Extended Abstracts of the 2003 International Conference on Solid State Devices and Materials, Tokyo, 2003, pp. 174-175

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High-power 200-mW 660-nm AlGaInP laser diodes with a low operating current

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1. Introduction

High-power 660-nm-band AlGaInP laser diodes are key devices for use as a light source for recordable or rewritable digital versatile discs (DVDs), such as DVD-R/RW/RAM. In these systems, high-speed recording is strongly required. The optical intensity of the laser beam focused on the optical disc must be increased to meet this requirement. In order to achieve this, effective optical coupling in the optical pick-up as well as high-power operation of 660-nm-band laser diode as a light source are indispensable. A weak optical confinement in the perpendicular direction is very effective for achieving these simultaneously.

We reported high-power 660-nm laser diodes with weak optical confinement in the perpendicular direction employing an AlInP current blocking layer [1]. These laser diodes exhibited a small aspect ratio and high COD and kink levels. However, the light output power of 90 mW for stable pulsed operation was not high enough for 8× or faster recording speed of the recordable DVD. This is due to the high operating current in spite of the minimized optical absorption achieved by the transparent AlInP current blocking layers. It was necessary to reduce the operating current for stable operation with higher light output power.

A buried ridge stripe structure fabricated by a three-step epitaxial growth (a three-step-growth structure) [2] has been widely used for transverse mode stabilized high-power AlGaInP laser diodes. In the three-step-growth structure, a p-GaAs contact layer is formed to facilitate p-side ohmic contact at the third growth. However, the p-GaAs contact layer may restrict the heat dissipated to the heat-sink when fabricating a laser in the junction down configuration. A buried ridge stripe structure fabricated by a two-step epitaxial growth (a two-step-growth structure) is therefore expected to improve the temperature characteristics by providing better heat dissipation than the three-step-growth structure.

Moreover, a dry-etching process for the ridge stripe formation promises to improve the temperature characteristics of the buried ridge stripe structure compared with the wet-etching process. A ridge stripe formed with the dry-etching process has steeper side-walls in the mesa-shape than one formed with the wet-etching process. This makes a difference in device resistance. Laser diodes in which the ridge strip is formed with the wet-etching process have higher resistance than those formed with the dry-etching process. Higher device resistance results in greater power consumption, which raises device temperature under laser operation. Forming the ridge stripe with the dry-etching process may thus improve the temperature characteristics.

In this work, we have introduced a two-step-growth structure and a dry-etching process for ridge stripe formation into the buried ridge stripe structure of the high-power laser diodes. As a result, an operating current of 280 mA at 70ºC with a light output power of 200 mW under the pulsed condition was attained. This is the lowest operating current reported so far, to our knowledge.

2. Laser structure

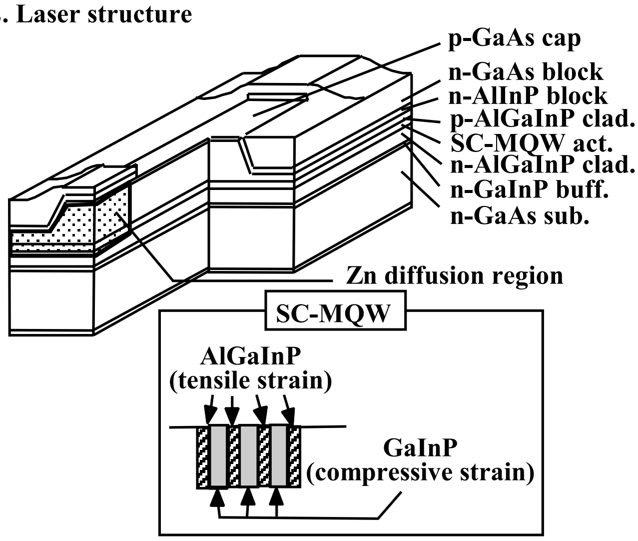

Fig. 1 Schematic structure of high-power laser diodes

The schematic device structure of the high-power laser diode is shown in Fig. 1. This is a buried ridge stripe structure fabricated by two-step epitaxial growth. Prior to this fabrication, the thermal distribution for the conventional three-step-growth structure and the two-step-growth structure were calculated according to the equation of heat conduction with the finite element method, and the result showed that the temperature at the active region for the two-step-growth structure was lower than that for the conventional three-step-growth structure. On this basis, the two-step-growth structure was adopted. Epitaxial growth was carried out by low-pressure MOCVD on an n-type (100) GaAs substrate with a misorientation of 9º 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 [3]. This active layer is sandwiched by an n-type AlGaInP cladding layer and a p-type AlGaInP cladding layer. 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}. The cavity length, including the window region, is 1100 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 heat-sink in a junction-down configuration.

