Surface-charge lithography for GaN microstructuring based on photoelectrochemical etching techniques

I. M. Tiginyanu,[a)] V. Popa, and O. Volciuc
Laboratory of Low-Dimensional Semiconductor Structures, Institute of Applied Physics, Academy of Sciences of Moldova, MD-2028 Chisinau, Moldova, and National Center for Materials Study and Testing, Technical University of Moldova, MD-2004 Chisinau, Moldova

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We show that host defects introduced at the surface of GaN epilayers by mechanical means (e.g., using needles, microscribers), or 2-keV-argon ion beam are resistant to photoelectrochemical etching in aqueous solution of KOH, presumably due to trapped negative charge. The spatial distribution of surface defects and related negative charge can be designed as lithographic mask for the purpose of GaN microstructuring. The possibility to fabricate GaN mesostructures using the approach involved is demonstrated. © *2005 American Institute of Physics*.
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The electrochemistry of semiconductor materials has played an important role in the development of microelectronic technology. In particular, many of the processes used in the integrated circuit technology are based on electrochemical principles. *In situ* illumination allows efficient control over electrochemical reactions of semiconductors in contact with liquids, one refers in this case to photoelectrochemical etching (PEC). The nonequilibrium minority carriers induced by light can stimulate spatially selective etching of the semiconductor material. For *n*-type semiconductor materials, one needs to create holes at the interface in order to stimulate the local dissolution.

Over the last years, PEC etching was used by many research groups for the purpose of demonstrating efficient wet etching of gallium nitride known as resistant to chemical attack.[1–4] GaN and related nitrides, with properties closer to ceramic materials than proper semiconductors, are considered promising for numerous applications such as the creation of full-color display systems, data storage devices, solar-blind ultraviolet detectors, new sensor technologies, wireless communications, solid-state lighting and high-power microwave generation for radar, etc.[5,6] Note that nitride-based light-emitting diodes and lasers for blue and UV spectral regions have been successfully commercialized. Further elaboration of device structures on GaN depends primarily upon the progress in growth technologies and material micro- and nanostructuring. In this work, we report the design of trapped charge at the surface of *n*-GaN that protects the semiconductor material against photoelectrochemical attack. We show that the ability to generate high-resolution patterns of surface defects and related trapped charge can, in principle, be used for microfabrication purposes.

The GaN layers used in our experiments were grown by low-pressure metalorganic chemical-vapor deposition (MOCVD) on (0001) *c*-plane sapphire. A buffer layer of about 25-nm-thick GaN was first grown at 510 °C. Subsequently a 0.5-μm-thick *n*-GaN 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}, while the density of threading dislocations was in the range of 10^9-10^{10} cm^{-2}. Radiation defects were created at the top surface of GaN layers by subjecting the samples to ion beam treatment using 2-keV-Ar ions at 3×10^{12} cm^{-2}. Photoelectrochemical etching was carried out in stirred 0.1 mol aqueous solution of KOH under *in situ* UV illumination provided by focusing the radiation of a 200 W Xe lamp to a spot of about 5 mm in diameter on the GaN surface exposed to electrolyte. No bias was applied to the sample during etching. The morphology of etched samples was studied using a TESCAN scanning electron microscope (SEM) operating at 20 kV.

PEC etching of *n*-GaN in KOH solutions is known to remove high-quality material and to leave whiskers or nanowires representing threading dislocations.[3,7,8] Figure 1 shows

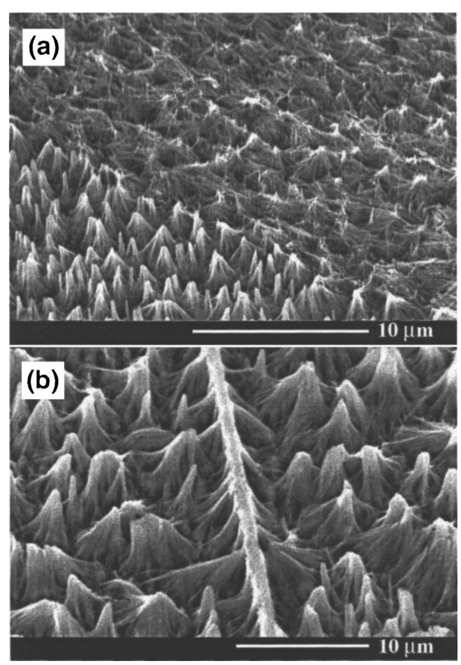

FIG. 1. SEM images taken from PEC etched GaN epilayers: (a) shows the distribution of nanowires before (left-bottom area) and after (right-top area) they were broken off mechanically, and (b) illustrates a line of defects among stacks of nanowires.

[a)]Electronic mail: tiginyanu@mail.md

