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Characterization of Kovar-to-Kovar laser welded joints and its mechanical strength

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Abstract

For the packaging of a pump laser in butterfly package, the most crucial assembly step is the fiber-to-laser diode coupling and attachment. The use of laser welding as the joining method offers several advantages if compared with the adhesive joints: strong joining strength, short process time and less contamination. This paper reports on laser welding process characteristics; weld strength and its fracture mode. The penetration depth and melt area of laser spot welds were found to be complicated functions of laser pulse energy, intensity, and beam diameter. Effects of pulse width, input power and size of the focal spot on the rate of energy input to the workpieces and consequently, the weld strength were reported. The weld strength was found to be dependent on the overlapping area between the two joining materials. Surface roughness, R_a, has influence on the fraction of energy absorbed, A, and therefore, affecting the penetration depth. Thermal analysis was carried out on the laser-welded joints and its heat-affected zone (HAZ) induced by various power densities was examined. These data are important in order to optimize and utilize the laser welding process as an effective manufacturing tool for fabrication of reliable pump laser.

Keywords: Absorptivity; Heat-affected zone; Laser spot weld; Penetration depth; Weld strength

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1. Introduction

The use of glass fiber as the transmission medium in communication networks has a reasonably long history. However, for most of the period, active optoelectronic components have been limited primarily to light sources and photodetectors. The resulting packaging solution has been the butterfly package [1]. For the packaging of a pump laser in butterfly package, the most crucial assembly step is the fiber-to-laser diode coupling and attachment. The use of laser welding as the joining method offers several advantages if compared with the adhesive joints: strong joining strength, short process time and less contamination. It also provides high-speed and high-volume production, and hence the packaging is potentially low cost. Laser welding is a high-energy beam process and the energy density of the laser is achieved by the concentration of light waves [2]. Application of laser welding technique to a semiconductor laser butterfly package requires mechanical elements such as submount, ferrule, weld-clips and housing to facilitate fiber handling and retention within the package [3].

Wang et al. [4–5] reported that the weld strength of invar–invar joint increases linearly with the increase in power density, however, decreases as the Au thickness increases. This observation was related to the increase in thermal conductivity of the welded material by Au coating, which may lead to the formation of Au solid solution in the welded sections [4–5].

Sub-micron misalignment or shifts induced during operation in a typical single mode fiber application may result in significant power loss or light coupling efficiency loss. This would greatly degrade the performance of the packaged module. Since mechanical strength in the weld joint is a prerequisite for not being subjected to misalignment, it is very critical to understand the effect of various welding parameters on the weld strength. If the laser welding process characteristic, weld strength and all other packaging parameters can be optimized, these shifts which are due to mechanical weakness could be minimized.

This study reports on laser welding process characteristics and the weld strength of the welds. Kovar-to-kovar welds that were produced by laser spot welding techniques were studied.

2. Experimental procedure

In the process of fabricating a butterfly pump laser, dual beam Newport Laser Weld™ Fiber Attachment Systems, LW 4200 was used for pigtail fiber assembly to the semiconductor laser. It is configured for 2-beam welding of butterfly or DIP packages in a horizontal optical axis configuration. The system consists of a Unitek Miyachi pulsed Nd:YAG laser and a fiber optic beam-delivery system. The laser beam power and energy were measured by using Newport Power meter, Model 1835-C.

The model proposed by Ion [6] was modified and used to perform the theoretical estimation on the temperature–time profile, width of heat-affected zone (HAZ),