Low internal loss InP/InGaAsP laser diodes fabricated using inductively coupled plasma etching

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Abstract Inductively coupled plasma (ICP) etching technique was applied to fabricate InP/InGaAsP buried-hetero structure laser diodes for high throughput fabrication. Low internal loss of 6cm^{-1} and high output power of 290mW at 1.48μm were obtained under extremely fast etching rate of 1.2μm/min for mesa structuring.

Dry-etching for InP/InGaAsP material system [1] is one of the key-technology for fabrication of opto-electronic devices, because it can attain accurate waveguide geometry-control for efficient power coupling into optical fiber, high uniformity for superior yield, and others. For the purpose of the actual implementation, however, the etching rate of conventional dry-etching techniques was relatively slow for efficient fabrication throughput. To overcome this issue, we introduced inductively coupled plasma (ICP) system [2], of which etching-rate reaches more than 1μm/min with low damage for the mesa structuring of InP/InGaAsP laser diodes. We exploited this technology for fabrication of high power laser diodes.

Figure 2 shows the light-current characteristics (pulsed operation: 1μs, 2kHz) of adjacent several 1.48μm strained multiple-quantum-well buried-heterostructure laser diodes (see Fig. 1) fabricated by using ICP. The waveguide width and the cavity length were 2μm and 1500μm, respectively. The etching-depth of the mesa was 2μm. Uniform lasing performances with threshold current of 20mA and slope efficiency of 0.2W/A were obtained as can be seen in Fig. 2. This is because we did not use wet-chemical etching, which might give worse geometry-control for mesa structuring. Figure 3 shows the inverse of external quantum efficiency $1/\eta_d$ as a function of cavity length, which was varied from 750 to 3000μm. In this figure, the results by using CH_4/H_2 reactive ion etching (RIE) are also shown for comparison. Low internal loss of 6cm^{-1}, and sufficient internal quantum efficiency of 83% were obtained for laser diodes fabricated by using ICP. It is considered that these laser diode performances are as superior as one of laser diodes by using regular wet-chemical etching process ever reported in general. In addition, these characteristics were even better than the characteristics by using RIE, although the etching rate of ICP (1.2μm/min) was approximately 100 times faster than one of RIE. Moreover, high output power of 290mW, which is the highest among InP/InGaAsP laser diodes fabricated by using dry-etching as to our knowledge, was obtained under CW operation as can be seen in Fig. 4. Therefore, it is considered that this ICP process dose not give any significant plasma damage that affects to laser diode performances, especially high output power, while realizing extremely high throughput. We expect this technology will contribute to the future high power laser diodes and semiconductor optical amplifiers [3].

References

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[2] J. Etrillard, et. al., J. Vac. Sci. Technol. A, 1997, **15**, pp. 626-632
[3] K. Hamamoto, et. al., Electron. Lett., 2000, **36,** (2), pp. 138-139

