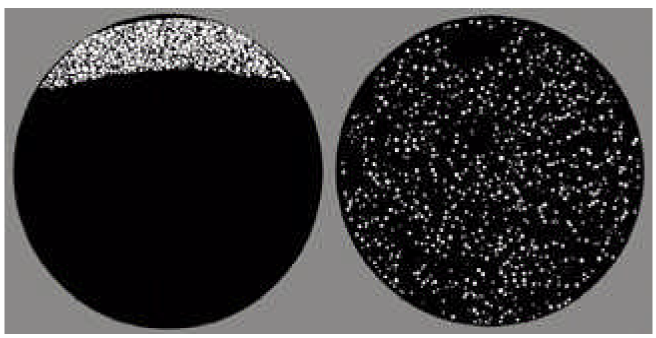
Coarsening in Solid-Liquid Mixtures Studied on the Space Shuttle

Ostwald ripening, or coarsening, is a process in which large particles in a two-phase mixture grow at the expense of small particles. It is a ubiquitous natural phenomena occurring in the late stages of virtually all phase separation processes. In addition, a large number of commercially important alloys undergo coarsening because they are composed of particles embedded in a matrix. Many of them, such as high-temperature superalloys used for turbine blade materials and low-temperature aluminum alloys, coarsen in the solid state. In addition, many alloys, such as the tungsten-heavy metal systems, coarsen in the solid-liquid state during liquid phase sintering. Numerous theories have been proposed that predict the rate at which the coarsening process occurs and the shape of the particle size distribution. Unfortunately, these theories have never been tested using a system that satisfies all the assumptions of the theory.



Photomicrographs of 10 vol % solid tin phase taken after samples were held 10 hr at 185 °C. Left: Ground experiment results show significant density-driven sedimentation and nonspherical particles. Because of the compacting of the particles (effective higher solid volume fraction) the coarsening rate was artificially increased and the result was a larger particle size. Right: STS-83 microgravity results show spherical, uniformly dispersed solid tin particles in a lead tin eutectic.

In an effort to test these theories, NASA studied the coarsening process in a solid-liquid mixture composed of solid tin particles in a liquid lead-tin matrix. On Earth, the solid tin particles float to the surface of the sample, like ice in water. In contrast, in a microgravity environment this does not occur. The microstructures in the ground- and space-processed samples (see the photos) show clearly the effects of gravity on the coarsening process. The STS-83-processed sample (right image) shows nearly spherical uniformly dispersed solid tin particles. In contrast, the identically processed, ground-based sample (left image) shows significant density-driven, nonspherical particles, and because of the higher effective solid volume fraction, a larger particle size after the same coarsening time.

The "Coarsening in Solid-Liquid Mixtures" (CSLM) experiment was conducted in the Middeck Glovebox facility (MGBX) flown aboard the shuttle in the Microgravity Science Laboratory (MSL-1/1R) on STS-83/94. The primary objective of CSLM is to measure the temporal evolution of the solid particles during coarsening. The particles were coarsened four times from 0 sec to 24 hours after a 9-min heat-up to 185 °C.

Quantitative analysis of the samples with a volume fraction of 10 percent solid is yielding data that are as spectacular as the microstructures. The data are so good that the kinetics and particle size distribution can be determined with unprecedented accuracy. CSLM has provided the first careful test of theory of Ostwald ripening by conducting the study at low solid volume fractions with the solids uniformly distributed in the sample.

CSLM hardware was developed and built jointly by the NASA Lewis Research Center and NYMA, Inc. CSLM has been selected for additional flight experiments as well as continued ground studies. Several new evaluation techniques have been developed, and numerous research papers have been published from this study by the principal investigator, Prof. Peter W. Voorhees, and his team.

Find out more about CSLM : http://exploration.grc.nasa.gov/CSLM/cslmrslt.htm

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