



STUDY OF SOME STRUCTURAL AND MAGNETIC PROPERTIES OF $Sr_2Me_2Fe_{11}(SnCo)_{0.5}O_{22}$ NANOFERRITES

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Abstract- Y-type hexagonal nanoferrite samples with composition $Sr_2Me_2Fe_{11}(SnCo)_{0.5}O_{22}$, where Me_2 is divalent ion namely Cu and Zn have been prepared by microwave assisted auto combustion method. Structure of the prepared samples have been characterized by XRD technique, shows a single Y-phase hexagonal ferrite structure. TEM analysis shows prepared samples is in nanometre range. The magnetic parameter viz. saturation magnetization, remnant magnetization and coercivity obtained from hysteresis loops show increased value for Cu substituted ferrite. The value of squareness ratio is 0.5, indicating that samples of single magnetic domain was produced .

Keywords- Nanoferrite, auto combustion, X-ray density, experimental density, magnetization, coercivity.

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Introduction

In the race of new inventions, new materials of technological importance have acquired much more attention due to their direct utility, particularly in the field of material science. Hexagonal ferrites have large utility in the field of material science. Ferromagnetic nonmaterial's are of particular interest, because at nanoscale, crystallites can exhibit a single magnetic domain. These nanomaterials, therefore exhibit different magnetic properties as compared to bulk. Y-type hexaferrites are interesting materials for their applications in high frequency devices due to its relatively large magnetic permeability, high electrical resistivity and low magnetic losses [1]. Hexaferrites are prepared by using various synthesis routes such as ceramic method, aerosol pyrolysis, chemical co-precipitation, sol-gel and citrate precursor [2-4] etc. Recently, microwave assisted auto combustion synthesis technique have been effectively used to produce powders in shorter time in comparison with the conventional synthesis. Microwave synthesis of materials is fundamentally different from the conventional synthesis in terms of its heating mechanism. In a microwave oven, heat is generated within the sample volume itself by the

interaction of microwave with the materials [5-6]. Microwave energy heats the materials at a molecular level, which leads to uniform heating, whereas, conventional heating systems heat the materials from outer surface to interior, which results into steep internal gradient.

In the present paper, we report the preparation of Y-type nanoferrites $Sr_2Me_2Fe_{11}(SnCo)_{0.5}O_{22}$, where Me_2 is divalent ion namely Cu and Zn by microwave assisted auto combustion method from metal nitrates and urea as a precursor. The aim of this work is to study the structural and magnetic properties of prepared samples in order to understand the effect of Cu and Zn ions on structural deformation as well as on the magnetization of growth.

Experimental technique

Synthesis of $Sr_2Me_2Fe_{11}(SnCo)_{0.5}O_{22}$ nanoferrites Y-type nanoferrites with the composition $Sr_2Me_2Fe_{11}(SnCo)_{0.5}O_{22}$ were synthesized by microwave assisted auto combustion method. Analar grade strontium nitrate, zinc nitrate, copper nitrate, ferric nitrate, cobalt nitrate and stannic chloride were used as

starting oxidizing materials and urea is used as reducing agent to supply requisite energy to initiate exothermic reaction amongst oxidants. Stoichiometric amount of starting materials and fuel were dissolved one by one, in 25ml of de-ionized water; stirred the solution for 1h at room temperature and irradiated in microwave oven with frequency 2.45GHz. Within few minutes of irradiation, solution started boiling and white fumes come out from the specially designed exhaust opening provided on the top of the oven. After 15 minutes solution gets burnt out and resulted into foamy brown powder. The powder obtained were ground for 1h in pestle mortar. Finally the powder was calcinated at 500°C for 1h and slowly cooled down to room temperature, then again ground them for 1h to get desired samples.

X-ray diffraction (XRD) were carried out using a Philips Expert Diffractometer with Cu K α radiation ($\lambda=1.5443 \text{ \AA}$). The lattice constants (a) and (c), volume of unit cell, theoretical density, porosity and physical structure were determined from X-ray diffractogram. The experimental density were calculated using relation $D=\text{mass}/\text{volume}$. TEM analysis of sample was carried out on a Philips CM 200 microscope. Moreover, various magnetic parameters such as saturation magnetization, coercivity, remanent magnetization etc. were measured with Lakeshore VSM 7304 with a maximum field of 10KOe.

