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STUDY ON THE SHEAR TEST CHARACTERISTIC OF LASER SOLDERING JOINT

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ABSTRACT

The purpose of this study is to make the experimental basis for the development of the laser-assisted three-dimensional micro-bonding technology. The basis of experiments was carried out on the melting of the solder balls in order to secure the laser soldering process technology. This research was to establish the concept on a solder ball bumping process using a fiber laser. After designing and manufacturing the nozzle to move micro solder balls and the laser focusing head, the solder ball bumping experiments were carried out. The laser soldering conditions are analyzed by using bumping experiments of the solder balls of 300 ㎛. To the development of personal and portable electronics such as mobile phones, laptop computers, IC card electronics, industry is making an effort to meet the needs of smaller and lighter products. As an example, the most densely Mount Solder bumping flip-chip packages are tried to apply the technology of laser soldering lead-free joints due to thermal damage and environmental problems, but have a large number of inputs and outputs. The needs to packaging technologies to interface from the macro/micro to micro/nano required recently. Through this research we aim to promote the sustainable development of the Korean electronic parts industry on laser soldering technology.

KEYWORDS: laser, soldering, shear, test, joint.

1. INTRODUCTION

With optical communication parts such as Opto-MEMS becoming miniaturized, the demand for ultra-fine packaging processes has increased, and bonding technologies such as fine soldering are the key element technology for them. The development of personal and portable electronic products such as mobile phone, notebook computer, and IC card has prompted electronic product manufacturers to strive to meet the demand for smaller and lighter products. For example, although the flip chip packaging of solder bumper -- which has the highest packaging density -- has many I/O terminals, there are efforts to apply lead-free laser soldering technology due to thermal damage and environmental problems. This study conducted a basic experiment of solder ball melting to secure the laser soldering process technology for flip chip packaging. Its purpose was to establish the solder ball bumping process using fiber laser. The condition for solder ball melting using laser was analyzed through a shear test after the bumping experiment of solder ball measuring 200 ㎛.

2. EXPERIMENT

Fig. 1 shows the block diagram of the laser soldering unit, and Fig. 2 presents the conceptual diagram of the laser soldering process using nozzles whose outlet is the same size as the solder ball. The laser soldering system used fiber laser. Fig. 3 shows a picture of the laser soldering system (a) and the screen of the vision system for observation (b).

We conducted a laser soldering test as shown in Fig. 4 to optimize the variables such as focal distance and laser output. We also analyzed the reaction characteristics of the laser according to the materials of the solder ball and substrate. The solder balls used in the basic experiment had diameters of 200 ㎛ and 300 ㎛. The substrate used two types of PCB material. Fig. 5 presents pictures of PCB 1 and PCB 2 used in the substrates for the experiment. The bump sizes of PCB 1 and PCB 2 were 250 ㎛ and 230 ㎛, respectively, and the pad composition was at least 97% gold.

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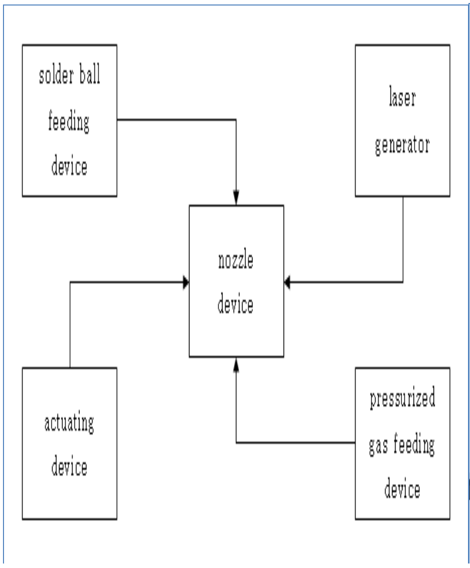


