# Effect of bismuth on improvement of Faraday Effect in YFeO3 Thin Films Grown by PLD

A.Beiranvand[1*], S. M. Hamidi[2], Z.Abooalizadeh[3], M. Mozaffari[1], J. Amighian[1], M. M. Tehranchi[2] and A. Yousif[4]

[1.] Department of Physics, Faculty of Science, University of Isfahan, Isfahan, Iran.
[2.] Magneto-Optic Institution, Department of Physics, Faculty of Science, Shahid Beheshti University, Tehran, Iran.
[3.] Department of Physics, Faculty of Science, Takestan Branch, Islamic Azad University, Takestan , Iran.
[4.] Department of Physics, College of Science, Sultan Qaboos University,P.O. Bax 36, PC123, Muscat, Sultanate of Oman
[*]Corresponding author: beyranvand_a@yahoo.com

**Abstract:** Thin magnetic films have been prepared by pulsed-laser deposition from targets of the orthoferrites: $Y_{1-x}Bi_xFeO_3$ (x=0, 0.1, 0.15 and 0.2). The targets created by sol-gel method and characterized via X-ray diffraction, Scanning electron microscope. All layers were deposited onto quartz substrates in a vacuum chamber evacuated down to $4\times10^{-5}$ mbar and the oxygen ambient gas pressure was 150mbar. After deposition, films were recrystallized with annealing procedure at 600 °C for 40 minutes. The magnetic behavior of the thin films was investigated using Faraday rotation measurement setup under a DC magnetic field. The results show that Faraday rotation angle increases as Bi content increases. [A. Beiranvand, S. M. Hamidi, Z. Abooalizadeh, M. Mozaffari, J. Amighian,M. M. Tehranchi and A. Yousif. **Effect of bismuth on improvement of Faraday Effect in YFeO3 Thin Films Grown by PLD**. *Life Sci J* 2013; 10(2s):181-184] (ISSN: 1097-8135). http://www.lifesciencesite.com. 31

**Keywords:** sol-gel; pulsed-laser deposition; orthoferrite; Faraday rotation.

## 1. Introduction

Orthoferrites have general formula $RFeO_3$, with R a rare earth or yttrium. Their space group is $D_{2h}$-$P_{nma}$, with a distorted peroveskite structure. In this structure, there is only on $Fe^{+3}$ site, octahedrally coordinated to six nearest oxygen ions[1]. These materials have attracted the particular attention of researchers for several decades owing to their magneto-optical properties, spin-reorientation transitions between antiferromagnetic phases exhibiting weak ferromagnetism, high velocity of domain walls and the highest domain wall motion velocity and other properties [2-3]. They are considered as promising materials with more outstanding performances than the famous garnet in several practical magneto-optical device applications, such as fast latching type optical switches, light spot position measurements, magneto-optical current sensors and magnetic field sensors [4]. These materials, like garnets, have a transparency window in the infrared [5] and have octahedrally coordinated $Fe^{+3}$ cations, which are the main source of Faraday rotation at infrared wavelengths [6]. Bi substituted garnet compounds have high Faraday rotation [7], but they have lattice parameters much larger than that of common substrate materials [8]. To overcome this difficulty we have investigated Faraday rotation of orthoferrites.

Transport and magneto-optic properties of orthoferrites have been studied extensively in the bulk form [9], but there have been few studies of their properties in thin films forms [10]. In this paper, we prepared Bi substituted yttrium orthoferrite nanopowders and from these samples we fabricated thin films by Pulsed laser deposition (PLD) technique and investigated their Faraday rotation under a DC magnetic field.

## 2. Material and Methods

$Y_{1-x}Bi_xFeO_3$(x=0, 0.1, 0.15 and 0.2) nanopowders have been synthesized by sol-gel method from high purity $Fe(NO_3)_3$, $Y(NO_3)_3$, $Bi(NO_3)_3$, citric acid and ethylene glycol. The single phase powders pressed at 4 tons into pellets (Φ=10mm and h~ 4mm) then sintered at 900°C in air for 9 hours. The pellets were used as targets that the physical structure of the targets was investigated using the standard X-ray diffraction (XRD) technique. To further investigate microstructure and topography of targets, we used the scanning electron microscopy (SEM) analysis.

