Dual wavelength high power laser diodes fabricated by Selective Fluidic Self-Assembly technique

Tomoaki Tojo¹, Kazuhiko Yamanaka¹, Brahm Pal Singh¹, Kazutoshi Onozawa¹, Daisuke Ueda¹, Ikuo Soga², Koichi Maezawa² and Takashi Mizutani²

¹Matsushita Electric Industrial Co. Ltd., Semiconductor Company, Semiconductor Device Research Center
1-1, Saiwai-cho, Takatsuki City, Osaka 569-1193, Japan
Phone: +81-72-682-7536, Fax: +81-72-682-7738, E-mail: tojo.tomoaki@jp.panasonic.com
²Department of Quantum Engineering, Nagoya University
Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan

1. Introduction
A dual wavelength, i.e. 660nm (red) and 780nm (infra-red), high power laser diode (LD) is a key device for an optical disk system that enables simultaneous read/write operation on a system handling a variety of disks like CD-R and DVD-R. For such a system, accurate positioning of the two light sources is critical because of the narrow margin of aberration in the optical system. To this end, there are two approaches; one is to fabricate two different waveguides on one chip (a monolithic integrated solution), the other is to place two different LD chips side by side on a same substrate (a hybrid integrated solution). However, none of these approaches has been successfully applied to mass production. The former has a poor yield and reliability issue due to the difficult process involving epitaxial growth of the two types of active layers. The latter approach, on the other hand, requires a highly accurate mechanical mounting system of the two different LD chips.

However, there exists a highly promising technique, called Fluidic Self-Assembly (FSA) [1], in which multiple micro-scale chips are self-assembled into the pre-recessed substrates in liquid with high accuracy. Furthermore, selectivity function is also realized in such a way that the chips with different structures can be selectively assembled to the recesses with the same shapes [2]. In this paper, we report successful application of such selective fluidic self-assembly (S-FSA) technique to the hybrid integration of dual wavelength LDs for the first time. In particular, the selectivity was achieved by introduction of new self-locking structures between the different guest-host pairs, i.e. the two different LD chips and the corresponding preformed recesses. The technique realized a high precision mounting with ±3µm, or well below the allowed aberration margin of the optical system. We demonstrated successful high power operation of the two LDs mounted as one component.

2. Fluidic Self-Assembly
Fig.1 schematically illustrates the principle of the FSA method [1-3]. The host substrate is placed on the base tilted in fluid. The chips scattered onto the substrate slide over it and fall into the recesses. The chips that are not captured by the recesses are collected and scattered again until all of the recesses are filled with chips. In the conventional FSA technique, the accuracy of the mounting was highly dependent on that of the dimension of the peripheral of the guest chips. In addition, in order to improve the assembling efficiency, the chips were needed to be embedded completely in the recesses of the host substrate. Therefore, it is necessary to set the depth of the recesses on the substrate larger than the thickness of the assembled chips. Thus, in order to apply this method to fabrication of a dual wavelength LD, the following issues should be addressed:
(a) To form an LD peripheral shape with higher accuracy than that fabricated by the conventional cleavage method
(b) To form a recess with a depth of LD (e.g.120µm) on a host substrate
(c) To control the mounting direction of each LD
(d) To realize selectivity function in which each LD is embedded in its own recesses exclusively

3. Approach
In order to address the above issues, we developed a novel method to selectively mount two LD chips on a substrate with a new self-locking structure of the host-guest pairs. On the bottom side of the guest, i.e. one LD, a key bump is formed by the gold plating with the height of 15µm. The reduction of the depth of the recess is achieved by embedding only this bump in the shape-matched recess of the substrate. Fig.2 shows a schematic of infrared and red LDs and a host substrate. The key bump of each LD is formed to align with the corresponding waveguide formed on the laser active layer. The peripheral shape and dimension of this bump is so formed to avoid potential inaccuracy in positioning resulting from variation of the cleavage positions of the LDs. The margin between the edge of the bump of LD and the wall of the recess is designed to be either 1µm or 3µm. This bump also enables distinction between the top and the bottom sides. Furthermore, since this bump is rotationally asymmetric, front and rear facets can automatically be selected. In addition, the final function of selectivity between the red and infrared LDs is accomplished by assigning two different shapes to the two LDs.

In this method, however, the mounted chips are left on the surface of the substrate, which interfere with the other chips sliding. To overcome this issue, we developed a mounting apparatus that vibrates the whole substrate avoiding the interruption of the self-assemble process.
4. Experimental

Fig.3 shows a schematic of the experimental setup of our mounting apparatus for evaluating S-FSA processes. LD chips are scattered onto the substrate fixed on a base in a liquid (ethanol). A mechanical vibrator is set under the base in order to assist the smooth sliding motion of the LD chips on the substrate. We observed an assembling process with a microscope fixed above the substrate. In this experiment, red LD chips and infrared LD chips are scattered sequentially into the system. Selective self-assembling of the red and infrared LD chips was confirmed as shown in Fig.4.

Fig.5 shows a front view of the operating two LDs. It is clear that the two emitting points are separated 110µm which is the designed distance. In Fig.6, histograms of the normalized number of the fabricated pairs as a function of the interval of the light emitting spots. It is clearly seen that the variation of the light emitting positions was confined within ±1µm and ±3µm with the recess-bump margins of 1µm (Fig.6a) and 3µm (Fig.6b), respectively. These figures demonstrated that we have succeeded in achieving the range of errors within ±3µm, or the required aberration margin. Fig.7 shows the L-I characteristics of the LDs. Sufficiently high power operation of these LDs is clearly demonstrated.

5. Conclusions

We developed a new selective fluidic self-assembly (S-FSA) technique, which makes it suitable for precise mounting. Using this technique, we fabricated a dual wavelength high power LD applicable to the optical recording system for the first time. We confirmed this LD satisfied the required precise positioning of the light emitting spots and the required high power optical characteristics.

References