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Mechanism of ohmic-contact formation between Ti electrodes and $Al_xGa_{1-x}N$

Takayuki NAONO*, Jun OKABAYASHI, Ken KANAI, Satoshi TOYODA, Hiroshi FUJIOKA[1,2], Masaharu OSHIMA, and Hisayuki MIKI[3]
Department of Applied Chemistry, The University of Tokyo, Bunkyo-ku, Tokyo 113-8656, Japan
[1]Institute of Industrial Science, The University of Tokyo, Meguro-ku, Tokyo 153-0041, Japan
[2]Kanagawa Academy of Science and Technology, Kawasaki, Kanagawa 213-0012, Japan
[3]Showa Denko K.K., Ichihara, Chiba 290-0067, Japan

1. Introduction

Ohmic contacts between metal electrodes and nitride semiconductors with low resistivities are required to improve the device performance. For *n*-type GaN, Ti-based contacts have been extensively used due to several advantages such as a low work function and cost performance [1-3]. The most important one is that Ti-based contacts decrease the resistance by a chemical reaction and behave as an ohmic characteristic by the annealing above 500 ˚C [4]. This behavior is explained by the creation of nitrogen vacancies at an interfacial GaN layer by the formation of metallic TiN compounds through the annealing [4,5]. Ti-based electrodes have been also examined for $Al_xGa_{1-x}N$ with low Al ratio, and the annealing process has been also performed after the deposition of electrodes [6]. To clarify the mechanism of low-resistance ohmic-contact formation at $Ti/Al_{1-x}Ga_xN$ interface, the investigations for energy-band structures are required. In this study, we have investigated the chemical reaction at a $Ti/n\text{-}Al_{02}Ga_{08}N$ interface by photoemission spectroscopy to discuss the mechanism of the ohmic-contact formation comparing to the results of the Ti/GaN interface.

2. Experimental

$Al_{02}Ga_{08}N$ and GaN samples used in this study were grown by metalorganic chemical vapor deposition on *c*-plain sapphire substrates. The thicknesses of both *n*-type GaN and $Al_{02}Ga_{08}N$ layer were 0.2 µm. To remove the surface contamination, samples were dipped into a boiled 39% HCl solution for 50 min. After that, the 0.3-nm thick Ti layer was evaporated in ultrahigh vacuum (UHV). Photoemission spectroscopy was performed at the beam line BL-1C of Photon Factory in KEK.

3. Results and discussion

Figure 1 shows current-voltage characteristics of Ti electrodes/$n\text{-}Al_{02}Ga_{08}N$ before and after the annealing at 500 ˚C for 10 min. The annealing drastically decreased the resistances, which was consistent with the case of Ti/GaN. The degree of decrease in the resistance of $Ti/Al_{02}Ga_{08}N$ was smaller than that of Ti/GaN.

Valence-band spectra for $Al_{02}Ga_{08}N$ and GaN taken at hν=100 eV are shown in Fig. 2. Spectral line shapes changed by annealing after the Ti deposition, suggesting the interfacial reaction. Satellite structures in Ti 2*p* photoemission spectra at 500 °C indicate the formation of the TiN compound at the interface. Similar phenomena were observed for Ti/GaN interface [4]. Furthermore, Ga 3*d*, N 1*s*, and Al 2*p* peaks shifted to the lower binding energy by annealing. The amounts of shifts for $Ti/Al_{02}Ga_{08}N$ were smaller than those for Ti/ GaN. These results indicate that the annealing process promotes the formation of TiN and AlGaN layers with N vacancies at the interface, resulting in decrease in contact resistivity.

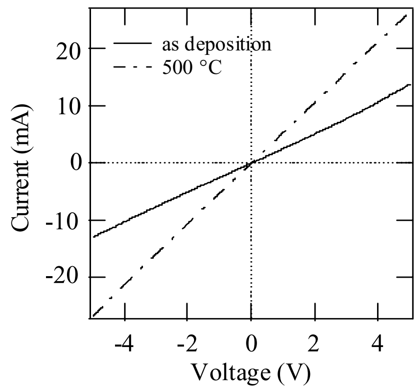

FIG. 1: Current-voltage characteristics of Ti electrodes/*n*-type $Al_{02}Ga_{08}N$ before and after the annealing at 500 °C

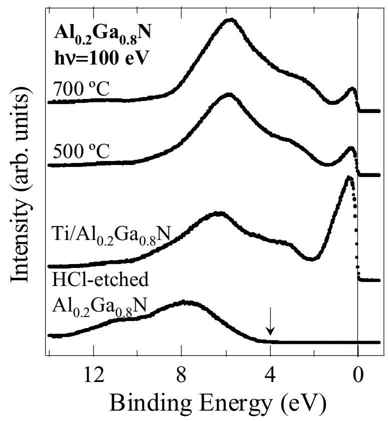

FIG. 2: Annealing-temperature dependence in valence-band spectra. Arrow shows a valence-band maximum for *n*-type $Al_{02}Ga_{08}N$

References

[1] J. D. Guo *et al.*, Appl. Phys. Lett. 68 (1996) 235.
[2] C. Lu *et al.*, J. Appl. Phys. 91 (2002) 9218.
[3] A. Motayed *et al.*, J. Appl. Phys. 93 (2003)1087.
[4] T. Naono *et al.*, Appl. Surf. Sci. 244 (2005) 277.
[5] K. Kim *et al.*, J. Appl. Phys. 91 (2002) 9214.
[6] M. W. Fay *et al.*, J. Appl. Phys. 96 (2004) 5588.

*naono@sr.t.u-tokyo.ac.jp