Investigation of water-enhanced degradation in SiO_2/GaN MOS structure

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Gallium nitride (GaN) is considered to be the next generation semiconductor toward power device applications. Several efforts have been devoted to GaN based MOSFETs for the last decade. Long-term stability is essential for the practical commercialization of these new power devices. In this study, ambient water moisture induced degradation of SiO_2/GaN MOS capacitor via aging in air was observed and investigated by electrical characterizations.

High pressure water vapor annealing (HPWVA) has been reported to improve the performance of SiO_2/GaN MOS structures [1]. Here capacitors with PECVD-deposited SiO_2 on n^+-GaN substrate, with and without HPWVA treatment (400°C, 0.5 MPa for 30 min) were prepared. Both samples were aged in air for different periods, followed by a series of electrical reliability tests.

Stress I-V and C-V measurements were conducted for evaluating the effect of water contamination with aging on the long-term stability of SiO_2/GaN MOS devices. Fig.1 shows the TZDB results of reference and HPWVA samples with different aging periods, an elevated leakage current with aging could be observed in both samples. Moreover, the increased currents tended to be saturated at oxide field (E_{ox}) range of 6-10 MV/cm, which was more obvious with longer aging time.

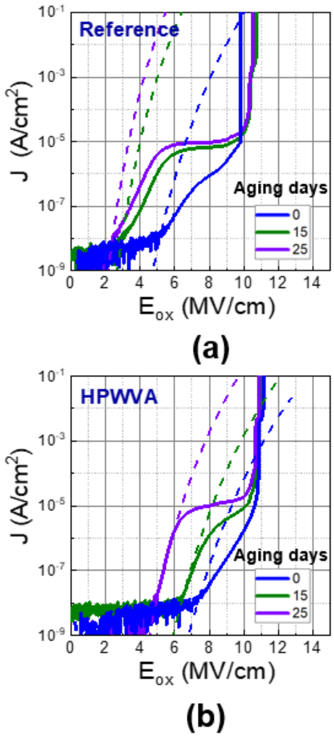

Figure 1. TZDB results with different aging periods for (a) reference and (b) HPWVA samples. The dash line shows the simulated currents without Q_n trapping when E_{ox} increases.

In particular, a space-charge-controlled field emission (SCC-FE) model [2] was applied to study the origin of this degradation. The substrate side effective electron affinity of SiO_2 (χ_{eff}) was assumed to vary with different aging conditions in this model. The dash lines in Fig. 1 represent the simulated SCC-FE currents without charge trapping, from which the χ_{eff} value increased with longer aging time. By assuming the negative sheet charge (Q_n) as a function of E_{ox}, the simulated J-E curves can be fitted into the experimental data. And the results indicate that Q_n can be greatly enhanced with longer aging time. Noting that similar negative charge build-up in SiO_2 by water related contamination has been reported [3]. As a result, the water enhanced larger Q_n and χ_{eff} values are responsible for the degradation behavior observed in aged SiO_2/GaN MOS capacitors.

[1] T.Lin, et al, Ecs J Solid State Sc, 8, 388 (2019) [2] A. Hiraiwa, et al, J. Appl. Phys, 123, 155303 (2018)

[3] F. J. Feigl, et al, J. Appl. Phys,52, 5665 (1981)