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A novel approach to compact braze aluminum alloys ①

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[Abstract] In order to ensure that the signal can be transported correctly, the microwave devices made of aluminum alloys must be assembled and brazed flaw-freely. A new approach of using contact reactive brazing (CRB) process to realize the compact brazing of aluminum alloys is put forward. The reason for this is that CRB, which realizes bonding depending on the liquid alloy produced by metallurgical reaction between the materials to be joined, overcomes the limitation of traditional brazing that the macroscopically disorganized filling flow of liquid filler metal would result in defects in brazed seam. Joint of LF21 (AA3003) with the compactness of over 95% is brazed by the method of CRB using Si powder as an interlayer. At last, the influence of the physical parameter related to the Si powder interlayer on the compactness of the joints is investigated in detail.

[Key words] microwave devices; brazed seam compactness; contact reactive brazing; defects
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1 INTRODUCTION

During the production of some microwave devices made of aluminum and its alloys, the compactness of the brazed seam is the governing factor that decides whether the signal can be transported correctly or not. However, the traditional salt bath, furnace and flame brazing often inevitably induce many defects in the seam, such as trapped gas or flux, due to the macroscopically disorganized filling flow of liquid filler metal[1]. Un-parallel clearance and slipping brazing process, which can decrease the flaw of joint in some extent[1], can not fit the precision brazing of the microwave devices. Diffusion bonding is also a method to gain flaw-free joint, however, the high pressure needed in bonding results in deformation at the interface of the joint that is forbidden in precision bonding. Contact reactive brazing (CRB), developed from the principle of diffusion bonding, is a special technology that completes joining by the liquid alloy produced by metallurgical reaction, such as eutectic reaction, between the materials to be joined[2, 3]. So CRB is used in bonding of metals[4], ceramic to metal[5, 6] and electronic devices[7～9]. On one hand, CRB can realize compact bonding by avoiding the flowing of liquid filler, on the other hand, the precision bonding can also be made by controlling the reaction between materials, especially when an interlayer is used[10]. According to this, the new approach for compact brazing LF21 (AA3003) aluminum alloy by CRB using Si powder as an interlayer was investigated.

2 PRINCIPLE STATEMENT

The process of CRB is described as follows. Two kinds of metals or one metal and one non-metal, where there is eutectic reaction between them, are heated to a temperature that is over their eutectic point, firmly contacting with each other under a low pressure (0.1～1 MPa). After a short holding time, a layer of liquid alloy would appear at the interface due to the inter-diffusion of the materials involved. The liquid fills the micro-clearance of the joint and realizes the bonding of these materials finally. In another word, the filler liquid metal in the CRB is produced in site by reaction between the materials to be brazed, instead of melting of prior added filler metal as that in traditional brazing.

The development and metallurgical reaction progress during CRB is shown in Fig. 1. At beginning, two surfaces to be brazed, which are ruglike microscopcially, are contacted in the whole range under the action of heat and pressure (Fig. 1(a)). After a certain holding time at brazing temperature, the metallurgical reaction would occur simultaneously at the contacting points, such as point *A* in Fig. 1, and result in the liquid alloy. The liquid spreads and fills the micro-hole around the contacting point[11], and speeds up the reaction which, in turn, increases the quantity of the liquid quickly (Fig. 1(b)). On the other hand, after the reaction and consumption of the contacting points, the new points, such as point *B* in Fig. 1, would contact each other due to the pressure, then the new reac-

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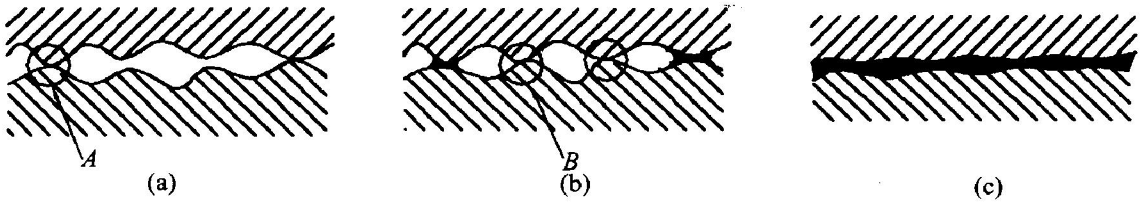

Fig. 1 Illuminating formation process of liquid alloy layer by metallurgical reaction

tion begins. The three progresses, contacting, reacting, and spreading of liquid around the reaction points, would go on continuously until a layer of liquid appears at the interface to be brazed (Fig. 1(c)).

