Effect of the Substrate Distance on the Mechanical Properties of SnBi-χAl_2O_3 Joint Welded by Ultrasonic-assisted Brazing

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Abstract. New ultrasonic-assisted brazing technology was adopted to weld mini butt joint by SnBi composite solder with 1.5wt% Al_2O_3 content and 0.5mm, 0.8mm and 1mm three kinds of copper substrate distance. The mechanical properties of the mini butt joint were characterized by means of the micro hardness tester and home-made micro mechanical test system. The fracture morphology of the samples were respected by scanning electron microscope. The results showed that the ultrasonic-assisted brazing method could promote the expansion of liquid solder on the substrate, improve the wettability, and full of the weld. With the substrate spacing of 0.5mm, 0.8mm to 1mm gradually increased, the micro hardness, tensile strength and elongation increased along with it. A hard brittle IMC strip formed between the composite solder and the copper substrate, which made the boundary brazing seam hardness was more important than that of the middle. The fracture mechanism of SnBi-χAl_2O_3 micro soldering joint is cleavage fracture, which shows the characteristics of brittle fracture.

Introduction

Recently, with the improvement of environmental protection awareness and the rapid development of microelectronics technology, the lead free solder has become a common requirement of human beings. The melting point of Sn-Bi lead free solder has a wide range from 138°C to 232°C. That can achieve welding at low temperature, and the technical performance and mechanical properties can also meet the user requirements. It is considered to be one of the best substitute of Sn-Pb solder. But the electronic packaging requirements call for further improvement, the lead-free solder of two elements system cannot meet the quality index of actual production. Therefore, the new direction of lead-free solder with modern high performance has been developed, that is to improve the comprehensive properties of the solder by adding third or even fourth elements to two elements alloy systems. Nano Al_2O_3 has high hardness and good dimensional stability, it has broad application space in the reinforcing and toughening field of various plastics, coatings, rubber, ceramics, refractories and other products. Nevertheless, there is little research on the addition of Al_2O_3 to Sn based solders.

New ultrasonic-assisted brazing technology was adopted by the experimental apparatus designed and manufactured by self. The comprehensive performance of SnBi solder was improved by adding Al_2O_3 reinforcement, in order to prepare the micro brazing joint. Influence of substrate distance on the mechanical properties of SnBi-χAl_2O_3 micro joints welded by ultrasonic-assisted brazing, so as to provide some data support for developing new lead free solder.

Experimental materials and methods

Experimental materials. In this experiment, the matrix filler metal is Sn-58Bi particles, the particle size is 40 to 55μm, and the additional reinforcement is the nano Al_2O_3 particles, the particle size is 50μm. The thickness of the pure copper used for brazing is 0.8mm.

Experimental methods. The nano Al_2O_3 particles were poured into the alcohol and dispersed by ultrasonic, then Al_2O_3 suspension was mixed with Sn-58Bi powder in a mortar. After mechanical stirring for twenty minutes, the solder was pasted into a mortar. Continue stirring to make it even mixed for twenty minutes. Finally, the composite filler metal was obtained, in which the mass fraction of Al_2O_3 was 1.5%. With new ultrasonic-assisted brazing technology, the two copper substrate of 50mm×20mm×0.8mm were fixed on the self-made fixture. The substrate spacing was 1mm, 0.8mm and 0.5mm, filled the SnBi-χAl_2O_3 composite solder between the substrates. The ultrasonic vibration head was pressed on one end far from the copper substrate of the clamp. The influence of brazing heating was very small, so it would be within the upper limit temperature 70°C of ultrasonic oscillator. The clamp to fix the copper substrate was placed on the heating stage when brazing, and the heating temperature was 220°C. When the solder started to melt, the ultrasonic vibration started. The acoustic wave vibration 20 KHz was transmitted on the welded specimen through ultrasonic tool head. The vibration power was 1000W, and the applied pressure was 0.5Mpa. After soldering, the ultrasonic tool head was removed, and the fixture was taken from the heating table, then waiting the welded piece to natural cooling.

Welded parts were processed into the metallographic specimen and micro tensile specimen by using a line cutting machine. The microhardness of the brazing seam zone was measured by HV-1000 micro hardness tester, the tensile strength and elongation of the micro tensile specimen was characterized by the self-designed micro mechanical test system, and the fracture morphology of joint was observed by FEI Inspect S50 scanning electron microscope. The tensile testing machine fixture and tensile specimen are illustrated in Fig.1.

