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Effects of Different Fe-doped GaN Buffer in AlGaN/GaN HEMTs on Si Substrate

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Abstract

In this work, we have fabricated AlGaN/GaN high electron mobility transistors (HEMTs) with different Fe-doped concentration GaN buffer on a Si substrate. In order to investigate the different concentration of Fe-doped GaN buffer on device characteristics, we compared their DC characteristic, breakdown voltage, low frequency noise, and pulse measurement behavior. It shows that increasing the Fe doped concentration could improve the gate leakage and buffer breakdown voltage.

Keywords: Fe-doped, AIGaN/GaN HEMT, Buffer layer, Si substrate.

1. Introduction

The AlGaN/GaN high electron mobility transistors have shown impressive improvements due to the high mobility and high saturation velocity of GaN [1]. The conventional AlGaN/GaN HEMT structure was not suitable for a high breakdown voltage (BV) as a result of the unstable off-state breakdown performance. In contrast to the AlGaN/GaN HEMT with an Fe-doped GaN buffer on Si showed much more stable and higher BVs by suppressing the earlier failure caused by Si breakdown [2]. We could achieve a high resistivity by doping GaN with deep level impurities. Fe is one such impurity, Fe-doped GaN buffer layer has highly resistive [3].

We fabricated four different Fe-doped concentration GaN buffer of AlGaN/GaN HEMTs on Si substrates to compare the gate leakage and BVs. We also use low frequency nosie and pulse IV to observe the characteristics.

2. Experiment

The structure was grown on silicon (111) substrate by MOCVD. The device structure is composed of different Fe-doped concentration GaN buffer layer, a GaN channel layer, a $Al_{0.25}GaN$ layer and GaN top layer. The Fe-doped concentrations of GaN buffer are 5E17, 6E17, 7E17, and 8E17, respectively.

We used reactive-ion etching (RIE) formed mesa isolation region to define the active region. The source and drain ohmic contacts metal were grown by evaporating Ti/Al/Ni/Au (25 nm/130 nm/50 nm/200 nm) in the e-beam evaporator, followed by rapid thermal annealing (RTA) at 850℃ for 30s in N_2 ambient. The gate was formed by evaporating Ni/Au (50 nm/200 nm) metals for schottky contacts as shown in Fig. l.

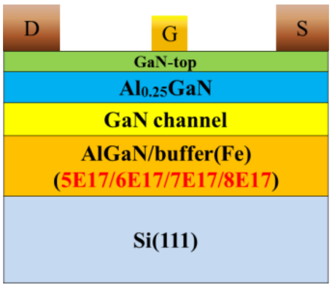


Fig. 1 The cross-sectional structure of Fe doped GaN HEMT.

3. Results and Discussion

To investigate the characteristics of devices, we measured DC characteristic, breakdown voltage, low frequency noise, and pulse measurement behavior.

Fig. 2 shows the I_{DS}-V_{DS} characteristic of different concentration of Fe doped GaN. The gate to source voltage (V_{GS}) was set 2V and the drain to source voltage (V_{DS}) was from 0 to 10 V. To compare the different concentrations characteristic, the I-V performances were measured. The I_{DS} maximum of 5E17, 6E17, 7E17, and 8E17 were 341 mA/mm, 324 mA/mm, 315 mA/mm, and 287 mA/mm, respectively. The inset of Fig. 2 shows the gate leakage current of devices. We could find that enhance Fe-doped concentration of GaN buffer will suppress the leakage current, but the drain current were reduced.

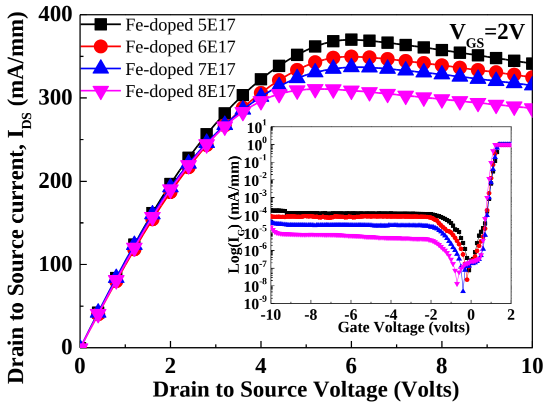


Fig. 2 The I_{DS}-V_{DS} and the log [I_{GS}]-V_{GS} characteristic of devices.

Fig. 3(a) shows the off-state breakdown voltages for four devices. The breakdown voltage (V_{BR}) of 8E17 was 193V. However, the Fe doped concentration of 5E17 shows lower V_{BR}. It should be the abrupt current increase by punch -through to Si substrate. We also measured buffer breakdown voltage for four devices which are plotted in Fig. 3(b).

The V_{BR} of 8E17 was 1257V. It was raised from 1074V to 1257V. There could infer from enhance Fe doped concentration obtain highly resistive in GaN buffer layer to improve breakdown voltages.

