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A study of microwave attenuation in Co-Gd substituted Ba-Sr M-type hexagonal ferrite

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Abstract: In the article characteristics of attenuation(α) and loss tangent total ($\tan\delta_t$) have examined from $Ba_{0.5}Sr_{0.5}Co_xGd_x\,Fe_{(12-2x)}O_{19}$ M-type hexagonal ferrites samples with CoGd composition (x=0.0, 0.2, 0.4, 0.6, 0.8 & 1.0). Investigation of hexagonal ferrite in X- band (from frequency range 8.2 GHz to 12.4 GHz) is done with the help of Vector Network Analyzer. With the substitution of Cobalt-II ions (Co^{2+}) and Gadolinium III ions (Gd^{3+}), samples deliver expansion in attenuation(α) and loss tangent total ($\tan\delta_t$). x=0.4 composition shows large attenuation(α) 50.879dB with frequency 12.4 GHz. This composition have scope of higher frequency absorber applications.

Keywords: Ferrites, Absorber, attenuation, loss tangent.

I. Introduction

Due to the tremendous advancement within the area of information and wireless communication /technology, there is requirement of such devices which can control or overcome the electromagnetic pollution around us. This electromagnetic interference (EMI) radiations or pollution can be responsible for the collapse of electronic devices and gadgets. There is a requirement of microwave safeguards or EMI silencers for electronic structure or frameworks to reduce this electromagnetic interference (EMI) radiations or pollution. Ferrites are useful in biomedical, electronic gadgets, microwave absorbers, forensic experts' suits, gyro-magnetic gadgets, RAMs, stealth, ovens etc. The dielectric property makes ferrite useful and can be applied in EMI suppressers / attenuators over the traditional or conventional dielectric materials. M-type hexagonal ferrite is ferri-magnetic in nature and is appropriate as microwave safeguards or EMI silencers. We have described in the paper the attenuation (α) characteristics of $Ba_{0.5}Sr_{0.5}Co_xGd_xFe_{(12-2x)}O_{19}$ M-type hexagonal ferrite with composition of CoGd (x=0.0, 0.2, 0.4, 0.6, 0.8 and 1.0).

II. Experimental

The CoGd doped M type hexagonal ferrites with compositions (x=0.0, 0.2, 0.4, 0.6, 0.8 and 1.0) were manufactured at 1150°C through standard ceramic method. The (α) of samples is determined from ($\varepsilon' - j\varepsilon''$) and ($\mu' - j\mu''$). The investigation range was X-band (from frequency 8.2GHz to 12.4 GHz). These properties were obtained with the help of Vector Network Analyzer (VNA), model of the VNA was Agilent-N5225A. Complex parameters were derived from S-parameters.

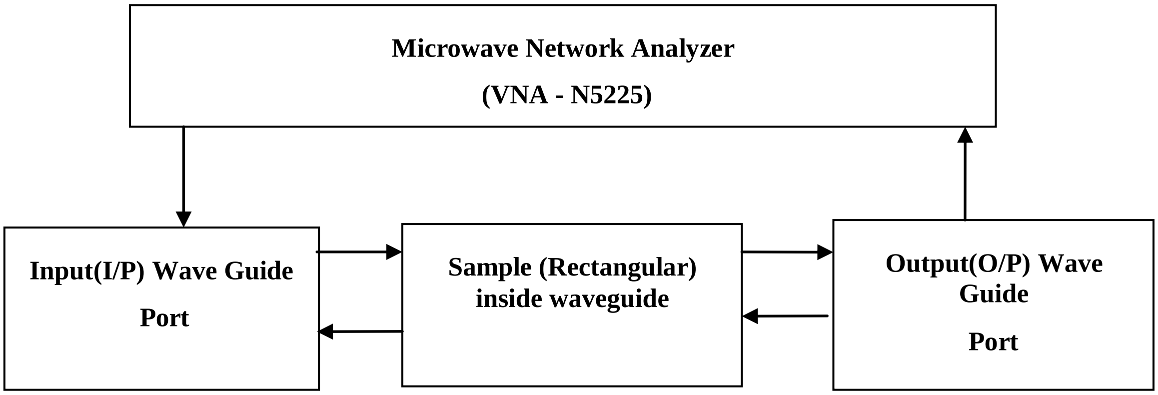

Fig. 1 Measurement setup for Microwave Absorption(α).

