Thermal Oxidization of MIS Interface between Etched GaN and ALD-Al_2O_3

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Abstract

This work reports on how thermal oxidization improves the interface qualities between the plasma etched GaN films and ALD-Al_2O_3. The 900 °C thermal oxidization process reduces a typical order of D_{it} from 10^{13} cm^{-2} to 10^{12} cm^{-2}, and boron and chlorine impurities from the order of 10^{20} cm^{-2} to 10^{19} cm^{-2}. These results indicate that the thermal oxidization process can contribute to manufacturing a high quality MIS interface of GaN-based electronic devices.

INTRODUCTION

GaN has been expected to be a material suitable for power switching applications because it has advanced material properties. In power applications, normally-off mode operation is essential to ensure the safety and a recessed-MIS gate structure realizes normally-off operation of GaN-based FETs.[1] While this gate structure exhibited an excellent performance of high V_{th}, the fabrication process still has problems such as fluctuation of V_{th} caused by plasma dry etching process. Recently, we have proposed thermal oxidization technique to control MIS interface qualities of GaN-based FETs to solve these problems.[2] This oxidation process , successfully produced uniform AlON layers and, thereby reduces D_{it} of the MIS interfaces.

In this study, we report on the effect of thermal oxidization on the MIS interface between plasma etched GaN and ALD-Al_2O_3.

FABRICATION AND MEASUREMENT METHOD

AlGaN/GaN epitaxial structures were grown by MOCVD on Si substrates. Thickness of AlGaN and GaN were 25 nm and 1 μm, respectively. 25-nm-thick AlGaN layer were fully etched by using BCl_3 dry etching. Thermal oxidization after recess-etching was executed at 900 °C for 3 min in N_2/O_2 ambient, followed by deposition of an ALD-Al_2O_3.

Surface morphologies of an as-grown AlGaN, a recess etched and a thermal oxidized GaN were observed by AFM. Impurity concentrations of MIS structure samples with a 50-nm-thick Al_2O_3 were measured by SIMS with Cs^+ ion beams. *C-V* characteristics of the MIS structures on etched GaN and a-20nm-thick ALD-Al_2O_3 were measured and D_{it} were estimated via photo-assisted *C-V* method.[3]

RESULTS AND DISCUSSIONS

AFM measurement results with the corresponding sample structures are listed in Fig. 1. The surfaces shows in Fig. 1(b) and (c) are as smooth as the one of Fig. 1(a). The etching and thermally oxidization processes do not have any deteriorating impact on GaN surfaces.

Figs. 2 show SIMS depth profiles of B and Cl impurity concentrations of samples depicted in Fig. 2(a) and (b). B and Cl originating from BCl_3 were detected at the etched GaN/ALD-Al_2O_3 interfaces. These impurities reduce from the order of 10^{20} cm^{-3} to 10^{19} cm^{-3} by thermal oxidization.

The favorable effects of thermal oxidation also appear in *C-V* curves of etched GaN/ALD-Al_2O_3 MIS structure samples. As shown in Fig. 3, the thermally oxidized sample can reach to a positive bias of +10 V, however the sample without the thermal oxidization can not reach the same level of positive bias due to a breakdown of ALD-Al_2O_3. In addition, a sharper *C-V* slope is obviously observed for the thermally oxidized sample.

D_{it} profiles compare etched GaN/ALD-Al_2O_3 MIS interface samples with and without thermal oxidization in Fig. 4. D_{it} was reduced from 10^{13} to 10^{12} cm^{-2} orders by the thermal oxidization process, presumably due to the reduction of B and Cl impurities mentioned above. This low D_{it}, meaning low interface trapped charges, is also responsible for the higher positive breakdown voltage discussed in *C-V* measurements.

CONCLUSIONS

The authors reported on the effect of thermal oxidization at the MIS interface between etched GaN and ALD-Al_2O_3. The results indicates that the thermal oxidization process contributes to the manufacturing of high quality MIS interface of GaN-based electronic devices.

