VACUUM BRAZING BETWEEN SiCp/6063 Al MMCs AND Fe-Ni ALLOYS

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Abstract:

This research paper deals with the joining of different materials such as SiC_p/6063Al MMCs and Fe-Ni alloys by means of vacuum brazing with active filler metal Ag47-Cu18-In17-Sn17-Ti1. With the optimal process parameters, i.e., brazing temperature 580 °C, soaking time of 30 min and vacuum degree of 6.5×10^{-3} Pa, the joint shear strength can achieve the maximum of 56 MPa. Once the brazing temperature of 580 °C has exceeded the solidus temperature of SiC_p/6063Al MMCs, the specimen can still keep the original shape due to the stiffness of composites. Sufficient diffusion between brazing filler metal and SiC_p/6063Al MMCs could occur across the interface in liquid phase considerably faster than that in solid phase. The component analysis indicates that the elements in filler metal such as Ag, Sn and In can diffuse into SiC_p/6063Al MMCs, which is believed to be beneficial for the joint quality.

1 Introduction

A driving force/a major factor in the electronic industry is the necessity of increasing the power of electronic and microwave devices. This has brought about the necessity of implementing new materials to be used in form of hermetic boxes or as carriers that allow for handling higher powers while fitting well into current technology. The conventional electronic packaging materials are Fe-Ni alloys, W/Cu and Mo/Cu alloy which are characterized by high densities and a low thermal expansion coefficient. SiC_p/Al MMCs is characterized by low density, the low coefficient of thermal expansion, high specific strength and stiffness, which are proved to be a new promising material in the area of electronic packaging [1]. Researchers [2, 3] described the advances of composite materials for electronic packaging and aerospace application. However, it is hard to replace all of the conventional electronic packaging materials at present. It is reasonable to use both of the conventional electronic packaging material and SiC_p/Al MMCs in the same case. Then the welding problem between SiC_p/Al MMCs and conventional electronic packaging material needs to be considered and solved. The joining performance of SiC particulate reinforced aluminum metal matrix composite has been investigated by vacuum brazing process and found that the bonding quality of SiC_p/Al and SiC_p/SiC_p interfaces in brazed joints of Al/ SiC_p-MMC may be regarded as the weak bonding, and the brazed joints containing more of these two kinds of interfaces would possess

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comparatively low joint strength [4]. For the joining of carbon fiber reinforced SiC composite and TC4, the brazing technology with Ag-Cu-Ti alloy powder as the brazing filler metal was utilized [5]. The brazed joint obtained the shear strength of 102 MPa at 900 °C for 5 min. Some researchers [6] noticed that with appropriate bonding parameters, ultrasonic brazing can make the SiC particles and Al contents are increased in the bond, and this distribution will contribute to the enhanced strength of the brazed bonds.

Vacuum brazing is a promising candidate for joining SiC_p/Al MMCs and conventional electronic packaging material since the joining temperature is quite low and therefore can avoid most of the harmful chemical reactions in high temperature condition. The joining of aluminum matrix composites has been investigated and indicated that the brazing technology was an appropriate method for its application [7, 8]. Researchers [9, 10] found that the key point for joining of particulate reinforced aluminum matrix composites was to solve the wettability of filler metal on SiC. The present study attempted to join the SiC particulate reinforced aluminum AA 6063 matrix composites (SiC_p/6063Al MMCs) and Fe-Ni alloys by vacuum brazing method.

The present study has attempted to join the different materials of SiC_p/6063Al MMCs and Fe-Ni alloys by means of vacuum brazing with active filler metal. The microstructure and back scattering as well as line scanning analysis have been carried out. In order to obtain the optimal vacuum brazing process, shear strength of the joint has been evaluated.

2 Experimental materials and process

The SiC_p/6063Al MMCs used in this study are fabricated by pressureless infiltration processing and contained 55% (in volume fraction) SiC particles with an average diameter of 14 μm. Figure 1 shows the distribution and size of SiC particles in the as-received composites. The nominal compositions of AA6063 with its melting range of 563-654 °C are given in Table 1. The conventional electronic packaging material Fe-Ni alloys is used in this study with nominal compositions of Fe54-Co17-Ni29. The dimension of both materials is 2 mm×10 mm×20 mm with the overlapping length of 10 mm.

