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Temperature Dependence of Current-Voltage of Ni Schottky Diodes on Cleaved *m*-plane n-GaN Surfaces

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Abstract

We fabricated Ni Schottky contacts on an *m*-plane n-GaN surface using crystal cleaving without any surface treatment, and conducted temperature-dependent current-voltage measurements. We found a trend that the Schottky barrier height increases and the ideality factor decreases as the temperature increases. These results can be interpreted by the surface patch model, in which the contact consists of a parallel connection of low-barrier and high-barrier regions.

1. Introduction

In commercially available GaN-based optical and electron devices, *c*-plane crystals are normally used. However, spatial separation of electrons and holes in the active layer due to the polarization along the *c*-axis makes the light-emitting efficiency low, and large induced sheet carrier density impedes an E-mode operation in high electron mobility transistors. One solution for eliminating the polarization effects is the use of non-polar or semi-polar orientations, but epitaxial growth of such crystals is still challenging.

In manufacturing semiconductor devices, a metal-to-semiconductor contact is one of the most important elements. An ideal metal-to-semiconductor interface would be provided by damage-free metal deposition on a clean and atomically flat semiconductor surface. In order to obtain such a clean surface, cleaving method was preferentially studied in Si and GaAs [1].

We have adopted crystal cleaving to form Au/Ni Schottky contacts on clean and flat *m*-plane HVPE-grown n-GaN surfaces, and reported that the Schottky barrier heights ($q\phi_B$s) and ideality factors (n-values) are 0.76±0.03 eV, and 1.025±0.020, respectively [2]. In this study, in order to reveal detail current transport mechanism, we conducted temperature-dependent current-voltage (*I-V-T*) measurements.

2. Device structure

Figure1 shows the device structure used in this study. A free-standing Si-doped (Si : 1.88×10^{17} cm^{-3}) n-GaN substrate was grown on a sapphire substrate by HVPE along the *c*-direction, and then peeled and polished in 474 μm thick in the *c*-plane. Just after we cleaved the wafer in the *m*-plane without any surface treatment, the sample was loaded into a vacuum chamber and a Ni Schottky metal layer (100 μmϕ) was deposited on the *m*-plane surface by electron beam evaporation. Finally, an InGa ohmic contact was formed on the same surface.

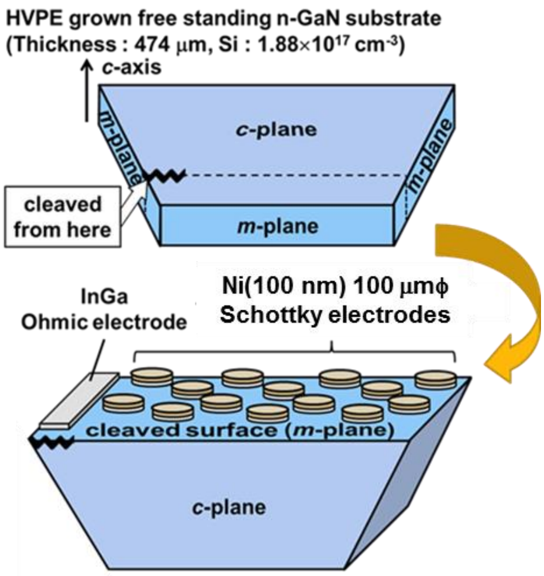

Fig. 1 Device structure.

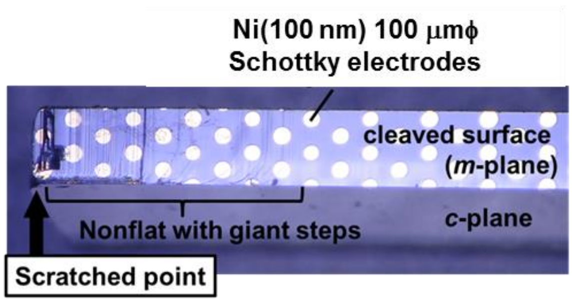

Fig. 2 Optical microscope image of Ni metal dots on a cleaved n-GaN surface.

3. Experimental results and discussion

A flat cleaved surface where far from the scratched point was obtained as shown in an optical microscope image of Fig. 2. In addition, laser microscope observation revealed that there were few macro steps up to 5 nm high even on