Fig. 1.Block diagram of the laser soldering unit

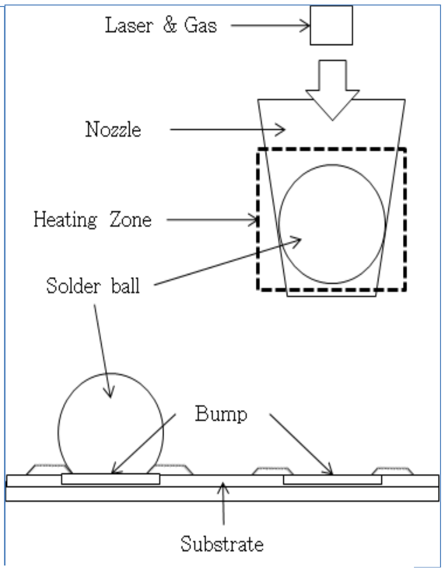
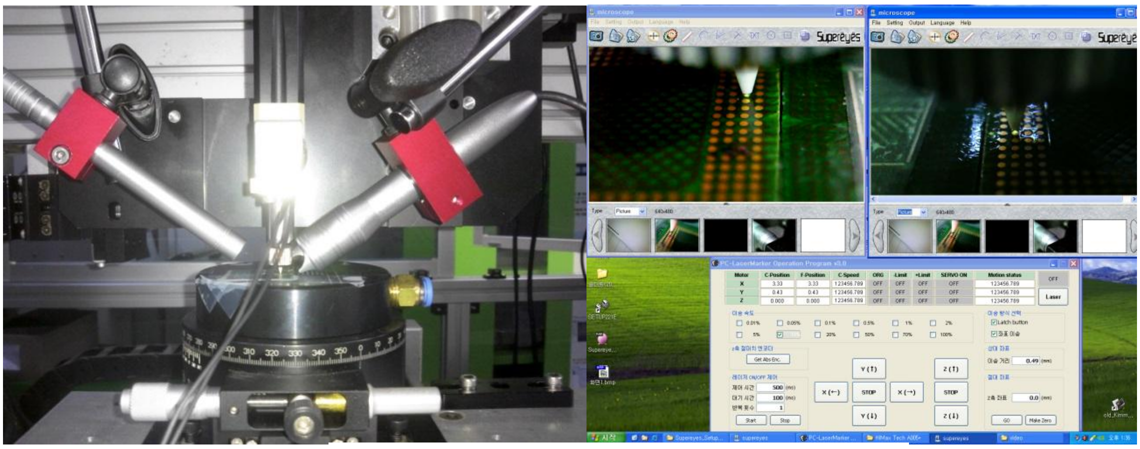


Fig. 2. Soldering process using nozzle



(a) *(b)*

Fig. 3. Laser soldering unit; (a) laser soldering head - automatic supply, (b) monitoring software by vision camera

