A NOVEL APPROACH TO COMPACTLY BRAZE ALUMINUM ALLOYS

Qian Yiyu, Dong Zhangui, Liu Jun.

The National Key Laboratory of Advanced Welding Production and Technology,

Department of Welding Technology, Harbin Institute of technology, China (150001)

Abstract: In order to ensure the signal could be transported correctly, the microwave devices made of Aluminum alloys must be assembled and brazed flaw-freely. In this paper, a new approach of using contact reactive brazing (CRB) process to realize the compact brazing of Aluminum alloys was put forward. The reason for this is that CRB, which realizes bonding depending on the liquid alloy produced by metallurgy 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% was 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 was investigated in detail.

[Key words] microwave devices; compactness of brazed seam; contact reactive brazing; defect

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 might decide whether the signal could be transported correctly or not. However, the traditional salt bath, furnace and flame brazing often inevitably induce many defects in 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 could decrease the flaw of joint in some extent [1], could not fit the precision brazing of 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 bonging, is a special technology that completes joining by the liquid alloy produced by metallurgy reaction, such as eutectic reaction, between the materials to be joined [2, 3]. So CRB is used in bonding of metal [4], ceramic to metal[5, 6] and electronic devices[7-9]. On the one hand, CRB could realize compact bonding by avoiding the flowing of liquid filler, on the other hand, the precision bonding could also be made by controlling the reaction between materials, especially 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 statements

The process of CRB is described as following. Two kinds of metals or 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 (0.1-1MPa). 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 reacting between the materials to be brazed, instead of melting of prior added filler metal as that in traditional brazing.

The development and metallurgy reaction progress during CRB is shown in Fig. 1. At beginning, two surfaces to be brazed, which were ruglike in the microscopcial, 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 metallurgy reaction would occur simultaneously at the contacting points, point A in Fig. 1, and result in the liquid alloy appearing. 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 consume of the contacting points, the new points, point B in Fig. 1, would contact each other due to the pressure, then the new reaction begins. The three progresses, contacting, reacting, and spreading of liquid around the reaction points, would go on continuously until a layer of liquid appeared at interface be brazed (Fig. 1 c).

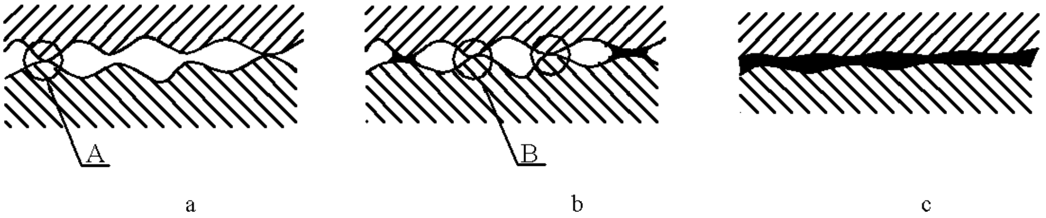


Fig. 1 Illuminating the formation process of liquid alloy layer by metallurgy reaction

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 could be concluded that the CRB avoids the macroscopically disorganized filling flow of liquid, which would result in flaws in the traditional brazing, and it is possible to realize compact brazing by this process.

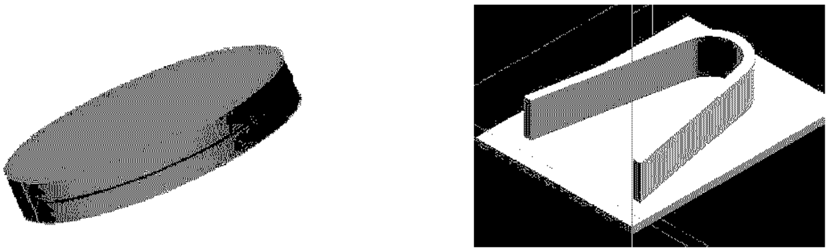
3 Experiment procedures and results

LF21 (AA3003) aluminum alloy 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 was often used in brazing of aluminum and its alloys, and the Al-Si alloys had good mechanical properties. Because Si was a kind of brittle material, it was used in the form of powder. In addition, some fluoride additive 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 Si powder, fluoride active and distilled water was printed on the surface of simple to be brazed, and dried in air or by heating to 150℃. Then the specimens were assembled together and brazed in vacuum furnace at the conditions as, air pressure in furnace was 4.0×10^{-3}Pa at the room temperature, and less than 8.0×10^{-3}Pa at brazing peak temperature was 600℃. the holding time at peak temperature was 15min。

