ICRANET2018-180502

SYNTHESIS AND DIELECTRIC PROPERTIES OF HOLMIUM DOPED STRONTIUM FERRITE FOR HIGH FREQUENCY APPLICATIONS

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Abstract

Hexagonal ferrites are important class of compounds which has wide variety of electrical and magnetic applications. Holmium doped Strontium ferrite with composition $SrFe_{12-x}Ho_xO_{19}$ with x = 0.0, 0.2, 0.4 were synthesized by wet chemical method known as simplified sol-gel method. Prepared samples were characterized by X-ray diffraction (XRD) for structural analysis. All samples were found hexagonal packed and belonging to P63-mmc space group. Electrical analysis was done using LCR meter and two probe method. The ac electrical conductivity of the sintered sample was measured as a function of frequency at room temperature and dc electrical resistivity was measured as a function of temperature in the range from room temperature to 450°C. It was observed that ac electrical conductivity has direct dependence on frequency and dc electrical resistivity has indirect dependence on temperature. The increase in resistivity as a function of temperature confirmed the behavior of semiconducting material. Moreover, dielectric constants ε′, ε″ (real and imaginary), dielectric loss (tanδ) of the sintered sample were also measured as a function of frequency at room temperature.

Main advantage of substituting Ho in M-type hexa-ferrites is in antenna to be cost effective, high gain, miniaturization of antenna and increase in efficiency.

Keywords: hexa ferrites; x-ray diffraction; dielectric loss; efficiency.

1. INTRODUCTION

Ferrites are basically nonconductive ferrimagnetic ceramic compound materials, which have numerous combination of oxides of iron like Hematite (Fe_2O_3) or Magnetite (Fe_3O_4) and some other metals oxide such as NiO_3, CuO, ZnO, MnO, CoO. Ni, Zn or Mn compounds.

They are better than other magnetic materials because of their high electrical resistivity and low eddy current losses [1]. Their properties depend upon synthesis conditions, composition, sintering temperature and grain size [2]. A lot of work have been done on M-type hexa-ferrites $MFe_{12}O_{19}$ (M= Ba, Sr, Pb) because they are considered one of the best permanent magnets [3]. Strontium hexa-ferrite $SrFe_{12}O_{19}$ can be utilized as magnetic fillers in microwave absorber components [4]. These materials can also be used in magnetic recording media, electronic devices and magneto-optical recording [5]. For application in microwave devices, dielectric properties like dielectric constant and dielectric loss are very significant because thickness of microwave absorbing layer is affected by dielectric constant and dissipation of the electrical energy. This dissipation may be due to electrical conduction, dielectric relaxation, dielectric resonance and loss from non-linear processes [6].

2. EXPERIMENTAL

All the samples of Sr-hexaferrites $SrFe_{12-x}Ho_xO_{19}$ with x= 0, 0.2, 0.4 were prepared by the WOWS sol gel technique [7] and calcined at 910°C for 20 min. The schematic diagram is shown in Fig. 1

2.1 X-ray diffraction properties

X-ray diffraction of the samples was done at room temperature using CuK_α (1.506Å). The X-ray density, d_x and measured density d_m were determined using the relation [8]

$$d_x = \frac{2M}{NV} \quad \ldots\ldots\ldots\ldots \quad (1)$$

M being the molecular weight of the sample, '2' is multiplied due to the fact that elementary cell contains two molecules [8] 'N' is the Avogadro's number and V is the volume of the unit cell of the hexagonal system.

The measured density was determined by the relation

$$d_m = m/\pi r^2 h \quad \ldots\ldots\ldots\ldots \quad (2)$$

where 'm' is the mass, 'r' is the radius and 'h' is the height of the sample. In general, the electrical properties of the ferrites depend upon chemical composition, methods of fabrication, sintering techniques, porosity and grain size.

2.2 Electrical characterization

The relationship between dc resistivity and temperature may be expressed as

$$\varrho = \varrho_o \exp(\Delta E/K_B T) \ldots\ldots\ldots\ldots \quad (3)$$

Here 'ϱ' is the resistivity at temperature T, 'ϱ_o' is the pre-exponential constant. 'K_B' is the Boltzmann's constant and 'ΔE' is the activation energy.

The dielectric constant is the ratio of charge that would be stored with free space as stored with the material under test. Dielectric constant $\acute{\varepsilon}$ in ferrites again depends on the structure resistivity and porosity.

