MICROCAVITY GaAlAs/GaAs SURFACE-EMITTING LASER WITH $I_{th} = 6$ mA

Indexing term: Semiconductor lasers

A circular buried microcavity 7 μm long and 6 μm in diameter has been realised. We obtained $I_{th} = 6$ mA, $\eta_d = 9\%$ and peak power ≥ 1 mW at 20·5°C at single mode. The first CW operation of a GaAlAs/GaAs surface-emitting laser with $I_{th} = 4{\cdot}5$ mA at 77 K was also realised.

This is the first demonstration of a microcavity GaAlAs/GaAs surface-emitting (SE) laser with $I_{th} = 4{\cdot}5$ mA (77 K, CW) and 6 mA (300 K, pulsed). The structure of the microcavity SE laser by selective meltback[1] is shown in Fig. 1. A circular buried heterostructure (CBH)[2,3] and a highly reflective TiO_2/SiO_2 multilayer Bragg reflector[4] have been introduced. A microcavity 7 μm long and 6 μm in diameter has been realised.

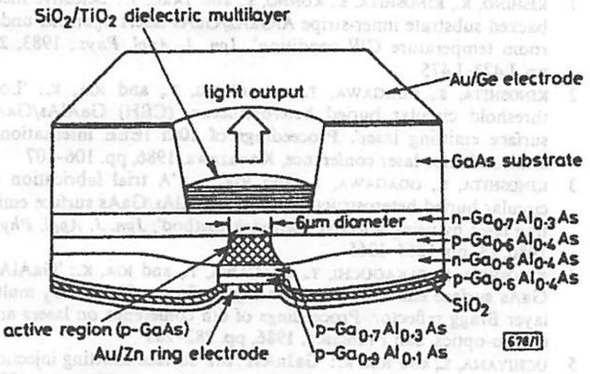

Fig. 1 *Structure of microcavity SE laser*

Fig. 2 shows the fabrication process. Each process is as follows:

(i) After fabricating an SiO_2 film on the DH wafer, a 1 mm-pitch, 30 μm-diameter SiO_2 mask pattern is formed.

(ii) A 30 μm-diameter circular mesa is fabricated by preferential etching of the GaAlAs cap and *p*-cladding layers with the mixture of 1N-NaOH:H_2O_2 (25:1·8) at 24°C for 7 min. The etching rate of this mixture for $Ga_{0\cdot7}Al_{0\cdot3}As$ is 0·4 μm/min, which is twice as fast as that for GaAs.

(iii) The most important process is to make a small-diameter active layer. This is performed by selectively melting back the GaAs active layer to make a constricted mesa in an LPE furnace for 20 s under the conditions of a meltback starting temperature of 800°C and an employed cooling rate of 0·5 deg C/min. The degree of undersaturation for Ga and As in the solution is taken to be 4°C, which is the temperature drop from that for saturation. During this process the *n*-GaAlAs cladding layer is hardly melted-back.

(iv) The *p*-, *n*- and *p*-$Ga_{0\cdot6}Al_{0\cdot4}As$ current blocking layers are successively grown around the mesa.

Finally, the short-cavity structure, electrodes, a TiO_2/SiO_2 multilayer Bragg reflector as the front mirror and the Au/SiO_2 rear mirror[5] are fabricated.

The present SE laser was mostly tested under pulsed conditions (1 μs pulse width, 6 kpulse/s) at 20·5°C. The light-output/current (*L/I*) characteristic is shown in Fig. 3. The threshold current was 6 mA. Although we used rather a long pulse, no decrease in the light output was observed for low-level excitation. We drove the device up to 40 mA. The differential quantum efficiency was 9%, and more than 1 mW peak power was obtained. The first CW operation at 77 K was achieved with $I_{th} = 4{\cdot}5$ mA.

