A Study on PtGeAu Thin Ohmic Contact for GaAs PHEMT

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ABSTRACT

We studied and optimized PtGeAu ohmic metal system for GaAs PHEMT. For Pt/Ge/Au=200/400/800Å, the minimum contact resistance was 0.125Ω-mm after alloying at 450°C for 20sec. PtGeAu ohmic metal system was found to be superior to conventional NiGeAu ohmic contact in terms of contact resistance, thermal reliability as well as surface morphology.

1. Introduction

Recently the demand for microwave and millimeter-wave devices such as MESFET and HEMT increases in the high frequency applications such as space communications and personal cellular phones. To enhance the high frequency performance, it is essential for devices to have short gate lengths. To this end, thin ohmic metal system with good edge definition is required for the exact gate alignment with E-beam lithography. The conventional NiGeAu ohmic contact has been widely used for n-GaAs devices.[1,2] However, due to the spaciously inhomogeneous reactions between GaAs and NiGeAu layer, the contact may have a high contact resistance, poor thermal reliability and a rough surface morphology.[3] To make up for these demerits, additional Au layer is normally added on the top of the NiGeAu contact including barrier metal layer.[4,5] However, in the short gate length process, this thick ohmic contact may induce a poor edge definition after alloying which can cause to the problem such as gate misalignment.

In our experiments, we developed PtGeAu thin ohmic contact which improves the characteristics of conventional NiGeAu ohmic contact. Besides optimizing the layer structure of PtGeAu ohmic contact, we compared the performances of PtGeAu and NiGeAu ohmic contact. Finally, we applied the PtGeAu thin ohmic contact to the fabrication of 0.15• PHEMT device.

2. Experiments and Discussions

We experimented several types of PtGeAu structures to optimize thicknesses of PtGeAu layer. To examine the effects of the Pt thickness, the experiments with three different Pt thicknesses (100, 200, 300•), while keeping Ge/Au thickness on 400/800• , were performed. Then, the experiments with other structures having different thicknesses of Ge/Au were carried out to investigate the effects of Ge/Au ratio. The optimized PtGeAu ohmic contact was compared with NiGeAu ohmic contacts. Table 1 shows the schematics of ohmic metal types and the P-HEMT epitaxial structure for experiments. For each sample, rapid thermal annealing was carried at 390 • 510°C for 20sec in H_2 atmosphere.

For PtGeAu and NiGeAu ohmic contacts, the surface morphology of alloyed contacts was examined with microscope and AES(Auger Electron Spectroscopy) analysis were carried out. Finally, thermal reliability test were performed at 350°C in N_2 atmosphere.

Figure 1 shows measured contact resistances as a function of alloy temperature. For the sample 1, 100• Pt thickness is thought to be too thin to play the proper role of diffusion barrier. The sample 3, which had a thickness of Pt over that of Ge/Au, showed the non-ohmic characteristics.

At 450^{o}C, the sample 2 showed the lowest contact resistance(0.125• -•). We compared the sample 2 with other structures kept on Pt thickness (Ge/Au=600/1200• , 400/1000• , 400/500•). From the results of measured contact resistances, we concluded that the sample 2 is the optimized structure of PtGeAu ohmic contact. In comparing with NiGeAu, PtGeAu(sample 2) ohmic contact showed the lower contact resistance and the stable results in broad alloy temperature range.

Figure 2 shows the surface morphologies of PtGeAu and NiGeAu ohmic contacts. PtGeAu ohmic contact shows the excellent surface morphology which is smooth and uniform. In NiGeAu, contact crystal grain and some "ball-up" are clearly visible, which results from the spaciously inhomogeneous reactions between GaAs and NiGeAu layer.

For both ohmic contacts, AES analyses were carried out. Figure 3 shows AES depth profiles of both ohmic contacts. In case of PtGeAu ohmic contact, $PtAs_2$ and Au_7Ga_2 are formed after alloy[6]. Au element, the dominant moving species, diffuses fast into GaAs and forms Au_7Ga_2 compound adjacent to GaAs. From the investigation of surface morphology, it is thought that $PtAs_2$ layer is stable and it plays an important role, in blocking the excess out-diffusion of Ge and As. In comparing with NiGeAu ohmic contact, we expect that the shallow diffusion of Pt in PtGeAu ohmic would yield better thermal reliability than NiGeAu ohmic contact. In NiGeAu ohmic contact, Ni and Ge diffuse deeply to GaAs. Deep diffusion of Ge reacts amphoterically, which may cause to the increased contact resistance and the thermal unstability problem.

Figure 4 shows the results of thermal annealing test. For both ohmic contacts, we measured the contact resistances for various annealing times at 350^{o}C. After 80 hours, the contact resistance of PtGeAu was increased from 0.125• -• to 0.37• -• . According to the Figure 4, PtGeAu ohmic contact is thermally more stable than NiGeAu ohmic contact. And the surface morphology of PtGeAu was rarely altered after annealing.

We applied the optimized PtGeAu ohmic contact to PHEMT device with 0.15• T-gate. Figure 5 shows the electrical characteristics of the fabricated PHEMT device which has 2×100• gate width. (Idss=510mA/mm, gm=570mS/mm. ft=90GHz, and fmax=220GHz)

3. Conclusion

A new thin ohmic contact, Pt/Ge/Au=200/400/800• shows the lowest contact resistance(0.125• -•) after 20sec alloy at 450^{o}C. In comparing with NiGeAu ohmic contact, PtGeAu ohmic contact shows excellent surface morphology, lower contact resistance and better thermal reliability. PtGeAu thin ohmic contact can be utilized for the fabrication of short gate length PHEMT devices, making up for the demerits of thick ohmic contacts[7] while having better characteristics than conventional NiGeAu ohmic contact. We have successfully applied the optimized Pt/Ge/Au ohmic structure to the fabrication of PHEMT device with 0.15• T-gate.

