Reliability Study of AlGaN/GaN HEMTs Device

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Abstract

AlGaN/GaN HEMTs devices are studied intensely because of its ability of operation at higher voltage with higher power density. As the study progress, it is realized that the reliability of the fabricated device is a quite important issue. From the reliability study of AlGaN/GaN HEMTs, it is found that the current degradation has relationships with the isolation structure. In this paper, the differences of current degradations between two isolation methods are studied and some interpretations concerning the source of these degradations are discussed.

INTRODUCTION

Recently AlGaN/GaN high electron mobility transistors (HEMTs) have made rapid progress in its characteristics as a high power microwave devices. With these progresses, many working groups study AlGaN/GaN structure intensively concerning versatile applications such as; for L-band applications including wireless base station of mobile communication systems [1, 2], for C-band and X-band applications, such as satellite communication systems or fixed wireless access systems [3-6]. Since AlGaN HEMTs were able to operate at higher voltage with higher power density than its competitors, the reliability of device at the circumstance of high voltage, high temperature is quite important issue. Concerning these reliability issues, there were some reports which explain degradation mechanisms with there own unique models [1, 7-11]. But unfortunately, these reports conclude there results without abundant amount of life tests data.

In this paper we discuss about the electrical reliability of AlGaN/GaN HEMTs and identify the fundamental mechanisms responsible for device degradation.

EXPERIMENT

Fig. 1 shows a cross sectional view of fabricated HEMTs. An undoped $Al_{0.25}Ga_{0.75}N$/GaN HEMT structure was grown on a 4H SiC substrate by MOCVD. Ti/Al were evaporated by E-beam thermal evaporator and annealed with RTA at N_2 ambient to form the source and drain electrodes. A Schottky gate electrode was formed with E-beam evaporated Pt/Au. SiN film was deposited by PE-CVD for surface passivation. The back side of the device was thinned to 150μm by mechanical polishing.

Two types of isolation structures were applied to the device. One is the mesa-isolation region, formed by Cl_2/Ar ECR-RIBE. The other is nitrogen-ion-implant isolated structure. Figure 2 shows a picture of the fabricated device. The outside of the area enclosed with dashed line is the isolation area. The gate width of the device is 960μm in total with the unit gate width of 160μm.

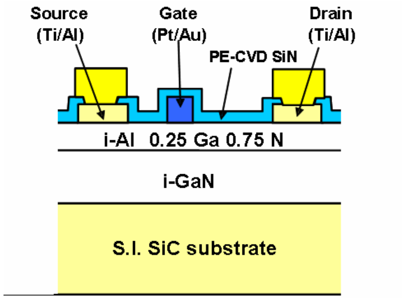


Figure 1 Cross-section of device structure.

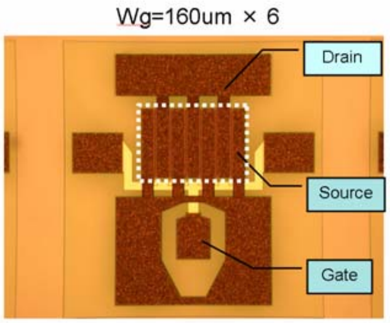


Figure 2 Photograph of AlGaN/GaN HEMT. The outside of the area enclosed with dashed line is the isolation area.

The reliability test of the fabricated devices is performed by accelerate tests with the conditions described below.

The DC tests run under constant drain bias, gate bias and channel temperature. The test condition was such that the drain voltages applied are 30V and 40V, and the channel temperatures are keep to 200°C, 250°C and 300°C. Channel temperatures ware measured with infrared image sensor. The saturated drain current (Idss) was measured by interrupting the DC test.

RESULTS AND DISCUSSION

Accelerate tests were performed under the conditions of drain bias (Vds) of 30V and channel temperature (Tch) of 250°C. Figure 3 shows the drain current changes as test progress. It is worth to mention that the mesa isolation structure showed only 5% of degradation of the saturation current at 1000 hours, while the ion-implant isolation structure showed 40% of that at 1000h.

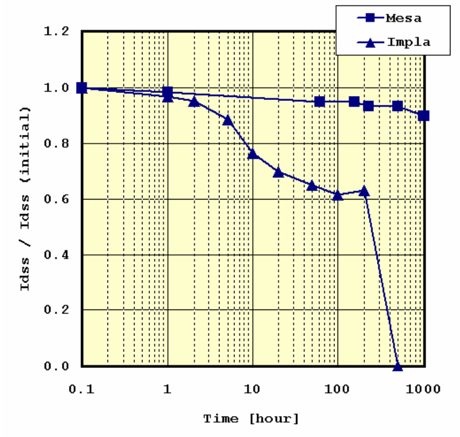
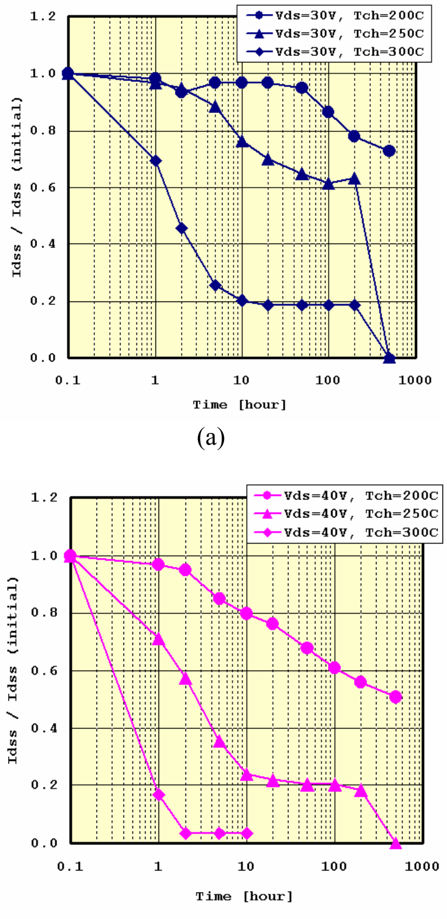


Figure 3 Accelerated test of mesa-isolation structure and ion-implanted isolation structure.

