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2-Dimentional Characterization of Ion-implantation Damage in GaN Schottky Contacts Using Scanning Internal Photoemission Microscopy

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Abstract

Nitrogen-ion-implantation damages on GaN have been characterized using scanning internal photoemission microscopy (SIPM). By focusing and scanning a laser beam over the Schottky contacts, the implantation damages were visualized as a photocurrent pattern. We found that the photocurrent decreased in the implanted regions due to carrier depletion, and the induced damages did not spread from the implanted regions within the special resolution of the equipment. This method is a powerful tool to map highly resistive regions.

1. Introduction

An ion-implantation technique is one of the most standard ways to fabricate transistors to form channel, contact, and isolation regions. This technique has been also applied for GaN field effect transistors. Especially, for device isolation, since ion-implantation has an advantage in surface planarization than mesa etching, N and proton implantations have been studied [1]. In general, isolation layers were characterized by sheet resistance using Hall and Van der Pauw measurements, or leakage current between devices. During the implantation, damages are induced at the same time, but distribution of the damages in a lateral direction has not been studied well. 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 ion-implantation damages in GaN Schottky contacts.

2. Device Fabrication and Characterization

Thin low-temperature AlN, 1-µm-thick undoped GaN and 1-µm-thick Si-doped n-GaN (8×10^{16} cm^{-3}) films were grown on sapphire substrates using MOCVD. N ion-implantations were conducted with an ion dose of 1×10^{14} or 1×10^{15} cm^{-2} at 80 keV in 42×108 µm^2 areas on the n-GaN surfaces. Activation annealing was not performed. Then, Ni (100 nm thick) Schottky contacts (200 µmϕ) were formed on the n-GaN surface including the implanted regions by electron beam evaporation.

SIPM measurements were conducted with blue, green and red laser beams ($\lambda = 447$, 517, 659 nm). The laser beams were focused at the metal/GaN interface and scanned over the contact. Photocurrent was detected at each wavelength, and Schottky barrier height ($q\phi_B$) was calculated based on the Fowler's equation [3]:

$$Y^{1/2} \propto h\nu - q\Phi_B \qquad (1)$$

where Y is the photoyield (photocurrent per single photon). From the Y maps at least two different wavelengths, we can calculate a $q\phi_B$ map. The diameter of the laser beam was less than 2 µm.

3. Results and Discussion

In the I-V characteristics, rectifying characteristics were preserved even after the ion-implantation. The $q\phi_B$ increased by 0.08 eV due to the implantation process.

In the SIPM results, the implanted region was clearly observed in the Y map at each wavelength. Y was significantly decreased and uniform, and $q\phi_B$ increased by 0.28 eV in the implanted region. As the ion dose increased, more decrease of Y was seen. These results indicate that carrier depletion by induce damages is responsible for low Y.

The line profiles of Y across the implanted region for the both ion doses were the same as that of the designed plantation pattern within the resolution of the equipment. It was found that spreading of the damages did not occur in the as-implanted condition.

4. Conclusions

The SIPM measurements were applied to map ion-implantation damages in GaN Schottky contacts. Y was significantly decreased in the implanted region. Spreading of the damages did not seen in the as-implanted condition. We found that this method is a powerful tool to investigate inhomogeneity of surface damages.

Acknowledgement

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References

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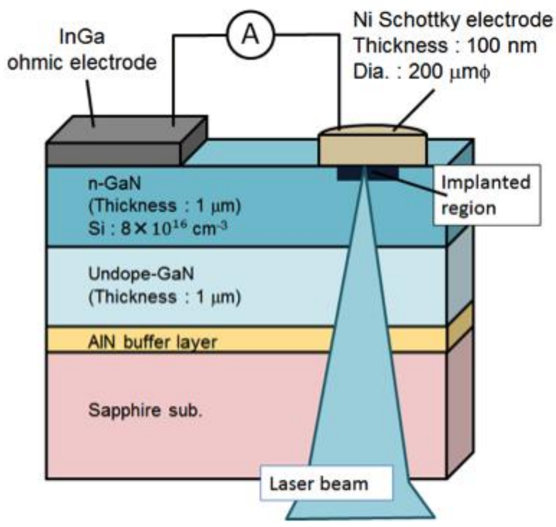

Fig. 1 Device structure.