REFERENCES

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ACRONYMS

MIS: Metal-Insulator-Semiconductor

ALD: Atomic Layer Deposition

D_{it} : Density of Interface States

FETs : Field-Effect Transistors

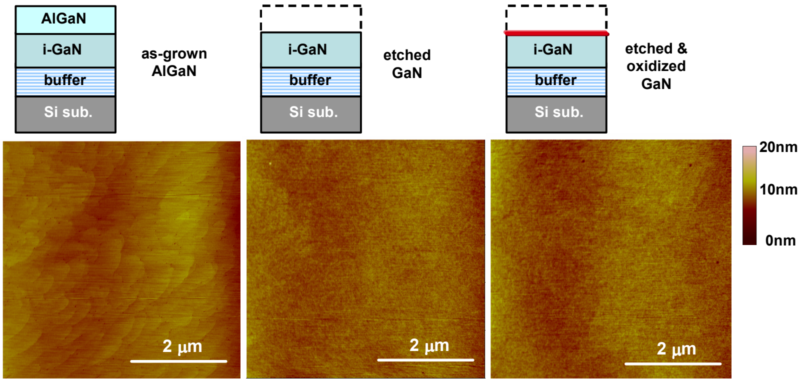
V_{th} : Threshold Voltages

MOCVD : Metal Organic Chemical Vapor Deposition

AFM : Atomic Force Microscopy

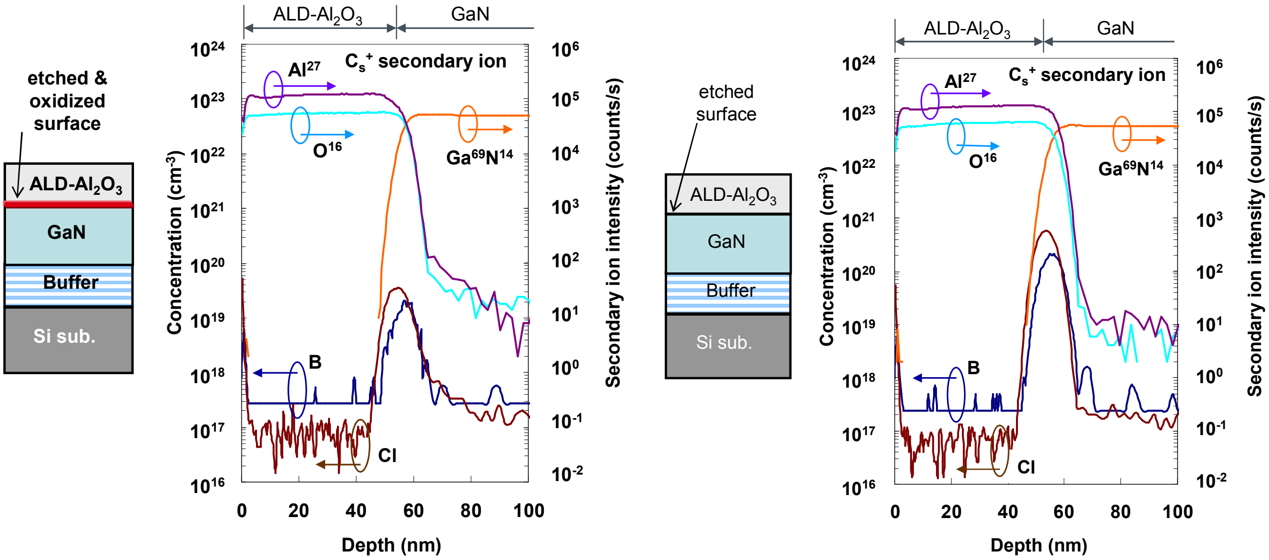
SIMS : Secondary Ion Mass Spectrometry

C-V : Capacitance-Voltage



(a) (b) (c)

Fig. 1. Surface morphologies of (a) as-grown AlGaN, (b) etched, and (c) oxidized GaN.



(a) (b)

Fig. 2. SIMS depth profiles of B and Cl impurity concentrations on MIS structure samples (a) with and (b) without the thermal oxidization.

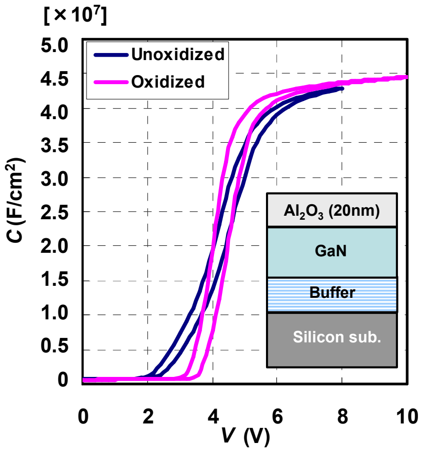


Fig. 3. C-V curves of etched GaN/ALD-Al_2O_3 MIS structure samples with and without the thermal oxidization.

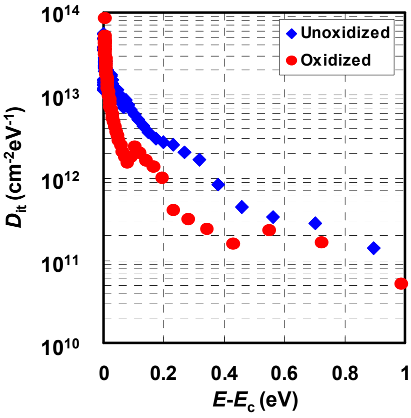


Fig. 4. D_{it} of etched GaN/ALD-Al_2O_3 MIS structure samples with and without the thermal oxidization.