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# MULTIPHYSICS CHARACTERIZATIONS OF VERTICAL GaN SCHOTTKY DIODES

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**Abstract - In this work, measurements from cathodo-luminescence (CL), micro-Raman spectroscopy and current-voltage I(V) have been coupled to assess the effects of physical parameters such as threading dislocations and effective doping level homogeneity on the electrical performances of vertical GaN Schottky diodes.**

*Keywords: Cathodo-luminescence (CL), micro-Raman spectroscopy, Current-voltage I(V), GaN Schottky diodes.*

## I. INTRODUCTION

Vertical GaN power devices are reported to be more suitable for high power applications because they offer more possibilities of getting high current densities, and higher breakdown voltage (BV) with respect to lateral ones [1]. However, some physical parameters such as ones due to structural defects (like threading dislocations (TDs)) and doping inhomogeneity in their drift layer may influence their electrical performance by degrading the device breakdown voltage (BV) and leakage current. Cathodoluminescence (CL) measurements highlight the presence of dislocation clusters. Thanks to Raman spectroscopy, 2D Raman mapping can be performed to observe the structural defects [2] and n-doping concentration distribution [3]. In this work, the  $E_2^h$  peak shift and width have been used to probe the defects and stress distribution, while the  $A_1$  (LO) peak shift has been employed to analyze the n carrier distribution in the epitaxial layer. The current-voltage I(V) characterization was done to check the effect of the stress, defects and carrier concentration distribution on the electrical performance of the diodes. Thus, this work indicates that the combination of optical and electrical characterization methods can be an efficient way to study vertical GaN power devices.

## II. EXPERIMENTAL DETAILS AND RESULTS

The 5  $\mu\text{m}$  Si n-doped homo-epi-structure has been grown by MOCVD (Metal Organic Chemical Vapor Deposition) method on a HVPE-grown GaN freestanding substrate. The vertical GaN Schottky diodes with different size (200  $\mu\text{m}$ , 100  $\mu\text{m}$  and 50  $\mu\text{m}$ ) have been fabricated. The Schottky contact (Ni/Au) and the ohmic contact (Ti/Al/Ni/Au) have been made by electron beam deposition technique (fig.1). Devices were isolated by chlorine based reactive ion etching. Micro-Raman spectroscopy measurements were carried out at room temperature using a confocal spectrometer (Renishaw Invia model) in back scattering geometry. The excitation laser source was of 532 nm. From the CL measurements, we have identified the presence of dislocations clusters in the epilayer of the diode (fig.2a). Then, we performed 2D Raman maps of the  $E_2^h$  and the  $A_1$ (LO) peak position in the area where these dislocations are identified by CL. A shift in the  $E_2^h$  position have also been observed (fig.2b) which confirms the presence of the TDs [4]. Fig.2c is a zoom on the dislocations cluster highlighting their shape and size, but we could not conclude on the type of TDs, whether they are of the screw, edge or mixed type. The obtained Raman result reveals good correlation between the Raman spectroscopy and the CL method and therefore confirms the efficiency of the micro-Raman spectroscopy as a powerful and non-destructive tool to probe the presence of the TDs. From I(V) measurements, we confirmed the absence of influence of the TDs on the diode electrical performances [5]. Moreover, it has been reported that the shift in the  $A_1$ (LO) position reflects changes in the plasma frequency due to a Plasmon phonon coupling mode called LOPC and can therefore be used to investigate changes in carrier density [6,7]. The  $A_1$  (LO) peak position map (Fig.3) shows a mean value at 733.6  $\text{cm}^{-1}$  with blue spots at lower value, around 733.3  $\text{cm}^{-1}$ . In addition, with the linear calibration equation ( $A_1$  (LO) position vs n carrier concentration) from ref. [7] for  $n < 10^{17} \text{cm}^{-3}$ , the  $A_1$ (LO) position mean value gives a net carrier concentration of ( $2.1 \times 10^{16} \text{cm}^{-3}$ ) which is the same order of magnitude ( $10^{16} \text{cm}^{-3}$ ) found with the capacitance-voltage (C-V) measurements. This light net carrier concentration ( $10^{16} \text{cm}^{-3}$ ) is essential to get a good device breakdown voltage. The blue zones highlighted by micro-Raman spectroscopy in Fig.3 could correspond to a lower effective doping level  $< 10^{16} \text{cm}^{-3}$  which may be due to local variations of the compensation by Carbon acceptors or by peculiar structural defects. Prospectively, more diodes will be studied for further analyses.

