International Journal of Electronics Engineering (ISSN: 0973-7383)
Volume 10 • Issue 1 pp. 326-330 Jan 2018-June 2018 www.csjournals.com

Study of Microwave Absorption Properties in Co –Sn dopedM-type Ba-Srhexagonal Ferrites

Jasbir Singh[a], Charanjeet Singh[b], Dalveer Kaur[c]
[a]Research Scholar, Department of Elect. & Comm. Engg, IKG PTU, Kapurthala, Punjab, India
[b]Corresponding Author, Deptt. of Elect. & Comm. Engineering, LPU Jalandhar, Punjab, India
[c]Deptt. of Elect. & Comm. Engineering, I.K.G. PTU, Kapurthala, Punjab, India
charanjeet2003@rediffmail.com

Abstract: Microwave absorption properties of $Ba_{0.5}Sr_{0.5}Co_xSn_xFe_{12-2x}O_{19}$ hexagonal M-type ferrites (x ranges from 0.0 to 1.0) substituted with Co^{2+} and Sn^{4+} cations were studied using absorber testing device method corresponding to thickness, substitution and frequency (X-Band).Ferrite composition was synthesized with the help of standard ceramic method. Analysis of microwave absorption properties has been done with the help of Quarter wavelength mechanism.In this study various parameters e.g Reflection loss: RL, Maximum absorber power: P_{abmax}, Matching frequency: f_{mat}, Calculated thickness: t_{cal}, Matching thickness: t_{mat}, Frequency band and Bandwidth for RL > -10 dB in $Ba_{0.5}Sr_{0.5}Co_xSn_xFe_{12-2x}O_{19}$ ferrites were calculated and the obtained values for the parameters were in close agreement with the theoretical values. Research shows that the substitutions of Co^{2+} and Sn^{4+} ions enhance the microwave absorption.On studying the absorption in relation to the frequency it was seen that for the compositions x = 0.2 and 1.0, the maximum absorbed power of 95.5 and 95.0 % were observed respectively at 8.2 GHz respectively. Higher microwave absorption occurs for the compositions x = 0.0, 0.2 and 1.0 governed by the mechanism of the quarter wavelength.

Keywords: Microwave absorption, Ceramic method, Reflection loss, Hexagonal ferrites.

1. Introduction

No doubt the escalation in technology has improved our lifestyle but hazards associated with it pose serious challenges to us. Electromagnetic pollution is one of them which lead to EMI (electromagnetic interference). Electronics devices working at millimeter and micrometer wavelength suffer from this problem even more severely.EMI can affect the functioning of these devices. Electronic devices operating at high frequency (GHz) produce waves or stray EM radiations which interferes and due to which error is produced in the data received by wireless receivers.

A number of copper tracks with thin width are used in the PCB of a computer, laptops, smartphones etc. to integrate numerous electronic components on it.Asper quarter wavelength mechanism: when the copper track's width becomes near to the ¼thof the wavelength of passing by signals having high frequency then the tracks work as an antenna which radiates factitious electromagnetic signal termed as EMI. This problem of EMI can be solved by using microwave absorbers. Hexagonal M-type ferrites are employed in various electronic devices wideband transformers, radio frequency coil, RAM, channel filters, gyromagnetic devices, tuning slug and antenna etc. [1-3] for microwave absorption. Ferrites have been chosen for this purpose because of better magnetic properties than conventional dielectric counterparts. Its ferrimagnetic nature, domain wall resonance, ferromagnetic resonance (FMR), magnetic and dielectric losses contribute towards the absorbing characteristics [4-6]. Review of related researches has shown various studies on microwave absorption in ferrites. Microwave absorption is studied by Yu et al. at Ku-band in Mn^{2+} ions doped $BaMn_xCo_{1-x}TiFe_{10}O_{19}$ hexagonal ferrite and the value of maximum obtained RL wasfound to be -30.5 dB in composition x = 0.6 at 2 mm thickness [7]. The role of impedance matching mechanism and quarter wavelength mechanism is emphasized by Nam et al. in $La_{1.5}Sr_{1.5}NiO_4$ ferrite and inferred absorption accompanied by -36.7 dB RL at thickness 3 mm[8]. Moradi et al. analyzed the enhancement in absorption with substitution and thickness of composition of Mn^{2+}, Mg^{2+}, Co^{2+} and Ti^{4+} ions in hexagonal Barium ferrite

