FROM PHOTONIC CRYSTALS TO METAMATERIALS: NEW CHALLENGES

I.M. Tiginyanu

Laboratory of Low-Dimensional Semiconductor Structures, Institute of Applied Physics, Academy of Sciences of Moldova, Chisinau MD-2028, Moldova
National Center for Materials Study and Testing, Technical University of Moldova, Bd. Stefan cel Mare 168, Chisinau MD-2004, Moldova
E-mail: tiginyanu@asm.md; tiginyanu@yahoo.com

Photonic crystals (PC) represent periodic dielectric structures designed to control the flow of electromagnetic radiation. Photonic crystals can be viewed as a subclass of a larger family of material systems called metamaterials in which the properties derive mainly from the structure rather than from the material itself. As an example of metamaterials one can mention materials having negative refractive index opening the possibility to develop new functionalities of optical devices and components, with performances beyond the physical limit of natural materials. Modern technologies allow one to tailor the structural units of metamaterials in shape and size and to tune the composition and morphology as a function of the concrete applications. In this report, we will present a review on photonic metamaterials, i.e. of artificially structured composite materials that can be engineered to have desired electromagnetic properties. The proposed approach is based on artificial spatial nanostructurization of semiconductor materials such as III-V and II-VI compounds using electrochemical etching techniques assisted by in-situ illumination, preliminary ion-beam treatment of samples etc. We demonstrate efficient and cost-effective possibilities for material nanostructuring by design, including long-range ordered nanotexturization based on self-arrangement phenomena, nanostructuring within domains for various optoelectronic purposes, formation of fractal-like structures, wires, tubes etc. Random lasing under electron and laser-beam excitations, nanotexturization-enhanced frequency up-conversion and Terahertz emission are reported. PC-based design of novel lenses based on semiconductor and dielectric materials is realized. Good focusing effect of microwave lenses exhibiting negative index of refraction was demonstrated. The impact of intrinsic disorder upon focusing performances is explored. We show that novel photonic materials can be fabricated on the basis of semiconductor-metal nanocomposites where the metal is in the form of dots and tubes deposited on the internal surface of nanochannels stretching perpendicular to semiconductor layers and membranes. 2D ordered arrays of metal nanotubes and nanowires were fabricated using the approach of templated electrodeposition. Novel PC-based focusing elements consisting of multi-layered dielectric columns are proposed.

This work was supported by U.S. Civilian Research and Development Foundation and Moldovan Research and Development Association under Grants nos. ME2-2527, MR2-995 and MOR2-1033-CH-03, INTAS under Grant no. 05-104-7567 as well as by the Supreme Council for Science and Technological Development of the Academy of Sciences of Moldova under the State Program on Nanotechnologies, Multifunctional Materials and New Electronic Microsystems.