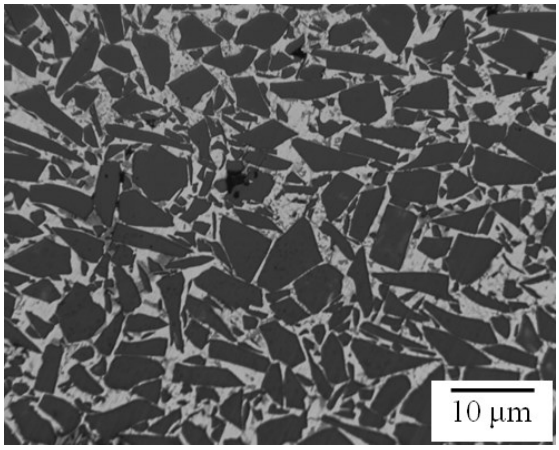

Figure 1. Microstructure of SiCp/6063Al MMCs with 55% volume fraction.

Table 1. Nominal compositions of AA6063 aluminum alloy (wt.%)

Element	Si	Mg	Fe	Cu	Mn
Content	0.2~0.6	0.45~0.9	0.35	0.1	0.1
Element	Cr	Zn	Ti	Al	
Content	0.1	0.1	0.1	Bal.	

Table 1 indicates that one of the key problems for brazing technique is the selection of brazing filler metal [11, 12]. In this research, the brazing filler metal Ag47-Cu18-In17-Sn17-Ti1 with the thickness of 40 μm produced by rapid solidification method is selected among other possible candidates because of the liquids temperature being lower than the incipient melting point of both SiC_p/6063Al MMCs and Fe-Ni alloys. In addition, it has a melting range of 475-530 °C.

Before vacuum brazing, quench-hardened layer and oxides on the surfaces of SiC_p/6063Al MMCs and Fe-Ni alloys induced by wire-cut process were removed by polishing using 800 # grinding paper. Then the specimens were properly cleaned by acetone and pure ethyl alcohol so as to remove any contaminants on their surfaces. The same processes were also carried out on the brazing filler metal. The vacuum brazing experiments were carried out in a commercial vacuum furnace with the heating rate of 20 °C/min up to the joining temperature of 550-590 °C. The vacuum degree of 6.5×10^{-3} Pa was selected for all of the vacuum brazing experiments. The soaking time was set to 30 min and then the specimen was cooled in the furnace. In some

experiments, the brazing temperature was considerably higher than the solidus of the SiC_p/6063Al substrate. Due to the high volume reinforcement (55%) and preparation technology (pressureless infiltration), SiC_p/6063Al has strong rigidity so that it can still keep the initial shape even at high temperature exceeding the solidus of SiC_p/6063Al substrate. Meanwhile, the overall property and microstructure of SiC_p/6063Al changed a little since the liquid content in liquid phase is quite sufficient.

The cross-sections of metallographic samples were prepared for metallographic analysis by standard polishing techniques without etchant. Microscopic examinations were performed using optical and scanning electron microscope equipped with an energy dispersive X-ray spectrometer. The shear test was carried out with an electronic universal experiment machine after performing the experiment.

3 Results and discussion

Figure 2 is the typical microstructure of welded joints between SiC_p/6063Al MMCs and Fe-Ni alloys. There was no evidence of oxide film and pore between the brazing filler metal and welded materials. The brazing filler metal Ag47-Cu18-In17-Sn17-Ti1 can join both of the SiC particles at the surface of composites and aluminum alloy matrix very well under the brazing temperature of 580 °C and soaking time of 30 min, as shown in Fig. 2.

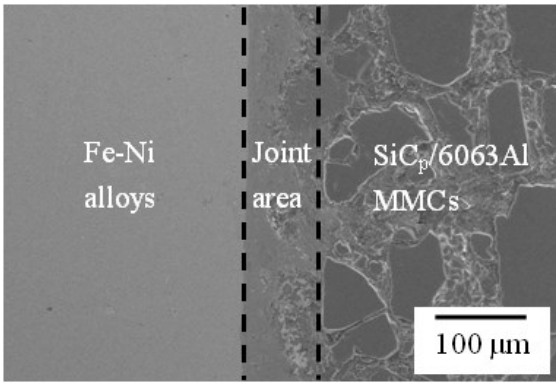

Figure 2. SEM image of the joint with soaking time of 30 min at 580 °C.

