Effect of the Substrate Distance on the Microstructure and 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 microstructure of the samples were observed by scanning electron microscope, and the composition of intermetallic compounds was detected by the energy disperse spectroscopy. 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 increase of the substrate distance, the alloy microstructure refined, the IMC zone at the interface gradually had a tendency to grow thin, and improved the reliability of the solder joint. Near the composite solder was IMC Cu_6Sn_5, and the copper substrate was IMC Cu_3Sn. Appropriate increase for the substrate distance will contribute to the micro hardness increase.

Introduction

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. However, Bi will be coarse and crystallize, when SnBi solder is used, that leads to material ductility. Especially in the long-term high temperature environment, the rich Bi phase is more comfortable to coarse and crystallize, result in reducing plasticity in the crude parts, even stripping off, exhibiting the brittle failure characteristics on the surface. New ultrasonic-assisted brazing technology was adopted by the experimental apparatus designed and built 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 microstructure and 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 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. 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 dimensions of the tensile specimen are illustrated in Fig.1. The metallographic sample is embedded by cold setting method, then the metallographic surface was ground with metallographic sandpaper and polished on the polishing machine. The specimen after preparation was corroded by 4% natal. The microstructure of solder alloy was observed by FEI Inspect S50 scanning electron microscope, the composition of the precipitate phase was analysed by OXFORD X-act/INCA 150 energy disperse spectroscopy. The microhardness of the brazing seam zone was measured by HV-1000 micro hardness tester.

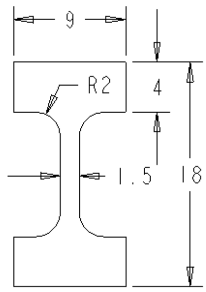

Fig.1 Dimensions of the tensile specimen

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.

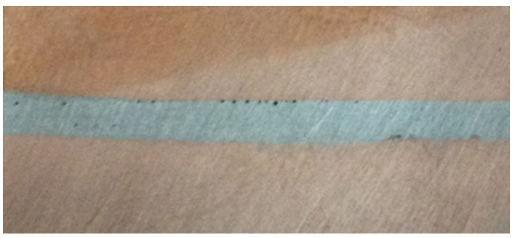

Fig.2 Specimen welded by ultrasonic-assisted brazing

Effect of the substrate distance on the microstructure of joint. Fig.3 is BSED photos of SnBi-χAl_2O_3 solder alloy for different substrate distance. From Fig.3, it can be seen that SnBi-χAl_2O_3 composite solder is a typical lamellar eutectic structure, and the color is gray, black and white. Fig.4 is the EDS analysis results of point A and point B in Fig.3 (d), it can educe that the area of the larger atomic number is white light, that is the Bi rich phase, while the area of the smaller atomic number is gray, that is the β-Sn rich phase. The lower part of the black area is the copper substrate. With the substrate spacing of 0.8mm, 0.5mm to 1mm gradually increased, 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. From the analysis results of point C and point D in Fig.4, near the composite filler metal is Cu_6Sn_5 IMC; while the point D of the gray bar, near the copper substrate is Cu_3Sn IMC.

