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Defect Observations of Ni/AlGaN/GaN Schottky Contacts on Si Substrates Using Scanning Internal Photoemission Microscopy

Kenji Shiojima[1], Hiroaki Konishi[1], Hiroyoshi Imadate[1], Yuya Yamaoka[2, 3], Kou Matsumoto[2], and Takashi Egawa[3]

[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] Taiyo Nippon Sanso Corp.
10 Ohkubo, Tsukuba, Ibaraki 300-2611, Japan
[3] Nagoya Inst. of Tech.,
Gokiso, Showa, Nagoya, Aichi 466-8555, Japan

Abstract

We have demonstrated scanning internal photoemission microscopy (SIPM) to characterize crystal defects in AlGaN/GaN hetero structure grown on Si substrates. SIPM visualized unusually grown regions due to cracking of the Si substrates. In these regions, photocurrent was large, which was consistent with leaky *I-V* characteristics. SIPM also detected small photocurrent regions on hillocks, which were not visible with an optical microscope.

1. Introduction

GaN related materials have been intensively developed for high-power amplifiers and switching devices. For these applications, GaN wafers grown on Si substrates have an advantage in cost. However, due to large lattice missmatch between GaN and Si, the crystal quality of epitaxial layers is not as good as those on free-standing GaN substrates [1].

On the other hand, we have developed SIPM that can map the electrical characteristics of Si, GaAs, SiC and GaN Schottky contacts [2, 3]. In this paper, we applied SIPM to characterize crystal defects in AlGaN/GaN layers grown on Si substrates.

2. Device Fabrication and Characterization

2.2-µm-thick buffer, 1.1-µm-thick undoped-GaN, 1-nm-thick AlN spacer, 25-nm-thick AlGaN barrier layers were grown on 8' Si substrates as shown in Fig. 1. The Al content of the barrier layer is 25%. Then, Ni (100-nm thick) Schottky contacts (200 µmϕ) were formed on the AlGaN surface by electron beam evaporation. Finally, InGa ohmic contacts were deposited on the same surface.

SIPM is based on the internal photoemission (Photoresponse (PR)) measurement. When a monochromatic light with a photon energy (hν) below the energy bandgap and exceling Schottky barrier height ($q\phi_B$) is incident on a metal/semiconductor interface, electrons in the metal can surmount the barrier generating a photocurrent, where Y is defined as photoyield that is photocurrent per number of incident photons. In the SIPM measurements, one focuses and scans the beam over the interface to obtain 2-dimensional imaging of Y.

Normally we use visible lights for GaN Schottky contacts, however, in this sample structure, Si substrates absorb the lights with hν > the energy bandgap of Si. Therefore, we polished the Si substrates to be around 30-µm thick so that the visible lights can go through while keeping the mechanical support of the GaN layer.

3. Results and Discussion

In the conventional PR spectrum as shown in Fig. 2, where a monochromatic light was illuminated over the contact, PR signal was detected around $\lambda = 660$ nm, even though a portion of the incident light was absorbed in the Si substrate. We also observed modulation in the spectra, which can be explained with the interference of the incident light in the Si substrate.

For the typical Ni dot, rectifying *I-V* characteristics and uniform distribution in the Y map with a red laser ($\lambda = 660$ nm) were obtained as shown in Figs. 3 and 4. On the other hand, the Ni dot including a crack showed large leakage current and a large Y pattern. These results indicate that the interface of Ni/unusually-grown layer on the crack has smaller $q\phi_B$. We also found a pattern of small Y regions for the dot without the same pattern in the microscope image. These regions can originate from Al-rich AlGaN regions on hillocks, which resulted in the interface with larger $q\phi_B$.

4. Conclusions

SIPM was applied to characterize crystal defects in AlGaN/GaN structure grown in Si substrates. Since unusually grown regions on cracks and hillocks were visualized by thinning the Si substrates, we confirmed that this method is utilized to investigate inhomogeneity of crystal quality and electrical characteristics.

Acknowledgement

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References

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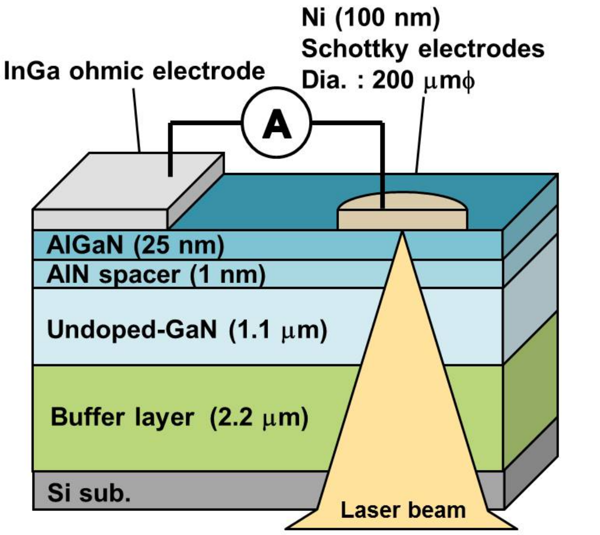

Fig. 1 Ni Schottky contacts formed AlGaN/GaN HEMT structure grown on Si substrates. Because the incident visible laser beam was absorbed, the Si substrates were thinned to be about 30 μm thick.

