Thin Solid Films 571 (2014) 45–50

Contents lists available at ScienceDirect

Thin Solid Films

journal homepage: www.elsevier.com/locate/tsf

Large Verdet constant in the Tb implanted gamma-Fe_2O_3 films

Peiwen Lv, Xian Wang, Feng Huang *, Zhang Lin

Key Laboratory of Optoelectronic Materials Chemistry and Physics, Fujian Institute of Research on the Structure of Matter, Chinese Academy of Sciences, Fuzhou, Fujian 350002, People's Republic of China

ARTICLE INFO

Article history:
Received 11 March 2014
Received in revised form 23 September 2014
Accepted 24 September 2014
Available online 2 October 2014

Keywords:
Gamma Fe_2O_3
Faraday rotation
Spin-glass

ABSTRACT

Gamma-Fe_2O_3 and Fe_2O_3:Tb films are grown on quartz substrate by RF magnetron sputtering deposition. (220) preferred Fe_2O_3 film is textured with pyramid and inverted pyramid, and its magnetic anisotropy is studied. Amorphous Fe_2O_3:Tb films are also fabricated and spin-glass behavior is found. Using Faraday rotation measurement, magneto-optical properties of various Fe_2O_3 films are studied, and it is found that the magneto-optical activity could be enhanced in the Tb-implanted gamma-Fe_2O_3 films and gamma-Fe_2O_3/SiO_2 complex films. Moreover, Large Verdet constants are found in the Fe_2O_3:Tb(10%) and Fe_2O_3:Tb(10%)/SiO_2 complex films.

1. Introduction

With an increasing demand for the high-speed communication system, optical network components (e.g., optical isolators, modulators and switches) have become more and more important in optoelectronic or photonic integrated circuits. In order to integrate these optical network components into the existing structures (e.g., waveguides and optic fibers), tremendous research efforts have been put into magneto-optical materials [1]. Unfortunately, traditional magnetic materials are neither porous nor transparent. The lack of transparency hinders the evaluation of their specific Faraday rotation, which is an important property coupling optical and magnetic behaviors of materials. To overcome the above-mentioned limitations, nanocomposite formed by trapping particles in inorganic porous media has become a potential candidate. Its structural confinement of particles allows the utilization of magnetic and optical properties of the nanocomposites [2–4]. Among them, γ-Fe_2O_3/SiO_2 nanocomposite has attracted much more attention due to its large Faraday rotation and high transparency [5–9]. Recently, such a material has already been used in the magnetic nanosensor on nanosatellite [10].

However, the preparation of γ-Fe_2O_3 involves complicated procedures and γ-Fe_2O_3 would undergo phase transition due to its instability [11–14]. The traditional synthetic methods, such as sol–gel, are quite complicated to produce uniform and reproducible particles in the nanometer size range. The influences of the preparation conditions on the obtained nanoparticle phase and on the properties of the final composite are not clear [15]. Additionally, lots of the physical properties of γ-Fe_2O_3 are still unrevealed.

In this work, we present a simple method to fabricate high quality γ-Fe_2O_3 film and γ-Fe_2O_3 nanocomposite film with large Magneto-Optic Faraday Effect (MOFE) and high transparency. With Tb implanted, the MOFE is greatly enhanced. And it could be a reliable and reproducible technique to produce γ-Fe_2O_3 and γ-Fe_2O_3 related films.

2. Experimental procedure

Commercial quartz substrates with a thickness of 0.5 mm are cleaned in the EtOH and deionized water. Then, these substrates are attached to a rotating substrate holder inside a RF magnetron sputtering machine. The base pressure of the system is 5×10^{-4} Pa and the chamber is purged with high purity argon gas (99.999%) through a gas flow controller. The targets are α-Fe_2O_3, Tb_2O_3 and SiO_2. Prior to the commencement of the sputtering process, the surface of the corresponding target is cleaned by continuous plasma. During the sputtering process, the films are deposited on quartz substrates heated at 450 °C with a sputtering power of 60 W under the chamber pressure of 5 Pa and argon gas flow rate of 20 cm^3/min.

Crystallinity of the films is characterized by Philip's PANalytical X'Pert Pro X-ray diffraction (XRD) using Cu Kα radiation. The XRD patterns are taken in the 10°–80° 2θ range with a step of 0.026° and with an exposure time of 20 s/step. The morphology of films is examined by a JSM-6700F scanning electron microscope (SEM) operating at 10 kV. EDX analysis is carried out on Oxford-INCA energy dispersive X-ray (EDX) spectroscopy with an operating voltage of 15 kV and scanning time of 300 s. The thicknesses of

---

* Corresponding author. Tel.: +86 591 83792630; fax: +86 591 83705474.
E-mail address: fhuang@fjirm.ac.cn (F. Huang).

