N94-13751

SOLIDIFICATION OF EUTECTIC SYSTEM ALLOYS IN SPACE
M-19

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It is well known that in the liquid state eutectic alloys are theoretically homogenous under 1 g conditions. However, the homogeneous solidified structure of this alloy is not obtained because thermal convection and non-equilibrium solidification occur. The present investigators have clarified the solidification mechanisms of the eutectic system alloys under 1 g conditions by using the in situ observation method; in particular, the primary crystals of the eutectic system alloys never nucleated in the liquid, but instead did so on the mold wall, and the crystals separated from the mold wall by fluid motion caused by thermal convection as shown in Figure. 1. They have also found that the equiaxed eutectic grains (eutectic cells) are formed on the primary crystals. In this case, the leading phase of the eutectic must agree with the phase of the primary crystals as shown in Figure 2.

In space, no thermal convection occurs so that primary crystals should not move from the mold wall and should not appear inside the solidified structure. Therefore no equiaxed eutectic grains will be formed under microgravity conditions.

Past space experiments concerning eutectic alloys have been classified into two types of experiments: one with respect to the solidification mechanisms of the eutectic alloy and the other to the unidirectional solidification of this alloy. The former type of experiment has the problem that the solidified structures between microgravity and 1 g conditions show little difference. This is why the flight samples have been prepared by the ordinary cast techniques on Earth. Therefore it is impossible to ascertain whether or not the nucleation and growth of primary crystals in the melt occur and the if primary crystals influence the formation of the equiaxed eutectic grains.

In this experiment, hypo- and hyper-eutectic aluminum copper alloys which are near eutectic point are used. The chemical compositions of the samples are Al-32.4mass%Cu (hypo-eutectic) and Al-33.5mass%Cu (hyper-eutectic). Long rods for the samples are cast by the Ohno Continuous Casting Process and they show the unidirectionally solidified structure as shown in Figure 3. Each flight and ground sample has been made of these same rods. The dimensions of all samples are 4.5 mm in diameter and 23.5 mm in length. Each sample is put in a graphite capsule and then vacuum sealed in a double silica ampoule. Then the ampoule is put in the tantalum cartridge and sealed by electron beam welding.

For onboard experiments, a Continuous Heating Furnace (CHF) will be used for melting and solidifying samples under microgravity conditions. Six flight samples will be used. Four samples are hypo-eutectic and two are hyper-eutectic alloys. The surface of the two hypo-eutectic alloy samples are covered with aluminum oxide film to prevent Marangoni convection expected under microgravity conditions. Each sample will be heated to 700 °C and held at that temperature for 5 min. After that the samples will be allowed to cool to 500 °C in the furnace and then they will be taken out of the furnace for He gas cooling. Figure 4 shows the heating and cooling diagrams for the flight experiments.

After collecting the flight samples, the solidified structures of the samples will be examined and the mechanisms of eutectic solidification under microgravity conditions will be determined.

It is likely that successful flight experiment results will lead to production of high quality eutectic alloys and eutectic composite materials in space.

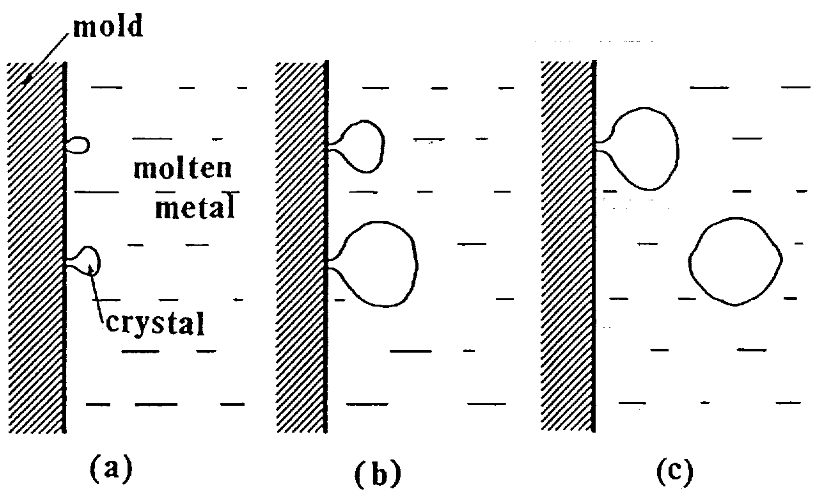

Figure 1. Schematic illustrations of the separation of primary crystals from the mold wall observed directly in some eutectic alloys under 1 g: (a) nucleation, (b) growth, (c) separation.

