Spatially resolved cathodoluminescence of GaN nanostructures fabricated by photoelectrochemical etching

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The emission properties of GaN nanostructures created by photoelectrochemical etching have been investigated by cathodoluminescence (CL) in the scanning electron microscope. Columnar structures with diameters of 150–250 nm formed near the surface of the as-grown GaN layers branch into nanowires with diameters of 20–60 nm, while islands with coral-like relief were observed at the bottom of the etched areas. CL emission of the observed nanostructures is dominated by free electron to acceptor transitions. Local CL spectra provide direct evidence of the existence of either compressive or tensile stress in different nanostructures. No free exciton luminescence was observed in GaN nanowires, supporting their relation to threading dislocations. © *2005 American Institute of Physics*. [DOI: 10.1063/1.1940734]

Over the last decade, GaN became one of the most intensively investigated semiconductors due to its potential applications in optoelectronics and high-frequency/high-power electronics. A serious obstacle to the realization of many device structures is the high content of threading dislocations in GaN epilayers, which are grown on lattice mismatched substrates due to the limited availability of GaN substrates. The impact of dislocations upon emission properties of GaN epilayers has been previously assessed by cathodoluminescence (CL).[1,2] Nonradiative recombination of free carriers at threading dislocations is thought to cause a deficiency of minority carriers and results in dark regions of the epilayer.[1] However, regions of enhanced emission have also been observed by cross-sectional CL and attributed to decorated dislocations.[2] Previous investigations[3–5] indicate that threading dislocations in *n*-GaN can be visualized by the formation of whiskers during photoelectrochemical (PEC) etching. The high resistance of whiskers to PEC attack was attributed to the negative charge inherent to threading dislocations in *n*-GaN.[4] Indeed, the photogenerated holes will not contribute to the etching process in case they exhibit fast recombination via defect states at dislocations. An alternative explanation is that dislocations represent regions of decreased potential and the photogenerated holes are repelled from them and confined in the surrounding areas stimulating their dissolution. In this work, CL microscopy and spectroscopy have been applied to correlate the local optical and structural properties of different GaN nanostructures created by PEC.

The GaN layers used were grown by low-pressure metalorganic chemical vapor deposition on sapphire substrates. A buffer layer of 25-nm-thick GaN was first grown at 510 °C. Subsequently, a 0.5-μm-thick *n*-GaN film followed by a Si-doped n^+-GaN film and a top *n*-GaN layer with 2.0 μm thickness each were grown at 1100 °C. The concentration of free electrons in the top *n*-GaN layer was 1.7×10^{17} cm^{-3}. PEC etching was carried out in a stirred 0.1 M aqueous solution of KOH for 10–30 min under *in situ* ultraviolet illumination provided by focusing the radiation of a 200 W Xe lamp on the GaN surface exposed to the electrolyte. No bias was applied to the sample during etching. The morphology of the etched layers was studied using a Jeol JSM-6335F field emission scanning electron microscope (SEM) and a Leica 440 Stereoscan SEM. The latter instrument was also used for CL investigations, carried out at 90 K using accelerating voltages of 5–15 kV and beam currents between 0.2 and 5 nA. CL spectra were recorded either using a charge coupled device camera with a built-in spectrograph (Hamamatsu PMA-111) or a Hamamatsu R928P photomultiplier working in the photon counting mode and a computer controlled Oriel 74100 monochromator.

Figure 1 shows high-resolution SEM images taken in

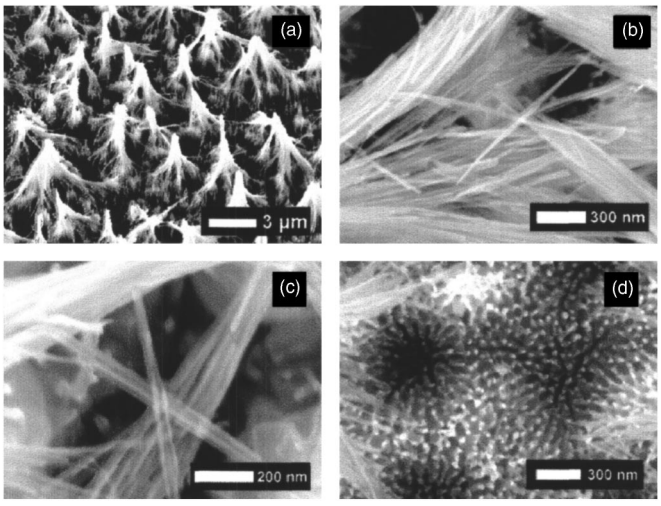

FIG. 1. SEM images taken in different areas of an etched GaN layer showing columnar structures (a), branches of nanowires stemming from the bottom of the columns (b,c) and islands with coral-like relief (d).

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