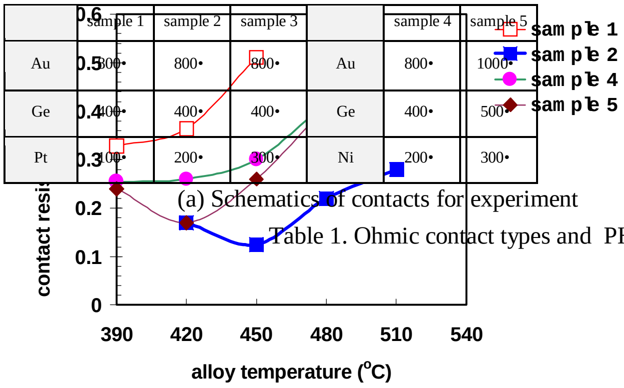
	sample 1	sample 2	sample 3		sample 4	sample 5
Au	800•	800•	800•	Au	800•	1000•
Ge	400•	400•	400•	Ge	400•	500•
Pt	100•	200•	300•	Ni	200•	300•

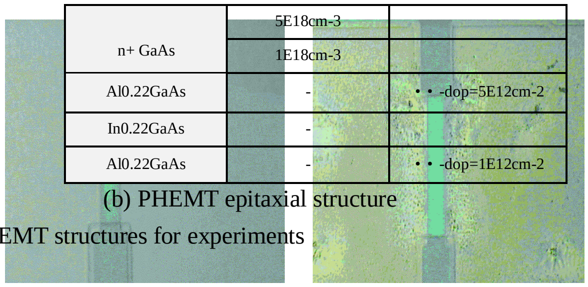
(a) Schematics of contacts for experiment

n+ GaAs	5E18cm-3	
	1E18cm-3	
Al0.22GaAs	-	• • -dop=5E12cm-2
In0.22GaAs	-	
Al0.22GaAs	-	• • -dop=1E12cm-2

(b) PHEMT epitaxial structure

Table 1. Ohmic contact types and PHEMT structures for experiments

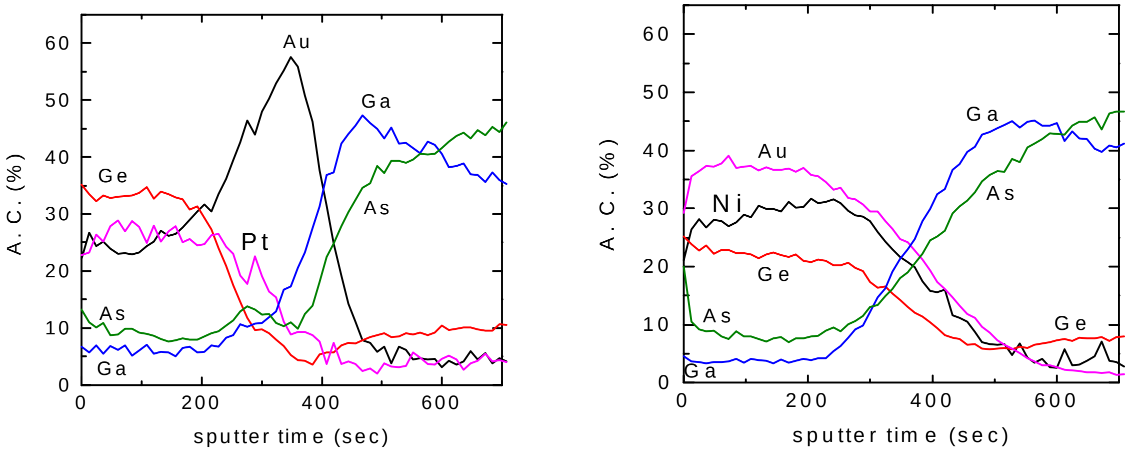




(a) PtGeAu ohmic contact (b) NiGeAu ohmic ontact

Figure 1. Comparison of contact resistances

Figure 2. Surface morphologies after alloy



(a) PtGeAu ohmic contact

(b) NiGeAu ohmic contact

Figure 3. AES depth profiles

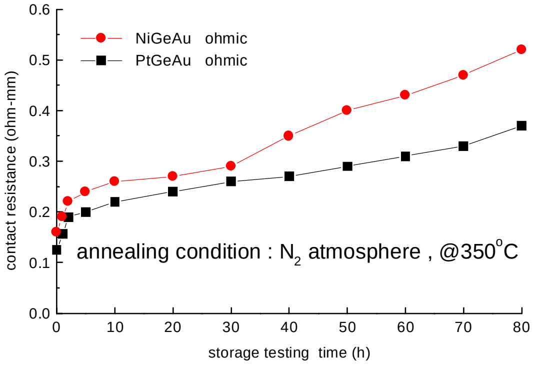


Figure 4. Contact resistances as a function of annealing time

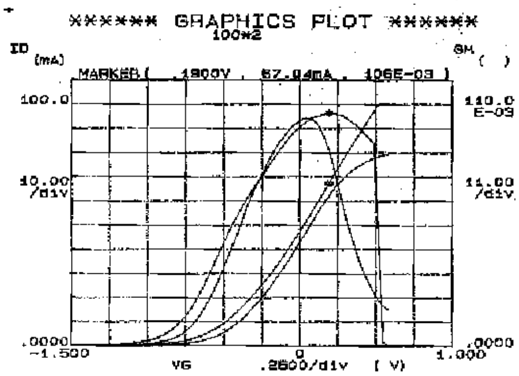


Figure 5. Electrical characteristics of the fabricated PHEMT device