Magnetic orthoferrite thin films have been deposited onto quartz substrates using a 355 nm pulsed laser beam produced from third harmonic of Nd:YAG laser (Ekspla NL311), which was focused on a target rotating at a frequency of 5 Hz. Typical laser parameters applied for deposition were as follows: pulse frequency of 10 Hz, laser fluency of 3 $J/cm^2$ and around 24000 pulses for one deposition. All depositions were carried out in a vacuum chamber evacuated down to $4\times10^{-5}$ mbar and the oxygen ambient gas pressure was 150 mbar. The resultant plasma cloud of material was condensed onto the substrate which was positioned directly in front of the target at a distance of around 3 cm. The substrates were not intentionally heated. After deposition, films were crystallized with rapid thermal annealing procedure at 600 °C for 40 minutes. Also the magnetic behavior of the thin films was investigated using Faraday rotation measurement setup under a DC magnetic field.

## 3. Results and discussion

The powders X-ray diffraction pattern (XRD) of the as-synthesized Bi substituted $YFeO_3$ nano-powders recorded by a Cu-Kα radiation (λ= 1.5406 Å) in the $2\theta$ range of 10°-90°. That one can see in Fig. 1. As can be seen in this figure,

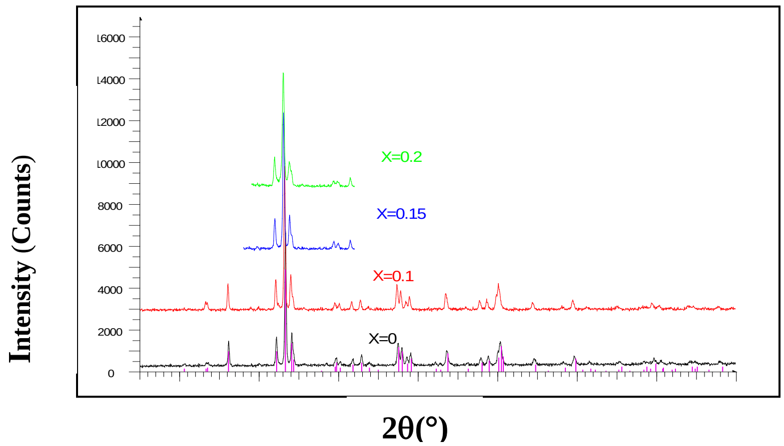


Fig. 1: XRD diffraction pattern of $Y_{1-x}Bi_xFeO_3$ film for x=0, 0.1, 0.15 and 0.2.

The refined lattice parameter and volume were calculated for all of samples that listed in table.1. As shown in this table, by doping Bi in ferrite structure, the lattice parameter and volume of structure enhanced that is the result of larger amount of ion radius of Bismuth (1.03Å) from Yttrium (0.9 Å).

**Table.1** Lattice parameters of $Y_{1-x}Bi_xFeO_3$

| Sample number | x | a (Å) | b (Å) | c (Å) | V(Å)$^3$ |
|---|---|---|---|---|---|
| S-1 | 0 | 5.562 | 7.576 | 5.257 | 221.518 |
| S-2 | 0.1 | 5.578 | 7.595 | 5.275 | 223.475 |
| S-3 | 0.15 | 5.597 | 7.630 | 5.292 | 226.124 |
| S-4 | 0.2 | 5.6 | 7.659 | 5.308 | 227.662 |

The elemental composition was determined by XRF analysis of the powders compact.

