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Effect of Dy –doping on Structural and Microstructural Properties $Sr_{1-x}Dy_xFe_{12}O_{19}$ M-Type Hexagonal Ferrites

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ABSTRACT: The effect of Dy-substitution in M-type strontium hexaferrite has been examined in a series of samples with the composition of $Sr_{1-x}Dy_xFe_{12}O_{19}$ (x = 0.0, 0.10, 0.20 and 0.30) have been prepared by employing the ceramic technique, in order to study the effect of Dy-doping on structural and microstructural properties of strontium hexaferrite. The samples were sintered at 1150^{o}C for 8 hours. The structural properties of the calcined samples were studied using X-ray diffraction (XRD), SEM technique and FTIR spectrum. The X-ray diffraction patterns shows that the prepared samples have a single phase and the effect of composition on the unit cell parameters, density and porosity has been studied. Spectrum of $Sr_{1-x}Dy_xFe_{12}O_{19}$ ferrites has been studied. The lattice parameters 'c' and 'a' was found to increase by increasing Dy-content whereas the X-ray density decreases and porosity increases by increasing Dy-content. Microstructural analysis by scanning electron microscopy (SEM) suggest that the compound have small grains distributed uniformly and non-uniformly on the surface of the sample and also shows that the grain size has been decreased by increasing the Dy-content in the composition $Sr_{1-x}Dy_xFe_{12}O_{19}$.

Keywords: Hexagonal ferrites, X-ray diffraction, SEM, IR spectrum

I. INTRODUCTION

The M-type hexagonal ferrites $MFe_{12}O_{19}$ (M= Sr , Ba or Pb) are important ferromagnetic oxides. Hexagonal Strontium ferrites have been intensively investigated during the last few decades due to their considerable importance to the electronic material industry. Their magnetic properties make them potential materials for use as permanent magnets, recording media and as components in microwaves and high frequency devices [1] because of their high intrinsic coercivity and characterize with high magneto crystalline anisotropy, moderate hard magnetic properties and high chemical stability, compared with other magnetic materials [2-5]. The common processing methods of hexagonal ferrites are conventional ceramic process of solid-stat reaction [6], co-precipitation method [7], sol-gel process [8] and molten salt method [9-10] etc. The conventional ceramic process which includes the mixing the raw materials, calculation, milling, pressing and sintering at 1150- 1350^{o}C [11]. In a fine particle form, Strontium ferrite is suitable for high -density recording media. Ultrafine Strontium ferrite powder with narrow particle size distribution is desirable to increase the capacity of information storage as well as to reduce the medium noise. Infrared (IR) spectroscopy is largely complementary to X-ray diffraction measurements. It points directly to the general nature of unknown substances, where it is able to detect and characterized non- crystalline compounds, such information being obtainable from the presence or absence of characteristic absorption bands. The frequencies at which there are absorption of IR radiation can be correlated directly to bonds with the compound [12-13]. The paper aims at synthesizing Dy substituted SrM hexaferrite by conventional ceramic technique. An attempt has been made to investigate the effect of Dy –rare earth ion on the structure and particle size of hexaferrite by employing XRD, SEM and FTIR techniques.

II. EXPERIMENTAL

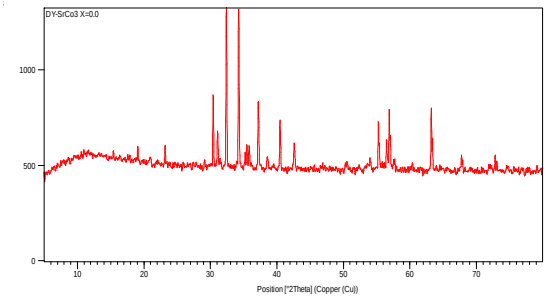
The hexagonal Strontium ferrites of nominal composition (x = 0.0, 0.10, 0.20 and 0.30) were synthesized starting from ball-milling mixtures of $SrCO_3$, Fe_2O_3 and Dy–rare earth ion for 12h. After drying at 60^{o}C for 6h, the powder mixture was heated at temperature of 800-1150^{o}C for 4 h in a lid –covered alumina crucible with a heating rate of 5^o C/min in air. Then after cooling to room temperature in furnace.

