D-2-06 Extended Abstracts of the 2020 International Conference on Solid State Devices and Materials, VIRTUAL conference, 2020, pp201-202

Mapping of Photoelectrochemical Etched Ni/GaN Schottky Contacts Using Scanning Internal Photoemission Microscopy -- Comparison between n- and p-type GaN samples --

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Abstract

We present the experimental results on mapping characterization of selectively photo-electrochemical (PEC) or inductively coupled plasma (ICP) etched p-type and n-type GaN Schottky contacts by using scanning internal photoemission microscopy (SIPM). The photocurrent increased by 4〜5 % in the PEC etched regions for both n- and p-GaN samples. The photocurrent increased by 10 % in the ICP etched regions for n-GaN as well, but significantly decreased by 69 % for p-GaN samples. PEC etching has less effect on Schottky characteristics than ICP etching especially in the p-type sample. SIPM sensitively visualized such etching pattern as an image.

1. Introduction

In the GaN-based device fabrication, ICP method have been widely used for the gate recces etching of AlGaN/GaN HEMTs, and device isolation etching, however, plasma-induced damage is a serious concern in terms of the stability and reliability of the devices. Meanwhile, photoelectrochemical etching induces less damage than ICP etching. We succeeded in forming a flat surface by PEC etching using a freestanding GaN substrate with low dislocation density [1].

We proposed SIPM that can map the electrical inhomogeneity of metal/semiconductor interfaces [2]. We have adapted SIPM to map dry-etched GaN Schottky contacts [3]. In this study, we conducted SIPM measurements for Ni Schottky contacts formed on selectively PEC or ICP etched surfaces of both n- and p-type GaN layers to characterize the mechanism of change in Schottky characteristics.

2. Device Structure and Characterization

Figure 1 shows the device structure used in this study. A 1-μm-thick n-GaN layer, and a 5-μm-thick n-GaN (Si = 1.5×10^{16} cm^{-3}) layer or a 1-μm-thick p-GaN (Mg = 1×10^{18} cm^{-3}) layer was grown on an n-GaN substrate by MOCVD. PEC etching was performed with an applied voltage of 1 V using a 0.01 M aqueous solution of NaOH as an electrolyte and an Hg-Xe lamp as a UV light source. The GaN surface in an area of 3.5 mmϕ was etched to a depth of about 20 nm. Meanwhile a region of 3-mm square was selectively etched by ICP using mixture gases of Ar and CF_4. Antenna and bias-power was 400 and 50 W respectively, the etching time was 1.5 min. After etching, 100-nm-thick Ni Schottky electrodes (200 μmϕ) were deposited using electron beam evaporation so that the etching pattern was included in the electrode areas. Finally, large-area InGa ohmic electrodes were formed.

In photoresponse (PR) measurement, a monochromatic light was irradiated from the semiconductor side to the metal/GaN interface, and a photocurrent was measured while sweeping photon energy ($h\nu$). This is known as the internal photoemission effect. Schottky barrier height ($q\phi_B$) can be determined from the measured photocurrent, using Fowler's equation, as follows: $Y \propto (h\nu - q\phi_B)^2$, where Y is the photoyield, which is the photocurrent per incident photon. In the SIPM measurements, a laser beam focused at the interface and scanned over the Schottky electrode to obtain a 2-dimentional image of the photocurrent.

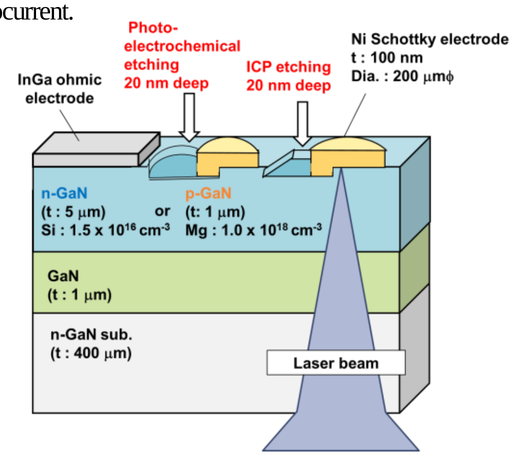

Fig. 1 Device structure. Ni Schottky electrodes were formed on the n-type or p-type GaN surfaces including selectively PEC or ICP etched regions.

3. Experimental Results and Discussion

In the forward *I-V* characteristics of the n-GaN contacts as shown in Fig. 2 (a), small variation was found among the samples. The unetched sample exhibited $q\phi_B$ = 1.15 eV, and n-value = 1.04. Even in the PEC and ICP etched samples, $q\phi_B$ decreased by only 0.03 eV. On the other hand, for the unetched p-GaN contacts as shown in Fig. 2 (b), $q\phi_B$ is as high as 2.65 eV, which is close to our previously reported value [4]. For the p-GaN contacts, the variation is large. The $q\phi_B$ decreased by 0.03 eV by PEC, and extremely increased by ICP.

The same trend in the variation was observed in the PR spectra (Fig. 3). A linear relationship according to Fowler's equation was found when $h\nu$ was up to 3.1 eV. The $q\phi_B$ was successfully obtained to be about 1.2 eV for all the n-type samples and 2.1 eV for the unetched and PEC etched samples. The p-type ICP etched sample exhibited exceptionally large $q\phi_B$ as well as the I-V results.