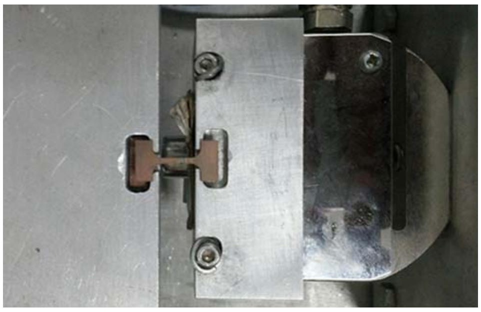

Fig.1 Tensile testing machine fixture and tensile specimen

Experimental results and discussion

Morphology of the brazing seam. By ultrasonic-assisted brazing, the ultrasonic vibration was applied to the fixture. The ultrasonic energy was transferred to the liquid solder between the solder copper substrate by using the fixture as a medium. So the solder could quickly fill in the weld bead by the action of ultrasonic vibration, and achieve the welding process. Fig.2 is welding parts prepared by ultrasonic-assisted brazing, from the figure it can be seen that solder fill the weld bead, the wetting property is good, and the welding quality is very fine. Compared with the existing ultrasonic soldering process, this ultrasonic method is more flexible. The ultrasonic energy transmits from the compacted base material to the wetting interface, the loss is very small.

Fig.2 Specimen welded by ultrasonic-assisted brazing

Effect of the substrate distance on the microhardness of joint. The central and boundary microhardness of the brazing seam for different substrate distance was measured. The loading force was 0.49N, and loading time 15s. Each part was measured at three points, and the average value was taken. The result is displayed in Fig.3. The figure demonstrates that with the increase of substrate distance, the central and boundary hardness of the brazing seam increase. This shows that when the micro solder joints prepared by ultrasonic-assisted brazing method. Appropriately increasing the substrate distance, which is helpful to improve the microhardness. It is also known from the figure that the welding parts with different substrate spacing, the boundary brazing seam hardness are greater than that of the middle. This is due to the formation of Cu_3Sn IMC and Cu_6Sn_5 IMC bands between the composite solder and the copper substrate. Compared with the relatively soft SnBi-χAl_2O_3 solder alloy, the hardness of Cu_3Sn IMC and Cu_6Sn_5 IMC is higher, so that improves the hardness of the brazing seam boundary.

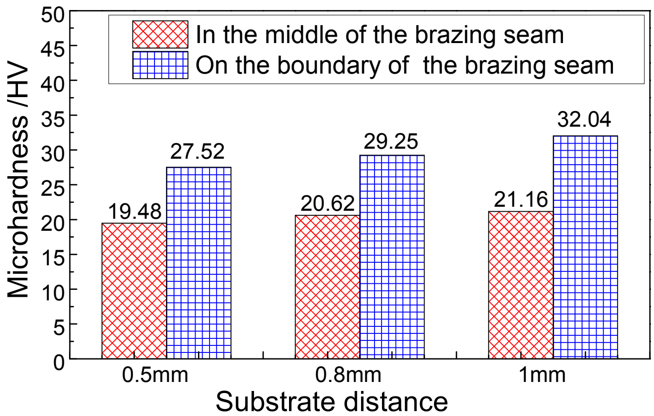

Fig.3 Microhardness photo of the central part and boundary of the brazing seam with different substrate distances

Effect of the substrate distance on the tensile properties and fracture morphology of joint. Fig.4 is the comparison chart of tensile strength and elongation of tensile specimens with distinct substrate distance. From Fig.4 it can be seen that with the increase of substrate distance, the tensile strength of the welded joint is from 66.25Mpa, 73.75Mpa, to 75.6Mpa; The elongation has been also shown an increasing trend, from 1.78%, 2.12%, to 2.26%. With the increase of substrate distance, there is a trend of gradual refinement of the microstructure of the alloy, and the IMC intermetallic compound in the interface between the solder alloy and the copper substrate is gradually thinned. The reduction of harmful phase, the improvement of microstructure, and the effect of refined grain strengthening, these all make the strength and plastic of the brazing joint improve. So when the substrate distance is from 0.8mm, 0.5mm to 1mm, the tensile strength and elongation has been increased all the time. New ultrasonic-assisted brazing technology was adopted to prepare SnBi-χAl_2O_3 micro brazing joint, which had high tensile strength and good ductility.

