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Synthesis and characterization of $Zn_{0.8}Cu_{0.2}Fe_2O_4$ nanoparticles

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Abstract

The present work aims to synthesize Zinc copper Ferrite (ZCF) Nanoparticles (NP's) by using low cost hydrothermal technique. Afterwards, the prepared ZCF NP's characterized by various techniques. In this connection, the presence of metal oxide bonds were confirmed by Fourier transform infrared spectroscopy (FTIR), Further, X-ray diffraction (XRD) analysis revealed the presence of cubic spinel structured NP's with single phase. The average particle and surface morphology is studied by using field emission scanning electron microscope (FESEM). In addition, the antimicrobial studies carried out against Proteus vulgaris. confirmed that the prepared NP's exhibit excellent antimicrobial performance against different pathogenic gram-positive and gram-negative bacteria.

Keywords: Spinel ferrite; Hydrothermal technique; Nanoparticles; Antimicrobial activity

1. Introduction

Nanoparticles with spinel ferrites structure have wide range of technological applications e.g., in high-speed digital tape or recording disks, ferro-fluids, multilayer chip inductor (MLCI), humidity sensor, rod antenna[1-9]. Due to their specific properties such as superparamagnetism, ferrite nanoparticles are also having various applications, such as magnetic refrigeration systems, bioseparation and inter-body drug delivery[10-12]. In addition, zinc ferrites are being used in gas sensing[13-15], absorbent materials[16], photocatalyst[17, 18] and catalytic application[19]. The unit cell of spinel ferrites is made up of oxygen atoms in cubic closed-packed arrangement shared in tetrahedral 'A' and octahedral 'B' sites. Depending on the substitution of cation the structural and chemical properties of spinel ferrite nanoparticles are affected by their synthesis methods, compositions and corresponding electric and magnetic properties. Ferrite nanoparticels doped with various metals, such as manganese, copper, chromium and zinc are usually employed to enhance some of their electric or magnetic properties [20-22]. For example, Zinc/Nickel ferrites act as soft magnetic materials with high frequency (because of good electrical resistivity and less eddy-current loss). Nickel ferrites offer a further development as softer magnetic materials [23]. In this work, we focused on effect of Cu substitutions on zinc ferrite nanocrystals prepared through the low cost hydrothermal method. Specifically, at room temperature we analysed the structural properties by using X-ray diffraction and optical properties of the prepared samples. Fourier Transform Infra-Red (FTIR) spectroscopy and morphology has been studied using Scanning electron microscope.

2. Sample Preparation

Among various synthesis techniques, hydrothermal technique is low temperature and inexpensive technique. Herein, we followed the low cost hydrothermal technique for preparing $Zn_{0.8}Cu_{0.2}Fe_2O_4$ nanoparticles. At the outset, all the precursors with high purity stirred as per the stoichiometric ratio on a magnetic stirrer for 120 minutes. As a result we got an aqueous solution. After that the solution was transferred to Teflon container which further kept in a stainless

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steel autoclave reactor. The hydrothermal reaction has been done in the hot air oven for 7 hours at 150⁰C. Later on the temperature is reduced to room temperature. Afterwards, the acquired solution is washed several times for removing contaminants. The precipitate dried naturally and grinded with the help of agate mortar. The obtained powder sample sent to various characterizations for studying their properties [24-26].

3. Results and Discussion

3.1. XRD analysis

The X-ray diffraction patterns for the $Zn_{0.8}Cu_{0.2}Fe_2O_4$ nanoparticles are shown in Figure 1. At 35.64^0, the strongest reflection peak at 2θ value was identified for each diffraction pattern of the samples and assigned diffraction peak typical for the spinel phase. Thus, the XRD patterns confirm the formation of single-phase cubic spinel structure. All the reflection peaks were identified and indexed in good agreement with the referred database of the JCPDS [27-29].

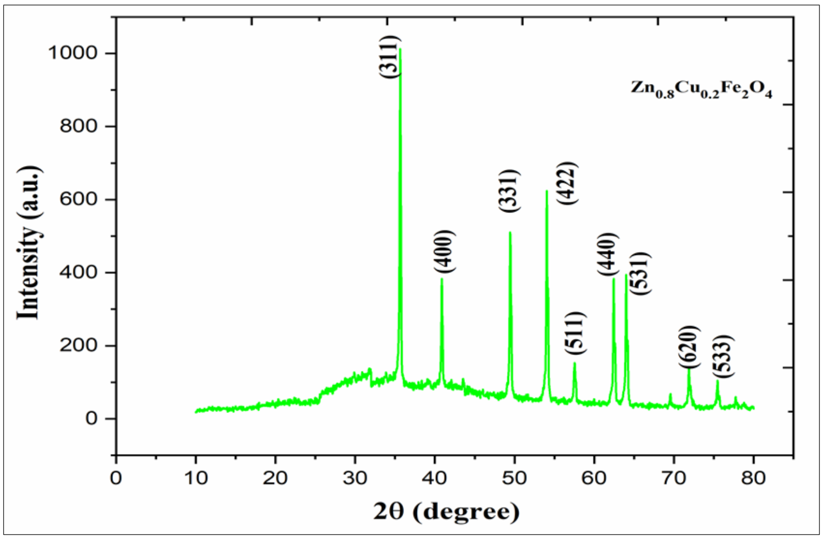

Figure 1 XRD Pattern of $Zn_{0.8}Cu_{0.2}Fe_2O_4$ nanoparticles

3.2. FTIR Analysis

The FTIR spectra at room temperature of the $Zn_{0.8}Cu_{0.2}Fe_2O_4$ nanoparticles were studied and it shown in Figure 2. Recorded FTIR spectra consists of six absorption bands and were observed around at 420, 509, 1328, 1642, 2344 and 3363 cm^{-1}. The two main absorption peaks of spinel ferrite are observed in the spectra. The absorption band at 420 cm^{-1} attributed to the stretching vibration of Fe-O in octahedral. These two absorption peaks could suggest the existence of the spinel-type structure. The bands at 1338 and 1643cm^{-1} correspond to the stretching vibration of the C-H bond. Other rational absorption peaks at 2345 and 3484cm^{-1} were less rigorous peak at are endorsed to the stretching and bending vibrations of H-O-H bonds on the surface [30-32].