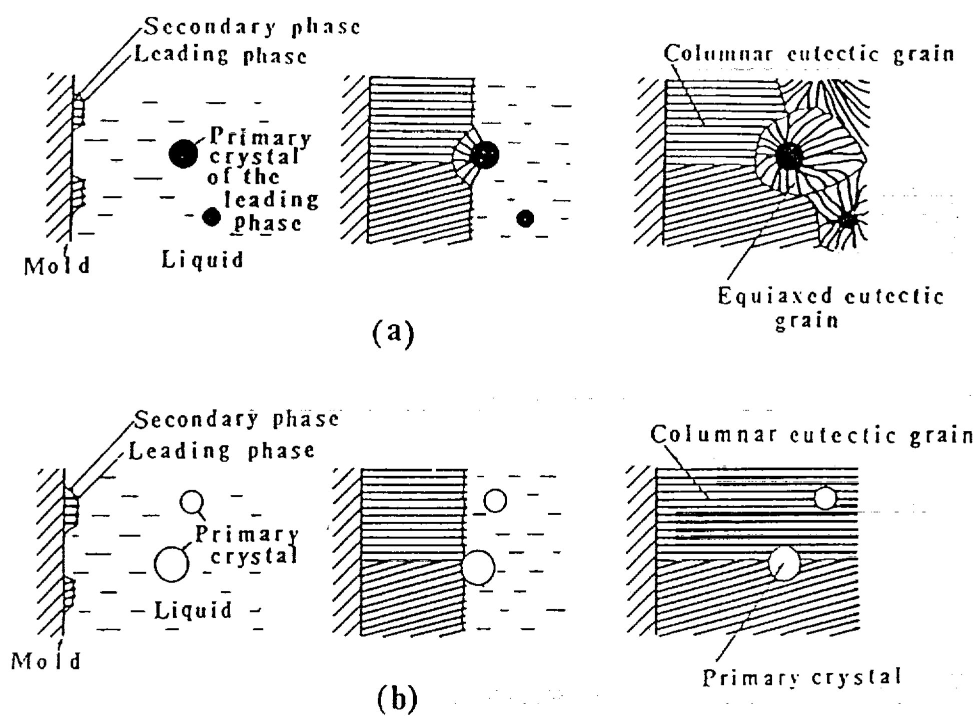

Figure 2. Schematic illustrations of the relation between the primary crystals and the eutectic grains. (a) Equiaxed eutectic grains formed on the primary crystals when the leading phase of the eutectic agrees with the phase of the primary crystal. (b) Formation of columnar eutectic grains are independent of the primary crystals. In this case the leading phase of the eutectic does not agree with the phase of the primary crystal.

