Optical properties of green synthesized $Cu_{0.6}Zn_{0.4}Fe_2O_4$

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Abstract: Nano sized $Cu_{0.6}Zn_{0.4}Fe_2O_4$ was green synthesized using Indian gooseberry with low cost and ecofriendly approach. A structural and optical property of prepared sample is determined and characterized using X-ray diffraction (XRD) analysis, Far Fourier transform infrared spectroscopy (Far FTIR) and UV-Vis spectroscopy. X-ray diffraction confirms spinel structure of Cu0.6Zn0.4Fe2O4. The value of average particle size & lattice parameter calculated from XRD analysis was found to be 8.36°A and 40.69 nm. Far FTIR confirms the presence of octahedral & tetrahedral functional groups. From UV-Vis spectroscopy, direct energy band gap value was found to be 3.068 eV..

Index Terms **– Green synthesis, ferrite, X-Ray Diffraction.**

I. INTRODUCTION

Ferrites attracted interest of many researcher because of having properties like high resistivity, high dielectric constant, high magnetic saturation, high Curie temperature & wide range applications in spintronics devices, satellite communication, memory device, magnetic sensors, transformers, magnetic refrigeration, contrast enhancement in magnetic resonance imaging, high density storage, magnetic recording area, multilayer chip inductor (MLCI), surface mount devices (SMD), biomedical applications like drug delivery, hyperthermia, bone tissue engineering, catalyst in chemical reaction[1]–[5].

Spinel ferrite has general formula AB_2O_4, where A & B are divalent & trivalent cations occupying tetrahedral (A) & octahedral position (B) in the face centered cubic lattice of oxygen anions. When divalent cations occupy tetrahedral (A) position, normal spinel ferrite is formed. When divalent cation occupies both tetrahedral (A) & octahedral site (B), inverse spinel ferrite is formed. Magnetic & electric properties of ferrite material are dependent on distribution of divalent & trivalent cations in the FCC structure of oxygen anions. $ZnFe_2O_4$ has normal spinel structure having Zn^{+2} at tetrahedral site (A) & Fe^{+3} at octahedral site (B) [6] while $CuFe_2O_4$ is example of inverse spinel structure with Cu+2 divalent cation at octahedral site (A) & trivalent cations Fe^{+3} is distributed over both octahedral (B) & tetrahedral site (A)[7]. In $CuFe_2O_4$, Cu^{+2} ions prefer 8 octahedral sites (B) and the remaining 8 octahedral sites filled by Fe^{+3} ions. The remaining 8 Fe^{+3} ions go to the tetrahedral site (A). In antiferromagnetic interaction, magnetic moments of Fe^{+3} ions cancel with each other & resulting magnetic momenta will only from Cu^{+2} ions. Distribution of ions over tetrahedral (A) & octahedral site (B) are responsible for various properties of ferrite, many attempts were made by researcher to improve to structural, magnetic, optical properties of using mixed Cu-Zn ferrite for wide range of applications.[8]–[10]

The preparation method had a great impact on the physical & chemical properties on material. Ferrites are prepared by many methods like precursor method[11], combustion method[12], co-precipitation method[13], hydrothermal method[14], sol-gel method [15]. Recent technological advances emphasize cost and environment efficient synthesizing techniques leading to many researchers to focus on green synthesis technique. Raghvendra Singh Yadav et al green synthesized nanostructure Zn Fe_2O_4 via honey mediated sol gel & reported structural, optical, magnetic, dielectric, electric properties [16]. Dana Gingasu et al used extract of Hibiscus Rosa Sinensis flower & leaf to prepare $CoFe_2O_4$ & $AgCoFe_2O_4$ to study antimicrobial potential[17] . Yan Cai green synthesized Soya bean sprout mediated superparamagnetic Fe_3O_4 nanoparticles[18] . Muhammad Imran Din et al studied $ZnFe_2O_4$ nanoparticles stabilized by Piper nigram plant extract [19]. Annrose Sunny et al reported magnetic properties of $CoFe_2O_4$ prepared using egg white extract [20] .

In the present paper, we are studying structural & optical properties of green synthesized $Cu_{0.6}Zn_{0.4}Fe_2O_4$ nanostructure using extract of Indian gooseberry mediated by sol-gel method. Indian Gooseberry is nutritious, easily available, low cost fruit having great importance in medicine. Indian gooseberry is a rich source of ascorbic acid which can be employed as a reducing agent in chemical reaction[21] .

