Summer Scholars Research Proposal

Title:
Particle jumps in a colloidal system.

Name of student and faculty mentor:
XXXX
Dr. XXXX
Department of Physics, Saint Joseph's University

Relevant coursework completed:
University Physics, Thermodynamics, Solid State Physics
Volunteer Research, Honors Research Project
2006 Barbelin Scholar for *Microscopy investigations of the re-entrant glass transition in a colloidal suspension.*

Project background:
This project is a continuation of a previous Barbelin Scholars project entitled *Microscopy investigations of the re-entrant glass transition in a colloidal suspension.* With the new experiences and knowledge it was possible to specify an interesting problem that so far has not been studied thoroughly: the nature of jumps in a colloidal system. Our motivation for studying these systems is a result of their common use as a model for understanding the nature of glass.

Although we encounter glass every day, there is still much that we do not know about it. For example, it is often believed that glass flows slowly, yet noticeably over a timescale of hundreds of years. The scientific community does not fare much better: in spite of much theoretical and experimental work, to date there is no consensus on a comprehensive theory that would describe glass. We do know that glass is an intermediate state of matter between a solid and a liquid. It is therefore a general description not limited to the quartz glass in windows. A glass is formed if a liquid is cooled at such a rate that the molecules do not have enough time to assume the crystalline array characteristic of solids. In this sense, a glass can be viewed as a 'disordered solid' on the micro scale or a 'very viscous liquid' on the macro scale.

Due to the size scale of molecular glass, it is difficult to study glass directly. In light of this, model systems have been developed, and some of the most popular have been colloidal suspensions. Colloidal suspensions are simply solid particles submerged in a liquid. In the context of glass research, micrometer size particles are used. Instead of lowering the temperature as in the forming of real glass, the concentration of these particles is increased and a transition analogous to the molecular glass transition occurs. Specifically, when the volume fraction – or the percentage of total volume taken up by the colloids – approaches $\phi_g \approx 0.58$, the dynamics slow dramatically.

The situation, as described so far, relates to particles that behave like hard spheres, i.e. interact only by direct contact, much like billiard balls. More interesting behavior, which can be also compared to molecular glass, can be observed upon introducing an attraction between the particles. A small attractive potential causes the glass transition to shift to higher volume fractions. Therefore, if we introduced an attraction to a glass at $\phi_g \approx 0.58$, the glass would melt to a liquid. However, a large attraction, causes the volume fraction of the glass transition to shift back to lower volume fractions: upon further increase in attraction, the liquid would return to a new glass phase. (See Fig. 1.) This glass – liquid – glass transition is known as the re-entrant glass transition and is central in our studies.

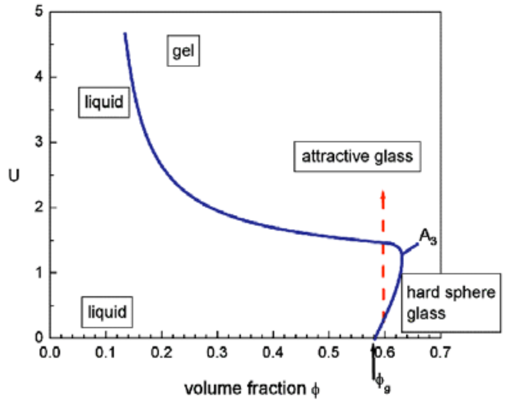

Figure 1. Phase diagram of the glass transition. On the vertical axis attractive potential is shown, on the horizontal – volume fraction. The blue line denotes the border between different phases. The red dashed line shows a path from a hard-sphere glass to a liquid and back to a glass - an attractive glass.

<u>Description of the proposed project:</u>

Our study will investigate how the colloidal particles "jump" as the re-entrant glass transition is approached. In a suspension with a high volume fraction, each particle is trapped in a cage formed by its neighbors, and can only move when a hole opens in that cage. Since the time a particle waits for such an opening is much greater than the time it takes to moves through the hole, we can treat these particles as if they jumped from position to position. Our goal is to quantify these jumps and how they change during the re-entrant glass transition. It is our hope that our work will contribute toward a better understanding of the glassy state, which is the ultimate goal of studying this model system.

As our model system we will use poly-(methylmetacrylate) particles ($d \approx 1.5 \mu m$) suspended in a decalin/cyclohexylbromide mixture. We will induce an attraction between the PMMA particles by adding a species of smaller particles (polystyrene). The polymers exert equal pressure in all directions on the PMMA particles. However, when two of the PMMA particles approach each other to a distance roughly equal to the polymers' radius, they will expel the polymers from between each other, causing a net pressure that pushes the colloids closer together. We can thus control the strength of the interaction (by changing the polymer concentration) and the range (polymer size). Using microscopy techniques we will record the motion of the colloidal particles and analyze it with computer software. We then plan to compare the results with predictions stemming from computer simulations.

Much of the work has already been done. We have verified the sizes of the colloidal particles and of the polymers. Many of the samples already analyzed during previous projects, can be now analyzed from the new perspective. Finally, all our previous results will be an excellent basis for a new series of samples.