The analysis above shows that filling of the joint in CRB is completed omnidirectionally in the range of the whole area to be brazed. At the same time, the spread range of the liquid produced by a single contact point is much small to the dimension of the joint, namely, it is micro flowing for the single contacting point's liquid. So it can be concluded that the CRB avoids the macroscopically disorganized filling flow of liquid, which would result in flaws in traditional brazing, and it is possible to realize compact brazing by this process.

3 EXPERIMENTAL PROCEDURES AND RESULTS

LF21 (AA3003) aluminum alloy plate with a thickness of 2 mm was used as base metal because most of the microwave devices are made of it. Si was selected as an interlayer according to the facts that Al-Si filler metal is often used in brazing of aluminum and its alloys, and the Al-Si alloys have good mechanical properties. Because Si is a kind of brittle material, it is used in the form of powder. In addition, some fluoride activator was used to activate the Si powder surface and avoid the influence of adsorbed air by Si powder on brazing.

At first, a thin layer of brazing suspension mixed with the Si powder, fluoride activator and distilled water was printed on the surface of sample to be brazed, and dried in air or by heating to 150 ℃. Then the specimens were assembled together and brazed in vacuum furnace under the conditions such as air pressure in furnace 4.0×10^{-3} Pa at the room temperature, and less than 8.0×10^{-3} Pa at brazing peak temperature (600 ℃), holding time at peak temperature 15 min.

The procedures of compactness measure of brazed seam are as follows: USIP12 type ultrasonic scanning equipment, which can give a resolution of 50 μm operated at a frequency of 10 MHz, was used to nondestructively examine the quality of the brazed seam. And the compactness was measured by processing the ultrasonic scanned image of the brazed joint. At last, the optic metallography and scanning electronic microscopy were used to analyze the quality of the brazed seam.

Two types of joints, lap and T-type, were brazed in this paper. Fig. 2 and Fig. 3 show the schematics of the typical joints, the ultrasonic scanned images and typical microstructure of the brazed joints. In the scanned images, the uniform gray in the brazed area shows that a compact brazed joint has been induced. The results of image processing of those images show that the compactness of the joints is over 95%, which is much higher than that of the traditional brazed seam (60% ~ 80%)[12].

4 OPTIMIZATION OF PARAMETERS RELATED TO Si INTERLAYER

Because a special interlayer, mixture of Si powder and fluoride, was used in the experiments,

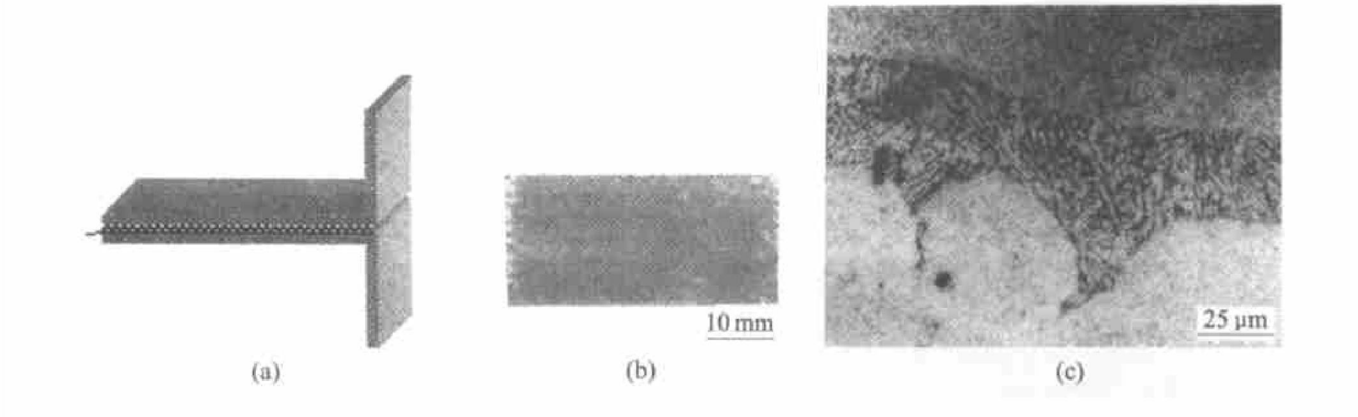

Fig. 2 Results of brazed lap type joint
(a) —Schematic of lap joint; (b) —Image of ultrasonic scanning of Fig. 2(a); (c) —Microstructure of lap joint

