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Sub-milliampere Lasing of Zn-diffused Mesa Buried-hetero $Al_xGa_{1-x}As/GaAs$ Multi Quantum Well Lasers at 77 K

A.Kurobe, H.Furuyama, S Naritsuka, Y.Kokubun and M.Nakamura

Toshiba R&D Center, 1 Komukai Toshiba-cho, Kawasaki,210, Japan

One of the greatest advantages of adopting multi quantum well (MQW) structure in semiconductor lasers is the reduction of threshold current.[1-3] In this paper we report extremely-low threshold semiconductor lasers fabricated by forming Zn-diffused mesa buried heterostructure (DMB) from low pressure MOCVD-grown AlGaAs/GaAs MQW wafers. CW threshold currents less than 1mA at 77K (880μA) and 2.4mA at 25 °C were obtained. These are the lowest thresholds ever achieved with any structure.

The active region consists of three GaAs quantum wells and four barrier layers having aluminum fraction of x_b=0.22. (see Fig.1) The width of wells and barriers were 7nm and 5nm, respectively. We used separate confinement structure of total width 150nm. The n- and p-$Al_{0.8}Ga_{0.2}As$ cladding layers were doped to $2x10^{18}$ cm^{-3}, whilst the $Al_{0.28}Ga_{0.72}As$ wave-guide layers and active layers were undoped. Optical confinement factor was optimized to be 3.5%/well with respect to the total width.

Fig.1 shows the geometry of this device which we call DMB-MQW laser. Zinc was diffused (640°C, 10min) to disorder active region selectively, such that both optical and electrical confinements could be achieved. Unique feature of this design is that Zn-diffusion is performed after deep mesa ething is done through active layers. This enhances the controllability of the stripe width defined by Zn-diffusion compared with a conventional fabrication process.[4] Coatings were applied to the facets of cleaved samples. Reflectivity of the front facet was R_f=70% and that of the rear facet was R_r=86%.

Fig.2 shows the room temperature light/current characteristics of the fabricated devices. The stripe width was 2.5μm. For an as-cleaved sample cw threshold current was 3.6mA and the differential quantum efficiency was 50% at a cavity length of 75μm. By applying coating to both facets of a 100-μm long sample, we obtained the threshold current as low as 2.4mA at 25°C. The threshold current further reduced with decreasing temperature, and 880μA was achieved at 77K (see Fig.3). The characteristic temperature T_0 changed from 119°C to 185°C below -20°C, and became less temperature- dependent near 77K.

We have fabricated lasers with stripe widths ranging from 1.5μm to 7.5μm. Threshold current variation with the stripe width (Fig.5) confirms that our lasers have electronic confinement as the result of disordering, although the confinement is not complete. The offset current I_{th}^0 shown in Fig.4 indicates a leakage current out of the active region. This is about 1mA for our lasers, and is half the value deduced from threshold current data reported for Si-diffused planar BH-MQW lasers.[2] To attain sub-miliampere threshold at room temperature with the present MQW structure, it is necessary to use BH structure which would suppress the offset current to values much less than 1mA.

References

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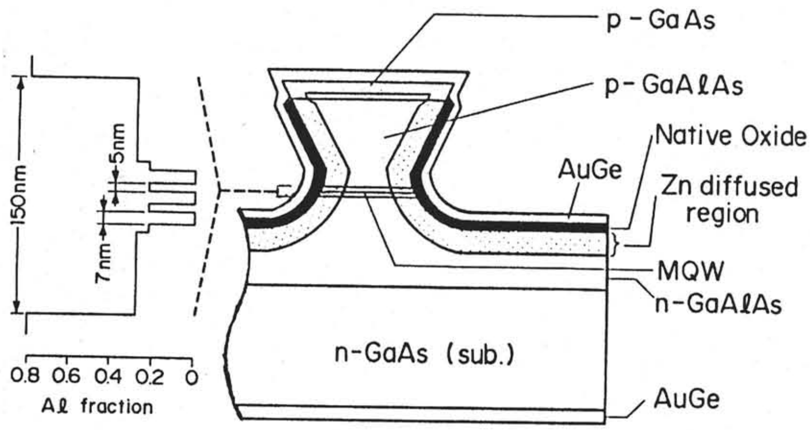

Fig.1

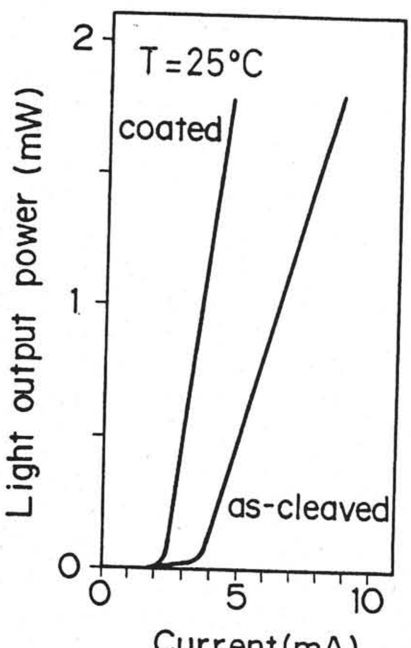

Fig.2

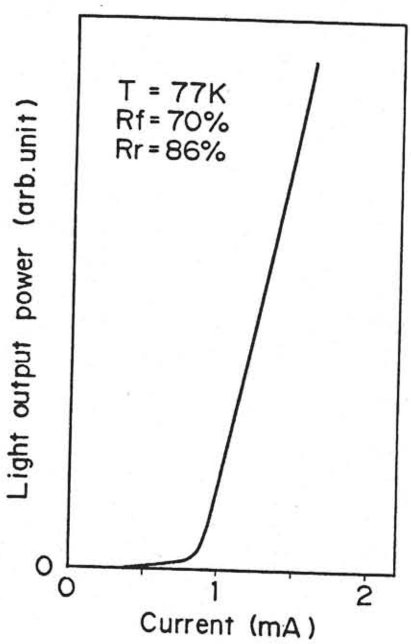

Fig.3

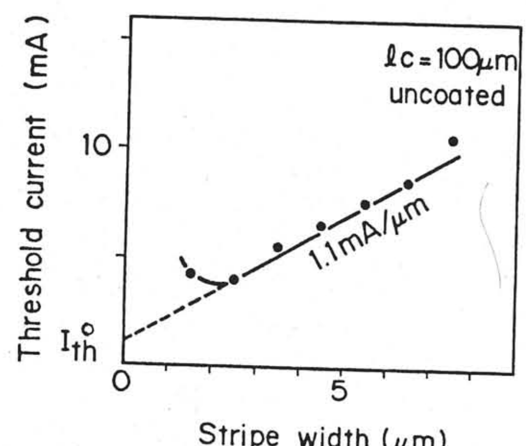

Fig.4

Fig.1. DMB-MQW laser structure.

Fig.2. Light/current characteristics of DMB-MQW lasers at 25℃. The stripe width is 2.5μm. Cavity lengths of as-cleaved and coated samples are 75μm and 100 μm, respectively.

Fig.3. Light/current characteristic of DMB-MQW lasers at 77K. Cavity length is 100 μm.

Fig.4. Threshold current dependence of stripe width for uncoated samples.