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Substitution Effect Of (Mn, Ti) to The Dielectric Properties of Barium-Strontium Hexaferrite for Absorbing Electromagnetic Waves

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Abstract. The objective of this work is to evaluate the ability of Mn-Ti substituted barium-strontium hexaferrite to absorb high frequency electromagnetic wave. To accomplish this objective, Mn-Ti substituted barium strontium hexaferrite of Ba0.5Sr0.5Fe12-x(Mn0.5Ti0.5)x with x = 0.1, x=0.3, x=0.5 were prepared through mechanical alloying route. Phase identification of the material obtained from XRD pattern indicating that the material is single phase for all variations of x. Coercivity and the remanent obtained by analyzing the hysteresis curve. The lowest coercivity at x = 0.5 for 77.86 kA/m but also lower the remanent of 0.088 kA/m. Dielectric properties of the material traced by calculating the value of permittivity and permeability of the material that was obtained with the parameters of the scattering vector network analyzer (VNA) in the 8GHz to 12GHz range.

Keywords: Electromagnetic wave absorber, Barium-Strontium Hexaferrite, mechanical alloying, Permittivity and permeability
PACS: 41.20.-q, 75.50.-y, 91.25.F

INTRODUCTION

With the development of radar, microwave communication technology, the study of electromagnetic wave absorbing material has increased in recent years. Barium-Strontium Hexafferites are special kinds of absorbing materials due to their dielectric and magnetic losses in microwave frequency band. Usually, the resistivity of the ferrites is very high. However, the magnetic loss these materials results from their ferrimagnetism, the resonance absorption of moving magnetic domains and spin relaxation in the high-frequency alternating electromagnetic fields [1, 2].

There are two important conditions required to be satisfied by lossy materials. The first is matched characteristics impedance, in which the intrinsic impedance of free space. This entails making the dielectric constant and magnetic permeability of the material equal to each other. Second, the incident electromagnetic wave must enter and be attenuated rapidly through the material layer, thus reducing the emerging wave to an acceptably low magnitude magnetic absorption materials made by dispersing magnetic fillers in an insulating matrix continue to play a leading role in the investigation and application of microwave absorption materials [3-5].

Substitution for the Fe^{3+} and Ba^{3+} is an effective method to vary the magnetic properties of barium ferrite. After the Fe and Ba ions are substituted with Sr, Mn–Ti, the saturation magnetization, coercivity, anisotropy constant and ferromagnetic resonant frequency of barium ferrite is changed in this study, the electromagnetic properties are investigated in Mn–Ti substituted barium-strontium ferrite. The reason for choosing those substitution compounds is their different static magnetic properties (especially, the coercivity and saturation magnetization) at the critical substitution ratio for in-plane anisotropy. Phase identification, magnetic properties, permittivity and permeability as function of high frequency microwave absorber of the $Ba_{0.5}Sr_{0.5}Fe_{12-x}(Mn_{0.5}Ti_{0.5})_xO_{19}$ were examined.

EXPERIMENTAL PROCEDURE

A ferrite series of the composition $Ba_{0.5}Sr_{0.5}Fe_{12-x}(Mn_{0.5}Ti_{0.5})_xO_{19}$, where in varies 0.1 to 0.5 in steps of

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0.2, was prepared by the conventional ceramic method. The samples were synthesized from stoichiometric mixture of $BaCO_3$, $SrCO_3$, Fe_2O_3, $MnCO_3$, TiO_2 of 99,9% purity. The mixture was milling for 10 h and sintered in air at 1050^{o}C for 4 h then pressed 7 kN to form pellets. The pressed materials were in the form of cylindrical with the thickness of 2 mm and the diameter of 2.5 mm, which were finally sintered at 1000^{o}C for 3 h.

X-ray diffraction (XRD) spectra of powders were performs by means of CoK α radiation and the diffraction points were recorded from 20^o to 100^o. The magnetic properties were measured using Permagraph magnet-physik Steingroever GmbH. The variations of coefficient absorption versus frequency were studied by measuring the voltage standing wave ratio (VSWR) on the X-band microwave. A network analyzer (VNA N5230C Agilent Technologies) was employed to determine the values of permeability and permittivity at different frequencies by using a reflection / transmission technique. For this purpose, cylinder samples of 25 mm and 2 mm thickness were tightly inserted into rectangular wave guide (RWG) was chosen for accurate measurement technique with cut off frequency at 6.56 GHz. The measurement of complex permeability and permittivity is related transmission reflection method of rectangular waveguide loaded with dielectric sample. The technique involves measuring two port complex scattering parameter with a vector network analyzer (VNA). The technique involves measurement of the reflected (S11) and transmitted signal (S21). Nicholson-Ross-Weir (NRW) technique provides a direct calculation of both the permittivity and permeability from the s-parameters [6-8].

RESULT AND DISCUSSION

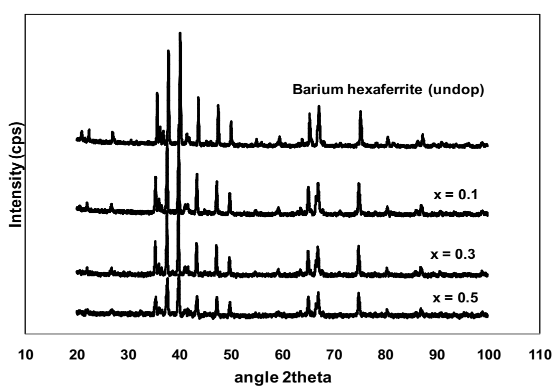

Figure 1. XRD patern Barium Strontium subtitute Mn, Ti as a function of angle 2theta.

