A STUDY ON THE ABSORPTION OF MICROWAVE ENERGY BY NANO-SYNTHESIZED STRONTIUM FERRITE PARTICLES IN X-BAND

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Abstract

High coercivity is necessary for the usage of microwave ferrites as microwave absorbers. One of the best materials is strontium hexaferrite, which is suited for usage as microwave components, especially microwave absorbers, owing to its high coercivity, strong unilateral magnetic anisotropy, and inexpensive cost in compared to other materials. Chemical co-precipitation was used to effectively create strontium nano hexa ferrites. By using fourier transform infrared spectroscopy and X-ray powder diffraction , the produced nanostructure was evaluated. Following the calcination of the sample at 6000C, the XRD result reveals the transition from amorphous to crystalline. For the X band of frequencies, the behavior of ferrite as a microwave absorber was also investigated.

Keywords: *Microwave absorption , Nanostructure*

Introduction

Radar absorbent materials, a recent development in microwave absorber technology, are unique materials that may be able to lessen electromagnetic signal reflection and hence enhance system performance. Microwave researchers have been interested in ferrites due to its potential usage in tiny circuits and as an electromagnetic wave absorber. Ferrites' non-conductivity makes it feasible for em waves to penetrate them. In contrast, the skin effect limits the usage of metals. It is regarded as the ideal material for a number of electronic applications in terms of power production, conditioning, and conversion due to its low eddy current losses [1]. A magnetic field inside a ferrite may start a conversation between an electromagnetic wave and the field [2–3]. Many useful gadgets have been created using this interaction [4]. The backbone of the ferrite structure, which may take the form of garnet, spinel, or magnetoplumbite, is thought to have a tightly packed lattice of oxygen anions.

M-type hexaferrites are intriguing for usage since they recently shown good characteristics in the microwave and millimeter wave regions of the electromagnetic spectrum [6-7]. A significant ferromagnetic oxide is M-type hexaferrite. These materials may be taken into consideration for their usage as permanent magnets due to their great chemical stability, high resistivity, high saturation magnetization, and strong corrosion resistance. Large unilateral magnetic anisotropy, cheap cost, and strong coercivity make them ideal for usage as microwave components.

Additionally, they have great electrical resistance and are stable [8] [9]. M-type hexagonal nanoferrites exhibit unique absorption properties at microwave frequencies due to their dielectric and magnetic losses. However, the magnetic losses in these materials come from the high frequency spin relexation and absorption of moving magnetic domains during resonance, alternating electromagnetic field. In light of these developments, it is evident that the field of microwave device technology is approaching a tipping point for positive change, one that might have a significant influence on a broad variety of fields involving the transmission, receipt, and manipulation of electromagnetic signals.

Large saturation magnetization and high coercivity are the goals of many initiatives, but increasing these values necessitates high temperatures, which increase particle size. To achieve smaller particle size, a variety of synthesis procedures are applied, including the sol-gel method, ball milling, sonochemical method, citrate gel, chemical co-precipitation, etc.

In this study, we chose chemical co-precipitation because it enables low temperature crystallization, which leads to the generation of nanosized particles owing to mixing of the starting ingredients on an ionic level, and because it is a low-cost approach for mass production. It has been investigated how changes in crystallinity and calcination temperature affect structural characteristics. Additionally, the size of the particles is estimated, and the behavior of nano-ferrites at microwave frequencies is investigated.

Experiment

Chemical co-precipitation was used to create the polycrystalline SrFe12O19 in aqueous environments, as stated by (Gholam et al. 2013). To create a homogeneous solution, the stoichiometric amounts of the sr and Fe chloride compounds—$SrCl_2.6H_2O$ by Fisher Scientifics (99% purity) and $FeCl_3.6H_2O$ by (Finer Chemical Ltd.) were dissolved in deionized water. The pH was then raised to 12 and 10 M alkaline sodium hydroxide (NaOH) was dropwise titrated into the solution until dark brown precipitates appeared. The final product was stored for 24 hours to age. Following filtering, it was washed repeatedly with water and then with ethanol. The produced gel was overnight dried at 600C in a furnace to eliminate any remaining moisture.

To produce crystalline Sr- hexaferrite, the dried precipitates were calcined for 4 hours in air at a temperature of 6000 C. For sample characterisation, prepared samples were ground into a powder. Fourier Transform infrared spectroscopy tests have verified the production of Sr hexaferrite (FTIR). X-Ray diffractometer (XPERT -PRO PW 3050/60) with CuK radiations were used for the structural study. The microwave bench and VSWR meter were used to study the absorption characteristics.

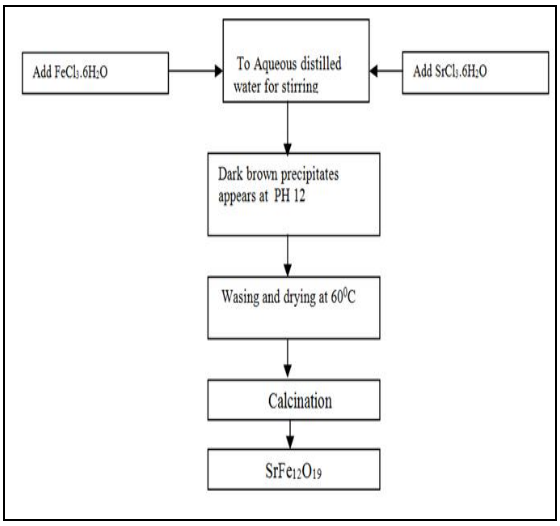

Figure - Method of Preparation and its flow chart

Results

Fourier Transform Infrared Spectroscopy

Fourier To ascertain how samples create ferrite, transform infrared spectroscopic experiments (FTIR) were conducted.

