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Study of Pure and La-Zn Doped Barium Hexaferrite Films deposited on Al_2O_3 Substrateby PLD Technique

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Abstract: *This article focuses on preparing a single layer $BaFe_{12}O_{19}$ and La, Zn doped $Ba_{0.8}La_{0.2}Fe_{11.8}Zn_{0.2}O_{19}$Barium hexaferrite film grown on Al_2O_3 substrate by PLD technique. The XRD and Raman spectra analysis indicates well formation of $BaFe_{12}O_{19}$ and $Ba_{0.8}La_{0.2}Fe_{11.8}Zn_{0.2}O_{19}$thin film on Al_2O_3 substrate without any impurity picks. The films exhibited a randomly oriented hexaferrite phase well-matched with the Al_2O_3 substrate. The magnetic hysteresis loop was used to determine the spontaneous magnetization and coercivity magnetic field. High magnetic coercivity 17Oe and lowsaturazation 35 emu/cm3were observed for the film $Ba_{0.8}La_{0.2}Fe_{11.8}Zn_{0.2}O_{19}$. FTIR absorption spectra also show that the tetrahedral configuration of barium hexaferritefor the both films.In present study structural, magnetic, and optical properties were systematically investigated at room temperature.*

Keywords: Barium Hexaferrite,Pulsed Laser Deposition,Magnetic, Raman spectra.

I. INTRODUCTION

Barium hexaferrite ($BaFe_{12}O_{19}$) materialshas been drawn the attention of researchers due to its high magnetic properties which make it suitable for various applications such as permanent magnets, magnetic recording and microwave devices [1-6]. This material is typically grown as a thin film for such applications, and the use of advanced thin-film deposition techniques like Pulsed Laser Deposition (PLD) has proven to be effective in producing high-quality barium hexaferrite films with tailored properties [7-9]. J. Kreisel et al. has been studied Raman spectra of $BaFe_{12}O_{19}$ thin films which is prepared by injection chemical vapor deposition methods on three different substrates: Al_2O_3 (001) $Gd_3Ga_5O_{12}$ (111) and Si (100) [10]. Xiaozhi Zhang et.al were studied $BaFe_{12}O_{19}$ thin films prepared on *c*-plane Al_2O_3 substrates by direct current magnetron sputtering method which show an out-of-plane magnetic anisotropy and the magnetic properties influenced by the substrate temperature [11]. Recently, optical and magnetic properties ofmetal (Sr, Cr, Sc) doped M-type $BaFe_{12}O_{19}$ hexaferrite films has been studied by Gara Kishor et.al. [12]. In the present article we have prepared pure and Lanthanum (La) and Zinc (Zn) doped $BaFe_{12}O_{19}$ thin film which can significantly modify the material's magnetic, and optical properties, making it suitable for a broader range of applications.

Material and Methods

$BaFe_{12}O_{19}$ and La, Zn co-doped $Ba_{0.8}La_{0.2}Fe_{11.8}Zn_{0.2}O_{19}$ powders were synthesized using the co-precipitation method [13]. The corresponding targets were obtained by pressing the powders into 20 mm diameter pellets and sintering them at 1000 °C for 8 hours [14]. The Al_2O_3 substrate was ultrasonically cleaned using methanol and acetone prior to film deposition. Thin films were fabricated using a KrFexcimer laser with a wavelength of 248 nm. During deposition, the laser operated with a pulse energy of 240 mJ, a pulse width of 20 ns, and a repetition rate of 10 Hz. The substrate was placed 5 cm from the target, and deposition was performed in a high-purity oxygen atmosphere (10 mTorr) at a substrate temperature of 650 °C for 40 minutes. The X-ray diffraction (XRD) patterns of the deposited films were recorded in θ–2θ geometry (where the sample moves by θ and the detector by 2θ, with the source fixed) using a standard diffractometer (Bruker D8 Advance) equipped with Cu Kα radiation (λ = 1.54 Å. Magnetic measurements

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were performed by SQUID- vibrating sample magnetometer (Quantum Design Inc., USA). The magnetic hysteresis loops at room temperature carried out with magnetic field range ±7 Tesla. The Raman measurements were carried out using Horiba JY HR-800 spectrometer with an 1800 g/mm grating and a CCD detector. We used a He-Ne excitation source (633 nm) laser beam focused into ~1µm diameter spot in backscattering geometry. The Fourier Transform Infrared (FTIR) spectra for both the film samples were recorded on Carry eclipse 6300 machine (JASCO, Japan) in the range of 600–4000 cm−1.