Figure 1 show the XRD pattern of $BaSrO.6Fe_{2-x}(MnTi)_xO_3$ ferrite sintered at 1050^{o}C for 4 h. X-ray diffraction analysis of all samples confirmed to the single phase hexagonal structure. Samples have been refined by using the analysis software GSAS rietveld. In the doped ferrite cases, the substitution of Mn^{3+} and Ti^{2+} seem arrange in hexagonal structure to fulfill the formation of single hexagonal phase.

It is observed that the undoped sample possess the largest coercive force (*H*c), the largest hysteresis loop area and the highest *B*r. The *H*c of pure bariun ferrite is very high (about 258.7 kA/m). With the substitution of (Mn, Ti) *H*c rapidly decreases from 316.4 kA/m, 135.5 kA/m and 77.86 kA/m x = 0.1; x = 0.3 and x = 0.5 respectively. Further substitution of Mn,Ti give rise to *B*r for x = 0.3 about 0.119 T

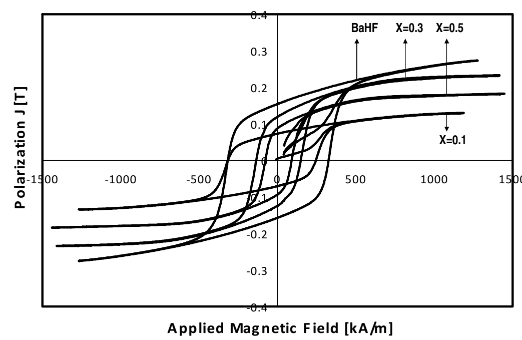

FIGURE 2. Hysteresis loop of BaHF and Mn-Ti substituted Barium Strontium Hexaferrite.

The change of magnetization is generally brought about by rotation of spin or domain wall displacement. This motion lag behind the applied magnetic field and consequently cause change of permeability and permittivity. The frequency dependence of μ and ε for barium strontium ferrite composites with $Mn^{3+}Ti^{2+}$ content x = 0.1, 0.3, and 0.5 shown in Figure 3. The permittivity shows insignificant variation with frequency for the variation x. However, for variation of x there is a significant change in intensity for several frequency. Permittivity value varies with the frequency tends to the same for all samples, where the maximum value occurs at a frequency of 7 GHz to 8 GHz and at 9.8 to 10.5 GHz. This may be due to significant contribution of $Mn^{3+}Ti^{2+}$ ions in addition to Fe^{3+} ions to interfacial polarization. Dielectric properties of polycrystalline ferrite are due to the occurrence of interfacial polarization and intrinsic polarization of electric dipoles. Interfacial polarization results from ferrits structure consist of grains that have a low conductivity and are separated by grain boundaries which have a higher resistivity.

TABEL 1. Detail data for hysteresis loops

Composition x	*B*r (T)	*H*cB (kA/m)	*H*cJ (kA/m)	*H*knee (kA/m)	(BH)max (kJ/m^3)	*H* max (kA/m)
$BaO6Fe_2O_3$(BaHF)	0.367	258.7	378.5	253.8	25.5	944.3
x = 0.1	0.073	54.01	316.4	73.60	1.0	1188
x = 0.3	0.119	73.39	135.5	39.94	2.3	1416
x = 0.5	0.088	46.67	77.86	20.26	1.1	1447

*B*r: residual induction, *H*c: coercive force, (BH)max: energy product, *H*max: net effective magnetization force.

The frequency dependence of μ and ε for Barium Strontium ferrite composites with $Mn^{3+}Ti^{2+}$ content x equal 0.1, 0.3, and 0.5 shown in Figure 3. Seen that there is the influence of frequency on the value of μ and ε at the same frequency region. The permittivity shows insignificant variation with frequency for the variation x. However, for variation x there is a significant change in intensity for several frequency.

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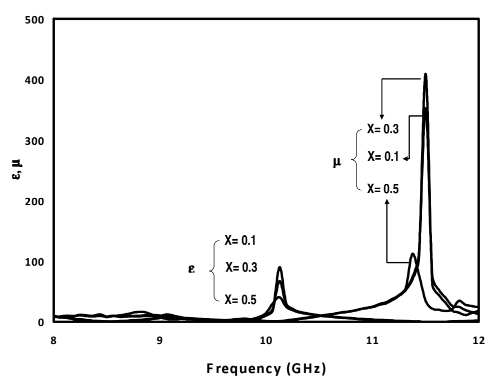

Figure 3. Permittivity and Permeability properties of Mn-Ti substituted barium strontium hexaferrite as calculated from scattering parameter data of VNA

Permeability varies with the frequency seen for all samples, where there is a maximum value at a frequency of 11 GHz to 12 GHz. The maximum value occurs at substitute x = 0.5, as shown in Figure 3. The observed magnetic spectra are in agreement with the mechanism of natural magnetic resonance involving domain-wall displacement and domain rotation. The relations expressing the resonance relaxation phenomena near the characteristic frequency of spin rotation or domain wall displacement are available in the literature. The higher values of permeability observed in these samples may be attributed to the presence of substitution of Mn, Ti between the neighboring crystallites and the spike phase at imaginary values of the constant transmission.

CONCLUSION

Magnetic permeability and electric permittivity of Mn-Ti substituted barium hexaferrites for $Ba_{0.5}Sr_{0.5}Fe_{12-x}(Mn_{0.5}Ti_{0.5})_xO_{19}$ (x = 0.1, x = 0.3 x= 0.5) compositions have been evaluated. Abrupt increase in permeability took place at frequencies between 11 GHz and 12 GHz. Increase in permittivity was obtained at frequency of 10.1 GHz. The increase in dielectric properties indicate Mn-Ti substituted ferrite materials posses a potential that microwave absorbers.

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