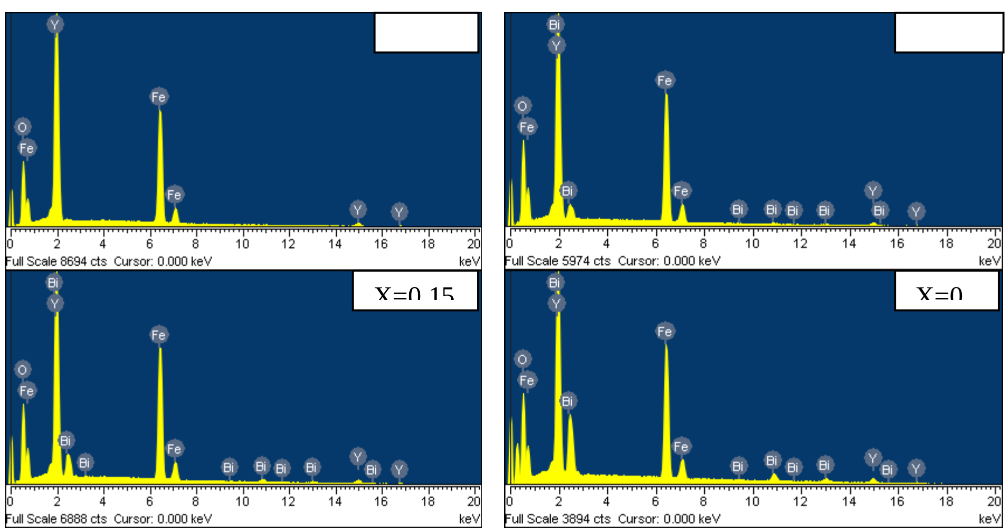


Fig. 2: XRF pattern of $Y_{1-x}Bi_xFeO_3$ powders for x=0, 0.1, 0.15 and 0.2.

To further investigate microstructure and topography, we used scanning electron microscope (SEM). SEM image of all the samples cleared in Fig. 3. As can be seen in this figure the size of nanoparticles is fewer than 100nm.

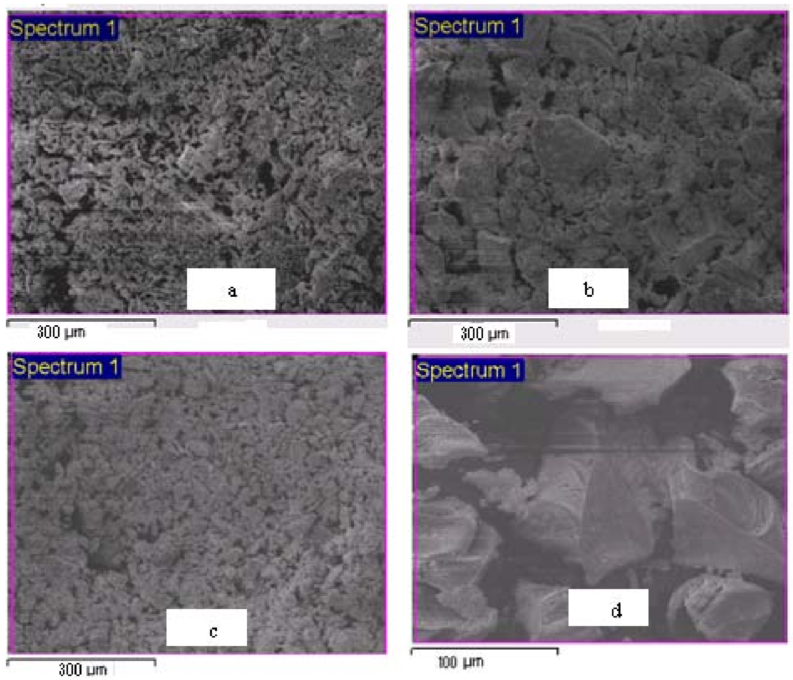


Fig. 3: Scanning electron microscopy (SEM) images of Y1-xBixFeO3 nanoparticles (a) x=0, (b) 0.1, (c) 0.15, (d) 0.2

Afterward, thin films that created from these nanopowders have been characterized that for example the XRD pattern of polycrystalline $Y_{0.8}Bi_{0.2}FeO_3$ (x=0.2) film shows in Figure 4. From which the relative intensities of diffraction peaks, indicates that the x=0.2 film slightly textured along the [111] direction. Similar results have been obtained for the $YFeO_3$ film [11].

