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Study of Structural and Electrical Properties of Cd+2 Doped Mn-Zn Ferrites Synthesized by Co-Precipitation Method

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Abstract

The main purpose of this work was to study the electrical, structural and optical properties of Cd-doped Zn based soft ferrites. A series of nano-particles with composition Zn0.5Mn0.5-xCdxFe2O4 (x= 0.00, 0.01, 0.03, 0.05, 0.07, 0.09) prepared by the co-precipitation route. After preparing, the samples sintered at temperature 900ºC for 6 hours. Different characterization techniques like XRD (X-Ray-Diffraction), FTIR (Fourier-Transform-Infrared-spectroscopy), UV-vis. and IV-characteristics were used to explore the effect of doping element (Cd) on the electrical, structural and optical properties of Nano-particles. XRD data confirmed the single phase of material with second phase of Fe2O3 and average crystalline size in range from 38.09-45.15 nm. The value of average lattice constant for the prepared material found in range from 8.4471 Å to 8.4763 Å. In FTIR data one prominent band is found in all sample and in some sample second band was found in range from 400-4000cm-1. IV-observation revealed the dependence of DC-resistivity on temperature and the value for activation energy (found in range from 0.1365 to 0.4332 eV/1000K. The UV-vis. analysis confirm the absorption peak for all samples at average wavelength 286 nm. At this wavelength absorption for all samples was in range from 2.8722-3.2956 (a.u). Due to suitable properties, these materials are useful in different fields like Recording-Media, high-frequency applications and many branches of electronic engineering etc.

Keywords: Nano structure, Co-precipitation method, XRD, Crystalline size, Resistivity, Activation energy

Introduction

From the last few years the ferrimagnetic materials developed a great interest of scientists due to many applications of these materials in different fields (Industrial, Electronic, technical and Defense area). Ferrites, the ceramic materials which basically formed due to the reaction between iron-oxides and metal-oxides. The common ferrites are ZnFe2O4 and scientists did lot of work on these ferrites and doped different elements in these ferrites to study the various properties of these ferrites. The MFe2O4 (Metal-Transition-Oxides) are materials having good magnetic properties due to which are useful in field of electronic-industry for electric purposes. These ferrites are useful in high frequency region due to their high value of permeability. The Manganese-Zinc ferrites are soft ferrites and they have low value of coercivity and high value of electrical resistivity. These two electric and magnetic properties make them useful in different fields like telecommunication as well as electronic. The preparation method of material effects the properties of material. The common method by which we can obtain nano-phase are Sol-Gel route, auto-combustion route and Co-precipitation route. According to the best of my knowledge a very less work is done in which the cadmium is doped in Manganese-Zinc ferrites. I doped the cadmium in manganese-zinc ferrites and studied the effect of Cd+2 ions on structural and electrical properties of the prepared material having composition Zn(0.5)Mn(0.5-x)Cd(x)Fe2O4 (x= 0.00, 0.01, 0.03, 0.05, 0.07, 0.09) [1].

Materials and Methods

A series of soft ferrites having chemical formula Zn(0.5)Mn(0.5-x)Cd(x)Fe2O4 (x= 0.00, 0.01, 0.03, 0.05, 0.07, 0.09) prepared by the chemical route called as co-precipitate route.

There are several methods by which we can prepare the ferrites such as hydrothermal process, Sol-Gel method, Auto-Combustion route and Co-precipitate method [19-24]. The co-precipitate method has some advantages over other methods due to which we used co-precipitate method to prepare the sample.

First, the chemicals weighted according to their mole ratio and dissolved the chemicals into beaker and stirred for 30 minutes. During the stirring process the solution of Sodium-Hydroxide added into the beaker to keep the pH about 12. During the stirring process the precipitates of the solution were seen. After stirring process, the solution which had precipitates located into the water bath for two hours at temperature about 80oC. Then the solution of precipitate filtered by filter paper and washed by De-ionized water, ethanol and methanol to reduce the impurity. After filtration process the prepared precipitates dried in oven for overnight at temperature 80oC. When the prepared sample dried completely then the sample grinded for half hour to get fine powder of sample and then placed the sample in furnace for six hours at 900oC to sinter the sample [2]. After sintering the sample, the sample again grinded for half hour in mortar and pestle to make fine powder. Finally, the sample prepared and ready for characterization. The mention process in above discussion explained by flow chart of co-precipitation method Figure 1.

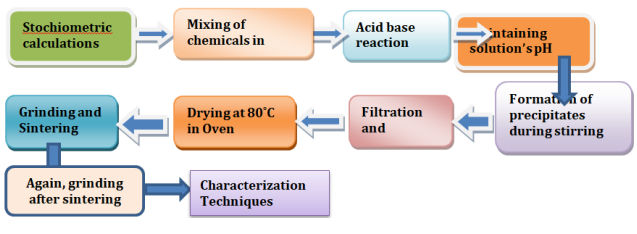

Figure 1: Flow Diagram of Experimental Procedure.

