Gate Leakage Current of AlGaN/GaN HEMTs Device Influenced by Substrate Defects

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Abstract

The gate leakage currents on the AlGaN/GaN HEMTs on 2-inch SiC epitaxial substrate are measured at Vgs=20 V. The defect image of the wafer observed by the optical surface analyzer and the photograph of fabricated devices on the wafer are superimposed. Comparing the gate leakage current map on the wafer, the relation between the gate leakage current and the location of the defect is found clearly

INTRODUCTION

AlGaN/GaN high electron mobility transistors(HEMTs) have rapidly made progress in the high power microwave devices. But many problems have remained at AlGaN/GaN HEMTs, such as the large gate leakage currents and the collapse of the drain current. Then the problems of the DC performances cause the lower RF performances of the high power microwave devices. J.W.P.Hsu et al.[1] described the problems of the device performances were carried out by the defects of the epitaxial wafers. But the relation between the defects of the epitaxial wafers and the device performances has not been clear yet. The present work is focusing on the relation between the defects and the gate leakage currents.

EXPELIMENT

The HEMTs been fabricated on 2-inch epitaxial SiC substrate. Figure 1 shows the surface morphology of the epitaxial layers on the substrate. It is observed by the optical surface analyzer[1]. The optical surface analysis is operated based on non-destructive surface inspection method. It can detect some kind of defects, such as micropipes, crystal dislocations, pits, scratches, contaminations and so on. The epitaxial wafer grown by MOVPE is delivered with the surface morphology by Hitachi Cable Ltd.[2]. It can be seen that some lines made of defects. The magnified differential interference microscopic image is shown in Figure 4. The micropipes and strains are observed on the wafer.

The HEMTs with the total gate width of 11.52 mm are fabricated on the wafer. They consist of 72 unit gate fingers. The finger width is 160 um. The schematic cross-sectional view is shown in Figure 2.

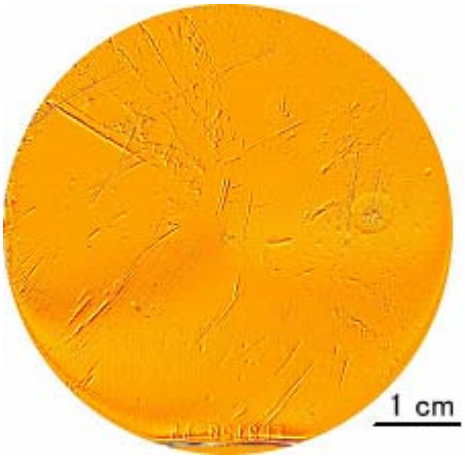

Figure 1 Surface morphology of epi HEMTs on 2 inch epitaxial wafer image

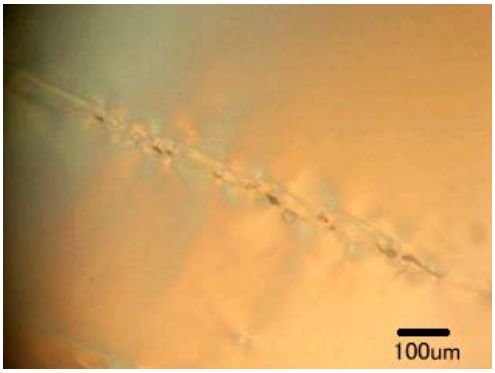

Figure 2 Microscope Image of concentrated defect area

RESULT AND DISCUSS

The gate leakage current (Igs) of the HEMTs are measured at Vgs=20V. Concerning with the location of the devices on the wafer, the Igs data are mapped on the wafer. Figure 4 shows the Igs map. To confirm the location of defects, the surface morphology image is superimposed on the overview of the HEMTs layout (Figure 5). It can be seen that there are some of HEMTs on the defects.

In Figure 6, the red colored boxes are the places where we detect abnormalities on gate leakage current. The gate leakage current of the devices at area A and B (the area enclosed by yellow oval shape) are compared with that of other areas and arranged at Figure 7. The gate leakage current of devices on defect area is about 30% larger than others. That suggested that the gate current leaked from dislocation or micropipes. Current depends on quality of wafer crystal. Investigating gate leakage current of HEMT device, defects come from SiC substrates can affect to HEMT devices.

