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Ultra-Thin GaN Membranes Fabricated by Using Surface Charge Lithography

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We report on fabrication of ultra-thin GaN membranes of nanometer scale thickness, by using the concept of surface charge lithography based on low-energy ion treatment of the sample surface with subsequent photoelectrochemical etching. The membranes prove to be transparent to both electrons and UV radiation, emit mainly yellow cathodoluminescence, and exhibit electrical conductivity. Successful fabrication of nanometer-thin membranes opens unique possibilities for exploration of two dimensional GaN-based structures predicted to be ferromagnetic with defect-induced half-metallic configuration which is of peculiar importance for spintronics applications.

Introduction

GaN is a wide band gap compound semiconductor (E_g = 3.4 eV at 300 K) exhibiting pronounced chemical and thermal stability with applications in high temperature and high power electronics, optoelectronics for light emitting diodes and lasers, etc. It is currently one of the most intensively studied semiconductor materials. Over the last decade many international research groups have been focused on developing and optimizing material nanostructuring. GaN nanorods (1,2), nanowires (3-5), nanotubes (6), nanopyramids (7) etc. have been fabricated by various methods including molecular beam epitaxy, metalorganic chemical vapor deposition (MOCVD), hydride vapor phase epitaxy, photoelectrochemical etching (PEC) techniques etc. Recently (8) we demonstrated the possibility for controlled fabrication of GaN nanowalls and nanowires by using the so called surface charge lithography (SCL) proposed earlier (9). SCL is a maskless approach based on direct writing on the surface of semiconductor by a focused ion beam of negative charge which shields the material against PEC etching. In this work, we demonstrate the fabrication of gallium nitride membranes with nanometer-scale thickness using the concept of the surface charge lithography. To our knowledge, no data about fabrication of nanometer-thin GaN membranes are available in the literature.

Experimental

The unintentionally doped wurtzite *n*-GaN layers used in our experiments were grown by low-pressure MOCVD on (0001) *c*-plane sapphire substrates. A buffer layer of about 25 nm-thick GaN was first grown at 510 °C. Subsequently a 3 μm-thick *n*-GaN layer was grown at 1100 °C. The concentration of free electrons was of the order of 10^{17} cm^{-3},