Modeling the Changes in the Electrical Properties of Vertical GaN-on-GaN pin Diodes Under Electrical Stress

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Introduction

We analyze and model the changes in the electrical properties of vertical GaN-on-GaN pin diodes submitted to electrical stress. The devices were grown via MOCVD on a GaN n^+ thick substrate ($1 \times 10^{18}\ cm^{-3}$) with on top: n^{++} buffer ($3 \times 10^{18}\ cm^{-3}$), UID drift layer ($1 \times 10^{16}\ cm^{-3}$, p layer ($1\times10^{19}$ cm^{-3}) and p^+ layer (2×10^{20} cm^{-3}). H_2 plasma treatment was performed after mesa etching to achieve the passivation of the p-GaN layers. Degradation tests were carried out at different current levels, to investigate the stability of the electrical characteristics of the samples. TCAD simulations were performed to fit experimental data and formulate hypotheses on the degradation mechanisms observed.

Experimental Procedures

The aim of the experimental tests was to address the stability of the devices under forward constant current stress at room temperature, in typical operation conditions. In the following we report on the results obtained on a 80 μm diameter diode, that has been tested for 2000 min at 100 mA by stopping the stress periodically to perform a characterization for monitoring the device behavior.

Results and Discussion

The DC characterizations during stress show an initial (< 100 min) V_{ON} (turn-on voltage) lowering, with no significant variation in series resistance, suggesting an increase in injection efficiency at the anode contact. For longer stress times (> 200 min) the turn-on voltage stabilizes, but the series resistance starts decreasing ($-$ 30%). We assume that the behavior is due to a hydrogen diffusion mechanism given the high Mg-H complex concentration in the contact layer [1]. The hydrogen would diffuse from the p^+ region towards the p^-. The H redistribution during stress would affect the device operation [2] the following way: 1) the initial diffusion would increase the Mg activation in the p^+, enhancing the hole injection efficiency (decrease in turn-on voltage), with minor effects on the R_S; 2) with longer stress times, the effects of hydrogen diffusion would modify the series resistance. To support this hypothesis, the changes in the hydrogen profiles were modeled by the Fick's second law ($D = 13 \times 10^{-16} \left[\frac{cm^2}{s}\right]$) [3]. The compensation induced by Mg-H complexes was simulated by adding an additional shallow donor, as previously proposed in [4]. A good matching with the experimental data was obtained and fine tuning was obtained by adjusting the concentration in the p- region for longer stress times. The simulation and experimental comparison are reported in Figure 1.

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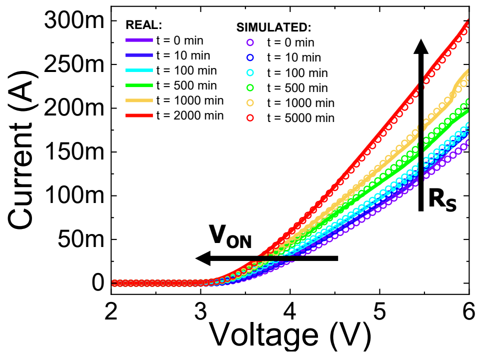

Figure 1 – Comparison of experimental and simulated data with the developed model

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