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Effect of Mn-Al-Cr Substitution on Structural and Magnetic Properties of Y Type Strontium Hexaferrite

Ashish Sangwan, Sanchia Mae Kharphanbuh, Deepak Basandrai, A.K.Srivastava*

School of Chemical Engineering and Physical Sciences, Lovely Professional University, Phagwara, Punjab, 144411, India

*Email: Srivastava_phy@yahoo.co.in

Abstract

We have synthesized Al-Mn-Cr doped Y-type hexaferrite $Sr_2Mn_2Al_{x/2}Cr_{x/2}Fe_{12-x}O_{22}$ (x = 0.0, 0.5, 1.0, 1.3, 1.9 and 2.5) using sol gel auto combustion method. To study structural properties, XRD, FESEM and FTIR have been used. VSM has been utilized to investigate magnetic properties of the material.In FTIR, Presence of two peaks at 500-600 cm^{-1} to 400-450 cm^{-1}give the idea of formation of hexaferrites. The XRD patternalso establish the formation of hexagonal Y-type hexaferrite. FE-SEM analysis show hexagonal structure which lie in nano-range. M-H loops have been used to calculate saturation magnetization, coercivity and retentivity of the material.

Introduction

Recently hexaferrites have attracted much attention due to its wide applications in high frequency circuits, micro-wave devices, recording media and permanent magnets [1].Numerous methods were employed in literature to synthesized hexaferrites, the most popular amongst was solid-state[2, 3], sol–gel (SG) [4–5], microwave-stimulated combustion [6], and hydro-thermal [7].Through sol gel method, we can control particle size and shape[8].

In the present research paper, we have synthesized $Sr_2Mn_2Al_{x/2}Cr_{x/2}Fe_{12-x}O_{22}$ (x = 0.0, 0.5, 1.0, 1.3, 1.9 and 2.5) using SG auto combustion to investigate the effect of Mn-Al-Cr dopant on themagnetic chattels of Y type strontium hexaferrite.

Synthesis Procedure

The SG auto combustion method has been utilized to blend the single phase $Sr_2Mn_2Al_{x/2}Cr_{x/2}Fe_{12-x}O_{22}$ (x= 1.3, 1.9, 2.5). The strontium nitrate, Manganese nitrate, Aluminum nitrate, Chromium nitrate and Ferric nitrate were taken as pro-genitor materials (Precursor). All

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

initiating materials as metal nitrates were liquified in distilled water distinctly in equalamount. After that to catalyze the reaction positively citric acid is added.

Amount of the ammonia (30%, AR. grade) is added in the solution for neutralization drop wise to control the pH near about 7-8. After that, neutralized solution is heated on magnetic stirrer at 80-85℃ temperature for 2-3 hours to get the homogenous gel of brown color. Now formed gel is dehydrated over an oven at 280-300℃ for 3 hours. As the temperature is increased, this started converting into ash i.e (auto combustion was done) which has been heated till it is becomes fluffy and loose powdered sample.Further powder sample was pre-sintered at 500℃ temperature for 2 hours after that heated at 900℃ temperature for 2-3 hours to remove impurities. At last, sample were sintered at 1000℃ temperature for 5 hours to get the Y- type hexagonal ferrite.

Results and Discussions

X-ray diffraction Study

XRD patterns of synthesized samples $Sr_2Mn_2Al_{x/x}Cr_{x/2}Fe_{12x}O_{22}$ (x=0.0, 0.5, 1.0,1.3, 1.9, 2.5) are shown in Fig. 1.The existence of peaks at hkl values (1 1 0), (1 1 3),(1 0 13),(0 1 14),(1 1 19) ,(0 0 18), (2 0 8) ,(1 0 19) , (0 1 20), (2 1 1) (2 0 17), (0 2 19), (0 0 27) ,(2 1 16) ,(0 3 12) ,(1 0 28) ,(2 1 19) ,(2 1 28) ,(3 1 8) reveals hexagonal structure of Y-type hexaferrite (JCPDS Card No.: 082-0472). The average size grain is calculated by using Shearer's formula which is given by the relation:

$$D = \frac{K\lambda}{\beta\cos\theta}$$

Here K is a constant and its value is 0.89[9,10,11], λ is(1.54Å).The grain size values are given in Table 1.It has been observed that grain size increases with increasing concentration of dopants.

