Extended Abstracts of the 1991 International Conference on Solid State Devices and Materials, Yokohama, 1991, pp. 735-736 **PC7-L2**

# Fabrication of GaAs/AlGaAs Lateral Current Injection Quantum Well Laser

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To integrate optical devices such as lasers, photodetecters, and amplifiers, the loss of optical waveguides should be kept as low as possible. We have already proposed a process of monolithical integration by the compositional disordering of a quantum well using ion implantation[1]. However the propagation loss of an integrated waveguide using this process was still as high as 4 $cm^{-1}$. The results of our recent measurements establish that absorption caused by carrier doping into the cladding layers increased loss by about 1.5 $cm^{-1}$. To eliminate this absorption loss, we fabricated the completely undoped lateral current injection (LCI) laser with a p-n junction is horizontally formed by ion implantation with silicon and zinc.

The schematic structure of this laser is shown in Fig. 1. We introduced a rib waveguide structure for prospective optical integration. The laser has a graded index separate confinement heterostructure (GRIN-SCH) single quantum well (SQW). For the first growth, seven layers of GRIN-SCH-SQW structure were successively grown on a (100)-oriented CrO-doped GaAs substrate by low-pressure metalorganic vapor phase epitaxy (MOVPE) at 780°C. These layers include a GaAs buffer layer (0.5 μm), an $Al_{0.6}Ga_{0.4}As$ cladding layer (1.5 μm), an $Al_xGa_{1-x}As$ GRIN layer (x=0.6-0.3, 0.15 μm), a GaAs SQW layer (9.6 nm), an $Al_xGa_{1-x}As$ GRIN layer (x=0.3-0.6, 0.15 μm), an $Al_{0.6}Ga_{0.4}As$ blocking layer (20 nm) and an $Al_{0.3}Ga_{0.7}As$ guiding layer (30 nm). After the first growth, a 2 μm-wide rib structure was wet-etched on the guiding layer. In the second growth, an $Al_{0.6}Ga_{0.4}As$ cladding layer (1.2 μm) was grown at 750°C. After this, a 4 μm-wide mesa-stripe structure was wet-etched on the cladding layer over the rib structure. In the third growth, a GaAs contact layer (0.25 μm) was grown, also at 750°C. Then one side of the mesa stripe was implanted with silicon under conditions of a 7° misorientation toward the <100> implanted angle, an energy of 100 keV and a dose level of $1x10^{15}cm^{-2}$. The other side was implanted with zinc under the same conditions as for silicon except at an energy of 150 keV. After this, silicon nitride was deposited by plasma chemical vapor deposition (CVD) as an encapsulant, and the device was annealed at 800°C for 2 hrs in an atmosphere of nitrogen. Then the silicon-nitride was removed and only the contact layer over the mesa stripe was wet-etched. Ohmic contacts were formed by the lift-off technique. A SEM photograph of the practical device is shown in Fig. 2.

Before the fabrication of the LCI laser, preliminary measurements were done to estimate the resistance of the device and to obtain a sufficiently deep diffusion of implanted ion. We first measured the contact resistivity and sheet resistance for various ion implantation conditions using the transmission line model (TLM) method[2]. Contact resistivity in the electrode needs to be less than $10^{-4}\Omega\ cm^2$ so that contact resistance in the practical device can be disregarded. From the measurements, it was found that AuGe/Au for the n-electrode and AgZn/Au for the p-electrode satisfied the above mentioned conditions. Further, it was found that the sheet resistance of the AlGaAs layer was several kΩ and one order of magnitude higher than that of the GaAs layer (several hundred Ω). For the structure previously reported[3], electric current must flow in the high resistance AlGaAs layer and this increases the resistance in the LCI laser. Therefore, three step growth was undertaken and the low resistance GaAs layer approached the active region by growing the GaAs layer after the formation of the mesa stripe structure. Due to structural reasons, the implanted ions are required to diffuse to a depth of 0.3 μm to form the p-n junction. Figure 3 shows the diffusion profiles of implanted silicon and zinc using SIMS analysis. It is found that the diffusion depths of silicon and zinc, which were implanted with a dose of $1x10^{15}cm^{-2}$, are sufficiently deep after annealing at 800°C over 2 hrs. However the diffusion conditions for zinc do not seem to optimize.

The CW lasing characteristic is shown in Fig. 4. A threshold current of 39 mA and a resistance of 10 Ω with a 1 mm-cavity were achieved. The resistance of the LCI laser was reduced using this structure.

Ref. [1]. T. Hirata, M. Maeda and H. Hosomatsu : Jpn. J. Appl. Phys., Vol. 28(1989), pp. L1429
[2]. For example, H. H. Berger : Solid-State Electron., Vol. 15(1972), pp. 145
[3]. A. Furuya, M. Makiuchi and O. Wada : Electron. Lett., Vol.24(1988), pp. 1282.

