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The Influence of AlGaN/GaN Schottky Barrier Diode (SBD) with SiH_4 Doping in Barrier Layer

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Abstract

In this work, we observed the influence of doping SiH_4 in the barrier layer (BL) of AlGaN/GaN Schottky Barrier Diode (SBD). Based on the forward and reverse-bias characteristics, the barrier layer doping SiH_4 improved forward current and reduces turn-on voltage (V_{on}). We obtained the stable performance at different temperature as AlGaN/GaN SBD doping SiH_4 in the BL.

1. Introduction

GaN-base materials was proved a great potential in high-power and high-speed electronic applications because of the superior material properties like high breakdown field, wide bandgap, and high electron mobility [1]. Because of their superior material properties, they can make device operate at high voltage and high temperatures conditions. The advantage of GaN schottky barrier diode (SBD) is low turn voltage (V_{on}), fast recovery time, especially fast switching speed and low switching loss which can improve the efficiency [2]. GaN on Si (111) growth technology was highly anticipated because it is low cost and large wafer size [3].
In this study, we investigate the forward and reverse-bias characteristics and reverse recovery measurement to discuss the doping SiH_4 concentration in the barrier layer.

2. Device Structure and Fabrication

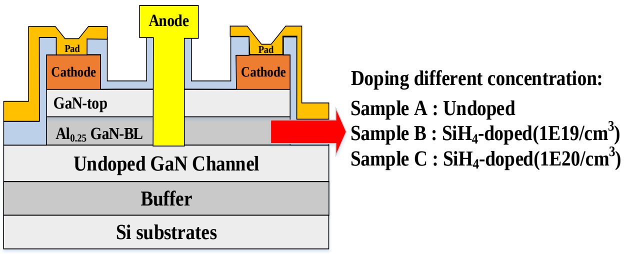

Fig. 1 Device and cross-section of AlGaN/GaN SBD with $L_a = L_c = L_{ac} = 20$ μm

The AlGaN/GaN HEMT wafer sample used for this study was grown by MOCVD on (111) silicon substrate. The epitaxial structure includes a 300 nm-thick undoped GaN channel layer and an 18 nm-thick $Al_{0.25}GaN$ schottky layer between the GaN channel layer and the 1.5 nm undoped GaN cap layer. In 18 nm-thick $Al_{0.25}GaN$ schottky layer, doping two SiH_4 concentration (1E19/1E20 per cm^3) on the top of 1 nm-thick undoped $Al_{0.25}GaN$ schottky barrier layer. In order to mark off an active region by a photoresist, and the mesa isolation region was removed by a reactive ion etching (RIE) chamber using BCl_3+Cl_2 mixed gas plasma. The cathode ohmic contacts metal Ti/Al/Ni/Au was deposited by electron beam evaporator, and then annealed by rapid thermal annealing at 850 °C for 30 s in a N_2 ambient. And then, a 100-nm-thick SiO_2 layer was deposited as passivation layer. Anode recess by inductively coupled plasma reactive ion etching (ICP-RIE) and the anode metal Ni/Au was also evaporated by electron beam evaporation system. Fig. 1 is the device structure and cross-section with L_a = 20 μm, L_{ca} = 20 μm and L_{ac} = 20 μm. The active region of the device is 0.01 mm^2.We used HALL measurement obtain the resistivity of the Sample A, B, C were 409.6, 280.3 and 264.8 ohm/sq.

3. Results and Discussion

Fig. 2 showed forward I-V characteristic of three samples at 300K and 350K. The forward current (I_F) of Sample A, B, C were 191,302 and 314 (A/cm^2) at 300K when voltage were 4V. Comparing the temperature from 300K to 350K, when the doping concentration higher, the decline rate of current were lower. The degradation of the Sample A, B, C were 47%, 27.2%, 21% at room temperature. Doping SiH_4 make the degree of degradation lower than undoped. Doping SiH_4 also can reduce the V_{on}, the Sample A, B, C of V_{on} were 1.4, 1.05, 1.3V. Table 1 showed the V_{on}, R_{on}, I_F (@4V) at 300K and 350K. We observed doping SiH_4 had the lower resistivity and stable state at different temperature.

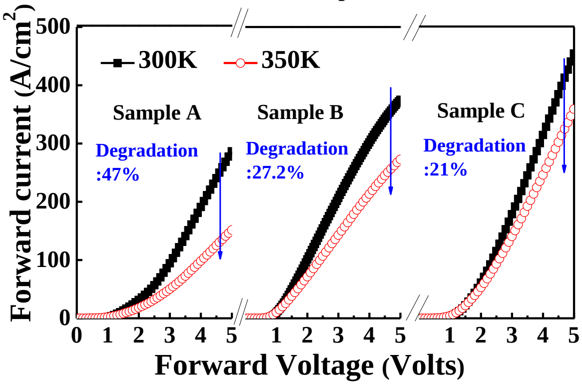

Fig. 2 The forward I-V characteristics of three samples at 300K and 350K

When we doped the more SiH_4 concentration, the band gap got narrower which caused tunneling effect easily. Therefore, the more doping concentration lead to the more leakage current raised at room temperature.

