World Academy of Science, Engineering and Technology
International Journal of Physical and Mathematical Sciences
Vol:10, No:8, 2016

An Experimental Study of Structural, Optical and Magnetic Properties of Lithium Ferrite

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***Abstract*—**Nanomaterials ferrites have applications in making permanent magnets, high density information devices, color imaging etc. In the present examination, lithium ferrite is synthesized by sol-gel process. The x-ray diffraction (XRD) result shows that the structure of lithium ferrite is monoclinic structure. The average particle size 22 nm is calculated by Scherer formula. The lattice parameters and dislocation density (δ) are calculated from XRD data. Strain (ε) values are evaluated from Williamson – hall plot. The FT-IR study reveals the formation of ferrites showing the significant absorption bands. The VU-VIS spectroscopic data is used to calculate direct and indirect optical band gap (Eg) of 1.57eV and 1.01eV respectively for lithium ferrite by using Tauc plot at the edge of the absorption band. The energy dispersive x-ray analysis spectra showed that the expected elements exist in the material. The magnetic behaviour of the materials studied using vibrating sample magnetometer (VSM).

***Keywords*—**Sol-gel, dislocation density, energy band gap, VSM.

I. Introduction

FERRITE material has been widely used in various technical applications including in magnetic refrigeration, detoxification of biological fluids, magnetically controlled transport of anti-cancer drugs, magnetic resonance imaging contrast enhancement, magnetic cell separation, magnetic devices, switching devices, recording tapes, permanent magnets, hard disc recording media, flexible recording media, read-write heads, active components of ferrofluids, color imaging, gas-sensitive materials and catalytic materials [1]-[7].

Lithium has attracted many researchers because of their unique properties as cathode for lithium-ion batteries and also due to low cost and toxicity. Lithium ferrite ($LiFe_2O_4$) is useful materials for microwave devices and memory core applications [8]-[10]. It is a versatile transition-metal oxide and a useful material in various present and future applications related to catalysis, electronics, photonics, sensing, medicine, and controlled drug release [11]. Nanoparticles have become widely utilized due to their enhanced and unique properties relative to bulk materials. Due to the small size of the nano-crystals, an important part of the atoms is located at the surface this is the reason why the sol-gel synthesis method gone on intensive development [12].

In the present work, we synthesize $LiFe_2O_4$ by sol gel method. The synthesized nanoparticles are characterized by XRD, FT-IR, UV-VIS spectroscopy and VSM.

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II. Experimental Method

The $LiFe_2O_4$ nanoparticles have been synthesized by sol-gel method. Citric acid ($C_6H_8O_7 \cdot H_2O$), ferric nitrate ($Fe(NO_3)_3 \cdot 9H_2O$) and lithium nitrate ($LiNO_3$) were used as starting materials. All the chemicals were analytical grade and used without further purification citric acid solution was prepared by slowly sprinkling citric acid in de-ionized water under continuous stirring to avoid clumping of the material in water. The sols were prepared by dissolving lithium nitrate, and ferric nitrate in de-ionized water in the ratio of 1:2. After constant stirring for three hours the capping solution was added to sols. The subsequent mixture was then heated to constant stirring till the gel obtained. Then the gel was kept in the muffle furnace for 2 days to evaporate the water molecules. The precursor color was changed. The precursor was then calcinized. After that it was crushed with the help of mortar for one hour to form the fine powder. Now a sample was taken for characterization.

III. Results and Discussion

The synthesized nanoparticle of lithium ferrite is subjected to following characterizations and the properties are also incorporated.

A. XRD Analysis

XRD Analysis to determine the nature of the crystal and its structure, size, strain and dislocation density are evaluated for the lithium ferrite is done with the help of The "D8 Advanced, BRUKER X-Ray Diffractometer" of wavelength λ=1.5406 A^0. Fig. 1 shows the XRD pattern of lithium ferrite nanoparticles and Table I gives the properties values of lithium ferrite.

