Coarsening in Solid-Liquid Mixtures (CSLM)

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The CSLM experiment examines the dynamics of particle-growth in a two-phase mixture. In a dispersion of particles in a matrix phase where diffusion between the particles is permitted, the larger particles grow at the expense of smaller particles, resulting in a reduction of interfacial area and thus minimizing the total energy. This coarsening process is known as Ostwald ripening. Ostwald ripening is a phenomenon that occurs in many metallurgical and other systems. For example, the second-phase particles in high temperature materials used in turbine blades undergo coarsening at the operating temperature of the turbine. The coarsening process degrades the strength of the blade since alloys containing many small particles are stronger than those containing a few large ones. Other systems that show coarsening are liquid-phase sintered materials such as tungsten carbide-cobalt alloys, iron-copper alloys, dental amalgam alloys used for fillings, and porcelain.

The kinetics of the coarsening are controlled by diffusional mass flow. The classical work by Lifshitz, Slyosov, and Wagner predicts that the average particle size R is proportional to the cube root of time t. Unfortunately, the theory is only valid in the limit of a vanishingly small volume fraction of coarsening phase. More recent theories that include the effect of finite volume fraction, and thus particle-particle diffusional interactions, predict that the exponent of the temporal power law will not be a function of the volume fraction, but the amplitude of the temporal power law, the rate constant, will depend on the volume fraction. The dependence of the rate constant, as well as the particle size distribution (PSD), on the volume fraction is different for each theory. One goal of this experiment is to measure these two parameters in order to judge on the validity of the different theories.

A system composed of solid Sn-rich particles in a Pb-Sn eutectic liquid was chosen in order to obtain fast particle coarsening and spherical particles. To avoid the large-scale settling of the particles due to the density difference between the solid and liquid, it was necessary to do the experiments in microgravity. In the ground-based experiments, only volume fractions above 70% guarantee a stable structure. At these high volume fractions the particle phase forms a stable network in which the particles cannot move. However, it appears that even at these high volume fractions slight settling is unavoidable. In addition, most theories do not make predictions on the coarsening rate at these high volume fractions. The theories are usually valid only for volume fractions below 30% and for non-contacting particles. In the experiments, particle volume fractions between 5% and 80% were used. This allows on the high end comparison to ground-based data and on the low end has a region where a comparison between theory and experiment can be made. Samples containing different volume fractions of Sn were coarsened for times ranging from 70 seconds to 24 hours.

Thus far, we have analyzed samples containing 10% particle phase. The results show clear evidence of non-steady-state coarsening. Using theoretical calculations of non-steady-state coarsening, it was possible to simulate the evolution of the average particle size as well as the PSD in detail. The agreement between theory and experiment is excellent. An evaluation of individual theories of Ostwald ripening, however, cannot be performed at this point, but may be possible once the results for higher volume fractions are available. A discussion of the results of the spaceflight experiment will be presented.