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Original Research Article

Synthesis of zinc ferrite nanoparticles and evaluation of their antifungal properties at different temperatures

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ABSTRACT

Zinc ferrite nanoparticles have been synthesized by the co-precipitation method where Polyethylene Glycol act as the capping agent. The sample structure and morphology of the product were analysed by powder XRD, FTIR, U-V visible spectroscopy and scanning electron microscope (FE-SEM). The prepared NPs were annealed at varying temperatures such as 500°C, 600°C and 700°C. The XRD data confirms the presence of nanosized $ZnFe_2O_4$ particles and the X-ray density of the sample and their particle size increases linearly along with the increase in annealing temperature, but the lattice parameter changes inversely. The FTIR data also provide information about nanosized zinc ferrite particles. The surface characteristics of $ZnFe_2O_4$ were observed by FESEM. The anti-fungal properties of zinc ferrite nanoparticles were also evaluated.

1. Introduction

The most positive feature of nanotechnology is the anomalous properties including soft magnetic nature and magnetic nanoparticles at various compositions.[1,2] They contribute typical applications in different technological and fundamental research areas such as bio-medical, and bio-processing and are used as a good catalyst among many other NPs.[3–5] Among the spinel ferrite compounds zinc ferrite exhibits superparamagnetic behaviour and prospective applications in many fields including photocatalysis, Magnetic Resonance Imaging (MRI), Li-Iron batteries and gas sensors. Various synthesis methods are proposed to prepare $ZnFe_2O_4$ nanoparticles such as the coprecipitation method, thermal decomposition, solvothermal, hydrothermal and ball milling. In this work superparamagnetic $ZnFe_2O_4$ NPs were synthesized by adopting the method of Co-precipitation method. Polyethylene glycol act as a capping element for the synthesis.[6–8] The most auspicious feature of nanotechnology is the magnetic nano parties of different compositions. Since they have applications in the biomedical field and have catalytic properties, it is significant to get further detailing about Zn ferrite nanoparticles and to enhance the application level or develop new one's careful studies based on their functional sample size and also along with that their antifungal behaviour is essential. Among the spiral ferrite compounds, zinc ferrite exhibits superparamagnetic behaviour and it has prospective applications in many fields. Such as photocatalysis, magnetic reasonable imaging, Lithium — ion batteries and gas sensors.[9,10]

In the present paper, to characteristics structure and morphology of nanoparticles by using XRD, FTIR, U. V visible spectroscopy. To assess the properties of synthesized nanoparticles by antifungal using the Agar-well diffusion method.

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2. Synthesis

2.1. Zinc ferrite nanoparticles is prepared as follows

Here we use one mol of ferric nitrate, one mol of zinc nitrate, 0.1 mol of polyethylene glycol (PEG), one mol of sodium hydroxide (NaOH), one mol of ammonium carbonate, Ferric nitrate and zinc nitrate are taken in a clean burette and the aluminium nitrate is taken in a clean pipette, while the rest of others are mixed well in a beaker and is subjected to magnetic stirring where all these get stirred well. Allow the solution from the burette to fall on the solution drop by drop and the colour of the solution begins to change. Once the stirring is over, the solution is removed from to test tubes and centrifugation is performed at a rate of 4000rpm for 15 minutes then settled precipitate is washed and separated from the test tubes. After that, it is heated to remove its water content and then it is crushed into powder using mortar. The powder is then heated using a muffle furnace at altered temperatures (500, 600 & 700°C) continuous for up to 4 hours to get the required aluminium doped zinc ferrite nanoparticle.

3. Results

3.1. XRD analysis

The crystallographic structure of the obtained $ZnFe_2O_4$ nanoparticles was identified by using XRD data. Average particle size, the lattice parameter and X-ray density can be measured.[11–14]

All the samples show diffraction peaks at (311) compared with the JCPDS card No: 82-1049, which confirms the synthesized product single-phase cubic in synthesized nanoparticles. The crystallite size can be measured using the shearer's equation. From Table 1 we observe that when temperature increases the crystallite size and particle size also increase while the lattice parameter decreases. The X-ray density increases with the increasing temperatures from 500°C to 700°C.