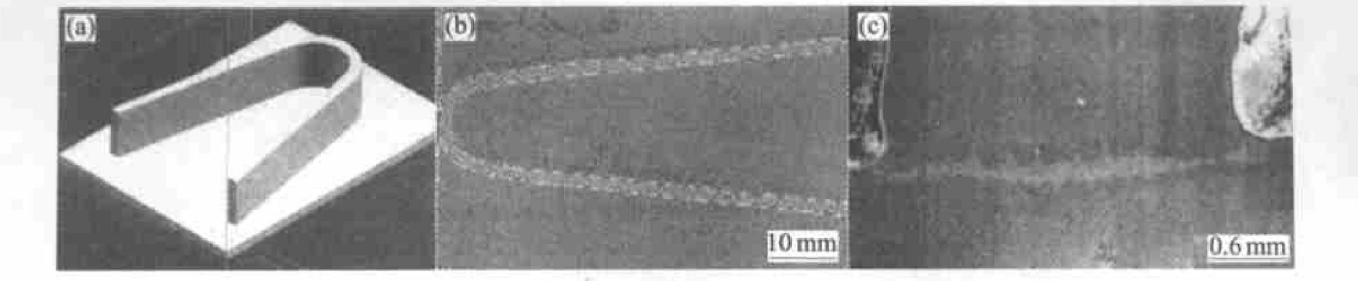

Fig. 3 Results of brazed T type joint
(a) —Schematic of T-type joint; (b) —Image of ultrasonic scanning of Fig. 3(a); (c) —Microstructure of T-type joint

the parameters, i. e. ratio of fluoride in interlayer mixture, particle size of Si powder and coating density of Si, would have influence on the compactness of the brazed seam. Through the experiments, the parameters involved were optimized.

4.1 Ratio of fluoride in brazing mixture

Fig. 4 shows the relationship between the ratio of fluoride in the mixture and the compactness of joint. The best ratio of fluoride is 20% ~ 25%, i. e. mixing Si powder and fluoride with the ratio of (3~ 4)∶1 could produce good joint with the compactness of over 95%. No or less activator was used, the surface of Si powder was not activated adequately so that there would be much reactive residue left in the seam (Fig. 5(a)). On the other hand, when much more activator was used, it was difficult for so more molten fluoride to flow out of the brazed range, so that some of it was trapped in the seam and formed flaws (Fig. 5(b)).

4.2 Particle size of Si powder

Fig. 6 shows the relationship between the compactness of joint and the particle size of Si powder. It can be seen that the Si powder with a size in the range of 350~ 500 mesh can make the highest compactness of joint, over 95%. Neither coarse nor fine Si powder is beneficial for gaining compact joint. When the coarse powder was used, for example 200~ 300 mesh, the chance of Si

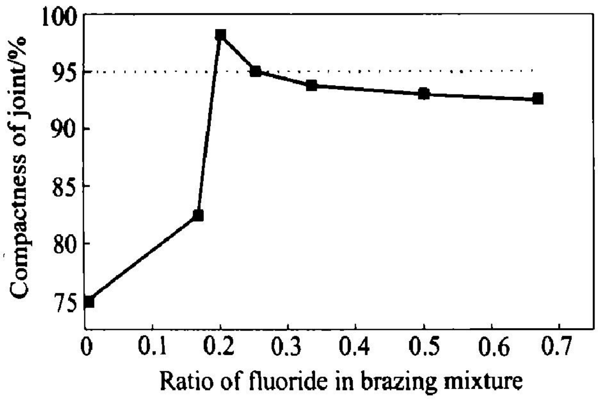

Fig. 4 Joint's compactness vs ratio of fluoride in brazing mixture

contacting with Al would reduce due to the fixed value of the Si coating density, which would result in the

