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High Quality Nonalloyed Pt Ohmic Contacts to P-Type GaN Using Various Surface Treatment

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1. Introduction

Due to the success in the development of GaN-based optical devices such as blue/ultraviolet light emitting diode (LED) and laser diode (LD),[1-2] the fabrication of high quality ohmic contacts with low resistance and excellent reliability is of great technological importance. To develop a continuous wave operating LD with long lifetime (>30,000 hr) and high performance operation, a specific contact resistance as low as 10^{-5} Ωcm^2 is required. As for the p-GaN, however, specific contact resistances were as high as $10^{-2} \sim 10^{-4}$ Ωcm^2.[3-6] In this work, we report on the lowest non-alloyed ohmic contact to p-GaN using various surface treatment ever reported so far.

2. Experiment

Metalorganic chemical vapor deposition (Emcore DGaN125^{TM}) was used to grow a 1-μm-thick p-GaN:Mg ($n_a = 1.8\times10^{17}$ cm^{-3}) on 2-μm-thick unintentionally doped GaN/ (0001) sapphire substrate. The GaN layer was ultrasonically degreased in trichloroethylene, acetone, methanol, ethanol, and rinsed in deionised (DI) water for 5 min. Prior to the fabrication of TLM patterns, mesa structures were patterned by inductively couples plasma using $Cl_2/Ar/H_2$. The surface treatment was performed as follows: (i) not-treated (termed here 'A-treated'); (ii) in BOE solution for 10 min (B); (iii) in $(NH_4)_2S_x$ solution for 10 min (C); (iv) first in BOE for 10 min and then in $(NH_4)_2S_x$ solution for 10 min (D); N_2 plasma treated with no DC bias, substrate holder temperature of 380 ℃, rf power of 50 W for 7 min (E); firstly, D-treated and then E-treated (F). After the first-step surface treatment, TLM patterns were defined by a photolithograhic technique. The all the patterned samples were dipped in BOE for 10 min. The Pt (25 nm) layer was deposited on the surface-treated GaN by electron beam evaporation. Current-voltage (I-V) data were measured at room temperature using a parameter analyzer (HP4155A) and effective Schottky barrier height (SBHs) were calculated using the Norde method [7] and I-V methods.[3,8]

3. Results and Discussion

Figure 1 shows the I-V characteristics of the various wet surface-treated Pt contacts on p-GaN. The A-treated Pt contact revealed nonlinear I-V behavior. The I-V behavior of the B-treated contact is fairly similar to that of the C-treated one. The D-treated contact shows a linear I-V characteristic. Specific contact resistances were determined from a plot of the measured resistances versus the spacings between the TLM pads. The specific contact resistance was determined to be 2.1×10^{-2} Ωcm^2 for the A-treated sample, 3.7×10^{-3} Ωcm^2 for the B-treated sample, 3.8×10^{-3} Ωcm^2 for the C-treated sample, and 2.0×10^{-5} Ωcm^2 for the D-treated sample. It is worth noting that the D-treatment resulted in a dramatic reduction (by about three orders of magnitude) in the specific contact resistance as compared to that of the A-treatment.

The I-V characteristics of the N_2 plasma surface-treated Pt contacts are shown in Fig. 2. The completely rectifying I-V characteristics are obtained for the E- and F-treated samples. It is noted that the N_2 plasma treatment can lead to the formation of Schottky contacts on p-GaN, indicating the possibility of the formation of a high voltage Schottky diode. The specific contact resistances were determined to be 1.2×10^{-1} Ωcm^2 for the E-treated sample and 1.3×10^{-1} Ωcm^2 for the F-treated sample.

The effective SBH of each contact was calculated using the Norde method. As for the wet-treated samples (A–D), the SBH is 0.37 (±0.015) eV for the A-treated contact, 0.33 (±0.015) eV for the B-and C-treated contacts, 0.30 (±0.01) eV for the D-treated contact. As for the plasma-treated samples, the SBH is 0.55 (±0.01) eV for the E-treated contact and 0.57 (±0.015) eV for the F-treated contact. It is noted that the SBHs of the wet-treated contacts (A–D) are lower than those of the plasma-treated contacts (E–F).

To compare the barrier heights, we employed the I-V method. The SBHs for the wet treated contacts (A–D) are measured to be in the range 0.43 (±0.015) – 0.49 (±0.01) eV. On the other hand, the SBHs of the plasma-treated samples (E–F) are in the range 0.69 (±0.018) – 0.71 (±0.015) eV. Our SBH of the A-treated sample is comparable to a value reported by Mori et al.[3] who also obtained their SBH using I-V results.