First of all calibration of the V.N.A. was done in air ahead to find the various parameters. 1st figure represents the measurement setup for absorption (α) in the desired microwave frequency level: VNA–N5225 is associated with port network to rectangular waveguide. Rectangular sample of ferrite was placed in waveguide. Higher frequency signal were send to sample through input (I/P) waveguide. Output waveguide send response to V.N.A., response output from V.N.A. was detected.
We find the attenuation(α) through the formula:

$$\alpha = \frac{\sqrt{2\pi}}{\lambda_0}\left[\varepsilon''\mu'' - \varepsilon'\mu' + [(\varepsilon'\mu'')^2 + (\varepsilon''\mu'')^2 + (\varepsilon''\mu'')^2 + (\mu'\varepsilon'')^2]^{0.5}\right]^{0.5}$$

here λ_o represent wavelength (in free space),
ε' represent permittivity, **ε''** represent dielectric loss,
μ' represent permeability and **μ''** represent magnetic loss respectively).

Relation used to calculate total loss tangent ($\tan\delta_t$) :

$$\tan\delta_t = \frac{\varepsilon''}{\varepsilon'} + \frac{\mu''}{\mu'}$$

III. Results and Discussion

The X-ray diffractograms confirmed the M-type crystal structure of OcGd doped $Ba_{0.5}Sr_{0.5}Fe_{(12-2x)}O_{19}$ hexagonal ferrites.

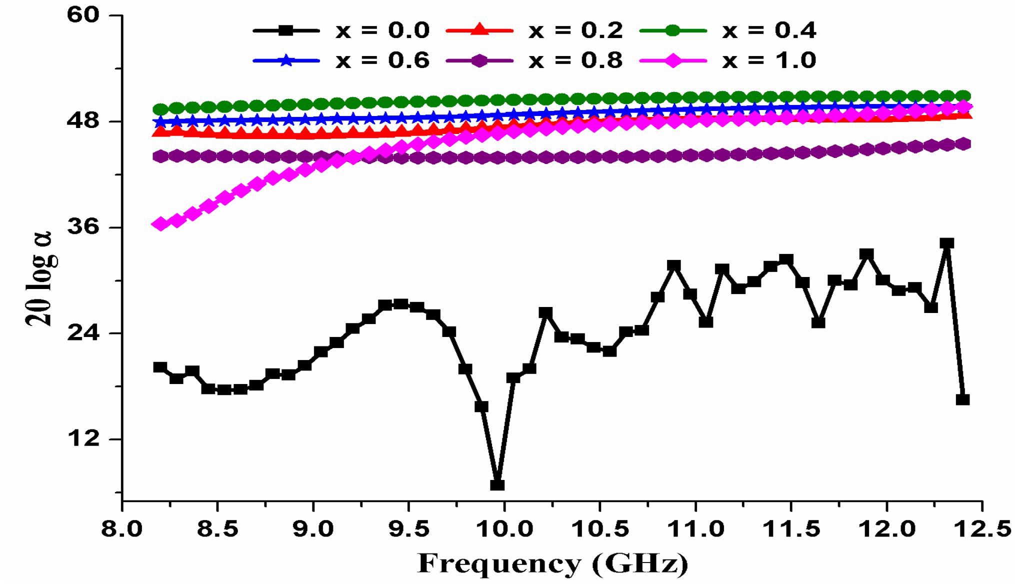

Fig. 2 Deviation of attenuation(α) verses frequency within $Ba_{0.5}Sr_{0.5}Co_xGd_xFe_{(12-2x)}O_{19}$ hexagonal ferrites.

