Extended Abstracts of the 2011 International Conference on Solid State Devices and Materials, Nagoya, 2011, pp620-621

Effects of Substrate Defects on the Gate Leakage Current of AlGaN/GaN Heterojunction FETs Fabricated on Na Flux Bulk GaN

R. Hasegawa[1], N. Yafune[2], H. Tokuda[1], Y. Mori[3], H. Amano[4], and M. Kuzuhara[1]

[1] Graduate School of Engineering, University of Fukui,
3-9-1 Bunkyo, Fukui 910-8507, Japan
Phone: +81-776-27-9714 E-mail: kuzuhara@fuee.u-fukui.ac.jp
[2] Sharp Corporation,
2613-1, Ichinomoto-cho, Tenri, Nara 632-8567, Japan
[3] Graduate School of Engineering, Osaka University,
2-1 Yamadaoka, Suita, Osaka 565-0871, Japan
[4] Graduate School of Engineering, Nagoya University,
Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan

1. Introduction

AlGaN/GaN heterojunction FETs (HEMTs) have attracted great interest in applications to high-voltage, high-power, and high-frequency electronic devices due to their outstanding material properties including high breakdown field, high saturation drift velocity, and stability at high temperatures. AlGaN/GaN heterostructures have been commonly grown on sapphire, SiC, and Si substrates. However, the large lattice mismatch between GaN and the substrate material gives rise to high dislocation density in the epitaxial layer typically on the orders of 10^8 to 10^{10} cm^{-2}, which is considered to be the origin of significant Schottky gate leakage in AlGaN/GaN HEMTs.

A free-standing GaN has emerged as a leading candidate to accommodate those issues related to lattice mismatch. A number of authors have reported that a free standing GaN substrate grown by hydride vapor phase epitaxy (HVPE) is effective to obtain ideal Schottky characteristics and to reduce reverse leakage current of Schottky diodes fabricated on n-GaN and AlGaN/GaN heterostructures[1,2]. Although additional defect generation is suppressed using GaN substrates, as-grown HVPE substrates still have a relatively high dislocation density on the order of $10^6 cm^{-2}$. A melt-grown method, such as Na-flux LPE method[3,4], has recently attracted significant attention to further reduce the defect density of a bulk GaN substrate.

In this work, we have fabricated an array of AlGaN/GaN HEMTs on a whole 30mm-diameter bulk GaN substrate grown by Na-flux method and investigated the effects of crystals defects on the gate leakage of Schottky-barrier gate AlGaN/GaN HEMTs.

2. Experiments

AlGaN/GaN heterostructures were grown by metalorganic chemical vapor deposition (MOCVD) on a free-standing GaN substrate grown by Na-flux method. A 30mm-diameter GaN substrate with a dislocation density on the order of 10^{-4} cm^{-2} was used in this experiment. The AlGaN/GaN epitaxial layers consist of an undoped GaN channel layer and a 25 nm undoped $Al_{0.25}Ga_{0.75}N$ barrier layer. The ohmic metallization consists of Ti/Al/Mo/Au and was annealed at 850 °C for 30 s in N_2 ambient. The Schottky metals used were Ni/Au. AlGaN/GaN HEMTs with a gate length of 3 μm and a gate width of 70 μm were fabricated. DC characteristics including Id-Vds, Id-Vgs, and Ig-Vgs were measured for 1000 FETs and electrical characteristics were compared with the defect profiles estimated by X-ray topography.

3. Results and discussion

There are two groups showing low and high gate leakage currents. Figure 1 shows the typical DC characteristics of the fabricated device for the low gate leakage one, where V_{gs} was varied from 2 V with a -1 V step. The maximum drain current (I_{dsmax}) was 400 mA/mm and the transconductance (g_m) was 100 mS/mm with a pinch-off voltage of -3.5 V. The relation between I_{dsmax} and gate-source leakage current ($I_{gs\ leak}$) defined at V_{gs}=-20 V is shown in Fig. 2. As is shown in the figure, no correlation was found between I_{dsmax} and I_{gsleak}, that is, I_{dsmax} is independent of $I_{gs\ leak}$. The I-V characteristics between gate and source are displayed in Fig. 3 for 1000 pieces of devices. As clearly seen, almost all the devices (983 pieces) showed $I_{gs\ leak}$ of less than 10^{-7} A/mm, while 17 devices exhibited a high leakage current of $>10^{-6}$ A/mm. In order to make the origin of gate current clear, the surface of the wafer was carefully observed with a microscope. An example of the photo is shown in Fig. 4. The defect near the gate electrode was found for the device showing relatively high leakage current, while the defect was less or not found for the device with low leakage current. Figure 5 displays the X-ray topograph image of the GaN substrate (before epitaxial growth) together with closed circles showing the device position exhibiting high gate leakage current. Although the defects are not clear by the image, a relatively good correlation was observed between the defects and the device area with a high gate leakage.

4. Conclusions

Gate leakage characteristics were estimated for AlGaN/GaN HEMTs fabricated on a bulk GaN substrate grown by Na-flux method. Clear correlation was observed between the substrate defects and the gate leakage for 1000 pieces of fabricated HEMTs.

Acknowledgements

This work was performed as a part of the project named "Development of Nitride-based Semiconductor Single Crystal Substrate and Epitaxial Growth Technology" by NEDO.