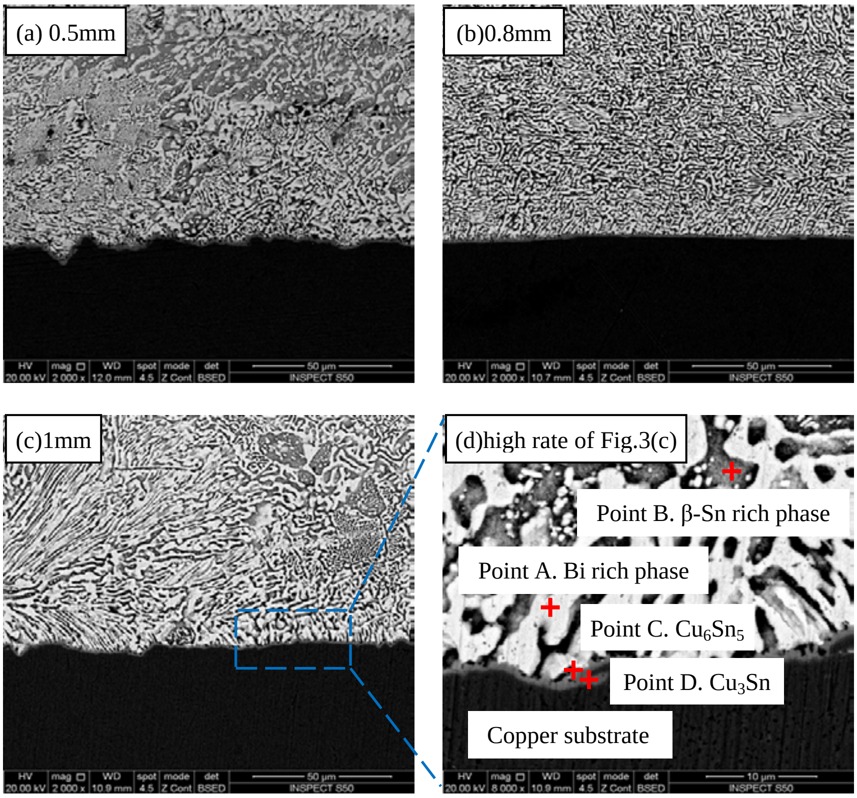

Fig.3 BSED photos of SnBi-χAl_2O_3 solder alloy

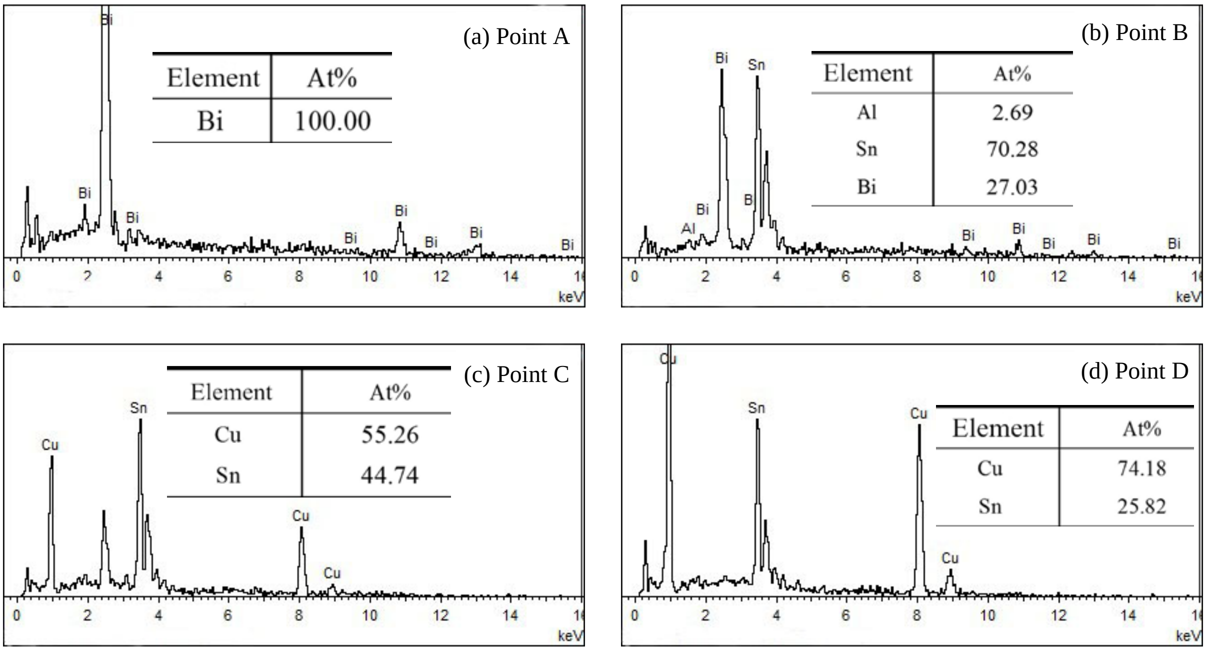

Fig.4 EDS point analysis of welding joint with substrate distance as 1mm

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 result is displayed in Fig.5. 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.

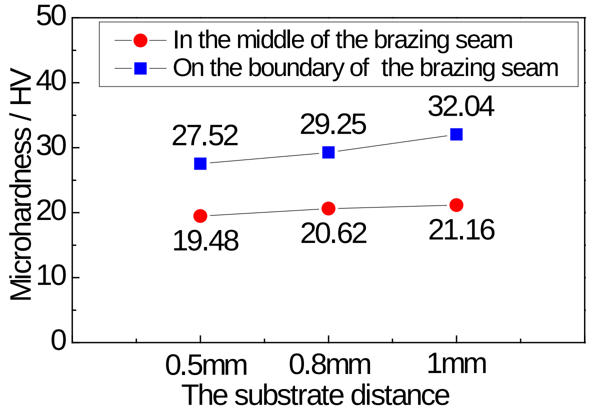

Fig.5 Microhardness photo of the central part and boundary of the brazing seam with different substrate distances

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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 from 0.8mm, 0.5mm to 1mm gradually increased, 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. Near the composite filler metal is Cu_6Sn_5 IMC, and near the copper substrate is Cu_3Sn IMC.

(3) Appropriate increase for the substrate distance will contribute to the micro hardness increase. A hard brittle IMC strip forms between the composite solder and the copper substrate, so the boundary brazing seam hardness is higher than that of the middle.

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