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Electrical Characteristics of Au/Ni Schottky Diodes on Cleaved *m*-plane Surfaces of Free-standing n-GaN Substrates

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Abstract

We have characterized Au/Ni Schottky contacts formed on *m*-plane n-GaN surface using crystal cleaving without any surface treatment. The Schottky barrier height ($q\phi_B$) and n-value from the current-voltage characteristics are independent of step heights at 0.76±0.03 eV, and 1.025±0.020, respectively, without the effect of macro steps formed on the cleaved surface, because the facets of the step are also an *m*-plane. The $q\phi_B$ of the *m*-plane contacts is about 0.11 eV smaller and the n-value is as good as those of the *c*-plane samples.

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 induce sheet carrier density impedes an E-mode operation in high electron mobility transistors. On the other hand, growth of a non-polar or semi-polar crystal GaN is still challenging.

Metal-to-semiconductor contact is one of most important elements in manufacturing semiconductor devices. 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 an atomically clean surface, cleaving method was preferentially studied in Si and GaAs [1, 2].

In this study, we adopted crystal cleaving to form Au/Ni Schottky contacts on clean and flat *m*-plane HVPE-grown n-GaN surfaces.

2. Device structure

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 Schottky metal layers (100 μmϕ) composed of Ni and Au were deposited on the *m*-plane surface by electron beam evaporation. Finally, an InGa ohmic contact was formed on the same surface.

3. Experimental results and discussion

Laser microscope observation revealed that there are few macro steps up to 5 nm high even on the cleaved surface, so that the dots either contain the steps or not.

Forward and reverse current-voltage (*I-V*) characteristics of 5 dots with a different step height on the same cleaved surface exhibited less diode-to-diode variation. They showed forward characteristics with a good linearity in a lower voltage region. Independent of the step height, the Schottky barrier heights ($q\phi_B$s) and n-values are constant at 0.76±0.03 eV, and 1.025±0.020, respectively. It is responsible that the facets of the steps are also an m-plane.

We compare the *I-V* characteristics with those of *c*-plane Ga-polarity n-GaN Schottky contacts in conjunction with carrier concentration [3]. It is clear that $q\phi_B$ of *m*-plane Schottky contacts is about 0.11 eV smaller than those of *c*-plane at the same carrier concentration. As for n-values, the *m*-plane samples showed as good as those of the *c*-plane samples. Therefore, it is speculated that cleaving method without any surface treatment can provide Schottky diodes as good as those formed on epitaxial-grown *c*-plane n-GaN.

4. Conclusions

We have fabricated and characterized Au/Ni Schottky contacts on cleaved *m*-plane HVPE-grown n-GaN surfaces. The contacts have a variation in containing step height up to 5 nm. The $q\phi_B$ and n-value are constant at 0.76±0.03 eV, and 1.025±0.020, respectively. The $q\phi_B$ of the *m*-plane contacts is about 0.11 eV smaller and the n-value is as good as those of the *c*-plane samples. It is confirmed that cleaving method can utilize to form Schottky contact on *m*-plane n-GaN surfaces in an easy fabrication process. For further study, metal work function dependence of $q\phi_B$ is investigating.

Acknowledgements

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References

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[2] N. Newman et al, Phys. Rev. B, **33** (1986) 1146.
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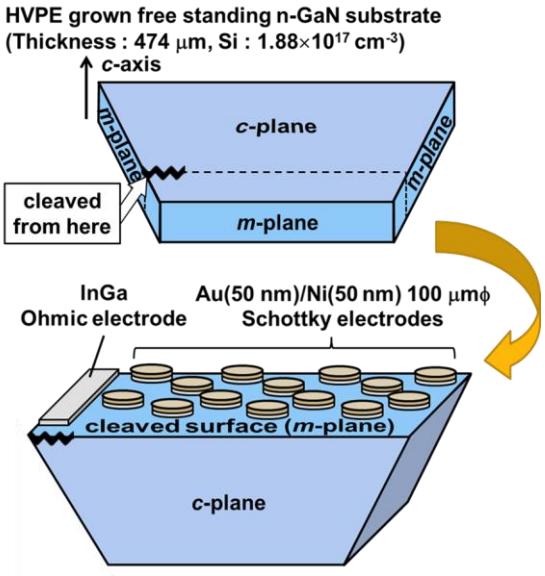

Fig. 1 Device structure.

