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Thermal Stability of Plasma-treated Ohmic Contact to n-GaN

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1. Introduction

Nitride-based electronic devices, such as heterostructure field effect transistors (HFETs) and heterostructure bipolar transistors (HBTs), are potentially very useful for high power and high temperature applications. To use these devices for such applications, good ohmic contacts with low contact resistance and good thermal stability are very important. In general, ohmic contacts to n-GaN with low contact resistance are not easily obtainable because of its wide bandgap. Surface treatment with plasma prior to metal deposition has been shown to be effective in improving the contact resistance. [1-6]. However, the thermal stability of the plasma-treated ohmic contacts has not been studied. In this work, the thermal stability of plasma-treated ohmic contacts was investigated by high temperature aging tests. We found that no obvious degradation of contact resistance was observed after aging at 600 °C for 2 hrs in N_2 and air ambient.

2. Experiment

The 2μm thick n-GaN films for this study were grown by metalorganic chemical vapor deposition (MOCVD) on c-plane sapphire substrates. The electron concentration and the mobility obtained by Hall measurement were 8.7×10^{16} cm^{-3} and 514 cm^2/Vs, respectively. After layer growth, mesa patterns for transmission line measurement (TLM) were defined by photolithography. Prior to contact metal deposition, the samples were treated by Cl_2/Ar plasma using an inductive coupled plasma (ICP) system. Contact metal, Ti/Al/Ti/Au (200/1500/450/550 Å), was then deposited and lifted-off to form the contact pads. The samples were annealed at 750 °C for 30s in N_2 ambient. Aging tests were carried out at temperatures ranging from 400 to 600 °C for 2 hrs in N_2 and air ambient. The TLM measurement was performed for the determination of the contact resistance.

Table I. Etch conditions and TLM data

No.	1	2	3	4	5	6
ICP power (w)	X	300				
Bias power (w)	X	5				
Pressure (mtorr)	X	15				
Cl_2 flow (sccm)	X	50				
Ar flow (sccm)	X	30	10	15	20	30
Time (min.)	X	1	2	2	2	2
Rc (Ω · mm)	0.638	0.614	0.48	0.45	0.21	0.28
ρ_s(Ω/□)	621.0	656.3	692.2	696.3	668.3	671.5
ρ_c(μΩ · cm^2)	6.6	5.7	3.4	2.8	0.68	1.2

3. Result and discussion

The conditions of the plasma treatment and the TLM results are shown in Table I. It should be noticed that a very low bias power of 5W was used in the plasma treatment to ensure a very slow etching rate for GaN. For the conditions used in here, only about 100-200 Å was etched during the plasma treatment. After annealing at 750 °C for 30s in a N_2 ambient, all samples showed good ohmic behavior. The contact resistances for samples with treatment time of 0, 1 and 2 min. (sample No. 1, 2, and 6), are 0.638, 0.614, and 0.28 Ω·mm, respectively. Hence, samples with a longer treatment time, 2 min., have much better improvement in contact resistance. Besides, we found that Ar flow rate could have a significant influence on contact resistance. Sample No. 5, which was treated with a flow rate ratio of Cl_2/Ar=50/20 for 2 min., in particular, showed the best electrical performance. Its contact resistance and specific contact resistivity are 0.21 Ω·mm and 6.8×10^{-7} Ω·cm^2, respectively.

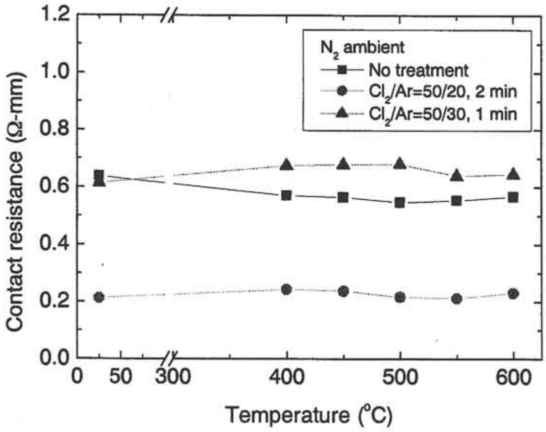

Fig.1 The aging test results of contact resistance

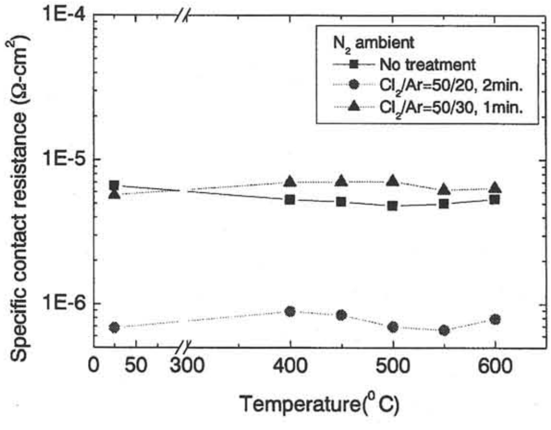

Fig. 2 The aging test results of specific contact resistivity

Fig. 1 and 2 show the aging test results of the contact resistance and specific contact resistivity with temperatures ranging from 400 to 600 °C in N_2 ambient. As a whole, there is no obvious degradation observed after aging at 600 °C for 2 hrs. It is generally believed that the improvement of contact resistance after plasma treatment is mainly due to the formation of nitrogen vacancies on the wafer surface [1-6]. Although the effect of high temperature aging on the recovery of the plasma-induced damages is largely unknown, the results obtained here indicate that this annealing effect does not lead to electrical degradation of plasma-treated ohmic contacts. For samples that were aged in air ambient, similar results were obtained as well, despite the metal surface seems to be oxidized to some degree. In addition, the electrical performance of plasma-treated ohmic contacts was measured at high temperatures. At 300 °C, sample No. 5 still has a very low contact resistance (0.412 Ω·mm) and specific contact resistivity (9.3×10^{-7} Ω·cm^2), which are lower than those measured at room temperature of samples without plasma treatment (sample No. 1).

4. Conclusion

With appropriate plasma treatment, ohmic contacts to n-GaN have lower contact resistance than those without plasma treatment. No obvious degradation of contact resistance was observed after aging tests in N_2 and air ambient, showing the thermal stability of plasma-treated ohmic contacts would not be influenced by the recovery of plasma-induced damages on the wafer surface. Moreover, plasma-treated ohmic contacts have lower contact resistance even at high temperatures. This is a great benefit to the nitride-based HFETs used for high power and high temperature applications.

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