GaInAsP/SOI Hybrid Laser with AlInAs-oxide Confinement Structure Fabricated by Plasma Activated Bonding

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***Abstract*— We realized GaInAsP/SOI hybrid Fabry-Pérot (FP) laser with AlInAs-oxide current confinement structure for PICs on a silicon platform. Using hybrid wafers by a plasma activated bonding technique, an AlInAs layer just above GaInAsP quantum wells was oxidized by wet oxidation. A threshold current of 50 mA and an external differential quantum efficiency of 11%/facet were obtained with the unoxidezed stripe width of 4.5 μm and the cavity length of 500 μm.**

Keywords—III-V/SOI hybrid laser; wafer bonding; oxidized AlInAs confinement structure

I. Introduction

Silicon photonics can give an attractive platform for low-cost and compact PICs except the lack of light sources. Some solutions have been proposed to include high performance light sources which could not be realized by conventional group IV materials and structures [1, 2]. Among them, III-V/SOI hybrid lasers by utilizing wafer bonding technique are widely studied and several groups achieved lasing operation [3]. Usually, such hybrid lasers use the proton implantation method to realize current confinement. However, this method cannot realize optical confinements at the same time like the buried hetero structure often used in conventional InP-based lasers. This time, we introduced oxidized AlInAs layer into the hybrid laser so as to confine both current and light, and realized III-V/SOI hybrid FP laser with improved lasing properties.

II. Experimental Results

Figure 1 shows the schematic cross sectional structure of the III-V/SOI hybrid laser. The III-V wafer consisted of GaInAsP 5QWs (6-nm compressively-strained GaInAsP well and 9-nm tensile-strained GaInAsP barriers) and 100 nm-AlInAs layer for oxidization. GaInAsP/SOI hybrid FP laser was fabricated by the following process. Firstly, an SOI wafer and an epitaxially grown GaInAsP/InP wafer were directly bonded by N_2 plasma activated bonding. Next, after removing the InP substrate and GaInAs etch-stop layer by HCl and H_2SO_4 solutions, SiN (300 nm) and SiO_2 (300 nm) were deposited. 5-9 μm-wide mesa stripes were formed by photolithography and ICP-RIE with $CH_4/H_2/Cl_2$ gases. After citric acid and NH_3 solution treatment, AlInAs layer was oxidized by the following sequence: 2-hours ramp-up time from 200°C to 480°C, 6-hours annealing at 480°C, and 2-hours cooling to 200°C. Figure 2 shows an IR microscopic top view of an oxidized mesa. The rate of oxidation was about 0.3 μm/hour. Next, SiO_2 was deposited for over cladding and SiO_2 windows were opened for electrodes. Figure 3 shows a microscopic top view of formed electrodes by Ti/Au evaporation after removing contact cap layers. Finally, laser cavities were formed by cleavage.

Figure 4 shows light output-current characteristics of a hybrid laser measured at a RT pulsed condition (1.0 μs pulse width and 0.1% duty cycle). This had an unoxidized width (stripe width) of 4.5 μm and the cavity length of 500 μm. A threshold current I_{th} of 50 mA (threshold current density of 2.2 kA/cm^2) and an external differential quantum efficiency η_d of 11%/facet were obtained. These values were improved compared with previous work (I_{th} = 64 mA, η_d = 9.8%/facet) without AlInAs confinement structure. Figure 5 shows its lasing spectrum at a bias current of $2I_{th}$, where FP modes at around 1522 nm with the resonant mode spacing of 0.56 nm were observed. Figure 6 shows light output-current characteristics for various unoxidized width (stripe width W_s) devices (the cavity lengths of 500 μm and 1000 μm). For devices with the stripe width W_s of 4.5 μm, lowest threshold current was obtained for both cavity lengths and lasing operation wasn't obtained with narrow mesa width of 1.5 μm and 2.5 μm. This is because the devices with less than 3.5-μm stripe width had insufficient optical gain.

References

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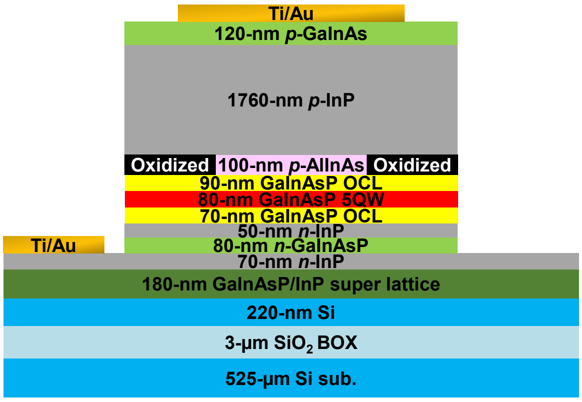

Fig. 1. Cross sectional structure of the fabricated laser.

