Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Optics and Lasers in Engineering 44 (2006) 147–154
OPTICS and LASERS in ENGINEERING

Effect of oxidation dynamics on the film characteristics of Ce:YIG thin films deposited by pulsed-laser deposition

Yoshiki Nakata[a,*], Tatsuo Okada[a], Mitsuo Maeda[a], Sadao Higuchi[b], Kiyotaka Ueda[b]

[a]*Graduate School of Information Science and Electrical Engineering, Kyushu University, 6-10-1 Hakozaki, Fukuoka 812-8581, Japan*
[b]*Central Research Institute of Electric Power Industry, 2-11-1 Iwadokita, Komae, Tokyo 201-8511, Japan*

Received 1 April 2004; received in revised form 1 February 2005; accepted 1 March 2005
Available online 13 June 2005

Abstract

Thin films with different compositions of Ce-substituted yttrium iron garnet (Ce:YIG ($Y_2CeFe_5O_{12}$)), Ga-doped Ce:YIG (Ce:Ga:YIG ($Y_2CeFe_{4.25}Ga_{0.75}O_{12}$)), and Gd-doped Ce:YIG (Ce:Gd:YIG ($Y_{1.6}CeGd_{0.4}Fe_5O_{12}$)) were deposited on gadolinium gallium garnet (GGG ($Gd_3Ga_5O_{12}$)) substrates in O_2 or Ar background gas by pulsed-laser deposition (PLD) technique. Crystalline films were obtained at a lower O_2 gas pressure of 20 mTorr or at higher Ar gas pressures of more than 100 mTorr. In addition, the behavior of YO molecules was visualized by two-dimensional laser-induced fluorescence (2D-LIF), in order to investigate the oxidation dynamics in the ablation plume. The oxidation dynamics and the crystallinity had close correlation.

Keywords: Cerium substituted yttrium iron garnet; Pulsed-laser deposition; X-ray diffraction analysis; Two-dimensional laser-induced fluorescence

*Corresponding author. Tel./fax: +81 92 642 3965.
E-mail address: nakata@ees.kyushu-u.ac.jp (Y. Nakata).

0143-8166/$ - see front matter
doi:10.1016/j.optlaseng.2005.03.003

1. Introduction

Ce-substituted yttrium iron garnet (Ce:YIG, $Y_{3-x}Ce_xFe_5O_{12}$) is a magneto-optic crystal which has a large Verdet constant and is a promising material for the magneto-optic devices, such as an optical isolator and a magnetic field sensor. In addition, Ga-doped Ce:YIG (Ce:Ga:YIG, $CeY_2Fe_{4.25}Ga_{0.75}O_{12}$) and Gd-doped Ce:YIG (Ce:Gd:YIG, $CeGd_{0.4}Y_{1.6}Fe_5O_{12}$) are interesting, because Ce:Ga:YIG film is thought to have better transmittance, and Ce:Gd:YIG film to have better stability against the temperature change [1]. For the sensor applications, miniaturization of the sensing part is necessary for spatially resolved measurement. So, the deposition of these thin films with good quality is required to fabricate such small sensors.

In the past experiments, Ce:YIG single crystals with small substitution by Ce, which reads to small Verdet constant, have been grown by liquid-phase epitaxy [2,3]. In addition, highly Ce-substituted YIG crystalline thin films with $x = 2.5$ and a large Faraday rotation at UV–IR region were obtained by using rf sputtering [4–6]. On the other hand, pulsed-laser deposition (PLD) has been known as a powerful, high speed and controllable deposition technique to grow complex oxide crystals. In PLD, the composition of the target is well transferred to the film, though the composition of the target has to be surveyed in the other methods to obtain a stoichiometric thin film [2,5,6]. So, by using a target containing much Ce in PLD, highly Ce-substituted film can be easily obtained. In addition, variety of gas and pressure can be used, and this result in the controllability of the chemical reaction in the deposition process. So, PLD technique has attracted an interest in the deposition of highly Ce-substituted and crystalline YIG films [7–9]. Here, it is interesting to know the relation between the crystallinity and the PLD process.

In this paper, we deposited the Ce:YIG thin films by PLD with different compositions of Ce:YIG, Ce:Ga:YIG and Ce:Gd:YIG, and its crystallinity was investigated by XRD (X-ray diffraction) method. In addition, in order to study the effect of the gas phase oxidation process on the crystallinity of the films, the behavior of YO molecules in the ablation plume during PLD process was directly observed by two-dimensional laser-induced fluorescence (2D-LIF) method.

2. Film deposition and characterization

2.1. Experimental setup

The experimental setup of PLD is shown in the previous paper [10]. Different sintered targets, such as Ce:YIG, Ce:Ga:YIG and Ce:Gd:YIG with 99.99% purity which were produced by Kojundo Chemical Lab. Co., LTD. were used. A vacuum chamber with base pressure of better than 5×10^{-5} Torr was filled with Ar (99.9999% purity) or O_2 (99.9999% purity) gas, and a rotating target inside the chamber was ablated by a KrF laser (248 nm). The laser energy was 50 mJ and the beam was focused by a focusing lens to an ablation fluence of 4.0 J/cm^2. The repetition rate of the ablation laser during deposition was 20 Hz. Substrate was