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In-Situ Mapping of Degradation of AlGaN/GaN MIS-HEMTs Using Video-Mode Scanning Internal Photoemission Microscopy

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Abstract

We demonstrated scanning internal photoemission microscopy (SIPM) for in-situ monitoring of the degradation of AlGaN/GaN MIS HEMTs. Under the drain-source voltage swept up to 20 V, photocurrent images of the gate electrode were taken in a video-mode. The symptom of the degradation was clearly detected at the edge of the gate on the drain side.

1. Introduction

AlGaN/GaN HENTs have been intensively developed for high-power amplifiers of the base stations in the wireless communication network. Because of large applied voltage and high temperature, a lot of studies on the device reliability have been conducted. Especially, two-dimensional observation would be a powerful tool to reveal the degradation mechanism [1].

On the other hand, we have developed SIPM that can map the electrical characteristics of Si, GaAs, SiC and GaN Schottky contacts [2, 3]. In this study, we have newly developed video-mode SIPM, and applied to monitor the degradation of AlGaN/GaN MIS HEMTs under the voltage stress.

2. Device Fabrication and Characterization

The eptaxial layers are grown by metal organic vapor phase epitaxy on a sapphire substrate and consist of a 21-nm-thick AlGaN barrier layer on a 2-µm-thick undoped-GaN channel and buffer layers as shown in Fig. 1. The Al composition ratio of the barrier layer is 25.5%.

The device fabrication process started with deposition of Ti/Al/Ni/Au metallization layers for source and drain ohmic electrodes. Then, device isolation was performed by inductive-coupled plasma reactive ion etching with Cl_2 gas. After ohmic annealing, a SiN film was deposited over the entire surface as a gate stack. Then, Ti/Ni metallization layers were deposited to form gate electrodes. Following to the contact-hole opening on the ohmic electrodes, Ti/Pt/Au metallization layers were deposited to form probing pad electrodes. SIPM measurements were conducted for the devices with a gate length of 10 µm and a gate width of 50 µm. The sample device exhibits a threshold voltage of -12 V, a maximum drain current density of 0.45 A/mm, and a transconductance of 50 mS/mm.

SIPM is based on the internal photoemission (Photoresponse (PR)) measurement as shown in Fig. 2. When a monochromatic light with a photon energy ($h\nu$) below the energy bandgap and exceling Schottky barrier height ($q\phi_B$) is incident on a metal/semiconductor interface, electrons in the metal can surmount the barrier generating a photocurrent, where Y is defined as photoyield that is photocurrent per number of incident photons. In the SIPM measurements, one focuses and scans the beam over the interface to obtain 2-dimensional imaging of Y. We repeated this measurement with a green laser (λ = 520 nm) under a constant gate-source voltage of -18 V (the FET was pinched-off) and a drain-source voltage (V_{ds}) swept up to 20 V for a video-mode. The beam diameter at the interface was less than 2 µm.

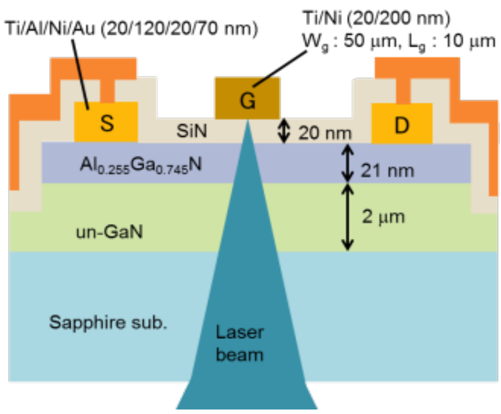

Fig. 1 AlGaN/GaN MIS HEMT structure grown on a sapphire substrate.

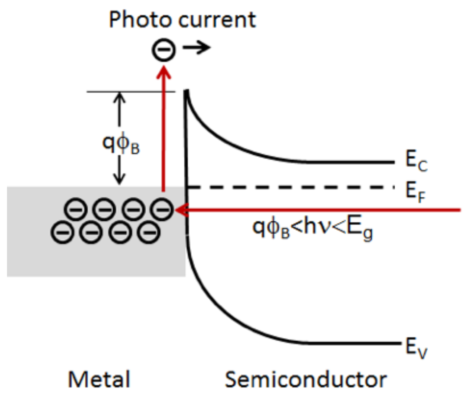

Fig. 2 Internal photoemission process in a metal/semiconductor interface.