In order to make the sintered magnet , the barium ferrite powder were wet mixed in acetone medium with addition of 4% polyvinyl alcohol (PVA) binder solution by using a ball mill. After drying, pellets were prepared by pressing at 600MPa in a 10kOe magnetic field applied along the pressing direction. Then the pellets were sintered in a resistance heated furnace for 3h at beach specified level of sintering temperature from 950 to 1250^{o}C. The crystal structure of the samples was examined by using a X-ray diffractometer (XPERT-PRO) with CuK_α radiation. The microstructure was investigated using scanning electron microscope (SEM, JEOL-JSM 6100). The absorption bands of the samples were measured by using FTIR-Spectrometer (Thermo, Model no.IS10- Nicolet).

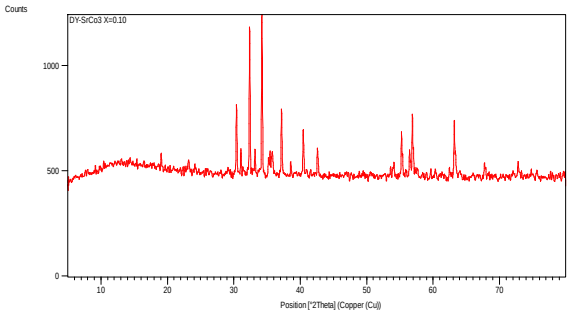
III. RESULT AND DISCUSSION

A. Phase Identification

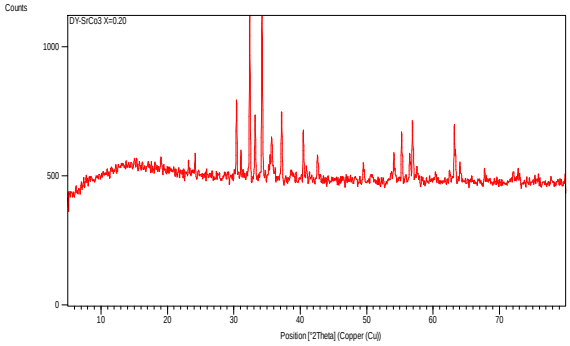
Fig. 1 shows the X-ray diffraction (XRD) pattern obtained for different molar concentration in the prepared samples of Sr_{1-x} $Dy_xFe_{12}Co_{19}$ ferrites sintered at 1250^{o}C for 3h. This analysis reveals that the prepared samples were almost single hexagonal M-type Phase. There are no peaks of Fe_2Co_3 and Dy_2O_3 phases in the graph which suggest that Sr ion is substituted by Dy ions. The respective peaks show that a magnetoplumbite structure has been formed. The variation in relative intensities of peaks may be related to the occupation of lattice sites by substituted ions. The lattice constants ‘a’ and ‘c’ with composition (x) for Sr_{1-x} $Dy_xFe_{12}O_{19}$ has been decreases continuously with increasing substituted amount of Dy ions. The peaks for the doped Strontium ferrites appear at the same position as for undoped ferrite, with different intensities. The result indicates that the formation of temperature of Sr_{1-x} $Dy_xFe_{12}O_{19}$ is about 1250^{o}C. It is about 50^{o}C higher than that of classical ceramic method for undoped strontium ferrite as indicated in the literatures. In the doped ferrites cases, the dopant of Dy^{2+} seem to dissolve / arrange in the hexagonal structure to fulfill the formation of single hexagonal phase.[15]



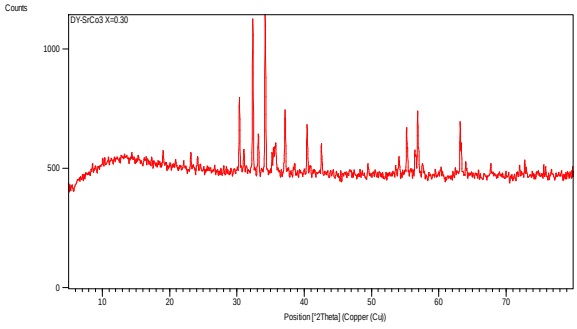
(a)



(b)



(c)



(d)