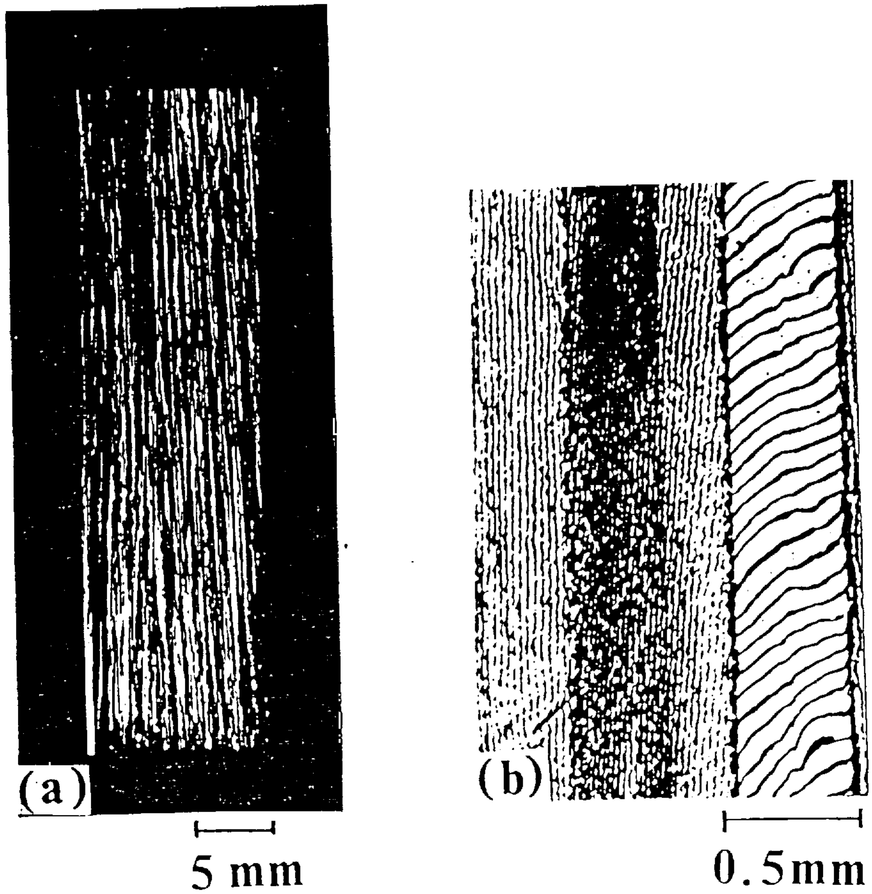

Figure 3. Unidirectionally solidified structures of Al-32.4 mass%Cu alloy used for sample: (a) macrostructure, (b) microstructure.

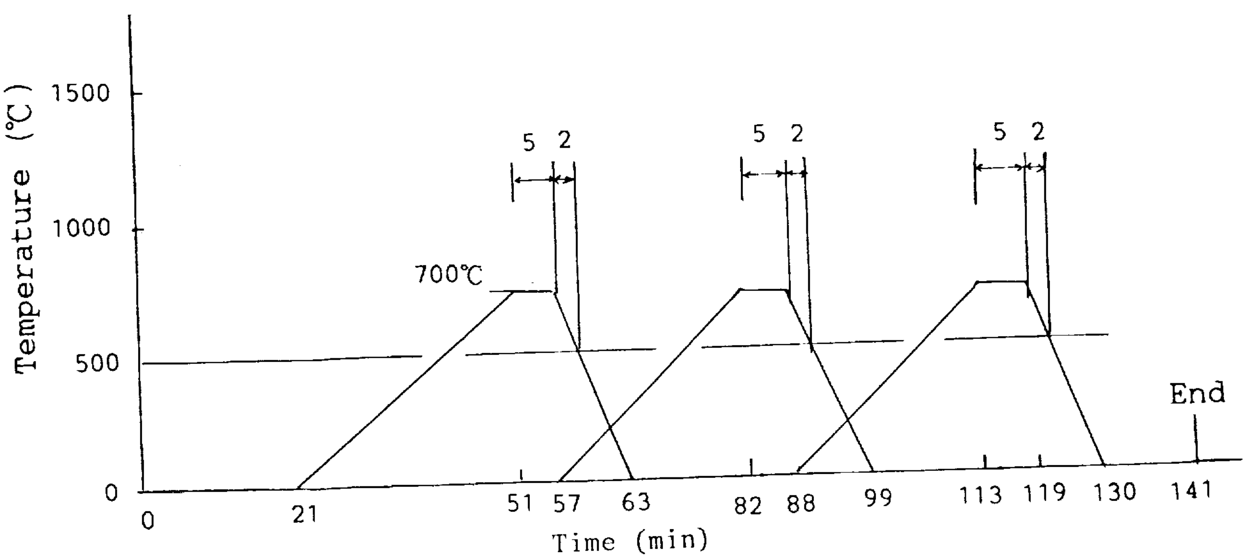

Figure 4. Heating and cooling curves for the samples.