Results and Discussion

The XRD pattern for the $BaFe_{12}O_{19}$ and La, Zn co-doped $Ba_{0.8}La_{0.2}Fe_{11.8}Zn_{0.2}O_{19}$ film deposited on Al_2O_3 substrate are shown in fig 1. The XRD pattern shows that the barium hexa ferrite diffraction peakwith crystal plane [106], [107], [114] and [1012]are observed for both the films which is similar as reported for $BaFe_{12}O_{19}$ [15]. XRD pattern conforms the formation of a randomly oriented barium hexaferrite phase deposited on the Al_2O_3 substrate without any impurity pick.

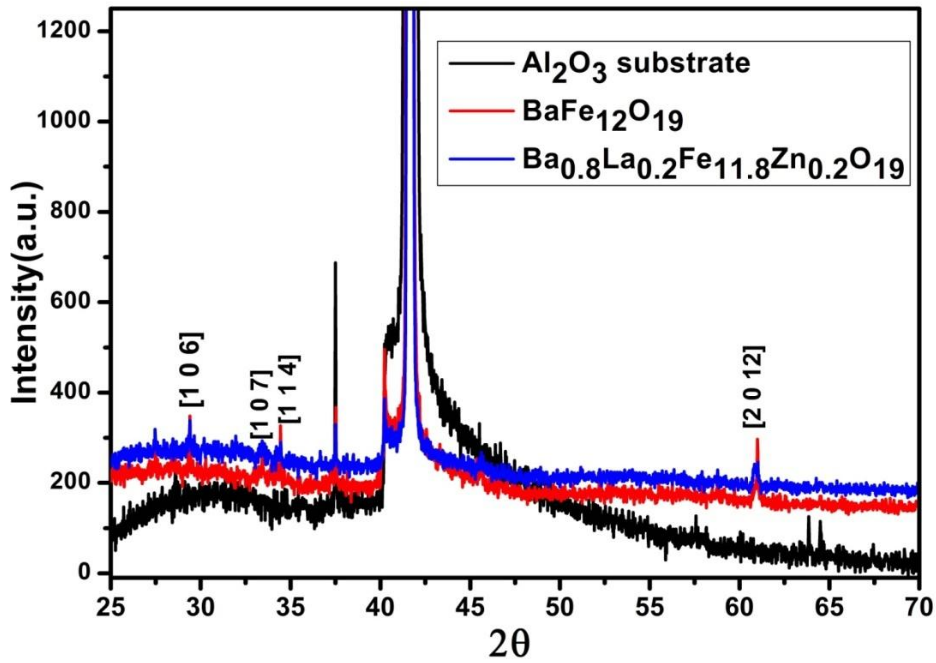

Fig.1: XRD pattern of $BaFe_{12}O_{19}$ and $BaLa_{0.2}Fe_{11.8}Zn_{0.2}O_{19}$ film grown on Al_2O_3substrate

The hysteresis loops for the $BaFe_{12}O_{19}$ and La, Zn co-doped $Ba_{0.8}La_{0.2}Fe_{11.8}Zn_{0.2}O_{19}$ film deposited on Al_2O_3 substrate were measured at room temperature anddepicted in Fig. 2. The measured value of coercivity (Hc) and saturation magnetization(Ms) for pure hexaferrite,$Ba_{0.8}La_{0.2}Fe_{11.8}Zn_{0.2}O_{19}$ film are 12 Oe, 17 Oe and 55 emu/cm^3, 35 emu/cm^{3}respectively. Further, the value of Hc increase with the doping content it may be due to the replacement of Ba^{2+} atom with the La^{3+} atom that's modify the magnetic interactions present in the material exhibits improved magnetic characteristics—such as magnetic anisotropy case higher coercivity and the saturationmagnetization decrease, it can be due to Zn^{2+} ion replacesFe^{3+}site within the crystal lattice, which influences the magnetic moments of the iron ions and decreases the magnetic saturation. However, it can enhance the stability of the material and lower eddy current losses at higher frequencies." The low saturation magnetization allows for easy switching and the high coercivity means that they can withstand a significant reverse magnetic field, which is useful in applications where the material's magnetic state needs to be changed frequently without losing energy.

The FTIR spectra of $BaFe_{12}O_{19}/Al_2O_3$ and $Ba_{0.8}La_{0.2}Fe_{11.8}Zn_{0.2}O_{19}/Al_2O_3$was recorded at room temperature and shown in Fig.3. The observed spectra was analyzed in the wavenumber range between 4000 and 500 cm−1. The FTIR absorption band observed at 700–600 cm−1 bond range was assigned to Fe–O stretching on tetrahedral site which

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presents in the hexaferrte phase [16,17]. The weaker absorption band found between 1200-1100 cm−1 are due to the stretching vibrations of, Ba-O-Ba, Ba-O-La and Fe-O-Zn, Fe-O-Fe bonds as reported in previous literature [18].

