Directly Modulated Membrane Lasers on Si

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1. Introduction

Membrane lasers, in which a thin active region is sandwiched by low-index materials, are essential for achieving extremely low power consumption with high-speed direct modulation. These devices are expected to be key components of datacom and computercom interconnects. In this context, we have already developed a photonic crystal laser [1, 2] and a membrane DFB laser [3], where the use of a buried heterostructure (BH) provides both good carrier confinement and good thermal conductivity. Fabrication cost is also an important issue. To reduce it, we have to employ large-scale wafers and Si CMOS fabrication technologies. In this talk, we will describe the fabrication of a membrane laser with its heterogeneous integration on Si substrate.

2. Membrane laser on SiO_2/Si substrate

Figure 1 shows the procedure for fabricating the membrane laser on SiO_2/Si substrate. We grow an InP-based MQW layer as an active region on InP substrate. InP and SiO_2/Si substrates are bonded to each other by employing an O_2-plasma-assisted direct-bonding technique [Fig. 1(a)]. After the InP substrate has been removed, remaining III-V layers, including the MQW layer, are used as a template for epitaxial growth [Fig. 1(b)]. Then, the MQW layer is removed down to the InP layer, except for the mesa stripe region, which is defined by an SiO_2 mask, and InP is selectively grown to bury the active region on the InP layer [Fig. 1(c)]. Zn-thermal diffusion and Si-ion implantation are employed to fabricate p- and n-type doping regions, respectively [Fig. 1(d)]. Finally, we deposit electrodes and fabricate the surface grating [Fig. 1(e)].

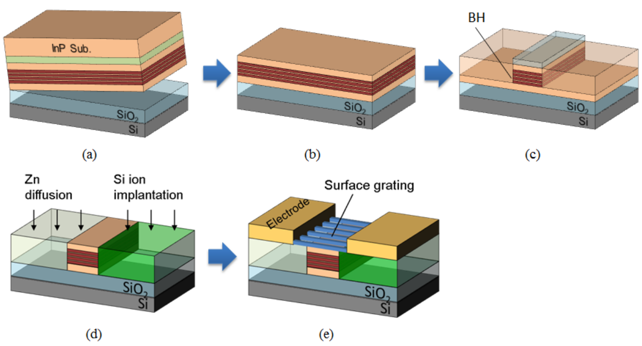

Fig. 1. Fabrication procedure for membrane laser.

An advantage of the proposed fabrication method is that epitaxial growth in the lattice-mismatch condition is not required when fabricating the BH. However, the difference in thermal expansion coefficients between the SiO_2/Si substrate and template introduces strain, which degrades the crystal quality of both the template and InP layer. To solve this problem, reducing template thickness is essential. Figure 2 shows photoluminescence (PL) maps after annealing at 610ºC, which is the same as the growth temperature, for various template thicknesses ranging from 250 to 850 nm on SiO_2/Si substrate. As the maps show, there was no degradation in PL when the template thickness was 250 nm, which is consistent with the calculated critical thickness.

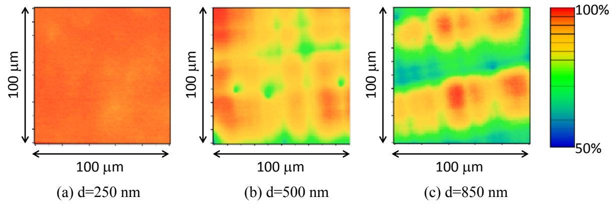

Fig. 2. PL maps of template after annealing at 610 ºC for various template thicknesses.

We fabricated membrane DFB lasers on SiO_2/Si substrate using the template thickness of 250 nm. Figure 3 shows the relaxation oscillation frequency of a fabricated DFB laser with 73-µm cavity length as a function of the square root of bias current above threshold for operating temperatures of 25, 50, and 75ºC. The respective slopes are 7.7, 7.0 and 5.5 GHz/mA$^{1/2}$.

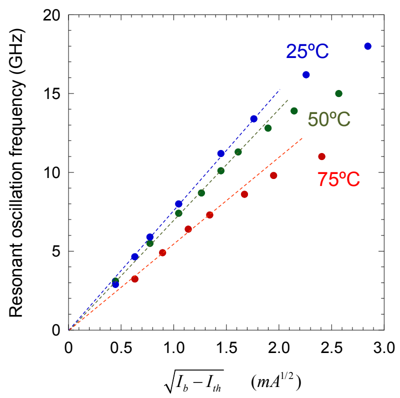

Fig. 3. Modulation efficiency of membrane DFB laser.

3. Conclusions

We demonstrated membrane-laser fabrication using BH growth on Si substrate. A fabricated laser exhibits high modulation efficiency.

References

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