Title	Impact Strength of Sn-Ag-Cu Solder Joints in Electroless Ni-P/Au Plating in Laser Reflow Soldering
Author(s)	Nishikawa, Hiroshi; Iwata, Noriya; Takemoto, Tadashi
Citation	Transactions of JWRI. 2012, 41(1), p. 33-36
Version Type	VoR
URL	https://hdl.handle.net/11094/23154
rights	
Note	

Impact Strength of Sn-Ag-Cu Solder Joints in Electroless Ni-P/Au Plating in Laser Reflow Soldering[†]

NISHIKAWA Hiroshi 1*, IWATA Noriya 2**, TAKEMOTO Tadashi 3***

Abstract

The laser has been utilized as a alternative heat source for the soldering process because of its unique properties such as localized heating, rapid rise and fall in temperature, non-contact heating and easily automated process. However, there is limited discussion of the laser reflow soldering and a lack of information exists about the performance of the resultant joints. In this study, the impact strength of Sn-Ag-Cu solder joints in electroless Ni-P/Au plating in laser reflow soldering was investigated using a ball impact test. As a result, it has been made clear that the impact strength of the solder bumps was affected by the heat source for the soldering process.

KEY WORDS: (Lead-free solder), (Laser reflow soldering), (Impact strength), (Ni-P/Au plating)

1. Introduction

Lead-free soldering is showing a global trend and conventional reflow soldering process has been widely used in the electronic industry. Typically, reflow soldering processes for BGA and other types of components may be performed in several different ways using a combination of radiation heating via IR with convection. Recently the laser has been utilized as a alternative heat source for the soldering process because of its unique properties such as localized heating, rapid rise and fall in temperature, non-contact heating and its easily automated process [1-3]. In addition, the laser process enables mounting of individual components and customized modifications of PCB assemblies. However, there is limited discussion of the laser reflow soldering and a lack of information exists about the performance of the resultant joints.

Among various lead-free solders, Sn-Ag-Cu solders are considered as the most promising for both conventional wave and reflow soldering processes. In soldering processes using Sn-Ag-Cu solders, the operation temperature is higher than that in the conventional Sn-Pb soldering process due to the high melting temperature of Sn-Ag-Cu solders. Then, as one of the basic characteristics of Sn-Ag-Cu solders, the high reaction rate of metals in molten solders; that is, the high dissolution rate of metals, is contrasted with a Sn-Pb eutectic solder [4, 5]. Therefore, during heating, a thick intermetallic compound (IMC) layer is easily formed at the interface between Sn-Ag-Cu solder and substrate. The IMC thickness at the interface for Sn-Ag-Cu solders drastically increases compared with that for a Sn-Pb eutectic solder. It is well known that an IMC thickness at the interface between the solder and substrate is very important for the reliability of the solder joint. Usually, nickel in lead-free finishes is used as a solderable diffusion barrier to control the rapid reaction between the solder and Cu pad. However, for the laser reflow soldering, there is limited information on the effectiveness of Ni plating to form the IMC layer at the interface and to concern the joint properties of the solder joint.

In the present study, a ball impact test was conducted and the impact strength of Sn-Ag-Cu solder joints on electroless Ni-P/Au plating in laser reflow soldering was investigated. In particular, the effect of isothermal aging on the impact strength was investigated considering the thickness and morphology of the IMC at the interface between the Sn-Ag-Cu solder and electroless Ni-P/Au plating.

2. Experimental

Sn-3.0 mass%Ag-0.5 mass%Cu solder ball with a 1 mm diameter was used in this study. **Figure 1** shows the schematic diagram of the test board. Electroless nickel-phosphorous (Ni-P) layer (5 μm) / immersion gold was deposited on a Cu pad of the FR4 board. The Cu pad was 800 μm diameter and 35μm thickness. A commercial rosin mildly activated (RMA) flux was used. Before soldering, the test boards were immersed in a 4 % HCl

† Received on June 18, 2012

* Associate Professor
** Graduate Student
*** Specially Appointed Professor

Transactions of JWRI is published by Joining and Welding Research Institute, Osaka University, Ibaraki, Osaka 567-0047, Japan

solution for 120 s and then the test boards and the solder balls were ultrasonically rinsed in an ethanol solution. After the solder balls were dipped in the flux, they were placed on the pads. The solder balls on the pads were heated by the laser irradiation in an air atmosphere using a laser soldering system (UNIX-413L2, JAPAN UNIX Co., Ltd.). The laser used in this system is a high-power diode laser (λ = 940 nm) with a 1.2 mm beam diameter on a focal plane. Laser irradiation conditions were controlled by laser power and heating time listed in **Table 1**. If the laser power was too low, the wetting behavior of the molten solder by the laser process could not be found on the pads. As a reference, conventional reflow soldering was performed at 523 K for 60 s in a nitrogen atmosphere. After soldering, the specimens were ultrasonically cleaned in an ethanol solution to remove residual flux from the solder joints. Some solder joints were then subjected to isothermal aging at 423 K for 168 h and 504 h.