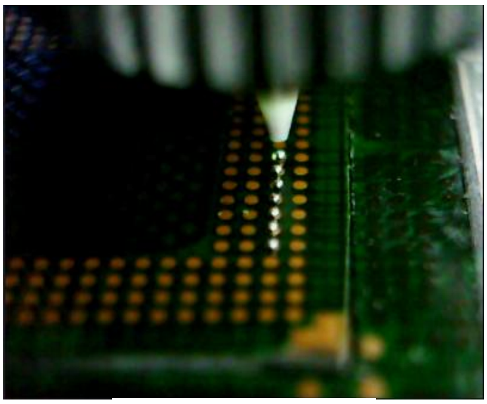


Fig. 4. Laser soldering test

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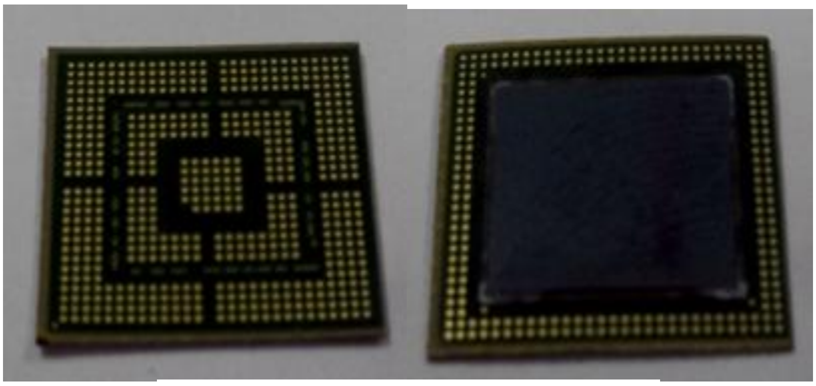
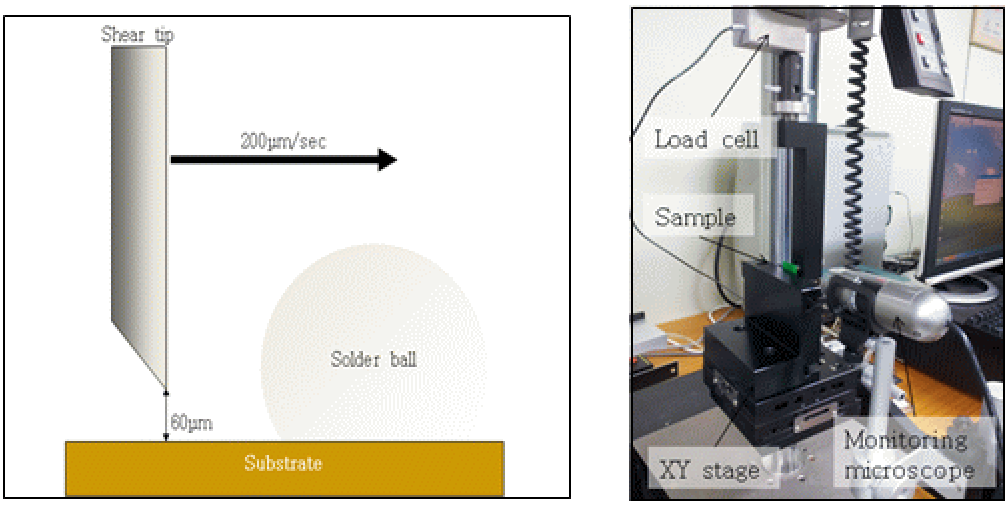


(a) PCB 1 *(b) PCB 2*

Fig. 5. PCB substrate for laser soldering

Table 1. Laser soldering conditions for PCB

PCB	Focal Length (mm)	Power (W)	Time (ms)
PCB 1	94	4.65	300
PCB 2	94	4.65	350



(a) ***(b)***

Fig. 6. Shear test unit; (a) schematic diagram, (b) photograph of shear test

We analyzed the soldering process while varying the process variables such as the distance between the nozzle specimens, gas pressure, laser output, and time. We verified the accuracy of the focal distance of the microscope and analyzed the effects of process variables on a 200 ㎛ solder ball using the 250 ㎛ bump. Although it melted more stably as the distance between the nozzle specimens decreased, the ball became flat. The crater at the top of the ball became smaller as the laser output decreased, and the overall spherical shape was maintained even as the gas pressure decreased. The table below shows the conditions of the basic experiment.

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Table 2.Final condition of laser soldering

Distance between the nozzle and PCB [mm]	Gas pressure [MPa]	Laser power [%]	Time [ms]
0.5	0.05	20	100

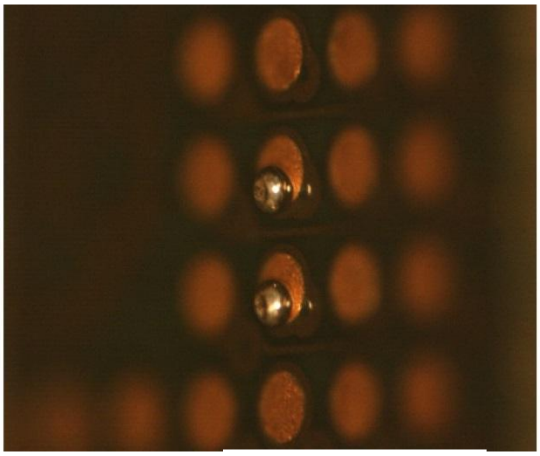
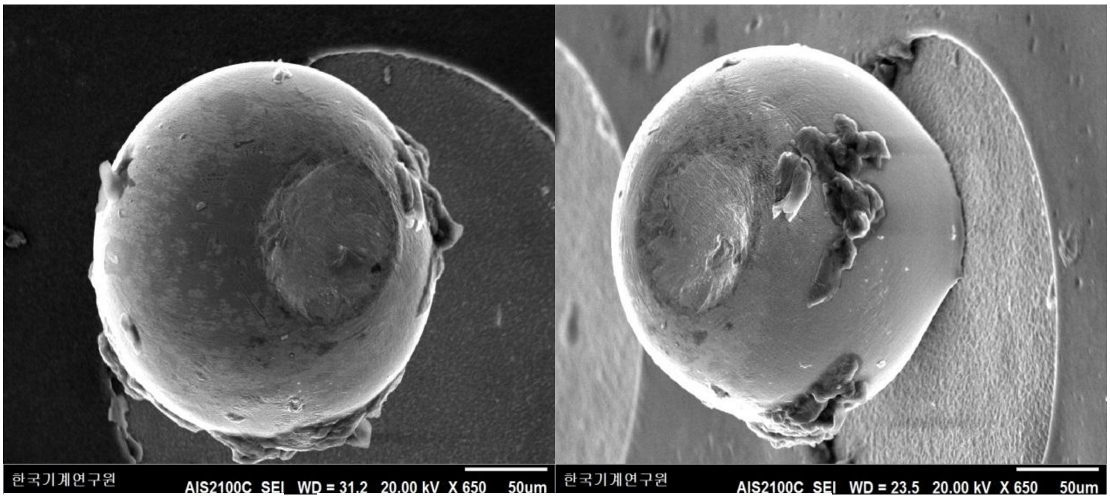


