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A Method Enables Height-Control of Bonding Chip for Edge-Emitting Laser Stacking

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Abstract

This paper presents a stacking method that enables mounting of an edge-emitting laser (EEL) to required position for feeding a coupling waveguide. The bonding laser chip is integrated to an interposer with embedding waveguide using an electrically conductive silver-filled adhesive. The post-bond in-plane offsets of the bonding EEL chip are determined by the accuracy of the bonder while the bonding height can be adjusted by balancing the external bonding forces with the surface tension of a certain adhesive volume. The experimental demonstration reveals the feasibility of using the approach for EEL devices stacking.

1. Introduction

As the conventional electrical interconnections are approaching critical limits of transmission bandwidth and physical integration, many researches have been done for photonics–electronics convergence in order to satisfy the continuous increase in demand for miniaturization and performance improvement of electronic products. Due to the intrinsic properties of optical signals, such as wide bandwidth, low latency, low power consumption, and low mutual interference, high S/N ratio, optical interconnects have been expected to be used as candidates for solving the bandwidth bottleneck problem with LSI chips. Since the optical performance of a system is highly dependent on the coupling approach for matching the light field of a component to the mode field of another component, high-precision heterogeneous integration technologies plays an important role in optical interconnection technology because beside the coupling principle, precisely positioning of chips/devices is essential for efficiently transferring optical energy.

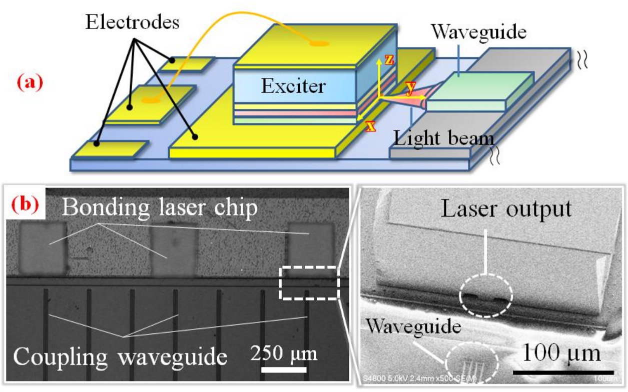

Fig. 1 Mounting of EELs for coupling to waveguides.

Several studies have been conducted concerning on-board optical interconnection using edge-emitting lasers (EELs) for butt-coupling to waveguides. In almost studies, solder reflow process was used for stacking of laser chips onto a board/substrate. In our study, we propose of an integration approach based on the flip-chip bonding technology using of an electrically conductive silver-filled adhesive, to stack EELs on to the interposer feeding for embedding waveguides (Fig. 1(a))[1]. In this paper, the demonstration of the approach to control the bonding height of EELs will be reported.

2. Demonstration of the Integration Approach

Conductive Adhesive based Height-Control Stacking

Electrically conductive silver-filled adhesives, which provide the electrical connection, mechanical bond, and thermal conduction functions, have been widely used for electronic components mounting. In this work, conductive adhesive was utilized for EEL stacking. The bonding approach is briefly shown in Fig. 2. First, a droplet of an adhesive is dispensed on Au pad on the substrate, at the proper bonding position. A liquid droplet placed on solid surface assumes a geometrical shape as described by Young's equation:

$$\cos\theta = (\gamma_{sv} - \gamma_{sl}) / \gamma_{lv} \qquad (1)$$

where, θ is the static contact angle, γ_{sv}, γ_{sl} are the solid-vapor, and solid-liquid energies, and γ_{lv} is the surface tension. In equilibrium condition, the contact angle between liquid and solid depends only upon the intrinsic nature of material. In this case, the hydrophobic property of Au surface and cohesive forces within the adhesive cause the

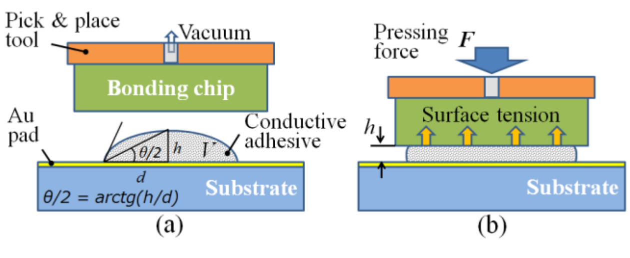

Fig.2 Stacking approach using conductive adhesive for adjusting the height of bonding chip. Final height is determined when the external forces balance with surface tension of the adhesive.

Table I Properties of silver conductive epoxy.

Parameter	Value
Viscosity (23°C)	2200 – 3200 cPs
Volume resistivity @ 23°C	≤ 0.0004 Ω-cm
Thermal conductivity	2.5 W/mK
Glass transition temperature (T_g)	≥ 80 °C

droplet to ball up and avoid contact with the surface. As a result, the droplet assumes the shape of a spherical cap (Fig. 2(a)). The EEL then is picked by a pick-and-place tool and aligned with, for example, the coupling waveguide on the substrate. Then, a downward force is applied to the bonding chip and the adhesive is cured to make a strong bond. The bonding height is determined when the external forces balance with the surface tension force of the adhesive (Fig. 2(b)), which is proportional to the volume of the adhesive. The volume can be estimated through the dimension of the droplet.