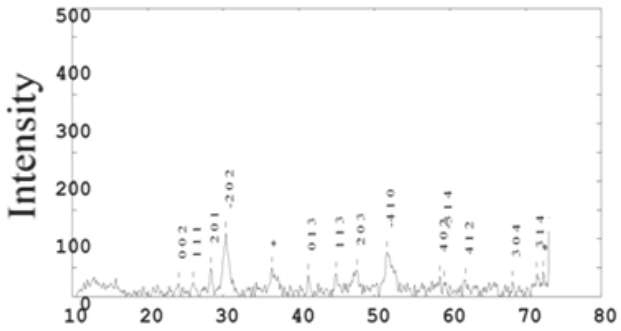

Fig. 1 XRD pattern of lithium ferrite nanoparticles

The average particle size of crystal is evaluated from XRD, by using the Debye Scherer's formula, [13].

$$D = \frac{K\lambda}{\beta \cos\theta} \quad (1)$$

where D is the average crystallite size of the phase under investigation, K is the Scherrer constant (0.89), λ is the wave length of X-ray beam used, β is the full-width half maximum (FWHM) of diffraction and θ is the Bragg's angle. The strain value is calculated with the help of Williamson-hall plot as shown in Fig. 2.

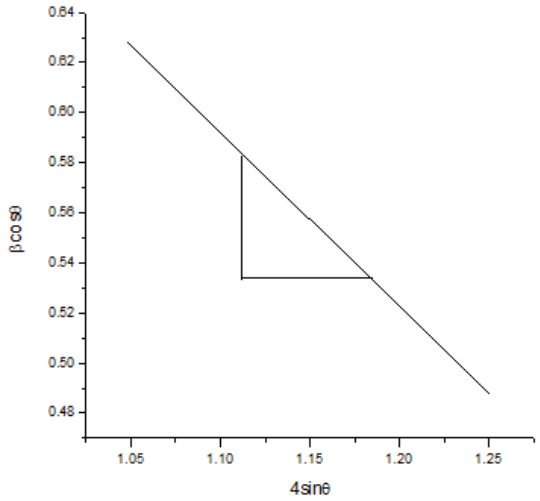

Fig. 2 Williamson-Hall plot

TABLE I
PROPERTIES FOR LITHIUM FERRITE

S. No.	Properties	$LiFe_2O_4$
1.	Crystal Structure	Mono-clinic
2.	Lattice Parameters	a =7.748054A^0, b=4.797752A^0 c= 7.516238A^0 α=γ ≠β
3.	Size of the crystal	22nm
4.	Strain	0.6822
5.	Dislocation Density	2.066x10^{-15} m^{-2}

B. UV-Visible Spectral Study

The UV-V is spectrometer of "JASCO, V-670" used to analyze the optical absorption of the nanoparticles. The regions from 200 to 2500 nm were studied at room temperature.

Fig. 3 shows the cut off wave length for lithium ferrite is 413 nm also the cut off present in the visible region. So the samples can be used for nonlinear optical devices, semiconductor, industrial catalysts, solar energy conversion devices etc. Figs. 4 and 5 sketches the tauc plot of lithium ferrite for direct and indirect band gap. The resultant values of direct and indirect band gap are 1.57 eV and 1.01 eV.