Fig. 7. Laser soldering test

SEM photography was used to analyze the uniformity of the laser soldering specimens under the conditions in Table 2 as shown in the figure below. A total of 20 soldering sessions were conducted using the bump measuring 250 ㎛ under the same condition. We then analyzed the photographs taken using digital microscope and SEM (scanning electron microscope).



(a) 90° ***(b) 45°***

Fig. 8. SEM photography of laser soldering by view angle

The height of the solder ball was measured using a 3D optical microscope after 10 performances of laser soldering to the bump measuring 250 ㎛ to verify uniformity. The table below lists the experiment condition of laser soldering, showing that more uniform soldering is possible after preheating the nozzle.

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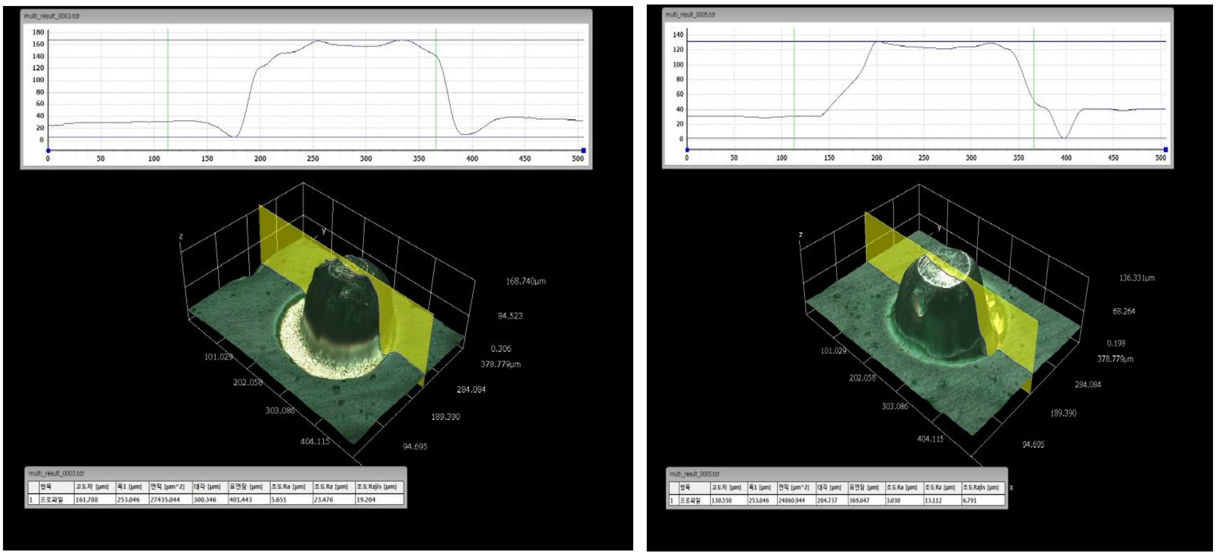
Table 3.Final condition of laser soldering

Distance between the nozzle and PCB [mm]	Gas pressure [MPa]	Laser power [%]	Time [ms]
0.7	0.07	20	100



(a) Laser power: 24.5%, Time: 40ms ***(b) Laser power: 25%, Time: 40ms***

Fig. 9. 3D photography of laser soldering according to laser power and time

Table 4.3D measurement of laser soldering specimens

	Height [μm]	Maximum Height [μm]
Sample A	94.783	117.998
Sample B	101.132	107.643

The shear test performed soldering under three types of test condition to measure the shearing strength of the bonded part. We checked the ball condition with digital microscope, SEM, and 3D photography before the shear test and analyzed the data after the test. The table below shows the data and result of each test.