The precise mechanism for the surface treatment dependence of the specific contact resistance is not clear as yet. However, a few points could be brought into discussion for possible mechanisms. As for the wet-treated samples (A–D), firstly, the reduction in the contact resistance could be attributed to the effective removal of the native oxide on the surface.[5] Secondly, the surface treatments could result in an increase in carrier concentration near the surface of the p-GaN layers. Thirdly, the improvement in the contact resistance may be associated with an increase in the contact area between the metal and the p-GaN layer, [6] since the surface treatment may cause the roughening of the layer surface. Therefore, we suggest that the improvement in the specific contact resistance could be due to either the removal of the native oxide, an increase in the carrier concentration, an increase in the contact area, or their combined effects. As for the E- and F-treated samples, the rectifying I-V behavior could be attributed to both the increase of nitrogen vacancy near the surface, which is known to act as donor, and the increase in the SBHs.

4. Summary and conclusion

The effects of the various surface-treatment on the ohmic properties of the Pt contacts to p-GaN:Mg (1.8×10^{17} cm^{-3}) were investigated. As for the wet surface-treated conditions, the not-treated sample produced 2.1×10^{-2} Ωcm^2, while the BOE/$(NH_4)_2S_x$-treated contact yielded 2.0 ($\pm$3.5)$\times10^{-5}$ Ωcm^2. The effective SBHs determined by Norde and I-V methods were in the range 0.30 – 0.37 and 0.43 – 0.49 eV, respectively. For the N_2 plasma-treated contacts, however, the I-V characteristics changed from ohmic into rectifying behaviour, which could be attributed to the increase in both the nitrogen vacancies near the p-GaN surface and the SBHs.

References

[1] S. Nakamura et al. Jpn. J. Appl. Phys. **34**, L797 (1995)
[2] S. Nakamura et al. Jpn. J. Appl. Phys. **35**, L217 (1996)
[3] T. Mori et al. Appl. Phys. Lett. **69**, 3537 (1996)
[4] J. S. Jang et al. J. Vac. Sci. Technol.B **16**, 3105 (1998)
[5] J. K. Kim et al. Appl. Phys. Lett. **73**, 2935 (1998)
[6] J. S. Jang et al. Appl. Phys. Lett. **74**, 70 (1999)
[7] H. Norde et al. J. Appl. Phys. 50, 5052 (1979)
[8] E.H. Rhoderick & R.H. Williams, Metal Semiconductor Contacts (Clarendon, Oxford 1988)

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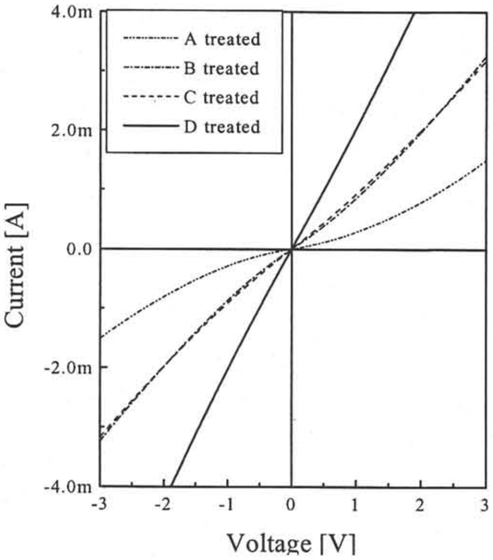

Figure 1. I-V characteristics of the wet-chemical treated Pt contacts on p-type GaN. High quality ohmic contact was obtained for the D-treated contact with a specific contact resistance of 2.0×10^{-5} Ωcm^2.

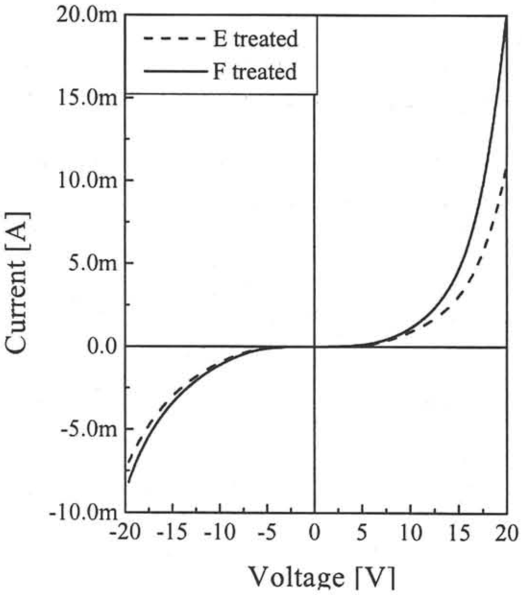

Figure 2. I-V characteristics of the N_2 plasma-treated contacts on p-GaN. The I-V behaviors of E- and F-treated contacts show that the ohmic property is changed into rectifying, as compared to the A- and D-treated contacts.