Results and Discussion

Structural Properties

The XRD patterns at room temperature of the investigated samples are shown in "Fig. (1)". Those patterns show obviously that all the synthesized samples have a single Y-phase hexagonal ferrite structure with space group R3m (No.166) without notable residuals of the original constituent nitrates. The values of lattice parameter a and c, cell volume v, experimental density Dx, X-ray density D and porosity P are depicted in Table1. It is shown that value of c, a and their ratio c/a for both samples are nearly same. This behaviour can be explained on the basis of ionic radii of substituted ions, where the ionic radius of Zn^{2+} ions is 0.074nm which is nearly of the same order as that of Cu^{2+} ions (0.072nm). This result is in accordance with the fact that all hexagonal ferrites (M-, Y-, W- type) are characterized by constant lattice parameter 'a' of the order of 5.88 Å [7]. The experimental density D (bulk density) values were found to be in general less than those of Dx (theoretical density) which are expected due to the presence of unavoidable pores created during firing. It is observed that experimental density of Cu^{2+} substituted sample is less than Zn^{2+} substituted but porosity is more. This behaviour may be attributed to the fact that that the presence of Cu^{2+} ions in hexagonal ferrite may affect the grain size development during calcinations and increase the porosity [8]. Thus we can conclude that replacing Zn by Cu retards the sintering process and decrease the grain size leading to enhance porosity.

The crystallite size was determined using the well known Scherrer formula [9] from the strongest peak. The formula, excluding the effects of the machine broadening to minimize errors is given below

$$D = \frac{k\lambda}{\beta \sin\theta}$$

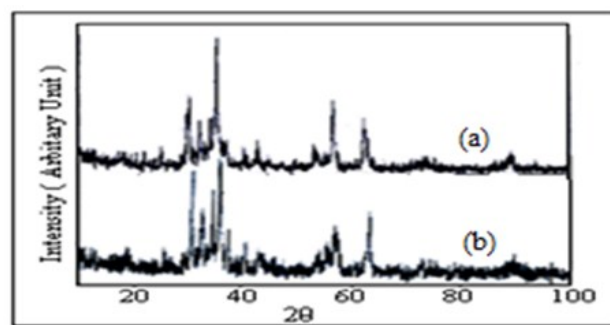


Fig. 1- XRD patterns a) $\text{Sr}_2\text{Zn}_2\text{Fe}_{11}(\text{SnCo})_{0.5}\text{O}_{22}$ b) $\text{Sr}_2\text{Cu}_2\text{Fe}_{11}(\text{SnCo})_{0.5}\text{O}_{22}$

Where D = average size of the crystallites, k = Scherrer constant ($k = 0.9$), λ = wavelength of radiation (1.5405 \AA), β = full width at half maximum height (FWHM) measured in radians and θ corresponds to the peak position. The crystallite size calculated is found to be in range of 11nm to 8.7nm, which is in agreement with result observed in TEM study (= 26nm), thus confirming the nano size of prepared samples.

Table 1- Structural data of samples

Sr.No.	Compound	Molecular Weight	a (Å)	c (Å)
1	$\text{Sr}_2\text{Zn}_2\text{Fe}_{11}(\text{SnCo})_{0.5}\text{O}_{22}$	1361.09	5.90	43.50
2	$\text{Sr}_2\text{Cu}_2\text{Fe}_{11}(\text{SnCo})_{0.5}\text{O}_{22}$	1357.44	5.85	43.69

Sr.No.	Cell Volume (Å) ³	Ex-perimntal Density (D) gm/ cm ³	X-Ray Density (Dx) gm/ cm ³	Grain Size (nm)	
				XRD	TEM
1	1313	3.72	5.16	11	--
2	1297	2.85	5.20	8.7	26

The TEM micrograph of the Cu substituted sample is shown in "Fig. (2)". It is apparent that nanocrystalline particles were formed with hexagonal shape of about 26nm of grain size.

