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Structural, Morphological and Magnetic Studies of Copper Aluminate ($CuAl_2O_4$) Nanoparticles by *Zingiber officinale* Extract Green Synthesis

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ABSTRACT

Copper aluminate nanoparticles ($CuAl_2O_4$ NPs) were synthesized successfully by a simple green route using *Z. officinale* extract. The *Zingiber officinale* (*Z. officinale*) plant is one of the well-known medicinal plants. $CuAl_2O_4$ NPs are known to be one of the multifunctional applications. The surface morphology and crystal structure of the synthesized $CuAl_2O_4$ NPs were characterized by powder XRD, FT-IR spectroscopy, SEM, TEM, and SAED analysis. The magnetic properties of the $CuAl_2O_4$ NPs were analyzed by VSM technique. The formation of cubic spinel structure $CuAl_2O_4$ NPs was confirmed by powder XRD. The average crystallite size of $CuAl_2O_4$ NPs was measured by sherrer formula and found to be 18.65 nm. The VSM results shows that spinel $CuAl_2O_4$ NPs are in magnetic nature.

***Key words*:** *Zingiber officinale* extract, Green synthesis, $CuAl_2O_4$ NPs, VSM

Recently, metal oxide nanoparticles have attracted significant attention in environmental technology, environmental catalysis, photocatalysts, sensors and biomedicine, etc. [1-5]. The superior physico-chemical properties of metal oxide nanoparticles allow for the development of novel products and a smooth path for new applications [6-9]. Surface effects and tiny size effects of such particles have been explored for this purpose. Copper aluminate nanoparticles ($CuAl_2O_4$ NPs) are a key component of modern electronic circuits, sensors, and catalysts, due to their low cost and high electrical conductivity [10]. $CuAl_2O_4$ NPs are now widely utilized in nano-electronics, with applications in magnetic devices, nano-sensors, electron emitters, and other electrical devices. Spinel $CuAl_2O_4$ NPs have been investigated for use as biomedicine and bioanalysis [11]. Dispersion of performed polymers, solvent evaporation, sol-gel and ionic gelation procedures, and other processes have all been used to make a significant number of $CuAl_2O_4$ NPs [12-15]. Traditional solvent extraction-evaporation, solvent diffusion, and organic phase separation procedures are harmful to the environment and physiological systems. However, most of the methods mentioned above have some drawbacks, such as expensive equipment and chemicals. Biosynthetic methods are one of the most efficient and practical methods for producing metallic nanoparticles, because they require relatively minimal equipment and highly mono distributed stable nanoparticles [16-18]. On the basis of this synthesis, useful chemical strategies have been developed. $CuAl_2O_4$ NPs were obtained using this approach under ecologically favorable reaction conditions.

Many scientists are now working to create green biosynthetic approaches that use plant extracts as reducing agents [19-21]. Metal oxide nanoparticles are now manufactured using reducing and/or stabilising chemicals derived from bacteria, fungus, yeasts, algae, or plants [22]. *Soybean*, *turbinaria conoides*, *zinger officinale (Z. officinale)*, and *garlic* extracts are examples of plant extracts [23]. In the present study, a simple and green biosynthetic route for the size and shape-controlled synthesis of $CuAl_2O_4$ NPs is proposed. The synthesized $CuAl_2O_4$ NPs have been characterized by powder XRD, FT-IR, SEM, HR-TEM, SAED and VSM analyses.

MATERIALS AND METHODS

Aluminum (III) nitrate (Merck), $Cu(NO_3)_2$ (Sigma Aldrich), the rhizome extract of *Z. officinale* was prepared. Briefly, the small pieces of *Z. officinale* rhizome was boiled in 100 mL of deionized water and filtered of to get the *Z. officinale* rhizome extract and it is used for the green synthesis of $CuAl_2O_4$ NPs. $CuAl_2O_4$ NPs were prepared using the *Z. officinale* extract. A stock solution of copper nitrate and aluminum (III) nitrate was prepared and added *Z. officinale* extract and the solutions were heated in the microwave oven. Finally, $CuAl_2O_4$ NPs were obtained.

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Characterization techniques

The structural and phase characterization was achieved using a Philips X'pert X-ray diffractometer with CuKα radiation at λ=1.540Å. Surface morphological studies of $CuAl_2O_4$ NPs have been performed with a Jeol JSM6360 HR-SEM technique. The TEM images were carried out by Philips -TEM (CM20).

