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Fabrication of photonic crystal circuits based on GaN ultrathin membranes by maskless lithography

Olesea Volciuc, Tudor Braniste, Vladimir Sergentu, Veaceslav Ursaki, Ion M. Tiginyanu, Jürgen Gutowski

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Abstract

We report on maskless fabrication of photonic crystal (PhC) circuits based on ultrathin (d~15 nm) nanoperforated GaN membranes exhibiting a triangular lattice arrangement of holes with diameters of 150 nm. In recent years, we have proposed and developed a cost-effective technology for GaN micro- and nanostructuring, the so-called surface charge lithography (SCL), which opened wide possibilities for a controlled fabrication of GaN ultrathin membranes. SCL is a maskless approach based on direct writing of negative charges on the surface of a semiconductor by a focused ion beam (FIB). These charges shield the material against photo-electrochemical (PEC) etching. Ultrathin GaN membranes suspended on specially designed GaN microstructures have been fabricated using a technological route based on SCL with two selected doses of ion beam treatment. Calculation of the dispersion law in nanoperforated membranes in the approximation of scalar waves is indicative of the occurrence of surface and bulk modes, and there is a range of frequencies where only surface modes can exist. Advantages of the occurrence of two types of modes in ultrathin nanoperforated GaN membranes from the point of view of their incorporation in photonic and optoelectronic integrated circuits are discussed. Along with this, we present the results of a comparative analysis of persistent photoconductivity (PPC) and optical quenching (OQ) effects occurring in continuous and nanoperforated ultrathin GaN suspended membranes, and assess the mechanisms behind these phenomena.