Extra pattern defectivity formation due to silicon oxynitride interaction with DUV Photoresist during pGaN gate patterning for HEMT device

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pGaN gate definition is one of the key process steps for HEMT Power GaN device fabrication. Particular attention should be paid during the patterning module to avoid the presence of defects that could be responsible for electrical failures. This study is focused on extra pattern defects that were observed at the in-line inspection after pGaN etch process step. The mechanism behind defect's formation and both the morphological and electrical impact will be explained. Finally, a possible integration flow that ensures the absence of these extra patterns will be described.
The physical characterization (TEM and EDX analyses) showed the presence of pGaN residues, arranged either in line or found as "grapes" agglomeration close to pGaN.
The extra patterns present over AlGaN can hide other types of defects saturating the defectivity maps. Also, reliability failures have been found and correlated with this type of defectivity.
A step-by-step analysis was carried out to define the mechanism of defects formation and the root cause. The patterning process makes use of a DUV (deep UV) photoresist and proceeds through three main steps: etching of the oxide hard mask (HM), stripping of the photoresist, etching of pGaN. The analysis, reported in Fig. 1, shows that defects with the same shape of the extra patterns were already present after the HM etch step. One of the hypotheses about this micro masking effect was the presence of photoresist residues above the oxide defects. These residues could have been generated by the interaction between the DUV photoresist and the oxide during the exposition of the mask. The hard mask is a TEOS layer prepared by means of Plasma Enhanced Chemical Vapor Deposition (PECVD) technique. After TEOS deposition, a layer of silicon nitride is deposited by Low Pressure Chemical Vapor Deposition (LPCVD) in ammonia ambient. This Si_3N_4 layer is subsequently removed from wafer front through a plasma etching. Time of Flight Secondary Ion Mass Spectrometry (ToF SIMS) analysis of the oxide showed a high component of SiN_x at the surface, meaning that the layer was partially converted into an oxynitride film. It's reported in literature that silicon oxynitride films are incompatible with DUV photoresist. The reactive nitrogenous species diffuse out of the oxide layer and chemically interact with the components of the polymeric material of the resist [1]. Amine radicals are known to neutralize the acid catalyst of such type of photoresist [2].
A solution was adopted to avoid any interaction between the oxynitride film and the photoresist material. With the new integration the extra patterns defects were eliminated and, regarding reliability, a large improvement in time to failure has been observed.

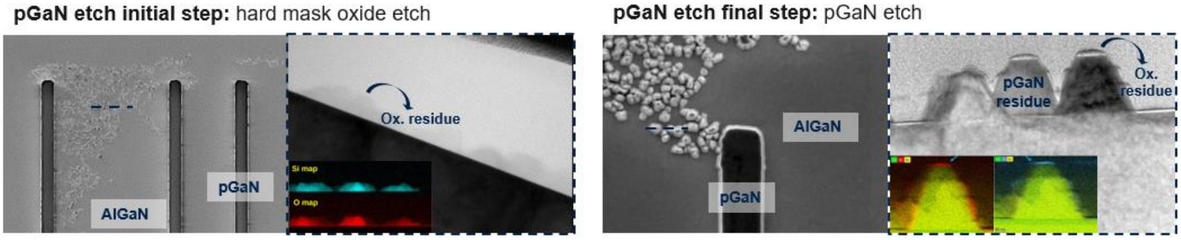

Figure 1 – SEM top view and TEM cross section of extra pattern defectivity formation above AlGaN during pGaN etch step.

References
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