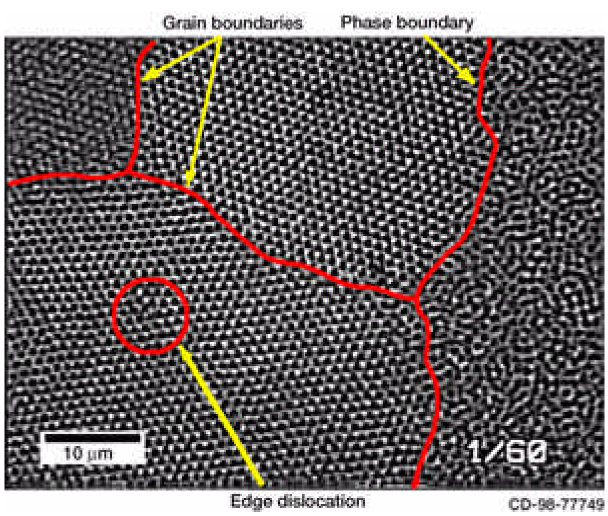
Microgravity Experiments Being Developed for Microscopic Study of Colloidal Spheres

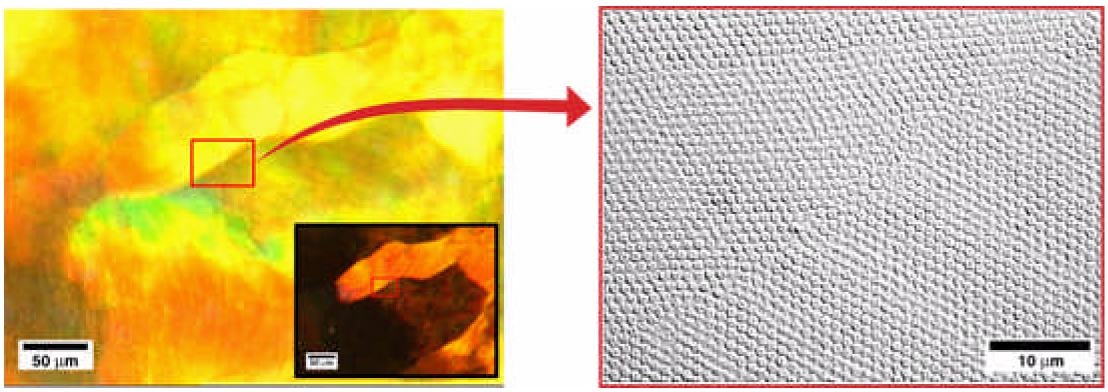
Microscopic spheres suspended in liquid become highly ordered under the proper conditions. Such collections of particles, called colloidal suspensions or colloids, are the subject of a series of ongoing microgravity experiments at the NASA Lewis Research Center. By studying the way these colloidal suspensions order themselves, scientists can better understand how atoms of a liquid become ordered to form a solid. In addition, highly ordered colloids have special properties that may make them useful in future high-tech applications. Work is underway at Lewis to develop an optical microscope to view these colloidal suspensions sphere by sphere in microgravity.

Previous Lewis experiments have studied the average properties and macroscopic features of colloidal suspensions using laser light scattering techniques and macrophotography. However, different techniques are needed to observe the behavior of individual spheres at specific locations within a suspension. Using a commercially available optical microscope, one can see local features and phenomena, as in the following photomicrograph.



Photomicrograph illustrating various local features in a suspension of 1.0-mm-diameter spheres.

The initial thrust in developing a microscope for microgravity research was to build up Lewis' expertise in applying optical microscopy to colloidal suspensions and to determine and demonstrate the core capabilities required for microgravity experiments. Many of the colloidal suspensions of interest contain 50 to 60 vol % spheres. To image beyond the surface of these high-volume-fraction colloids, one must closely match the optical index of refraction of the liquid and the spheres, rendering the spheres invisible under normal illumination. However, recently at Lewis several well-established optical contrast techniques from the biological and materials science fields were combined with real-time image-processing hardware to successfully image high-volume-fraction suspensions of spheres ranging from 0.5 to 1.2 µm in diameter. Both Nomarski Differential Interference Contrast (DIC) and phase contrast techniques have produced images of colloidal crystals well beyond the walls of experiment cells. In addition, darkfield and oblique illumination techniques have been used to distinguish between colloidal crystal grains, bridging the gap between microscopic and macroscopic imaging as shown in the following figure.



Left: Darkfield illumination. Colloidal crystal grains are delineated by color variations produced by Bragg scattering from different crystallographic planes. Inset: Oblique illumination of same region. Right: Differential Interference Contrast technique image of dark-bordered region of image on left. Note grain boundary running from lower left to upper right.

NASA Lewis and Dynacs Engineering Company, Inc., engineers have begun developing concepts for the flight instrument, currently planned to be the first piece of experiment hardware in the Fluids Integrated Rack aboard the International Space Station. This microscope will support the Physics of Hard Spheres Experiment-2 (PhaSE-2; principle investigator, Paul Chaikin of Princeton University) and the Physics of Colloids in Space-2 experiments (PCS-2; principal investigator, David Weitz of the University of Pennsylvania). Current plans call for the contrast techniques described here, light-scattering optics, confocal imaging, on-orbit sample homogenization, and the capability for programmed and ground-controlled operations.

In addition to the microgravity activities just described, hardware is nearly complete for a separate series of ground-based experiments that actually depend on gravity to control the formation of colloidal crystals. These experiments, supported by the Lewis Director’s Discretionary Fund (DDF), will use a fixture that allows the microscope to rotate to various angles with respect to gravity. The first use of this apparatus will be to study the sedimentation-induced growth of long, thin columns of colloidal crystals that bear similarities to columnar growth commonly seen in commercial metal castings. The thrust of this DDF-sponsored research is to begin applying the results of colloidal sphere experiments to a wide range of materials science topics.

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