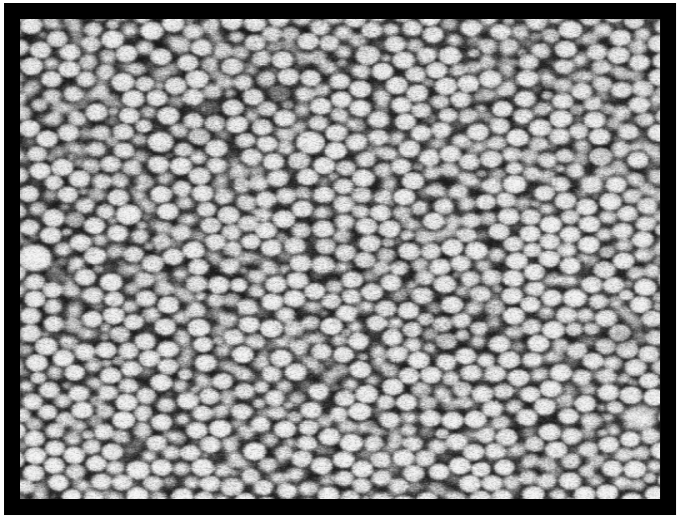
When a liquid is slowly cooled, the particles arrange into an ordered array and the substance becomes an equilibrium crystal. Rapid cooling, on the other hand , can bring the liquid out of equilibrium and often leads to the formation of a glass. One of the biggest challenges is to understand the nature of a glass and glass transition: how do the microscopic motions of its constituent particles, which are structurally arranged very similarly to a liquid, lead to a solid-like behavior of the substance as a whole?

Unfortunately, individual particles in atomic and molecular glasses are too small to be observed directly. In order to circumvent this issue, we use colloid hard spheres as a model system which exhibits a glass transition. The glassy state is achieved via abrupt densification, an analog of rapid cooling. We apply a shear deformation at different rates and visualize the 3-dimensional particle motion using confocal microscopy. The time dependent position of every particle is obtained with high precision using digital image processing. This information can be analyzed to gain insight as to both the local and global structure and kinetics. In particular, we demonstrate that properties of a colloid glass are dominated by the total amount of accumulated strain and are practically insensitive to the rate with which this strain builds up.

Understanding the relationship between the particle dynamics and bulk behavior of a glass is of fundamental interest, but also with enormous potential for engineering applications. Insight into the connection between micro- and macroproperties of materials increases one's ability to predict their response to changing environment (e.g., to stress or strain) and to control their functionality.



Particles (white circles) are imaged in 3 dimensions with Laser Scanning Confocal Microscopy. The movie shows a top-down view of a slice 60x60 micron square, imaged at 30s/frame. Particles travel upwards, in the direction of the applied shear deformation. Special software is used to extract the particle coordinates in 3D based on the pixel intensity, allowing for analysis of the particle dynamics.

Supported by Herschel Smith Undergraduate Fellowship and NSF DMR-0213805