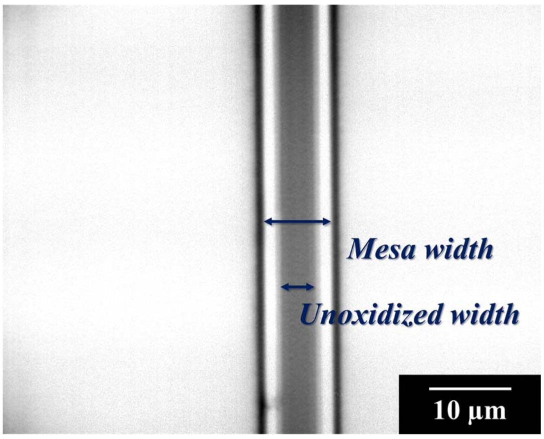

Fig. 2. IR microscopic top view of an oxidized mesa.

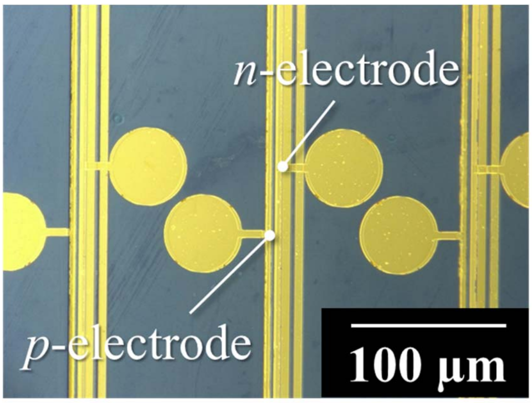

Fig. 3. Top view of the fabricated lasers.

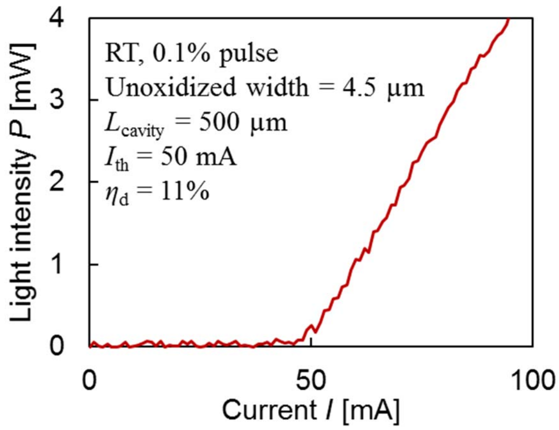

Fig. 4. Light output-current characteristics of a fabricated hybrid laser with the unoxidezed width of 4.5 μm and the cavity length of 500 μm.

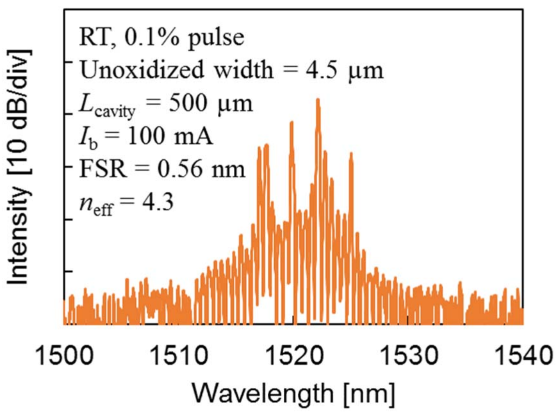

Fig. 5. Lasing spectrum of the hybrid laser shown in Fig.4.

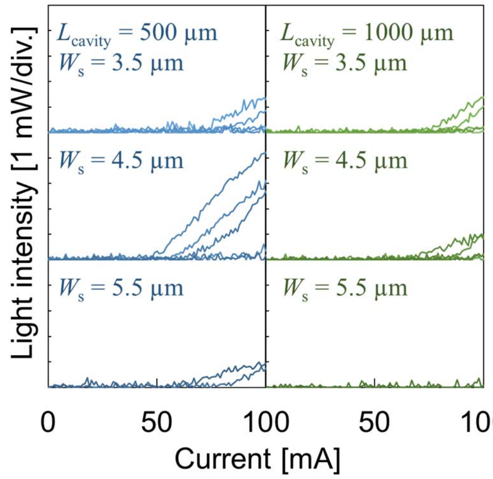

Fig. 6. Unoxidized width dependence of light output-current characteristics.

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