Self-Organized Molecular Beam Epitaxial Growth of AlGaN/GaN Nanostructures for Optoelectronic Applications

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III-Nitrides have raised a great deal of interest during the last decade due to their excellent properties as blue and ultraviolet emitters and detectors. However, one of the main problems is still the lack of a commercially available GaN lattice-matched substrate for the epitaxial growth. This fact forces that all the existing devices have to be grown heteroepitaxially using substrates such as sapphire (Al_2O_3) or SiC-6H, resulting in a material with very high density of defects, which decreases the efficiency and degrades the operation of the optoelectronic device.

This work reports on a self-organized growth method by plasma-assisted molecular beam epitaxy (PA-MBE) to fabricate GaN-based nanocrystals with outstanding crystal quality. The highly N-rich growth conditions promote the "Ga-balling" effect during the nucleation and the subsequent growth by a vapor-liquid-solid (VLS) mechanism that leads to the formation of nanocolumns with diameters ranging from 20–60 nm, that exhibit very narrow and intense photoluminescence (PL) emission. The uniform columns are defect-free, as no traces of any extended defects were found by transmission electron microscopy, TEM, with a perfect alignment in both the growth direction and the epitaxial plane.

Hexagonal, single crystal GaN and AlGaN nanocolumns are grown and characterized with optical (photoluminescence, cathodolumisnecence and Raman) and structural (TEM, SEM and XRD) techniques. The nominal Al concentration in the AlGaN alloy is controlled by adjusting the Al molecular flux to the total III-element (Ga + Al) flux ratio while keeping constant the amount of active nitrogen and growth temperature, obtaining alloys with Al contents in the range of 16 to 50 %. Both GaN and AlGaN nanocolumns are strain-free as observed by Raman and TEM measurements.

Finally, GaN Quantum Discs embedded in AlGaN nanocolumns are fabricated. High-resolution TEM photographs demonstrate that the discs are bounded by atomically flat interfaces without the appearance of misfit dislocations. Strong optical emission is obtained from this set of nanodiscs revealing quantum confinement effects. This type of nano-structure opens the door for the fabrication of highly-efficient GaN-based nanocavities to be applied for future light emitters on Si(111) substrates.