The lasing spectrum at $I = 20$ mA is shown in Fig. 4, which shows the single mode. The near-field pattern of this SE laser was a circle of $2r \simeq 6\,\mu$m in diameter as shown in Fig. 4. In

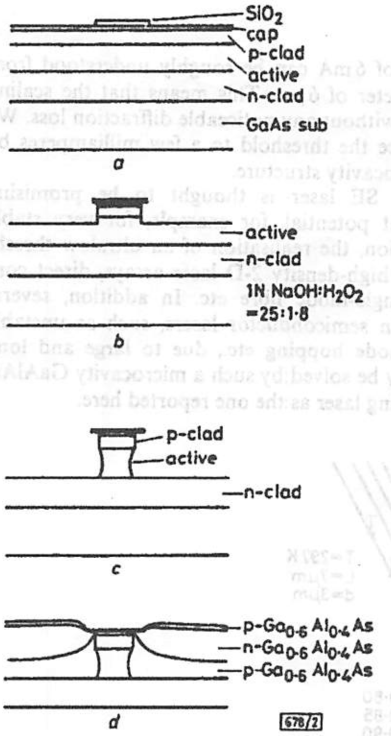

Fig. 2 *Fabrication of microcavity SE laser*

a Formation of SiO_2 mask
b Etching of cap, *p*-cladding and active layers
c Second LPE, then selective meltback
d Regrowth of blocking layers

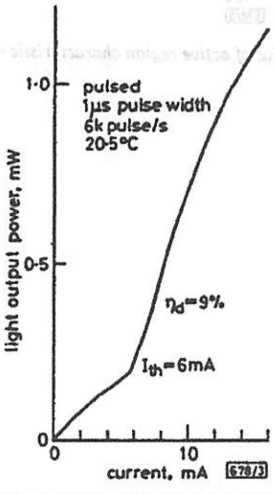

Fig. 3 *Light-output/current (L/I) characteristic*

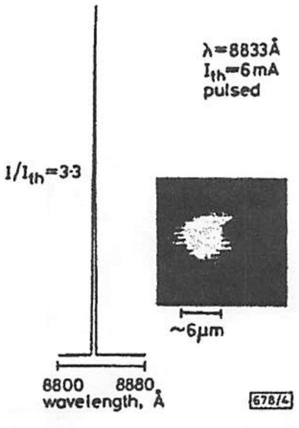

Fig. 4 *Spectrum and near-field pattern of microcavity SE laser*

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fact, the threshold of 6 mA can be roughly understood from Fig. 5 for the diameter of 6 μm. This means that the scaling law, $I_{th} \propto r^2$, holds without any noticeable diffraction loss. We can expect to reduce the threshold to a few milliamperes by optimising the microcavity structure.

The microcavity SE laser is thought to be promising because of its great potential, for example, for very stable single-mode operation, the realisation of an ultralow threshold (<1 mA) laser, high-density 2-D laser arrays, direct connectability to a single-mode fibre etc. In addition, several existing problems in semiconductor lasers, such as unstable DSM operation, mode hopping etc., due to large and long optical cavities, may be solved by such a microcavity GaAlAs/GaAs surface-emitting laser as the one reported here.

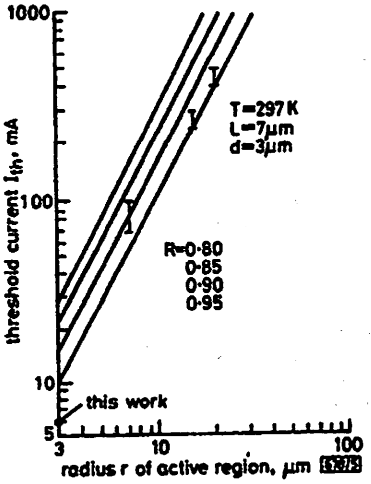

Fig. 5 *Threshold current against radius of active region characteristic*

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K. IGA
S. KINOSHITA
F. KOYAMA

Tokyo Institute of Technology
4259 Nagatsuta
Midori-ku, Yokohama 227, Japan

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