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Study on Vacuum Welding Process of Slab Laser Module

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Abstract. To raise the capability of heat-sinking of slab laser amplifier, which is the type of conduction cooling, we need to weld crystal and heat sink with micro channel together. Slab laser module with high power and good beam quality is required to reduce welding void ratio and lower thermal distortion. In this paper, we offer a welding process of slab laser module with large size. With an accurate travel control system, it can adjust welding gap between slab and heat sink. We get low welding void rate of 2.3% in large area of 3600 mm^2 with the system by measuring in ultrasonic scanning microscope.

Introduction

With good features as good beam quality, high efficiency, light weight and small volume, Laser diode (LD) pumped solid state laser, showed obvious advantages at high power and good beam quality of solid laser applications. The power and beam quality of solid laser are mainly limited by the thermal effect of solid laser gain medium [1]. W. S. Martin et al. [2] have found that slab solid-state lasers can improve the serious thermal effects of traditional solid-state lasers. With light path as word "N" and large area of sheet conduction cooling technology, slab gain medium can ensure effective cooling and reduce the heating effect, so it can be used as an excellent solid state laser gain medium of high average power and beam quality [3-5]. As the slab laser gain medium size becomes bigger, the welding area extends, and the empty welding of the welding layer increases, the thermal distortion of slab laser gain medium module is more and more serious, therefore, we need to study the appropriate welding technology to improve welding quality of slab laser gain medium module and to enhance the quality and power output of solid state laser beam.

Isothermal solidification process was defined as "liquid-solid mutual diffusion process" by Lenard Bernstein [6], which is the process that high melting point metal components and low melting point metal components diffuse or react each other in constant temperature which is slightly higher than the melting temperature of the low melting point elements, and eventually forming metal compounds or solid solution. The metal indium has the advantages of low melting point, low yield strength and good ductility, and is very good in infiltration with gold, which can form an infinite mutual alloy. Due to the welding products are intermetallic compound which has high mechanical strength and good thermal conductivity, therefore, the Au-In binary alloy system can be used as welding system applied on the encapsulation of slab laser gain medium module.

In this paper, we study the welding technology of the Au-In binary alloy system, and obtain lower void welding layer of the slab laser gain medium module.

Experimental

Experimental equipment and materials

The inside structure of heat sink of slab laser gain medium module is micro-channel, and we can't use the ultrasonic scanning microscope to observe the welding quality directly, so K9 glass plate and pure copper plate is used as welding module simulator in this experiment.

We select K9 glass plate, which size is 130mm x 30mm x 3mm, and the surface processing precision is less than 0.5 μm; and we use the pure copper plate, which dimension is 120mm x 80mm x 10mm, and

the surface processing precision is less than 1 μm; and we have high purity indium of 99.999% as solder.

Metal coating equipment: vacuum metallization equipment HS500.

Indium film plating equipment: vacuum steaming indium equipment HF700 -Ⅱ .

Welding equipment: vacuum welding equipment ZSH-500.

Detection equipment: ultrasonic scanning microscope PVA-SAM 300.

Metallization of K9 glass plate and copper plate

The surface of K9 glass plate could not be wetted by solder indium, so the contact surface must be metallized. Firstly, a layer of 100nm ~ 300nm titanium is precoated on the surface of K9 glass plate, as a transition layer of non-metal and metal binding. Secondly, the surface of titanium layer is coated with nickel of 100nm ~ 300nm, as the barrier layer. Finally, in order to improve the wettability of the solder, the gold of 100nm ~ 300nm is plated on the surface of the nickel and used as the reaction layer.

Copper and indium can react to produce intermetallic compounds, and copper is easily oxidized in the air. Therefore, a layer of nickel is coated on the surface of copper plate as a barrier layer. The plating gold of 100nm ~ 300nm is used as the reaction layer of solder to improve the wettability of the solder indium.

Evaporation of indium layer

The solder layer is obtained by evaporation. The cleaned copper plate was put into the vacuum evaporation equipment, and the vacuum is evacuated to 8 x 10^{-3}pa, the evaporation current is 230A, the rotary speed is 20 RPM, and the evaporation time is 2h. Finally, the thickness of indium layer is 15 μ m ~ 20μ m.

Welding

Indium is very easy to react with oxygen in the air, and the solder wettability becomes worse, and the welding cavity and virtual welding are serious, and the thermal distribution is even worse. Therefore, we use the heating method of vacuum heat radiation for welding. Before welding, the surface of K9 glass plate should be cleaned to remove dirt and stains. And we use anhydrous ethanol to clean the surface of K9 glass and bath it in 15 min.

We have two methods of welding for comparison: one is to place the K9 glass plate directly on the indium layer of copper plate; the other to use the sophisticated stroke control system to adjust the size of welding gap.