In order to analyze elements distribution near the brazing seam, back scattering and line scanning analysis were performed on joint. The line scanning location lies on the white line throughout the brazing seam area as shown in Fig. 3. The result indicates that the brazing filler metal dissolved some Fe-Ni alloys across the interface because Fe, Co and Ni spectral lines closed to the interface were much higher than the base line. The line scanning results also indicate that elements of Al, Si, Mg, Fe, Co and Ni which come from the composites and Fe-Ni alloys and are found in the middle area of weld seam besides the elements of Ag, Cu, In, Sn and Ti belong to brazing filler metal. That means that the brazing temperature condition of 580 °C and 30 min soaking time is sufficient for mutual diffusion and dissolution between brazing filler metal and welded materials.

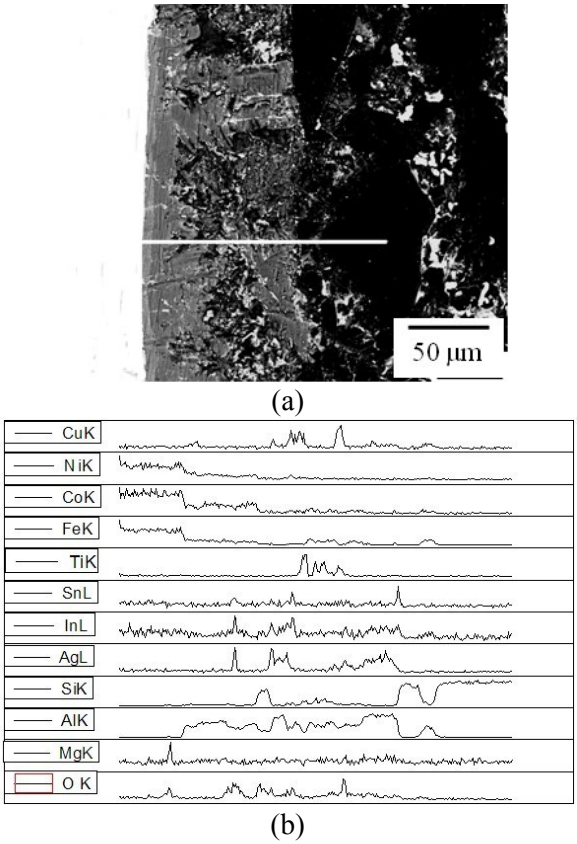

Figure 3. Line scanning analysis of brazing seam with soaking time 30 min at 580 °C: (a) location and (b) results.

In general, the filler metal can only diffuse into the base material at the very small depth, which is, in most instances of brazing, about a few microns. However, it can be found from Fig. 3 that there were many white areas in SiC_p/6063Al MMCs, which is on the right side of the joint and far from

the centre of welded joint containing the elements from filler metal. In order to understand the diffusion behavior of brazing filler metal, the component analysis in this kind of white area were performed. As shown in Fig. 4, the white area obviously contains Ag and Al elements. This result suggests that some elements in brazing filler metal such as elements Ag, Sn and In should diffuse into SiC_p/6063Al MMCs very well under appropriate brazing condition, thus improving the joint properties.

Under the brazing temperature (570 °C, 580 °C and 590 °C), SiC_p/6063Al MMCs melted partly with a few amount of liquid phase, because the solidus temperature of SiC_p/6063Al MMCs was 563 °C. As it is well-known, diffusion in liquid phase occurs much faster than that in solid phase. As a consequence, diffusion between brazing filler metal and SiC_p/6063Al MMCs could occur sufficiently well across the interface under experimental vacuum brazing condition. This is corroborated by the results of the researcher [13], which indicates that the small amount of liquid phase in composites accelerates the diffusion velocity of brazing filler metal into the composites.

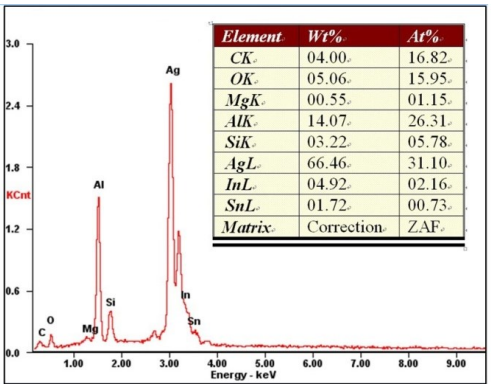

Figure 4. Point scanning analysis of white area in SiC_p/6063Al MMCs with soaking time 30 min at 580 °C,

In order to find out the optimal vacuum brazing process, shear strength of the joints brazed at different temperatures were measured, as shown in Fig. 5. The soaking time of 30 min was selected for the whole process because it had less effect on the shear strength if compared with the brazing temperature. It can be found that the maximum value of 56 MPa was achieved with the brazing temperature of 580 °C. When the brazing temperature was less than 580 °C, the joint shear strength increased with an increase in the brazing temperature. The reason for that was that metals could diffuse sat a better rate by increasing the brazing temperature. However, when the brazing temperature exceeded 580 °C, the shear strength was steeply decreased. When the temperature reached 590 °C, the shear strength of the joint was only 18 MPa. The main reason for that was the joint deformation due to the appearance of too many liquid phases at such a high temperature. The researcher [14] also indicates that it is important to control the liquid content in composites during brazing. Less liquid in composites will improve the diffusion condition between the filler metal and composites. However, if there were too many liquid phase in composites, the joint would deform leading to the brazing failure.

