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Preparation of Yttrium Iron Garnet Thin Film by Mist CVD Method

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1. Introduction

Yttrium iron garnet (YIG), a prototype of garnet-type ferrite, with the chemical formula of $Y_3Fe_5O_{12}$ has been widely used as magneto-optical devices based on the Faraday effect. A usual approach to attain intense Faraday effect is to substitute Y by Bi and other rare-earth elements. These garnets often meet a problem that the substitution content is limited in the case of bulk forms [1,2]. In the present study, we have synthesized YIG thin film by mist chemical vapor deposition (CVD), an emerging method known as a potential candidate for low-cost, large-area, and industrial-scale process. Indeed, mist CVD method is simple and inexpensive; so long as reagents can be diluted in solvents and ultrasonically atomized, thin film can be grown efficiently and homogeneously under atmospheric pressure [3]. More importantly, mist CVD method possesses both merits of solution process and vapor deposition process; the method is applicable for synthesis of high-quality metastable phase thin film such as $Bi_3Fe_5O_{12}$.

2. Experiments and Results

Polycrystalline YIG thin films were grown on silica glass substrates. The precursor solution was prepared by dissolving tris(acetylacetonato)iron(III), $Fe(C_5H_8O_3)_3$, and tris(acetylacetonato)yttrium(III) hydrate, $Y(C_5H_8O_3)_3 \cdot nH_2O$ in *N,N*-dimethylformamide (DMF). The total concentration of [Fe]+[Y] was kept to be 0.050 mol/L. The precursor solution was ultrasonically atomized by using a 2.4 MHz transducer, and the mist particles were transferred to the reaction area with nitrogen (N_2) carrier gas at the flow rate of 3L/min. The substrate temperature and process time was set as 500°C and 30min, respectively. The mist particles were supplied at a rate of 0.25 mL/min. Because as-prepared thin films are amorphous, post-annealing was carried out at 800°C for 60 min. The crystal structure of the films was analyzed by using X-ray diffraction (XRD). The film thickness was evaluated from the cross-sectional image of a field emission scanning electron microscope (FE-SEM). Faraday rotation angle was measured at room temperature by a polarization modulation technique with a xenon lamp as a light source. The magnetic properties of the films were measured by superconducting quantum interference device magnetometer (SQUID).

It was observed that the element Y could be hardly found in the deposited film when aqueous solution was used. Various kinds of conventional solvents were tested for preparation of YIG thin film, and consequently, DMF is more appropriate.

Various molar ratios of $Fe(C_5H_8O_3)_3$ / $Y(C_5H_8O_3)_3$ were examined, and as a result, when the ratio of [Y] / [Fe] of the precursor solution equals 1.500, the single phase of YIG can be obtained, as revealed by XRD pattern shown in Fig.1(a). Fig.1(b) depicts the cross sectional SEM image of YIG thin film, from which the thickness was estimated to be 353 nm. The wavelength dependence of Faraday rotation angle is illustrated in Fig.1(c). The Faraday rotation angle $\theta_F = 0.935\times10^4$ deg/cm at 487 nm and the maximum value $\theta_F = 2.448\times10^4$ deg/cm at 444 nm are obtained from Fig.1(c). The room temperature magnetization as a function of external magnetic field is shown in Fig.1(d). A hysteresis loop is clearly observed, indicating that the present YIG thin film exhibits ferromagnetic behavior at room temperature. The magnetization is saturated at about 0.05 T and reaches about 90 emu cm^{-3}.

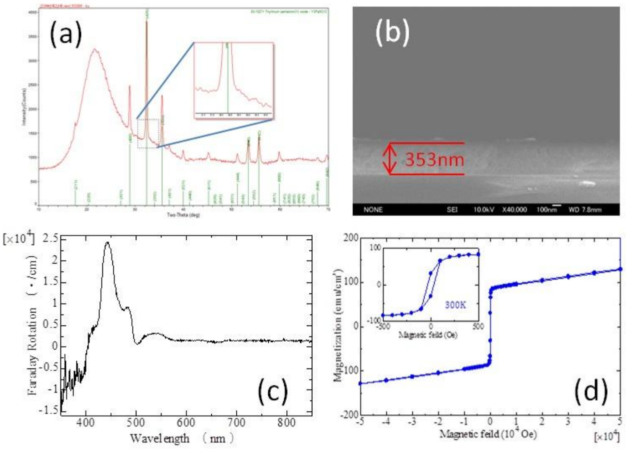

Figure 1 XRD pattern (a); cross sectional SEM image (b); Faraday rotation (c); and magnetization curve (d) of polycrystalline YIG thin film on silica glass substrate.

3. Conclusions

High-quality polycrystalline single phase YIG thin film was prepared by mist CVD method and large Faraday rotation angle was obtained. We believe that the mist CVD method is an effective way to obtain oxide thin films.

References

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