Low damage Etching processes developments for GaN-based devices patterning

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Gallium Nitride becomes more and more present in various microelectronic applications thanks to its different interesting properties. Its crystallographic (wurtzite cell) and thermodynamic parameters are exploited for the new generation of Power (High Electron Mobility Transistor "HEMT" and Diode) and RF devices, to support high voltage, high current, high operating temperature and frequency [1]. On another hand, its direct wide-band gap (3.4eV) permits the GaN to be a good material for photon emission, and therefore is exploited into LED, microLED and displays.

The fabrication of these different GaN-based devices is not trivial, as some processing steps – especially plasma etching – can be critical for the GaN material integrity, affecting the final device functioning. For the patterning step, the most important requirement is the use of **low-degrading plasma processes**. For "pGaN gate" and "Recessed-gate" HEMT, electrical performances are directly linked to GaN damaged, especially at gate bottom [2]. For LEDs, a particular attention on pixel sidewalls is needed to limit damages and maximize the photon emission [3].

Moreover, depending on the application, GaN etching step need to comply morphological requirements. For instance, pGaN etching need to be selective to the underneath AlGaN barrier layer in "pGaN-gate" HEMT devices [4], vertical profiles need to be obtained in "Recessed-gate" transistors and LEDs, and a perfect control of the etching rate is needed for partial etching of few nanometres of thin AlGaN barrier in RF HEMTs.

In this talk, we describe different studies and plasma approaches done at Leti to address those challenges. The understanding of GaN etching and degradation mechanisms was investigated to identify and focus on key-parameters, for each application. To reduce Plasma-Induced damage, GaN Atomic Layer Etching [5] was implemented for low-degrading plasma solution to improve Power devices properties. As described in Fig. 1, the added degradation brought by plasma etching is reduced using ALE Cl_2/Ar process, compared to the ICP RIE reference. The ALE chemistry is an important parameter we studied, as the use of Helium instead of Argon which shows higher degradations [5]. By nature, ALE and cycling processes lead to very slow etching rates. Therefore, other low-degrading technics with better throughputs have been studies, such as bias pulsing or Quasi-ALE.

To also better comply with morphological criteria, the impact of plasma parameters and etching environment on profile were studied. The Fig. 2 reports the study of the GaN etching mechanism in a Cl_2/BCl_3 RIE process with a photoresist mask. The chemical analysis of remaining byproducts on sidewalls (containing Cl, C and Ga traces) and a plasma parameters parametric study allow us to propose a mechanism ruling the sidewall passivation phenomenon, and to tune the process to optimize the etching profile (more vertical). The same investigation has been also done for etching using hard mask (SiO_2, SiN) for comparison.

References

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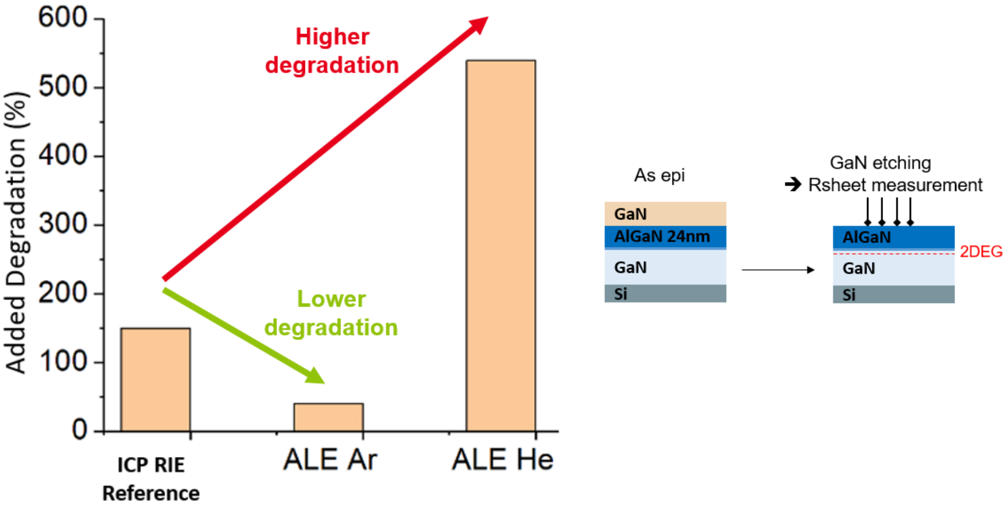

Fig. 1 : Added degradation measured by R_{sheet} after GaN etching by ICP RIE reference process, compared to ALE Cl_2/Ar and ALE Cl_2/He processes

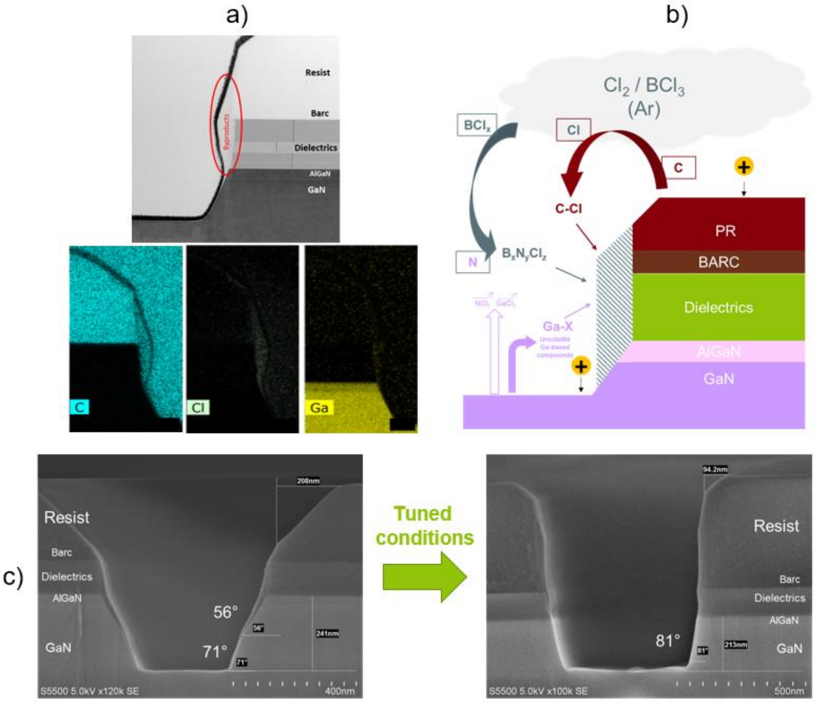

Fig. 2 : Morphological study of GaN trench etching in Cl_2/BCl_3 - based process with a photoresist mask. Chemical analysis of post etching sidewall byproduct (a), proposal of a mechanism for sidewall passivation (b), and finale profile optimization (c)