II. EXPERIMENTAL PROCEDURE

All the chemical reagents used in preparation $Fe(NO_3)_3.9H_2O$, $Zn(NO_3)_3.6H_2O$, $Cu(NO_3)_3.3H_2O$ are nitrates of all metal ions of analytical grade & used without any purification. Fresh Indian gooseberry fruits were purchased from the local market of Nashik and its extract is used as a reducing agent in green synthesis of $Cu_{0.6}Zn_{0.4}Fe_2O_4$. All the solutions of metal nitrates of respective stoichiometric proportion are prepared in different beakers in 50ml double distilled water & stirred for 20 minutes to form a homogenous mixture. All these solutions are added in 20 ml fresh prepared Indian gooseberry juice drop wise & kept for stirring with continuous heating at 100°C for. After 3 hours the solution will convert in gel form & afterwards in raw powder form with auto ignition. This raw powder is grounded in & subjected to heat treatment of 700°C for 4 hours.

Structural information of powdered sample of $Cu_{0.6}Zn_{0.4}Fe_2O_4$ is obtained through X-ray diffraction (XRD) using Brooker D8 advance machine by Cu Kα radiation. Active vibrational modes in structure were confirmed by Fourier Transform Infrared Spectra (FTIR) using Perkin Elmer Spectrophotometer. Using Ultraviolet spectroscopy, optical properties of powdered sample are determined.

III. RESULT AND DISCUSSION

3.1 Structural analysis

Fig.1 shows XRD pattern of green synthesized $Cu_{0.6}Zn_{0.4}Fe_2O_4$. The diffraction pattern is obtained to analyze phase, crystalline size, and lattice parameter of the prepared sample. The sample shows cubic spinel structure with spatial Fd3m group. The XRD peaks of the sample represent spinel phase corresponding to plane (111), (200), (311), (222), (400), (422), (511) and (440) that fit with JCPDS card no.82-1042. The value of lattice constant is 8.36 °A and average crystalline size is 40.69 nm. These values are calculated using Debye-Scherer formula

$$a = d_{hkl}\sqrt{h^2 + k^2 + l^2} \ \& \ D = \frac{0.9\lambda}{\beta cos\theta}$$

Where, a is lattice constant, d_{hkl} - inter-planar distance, hkl - Miller indices, D - average crystalline size, λ - wavelength of x-ray radiation used, β - full width half maxima for most intense peak, θ -Bragg's angle for the most intense peak.

3.2 FTIR analysis

Fig.2 shows far FTIR spectra of green synthesized $Cu_{0.6}Zn_{0.4}Fe_2O_4$. The far FTIR gives information about the crystal's vibration mode. Far FTIR spectra is recorded in the region 300 to 700 cm-1. FTIR spectra shows, position of two strong bands at 400 cm-1 & 580 cm-1 confirms spinel structure of ferrite [22]. First band appearing in the wavelength at 400 cm-1 can be attributed to vibration of bond between octahedral metal ion & oxygen ion. The second band at 580 cm-1 shows vibration of tetrahedral metal ions & oxygen ions. [23].

3.3 Optical properties (UV-Visible spectral analysis)

Optical behavior & energy band gap value of Indian gooseberry mediated green synthesized $Cu_{0.6}Zn_{0.4}Fe_2O_4$ is determined using UV-Visible absorbance in between 300 – 800 nm using UV-Visible spectrometer. Optical band gap energy is calculated using Tauc's plot using relation given bellow

$$(\alpha h\vartheta)^{\frac{1}{n}} = A(h\vartheta - E_g)$$

Where A is constant, α is absorbance coefficient, $h\vartheta$ is incident photon energy, E_g is band gap energy, n is the constant whose value is depend upon type of transition of electron (in this case for direct allowed transition $n = \frac{1}{2}$). Direct bandgap energy is calculated from the graph$(\alpha h\vartheta)^2$ verses $h\vartheta$ and then extrapolating the straight portion on energy axis at $\alpha = 0$. The straight line plot shown in figure 3 implies the direct energy band gap value of green synthesized $Cu_{0.6}Zn_{0.4}Fe_2O_4$ is 3.068 eV. Similar results are found to Talaat M Hammad et.al. [24] & Surendra singh et al.[25]

IV. CONCLUSION

In the present study, synthesis of $Cu_{0.6}Zn_{0.4}Fe_2O_4$ has been achieved using Indian gooseberry with eco-friendly, low cost green approach. The spinel structure of $Cu_{0.6}Zn_{0.4}Fe_2O_4$ is confirmed by XRD analysis. Using XRD analysis values of lattice constant and average particle size were found to be 8.36 °A and 40.69 nm . Far FTIR analysis confirms the presence of tetrahedral & octahedral sites at 400 cm-1 & 580 cm-1 which also confirms spinel structure. From UV- vis spectroscopy and using Tauc's plot, the value of direct bandgap was 3.068 eV.

