Quest Journals
Journal of Research in Environmental and Earth Sciences
Volume 10 ~ Issue 12 (2024) pp: 66-70
ISSN(Online) :2348-2532
www.questjournals.org

Research Paper

Environment-Friendly Synthesis of Copper Ferrite Nanoparticles and Their Characterizations

Iraj Batool, Jafar Khan Kasi, Ahmed Bilal, Shehzad Ahmed, Ajab Khan Kasi
Department of Physics, University of Balochistan, Quetta, Pakistan

Abstract
In green Nano biotechnology a number of methods are used to create nanoparticles via virus, microbes and plants. Plant mediated synthesis is better than microbes due to its availability and nontoxic properties. In this study we create Copper ferrite Nano particles by using mint extract by auto –combustion. Traditional characterization techniques such as XRD, FTIR and VSM have been employed. XRD verified the crystalline nature of copper ferrites. The magnetic properties of Copper ferrite Nano particleshave been investigated by VSM, the analysis showed Copper ferrite Nano particles are paramagnetic in nature as it lacks remnant and coercivity. FTIR analysis indicates the presence of phenolic contents as the stabilizing agent. The peaks reveal the different functional groups. The above mentioned results show ecofriendly synthesis of copper ferrite nanoparticles by mint look to take part in providing the compositional stability and consistency stability of the NPs.

I. Introduction

Ferrites are generally chemical compounds that are mostly composed of iron oxides and can be obtained as powder or as ceramic entities having ferromagnetic characteristics [1]. Ferrite nanoparticles are captivating material because of their diverse physical, structural, electrical, and magnetic characteristics. They could be utilized in many different areas [2].

The ferrites are categorized as garnet,spinel and hexagonal [1,3]. The nanoparticles that are frequently researched due to their utility and intriguing properties is spinel ferrites [4-5]. Due to the remarkable physical, optical, magnetic, and electrical characteristics of spinel ferrite (SF) nanomaterials have drawn interest recently for applications such as high-density data storage, catalysts, gas sensors, information storage systems, lithium-ion batteries that can be recharged, magnetic bulk cores, adsorbents, magnetic fluids, microwave absorbers, and medical diagnostics [6-8].The structure of spinel ferrites is of the form MFe_2O_4.Among various ferrite NPs, $CuFe_2O_4$ nanoparticles are of significant importance in research for investigating correlations between grain size, crystal phasesand their physical properties. Copper ferrite is also considered as the mostpromising soft magnetic material [9]. Because of its high resistivity and low eddy current loss for high frequency applications like electromagnetic interference and inductors for multilayer chips refiners [10-11]. Copper nanoparticles have been created by chemical, physical and biological (green) methods. The creation of $CuFe_2O_4$ nanoparticle can be accomplished using a variety of developed techniques such as self-high-synthesis (HTS), polymer matrix precipitation, citrate composition [12], sol-gel thermal decomposition, electrochemical methods, hydrothermal methods, co-precipitation, solid state method [13],sono chemical and microwave techniques but all are time-consuming, costly, and rely on hazardous substances as solvents, precipitating agents, or stabilizing agents [14-15]. Chemical techniques typically consist of multiple chemical molecules or species which could increase particle toxicity and reactivity which impair human health and the environment. The synthesis by the use of natural chemicals as catalysts of metal or metal oxide nanoparticles has proven to be a successful, non-toxic, and ecologically acceptable method [4, 16]. Green extraction techniques refer to a group of eco-friendly technologies that can be used to extract certain components from natural items including fruits, herbs, and plants [17]. Generally speaking, green extraction uses physical techniques like pressurized liquid extraction, ultrasound-assisted extraction, microwave-assisted extraction, or carbon dioxide extraction along with non-toxic solvents like water [18]. Green Nano-biotechnology is generally defined as the use of various biotechnological methods to synthesize nanoparticles or nanomaterials via biological processes such as microbes, plants, and viruses.Plant-mediated synthesis of nanoparticles is preferable to bacteria, algae, and fungi, [19,20].A sustainable way of producing $CuFe_2O_4$ nanoparticles through*Morus alba L. leaf*[3], Simarouba glouca plant's aqueous leaf extract [14], honey[11],tragacanthgum [21], hen egg white[22] and aloe Vera [15] andEclipta prostrata [23]. All are used as a reducing and capping agent by using mediated sol gel method and annealed effect sol gel method and solution combustion.Mint has been most widely used herb for pharmaceutical purposes but it has not been used as a stabilizing/capping agent for the synthesis of $CuFe_2O_4$ nanoparticles. Therefore, the motive of this research is to fill this gap (to prepare stabilized nanoparticle). The result of this research will be useful in the environmental friendly synthesis of ferrite nanoparticles that would be further used in number of applications

