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Study of Sr hexaferrite prepared by ceramic method within x-band waves

A F Hadi

Physics Department, College of Education for Pure Science, Karbala University, Iraq

abbasfadhel7719@yahoo.com

Abstract

Strontium hexaferrite bulk samples ($\text{SrFe}_{12}\text{O}_{19}$) were prepared via ceramic method with the dimensions of { diameter ($D = 3 \text{ cm}$) and thickness ($t = 2.5 \text{ mm}$) }, and investigated using the vector network analyzer within X-Band waves (frequency bandwidth (8-12) GHz). Three samples have been sintered from this type of ferrite with three temperatures (1000, 1050, 1100) °C. The samples which were sintered with 1050°C and 1100°C having best absorption from the other samples, because the ferrite is not completely formed in this temperature and the ferrite was passed with different phases led to the absorption of the microwave. The results of X-ray diffraction (XRD) showed compatibility with standard results except for some secondary phases with the ferrite samples.

Key Words :- Hexaferrite, Network analyzer, Ceramic method, X-Ray Diffraction.

1. Introduction

The hexagonal iron oxides are an interesting series of ferrimagnetic oxides with hexagonal structures [1]. The general structure of M type hexaferrite ($\text{A}_{0.6}\text{Fe}_2\text{O}_3$ or $\text{AFe}_{12}\text{O}_{19}$, where A is a divalent ion such as Ba^{2+} , Sr^{2+} , Pb^{2+} , etc.), which is hexagonal with space group $P6_3/mmc$, is constructed from 4 building blocks, namely S, S*, R, and R* [2], this material is the main component of the permanent magnet material of trade name ferroxdure [3]. Hexagonal strontium ferrite SrM possesses excellent electro-magnetic properties with an easy magnetization along the c-axis. It is widely used in stealthy technique, permanent magnets, magnetic recording media and electromagnetic interference shielding areas, and has good chemical stability, corrosion resistance and uniaxial magneto crystalline anisotropy. [4]. Hexagonal ferrites can be classified according to crystal structure into six types: M, W, Y, Z, U and X types [5].

2. Mass Calculation

In this study, one compound of hexagonal ferrite was prepared, with formula ($\text{SrFe}_{12}\text{O}_{19}$), as bulk samples with (2.5 mm) thickness. It is very important to choose the raw materials with very high purity, to avoid any influence on the compound properties. The weights of the used



raw materials were accurately calculated from its atomic weights. To prepare one mole of (SrFe₁₂O₁₉) compound, we calculated the mass of its raw materials as shown [6] :-

$$\text{SrCO}_3 = 87.6 + 12 + (3 \times 16) = 147.6 \text{ g}$$

$$\text{Fe}_2\text{O}_3 = (2 \times 55.85) + (3 \times 16) = 159.7 \text{ g}$$

Table (1) shows the mass ratios for the preparation of samples for type ferrite material prepared.

Table 1. The mass ratios of the samples.

Ferrite Formula	Mass (g)	Mass (g)	Total mass (g)
SrFe ₁₂ O ₁₉	SrCO ₃	Fe ₂ O ₃	157.98
	147.6	159.7	
	1/7	6/7	
	21.09	136.89	

3. The measurements of Network analyzer

To measure the four parameters in a scattering matrix: S₁₁, S₁₂, S₂₁ and S₂₂ the network analyzer device used in this research. In the NRW algorithm, the reflection and transmission are expressed by the scattering parameters S₁₁ and S₂₁. The reflection coefficient (R) is given by [7]:-

$$\text{dB} (S_{11}) = 10 \log R \quad \dots\dots\dots(1)$$

After calculating (R) of eq. (1) can be adjusted to obtain attenuation coefficient of the following equation:-

$$\text{Attenuation coefficient} = 20 \log R \quad \dots\dots\dots(2)$$

The transmission coefficient is given by [8]:-

$$\text{dB} (S_{21}) = 10 \log T \quad \dots\dots\dots(3)$$

Now to obtain absorbability (A²) one can use values calculated from eq 1,2 and 3 as follow:-

$$R^2 + T^2 + A^2 = 1 \quad \dots\dots\dots(4)$$

Where, R² the reflectivity, T² the transmittance and A the absorption coefficient.

4. Tests of X-Ray Diffraction

Using X-ray diffraction (XRD), phase analysis was performed to inspect the crystalline structure of the prepared samples after sintering, using Cu-K α radiation and wavelength $\lambda = 1.5406 \text{ \AA}$; the range of the Braggs angles are taken ($2\theta=20^\circ - 60^\circ$) for the samples. By using Braggs law [9]: -

$$2d \sin\theta = n \lambda \quad \dots\dots\dots(5)$$

The interplaner distance (d) can be measured from eq5, and then comparing the resultant X-ray patterns with international standard (ICDD) International Centre for Diffraction Data which is the American Standard for Testing Materials (ASTM).