To evaluate the impact strength of the joint, an impact test [6-8] was performed using a micro-impact tester (MI-S, YONEKURA Mfg. Co., Ltd.). The test conditions were as follows: an impact height of 100 μm and an impact speed of 1 m/s. **Figure 2** shows a typical load-displacement curve obtained from the micro-impact tester. In this study, the maximum load and total energy of the load-displacement curve shown in this figure were investigated to evaluate the impact strength of the joint. An average value based on 10 measurements for each soldering condition was adopted.

.

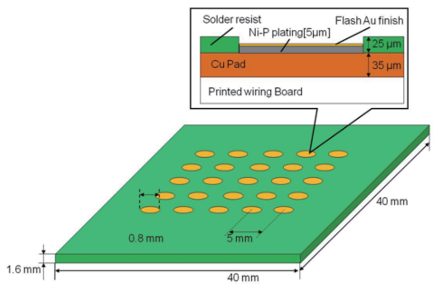

Fig. 1 Schematic illustration of test board used in this study.

Table 1 Laser irradiation conditions used in this study.

Laser power (W)	Heating time (s)
20	15, 20, 30, 40
40	0.5, 1

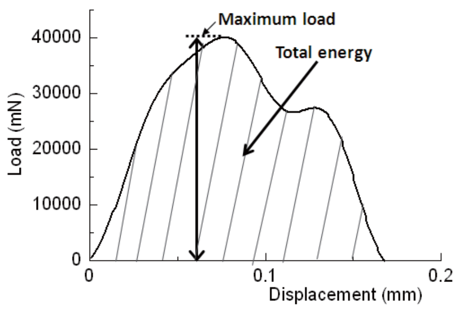

Fig. 2 Typical example of load- displacement curve obtained by a micro-impact tester.

Some specimens before the ball impact test were cut and their cross-sections were polished to observe the solder/electroless Ni-P interface and the solder matrix by scanning electron microscopy (SEM)

3. Results and discussion

The influence of the heating parameters such as laser power and heating time of the diode laser on the maximum load and the total energy obtained from the ball impact test was investigated. The relationship between the maximum load and heating parameters is shown in **Fig. 3(a)** and the relationship between the total energy and heating parameters is shown in **Fig. 3(b)**. The maximum loads at 20 W with a long heating time are larger than those at 40 W with a short heating time. At the same laser power, there is little difference in the maximum load by the heating time. Then, the total energies at 20 W are also larger than those at 40 W. At the same laser power, there is little difference in total energies by the heating time. So, just after the laser reflow soldering, the joint properties of the joints at 20 W were better than those of the joints at 40 W. Then, two laser irradiation conditions to examine in detail were chosen: 20W for 20 s and at 40 W for 1 s.

Figure 4 shows SEM images of the interface formed on the Ni-P/Au plating in as-soldered condition, which were respectively subjected to the laser soldering

