Doping inhomogeneity at the nanoscale in GaN:Si studied by electrochemical etching

A. Feduniewicz-Żmuda [1], M. Siekacz [1], N. Fiuczek [1], O. Gołyga [1], M. Sawicka [1],
K. Sobczak,[2] and C. Skierbiszewski [2]

[1] *Institute of High Pressure Physics, PAS, Sokołowska 29/37, 01-142 Warsaw, Poland.*
[2] *Faculty of Chemistry, Biological and Chemical Research Center, University of Warsaw,*
Żwirki i Wigury 101, 02-089 Warsaw, Poland.

Electrochemical etching (ECE) has recently emerged as a very useful method to fabricate porous GaN of a decreased refractive index [1] e.g. for cladding layers in laser diodes [2] or for removal of sacrificial layers and structure lift-off [3]. Due to high selectivity against n-type doping, ECE technique can also serve as a tool to detect inhomogeneity in Si doping in GaN grown by plasma-assisted molecular beam epitaxy (PAMBE) [4]. We showed that surface morphology – atomically flat or step-bunched – impacts the Si incorporation and leads to doping inhomogeneity at the nanoscale.

In this work we focus on the extremely high Si doping of GaN up to $1\cdot10^{20}$ $\mathrm{cm^{-3}}$ and its consequences for the surface morphology and the electrical properties within the layer. We study GaN:Si^{++} layers grown by PAMBE on GaN/Sapphire templates. First, we observe the enhanced growth rate along the a-direction $\langle 11\bar{2}0\rangle$ that causes the emergence of the hillocks with star-shaped arms, that we call “nanostars”, see Figure 1(a). Second, we investigate local Si content and measure only a 10% Si composition decrease in the nanostar by energy-dispersive X-ray spectroscopy (EDX) and third, we use ECE to study electrical properties at the nanoscale. Because the nanostars are less conductive than the surrounding layer, they are not etched during ECE, see Figure 1(b). We discuss the origins of the decreased nanostar conductivity and attribute it to an increased compensation that is most likely caused by the complexes of Si substitutional and vacancies.

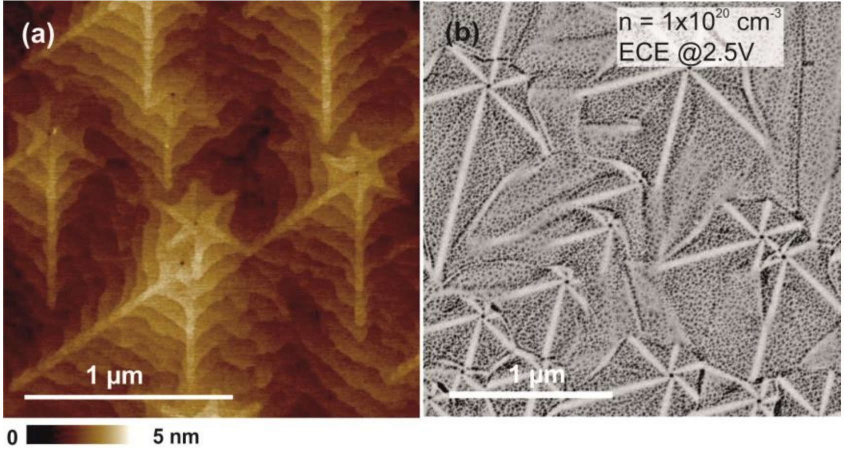

Figure 1 (a) Surface morphology of GaN:Si layer n=$1\cdot10^{20}$ $\mathrm{cm^{-3}}$, (b) SEM after ECE at 2.5V.

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