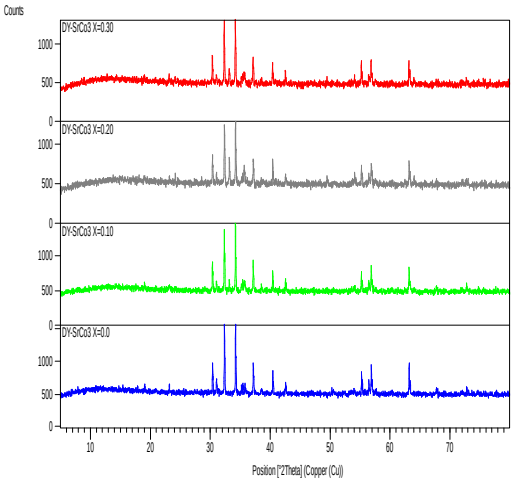
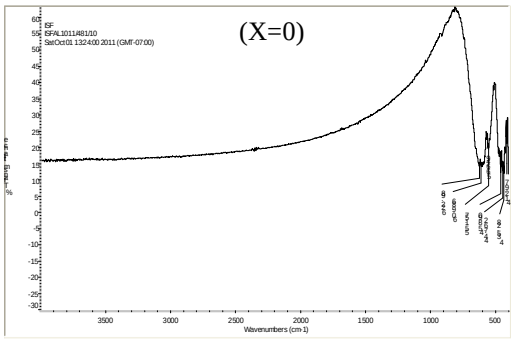


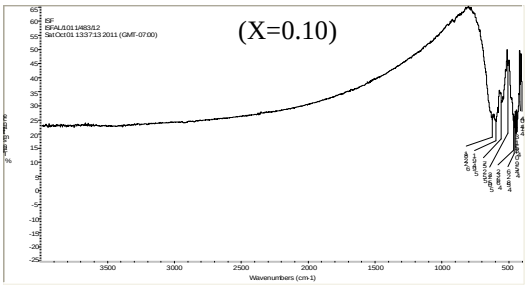
Fig. 1. XRD Patterns of $Sr_{1-x}Dy_xFe_{12}O_{19}$ for compositions (a) X=0 , (b) X = 0.10 , (c) X = 0.20 and (d) X = 0.30

B. FTIR Measurement Results

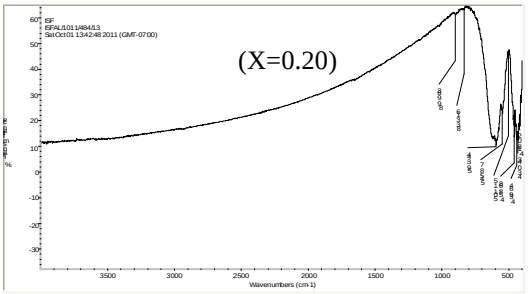
Fig. 2. Shows the IR spectra of the four prepared compositions of $Sr_{1-x}Dy_xFe_{12}O_{19}$ (X = 0, X = 0.10, X = 0.20 and X = 0.30). For the sample of X=0.0, two absorption bands can easily observed. By introducing Dy+ ion to the compositions a more bands appears and bands becomes sharper and often shifted towards higher frequencies. The band υ_3 shows the maximum absorptions as compared to the bands υ_1 and υ_2. The frequencies at which there is absorption of IR radiation can be correlated directly to bonds within the compound [14].



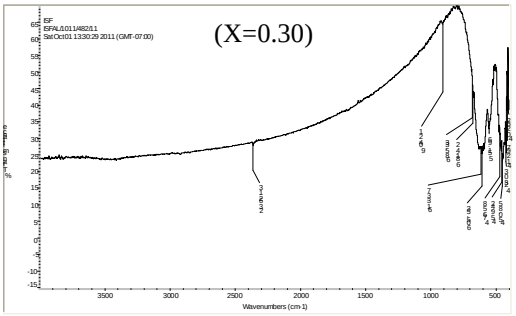
(a)



(b)



(c)



(d)

Fig. 2. FTIR of $Sr_{1-x}Dy_xFe_{12}O_{19}$ for compositions (a) X = 0 (b) X = 0.10 , (c) X = 0.20 and (d) X = 0.30.

