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Research Note

Solder with discontinuous melting point in semiconductor laser arrays and stacks

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Abstract

High power semiconductor laser arrays must be mounted in the epitaxy-side down configuration for good heat transfer and so require a well-controlled solder. Selection of solder is very important in semiconductor laser arrays and stacks. Usually, the solder consists of two layers. The outer layer prevents In from oxidation. A new type of solder with several layers of Au between the two layers of In was made, which constitutes of multi-layer of W/Ni/Au/In/Cu. In packaging, the Au layer in the solder does not melt. Quick temperature decrease can avoid expansion of the solder. The solder cannot oxidize during packaging.

Keywords: Semiconductor laser; Solder; Semiconductor laser array

1. Introduction

Semiconductor laser arrays and stacks arouse a great deal of interest. Selection of the solder is of utmost importance in packaging arrays and stacks. Because the solder directly contacts the laser bar, the quality of the solder directly relates to lifetime and heat spread of the laser. Indium is a material most widely used in packaging [1,2], because indium is a soft solder with good extensibility. However, it oxidizes easily, and it has a deadly shortcoming, i.e., indium whiskers will grow on the surface of the coat of the laser cavity. Thus, the laser will short-circuit and be damaged [3,4].

Au–Sn alloy is also used, but it has poor extensibility [5]. When the laser is operating, discrepancy between thermal expansion coefficient of the laser bar and the solder will result in damage of the laser bar.

2. Results and discussion

A type of solder was made, which has the following characteristics: good expansibility, hard oxidation, hard to grow whiskers and easy fabrication. First, sputter 50 nm wolfram onto copper heat-sink. Then, galvanize 50 nm Ni [6] and 2 μm Au onto it. Subsequently, evaporate 1 μm indium. Ten layers of 500 Å Au and 500 Å In couple are evaporated in turn, and 1.5 μm Au layer; then, another 10 layers of 500 Å Au and 500 Å In couple, and 2 μm In. The last layer is 5000 Å Cu [7]. Fig. 1 shows the structure of multi-layer solder.

The 20 layers of the Au–In besides 1.5 μm Au layer will form Au–In alloy. When the In becomes liquid, the liquid has intimate contact with the gold layer and thus reacts with the gold to form $AuIn_2$. When this reaction occurs, a joint is essentially produced. However, 1.5 μm Au layer does not melt. Thus, distribution of melting point in the solder is as shown in Fig. 2.

The symbols of metals marked in the diagram refer to their melting points, respectively.

During the process of sintering, 1.5 μm Au layer will not melt, and form pattern as is shown in Fig. 3.

If the Au layer is not sandwiched, a pattern will be formed as is shown in Fig. 4. The In will creep onto the cavity of the laser bar. Catastrophic optical damage will occur.

Copper is used as barrier layers, which protects oxidation as can be seen from the In–Cu equilibrium phase diagram (Fig. 5) [8].

The alloy with indium composition of 59.5–100 wt% is a mixture of $Cu_{11}In_9$ compound and indium with a solidus

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Cu
In
Ten layers of Au-In
Au
Ten layers of Au-In
In
Au
Ni
W
Heat-sink

Fig. 1. Structure of the solder.

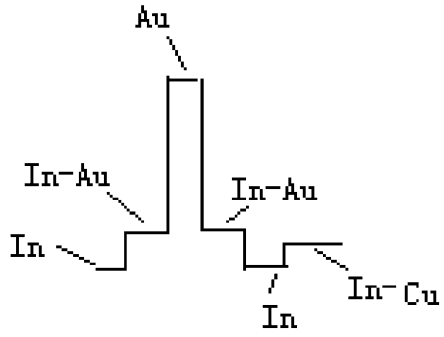

Fig. 2. Distribution of melting point in the solder.

