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Mapping of Si/SiC Hetero p-n Junctions Using Scanning Internal Photoemission Microscopy

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Abstract

We have demonstrated scanning internal photoemission microscopy (SIPM) to map p^+-Si/n-SiC hetero p-n junctions. By focusing and scanning a laser beam over the junction, a photocurrent map was clearly obtained, and nm-deep scratches were visualized as a pattern. We found that this method is a powerful tool to investigate inhomogeneity of the heterojunctions.

1. Introduction

SiC is progressing as a material for power devices, and the combination of SiC with Si technologies has potential applications. Growth of SiC on Si to form heterojunctions is interest of realizing electron devices and solar cells. However, the large lattice mismatch between Si and SiC has limited their intrinsic performance. An alternative approach to achieve Si/SiC heterojunctions with high mechanical strength can be realized by using surface-activated bonding [1]. On the other hand, we have developed SIPM that can map the electrical characteristics of SiC and GaN Schottky contacts [2]. In this paper, we applied SIPM to characterize inhomogeneity of Si/SiC hetero p-n interfaces.

2. Device Fabrication and Characterization

We prepared p^+-Si (100) substrates and n-SiC epitaxial layers grown on n^+-4H-SiC substrates. Al/Ni/Au multilayers for ohmic contacts were evaporated on the backsides of p^+-Si and n^+-SiC substrates, respectively. Then, we bonded each of the p-type substrate to the SiC epitaxial substrate so that p^+-Si/n-SiC junctions were fabricated. Finally, the ohmic contacts on p-type Si and n-type SiC were sintered by rapid thermal annealing at 800 °C for 60 s in N_2 gas ambient [3].

Firstly, photoresponse (PR) measurement was conducted, in which a photocurrent was detected under illumination of a monochromatic light from the SiC side. Based on the internal photoemission effect, a PR spectra is expressed by the Fowler's equation [4]:

$$Y^{1/2} \propto h\nu - V_{th} \quad (1)$$

where Y is the photoyield (photocurrent per single photon), and V_{th} is the threshold energy.

Next, SIPM measurement was conducted by focusing and scanning green and red laser beams (λ_1 = 660 and λ_2 = 516 nm) over the junction. The diameter of the laser beam was less than 2 μm. From the Y maps at two different wavelengths, we can calculate a V_{th} map.

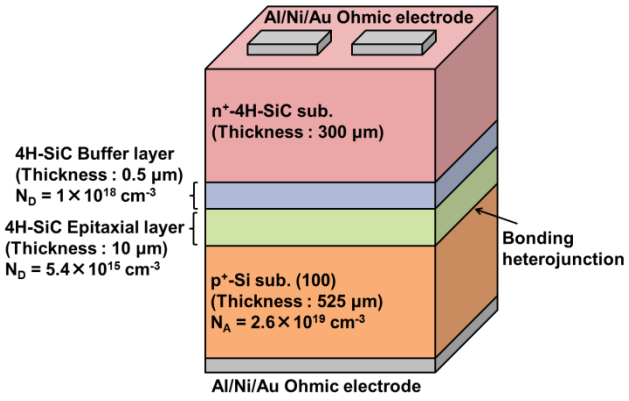

Fig. 1 Device structure.

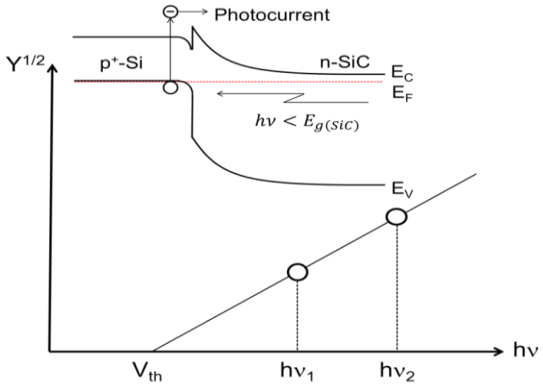

Fig. 2 Energy band diagram of the p^+-Si/n-SiC heterojunction and a PR spectra.

3. Results and Discussion

In the PR spectra, a large peak at the fundamental absorption edge near the band gap of SiC was observed. On the lower side of the peak, a linear region can be seen between 1.4 and 2.5 eV based on Eq. (1). The V_{th} was obtained to be 1.34 eV, which is consisted with energy difference from the top of the valence band of the p-Si side to

the bottom of the conduction band of the n-SiC side at the interface [3].

In the SIPM results, randomly-oriented sharp lines and aligned trenches are seen in the Y map. A similar pattern can be observed in an atomic force microscope image of the epitaxial SiC surface before bonding. Even in nm-deep scratches, there is a gap between Si and SiC at the junction. The photocurrent was not detected in these regions. In the V_{th} map, the same V_{th} values were obtained as the PR result where the junction was properly formed. These results tell us that SIPM is available for not only metal-semiconductor contacts but also semiconductor-semiconductor heterojunctions, and significantly sensitive for nm-order surface morphology.