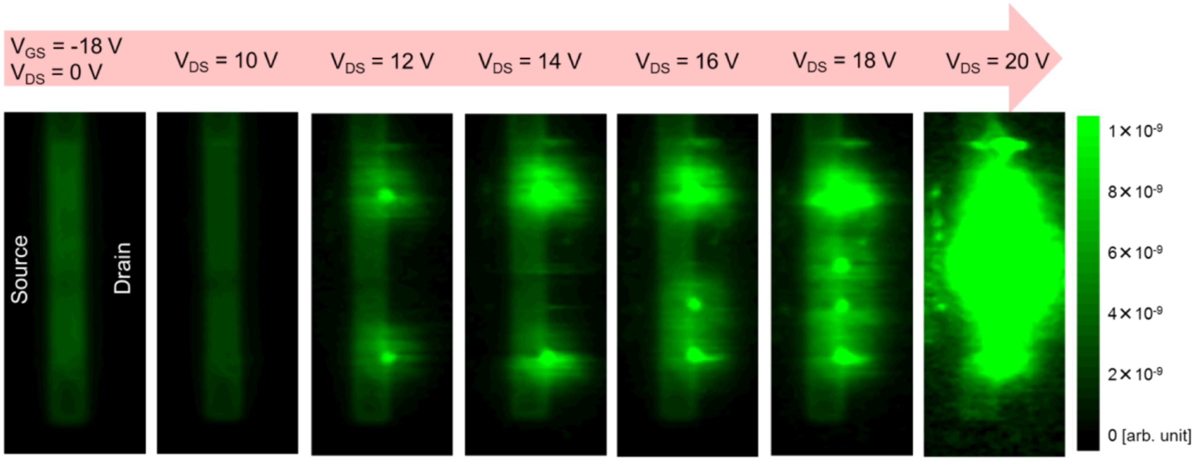

Fig. 3 Video-mode SIPM results for the gate electrode under the drain-gate stress voltage swept up to 20 V.

3. Results and Discussion

Figure 3 shows video-mode SIPM results of the gate electrode under the voltage stress. Up to V_{ds} = 10 V, uniform signal was detected over the electrode. When V_{ds} = 12 V, two regions with large Y appeared on the edge of the drain side. As the applied voltage increased, signal intensity and number of the regions increased. We confirmed that nondestructive monitoring of the initial stage of the degradation was succeeded by using SIPM measurements.

No degradation pattern was found in the optical microscope images after the voltage stress as shown in Fig. 4 (a). On the other hand, in the SIPM results without an applied voltage as shown in Fig. 4 (b), the degraded regions were clearly observed. SIPM is sensitive for such interfacial reaction. As for the *I-V* characteristics as shown in Fig. 5, after the voltage stress, obviously both forward and reverse currents increased. We can devise a model that the interfacial phase with lower $q\phi_B$ was formed upon a strong electrical field at the gate edge.

4. Conclusions

Video-mode SIPM was applied to characterize degradation of AlGaN/GaN MIS HEMTs. In-situ monitoring under the applied voltage up to 20 V was successfully conducted and the degraded regions were detected on the gate edge. We confirmed that this method is useful for the nondestructive monitoring of the initial stage of the degradation.

Acknowledgements

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References

[1] J. A. del Alamo, and J. Jho, Microelectronics Reliability, **49,** 1200 (2009).

[2] T. Okumura and K. Shiojima., Jpn. J. Appl. Phys.**28**, L1108 (1989).

[3] K. Shiojima et al., Appl. Phys. Express **8**, 046502 (2015).

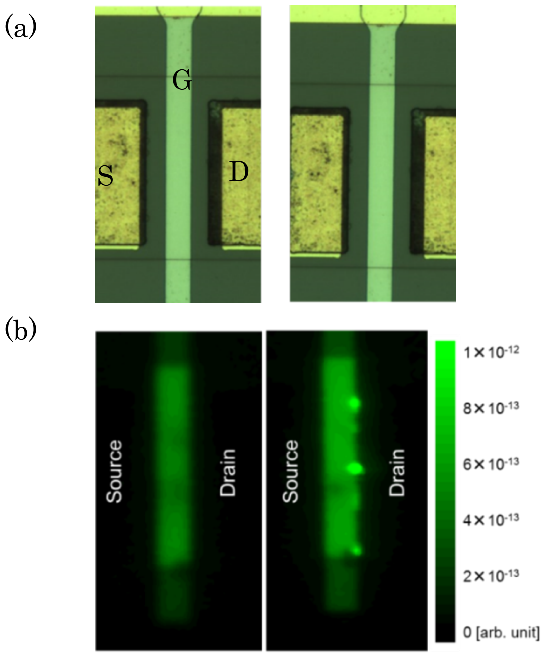

Fig. 4 (a) Optical microscope images and (b)Y maps without a bias voltage before and after the voltage stress conducted in the measurement shown in Fig. 3.

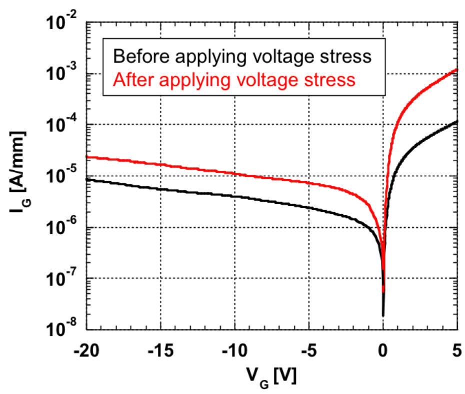

Fig. 5 Gate *I-V* characteristics of the device shown in Fig. 4.