Table 5. Condition of laser soldering before the shear test

#	Sample	Condition of laser soldering				
		Distance between the nozzle and PCB [mm]	Gas pressure [MPa]	Laser power [%]	Time [ms]	Number of repetitions (waiting time)
A	Sample A	0.7	0.07	30	3	2 (100ms)
B	Sample B	0.7	0.07	24.5	40	1
C	Sample C	0.5	0.05	25	500	1

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We obtained excellent bonding strength in condition C among test conditions A, B, and C. Unlike other conditions, condition C set lower power and longer emission time for soldering. The test focused on the uniformity of solder ball and shearing strength using the bump measuring 230 μm. As shown in Figure 10, sample C was soldered 10 times from left to right. We then fabricated the samples in the rectangle drawn in a dotted line and observed them with digital microscope and SEM prior to the shear test.

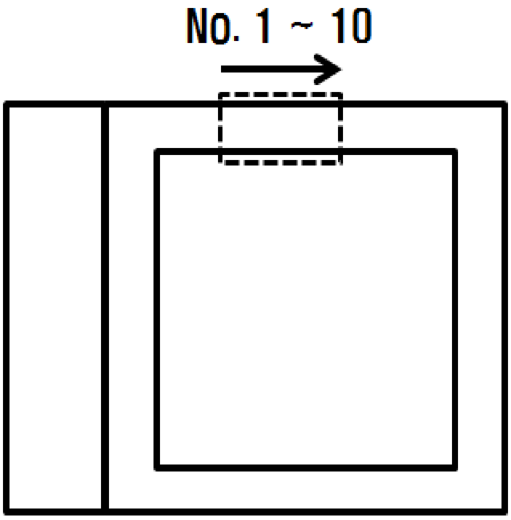
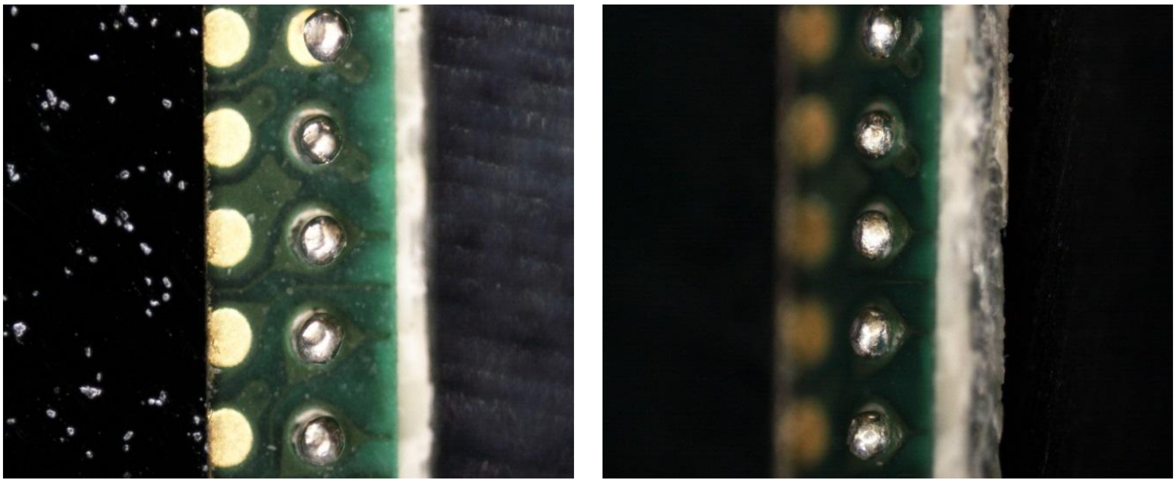


Fig. 10. Schematic of sample (#C)