5. Results and Discussions

The absorbance tests of the $\text{SrFe}_{12}\text{O}_{19}$ samples have been carried out at frequency bandwidth (8-12) GHz. The $\text{SrFe}_{12}\text{O}_{19}$ samples were sintered at (1000, 1050, 1100) °C.

This study calculated the R, Atten. Coeff., R^2 , T, T^2 , and A^2 and recorded all the values in the tables.

Table (2) shows that the values of S_{11} and S_{21} vary by frequency, and then all the parameters have been changed such as reflection coefficient, attenuation coefficient, reflectivity, transmission coefficient, transmittance, and absorbance, due to the absorption of ferrite of the waves depends on the frequency.

Clearly the increase in the value of S_{11} (negative value), reduces the reflection coefficient, increases the attenuation coefficient (negative value) and reduces the values of reflectivity. The increase in the values of S_{21} (negative value), reduces the transmission coefficient and reduces transmittance. The values of absorbance are also increasing when the increase each of the values of S_{11} and S_{21} , which means that the best desired results when the values of S_{11} and S_{21} are at the maximum value, and all the values of parameters in tables depended upon the values of sintering temperature of the samples.

Figures (1) and (2) explain that the appearance of peaks at frequencies (8, 11, 12) GHz at 1000°C, 1050°C and 1100°C. The highest value of the attenuation coefficient at 1000°C are (-31.109) dB and (-19.481) dB at frequency (8) and (12) GHz, at 1050°C is (-17.008) dB at frequency (11) GHz. While the best values of absorbance are at 1050°C and 1100°C at frequency (11.5) and (12) GHz.

Table 2. Listed the Parameters of $\text{SrFe}_{12}\text{O}_{19}$ samples

Freq. (GHz)	S_{11} 1000°C	S_{11} 1050°C	S_{11} 1100°C	R_1	R_2	R_3	Att.cof. 1000°C	Att.cof. 1050°C	Att.cof. 1100°C	R_1^2	R_2^2	R_3^2
8.0	-15.554	-1.341	-1.799	0.028	0.734	0.661	-31.109	-2.682	-3.598	0.001	0.539	0.437
8.5	-3.301	-3.999	-3.521	0.468	0.398	0.445	-6.602	-7.998	-7.042	0.219	0.159	0.198
9.0	-2.707	-1.915	-1.616	0.536	0.643	0.689	-5.414	-3.829	-3.232	0.287	0.414	0.475
9.5	-1.882	-2.542	-2.593	0.648	0.557	0.550	-3.764	-5.084	-5.185	0.420	0.310	0.303
10.0	-2.241	-2.140	-1.953	0.597	0.611	0.638	-4.482	-4.280	-3.905	0.356	0.373	0.407
10.5	-5.816	-4.821	-1.722	0.262	0.330	0.673	-11.633	-9.641	-3.444	0.069	0.109	0.453
11.0	-2.176	-8.504	-6.312	0.606	0.141	0.234	-4.352	-17.008	-12.623	0.367	0.020	0.055
11.5	-8.947	-7.807	-2.523	0.127	0.166	0.559	-17.894	-15.614	-5.046	0.016	0.027	0.313
12.0	-9.741	-3.382	-6.587	0.106	0.459	0.219	-19.481	-6.764	-13.173	0.011	0.211	0.048

Freq. (GHz)	S_{21} 1000°C	S_{21} 1050°C	S_{21} 1100°C	T_1	T_2	T_3	T_1^2	T_2^2	T_3^2	A_1^2	A_2^2	A_3^2
8.0	-1.224	- 13.529	-7.809	0.754	0.044	0.166	0.569	0.002	0.027	0.430	0.459	0.536
8.5	- 16.503	-5.751	-6.836	0.022	0.266	0.207	0.001	0.071	0.043	0.781	0.771	0.759
9.0	-8.192	-8.456	-9.272	0.152	0.143	0.118	0.023	0.020	0.014	0.690	0.566	0.511
9.5	-2.314	-2.284	-1.507	0.587	0.591	0.707	0.345	0.349	0.499	0.235	0.341	0.197
10.0	-1.989	-2.097	-1.376	0.633	0.617	0.728	0.400	0.381	0.531	0.244	0.246	0.063
10.5	-1.866	-1.952	- 10.953	0.651	0.638	0.080	0.424	0.407	0.006	0.508	0.484	0.541
11.0	-1.713	-1.595	-3.052	0.674	0.693	0.495	0.454	0.480	0.245	0.178	0.500	0.700
11.5	-1.107	-5.478	-5.670	0.775	0.283	0.271	0.601	0.080	0.073	0.383	0.892	0.614
12.0	-1.949	-9.839	-3.291	0.638	0.104	0.469	0.408	0.011	0.220	0.581	0.779	0.732