II. Material and Method

Preparation of Plants Extract:

The fresh leaves of mint were used to make an aqueous extract of mint. The leaves were wash with DI water to remove dust and organic impurities. Approximately 0.5 g of mint powder was added to a 150ml of deionized water and heated at 40°C, 50°C, 60°C, 70°C and 80°C for 30mins. A light green solution was obtained during heating. By cooling the light green colored solution was filtered by Whatman No.1 filter paper and collected in bottle that would place in refrigerator for additional usage. In addition, the extract's maximum reducing capacity was ascertained by measuring the total phenolic contents of all extracts obtained at various temperatures.

Synthesis of Copper Ferrite Nanoparticles

The process of creating copper ferrite nanoparticles was completed by using stoichiometric ratio (1:2) of copper nitrate and iron nitrate. Add 1g of copper nitrate with 2g of iron nitrate in a beaker with 50ml of DI water and stir for 10 minutes. The stirring procedure keeps going to guarantee that the solution is well-mixed and that the components are evenly distributed at room temperature. Then add 20 ml concentration of extract in the solution and heat the mixture at 60°C for 30 mints. After that the obtained solution was heated at 100C. At first, it looked like a gel, but it auto-combusts to produce a black powder. The obtained black powder was cleaned with DI water and centrifuged. At the end the powder was dried for 3 hours at 100°C. The blackish-brown color of powder showed the formation of copper ferrites nanoparticles.

III. Result and Discussion

XRD Analysis

XRD is a crucial technique, it provides insights into structural, compositional and physical properties. XRD pattern of sample CF that are annealed at 100°C for 5 hours

The XRD pattern in figure 3.1 illustrated the peak of CuFe2O4 at 2θ. The peaks represent actual synthesis of $CuFe_2O_4$, The XRD patterns ensure that the material had been transformed into the desired ferrite. The experimentally determined d-spacing value and the corresponding intensity values of each reflection peak are completely consistent with the standard JCPDS Card no. (01-072-1174) for copper ferrite, respectively. It has been observed that the increase in extract's concentration will cause increased peak intensity. The density of synthesized particles is 2.70 g/cm^3 and volume of unit cell is $588.52x10^6 pm^3$.

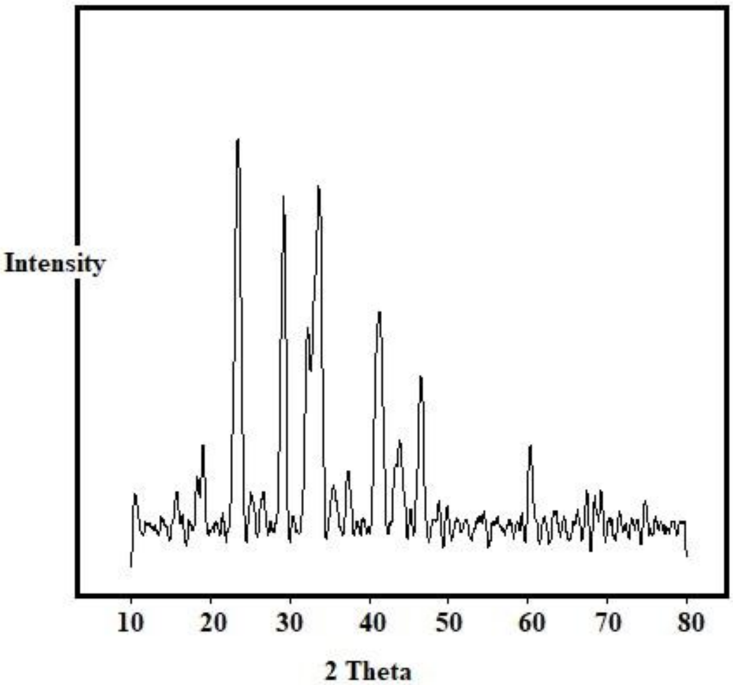

Figure 1 XRD pattern of mint leave extract

FTIR Analysis

The Fourier transform infrared spectroscopy (FTIR) method is used to determine the frequency of functional groups in a given material as depict in figure 3.2. According to the FT-IR spectrum analysis, there are two absorption band ranges. Two absorption bands for the ferrite's spinel structure were seen in the 400–1000 cm-1 range: ν_1 at 565 cm^{-1} and ν_2 at 421 cm^1. The band, ν_1, indicates the metal's (Fe ↔ O) intrinsic stretching vibrations at the tetrahedral location where the metal's (Cu ↔ O) stretching vibrations at the octahedral location are responsible for the ν_2. The synthesis of CuFe2O4 spinel ferrite nanoparticles is confirmed by the existence of distinctive absorption bands. Infrared active phonon modes' wave number (v) is connected to effective mass (μ) of metal–oxygen and force constant (F) via the following relation:

