Luminescence sensing based on GaN NWs implanted with lanthanide ions

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Abstract

Low dimensional structures such as GaN nanowires (NWs) are expected to offer potential advantages for nanophotonics and nanoelectronics due to the increase in the light-extraction efficiency owing to their non-planar geometry and higher compatibility with different substrates, as is the case of silicon widely used in nowadays technology [1]. GaN NWs have been doped with rare-earth (RE) ions in order to tune the visible light emission. However, *in-situ* doping of these NWs poses some challenges essentially due the inhomogeneous dopant distributions, morphology changes or phase separation. An alternative approach to the doping process is using ion implantation since it allows the introduction of impurities in a controlled way and without solubility limits [2].

GaN nanowires implanted with europium, praseodymium and erbium ions were analysed by photoluminescence (PL). The red $^5D_0 \rightarrow {}^7F_2$ and $^3P_0 \rightarrow {}^3F_2$ luminescence transitions of the Eu^{3+} ($4f^6$) and Pr^{3+} ($4f^2$) ions, respectively, were optically activated after the recovery of the lattice damage by thermal annealing treatments. The peak position and spectral shape of the ions luminescence agrees with those observed in GaN layers (see Figure 1). On the contrary, for the case of the erbium implanted NWs no intra-$4f^{11}$ transitions were identified in the visible and infra-red spectral range [3]. Besides the lanthanide luminescence, the heat treated GaN NWs exhibit the band edge recombination and a broad deep level emission (~ 470-700 nm) centred in the yellow spectral range. The yellow luminescence (YL) is one of the most studied defects in GaN films. However, the YL behavior in the GaN NWs strongly depends on the ion implantation and thermal annealing treatments. In fact, the YL can be induced/enhanced by ion implantation and the role of the surface states cannot be discarded in these high surface-to-volume ratio nanostructures. As corroborated by room temperature optical experiments, the luminescence intensity of the GaN NW yellow band acts as a sensor when the samples were exposed to hydrogen plasma etching and wet chemical acid bath. The stability of the YL in untreated and treated samples was studied as a function of illumination/irradiation time in air and vacuum [4], and the PL studies after the treatments reveal the sensitivity of the YL intensity with the different treatments (Figure 2).

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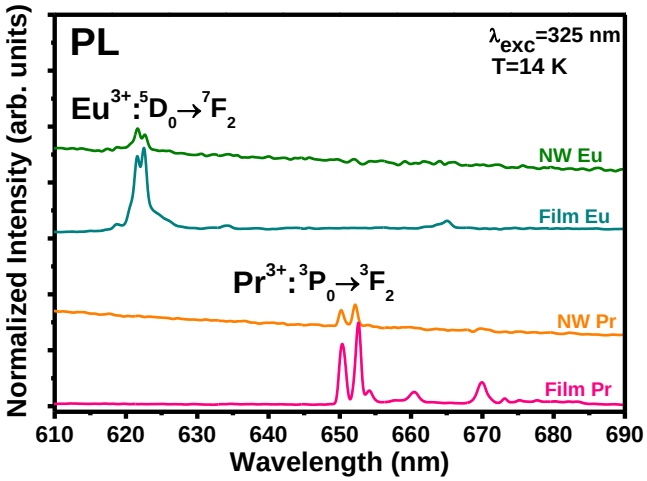

Figure 1 - Comparison between the PL emission of the GaN NWs doped with Eu^{3+} and Pr^{3+} ions and the GaN films doped with the same ions.

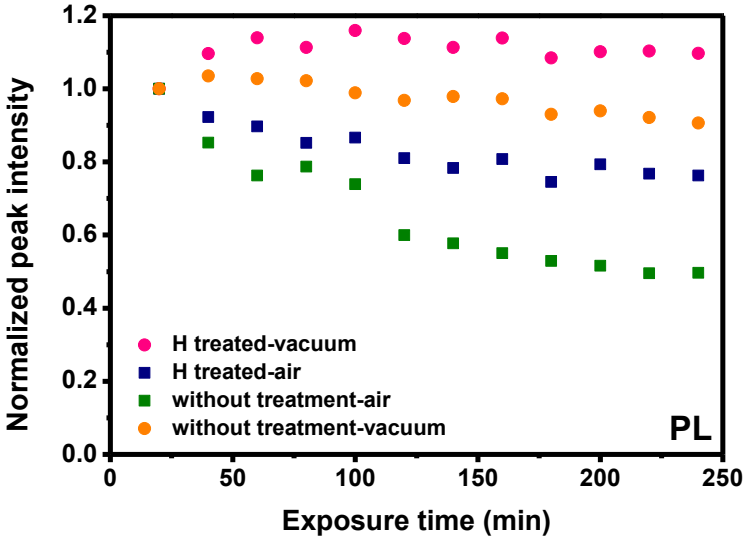

Figure 2 - Maximum peak intensity of the yellow band for the annealed GaN:Er NWs before and after the treatment with H plasma, as a function of the He-Cd laser exposure time. The data are normalized to the maximum of first spectrum (20 min) for each ambient.