[9]. Sadiq et al. found the reflection loss of -24.84 dB in Mn^{2+} and Sm^{3+}ion co-doped X-type hexagonal ferrite at 10.1 GHz [10]. Bercoff et al. investigated about the enhancement of absorption with the substitution of Yttrium ions in Ni-Zn spinel ferrite [11].

In this paper, researcher report microwave absorption properties of $Ba_{0.5}Sr_{0.5}Co_xSn_xFe_{12-2x}O_{19}$ (x varies from 0.0 to 1.0 in steps of 0.2) ferrites synthesized by a standard ceramic method and analyze absorption using the mechanism of the quarter wavelength.

2. Experimental method

The experimental set up of the Standard ceramic method [12] was employed for the synthesis of M-type hexagonal ferrites with composition $Ba_{0.5}Sr_{0.5}Co_xSn_xFe_{12-2x}O_{19}$ (x varies from 0.0 to 1.0 in steps of 0.2). The starting material used were AR grade of Strontium carbonate ($SrCO_3$, 99.99% pure**,** Sigma-Aldrich**),** Cobalt carbonate ($CoCO_3$, 99.99 % pure, Sigma-Aldrich), Barium carbonate ($BaCO_3$, 99.98 % pure, Merck, Germany), tin oxide (Sn_2O_4, 99.99 % pure, Sigma-Aldrich) and Ferric oxide (Fe_2O_3, 99.99% pure, Merck, Germany).

The chemicals involved in stoichiometric amount were first ground along with distilled water with the help ofmortar and agate pestle for 8 hours. The temperature of 1000 °C was maintained in an electric furnace for pre-sintering which continued for 10 hours. Slow cooling was done at the rate of 5 ºC/ min to obtain the room temperature followed by the process of re-grounding.Then sieving was done by using220 B.S.S mesh sized sieves. The pellets were prepared at a uniaxial pressure of 75 KN/m^2 with the help ofthe hydraulic press.Again the sintering of the pellets was done for 15 hours at a temperature of 1150 °Cby maintaining the rates of heating &cooling at ± 5 °C/ min.

The microwave absorption characteristics of $Ba_{0.5}Sr_{0.5}Co_xSn_xFe_{12-2x}O_{19}$(x= 0.0 to 1.0) ferrite were investigated at X-band using[13-14] Absorber Testing Device (ATD) method in relation tofrequency,thickness and substitution.

8 to 12 GHz ranged frequencies at X-band were produced in the rectangular slotted waveguidehaving length and breadth as 22.86 and 10.16 millimeter respectively by microwave frequency synthesizer. The microwave frequency synthesizer is followed by an isolator which permits the unattenuated microwave to transmitin one specific direction and blocks it in the opposite direction. The used directional coupler has three ports out of which one is a primary input port and other two are secondary output ports. The metal plate backed ferrite composition was attached at the output 1 of secondary port and the power meter was used at the secondary output port 2 for measuring the reflected signal from the ferrite sample and for calculation of parameter S_{11}.

Following relation is used to calculate the reflection loss (RL):

$$RL\ (dB) = 20 \log_{10}(|S_{11}|) \qquad (1)$$

90% of the microwave absorbed power is exhibited by theRL of -10 dB.The higher value of reflection loss leads to increment in the microwave absorption and vice versa.

Reflected Power (%) iscalculated as:

$$\text{Reflected Power}\ (\%) = (P_r/P_{rw}) \times 100 \qquad (2)$$

Here $P_r$corresponds to thereflected power from the metal plate backed sample by and P_{rw}isthereflected power from themetal without the sample.

