Nucleation and growth of GaN nanowires by plasma-assisted molecular beam epitaxy

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The last decades, nanowires (NWs) have been under intense research because of their unique characteristics, their high crystal quality and their promising applications. In this work, the spontaneous nucleation and growth of GaN nanowires on Si(111) by plasma assisted molecular beam epitaxy have been investigated.

The height, diameter and density of GaN NWs were determined by field emission scanning electron microscopy (FE-SEM). X-ray diffraction rocking curves (XRD RCs) were obtained to compare the crystallographic alignment of the NWs. Their optoelectronic properties and structural quality were evaluated by photoluminescence spectroscopy. High resolution transmission electron microscopy (HR-TEM) was used to study the GaN/substrate interface and to identify the nucleation sites and the epitaxial relationship of the GaN (0001) NWs and the Si (111) substrate.

Samples of GaN NWs were grown either after intentional nitridation of the Si surface by the active nitrogen beam or after initial growth of an AlN interlayer (IL), with thickness varied between 1 monolayer and 15 nm. The results highlight the competing formation of AlN and SixNy interlayers at the GaN NW/Si interface. A ~1.5nm AlN IL, probably with significant residual strain at the end of its growth, facilitates the nucleation of GaN NWs on top of it while it simultaneously prevents the formation of amorphous silicon nitride at the interface. A thicker AlN IL, which should be closer to a strain free condition, favors the nucleation and lateral growth of 3D GaN islands which coalesce into a continuous GaN film.

To study the effect of the substrate temperature, NWs were grown at temperatures in the range between 730°C-780°C, either keeping the temperature constant throughout the growth or following a two-step growth process win NW nucleation at lower temperature than the final one. For those samples that were grown at a constant temperature, the highest studied substrate temperatures revealed a significant suppression of NW nucleation and growth. The NW nucleation at low temperature is madatory for growing NWs at substrate temperatures higher than 790°C.

The results highlight the critical role of the nucleation step for the overall spontaneous GaN NW growth.

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