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# Photoemission study on interfacial reaction of Ti/n-GaN

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## Introduction

Low resistance Ohmic contacts are essential to improve the performance of GaN-based optoelectroic and electronic devices. For n-type GaN, Ti-based contacts have been extensively studied because of a merit of the low work function [1-4]. Ti-based contacts are reported to behave as Ohmic characteristic after annealing above 500 °C [5]. This behavior is explained by the creation of nitrogen vacancies in interfacial GaN layer by the formation of TiN compounds through the chemical reaction between GaN and Ti metal [6]. To clarify the mechanism of low-resistance Ohmic-contact formation, the investigation into the energy-band structures has been required. Photoemission spectroscopy is one of the most powerful techniques to investigate the chemical states and the band structure. In this report, we discuss the annealing effect in the electronic structure and the mechanism of Ohmic-contact formation using synchrotron radiation photoemission spectroscopy.

## Experimental

The n-type GaN films used in this study were grown by metal-organic chemical vapor deposition on c-plain sapphire substrates. The thickness of n-GaN layer and Si concentration were 3 μm and $2\times10^{18}$ $cm^{-2}$, respectively. To remove the surface contamination, the GaN samples were dipped in a 39% HCl solution for 10 min. After that, the 0.3 nm - thick Ti layer was evaporated under the ultra-high vacuum (UHV) condition using the electron-bombardment evaporator. Photoemission spectroscopy was performed *in situ* at the beam line BL-1C, Photon Factory, KEK. Valence-band spectra were measured at the photon energy of 100 eV. Core-level spectra were also measured with an Al Kα x-ray source. Annealing was performed under the UHV condition at 500 °C and 700 °C for 10 min.

## Results and discussion

Figure 1 shows the annealing-temperature dependence of Ti 2*p* core level spectra. By the annealing at 500 °C, spectra show the chemical shift of 200 meV toward higher binding energy and the satellite structures appeared, indicating the formation of TiN compounds. On the other hand, Ga 3*d* and N 1*s* peaks shifted to the lower binding energy side by annealing.

Figure 2 shows the annealing-temperature dependence of valence-band spectra. Clear Fermi edge appeared by Ti-metal deposition. By annealing at 500 °C, valence-band line shapes drastically changed from the convolution of GaN and Ti to probably that of TiN and GaN.

These results indicate that annealing process promotes the TiN formation and the GaN layer with N vacancies exists at the interface, which can be correlated with the Ohmic contact formation.

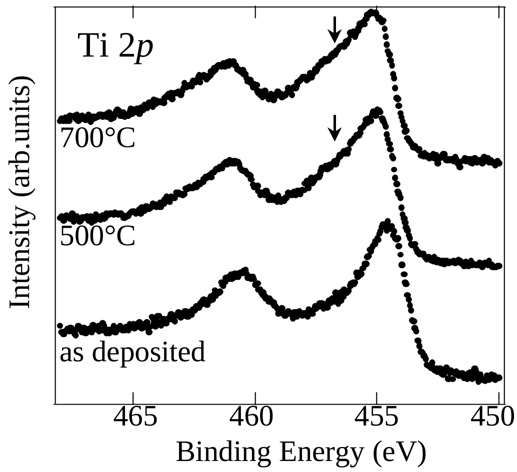


FIG. 1: Annealing-temperature dependence of Ti 2*p* core level spectra.

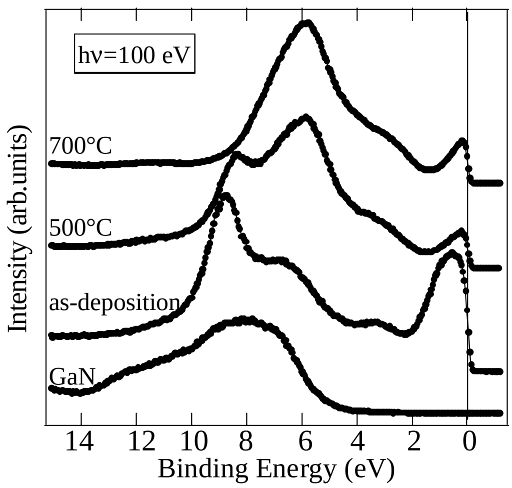


FIG. 2: Annealing-temperature dependence of valence-band spectra.

## References

[1] J. D. Guo *et al.*, Appl. Phys. Lett. **68**, 235 (1996).
[2] J. Yun *et al.*, Jpn. J. Appl. Phys. **41** (2002) L 418-L421.
[3] C. Lu *et al.*, J. Appl. Phys. **91**, 9218 (2002).
[4] A. Motayed *et al.*, J. Appl. Phys. **93**, 1087 (2003).
[5]K. Kim *et al.*, J. Appl. Phys. **91** (2002) 9214.
[6]Y.J. Lin *et al.*, J. Appl. Phys. **95** (2004) 571.