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Study of $SrEr_{0.04}Fe_{1.96}O_4$/PANI nano-composites for high-frequency applications

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Abstract

High-frequency nanocomposites have gained attention as electronic and telecommunication technologies. These nanocomposites consist of ferrite and a polyaniline matrix. Sol-gel technique was used to generate the ferrite nanomaterial, and in-situ synthesis was used to generate the polyaniline. The X-ray diffraction (XRD) analysis elucidated the existence of a single-phase structure comprising $SrEr_{0.04}Fe_{1.96}O_4$ ferrite particles dispersed throughout the polyaniline matrix. To counteract the amorphous nature of polyaniline, adding spinel ferrite to nanocomposites boosted their crystallite size (20nm–56nm). When ferrite was combined with polyaniline, the dielectric constants and dielectric loss ($\varepsilon', \varepsilon''$) were found to decrease as a function of frequency. The ferromagnetic characteristics of the manufactured composites were discovered through hysteresis loop analysis. Saturation Ms, remanence Mr, and coercivity Hc all increased with ferrite content. Direct current (dc) resistivity and activation energies of the composite sample enhanced with concentration of polyaniline in ferrites. Improvements in all the properties of nanocomposites (FP4) may be suitable candidates for high frequency applications.

Introduction

Today, there is a great deal more that can be said about nano-structured and nanocomposite materials than ever before. New, somewhat enhanced compounds with extraordinary properties are being quickly developed in this field [1]. Nanocomposite materials are a catch-all term that refers to various systems with

the common characteristic of being structured from and fused using aspects of distinctive attributes at the nano-metric scale. These systems range from molecular compounds to one-, two-, and three-dimensional materials [2]. One of the primary focuses of current research is finding ways to exert control over nanostructured materials using state-of-the-art processing techniques. The features of the mother components, in addition to the architecture and interfacial types of the composites, determine the quality of the resulting nanocomposite [3]. Numerous industries, including those dealing with microfluidics, administering a pharmaceutical compound, triggers, intramuscularly encased brands, epithelia, plastic packaging, aviation, paints, plasters, flame-resistant products, healthcare products, commodities, etc., will benefit mainly from the consumption of nanocomposites [4].

Polyaniline (or PANI) has garnered a lot of attention in creating innovative components for the assembly of electrical equipment because of its high electrical purity, excellent insulation, configurable synthesis conditions, environmental stability, and simplicity of fabrication [5,6]. PANI's potential for excellent shielding performance stems from its ability to reflect and collect electromagnetic (EM) radiation. Polyaniline (or PANI) is a standout example of a typical dielectric material that may be found among conducting polymers. The current surge in interest for conductive PANI/ferrite composites could be credited for existing because to the reason that PANI and ferrite have properties that complement one another [7,8]. Ferrite spinel nanostructures are among the most notable inorganic nanoparticles due to their distinctive physical, photonic, electrostatic, mechanical, and enzymatic properties in contrast to their bulk equivalents [9]. Not only are the qualities of ferrites reliant on the elemental makeup of the material, but they are also based on other factors of the particles, such as geometry, particle shape, and other characteristics [10]. Integrating ferrites into the composition of PANI boosts its degradation rate, but may weaken its ionic properties. Furthermore, the electrical qualities of the PANI/ferrites may be considerably improved and varied by better planning of the concentration of the ferrites' elements and, in some situations, through the use of various processing methods. Cloud storage, laser diodes, mechanical cooling, mechanically assisted overheating, biologically relevant filtration, administering medications, biosensors, and probably a lot more might derive from these combinations [11].

By performing in situ polymerization, T.H. Ting et al. synthesized a composite structure consisting of NiZn ferrite capped with polyaniline. Polyaniline/NiZn ferrite composites' manufacturing methods were studied using spectroscopy. It was shown that adjusting the polyaniline content of NiZn ferrite expands the spectrum of light absorbed by the material [12]. The study on in situ polymerization was used to manufacture nano-composites of polyaniline/$Mn_{0.8}Zn_{0.2}Fe_2O_4$ (PANI/MZFO) with varying quantities of ferrite. Hysteresis is evidence that the inclusion of ferrite improved the material's magnetic properties. By substituting MZFO for a metallic conductor, the material became semiconducting [13]. Heterogeneous sol-gel combustion involves dissolving metal nitrates and organic chelating ligands like citric acid in deionized water to create a homogeneous aqueous solution with an atomic order. Aqueous sol-gel combustion is a step in this process. It is low cost, robust construction, and convenience in portability make it a popular choice, and its ease of use, accuracy, and precision in measuring even the smallest particles make it a popular choice. It is faster because fewer stages are involved in the sample preparation procedure when using sol-gel [14,15].

The SrEr0.04Fe1.96O4/PANI nano-composites have shown promising potential for high-frequency applications owing to their unique properties and characteristics. Several parameters make them suitable

for these applications. Firstly, the composite material has a high electrical conductivity, which is an essential requirement for high-frequency devices. The presence of polyaniline (PANI) in the composite enhances its electrical conductivity, making it suitable for applications such as antennas and electromagnetic shielding. Secondly, the composite material has high magnetic properties due to the presence of strontium and iron in its structure. This property makes it suitable for use in microwave devices that require high magnetic susceptibility. Thirdly, the composite material has a high dielectric constant, which is a crucial parameter for applications such as capacitors and energy storage devices. The presence of rare-earth (RE) elements, such as erbium, in the composite structure enhances its dielectric properties, making it suitable for use in high-frequency capacitors. Lastly, the composite material has a nanoscale structure, which enhances its surface area and allows for better interaction with electromagnetic fields. This property makes it suitable for use in devices such as microwave absorbers and sensors. Overall, the $SrEr_{0.04}Fe_{1.96}O_4$/PANI nano-composites have several properties that make them suitable for high-frequency applications, including high electrical conductivity, magnetic properties, dielectric constant, and a nanoscale structure. These parameters make them a promising candidate for various high-frequency devices and applications.

