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Effect of Gate Insulator Material on Dynamic On-Resistance in GaN MIS-HEMT on 6-inch Si

S. Akiyama[1], Y. Watanabe[1], T. Wakabayashi[1], K. Nukui[1], Y. Kotani[1], T. Ogino[1],T. Hosoda[1], M. Kanamura[2], K. Joshin[2] and T. Kikkawa[2]

[1] Power Device Div., Fujitsu Semiconductor LTD.
Fujitsu Semiconductor LTD, 3 Kougyoudanchi, Monden-machi, Aizuwakamatsu, Fukushima, 965-8502, Japan
Tel: +81-242-38-2720, Fax: +81-242-28-5426, e-mail: {akiyama.shinich, watanabe.yos-13, g-waka, nukui.kenji, kotani.yoshiyuk, ogino.tsutomu, hosoda.tsutomu }@jp.fujitsu.com
[2] Advanced Devices Lab., Fujitsu Laboratories LTD.
Fujitsu Laboratories Ltd., 10-1 Morinosato-Wakamiya, Atsugi, Kanagawa, 243-0197, Japan
e-mail,{ kanamura.masahi, joshin, kikkawa.toshi,}@jp.fujitsu.com

Abstract

The effect of gate insulator material of AlGaN/GaN high electron mobility transistors (HEMTs) on dynamic on-resistance has been studied for high power conversion applications. Metal insulator semiconductor (MIS) HEMTs, grown on Si (111), were fabricated at the 6-inch LSI mass production line. The gate insulator films of HEMTs have been compared using atomic layer deposition (ALD). ALD-Al_2O_3 and -AlON were investigated focusing on the dynamic on-resistance. The dynamic on-resistance varied associated with insulator material and process conditions of rapid thermal annealing (RTA) temperature. High voltage switching test showed the device using ALD-AlON with 700°C RTA has better performance of dynamic on-resistance at 400V with excellent uniformity over the 6-inch wafer, compared with the device using ALD-Al_2O_3.

1. INTRODUCTION

AlGaN/GaN HEMTs have demonstrated good performance for power devices [1]. For high-voltage power device, the suppression of gate leakage current is very important. There are many report of studying MIS-HEMTs and its gate insulator materials [2]. And the dynamic on-resistance is also well reported as a major issue [3]. However there are few reports of gate insulator material effect on dynamic on-resistance. In this investigation, we have compared ALD-AlON of several process conditions with ALD-Al_2O_3 in dynamic on-resistance over the GaN on Si using the 6-inch LSI mass production facility.

2. EXPERIMENRAL

The devices were fabricated on AlGaN/GaN HEMT epitaxial structure. Fig.1 shows the cross-sectional schematic view of the GaN MIS-HEMT. To suppress current collapse, we used n-type doped GaN cap layer.

The epitaxial growth technologies extended up to 6-inch diameter as shown Fig.2. The processing at the existing Si LSI mass production line can minimize fabrication cost, and also provide stable quality of device and quick turnaround time.

Al_2O_3 and AlON films were deposited by using ALD method at 380°C. Trimethylaluminum (TMA) was used as the source of aluminum, O_3 was used as the oxidant source, and NH_3 was used as the source of nitrogen. Table 1 shows various gate insulator and its process conditions. AlON was prepared by lamination technique of Al_2O_3 and AlN. RTA as the post deposition anneal was done in a N_2 ambient for 60 sec.

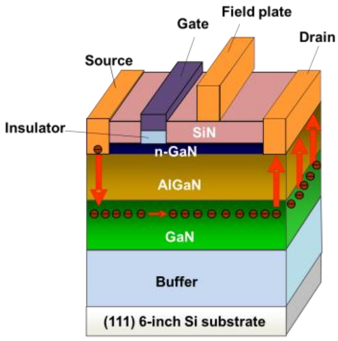

Fig. 1 Schematic cross-sectional view of normally-on type AlGaN/GaN MIS-HEMT structure used in this work.

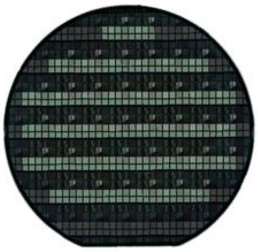

Fig. 2 Photograph of fabricated GaN MIS-HEMTs over 6-inch Si wafer.

Table 1 Sample conditions of the gate insulator materials

Type	Deposition Method	R.I. (as-depo)	Thickness	Post Deposition Anneal
AlON	$(Al_2O_3\ x1 + AlN\ x4)^n$	1.61	50nm	700°C
				800°C
Al_2O_3	$(Al_2O_3)^n$	1.56		620°C

3. RESULT AND DISCUSSION

Fabricated device showed three-terminal breakdown voltage of 800 V. Fowler-Nordheim (FN) tunneling was well known as a method of understanding the physical mechanisms of current leakage. Fig. 3 shows FN plot of each gate insulator materials. Liner slope was observed at data of AlON with 700°C and 800°C anneal, so that AlON has ideal conduction behavior. It means excellent film quality and good interface between insulator and semiconductor. On the other hand, The Al_2O_3 data was not linear, implying that FN tunneling did not occur in the Al_2O_3. It can be assumed that there was other conduction mechanism in the Al_2O_3.