$$\nu = 1/2\pi c\sqrt{f/\mu}$$

The peak position at 1304 cm^{-1} belongs to C-N stretching where the peak appears at 1622 associated C=C aromatic ring. A wide absorption band at 3317cm^{-1} to 3443 cm^{-1} denote a stretching pattern for H_2O molecules and shows that the NPs' surface has a lot of OH groups of phenolic content that exist in plants extract and contributes as a capping agent. When water molecules (at atmospheric moisture) connect with the 0H group of phenols, hydrogen bonds are formed.

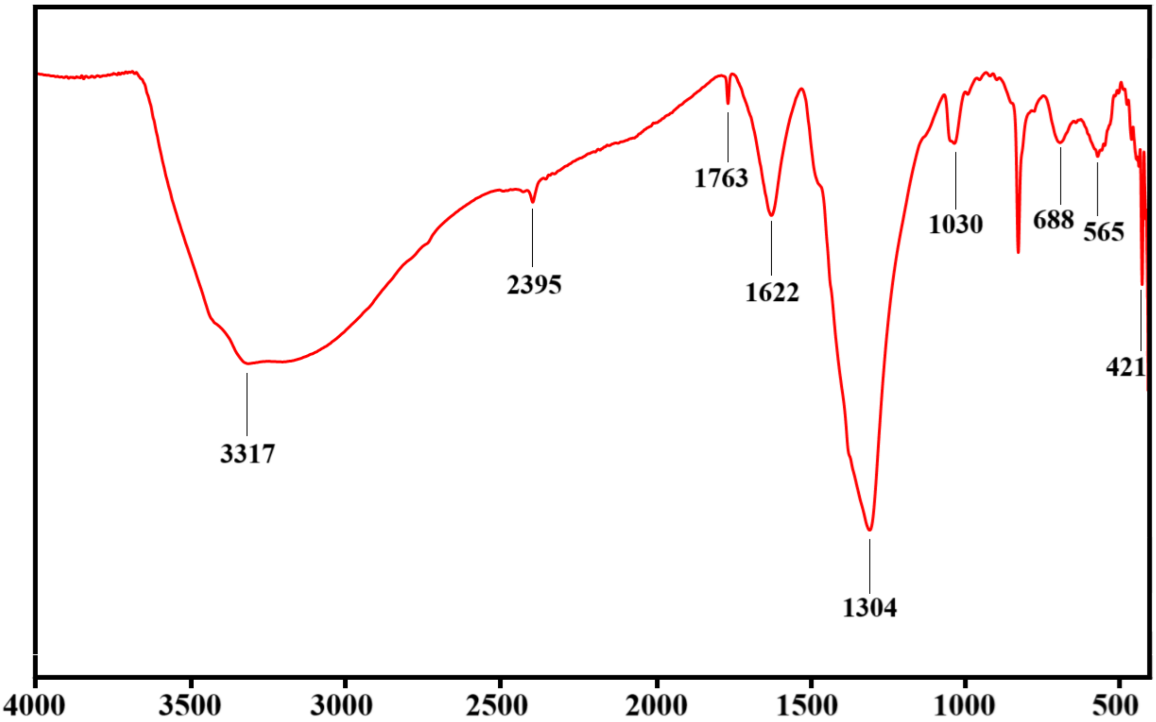

Figure 2: FTIR pattern of mint leave extract

VSM Analysis

The magnetic characteristics of nanoparticles are demonstrated by the VSM magnetic measurements for copper ferrites NPs. Figure 4.3 illustrates CuFe2O4 nanoparticles' hysteresis curve generated by mint and sol gel auto combustion process. Since the sample of synthesized copper ferrite nanoparticles shows a conventional "S" formed hysteresis curve. The value of saturation magnetization (*Ms*) is obtained at 0.059 emu/g. These values were used to classify the nanoparticles as a paramagnetic material as it lacks remnants magnetization or coercivity. The particle size is one of the elements that affected the magnetic characteristics. The saturation magnetization value increases with particle size.

