Integration of GaInAsP Laser Diode on Direct-Bonded Thin Film InP-Si Substrate

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Abstract

To realize a maximum and a qualitative output in the fabrication and integration of optical devices, Metal Organic Vapor Phase Epitaxy(MOVPE) growth on the wafer bonded substrates are of great interest for the researchers especially in the silicon photonics. In particular, we conceptualized and demonstrated MOVPE growth on wafer bonded InP/Si substrate and obtained lasing around 1.2 μ m. Prior to the growth, the preparation and making of wafer direct bonded InP/Si substrate is necessary in order to achieve an increase in the bonding strength, cleanliness and surface roughness without deformation for double heterostructure crystal growth. Among the various bonding techniques, in our study, we had employed the "Hydrophilic Wafer Bonding" which has advantages like surface roughness, cleanliness and uniform bonding.[1] To exhibit efficient and active laser chips, we report the formation of GaInAsP epitaxial crystal layers grown on the InP/Si directly bonded substrate for the fabrication and the measurements of laser diode at 1.2 μ m. Before starting the bonding process, commercially available InP (100) and Si (100) substrates are cleaned with HF solution. Mechanism of InP-to-Si bonding applying the hydrophilic wafer bonding process can be categorized into two stages viz., 1. Treatment with H_2SO_4: H_2O and adhesion at R.T 2. Heat treatment: In the heat treatment, we have changed the temperature from 100°C up to 400°C to reduce the void formation and applied the pressure. During wafer bonding process, we find that the 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 leading to strong bonding formation. Fig.1 shows the successfully bonded InP/Si wafer after the completion of the bonding process. 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 (250 μ m), n-InP(330 nm), i-GaInAsP (170 nm, active layer), P^- InP (500nm), P^+ InP (500 nm), P^+GaInAs (25 nm, contact layer) as shown in Fig. 2. We report here the lasing characteristics at the room temperatures. The ratio of GaInAsP was maintained at $Ga_{0.25}In_{0.75}As_{0.45}P_{0.55}$.[2] Electrodes were formed using Au-Zn on p-InP and Au-Al on n-Si by evaporation technique. Fig.3. shows the significant measurement of lasing spectrum of the chip cleaved with size 250 μ m *90 μ m at 1.238 μ m. As we increased the injection current, the lasing peak increased showing clear peaks. Thus we have successfully integrated GaInAsP laser diode on the InP/Si directly bonded substrate by MOVPE growth.

Fig. 1. Photo of Fabricated InP/Si wafer.

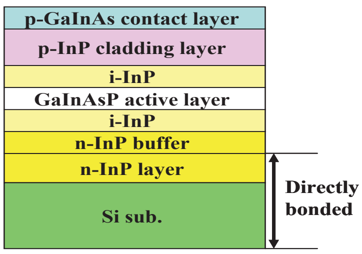

Fig. 2. Schematic image of grown structure

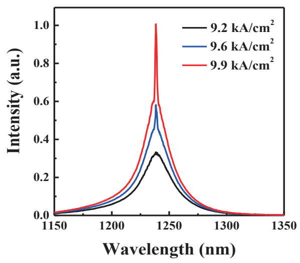

Fig. 3. Lasing Spectrum

[1] K. Matsumoto, R. Kobie, and K. Shimomura, "Thermal treatment for preventing void formation on directly-bonded InP/Si interface," *Jpn.J.App.Phys.,* **vol. 53,** 116502, Oct.2014.

[2] K. Matsumoto, K. Shimomura, Y. Kanaya, J. Kishikawa, Y. Yamamoto, T. Sukigara and T. Nishiyama "Epitaxial Grown GaInAsP-InP Laser on Wafer Bonded InP/Si Substrate," *42nd International Symposium on Compound Semiconductors* (ISCS), Wel106.6, CA, USA, Jun.2015.