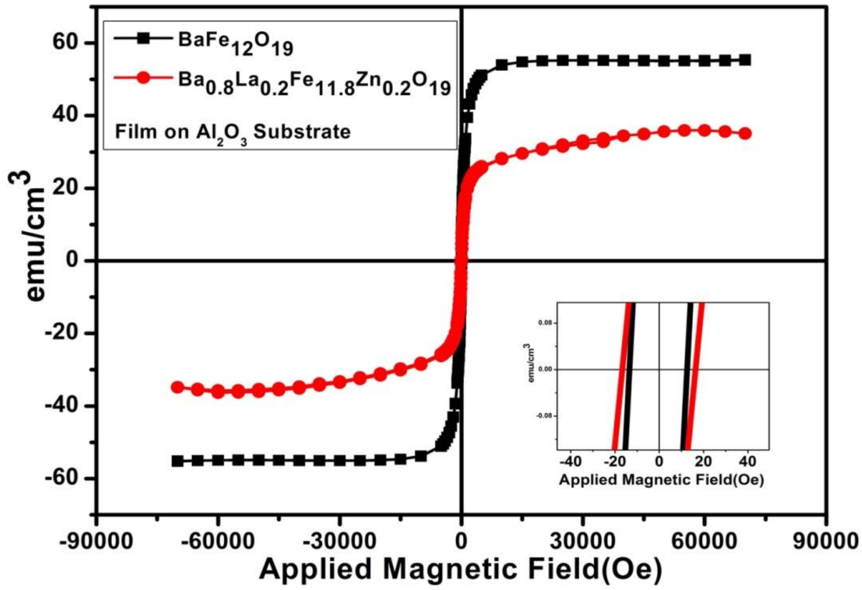

Fig.2: Magnetization of $BaFe_{12}O_{19}$ and $Ba_{0.8}La_{0.2}Fe_{11.8}Zn_{0.2}O_{19}$ film grown on Al_2O_3substrate

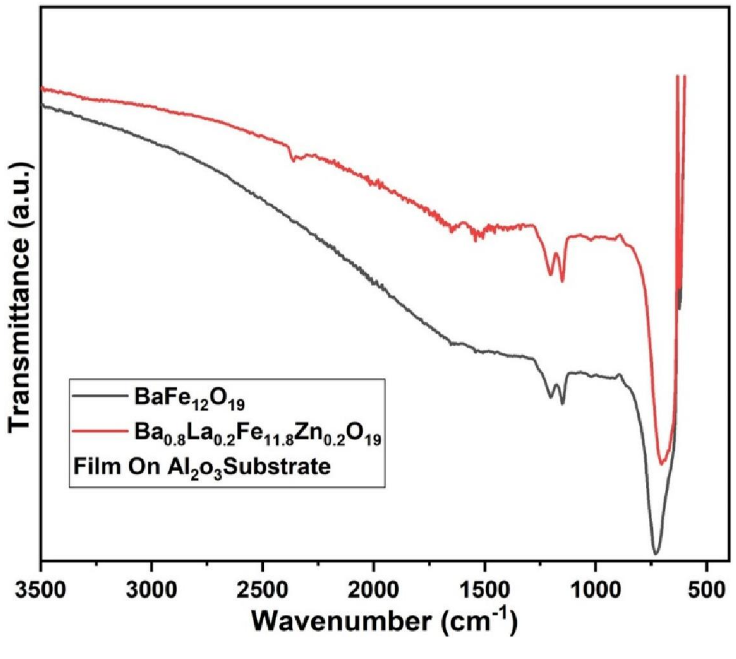

Fig.3: FTIR Spectra of $BaFe_{12}O_{19}$&$Ba_{0.8}La_{0.2}Fe_{11.8}Zn_{0.2}O_{19}$ film grown on Al_2O_3substrate

The Raman spectrum shown in Fig. 4 was recorded using an Acton SP-2500i single spectrograph, which is part of a scanning probe microscopy–integrated Raman system (WiTec, Germany), and a Trivista TR557 triple monochromator system (USA) equipped with air-cooled CCD detectors. The Barium hexaferrite crystal is theoretically predicted to exhibit 42 Raman-active modes (11 A_1g, 14 E_1g, and 17 E_2g). It is important to note that the 33 Raman modes (10 A_1g, 13 E_1g, and 10 E_2g) reported by Kreisel*et al [19]* for single-crystal Raman measurements arise from the combination of spectra recorded under different polarization configurations. In contrast, an individual polarized Raman spectrum reveals only about 10–12 observable peaks.The experimental Raman data for the $BaFe_{12}O_{19}/Al_2O_3$ film show only two spectral peaks at 317 cm^{-1}, corresponding to the octahedral (2a) site, and at 709 cm^{-1}, assigned to the tetrahedral ($4f_1$)

