Extended Abstracts of the 2009 International Conference on Solid State Devices and Materials, Sendai, 2009, pp508-509

Effects of Pre-treatment on Passivation of AlGaN/GaN on Silicon HEMTs

Ji Ha Kim[1, 2], Hong Goo Choi[1], Hong Joo Song[1], Cheong Hyun Roh[1], Jun Ho Lee[1], Jung Ho Park[2] and Cheol-Koo Hahn[1]

[1]Korea Electronics Technology Institute, 68 Yatop-dong, Bundang-gu, Seongnam, Gyeonggi-do 463-816, Korea
Phone: +82-31-546-6566, Fax: +82-31-546-6568, Email: jihatop@hotmail.com
[2]Department of Electronics Engineering, Korea University, Anam-dong, Seongbuk-gu, Seoul 136-701, Korea

1. Introduction

Due to electrical advantages of gallium nitride (GaN), such as high breakdown electrical field, large two-dimensional electron gas (2-D) concentration, and high electron saturation velocity, AlGaN/GaN high-electron-mobility transistors (HEMTs) have recently received significant attention for high output power, high frequency, and high temperature applications. Moreover, AlGaN/GaN grown on silicon substrate can be more useful than any other substrates in the viewpoint of low cost, large size and thermal conductivity.

However, even though commercial products are becoming available at frequencies up to several GHz, there are some technical issues. Among them, RF-dispersion (current collapse) phenomenon is most important pending problem. [1,2]

In this work, we tried various pre-treatment methods to overcome the RF-dispersion phenomenon [3,4]. Among various pre-treatment methods, optimized NH_3 plasma treatment is found to be most effective.

2. Experiment

The epilayer of devices is consists of a 2μm-thick unintentionally doped GaN buffer/channel layer, a 17.5 nm undoped $Al_{0.26}Ga_{0.74}N$ barrier and a 2 nm undoped GaN capping layer. The 350nm deep mesa etching was applied for device isolation. The drain-source distance is fixed to 10μm. The Ni/Au was used for Schottky gate metal with its length/width of 0.8μm/96μm. Ohmic contact was carried out evaporating Ti/Al/Ni/Au and rapid thermal annealing (RTA) at 900℃.

After gate definition, wet and plasma pre-treatments were applied and deposition of a 100 nm-thick SiO_xN_y passivation was followed. Pre-treatment was carried out in two steps. After dipping the sample in NH_4OH for 4-mins at 50℃, N_2/NH_3 plasma was applied for 240sec/120sec with the power of 60W. More details of the pre-treatment conditions are described in table Ⅰ.

DC/pulsed I-V and RF measurements are carried out to characterize electrical properties of the device. For the pulsed-IV measurement, V_{DS} = 15V, V_{GS} = -2V were applied with pulse width/period of 500ns/1ms, respectively.

3. Results and Discussion

The DC and RF electrical characteristics of AlGaN/GaN HEMTs depending on the pre-treatments conditions are shown in TableⅡ.

Fig.1 shows the DC and pulsed I-V characteristics of fabricated device depending on the pre-treatment condition. Without pre-treatment, around 63% under V_{DS} = 15V of RF-dispersion was observed in the pulsed I-V measurements (Fig. 1(a)). By applying only NH_4OH pre-treatment (Fig. 1(b)), RF-dispersion was not enhanced. On the contrary RF gate voltage swing was reduced. This is thought to be caused by 2-DEG carrier density reduction in the channel during chemical process. With optimized additional pre-treatment with N_2 and NH_3, RF-dispersion was drastically reduced to 9% and 1%, respectively (Fig. 1 (c), (d)). As compared in the figures, NH_3 plasma pre-treatment is found to be more effective for the pre-treatment. According to Edward et. al, NH_3-plasma is better candidate than N_2-one because it could be dissolved under lower power with additional H^+-passivation effect. This means that the H^+-passivation effect is the dominant reason of the enhanced pre-treatment result. Although it is the subject open to dispute, according to our experiments however, it is believed that H^+-passivation effectively reduces the trap density in the AlGaN/GaN layer [4, 5] and this is the dominant reason of the reduced RF-dispersion.

Load-source-pull measurement was also carried out. Details of pre-treatment effects on the device DC/pulsed I-V and RF properties will be discussed in detail

4. Conclusions

We have studied on the pre-treatment effect in the AlGaN/GaN-on-Si HEMTs. In our experiments, optimized NH_3-plasma is found to be most effective method of pre-treat during device process. RF-dispersion could have been reduced less than 1%.

Acknowledgement

This work was supported by the IT R&D program of MKE/IITA[2007-F-044-03, Development of GaN power amplifier for 4G base station].