Results and discussion

The prepared sample having chemical composition Zn(0.5)Mn(0.5-x)Cd(x)Fe2O4 (x= 0.00, 0.01, 0.03, 0.05, 0.07, 0.09) prepared by the soft-chemical route called co-precipitation route characterized by different characterization techniques. We characterized the sample by four techniques in which XRD (X-Ray-Diffraction), IV-Characteristics, FT-IR (Fourier-Transform-Infrared-Spectroscopy and UV-Visible. The details of results which we got by these characterization techniques are explained as follows.

Structural analysis

In this portion, we explained the structural information of the prepared sample. The sample of cadmium doped zinc-manganese-ferrite characterized by the XRD (X-ray-diffraction) and calculated different parameters like interplanar-distance (d), Full-Width-Half-Maxima (), Lattice-Constant (a), volume (V), size of crystalline (D) and the density of x-ray (). We used following expressions to calculate the required parameters [3].

By using plane-spacing relation,

Where 'k' is shape-factor having value 0.89-0.90, '' denote wavelength of x-rays, '' denote the value of full-width-half-maxima and D be the size of crystalline.

And the density of x-rays can be obtained by following relation,

Where 'V' be the unit-cell volume, 'M' be the molecular-weight of the sample and 'NA' be the Avogadro's-number (6.0221 x 1023 per mol) Figure 2.

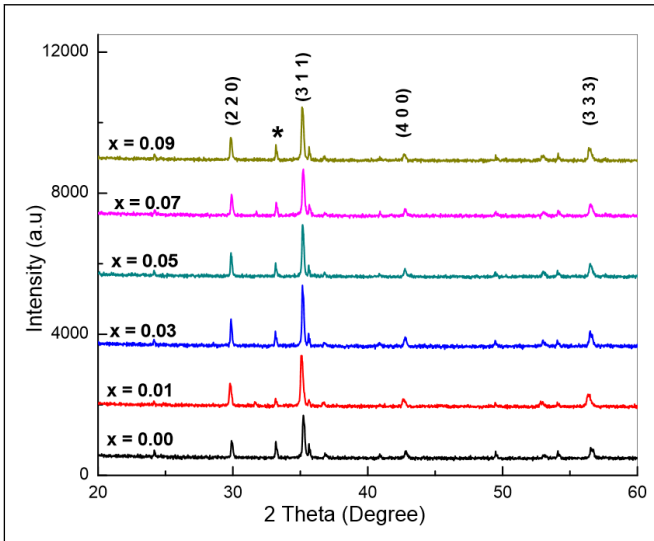

Figure 2: XRD pattern of Zn(0.5)Mn(0.5-x)Cd(x)Fe2O4 (x= 0.00, 0.01, 0.03, 0.05, 0.07, 0.09).

The figure shows the X-Ray-Diffraction of Zn(0.5)Mn(0.5-x)Cd(x)Fe2O4. From XRD results we seen that sample exhibit simple cubic structure having major phase the second phase was also observed which is of Fe2O3.

The secondary phase of Fe2O3 was obtained at the boundaries due to the high reactivity between the ferric and cadmium ions. The prepared ferrites are spinel ferrites. The spinel structure of the prepared sample was confirmed by the peaks which comparable to planes (220), (311), (400) and (333/511). It had been found different parameters like lattice-constant, crystalline-size and density of x-rays with help of XRD data. It had been observed the value of lattice constant found in range from 8.4471 Å to 8.4763 Å. The value for crystalline size observed in range from 38.09 nm to 45.15 nm. The value for density of x-rays found in range from 5.1572 g/cm3 to 5.2846 g/cm3.

FTIR spectra analysis

The FTIR (Fourier-Transform-Infrared-Spectroscopy) observation done in range from 450 cm-1 to 4000 cm-1 and range of transmittance percentage was in range from 70 to 100 as shown in figure 2. One prominent band is observed at wavenumber range from 539.14 cm-1 to 540.35 cm-1 in all samples by which we confirmed the band-formation at octahedral-sites between metal-ions and oxygen-ions. The second band was observed in between of 1100 cm-1 to 1600 cm-1.in some samples which confirmed the presence of tetrahedral-sites. The formation of these bands is due to the vibration of atoms at octahedral and tetrahedral sites Figure 3.

