Selective-area growth of Ga-polar GaN nanowires by continuous flow MOVPE: polarity and dislocation filtering

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GaN (and its alloys) is currently the second most employed semiconductor after Si. Its applications spread from optoelectronics, where it has allowed the fabrication of blue laser diodes as well as light emitting diodes, to high power electronics, where it can play a major role together with SiC. However, GaN epitaxial layers are deposited on non-native substrates. This induces large strain accumulation and a high density of structural defects, in particular threading dislocations, which result in the degradation of the device quality. In this context, GaN nanowires have been proposed as a solution to overcome these problems as they allow efficient strain relaxation thanks to their free lateral surfaces as well as a dislocation free growth even on foreign substrates.

The selective area growth of GaN nanowires (NWs) is the favored method in order to achieve a high reproducibility and high homogeneity in terms of size and optoelectronic properties. However, this approach seems to be also a source of defects (new dislocations) and polarity inversion domains [1, 2], due to the growth on a masked substrate. This represents a major difficulty since the absence of defects is supposed to be one of the main advantages of the nanowires as compared to planar structures. Furthermore, the polarity of the NWs has a strong impact on their optical characteristics, due to unequal impurity/dopant/point defect incorporation: the presence of polarity inversion domains leads to inhomogenous optical properties within individual nano and microwires[3,4]. Thus, pure polarity GaN NWs should be obtained in order to have uniform optical properties.

In this work we show that GaN NWs can be defect-free and purely Ga-polar even on a patterned substrate. The GaN NWs were grown on masked Ga-polar GaN-on-sapphire templates by continuous-flow MOVPE [5]. A detailed TEM study has been performed to fully characterize the structural quality of our site-controlled GaN nanowires, especially in the region close to the dielectric mask.

We show that the size of the aperture in the dielectric mask (from 200 nm to about 800 nm) determines the presence or absence of threading dislocations coming from the underlying template, which results in dislocation-free nanowires for the smallest aperture diameters. No additional dislocations or inversion domains are observed at the mask border or on top of the mask, and this irrespective of the mask nature (SiO_2 or SiN). For GaN nanowires grown on larger diameter apertures, the probability for a threading dislocation from the underlying template to propagate into the nanowire is larger than one, but we show that dislocations bend toward the lateral free-surfaces thanks to a 3D growth mode.

Finally, CBED measurements allow us to demonstrate that the Ga-polarity of the underlying GaN-on-sapphire template is conserved in all nanowires irrespective of the aperture size, even in the nanowire regions grown laterally above the mask. The pure Ga-polarity assures spatially homogeneous optical properties as evidenced by cathodoluminescence.

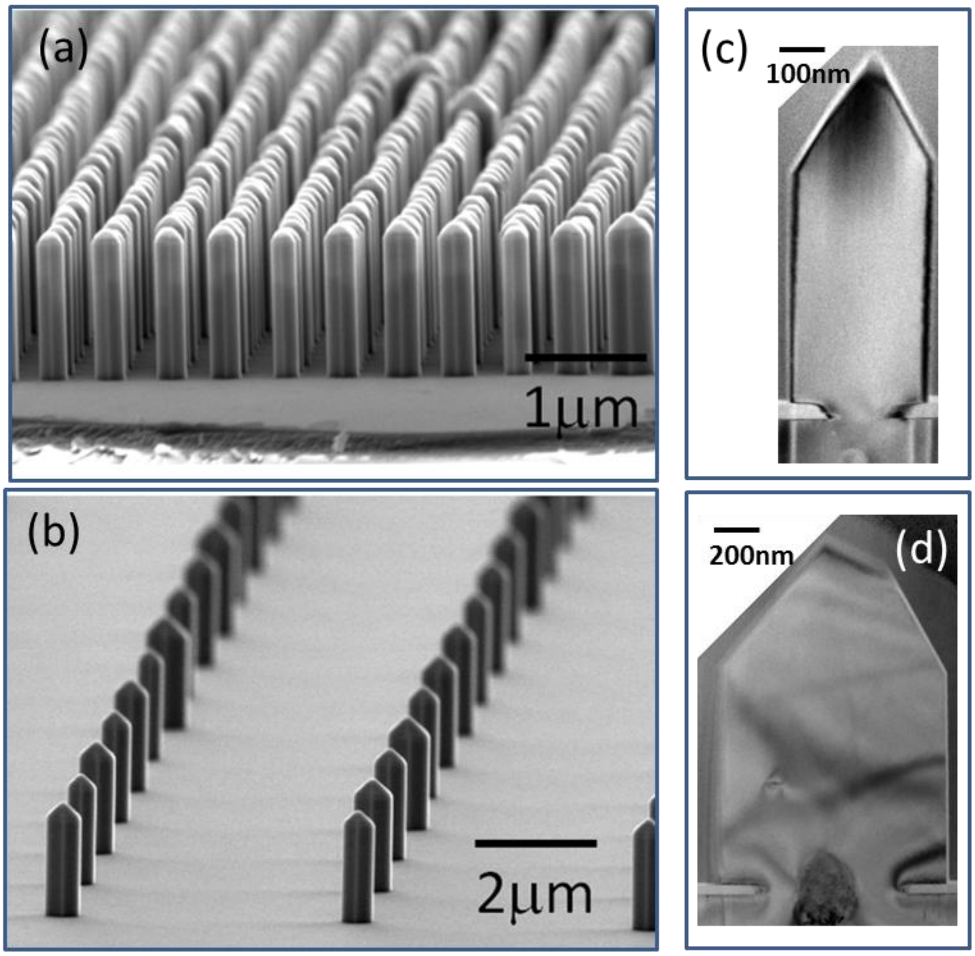

Figure 1: SEM images of GaN NWs grown on masked GaN-on-sapphire templates with a 500nm (a) and a 5000nm (b) pitch pattern. Bright field images along the [10-10] zone axis with g=000-2 of a NW grown on a 200nm (c) and a 630nm (d) mask opening.

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