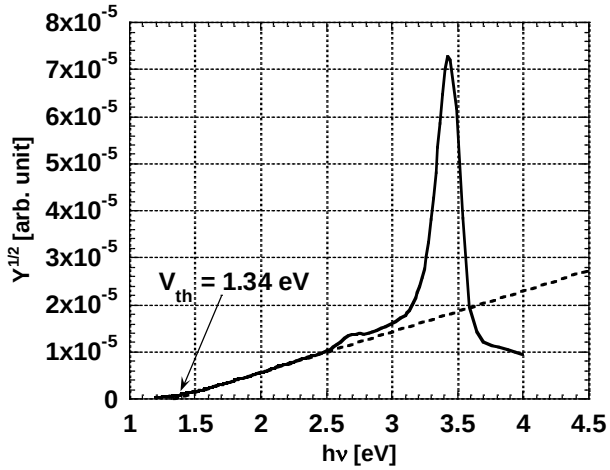

Fig. 3 PR spectra of the p^+-Si/n-SiC heterojunction.

4. Conclusions

The p+-Si/n-SiC hetero p-n junctions were characterized by PR and SIPM measurements. In the PR spectra, a linear relationship was found between $Y^{1/2}$ and hν. The V_{th} was obtained to be 1.34 eV. In the SIPM results, Y and V_{th} maps were clearly obtained, and nm-deep scratches were sensitively visualized as a pattern. We found that this method is a powerful tool to investigate inhomogeneity of the heterojunctions.

Acknowledgement

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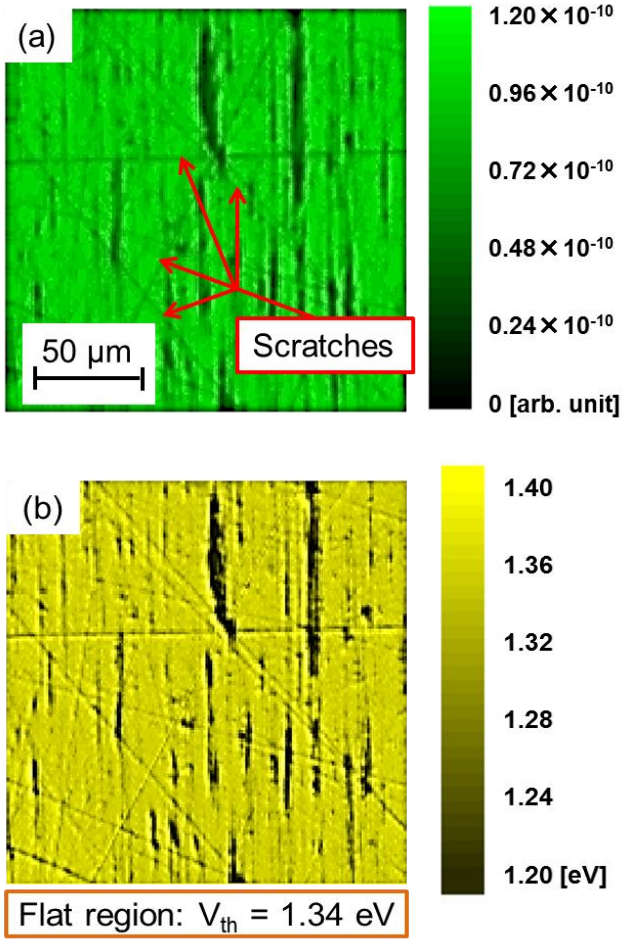

Fig. 4 (a) Y (λ = 516 nm) and (b) V_{th} maps of the p^+-Si/n-SiC heterojunction by SIPM.

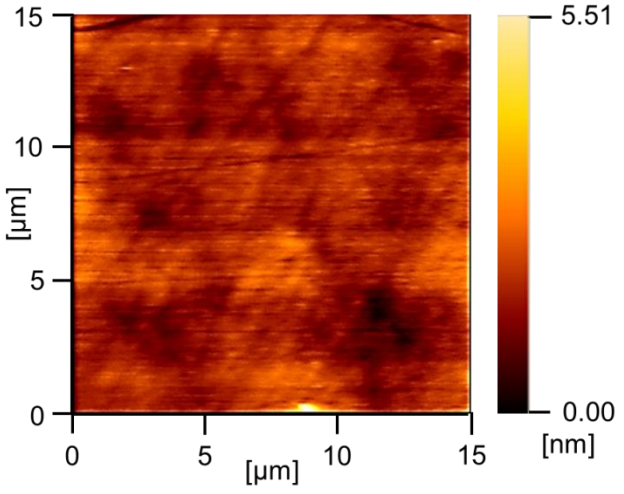

Fig. 5 AFM image of the SiC epitaxial layer surface before bonding.