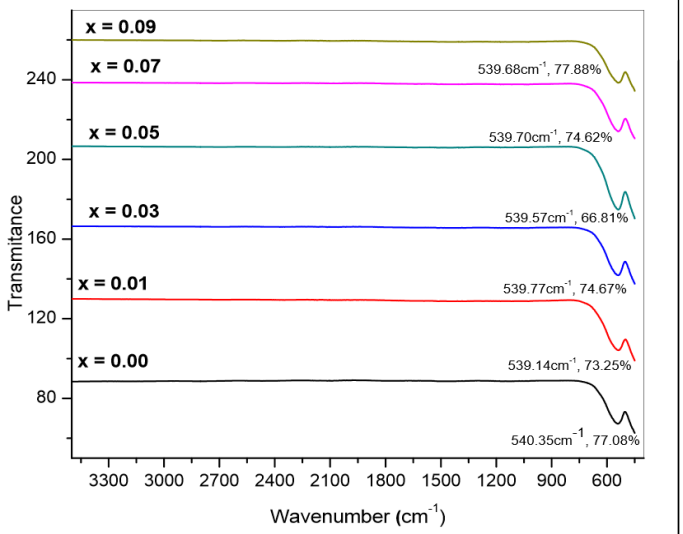

Figure 3: FTIR Spectrum of Zn(0.5)Mn(0.5-x)Cd(x)Fe2O4 (x= 0.00, 0.01, 0.03, 0.05, 0.07, 0.09).

Current-Voltage Analysis

In this section, we described the electrical properties of the prepared sample. The prepared samples were examined by the Keithley-Electrometer 2401 model and collected results at different temperatures. In this type of characterization first we prepared the pellets of the materials under discussion with help of hydraulic press and kept the pressure about 15 ton for time about half an hour. After

making pellets the prepared pellets were placed to found the electrical properties of samples. Each sample was examined at different values of temperatures like 250oC, 300oC, 350oC, 400oC, 450oC, 500oC, 550oC and 600oC. The value of DC-resistivity was calculated by using the relation of equation 4.7.

In the above equation, the "A" denote the area of pellet, "d" denote the pellet's thickness, "R" is the resistance of sample and □ denotes the resistivity of sample. First, we found the resistance of sample with help of IV-Graph because slope of IV-Graph is equal to inverse of resistance of sample. The values of resistance of every sample at all temperatures were calculated with help of relation 10 and then using expression 7 the resistivity of sample at all temperatures were calculated. The graph between temperature and resistivity as shown in Figure4.

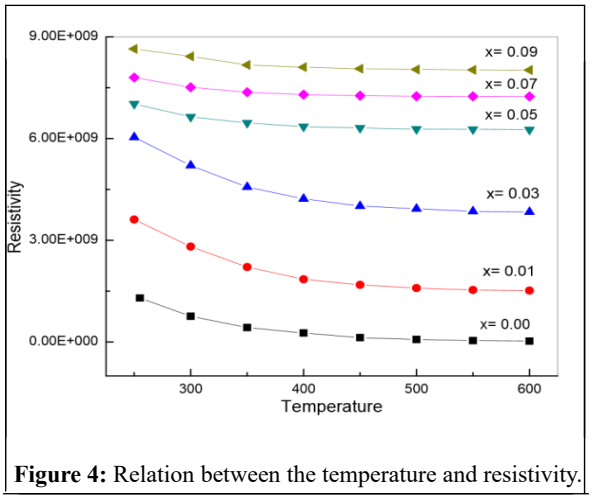

Figure 4: Relation between the temperature and resistivity.

It was described from the relation between temperature and resistivity that the resistivity of all samples decreased by increasing the temperature. When the temperature increased the resistivity decreased.

Activation Energy

In order to calculate the activation energy for each sample, we described the relation between the resistivity and the temperature. T Arrhenius-equation described the relation between temperature and the resistivity as given in equation 4.11.

In the above expression represents the activation-energy of the material and 'T' is the absolute temperature and K represents the Boltzman-Constant.

It is clear from the figure that the DC-resistivity varies with temperature. By solving equation 11 we can find the expression for the activation energy of material [4].

Where m is the slope and k is the boltzman-constant. If we have values of Boltzman-Constant and slope then we can find out the activation energy of material.

The slope in equation 14 found with help of graph between ln and 1000/T as shown in Figure 5.

