Dissertations

Effect of Colloidal Interactions on Formation of Glasses, Gels, Stable Clusters and Structured Films

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Abstract
Colloidal suspensions are ubiquitous because of their vast industrial and household usage. We demonstrate that interactions between colloidal particles play a crucial role in manipulating the phase behavior and thereby the macroscopic properties of a variety of colloidal materials, including structured films, gels, glasses and stable clusters. First, we examined films comprised of two different colloidal particles and investigated the impact of colloidal interactions in manipulating the extent of segregation in the dried films. A transport model was used to predict the volume fraction profiles of the particles as a function of film thickness, which showed that segregation could be altered by changing the particle interactions. Experimental studies were carried out using different charged latex particles and varying the pH to change the interactions, and the results from experiments and model show a very good agreement to capture the extent of segregation. Second, we studied the effect of adding low molecular weight adsorbing and non-adsorbing polymers to suspensions to modify the interparticle interactions. We studied the structural dynamics and bulk rheology of a disk-shaped clay colloid, laponite® , and polymer. Under basic conditions laponite® forms a

repulsive colloidal glass. We show that low concentrations of an adsorbing polymer retards glass formation, whereas at higher concentrations an attractive glass is formed. Thus, we obtain a type of re-entrant glass transition, which is a first of its kind observed in anisotropic colloids with adsorbing polymer. On the other hand addition of a non-adsorbing polymer to laponite® suspensions triggers the formation of particle clusters, and increasing the concentration of polymer increases the strength of attraction between the particles and the size of the clusters.

To further understand formation of stable clusters, we utilized population balance equations (PBE) models to study aggregation of charged colloids under quiescent conditions. We considered particles with a DLVO-type potential, where the interactions are a sum of van der Waals attraction and electrostatic repulsion. Under certain conditions, the net repulsion between large aggregates and a single particle acts as a barrier against further aggregation, and clusters reach a stable size. The PBE model was used to map out regimes of uncontrolled aggregation, controlled aggregation, and no aggregation as a function of ionic strength and colloid weight fraction. The model was tested using experimental data on charged latex particles with different colloid weight fractions and ionic strengths. The model was able to predict the regime of controlled aggregation and final size of aggregates very well. However, the rate of aggregation predicted by the model was much faster than observed experimentally. Finally, we explored aggregation of latex particles in a shear environment similar to that used in industrial toner production processes. We studied the effect of temperature, pH and coagulant concentration on aggregation and showed that there is a optimum variable space to have aggregates of controlled size and distribution.