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Magnetic Elucidation of Copper-Zinc-Iron-Manganese Ferrospinels

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Abstract:

Quaternary ferrospinels having formula $Cu_{1-x}Zn_xFeMnO_4$ ($0.0 \leq x \leq 1.0$) were prepared by citrate-gel auto-combustion route. Their magnetic hysteresis parameters viz. Saturation magnetization (Ms), coercivity (Hc) and remanent magnetization (Mr) and magnetic moment (n_B) were studied. The non-linear trend with the zinc concentration amongst the series are unique. The diamagnetic Zn^{+2} ions make them versatile for various electro-magnetic appliances.

Keywords: Citrate precursor; Ferrospinels; Hysteresis loop; non-linear; Magnetic moment

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I. INTRODUCTION:

The magnetic semiconducting ferrospinels (AB_2O_4) occupied a wide range of technological abilities in microwave appliances, TV sets, radio frequency circuits, antennas, transformers, high speed digital tapes etc. [1-5]. The magnetic behavior of these materials are tuned with the help of it chemical composition, method of synthesis, choice of ions, sintering temperature & time, proper precursor, crystal structure, grain size, porosity and many more [6-8]. Due to its versatile nature like durability, rigid stability, relatively inexpensiveness, low power loss, easy to prepare, expected stoichiometry, magnetism with low dielectric loss and high resistivity these compounds cannot be replaced by others [9-10]. Nanostructured ferrospinels are desperately expedient in magnetic recording, Gas sensors, catalysis, surface chemistry, Ferro-fluids, biomedical use as magnetic separation, targeted drug delivery and hyperthermia [11-15]. The distribution cations amongst tetrahedral (A-site) and octahedral (B-site) in spinel lattice makes them dynamic in technologically significant in electro-magnetic devices [16-18]. The electric conduction mechanism is recognized on the basis of thermal dependent e^-hopping process [19-20] and not with thermal creation of charge carriers. With this perspectives quaternary system is planned to reaper and insight on its magnetic behavior.

II. MATERIALS AND METHODS:

High pure hydrated salts of copper nitrate, zinc nitrate, ferric nitrate and manganese nitrate were mixed together in stoichiometric amount in the presence of citrate acid to form respective metal-citrate complex. Ferrospinels with chemical composition $Cu_{1-x}Zn_xFeMnO_4$ with x = 0.0, 0.25, 0.5, 0.75 & 1.0 using citrate-gel auto-combustion route [21-23].

The above metal citrate complex solution was mixed together and heated @ 100°C with constant stirring. During heating the solution become viscous and converted into gel. The viscous gel automatically combusted and burnt with glowing fire. The burnt material gave a floppy powder by complete. The prepared powder samples were sintered at 700°C for 4 hrs to get pure composites.

The magnetic measurements were carried out using high field hysteresis loop tracer at room temperature by constant magnetic field of 10 kOe. From the the obtained loops various magnetic parameters were investigated.

III. MAGNETIC HYSTERESIS:

Hysteresis loops of various compositions of the system are shown in Fig. 1. Various magnetic parameters like, saturation magnetization, coercive field, remanent magnetization and magnetic moment are reported in Table 1. From Fig. 1, it is observed that all the specimens are of ferrimagnetic nature except $ZnFeMnO_4$. The high value of coercivity may be due to presence of anisotropy. The decrease in value of saturation magnetization and magnetic moment (Table 1) with increase in x is due to substitution of Zn^{2+} ions, which does not have magnetic moment as compared to $Cu^{2+}(1\mu_B)$ and Fe^{3+} ($5\mu_B$). Another reason may be that, Zn^{2+} ions strongly prefer to occupy A site [24], due to which Fe^{3+} ions will shift from A site to B site. Because of that shift the AB (J_{AB}) interactions become weak in zinc rich spinels and result decrease in magnetic moment.

Saturation magnetization increases on the substitution of zinc ions (x = 0.25) and thereafter decreases linearly. The increase in M_S up to certain concentration of Zn^{2+} ions is due to the availability of Fe^{3+} and Cu^{2+}

at A site to strengthen the A-B interaction by disturbing the antiparallel spin alignment at B site. While with further addition of Zn^{2+} ions, which prefer to occupy A site and as a result, Fe^{3+} ions shift towards B sites [25-26]. The decrease in concentration of copper ions at A site and migration of Fe^{3+} ions towards B site results in the weakening of AB resulting in deceasing magnetization values [27-31].