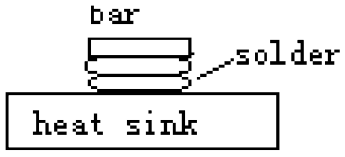

Fig. 3. Solder with Au-sandwiched layer when the solder melts.

temperature of 153°C. As the indium composition of the alloy reduces to 59.5 wt%, melting temperature of the alloy jumps from 153°C to 310°C, the melting point of the $Cu_{11}In_9$ compound. Studies of Cu–In thin film couples showed that copper reacts with indium even at room temperature to form inter-metallic Cu-In. As a result, the In–Cu constitution converts into In–CuIn, a stable compound. The outer Cu–In layer can protect the inner indium layer from oxidation after the heat-sink is removed from the vacuum chamber and exposed to atmosphere.

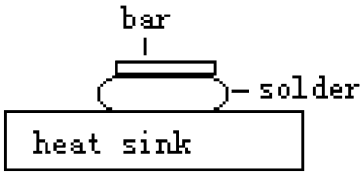

Fig. 4. Solder without Au-sandwiched layer when the solder melts.

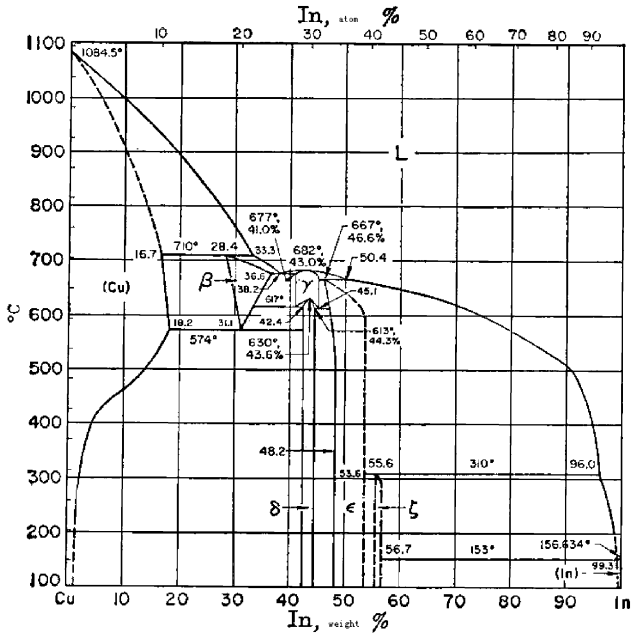

Fig. 5. In–Cu equilibrium phase diagram.

3. Conclusion

In summary, this alloy is stable and can protect indium from oxidation and whiskers growth. By the use of this solder, we have assembled semiconductor arrays with peak power 100 W.

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References

[1] Maiorov M, Menna R, Khalfin R. 11.5W CW 1.83 μm diode laser array. IEEE Photonics Technol Lett 1999;11(8):961–3.
[2] Kan H, Kanzaki T. High-Power 2-D laser diode arrays for pumping solid state lasers. SPIE 1998;3264:18–20.
[3] Fujiwara K, lmai H, Fujiwara T. Analysis of deterioration in In solder for GaAlAs DH lasers. Appl Phys Lett 1979;35(11):661–3.
[4] Jandeleit J. Nicolas wiedmann Reliability and degradation mechanisms of high power diode lasers. SPIE 1999;3626:217–21.
[5] Simic V, Marinkoviv Z. Stability of compounds in thin film metal couples in the course of long ageing at room temperature. Thin Solid Films 1998;209:181–7.
[6] Ckwan-Ying Lee, Kwang-Lung Lin. Materials interaction in Pb–Sn/Ni–P/Al and Pb–Sn/Ni–B/Al solder bumps on chips. Thin Solid Films 1993;229:63–75.
[7] Freer JL, Morris JRJW. Microstructure and creep of eutectic indium/yin on copper and nickel substrates. J Electron Mater 1992;21(6):647–52.
[8] Yu J, Yi W, Chen B, Chen H. Constitution of Binary Alloys. 1987.