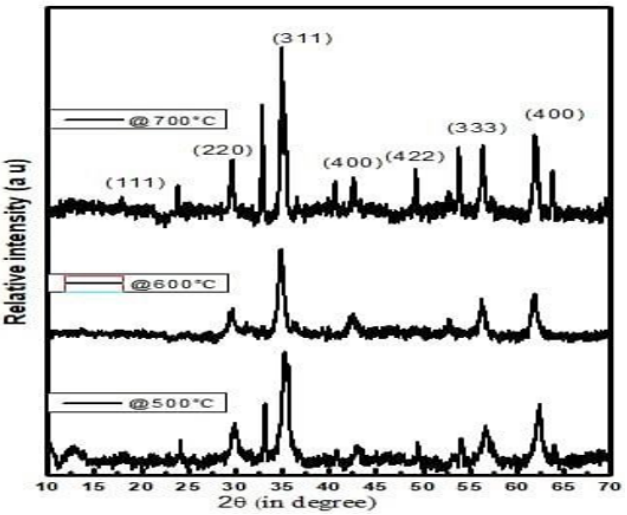

Fig. 1: The XRD pattern of $ZnFe_2O_4$ nanoparticles synthesized at 500^0C, 600^0C and 700^0C. The graph shows XRD analysis at different temperatures. The observed peak position and intensities showed that all the samples had the finite structure.

3.2. FE-SEM analysis

The FESEM images exhibit agglomerated branches of spherical shaped nanoparticles, because of their high surface energy. The FESEM images show that thus agglomeration of zinc ferrite nanoparticles because of the effect of the capping agent on modifying crystal size.[15–17]

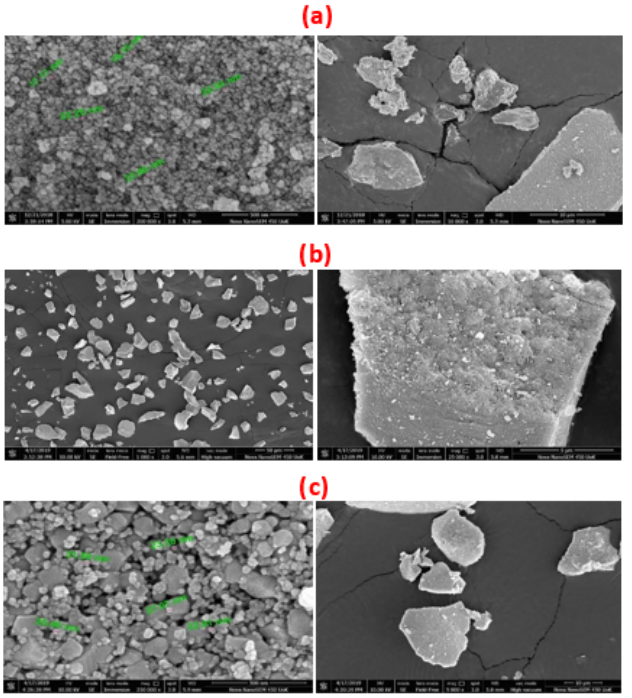

Fig. 2: FE-SEM Images (a) at 500°C (b) 600°C (c) 700°C

3.3. FTIR analysis

All samples exhibited peaks near 530cm-1corresponding to the Fe-O stretching frequency near 425cm-1 peaks indicated zinc ferrites nanoparticle. The present study suggests a linear variation between crystallite size and temperatures. This observation from the FTIR study strongly supports the result observed by XRD values. All samples have absorption

Table 1: The values of crystalline size (nm), particle size (nm) in FE-SEM, lattice constant(a), X-ray density, cell volume and specific surface area (S)

Temperature	Crystallite size in (nm) XRD	Particle size in (nm) FE-SEM	Lattice constant (a) value in (Å)	X-ray density dx(g/cm^3)	Unit cell Volume (a)^3	Specific surface area (S) (m^2/g)
500^{0}C	5.99	4.48	8.44135	5.3241	601.499	18.846
600^{0}C	6.615	5.06	8.41585	8.374	596.062	16.92
700^{0}C	10.39	9.59	8.38155	5.438	588.805	10.64

Table 2: Thevalues of bond length A-O (Å), bond length B-O (Å), ionic radius rA and ionicradius rB

Temperature	Bond Length in A-O sites (Å)	Bond Length in B-O sites (Å)	Ionic radius rA (Å)	Ionic radius rB (Å)
500^{0}C	3.66	5.2	4.98	5.714
600^{0}C	3.64	5.26	4.96	5.7
700^{0}C	3.63	5.24	4.95	5.66

