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Solid state epitaxy of amorphous yttrium iron oxide films sputtered on GGG (111) substrates

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1. Introduction

Yttrium Iron Garnet (YIG) materials were used in many application fields such as an optical instrument and high frequency equipment because of their superior magneto-optic properties as well as excellent magnetic properties in the microwave frequency. Its dimension also varied from 100 nm thin films to bulk materials.

YIG films of several ten or hundred μm thick are used for the application of microwave components such as MSW (Magnetostatic Wave) filters, for which liquid phase epitaxy (LPE) method was usually employed. Single crystalline or epitaxial films with very high purity can be easily obtained by sputtering also. However, it is difficult to deposit epitaxial films by sputtering because YIG films are normally deposited a temperature higher than 700°C.

In this study, a possibility for the solid state epitaxy(SSE) of YIG films was attempted, for which amorphous yttrium iron oxide films were sputtered on gadolinium-gallium-garnet(GGG) (111) substrates at room temperature and then subsequently annealed at a high temperature under various atmosphere. Magnetic and structural properties of the films were investigated by VSM, FMR and XRD.

2. Experimental procedure

For the preparation of $Y_{3-x}Fe_{5+x}O_{12}$ (x=0, 0.16, 0.32, 0.48) target of 2 inch diameter and 3 mm thick, 99.999% Fe_2O_3 and Y_2O_3 powder were weighed, mixed with deionized water, ball-milled, dried in the air, sintered at 1200°C, fine-milled and compacted.

YIG films of 1-3.3 μm thick were prepared on GGG (111) by a magnetron sputtering equipment from 5 cm diameter sources at 20, 30 and 150 W with a source to substrate distance of 5 cm. YIG films were deposited at an Ar pressure of 3-5 mTorr at room temperature and at 700 - 750°C. The sputtered films were annealed at 650-800°C for up to 270 min. Magnetic and structural properties were examined by VSM and XRD.

3. Results and discussions

For the epitaxial growth of YIG films by sputtering, three kinds of different methods were employed in this study. The first one is to sputter YIG films directly on GGG (111) at a high temperature. The second one is to deposit YIG films on GGG (111) at a high temperature and then subsequently anneal in the air at a high temperature. The Final one is that amorphous yttrium iron oxide films were deposited on the GGG (111) substrates at room temperature and then transformed to YIG films during annealing in the air at a high temperature. In the first and second method, films showed very low Ms of around 20 emu/cc when compared with YIG Ms value of 135 emu/cc.

In the final method of solid state epitaxy, the films shows good epitaxial properties. Figure 1 and 2 show XRD patterns of YIG films grown by solid state epitaxy on GGG(111) substrates. In Fig. 1, No other peaks except (444) and (888) are shown. Small peaks in Fig. 1 were diffracted from GGG substrates. In order to confirm epitaxial growth, (888) peaks were magnified because lattice parameters of YIG and GGG are almost same ($d_{GGG(444)}$=0.19723, $d_{YIG(444)}$=0.19728 nm). Fig 2. shows very clear YIG(888) diffraction peak.

When solid amorphous films were epitaxially grown on single crystal substrates, the growth direction should be parallel to the film normal. In this case the growth rate should be constant until SSE reaction are completed. Figure 3 shows time dependence of magnetic moment of 3.3 μm YIG film. In Fig. 3 almost linear dependence of magnetic moment on the annealing time can be seen, which means that our films were grown by SSE on GGG(111) substrate. Figure 4 shows VSM loops of 3.3 μm YIG film. More detailed experimental results and discussions will be given.

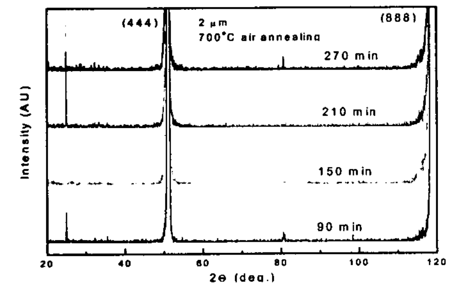

Fig. 1 XRD patterns of 2 μm YIG film epitaxially grown by SSE on GGG(111).

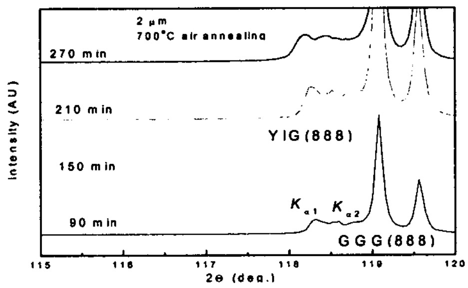

Fig. 2 YIG(888) confirmed epitaxial growth of the film.

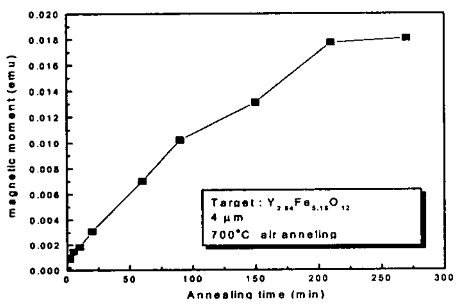

Fig. 3 Variation of magnetic moment of 3.3 μm YIG film with annealing time.

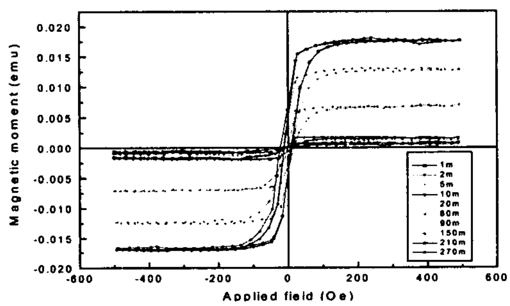

Fig. 4 VSM profiles of YIG films.