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Study on optical, magnetic and structural Properties of $CuFe_2O_4$ by Co-precipitation technique

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Abstract - *Ferrite nanoparticles have betrothed substantial significance in the contemporary epoch due to their unrivalled feasibility in the scientific and technological areas of research. Nanosized spinel ferrites are the noteworthy group of materials, which have radically modulated the contemplation of research humanity due to their exceptional structural, optical and magnetic properties. These properties are catered in $CuFe_2O_4$ which make it an appropriate contender in the areas of applied optics and telecommunication. A credible and reasonably feasible co-precipitation method has been the core of consideration in recent years to synthesize these nanoparticles. The synthesized samples are characterized by powder X-ray diffraction which evidence the occurrence of sharp diffraction peaks crystallite size has been vague to be 11.04 nm. TEM micrograph exposed the structural characterization clearly divulge their cubic nature and prominent crystallinity. The FT-IR measurements carried out in the range of 4000-400 cm^{-1} elucidate the presence of functional groups. UV-visible spectral analysis (UV-vis) reveals the optical property and hence optical band gap is found out using Kubelka-Munk plot*.

***Key Words*: copper ferrite ($CuFe_2O_4$); Co-precipitation; X-ray technique; FTIR;**

1. INTRODUCTION

Ferrites nanomaterials are more momentous due to its optical, electrical and magnetic properties, which makes it a functional set of materials for various scientific and industrial applications [1], such as flexible recording media, superconductors, magnetic refrigerator, gas-sensitive materials, magnetic resonance imaging contrast enhancement, Li-batteries [3-5] etc. Among inverse spinel ferrites, copper ferrite has imperative properties such as thermal and chemical stability. The band gap of bulk copper ferrite ($CuFe_2O_4$) is 1.92 eV [6]. There are different synthesis routes adopted to synthesize $CuFe_2O_4$ are many such as co-precipitation, microemulsion method, sol-gel, ball milling, hydrothermal method, solvothermal synthesis and ceramic method, etc. Among these routes, chemical precipitation is facile method to synthesis inverse spinel $CuFe_2O_4$ nanoparticles at low temperature. There some significant advantages in co-precipitation method such as high purity, uniform crystallite size formation and possibilities to modify the particle surface along with homogeneity [7].This work elucidates the synthesis of spinel Nickel ferrite nanoparticles by chemical route and their properties were studied.

2. Material Synthesis

The chemical was used without further purification, copper nitrate and ferric nitrate was taken in a ratio of 1:2. The chemical was dissolved in 100 ml of double distilled water with a continuous stirring in order to attain homogeneity. Then, 2 M of the NaOH was added in drops as a mineralizer into the above solution inorder to attain pH 9 and then the mixer was kept at an ambient temperature for 2 hours. The precipitate washed several times using double distilled water and ethanol inorder to remove nitrate from the precipitate. The product was dried in an oven at 80 °C under atmosphere for overnight; the resultant by-product was grounded and then annealed at 500 °C for 3 h in a muffle furnace. The obtained nanopowder was given for characterization to study its properties.

3. Results and discussion

XRD analysis of $CuFe_2O_4$ nanoparticles was performed on 3003 TT X-ray diffractometer with CuKα radiation (λ=1.540598 Å). Fig. 1 depicts the diffraction peaks of inverse spinel $CuFe_2O_4$ with a lattice parameter of 8.352 Å for the as-synthesis sample. The speck size was determined by using Scherer's formula, $\Phi = k\lambda/\beta\cos\theta$, where θ and β are the diffraction angle and full-width at half-maximum, Φ is the grain size in nm, k is a constant

equal to 0.89 and λ is the X-ray wavelength respectively. The crystallite size for the as-synthesized sample was found to be 11.04 nm.

FTIR spectroscopy for the as-synthesized sample $CuFe_2O_4$ was performed on a Perkin Elmer spectrometer was analysed in the range of 400-4000 cm^{-1}. Fig.2 depicts the functional group with oxygen in tetrahedral and octahedral sites. The main absorption band characteristics of $CuFe_2O_4$ occur at 428 and 577 cm^{-1} corresponds to stretching vibrations of metal-oxygen located at octahedral and tetrahedral sites. The absorption peaks at 1546 and 3563 cm^{-1} is due to moisture present in the as-synthesized sample. The optical absorption spectrum for $CuFe_2O_4$ nanoparticles by co-precipitation method is shown in Fig.3a. The absorption coefficient (α) corresponds with the band gap (E_g) is given by, $\alpha h\nu = B(h\nu - E_g)^{1/2}$, where B is a constant in direct transition and hν is the energy of photon. By extrapolating the linear segment of the energy axis at zero absorption gives the band gap of $CuFe_2O_4$. The as-synthesized has a blue shift of the absorption edge compared to the bulk counterpart. The loop shows the soft magnetic property of the material which carries implication application in memory devices. Obtained rententivity, Coercivity and magnetic moment value for the $CuFe_2O_4$ nanoparticle is 3.624×10^{-3}emu/g, 302.85 G and 0.0119 respectively. TEM micrograph of the $CuFe_2O_4$ nanoparticle synthesized by coprecipitation technique was analysed for its morphology and the size distribution in Fig.5. The varying pH had no obvious effect on the morphology, but it affects the crystallite size, which demonstrates that the as-synthesized $CuFe_2O_4$ nanoparticles is spherical and monodisperse with a grain size of 10 nm, which is smaller than XRD crystallite size calculation.