The calculation of Absorbed power was done using the expression:

$$\text{Absorbed Power}\ (\%) = 100 - \text{Reflected Power}\ (\%) \qquad (3)$$

3. Results and discussion

3.1Microwave Absorbed Power

Figure 1depicts the plots of P_{ab} (absorbed power)in relation tosubstitution and frequency of Co^{2+} and Sn^{4+} cations in $Ba_{0.5}Sr_{0.5}Co_xSn_xFe_{12-2x}O_{19}$ hexagonal ferrites. x = 0.2 and x=0.0 shows the highervalue of absorbed power P_{ab} over the entire investigated frequency region.

Over the different frequency regions, the absorbed power >91 % has been observed. x = 0.2 and 0.6 exhibited maximal and minimal P_{ab} values of 95.5 and 91.5 % at 8.2GHz and 11.56 GHz respectively.

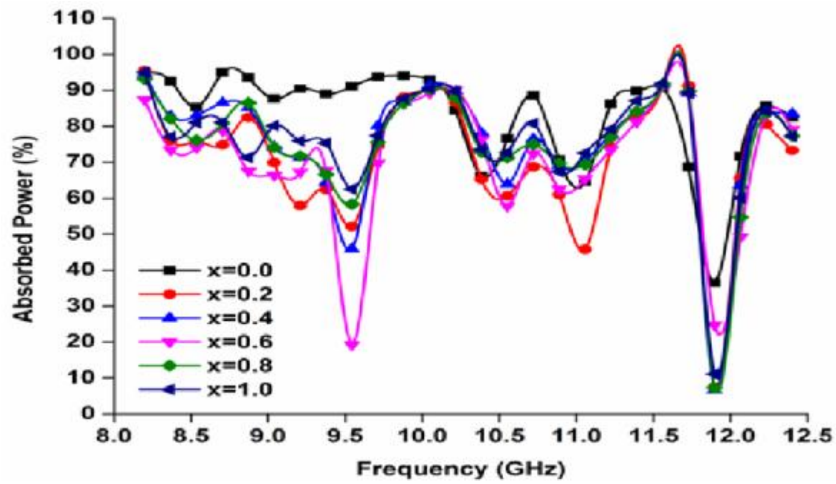

Figure 1. Plots of P_{ab} (absorbed power) vs. frequency (GHz) and substitution (x) of Co-Sn ions in$Ba_{0.5}Sr_{0.5}Co_xSn_xFe_{12-2x}O_{19}$ hexagonalferrites.

Table 1 depicts Reflection loss: RL, Maximum absorber power: P_{abmax}, Matching frequency: f_{mat}, Calculated thickness: t_{cal}, Matching thickness: t_{mat}, Frequency band and Bandwidth for RL > -10 dB in $Ba_{0.5}Sr_{0.5}Co_xSn_xFe_{12-2x}O_{19}$ ferrites. In the doped composition$P_{abmax.}$ value showed varying trends. For compositions x = 0.0, 0.2 and 1.0 higher values of absorbed power.(P_{abmax}) at 8.2 GHz has been observedwhile for compositon x = 0.4, 0.6 and 0.8 slighty lower value of $P_{abmax.}$is seen at 8.2, 11.56 and 8.2 GHz respectively.

Table 1
Maximum absorber power (P_{abmax}(%), Matching Frequency(f_{mat}), Calculated thickness, Frequency band and Bandwidth for RL > -10 dB in $Ba_{0.5}Sr_{0.5}Co_xSn_xFe_{12-2x}O_{19}$ ferrites.

Compositio n	P_{abmax} (%)	Matching Frequency (f_{mat}) (GHz)	Thickness t=n.λ/4 (mm) (calculated)	Frequency band RL > - 10dB (GHz)	Bandwidt h (MHz)
x=0.0	94.9	8.2	2.3	9.37 – 10.21	840
x=0.2	95.5	8.2	2.8	9.88 - 10.21	330
x=0.4	94.7	8.2	2.2	9.88 - 10.21	330
x=0.6	91.5	11.56	2.9	11.39 – 11.72	330
x=0.8	93.2	8.2	2.1	11.39 – 11.72	330
x=1.0	95.0	8.2	2.3	9.88 - 10.21	330

3.2 Quarter Wavelength Mechanism

As perQuarter Wavelength Mechanism “when the ferrite material’s thickness is approximately equivalent to the quarter wavelength of propagating wave through it then the signal will be completely attenuated” [15, 16].

