Bi-Ssubstituted Iron Garnet Multilayer Structures

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In this encyclopaedia entry, we are reporting on the unconventional magnetic switching properties of sputtered all-garnet multilayer thin film structures. Within the scope of this study, thin magnetic trilayers were fabricated on both garnet and glass substrates, in which magneto-soft material layers are sandwiched in-between two magneto-hard garnet material layers of identical composition type.

Keywords: magnetic switching ; garnet multilayers ; multi-state hysteresis

1. Introduction

In the field of thin-film materials, magneto-optic (MO) garnet materials (single layer and multilayer structures) together with the nano-structured magnetic photonic crystals (MPCs) become a pioneering research topic all over the world. These materials possess very attractive functional properties and strong applications potential, are suitable for use in information technology and all-optical reconfigurable signal processing devices, optical sensors, magnetic field visualizers, and integrated optical isolators. For the successful practical implementation of these garnet materials, fabrication of high-quality thin film nanostructures (of either the single- or multi-layer type) is required, with a good degree of control over their microstructure, surface and interface quality, and the optical and magnetic behaviours[1]. RF magnetron sputtering allows precise control over the thin film deposition process parameters, thus addressing the issues related to synthesizing high-quality thin films and multilayers. In order to investigate the potential of obtaining special magnetic properties that are not attainable easily using single-layer garnet thin films, we prepared all-garnet multilayer structures using two record-performance highly-Bi-substituted iron garnet materials having dissimilar magnetic behaviours (magnetic anisotropy, switching fields and saturation magnetizations). Both garnet material types possessed very large specific Faraday rotation across the visible spectral range (≈ 6 °/µm at 532 nm and ~ 1.6 °/µm at 635 nm[2][3]) and high magneto-optic (MO) quality.

