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Effect of aluminum on magnetic properties of nanocrystaline copper ferrite

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ABSTRACT

Aluminum substituted copper ferrite samples $CuFe_{2-2y}Al_{2y}O_4$ (where y=0.0, 0.05, 0.15 & 0.25) have been synthesized by conventional oxide ceramic way. The effect of aluminum on structural and magnetic properties is studied. Meanwhile the types of phase formed and the magnetic properties of the produced samples are investigated using X-ray diffraction. Cation distribution is estimated on the basis of magnetic moment per unit cell in Bohr magnet on calculations. All aluminum substituted copper ferrite samples exhibits the single domain to supper paramagnetic (SD – SP) transition near Curie temperature.

Key words: Nanocrystalline ferrite, copper ferrite, prolate type distortions, single domain to super-paramagnetic (SD-SP) transition.

INTRODUCTION

Copper ferrite exhibits inverse spinel tetragonal structure (1-3). Huheey (4) reported that Cu^{2+} (d^9) ion is the John-Teller ion. Degree of inversion in copper ferrite depends upon heat treatment during the preparation (5). When the concentration of Cu^{2+} ion is larger on octahedral (B) site than tetrahedral (A) site, it produces the square bond SP^2 orbital (6), that would give rise the macroscopic tetrahedral observable crystal structure. Tetragonality ratio for slow cooled copper ferrite is reported (7-9) in the range of 1.03 to 1.07 when Cu^{2+}, Mn^{3+}, Cr^{3+} occupies

(B) site and produces prolate distortion (c/a) >1 and when Cr^{3+}, Mn^{4+}, Ni^{2+} occupied on (A) site produces oblate distortions (c/a) < 1, (10, 11). When critical factor of these elements occupy either sites then they only distort the lattice. Cu^{2+} produces tetragonal distortions in the cubic spinel. 70% of copper occupies on (B) site (12). 10 to 40% occupancy of Cu^{2+} at (A) site in $CuFe_2O_4$ is reported (13). It is interesting to study the nature of distorted inverse spinel tetragonal structure of copper ferrite by substituting Al^{3+} ion in the lattice of copper ferrite.

METHODOLOGY

The compositions of $CuFe2_{-2y}Al_{2y}O_4$ (where y=0.0, 0.05, 0.15 & 0.25) nanoparticle size poly-crystalline ferrites were prepared by standard ceramic route. For this, AR grade Fe_2O_3, $_{Al2O3}$ and CuO were used. The sintering process was carried out at 1000^0C for 48 hours. The X-ray powder diffractometry route was used for the study of completion of the solidstate reaction. Saturation magnetization of each composition was carried out using high field hysteresis loop tracer. AC susceptibility of slowly cooled samples was measured in the temperature range 300-800 ^0K using Helmholtz's double coil set-up operating at 263 Hz with constant field of 7 Oersted.

RESULT AND CONCLUSION

Close inspection of (fig.2) depicts the normalized AC susceptibility (χ/χ_{RT}) as a function of temperature. For all synthesized ferrite samples; normalized AC susceptibility slowly increases with rising temperature up to certain point, beyond which it drops off sharply but goes on decreasing slowly with increase in temperature. Increase of normalized AC susceptibility up to crystallographic phase transition temperature (T_P) suggests that the prepared ferrite samples exhibit single domain structure, while the exponential decrease in the normalized AC susceptibility (paramagnetic tail) beyond (T_p) indicates the single domain to super paramagnetic (SD-SP) transition.

The sharp drop in normalized susceptibility near phase transition suggests that impurity phases are not formed in the present ferrite samples. This fact is also confirmed by X-ray diffraction analysis.