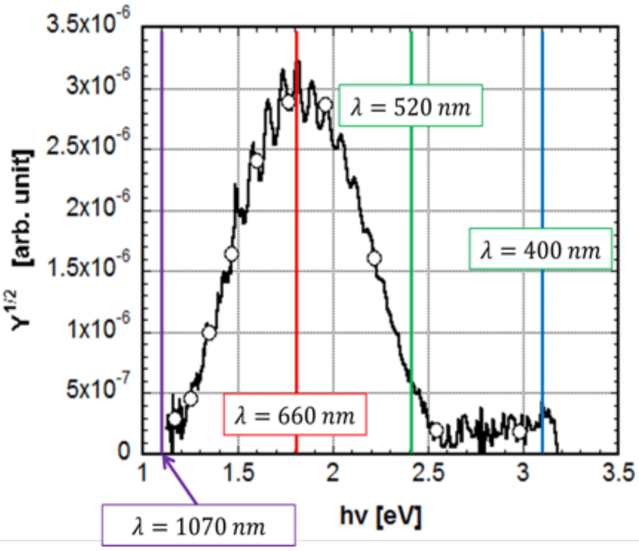

Fig. 2 Typical PR spectra of the Ni/AlGaN/GaN Schottky contact. The signal was detected around $\lambda = 660$ nm.

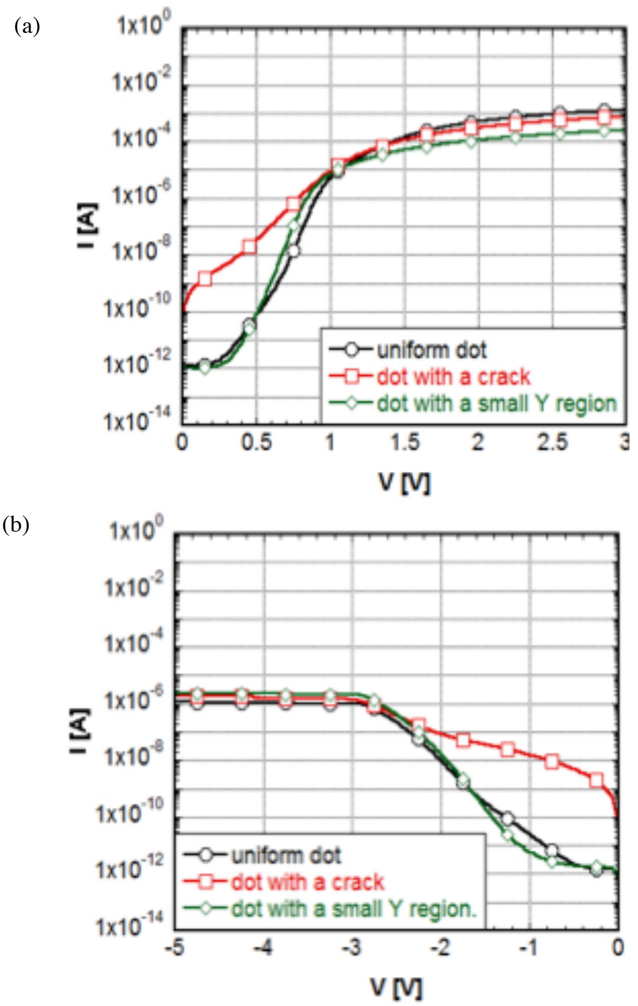

Fig. 3 (a) Forward and (b) reverse I-V characteristics of the Ni/Al-GaN/GaN Schottky contacts: (i) uniform, (ii) with a crack, and (iii) with a small *Y* region.

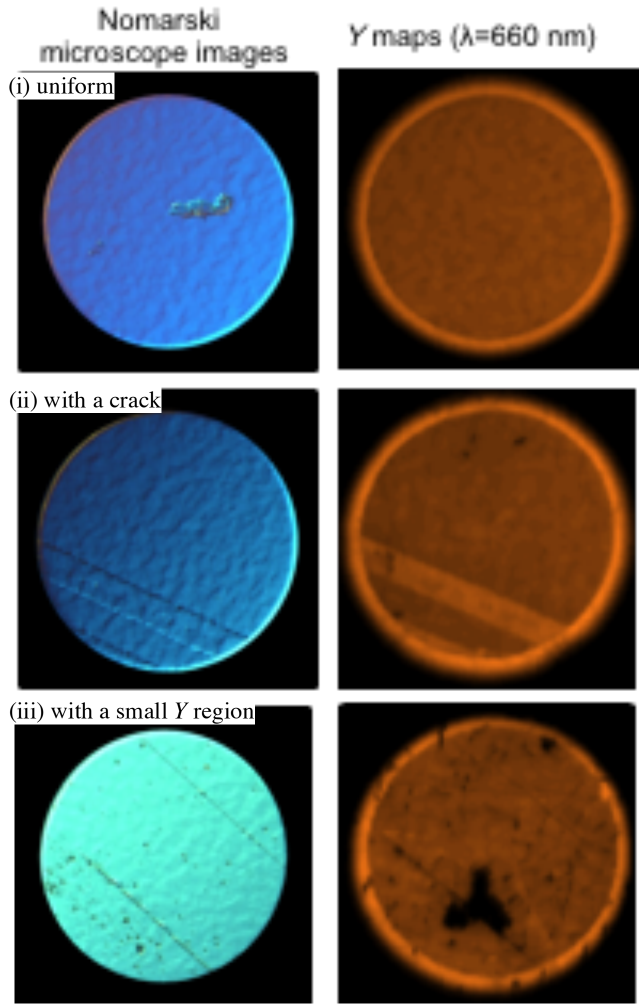

Fig. 4 Microscope images and Y maps at λ = 660 nm of the same Ni/AlGaN/GaN contacts as shown in Fig. 3.