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2-Dimentional Characterization of 3C-SiC Layers Using Scanning Internal Photoemission Microscopy

Kenji Shiojima[1], Masato Shingo[1], Naoto Ichikawa[2], Masashi Kato[2]

[1] Graduate School of Electrical and Electronics Engineering, Univ. of Fukui
3-9-1 Bunkyo, 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 4H-SiC substrates have been characterized by using scanning internal photoemission microscopy (SIPM). By focusing and scanning a laser beam over the Ni Schottky contacts formed on the 3C-SiC layer, domain boundaries were clearly visualized as a photocurrent pattern. By combining photocurrent maps with red and green lasers, we found that Schottky barrier height is lower and larger recombination occurs in the boundary regions.

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/3C-p-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 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 4H-p^+-SiC substrates with an off-angle of 0.7° toward [$11\bar{2}0$] direction. 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 exceling Schottky barrier height ($q\phi_B$) is incident on a metal/p-type semiconductor interface, holes in the metal can surmount the barrier generating a photocurrent. The $q\phi_B$ can be determined from the photocurrent, using Fowler's equation; $Y^{1/2} \propto h\nu - q\phi_B$. Where Y is the photoyield that is photocurrent per number of incident photons. When the photon energy is close to the energy bandgap, due to fundamental absorption, a large photocurrent can flow. In the SIPM measurements, one focuses and scans the beam over the interface to obtain 2-dimensional imaging of Y with different wavelengths; red (λ = 659 nm) and green (λ = 517 nm). The diameter of the laser beam was less than 2 μm.

3. Results and Discussion

Conventional PR measurements were conducted, where a monochromatic light was illuminated over the contact. In a square-root-plot of the PR spectrum, two linear regions based on the Fowler's equation can be seen in the lower energy side of the fundamental absorption peak. These regions indicate that the contact consists of a parallel connection of two different interfaces with $q\phi_B$'s = 1.33 and 1.85 eV. We also expect that, in the SIPM measurements, the red laser can excite electrons to surmount the lower $q\phi_B$ based on the internal photoemission, and the green one can mainly generate current due to the absorption in 3C-SiC.

In the SIPM results, domain boundaries of 3C-SiC crystals were clearly visualized in the Y maps as observed in the optical microscope image. In the red map, Y was significantly increased in the boundaries, but the opposite contrast was seen in the green map. These results indicate that the Ni/p-SiC contact formed on the domain boundaries has a lower $q\phi_B$ and larger recombination probability, because of different crystal orientation and poor crystal quality.

4. Conclusions

SIPM measurements were applied to map 3C-p-SiC epitaxial layers. The domain boundaries were clearly visualized in the Y maps and had a lower $q\phi_B$ and larger recombination probability. We found that this method is a powerful tool to investigate inhomogeneity of crystal quality and electrical characteristics.

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References

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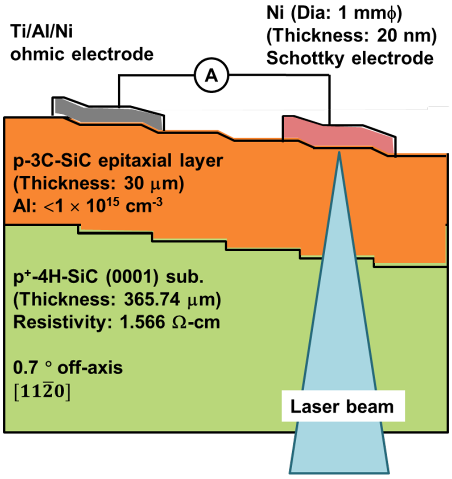

Fig. 1 Device structure.

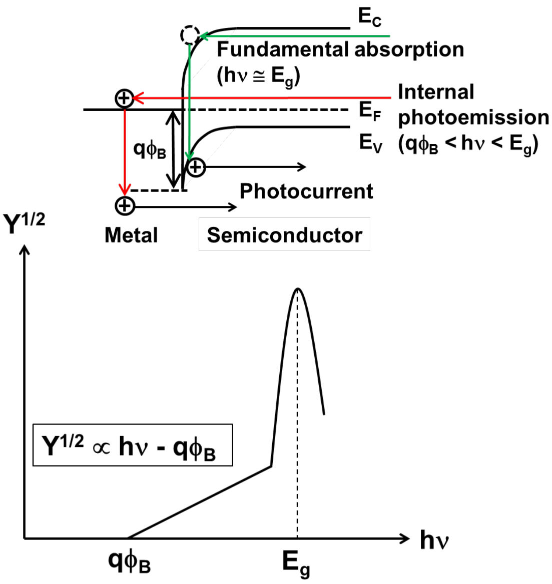

Fig. 2 Energy band diagram of a metal/p-type semiconductor Schottky contact and an internal photoemission spectrum.