For ion-implant isolation devices, the acceleration tests with different drain voltages and channel temperatures are performed. Figure 4(a) shows the degradation of saturation current when the drain voltage is 30V with the channel temperatures of 200°C, 250°C and 300°C. Figure 4(b) shows same but with the drain voltage set to 40V. The channel temperature was estimated by the thermal resistance which was measured from the infrared image sensor. It is clear that the degradation depends on the drain voltage and the channel temperature at the same time. The degradation became 98% at Vds=40V and Tch=300°C. From these results, the estimated activation energy is about 1.4eV.



(a)

(b)

Figure 4 The voltage and channel temperature dependency on ion-implant isolation structure device at (a) Vds=30V (b) Vds=40V.

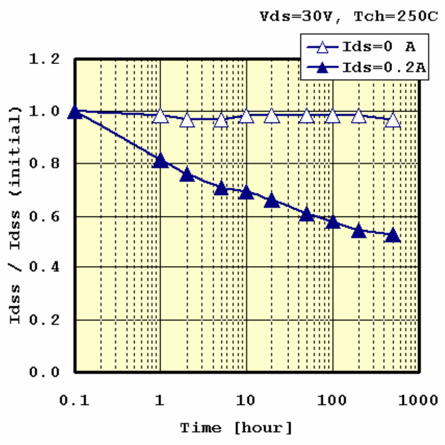
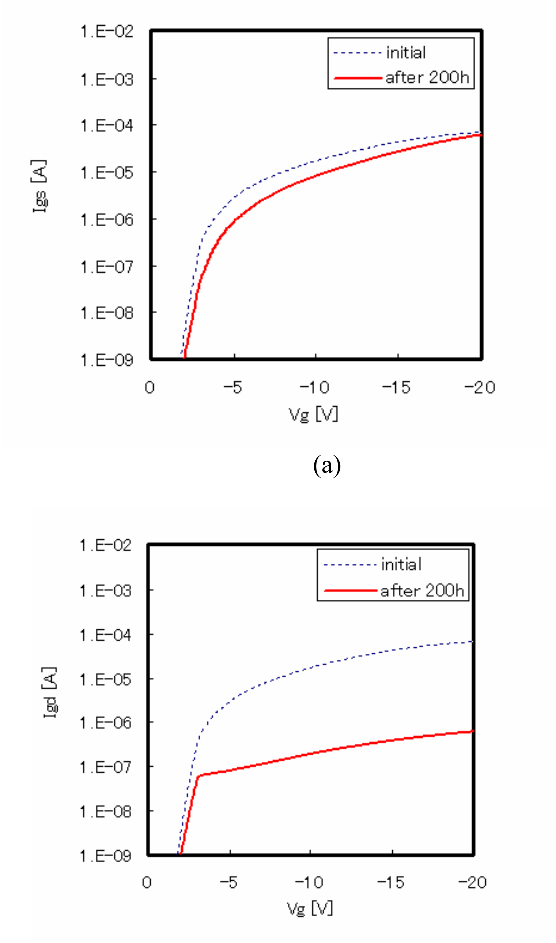


Figure 5 Accelerated tests of On-state and Off-state.

Figure 5 shows the accelerated test result of on and off-state (Ids=0, Vgs=-5V, Vds=30V) condition. Not likes on-state accelerate test, no degradations are observed for off-state accelerate test. This result indicates that the degradation does not caused by one of the electrical field or the temperature alone, but the drain current is also a one of the key factor for the degradation. Figure 6 shows the gate-source and the gate-drain reverse leakage current of the device measured before and after the accelerate test. It is clear from the figure that the reverse leakage currents of the gate-drain was decreased significantly while the gate-source reverse leakage currents shows little changes.

These results clearly indicate that the degradation of the currents is neither caused by the source/drain electrode nor gate metal sinking. In addition, the surface charge effect at gate edge is not believed to the reasons.



(a)

(b)

Figure 6 Two terminal reverse current of (a) gate-source and (b) gate-drain.

From these results it is concluded that the current degradation was caused by the hot carriers. The hot carriers were injected to GaN or AlGaN layer between gate and drain electrode.

It could be assumed that the mesa type structure prevents the electron injections by side-gate effect.

CONCLUSIONS

An investigation of DC life tests of an AlGaN/GaN HEMTs device has been performed. We compared two types of isolation structures, such as implantation-isolated and mesa-isolated device. The current degradation of the implantation-isolated structure device was depends on channel temperature, drain bias and on-state-drain current. But at off-state no degradation was occurred. From these results, we confirm that these degradations were caused by hot carriers. The mesa-isolation structured device preventing current degradation by side gate effect.

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ACRONYMS

HEMTs: high electron mobility transistors
AlGaN: Aluminum Gallium Nitride
SiC: Silicon Carbide
MOVPE: Metal Organic Vapor Phase Epitaxy
ECR-RIBE: Electron Cyclotron Resonance Ion Beam Etching