The K9 glass plate is placed directly on the steaming indium layer of copper plate, and the whole module is put into the vacuum welding equipment. When the degree of vacuum reaches to 6 x 10^{-3} Pa, we start to heat, and the heating temperature curve is shown in figure 1.

The cooper plate and K9 glass plate is placed in the fixed place of sophisticated stroke control system, after adjusting the relative position of K9 glass and cooper plate, we put the whole system into the vacuum welding equipment, and lead the wire of the system out of the vacuum welding equipment. When the degree of vacuum reaches to 6 x 10^{-3} Pa, we start to heat, and when the heating temperature reaches to 195 ˚C, we adjust the sophisticated stroke control system to make the K9 glass contact with cooper plate, and adjust the welding gap for 12μm.

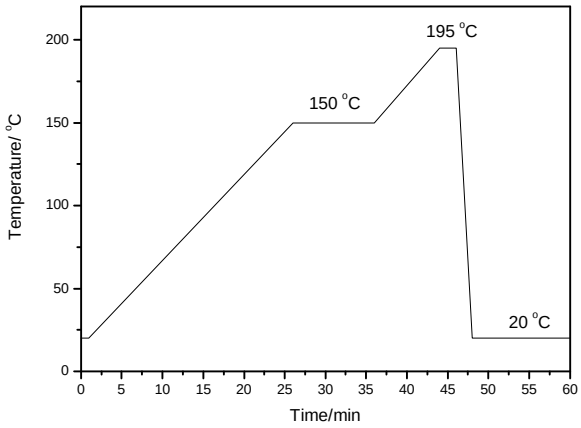
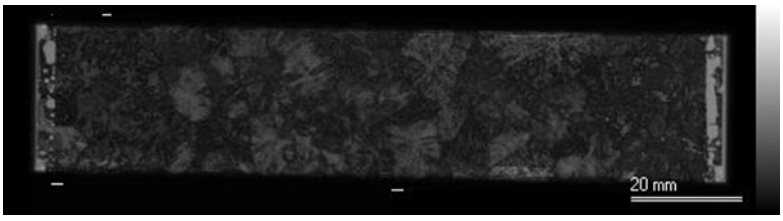


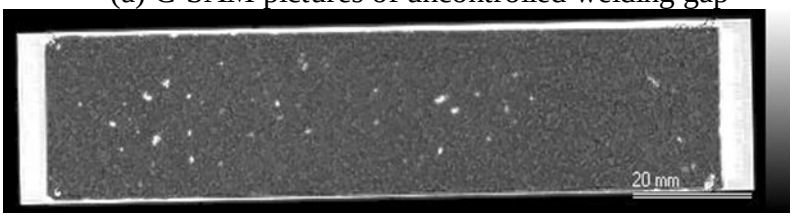
Fig.1 Heating temperature curve of welding

Results

Indium welding with large area, in theory, using the principle of capillarity, liquid indium can be filled the space between the copper plate and K9 glass plate. But due to the radiation heating of welding process in vacuum environment, the heat conduction is very slow, and the air between indium layer and K9 glass plate is failed to discharge, first melt indium can random form of encirclement, in which the air packed; besides, the capillary pressure of the liquid indium is affected by the welding seam size, and the entire welding layer cannot be filled evenly. If the welding interface is void or virtual soldering, the solidified tissue is loose, and the white or white gray highlights can be seen through ultrasonic scanning microscope, as shown in fig.2 (a). Fig.2 (b) is an ultrasonic scanning diagram for the simulation of controlled welding seam. The binarization of the ultrasonic scanning microscope images is done by MATLAB, and we calculate the void rate of the welding layer of two solder ways. The void rate of uncontrolled welding gap is 48.5%, but the controlled one is 2.3%, the welding void rate is reducing more than 95%.



(a) C-SAM pictures of uncontrolled welding gap



(b) C-SAM pictures of controlled welding gap

Fig.2 The contrast of C-SAM pictures of two welding ways

With the precise stroke control system, the K9 glass plate is suspended to the position of 5mm from the copper plate, and through vacuum pump, the air between the welding layer and the K9 glass panel can be discharged completely. When the welding furnace reaches to indium melting temperature, the K9 glass plate is precisely pressed on the melt indium by controlling the precise schedule control

system, and the welding gap can be adjusted to 12μm, then the liquid indium is distributed evenly in the welding layer.

Conclusion

We get low welding void rate of 2.3% in large area of 3600 mm^2 with the system by measuring，which is reducing more than 95% by comparing with the uncontrolled one. It can vastly reduce the void rate of welding gap and greatly enhance the effective welding area by using the precise stroke control system, which can completely discharge the air between the welding layer and the K9 glass plate and make the liquid indium distributed evenly in the welding layer by accurately adjusting the distance of welding gap.

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