e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022



# Antibacterial activity and magnetic properties of Sr-$NiFe_2O_4$ nanoparticles synthesizedby simple microwave combustion method

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**Abstract**

Microwave combustion method (MCM) was used to synthesize of spinel Sr-$NiFe_2O_4$ NPs by employing the fuel Urea. The physical characteristics were obtained by following methods viz. powder XRD, SEM, EDX, FT-IR and VSM techniques. The diffraction studies revealed that the average crystallite size exist in the band of 15.22 nm to 25.55 nm. The HR-SEM pictures revealed the agglomerated and spherical morphology of spinel Sr-$NiFe_2O_4$ nanoparticles. Elemental analysis ensured that the existence of Ni, Sr, O and Fe ions. The broad peaks at 439 $cm^{-1}$ and 585 $cm^{-1}$ corresponds to octahedral metal stretching and tetrahedral metal stretching of Sr-$NiFe_2O_4$ respectively. Magnetic results revealed that the prepared NPs are ferromagnetic in nature. The antibacterial activity (ABA) of gram-positive *Staphylococcus aureus*, *Bacillus subtilis* have been investigated using Sr-$NiFe_2O_4$ NPs. It was found that the improved activity is intensified with smooth $Sr^{2+}$ doping as it causes a decrease in the grain size.

**Key words:** Sr-$NiFe_2O_4$; Microwave combustion; Antibacterial activity; VSM technique.

## 1. Introduction

Recently, magnetic spinel ferrites are great important in the field of materials science, due to their enhanced structural, morphology, optical, magnetic and vibrational properties and also they have been widely used for applications such as magnetic fluid for the purpose of information storage, drug delivery, and many more [1-4]. The general formula for cubic spinal structure-based ferrite is $MFe_2O_4$,. The $M^{2+}$ and $Fe^{3+}$ ions occupy two distinct sites namely $A^{2+}$ and $B^{3+}$ [4, 5]. Based on the theory of Wyckoff positions, the spinels exhibit three different crystal structures namely normal, inverse and mixed. In case of normal spinel structure $A^{2+}$ and $Fe^{3+}$ ions sits in the A- and B- sites respectively [$A^{2+}$[$Fe^{3+}$]$O^{2-}$]. While, $A^{2+}$ and $Fe^{3+}$ ions occupies B- and A- sites in case of inverse spinel [6-10].

Different techniques such as hydrothermal, microwave, sol-gel, ball milling, co-precipitation, solvothermal, and auto combustion [11-15] are widely utilized. However, the above techniques are high cost, difficult to synthesis, more time and even low yield [16-20]. Microwave combustion provides many advantages like gentle chemistry route, economic, simple preparation, etc. It is found that fuel plays a critical role in tuning the physical properties such as structure, morphology, magnetism etc [21-25]. In this paper Sr-$NiFe_2O_4$ NPs was synthesized through MCM. Further, morphology, phase, and magnetic properties were studied in detail using various physica characterization techniques.

## 2. Experimental

2.1 Materials and method

Analytical grade Iron nitrate ($Fe(NO_3)_3.9H_2O$), L-arginine ($C_6H_{14}N_4O_2$), Nickel nitrate ($Ni(NO_3)_2.6H_2O$) and Strontium nitrate ($Sr(NO_3)_2$) attained from SD fine, India, and were utilized as it is without undergoing an additional purification process. A homogenous solution is attained by mixing precursors namely nickel nitrate and iron nitrate by maintaining a molar ratio of 1:2. It is further added to urea solution, and this solution was mixed for a period of 1hr. Here, urea is used as fuel and, nitrates precursor plays the role oxidizer [26-30]. Silica crucible was kept inside the microwave oven (SAMSUNG, India make). Then, solution went through process namely boiling and dehydration. Upon achievement of spontaneous combustion by the solution, ignition occurred which results in rapid flame fluffy production of Sr-$NiFe_2O_4$. Further, the obtained samples were calcined at 550 °C for 150 min.