RESULTS AND DISCUSSION

HR-SEM analysis

HR-SEM pictures of $CuAl_2O_4$ NPs are demonstrated in Fig. 1 suggests that nanoparticles like morphology with exact separation, with the diameter range 15-20 nm. Also, exhibits homogeneous particles and agglomerated sphere shape of $CuAl_2O_4$ NPs. The $CuAl_2O_4$ NPs have been organized the use of a microwave oven operated at a strength of 850W with inside the gift observe, could have produced extensive quantity of warmth in the course of the combustion method. This could have resulted with inside the formation of $CuAl_2O_4$ NPs in line with the subsequent whole combustion the use of *Z. officinale* rhizome extract as a fuel.

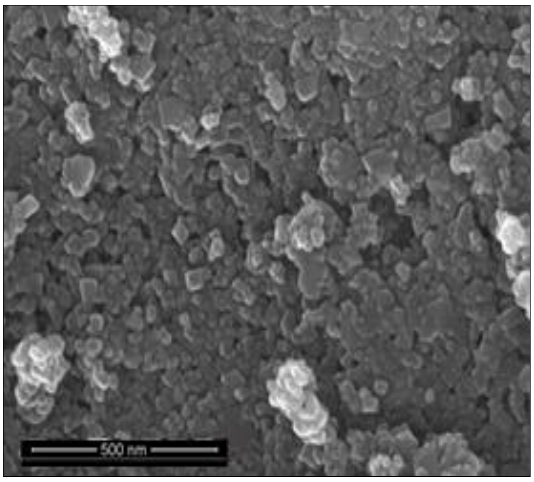

Fig 1 HR-SEM image of $CuAl_2O_4$ NPs

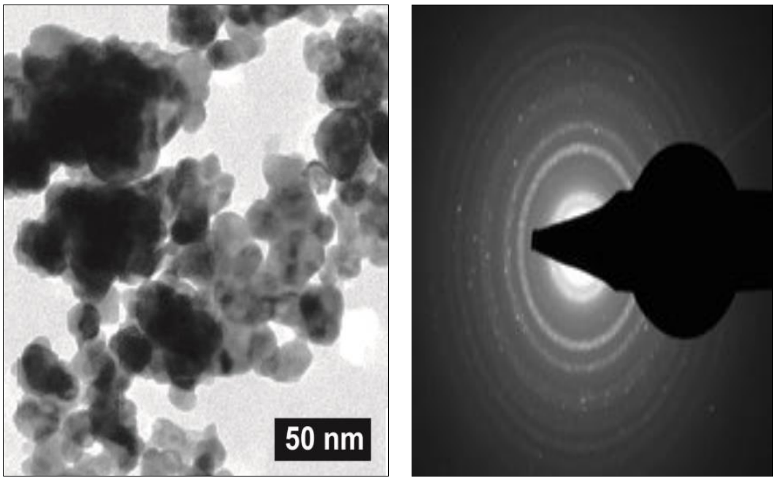

Fig 2 HR-TEM image of $CuAl_2O_4$ NPs

HR-TEM studies

Fig. 2a,b shows the HR-TEM image and SAED pattern of $CuAl_2O_4$ NPs. HR-TEM analysis was used to calculate the particle size of the $CuAl_2O_4$ NPs. It exhibits that almost all the $CuAl_2O_4$ NPs are of spherical shape with no agglomeration and are well dispersed particle size ranges from 15-17 nm, which is in good agreement with the crystallite size calculated form XRD results. The SAED pattern has been obtained and confirmed that the $CuAl_2O_4$ NPs are well crystalline. Both HR-TEM images and SAED patterns confirmed that the prepared spherical $CuAl_2O_4$ NPs are well crystalline nature.

FT-IR spectra

Fig. 3 shows the FT-IR spectra of $CuAl_2O_4$ NPs. The peaks in 458 and 652 cm^{-1} are related to $CuAl_2O_4$ NPs metal - oxygen groups. The broad absorption bands at 3420 cm^{-1} can be assigned to O-H vibration modes. The band at 1625 cm^{-1} indicates the O-H group. FT-IR spectral study confirmed that the protein present in *Z. officinale* extract acts as a reducing agent and stabilizer for the $CuAl_2O_4$ NPs and prevents agglomeration [24].

Powder XRD analysis

The $CuAl_2O_4$ NPs were also analyzed by XRD pattern to determine their crystalline structure (Fig. 4). No peaks of other impurity crystalline phases have been detected [25]. All the peaks in XRD pattern can be readily indexed to a cubic spinel structure of $CuAl_2O_4$ NPs. The lattice parameter of $CuAl_2O_4$ NPs has been calculated and is found to be 3.735 Å. The crystallite size of $CuAl_2O_4$ NPs is calculated using sherrer equation and found to be 15.85 nm.

