RESEARCH OF WETTABILITY OF IN SOLDER ON AL₂O₃ CERAMIC DURING LASER BEAM HEATING

Igor Kostolný, Roman Kolečák, Jozef Bárta

Slovak University of Technology in Bratislava, Faculty of Materials Science and Technology in Trnava, Institute of Production Technologies Paulínska 16, 91724 Trnava, Slovak Republic

Abstract

The work deals with investigation of wettability of In solder on Al₂O₃ ceramic substrate heated by laser beam. The soldering process was realized without using of flux. Designed laser beam power was 1.1 kW and 0.5 kW. The In solder of high purity of 5 N was used for soldering. Wettability of solder on substrate, microstructure of joints and EDX analysis on interface were evaluated. Satisfying value of wettability was observed only with power of laser beam 1.1 kW. Lower power due to the high surface tension not allowing connection with a satisfactory value of wettability. Observation of microstructure confirmed the creation of reaction zone on joint boundary. EDX analysis identified the phase boundary which is composed of mixture of Al + In and InO₂.

Keywords: solder; wettability; microstructure; EDX analysis, laser beam

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1. Introduction

Ductile soft active solders can joining unusual combinations of metallic materials (eg. stainless steel, Mo, W) and mostly non-metallic brittle materials (fused silica, sapphire, carbon, silicon). The basic material of soft active solders can be tin, lead or indium and created alloys based on these metals. Such joints are applied in electronics and electrical engineering, where it is sufficient to lower strength and thermal resistance of the joint. For example the connection of the heat exchangers to the ceramic electronic substrate of Al_2O_3 [1]. At present, however, they prefer soft lead-free solder mainly due to environmental friendliness and standards. Soldering of ceramic materials research deals with a number of universities and researchers in the world. The authors [2, 3, 4, 5, 6] studied soldering of copper and Al_2O_3 . Soldering by ultrasound ensure proper wetting and interaction between Sn solder and ceramic substrates.

The use of CuAgTi solder was successful in joining copper and Al_2O_3 ceramic. To improve wettability of solder $\text{Sn}_{3.5}\text{Ag}_4\text{Ti}$, a small amount of Ce and Ga was added. Best achieved wetting angle was 46° . The authors of [7, 8, 9, 10] used solder alloys based of Cu and Sn with the addition of Ti to improve wettability of solders on Al_2O_3 ceramic substrate. This was due to lowering of interfacial tension by absorbing to liquid side of the joint. Likewise, reduction of tension by forming an oxide layer TiO_2 at solid side of the interface.

The addition of In to the basic Zn solder and analyze its properties are dealt by authors [11, 12]. A small amount of In to Zn-Al solder decreases the melting temperature. It also resulted in an increase of electrical resistance compared to Zn-Al eutectic solder. The contact angle of the Al and Cu substrate is reduced with increasing of In content. A comprehensive overview of wettability of different solder alloys on ceramic material Al_2O_3 is current problem of various research papers in the world. This work therefore deals with research of wetting of In solder on Al_2O_3 ceramic material.

2. Experimental

The ceramic material aluminum oxide (Al_2O_3) was used as a base material in experiments. Al_2O_3 substrate itself has been cut by water jet to size $\varnothing 15$ mm (FIG. 1). Solder used for research of wettability was In having a purity of 5 N.

Fig. 1. Al_2O_3 substrate

Design of solder / substrate joint was carried out on solid-state disk laser with a maximum power of 2 kW from the Trumpf company. Before soldering, the samples were thoroughly cleaned. For each sample, defocused beam of focus position 15 mm above the material was prepared. Designed laser beam power was 1.1 kW, and 0.5 kW. Schematic of laser beam soldering is illustrated in FIG. 2.

Fig. 2. Scheme of laser beam soldering

After completion of joints, samples have been cut for the analysis of solder wetting angle. Analysis of the microstructure of joints were taken using scanning electron microscopy (SEM). The joint interface was evaluated by EDX analysis. Analyses were carried out on the equipment JEOL JSM - 7600F.

3. Experimental results

Wetting angle measurement was carried out on two samples (fig. 3). Soldering with laser power of 1.1 kW (fig. 3 a) reached the contact angle of 81° . The value of the surface energy is high, but in this case, a contact angle made best value. By reducing the power of laser beam to 0.5 kW, the contact angle of 123° was measured. Whereas the maximum satisfactory contact angle must be less than 90° , this angle was evaluated as unsatisfactory.

Fig. 3. Wetting behavior of In/ Al_2O_3 a) 1,1 kW; b) 0,5 kW

The microstructure of In solder / Al_2O_3 substrate joints is shown in fig. 4. The interface of joint is clearly visible. Dark particles in solder are the remains of SiC grinding wheel, which incurred during metallographic preparation of samples. Based on microstructure of the joint, interaction between the solder and substrate is obvious.

Fig. 4. Microstructure of joints interface In/ Al_2O_3 a) 1.1 kW; b) 0.5 kW.

EDX analysis was performed to determine the chemical composition of the interface of solder / substrate and to determination of the reactions that arose during soldering. The mixture of $\text{Al} + \text{In}$ and InO_2 oxide were observed on interface in both cases. The measured reaction layer with thickness of 10 microns was observed after soldering with laser power of 1.1 kW. Conversely, the use of 0.5 kW, the thickness was lower by a half. The very formation InO_2 reduces the surface tension between the solder and the substrate and thus enables better wetting of the substrate.

Fig. 5. EDX analysis of In/Al₂O₃ a) 1,1 kW; b) 0,5 kW

4. Conclusions

The work deals with the research of wettability of In solder on Al₂O₃ ceramic substrate during laser beam heating. Designed laser beam power was 1.1 kW and 0.5 kW. Soldering was carried out in the absence of flux. Prepared In solder was produced in high purity of 5 N. The work evaluated the resulting contact angle, microstructure of the joints by scanning electron microscopy and EDX analysis to determine the phase composition of boundary. The results obtained can be summarized as follows:

- wettability of In on Al₂O₃ ceramic substrate was satisfactory with power of laser beam 1.1 kW. Achieved wetting angle was 81°. With the reduction of power to 0.5 kW, wetting angle increase to 123°,
- microstructure of the joints confirmed the formation of reaction layer between solder and substrate,
- EDX analysis revealed the presence of a Al + In mechanical mixture and formation of In₂O₃ surface oxide layer,
- better wetting angle was achieved due to reduction of surface tension by formation of In₂O₃.

It was found that the In solder wets Al₂O₃ ceramic substrate and creates a stable phases at the interface by correct parameter setting of laser beam soldering. Further research should deal with the study of the joint strength of this ceramic material using In as the solder.

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