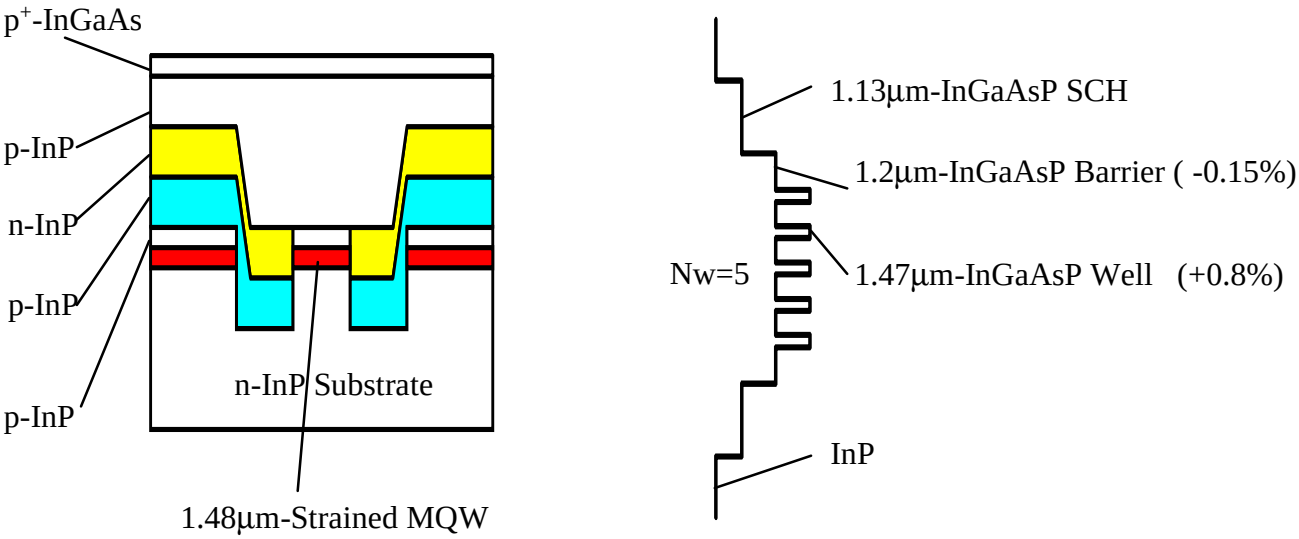

Fig. 1. Device structure

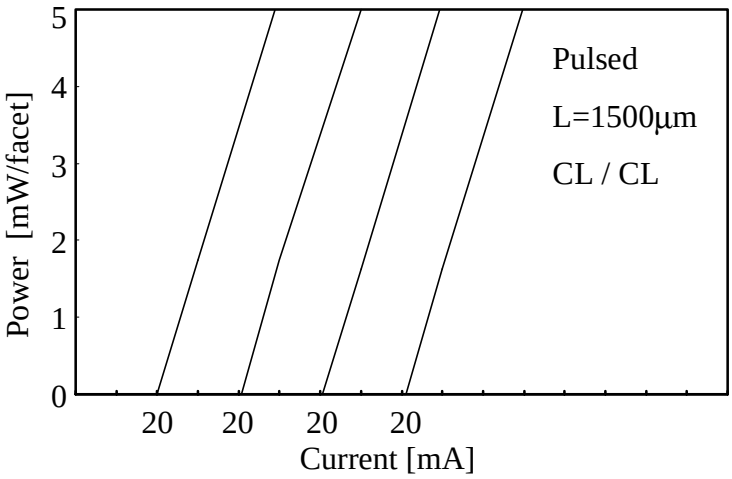

Fig. 2. Uniform LD characteristics

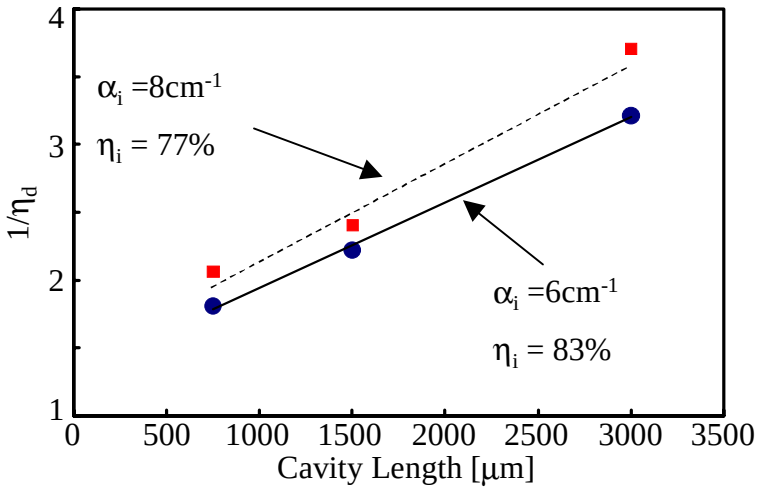

Fig. 3. Internal loss (α_i) and internal quantum efficiency (η_i)

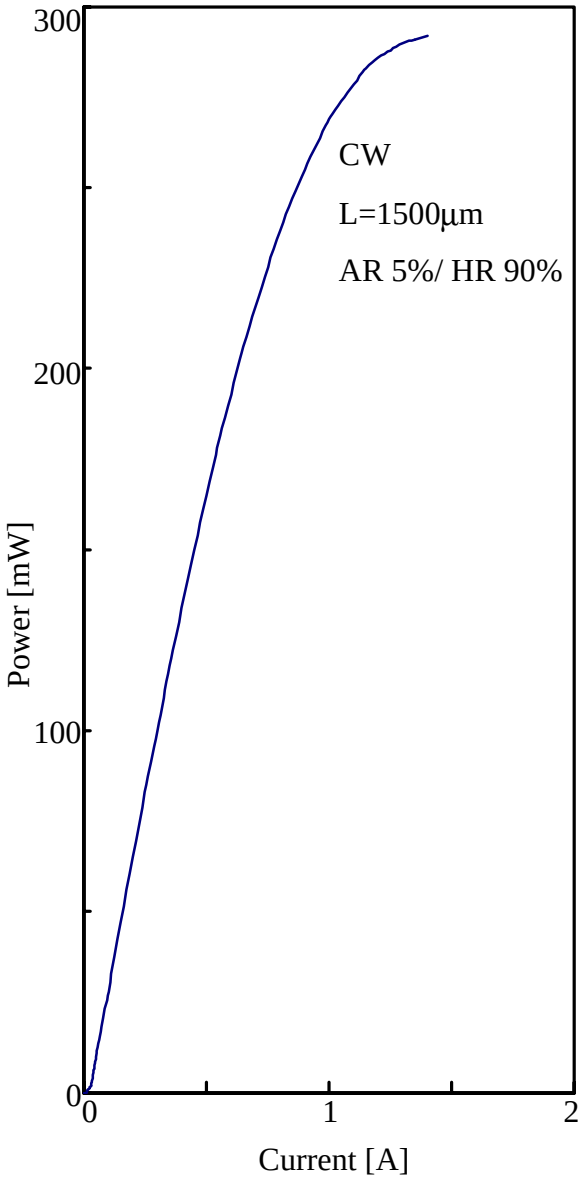

Fig. 4. Output power of the fabricated LD