n^+Si/pGe Heterojunctions Fabricated by Narrow Membrane Bonding

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1. Introduction

The abruptness of the doping profile in a pn junction is highly demanded to ultimately control junction properties, and the heterojunction is also desirable to improve diode characteristics [1]. Using conventional epitaxy, abrupt Si/Ge heterojunctions with abrupt doping profile are hard to be formed because of severe limitations due to the traditional high temperature process and 4.2% lattice mismatch in Si/Ge. An alternative approach is a direct bonding of semiconductor materials which would ideally provide a complete freedom of material choice [2]. In addition, nearly no inter-diffusion of atoms at the interface is expected, leading to ultimately abrupt junctions. It is, however, an intrinsic challenge how to passivate the interface defects. In this work, n^+-Si/p-Ge heterojunctions fabricated by narrow membrane bonding are demonstrated.

2. Experiment

Bonded n^+Si/pGe heterojunctions were made starting from a SOI wafer with 70-nm-thick Si layer and a GeOI wafer with 60-nm-thick Ge layer. The SOI wafer was doped using PSG with $1\text{x}10^{18}$ cm^{-3}. Optical lithography was used to form 2μm-wide Ge and Si wires. The patterned SOI wafer was immersed in 5% HF solution for 2.5 hours to etch away the buried oxide layer. Then Si wires were picked up from the handle wafer SOI onto the thermal release tape. After cleaning using HF and acetone, Si wires were released from the tape to the patterned GeOI substrate by heating at 150°C for 3s. Annealing in O_2 at 400°C for 30s was done for about 1 nm SiO_2 growth to form the mask for subsequent processes. Si/Ge crosses were made with H_2O_2 and NH_3 for etching Ge and TMAH for etching Si. Al electrodes were formed and annealing in N_2 was done.

3. Results and Discussion

Fig.1 shows an SEM image of the bonded junction with 2μmx2μm. **Fig. 2** shows I–V characteristics of three typical bonded n^+Si/pGe heterojunctions. The on/off ratio can reach $1\text{x}10^2$ at -2V and 2V, and the turn-on voltage is around 0.4V which is roughly as theoretically expected, while Si/Ge heterojunctions made by large area membrane bonding with high turn-on voltage and with highly conductive junctions were so far reported [3][4]. In the on-state of an ideal n^+Si/pGe heterojunction, the difference of Si/Ge bandgaps leads to a much higher potential for the diffusion of holes than electrons as shown in **Fig.3**, in which the n^+Si/pGe band diagram in forward bias regime is illustrated considering the ultra-thin interface layer, which may be SiO_x layer naturally formed in the present process [5]. Therefore the on-current behaves like a n^+p Ge junction and hole carriers is ignorable, and the turn-on voltage is almost the same as that in Ge (0.3V) and much smaller than that in Si (0.7V). The results suggest that the interlayer may help passivate the defects formed intrinsically at the interface. The traps at the interface, however, are responsible for reverse leakage current due to the trap assisted tunneling.

Several challenges remain in the future. 1) Since the junctions are fabricated by surface to surface bonding, the contamination at both surfaces must be controlled. 2) The interface traps should be passivated to reduce the reverse leakage current. Although the interlayer formation control is obviously the key to further improvement, the simple process as well as abrupt dopant profile is quite viable and promising.

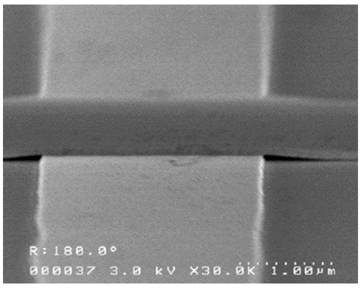

Fig. 1 An **SEM** image of the bonded junctions (areas: 2μm×2μm).

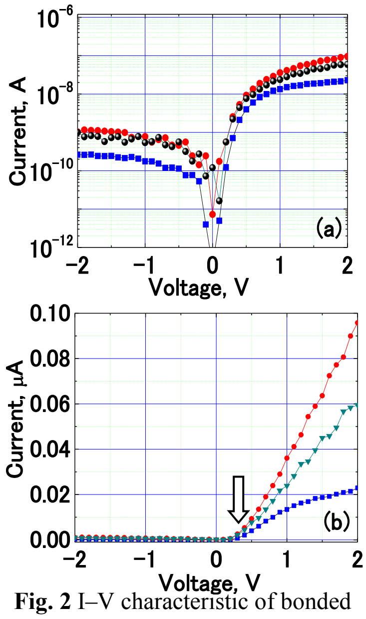

Fig. 2 I–V characteristic of bonded Si/Ge heterojunctions in (a) semi-log scale and (b) linear scale.

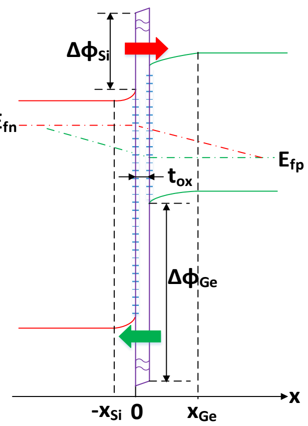

Fig. 3 Schematic representation of the n^+Si/pGe junction band diagram in forward bias regimes.

Reference:

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