Influence of substrate type and orientation on the morphology and optical properties of selective area growth of GaN and InGaN nanocolumns

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A relevant issue concerning optoelectronic devices based on III-nitrides is the presence of strong polarization fields that may reduce efficiency. This is the case in layers grown along the c-axis and, a huge effort is nowadays dedicated to the growth of high quality non-polar and semi-polar material [1], with a particular emphasis on non-polar LEDs [2]. Much research effort has also been dedicated in the last few years to the selective area growth (SAG) of III-nitride nanocolumns (NCs) due to their unique properties and high potential for optoelectronic applications.
The first part of this work reports on the SAG by plasma assisted MBE of GaN NCs and GaN/InGaN nanostructures on GaN templates with different orientations: *c*-plane (polar), semi-polar and *a*-plane (non-polar) on sapphire. Consistent with results obtained by other epitaxial techniques, vertical growth rate is slower when growing on a-plane as compared to c-plane, under the same growth conditions. In addition, lateral growth is negligible for SAG growth on c-plane, but it turns into significant values in the case of a-plane. This lateral growth may allowed for successful coalescence of neighbouring high crystal quality NCs leading to compact two-dimensional layers with lower defect density that could be used as templates for subsequent growth of more efficient devices on top.
At the same time, all reports on successful SAG of III-nitride NCs used masked GaN templates on sapphire substrates, where the homoepitaxial character of the growth eased the process, in contrast to the self-assembled one, where a substantial mismatch (heteroepitaxy) is needed. However, the achievement of SAG of III-nitride nanocolumnar heterostructures on Si substrates is highly desired for cheap, easy to process devices, like Light Emitting Diodes (LED). A few attempts aiming to SAG of GaN NCs directly (no buffer) on masked (Ti, SiO2) Si substrates showed that multiple, very thin NCs nucleate within each mask nanohole, thus, posing severe limitations on the geometry and NCs size choice [3,4]. These previous results indicate that the nucleation of an individual GaN NC within the mask nanohole was difficult, likely due to a poor wetting or low Ga atoms mobility.
The second part of this work reports on the fabrication of high quality doped and undoped GaN buffer layers on top of Si(111) substrates which are successfully used as templates for the SAG of GaN and InGaN NCs. A significant improvement of the crystal quality of the SAG GaN NCs compared to the GaN/Si templates was indicated by low temperature PL measurements. It is also proved that the optical quality of the SAG GaN is comparable to the optical quality of self-assembled GaN NCs. Finally, polarity measurements of both the GaN buffer layer and the SAG GaN NCs are also performed, indicating a change of polarity from one layer to the next one.

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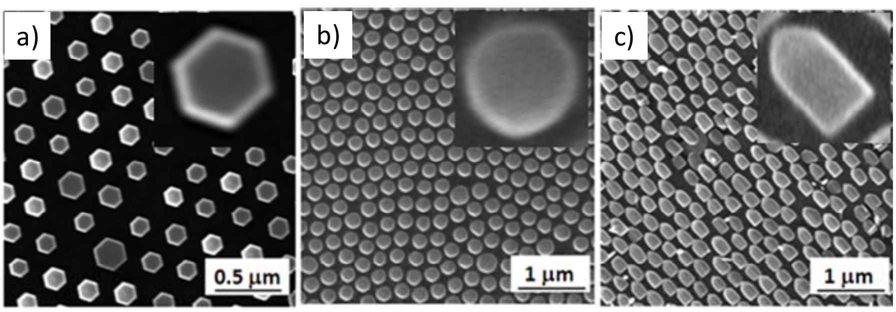

Fig. 1 Top view SEM pictures of SAG GaN NCs grown on GaN templates with different orientations, showing the different morphologies: (a) c-plane (polar), (b) semi-polar and (c) a-plane (non-polar)