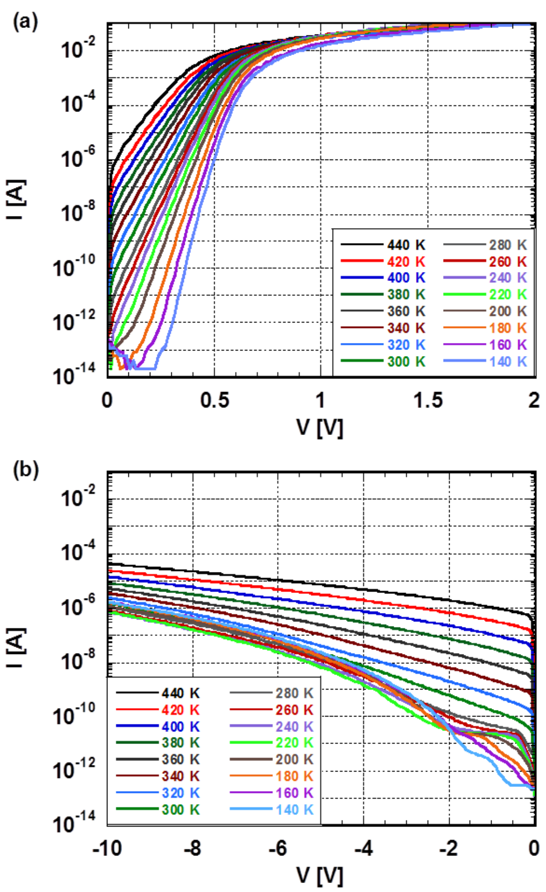

Fig. 3 (a) Forward and (b) reverse *I-V-T* characteristics of the Ni/*m*-plane n-GaN Schottky contacts.

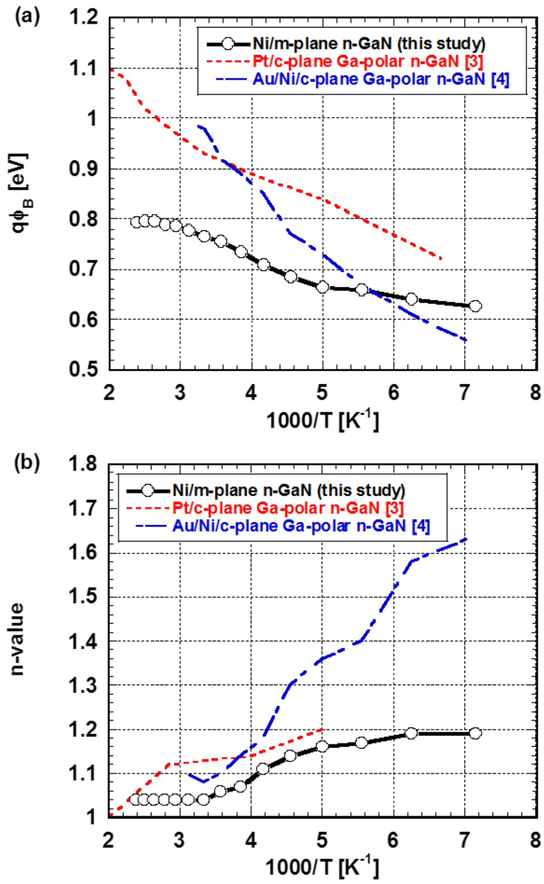

Fig. 4 Temperature dependences of (a) qϕ_B and (b) n-value obtained from forward *I-V-T* results of the Ni/*m*-polar n-GaN contacts, comparing with reported values of *c*-plane Ga-polar n-GaN contacts.

the cleaved surface, so that the dots either contain the steps or not. The effect of the containing steps was not observed in the *I-V* characteristics, because the steps were also consisted with *m*-plane facts.

We conducted *I-V* measurement in a temperature range from 140 to 440 K. Figures 3 show (a) forward and (b) reverse *I-V* results. Basically, the currents increased with the temperature increase for both forward and reverse directions, except of the reverse characteristics in a very-low temperature range.

We calculated qϕ_B and *n*-value using the thermionic emission method. The results as a function of the temperature are shown in Figs. 4 (a) and (b), comparing with reported values of *c*-plane Ga-polar n-GaN contacts [3, 4]. For both *m*- and *c*-plane contacts, there is a trend that qϕ_B increases and the *n*-value decreases as the temperature increases. Especially, the *m*-plane contacts showed particular values; qϕ_B ≈ 0.79 eV, *n*-value ≈ 1.04 in a higher temperature, and qϕ_B ≈ 0.64 eV, *n*-value ≈ 1.20 in a lower temperature.

These results can be interpreted by the surface patch model [3], in which the contact consists of a parallel connection of low-qϕ_B and high-qϕ_B regions. In a lower temperature, the current preferentially flows through the low-qϕ_B region. In a higher temperature, energy of the free electrons are large enough to surmount the high-qϕ_B.

4. Conclusions

We conducted *I-V-T* measurements for Ni Schottky contacts formed on an *m*-plane n-GaN surface. We found a similar trend to *c*-plane n-GaN contacts that qϕ_B increases and the *n*-value decreases as the temperature increases. These results can be interpreted by the surface patch model, in which the contact consists of a parallel connection of low -qϕ_B and high-qϕ_B regions.

Acknowledgements

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References

[1] N. Newman et al, Phys. Rev. B, **33** (1986) 1146.
[2] M. Naganawa et al, JJAP, **55** (2016) 04EG06-1.
[3] T. Sawada et al, Appl. Surf. Sci. **190** (2002) 326.
[4] S. Dagan et al, Physica E **41** (2009) 646.