When the signal passes through ferrite sample metal plate backed sample it gets divided into two parts (1) part one gets reflected by the front face of the material (2) second part after propagating through the material gets reflected by the metal plate. Rejoining of both the parts occur at the front surface but due to being 180°out of phase with each other they cancel out each other which results in zero total reflection.

The expression showing this mechanism is

$$t_m = \frac{n\lambda_0}{4} \qquad \text{where n = 1, 3, …5…….etc.} \tag{4}$$

$$\lambda_0 = \frac{\lambda}{\sqrt{\mu\varepsilon}} \tag{5}$$

Where t_m (calculated or theoretical thickness), λ_0 (wavelength of the signal in a material), λ (wavelength of the signal in air), μ (complex permeability) and ε(complex permittivity) are the various parameters. Nicholson Ross method is employed for the derivations ε and μ from S-parameters [17].

The Contribution of the quarter wavelength mechanism forvarious compositionsvia calculated or theoretical thickness ($t_{cal} = n\lambda_o/4$) is shown in Table 1.

Results tabulated in table 1 shows that x = 0.0, 0.2 and 1.0 havemaximum absorbed power of 94.9, 95.5 and 95.0 % in all compositions due to calculated thickness as per the mechanism of the quarter wavelength,while, x = 0.4, 0.6 and 1.0manage to havegood absorbed power.

The bandwidth of-10 dB is exhibited by all the compositions are shown in table 1; -10dB bandwidth corresponds to the spectrum of frequencies for which RL > -10dB. x = 0.2, 0.4and 1.0 shows330 MHz Absorption Bandwidth (ABW) at similar frequency band ranging from 9.88 GHz to 10.21 GHzand x=0.6and 0.8 shows same absorption bandwidth at 11.39 to 11.72 GHz. However, compositionx = 0.0 has ABW of 840MHz at the frequency band from 9.37 to 10.21.

4. Conclusions

The standard ceramic method was used to prepare $Ba_{0.5}Sr_{0.5}Co_xSn_xFe_{12-2x}O_{19}$ (x varies from 0.0 to 1.0) ferrite powderedsamples whose microwave absorption property was analyzed and found to increase with the effect of doping of Co^{2+} and Sn^{4+} cations. Investigation showed that the compositions x = 0.0, 0.2 and 1.0 own maximum contribution fromthe mechanism of quarter wavelength leading towards higher microwave absorption. Maximum microwave absorption or EMI reduction characteristics are reported in x=0.2 composition with 95.5 % absorbed power atthe thickness and matching frequency of 2.9 mm and 8.2 GHz respectively. All the doped compositions showed an absorption bandwidth of 330 MHz and for undoped composition; its value comes out to be 810 MHz at -10 dB. This prepared hexagonal ferrite composition can be potentially used as microwave absorber or EMI suppresser.

Acknowledgement:

We express our deepest gratitude towards the Inder Kumar Gujral Punjab Technical University, Kapurthala, Punjab for providing us an opportunity to carry out the research work.

References

[1]. X. Huang, J. Zhang, M. Lai, T. Sang, "Preparation and microwave absorption mechanisms of the NiZn ferrite nanofibers", J. Alloys Compd. 627, (2015) 67-373.

[2]. U.R. Lima, M.C. Nasar, M.C. Rezende, J.H. Araugo, "Ni–Zn nanoferrite for radar-absorbing material", J. Magn. Magn. Mater. 320, (2008) 1666-1670.

[3]. J.C. Aphesteguy, A. Pamiani, D. Digiovanni, S.E. Jacobo, "Microwave-absorbing characteristics of epoxy resin composites containing nanoparticles of NiZn and NiCuZn ferrites", Physica B 404, (2009) 2713-2716.