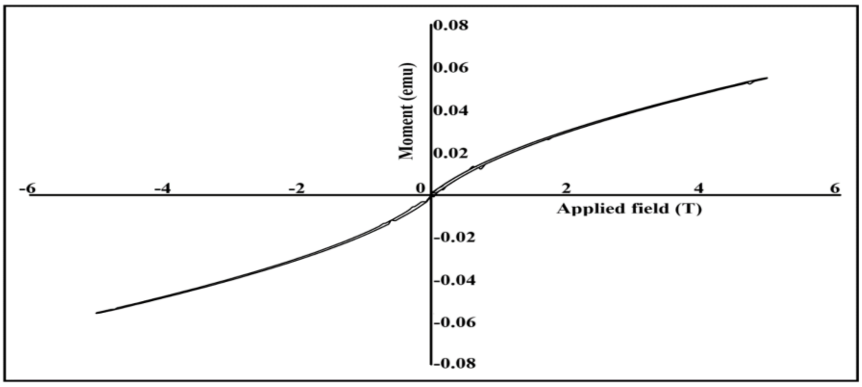

Figure 3: Shows VSM analysis of mint leave extract

IV. Conclusion

We successfully made $CUFe_2O_4$ Nano particles using an aqueous extract of the mint that low-cost and easily accessible and it is first ever reported that copper ferrites are made by mint extract. As copper ferrite is frequently used in many applications. Instead of employing hazardous chemicals as stabilizing agent, an aqueous extraction of plant was used. The formation of $CUFe_2O_4$ nanoparticles validates the extract's role as a stabilizing agent. The XRD peaks coincided with ICDD (JCPDS card no 10-0325), confirming the crystalline structure and spinel state of CUF_e2O_4nanoparticles. FTIR data supported the spinel structure and phenolic content's role as a reducing and stabilizing agent. Nanoparticles are paramagnetic nature was confirmed by M-H hysteresis curve. This research will help in medical applications requiring environmentally acceptable magnetic ferrite nanoparticles with excellent physical and structural properties.