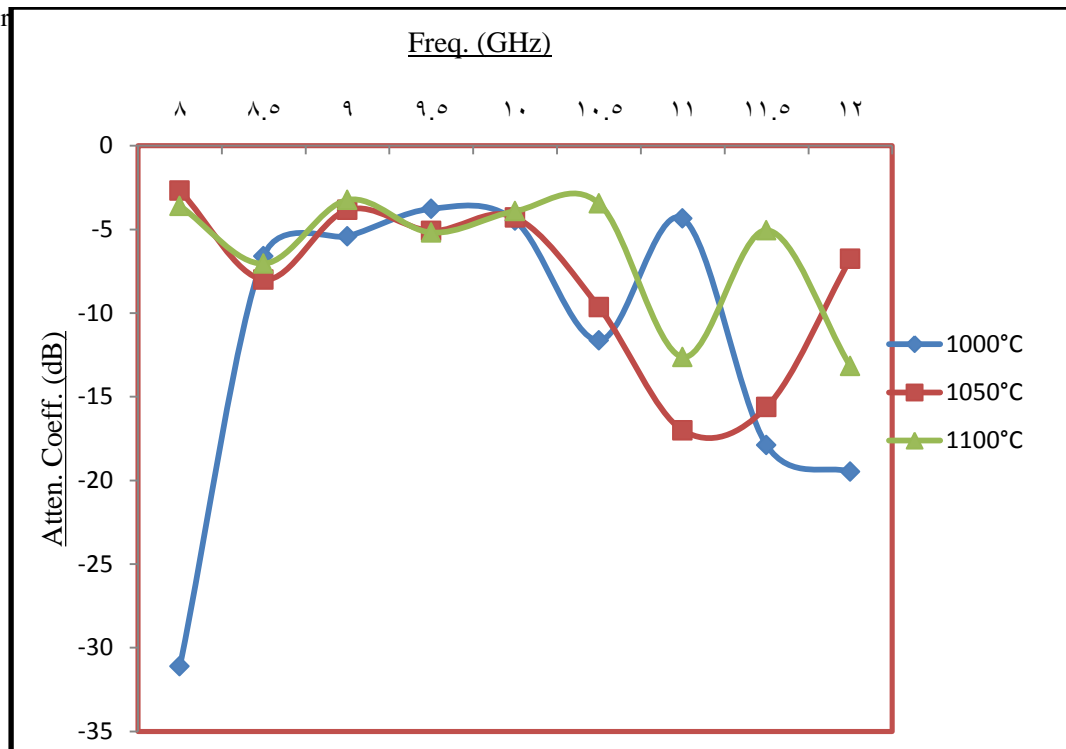


Figure 1. The attenuation coefficient curves as a function of frequency for $\text{SrFe}_{12}\text{O}_{19}$ samples.

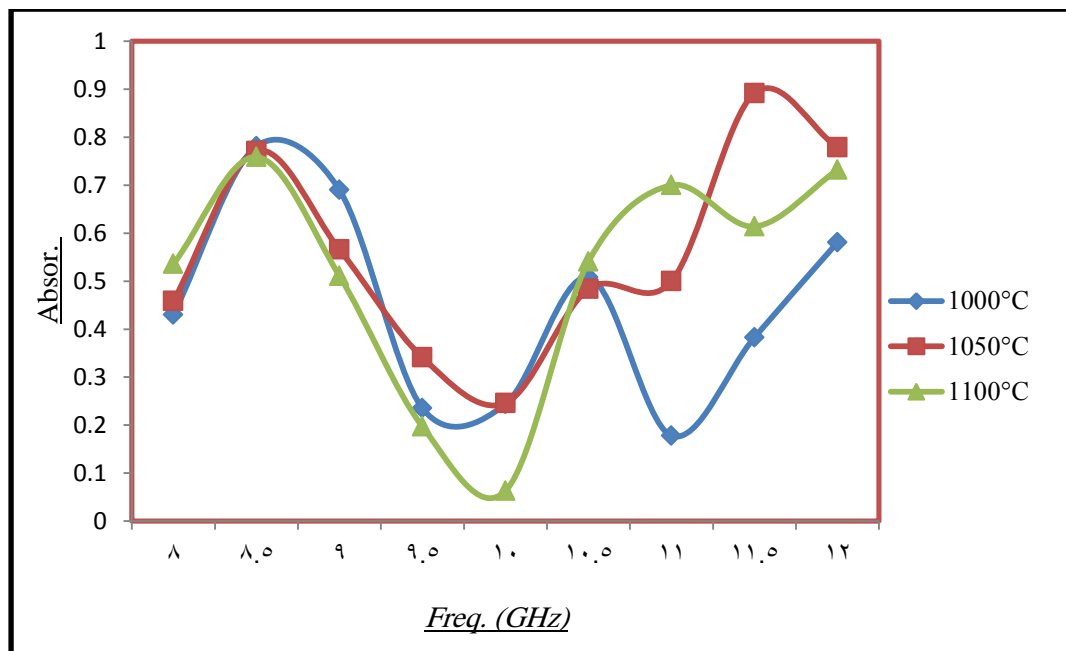


Figure 2. The absorbance curves as a function of frequency for $\text{SrFe}_{12}\text{O}_{19}$ samples.