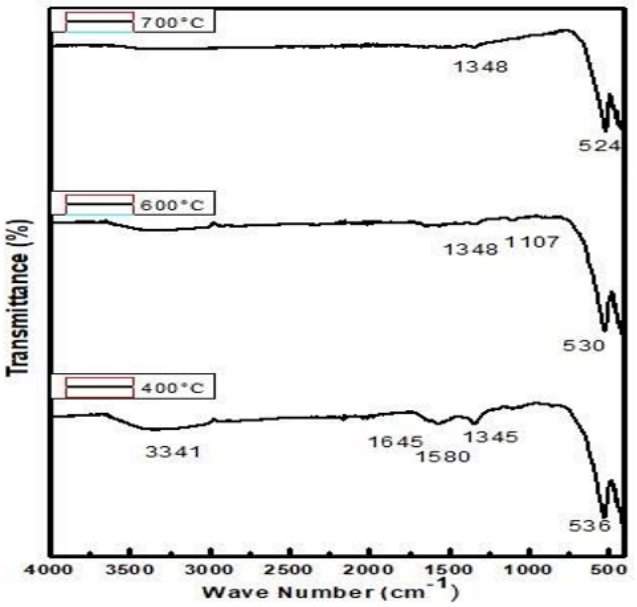

Fig. 3: FTIR spectra of zinc ferrite nanoparticles annealed at 400^{0}C, 600^{0}C, and 700^{0}C are shown.

bands in the region of 500-550 cm-1 and 400-450 cm-1. The high-frequency band is due to the stretching vibration of the unit cell in the tetrahedral A sites and the lower is due to the metal-oxygen in the octahedral B site i.e., high- the frequency band is due to the Zn-O stretching and the lower frequency corresponds to Fe-O stretching which confirms the formation of ZnFe2O4 nanoparticles. From the spectrum, some other absorption bands are also observed in the range 3750-3000 cm-1, 1750-1500 cm-1 and 1500-1250 cm-1 representing stretching frequencies of N-H bond and C=O and also O-H stretching vibrations respectively. As the temperature increases the bonds other than Zn-O, Fe-O and O-H bonds disappear. The appearance of the O-H bond indicates the presence of water in the sample. [12–15]

3.4. U-V analysis

The change in characteristic properties of the synthesized sample towards the effect of light was investigated by UV-Visible spectral data. Figure 4 shows the spectra in the sample range of wavelength 200-800 nm. Band gap energy obtained for $ZnFe_2O_4$ is reducing with an increase in temperature.

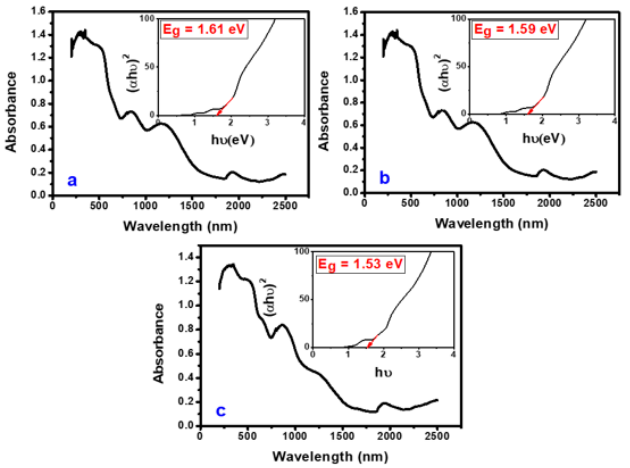

Fig. 4: Tauc plot of zinc ferrite samples (a) at 500°C (b) at 600°C and (c) at 700°C

3.5. Anti-fungal analysis agar-well diffusion method

The Biological activity and antifungal ability of samples were estimated by conducting Agar well diffusion technique. For that purpose, the analysing samples have purposefully interacted with test organisms that are seeded in a test plate. [16,17] The results were obtained in the form of a circular zone of inhibition. The results were evaluated according to the diameter of the zone. The test plates were kept overnight for the growth of species. Aspergillus Niger was considered as a standard for the analysis.

Wells of nearly 10 mm was used and samples of varying concentration such as 25μg/mL and 1000μg/ mL were added to these wells. The circular zone of inhibition was estimated after incubation at room temperature overnight and compared with that of the standard. From the antifungal activity of the prepared samples, it was found that they are active against the fungal pathogen Aspergillus Niger except at 700°C. We can conclude as the temperature increases the zone of inhibition reduces and at 700°C it will inactive.