2.*2. Antibacterial activity*

The antibacterial activity (ABA) of spinel Sr-$NiFe_2O_4$ NPs was analyzed by their zone of inhibitions on the human pathogens (HP) gram-positive *S. aureus (Staphylococcus aureus*), *B. subtilis* (*Bacillus subtilis*). An instant culture of all microorganisms was attuned to an OD of 0.1 and wiped onto Mueller Hilton (MH) agar plates. By a cork borer (CB), holes were stamped on the agar, followed by adding of the standard solutions containing the synthesized Sr-$NiFe_2O_4$ NPs (10µg/mL). The plates were incubated at 37˚C for 24 h and the precinct of inhibitions on the human pathogens was dignified in diameter.

## 3. Results and discussion

### *3.1. X-ray diffraction analysis*

The XRD pattern (Fig. 1) is used determine the crystallite size and phase purity of prepared spinel Sr-$NiFe_2O_4$ NPs. The observed diffraction peaks at 2θ values are indexed to (220), (311), (222), (400), (422), and (622) respectively. All the observed diffraction peaks perfectly matched with JCPDS card number 44-1484 signifying the formation of $NiFe_2O_4$ [24].

The impurity peaks corresponds to α-$Fe_2O_3$ phase verified by the card ICSD – 088418 data for Sr doped nickel ferrite. This impurity phase may be associated with the combustion in oxygen rich environment for during the preparation [25]. Debye Scherrer's method is used to deduce average crystallite ($L$) of the prepared NPs along the reflection plane (311) using Eq. (1). where, $\lambda$, the X-ray source wavelength (0.15406 nm); $L$, is the average crystallite size; $\beta$, the full width at half maximum (FWHM) of the observed diffraction peak; and $\theta$, the diffraction angle. The value of ($L$) was found to exist between 14.25 nm to 27.52 nm, in range.

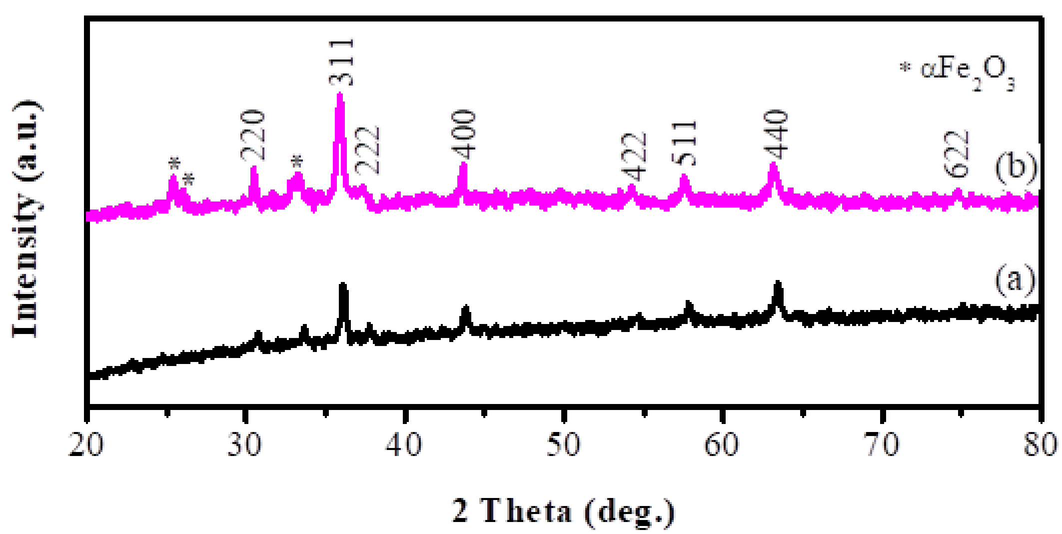



Figure 1. XRD patterns of Sr-$NiFe_2O_4$ nanoparticles.

