MODIFICATION OF MAGNETIC PROPERTIES IN LUTETIUM-IRON GARNET CAUSED BY HEAVY ION IRRADIATION

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Swift ion-beam irradiation affects physical properties of materials through radiation damages. In garnet ferrites, a heavy ion-beam creates a non-magnetic amorphous defect along the beam track [1, 2]. A transmission-electron-microscope (TEM) image of the ion track is shown in Fig. 1. As shown in Fig. 1, the diameter of the amorphous ion track is about 20 nm and the length of it is more than few micrometers.

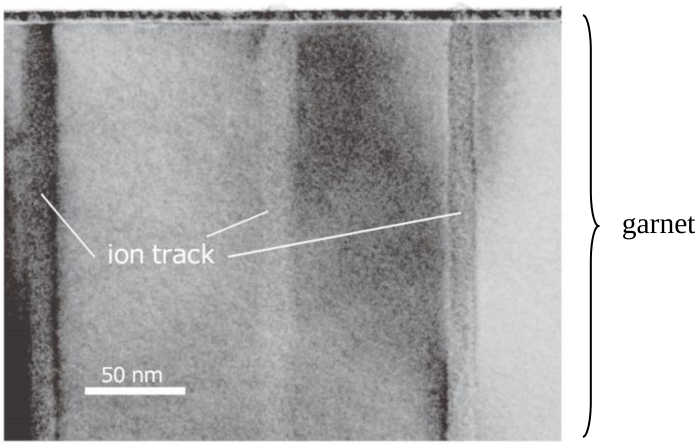

Figure 1. Transmission-electron-microscope image of ion tracks in a garnet film.

Garnet ferrite is known as one of the best materials for magneto-optics. Because the ion beam track is small enough to light wavelength, control of magnetic properties by ion-beam irradiation will be utilized to fabricate functional magneto-optical devices. In this work, we investigated the radiation effects of bismuth doped lutetium-iron garnet (Bi:LuIG) which shows very strong magneto-optical Kerr effect. Using the tandem accelerator in the JAEA Tokai laboratory we irradiated various dose fluences of 300 MeV gold ion beam onto Bi:LuIG thin films with 3 μm thickness, and measured their magnetization hysteresis curves.

Saturation magnetization of the irradiated Bi:LuIG is monotonically decreasing with increasing of the fluence. The change of magnetization is well explained by the ion-beam coverage model [1] as

$$M(\Phi) = M(\Phi = 0) \times (1 - \exp(-\pi r^2 \Phi)), \tag{1}$$

where M is the magnetization, Φ is the ion beam fluence, r is the average radius of the ion tracks. The estimated value of r from the fitting of the magnetization change, 10.9 nm, is consistent with the TEM image.

In addition, we observed the increase of magnetic coercivity, the magnetic field strength required for magnetization reversal, when the beam fluence is more than 2×10^{11} ions/cm^2. To reveal the origin of the coercivity enhancement, we performed micro-magnetic simulations by using mumax3 software [3]. The simulation results well reproduce the magnetization hysteresis curves, and indicate that the combination of hard-axis type magnetic anisotropy of Bi:LuIG and micro grain structure generated by the ion beam irradiation causes the increase of coercivity. We will talk about the details of the experiment and simulation results in this meeting.

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REFERENCES

[1] G. FUSCH, F. STUDER, E. BALANZAT, D. GROULT, J. C. JOUSSET, B. RAVEAU, Nucl. Instrum. Methods Phys. Res. B **12** (1985) 471-478.
[2] S. OKAYASU, K. HARII, M. KOBATA, K. YOSHI, T. FUKUDA, M. ISHIDA, J. IEDA, E. SAITOH, J. Appl. Phys. **128** (2020) 083902.
[3] https://mumax.github.io/