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

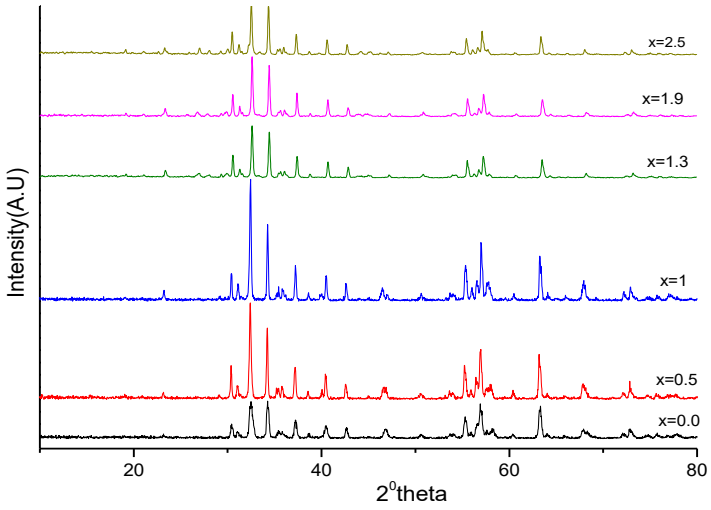

Figure 1. XRD spectra of the strontium hexaferrite $Sr_2Mn_2Al_{x/2}Cr_{x/2}Fe_{12-x}O_{22}$ with different composition.

The lattice constants a and c are calculated by using the formula

$$\frac{1}{d_{hkl}^2} = \frac{4}{3}\frac{h^2 + hk + k^2}{a^2} + \frac{l^2}{c^2}$$

To calculate a and c, we have taken hkl values (0 0 18) and (0 1 14) corresponding to 2θ at 37.2° and 34.5° respectively. The cell volume are also calculated by using $V = 0.8666a^2c$.

Table 1: Lattice constants, Volume of unit cell, grain size of $Sr_2Mn_2Al_{x/x}Cr_{x/2}Fe_{12x}O_{22}$ (x = 0, 0.5, 1, 1.3, 1.9, 2.5)

Sample composition X	D (nm)	a (Å)	c (Å)	V ($Å^3$)
0.0	26.73999	5.86956	43.45254	1297.317

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

0.5	52.54118	5.88791	43.51896	1306.492
1.0	58.07462	5.88029	43.46748	1302.509
1.3	56.9566	5.85848	43.30242	1287.957
1.9	78.91632	5.85954	43.32222	1287.877
2.5	78.32129	5.86954	43.40368	1295.819

From the above, it can be concluded that with increased in concentration of Al- Mn-Cr the value of "c" increases and the value of "a" remains almost constants.

FTIR Study

FTIR can be used to get the information of attached functional groups. FTIR spectra of $Sr_2Mn_2Al_{x/2}Cr_{x/2}Fe_{12-x}O_{22}$ were recorded as shown in Fig. 2. The presence of peaks near the 500-615 cm^{-1} also 450-460 cm^{-1} confirms the formation of the Y-type strontium hexaferrites which is common feature of all hexaferrites [12,13,14,15]. These peaks are due to stretching vibration of Fe^{3+}-O^{2-} in octahedral and tetrahedral sites. The peaks near 1510 to 1520 cm^{-1} is due to the presence of the CO_2 whichconfirms the symmetric and asymmetric bands related to citric acid. The bands closer to 3200-3200 cm^{-1}reveals the presence of the hydroxyl group of carboxylic.The peaks in the range $1550cm^{-1}$ to $1490cm^{-1}$ are due N-O stretching vibration of NO^{3-} ions. Peaks lying between $1760cm^{-1}$ to $1650cm^{-1}$ show the stretch of C-O bond which indicates the presence of carboxylic acid. The peak at $2366cm^{-1}$ is due to CO_2while the peaks in the band range of $3850cm^{-1}$ to $3500cm^{-1}$ are due O-H vibration of the water molecules (Fig. 2).