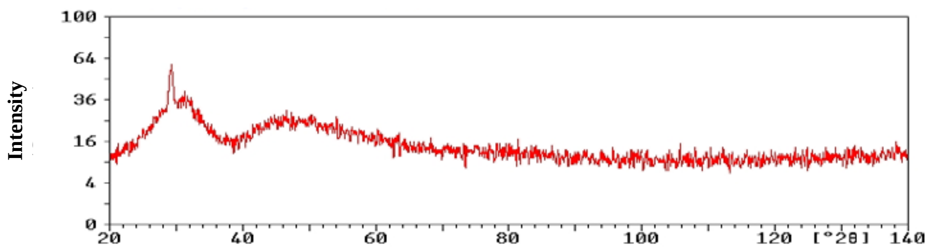


Fig.4. XRD diffraction pattern of $Y_{0.8}Bi_{0.2}FeO_3$ film

Faraday rotation angles of the x=0 and 0.1 samples were negligible so a reliable measurement was not possible. Figure 5 shows Faraday rotation vs magnetic field curves for x=0.15 and x=0.2 at a wavelength of 635 nm. This indicates Faraday rotation angle increases with larger content of Bi.

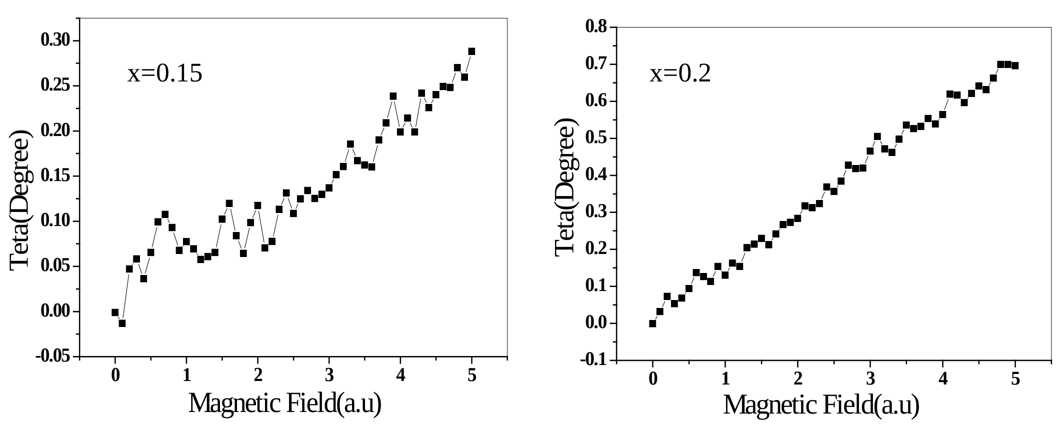


Fig.5. Faraday rotation angle vs. magnetic field curves

Increasing Faraday rotation by adding more Bi content shows that not only Fe-O bonds but also the other bonds must be considered [12]. By substitution of Bi with larger ionic radius for Y with smaller ionic radius, the canting angle and disturbance of orthoferrite structure are increased [13]. By increasing of canting angle the magnetization is enhancement. Probably due to increasing of internal magnetization could increase Faraday rotation angle in the samples.

## 4. Conclusion

Morphology of Y1-xBixFeO3 powders showed they are single phase and nano scale. Their pellets were used as targets, and thin films were prepared by PLD methods. Fraday rotation of thin films increases in magnetic field as Bi continent increases. It is probably due to rising magnetization of the samples.

**Corresponding author:**
Azar Beiranvand
Department of Physics, Faculty of Science, University of Isfahan, Isfahan, Iran
Email: beyranvand_a@yahoo.com

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