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Nd:YAG laser surface treatment of copper to improve the wettability of Sn3.5Ag solder on copper

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Abstract

Nd:YAG laser surface treatment of copper was found to affect the wettability characteristics of SnAg eutectic lead-free solder on copper. The basic process phenomenon was investigated and the microstructure and wetting characteristics of the solder was determined using optical microscopy and X-ray diffraction techniques. To analyze mechanism of the microstructure changes in the surface layer after laser treatment, a finite element modeling (FEM) model was proposed, the simulated temperature distribution and temperature gradient distribution in the surface layer were presented. The results showed that laser surface treatment can improve the wetting characteristics of the Sn3.5Ag solder on the copper and the mechanism was discussed in detail. The work has shown clearly that laser irradiation can be used to improve the wettability of Sn3.5Ag solder on copper.

Keywords: Wettability; Laser; Copper; Sn–Ag solder; Surface energy

1. Introduction

Due to the toxicity of Pb present in Sn–Pb solders used in many electronic products, alternative solders need to be considered. Many studies of lead-free solders and soldering have been performed from this viewpoint (for example, [1–3]). Most of them have focused on Sn-based alloys. In particular, Sn–Ag alloys are expected to be a substitute for the Sn–Pb eutectic solder, because they have better mechanical properties (ductility, creep resistance and thermal resistance) than the Sn–Pb solder [4]. Thus, the Sn–Ag alloy system was applied as the first lead-free solder in the world [5,6], although the melting temperature is higher and the wettability is poorer than conventional Sn–Pb eutectic solder. Since the implementation of Sn–Ag alloys in many electronic products has been spreading gradually, more studies are required to investigate their material characteristics in terms of melting temperature, solderability, mechanical strength, ductility, creep resistance, thermal fatigue resistance, corrosion resistance, and so on. Of these, the wettability is very important, because these determine solder joint geometry then the distribution of stress and strain.

To date, very little work has been published with regard to the use of laser for modifying surface properties of materials in order to improve soldering wettability. Notwithstanding this, it was recognized within the published work that laser irradiation of material surface can improve their wettability characteristics. Previously Zhou and Dehosson [7,8] and Kadolkar and Dahotre [9] carried out work on laser coating of aluminum alloys with ceramic materials (SiO_2, Al_2O_3, etc.), reporting on the well documented fact that generated oxide layers often promote metal/oxide wetting. Kikuchi et al. [10] used pulsed laser irradiation to modify selected area of aluminum to promote local metal deposition in electroplating or electroless plating, and emphasized that oxide film can be removed from aluminum substrate, which can promote subsequent metal deposition. Bahners et al. [11,12] had observed and

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comprehensively detailed the changes in properties of various textile fibers, including adhesion and wetting properties, with a view to developing an alternative to the conventional methods of chemical agents addition or wet-chemical pre-processing. György et al. [13,14] studied the surface morphology and microstructure of titanium after Nd:YAG laser irradiation, and the relationship between microstructure and laser influence was found. Lawrence et al. [15–18] did some work to improve the wettability of carbon steel, alumina/silica-based oxide with high power diode laser, and believed that the surface energy can be affected by three aspects: i) surface oxygen content; ii) surface roughness; iii) surface microstructure, but the changes of the surface microstructure and the reasons of these changes with regard to the material's surface energy were not reported.

The content described in this paper, that of using 500 W Nd:YAG laser to alter the surface energy of copper can be used to improve the wettability of Sn–Ag eutectic solder on copper surface in soldering process.

2. Experimental procedures

The solder used in the wetting experiment was Sn3.5Ag eutectic solder ball (diameter of 0.76 mm), BGA flux was used in the wetting experiment to protect the molten solder from the contact with ambient atmosphere, the copper specimens before and after laser treatment were cut to 3×3 mm plates, and wetting test between Sn3.5Ag solder and copper plates was done in a hot air reflow oven. The diameter of solder ball was 0.76 mm, the heating temperature was 265 °C and dwell time was 60 s.

To investigate the effect of laser surface treatment on the wettability of Sn–Ag solder on copper, before the wetting experiment, the copper surface before and after laser treatment was slightly polished to the same roughness to avoid the effect of copper surface topography on the wettability.

During the laser surface processing procedure, the laser beam was traversed across the copper samples by means of a CNC positioning table at speed of 2 mm/s. For the pulse laser used in the experiment, the laser pulse frequency and scanning speed must keep the relationship to ensure that all the laser scanning area can be treated. Different powers were used in the experimental procedures, including 2000 W and 4000 W, the laser pulse frequency was 16 Hz and pulse duration was 8 ms. Argon gas was used to protect the materials from oxidation.

In order to analyze the mechanism of the laser treatment on wettability, specimens before and after laser treatment were sectioned with a Struers cutting machine using a diamond-rimmed cutting blade, and then polished with cloth and diamond suspension paste down to 1 μm. The sectioned samples were examined by optical microscope view and XRD analysis.

3. Results

3.1. Contact angle and wettability characteristics

Wetting experiments were conducted between solder balls and laser treated copper, the Sn–Ag eutectic solder balls (diameter of 0.76 mm) were used in the experiment, the heating temperature was 265 °C and dwell time was 60 s. The results of wetting experiments revealed that the contact angles decreased from 42° to 31° when the processing laser power is 2000 W compared with the untreated copper surface; and when the laser power was 4000 W, the contact angle decreased from 42° to 32°. The results showed that the wettability of Sn–Ag on copper was improved after 2000 and 4000 W laser irradiation in contrast to the untreated copper.

Optical micrographs in Fig. 1 showed the wetting properties of Sn–Ag eutectic solder wetting on the untreated and after 2000 W laser treated copper surface, Fig. 1(a) and (b) were the cross section micrographs of untreated surface as soldered and 2000 W laser treated surface as soldered, respectively. The micrographs could give a visual inspection on the wettability characteristics of Sn–Ag solder on copper after laser surface irradiation.

3.2. Surface microstructure after laser irradiation

Fig. 2 showed the optical microphotographs of the surface layer microstructure before and after laser irradiation with different heating energy, Fig. 2(a) was the untreated copper surface. Fig. 2(b) and (c) were the

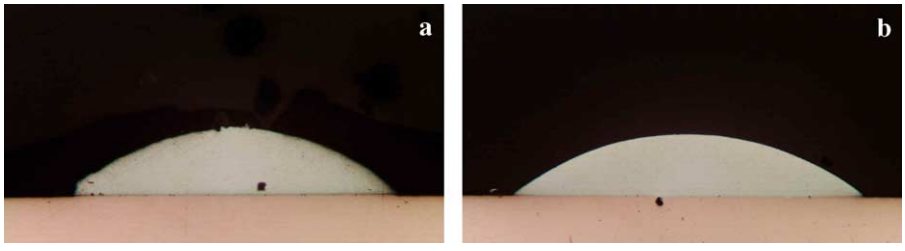

Fig. 1. Contact angles for (a) the untreated surface, (b) the 2000 W laser treated.