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Application of laser spot cutting on spring contact probe for semiconductor package inspection

Dongkyoung Lee [a,*], Jungdon Cho [b], Chan Ho Kim [a], Seung Hwan Lee [a]

[a] Department of Mechanical and Automotive Engineering, Kongju National University, Cheonan 31080, Republic of Korea
[b] IWIN Co., Ltd, Chungbuk Technopark, Yangcheong-ri, Ochang-eup, Chungbuk 28116, Republic of Korea

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ABSTRACT

A packaged semiconductor has to be electrically tested to make sure they are free of any manufacturing defects. The test interface, typically employed between a Printed Circuit Board and the semiconductor devices, consists of densely populated Spring Contact Probe (SCP). A standard SCP typically consists of a plunger, a barrel, and an internal spring. Among these components, plungers are manufactured by a stamping process. After stamping, plunger connecting arms need to be cut into pieces. Currently, mechanical cutting has been used. However, it may damage to the body of plungers due to the mechanical force engaged at the cutting point. Therefore, laser spot cutting is considered to solve this problem. The plunger arm is in the shape of a rectangular beam, 50 μm (H) × 90 μm (W). The plunger material used for this research is gold coated beryllium copper. Laser parameters, such as power and elapsed time, have been selected to study laser spot cutting. Laser material interaction characteristics such as a crater size, material removal zone, ablation depth, ablation threshold, and full penetration are observed. Furthermore, a carefully chosen laser parameter ($E_{total} = 1000$ mJ) to test feasibility of laser spot cutting are applied. The result show that laser spot cutting can be applied to cut SCP.

1. Introduction

After wafer fabrication, the wafers are cut to individual semiconductor chips. These semiconductor chips are packaged. After packaging, the semiconductor devices are electrically tested so that defects are classified. The test interface between a Printed Circuit Board (PCB) and the semiconductor devices consists of densely populated spring-loaded contact probes [1]. These probes are called Spring Contact Probe (SCP) [2]. The SCP provides an electrical interface between the semiconductor package and PCB. A standard SCP typically consists of a plunger, a barrel, and an internal spring [3]. Configuration of SCP is shown in Fig. 1.

Plungers are made from beryllium copper (BeCu) or steel. Barrels are made from nickel-silver, bronze or brass. The plungers and barrels are typically coated with gold (Au) to improve electrical performance. Springs are made from steel with gold coating. The plunger tip at one end is to make contact with the PCB while the plunger tip at the other end is used to contact the semiconductor package. Plungers are manufactured together by a stamping process to improve productivity. After stamping, plunger connecting arms are cut into pieces. Currently, a mechanical cutting is used. However, mechanical force engaged at the cutting point may damage to the body of plungers. Furthermore, when mechanical stress is accumulated, fracture can occur. Moreover, cutting tool wears over time. This tool wear results in process instability and poor cut quality. If then, inspection performance becomes deteriorated and a production yield during semiconductor manufacturing processes decreases. Thus, laser spot cutting is applied to solve these problems as well as to improve both cut quality and productivity simultaneously.

Laser cutting is very popular industrial application [4] since it has many advantages. The advantages are listed as follows

- Contact-free process.
- High energy concentration.
- Fast processing time.
- Small heat-affected zone (HAZ).
- Applicability to almost every material.

Thus, laser cutting has been applied to many different types of materials such as battery electrodes [5–12], Carbon Fiber Reinforced Plastic [13–15], and steel [8,16–18]. Laser cutting uses laser to cut materials and separates a workpiece into two or more pieces. When applying laser cutting, there exists relative motion during cutting process. If laser cutting is applied to a workpiece, which

* Corresponding author.
E-mail address: ldkkinka@kongju.ac.kr (D. Lee).

