Coarsening in Solid-Liquid Mixtures-2
A Materials Science Experiment for the International Space Station

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The Coarsening in Solid-Liquid Mixtures-2 (CSLM–2) experiment is a materials science space flight experiment whose purpose is to investigate the kinetics of competitive particle growth within a liquid matrix. During this process, called coarsening, small particles shrink by losing atoms to larger particles, causing the larger particles to grow. In this experiment solid particles of tin will grow (coarsen) within a liquid lead-tin matrix. By conducting this experiment in a microgravity environment, scientists can study a greater range of solid volume fractions, and the effects of sedimentation present in terrestrial experiments will be greatly reduced. Moreover, coarsening data can be produced for the first time that can be compared directly to theory with no adjustable parameters (such as material transport due to convection). This will allow a greater understanding of the factors controlling the morphology of solid-liquid mixtures during coarsening. The science team is headed by Professor Peter Voorhees of the Department of Materials Science and Engineering, Northwestern University.

Figure 1 shows the lighter tin particles (in white) floating on the denser lead-tin matrix (in black) in a terrestrial gravity environment. Figure 2 shows the distribution of tin within the matrix in the microgravity environment of space. The CSLM–2 experiment is slated to fly onboard the International Space Station (ISS) in the fall of 2002. The experiment will be performed in the Microgravity Science Glovebox (MSG) installed in the U.S. Laboratory Module.

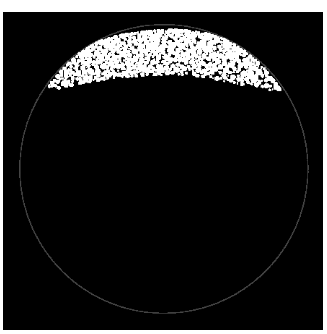

Figure 1.—Lighter tin particles float on the solid-liquid eutectic mixture in normal Earth gravity.

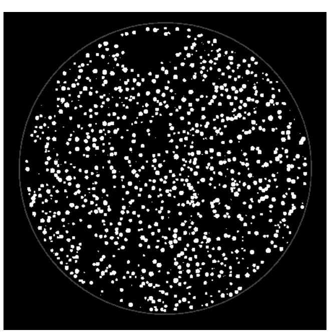

Figure 2.—The low-gravity environment of space eliminates effects such as buoyancy.

The coarsening of particles within a matrix is a phenomenon that occurs in many metallic and other systems. For example, the second-phase particles in high-temperature turbine blade materials undergo coarsening at the operating temperature of the turbine. The coarsening process degrades the strength of the turbine blade because turbine alloys containing a few large particles are weaker than those containing many small ones. Coarsening occurs in liquid-phase sintered materials such as tungsten carbide-cobalt, iron-copper, dental amalgam for fillings, and porcelain. The growth of liquid droplets in a vapor phase that occurs inside rain clouds (particularly near the equator, where the vapor pressure of water is high) is a commonplace example of the coarsening phenomenon. The CSLM–2 study will help define the mechanisms and rates of coarsening that govern all these systems.

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The matrix is eutectic liquid and the solid particles are Sn-rich. (A eutectic is an alloy composition with the lowest melting point.) Sample specimens are prepared by casting off-eutectic alloys of Pb-Sn into a chilled block and then severely cold-working the resulting ingots. After cold work, recrystallization takes place at room temperatures and results in a distribution of fine equiaxed grains. When the "green" samples are placed in an appropriate furnace and heated to a temperature (185 °C) just above the resulting eutectic temperature of Pb-Sn (~183 °C), the resulting eutectic liquid penetrates the grains of the structure, producing a dispersion of solid Sn-rich particles floating in a near eutectic-composition liquid. These particles will quickly form spheres as coarsening proceeds. After a controlled period of time, the samples will be rapidly cooled to approximately 30 °C and stored at –20 °C onboard the ISS and at –80 °C in the laboratory to freeze the structure of the coarsened samples until the particle size and distribution are measured.

The Experiment

The CSLM–2 experiment is scheduled for delivery to the ISS in November 2002 via the Space Shuttle STS–113, ISS Flight 11A. Additional samples will be flown to the ISS on future flights.