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site. In contrast, the $Ba_{0.8}La_{0.2}Fe_{11.8}Zn_{0.2}O_{19}/Al_2O_3$ film exhibits six spectral peaks: 374 cm⁻¹ associated with the octahedral (12k) site, 461 cm⁻¹ corresponding to octahedral (2a + 12k) sites, 532 and 585 cm⁻¹ attributed to octahedral (12k) sites, 613 cm⁻¹ assigned to the octahedral (4f₂) site, and 709 cm⁻¹ corresponding to the tetrahedral (4f₁) site.

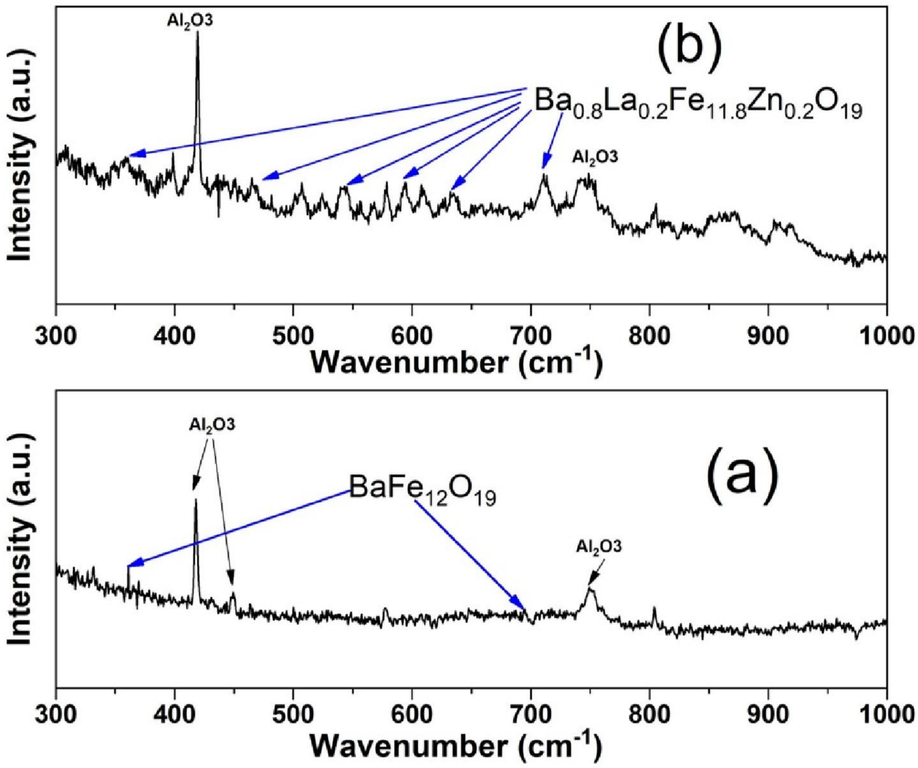

Fig.4: Raman Spectra of $BaFe_{12}O_{19}$(a) &$Ba_{0.8}La_{0.2}Fe_{11.8}Zn_{0.2}O_{19}$ (b) film grown on Al_2O_3substrate.

II. CONCLUSION

In this study, pure $BaFe_{12}O_{19}$ and La, Zn co-doped $Ba_{0.8}La_{0.2}Fe_{11.8}Zn_{0.2}O_{19}$ thin films were successfully deposited on Al_2O_3 substrates using pulsed laser deposition (PLD) technique.X-ray diffraction analysis confirmed the formation of a single-phase barium hexaferrite structure for both films. FTIR spectroscopy further confirmed the formation of the hexaferrite phase, indicating successful incorporation of La and Zn ions into the hexaferrite lattice.Magnetic measurements revealed a clear influence of La and Zn co-doping on the magnetic behavior of the films. Compared to pure $BaFe_{12}O_{19}$, the co-doped film showed an increase incoercivity from 12 Oe to 17 Oe. and Conversely, the saturation magnetization decreased from 55 emu/cm³ to 35 emu/cm³.The optimized combination of high coercivity, reduced saturation magnetization, and structural stability makes these PLD-grown films promising candidates for high-frequency devices, magnetic recording media, and microwave applications.

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