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Low Resistance and Thermally Stable Pt/W/Au Ohmic Contacts to P-Type GaN

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1. Introduction

Great deals of efforts have been made to improve the contact resistance and thermal stability of contacts to p-GaN. Mori et al. investigating electrical properties of ohmic contacts on p-GaN using Pt, Ni, Au, and Ti single layers reported a specific contact resistance of 1.3×10^{-2} Ωcm^2.[1] Jang et al. investigating ohmic contacts to p-GaN using Ni/Pt/Au metallisation schemes showed that the anneal of the metal schemes at 500 °C for 30s results in ohmic behaviour with a specific contact resistance of 2.1×10^{-2} Ωcm^2.[2] Sheu et al. investigating the effect of thermal annealing on the Ni/Au contacts to p-GaN reported that the contact annealed at 700 °C for 10min produces ohmic behavior with a specific contact resistance of 1.2×10^{-2} Ωcm^2.[3] Cao et al., investigating thermal stability of W and WSi$_x$ contacts on p-GaN, reported a specific contact resistance of $\sim10^{-2}$ Ωcm^2 for the 300 °C annealed WSi$_x$.[4] In this work, we report a new Pt/W/Au metallisation scheme to achieve a low resistance and thermally stable ohmic contact to the moderately doped p-GaN (3×10^{17} cm^{-3}). It is shown that specific contact resistances and Schottky barrier heights (SBHs) depend sensitively on annealing temperature.

2. Experiment

p-GaN ($n_a = 3.0\times10^{17}$ cm^{-3}) was ultrasonically degreased with trichloroethylene, acetone, methanol, and deionised (DI) water for 5 min. After the TLM patterning, the patterned layers were dipped into buffered oxide etch (BOE) for 30 s to remove the native oxide layer on p-GaN. Metallisation patterns were defined using a lift-off technique. The samples were then rinsed in DI water, blown dry by N_2, and immediately loaded into an electron beam evaporation chamber (PLS 500). The thickness of metal layers was 15 nm for Pt, 15 nm for W, and 35 nm for Au. The samples were rapid-thermal-annealed for 1 min under a N_2 ambient to achieve a good ohmic contact.

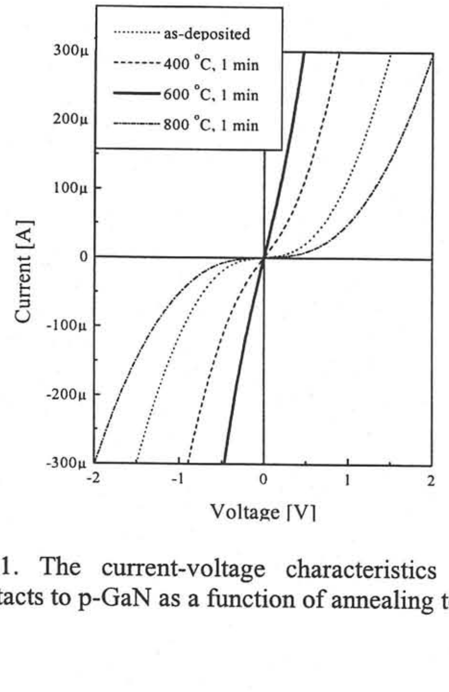


Fig.1. The current-voltage characteristics of Pt/W/Au contacts to p-GaN as a function of annealing temperature.

3. Results and Discussion

Figure 1(a) shows the current-voltage (I-V) characteristics of the Pt/W/Au contacts on p-GaN. The as-deposited contact exhibits near rectifying I-V behaviour. An increase in the annealing temperature leads to linear I-V behaviour. However, further increase in the annealing temperature, namely, annealing at 800 °C severely degrades the I-V characteristics and so yields rectifying behaviour. Specific contact resistances were determined from a plot of the measured resistances versus the spacings between the TLM pads. The least square method was used to fit a straight line to the experimental results. A plot of the resistance as a function of the spacings for the as-deposited and annealed samples is shown in Fig. 2. Specific contact resistances (ρ_c) were determined to be 5.01×10^{-2} Ωcm^2 for the as-deposited sample, 5.08×10^{-3} Ωcm^2 for the 400 °C sample, 1.34×10^{-3} Ωcm^2 for the 600 °C sample, and 1.89×10^{-1} Ωcm^2 for the 800 °C sample. The specific contact resistance decreases

