Materials Science

3A/2009S2-008

Garnet superlattice films as a transparent room-temperature polar magnet

Daisuke OKUYAMA*[1], Yoshiharu KROCKENBERGER[1], Jong Seok LEE[2,3], Hironori NAKAO[4], Youichi MURAKAMI[4], Masashi KAWASAKI[1,3,5,6], Yoshinori TOKURA[1,2,3,5]
[1]CMRG, ASI, RIKEN, Wako 351-0198, Japan
[2]ERATO-MF, JST, Tokyo 113-8656, Japan
[3]Department of Applied Physics and QPEC, University of Tokyo, Tokyo 113-8656, Japan
[4]CMRC and Photon Factory, Institute of Materials Structure Science, KEK, Tsukuba 305-0801, Japan
[5]CERG, ASI, RIKEN, Wako 351-0198, Japan
[6]WPI Advanced Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan

Introduction

The magnetic state on interface has been attracting an interest because the space inversion and time reversal can be simultaneously broken, resulting in an emergence of the unconventional magneto-electric coupling effect. In recent, a great attention has been paid to a tailor-made magnetic heterostructure, tricolor superlattice; when a ferromagnet faces other materials, the polar/magnetic interface can have a chance to host the magneto-electric function by realizing the toroidal moment.

Experimental results and Discussions

We investigated a tricolor superlattice consisting a ferrimagnetic $Y_3Fe_5O_{12}$ (YIG) with a quite high transition temperature of ~560 K, paramagnetic $Gd_3Ga_5O_{12}$ (GGG), and diamagnetic $Ca_3Sc_2Si_2TiO_{12}$ (CSST) fabricated on GGG (110) substrate. In this way, the combination of three different materials forms a polar structure along the stacking direction as shown in Fig. 1(a).

The prepared tricolor superlattice was characterized by reflection high-energy electron diffraction (RHEED) system and synchrotron x-ray diffraction, because a realization of a repetition sequence and a hetro-interface structure is important. RHEED oscillations were observed during the growth of superlattice (See Fig. 1(b)). The growth mode was designed so that YIG, GGG, and CSST layer thickness corresponds to 8 layer units (3.5 nm). Figure 1(c) shows the (4 4 0) diffraction profile of the tricolor superlattice observed by using synchrotron x-ray. Clear satellite peaks appear on the both sides, from which the periodicity of the superlattice was deduced to be 12.7 nm (each YIG, GGG, and CSST layer is ~4.2 nm), 21 % thicker than the designed. Presumably, this is because the growth of the film proceeded in a mixed mode consisting of step flow and nucleation and coalescence, only the latter of which contributes to the RHEED oscillation.

To reveal the interface magnetism, we examined the SHG of light in a external magnetic field applied in either the x or $-x$ direction shown in Fig. 1(d). Figure 1(e) displays the analyzer angle dependence of the SHG intensity. The SH signal exhibits appreciable magnetic-field directional dependence; maximal intensities arround 90 ± 20° for ± H. Herer, ± 20° corresponds to the nonlinear magnetic optical Kerr rotation. The emergence of SH and large Kerr rotation clearly demonstrate that both the space inversion and the time-reversal symmetries are simultaneously broken at the interfaces of the tricolor superlattice. Detailed information is found in ref. [1].

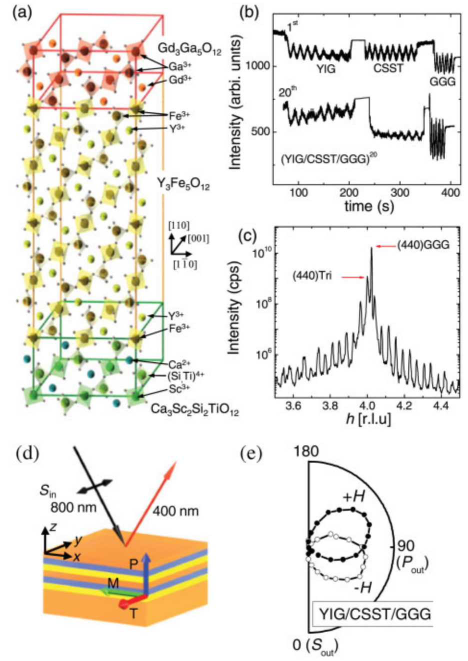

Fig. 1: (a) A schematic view of the tricolor superlattice. (b) The intensity oscillation in the RHEED. (c) Synchrotron x-ray diffraction pattern. (d) Schematic diagram of the SHG experiment. (e) Polarization characteristic of SH light as a function of the analyzer angle.

References

[1] Y. Krockenberger et al., Phys. Rev. B **83**, 214414 (2011).

* okuyama@riken.jp