[4] P. Meng, K. Xiong, L. Wang, S. Li, Y. Cheng, "Tunable complex permeability and enhanced microwave absorption properties of $BaNi_xCo_{1-x}TiFe_{10}O_{19}$",G. Xu, J. Alloys Compd. 628, (2015)75-80.

[5]. J. Liu, J. Zhang, P. Zhang, S.Wang, C. Lu, Y. Li, M. Zhang, "Tunable microwave absorbing properties of barium hexa-ferrite nano powders by surface carbonized layers", Mat. Lett. 158, (2015) 53-57.

[6]. P. Meng, K. Xiong, L. Wang, S. Li, Y. Cheng, G. Xu, "Tunable complex permeability and enhanced microwave absorption properties of $BaNi_xCo_{1-x}TiFe_{10}O_{19}$", J. Alloys Compd. 628, (2015) 75-80.

[7]. L. Wang, H. Yu, X. Ren, G. Xu, "Magnetic and microwave absorption properties of $BaMn_xCo_{1-x}TiFe_{10}O_{19}$", J. Alloys Compd. 588 (2014) 212–216.

[8]. P. T. Tho, C. T. A. Xuan, D.M. Quang, T.N. Bach, T.D. Thanh, N.T.H. Le, D.H. Manh, N.X. Phuc, D.N.H. Nam, "Microwave absorption properties of dielectric $La_{1.5}Sr_{0.5}NiO_4$ ultrafine particles", Mater. Sci. Eng., B 186 (2014) 101–105.

[9]. R. S. Alam, M. Moradi, H. Nikmanesh, J. Ventura, M. Rostami, "Magnetic and microwave absorption properties of $BaMg_{x/2}Mn_{x/2}Co_xTi_{2x}Fe_{12-4x}O_{19}$ hexaferrite nanoparticles", J. Magn. Magn. Mater. 402 (2016) 20–27.

[10]. Imran Sadiq, ShahzadNaseem, Muhammad NaeemAshiq, M. AsifIqbal, Irshad Ali, M.A. Khan, ShanawarNiaz and M. U. Rana, "Spin canting effect and microwave absorption properties of Sm-Mn substituted nanosized material", J. Magn. Magn. Mater. 406 (2016) 184–191.

[11]. Silvia E. Jacobo, Paula G. Bercoff, "Structural and electromagnetic properties of yttrium-substituted Ni–Zn ferrites range", Ceram. Int., 42 (2016) 7664–7668.

[12]. Charanjeet Singh, S. Bindra Narang, I.S. Hudiara, Yang Bai, Koledintseva Marina, "Hysteresis analysis of Co–Ti substituted M-type Ba–Sr hexagonal ferrite", Mat. Lett. 63 (2009) 1991-1994.

[13]. M.R. Meshram, N.K. Agrawal, B. Sinha, P.S. Misra., "Characterization of M-type barium hexagonal ferrite-based wide band microwave absorber", J. Magn. Magn. Mater. 271 (2004) 2007-2014.

[14]. P. Singh, V. K. Babbar, A. Razdan, R. K. Puri and T. C. Goel, "Complex permittivity, permeability, and X-band microwave absorption of CaCoTi ferrite composites", J. App. Phys. 87 (2000) 4362-4366.

[15]. B. Wang, J. Wei, Y. Yang, T. Wang, F. Li,"Investigation on peak frequency of the microwave absorption for carbonyl iron/epoxy resin composite", J. Magn. Magn. Mater. 323 (2011) 1101–1103.

[16]. N.-N. Song, Y. J. Ke, H.-T. Yang, H. Zhang, X.-Q. Zhang, B.-G. Shen, Z.-H. Cheng,"Integrating giant microwave absorption with magnetic refrigeration in one multifunctional intermetallic compound of $LaFe_{11.6}Si_{1.4}C_{0.2}H_{1.7}$", Sci. Rep. 2291 (2013) 1–5.

[17]. A.M. Nicolson and G.F. Ross, "Measurement of the Intrinsic Properties of Materials by Time-Domain Techniques", IEEE Trans. Instrum. Meas. IM-19 (1970) 377-382.