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

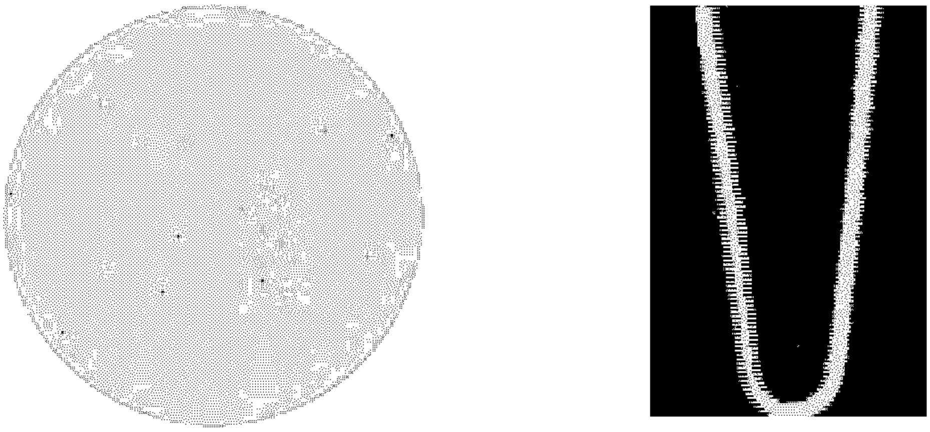
Two types of joints, wafer lap and T-type, were brazed in this paper (see as Fig. 2). Fig. 3 was the ultrasonic scanned images of brazed joints. In the scanned images, the uniform green in the brazed area showed that a compact brazed joint had been induced. The results of image processing of those images show the compactness of the joints are over 95%, which is much higher than that of the traditional brazed seam (80-85%) [12]。



a b

Fig. 2 The types of joints brazed in experients

a) Wafer lap joint b) T-type joint



a b

Fig. 3 Image of ultrasonic scanning of brazed joints

a) Wafer lap joint b) T-type joint

4 Optimization of the parameters related to Si interlayer

Because a special interlayer, mixture of Si powder and fluoride, was used in experiments, 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 showed the relationship between the ratio of fluoride in the mixture and the compactness of joint, where the quantity of the fluoride was increasing from A to G. The best ratio of fluoride was C, which could produce good joint with the compactness of over 95%. No or less active were used, the surface of Si powder was not activated adequately so that there would be much reactive residue left in seam (see Fig. 5a). On the other hand, If much more active 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 form flaws (see Fig. 5b).

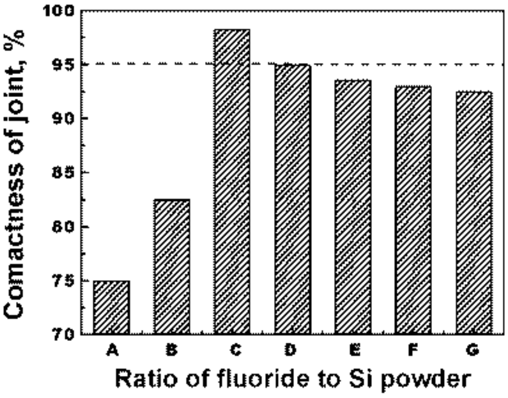


Fig. 4 Joint's compactness vs ratio of fluoride in brazing mixture

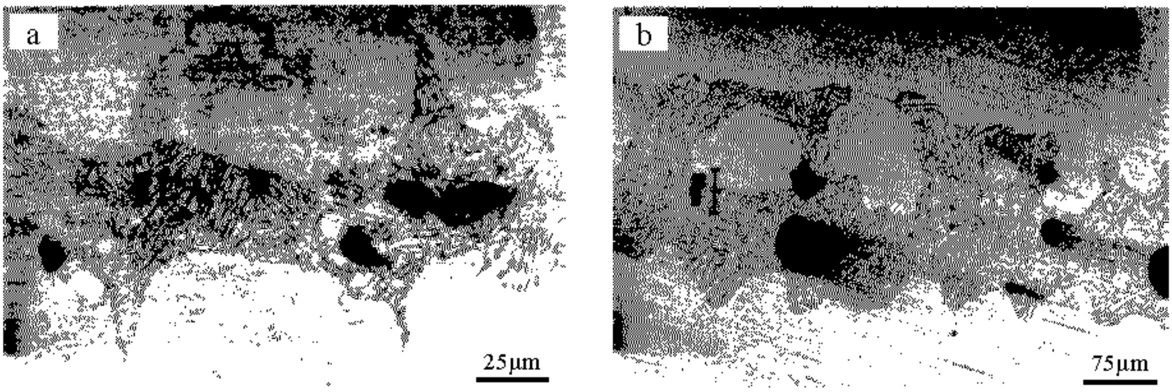


Fig. 5 Defects in brazed joint with different quantity of fluoride: a) 16.7% and b) 66.7%.

