Directional solidification of Al–Cu–Ag alloy

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Abstract Al–Cu–Ag alloy was prepared in a graphite crucible under a vacuum atmosphere. The samples were directionally solidified upwards under an argon atmosphere with different temperature gradients ($G = 3.99–8.79$ K/mm), at a constant growth rate ($V = 8.30$ µm/s), and with different growth rates ($V = 1.83–498.25$ µm/s), at a constant gradient ($G = 8.79$ K/mm) by using the Bridgman type directional solidification apparatus. The microstructure of Al–12.80-at.%–Cu–18.10-at.%–Ag alloy seems to be two fibrous and one lamellar structure.

The interlamellar spacings ($\lambda$) were measured from transverse sections of the samples. The dependence of interlamellar spacings ($\lambda$) on the temperature gradient ($G$) and the growth rate ($V$) were determined by using linear regression analysis. According to these results it has been found that the value of $\lambda$ decreases with the increase of values of $G$ and $V$. The values of $\lambda^2 V$ were also determined by using the measured values of $\lambda$ and $V$. The experimental results were compared with two-phase growth from binary and ternary eutectic liquid.

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1 Introduction

Many commercial materials are multicomponent alloys, whose properties are determined by the microstructure that develops during solidification and subsequent processing stages. One of the essential challenges in material science is to understand how multiphase microstructures form and how they can be controlled via deliberate selection of alloy composition and processing parameters. Multiphase solidification in multicomponent alloys is pertinent to many commercial materials and industrial processes, while it is also possible to raise challenging questions from a fundamental point of view. Within the past few years research activities dedicated to multiphase solidification of ternary and multicomponent alloys have experienced considerable amplification.

Multiphase solidification of multicomponent materials attracts pronounced academic interest as well. The study of the solidification behavior of multicomponent and multiphase systems is an important question in understanding the different properties of these materials. Whereas fundamental knowledge on solidification has been developed mainly for pure materials and for binary alloys exhibiting single-phase growth (solid solution) and/or two-phase growth in eutectic and peritectic class reactions, the process of microstructure formation during solidification is less understood for the cases where multiphase reactions occur along the solidification path of these alloys. A comprehensive overview with respect to the last topic is given by Hecht et al. [1]. Alloys of eutectic composition may also serve as model alloys for the investigation of pattern formation during directional solidification of eutectics [2–8].

The thermophysical properties of Al–Cu–Ag alloy are well known and the microstructures of three-phase growth
from eutectic Al–Cu–Ag liquid are very useful to extend the present theoretical models developed for coupled two-phase growth. Thus purpose of this work was to experimentally investigate the dependence of interlamellar spacings ($\lambda$) on the temperature gradient and the growth rate ($V$) in the Al-12.80-at.-%–Cu-18.10-at.-%–Ag alloy and compare the results with the previous experimental results for ternary and binary alloys.

2 Experimental details

2.1 Material preparation and processing

Using a vacuum melting furnace and a hot filling furnace an Al-12.80-at.-%–Cu-18.10-at.-%–Ag alloy has been prepared under a vacuum atmosphere by using 99.99% pure aluminum, 99.9% pure copper, and 99.99% pure silver. After allowing time for melt homogenization, the molten alloy was poured into 10 graphite crucibles (250 mm in length, 4 mm ID, and 6.35 mm OD) held in a specially constructed hot filling furnace at approximately 30 K above the melting point of alloy. The molten metal was then directionally solidified from bottom to top to ensure that the crucible was completely full.

Then each specimen was positioned in a computer-controlled Bridgman type furnace (Fig. 1). Unidirectional solidification of the samples with a moderate thermal gradient which is between 3.99 and 8.79 K/mm is performed with a maximum furnace temperature of 1300 K.

In the experimental technique, the sample was heated about 50–300 K above the melting temperature and after stabilizing the thermal conditions in the furnace under an argon atmosphere, the specimen was grown by pulling...