In this work, silver conductive epoxy (EPO-TEK H20E) is used as the adhesive for chip mounting. Mechanical, electrical and thermal properties of the epoxy are listed in Table I. With the currently commercialized dispenser, for example pico-liter needle dispenser (Applied Micro Systems Inc.) [2], volume of the adhesive can be controlled precisely. For demonstrating purpose, adhesive droplets were generated on Au pad surface by using a pick-and-place collet.

Laser chips were mounted to a using a high precision flip–chip bonder (Mitaka Kohki Co. Ltd., ATM-90). The bonder is equipped with two handling arms (left and right) then those were respectively used for dispensing and bonding purposes. EEL chips with dimension of 250 µm × 300 µm × 130µm (length × width × thickness) were mounted to couple to certain waveguides for demonstration the bonding approach (Fig. 1(b)). Loading of 10 gf and curing conditions of 100 °C for 30 min were implemented.

Experimental Results

The 3 times experimental results that show the ability of controlling the volume of the dispensed adhesive droplets are shown in Fig. 3 (a). The results of mounting EELs on a substrate are shown in Fig. 3 (b) and Fig. 4. Laser chips were mounted to align with coupling waveguide. The alignment accuracies in x-, y-axis are within 2 µm ranges, i.e., the mounting accuracy of the bonder, estimated through bonding of transparent glass test chips [3]. Results on controlling the height of the laser chips are shown in Fig. 4. Final heights were obtained through mounting of laser

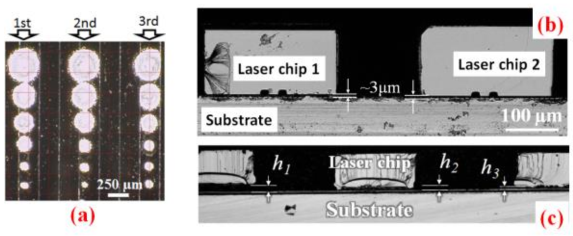

Fig. 3 Silver conductive epoxy droplet dispensing (a) and cross sectional view of the stacked chips (b, c).

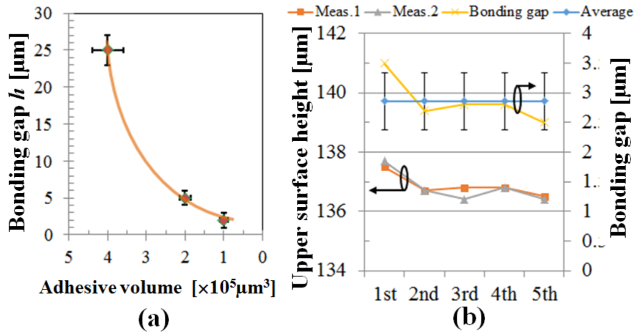

Fig.4 Bonding laser chip heights corresponding to volume of adhesive (a) and reducibility estimation (b).

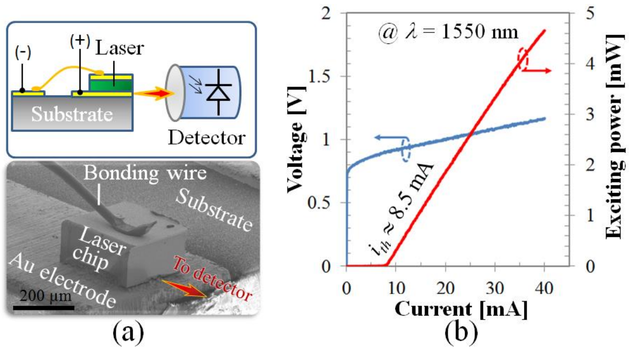

Fig. 5 Measurement setup for electrical-optical characterization of the bonded laser chip (a) and the measured results (b).

chip using different amounts of adhesive with the same applying force of 10gf. Besides, wire bonding was also implemented, connecting the upper electrode of the laser. The electrical properties of the bonded structure as well as optical property of the laser chip were examined. The measurement setup is presented in Fig 5(a). Emitting performance of the laser chip was confirmed as shown in Fig. 5(b), reveals that the silver epoxy can be used for mounting of optical devices. The evaluations of the coupling coefficient from the lasers to waveguides are in progress.

3. Conclusions

Using conductive adhesive, the low temperature stacking process of EEL chips can be implemented at 100 °C, i.e., much lower temperature compared with a conventional solder reflow process. The post-bond height of the laser chip can be reproducibly adjusted, without using of any stoppers, through determining the volume of the adhesive. The results obtained in this work imply that the use of this low-temperature, height controllable approach for stacking of EEL continues to look highly promising.

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