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Nomenclature

α	thermal diffusivity
D	diameter of a crater
E	generated pulse energy per one pulse
F_{th}	ablation threshold
F_0	peak fluence
$F_{th}(1)$	ablation threshold fluence using one laser pulse
$F_{th}(N)$	ablation threshold fluence using N laser pulses
f	repetition rate
l_{th}	thermal depth
N	number of pulses
P_{peak}	peak power
P_{avg}	laser average power
s	incubation coefficient
Δt	pulse duration
w_0	laser beam diameter

Abbreviations

H	height
HAZ	Heat Affected Zone
PCB	Printed Circuit Board
SCP	Spring Contact Probe
SEM	Scanning Electron Microscope
W	Width

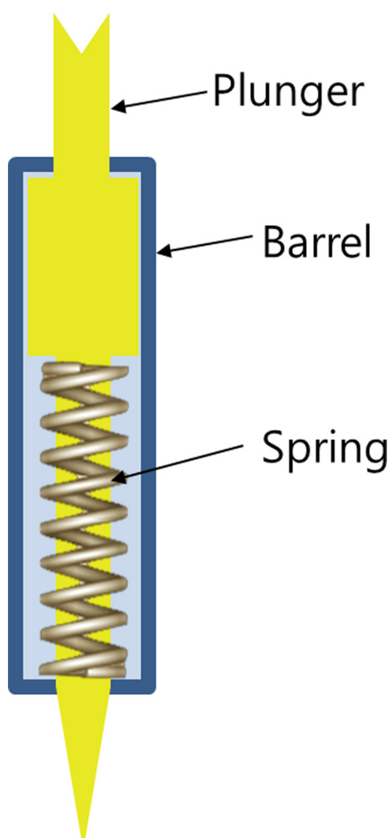

Fig. 1. Configuration of SCP.

is about the size of material removal zone as shown in Fig. 2, relative motion may not be required. Thus, laser spot cutting is a technology using laser to separate a workpiece into two or more pieces without relative motion. To find proper laser parameters for laser spot cutting, interaction characteristics between SCP and laser need to be understood. Full penetration, material removal zone, and crater size are investigated to evaluate interaction characteristics. In addition, ablation threshold, and incubation coefficient are obtained. Moreover, chosen laser parameters are applied to cut the plunger connecting arm. This paper is organized as follows.

First, an experimental setup and design are described. Second, a SCP sample preparation is explained. Third, interaction characteristics are evaluated. Fourth, carefully chosen laser parameter is applied to cut SCP. Finally, conclusions are summarized.

2. Experiments

Although not always the case, the typical diameter of barrel, spring and plunger is 1.5 mm, 1.2 mm and 0.9 mm, respectively. BeCu with thickness of 47 μm is prepared using stamping process and then 4 μm Au is coated on the top and bottom of BeCu. Total thickness of the sample is 55 μm which is shown in Fig. 3(a). Rectangular samples have been used for investigating interaction characteristics. For the laser spot cutting, SCP samples are used. Connected plunger arms are shown in Fig. 3(b). A barrel and spring are not considered for SCP samples in this study. All samples are connected. The plunger arm's dimension is 50 × 90 μm as shown in Fig. 3(c).

This study uses nanosecond laser, since many nanosecond laser is available at a cheaper price. Ytterbium pulsed fiber laser (IPG-YLPM) is used for experiments. Fig. 4 shows schematic of experimental setup. The laser has selectable pulse durations in the range of 4 ns to 200 ns. We use 200 ns pulse duration. In this laser pulse duration, there is enough time for thermal energy propagation [19]. Thus, a relatively large melt pool can be created compared to ultrafast lasers. Moreover, evaporation may occur from the molten workpiece. Wavelength is 1064 nm and maximum average output laser power is 20 W. The laser beam is focused on the top surface of the workpiece. A spot size at a focal position is 30 μm. The laser beam has a Gaussian distribution. This fiber laser is connected to 3D galvo-scanner (RAYLASE AS-12Y).

To obtain high productivity, the maximum average output laser power is used. Total irradiated laser energy is chosen as independent variables. Repetition rate is set to 20 kHz. The number of pulses is varied to adjust the total laser energy. Laser parameters used are tabulated in Table 1. Average output laser power is set to 20 W. The maximum average output laser power is used since this parameter is closely related to the process efficiency and productivity. Pulse energy can be calculated as

$$E = P_{avg}\Delta t = \frac{P_{peak}}{f} \tag{1}$$

where E is the pulse energy, P_{avg} is the average output laser power, Δt is the pulse duration, P_{peak} is the peak pulse power and f is the repetition rate. To measure the ablation profile, a confocal microscope is utilized (Olympus OLS4000). In addition, interaction characteristics are observed by looking at the sample surface using Scanning Electron Microscope (SEM).

3. Results and discussions

Before applying laser spot cutting to SCP, interaction characteristics are observed. First, a crater size and an ablation threshold are