Figure. 4 shows SIPM *Y* maps of the partially PEC or ICP etched contacts on (a) n-GaN and (b) p-GaN. Even though the PEC etching is damage-less, but *Y* increased slightly in the PEC etched regions by 5 % for the n-type and 15 % for the p-type. SIPM sensitively visualized PEC etching pattern, because the reference (unetched) region is located in the same dot. Whereas the influence of the ICP etching is larger than that of PEC (increased by 10 % for the n-type and decreased 80 % for the p-type). These results indicate that the ICP etching actually induced donner-type damages, which compensate acceptors in the p-type GaN surface.

4. Conclusions

The effects of PEC and ICP etching on both n-type and p-type GaN Schottky contacts were characterized by *I-V*, PR and SIPM. The influence of PEC on the Schottky characteristics was smaller than that of ICP for both n- and p-types. SIPM sensitively visualized such etching pattern as an image

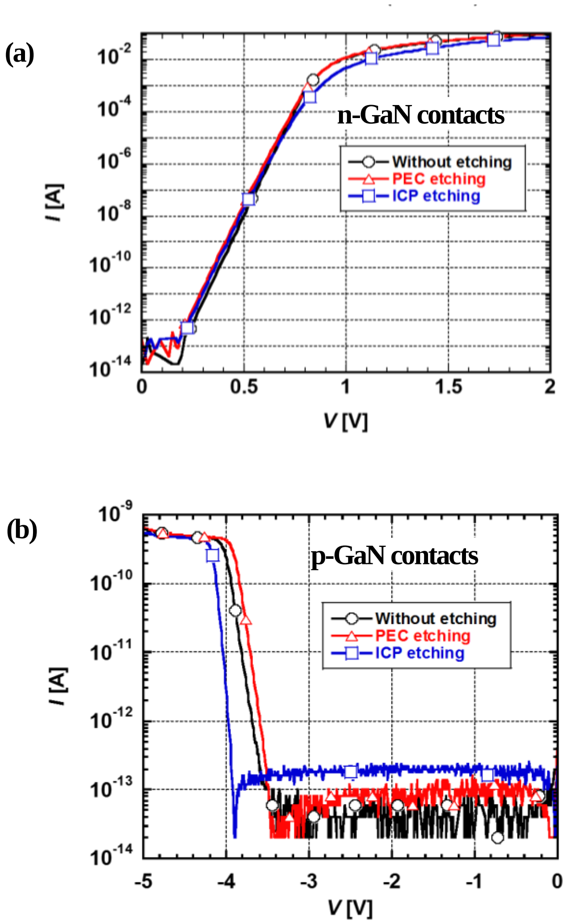

Fig. 2 Forward *I-V* characteristics of the (a) Ni/n-GaN, and (b) Ni/p-GaN contacts etched by PEC or ICP etching.

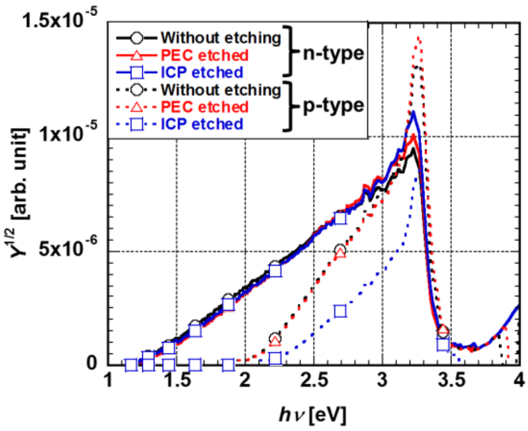

Fig. 3 PR spectra of the n- and p-GaN contacts by PEC or ICP etching.

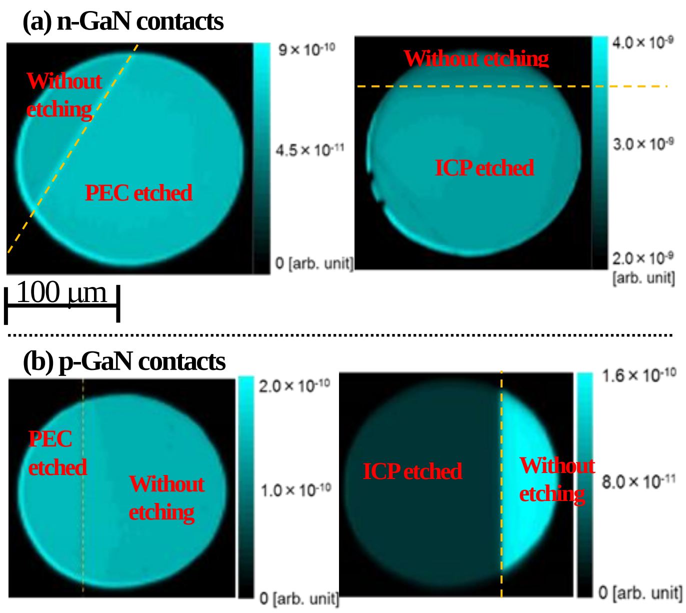

Fig. 4 *Y* maps (λ = 447 nm) of the (a) Ni/n-GaN, and (b) Ni/p-GaN contacts with partially etched regions by PEC or ICP etching.

Acknowledgements

A part of this work was supported by a Grant-in-Aid for Scientific Research (C) 18K04228 of the Ministry of Education, Culture, Sports, Science, and Technology.

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