Carrier dynamics and recombination in GaN quantum discs embedded in AlGaN nanocolumns

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The growth of defect-free, self organized Ga(Al)N nanocolumns by molecular beam epitaxy (MBE) has been recently demonstrated. Under N-rich conditions, the reduced Ga surface mobility develops into a columnar growth, most likely due to a vapor-liquid-solid process. The nanocolumns size and density can be controlled by the III-metal to N flux ratio, whereas the Al to Ga flux ratio controls the nanocolumns composition [1]. Quantum discs (QD) of GaN embedded in AlGaN columns were successfully grown, thus opening a fascinating scenario for novel optoelectronic applications, such as quantum dots in a nanopillar cavity, monolitically grown by MBE. In addition, transmission electron microscopy measurements have shown the lack of any extended defects, while photoluminescence (PL) measurements revealed the presence of quantum confinement effects in the GaN quantum discs [2].

In this work we address the study of carrier dynamics and recombination by time resolved PL in GaN quantum discs embedded in $Al_{0.16}Ga_{0.84}N$ nanocolumns, grown by MBE on AlN buffered Si (111) substrates. The nanostructures consist of 5 GaN QDs, 4 nm thick, separated by 10 nm spacer layer and embedded in $Al_{0.16}Ga_{0.84}N$ nanocolumns 1.6 μm high. A reference $Al_{0.16}Ga_{0.84}N$ nanocolumnar sample (without GaN QDs) was also investigated for comparison. PL was excited by the SHG of a synchronously pumped ps dye laser (306 nm), dispersed by a 200 mm monochromator and detected by a MCP in the temperature range from 8 K to room temperature. Time correlation of single photon counting technique was used to time resolve the PL signal with an experimental response faster than 100 ps FWHM.

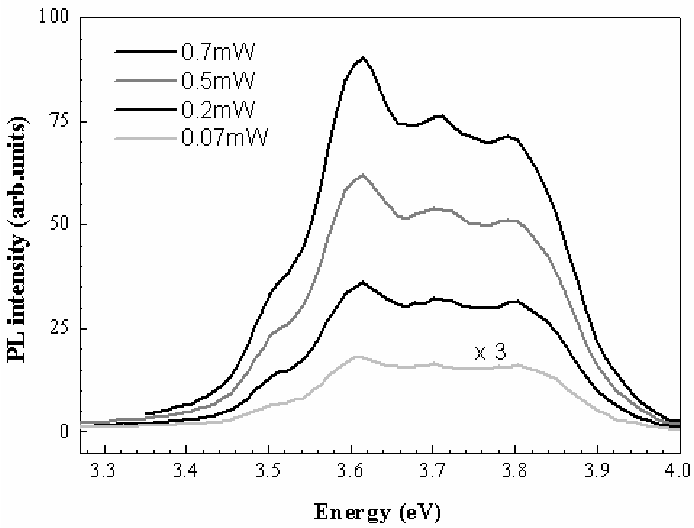

Fig.1Low T PL spectra for different excitation power of the 5 GaN QDs embedded in $Al_{0.16}Ga_{0.84}N$ nanocolumns

Four different contributions can be resolved in the PL emission band (see Fig.1). From time resolved PL spectra, and compared to the reference sample, we can associate two bands to the emission from the barrier, related to exciton (3.813 eV) and impurity recombination (3.510 eV) respectively, while the emission band 3.622 eV is due to the fundamental transition of the QDs. The attribution of the last PL band at 3.71 eV is more complicated; we tentatively assign it to extrinsic recombination from the barriers, even if a contribution from the QDs cannot be excluded. All PL time decays are non exponential, with a quite fast initial decay time (nearly 300 ps) followed by a long recombination tail (several ns). The decay of the emission from the barrier is much longer than the QDs rise time, denoting that the AlGaN emission in the structures comes from zones which do not transfer carrier to the QDs, very likely due to the strong carrier localization. Temperature dependent measurements confirm the previous assignments and point out a thermal quenching process associated to carrier escape out of the QDs followed by a non radiative recombination at surface defects.

References
[1] E. Calleja et al., PRB 62, 16826 (2000)
[2] J. Ristić et al., PRB 68, 125305 (2003)