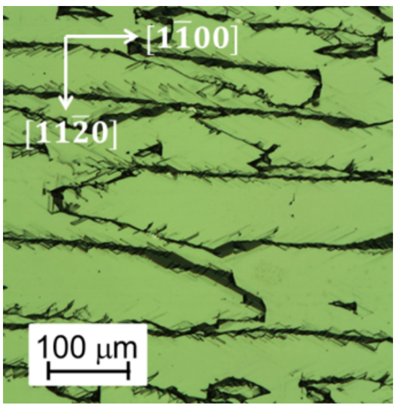

Fig. 3 Optical microscope image of the Ni/3C-SiC contact.

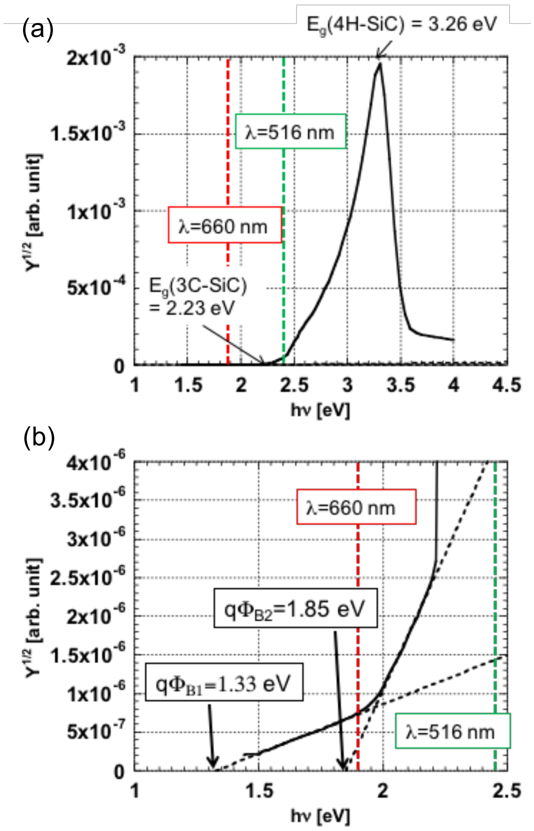

Fig. 4 Photoresponse spectra of the Ni/3C-SiC contact ((a) whole and (b) magnified).

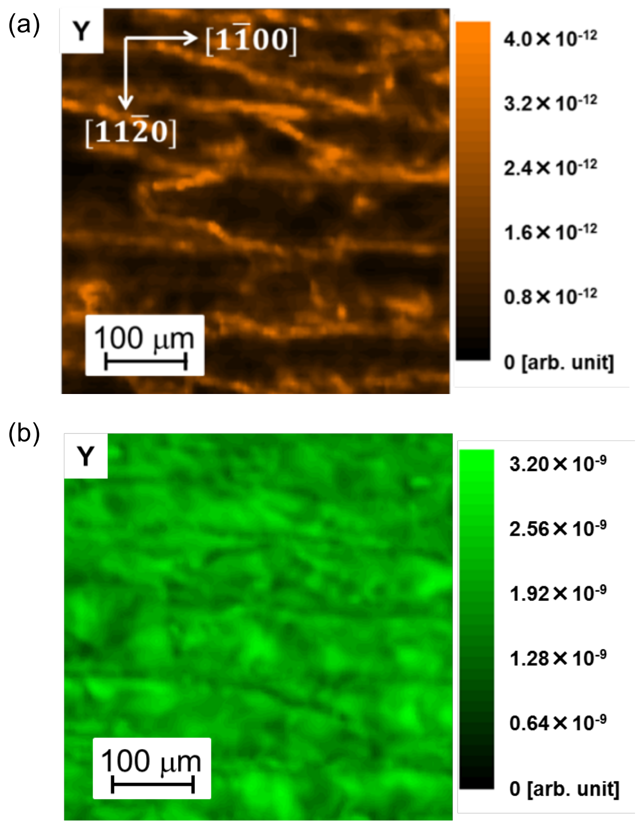

Fig. 5 Y maps of the Ni/3C-SiC contact at λ = (a) 660, and (b) 516 nm in the same frame as shown in Fig. 3.