Electrical behavior of vertical Schottky diodes on GaN homoepitaxy

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Lateral power devices using GaN/Si structures are already undergoing industrial development. Nevertheless, high breakdown voltage (>1 kV) for these devices would imply large area (gate–drain or anode–cathode important spacing) detrimental for current density per chip [1]. Consequently, in order to address higher power applications approaching the theoretical limits of GaN in the 1kV-10kV range, vertical power devices (diodes, MOSFETs) are necessary. Toward this end, as a first step, we fabricated simple Schottky diodes on GaN/GaN substrates to allow material characterization to be performed. The epitaxial layers were grown by MOCVD in a Close Coupled Showerhead system at T=1020°C on a freestanding GaN substrate provided by Saint-Gobain Lumilog. The structure consists of a 5 µm thick film doped by silicon with an average doping level N_d-N_a extracted from CV measurement of 8.7x10^{15} cm^{-3} grown on top of a 0.1 µm n+ GaN buffer layer doped at 4x10^{18} cm^{-3}. The 2µm mesa structures were realized by Cl_2 ICP-RIE etching. The front Schottky contact is composed of Pt/Au which overlaps the fluorine implanted regions to reduce peak electric fields. For further electric-field reduction, field-plates are formed on top of an SiN/SiO_2 insulator stack. The backside Ohmic contact is Ti/Al/Ni/Au. Current - Voltage measurements as function of the temperature in the range 80 K – 480 K were performed for fine characterization of the Schottky contact. As the ideality factor (n) and barrier height (ϕ_B) variations with temperature did not follow a thermionic model, barrier height fluctuations were considered, as proposed first by Werner [2]. Using this model, we have extracted, in the temperature range 280 K - 480 K, an average barrier height ($\overline{\phi_B}$)of 1.31 eV with a relatively large standard deviation (σ) of 0.15 eV. The n(T) variation was also analyzed in order to extract the field sensibility of (i) the mean barrier height variation (ρ_2 = -0.1) and (ii) the barrier height standard deviation (ρ_3 = -15 mV). The corrected Richardson plot using $\overline{\phi_B}$ and σ values is linear and gives a Richardson constant of 31.5 $A.cm^{-2}.K^{-2}$. This is close to the commonly used value of 26.4 $A.cm^{-2}.K^{-2}$ calculated using electron effective mass [3] showing coherence in the analysis by Werner's model. The inhomogeneities in barrier height observed may arise from different origins such as interface roughness, atomic steps, grain boundaries in the metal, melting of different metal phase at the interface, extended defects (dislocations) or point defects in the active layer and may cause long-term reliability problems. For a deeper understanding of their origin, we will resent results from material characterization techniques such as DLTS (deep level transient spectroscopy) and micro-Raman spectroscopy mapping of the epitaxial layers.

References

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Supplementary information

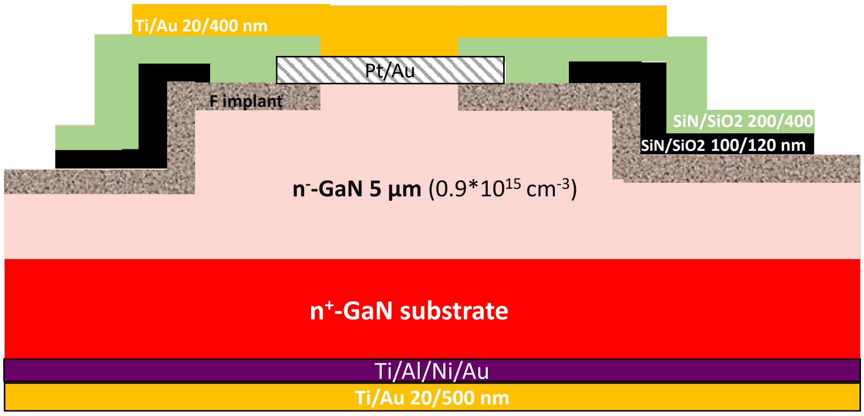

Figure 1: Schematic cross section of the vertical Schottky diodes.

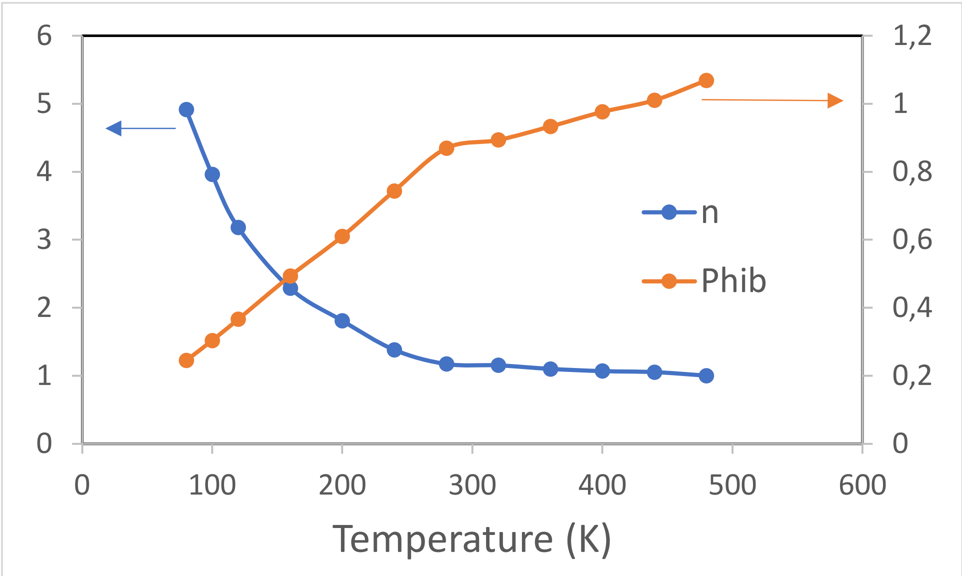

Figure 2: Ideality factor and barrier height variation with temperature. Barrier height scale is in eV.