Investigation of the bonding strength and electrical characteristics of Si/Si, Si/InP and Si/GaAs interfaces bonded by surface activated bonding at room temperature and the influence of sputtering time and energy

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Abstract

Surface activated bonding (SAB) is a method that joins two similar and/or dissimilar clean surfaces by means of the adhesive force of surface atoms in an ultra high vacuum (UHV) at room temperature (RT). SAB has been found to be a key technique for the monolithic integration of similar and dissimilar semiconductors for fabricating optoelectronic devices. SAB is greatly attractive because of its capability of producing interfaces free from the dislocation and thermal stress that produce due to the lattice misfit and discrepant thermal expansion coefficients in the heteroepitaxial growth as well as the direct wafer bonding processes. In addition, SAB can integrate materials regardless of their orientation. This article reports on the bonding of Si, InP and GaAs wafers surfaces using SAB method at RT and the investigation of the bonding strength including the influence of sputtering time and energy on the electrical characteristics of bonded interface.

Bare samples of (100) orientation having dimension of (5X5X0.45) and (10X10X0.35) mm^3 were used. The resistivity of all samples was in the ranges of 0.002-0.03 Ohm.cm. Si samples were cleaned with a standard chemical cleaning process of semiconductors. On the other hand, GaAs and InP sample were cleaned with acetone and ethanol only. Then the samples were separately cleaned by sputtering with 0.6 and 1.5 keV Argon fast atom beam (Ar-FAB) ions dose rate of 2.38×10^{14} i/cm^2•s in the processing chamber in a pressure of $<10^{-6}$ Pa for 15-600 seconds. Finally the bonding of p-Si/n-Si, p-Si/n-InP and p-Si/n-GaAs was performed at RT in an UHV.

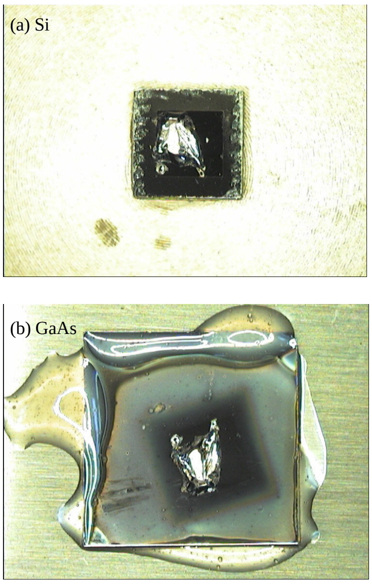

Figure 1. Typical bulk fracture of Si/GaAs bonded interface after tensile test.

Bonding of p-Si/n-Si, p-Si/n-InP and p-Si/n-GaAs has successfully been performed through the SAB method at RT. Bulk strength of the interface of p-Si/n-Si and p-Si/n-GaAs is achieved (Fig. 1). On the other hand, p-Si/n-InP were visibly separated from the interface after tensile test. A weak phase of indium is detected on the p-Si by X-ray Photoemmision Spectroscope (XPS) (Fig. 3) after debonding. In fact, the p-Si and n-InP samples are debonded from the interface of In/InP, but not across the bonded interface of Si and In that is confirmed by XPS and Atomic Force Microscope (AFM) (Fig. 2). Current-voltage results show non-existence of a high resistance interface layer across the interface. Remarkable dependence of sputtering time and energy on the interface current regardless of sample types is found to be due to the accumulation of sputtering induced defects (Fig. 4).

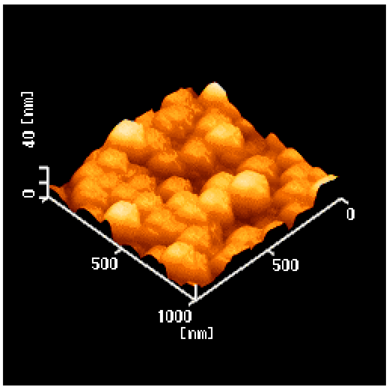

Figure 2. AFM image of p-Si after debonding.

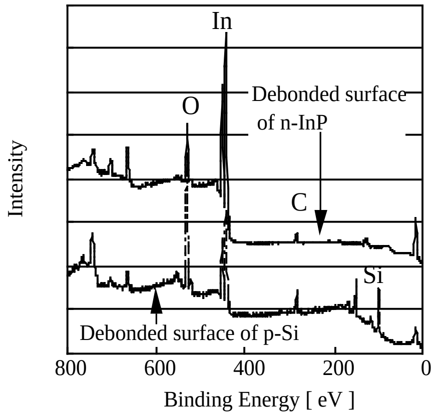

Figure 3. XPS spectra of p-Si and n-InP after debonding.

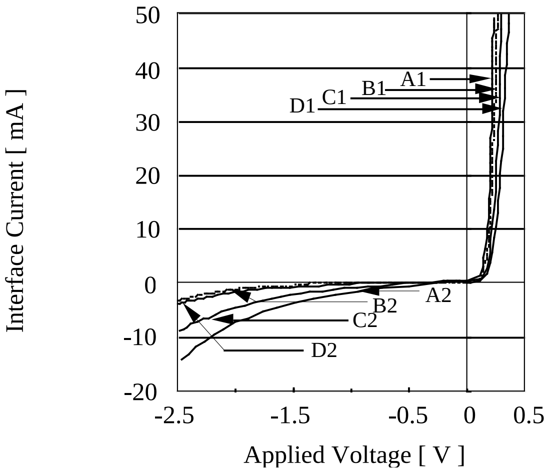

Figure 4. Ar-FAB energy and time dependence of interface current of p-Si and n-InP bonded at RT.