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Synthesis and Characterization of Tin Ferrite Nano Structures using Hydrothermal Method

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ABSTRACT

Spinel ferrite substance $SnFe_2O_4$ has potential uses in a variety of industries, including catalysis, energy storage, and environmental remediation. This paper provides an overview of current developments in the synthesis, characterization, and uses of $SnFe_2O_4$. The spinel structure oxides of MFe_2O_4 (M: Fe, Co, Ni, Cu, and Zn) due to their high theoretical specific capacity, outstanding safety, cheap cost, and environmental friendliness. Tin Ferrite ($SnFe_2O_4$), one of these materials, has drawn interest for its magnetic characteristics and photocatalytic reactivity. It features an inverted spinel structure. The key procedures for producing $SnFe_2O_4$ and related composites, including Co-precipitation, hydrothermal, solvothermal, and sol-gel processes, are outlined. The use of $SnFe_2O_4$and its composites for environmental remediation is highlighted by these synthesis techniques. The samples created using the hydrothermal approach often exhibit benefits of excellent crystallinity, good dispersion, tiny particle size and uniform size distribution when compared to samples created using other methods. $SnFe_2O_4$ nanoparticles were synthesized by the hydrothermal method and characterized using X-ray diffractometry, Scanning Electron Microscopy. The SEM image shows many uniform nanoparticles with a spherical morphology. $SnFe_2O_4$ were planned to characterize the nano composites by X-ray diffraction, SEM, EDS and photocatalyst to understand the morphology, structural and optical properties. Overall, our findings show that the hydrothermal approach for the successful production and characterization of $SnFe_2O_4$ nanoparticles with prospective uses as an effective. $SnFe_2O_4$ has a lot of promise for use in many different applications and is a promising material overall.

Keywords: $SnFe_2O_4$, hydrothermal method, characterization.

1. Introduction

$SnFe_2O_4$ is a magnetic material with important applications in basic science and technology. Lately, some experimental research on $SnFe_2O_4$ material were conducted using various techniques of production and characterisation [1]. These research have shown significant physical properties of this ferrite-like magnetic material at ambient temperature, including a high magnetic moment with a semiconductor characteristic. It has ferromagnetic and half-metallic properties [2]. Since $SnFe_2O_4$ is a spinel oxide, it has a cubic crystal structure with oxygen atoms organised in a face-centred cubic lattice. Tin and iron ions occupy the tetrahedral (A) and octahedral (B) positions in the spinel structure of $SnFe_2O_4$. $SnFe_2O_4$ has the chemical formula $[(Sn(II),Fe(III))O_2]Fe(III)O_2$, where the Roman numbers in parenthesis denote the oxidation state of the metal ions. $SnFe_2O_4$ is a ferromagnetic material, which means that its magnetic moments are aligned in opposing directions in separate sublattices, resulting in a net magnetic moment [4, 5]. $SnFe_2O_4$ electrical characteristics is a semiconductor material with a large bandgap, making it valuable in electronic and optoelectronic applications. $SnFe_2O_4$ has remarkable optical features, such as significant absorption in the visible area and photoluminescence, which makes it useful in photovoltaic and other optoelectronic devices [6].

$SnFe_2O_4$ nanomaterials may be created using a variety of techniques, including chemical precipitation [3], sol-gel [7], hydrothermal [8], and solvothermal processes [9]. The particle size, crystallinity, flaws, shape, and surface area of SnFe2O4 nanomaterials are only a few of the many variables that affect their overall attributes [10]. A proper degree of surface imperfections may boost light absorption and carrier collection, which would improve the efficiency of pollutants degradation [11]. Moreover, SnFe2O4 nanomaterials with various morphologies might have various band topologies, which could have an immediate impact on the placements of the energy bands. The hydrothermal technique of synthesis is the most effective for producing nanoscale $SnFe_2O_4$.

The hydrothermal method's fundamental tenet is to conduct the reaction in an autoclave vessel at high pressures and temperatures. Materials with regulated size, form, and crystallinity may be produced using the hydrothermal process. The technique has become more well-liked because it can create materials of good quality with great qualities for a variety of applications. The reactants are normally combined in water before being added to an autoclave and heated to a high temperature under pressure in the hydrothermal process. Depending on the materials being synthesised, the autoclave's internal pressure can range from a few atmospheres to several hundred, and its temperature can range from room temperature to several hundred degrees Celsius [8,12].