In the picture number 2 deviation shows between the attenuation(α) with respect to frequency within CoGd doped M type hexagonal ferrites with compositions of CoGd (x=0.0, 0.2, 0.4, 0.6, 0.8 and 1.0). The deviation in attenuation(α) were observed in this congregation, attenuation(α) undergoes slight increases with increase in frequency. Higher attenuation(α) comes near higher frequency-region. The arrangement shows higher attenuation(α) 50.879 dB in CoGd x= 0.4 at the 12.4 GHz frequency. Lowest attenuation 6.77 dB come in with sample without doping x=0.0 at 9.964 GHz frequency.
In the picture number 3 deviation shows between dielectric loss tangent($\tan\delta_\varepsilon$) with respect to the x-band frequency in the CoGd M-type doped hexagonal ferrites with composition of CoGd (x=0.0, 0.2, 0.4, 0.6, 0.8 and 1.0). Non linear variation observed in dielectric loss tangent verses investigated frequency region. Highest dielectric loss

tangent 0.14 comes in sample of x=0.4 composition at 12.40 GHz frequency and lower dielectric loss tangent 0.0001 was observed in x=0.8 composition at 11.56 GHz frequency.

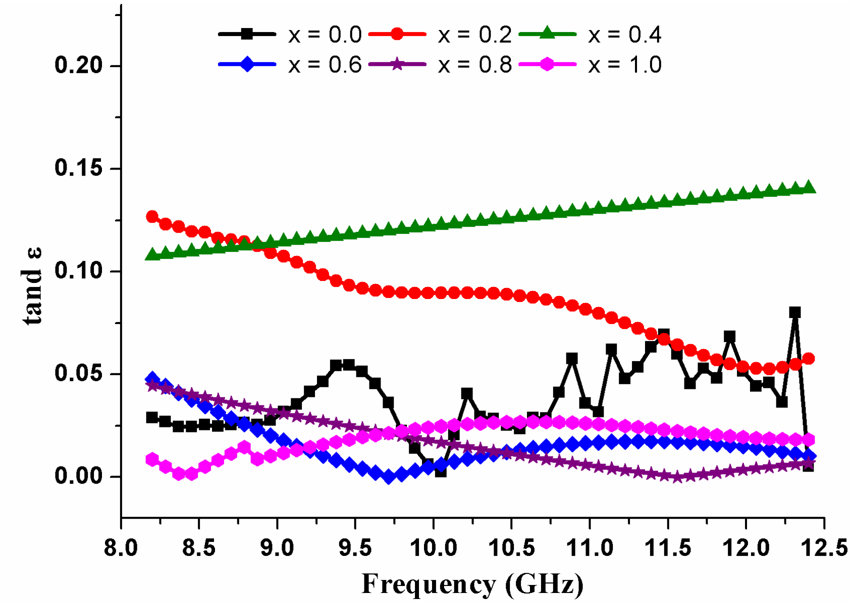

Fig. 3 Deviation of tanδ_ε verses frequency in $Ba_{0.5}Sr_{0.5}Co_xGd_xFe_{(12-2x)}O_{19}$ hexagonal ferrite.

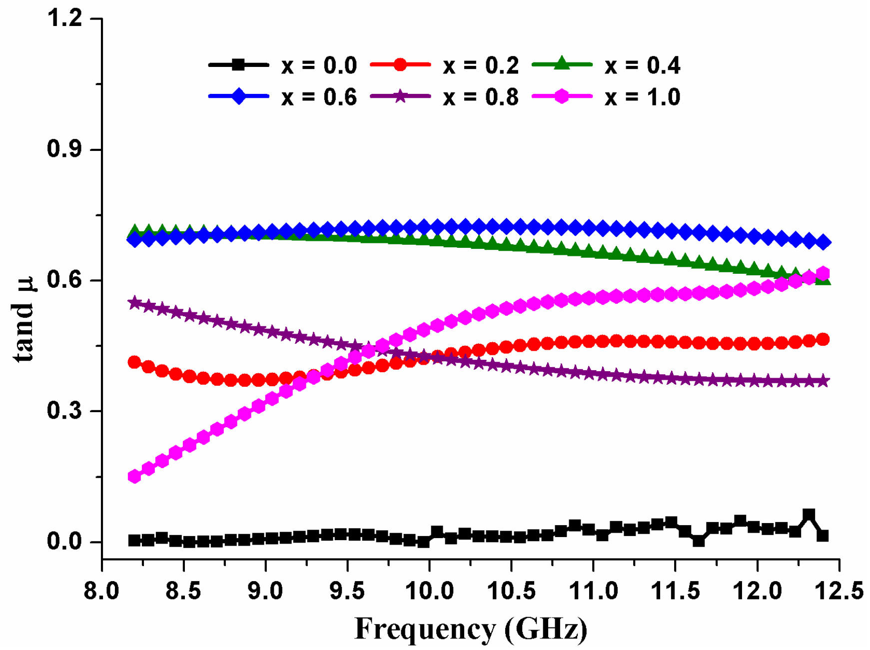

Fig. 4 tanδ_μ verses frequency in $Ba_{0.5}Sr_{0.5}Co_xGd_xFe_{(12-2x)}O_{19}$ hexagonal ferrite.