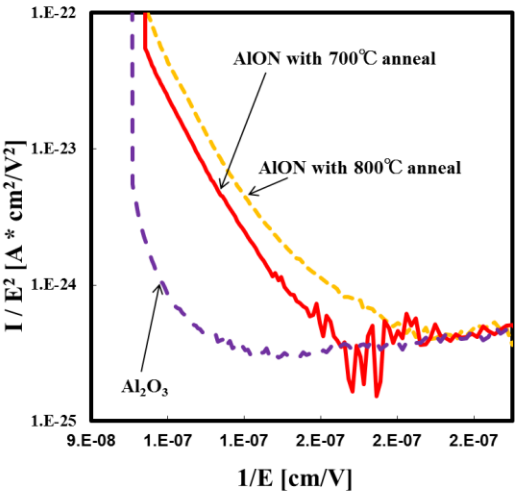

Fig. 3 Data are presented as a FN plot showing the dependence of leakage current divided by electric field squared versus reciprocal electric field. The liner slope implies FN tunneling in insulator.

The dynamic on-resistance (dynamic R_{on}) is defined as the on-resistance measured at switching on and off state. The on-state time of switching is 100 μsec. Dynamic R_{on} ratio is defined as the dynamic R_{on} at each drain voltage divided by dynamic R_{on} at drain voltage of 100 V.

Fig.4 showed dynamic R_{on} ratio dependence on drain voltage. Higher drain voltage caused larger dynamic R_{on}. Fig.5 showed dynamic R_{on} ratio at drain voltage 400 V over the 6-inch wafer. GaN MIS-HEMT using AlON with 700°C anneal for gate insulator film have the smallest dynamic R_{on} ratio and the best characteristics of dynamic R_{on} ratio uniformity over 6-inch wafer. We think gate insulator effect on dynamic R_{on}. Better insulator quality and better interface between insulator and semiconductor can improve the characteristics of dynamic R_{on}.

4. CONCLUSIONS

Effect of gate insulator material on dynamic R_{on} was investigated by comparing AlON of several process conditions with Al_2O_3. And we have successfully fabricated well uniformed device across a 6-inch wafer with small change of dynamic R_{on} till 400 V using an AlON insulator.

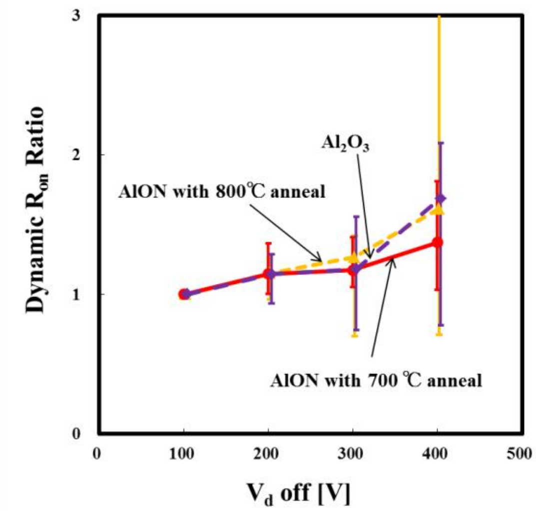

Fig. 4 Measurement results of dynamic R_{on} ratio versus drain voltage. Dynamic R_{on} ratio is defined as the dynamic on-resistance at each drain voltage divided by the dynamic on-resistance at drain voltage of 100 V. Error bar was inserted corresponding to the variation across a wafer.

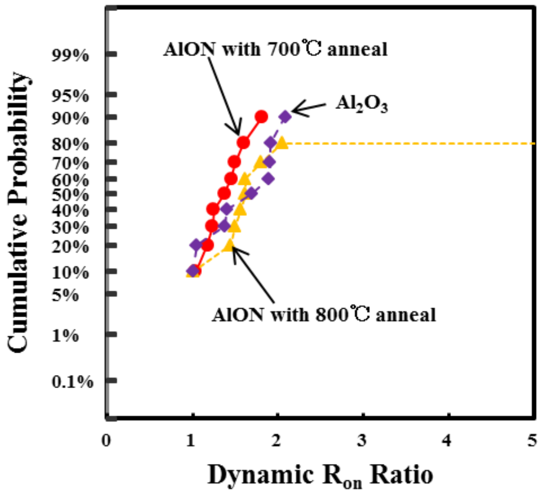

Fig. 5 Cumulative probability distribution of dynamic R_{on} ratio at V_d=400 V across an all over the 6-inch wafer.

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