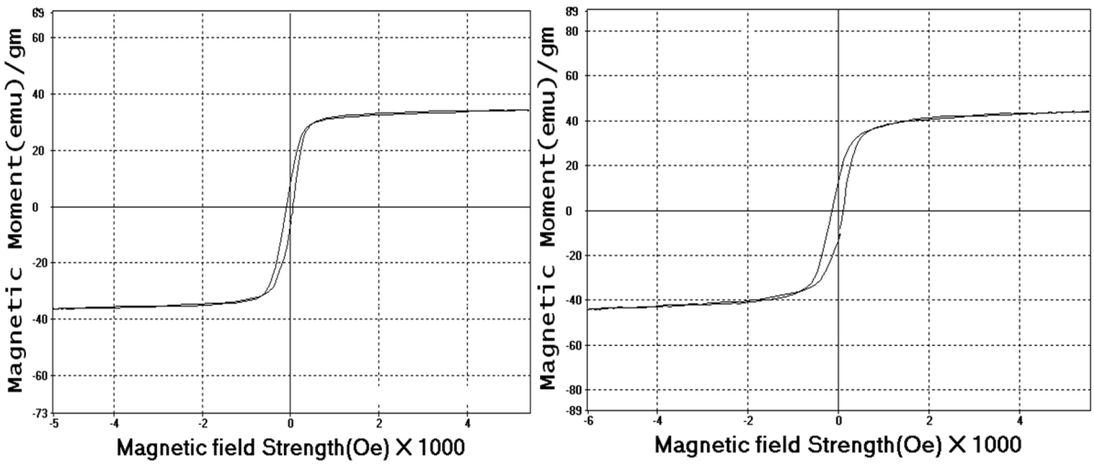

Fig. 5.16 Hysteresis loop for the $Cu_{0.75}Zn_{0.25}FeMnO_4$ sample

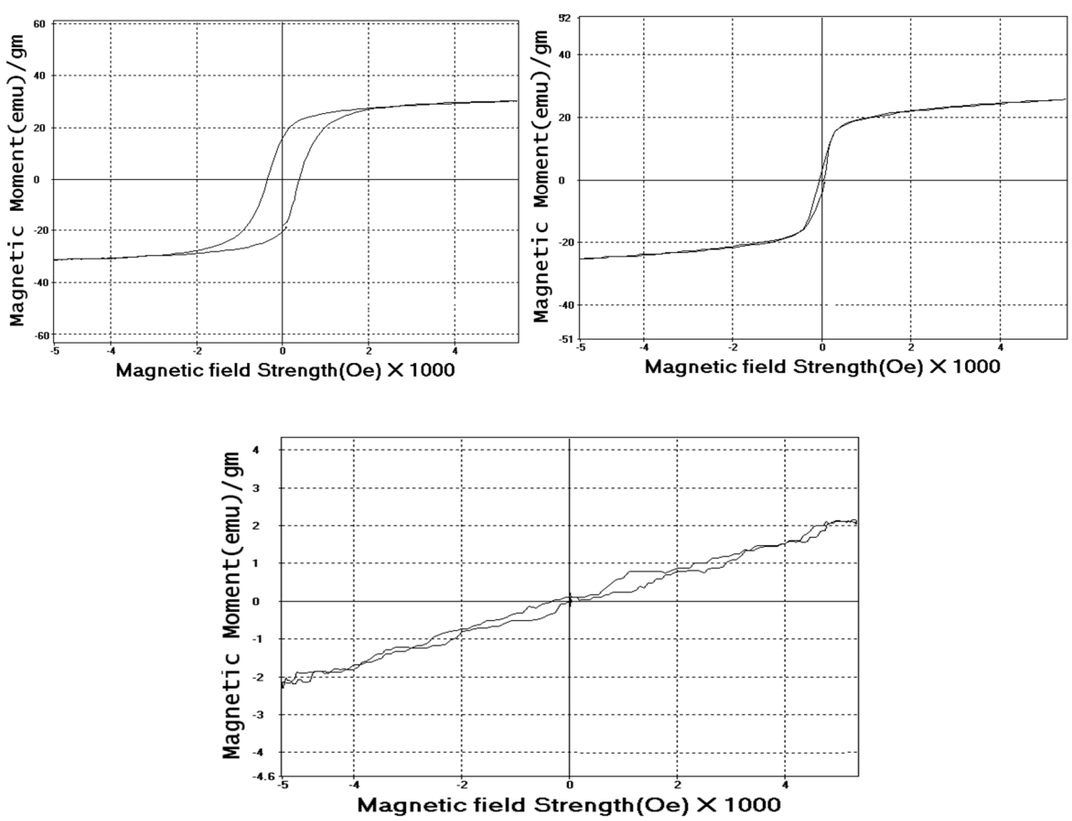

Fig. 1 Hysteresis loop for the $Cu_{1-x}Zn_xFeMnO_4$ ($0.0 \leq x \leq 1.0$) samples

Composition (x)	Saturation magnetization (Ms) emu /g	Remanent magnetization (Mr) emu /g	Coercive field (Hc) Oe	Magnetic moment (n_B)
0.0	34.44	21.19	368.93	1.47
0.25	44.30	28.04	124.36	1.90
0.5	30.26	14.81	76.28	1.30
0.75	25.83	1.97	47.45	1.10
1.0	2.14	0.04	5.19	0.21

Table No 1 Magnetic Hysteresis data for $Cu_{1-x}Zn_xFeMnO_4$ system.

IV. CONCLUSION:

The magnetic features of Cu-Zn ferromanganate nanoparticles ($Cu_{1-x}Zn_xFeMnO_4$) showed dependence upon the concentration of zinc. The saturation magnetization increases with increase in the concentration of

zinc up to x = 0.25and then decreases. The A-B interaction amongst the cation through oxygen ion are mainly responsible for nonlinear trend in magnetization in $CuFeMnO_4$ with the substitution of Cu^{+2} ions by Zn^{+2} ions.

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