References

[1]. Kharisov, B. I., Dias, H. R., &Kharissova, O. V. (2019). Mini-review: Ferrite nanoparticles in the catalysis. Arabian Journal of Chemistry, 12(7), 1234-1246.
[2]. Abu-Elsaad, N. I., & Abdel hameed, R. E. (2019). Copper ferrite nanoparticles as nutritive supplement for cucumber plants grown under hydroponic system. Journal of Plant Nutrition, 42(14), 1645-1659.
[3]. Masunga, N., Mmelesi, O. K., Kefeni, K. K., & Mamba, B. B. (2019). Recent advances in copper ferrite nanoparticles and nanocomposites synthesis, magnetic properties and application in water treatment. Journal of Environmental Chemical Engineering, 7(3), 103179.
[4]. Cahyana, A. H., Liandi, A. R., Yulizar, Y., Romdoni, Y., &Wendari, T. P. (2021). Green synthesis of CuFe2O4 nanoparticles mediated by Morus alba L. leaf extract: Crystal structure, grain morphology, particle size, magnetic and catalytic properties in Mannich reaction. Ceramics International, 47(15), 21373-21380.
[5]. Naseri, M. G., Saion, E. B., Ahangar, H. A., &Shaari, A. H. (2013). Fabrication, characterization, and magnetic properties of copper ferrite nanoparticles prepared by a simple, thermal-treatment method. Materials Research Bulletin, 48(4), 1439-1446.1
[6]. Tatarchuk, T., Bououdina, M., Judith Vijaya, J., & John Kennedy, L. (2017). Spinel ferrite nanoparticles: synthesis, crystal structure, properties, and perspective applications. In Nanophysics, Nanomaterials, Interface Studies, and Applications: Selected Proceedings of the 4th International Conference Nanotechnology and Nanomaterials (NANO2016), August 24-27, 2016, Lviv, Ukraine (pp. 305-325). Springer International Publishing
[7]. Subha, A., Shalini, M. G., Sahu, B., &Sahoo, S. C. (2018). Structural transformation and magnetic properties of copper ferrite nanoparticles prepared by sol–gel method. Journal of Materials Science: Materials in Electronics, 29, 20790-20799.
[8]. HatamiKahkesh, K., Baghbantaraghdari, Z., Jamaledin, D., DabbaghMoghaddam, F., Kaneko, N., &Ghovvati, M. (2023). Synthesis, characterization, antioxidant and antibacterial activities of zinc ferrite and copper ferrite nanoparticles. Materials Chemistry Horizons, 2(1), 49-56.
[9]. Sarkar, B. J., &Bandyopadhyay, A. (2021). Studies of magnetic behavior of chemically synthesized interacting superparamagnetic copper ferrite nanoparticles. Journal of Materials Science: Materials in Electronics, 32, 1491-1505.
[10]. Kuznetsov, M. V., Morozov, Y. G., & Belousova, O. V. (2013). Synthesis of copper ferrite nanoparticles. Inorganic materials, 49, 606-615.
[11]. Yadav, R. S., Kuřitka, I., Vilcakova, J., Havlica, J., Masilko, J., Kalina, L.,&Enev, V. (2017). Structural, dielectric, electrical and magnetic properties of CuFe 2 O 4 nanoparticles synthesized by honey mediated sol–gel combustion method and annealing effect. Journal of Materials Science: Materials in Electronics, 28, 6245-6261.
[12]. Mulud, F. H., Dahham, N. A., &Waheed, I. F. (2020, November). Synthesis and characterization of copper ferrite nanoparticles. In IOP Conference Series: Materials Science and Engineering (Vol. 928, No. 7, p. 072125). IOP Publishing.
[13]. Bilal, A., Kasi, J. K., Kasi, A. K., Bokhari, M., Ahmed, S., & Ali, S. W. (2022). Environment friendly synthesis of nickel ferrite nanoparticles using Brassica oleracea var. capitate (green cabbage) as a fuel and their structural and magnetic characterizations. Materials Chemistry and Physics, 290, 126483.
[14]. Sreekala, G., Beevi, A. F., Resmi, R., &Beena, B. (2021). Removal of lead (II) ions from water using copper ferrite nanoparticles synthesized by green method. Materials Today: Proceedings, 45, 3986-3990.
[15]. Manikandanath, N. T., Isaac, R. R., Sanjith, S., Kumar, P. R., Anooj, E. S., &Vallinayagam, S. (2021). Superb catalytic activity of as-green synthesized copper ferrite's thermal decomposition of ammonium perchlorate. Journal of Molecular Structure, 1234, 130161.
[16]. Ramazani, A., TaghaviFardood, S., Hosseinzadeh, Z., Sadri, F., &Joo, S. W. (2017). Green synthesis of magnetic copper ferrite nanoparticles using tragacanth gum as a biotemplate and their catalytic activity for the oxidation of alcohols. Iranian Journal of Catalysis, 7(3), 181-185.
[17]. Ahmed, S., Kasi, J. K., Kasi, A. K., Bokhari, M., Bilal, A., & Ali, S. W. (2023). Phyto-mediated synthesis of enhanced band gap ZnO and TiO2 nanoparticles using Pisumsativum peels extract: comparison of their structural, optical, photocatalytic and antifungal characteristics. Chemical Papers, 77(12), 7697-7715.
[18]. Putra, N. R., Yustisia, Y., Heryanto, R. B., Asmaliyah, A., Miswarti, M., Rizkiyah, D. N., ... &Rohman, G. A. N. (2023). Advancements and challenges in green extraction techniques for Indonesian natural products: A review. South African Journal of Chemical Engineering, 46(1), 88-98.
[19]. Iravani, S. (2011). Green synthesis of metal nanoparticles using plants. Green Chemistry, 13(10), 2638-2650.
[20]. Alao, I. I., Oyekunle, I. P., Iwuozor, K. O., &Emenike, E. C. (2022). Green synthesis of copper nanoparticles and investigation of its anti-microbial properties. Advanced Journal of Chemistry-Section B, 4(1), 39-52.
[21]. Atia, T. A., Altimari, P., Moscardini, E., Pettiti, I., Toro, L., &Pagnanelli, F. (2016). Synthesis and characterization of copper ferrite magnetic nanoparticles by hydrothermal route. Chemical Engineering Transactions, 47, 151-156.
[22]. Chung, I. M., Abdul Rahuman, A., Marimuthu, S., Vishnu Kirthi, A., Anbarasan, K., Padmini, P., &Rajakumar, G. (2017). Green synthesis of copper nanoparticles using Ecliptaprostrata leaves extract and their antioxidant and cytotoxic activities. Experimental and therapeutic medicine, 14(1), 18-24.
[23]. Udhaya, P. A., Ahmad, A., Meena, M., Queen, M. A. J., Aravind, M., Velusamy, P., ... & Ali, S. (2023). Copper Ferrite nanoparticles synthesised using a novel green synthesis route: Structural development and photocatalytic activity. Journal of Molecular Structure, 1277, 134807.