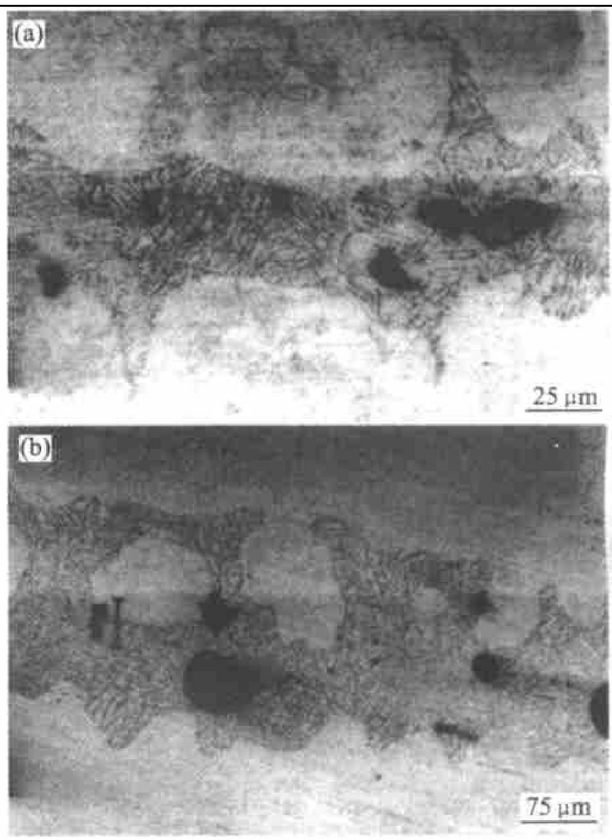

Fig. 5 Defects in brazed joint with different quantities of fluoride
(a)—16.7%; (b)—66.7%

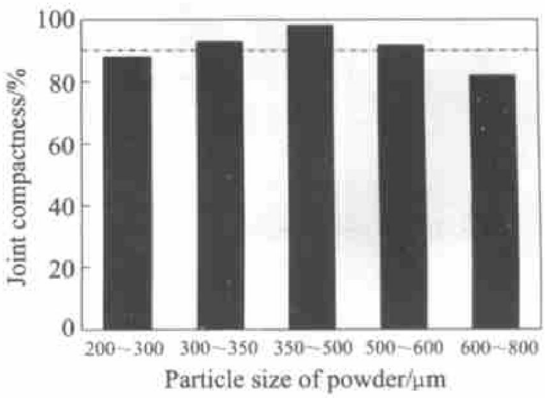

Fig. 6 Joint's compactness vs particle size of Si powder

reduction of reaction points and the increase of the range of the liquid flowing. In reverse, when fine Si powder was used, for example 600 ~ 800 mesh, surface-to-volume of Si would increase which resulted in more air would be adsorbed by Si surface and the more of Si would be oxidized. Thus, some reactive residue would leave in the seam to lower the compactness of joint.

4.3 Coating density of Si powder

Another parameter of Si powder interlayer is the coating density, the mass of Si in unit area of surface. The compactness of joint depending on the coat density of Si powder is shown in Fig. 7. The Si powder density of 15~ 30 g/m^2 is the most proper. In the case of high density of Si, there would be some Si powder un-reacted left in the seam during normal holding time. Some extra Al-Si liquid alloy would flow out of the joint to form humps when long holding time is used to ensure the Si interlayer to be reacted and consumed. In the case of low density of Si, it is natural that there is not enough liquid produced by the reaction between Si and Al, so that the joint must be filled incompletely.

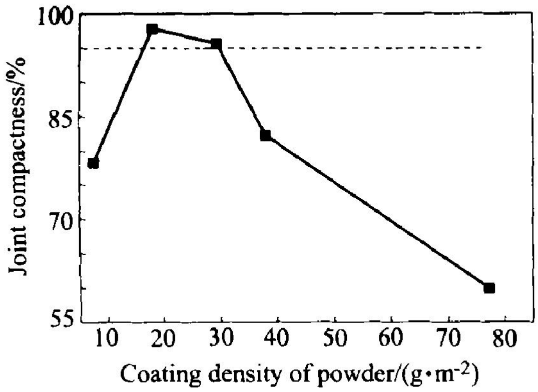

Fig. 7 Joint's compactness vs coating density of Si powder

5 CONCLUSION

From the experiment and analysis results, it can be concluded that a new approach of adopting CRB to compact brazing Al alloy is put forward in this paper. By this method, the joint of LF21 (AA3003) with a compactness of over 95% is brazed using Si powder as an interlayer. The optimized parameters related to the Si powder interlayer are as follows: the ratio between the Si powder and fluoride activator= (3~ 4)∶1, the particle size of Si powder= 350 ~ 500 mesh, and the coating density of Si on Al alloy surface= 15~ 30 g/m^2.

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