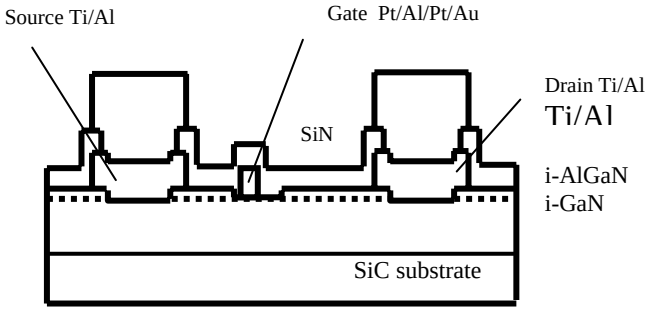

Figure 3 Schematic cross-section of HEMT device

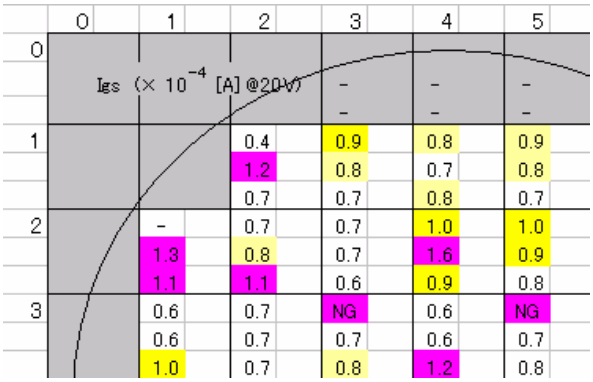

Figure 4 Map of gate leakage current on wafer

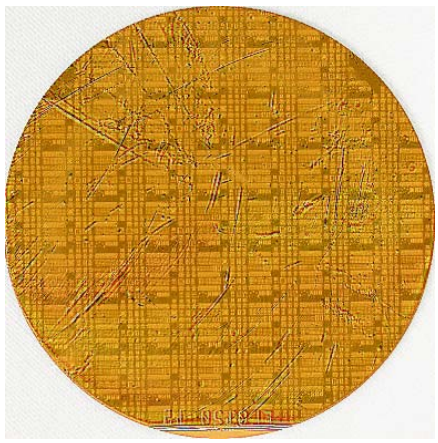

Figure 5 Superimposed fabricated device

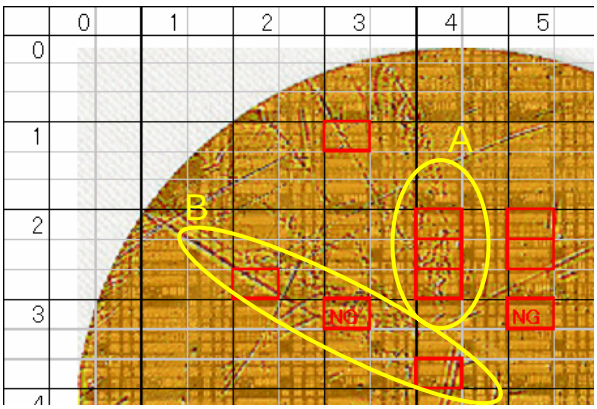

Figure 6 Defects concentrated area encircled A and B Gate leakage current devices are shown in square.

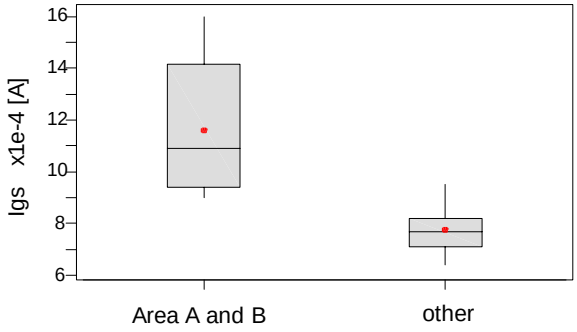

Figure 7 Box plot of gate leakage current comparing A, B area and other area

Conclusions

An investigation of the leakage current in an AlGaN/GaN HEMT device has been performed. As the result, we confirm that the detected defects must decrease the mass production yield of FETs. It also means that the observation by the surface analyzer is found to be very useful and to evaluate the SiC substrate. For the development, we can clearly recognize that the effects of the device property come from device process or material, by using this comparison method. It must accelerate the development speed. Thus, the clear relation was found between the leakage current and the defects detected by the optical surface analyzer.

References

[1] J. W. P. Hsu et al., Appl. Phys. Lett. 81, 79 (2002)

[2] L. Bechtler et al., Proc. SPIE Int. Soc. Opt. Eng. 4944, 109 (2003)

[3]] T. Tanaka, et al., 2004 GaAs MANTECH Technical Digest, 11B.3

Acronyms

HEMT: High Electron Mobility Transistor
GaN: Gallium Nitride
AlGaN: Aluminum Gallium Nitride
SiC: Silicon Carbide
MOVPE: Metal Organic Vapor Phase Epitaxy