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Low Threshold 1.3-μm AlGaInAs Buried-Heterostructure Lasers

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I. Introduction

1.3-μm semiconductor lasers that can operate over a wide temperature range without thermoelectric coolers are important light sources for subscriber networks and optical interconnections. AlGaInAs/InP lasers have been demonstrated to have excellent temperature characteristics [1], and thus are good candidates for uncooled applications. Most of the laser structures reported so far in the AlGaInAs/InP materials are, however, the ridge waveguide type and there are only few reports on buried-heterostructure (BH) lasers [2-3], which usually show a lower threshold current, a more circular output beam and a lower thermal resistance than ridge lasers. This is mainly because the regrowth of current blocking layers is believed to be difficult in this material system due to the oxidation of the etched side-walls of the Al-containing layers.

In this paper, we report successful fabrication of 1.3-μm AlGaInAs MQW BH lasers. The current blocking layers could be smoothly regrown using the simple HF pretreatment. The threshold current as low as 7.5 mA and characteristic temperature T_0 as high as 80 K have been successfully achieved.

II. Device Structure and Fabrication

Fig. 1(a) shows the schematic conduction band diagram of the active layer. The structures were grown on (100) n-InP substrates by MOVPE. The growth temperature was 670°C. The strained MQW structures consisted of seven 1% compressively-strained AlGaInAs wells (λ_w= 1.4 μm, d_w= 60 Å) and unstrained AlGaInAs barriers (λ_b= 1.0 μm). The MQW was enclosed with 0.1-μm-thick GaInAsP (λ_g= 1.05 μm) SCH layers. A p-doped AlInAs electron stopper layer (ESL) was inserted between the MQW and p-side GaInAsP SCH [4-6].

Fig. 1(b) shows the SEM cross section of the fabricated BH lasers. The mesa width was 2 μm. The p- and n-InP current blocking layers were grown at 580 °C, immediately after HF treatment of the mesa side-walls. The doping concentrations of p- and n -InP were 5×10^{17} and 1×10^{18} cm^{-3}, respectively. As shown in Fig. 1(b), it can be observed that InP current blocking layers were smoothly regrown on the side-walls of the AlGaInAs MQW layers with no evidence of voids.

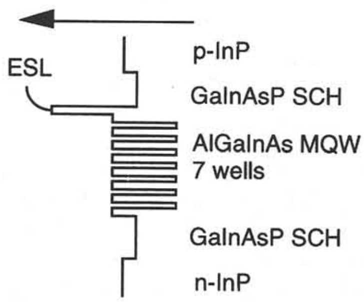

Fig. 1 (a) Schematic conduction band diagram of the active layer.

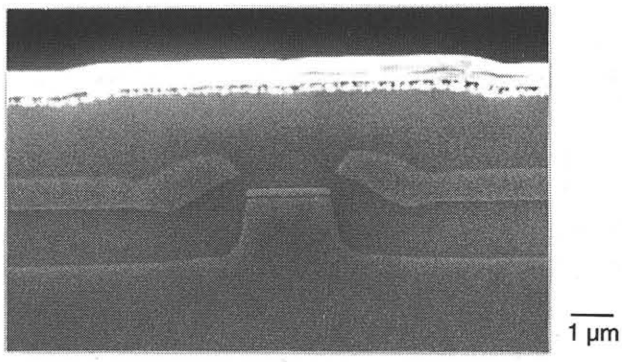

Fig. 1 (b) SEM cross-section of the fabricated BH lasers.

III. Characteristics

The finished devices were mounted on Si heat sinks with a junction-up configuration. For reference, ridge waveguide lasers were also fabricated. Typically, the threshold current I_{th} of the BH lasers at room temperature was 11 mA for as-cleaved 350-μm-long devices under CW operation, which was about 30 % lower than that of the ridge lasers. This result implies there is considerable lateral leakage current in the ridge structures. Fig. 2 shows the temperature dependence of I_{th} and slope efficiencies η for the BH and ridge lasers. In contrast to the lower I_{th} at room temperature, the BH lasers exhibited rather high I_{th} at temperatures above 100 °C. The characteristic temperature T_0 was found to be 73 K between 20 and 80 °C for the BH lasers, while that of the ridge lasers was 80 K. η was almost the same for two types of lasers at room temperature, but η of the BH lasers decreased more rapidly than that of the ridge lasers. These poorer temperature characteristics of the BH lasers seem to be due to the large increase rate of the leakage current through the p-n-p-n blocking layers with increasing temperature. The temperature characteristics will be improved by the optimizing carrier concentration and thickness of current blocking layers.

A maximum CW operating temperature (T_{max}) as high as 155 °C has been achieved with the BH lasers of 350-μm-length and HR-coated rear facet (97 %), which is about the same as that of the ridge lasers.

The lowest I_{th} was obtained with the lasers of 200-μm-long cavity. Fig. 3 shows the light-current characteristics at various temperatures for the 200-μm lasers with the HR-coated rear facet. I_{th} and η were 7.5 mA and 0.47 W/A, respectively, at room temperature. T_0 between 20 and 80 °C was measured to be 80 K in the case of this laser. It is noteworthy that the operating current at the output power of 10 mW at 80 °C was as low as 40 mA, which makes this laser attractive for uncooled applications.

IV. Conclusion

1.3-μm AlGaInAs/InP strained MQW BH lasers have been successfully fabricated. InP current blocking layers could be smoothly regrown using the simple HF pretreatment. For the 200-μm-long device with the high-reflective-coated rear-facet, I_{th} was as low as 7.5 mA and T_0 was 80 K. T_{max} as high as 155 °C was achieved. The BH lasers of AlGaInAs MQW are good candidates for uncooled applications.

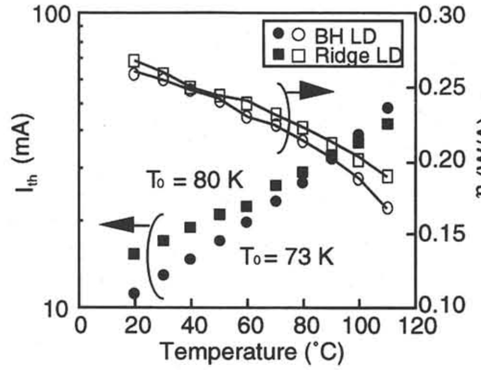

Fig. 2 Temperature dependence of I_{th} and η for the BH and ridge lasers.

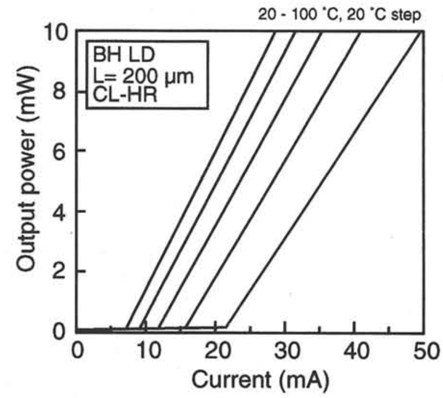

Fig. 3 Light-current characteristics at various temperatures for the 200-μm lasers with the HR-coated rear facet.

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