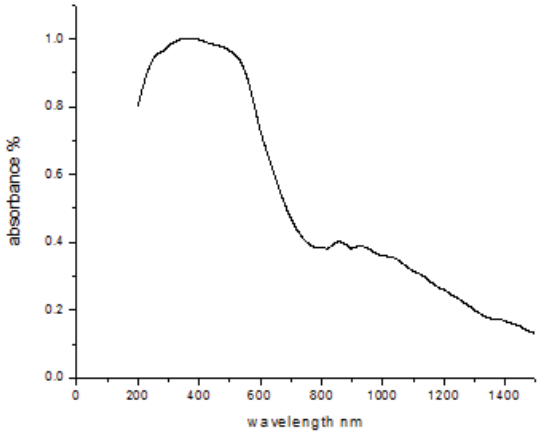

Fig. 3 Absorbance spectra of lithium ferrite

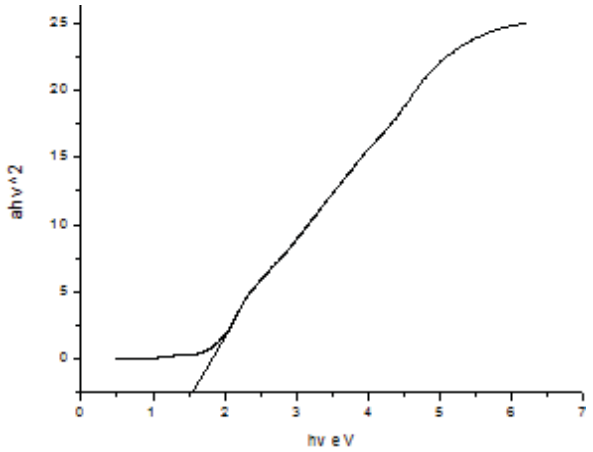

Fig. 4 Direct band gap tauc plot for lithium ferrite

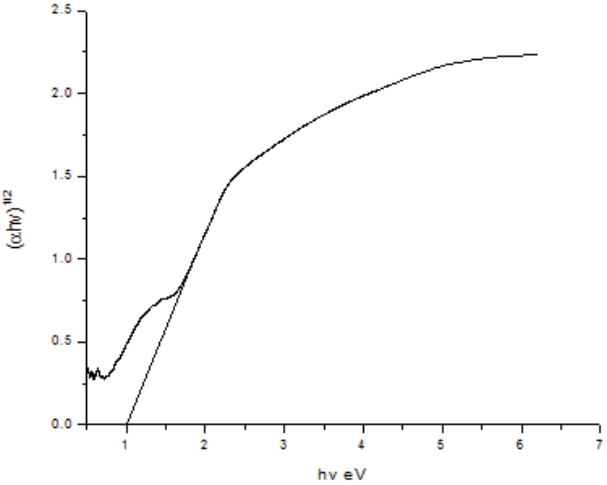

Fig. 5 Indirect band gap tauc plot for lithium ferrite

C. FT-IR Analysis

FTIR spectrum analysis for lithium ferrite nanoparticles is synthesized using sol-gel method in the range of 400 to 4000 cm^{-1}. The FTIR analysis shows that the change in temperature changes the nature of the bond of the samples. The band around the 400cm^{-1} to 700 cm^{-1} corresponds to the presence of

metal oxide. The presence of metal oxide is stretched in the region of 474.49cm^{-1} and 588.29cm-1. The IR bands at 671.76 cm^{-1}, 840.96 cm^{-1} and 954.76 cm^{-1} corresponding to the vibrations of V-O-V and O-(V)3. Fig. 6 shows the FTIR Spectrum for lithium ferrite. The peak range of both the samples range from 3200-3600 shows the O-H bond Stretching. The range of 1620-1680 corresponds the bond present is C=C bond stretching.

