Surface charge lithography for GaN micro- and nanostructuring

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ABSTRACT

We demonstrate the possibility for controlled micro- and nanostructuring of GaN layers by low-dose focused-ion-beam (FIB) treatment with subsequent photoelectrochemical (PEC) etching. The proposed novel maskless approach based on ultra-fast direct writing of surface negative charge that shields the material against PEC etching allows one to fabricate GaN nanowalls and nanowires with lateral dimensions as small as 100 nm. Compared with commonly used lithography masks and/or FIB etching approaches for patterning GaN, the surface charge lithography enables one to fabricate high-aspect ratio micro- and nanostructures and mitigates the need for additional mask layers on the surface prior to etching, and is much faster than FIB etching alone reducing furthermore the ion exposure of material and therefore reducing ion beam damage. We show, in particular, the possibility to etch voids in between structures as narrow as 200 nm and to fabricate GaN suspended membranes and sub-micrometer hollow squares with the thickness defined by the main projection range of implanted ions. The obtained results demonstrate the feasibility of maskless device fabrication based on low-dose FIB direct writing with subsequent wet etching.

Keywords: Nanostructuring, GaN, photoelectrochemical etching, focused ion beam, nanowires, suspended membranes, maskless device fabrication

1. INTRODUCTION

GaN is a wide band-gap semiconductor compound (E_g = 3.4 eV at T = 300 K) which finds applications in high-power and high-temperature electronics, solar-blind ultraviolet detection, solid-state lighting, new sensor technologies etc. [1]. Currently it is one of the most intensively studied semiconductors, special conferences and symposia being dedicated to this important micro-opto-electronic material. Among many unique properties of GaN one can mention high stability to aggressive chemical media, high radiation hardness of nanostructures, intense luminescence inherent to GaN-based structures in spite of high dislocation densities reaching values as high as 10^{10} cm^{-2} etc. [1-3].

Due to the high chemical stability of GaN and related nitrides and associated difficulties in wet etching, over the last years many research groups contributed to the development of various approaches of reactive ion or dry plasma etching [1,4]. In spite of relative progress in the promotion of such approaches, their wide implementation is impeded by high amount of damage introduced in the fabricated mesastructures and challenges in producing high aspect ratio structures. Note that the latter obstacle is inherent also to focused-ion-beam etching exploited to fabricate GaN-based nanostructures [5,6].

A few years ago we proposed a novel approach for GaN microstructuring [7], the so called Surface Charge Lithography (SCL), based on photoelectrochemical etching of samples preliminarily treated by a low-energy low-dose focused ion beam. The low-energy FIB creates surface defects which trap electrons thus generating a surface layer of bound negative

Gallium Nitride Materials and Devices IV, edited by Hadis Morkoç, Cole W. Litton, Jen-Inn Chyi,
Yasushi Nanishi, Joachim Piprek, Euijoon Yoon, Proc. of SPIE Vol. 7216, 72160Y
© 2009 SPIE · CCC code: 0277-786X/09/$18 · doi: 10.1117/12.803679