Novel optical-mode converter between III-V/SOI hybrid devices

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In order to realize photonic integrated circuits, we proposed III-V/SOI (Silicon-on-Insulator) hybrid lasers and SOAs (Semiconductor Optical Amplifiers) on Si platform using N_2 plasma activated bonding [1-2]. In the hybrid devices as it is shown in Fig. 1, optical mode converter is required for connecting Si waveguides and a III-V/SOI hybrid device because they have quite different optical mode field. Usually, a taper structure at the ends of hybrid section is introduced for obtaining high coupling efficiency, but formation of sufficiently narrow width tip for avoiding lasing of SOA is difficult, resulting in few report of hybrid SOA operation [2]. This time, for reduction of coupling loss and reflection which were caused by widening the tip width, we designed an optical mode converter by introducing an interlayer gap between Si waveguide and III-V layer while some of other groups use a SOI wafer with thick top-Si layer,.

Figure 2 shows a schematic structure of a proposed optical mode converter. In this time, we calculated the transmittance and reflection from (a) to (d) in Fig. 2. An input Si waveguide had 220-nm thick, 30-nm rib layer and 2-μm width. A III-V 1st mesa consisted of 180-nm thick GaInAsP/InP superlattice, 80-nm thick InP, 50-nm GaInAsP, and 50-nm InP.

Figure 3 shows a taper length L dependence of coupling efficiency for each interlayer gap H_{gap} when tip width is 500 nm. This indicates higher coupling efficiency can be obtained in wider interlayer gap H_{gap} and the coupling efficiency saturated over 30-μm taper length.

Figure 4 and 5 show calculation results of a III-V tip width $W_{tipIII\text{-}V}$ dependence of coupling efficiency and reflectivity for each interlayer gap H_{gap} when the taper length L is 100 μm. The coupling loss and reflectivity at H_{gap} = 0 nm increase with the wider tip width, but by introducing the interlayer, changes of them are very small up to $W_{tipIII\text{-}V}$ = 500 nm and reflection can keep under -40dB.

Figure 6 shows cross-sectional images of optical mode fields with H_{gap} = 0 nm and H_{gap} = 200 nm in the conditions of $W_{III\text{-}Vtip}$ = 500 nm and L = 100 μm. It is found out that unwanted reflection can be reduced by insert an interlayer and light behave as propagating in a directional coupler. From this figure, reduction of coupling loss and reflection is confirmed.

References

[1] Y. Hayashi *et al.*, "Low Threshold Current Density Operation of a GaInAsP/Si Hybrid Laser Prepared by Low-Temperature N_2 Plasma Activated Bonding," *Jpn. J. Appl. Phys.* vol. 52, no. 6, pp. 060202-1-3, May 2013.

[2] Y. Hayashi *et al.*," GaInAsP/silicon-on-insulator hybrid laser with ring-resonator-type reflector fabricated by N_2 plasma-activated bonding" *Jpn. J. Appl. Phys.* vol. 55, no. 8, pp. 082701-1-7, Aug. 2016.

[3] S. Cheung *et al.*, "Highly efficient chip-scale III-V/silicon hybrid optical amplifiers," *Opt. Express*, vol. 23, no. 17, pp. 22431-22443, Aug. 2015.

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Figures

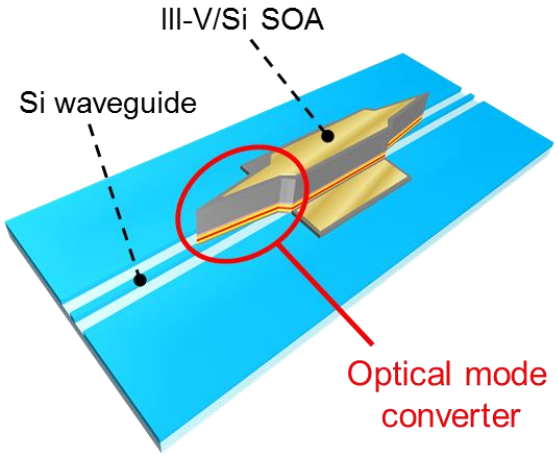

Fig. 1. Schematic image of the III-V/SOI hybrid device.