(a) 90° *(b) 45°*

Fig. 11. Sample C; No. 1 ~5

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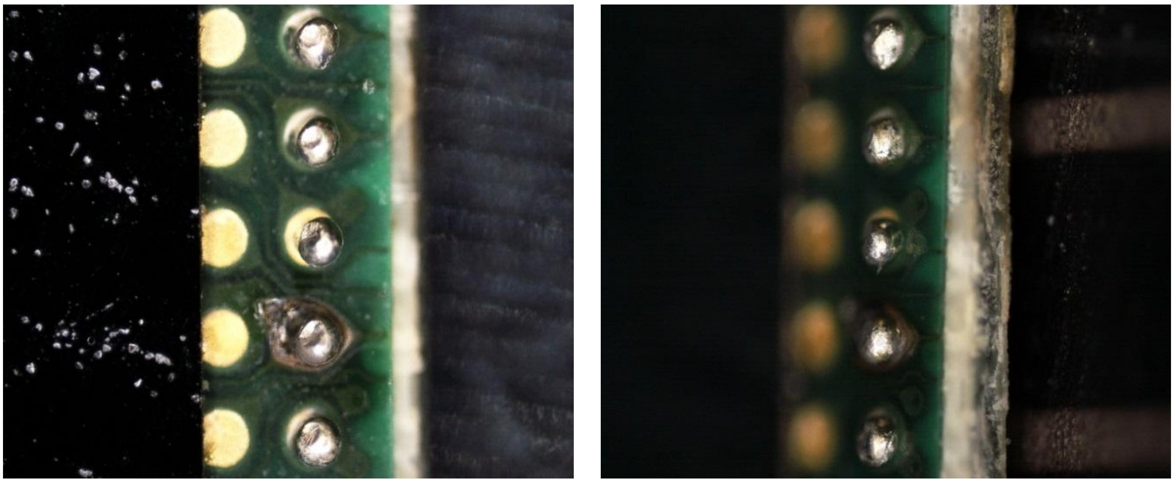
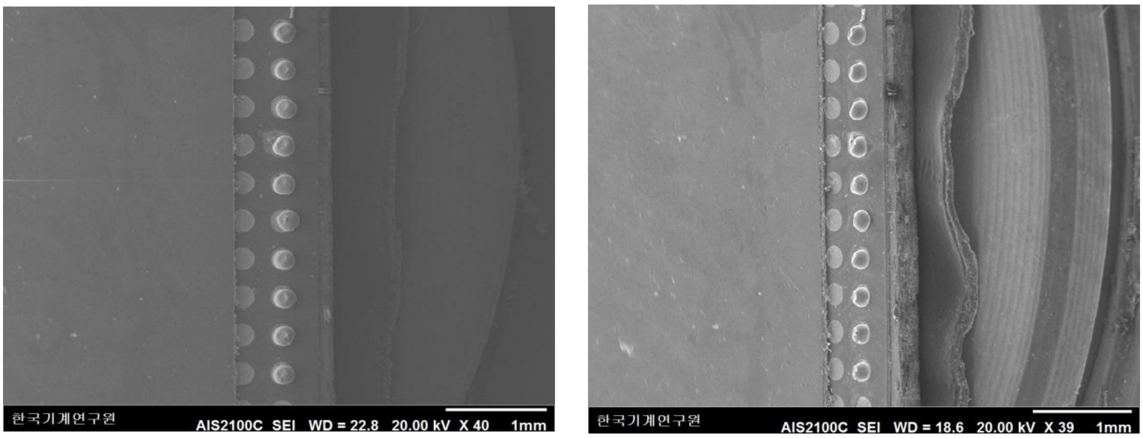


(a) 90° *(b) 45°*

Fig. 12. Sample C; Nos. 6 ~10



(a) 90° *(b) 45°*

Fig. 13. SEM photography of laser soldering sample C; Nos. 1 ~10

The test showed that the result of sample C was more uniform than that of samples A and B and indicated that the impact of process variable on the melting of the ball decreased with longer emission time and lower output and gas pressure. The bump measuring 230 ㎛ showed better soldering result than the 250 ㎛ bump. We then compared the digital microscope images and SEM photography after the shear test.

Table 6.Results of shear test of sample C after laser soldering

Sample no.	Test items	Unit	Test result	Measurement condition
1	Shear load	gf	158	- Shear height: 30 ㎛ - Shear speed: 200 ㎛/s
2			151	
3			122	
4			79	
5			147	

