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Title: "Colloids and Nucleation"
Final Technical Report
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The objectives of the work funded under this grant were to develop a microphotograpic technique and use it to monitor the nucleation and growth of crystals of hard colloidal spheres. Special attention is given to the possible need for microgravity studies in future experiments.

A number of persons have been involved in this work. A masters student, Keith Davis, began the project and developed a sheet illumination apparatus and an image processing system for detection and analysis. His work on a segmentation program for image processing was sufficient for his master's research and has been published [1]. A post doctoral student Bernie Olivier and a graduate student Yueming He, who originally suggested the sheet illumination, were funded by another source but along with Keith made photographic series of several samples (that had been made by Keith Davis). Data extraction has been done by Keith, Bernie, Yueming and two undergraduates employed on the grant. Results are published in Langmuir [2].

These results describe the sheet lighting technique as one which illuminates not only the Bragg scattering crystal, but all the crystals. Thus, accurate crystal counts can be made for nucleation rate measurements. The strange crystal length scale reduction, observed in small angle light scattering (SALS) studies, following the initial nucleation and growth period, has been observed directly. The Bragg scattering (and dark) crystal size decreases in the crossover region. This could be an effect due to gravitational forces or due to over-compression of the crystal during growth. Direct observations indicate a complex morphology for the resulting hard sphere crystals. The crystal edges are fairly sharp but the crystals have a large degree of internal structure. This structure is a result of (unstable) growth and not aggregation.

As yet unpublished work compares growth exponents data with data obtained by SALS. The nucleation rate density is determined over a broad volume fraction range (0.505 to 0.575) and compared to classical nucleation rate calculations. The experimental nucleation rate density varies with volume fraction more slowly than expected theoretically. Gravity may influence nucleation because crystal nuclei are more dense than the surrounding fluid and may be gravitationally convected. The largest observed crystal size was near volume fraction 0.52. Near the freezing point, crystals should grow to large size because nuclei are sparse and there is plenty of room to grow without contacting other crystals. Near melting the opposite is true, with crystals growing into one another shortly after nucleation. The maximum crystal size seen near 0.52 volume fraction suggests that gravitational stresses are limiting crystal growth near freezing.

Thus we have developed a useful light scattering technique for real space observation of all crystals present in the scattering volume and have found evidence that gravity does have profound effect on earth based measurements of hard sphere colloidal particle thermodynamics. In addition, an undergraduate student was employed to follow up on a multiple scattering suppression technique, similar but not identical to one developed at NASA Lewis. This work resulted in another NASA supported publication [3].

References:

[1] K. A. Davis, S. T. Acton, and B. J. Ackerson, IEEE Southwest Symposium on Image Analysis and Interpretation, **IEEE Cat. No. 96TH8166**, 178 (1996).

[2]Y. He, B. Olivier and B. J. Ackerson, MORPHOLOGY OF CRYSTALS MADE OF HARD SPHERES, Langmuir **13** 1408 (1997).

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