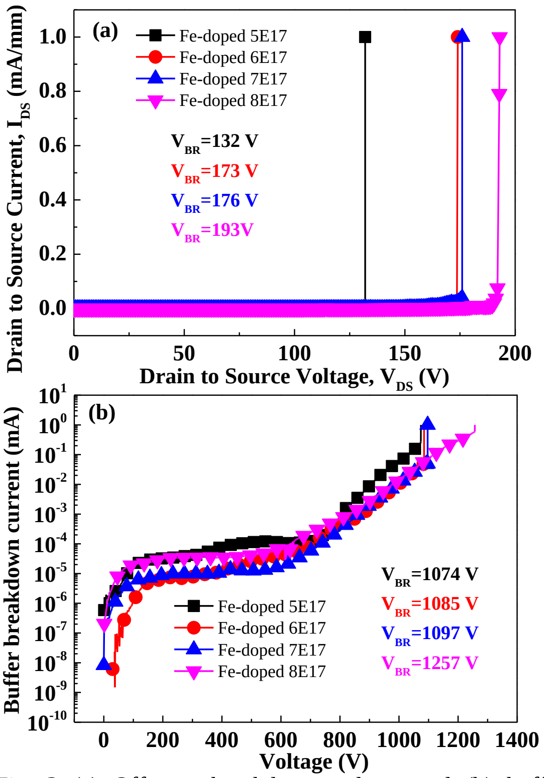
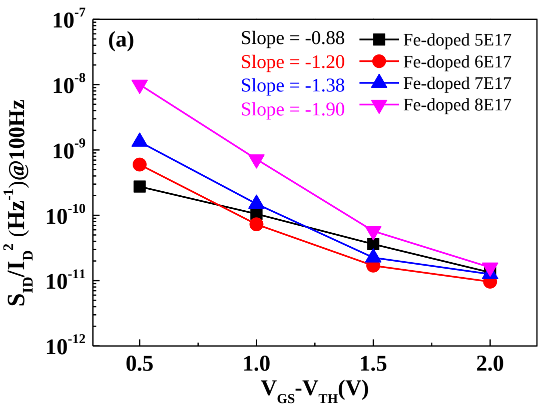


Fig. 3 (a) Off-state breakdown voltage and (b) buffer breakdown voltage of devices.

To investigate the trapping phenomena in the different concentration of Fe doped GaN HEMT, the l/f noise for the four devices were measured at various gate bias voltages. The slope of the normalized drain current noise spectral density (S_{ID}/I_D^2) approaches -1, then it is followed the mobility fluctuation model. While the slope becomes -2, it is followed the carries number fluctuation model.

Fig.4 (a) shows the slope at l00 Hz for the four devices. The slope of 5E17, 6E17, 7E17, and 8E17 were -0.88, -1.2, -1.38, -1.9, respectively. And we obtain Hooge's constant as shown in Fig. 4(b). It follows from the Fig. 4(b) that the values of the Hooge's constant increased for the more concentration.



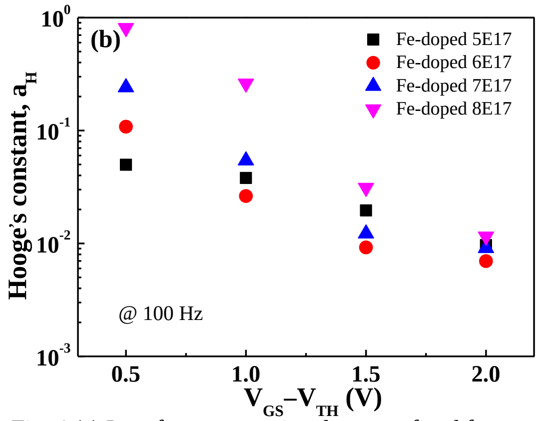


Fig. 4 (a) Low frequency noise slope at a fixed frequency of l00Hz and (b)Hooge's constant of devices.

In order to verify the trapping phenomena, we measured pulse IV as shown in Fig. 5 to observe the current decrease percent of devices. We take the point of I_{DS} when V_{DS}= 10 V, and pulse width were 50us, 500us, 1ms, and 10ms. From this picture we could find enhancing Fe-doped concentration will increase the buffer trap and cause current collapse result in the decrease percent of pulse IV.

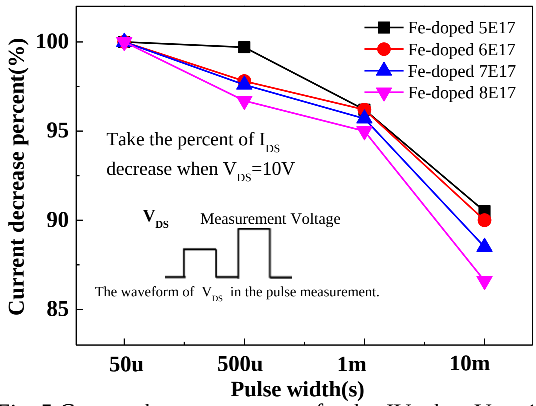


Fig. 5 Current decrease percent of pulse IV when V_{DS}=10V.

4. Conclusion

We have fabricated AlGaN/GaN HEMTs with different Fe-doped concentration GaN buffer on a Si substrate. It shows that increasing the Fe doped concentration could suppress the gate leakage about 1 order and improve buffer breakdown voltage from 1074V to 1257V. However, enhance Fe-doped concentration will cause current collapse which observed in low frequency noise and pulse measurement.

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