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

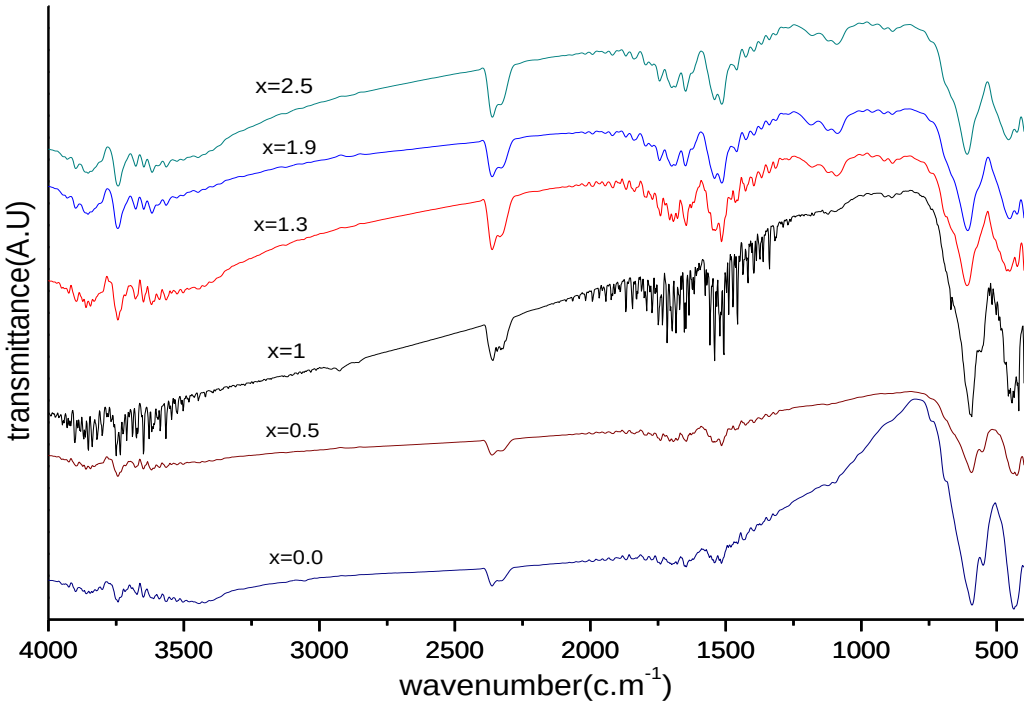

Figure 2. FTIR spectra of $Sr_2Mn_2Al_{x/2}Cr_{x/2}Fe_{12-x}O_{22}$ hexaferrites at temperature 1000℃.

FE-SEM Study

Room temperature FE-SEM micrographs of $Sr_2Mn_2Al_{x/2}Cr_{x/2}Fe_{12-x}O_{22}$ hexaferrites has been shown in Fig. 3. There are hexagonal type structure with uneven distribution.