Understanding a material's physical, chemical, and structural characteristics is critical for determining its prospective uses. The characteristics of $SnFe_2O_4$, a spinel ferrite material with potential uses in a variety of domains, including catalysis, energy storage, and environmental remediation, have recently been investigated using a variety of characterisation techniques. $SnFe_2O_4$'s crystal structure, shape, size, elemental content, surface area, and other characteristics have been examined using characterisation techniques such X-ray diffraction (XRD), scanning electron microscopy (SEM), and energy-dispersive X-ray spectroscopy (EDS)analysis. $SnFe_2O_4$ shape, size, and distribution are seen using SEM, while its crystal structure and phase purity are determined using XRD. The elemental makeup of $SnFe_2O_4$ is revealed by EDS, which is crucial knowledge for its use in catalytic and adsorption processes. This study lists the most current developments in the characterisation of $SnFe_2O_4$ using a variety of approaches and examines how they may be applied in a number of different domains. The numerous characterisation approaches are covered in the first section's concepts and uses, while the second section concentrates on how to apply these methods to study the characteristics of $SnFe_2O_4$[12-15].

$SnFe_2O_4$ is chemically stable, which means it may be utilised in hostile settings without deterioration. Overall, $SnFe_2O_4$ is a promising material for a range of applications, including sensors, catalysts, and energy storage devices, due to its unique mix of magnetic, electrical, and optical characteristics. The study ends with future directions for $SnFe_2O_4$ research, including, characterization investigation of fresh uses, and enhancement of their effectiveness.

2. Experimental

2.1 Materials

Chemicals used in the experiment were stannous chloride ($SnCl_2.2H_2O$), iron nitrate (Fe $(NO_3)_3.2H_2O$), and sodium hydroxide (NaOH). The chemical reagents were analytical grade and utilized without additional purification after being bought from Merck Chemicals (Mumbai, India). For sample preparation and dilution, deionized water was utilized. The purity of each chemical was greater than 99%. The experiment's glassware was all acid-washed.

2.2 Synthesis of $SnFe_2O_4$ nano particle

$SnFe_2O_4$ produced using a hydrothermal process. A homogeneous solution was created by dissolving 0.3 moles of $SnCl_2.2H_20$ and 0.6 moles of $Fe(NO_3)_3.2H_2O$ in 30 mL of deionized water while using a magnetic stirrer. By gradually adding NaOH solution, the aforementioned solution was brought to Ph 11. After that, the solution was put into a Teflon-lined, clean autoclave and heated there for 15 hours at 180°C. The precipitate was cleaned with filtered water to get rid of contaminants after cooling. The solution was centrifuged for 10 minutes at 10,000 rpm, dried in a hot air oven for two hours, and ground into a powder.

3 Results and discussions

3.1 XRD analysis

XRD was used to determine the crystal phase, structural make-up, and average crystallite size of the produced nanostructure. XRD tests were used to assess the phase and purity of pure $SnFe_2O_4$ nanocomposites. Figure 3.1 depicts the XRD pattern of a pure $SnFe_2O_4$ nanocomposite. It shows distinctive peaks at diffraction angles of 18.22°, 30.23°, 35.63°, 43.23°, 52.99°, 57.23°, and 62.84°, which correspond to the crystal planes of (111), (220), (311), (400), (422), (511) and (440), respectively. Diffraction peaks and matching plans for SnFe2O4 materials (JCPDS 11-0614). From the findings of this obtained pattern XRD, it is obvious that no impurities were discovered because no additional materials were visible.

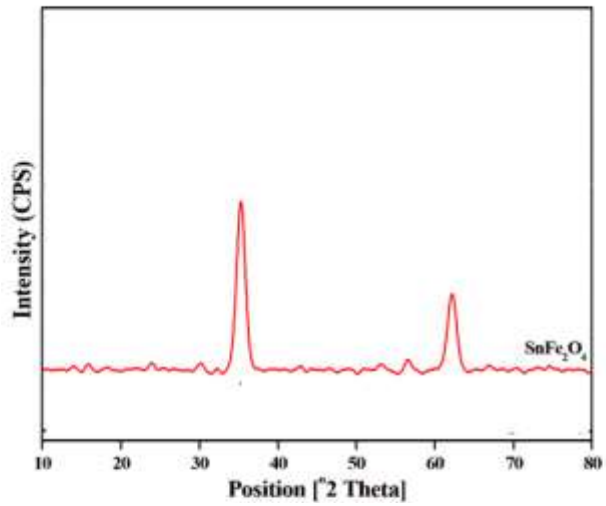

Figure 3.1: XRD patterns of $SnFe_2O_4$ nano composite

3.2 SEM analysis:

SEM stands for scanning electron microscopy. It is a type of electron microscopy that uses a focused stream of electrons to scan a sample's surface and obtain high-resolution images of its topography and structure. To determine the grain size, shape, and growth process of nanoparticles, SEM was used. Figure 3.2 displays SEM images of $SnFe_2O_4$ nanostructures. The SEM micrographs show that nano rods and spherical shaped particles may be seen in non-uniform distribution. Only tin composites and iron oxides are produced in SEM micrographs; no additional impurities are present. SEM micrographs of nanostructures with grain sizes of 100 nm and 200 nm have been obtained.