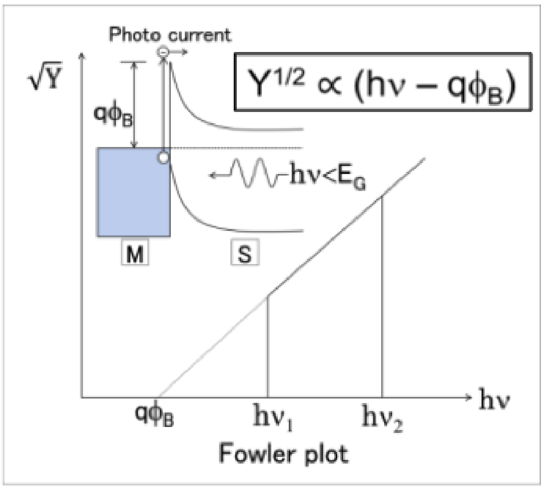

Fig. 2 Energy band diagram of the metal/semiconductor Schottky contacts and an internal photoemission spectrum.

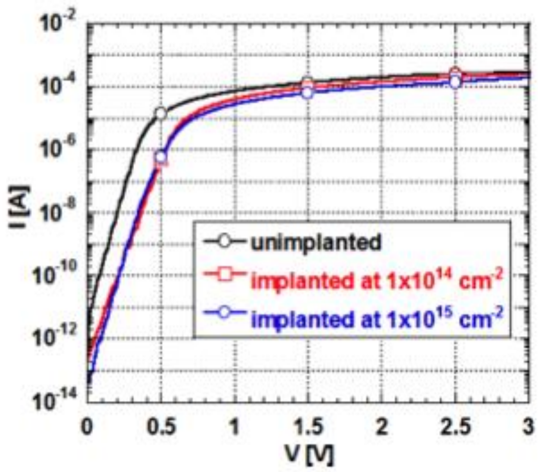

Fig. 3 Forward I-V characteristics of ion-implanted GaN Schottky contacts.

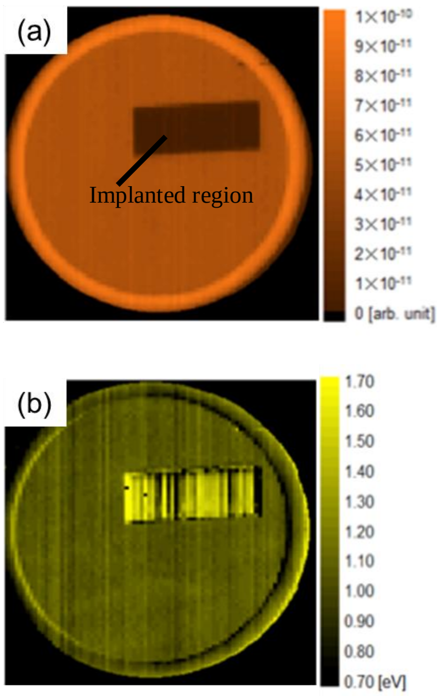

Fig. 4 (a) Y (λ = 660 nm) and (b) $q\phi_B$ maps of the ion-implanted n-GaN Schottky contacts at an ion dose of $1{\times}10^{14}$ cm^{-2} by SIPM.

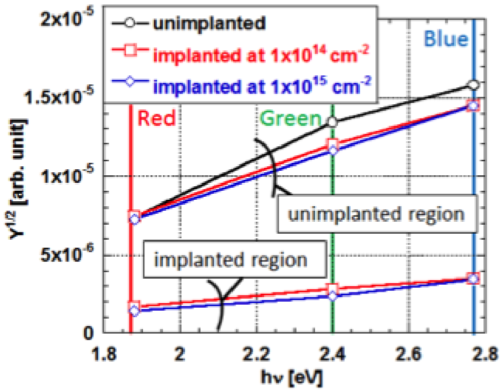

Fig. 5 Internal photoemission spectra of the ion-implanted n-GaN Schottky contacts.

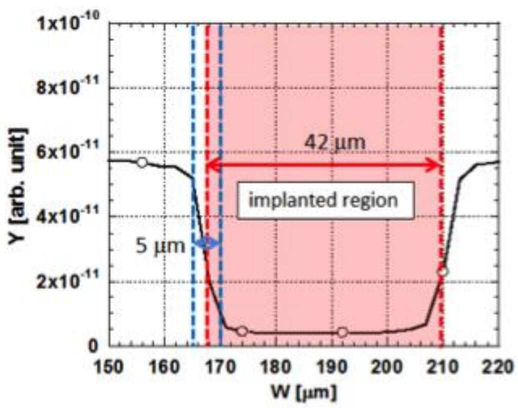

Fig. 6 Measured line profile of Y across the implanted region at an ion dose of $1{\times}10^{14}$ cm^{-2}.