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A b s t r a c t

Title	Fabrication and Fundamental Properties of Two-Dimensional Magnetophotonic Crystals for Magneto-Optic Micro-Devices (光磁気マイクロデバイスへの応用に向けた２次元磁性フォトニック結晶の形成と基礎特性に関する研究)

(800 words)

Artificial structures composed of alternating dielectric materials with different refractive indices, known as photonic crystals (PCs), have been shown to manipulate the flow of light. For magnetophotonic crystals (MPCs) – PCs with magnetic constituents, characteristics of light beams can be controlled by the external magnetic field. Strong enhancement of magneto-optical (MO) responses for magnetic materials built into one-dimensional MPCs with various designs are experimentally demonstrated and found applications. As for MPCs with higher periodicities not only enhancement of MO responses are possible but also such novel functions as the magnetic superprism effect and the three-port circulator are theoretically predicted. Theoretical predictions and experimental studies the superprism effect in non-magnetic PCs show the attractive applicability of two-dimensional (2D) PCs for wavelength multiplexing/demultiplexing. However, experimental performances of 2D MPCs have never been demonstrated in literature. In this work, we have demonstrated new approaches for fabrication of 2D MPCs made of bismuth-substituted yttrium iron garnet (Bi:YIG) together with their optical and MO responses.

One of representatives of 2D MPCs were patterned single Bi:YIG layers deposited on top of thin opal films fabricated by vertical deposition. The Bi:YIG layer was fabricated by rf-dual ion-beam sputtering (RF-DIBS) using a $Bi_1Y_{2.5}Fe_5O_x$ sputtering target. Being sputtered on top of the opal film, the Bi:YIG layer transposed the shape and the 2D symmetry of the opal (111) surface. 2D periodicity set by the (111) hexagonal layer of opals provided diffraction from the 2D Bi:YIG layers in a narrow spectral range. Large enhancement of the Kerr rotation associated with this diffraction was observed together with the change of the sign of rotation. Note that the large absolute modulations of the MO response in extremely narrow spectral ranges can be attractive for sensing applications. Structural parameters of the magneto-optical 2D gratings were found to govern the magnitude of the Kerr rotation. By sputtering and additional etching, the resultant 2D patterned Bi:YIG films had two realizations. As-sputtered films had a spherical profile of structural elements. The spherical Bi:YIG scatterers can be transferred into conical ones via the sputter etching process. Etching was found to be useful for increase in the quality of the Bi:YIG

grating. This effect was manifested in the spectra of the Kerr rotation where an increase in the rotation was observed. This result showed that diffraction-enhanced Kerr rotation in the vicinity of 2D-related stop bands occurred due to resonant light coupling to the 2D structure of Bi:YIG, illustrating that the diffracted rays gained longer optical paths in Bi:YIG.

Bulk-type 2D MPCs fabricated by the autocloning method where Bi:YIG/SiO_2 multilayers were sputtered on the top of one-dimensional arrays of photoresist bars. Resultant corrugated multilayers had the sinewave quasi-2D structure. Such sinusoidal symmetry together with structural parameters of the samples defined optical spectra in which spectrally neighboring bands were observed. Polarization-resolved transmission spectra and diffraction experiments showed that light coupling to the structure happened due to a superimposition of several diffraction channels. For such a multiple Bragg diffraction regime, an enhancement of the Faraday rotation was detected together with a large reverse rotation. Moreover, the superprism regime has been observed for rays from photonic band gaps; the angle of polarization rotation for these rays was also significantly enhanced. It is worthy of note that an active photonic crystal superprism device using the MO effect is a magnetic field-controlled multiplexer. Results of this studies showed that further development on 2D and 3D nanostructuring of MO (or other active) materials is important for increasing the light–active material coupling efficiency and open up possibility for alteration flow of light by applying external fields.

To examine functionalities of the samples under study upon magnetization, numerical simulations by the finite element method have been performed. Results of simulations were in good agreement with experimental data. Magnetic superprism effect, switching of light propagation direction at magnetization alteration, has been demonstrated in quasi-2D MPCs for the samples built from magnetic constituents with larger magneto-optical activity than that of Bi:YIG. This showed that for experimental realizing the magnetic superprism effect further searches for structure designs and appropriate materials are necessary.