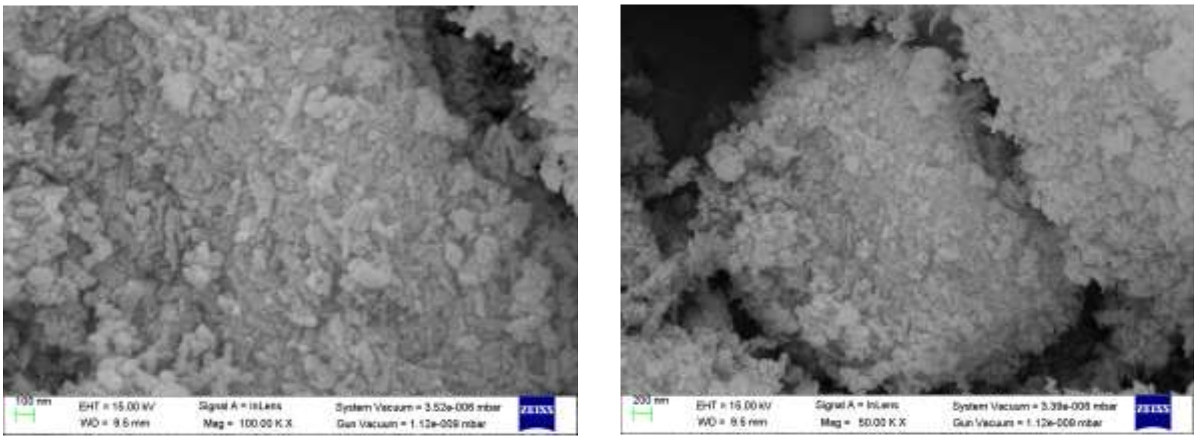

Figure 3.2: SEM micrographs of SnFe2O4 nanocomposites

3.3 EDS analysis:

Energy-dispersive X-ray spectroscopy (EDS or EDX) is used in analytical chemistry and materials science to analyze the elemental composition of a sample. With this technique, a sample is bombarded with electrons, causing the sample's atoms to emit X-rays with certain energies. Figure 3.3 depicts the $SnFe_2O_4$ nanoparticle EDS spectrum. Specific peaks belonging to O, Fe, and Sn species could be seen in $SnFe_2O_4$ nanostructures. No further components are acquired.

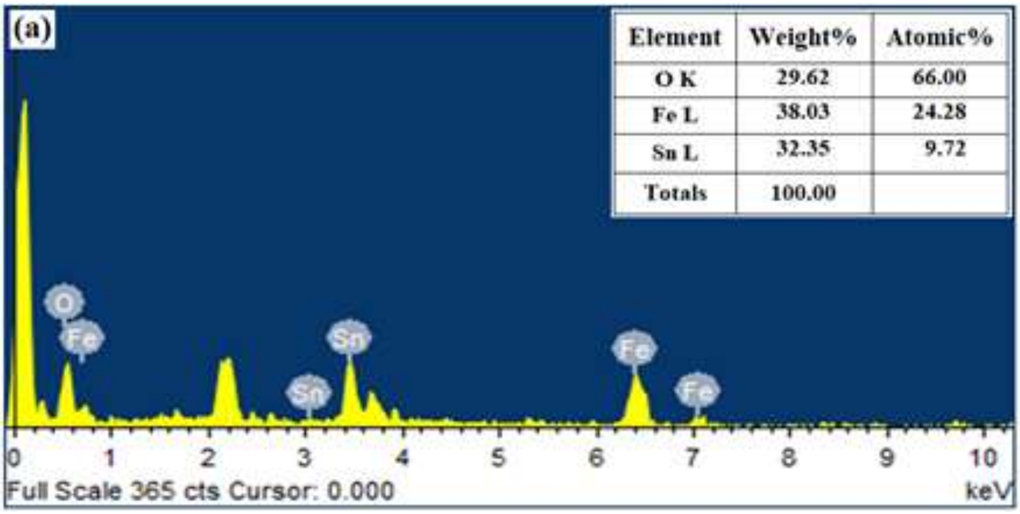

Figure 3.3: EDS patterns of $SnFe_2O_4$ nano composite

4. Conclusion:

The hydrothermal approach was used in the current work to effectively manufacture an unique $SnFe_2O_4$ nano composite material. EDS attached SEM analysis was used to describe the created nano powder. The $SnFe_2O_4$ composite nanomaterials XRD studies identify distinct, high intensity diffraction peaks. It attests to the $SnFe_2O_4$ nanoparticles' crystallinity. SEM images show that $SnFe_2O_4$ has a non-uniform dispersion of spherical particles. The EDX examination revealed the presence of O, Fe, and Sn in the $SnFe_2O_4$ nanomaterials, demonstrating the purity of the generated nano powder. In lithium-ion batteries, sodium-ion batteries, and supercapacitors, $SnFe_2O_4$ can be used as an electrode. To increase the energy density and cycle life of these materials and to improve their electrochemical performance, researchers can modify their characteristics.

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