Extended Abstracts of the 2001 International Conference on Solid State Devices and Materials, Tokyo, 2001, pp. 608–609

E-8-4

Reduction in Operating Current of High-Power 660-nm Laser Diodes Using a Transparent AlGaAs Cap Layer

Ryoji Hiroyama, Daijiro Inoue, Yasuhiko Nomura, Yasuhiro Ueda, Masayuki Shono and Minoru Sawada

Microelectronics Research Center, SANYO Electric Co., Ltd.
1-18-13 Hashiridani, Hirakata, Osaka 573-8534, Japan
Phone:+81-72-841-1278 Fax:+81-72-841-1412 E-mail: r_hiroyama@rd.sanyo.co.jp

1. Introduction

High-power 660-nm laser diodes are key devices for the light sources of high-density recordable or rewritable optical disc systems such as DVD-R/RW/RAM. A high-speed recording is strongly required in these systems. The optical intensity of the laser beam focused on optical discs must be increased to meet this requirement. A high-power operation of 660-nm laser diodes as the light sources is indispensable to achieve this. A small aspect ratio for the beam divergences is also necessary to enable effective optical coupling with the objective lens.

For high-power operation, the catastrophic optical damage (COD) level must be increased. A weak optical confinement at the active layer increases the COD level because of the low optical density at the facets. It also reduces an aspect ratio for the beam divergences because of the small beam divergence perpendicular to the junction. High-power operation and small aspect ratio are expected to be achieved simultaneously by weak optical confinement at the active layer.

The weak optical confinement, however, enhances the optical absorption of the laser beam, if the device contains materials having smaller band-gap than the emission energy. As a result, operating current of the device increases. In high-power 660-nm laser diodes with buried ridge stripe structures, GaAs is widely used as a current blocking layer and a cap layer. It can act as an optical absorber because of its small band-gap.

It was recently reported that a high light output power and a small aspect ratio of beam divergence were simultaneously achieved for 660-nm laser diode by replacing GaAs with AlInP for current blocking layer [1]. Since the AlInP current blocking layer, which has a larger band-gap than the emission energy, is transparent to the laser beam, the optical absorption is minimized at this layer. On the other hand, optical absorption at the cap layer should be suppressed for further improvement of the device characteristics such as a higher COD level and a lower operating current.

In this work, we have replaced GaAs with AlGaAs as the cap layer which is transparent to the laser beam in order to reduce the optical absorption for the first time. High power and low operating current have been achieved with this newly developed device structure.

2. Laser structure

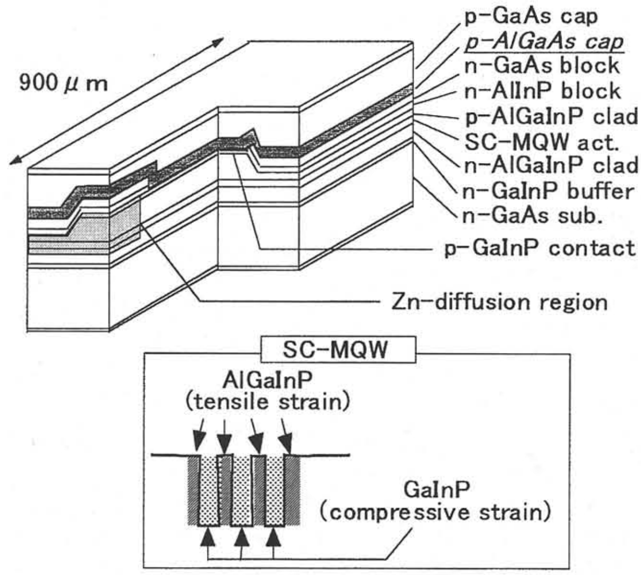

Fig. 1 Schematic structure of a high-power laser diodes

The schematic structure of high-power laser diode is shown in Fig. 1. Epitaxial growth was carried out by low-pressure MOCVD on an n-type (100) GaAs substrate with a misorientation of 9° toward the [011] direction. The active layer is a strain-compensated multiple quantum well (SC-MQW) structure composed of compressively strained GaInP wells, tensile strained AlGaInP barriers and AlGaInP optical confinement layers [2]. This active layer is sandwiched by an n-type AlGaInP cladding layer (2.0 μm) and a p-type AlGaInP cladding layer (1.5 μm). The window regions are formed in the vicinity of both facets by Zn-diffusion. A ridge stripe waveguide is selectively buried with an n-type AlInP/n-type GaAs current blocking layer. The refractive-index difference in the parallel direction is designed to be 3×10^{-3}. A p-type AlGaAs/GaAs cap layer is formed instead of the p-type GaAs cap layer. This AlGaAs cap layer is transparent to the laser beam. The cavity length including the window region is 900 μm. The laser facets are coated, with the reflectivity of the front and rear facets 5% and 95%, respectively. The laser chips are mounted on the heatsink in a junction-down configuration..

