Romanian Reports in Physics, Vol. 67, No. 4, P. 1319–1321, 2015

Dedicated to
International Year of Light 2015

FLEXIBLE PHOTONIC CRYSTALS BASED ON ULTRATHIN MEMBRANES

ION TIGINYANU

Academy of Sciences of Moldova, 1 Stefan cel Mare Av., Chisinau 2001,
Republic of Moldova, E-mail: tiginyanu@asm.md

Received September 10, 2015

Abstract. A breakthrough is reported in the maskless fabrication of flexible photonic crystals based on ultrathin inorganic membranes. Taking into account the concept of Surface Charge Lithography proposed previously [1], a technological route is developed for the fabrication of ultrathin gallium nitride membranes nanoperforated in a controlled fashion. The route is based on direct writing of negative charges on the surface of semiconductor crystalline substrates. Flexible photonic crystals with embedded waveguides, beam splitters etc. are demonstrated and results of modelling of their characteristics are discussed.

We report on a breakthrough in the maskless fabrication of flexible photonic crystals based on ultrathin (thickness up to 15 nm) inorganic membranes. Taking into account the concept of Surface Charge Lithography proposed by us previously [1], a technological route has been developed for the fabrication of ultrathin gallium nitride membranes nanoperforated in a controlled fashion. The Surface Charge Lithography is a maskless approach based on direct writing of negative charges on the surface of a semiconductor by a focused ion beam. The negative charges were found to shield the material against photoelectrochemical (PEC) etching. Using direct writing of negative charges with subsequent PEC etching of specimens under UV irradiation, ultrathin GaN membranes suspended on specially designed GaN microstructures have been fabricated [2, 3]. In this communication, flexible photonic crystals with embedded waveguides, beam splitters and cavities are demonstrated and the results of modelling of their characteristics are presented. In particular, calculation of the dispersion law, in the approximation of scalar waves, in nanoperforated ultrathin membranes exhibiting a triangular lattice arrangement of holes with diameters of 150 nm is indicative of the occurrence of both surface and bulk modes, and there is a range of frequencies where only surface modes can exist. It is shown that the degree of localization of the electromagnetic field of surface modes in nanoperforated membranes may be orders of magnitude stronger as compared to non-perforated membranes. The surface modes can be used for the transmission of electromagnetic energy along the surface in waveguides, resonators etc. Taking into account the high flexibility of the developed GaN nanoperforated membranes, they can be easily incorporated in optoelectronic and photonic integrated circuits where the surface modes are expected to propagate without significant losses even in deformed or bent membranes. Advantages of the occurrence of two types of modes in ultrathin nanoperforated membranes from the point of view of their incorporation in modern photonic circuits are discussed.

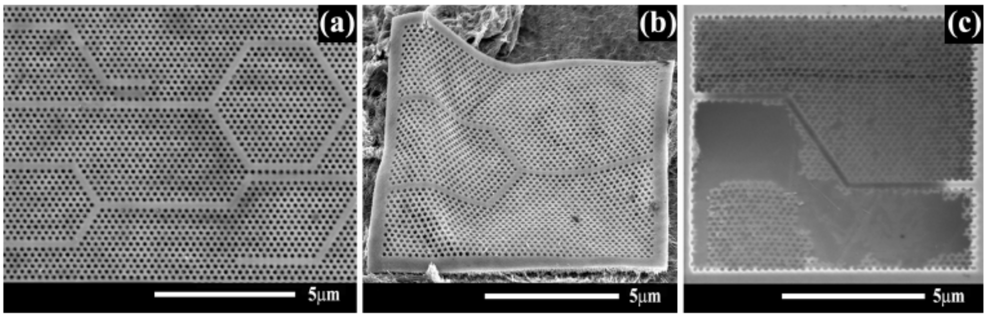

Fig. 1 – SEM images taken from GaN membranes nanoperforated by design using Surface Charge Lithography: a) top image taken from a suspended membrane; b) oblique image demonstrating the flexibility of the membrane; c) oblique image taken from partially broken membrane in order to demonstrate that the material underneath has been removed by photoelectrochemical etching.

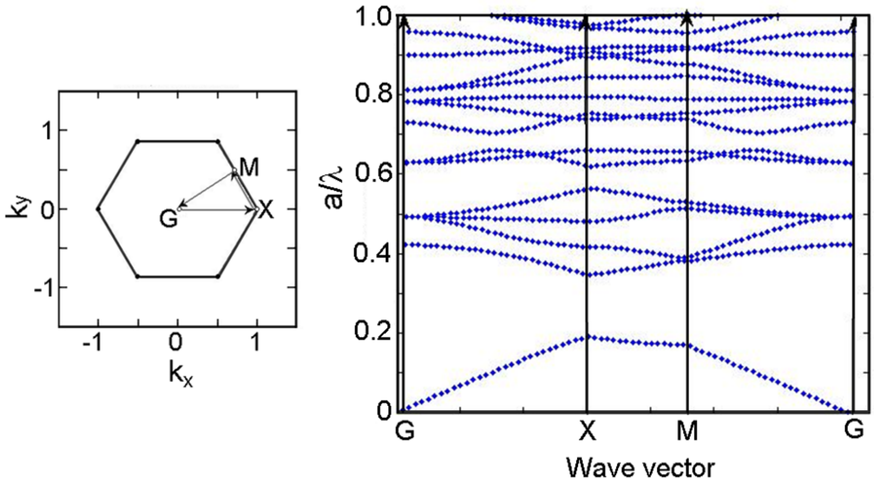

Fig. 2 – Irreducible part of the 1st Brillouin zone (left) and the photonic band structure of a triangular lattice for a GaN two-dimensional photonic crystal with R = 0.25a (R – radius of holes; a – lattice constant), calculated for TM modes (right).

Acknowledgements. The author would like to acknowledge partial financial support from the Science and Technology Center of Ukraine under Grant no 5933.

REFERENCES

1. I. M. Tiginyanu, V. Popa, O. Volciuc, Appl. Phys. Lett. **86**, 174102 (2005); Award of Excellence at the Invention and New Product Exposition INPEX-2005 in Pittsburgh, USA.
2. O. Volciuc, T. Braniste, I. Tiginyanu, M. A. Stevens-Kalceff, J. Ebeling, T. Aschenbrenner, D. Hommel, V. Ursaki, J. Gutowski, Appl. Phys. Lett. **103**, 243113 (2013).
3. O. Volciuc, T. Braniste, V. Sergentu, V. Ursaki, I. M. Tiginyanu, J. Gutowski, Proc. SPIE **9519**, 951904 (2015).