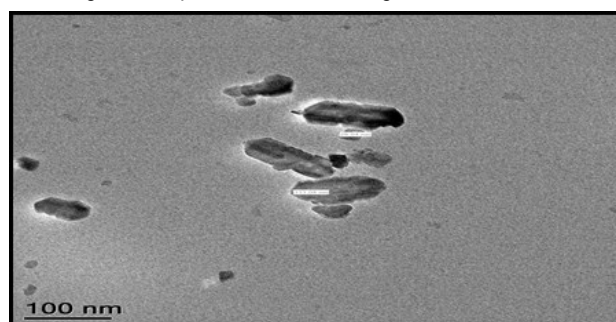


Fig. 2- TEM micrograph of $\text{Sr}_2\text{Cu}_2\text{Fe}_{11}(\text{SnCo})_{0.5}\text{O}_{22}$

Magnetic Properties

The field dependent magnetization of the samples was measured at room temperature on a vibrating sample magnetometer with a maximum applied field of 10kOe. The Hysteresis loops of the samples are shown in "Fig. (3)" and magnetic parameters such as saturation magnetization (M_s), remnant magnetization (M_r),

squareness ratio $\frac{M_r}{M_s}$ and intrinsic coercivity (H_c) are summarized

in Table 2. It is observed that values of all magnetic parameters of Cu substituted ferrite are comparatively more than that of Zn substituted ferrite; this is due to the fact that Cu is magnetic and Zn is non magnetic in nature. The VSM measurements show that the intrinsic saturation M_s , is reach when a high H field is applied. This saturation is the state when the material cannot absorb a stronger magnetic field such that an increase of magnetization force produces no significant change in magnetic flux density. The copper ion occupies the octahedral sites in the structure of Y-ferrite and Cu^{2+} ions distort the crystalline field due to their electronic configuration, and this behaviour results in increase in saturation magnetization [10].

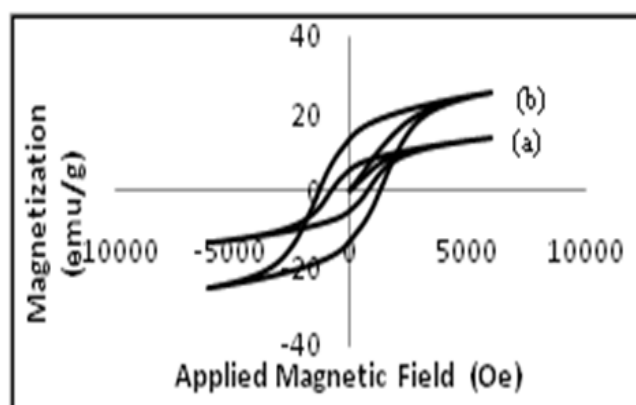


Fig. 3- Hysteresis loop of a) $\text{Sr}_2\text{Zn}_2\text{Fe}_{11}(\text{SnCo})_{0.5}\text{O}_{22}$
b) $\text{Sr}_2\text{Cu}_2\text{Fe}_{11}(\text{SnCo})_{0.5}\text{O}_{22}$

The squareness ratio is essentially a measure of squareness of the hysteresis loop and its value is about 0.5, indicating that sample of single magnetic domain was produced [11]. The coercivity also called coercive force, of the ferromagnetic samples, is referring to the intensity of the magnetic field required to reduce the magnetization of the sample to zero. The value of intrinsic coercivity in case of Cu substituted ferrite is more than Zn substituted is due to the decrease in grain size in Cu ferrite, this resembles with literature report about inverse nature of coercivity with grain size [12].

Table 2- Room temperature magnetic parameters

Sr. No.	Compound	M_s (emu/g.)	M_r (emu/g.)	M_r/M_s	H_c (Oe)
1	$\text{Sr}_2\text{Zn}_2\text{Fe}_{11}(\text{SnCo})_{0.5}\text{O}_{22}$	13.44	5.2	0.39	769
2	$\text{Sr}_2\text{Cu}_2\text{Fe}_{11}(\text{SnCo})_{0.5}\text{O}_{22}$	25.45	13.3	0.52	1210

Conclusions

All the synthesized samples have a single Y-phase hexagonal ferrite structure. The experimental density of Cu^{2+} substituted sample is less than Zn^{2+} substituted but porosity is enhanced, this may be to the fact that the presence of Cu ions in hexagonal ferrite may affect the grain size development during calcinations and increase the porosity. The grain size of the samples is in nanometre range. The squareness ratio about 0.5, indicating that sample of single magnetic domain was produced. The value of coercivity in case of Cu substituted ferrite is more than Zn substituted is due to the decrease in grain size in Cu ferrite.

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