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Abstract (Doctor)

Title of Thesis	Development of high-performance magnetic garnets for magnetic holographic memory and its application to multilayer recording media
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Approx. 800 words

Magnetic holographic memory is a promising candidate for next-generation data storage because it enables high recording density through multiple recording, fast data transfer, and rewritable operation. Transparent bismuth-substituted rare-earth iron garnet (Bi:RIG) films are attractive recording media for this system due to their high Faraday rotation angle. In magnetic holograms, magnetisation patterns similar to optical interference fringes are recorded via thermomagnetic recording and reconstructed using the Faraday effect. However, the reconstructed signal intensity from magnetic holograms recorded in Bi:RIG films remains limited due to insufficient residual Faraday rotation of the magnetic hologram. Therefore, this thesis focuses on the compositional optimisation and thermal-structural design of Bi:RIG-based recording media.

First, Al^{3+} and Ga^{3+} substitution at the Fe site of Bi-substituted yttrium iron garnet films were investigated to reduce optical absorption while maintaining the Faraday rotation angle. The films were prepared by the metal-organic decomposition method and evaluated using X-ray diffraction, Faraday rotation, optical transmittance, and figure of merit analysis. X-ray diffraction confirmed the formation of the garnet phase in the prepared films. Both substitutions reduced the extinction coefficient by replacing optically active Fe^{3+} ions with non-magnetic ones; however, the Faraday rotation decreased with increasing substitution amount. In the Ga-substituted series, magnetic compensation and sign reversal of the Faraday rotation were observed at Ga contents between 1.7 and 1.9, indicating strong composition sensitivity. Although Fe-site substitution reduced optical absorption, the figure of merit remained limited because of insufficient Faraday-loop squareness.

To improve the Faraday-loop squareness and residual Faraday rotation, Dy^{3+} substitution at the rare-earth site was introduced in combination with Al^{3+} or Ga^{3+} substitution at the Fe site. Dy substitution increased coercivity and improved loop squareness through its large magnetostrictive effect, thereby contributing to enhanced residual Faraday rotation at zero magnetic field for suitable compositions. Among the investigated compositions, $\text{Bi}_{1.0}\text{Dy}_{1.4}\text{Y}_{0.6}\text{Al}_{1.0}\text{Fe}_{4.0}\text{O}_{12}$ showed the best overall balance of residual Faraday rotation, squareness ratio, and extinction coefficient. This composition achieved a figure of merit of 10.95, exceeding that of the reference Bi:RIG film, and

was selected as the optimum recording-layer composition.

A Bi:RIG/GGG multilayer recording structure was designed using a quantitative thermal diffusion model. For each effective hotspot temperature, an acceptable demagnetized length, x_{DM} , was first defined as the design criterion, and the Bi:RIG layer thickness was then selected from the calculated relationship between x_{DM} and d_{RIG} . The GGG heat-dissipation layer thickness was selected as 403 nm by satisfying both the optical half-wavelength condition and the thermal separation requirement for the shared GGG-HDL layer between neighbouring Bi:RIG layers. Based on these criteria, a Bi:RIG/GGG multilayer structure with seven Bi:RIG recording layers and a cumulative Bi:RIG recording thickness of 2600 nm was proposed for an initial hotspot temperature of 600°C. In this structure, the Bi:RIG recording layers are separated by shared GGG heat-dissipation layers to suppress thermal interaction between neighbouring recording layers.

RF magnetron sputtering was investigated as a deposition method for preparing thickness-controlled Bi:RIG films required for multilayer recording structures. Films deposited from the optimum-composition target initially showed a Bi content of approximately 0.7, which was lower than the nominal target value of 1.0, resulting in limited Faraday rotation. The placement of a Bi₂O₃ chip on the sputtering target increased the Bi content to approximately 1.0–1.3 and improved the Faraday rotation angle to a maximum of 3.3 deg./μm. However, the extinction coefficients of all sputtered films remained higher than the target value of 0.019, indicating that further optimisation of sputtering conditions is required.

Overall, this thesis demonstrates that the performance of Bi:RIG-based magnetic hologram recording media can be improved by combining compositional optimisation with multilayer structural design. The material study identified Bi_{1.0}Dy_{1.4}Y_{0.6}Al_{1.0}Fe_{4.0}O₁₂ as a high-performance recording composition, while the thermal diffusion analysis established a quantitative thickness-design method for controlling lateral heat spreading in Bi:RIG/GGG multilayer media. These results provide material-design and structural-design guidelines for the development of high-performance magnetic holographic recording media.