In the picture number 4 deviation shows between magnetic loss tangent(tanδ_μ) with respect to x-band frequency in the CoGd doped hexagonal ferrites having composition (x=0.0, 0.2, 0.4, 0.6, 0.8 and 1.0). There is increase of tanδ_μ observed in the configuration x(0.2, 0.6 and 1.0) where as decrease in tanδ_μ observed in configuration x(0.4 and 0.8) in the x-band frequencies region. The highest magnetic loss tangent 0.723 comes in composition x=0.6 at 10.3 GHz and the lowest magnetic loss tangent 0.0002 was observed with sample without doping (x=0.0) of composition near 9.964 GHz frequency.

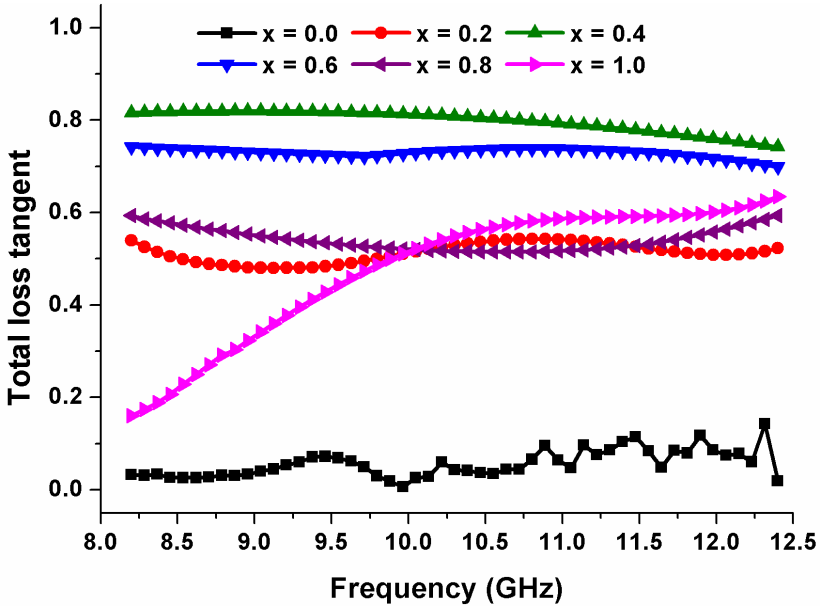

Fig. 5 Deviation of tanδ_t verses frequency within $Ba_{0.5}Sr_{0.5}Co_xGd_xFe_{(12-2x)}O_{19}$ hexagonal ferrites.

In the picture number 5 deviation shows between total loss tangent (tanδ_t) with respect to frequency within CoGd doped M type hexagonal ferrites with compositions of CoGd (x=0.0, 0.2, 0.4, 0.6, 0.8 and 1.0). The deviation of total loss tangent observed within the examined frequency area. Non linear increase in total loss tangent observed in compositions of CoGd (x=0.0, 0.2, 0.8 and 1.0), whereas in composition of CoGd (x=0.4 and 0.6) total loss tangent undergoes decreases with frequency. Total loss tangent comes highest 0.819 at 8.872 GHz in composition of CoGd x=0.4. Lowest total loss tangent 0.006 comes in sample without doping (x = 0.0) of composition near 9.964 GHz frequency

Table 1. Maximum and Minimum Attenuation (α) and Total loss tangent (tanδ_t) in $Ba_{0.5}Sr_{0.5}Co_xGd_xFe_{(12-2x)}O_{19}$ hexagonal ferrites

