Correlation of the initial AlN layer and vertical direction current leakage of AlGaN/GaN high-electron-mobility transistors (HEMTs) on Si substrates

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1. Introduction

AlGaN/GaN high-electron-mobility transistors (HEMTs) on large-diameter Si substrates are promising for future applications because of their low cost and good thermal conductivity. Much work has been devoted to improving the performance of HEMTs grown on Si to widen their applications [1]. One issue encountered in these devices is the device performance reliability. To improve the current leakage of the device, one solution is to increase the total thickness of the device [2]; however, the resultant breakdown voltage is still low compared with the ideal breakdown voltage. Thus, further improvement of the reliability is needed in this material system. We report on the correlation between the vertical direction current leakage of HEMTs and characteristics of the initial AlN layer of the AlGaN/GaN HEMTs on Si substrates.

2. Experiment

In this report, single AlN nucleation layers were grown and compared with high-electron-mobility transistor (HEMT) devices using the same growth conditions as the single AlN layers. All the samples in this report were grown on 8-inch P-type Si substrates using a MOCVD system (Taiyo Nippon Sanso Corp., UR26K).

Two types of single AlN (thickness = 150 nm) on Si substrates were grown using different growth conditions (Samples A and B). A scanning electron microscope (SEM) was used to compare the surface conditions, and X-ray diffractometry (XRD) was employed to determine the crystal quality.

Figure 1 presents a schematic of the HEMT epi structure and circuit of the current-voltage (I-V) measurement. Two types of HEMT structures (Samples C and D) were grown under the same growth conditions except for that of the initial AlN layer. The AlN growth conditions were the same as those for the previous AlN single layers (Samples A and B). The device structure for the I-V measurement was prepared on the HEMT structures using the procedure described below. The mesa structure was formed by reactive ion etching (RIE). The ohmic electrode (Ti/Al/Ni/Au = 15/80/12/40 nm) was stacked using electron beam (EB) deposition followed by rapid thermal annealing (RTA) (nitrogen atmosphere, 850°C, 30 s). The vertical direction current leakage characteristics were measured using a semiconductor parameter analyzer (Agilent Technologies B1505A).

3. Results and discussion

Figure 2 shows the full-width at half-maximum (FWHM) of the X-ray rocking curve (XRC) of AlN (0002) and the surface SEM images of the AlN single layers (Samples A and B). The FWHM of Sample A (1472 arcsec) is smaller than that of Sample B (2038 arcsec). The pit density of Sample A was about half that of Sample B.

Figure 3 presents the I-V curve of the HEMT structures. The current leakage for sample C is very high and unreliable, whereas that for sample D is dramatically improved and reliable. These findings result from the improvement of crystal quality of the AlN nucleation layer.

4. Conclusion

We studied the vertical direction current leakage of AlGaN/GaN HEMT structures with initial AlN layers of different qualities. A correlation between the vertical direction current leakage of the AlGaN/GaN HEMT structure and the characteristics of the initial AlN layer of the AlGaN/GaN HEMT was observed. It is noticeable that the quality of the AlN nucleation layer affects the vertical leakage current.

Sample name of HEMT structure	Sample C	Sample D
Growth condition of initial AlN layer	Sample A	Sample B
Growth condition of another layer	Same condition	

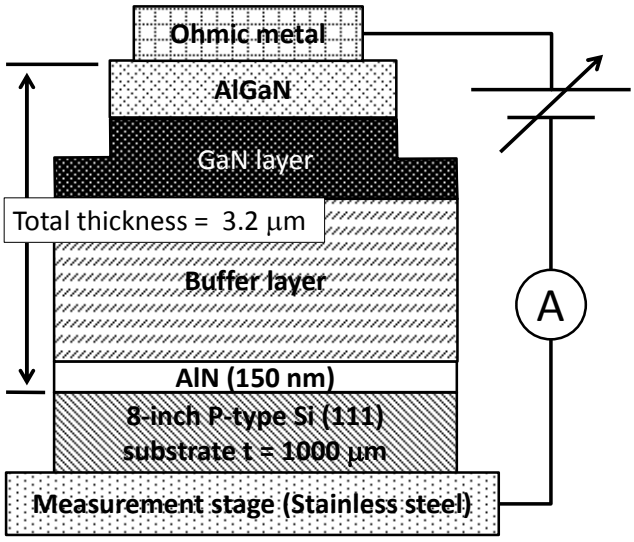


Fig. 1 AlGaN/GaN HEMT structure and circuit of the current-voltage measurement.

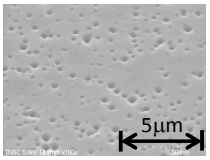
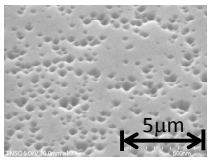
AlN Sample	Sample A	Sample B
SEM image of AlN surface		
Pit density (cm^{-3})	1.60×10^{10}	2.96×10^{10}
FWHM of AlN(0002) (arcsec)	1472	2038

Fig. 2 Characteristics of initial AlN layer used in this experiment.

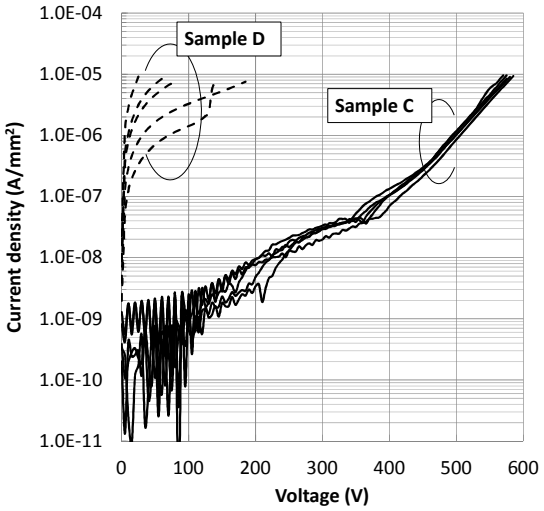


Fig. 3 Characteristics of the current-voltage curve of the HEMT structures.

References

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