C. SEM Microstructures

Fig. 3. Shows the microstructures of prepared samples. It indicates that the M-type ferrite grains are homogeneous hexagonal shaped crystals [15]. It was found that the average grain size estimated from SEM was approximately 1µm and it was almost dependent on the composition *X* (x = 0.0, 0.10, 0.20 and 0.30). The complex permeability spectra of polycrystalline ferrite depend not only on the chemical composition of the ferrite but also on the post-sintering density and the microstructures such as grain size and porosity.

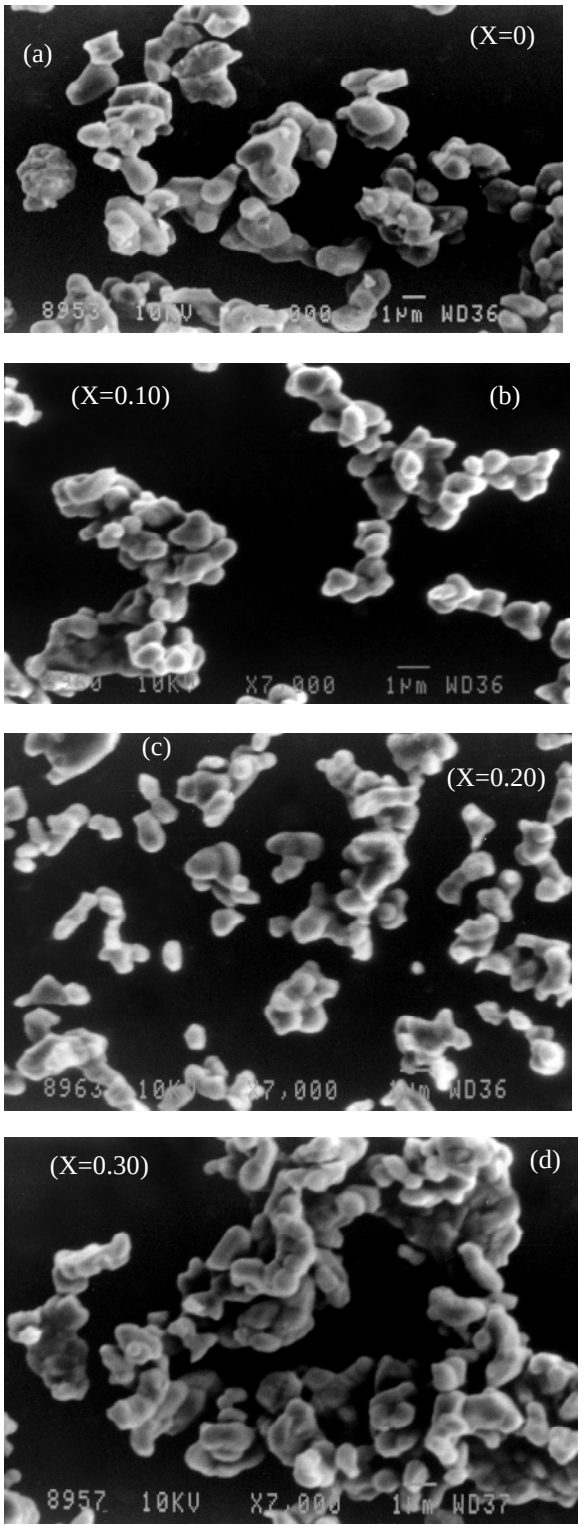


Fig.3. SEM Photographs of $Sr_{1-x}Dy_xFe_{12}O_{19}$ for compositions (a) X = 0 , (b) X = 0.10 , (c) X = 0.20 and (d) X = 0.30.

CONCLUSION

Sr_{1-x} $Dy_xFe_{12}O_{19}$ hexaferrite are prepared by the usual ceramic technique. X-ray diffraction pattern shows that the prepared samples have a single phase structure. The lattice parameters 'c' and 'a' was found to decreases by increasing Dy-content whereas the X-ray density decreases and porosity increased by increasing Dy-content. SEM suggests that the compound have small grains distributed on the surface of the sample and also shows the grain size has been decreases by increasing the Dy-content in the composition $Sr_{1-x}Dy_xFe_{12}O_{19}$. FTIR pattern suggests that the frequency at which there are absorption of IR radiation can be correlated directly to the bonds within the compound.

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