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Effects of soft beam energy on the microstructure of Pb37Sn, Au20Sn, and Sn3.5Ag0.5Cu solder joints in lensed-SM-fiber to laser-diode-affixing application

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Abstract

This paper reports on the effectiveness of soft beam energy as a heat source to form an optimum solder joint to fix a lensed fiber permanently on a Ni/Au-plated substrate. Solders, i.e., Pb37Sn, Au20Sn, and Sn3.5Ag0.5Cu (SAC) [wt%] were evaluated for this fluxless application. The microstructures of the solder joints have been examined using scanning electron microscopy (SEM), in order to understand the response of these solder materials to the focussed white light. Obviously, the exposure time has a greater effect on the soldering temperature before reaching the peak temperature, which is determined by the power. A power setting of 40 W can reach approximately 340 °C, 30 W can reach about 310 °C while 25 W can easily reach 260 °C. In general, a higher soldering temperature than the melting temperature is required to form good wetting solder joints for fluxless applications. However, too high an input thermal energy may result in premature aging for the cases of Pb37Sn and SAC, and lateral cracks for the case of Au20Sn. The thermal cracks and voids observed in Au20Sn solder joint were attributed to the fact that the soft beam heating profile does not suit the AuSn preform. Out of these three solder types, SAC demonstrated just the right response to the soft beam, i.e., good wetting, fine and homogeneous structure, and no cracks or other visible failures.

Keywords: Dendrites; Globular; Fluxless soldering; Lamellar; Microstructure

1. Introduction

The most critical assembly process in packaging a laser diode in a butterfly package is the lensed fiber to laser diode alignment and affixing. Fig. 1 shows the schematic diagrams of this lensed-fiber-affixing joint, which requires sub-micrometer accuracy for the maximum optical power coupling efficiency. A laser-welding technique is the most popular method to permanently fix the lensed fiber that is attached in a metal ferrule onto the heat sink using a weld clip, as shown in Fig. 1a. Alternatively, focused light energy beams such as laser beams and soft beams have been increasingly employed to provide sufficient heat energy to melt solder materials [1]. These soldered joints that hold permanently metallized fibers to gold-plated substrates are shown in Fig. 1b.

Soldering is a metallurgical joining technique in which the molten solder spreads upon and chemically reacts with the solder pad metallization. The optimum microstructure required for a solder joint is a large-grained, finely divided eutectic or near-eutectic structure [2,3]. This can be achieved by minimizing heat input and process time which causes rapid cooling during a soft beam soldering process. A bare substrate, Kovar^{TM} in this case, is not suited to direct soldering; thus, it is often electroplated with Au/Ni metallization to enhance its solderability. The noble Au surface layer is critical to the success of fluxless soldering where it prevents oxidation of the underlying Ni layer before and during soldering. Fluxes are undesirable for this application because the flux residue may flake-off and interfere with optical signals transmitted between the fiber and the laser diode inside the package [4–7].

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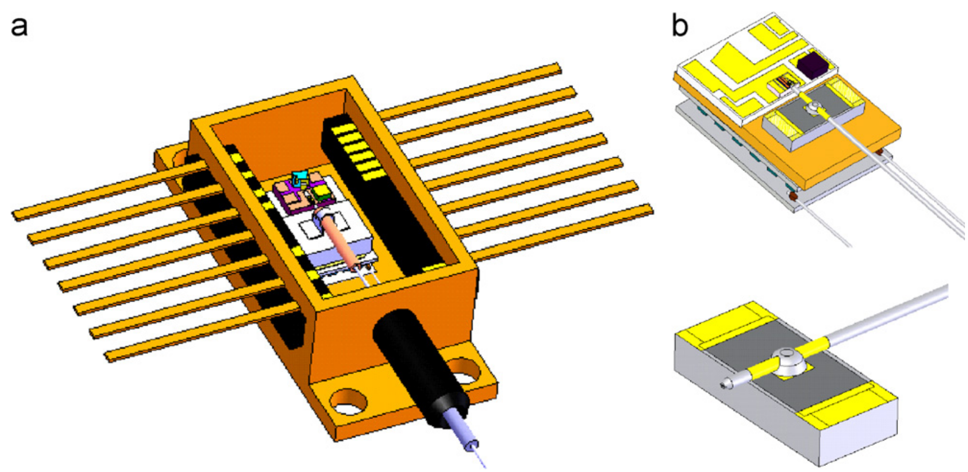