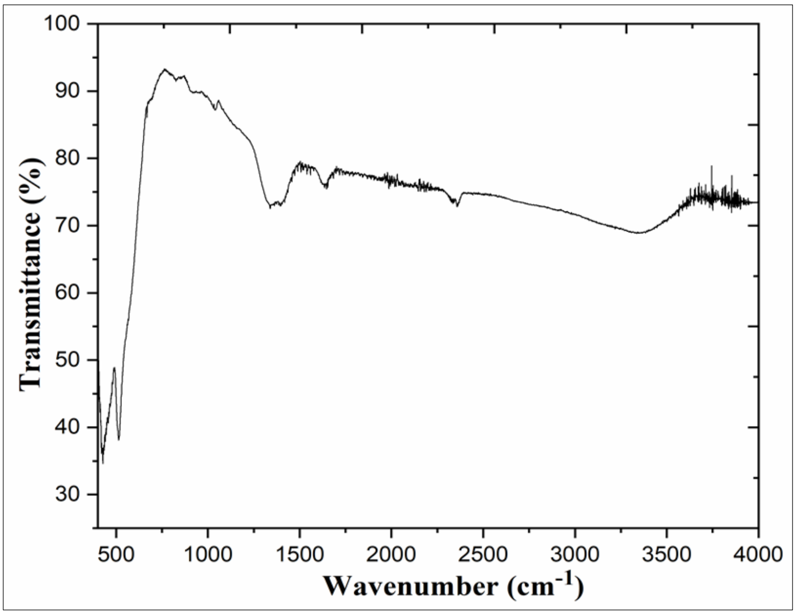

Figure 2 FTIR image of $Zn_{0.8}Cu_{0.2}Fe_2O_4$ nanoparticles

3.3. SEM and Antimicrobial Analysis

Surface morphology and size of the synthesized $Zn_{0.8}Cu_{0.2}Fe_2O_4$ nanoparticles were explored by Scanning Electron Microscopy. These nanoparticles expressed spherical and few cubic structure with homogenous [33-36]. These synthesised particles are showing irregular sizes, shapes and cohesion of grains is because of magnetic attraction of nanoparticles as shown in figure 3 and can affect their biological activity and internalization, such as anti-bacterial effect. Due to smooth surface of synthesised nanoparticles have capable to contact with a bacterial cell wall[37, 38]. Also, with small size spherical nanoparticles indicates increased anti-bacterial activity compared to the spherical NPs with a larger size due to having a higher surface area.

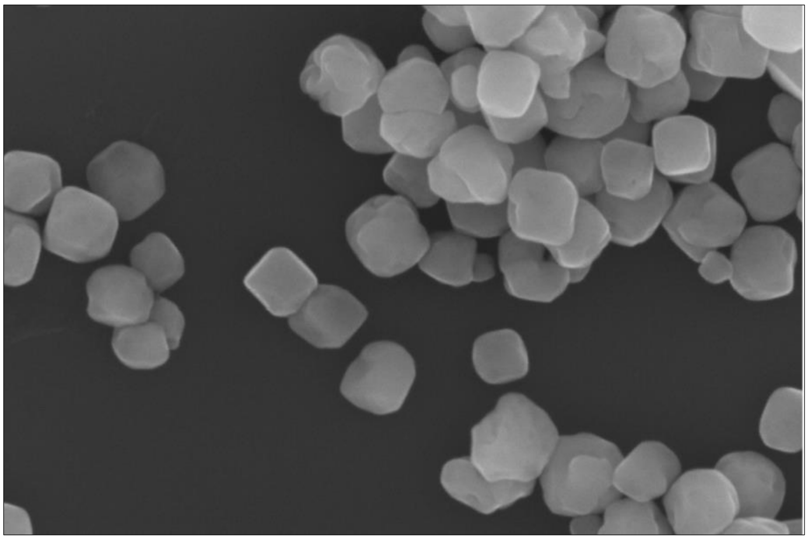

Figure 3 SEM image of $Zn_{0.8}Cu_{0.2}Fe_2O_4$ nanoparticles

4. Conclusion

$Zn_{0.8}Cu_{0.2}Fe_2O_4$ nanoparticles were prepared with the help of low cost hydrothermal method. XRD studies confirm the good crystallanity of the prepared nanoparticles. Further, FTIR measurements displayed significant peaks for the transition metal ferrites of Zn and Cu. In addition, SEM analysis disclosed that, it is detected that the size and shape of the crystallites are not uniform due to magnetic behavior. Hence, the outcomes suggested that doped copper element strongly influenced the microstructure, also enhances the anti-microbial behavior which in turn can serve as potential candidates for antimicrobial applications.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

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