The results shown in fig. (3) demonstrate the completion of the $\text{SrFe}_{12}\text{O}_{19}$ phase of the hexagonal structure at the sintering temperature 1100°C , obviously it is a polycrystalline. The pattern exhibits the Bragg reflection at the diffraction angles ($2\theta^\circ$) which give interplaner distances (d), which matched perfectly with the international standard (ASTM) as shown in table (3).

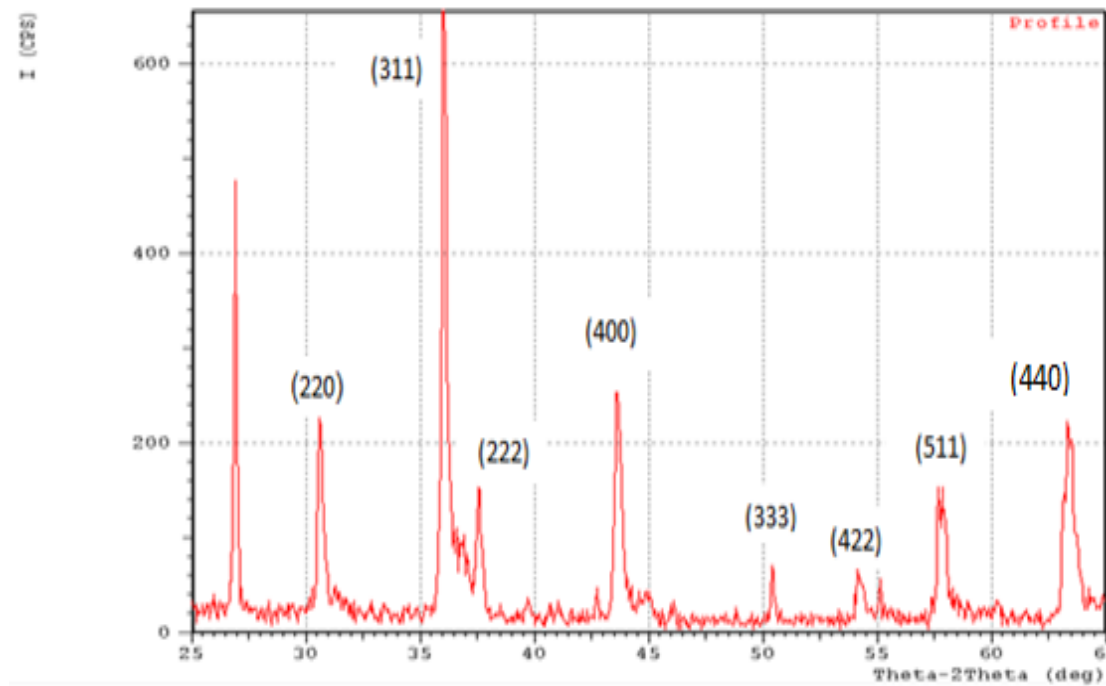


Figure 3. XRD pattern of $\text{SrFe}_{12}\text{O}_{19}$ at $T=1100^\circ\text{C}$.

Table 3. The interplaner distances (d) and ($2\theta^\circ$) of XRD pattern of $\text{SrFe}_{12}\text{O}_{19}$ comparing with the ASTM card at $T=1100^\circ\text{C}$.

$2\theta^\circ$	$d(\text{\AA})$ EXP.	$d(\text{\AA})$ ASTM	hkl
31.695	2.913	2.900	220
36.400	2.589	2.780	311
37.280	2.442	2.420	222
43.756	2.091	2.070	400
51.380	1.854	1.870	333
54.130	1.717	1.690	422
57.220	1.609	1.590	511
63.450	1.499	1.470	440

6. Conclusions

At frequency bandwidth (8-12) GHz, a number of resonance peaks were appeared especially (8, 11, 12) GHz for all samples. The sintering temperature has an important influence in forming ferrite materials, the attenuation coefficient and the absorption. Also it was shown that the best values of the absorptivity and the attenuation coefficient were obtained at the sintering temperature 1050°C and 1100°C, this means that the best values of sintering temperature are at 1050°C and 1100°C, because the ferrite is not completely formed in this temperatures and the ferrite was passed with different phases led to the absorption of the microwave. The results of XRD test showed compatibility with standard results (ASTM) card.

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