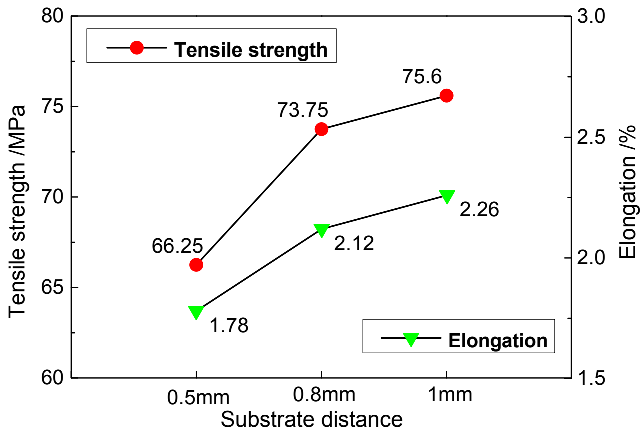

Fig.4 Tensile strength and elongation of tensile specimens with different substrate distance

Fig.5 is the fracture morphology of tensile specimens with different substrates distance. The fracture locations are located in the composite solder of the brazing joints. It is indicated that the bonding force between the substrate and the solder is very strong. From Fig.5(a) it can be observed that when the substrate spacing is 0.5mm, the cleavage step of fracture is wide and clear. It is cleavage fracture, and shows obvious brittle behaviour. While in Fig.5(b), when the substrate spacing is 0.8mm, the cleavage step width decreases, it is still the cleavage fracture. In Fig.5(c), when the substrate spacing is 1mm, the cleavage step width is smaller, and closer between the steps. It shows the keen ability to resist deformation, and the tensile strength further improves.

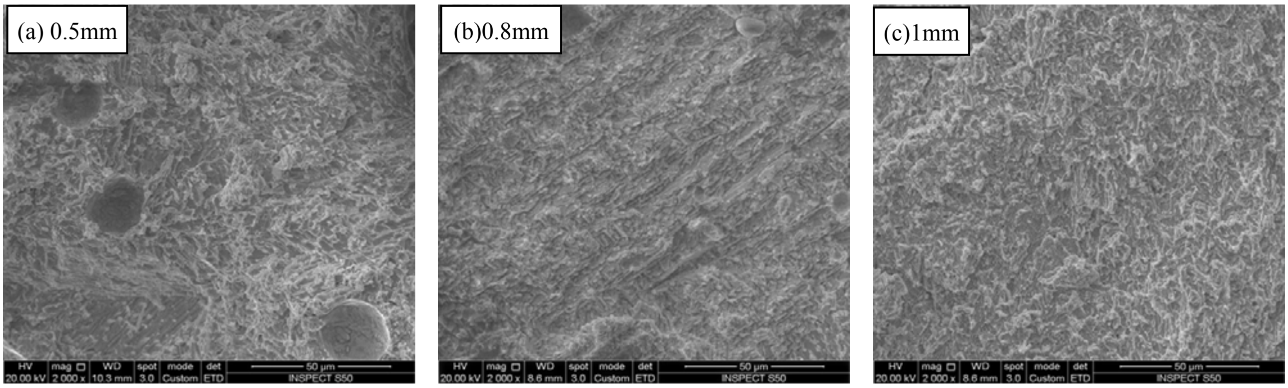

Fig.5 Fracture morphology of tensile specimens with different substrates distance

Conclusions

(1) The ultrasonic-assisted brazing method could promote the expansion of liquid solder on the substrate, improve the wettability, and full of the weld.

(2) When the substrate thickness was 0.8mm, with the substrate spacing of 0.8mm, 0.5mm to 1mm gradually increased, the micro hardness increased along with it. A hard brittle IMC strip formed between the composite solder and the copper substrate, which made the boundary brazing seam hardness is higher than that of the middle.

(3) Appropriate increase for the substrate distance will contribute to the increase of tensile strength and elongation. The fracture mechanism of SnBi-χAl_2O_3 micro soldering joint is cleavage fracture, which shows the characteristics of brittle fracture.

Acknowledgements

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