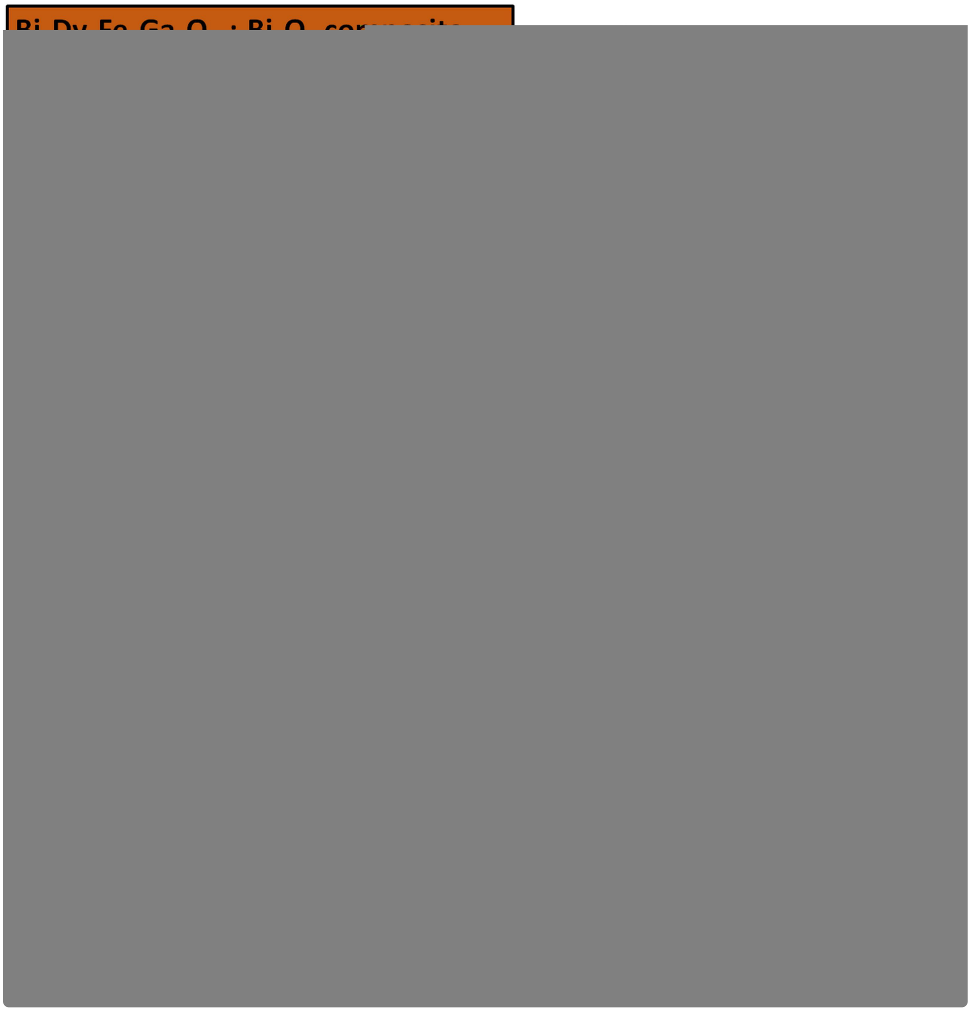

Figure 1: (**a**) Schematic diagram of an exchange-coupled all-garnet trilayer structure with the initially unexpected (hybrid-type) alteration of magnetic properties; (**b**) results of processing an X-ray diffraction dataset obtained from an annealed all-garnet multilayer sample; (**c**-**e**) unconventional magnetic hysteresis loops measured in an all-garnet multilayer structure (deposited onto GGG and glass substrates) with an external magnetic field applied in the direction perpendicular to the film plane.

2. Unconventional Magnetic Properties in Bi-Substituted Iron Garnet Multilayer Structures

We characterised the magnetic switching behaviour of trilayers defined as (Sub /(500 nm $Bi_2Dy_1Fe_4Ga_1O_{12}$: 17 vol. % Bi_2O_3)/500 nm $Bi_{1.8}Lu_{1.2}Fe_{3.6}Al_{1.4}O_{12}$/(500 nm $Bi_2Dy_1Fe_4Ga_1O_{12}$: 17 vol. % Bi_2O_3)), by way of measuring their Faraday rotation hysteresis loops using a calibrated electromagnet and Thorlabs PAX polarimeter. The samples were prepared on glass (Corning Eagle XG) and also GGG (111) substrates; the sputtering deposition was followed by post-deposition annealing crystallisation (heat treatment process,1 h at 570 °C) conducted in air atmosphere. The amount of extra bismuth oxide content co-sputtered from a separate target (17 vol. %) was selected to facilitate a notable increase in specific Faraday rotation whilst at the same time avoiding a significant reduction in the upper limits of annealing temperature range. X-ray diffraction (XRD) measurements (performed in the range of 2θ angles between 20° and 70°) revealed the body-centered cubic lattice structure of different constituent garnet materials present inside annealed trilayers. Their microstructure type has been identified as being nanocrystalline on both substrate types. A notable and unexpected feature of hysteresis loop behaviour was the presence of an "intermediate saturation" state exhibiting the maximum Faraday rotation, which then was followed by conventional magnetisation saturation state with reduced Faraday rotation, at increasing external magnetic fields above about 1 kOe. The final saturated Faraday rotation was observed at near 1.6 kOe, at below 50% of the maximum Faraday rotation angle seen at smaller fields[1]. These exchange-coupled all-garnet multilayer structures demonstrated an attractive combination of optical and magnetic properties, and are of interest for emerging applications in optical sensors and isolators, ultrafast nanophotonics, magneto-plasmonics and possibly spintronics.

The objective of this work is to investigate the potential of obtaining and controlling these special magnetic switching properties observed in the described trilayer types that are not attainable normally in any single-layer magnetic thin films. Our prior studies of magnetic switching behaviour in garnets and the possible role of interface related exchange coupling phenomena[1][4] have resulted in an unexpected finding of some very peculiar hysteresis loop types in all-garnet trilayers. We note that the unconventional magnetic behaviour has only been observed in trilayers employing co-sputtered nanocomposite-type outer magneto-hard layers. Further studies are needed to achieve better control over the magnetic properties in garnet multilayer structures having different combinations of high-performance garnet materials of various optimized thicknesses as well as stoichiometry types.

References

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