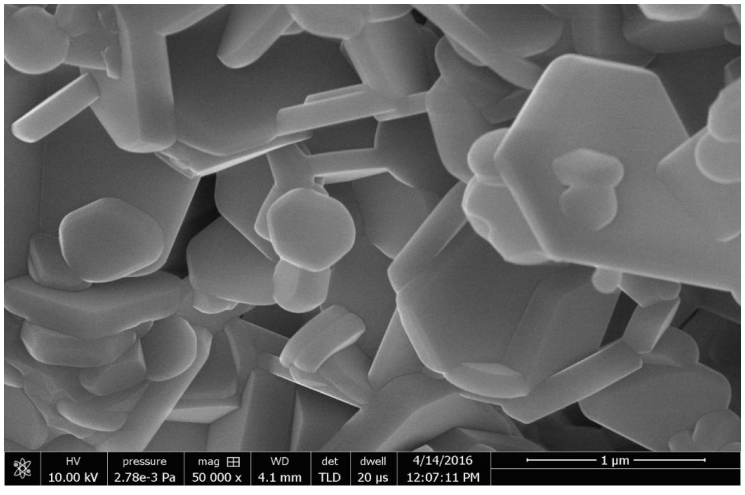

Figure.3. FE-SEM image for composition x=1.9

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

VSM STUDY

The saturation magnetization (M_s), retentivity (M_r) and coercivity (H_c) of $Sr_2Mn_2Al_{x/x}Cr_{x/2}Fe_{12x}O_{22}$ (x = 0, 0.5, 1) have been premeditated from hysteresis loop. The Coercivity, saturation magnetization and retentivity of the samples are reported in Figure 3 and Table 2.The Coercivity lies in the range 3823.65 - 5881.73 Oe and the saturation magnetization lies in the range 20.98 - 27.68 for different composition. With increasing the amount of co-dopants Al-Cr, M_s and M_r decreases but H_c increases as the dopants concentration increases. The magnetic property is due to Mn^{2+} ions in tetrahedral sites and Fe^{+3} ions in the tetrahedral and octahedral sites.

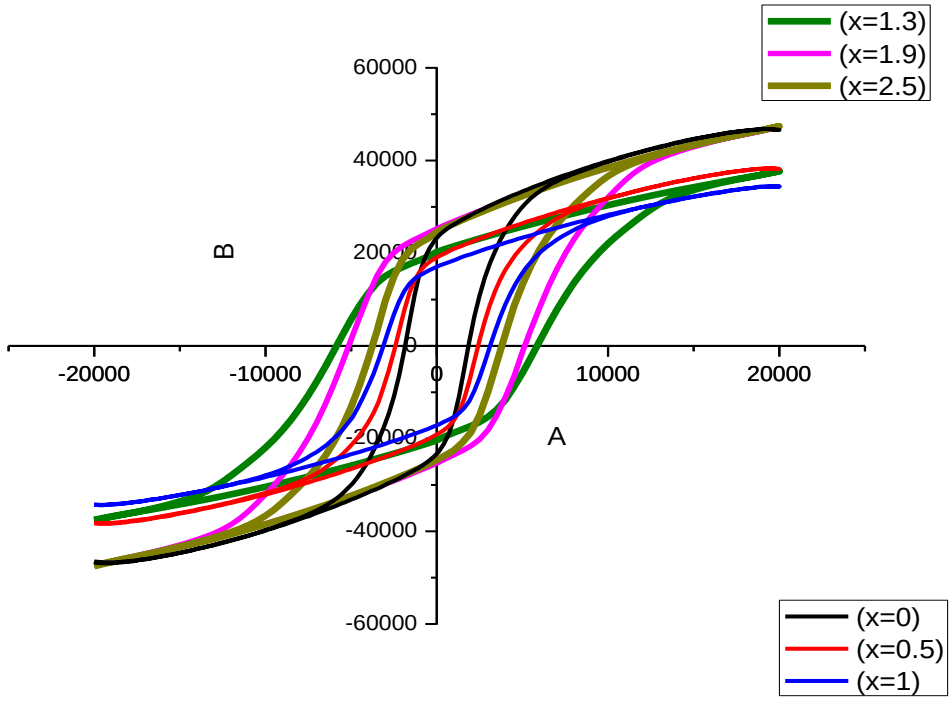

Figure 3: M-H loop of $Sr_2Mn_2Al_{x/2}Cr_{x/2}Fe_{12-x}O_{22}$ (A= H, B= M)

Table 2 . Coercivity (H_c), saturation magnetization (M_s), retentivity (M_r) values of $Sr_2Mn_2Al_{x/2}Cr_{x/2}Fe_{12-x}O_{22}$

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

Composition (x)	M_s(emu/g)	M_r(emu/g)	H_c(Oe)
0	46462.715	22862.606	1849.58
0.5	38042.885	18818.629	2393.91
1	34231.084	16989.894	3149.30
1.3	27.41	14.69	5171.33
1.9	21.98	11.8	5881.73
2.5	14.34	14.34	3823.65

Conclusion: The sample with chemical composition $Sr_2Mn_2Al_{x/2}Cr_{x/2}Fe_{12-x}O_{22}$ (x = 0.0, 0.5, 1.0, 1.3, 1.9 and 2.5) was prepared using sol gel auto combustion method and characterized by XRD, FESEM and FTIR. The relative decline in static magnetization and retentivity can be seen with increase in dopant concentration but at the same side coercivity increases. Hence, dopant concentration has significant effect on the magnetic properties of the material.

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ISSN: 0971-1260
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