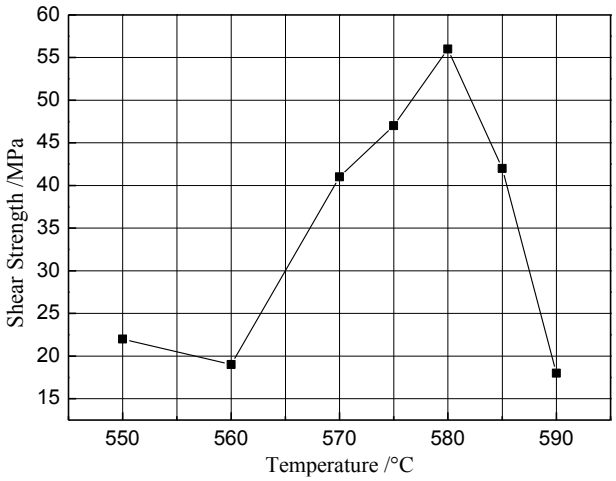

Figure 5. Shear strength of the joint brazed at different temperatures with soaking time 30 min.

Figure 6 showed the fracture morphology of brazing joint which was brazed at the temperature of 580 °C and brazing time of 30 min. The fracture observation showed that the joint exhibited brittle fracture. For the most joint of SiC_p/6063Al MMCs and Fe-Ni alloys, the breakage distribution usually occurred across the interface of filler metal and SiC_p/6063Al MMCs. As shown in Fig. 6, some tearing can be found in SiC particle. It means that some elements in filler metal have reacted with SiC particle in composite. Generally, the reaction between SiC and filler metal did well to the increasing of joint mechanical performance.

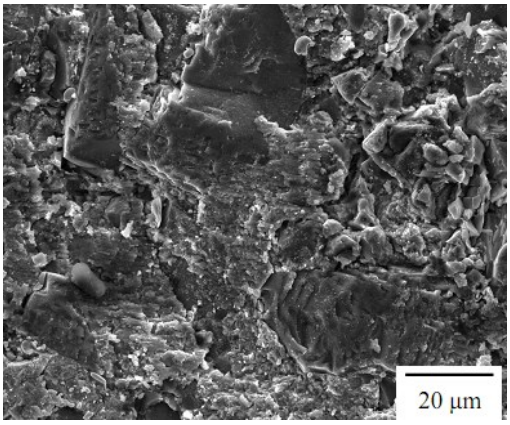

Figure 6. Fracture morphology on the side of SiC_p/6063Al MMCs.

4 Conclusion

Based on the work, the following remarks and conclusions can be made:

(1) With the brazing filler metals Ag47-Cu18-In17-Sn17-Ti1, SiC_p/6063Al MMCs and Fe-Ni, alloys can be welded together very well by means of vacuum brazing technique. There has been no evidence of oxide film and pore between the brazing filler metal and welded materials.

(2) For the vacuum brazing of SiC_p/6063Al MMCs and Fe-Ni alloys, the optimal technological parameters are: the brazing temperature of 580 °C, 30 min soaking time and vacuum degree of 6.5×10^{-3} Pa. With the optimal technological parameters, the shear strength of joint can achieve the maximum of 56 MPa.

(3) At the temperature lower than 580 °C, the joint shear strength was increased with the brazing temperature which resulted from the fact that better diffusion can be expected by increasing the brazing temperature. When the brazing temperature exceeded 580 °C, the shear strength was steeply decreased. The main reason for that was the joint deformation due to the appearance of too many liquid phases at such a high temperature.

(4) The brazing filler metal dissolved some Fe-Ni alloys across the joint interface. Due to the partial melting of SiC_p/6063Al MMCs, sufficient diffusion between brazing filler metal and SiC_p/6063Al MMCs could occur with the appearance of liquid phase. Some elements in brazing filler metal such as Ag could diffuse into SiC_p/6063Al MMCs very well.

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