Lasing Operation of Lateral-Current-Injection Membrane DFB Laser with Surface Grating

T. Shindo*, M. Futami*, T. Okumura*, R. Osabe*, T. Koguchi*,
T. Amemiya**, N. Nishiyama*, and S. Arai**.
* Dept. of Electrical and Electronic Engineering, Tokyo Institute of Technology
** Quantum Nanoelectronics Research Center, Tokyo Institute of Technology
2-12-1-S9-5, O-okayama, Meguro-ku Tokyo 152-8552, Japan
Tel :+81-3-5734-2555 Fax:+81-3-5734-2907 Email: shindou.t.aa@m.titech.ac.jp, arai@pe.titech.ac.jp

Abstract

Toward the light source for on-chip interconnection, a current-injection-type semiconductor membrane distributed feedback (DFB) laser was demonstrated with a surface gating structure. A threshold current of I_{th}=24 mA was obtained with a cavity length of 590 μm and a stripe of 1 μm.

1. Introduction

It is predicted that the performance of LSI technology will soon hit a ceiling owing to global wiring data capacity with technological progress. One promising approach to overcome this predicted problem is replacing the electrical global wiring on a chip with an optical interconnection and an ultra-low power consumption operation of semiconductor light sources is strongly required. Optically pumped modulation of a lateral propagation type membrane photonic crystal laser has been reported with the low power dissipation of 8.76 fJ/bit because of its strong optical confinement effect [1]. However, electrical pumping of such laser has not been realized yet.

We have been investigating a semiconductor membrane laser which has a thin semiconductor core layer and low refractive-index cladding layers such as SiO_2 or BCB [2]. To realize a current injection type membrane laser, an introduction of a lateral-current-injection (LCI) structure [3] has been proposed and a room-temperature (RT) pulsed operation of DFB structure with wire-like active regions was demonstrated with relatively high threshold current >80 mA [4]. In this paper, we would like to report much lower threshold current of 24 mA a LCI membrane DFB laser by adopting a surface grating structure [5].

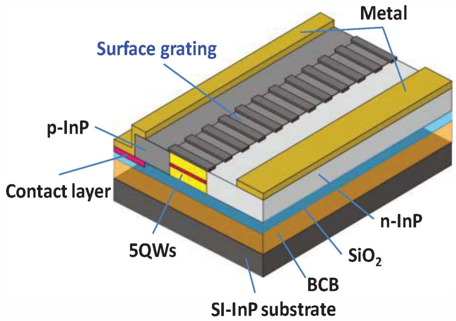

Fig. 1 Schematic device structure of LCI membrane DFB laser.

2. Device structure and fabrication process

Figure 1 shows the schematic structure of the fabricated LCI membrane DFB laser with a surface grating structure, where the total core layer thickness was about 470 nm, and top and bottom cladding layers were composed of air (n = 1) and SiO_2 (n = 1.45), respectively. Due to the introduction of the low refractive-index cladding layer structure, the optical confinement factor of the active layer can be enhanced about 2 times higher (2%/well) than that of conventional lasers with semiconductor cladding layers. The core layer consists of 1% compressively-strained 5-quantum-wells (CS-5QWs, 6 nm thick) sandwiched by symmetric GaInAsP optical confinement layers (OCLs) and a 50 nm-thick InP cap layer. First, p- and n-InP side cladding layers for the LCI structure were formed by two-step selective area growth [4,5]. After depositing 1 μm-thick SiO_2, 2 μm-thick BCB was coated on the regrown wafer and a host InP substrate, and the wafer was attached upside down to the host

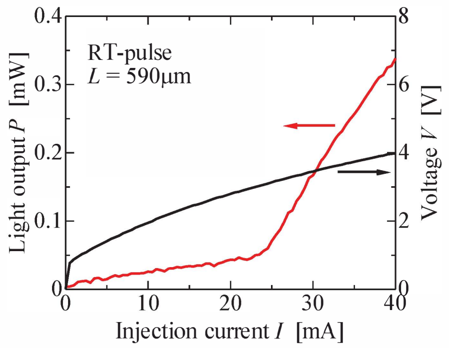

Fig.2 Lasing characteristics of the current injection-type membrane laser.

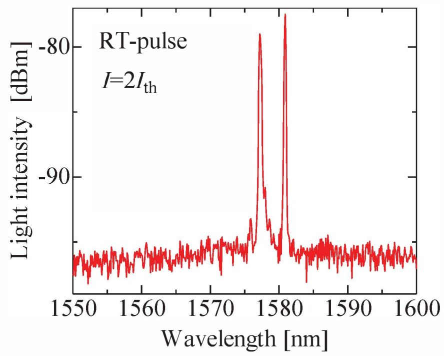

Fig.3 Lasing spectrum of the current injection-type membrane laser.

substrate. Then the InP and etch stop layers of the regrown wafer were removed by polishing and wet chemical etching. Next, Ti/Au electrodes were deposited on both p-GaInAs contact layer (the p-InP side cladding was partially removed to expose this contact layer) and n-InP layer. Finally, the surface grating pattern was formed by electron-beam lithography and CH_4/H_2 reactive-ion- etching on the top InP cap layer at the laser stripes. The grating period and the depth were 255 nm and 30 nm, respectively. The index-coupling coefficient of this grating was estimated to be κ=150 cm^{-1}.

3. Device structure and fabrication process

Figure 2 shows a light output and voltage-current characteristics of the LCI membrane DFB laser with a surface grating structure under room-temperature pulsed condition (1μs-width, 1ms-period). The cavity length and the stripe width were L=590 μm and 1 μm, respectively. As can be seen, a threshold current of 24 mA, which was much lower than that in the previous report, was obtained. The differential series resistance and the voltage at the threshold were around 66 Ω and 3.1 V, respectively. The series resistance is about 2.6 times higher than that of LCI-DFB laser with a 400-nm-thick core layer on SI-InP substrate [5]. A continuous-wave operation was not obtained because of heat generation due to the high series resistance. By optimizing the doping concentration of the p-InP and n-InP regions, and narrowing the interspace between the electrodes and the laser stripe, the series resistance can be reduced. In addition, by introducing thin core layer thickness (~200 nm) the threshold current can be reduced due to the enhancements of the optical confinement factor and index-coupling coefficient of the grating. Figure 3 shows the lasing spectrum of the membrane DFB laser at two times the threshold. As can be seen, a two mode operation (1577.2 nm and 1580.9 nm) was obtained. Since the stopband width calculated from the grating structure is 3.5 nm which is in good agreement with the measured difference between two-modes of 3.7 nm, these lasing modes might be attributed to relatively high κL=8.85 of the DFB cavity without phase-shift region.

4. Conclusions

For on-chip optical interconnection light source, we demonstrated the current injection-type semiconductor membrane laser with surface grating structure. As a result a threshold current of 24 mA was obtained under RT pulsed condition.

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