Cu-Diamond Heat Spreaders for High-Power Semiconductor Lasers

1. Outline

Semiconductor lasers offer better features than existing laser beam sources, being smaller in size and achieving higher efficiency and a longer service life.

Their applications in society are advancing in many fields such as health care, sensing, and sheet-metal working. Moreover, they are drawing great attention from the perspective of carbon neutrality.

In recent years, research on semiconductor lasers has been underway in the field of laser nuclear fusion.

Given the backdrop described above, the semiconductor laser market is expected to continue to grow in the future. Accordingly, further improvements in performance and beam quality are required.

In addition to laser diodes (LD) technology, a highly important factor in enabling improved performance is the heat spreaders provided to efficiently release heat generated during LD oscillation and avoid thermal distortion.

This article describes a composite material consisting of copper and diamond (Cu-Dia), which is suitable for use as heat spreaders for high-power semiconductor lasers due to its high heat dissipation, low thermal expansion, and other features.

2. Features

2-1 A.L.M.T. ’s original high-thermal-conductivity material

The heat spreaders for semiconductor lasers are mounted directly below an LD chip by means of direct solder bonding (Fig. 1).

For these heat spreaders, a composite material of high-thermal-conductivity copper tungsten alloy (Cu-W) and aluminum nitride (AlN) have been used.

However, with increasing power, the amount of heat generated by the LD chip increases and the need for a material with higher heat dissipation capability has emerged.

Therefore, A.L.M.T. Corp. has commercialized heat spreaders made of Cu-Dia with a thermal conductivity of 550 W/(m·K), which is twice or more that of Cu-W or AlN. Figure 2 shows the results of a simulation analysis investigating the thermal performance of Cu-Dia.

The analysis results indicate the advantages of Cu-Dia over conventional Cu-W, with thermal resistance and thermal stress applied to LD decreasing by 24% (dT: –9°C) and 42%, respectively.

2-2 Sharp edge formation

Heat spreaders placed immediately beneath LD chips are known to require sharp edges so as not to interfere with laser emission or accumulate heat.

Consisting of soft copper and hard diamond, Cu-Dia is a hard-to-machine material.

Nevertheless, A.L.M.T. Corp. has established its original machining method and has accomplished sharp edges with a corner radius of 5 µm or less (Fig. 3).

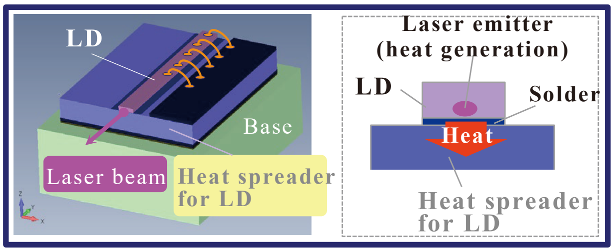


Fig. 1. Usage example of heat spreaders for semiconductor lasers

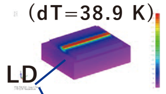
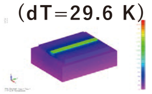
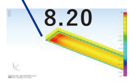
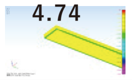
	Rf. Cu-W	Cu-Dia
Coefficient of average linear thermal expansion [$\times10^{-6}$/K]	6.5	6.0
Thermal conductivity[W/(mK)]	205	550
Thermal resistance [K/W] (dT)	1.30 K/W (dT=38.9 K) 	0.99 K/W (dT=29.6 K) 
Thermal stress applied to LD [MPa]	8.20 	4.74 

Fig. 2. Thermal performance shown by analysis models

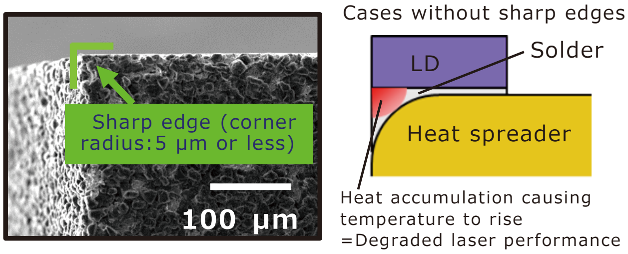


Fig. 3 Example of Cu-Dia edge formation

2-3 Quality stabilization after metallization

The surface of heat spreaders generally has a thin metal film formed on it, through a process of metallization using gold tin, gold, platinum, or nickel, in order to ensure good bonding to an LD chip.

So, the thermal characteristics after metallization are also important. By controlling trace elements in Cu-Dia, we have succeeded in achieving a more stabilized level of thermal conductivity than that of conventional products, as illustrated in Fig. 4 (improved products).

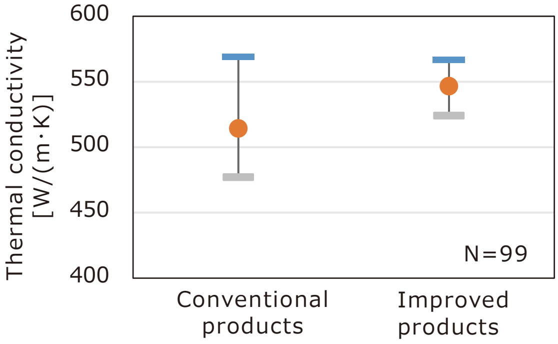


Fig. 4. Measurement results for post-metallization thermal conductivity

3. Conclusion

For high-power, reliable laser oscillation of semiconductor lasers, it is important to provide high-heat-dissipation heat spreaders, such as one made of Cu-Dia. A.L.M.T. Corp. is capable of controlling raw materials and performing precision machining and metallization in line with market needs. A.L.M.T.'s Cu-Dia is expected to help develop laser oscillators in the future that boast high performance and beam quality.