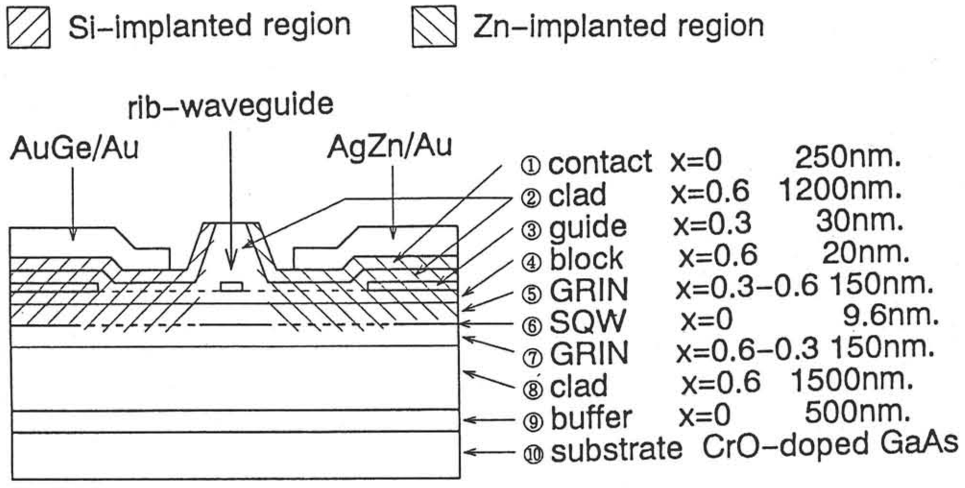


Fig. 1 Schematic cross section of lateral current injection laser.

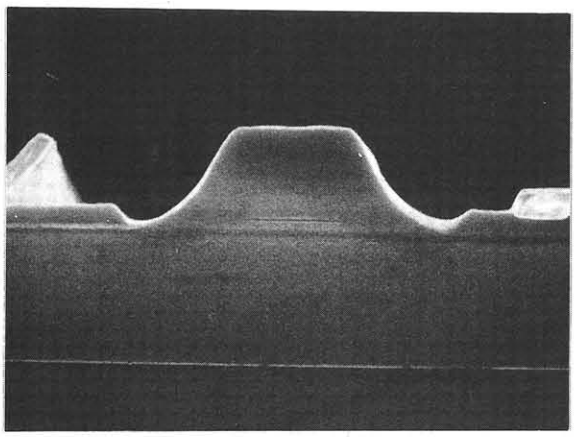

Fig. 2 Scanning electron microgragh of a cross-sectional view of the LCI laser.

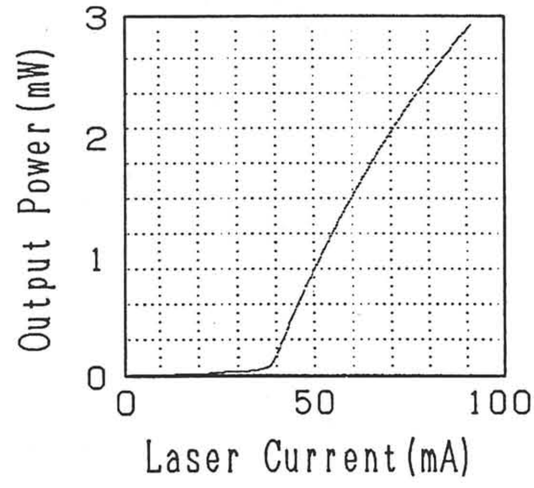


Fig. 4 CW lasing characteristic of an LCI laser.

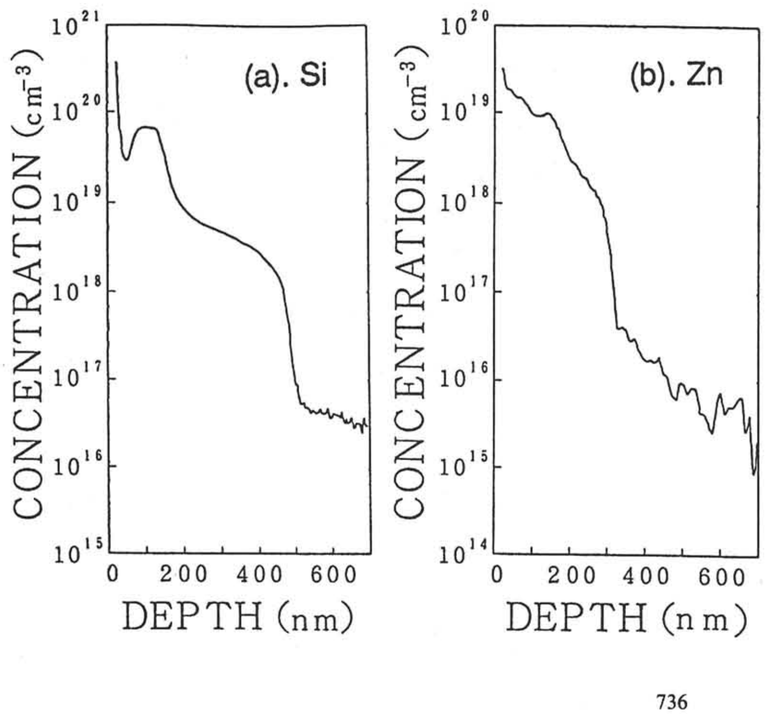


Fig. 3 SIMS profiles of Si and Zn, with a dose of $1 \times 10^{15}$ cm$^{-2}$, after annealing at 800°C for 2 hrs.
(a) Si-implanted at 100 keV.
(b) Zn-implanted at 150 keV.