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Observations of Inhomogeneity of 3C-SiC Layers Grown on 6H-SiC Substrates Using Scanning Internal Photoemission Microscopy

Kenji Shiojima[1], Naoki Mishina[1], Naoto Ichikawa[2], and Masashi Kato[2]

[1] Graduate School of Electrical and Electronics Engineering, Univ. of Fukui
3-9-1 Bonko, Fukui 910-8507, Japan
Phone: +81-776-27-8560 E-mail: shiojima@u-fukui.ac.jp
[2] Dept. of Eng. Phys., Electron. & Mech., Nagoya Inst. of Tech.,
Gokiso, Showa, Nagoya, Aichi 466-8555, Japan

Abstract

3C-SiC layers epitaxially grown on 6H-SiC substrates have been characterized by using scanning internal photoemission microscopy (SIPM). SIPM clearly imaged domain patterns consisting of 3C- and 6H-SiC. SIPM also revealed that boundaries of the domains have lower Schottky barrier. These results are consistent with the current-voltage characteristics.

1. Introduction

Among the SiC poly-types, 3C-SiC has advantages of an isotropical crystal structure and high electron and hole mobilities for electron device applications [1]. Moreover, electrolyte/ p-3C- SiC Schottky interfaces have been applied for photocathodes in hydrogen production of water splitting because of suitable energy bandgap for visible light absorption and chemical stability in solution [2]. However, due to lack of 3C-SiC bulk crystals, heteroepitaxial growth on Si, 4H-, or 6H-SiC substrate is not avoidable. Thus, the crystal quality of 3C-SiC is not as good as those of 4H-and 6H-SiC.

On the other hand, we have developed SIPM that can map the electrical characteristics of Si, GaAs, SiC and GaN Schottky contacts [3]. In this paper, we applied SIPM to characterize inhomogeneity of 3C-SiC layers grown on 6H-SiC substrates by forming Schottky contacts.

2. Device Fabrication and Characterization

3C- 30-μm-thick Al-doped p-SiC (Al<1×10^{15} cm^{-3}) films were grown on 6H-semi-insulating-SiC (0001) substrates without an off-angle (Fig. 1). Then, Ti/Au/Ni ohmic contacts were deposited on the 3C-SiC surface, and annealed at 1000°C for 5 min. Finally, Ni (20 nm thick) Schottky contacts (1 mmϕ) were formed on the same surface by electron beam evaporation.

SIPM is based on the internal photoemission (Photoresponse (PR)) measurement. When a monochromatic light with a photon energy ($h\nu$) exceling Schottky barrier height ($q\phi_B$) is incident on the Ni/p-type 3C-SiC interface, holes in the metal can surmount the barrier generating a photocurrent. Where photoyield (Y) is defined as photocurrent per number of incident photons. When $h\nu$ is close to the energy bandgap of 3C-SiC, 2.2 eV, due to fundamental absorption, a large photocurrent can flow as shown in Fig. 2. In the SIPM measurements, one focuses and scans the beam over the interface to obtain 2-dimensional imaging of Y with different wavelengths; red ($\lambda = 660$ nm) and green ($\lambda = 517$ nm). The diameter of the laser beam was less than 2 μm.

3. Results and Discussion

We found a variation in surface morphology, where the surfaces consist of rough and flat regions. Conventional PR measurements were conducted, and, in the case a monochromatic light was illuminated all over the contact. In a square-root-plot of the PR spectrum, a linear region can be seen in the lower energy side of the fundamental absorption peak of 3C- and 6H-SiC (Fig. 3) for most of the samples. We can expect that, in the SIPM measurements, the red laser can excite carriers to surmount $q\phi_B$ based on the internal photoemission, and the green one can mainly generate photocurrent due to the absorption in 3C-SiC. However, the contact (dot 1) with an entire rough surface showed no linear region in PR spectra and much smaller reverse biased current in I-V characteristics (Fig. 4).

In the green SIPM results (Fig. 5), the flat regions were clearly visualized with a large Y signal as observed in the optical microscope image. SIPM revealed that the flat and rough regions were originated from 3C- and 6H-SiC domains, respectively. These results are consistent with the PR and I-V results. In the red map, Y was significantly increased in the boundaries only between 3C- and 6H-SiC domains. These results indicate that the Ni/p-SiC interface formed on such boundaries has a lower $q\phi_B$, because of large miss-orientation.

4. Conclusions

SIPM measurements were applied to map 3C-p-SiC epitaxial layers on 6H-SiC substrates. The properly grown 3C-SiC regions and domain boundaries were clearly visualized in the Y maps. We found that this method is a powerful tool to investigate inhomogeneity of both crystal quality and electrical characteristics.

Acknowledgement

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References

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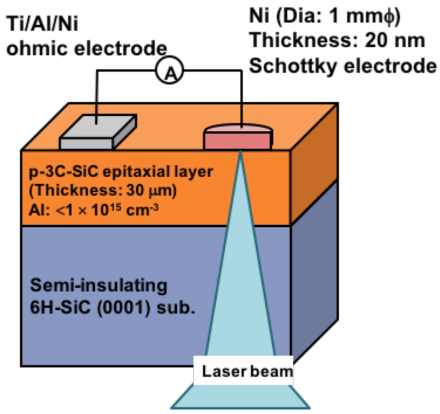

Fig. 1 Device structure.