Table 3: The antifungalactivity of zinc ferrite nanoparticles at different concentration 250μg/ml, 500μg/ml, 1000μg/ml at 500^{0}C

Sample	Concentration (μg/ml)	Zone of exhibition (mm)
	250	Nil
500^{0}C	500	12
	1000	14
Clotrimazole	100	21

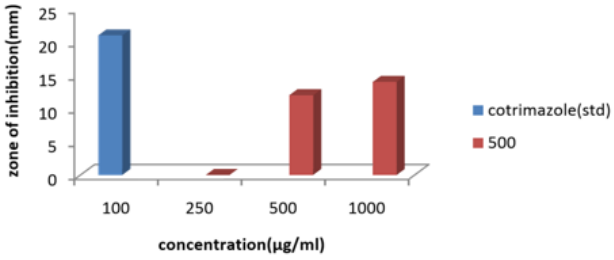

Fig. 5: Anti-fungal analysis of zinc ferrite NPs at 500°C

Table 4: The antifungalactivity of zinc ferrite nanoparticles at different concentration 250μg/ml, 500μg/ml, 1000μg/ml at 600^{0}C

Sample	Concentration (μg/ml)	Zone of exhibition (mm)
	250	Nil
600^{0}C	500	12
	1000	14
Clotrimazole	100	26

Table 5: The antifungalactivity of zinc ferrite nanoparticles at different concentration 250μg/ml, 500μg/ml, 1000μg/ml at 700^{0}C

Sample	Concentration (μg/ml)	Zone of exhibition (mm)
	250	Nil
700^{0}C	500	Nil
	1000	Nil
Clotrimazole	100	21

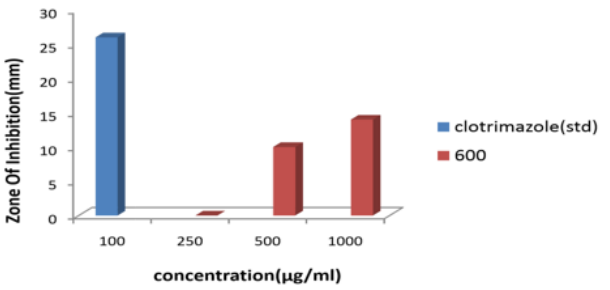

Fig. 6: Antifungal activity of zinc ferrite NPs at 600°C

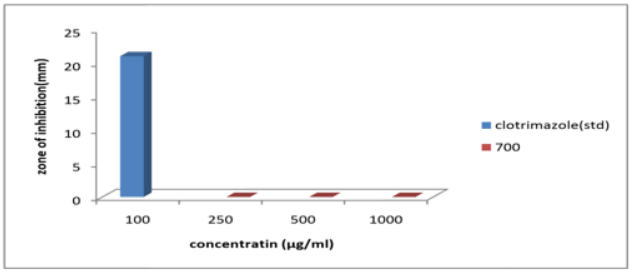

Fig. 7: Anti-fungal analysis of zinc ferrite NPs at 700

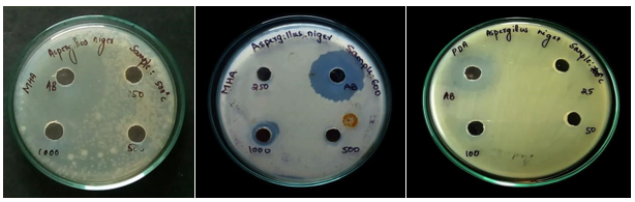

Fig. 8: Anti-fungal analysis of zinc ferrite NPs at 500°C, 600°C and 700°C.

4. Conclusion

Zinc ferrite nanoparticles were successfully prepared by the coprecipitation method using PEG as a capping agent. The XRD confirms the crystal structure and phase purity of the sample. The FESEM of $ZnFe_2O_4$ nanoparticles shows the spherical agglomerated particles' antifungal activity showed the application of zinc ferrite NPs in inflammation and cancer therapy. FTIR study confirmed the presence of zinc ferrite NPs at all annealing temperatures. The optical study uses UV visible spectroscopy and can notice with the increase in temperature the bandgap energy decreases. From the antifungal activity of the prepared samples, it was found that they are active against the fungal pathogen Aspergillus Niger except at 700°C.

5. Source of Funding

None.

6. Conflicts of Interest

The authors have no conflicts of interest.

7. Acknowledgment

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