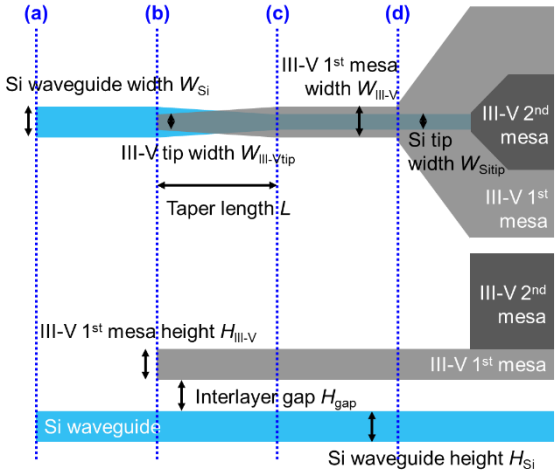

Fig. 2. Calculation model of taper structure (calculated from (a) to (d)).

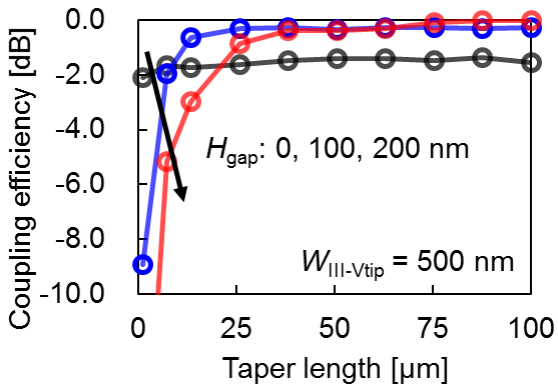

Fig. 3. Taper length dependence of coupling efficiency for each interlayer gap H_{gap}.

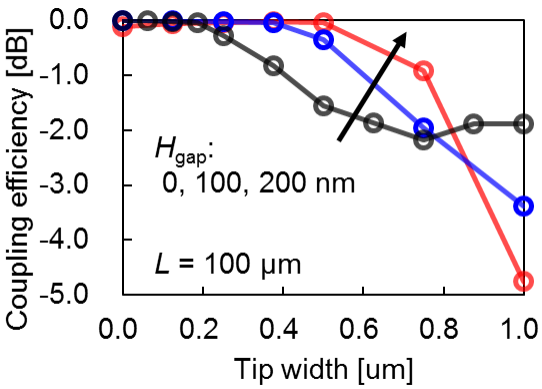

Fig. 4. Tip dependence of coupling efficiency for each interlayer gap H_{gap}.

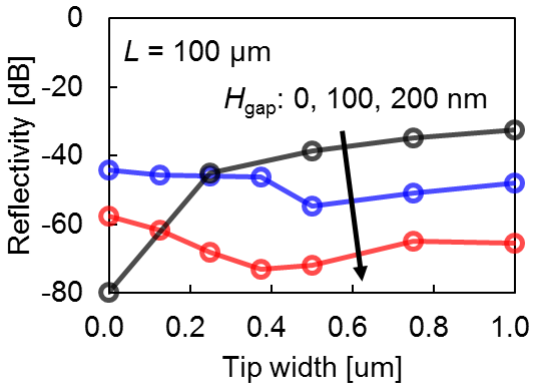

Fig. 5. Tip dependence of reflectivity for each gap thickness H_{gap}.

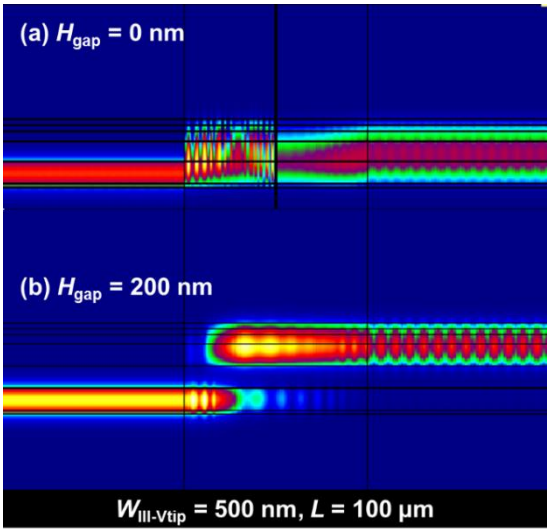

Fig. 6. Optical mode fields when (a)H_{gap} = 0 nm, and (b)H_{gap} = 200 nm.