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The Deflection of the Magnetic Ring for the Magnetic System $Co_xCu_{1-x}Fe_2O_4$

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Abstract: In this study, cobalt and copper ferrite compounds were prepared by co-precipitation method, the nanocompound ($Co_xCu_{1-x}Fe_2O_4$) was then prepared by mixing cobalt ferrite and copper ferrite with different ratios of cobalt. The structural, morphological and magnetic properties of the resulted nanoparticles were studied. The XRD measurements showed dominant and high peaks located at 35.54° and 35.31° belong to the (311) $CoFe_2O_4$ and (211) $CuFe_2O_4$ planes, respectively at the same time, a decrease in grain size was observed with an increase in the ratio of copper ferrite as well as a decrease in the expansion of the magnetic hysteresis ring by increasing copper ratio.

Key words: Cobalt ferrite, copper ferrite, vibrating sample magnetometer, compounds, measurements, dominant

INTRODUCTION

Now a days, nanomaterial science and nanotechnology has become very popular among scientists, engineers and industrialists due to its various applications in diverse field. Many works have been done on both bulk and nanomagnetic spinel ferrite compounds (Kumar *et al.* 2010; Shankar and Thapa, 2013; Xavier *et al.* 2013). Cobalt Ferrite ($CoFe_2O_4$) belongs to the spinel oxide family it exhibits face-centred cubic structure in which every unit cell containing 32 of O^{2-}, 8 of Co^{2+} and Fe^{3+} ions. The lattice of oxygen ions are distributed with 64 tetrahedral, 32 octahedral and 24 cations. The $8Co^{2+}$ and $8Fe^{3+}$ cations occupy half of the octahedral sites while the other $8Fe^{3+}$ ions occupy 8 of the 64 tetrahedral sites, therefore $CoFe_2O_4$ is a good example for an inverse spinel structure (Smit and Wijn 1959; Giannakopoulou *et al.* 2002). $CoFe_2O_4$ has been studied by many research groups due to it's remarkable physical properties such as high cubic magnetocrystalline anisotropy, high coercively, moderate saturation magnetization, high mechanical and chemical stability and electrically insulating behavior. These properties make $CoFe_2O_4$ has unique properties make it suitable for technological applications such as magnetic recording devices, gas sensors, catalysis, ferrofluids and medical applications such as drug delivery, biosensor and contrast enhancers in magnetic resonance imaging (Hashim *et al.* 2012; Murugesan and Chandrasekaran, 2015). Cobalt ferrite is synthesized by several methods such as sol-gel (Melo *et al.* 2015), hydrothermal (Kooti *et al.* 2013), co-precipitation (Herrera *et al.* 2013), thermal decomposition (Khan *et al.* 2014) and micro emulsion (Sharma and Ghose, 2014). Among these methods, the co-precipitation methods has many advantages such as homogeneity, small obtained particle size, high purity, low temperature preparation and simple process (Feng *et al.* 2013).

MATERIALS AND METHODS

Experimental procedure: High purity $CoCl_2.6H_2O$, $CuCl_2.2H_2O$ and $FeCl_3$ powders where used to prepare $CoFe_2O_4$ and $CuFe_2O_4$ by using co-precipitation method. An amount of powders was dissolved in 800 mL of distilled water with uniform heating of 60°C using magnetic heating stirrer. The pH of solutions was adjusted to be 8-9 by using ammonia solution and pH-m, then the solution was filtered using Buchner filter and filter paper for 24 h. After dehydration process, the dried mixture was combusted for 6 h and then grinded to get a loose powder. Finally, the powder sintered at 400°C for 6 h and subsequently grinded again to get very fine particles of $CoFe_2O_4$. Same steps were done to obtain $CuFe_2O_4$ (Table 1).