***3.2.*** Scanning electron microscopy (SEM)The HR-SEM images of spinel $Ni_{1-x}Sr_xFe_2O_4$ (x= 0 to 0.5) NPs revealed homogeneous spherical morphology. Further the particles exhibited

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022


coalescence and agglomerated, which mainly occurs due to the microwave combustion reaction during the process of synthesis [25- 30]. The energy dispersive X-ray analysis confirms that the nickel ferrite nanoparticles comprises of the elements Ni, Fe and O. Further, Fig.3 shows that all the elemental peaks of the elements Sr, Ni, Fe and O, corresponding to the formation of Sr doped $NiFe_2O_4$ nanoparticles.

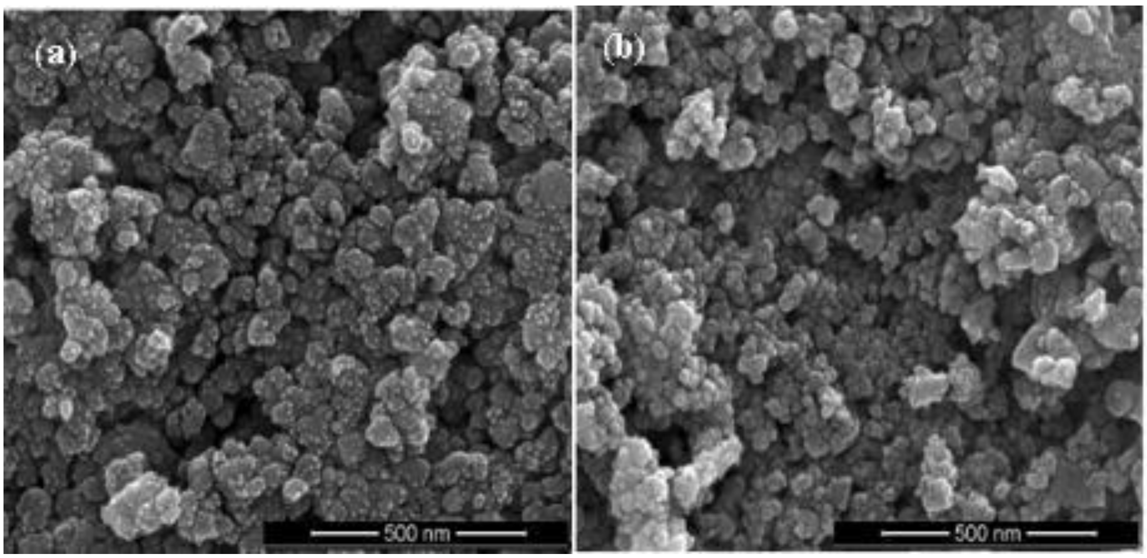
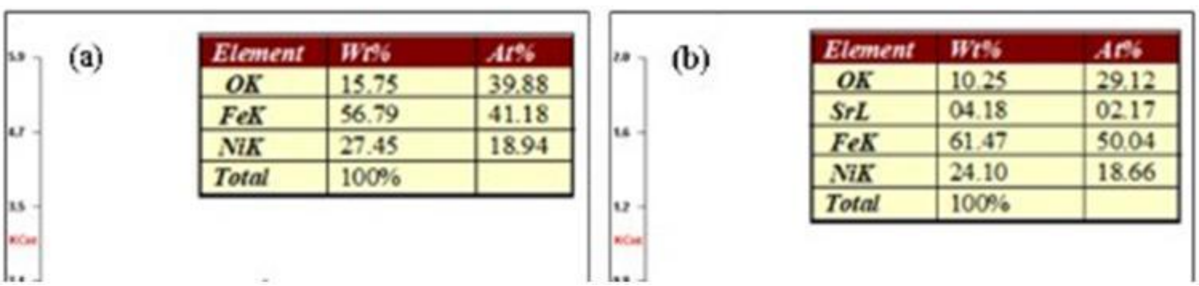