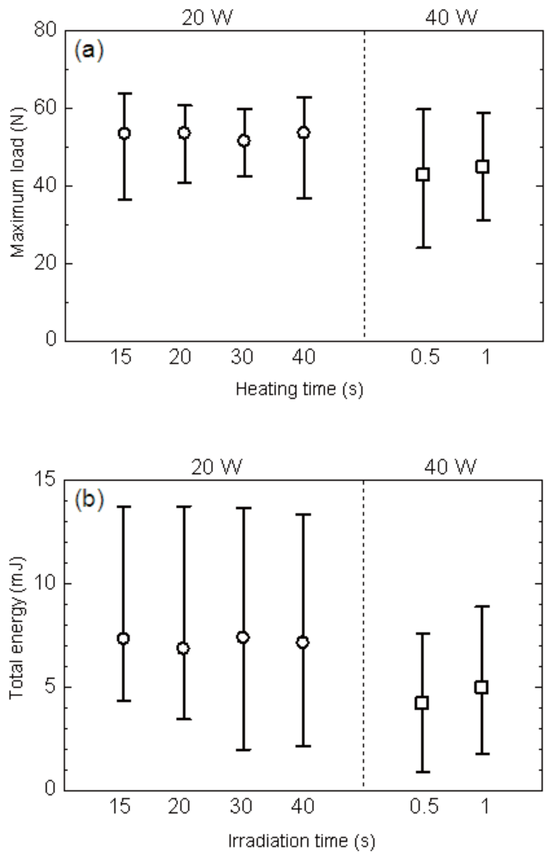

Fig. 3 Effect of laser power and heating time of laser process on joint properties for Ni-P/Au plating obtained by impact test. (a) Maximum load, (b) Total energy

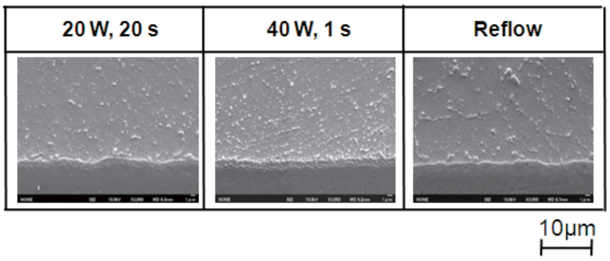

Fig. 4 SEM images of joint interfaces on Ni-P/Au plating by laser process and reflow process in as-soldered condition.

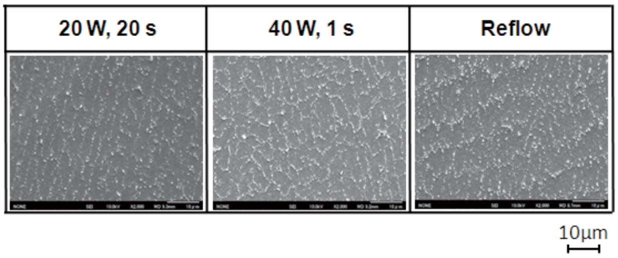

Fig. 5 SEM images of microstructure of solder matrix by laser process and conventional reflow process in as-soldered condition.

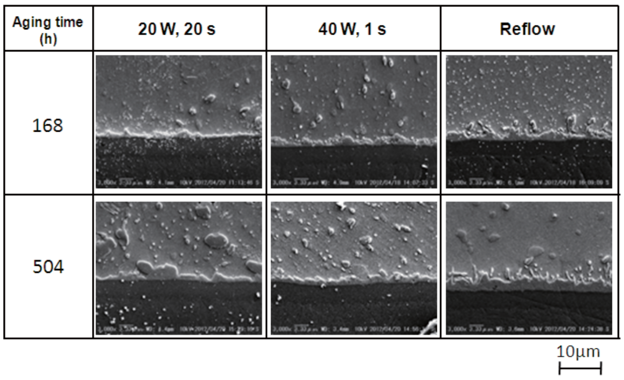

Fig. 6 SEM images of joint interfaces on Ni-P/Au plating by laser process and reflow process after aging for 168 h and 504 h.

and the conventional reflow soldering. Compared with the Cu pads, in the case of electroless Ni-P/Au plating, there is little difference in the IMC formation at the interface for both the laser process and the conventional process. Then, for both cases, the IMC thickness shown in Fig. 4 was very thin. Although the time above the melting temperature of the solder for the laser soldering is much shorter than that for the reflow soldering, Ni-P layer may work well as a diffusion barrier between the Cu pad and the solder matrix.

Typical SEM micrographs of the solder matrix just after soldering are shown in **Fig. 5**. Generally, in the case of Sn-3.0Ag-0.5Cu solders, the microstructures after soldering are composed of dendrites of β-Sn phase, which is formed as the primary phase, and network band, which is the β-Sn/Cu_6Sn_5/Ag_3Sn eutectic phase. Fine Cu_6Sn_5 and Ag_3Sn particles are dispersed in β-Sn. The microstructure is depending on the cooling rates, and the time and temperature above the melting temperature. As