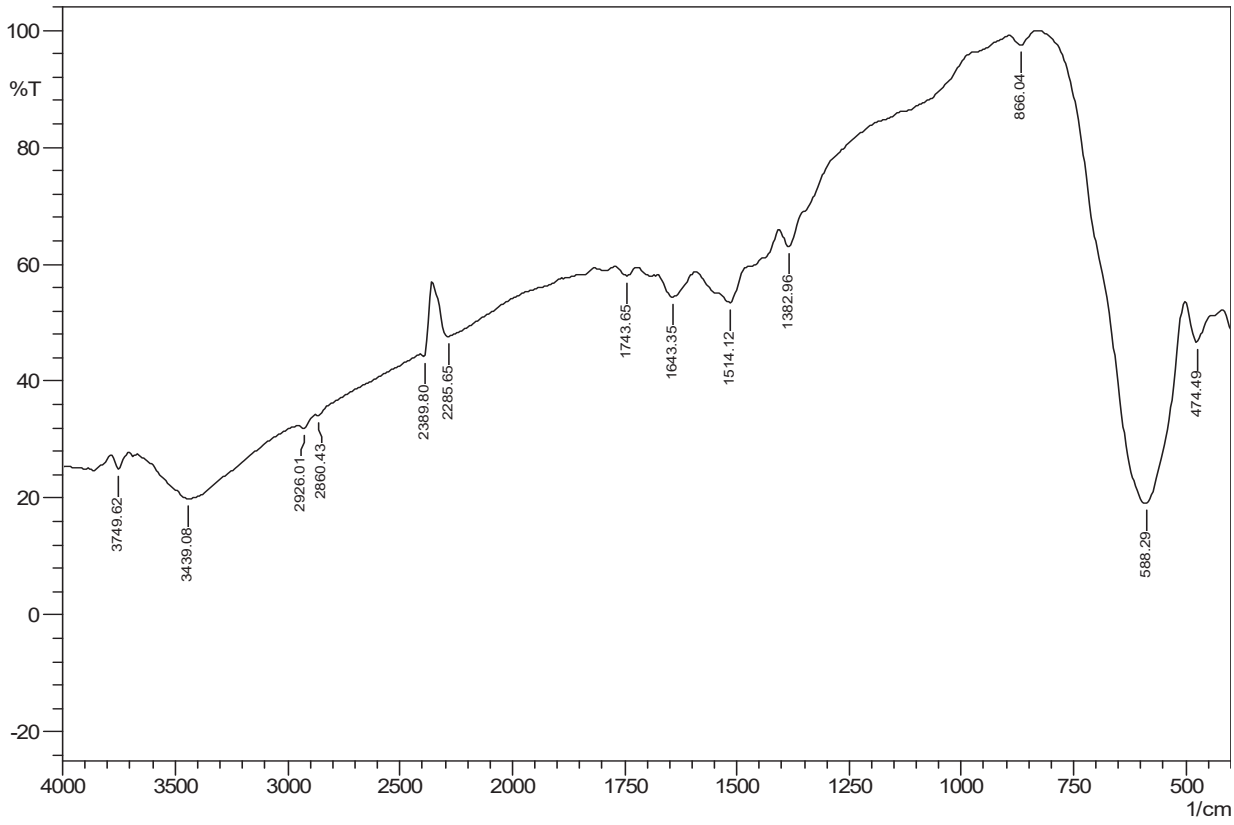

Fig. 6 FTIR Spectrum for lithium ferrite

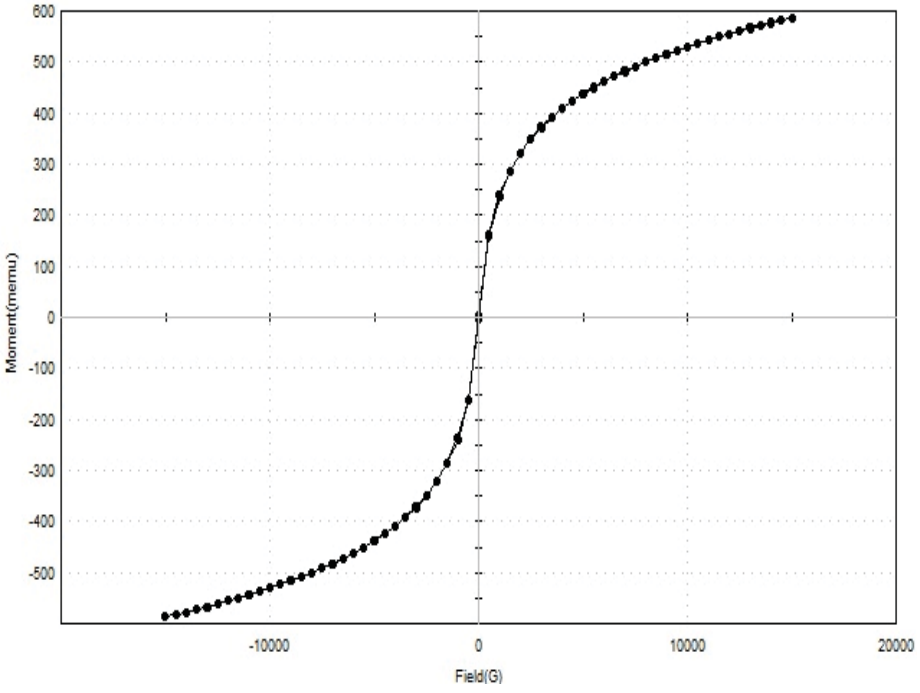

Fig. 7 VSM curve for lithium ferrite

D. Vibrating Sample Microscope

The vibrating sample microscope is calculated at room temperature for a sample. The low coercive value indicates that particle can be easily magnetized without any flux loss. This significant property allows this type of Ferrite can be used in fabrication of magnetic storage media and also Ferrites, typically spinel ferrite and magnetoplumbite ferrite, can be used as recording materials, microwave devices, humidity sensors, pigments etc. A sample exhibits an excellent soft magnetic property with super paramagnetic behaviour [14], [15]. Fig. 7 shows the magnetic property of lithium ferrite and the corresponding values are listed in Table II.

TABLE II
MAGNETIC PROPERTIES FOR LITHIUM FERRITE

S. No.	Properties	$LiFe_2O_4$
1	Coercivity	16.099 G
2	Magnetization	0.58657 emu
3	Retentivity	5.3467 emu

IV. CONCLUSION

The present work was aimed at synthesizing pure lithium ferrite nanoparticles using sol-gel technique. The XRD values show the sample is monoclinic in structure. The strain value and dislocation density are also calculated. The particle size is 22nm. So it exhibits the sample is nanomaterials. The UV-Vis values show the cut-off value present in the visible region. So we can use it in many optoelectronic devices like photovoltaic cells, photoconduction cells, photodiodes, lasers and CD players etc. The VSM results show the samples have super paramagnetic nature which can be used as recording materials, microwave devices, humidity sensors, pigments etc.

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