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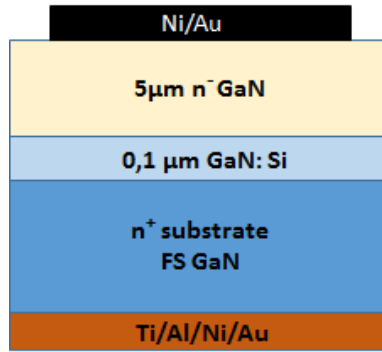


Fig. 1: Cross section image of the vertical GaN Schottky diode.

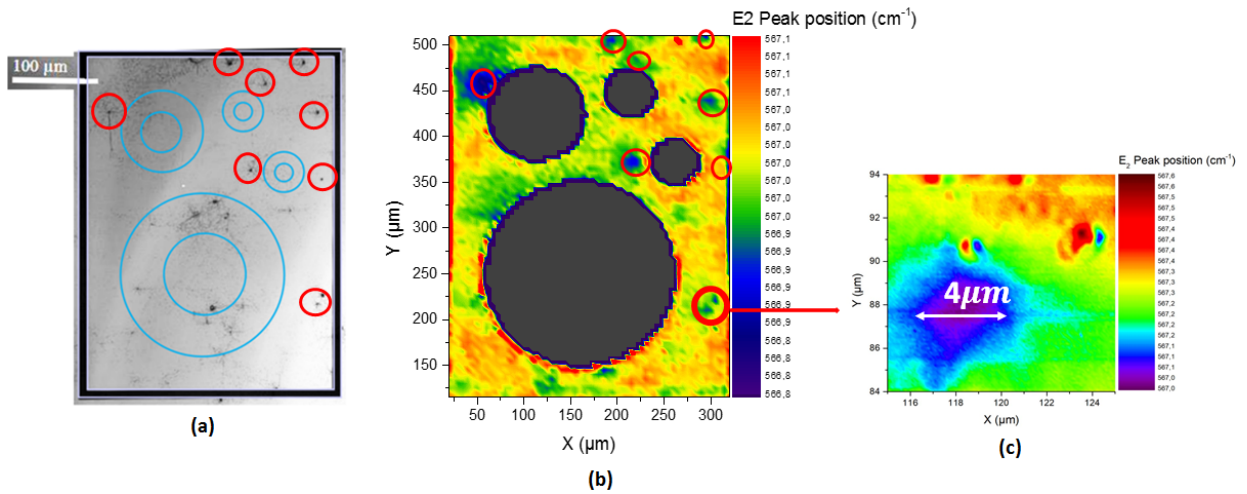


Fig. 2: (a) Cathodo-luminescence image of the dislocation clusters highlighted in red circles (CL was performed before Schottky contact deposition). (b)  $E_2^H$  Peak position Raman map showing the dislocation clusters in red circles. The dark disks are the diode Schottky contacts which diameters of 200 $\mu$ m, 100 $\mu$ m and 50  $\mu$ m. (c) Zoom on the dislocations cluster nearby the 200 $\mu$ m diode.

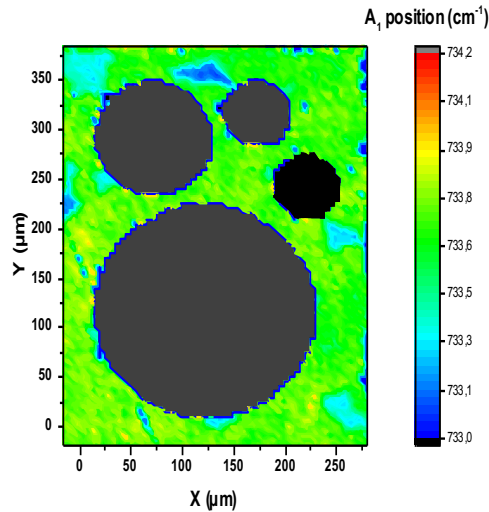


Fig. 3:  $A_1$  (LO) peak position Raman map. The dark disks are the diode Schottky contacts which diameters of 200 $\mu$ m, 100 $\mu$ m and 50  $\mu$ m.