Fig. 1. A schematic diagram of a 980 nm pump laser in a butterfly package where the lensed fiber was fixed by (a) a laser-welded clip, (b) a soldered joint.

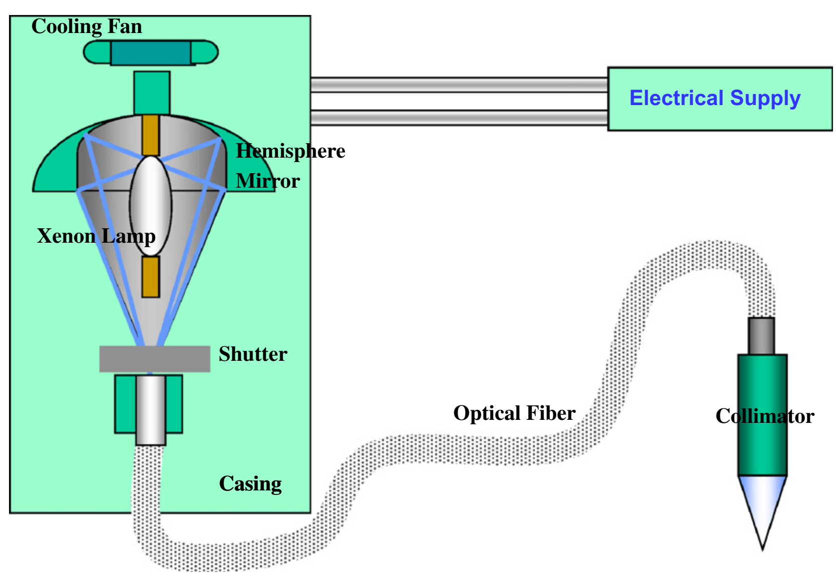

Fig. 2. A schematic diagram of the principle of soft beam heating system.

Soft beam is a trademark of the light beam heater developed by Panasonic Factory Automation Company. The white light from a xenon-arc lamp is converged into a lightguide, which is connected to a collimator that focuses the light beam to a circular spot diameter of 1 mm. The working principles of a soft beam are shown in Fig. 2. When the light beam is focused on the surface, a part of it is reflected and a part absorbed, which results in an increase in the temperature of the workpiece. Thus, light energy is converted into heat energy depending upon the absorption coefficient of the material. The fiber optic guided light beam from a xenon lamp is used as a heating source for microsoldering applications. The advantages of the soft beam are the relatively low peak temperature compared to a laser source, no physical contact to the joining area, a relatively mild process, computer controllable, and a short process time that allows for high accuracy and fluxless applications. A lumped parameter mathematical model has been developed by Syed and Woods [1] to compare the thermal dynamic response of each soldering method. Laser soldering has been widely used in industry; however, there is limited discussion of the soft beam soldering process and the performance of the resultant joints. Therefore, the application of a soft beam heating system in soldering will be discussed in this report.

The aim of this study is to evaluate the applicability of fluxless soldering technology to attach single-mode lensed fibers permanently using soft beam energy. This paper will discuss the effectiveness of soft beam energy as a heat source to form an optimum solder joint on a Ni/Au-plated substrate. Examinations being carried out on Pb37Sn, Au20Sn, and SAC solders include observation of interfacial phenomenon at joints, application of this fluxless soldering technology, and the thermal response of solder balls and Au20Sn preforms.