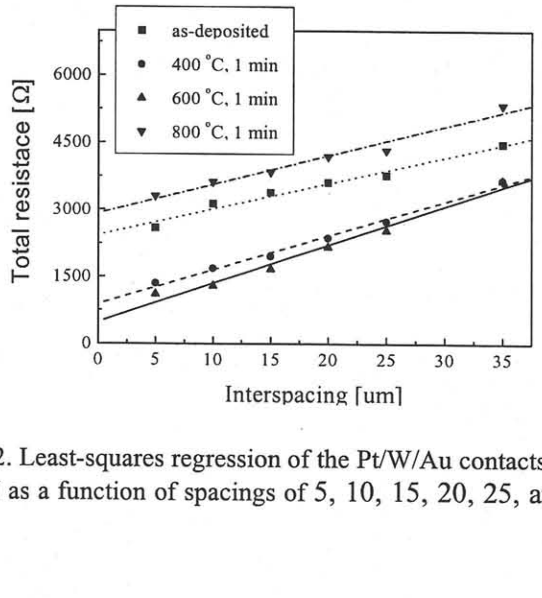


Fig.2. Least-squares regression of the Pt/W/Au contacts on p-GaN as a function of spacings of 5, 10, 15, 20, 25, and 35 μm.

(by approximately one or two orders of magnitude) with increasing annealing temperature. In order to investigate the electrical ohmic mechanism, the effective Schottky barrier heights (SBHs) were calculated using the Norde method.[5] The F(V) function is defined as:

$$F(V)=\frac{V}{2}-\frac{kT}{q}\ln\frac{I(V)}{AA^{**}T^{2}}$$

where I(V) is taken from the I-V curve. From the minimum value of the F(V) –V curve, the effective Schottky barrier height (Φ_b) can be expressed as:

$$\Phi_b=F(V_o)+\frac{V_o}{2}-\frac{kT}{q}$$

where $F(V_o)$ is the minimum point of F(V) and V_o is the corresponding voltage. Fig. 3 shows a plot of F(V) vs V for the various annealed samples. The calculation showed that the SBH is around 0.53 eV for the as-deposited contact, 0.46 eV for the 400 °C sample, 0.43 eV for the 600 °C sample, and 0.55 eV for the 800 °C sample. It is noteworthy that the annealing temperature dependence of the SBHs is closely similar to that of the specific contact resistances.

Auger electron spectroscopy (AES) depth profile was used to investigate the interfacial reactions between the metallisation scheme and p-GaN. The AES results indicate that the W layer plays a role in preventing the out-diffusion of the Pt, i.e., acting as a diffusion barrier; the thermally stable W layer plays a part in keeping the sharp and planar interface.[6] The surface morphology of the samples were investigated using atomic force microscope (AFM). Fig. 4(a) shows an AFM image of the sample annealed at 600 °C, revealing a fairly uniform and featureless surface. Fig. 4(b) shows an AFM image of the sample annealed at 800 °C. The surface is significantly degraded and shows large islands probably due to a 'balling-up' effect. Therefore, the degradation of the I-V characteristic (Fig. 1) may be related to the deterioration of the interfacial contacts due to the breaking up of the contact schemes.

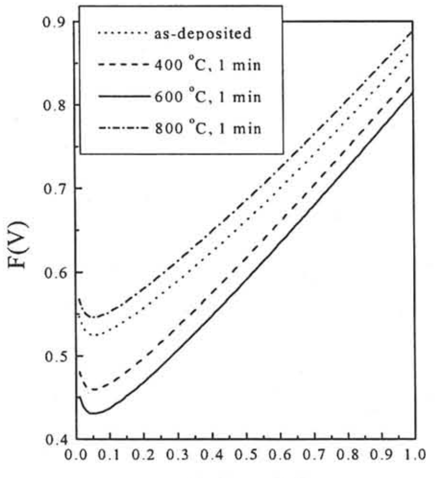
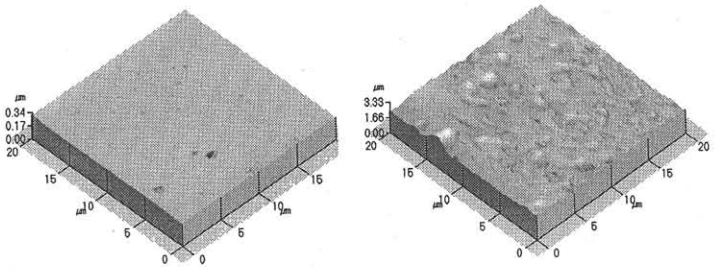


Fig.3. A plot of F(V) vs V for the Pt/Ni/Au contacts as a function of annealing temperature.



(a) 600 °C for 1 min (b) 800 °C for 1 min

Fig.4. AFM images of the Pt/W/Au contacts to p-GaN.

4. Summary and conclusion

We investigated a new metallisation scheme to p-GaN using a Pt(15 nm)/W(15 nm)/Au(35 nm) multilayer. The Pt/W/Au scheme showed a specific contact resistance (ρ_c) of 1.34×10^{-3} Ωcm^2 when annealed at 600 °C for 1 min in a flowing N_2 ambient. The SBHs decreased from 0.53 to 0.43 eV, as the annealing temperature increased. It was found that the thermally stable W layer plays a role in blocking out-diffusion of the Pt and hence resulting in the sharp metal/GaN interface.

References

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