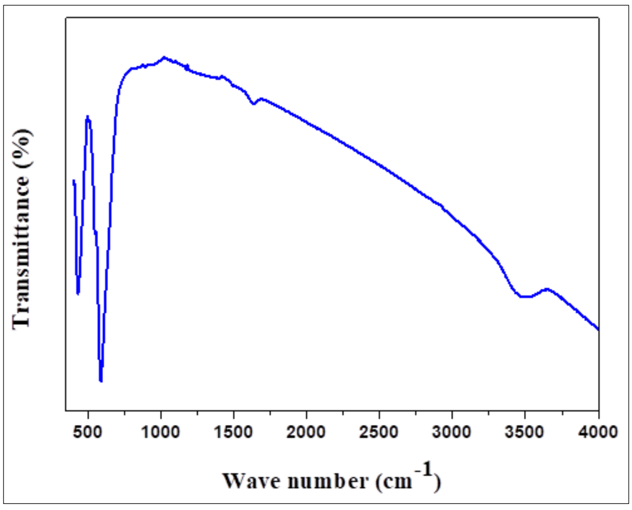

Fig 3 FT-IR pattern of $CuAl_2O_4$ NPs

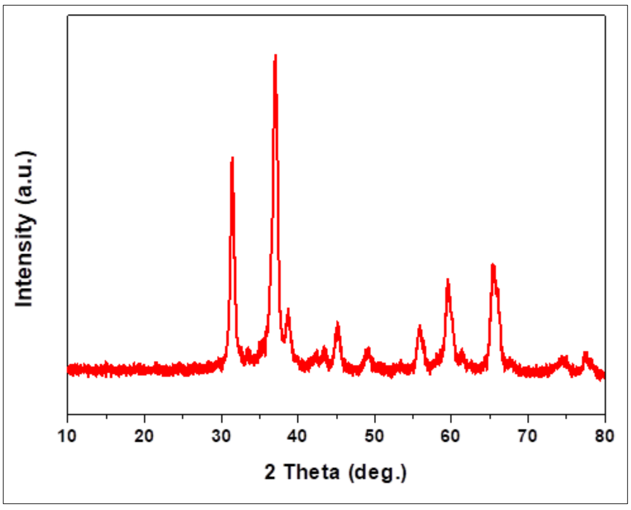

Fig 4 XRD pattern of $CuAl_2O_4$ NPs

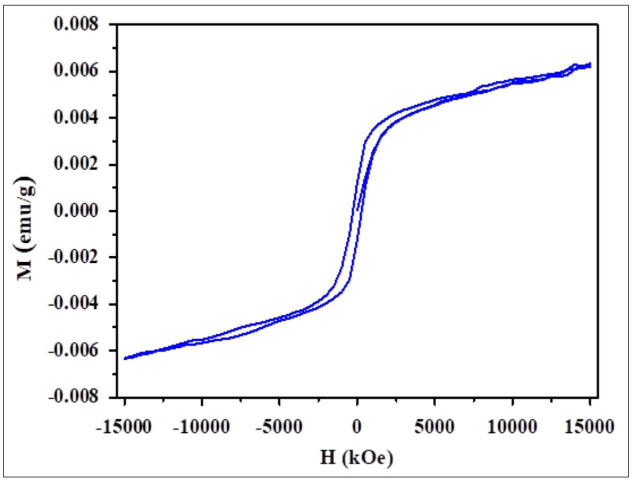

Fig 5 VSM analysis of $CuAl_2O_4$ NPs

VSM analysis

The magnetic properties of $CuAl_2O_4$ NPs at room temperature (RT) and ±15kOe applied field are shown in Figure 5. The saturation magnetization (M_s) for the synthesized $CuAl_2O_4$ NPs was 6.854×10^{-3} emu/g. The obtained result shows paramagnetic nature properties [26-31]. Additionally, the amount of magnetic saturation of $CuAl_2O_4$ NPs depends on their size, crystallinity and structure. The spinel structure and paramagnetic behaviour of $CuAl_2O_4$ NPs were confirmed by XRD and VSM analyses.

CONCLUSION

Spinel $CuAl_2O_4$ NPs have prepared by a simple method, which is greener and environmentally suitable, cheap and best method using *Z. officinale* extract. The shape and size of the $CuAl_2O_4$ NPs are controlled by using *Z. officinale* extract. Powder XRD, FT-IR, HR-SEM, HR-TEM, SAED and VSM studies were confirmed the crystallite/ particle size and shape of $CuAl_2O_4$ NPs. The experiments suggest the possibility to use this material in water purification, air filtration, air quality management, antibacterial packaging etc.

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