Nano composite of $Co_xCu_{1-x}Fe_2O_4$was prepared by mixing the above ferrites with different ratios of cobalt (x = 0, 0.25, 0.75, 0.90 and 1). After combusting the results, they pressed to (5 ton./cm^2) to get

Table 1: Preparation conditions of prepared samples

Sample	x	$Co_xCu_{1-x}Fe_2O_4$
S_1	0	$CuFe_2O_4$
S_2	0.25	$Co_{0.25}Cu_{0.75}Fe_2O_4$
S_3	0.75	$Co_{0.75}Cu_{0.25}Fe_2O_4$
S_4	0.90	$Co_{0.90}Cu_{0.10}Fe_2O_4$
S_5	1	$CoFe_2O_4$

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disks while they pressed to (3 ton./cm^2) to get belts. The final sintering was at 800°C. The crystallite structures of the prepared samples were studied by using Philips PW1710 X-ray diffractometer with a Cu-K$_\alpha$ radiation source (λ = 1.5405 Å). All prepared samples were denoted as in Table 1. Magnetic properties were studied by using Vibrating Sample Magnetometer (VSM).

RESULTS AND DISCUSSION

The structural characterizations and phase formation for cobalt and copper ferrites were carried out using X-ray diffraction at room temperature. Figure 1a and c shows the XRD patterns of $CoFe_2O_4$ and $CuFe_2O_4$ after initial combustion, respectively in which there are sharp peaks located at 2θ equal to 35.64° and 35.59° correspond to the (311) $CoFe_2O_4$ and (211) $CuFe_2O_4$ planes, respectively in addition to other peaks of unidentified phases belong to impurities. After final combustion, Fig. 1b and d, one can observe a dominant and high peaks located at 35.54° and 35.31° belong to the (311) $CoFe_2O_4$ and (211) $CuFe_2O_4$ planes, respectively. This findings are in agreement with (JCPDS-77-0426) for $CoFe_2O_4$ and (JCPDS-34-0425) for $CuFe_2O_4$. The sharpness of peaks indicated the high crystalline nature of the expected cubic spinel structure, therefore, our conditions are required to prepare the spinel structure of cobalt and copper ferrites precipitates. The mean crystallite size D of the cobalt and copper ferrites was calculated using Debye-Scherrer formula (Abud *et al*. 2013) for the strongest peak after final combustion as follows:

$$D = \frac{0.9\lambda}{B\cos\theta}$$

Where:

λ = The wavelength of the X-ray
B = The FWHM (in radians)
θ = The diffraction angle

The values of D are listed in Table 2 in which the value of D for $CuFe_2O_4$ is greater than that one of $CoFe_2O_4$ that is due to the cation radius of cobalt is greater than cation radius of copper. The magnetic measurements of the ferrites samples were recorded at room temperature by using VSM. The magnetic deceleration can help to understand the magnetic behavior of the samples as well

