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GaInAsP/InP Surface Emitting Injection Lasers

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A conventional injection semiconductor laser consists of two end mirrors perpendicular to the active layer,[1-3] so that, the light output is parallel to the wafer surface. If an injection laser with the light output perpendicular to the wafer surface could be obtained, it would be very easy to fabricate a laser array. In relation to this aim, a distributed Bragg reflector laser with 4th order grating can emit light perpendicular to the wafer surface.[4]

In this letter, a noble GaInAsP/InP laser called a surface-emitting injection laser is reported. The Fabry-Perot resonator consisted of both surfaces of the wafer and its axis was perpendicular to the active layer. The light output could be obtained from one of the wafer surfaces. To the authors' knowledge, this is the first report about such a laser.

Double-heterostructure (DH) GaInAsP wafers[5-8] were prepared by the LPE technique. Three layers, an n-type InP layer (Te doped), an undoped GaInAsP active layer, and a p-type InP layer (Zn doped) were grown sequentially on a (100) n-type InP substrate in a rotary carbon boat at a cooling rate of 0.8°C/min and a growth temperature of the active layer of 635°C.[9] During the growth of DH wafers for surface-emitting injection lasers, it is essential that the grown surface acting as a resonator mirror is mirrorlike and the active layer is thick, so as to reduce the threshold current. There was no melt removal problem at all. It was found experimentally that better *V-I* characteristics for the thicker active layer could be obtained by increasing the Zn concentration (about $1\times10^{18}/\text{cm}^2$) of the p-type InP layer. As the active layer is close to the circular electrode, the current injection to the active layer is estimated to be localized near the circular electrode.

After sputtering SiO_2 film onto the grown surface, circular holes of 50–100 μm diameter for p-side electrodes were opened by conventional photolithographic techniques. Next the n-side surface of the wafer was mechanically polished to form another reflector. In the polishing process, the polished surface was kept parallel to the grown surface. Following the reflector formation, n-side ring electrodes were provided by evaporating Au/Sn. Next, p-side circular electrodes of 50–100 μm diameter were formed by evaporating Au/Zn onto the circular holes. Alloying was done at 400°C for 5 min. Finally, an Au coating a few tenths of a micrometer thick was formed on the n-side surface to increase the reflectivity of the resonator mirror. Then the wafer was cut into 500 μm × 500 μm chips and the laser chips were mounted on Au-plated copper mounts, p-side down.

Figure 2 shows an example of the emission

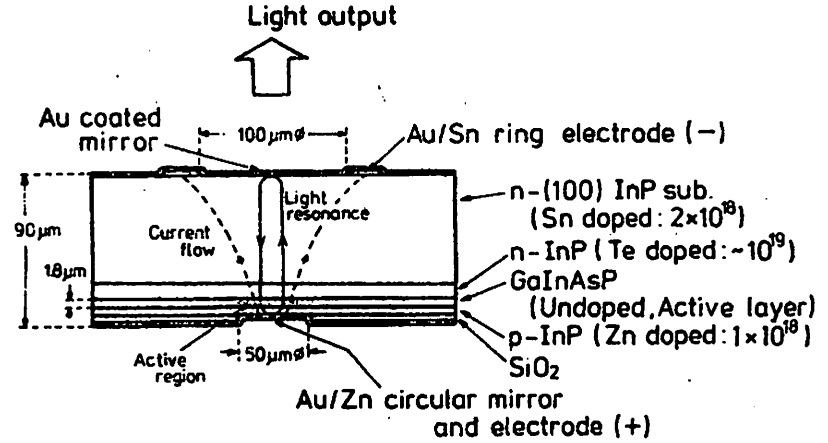

Fig. 1 Schematic structure of GaInAsP/InP surface emitting injection laser.

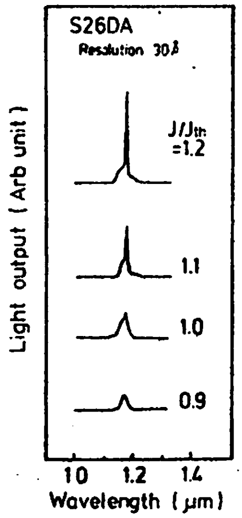

Fig. 2. Emission spectrum of a surface emitting injection laser driven with 400 ns current pulse with 1 kpps repetition at 77 K.

spectrum of a surface-emitting injection laser prepared in this way and driven by 400 ns current pulses at 1 kpps repetition at 77 K. The light output was detected by an S-1 photomultiplier tube. The threshold current density J_{th} was 11 kA/cm^2 (circular electrode diameter of 100 μm) and the lasing wavelength was 1.18 μm. It was found that J_{th} of the laser with Au coating on the n-side mirror is less than one fourth of that with no Au coating.

Figure 3 shows the light output vs. injection current curve for a surface-emitting injection laser detected by a Ge solar cell. A light output of several mW was obtained. From observation of the near-field pattern, the radiation area was located on the p-side circular electrode.

It is estimated that the surface-emitting laser can be operated at room temperature by increasing the thickness of the active layer and reducing the diameter of the injection area.

In conclusion: we report here on the fabrication and lasing properties of a surface-emitting injection laser.

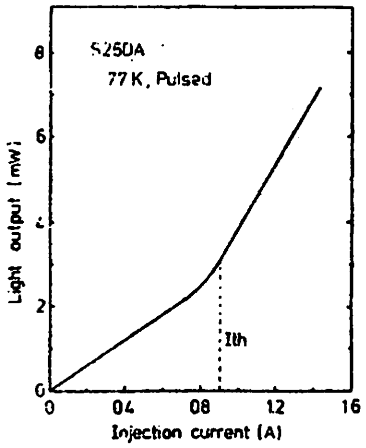

Fig. 3. Light output vs. injection current characteristic of a surface emitting injection laser.

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