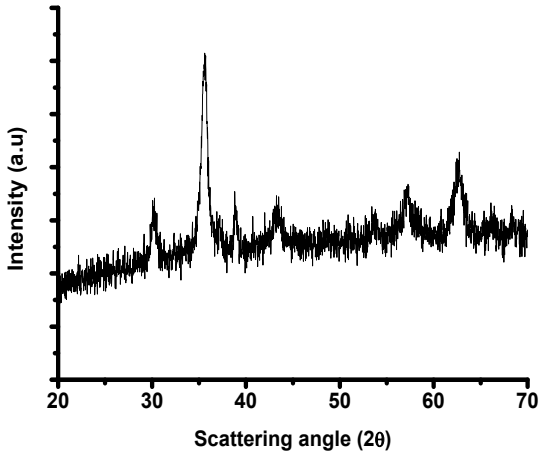


Fig.1 XRD diffraction pattern of $CuFe_2O_4$

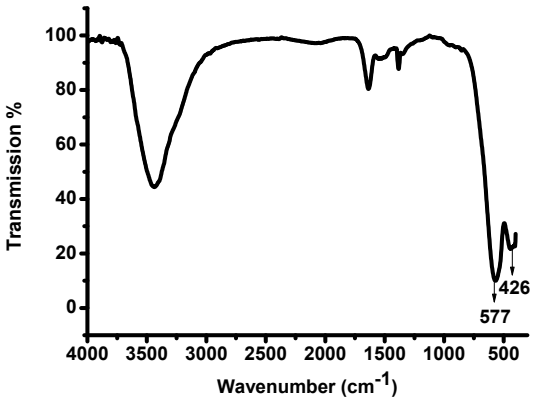
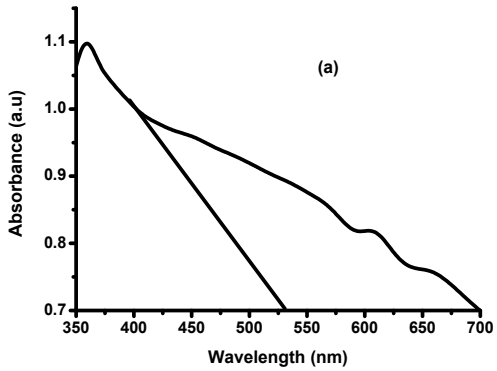


Fig. 2 FTIR spectrum of $CuFe_2O_4$ nanoparticles



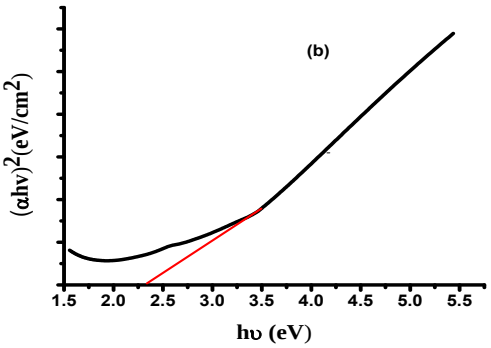


Fig. 3 a) Optical absorption spectra of $CuFe_2O_4$ nanoparticles as-synthesized using co-precipitation and b) their comparison plot of $(\alpha h\nu)^2$ versus photon energy ($h\nu$).

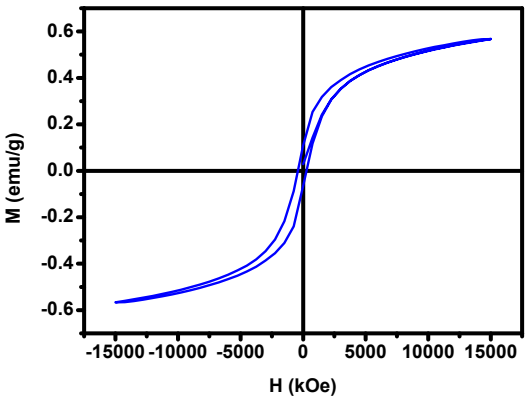


Fig.4 Hystersis loop for $CuFe_2O_4$ nanoparticle

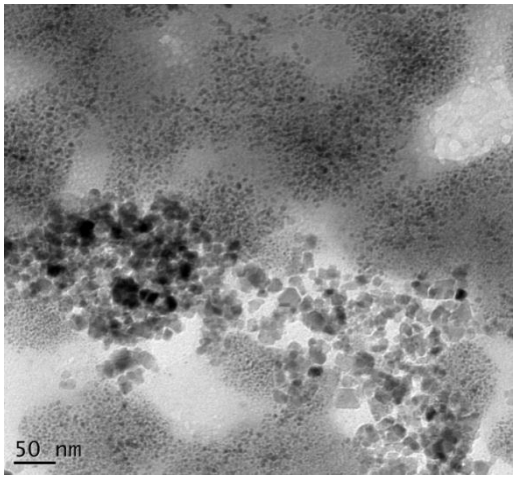


Fig.5 TEM for $CuFe_2O_4$ nanoparticle

The arrangement of the particles allows in determining the size distribution generated in Fig. 5 which reflects the TEM micrograph of the CuFe2O4 sample prepared by co precipitation route. The pH had no obvious influence on the structure, but it affects the crystallite size, which demonstrates that the $CuFe_2O_4$ nanoparticles is cubically spherical and mono disperse with average grain size was found to be 17 nm, which is smaller than Scherrer calculation.

4. Conclusion

In this investigation, inverse spinel phase $CuFe_2O_4$ nanoparticle was economically synthesized by co-precipitation route, ensuing its significant structural, magnetic and optical properties. We may therefore conclude that, a $CuFe_2O_4$ nanoparticle is an incredible and imminent magnetic material for advance investigations and memory device applications.

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