3. Device characteristics

Figure 2 shows the internal loss for devices with a GaAs cap layer and an AlGaAs cap layer. The evaluated devices didn't have facet coating or the window-mirror structure.

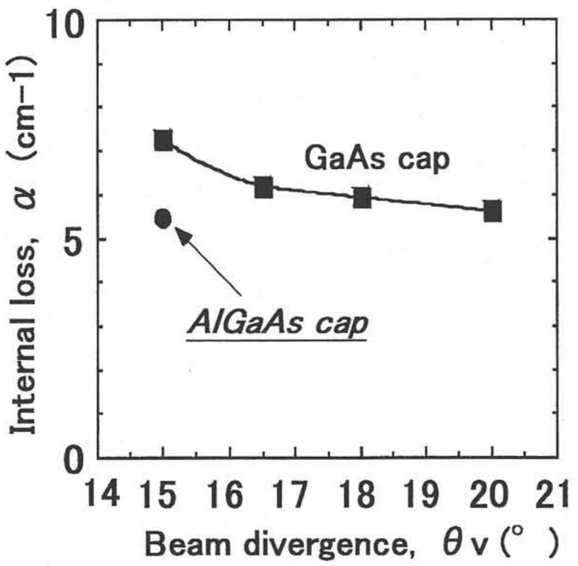

Fig. 2 Internal loss for the devices with AlGaAs and GaAs cap layers

The internal loss for the device with GaAs cap layer increases with decreasing the beam divergence perpendicular to the junction resulting from weakening the optical confinement at the active layer for a higher COD. This is dominantly due to the increase in the optical absorption at the GaAs cap layer, since enlarged spot size resulting from weakening the optical confinement at the active layer enhances the optical absorption at the GaAs cap layer. On the other hand, the internal loss for the device with the AlGaAs cap layer is smaller than that for the device with the GaAs cap layer because the AlGaAs cap layer, which is transparent to the laser beam, reduces the optical absorption at the cap layer. This result shows a transparent AlGaAs cap layer is effective for reducing internal loss, especially for laser diodes with weak optical confinement at the active layer for a higher COD.

Figure 3 shows the current versus light output power characteristics for the device with the GaAs cap layer and device with the AlGaAs cap layer under a pulsed condition (width: 100 ns, repetition: 5 MHz). The beam divergences perpendicular to the junction for these devices are around 15.0°. The threshold current of 35 mA and slope efficiency of 0.95 W/A for the device with the AlGaAs cap layer are drastically improved compared with those for the device with the GaAs cap layer because of the internal loss reduction. The operating current of 180 mA at 100 mW decreases to 140 mA by replacing the GaAs cap layer with the AlGaAs cap layer.

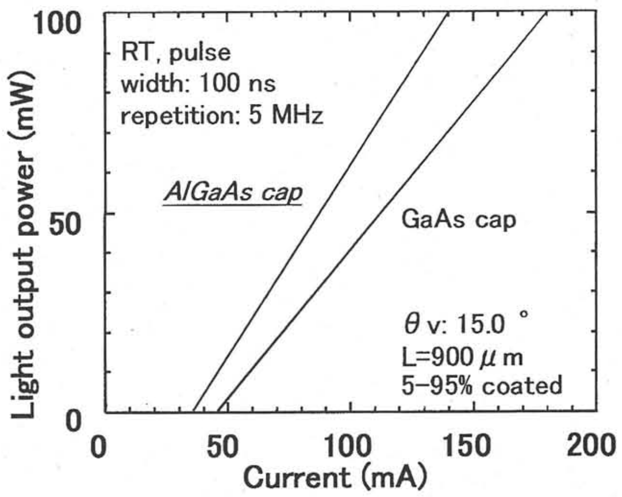

Fig. 3 Current versus light output power characteristics for the devices with AlGaAs and GaAs cap layers

The life test for the laser diodes with the transparent AlGaAs cap layer has been carried out under the pulsed condition at 60°C with a light output power of 100 mW, which is the highest ever reported for real index-guided 660-nm laser diodes. These devices have been operating stably for 200 h with the operating current of around 210 mA.

4. Conclusion

A transparent AlGaAs cap layer was introduced instead of a GaAs cap layer in high-power 660-nm AlGaInP laser diode for the first time in order to decrease the optical absorption at the cap layer. The operating current of high-power 660-nm AlGaInP laser diode has thus been drastically reduced. These laser diodes with the transparent AlGaAs cap layer have been operating stably for 200 h under a pulsed condition at 60°C with the highest light output power of 100 mW ever reported for 660-nm real index-guided laser diodes.

References

[1] R. Hiroyama, D. Inoue, Y. Nomura, M. Shono and M. Sawada, *Proceeding of 13th International Conference on Indium Phosphide and Related Materials 2001* (2001), to be published.

[2] S. Honda, T. Miyake, T. Ikegami, K. Yagi, Y. Bessho, R. Hiroyama, M. Shono and M. Sawada, Electron. Lett. **36**, 1284 (2000).