4.2 Particle size of Si powder

Fig. 6 showed the relationship between the compactness of joint and the particle size of Si powder. It could be seen that Si powder with a sizes in the range of P-3 could make the highest compactness of joint, over 95%. Neither Coarse nor fine Si powder was benefit for gaining compact joint. When the coarse powder was used, for example P-1, the chance of Si contacting with Al would reduce due to the fixed value of the Si coating density, which would result in the reducing of reaction points and the increase of the range of the liquid flowing. In reverse, when fine Si powder was used, for example P-5, 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 was showed in Fig. 7. The Si powder density of 15~30 g/m^2 was 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 the long holding time was used to ensure the Si interlayer to be reacted and consumed. In the case of low density of Si, it is nature that there was not enough liquid produced by the reaction between Si and Al, so that the joint must be filled incompletely.

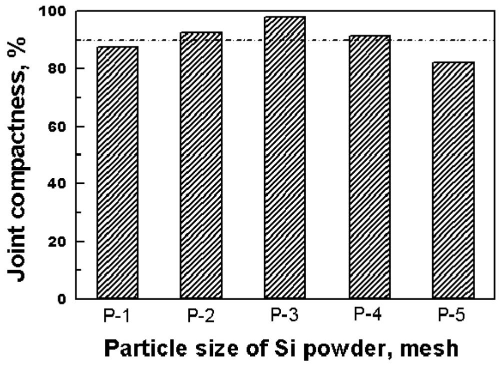


Fig. 6 Joint's compactness vs particle size of Si powder

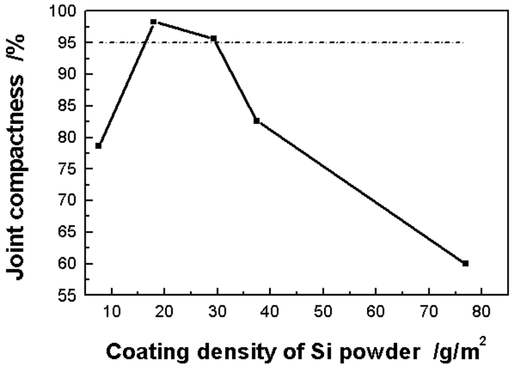


Fig. 7 Joint's compactness vs coating density of Si powder

5 Summaries

From the experiment and analysis results, it could be concluded that a new approach of adopting CRB to compact brazing Al alloy was put forward in this paper. By this method, the joint of LF21 (AA3003) with a compactness of over 95% was brazed using Si powder as an interlayer. The optimized parameters related to the Si powder interlayer were gained through experiments.

[Foundation item] Project (118.10.1.18) Supported by National Defense Pre-research Foundation
[Received date] 2001-11; [Accepted date]

Reference

1. CHEN Ding-hua, QIAN Yi-yu, LI Yan. Study on the mechanism of filling of the filler metal [J]. Hanjie xuebao/ Transaction of the China Welding Institution (in Chinese). 1981(1): 1-8.
2. Frolov I A. Contact reactive brazing of copper to steel via a manganese interlayer [J]. Welding Production. 1972, 19(10): 28-31.
3. Kruchinin V P and Metelkin I I. Contact reactive brazing of ceramics to metal. Welding Production [J]. 1972, 19(12): 68-73.
4. Takehiko W and Hiyasa S. Eutectic bonding of Al pipe to Cu pipe [J]. Journal of the Japan Welding Society. 1998, 16(1): 35-44.
5. Wu Y C. Eutectic bonding of nickel to yttria-stabilized zirconia [J]. Journal of Materials Science Letters. 1990, 9(5): 583-586.

6. Jankowski A F and Hayes J P. Eutectic bonding of a Ti sputter coated carbon aerogol wafer to an Ni foil [J]. Surface & Coating Technology. 1994, 12:68-69.
7. Tiensuu A L and Bexell M. Assembling three-dimensional microstructure using gold-silicon eutectic bonding [J]. Sensors and Actuators. 1994, 45(3): 227-236.
8. Wolffenbuttel R F and Wise K D. Low-temperature silicon wafer-to-wafer bonding using gold at eutectic temperature [J]. Sensors and Actuators. 1992, 43: 223-229.
9. Masanori N and Noboru G. Highly reliable Au-Sn eutectic bonding with background GaAs LSI chips [J]. IEEE Trans. CHMT. 1991, 14(3): 523-528.
10. WANG Guo-zhong, FAN Fu-hua. QIAN Yi-yu. Influence of brazing conditions on the joint precision in contact reactive brazing of copper devices [A]. Proceeding of the first conference of China electronic society [C]. Harbin, China. (in Chinese) 1993: 27-32
11. CHEN Ding-hua, QIAN Yi-yu, HUANG Ji-hua. Mechanism of A1/Cu contacting reaction brazing [J]. Jinshu Xuebao/ Acta Metallurgica Sinica. (in Chinese) 1989 25(1): B42-B47.
12. ZHOU, Xi. Brazing and soldering [M]. China Machine Press. Beijing, (in Chinese) 1988: 139-143.