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Interfacial Characteristics of Al-Cu Foam Cast Composites for High Conductivity Applications

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To optimize the conductivity and the weight lightning, Al-Cu composites were prepared through an suction casting procedure. Pure copper metal foam was infiltrated by aluminum melt by applying the vacuum, and then warm rolling was conducted to remove some remaing pores at the inferface between the Cu foam and the aluminum matrix. Even though the casting time was short, a significant dissolution of Cu into the melt was observed. And various AlCu intermetallic compounds were found to occur at the interface during the isothermal heating process after the casting. The average thickness of the AlCu intermetallic compound tended to increase in proportion to the heating time. The electrical and thermal conductivity of the cast composites were found to be comparatively low, mainly attributed to the incomplete interfacial contact.

Keywords: *aluminum composites, copper foam, conductivity, intermetallic compound*

1. Introduction

Metal matrix composites (MMCs) or hybrid structure metallic materials in which different metals with various properties are joined have recieved attention for many industrial applications. There are numerous methods to fabricate MMCs or the hybrid materials such as casting, accumulative roll bonding (ARB) and powder metallurgy processes [1-3]. Among the many available methods, compound casting is an econmic process in which solid state metal and liquid state metal are brought into contact [3,4].

Recently, copper foam materials are commericially available, so high conductivity Al/Cu composites may be easily fabricated by infiltrating aluminum melt into the copper foam. In this research a vacuum suction casting method was also employed to produce the Al/Cu foam composites, followed by isothermal heating processes to strengthening Al/Cu interfaces. This article aims to investigate the microstructural evolutions with respect to the heat treatments of cast Al/Cu composites and the resultant properties of them.

2. Experimental Procedure

A piece of copper foam (Metalfoam, Korea) was inserted in a quartz tube with the inner diameter of 8mm, and pure aluminum melt at the temperature of about 750^{o}C was infiltrated into the prepositioned pure Cu foam by a vacuum suction apparatus. Then, the fabricated cast Al/Cu composite cylinder was warm-rolled (annealed at 300^{o}C before rolling) and isothermally heated under different conditions.

The electrical and thermal conductivities of the specimens were evaluated by using a contact-type tester (Fischer, Sigmascope SMP10) and laser flash analyzer (Netzsch, LFA447), respectively. The microstructural analyses were performed using optical microscope, scanning electron microscope (SEM, JEOL, JSM-5610) equipped with energy dispersive X-ray spectrometer (EDS), and X-ray diffractometer (XRD, Rigaku, Smartlab).

3. Results and Discussion

3.1 Dissolution of Cu Insert

Significant dissolution of copper occurred during the suction casting process. Based on SEM-EDS analyses, Al-Al_2Cu eutectic phases were formed around the prepositioned copper foam due to the dissolution. This dissolution is known to be generally proportional to the square root of contact time, and can be increased by a dynamic agitation [5]. In this experiment, aluminum melt is suctioned and forced to flow through tortuous paths in the prepositioned copper metal foam. Therefore, it is assumed that the flow rate was high and the surface area of the Cu foam was also large, resulting in the significant dissolution.

obtained value was about 101.3(W/mK). Considering that the thermal conductivity of pure aluminum is 237(W/mK), the conductivity of cast composite seems to be considerably low.

3.2 Interfacial Reactions during Annealing

Apparently, diffusion and reactions took place at the Al/Cu interface during a isothermal heating process. Two distinct intermetallic compounds and one transient phase between them were observed in the heated specimens. The two compounds were identified as AlCu and Al_2Cu, respectively. The average thickness of the AlCu intermetallic compound was increased during the isothermal heating at 400°C.

Fig. 1 shows that the thickness of AlCu intermetallic compound heated at 400°C generally follows a parabolic relationship. This suggests that the reactive diffusion is controlled by volume diffusion because the square root of the compound thickness (l) is proportional to the heating time (t): $l^2 = kt$ where k is the parabolic coefficient [6-7].

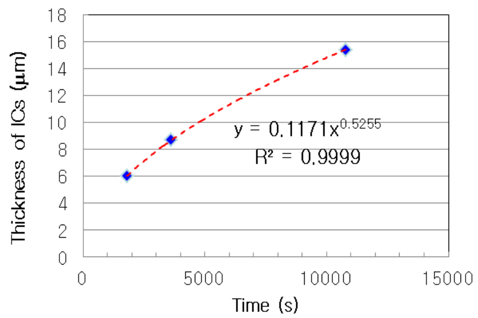

Fig. 1 Thickness variation of AlCu intermetallic compound formed at the Al/Cu interface of composites during isothermal heating at 400°C

3.3 Electrical and Thermal Conductivity

The electrical conductivity of composite specimens measured is compared with respect to the preparation method in Fig. 2. The conductivity is apparently higher in the case of higher rolling thickness reduction ratio, probably owing to the increased contact area with reduced porosity at the interface. Isothermal annealing could enhance the conductivity of both rolled specimens with different reduction ratios, howerver clearly greater improvement was made for the case of low reduction ratio. It is postulated that some pores diffused out and the interfacial contact became closer during the anealing. It has been also known that the conductivity is improved if the residual stress level is reduced.

The thermal conductivity of the cast composite specimens with 80% reduction ratio after annealing was also measured by a laser flash method, the

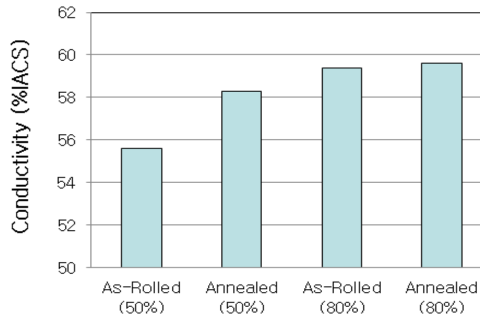

Fig. 2 Electrical conductivity of Al/Cu composites with different rolling thickness reduction ratios

4. Conclusions

A singnificant dissolution of copper preform into aluminum melt occurred during the suction casting, and some AlCu intermetallic compound formed at the insert/matrix interface. The average thickness of the intermetallic compound increased following a parabolic relationship.

The electrical and thermal conductivity of the hybrid spcimens were considerably low, implying an incomplete interficial bonding. Additional plastic forming was found to improve the conductivity a little, presumely attributed to an increased contact area.

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