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Abstract

Title	Study on Magnetophotonic Multilayer Films and Their Functionalities for Optical Devices (磁気光学多層膜と光デバイス応用に向けた機能に関する研究)

(800 words)

Artificial structuring of ordinary materials (metals, dielectric materials, magnetic materials and semiconductors) bring new media with fascinating performances that attract scientific attention from fundamental and application point of views. The present thesis focuses on the idea of drastic improvement of exciting magneto-optical (MO) materials and devices.

For novel MO devices operating light from the visible and infra-red ranges, nano-structuring has been found to strongly enhance their responses. One can even say that the control over MO effects is realized through nano-structuring. Here, one-dimensional (1D) magnetophotonic crystals (MPCs) having various designs are considered. Fabrication and properties of MPCs (or MO multilayers) made of ferromagnetic and paramagnetic MO materials are studied. The content of the thesis is structures such that 1D MPCs are categorized by the type of resonance (or type of defect) and properties of constituent materials.

MPCs supporting so-called optical Tamm state (OTS) and the enhancement of the MO response are discussed. It is shown that such OTS localized modes can be excited at the surfaces or boundaries of magnetic multilayers. Micro-cavity modes (MCM) in MPCs terminated by gold thin layers are shown to support the surface plasmon resonance (SPR) and OTS simultaneously. The overlap between OTS and SPR resonances is demonstrated to significantly improve sensing when detecting binding events in the biomolecular interactions.

Dual-cavity MPCs that can provide the Faraday rotation of 45° and transmissivity of 100% (characteristics needed for the MO isolators) have been predicted theoretically. However, experimental verification of this prediction revealed poor responses of the dual cavities because of the destructive interference. To overcome this, a new fabrication process is suggested. The use of an ion beam sputtering system with an *in-situ* optical thickness monitor and a direct bonding process made it possible to achieve dual-cavity MPCs with upgraded structure and responses. The fabricated sample showed a double peak in the MO spectrum that is a fingerprint of the dual-cavity MPC.

Thin electro-optical (EO) layers have been used to control the phase of the light in the micro-cavity MPCs. For the EO/MO-cavity MPCs, controlling the MO effect using the applied voltage is theoretically and experimentally demonstrated. Low power consuming magneto-optical spatial light modulators (MOSLMs) are discussed. The alteration of MOSLMs characteristics is realized by the modulation of the refractive index of the EO layer adjacent to the MO layer and sandwiched between two dielectric mirrors. Special attention has been paid to fabrication of the transparent electrodes controlling the dielectric constant of the EO layer. Modulation by the applied voltage is discussed for MOSLMs based on the low absorbing paramagnetic materials; the polarization large rotation angle of 90° and transmissivity of 90% are theoretically shown for light with short wavelengths.

Magnetophotonic crystals and related devices are shown to provide new functional performances. These magneto-optical media are proved to improve or overcome the problems faced in previous studies and suggest their new applications to biosensing and spatial light modulators.