Table 1 DC characteristics of three samples at 300K and 350K

	Sample A		Sample B		Sample C	
	300K	350K	300K	350K	300K	350K
V_{on}(V)	1.4	1.65	1.05	1	1.3	1.25
R_{on} (mΩ-cm^2)	4.14	8.3	4.19	5.67	2.94	4.02
I_F@4V (A/cm^2)	191	98.2	302	213	314	240

Fig. 3 exhibited the reverse I-V characteristic of three samples. Due to the tunneling effect, the Sample B and Sample C were kept the same order but Sample A rose three order from 300K to 350K. The SBD doping SiH_4 in the BL make low temperature dependence of leakage current.

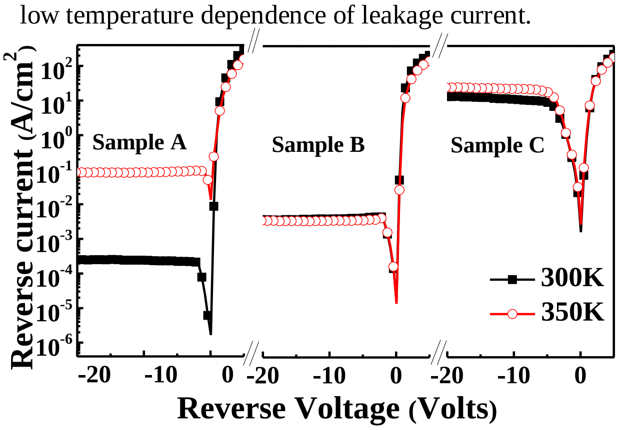

Fig. 3 The reverse I-V characteristics of three samples at 300K and 350K.

Fig. 4 shows the breakdown characteristics of these three samples. The breakdown voltage (V_{BR}, defined as the reverse bias voltage at diode current reaches 1 mA) measured the Sample A, B, C were 679 V, 488V, 97V. Doping the SiH_4 increased the electric field lead to the deterioration of the breakdown voltage.

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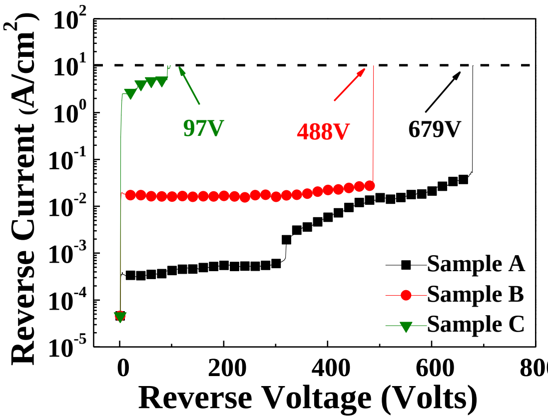

Fig. 4 The breakdown voltage of three samples at room temperature.

The specific R_{on} (the resistance of forward voltage at 3V to 4V) of Sample A and Sample B were close at the 300K but the temperature increasing, the R_{on} slope of sample B were smaller. As shown in Fig. 5. When the temperature rose, the specific R_{on} slope of the more doping concentration were smaller.

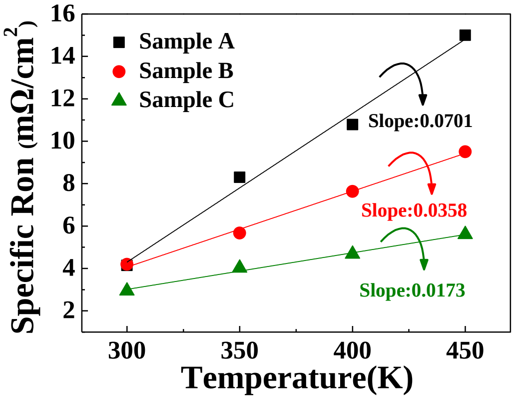

Fig. 5 Specific Ron characteristics of three samples from 300K to 450K

Q_{rr} depends on several factors: the junction capacitance, the parasitic capacitances shunt to the schottky diode and the impurities with deep levels in the bandgap. As shown in Fig.6, The Trr and the Qrr of the undoped was better than SiH_4 doping. The insert table were the T_{rr} and Q_{rr} of three devices.

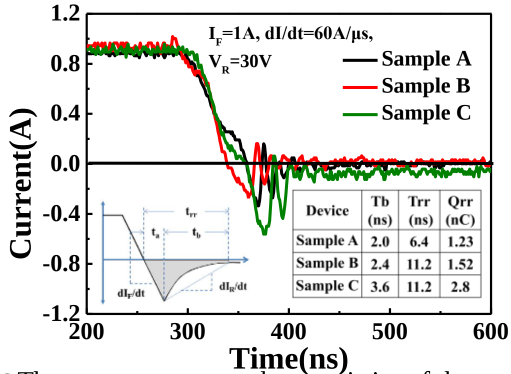

Fig. 6 The reverse recovery characteristics of three samples.

4.Conclusion

In this work, we fabricated different SiH_4 concentration in BL of AlGaN/GaN SBD. Based on the DC measurement results, doping SiH_4 in the barrier layer can increase the forward current, reduce the V_{on}, had better specific R_{on} and more stable at different temperature. We investigated the effect of the SiH_4 concentration which showed the more concentration improved the forward current but the leakage current increased.The doping concentration also effected the breakdown voltage and reverse recovery characteristic. Therefore, we can dope the suitable SiH_4 concentration in the BL.

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