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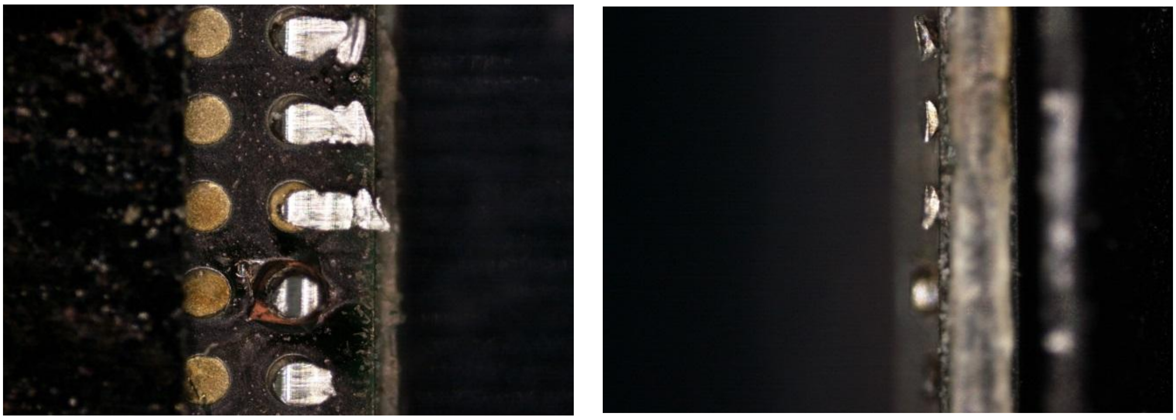
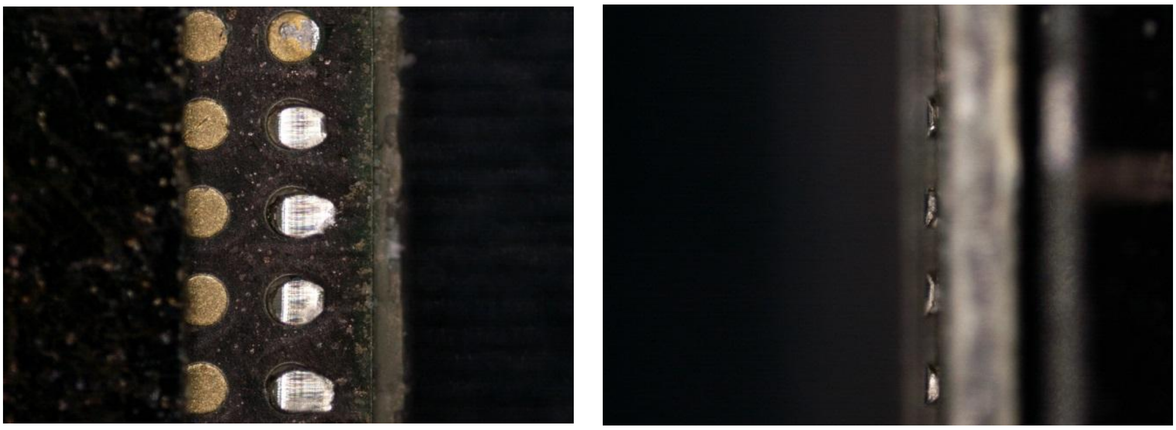
6			103	
7			167	
8			168	
9			172	
10			155	

The average shear strength of sample C after excluding the minimum and maximum shear strengths was 147gf (≒1.5N). No. 4 showed low shear strength, with the digital microscope and SEM indicating that it is attributable to the bump damaged during soldering. No. 6 showed rupture and low shear strength. Sample C, which had low output and gas pressure with long emission time, yielded general-level shear strength. The following pictures show the ruptured surface after the shear test:



(a) 90° *(b) 0°*

Fig. 14. Fracture surface of sample C; Nos. 1 ~5



(a) 90° *(b) 0°*

Fig. 15 Fracture surface of sample C; No. 6 ~10

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3. RESULTS AND DISCUSSION

We obtained the optimal laser soldering condition and secured the laser soldering process by observing the bonding condition after the laser soldering test on the PCB substrate using the solder ball with diameter of 200 ㎛ and the shear test. We concluded that the fine pitch packaging requires a technology for precisely controlling the ball and substrate positions as well as the precise adjustment of the laser output and gas pressure. We studied the laser soldering characteristics for the PCB substrate and the solder ball and secured the process condition to obtain adequate bonding strength by analyzing the shear test characteristics. The demand for ultra-fine bonding technologies such as flip chip packaging and 3D printing has recently increased. The advancement of the current 2D laser soldering technology to 3D bonding technology will have a significant ripple effect on the relevant industries and will also facilitate the continuous development of the electronic parts industry.

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