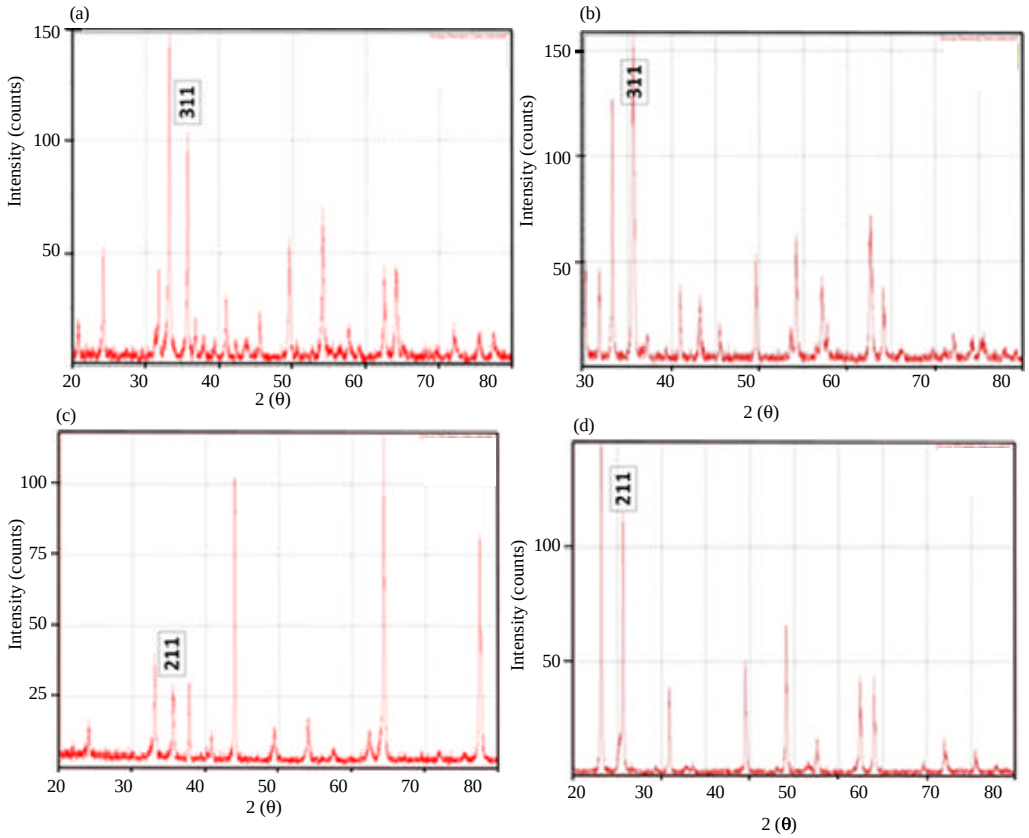

Fig. 1: XRD patterns of: a) $CoFe_2O_4$ after initial combustion; b) $CoFe_2O_4$ after final combustion; c) $CuFe_2O_4$ after initial combustion and d) $CuFe_2O_4$ after final combustion