With and without calcination, FTIR spectra of both materials were completed over the range of 4000 - 400 cm-1 (wave number). The produced powder was combined with KBr, pelletized, and FTIR spectra were captured using an FTIR spectrometer from Perkin Elmer-USA. Hexaferrite powder's transmittance dropped when bordering fields were absorbed by it. When compared to previous published investigations, the FTIR spectra of strontium hexaferrite powders exhibit three distinctive transmittance peaks of hexaferrite at 408 cm-1, 481 cm-1, and 534 cm-1 [10].

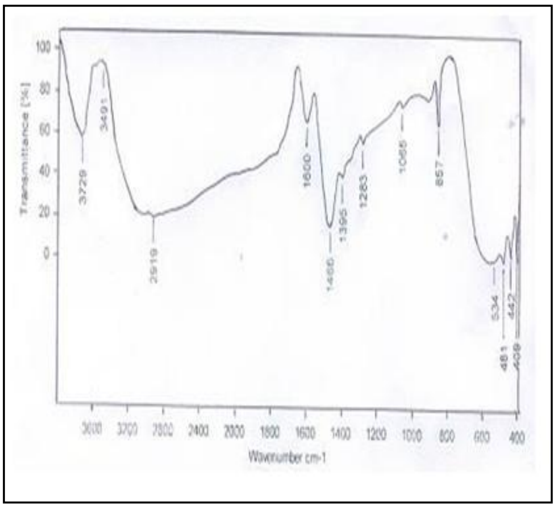

Figure - FTIR-spectrum of Calcined Powder

XRD (X-Ray Diffraction)

On a PAN analytical (Netherlands) X-ray Diffractometer model X-PERT PRO with a wavelength ()= 1.54 °A for CuK and a scattering angle range (°2Theta) of 20° to 80° with a scan rate of 0.0170°/sec and specimen length of 10mm, phase identification and structure analysis were performed at Punjab University.

Using Scherre's equation, the particle size d is determined from the broadening of the X-ray line (1)

$$d = \frac{k\lambda}{\beta Cos\theta}$$

(1)

Where k is the shape factor and may be chosen to be 0.9 and is the X-ray wavelength. The Bragg angle is equal to the FWHM (full width at half-maximum) given in units of 2. Recorded and evaluated is the X-Ray diffraction pattern for both calcined and uncalcined samples. Strontium hexaferrite's XRD patterns are shown in Figures 3 and 4, respectively, with and without calcinations. All of the peaks have been located and compared to JCPDS data. JCPDS 84-1531 is the standard data set used for indexing.

The pattern reveals that the material was formed into nanoscale particles by showing peak creation and broadening during calcinations. Using the Scherrer equation (1), it was determined that the primary peaks at 2 = 33.1786 and 35.6684 had an average crystallite size of around 50 nm.

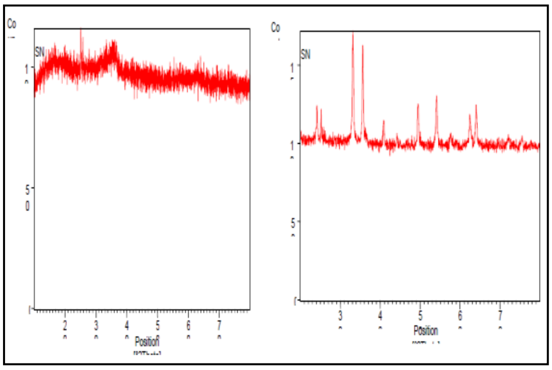

Figure- Synthesized Sample pattern a) Without Calcinations b) With Calcination at 600^{0}C

Microwave Absorption of Hexaferrite Nanomaterial

Strontium hexaferrite's poor transmittance and high absorption were noted utilizing a microwave bench and VSWR meter to study its microwave activity. Due to the addition of strontium hexaferrite powder, a significant level of absorbance in the X band was detected. Cellophane tape was used to secure the sample within the microwave bench. When the microwave bench was first set up, the VSWR meter was used to measure the minimal loss.

The cellophane tape was then utilized as a route obstacle, and the insertion loss was assessed and found to be minimal. Cellophane tape was used to create the sample holder, which was used to modify the powdered sample before inserting it into the waveguide to measure loss using a VSWR meter. In each phase, the sample percentage was raised by 100 mg, and 10 such readings were recorded.

Figure depicts the setup of a microwave bench for evaluating waveguide absorption loss brought on by the presence of a sample of powdered hexaferrite. A graph showing the relationship between the absorption level and sample amount was created using the VSWR meter results.

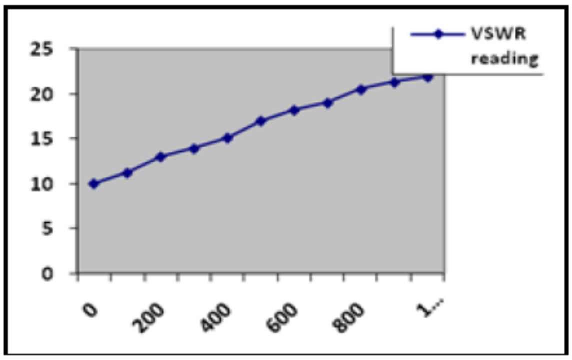

Figure- Microwave Absorption Vs wt. of Nano-ferrite Powder

Conclusion

According to research, the chemical co-precipitation approach is a more effective and convenient way to create strontium hexaferrite nano-material. First, the synthesis procedure was carried out without calcining the material, and then it was done with calcination. These samples' XRD patterns show how their amorphous structure changed into a crystalline one. The synthesized strontium nano hexaferrite has an average particle size of 44 nm. According to the results of the waveguide experiment, strontium hexaferrite nanomaterial is an effective X band electromagnetic wave absorber.

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