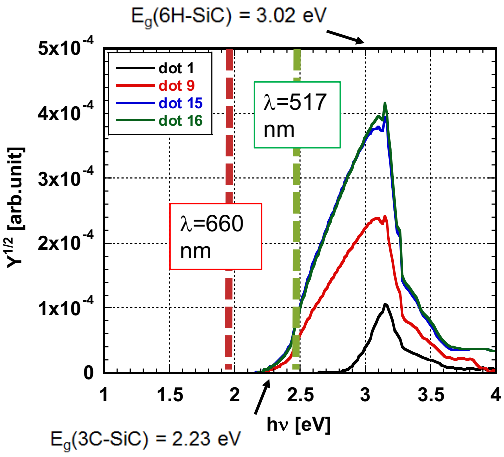

Fig. 3 Photoresponse spectra of the Ni/p-3C-SiC contact.

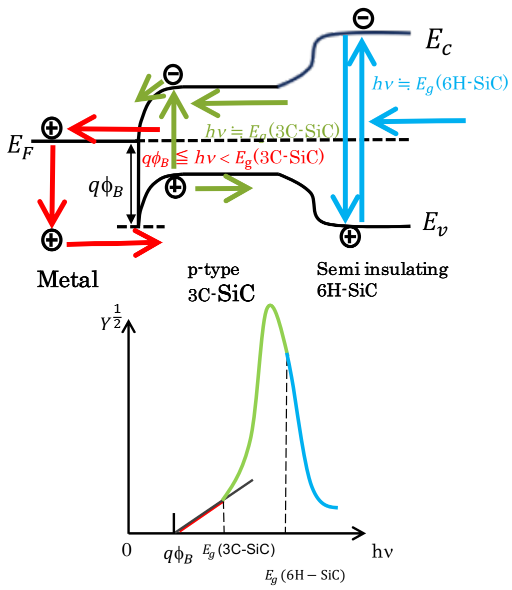

Fig. 2 Energy band diagram and internal photoemission spectrum of a metal/p-3C-SiC/SI-6H-SiC Schottky contact.

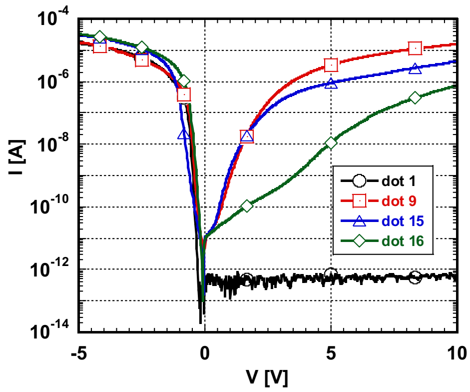

Fig. 4 I-V characteristics of the Ni/p-3C-SiC contacts.

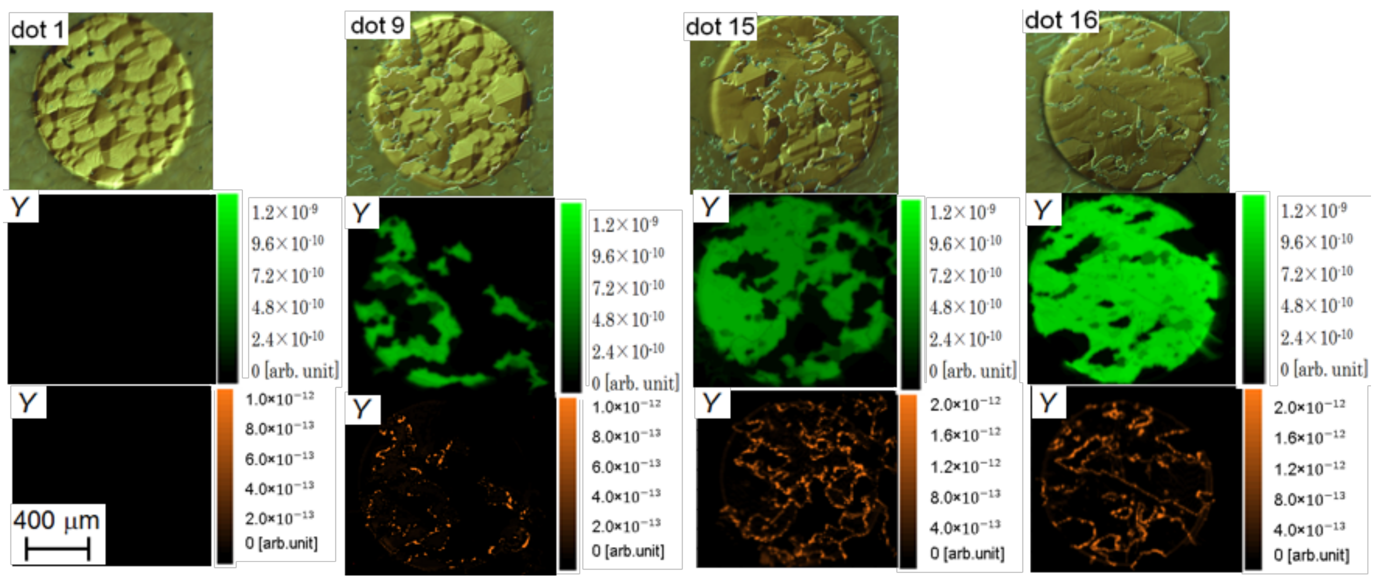

Fig. 5 Optical microscope images and Y maps with the green ($\lambda = 517$ nm) and red (λ = 660 nm) lasers of the Ni/3C-SiC contacts. The contacts have a larger area of the flat surface regions from dot1 to 16 in turn.