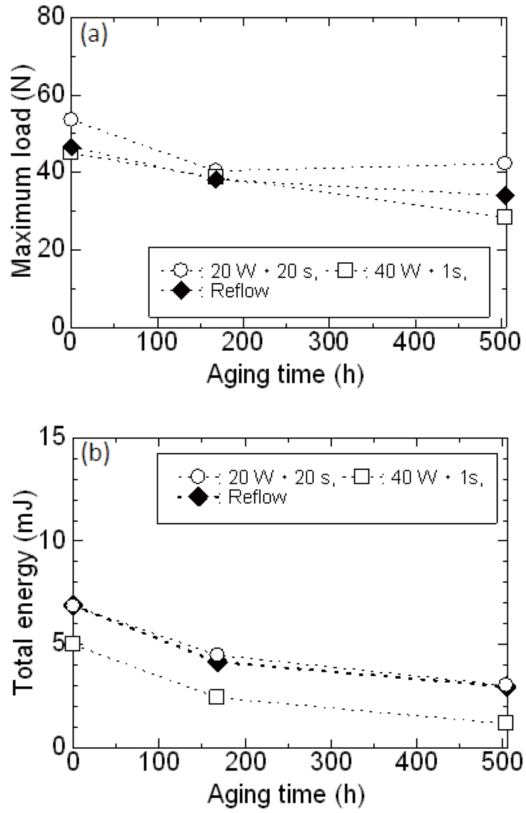

Fig.7 Effect of aging time on impact strength of joints soldered on Ni-P/Au plating. (a) Maximum load, (b) Total energy.

shown in Fig. 5, the microstructures of the solder matrix for the laser reflow soldering are different from that for the conventional reflow soldering. In the case of the laser soldering, the average size of the primary β-Sn phase is smaller and narrower than that of the reflow soldering. This is because the cooling rate of the laser soldering is much faster compared with the reflow soldering.

The SEM micrographs of the interface in **Fig. 6** show the effect of aging time on growth of the IMC layer during the isothermal aging. This figure shows the interfaces for the laser reflow soldering and the conventional reflow soldering which were heat-treated at 423 K for 168 h and 504 h. During aging, the thickness of the IMC lay at the interface gradually increased with the increase of the aging time. However, there is little effect of heating method on the growth and morphology of the IMC layer at the interface.

Figure 7 shows the effect of aging time on joint properties such as maximum load and total energy on the Ni-P/Au plating. The effect for maximum load is shown in Fig. 7(a), and the effect for total energy is shown in Fig. 7(b). Regardless of aging time, the maximum load of the joints soldered by the laser process at 20 W for 20 s was clearly higher than those soldered by the reflow process. And the total energy of the joints soldered by the laser process at 20 W for 20 s was almost similar with those soldered by the reflow process. On the other hand, for the laser process at 40 W for 1 s, both the maximum load and total energy of the joints was almost similar with or lower than those soldered by the reflow process regardless of aging time. Therefore, the impact strength of the joints soldered by the laser process at 20 W for 20 s was superior to those of joints soldered by the conventional reflow process.

4. Conclusions

The impact strength of the joints soldered by the laser reflow soldering was evaluated by a ball impact test.
(1) For the Ni-P/Au plating, there is little difference in the IMC formation and growth between the laser reflow soldering and conventional reflow soldering.
(2) The impact strengths of the joints soldered by the laser process at 20 W for 20 s were superior to those of joints soldered by the conventional reflow process.

Acknowledgment

This research was supported by Japan Society for the Promotion of Science (JSPS) on Grand-in-Aid for Scientific Research (C) (22560721)

References

[1] J-H. Lee, Y-H Lee and Y-S. Kim, Scripta Mater., 42 (2000) 789-793.
[2] C. Chaminade, E. Fogarassy and D. Boisselier, Appl. Surf. Sci., 252 (2006) 4406-4410.
[3] W. Liu, C. Wang, Yanhong Tian and Mingyu Li, J. Alloy. Compd., 458 (2008) 323-329.
[4] A. Sharif and Y.C. Chan, Mater. Sci. and Eng. B, 106 (2004) 126-131.
[5] T. Takemoto, U. Uetani, and M. Yamazaki, Soldering & Surf. Mount Technol., 16 (2004), 9-15.
[6] M. Date, T. Shoji, M. Fujiyoshi, K. Sato and K. N. Tu, Scripta Mater., 51 (2004) 641-645.
[7] Y. S. Lai, H. C. Chang and C. L. Yeh, Microelectron. Reliab., 47 (2007) 2179-2187.
[8] Y. Xu, S. Ou and K. N. Tu, J. Mater. Res., 23 (2008) 1482-1487.