D. Analysis Of Welding Induced Submicron Movements In Laser Micro-Welding Of Optoelectronic Packages

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Introduction

Laser micro-welding is one of the preferred techniques for optic fiber attachment in optoelectronic devices, because of its inherit attributes of strength, cleanliness and long term reliability. For high performance laser-based transmitters in light-wave communication systems, the alignment tolerance required for efficient light coupling between the pump laser and the optical fiber is extremely tight, usually in the sub-micron range. This stringent alignment tolerance must be maintained throughout the entire assembly process. Due to the localized heating from micro-laser welding, welding induced movement of the optic fiber relative to pump laser can significantly affect the coupling efficiency and the performance of the optoelectronic devices. Although the post-weld-shift (PWS) cannot be completely eliminated, minimizing the PWS has been one of the main research topics in micro-laser welding for telecommunication laser diode packaging applications.

Technical Approach

In this study, the PWS during micro-laser spot welding of 40G optoelectronic modules have been numerically modeled and experimentally studied. The pulsed Nd:YAG laser (1.06 μm wavelength) is used in single shot burst mode to attach a weld clip to a weld pedestal, and ferruled optical fiber to the weld clip. The numerical simulations were performed with the finite element method, treating the spot micro-laser welding process as a transient thermomechanical deformation process. The energy from the welding laser was treated as a transient Gauss distribution. Temperature dependent material properties were used. Factors considered in this study included material selection, laser power, weld parameters, and beam balancing.

Results and Discussion

The laser pulse energy varied from 1 to 4 Joules, with pulse duration from 2 to 5 micro-seconds. Under these welding conditions, the heat flow mode in the molten welding pool is primarily conductive, producing a semi-spherical shaped spot weld. The face diameter of the weld is between 0.15 to 0.45 mm, and the face diameter to penetration depth ratio is approximately 1.2 for most welds produced. The predicted weld shape and size from the finite element model compared very well with the experimental measurement results over the range of welding parameters investigated in the study. This established the basis for utilizing the numerical model to investigate the distortion of the welded modules, as experimentally measuring the sub-micron movements of the module is very difficult.

Material selection is critical for manufacturability, reliability and performance of the laser welded optoelectronic modules. Among the three alloys studied (Kovar, SS304L, and SS316), the Kovar alloy shows the least PWS, due to the low thermal expansion coefficient of Kovar. Due to the thermal expansion mismatch, dissimilar welds between different alloys were particularly poor in terms of the PWS. The Kovar-to-SS316 weld exhibited 40% more distortion as compared to the Kovar-to-Kovar case.

To minimize the PWS, the optic fiber housing is often designed to be symmetric about the axis of the optic fiber so that two symmetric welds can be produced simultaneously using a beam multiplexing unit. In practice, the energy levels delivered to the surface of the part are often different due to the inherent limitations of the beam multiplexing system. This energy imbalance results in two spot welds with different sizes, and introduces a shift of the optic fiber toward to the larger weld. The numerical simulation reveals that, for the specific module design studied, the energy imbalance should be under 10% in order to keep the horizontal PWS below 0.5 μm to meet the coupling efficiency requirement. Improvements on other aspects of the device design based on the findings from the numerical simulations will be also discussed.

Conclusions

A finite element based numerical model has been developed as an effective tool for evaluation of post-weld shift of a micro-laser welded prototype optoelectronic butterfly package. The key parameter governing the horizontal PWS is the beam balance. Other important process parameters are the welding energy and weld location. The numerical model can be also utilized to assist the fiber housing design to compensate certain deformation modes, to minimize the overall PWS.