Fabrication of 1.5μm GaInAsP LD on InP/Si Substrate using Hydrophilic Wafer Bonding Technique

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1.Introduction

Recent times, 1.5 μm laser emission on silicon platform has received a great deal of attention among the researchers. Our proposal to demonstrate MOVPE growth on wafer bonded InP/Si substrate is a unique approach for the monolithic integration. In the previous paper, we have already demonstrated 1.2 μm LD on InP/Si substrate. [1] In this paper, we have obtained for the first time 1.5 μm LD on the InP/Si substrate using the direct wafer bonding method.

2. Fabrication Process

For the fabrication process, we used commercially available (100) n-InP and (100) n-Si substrate polished on one side. The n-InP substrate goes through cleaning process using methanol and isopropyl alcohol. The Si substrate was dipped in HF to remove the native oxide and in NH_3:H_2O_2:H_2O for the removal of organic contaminants. Then, both the GaInAs/InP/GaInAs layer and the Si substrate surfaces were immersed in H_2SO_4:H_2O_2:H_2O solution, followed by rinsing in deionized (DI) water. The InP layer was then adhered with the Si substrate in DI water. Finally, the bonded sample underwent heating process by changing the temperature up to 400^0C in a N_2 atmosphere for several hours with some weight. During wafer bonding process, phosphorous atoms begin to desorb from the InP surface and then the migration occurs which results in the rearrangement of the atoms at the bonded interface. Through this process, InP/Si substrate was fabricated. [2] The epitaxial growth was performed in the low-pressure MOVPE in vertical flow rotating disk reactor using hydrogen as carrier gas. The growth temperature was set to be 630° C and the pressure was 60 Torr. The precursors namely TBA, TBP, TEG, TMI, DTBSi and DEZn were employed and the growth structure consists of: n-InP (1000nm)/n-Si (250μm), n-InP (330 nm), i-GaInAsP (170 nm, active layer), p - InP (900nm), p^+GaInAs (25 nm, contact layer). The ratio of GaInAsP was maintained at $Ga_{0.49}In_{0.51}As_{0.31}P_{0.69}$. Fig 1. shows the epitaxial III-V layer structure grown on the InP/Si substrate by MOVPE.

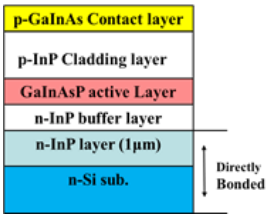

Fig. 1. Epitaxial Layer structure

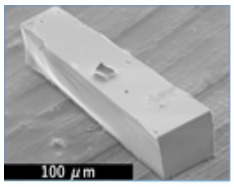

Fig.2 SEM image of the LD chip

After the MOVPE growth process, electrodes were formed using Au-Zn for p-InP layer and Au-Al for n-Si by evaporation technique. Fig.2 shows the SEM image of the fabricated LD chip. Both the facets of the laser chip were manually cleaved for the fabrication of Fabry-Perot LDs.

3.Results and Discussion

Fig.3 shows the lasing spectrum obtained at 273 K using the optical spectrum analyzer. The chip size is found to be 273 μm*62 μm. The peak wavelength of the obtained lasing spectrum at the maximum injection current 14.8 kA/cm^2 is 1508 nm which reveals that our fabrication process of InP LD on silicon substrate can become a novel platform for the future silicon photonic light sources.

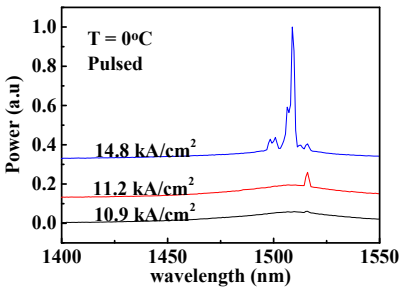

Fig. 3. Lasing Spectrum

References

[1] K.Matsumoto, "Room-temperature operation of GaInAsP lasers epitaxially grown on wafer-bonded InP/Si substrate," *Applied Physics Express,* 9, 062701, May 2016.
[2] K. Matsumoto, Junya Kishikawa, Tetsuo Nishiyama, Yuya Onuki, and Kazuhiko Shimomura, "Novel integration method for III-V semiconductor devices on silicon platform," *Jpn.J.App.Phys.,* 55, 112201, Sep.2016.