Figure 2. HR-SEM images of Sr-$NiFe_2O_4$ Samples




| Element | Wt% | At% |
|---|---|---|
| OK | 15.75 | 39.88 |
| FeK | 56.79 | 41.18 |
| NiK | 27.45 | 18.94 |
| Total | 100% | |

| Element | Wt% | At% |
|---|---|---|
| OK | 10.25 | 29.12 |
| SrL | 04.18 | 02.17 |
| FeK | 61.47 | 50.04 |
| NiK | 24.10 | 18.66 |
| Total | 100% | |

Figure 3. EDX spectra of Sr-$NiFe_2O_4$ samples.

### *3.3. FT-IR spectra*

The FT-IR spectrum of Sr-$NiFe_2O_4$ nanoparticles was shown in Fig. 4, which was logged in the range of 4000-400 $cm^{-1}$ at RT. H-O stretching is due to the presence of broad peaks at 3438 $cm^{-1}$ [31]. C-H stretching vibration is associated with the peaks at 2925 and 285355 $cm^{-1}$ [4]. C-O stretching vibration on the particle surface is attributed to the absorption peaks at 1725, 1632

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022


and 1395 $cm^{-1}$ [32]. The peaks at 1015-1205 $cm^{-1}$ corresponds to the vibration of spinel structure NPs respectively [33]. The M-O stretching of octahedral sites is caused due to the bands at 4375, 454 $cm^{-1}$. The M-O stretching at the tetrahedral sites of the spinel is due to the band at 585$cm^{-1}$[34].

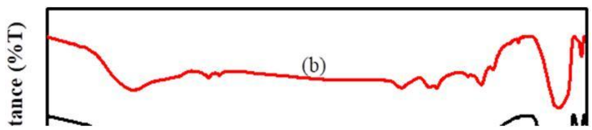



Figure 4. FTIR spectra of Sr-$NiFe_2O_4$ nanoparticles.

### *3.4. Magnetization analysis*

Magnetic hysteresis curve (**Fig. 5**) of the Sr-$NiFe_2O_4$ NPs was measured at RT (300 K) and the stimulated field was ranged in between -15 kOe to +15kOe. The values coercivity $H_c$, $M_r$ and $M_s$ were obtained from the hysteresis curve, and it was found to be ferromagnetic in nature. The coercivity values of doped and undoped nanoparticles was found to be 295.15 Oe, 295.42, 302.92 for ($x$= 0.3), further a decline in value to 285.85 Oe ($x$= 0.5). This variation is due to cationic redistribution and high anisotropy [30-36].

### 3.5 Antibacterial activity

Antibacterial activity of spinel Sr-$NiFe_2O_4$ nanoparticles (**Fig. 6**) were examined beside gram-positive *S. aureus (Staphylococcus aureus*), *B. subtilis* (*Bacillus subtilis)* bacterial strains, respectively. From this result, it was originated that there is no zone of inhibition was obtained over the control. Moreover, a greater concentration of Sr substitution impact enhanced ABA than the lower concentration of Sr-$NiFe_2O_4$ products [37]. The obtained reduced particle size and higher surface area with the surface volume ratio of the samples performance a vibrant character in the antibacterial activity of samples.

## 4. Conclusions

Sr-$NiFe_2O_4$ nanoparticles were successfully synthesized by microwave combustion method. Powder XRD analysis was confirmed the cubic spinel structure. SEM pictures revealed the spherical morphology of the prepared NPs, while EDX studies further ensured

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022


existence of elements confirming the spinel structure. \ FT-IR bands at 436 $cm^{-1}$ and 585 $cm^{-1}$, which are octahedral and tetrahedral metal stretching of ferrite NPs. The magnetization parameters are determined from the hysteresis loop. Antibacterial activity (ABA) of the samples was found that Sr-$NiFe_2O_4$ display enhanced antibacterial activity, due to the smaller particle size and higher surface area with the surface volume ratio of the samples.

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