Composition x	Maximum α (dB)	Frequency (GHz)	Maximum tanδ_t	Frequency (GHz)	Minimum α (dB)	Frequency (GHz)	Minimum tanδ_t	Frequency (GHz)
0	**34.210**	**12.316**	**0.142**	**12.316**	**6.77**	**9.964**	**0.006**	**9.964**
0.2	**48.837**	**12.4**	**0.542**	**10.804**	**46.498**	**8.956**	**0.479**	**9.124**
0.4	**50.879**	**12.4**	**0.819**	**8.872**	**49.351**	**8.2**	**0.741**	**12.4**
0.6	**49.710**	**12.4**	**0.742**	**8.2**	**47.955**	**8.2**	**0.698**	**12.4**
0.8	**45.504**	**12.4**	**0.593**	**`8.2**	**43.940**	**9.712**	**0.514**	**10.636**
1	**49.711**	**12.4**	**0.634**	**12.4**	**36.433**	**8.2**	**0.159**	**8.2**

Table 1 lists the maximum attenuation (α) in CoGd doped hexagonal ferrite with composition (x=0.0, 0.2, 0.4, 0.6, 0.8 and 1.0). Highest attenuation 50.879dB observed in composition x=0.4 with 12.4 GHz frequency. Lower attenuation(α) 6.77dB comes in sample with no doping (x=0.0) near 9.964 GHz frequency. Similarly maximum total loss tangent 1.043 observed in sample of x = 0.2 near 12.40 GHz and minimum total loss tangent (0.008) in sample of x = 1.0 at 9.88 GHz frequency in X-band frequency respectively.

Table 2. Maximum and Minimum of $\tan\delta_\varepsilon$ and $\tan\delta_\mu$ in $Ba_{0.5}Sr_{0.5}Co_xGd_xFe_{(12-2x)}O_{19}$ hexagonal ferrite

Composition x	Maximum $\tan\delta_\varepsilon$	Frequency (GHz)	Maximum $\tan\delta_\mu$	Frequency (GHz)	Minimum $\tan\delta_\varepsilon$	Frequency (GHz)	Minimum $\tan\delta_\mu$	Frequency (GHz)
0	**0.08**	**12.316**	**0.062**	**12.316**	**0.002**	**10.048**	**0.0002**	**9.964**
0.2	**0.126**	**8.2**	**0.465**	**12.4**	**0.052**	**12.148**	**0.371**	**8.872**
0.4	**0.140**	**12.4**	**0.708**	**8.2**	**0.107**	**8.2**	**0.601**	**12.4**
0.6	**0.047**	**8.2**	**0.723**	**10.3**	**0.0003**	**9.712**	**0.688**	**12.4**
0.8	**0.044**	**8.2**	**0.549**	**`8.2**	**0.0001**	**11.56**	**0.369**	**12.232**
1	**0.026**	**10.636**	**0.616**	**12.4**	**0.001**	**8.452**	**0.151**	**8.2**

Table 2 lists the maximum $\tan\delta_\varepsilon$ within CoGd doped hexagonal ferrite in composition (x= 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0). Highest $\tan\delta_\varepsilon$ 0.44 comes in composition x = 0.8 is observed at 8.2 GHz frequency and lowest $\tan\delta_\varepsilon$ 0.0001 in sample of x = 0.8 near 11.56 GHz frequency. Similarly $\tan\delta_\mu$ is maximum (0.723) obtained in the sample of x = 0.6 near 10.3 GHz frequency and minimum $\tan\delta_\mu$ (0.0002) observed in the sample with no doping x = 0.0 near 9.964 GHz frequency in X-band frequency respectively.

IV. Conclusions

In conclusion the final analysis of CoGd doped $Ba_{0.5}Sr_{0.5}$-$Fe_{(12-2x)}O_{19}$ M type hexagonal ferrite shows the improvement in the value of α and $\tan\delta_t$ with substituted of Gd^{3+} & Co^{2+} ions. Highest microwave attenuation (α) 50.879 dB observed near 12.40 GHz frequency in the sample of x=0.4. Higher total loss tangent 0.819 at 8.872 GHz in composition of x=0.4. Lowest attenuation 34.210 dB come in sample with no doping x= 0.0 near 12.316 GHz frequency, lowest 0.006 total loss tangent comes in sample with no doping x= 0.0 near 9.964 GHz. Investigation of composition shows its utilization and scope in reduction of EMI as well as higher frequency absorber applications.

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