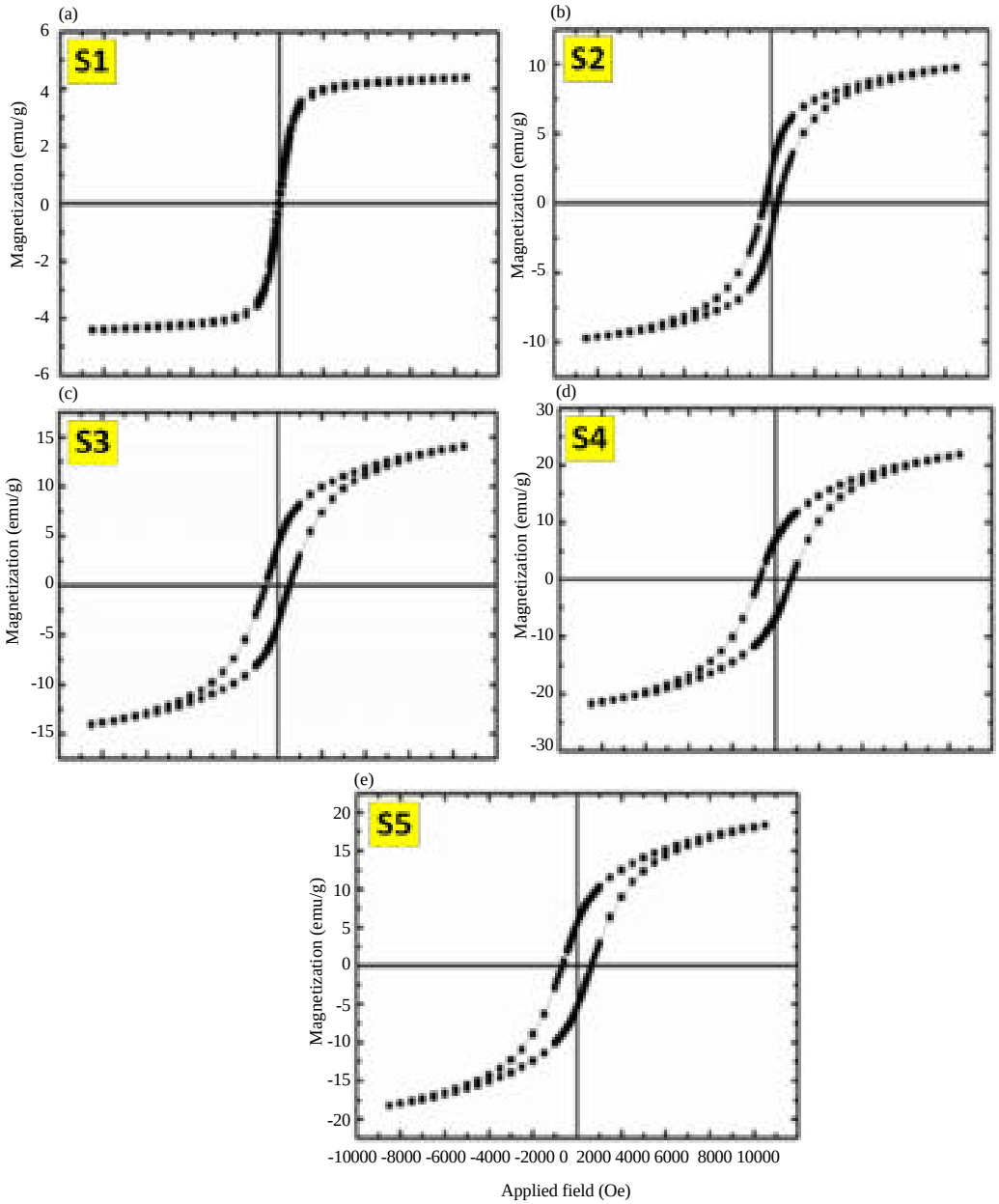

Fig. 2: a-c) Magnetic hysteresis curves of $Co_xCu_{1-x}Fe_2O_4$ with different ratios of Co at sintering of 800°C for 6 h

Table 2: The diffraction peak positions, FWHM and particles sizes of prepared samples after final composition for 6 h at 800°C

Sample	2°	FWHM°	D (nm)
$CoFe_2O_4$	35.5457	0.27830	31.3230
$CuFe_2O_4$	35.5530	0.22470	38.7956

as provide us the information about certain magnetic factors such as saturation magnetism, coercive force and remaining magnetism. Figure 2 shows the magnetization as a function of the strength of the applied magnetic field for all compounds. In which the narrow hysteric rings indicate that these materials are soft-ferrites; This result was confirmed by XRD data. At the same time, Magnetic saturation (Ms), remaining Magnetism (Mr), coercive force (Hc) and the ratio of Mr/Ms were calculated and summarized in Table 3. It is observed that all above coefficients were increased with increasing the ratio of cobalt; this increasing is due to the difference in the crystallization and size of nanoparticles as well as to the distribution of positive ions in the four and eight-surface locations. A gradual decrease in saturation and alkaline magnification is noticed with increasing cobalt ratio in the compound