http://dx.doi.org/10.1016/j.tsf.2014.09.049
0040-6090/

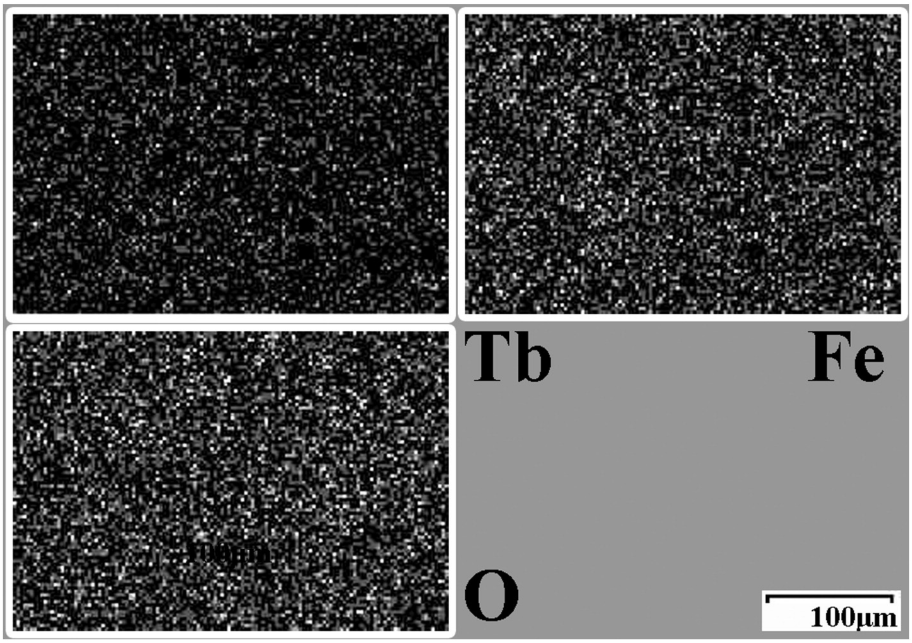

Fig. 1. AES elemental homogeneity mapping for Tb, Fe and O elements for Fe_2O3:Tb(10%).

the films are measured by a Veeco Surface profilometer, and the element components of the films are detected by the Jobin-Yvon Ultima2 inductively coupled plasma (ICP) atomic emission spectrometer (AES). Atomic force microscopy (AFM) is carried out in a tapping mode with RTESP tip on the JSPM-5200 JEOL instrument. The magnetic properties of the crystals are investigated using the Quantum Design MPMS XL magnetometer. Measurements of Faraday rotation are made using standard, normal-incidence geometry with the magnetic field parallel to the propagation of the light (532 nm). XPS measurements are performed on a Thermo Scientific ESCALAB 250 system with Mg Kα source. All the binding energies are calibrated by C1s peak at 284.8 eV of the surface adventitious carbon.

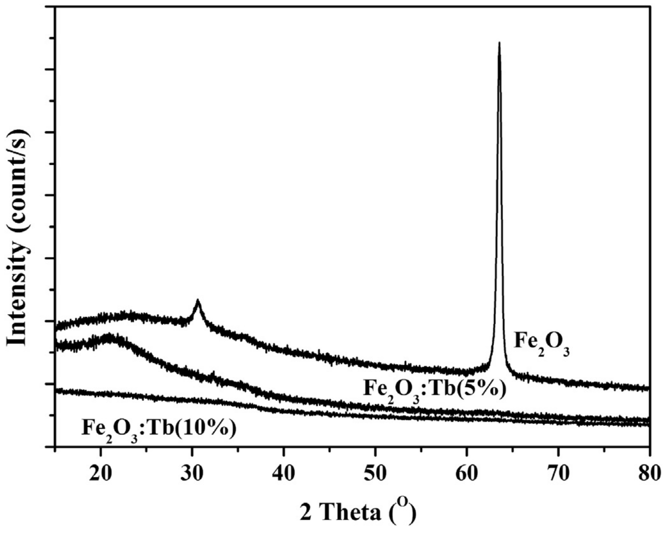

Fig. 2. The θ–2θ scan of films on quartz substrate as Fe_2O_3, Fe_2O_3:Tb(5%) and Fe_2O_3: Tb(10%).

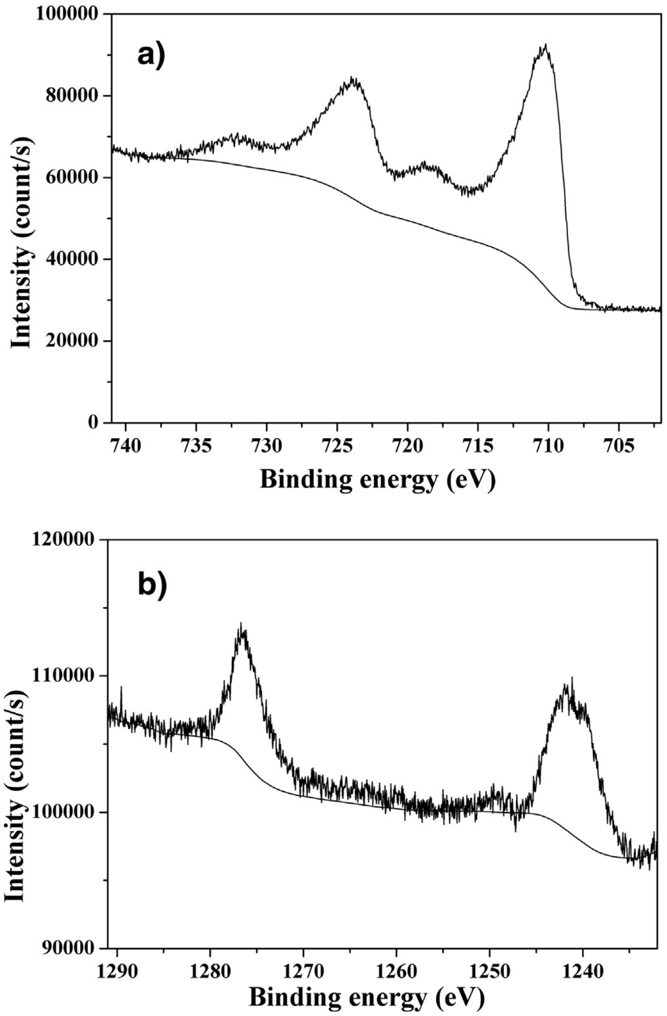

Fig. 3. XPS spectrum of Fe (a) and Tb (b) in the deposited film.