References

[1] J. Suda et al., Appl. Phys. Express, **3** (2010) 101003.
[2] S. W. Kaun et al., Appl. Phys. Express, **4** (2011) 024101.
[3] H. Yamane et al., J. Cryst. Growth, **186** (1998) 8.
[4] T. Iwahashi et al., J. Cryst. Growth, **253** (2003) 1.

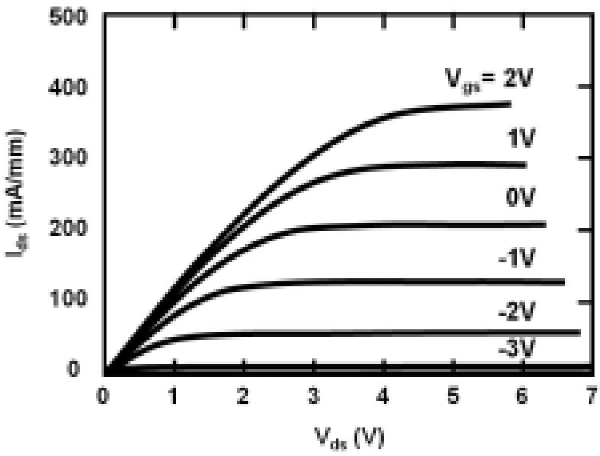

Fig. 1 DC characteristics of the fabricated HEMT (low gate leakage current device).

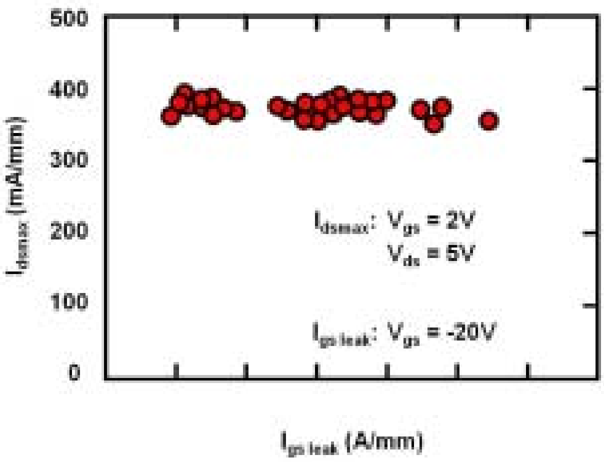

Fig. 2 Maximum drain current (I_{dsmax}) as a function of gate-to-source leakage current ($I_{gs\ leak}$).

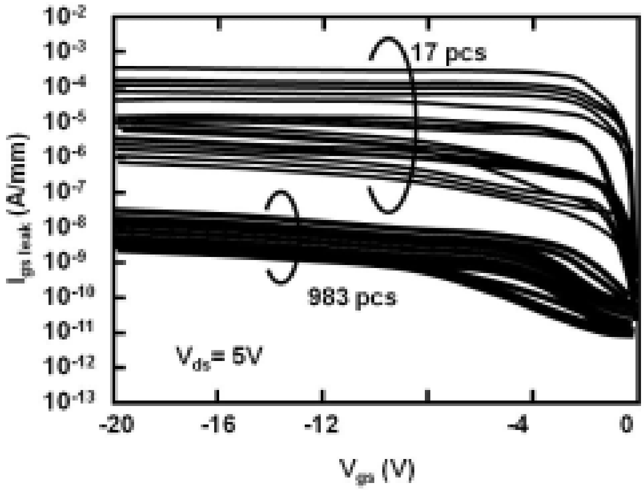

Fig. 3 I-V characteristics between gate and source for the fabricated 1000 pieces of HEMTs.

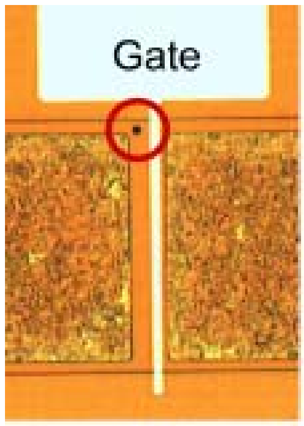

Fig. 4 Photo of the fabricated HEMT, where the defect is found (see the circled black dot).

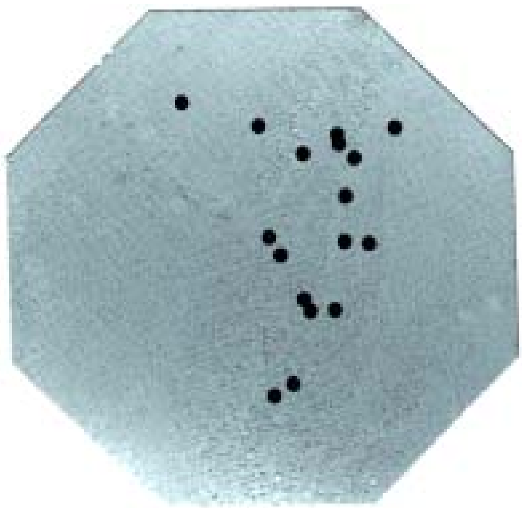

Fig. 5 Top view of X-ray topograph image for GaN substrate (before epitaxial growth). Black dots show the device areas with high gate leakage current.