The authors have chosen polyaniline (PANI) as the organic component in the composite material due to its high electrical conductivity. The presence of PANI enhances the electrical conductivity of the composite material, making it compatible for use in high frequency applications. Overall, the authors have carefully chosen the specific composition of $SrEr_{0.04}Fe_{1.96}O_4$/PANI nano-composites to optimize their dielectric, magnetic, and electrical properties. These properties make the composite material a promising candidate for various high-frequency applications.

Nano-sized $SrEr_{0.04}Fe_{1.96}O_4$ was added to polyaniline to alter its compositional, chemical stability, and ionic conductivity; this paper details those changes. Although reports and articles that outline the discoveries of numerous academics' research on the theme have been released, extra data are required to assess these factors' influence on composite materials correctly.

Section snippets

$SrEr_{0.04}Fe_{1.96}O_4$ preparation

According to the study's conclusions, no known compounds with prospective laboratory applications are incapable of being employed in their natural state. Chemical knowledge was acquired by synthesizing $SrEr_{0.04}Fe_{1.96}O_4$ferrite using sol-gel nitrate-citrate auto combustion. In order to dissolve strontium, erbium, and iron nitrates given below as ($Sr(NO_3)_2$, $Fe(NO_3)_3.9H_2O$, and $Er(NO_3)_3.6H_2O$) in deionized (DI) water at a molar ratio of 1:1, citric acid, which has the molecular formula $C_3H_4OH(COOH)_3$ …

X-ray diffraction

To verify phase purity and carry out a computational evaluation of the structure, XRD was applied to all of the $SrEr_{0.04}Fe_{1.96}O_4$/PANI samples. After being generated, the spinel ferrite $SrEr_{0.04}Fe_{1.96}O_4$structure was examined using XRD. The spinel ferrite XRD pattern is shown in Fig. 1. The lines hkl (220), (311), (222), (400), (422), (511), (440), and (440) are most likely $SrEr_{0.04}Fe_{1.96}O_4$spinel ferrite. The spinel's cubic shape is retained by these parallel planes. The PANI matrix causes the…

Conclusion

The nanocomposites of ferrite/polyaniline samples were synthesized by sol-gel/In-situ process. Peak intensity (311) of the ferrite sample seems to be broadened by the addition of polymer content. The XRD findings reveal the spinel crystalline phase and the size of the crystal vary from 20nm to 56nm. The lattice constant shows the increasing trend from 8.33Å to 8.44Å. Magnetic properties of the ferrite samples were improved with polyaniline content. The saturation M_s increase from 24.62 to…

Author's statement

All the authors have contribution in the work and they are known with the submission.…

Data availability

Data will be made available on reasonable request.…

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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References (52)

A.V. Trukhanov *et al.*
Control of electromagnetic properties in substituted M-type hexagonal ferrites
J. Alloys Compd. (2018)

A.V. Trukhanov *et al.*
Pecularities of the magnetic structure and microwave properties in Ba (Fe1-xScx) 12O19 (x< 0.1) hexaferrites
J. Alloys Compd. (2020)

A.V. Trukhanov *et al.*
Features of crystal and magnetic structure of the BaFe12-xGaxO19 (x≤ 2) in the wide temperature range
J. Alloys Compd. (2019)

M.A. Almessiere *et al.*
Impact of Eu3+ ion substitution on structural, magnetic and microwave traits of Ni–Cu–Zn spinel ferrites
Ceram. Int. (2020)

C. Dhand *et al.*
Recent advances in polyaniline based biosensors
Biosens. Bioelectron. (2011)

C. Bavatharani *et al.*
Electrospinning technique for production of polyaniline nanocomposites/nanofibres for multi-functional applications: a review
Synth. Met. (2021)

M.A. Almessiere *et al.*
Correlation between microstructure parameters and anti-cancer activity of the [Mn0. 5Zn0. 5] (EuxNdxFe2-2x) O4 nanoferrites produced by modified sol-gel and ultrasonic methods
Ceram. Int. (2020)

R.M. Khafagy
Synthesis, characterization, magnetic and electrical properties of the novel conductive and magnetic Polyaniline/MgFe2O4 nanocomposite having the core–shell structure
J. Alloys Compd. (2011)

T.H. Ting *et al.*
Synthesis and microwave absorption characteristics of polyaniline/NiZn ferrite composites in 2–40 GHz
Mater. Chem. Phys. (2011)

M.A. Gabal *et al.*
Synthesis, characterization and electrical conductivity of polyaniline-Mn0. 8Zn0. 2Fe2O4 nano-composites
Int. J. Electrochem. Sci. (2016)

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Cited by (3)

Sol–gel preparation of spinel ferrites/polyaniline composites for electromagnetic interface shielding ↗
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