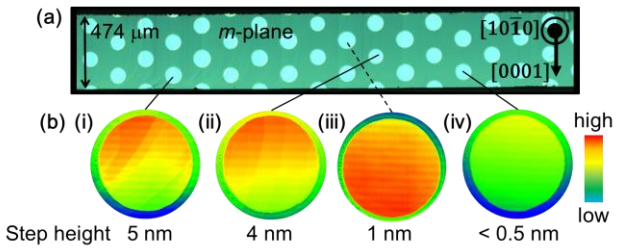

Fig. 2 Images of metal dots on a cleaved n-GaN surface observed by (a) a differential interference contrast microscope and (b) a laser microscope.

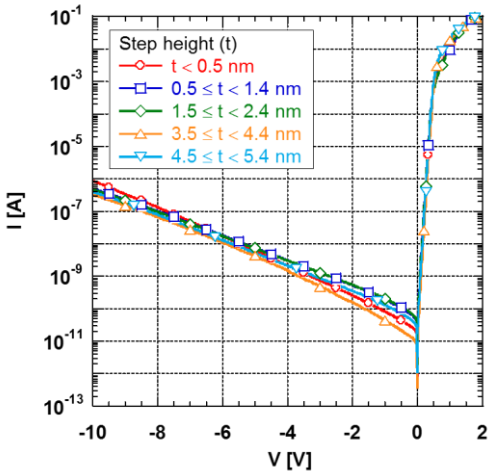

Fig. 3 *I-V* characteristics of *m*-plane n-GaN contacts with a variation of macro step heights.

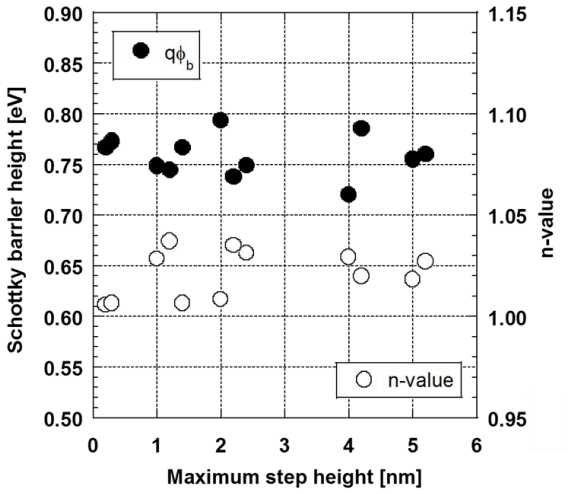

Fig. 4 Schottky barrier height and n-value vs. maximum step height.

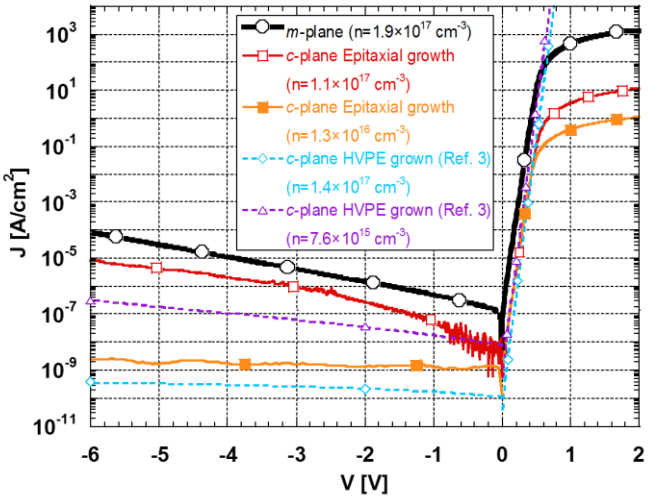

Fig. 5 *I-V* characteristics of *m*-plane and *c*-plane n-GaN contacts.

Table I Obtained parameters of *m*-plane and *c*-plane n-GaN by *I–V* measurements

	n [cm^{-3}]	qϕ_B [eV]	n-value
m-plane	1.9×10^{17}	0.76	1.02
c-plane Epitaxial	1.1×10^{17}	0.96	1.07
c-plane Epitaxial	1.3×10^{16}	0.82	1.04
c-plane HVPE [3]	1.4×10^{17}	0.87	1.04 – 1.05
c-plane HVPE [3]	7.6×10^{15}	0.93	1.02 – 1.04