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Gamma Radiation Effects on the Ohmic Contact of AlGaN/GaN HEMTs

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1. Introduction

High Electron Mobility Transistors (HEMTs) based on AlGaN/GaN heterostructure and other related alloys have shown the potential for microwave, high power and high frequency application [1, 2]. To extend this device to a radiation environment such as space, the effects of various radiations, such as gamma-ray, on device performances should be investigated.

Previous investigation has shown that gamma radiation will result in defects on GaN epitaxial layer [3]. It has also been demonstrated that the performances of AlGaN/GaN HEMTs had no obvious changes after total dose of 3.0×10^8 rad in gamma-ray irradiation [4, 5]. In this paper, the gamma-ray radiation effect on the ohmic contact with total dose from 1.0×10^7 rad to 1.0×10^8 rad will be reported, even though that the performance of the wafer itself almost had no change was also confirmed.

2. Experiments

The AlGaN/GaN HEMT structure was grown on (0001) sapphire substrate. As shown in Fig. 1, it consists of a buffer layer, a 3 μm undoped GaN layer, a 6 nm undoped AlGaN barrier, a 12 nm Si-doped AlGaN layer with doping concentration of 4×10^{18} cm^{-3}, and finally a 6 nm undoped AlGaN barrier layer. The Al mole fraction of all the AlGaN layers is about 25 %.

Device process began with ohmic contact formation using lift-off technique and electron-beam-evaporated Ti/Al/Ni/Au (50/200/40/30 nm) with annealing temperature of 850 ºC and time of 1 minute, in N_2 ambient by a furnace. The next step was device isolation by BCl_3-based dry etching with depth about 60 nm. Ni/Au (50/20 nm) by electron beam evaporation was utilized as Schottky gate. Finally, a 1.5 μm Au layer was deposited on the pads by electroplating. The samples were irradiated by 10^4 TBq ^{60}Co Sources at Takasaki JAERI. The total dose of the gamma-ray was 1×10^7 rad (AlGaN/GaN) or 3×10^8 rad (AlGaN/GaN) at dose rate 1×10^6 rad/h (AlGaN/GaN).

3. Results and discussion

Current-voltage (I-V) and transfer characteristics are shown in Fig. 2 and Fig. 3, respectively, with gate length of 4 μm and gate width of 50 μm. Drain current was found to increase by about 13.4 %, while peak transconductance by 13.3 % after 1.0×10^8 rad gamma irradiation. According to the I-V characteristics, ohmic contact was also found to have improvement after irradiation. No changes were observed in threshold voltage and gate leakage current from Fig. 3 and Fig. 4, respectively.

The drain conductance is shown in Fig. 5. In high drain bias range, the slopes of both before and after irradiation are consistent, indicating that the channel mobility had no degradation after irradiation. In the low drain bias range, the drain conductance becomes higher than that of before irradiation due to the improvement on ohmic contact. Table I shows the ohmic contact resistances and sheet resistances from transmission line model (TLM) measurement before and after gamma irradiation. It can be seen that both of the ohmic contact resistance and sheet resistance had no changes. This can be confirmed from Fig. 6, where the resistance between the source and drain at gate bias before and after the gamma irradiation is shown. The shifts of resistance between source and drain near 0 V drain bias were found to keep constant before and after irradiation. The inconsistency on ohmic contact between the I-V curve and the TLM measurement may be due to the difference of measurement current, where the measurement current was in the range of -10 μA~10 μA in the TLM method.

The mechanism of improvement on ohmic contact is considered to be the increase of metal sintering at the metal and AlGaN interface after irradiation, as well as the increased interdiffusion among the multi-layer ohmic metals.

4. Conclusions

Gamma ray radiation effect on the ohmic contact with total dose from 1×10^7 rad to 1×10^8 rad has been investigated. It was confirmed that the ohmic contact improved after irradiation, while the performance of the wafer itself almost had no change.

Acknowledgement

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References

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Table I Ohmic contact resistances (R_C) and sheet resistances (ρ_S) before and after gamma irradiation.

	#1 ($1.0x10^7$rad)		#2 ($1.0x10^8$rad)	
	Before	after	before	after
R_C (Ωmm)	2.98	3.03	3.96	3.96
ρ_S ($\Omega/\square$)	399.2	400.0	412.6	417.6

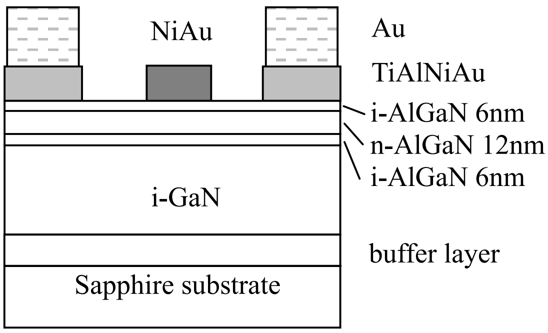

Fig.1 AlGaN/GaN HEMT structure.