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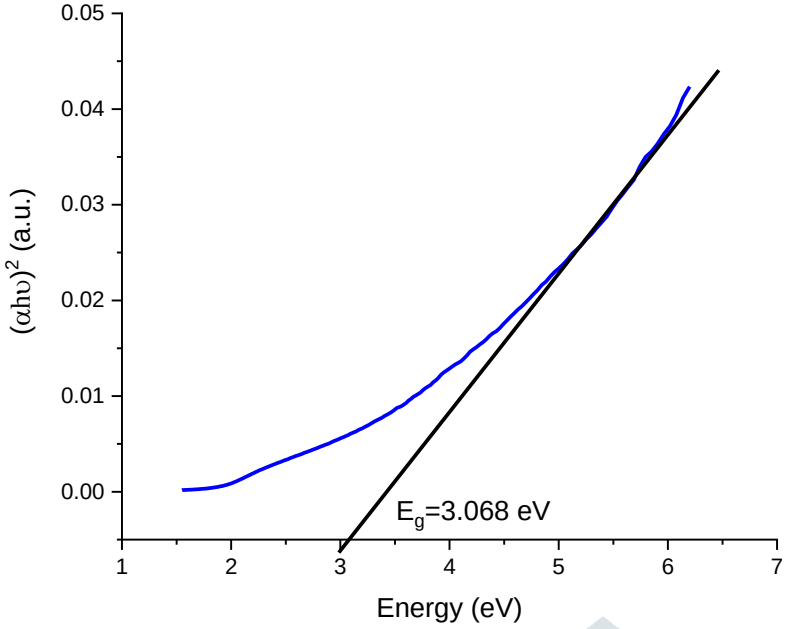

Figure 3

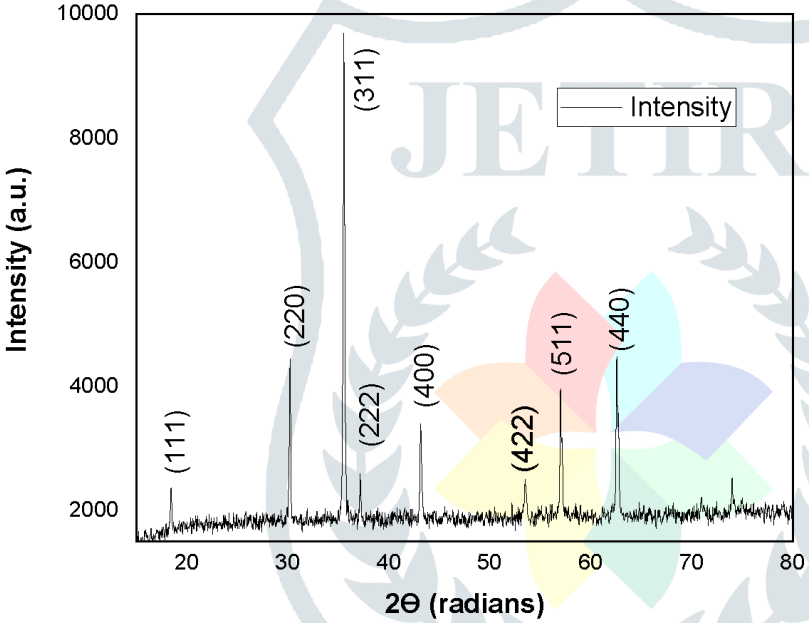

Figure 1

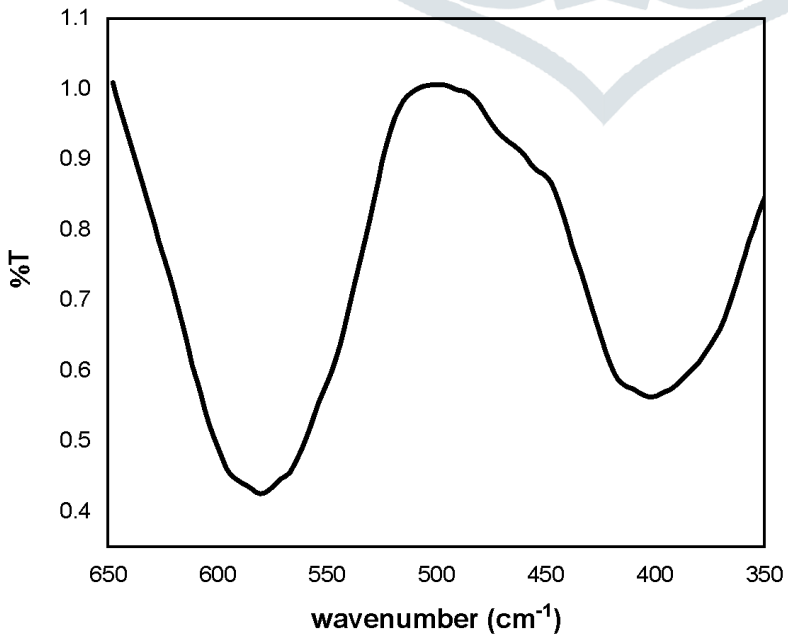

Figure 2