Hardware

The flight hardware consists of a sample processing unit (SPU); an electronics control unit (ECU); a base plate; and sundry electrical harnesses, data cables, and vacuum hoses. The SPU (figure 3) incorporates the sample chamber assembly (SCA), which contains the samples and heating unit, a water reservoir, a pressurized air cylinder, and a vacuum connector. The ECU (figure 4) contains the power regulator, display, and computer circuit boards that control the experiment. The flight hardware will operate in the MSG (figure 5) on top of the Glovebox Integrated Microgravity Isolation Technology (g-LIMIT). The MSG will provide power, vacuum, cooling, and containment for the CSLM–2 experiment. The g-LIMIT will provide isolation from ISS accelerations and vibrations, and will measure the microgravity environment for correlation with sample results.

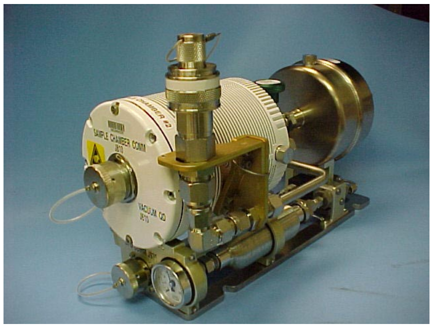

Figure 3.—Sample processing unit.

Figure 4.—Electronics control unit.

Operations

The SPU heats material samples up to 185 °C in less than 9.5 minutes, holds at temperature for a predetermined time at 185 °C ±0.1 °C, and then quenches the samples to room temperature in less than one minute. The SPU sample holder can house four lead-tin samples of 12-mm diameter and 6-mm thickness, which are heated simultaneously.

The heating unit is composed of several sets of thin foil kapton heaters that are integrated into the sample holder assembly. The heater sandwiches provide uniform heating density via a 0.0001-inch separation between heating elements. These heaters are composed of kapton, CuNi heating elements, and adhesive. The kapton heaters are space qualified and can operate up to 200 °C.

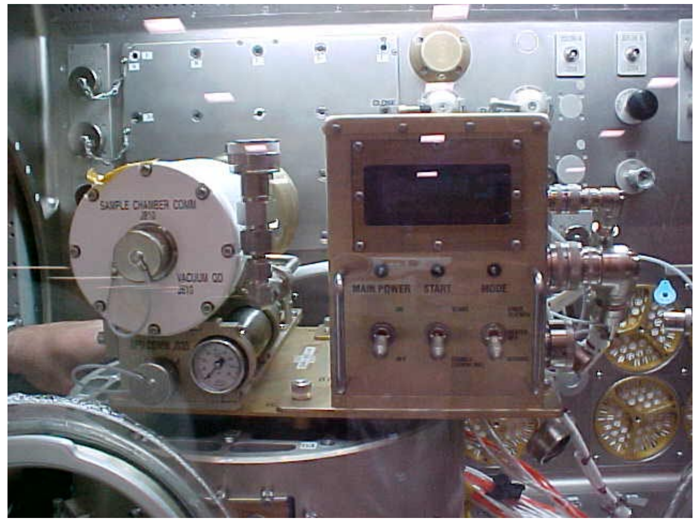

Figure 5.— SPU and ECU on g-LIMIT within MSG working volume.

Post-Operations

After processing, power to the CSLM–2 hardware will be shut off and cables will be removed. The SCA is detached from the SPU base plate and quench reservoir, removed from the MSG, and stowed in an ARCTIC freezer. The remainder of the SPU is stowed. A new SPU can now be set up within the MSG.

The SCA is stowed in the ARCTIC to prevent any change in the structure of the sample after processing. Two entire sample chambers are stowed in one ARCTIC freezer at –20 °C until preparations for return to Earth. Two ARCTIC units are required to cold stow the four furnace units. The quench water within the furnace chamber will freeze, but it is of insufficient quantity to burst the chamber. PI lab tests have shown that samples within the sample holder show no damage when immersed in water and then frozen at –20°C.

The engineering, design, and development of the CSLM–2 flight system is being performed by ZIN Technologies, Inc., under contract to NASA Glenn Research Center.

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