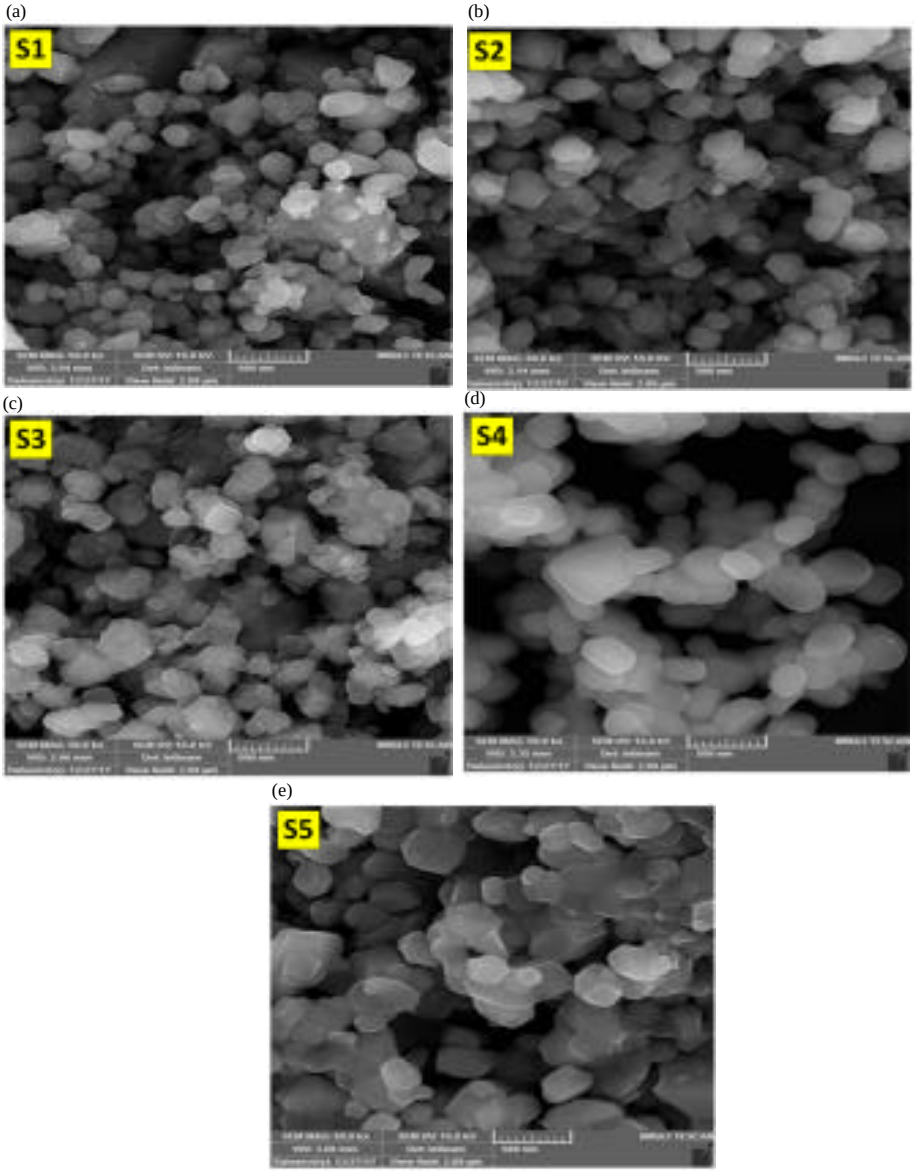

Fig. 3: a-e) FESEM images of $CoxCu_1$-xFe_2O_4 with different ratios of Co

Table 3: Magnetic saturation (Ms), remaining Magnetism (Mr) and coercive force (Hc) as a function of cobalt ratio

Sample	Ms	Mr	Hc	Mr/Ms
S_1	4.388	0.363	87	0.083
S_2	9.726	2.225	293	0.229
S_3	14.06	3.978	520	0.283
S_4	18.33	5.531	657	0.302
S_5	21.87	6.883	731	0.315

$Co_xCu_{1-x}Fe_2O_4$ due to the rearrangement of cations tetrahedral and octahedral where cobalt and iron occupy more locations in four-surface locations. Because of the magnetic behavior of copper is lower than cobalt. It is clear that th coercive force decreased with decreasing the copper ratio in $Co_xCu_{1-x}Fe_2O_4$; this can be attribute to the decrease in the anisotropic field which in turn reduces the energy of the area wall. FESEM images were used to investigate the surface morphology of the cobalt doped ferrite ($Co_xCu_{1-x}Fe_2O_4$) with different ratio (0, 25, 0.75, 0.90 and 1) as shown in Fig. 3. The agglomeration process formed large clusters of particles. All samples exhibit nanoparticles with size increased with increasing cobalt ratio. The average diameter of particles for all samples is 97.82 nm as shown in Fig. 3 .The increasing in the particle size ascribe to the formation of Cu-O-Fe bonds on the surface which is turn retards the growth of crystal grains and assists to the separate particles.

