The role of Ehrlich-Schwöbel barrier in the elongation mechanism of catalyst-free GaN nanowires grown by molecular beam epitaxy

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III-nitride-based light emitting diodes are now firmly established as the current solution for solid state lightning and related applications, despite the lack of adapted substrate leading to a high defect density in the epitaxial layers. Regarding nanowire-like structures grown by plasma-assisted molecular beam epitaxy (PA-MBE), typically 100 nm diameter, advantage is taken from the eased elastic strain relaxation resulting from the large aspect ratio of such objects. This allows a large mismatch accommodation in axial heterostructures and leads to quasi-defect free crystals.

In this study, we report on GaN PA-MBE regrowth on selective area-grown Ga-polar GaN columns with different pitches and sizes, ranging in diameter from nanowires to micro-columns. It is shown that the metal/nitrogen ratio, the growth temperature and the GaN columns geometry are interrelated parameters affecting the nanowire morphology. Then, the MBE grown section morphology can range from pyramids exhibiting semi-polar facets to nanoparasol-like structures with flat top and widening rate depending on the combination of aforementioned parameters.

Furthermore, the growth kinetics mechanism of GaN catalyst-free nanowires has been investigated by using the different morphologies previously described. For various diameter values of the upper flat surface, observation of either smooth or rough surface of the overgrown GaN section provides clues on the nucleation mechanism and Ga diffusion length, which is governed by both growth temperature and Ga/N flux ratio (Figure 1). In particular, edge nucleation on nanowire top is observed under N-rich conditions. This is assigned to an accumulation of gallium near the edges due to the potential energy barrier for moving to another crystallographic plane, similar to the case of “inverted wedding cake” previously described in ZnO nanowires [1].

[1] X. Yin et al, Inverted Wedding Cake Growth Operated by the Ehrlich–Schwoebel Barrier in Two-Dimensional Nanocrystal Evolution, Angewandte Chemie International Edition **55** 2217-2221 (2016)

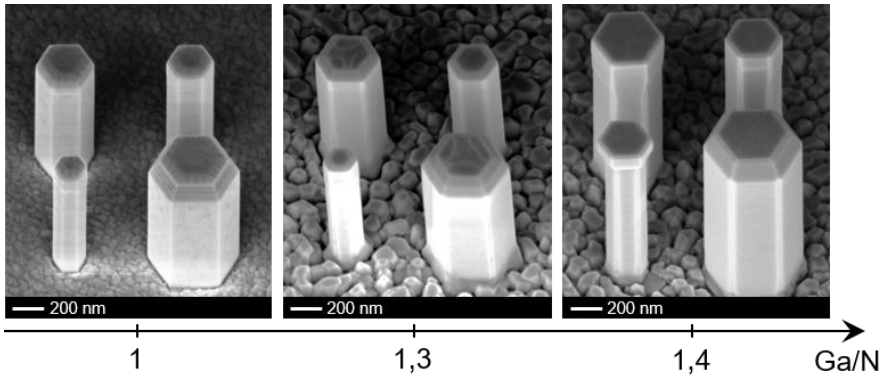

Figure 1 : Bird eye view SEM images of GaN wires after a GaN overgrowth with a variation of gallium/nitrogen ratio leading to a variation of gallium diffusion length, nuclei density and top surface roughness.