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A study of ohmic contacts to p-GaN

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INTRODUCTION

GaN is a promising materials for applications in the blue/ultraviolet (UV) light emitting diodes (LEDs)[1], and laser diodes (LDs) [2]. High quality ohmic contacts are very critical to these applications since the qualities of ohmic contact system play an important roles in the high efficient device operations.

For the n-GaN, there have been many reports about ohmic contacts and the specific contact resistance were as low as from $10^{-8}\Omega cm^2$. However, for the ohmic contacts on p-GaN, much fewer study were reported and the specific contact resistivity was much lower than that of n-GaN. In this paper, we report a new Ni/Pt/Au metallization scheme and discuss the mechanism of ohmic formation

Experimente Methods

The GaN films used in this study were grown by MOCVD method with AlN buffer layer over c-plane sapphire substrate. The doping concentration of p-GaN layer measured by the Hall measurement was 9.4×10^{16} cm^{-3}. Contact metals were deposited with e-beam evaporator. Their deposition sequence was Ni/Pt/Au and their thickness were 20/30/80 nm. A rapid thermal annealing (RTA) process in Ar atmosphere was empolyed to find a good ohmic contact condition at temperatures varying from 300℃ to 850℃. A current-voltage (I-V) data were measured with HP4155A and the specific contact resistance was calculated by the c-TLM method [3]

Auger electron spectroscopy (AES) depth profiles were performed to investigate the interfacial reactions between metals and GaN. Atomic force microscope (AFM) and scanning electron microscopy(SEM) were used to observe the surface morphology.

RESULTS AND DISCUSSIONS

Fig. 1 shows I-V characteristics of the Ni/Pt/Au contacts on moderately doped p-GaN. The as-deposited Au/Pt/Ni/p-GaN contacts exhibited a near rectifying characteristic behavior, which is probably due to formation of Schottky contact because work function of metals used in our experiment is lower than that of p-GaN. When the contacts were annealed at 500℃ for 30sec, the contact showed a linear behavior and the specific contact resistance calculated by c-TLM was $2.1x10^{-2}\Omega cm^2$. When the contacts were annealed above 600℃, the I-V characteristics was degraded again. This phenomenon is probably due to the increase of depletion region by the compensation at the interface.

The relationship between the annealing time (at 500℃) and the specific contact resistance was further investigated as shown in Fig. 2. The lowest specific contact resistance was obtained at 30sec. With increasing an annealing time above 30sec, the specific contact resistance was increased by about one of magnitude.

AES depth profiles for Ni/Pt/Au metal contacts on p-GaN as a function of annealing temperature showed that Ni/Pt/Au layers do not react with p-GaN epilayer annealed at 350℃ for 30sec. When the samples were annealed at 500℃, Ni diffuses into Pt layer, being intermixing with Pt which also diffuses into Ni and GaN layer as shown in Fig. 3(c). A small amount of Ga was also diffused into Ni layer. We suggest that a low specific contact resistance can be attributed to the diffusion of Pt into vacancies by the outdiffused Ga, resulting in an increase of p-doping concentration at the interface. It is also suggested that Pt prevents the formation of nitrogen vacancies which are detrimental to contact performance and may act as an acceptor.

AFM and SEM showed that the surface morphology with good ohmic contacts was very smooth. However agglomeration and islands were observed on the samples annealed at 600℃ and 700℃ respectively. These islands were formed to reduce the total interfacial energy of the system.

CONCLUSIONS

We have investigated a Ni/Pt/Au contacts on p-GaN. The ohmic contacts were formed when the samples were annealed at 500℃ for 30sec and the specific contact resistace was $2.1\times10^{-2}\Omega cm^2$. From AES depth profiles, we suggest that Pt plays an important role in the formation of ohmic contacts an acceptor.

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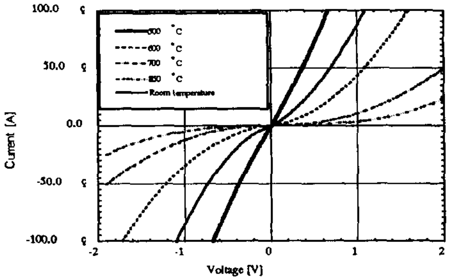

Fig. 1. The I-V characteristics of Ni/Pt/Au contacts on p-GaN.1

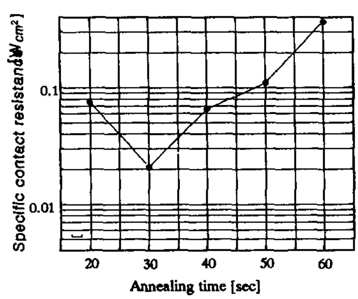

Fig. 2. The relationship between the annealing time at 500℃.

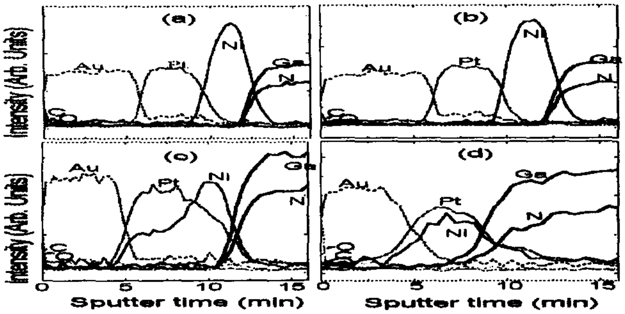

Fig. 3 AES depth profile for Ni/Pt/Au contacts on p-GaN annealed at (a) RT, (b) 35 0℃, (c) 500℃, and (d) 700℃.