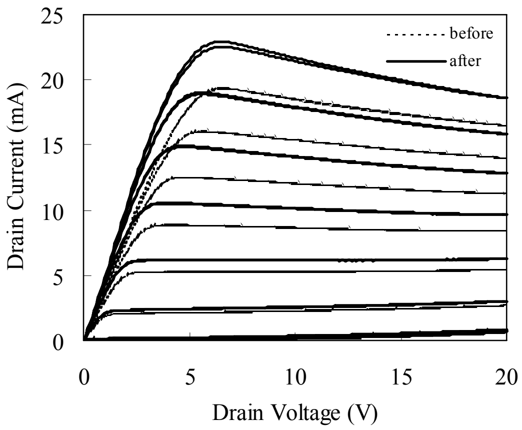

Fig. 2 I-V characteristics before and after $1.0x10^8$ rad gamma irradiation with Vg from 1V and step of –1V from the top.

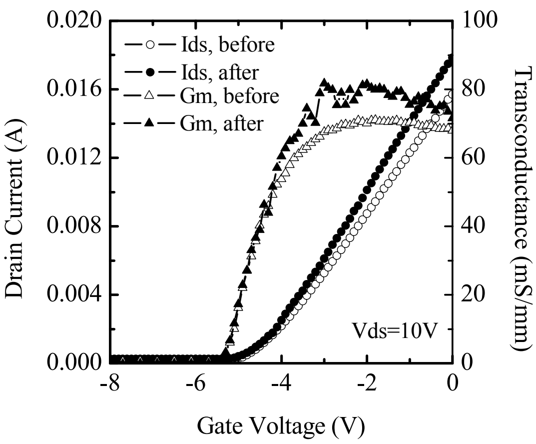

Fig. 3 Drain current and transconductance changes before and after $1.0x10^8$ rad gamma irradiation.

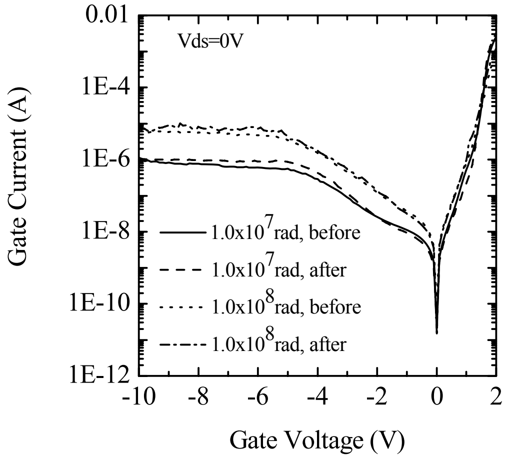

Fig. 4 Gate leakage currents at different total doses before and after gamma irradiation.

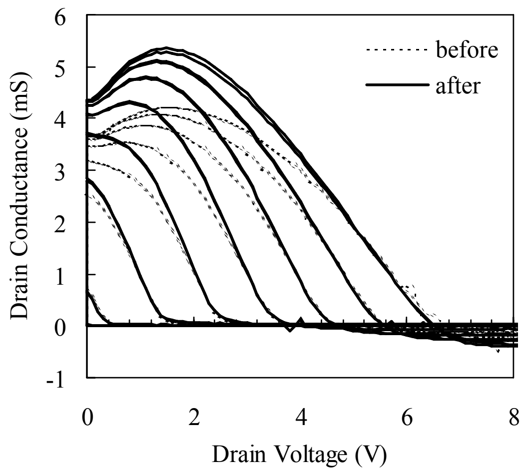

Fig. 5 Drain conductance before and after $1.0x10^8$ rad gamma irradiation with Vg from 1V and step of –1V from the top.

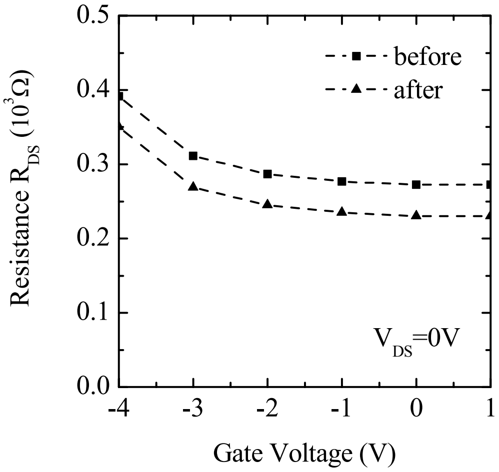

Fig. 6 Resistance between the source and drain at the bias of V_{DS}=0V before and after $1.0x10^8$ gamma irradiation.