CONCLUSION

In summary, cobalt and copper ferrite compounds were prepared by co-precipitation method. The structural and magnetic properties of the resulted nanoparticles were studied. The XRD measurements showed dominant and high peaks located at 35.54° and 35.31° belong to the (311) $CoFe_2O_4$ and (211) $CuFe_2O_4$ planes. These results confirm that the ferrites have good crystalline quality with cubic spinel structure. The magnetic characteristics of $Co_xCu_{1-x}Fe_2O_4$ with different ratios of cobalt were investigated. The magnetic saturation, remaining magnetism and coercive force were increased with increasing the ratio of cobalt.

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REFERENCES

Abud, S.H., A. Ramiy, A.S. Hussein, Z. Hassan and F.K. Yam, 2013. A comparative study of the structural and electrical properties of n-type InGaN epilayer grown by MBE and commercially. Superlattices Microstruct., 60: 224-230.

Feng, J., L. Su, Y. Ma, C. Ren and Q. Guo *et al*., 2013. $CuFe_2O_4$ magnetic nanoparticles: A simple and efficient catalyst for the reduction of nitrophenol. Chem. Eng. J., 221: 16-24.

Giannakopoulou, T., L. Kompotiatis, A. Kontogeorgakos and G. Kordas, 2002. Microwave behavior of ferrites prepared via sol-gel method. J. Magnetism Magn. Mater., 246: 360-365.

Hashim, M., Alimuddina, S. Kumar, B.H. Koo and S.E. Shirsath *et al*., 2012. Structural, electrical and magnetic properties of Co-Cu ferrite nanoparticles. J. Alloys Compd., 518: 11-18.

Herrera, A.P., L. Polo-Corrales, E. Chavez, J. Cabarcas-Bolivar and O.N. Uwakweh *et al*., 2013. Influence of aging time of oleate precursor on the magnetic relaxation of cobalt ferrite nanoparticles synthesized by the thermal decomposition method. J. Mag. Mater., 328: 41-52.

Khan, M.A., M. Sabir, A. Mahmood, M. Asghar and K. Mahmood *et al*., 2014. High frequency dielectric response and magnetic studies of $Zn_{1-x}Tb_xFe_2O_4$ nanocrystalline ferrites synthesized via micro-emulsion technique. J. Magnetism Magnetic Mater., 360: 188-192.

Kooti, M., S. Saiahi and H. Motamedi, 2013. Fabrication of silver-coated cobalt ferrite nanocomposite and the study of its antibacterial activity. J. Mag. Mater., 333: 138-143.

Kumar, P., S.K. Sharma, M. Knobel and M. Singh, 2010. Effect of La^{3+} doping on the electric, dielectric and magnetic properties of cobalt ferrite processed by co-precipitation technique. J. Alloys Compd., 508: 115-118.

Melo, R.S., F.C. Silva, K.R.M. Moura, A.S. De-Menezes and F.S.M. Sinfrionio, 2015. Magnetic ferrites synthesised using the microwave-hydrothermal method. J. Mag. Mater., 381: 109-115.

Murugesan, C. and G. Chandrasekaran, 2015. Impact of Gd^{3+} substitution on the structural, magnetic and electrical properties of cobalt ferrite nanoparticles. Res. Adv., 2015: 73714-73725.

Shankar, A. and R.K. Thapa, 2013. Electronic, magnetic and structural properties of the filled skutterudite $EuFe_4P_{12}$: LSDA and LSDA+U calculation. Phys. B: Cond. Matter, 427: 31-36.

Sharma, R.K. and R. Ghose, 2014. Synthesis of nanocrystalline CuO-ZnO mixed metal oxide powder by a homogeneous precipitation method. Ceram. Intl., 40: 10919-10926.

Smit, J. and H.P.J. Wijn, 1959. Ferrites. Philips Technical Library, Eindhoven, Netherlands, Pages: 387.

Xavier, S., S. Thankachan, B.P. Jacob and E.M. Mohammed, 2013. Effect of sintering temperature on the structural and magnetic properties of cobalt ferrite nanoparticles. Nanosystems Phys. Chem. Math., 4: 430-437.