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無容器プロセスによる Cu-Co 合金の溶融凝固

Melting and solidification of Cu-Co alloy by containerless process

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1. Introduction

Cu-Co and Fe-Cu alloys are peritectic alloys with a near-horizontal liquid phase line in a wide composition range of the alloy phase diagram. 2-phase separation occurs in Fe-Cu alloys with the onset of supercooling, suggesting the existence of a metastable solubility gap just below the liquidus line[1)]. Therefore, a similar phenomenon is expected to occur in Cu-Co alloys. The phase-separation structure of an alloy is determined by several factors, including composition of the constituent elements, cooling rate, undercooling, and melt convection[2)]. When Cu-Co alloys are melted and solidified in a container, the problem arises that sufficient undercooling cannot be obtained due to contact with the container. Therefore, the gas jet levitation method, a containerless processes, is used. Contact with the container is avoided, sufficient undercooling occurs, and a two-phase separation phenomenon is expected to occur. In this study, Cu-Co alloy is melted and solidified using the gas-jet levitation method. The objective is to understand the phase separation phenomenon during undercooling by analyzing the temperature profile and observing the internal microstructure.

2. Experimental method

Cu-Co alloys with a volume of approximately 14 mm^3 were prepared from samples of pure Cu 99.9% and pure Co 99.9%. The composition of the Cu-Co alloys ranged from Cu-10at%Co to Cu-90at%Co in 10% increments. Sample preparation and experiments were performed in a glove box, which was filled with Ar gas with an oxygen concentration of less than 30 ppm. Boron nitride, which has a low coefficient of thermal expansion and excellent heat resistance, was used as the specimen base. A two-color pyrometer and a semiconductor laser were installed. Ar gas was injected into the bottom of the sample, and the sample was levitated while being irradiated by the semiconductor laser to obtain temperature data during melting and fusion. After the experiment, the cross-sectional structure was observed using EPMA and optical microscopy.

3. Experimental Results and Discussion

Figure 1 shows the temperature data of Cu-60at%Co, and Figure 2 shows the cross-sectional structure taken by optical microscopy.

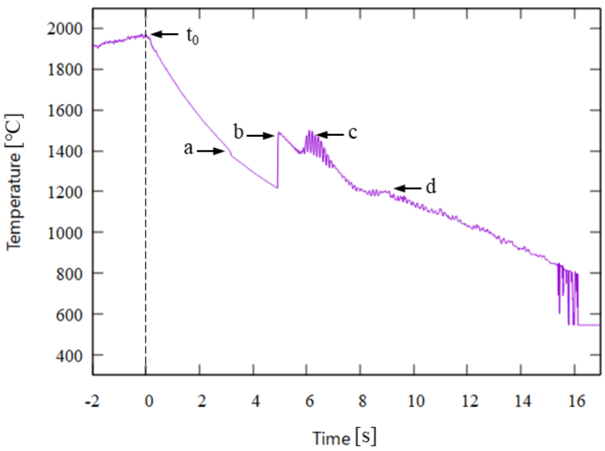

Figure 1. temperature data for Cu-60at%Co
(t_0: the laser irradiation was turned off, a: was presumed to be a liquid-liquid phase separation, b: The solidification reaction of the Co-rich phase occurred, c: was presumed to be a delayed thermal radiation of the Co center, d: solidification reaction of the Cu-rich phase occurred)

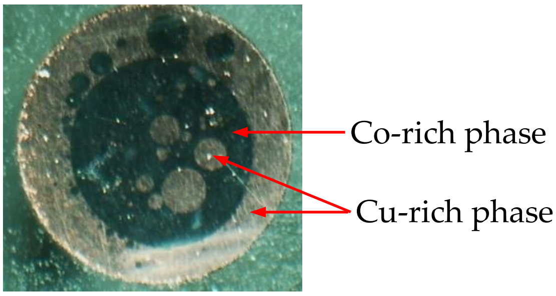

Figure 2. cross-sectional structure of Cu-60at%Co taken by optical microscopy

In Figure 1, the laser irradiation was turned off at t_0 and cooling was started. About 3.3 seconds, a change in the slope of the cooling curve was observed at 1400°C, which was presumed to be a liquid-liquid phase separation. The solidification reaction of the Co-rich phase occurred about 5 seconds, and the solidification reaction of the Cu-rich phase occurred about 8.5 seconds. We assume that the temperature change at 6 seconds are solidification of Co-rich phase which is remained in liquid phase. Figure 2 shows a macroscopic separation of the Co-rich phase around the center and the Cu-rich phase at the outside. Small Cu rich droplets were observed in Co-rich phase. The surface tension of Cu is 1.257[N/m][3] at 1014-1725°C, while the surface tension of Co is 2.03[N/m] at 1200°C and 1.80[N/m][4] at 1900°C. In the case of previous Fe-Cu studies[1], liquids with low surface tension cover the outside of sample. Therefore, the Cu-rich phase covered the outside and the Co-rich phase was at the center of sample.

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