

Reliability of GaN High Electron Mobility Transistors

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Sponsorship: SMART

High electron mobility transistors (HEMTs) based on AlGaIn/GaN heterostructures have been studied in the literature for a variety of high-frequency and high-power applications. To minimize lattice mismatch and suppress defects generation, HEMTs under study are mostly fabricated on sapphire or SiC substrates. Currently, there is strong interest to fabricate GaN HEMTs on silicon substrates due to its low cost and compatibility with complementary metal-oxide-semiconductor (CMOS) integration technology. However, market adoption of this technology is still limited by the HEMT device reliability.

We have investigated the effects of Si_xN_{1-x} passivation density on the reliability of AlGaIn/GaN-on-Si HEMTs. Upon stressing, devices degrade in two stages: fast-mode degradation, followed by slow-mode degradation (Figure 1). Both degradations can be explained as different stages of pit formation at the gate-edge. Fast-mode degradation is caused by pre-existing oxygen at Si_xN_{1-x}/AlGaIn interface. It is not significantly affected by the Si_xN_{1-x} density. On the other hand, slow-mode degradation is associated with Si_xN_{1-x} degradation caused by electric-field induced oxidation. By using high density Si_xN_{1-x}, the slow-mode degradation can be minimized.

Devices for research purpose are usually designed and fabricated in a way that certain failure can be magnified to better study the failure mechanism. However, commercial devices focus more on reliability and performance maximization. In ongoing research, we are also interested in characterizing the reliability of commercial GaN HEMTs produced by CREE Inc. A statistical reliability model will be developed and comparison with devices produced by SMART-LEES will be made. Figure 2 shows the initial characterization of GaN HEMTs produced by CREE Inc. Reliability testing of these devices is underway.

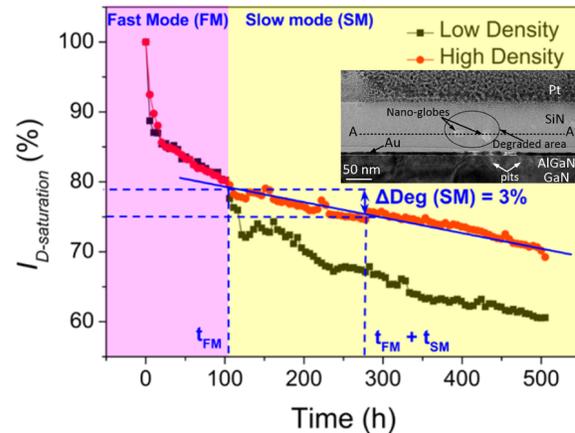


Figure 1: Typical electrical degradation of a device during stressing for devices with different passivation. There are two stages of degradation, a fast mode (FM) and a slow mode (SM). The inset shows the TEM cross section image of a degraded device.

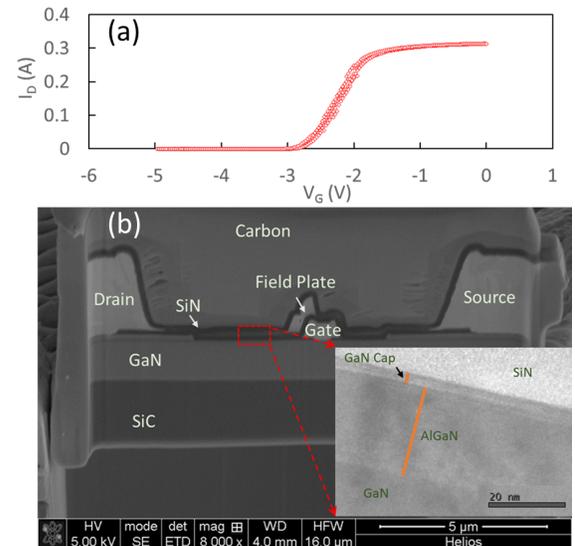


Figure 2: Initial characterization of GaN HEMTs produced by CREE Inc. (a) I_D - V_G before stressing; (b) cross-section characterization with SEM, FIB and TEM

Further Reading

- W.A. Sasangka, Govindo J. Syaranamual, Y. Gao, R. I Made, C. L. Gan, Carl V. Thompson, "Improved reliability of AlGaIn/GaN-on-Si high electron mobility transistors (HEMTs) with high density silicon nitride passivation," *Microelectronics Reliability* 76-77 (2017) 287-291.