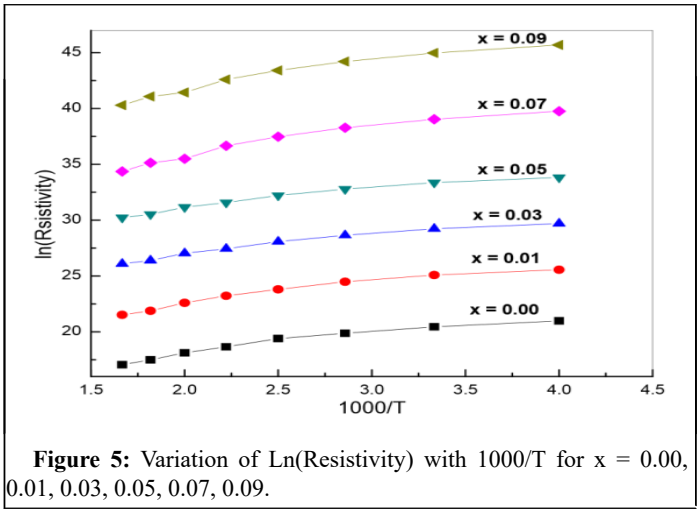

Figure 5: Variation of Ln(Resistivity) with 1000/T for x = 0.00, 0.01, 0.03, 0.05, 0.07, 0.09.

With help of the above graph we calculated the slope and then by using equation (14) we calculated the activation energy for each sample [5].

Which is found in range of 0.1365 eV/1000K to 0.1880 eV/1000K. The value of activation energy for all samples given below in Table 1.

Value of x	0.00	0.01	0.03	0.05	0.07	0.09
Activation Energy (eV/1000K)	0.1458	0.1527	0.1365	0.1553	0.4332	0.1880

Table 1: Activation energy of Cd doped Zn Mn ferrites for x = 0.00, 0.01, 0.03, 0.05, 0.07, 0.09.

UV-Visible spectrum

In this section, we discussed the optical properties of the prepared samples of chemical formula Zn(0.5)Mn(0.5-x)Cd(x)Fe2O4 (x= 0.00, 0.01, 0.03, 0.05, 0.07, 0.09). it had been observed the prominent band for absorption in ultraviolet region at wavelength 286 nm. The absorption bands are shown in figure 4.

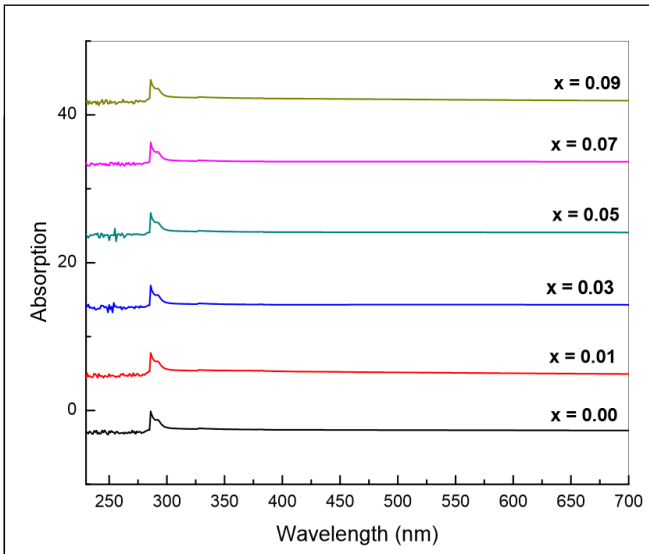

Figure 6: UV-vis. absorption spectrum of Zn(0.5)Mn(0.5- x)Cd(x)Fe2O4 (x= 0.00, 0.01, 0.03, 0.05, 0.07, 0.09).

The values for absorption found in all samples placed in table 2 corresponding to their concentration. It is seen that the absorption lies in range from 2.8722 to 3.2956.

Concentration	0.00	0.01	0.03	0.05	0.07	0.09
Absorption	2.9089	3.2584	3.2956	2.9331	2.8722	3.1847
Frequency (nm)	286.3810	286.4903	286.2644	286.2544	286.4950	286.4903

Table 2: Absorption of samples for x = 0.00, 0.01, 0.03, 0.05, 0.07, 0.09.

Conclusion

The Cd doped Zn-Mn ferrites were prepared with co-precipitation method. The prepared ferrites exhibited the structure of spinel ferrites. The prepared sample had not single-phase sample but was secondary phase which was of Cd2O3. It had been confirmed the formation of spinel-phase.

The lattice constant found in range from 8.4471 Å to 8.4763 Å and crystalline size found in range 38.09 nm to 45.15 nm. The x-rays density value found in range from 5.1572 g/cm3 to 5.2846 g/cm3. The FT-IR data revealed the vibration of atoms at octahedral and tetrahedral sites.

In FTIR data one band is found in all sample and in some sample two bands were found in range from 400-4000cm-1. IV-observation revealed the dependence of DC-resistivity on temperature and the value for activation energy (found in range from 0.1365 to 0.4332 eV/1000K. The UV-vis. analysis confirm the absorption peak for all samples in ultraviolet region at average wavelength 286 nm. At this wavelength absorption for all samples was in range from 2.8722-3.2956. Due to the properties mentioned above these materials are useful in field of Telecommunication, industry and electronic-field.

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