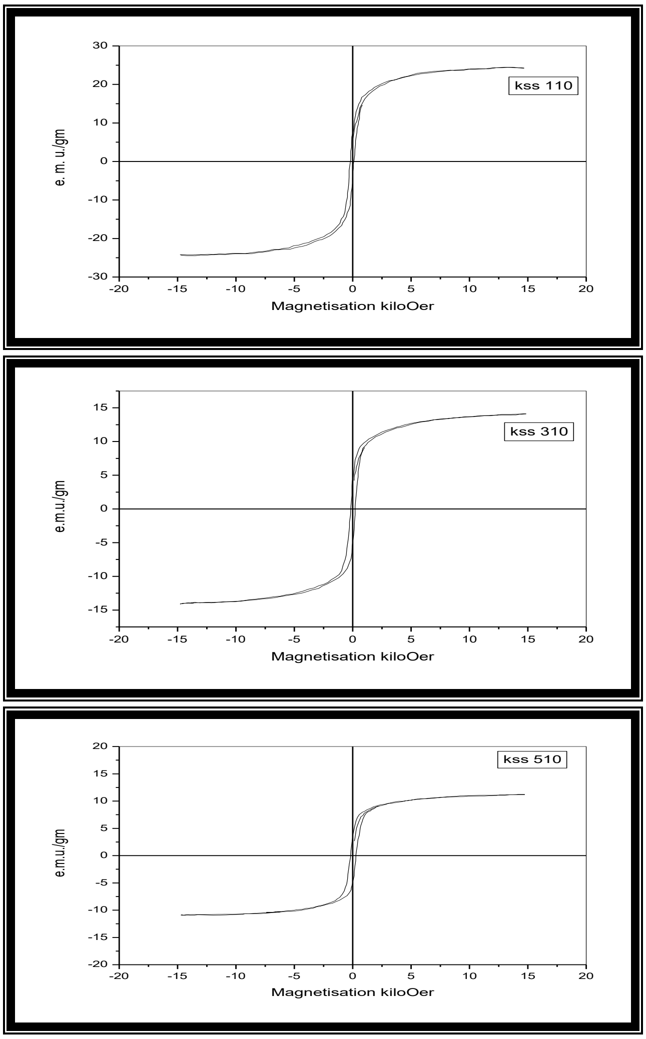

Fig.1 Hysteresis loop of mixed ferrites $CuFe_{2-2y}Al_{2y}O_4$ system for y = .05, 0.15 and 0.25

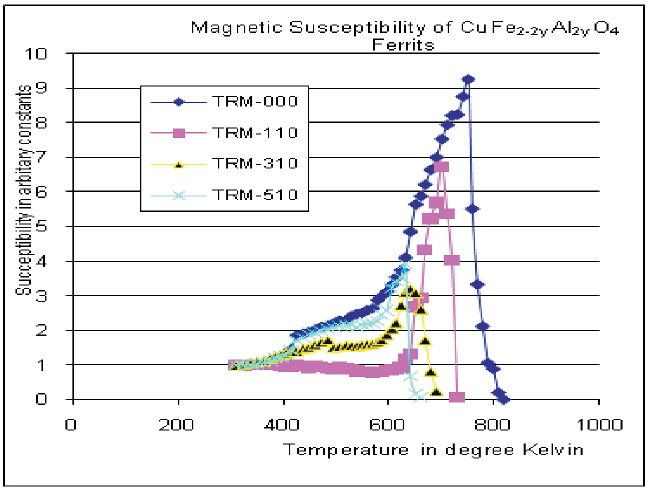

Fig.2 Magnetic Susceptibility of mixed ferritesCu Fe Al O system

Table1 : Magnetization data of ferrite $CuFe_{2-2y} Al_{2y} O_4$ system

Sample Id	Y	Curie Temp. in ^{0}k		Saturation Magnetization (σ_s) in emu/gm	Magnetic moment per unit cell (n_B) in Bohr magnetron
		from Loria sinha method	From magnetic susceptibility Expt.		
TRM000	0.00	748	768	30.35	1.300
TRM110	0.05	690	730	24.75	1.026
TRM310	0.15	651	700.5	14.17	0.5852
TRM510	0.25	631	668.5	11.21	0.4514

The paramagnetic tail indicates the existence of super paramagnetic cluster in the sample by addition of Al^{3+} in the host lattice of copper ferrite.The Curie temperature of such samples can be determined by drawing a tangent to the paramagnetic tail on the temperature axis..Similar type behavior is observed by Karche et.al,(17) in $Cd_xMg_{1-x}Fe_2O_4$ ferrite sample for x = 0.4.The Curie temperatures estimated from normalized AC susceptibility variation with temperature experiment are in excellent agreement with their values measured by Loria Sinha method.

CONCLUSION

Addition of Al^{3+} content in the host lattice of the tetragonal copper spinel ferrite suppresses the tetragonal prolate type distortions and hence crystal structure turned into cubic spinel. All synthesized ferrite samples exhibits single domain to super paramagnetic transition. Super paramagnetic cluster is enhanced because of summation of Al^{3+} in the host lattice of copper ferrite. Al^{3+} affects the structural properties and magnetic properties. Particle size of all prepared samples is found within the nano range.

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