Bonding of p-Si/n-InP wafers through surface activated bonding method at room temperature

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Abstract

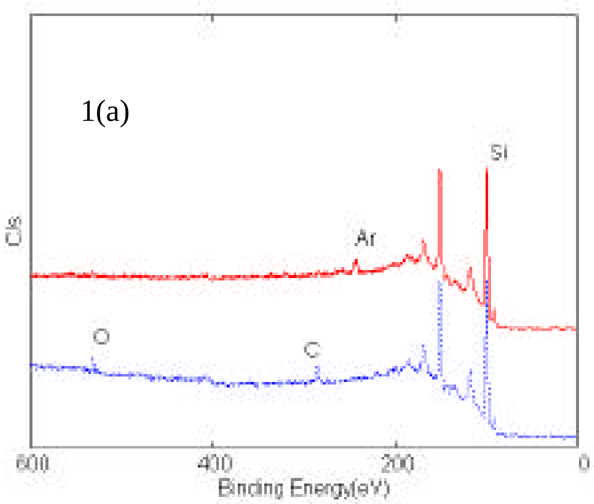
Silicon (Si) is transparent at the wavelength of Indium Phosphide (InP) based lasers, therefore, bonding between Si and InP is indispensable in the integration of quantum devices as well as microelectronic interconnection. Although bonding of lattice mis-matched Si and InP is possible through conventional bonding method, due to the discrepant thermal expansion coefficients the bonded interface suffers greatly from poor crystalline quality. However, surface activated bonding (SAB) method has successfully been implemented in integrating of dissimilar materials for quantum device as well as microelectronic interconnection applications. SAB is a method for joining two similar and/or dissimilar clean surfaces by means of the adhesive force of surface atoms under an external load in ultra high vacuum (UHV) at room temperature. The surfaces of two wafers to be bonded are cleaned by Argon fast atom beam (Ar-FAB). The purpose of this paper is to bond between the p-Si and n-InP wafers surfaces using SAB method at room temperature and further to investigate the performance of bonding interface.

Bare samples of p-Si (100) and n-InP (100) having dimension of (5X5) and (10X10) mm^2, respectively, were used. p-Si sample was cleaned with H_2SO_4 (4) and H_2O_2 (1) solution at 65 C for 10 min followed by a dip in 3% HF to remove oxide layers and then dried by blowing of nitrogen. n-InP sample was cleaned only with acetone and ethanol. The samples were sputtered cleaned with a 1.5 kV Ar-FAB of dose rate of 2.38×10^{14} $i/cm^2 \cdot s$ in the processing chamber for 180 seconds. Samples surfaces were investigated before and after sputtering using X-ray Photoemission Spectroscopy (XPS) and the results are shown in Fig. 1. The peaks of carbon and oxygen before sputtering in both samples are disappeared due to Ar exposure, indicating clean and active surfaces free from native oxide and absorbent. Usually active surface can be dirty with elapsing time even keeping at an UHV of 10^{-7} Pa, so samples with active surfaces were transferred to the bonding chamber as quickly as possible and bonding was performed with a load of 40 kgf.

Electrical measurements especially current-voltage (I-V) characteristics can give direct information about the condition of interface unless internal potential barriers withstand carriers. Electrodes were made before bonding by depositing Au at room temperature and Ni

at 723 K, respectively for p-Si and n-InP. Ohmic contacts are achieved in both samples. Fig. 2 shows I-V characteristic of p-Si and n-InP bonded interface. Typical p-n junction behavior is found, and perhaps no high resistance layer is generated across the interface. Reproducible I-V characteristics are observed in this work.

Fig. 3 shows the interface morphology of p-Si/n-InP bonded through SAB method. No bubbles are visible across the interface. In fact, a 300 nm wide intermediate layer is found to be due to possible artifacts during preparation of TEM sample and/or any absorbent effects on cleaned surfaces during transport. Further investigations are in progress.



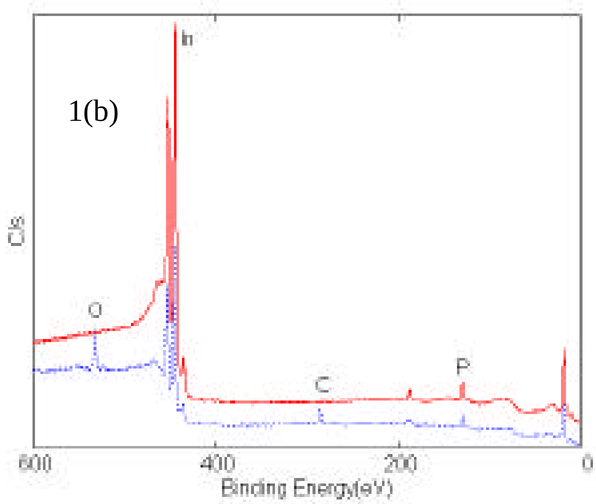


Fig. 1. XPS results of (a) p-Si and (b) InP before (lower curve) and after (upper curve) Ar-FAB sputtering.

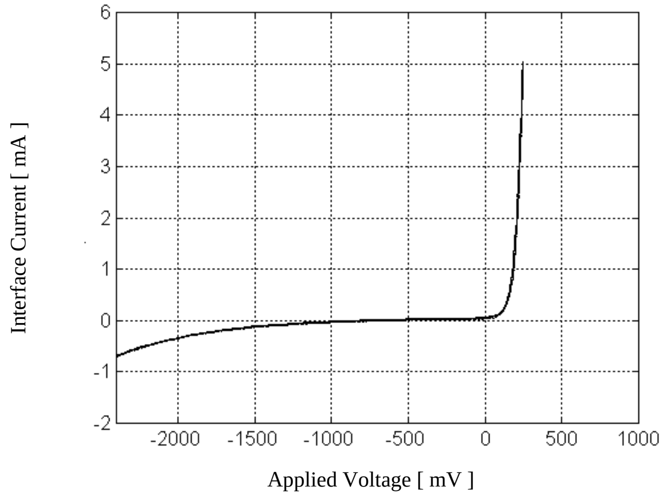


Fig. 2. I-V behavior of p-Si/n-InP interface bonded through SAB method.

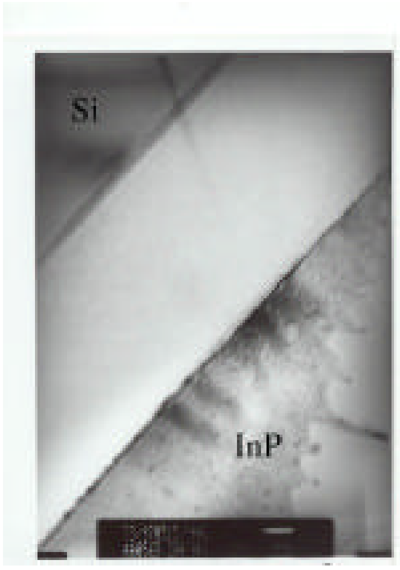


Fig. 3. TEM picture of n-Si/p-InP interface bonded through SAB method.