3. Device characteristics

Figure 2 shows the characteristic temperature (T_0) for the laser diodes with the structure shown in Fig. 1 fabricated by using the wet-etching process and the dry-etching process for ridge formation. As shown in Fig. 2, T_0 for the laser diode fabricated with the dry-etching process increased from 133K and 88K to 162K and 110K in the ranges lower and higher than 60ºC, respectively, compared with the wet-etching process.

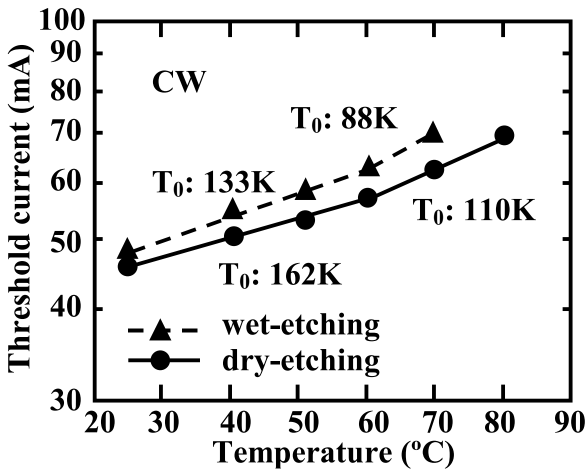

Fig. 2 Characteristic temperature for the laser diodes fabricated with wet-etching process and dry-etching process.

Figure 3 shows the temperature dependence of light output power versus current characteristics for the laser diodes fabricated with the dry-etching process under the pulsed condition with a width of 100 ns and repetition of 5 MHz. The threshold current and slope efficiency at 25ºC are 45 mA and 1.0 W/A, respectively. The operating current at 70ºC with a light output power of 200 mW is 280 mA. The light output power of 200 mW is maintained even at 80ºC. The oscillating wavelength was approximately 658 nm.

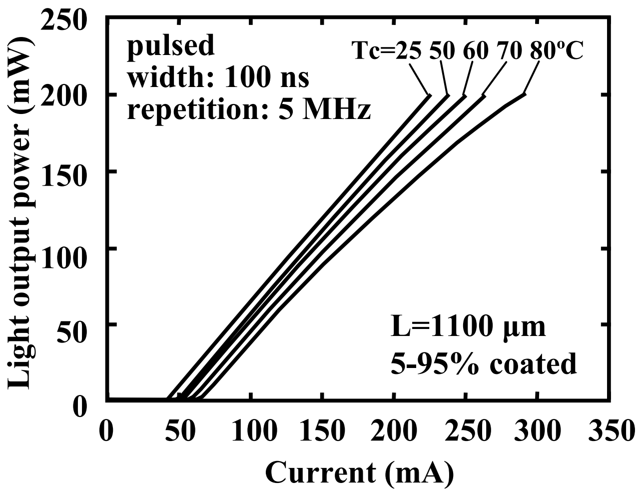

Fig.3 Temperature dependence of L-I characteristics

A life test for these laser diodes has been carried out under the pulsed condition with a light output power of 200 mW. These laser diodes have been operating stably for nearly 1000 h.

4. Conclusion

A two-step-growth structure and dry-etching process for ridge stripe formation have been introduced into the buried ridge stripe structure of high-power 660-nm laser diodes with AlInP current blocking layers, instead of the three-step-growth structure and wet-etching process, in order to reduce an operating current. Operating current with a light output power of 200 mW under the pulsed condition at 70ºC for the fabricated laser diode was the lowest value of 280 mA ever reported so far. Furthermore, a stable pulsed 200-mW operation at 70˚C was achieved.

References

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