References

[1] R. Ventry, Naiqain Q. Zhang, S. Keller, and Umesh K. Mishra, *IEEE Transsactions on Electron Devices*, vol. 48, no. 3, 2001
[2] T. Mizutani, Y. Ohno, M. Akita, S. Kishimoto, and K. Mawzawa, *IEEE Transsactions on Electron Devices*, vol. 50, no. 10, 2003
[3] T. Hashizume, S. Ootomo, S. Oyama, M. Konishi, and H. Hasegawa, *J.Vac.Sci.Techno*l.B, vol. 19, no. 4, 2001
[4] A.P. Edwards, J.A. Mittereder, S.C. Binari, D.S. Katzer, D.F. Sorm, and J. A. Roussos, *IEEE Electron Device*

Letters, vol. 26, no. 4, 2005

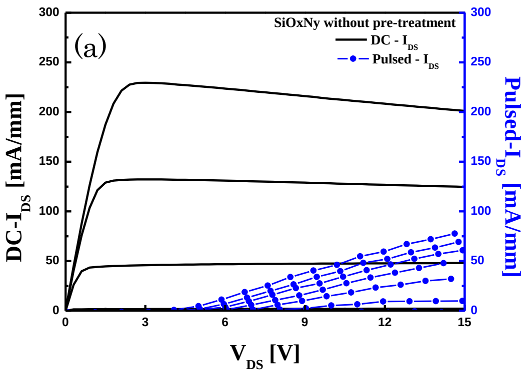
[5] T. Hashizume, S. Ootomo, T. Inagaki, and H, Hasegawa, *J.Vac.Sci.Technol*.B, vol. 21, no. 4, 2003

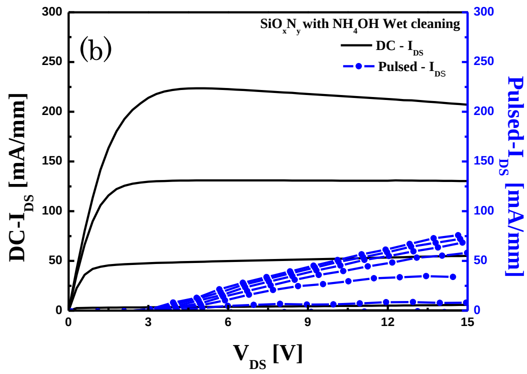
Table Ⅰ. N_2 and NH_3 plasma pre-treatment conditions by PECVD

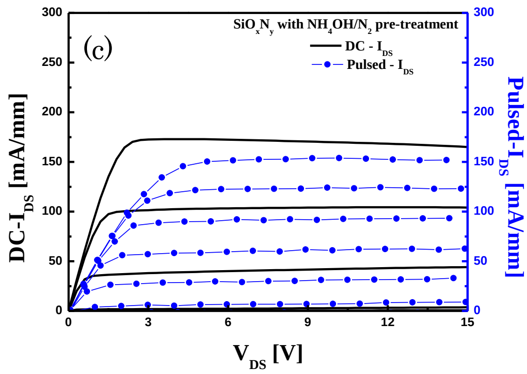
	RF-power(W)	Presure (mTorr)	Gas (sccm)	Process time(seconds)
N_2 plasma treatment	60	300	300(N_2)	240
NH_3 plasma treatment	60	300	9(NH_3)	120

TableⅡ. DC and RF electrical characteristics of AlGaN/GaN-on-Si HEMTs. Without pre-treatment(#1), NH_4OH(#2), NH_4OH/N_2(#3) and NH_4OH/NH_3(#4) pre-treatment on SiO_xN_y passivation.

	$I_{DS,MAX}$ (mA/mm)	gm (mS/mm)	V_{TH} (V)	f_T (GHz)	f_{MAX} (GHz)	Recovery current collapse rate(%)
#1 (without pre-treatment)	237.39	160.21	-2.4	2.65	10	-
#2 (NH_4OH pre-treatment)	235.33	160.32	-2.4	2.6	9.7	-
#3 (NH_4OH/N_2 pre-treatment)	184.02	124.57	-2.2	3.2	11	91
#4 (NH_4OH/NH_3 pre-treatment)	110.76	114.45	-1.5	2.95	9.45	99







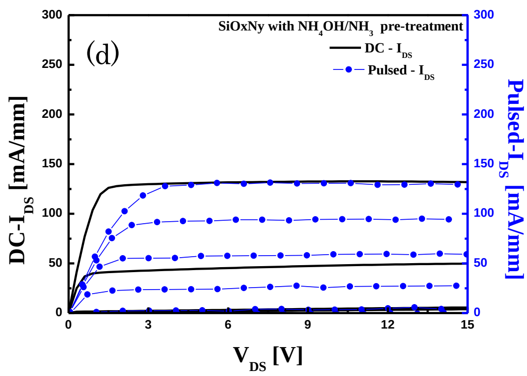


Fig.1 The DC(solid line) and Pulsed – IV(circle symbol line) with pre-treatments on SiO_xN_y (1000 Å) passivation of AlGaN/GaN on Si HEMTs. (a)without pre-treatment, (b)NH_4OH, (c)NH_4OH/N_2 and (d) NH_4OH/NH_3 pre-treatment.