The dielectric constant is calculated using the elementary relation [8]

$$\acute{\varepsilon} = Ct/\varepsilon_o A \ldots\ldots\ldots\ldots \quad (4)$$

Where 'C' is the capacitance of the pellet in Farad,'t' is the thickness of the pellet in meter and 'A' is the cross-sectional area of the surface of the pellet and 'ε_o' is the permittivity of the free space (8.854×10^{-12} F/m)

The AC conductivity as a function of frequency (20 Hz –3 MHz) at different temperatures (100°C, 200°C, 300°C, 400°C) and was determined using the formula [7]

$$\sigma_{ac} = \omega\, \varepsilon_o\, \varepsilon'\, \tan\delta \ldots\ldots\ldots\ldots \quad (5)$$

Where ε_o, ε' are defined above, 'ω' is the angular frequency ($2\pi f$) and $\tan\delta$ is the loss factor.

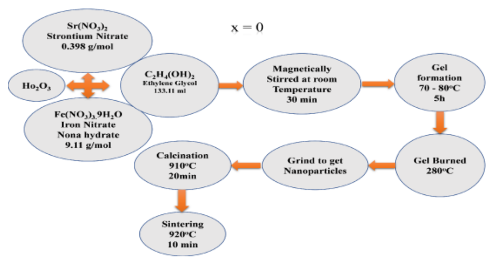

Fig.1. Schematic of Sr-hexa ferrites synthesis.

3. RESULTS

Indexed pattern of sintered samples are shown in Fig. 2. Lattice constant and related properties are recorded in Table 1.

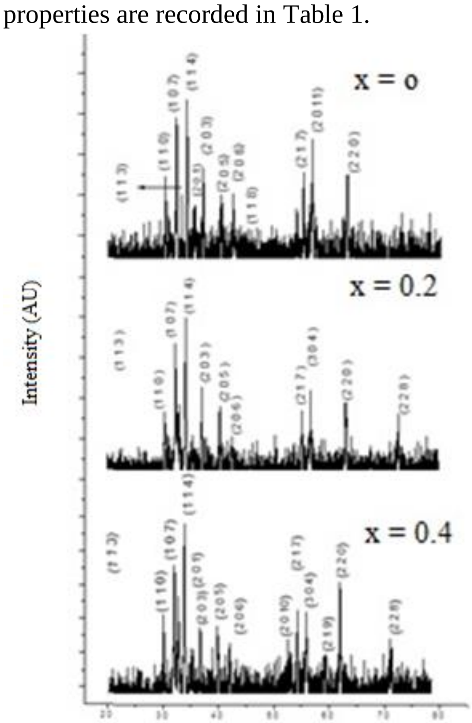

Fig.2. X-ray diffraction pattern at room temperature of sintered samples.

Table 1.
X-ray diffraction analysis of $SrFe_{12-x}Ho_xO_{19}$ ferrites. Average crystallite size corresponds to peak (114).

Concentration of Ho	*x*=0	*x*=0.2	*x*=0.4
Lattice Constant a (Å)	5.89	5.897	5.9032
Lattice Constant c (Å)	23.1	23.13	23.14
Lattice Constant c/a	3.9219	3.92233	3.91991
X-ray Density d_x (gcm^{-3})	5.11	5.21	5.32
Measured Density d_m (gcm^{-3})	2.61	2.53	2.51
Porosity %	48.7	51	52.7
Average crystallite size (nm)	56.31	67.571	67.566

The dc conductivity is shown in Fig. 3. It appears that conductivity increases for x = 0.2 and then decreases for x = 0.4. Similarly Fig. 4 shows the ac conductivity of these samples. Again similar observations are noted. It appears that for higher concentration of Ho in the lattice decreases conductivities but lower doping is beneficial for high frequency application in these materials.

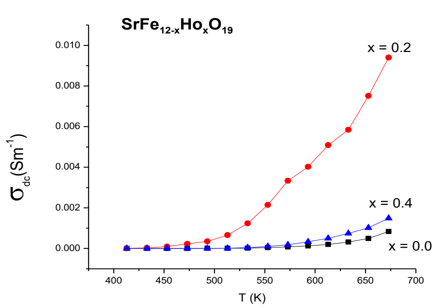

Fig. 3. The dc conductivity of samples as a function of temperature

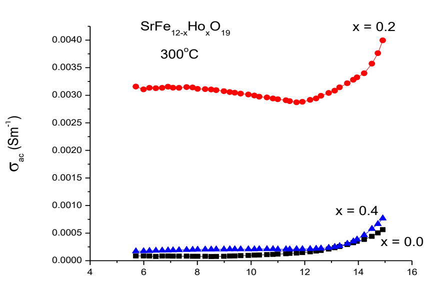

Fig.4. The ac conductivity of samples as a function of frequency at 300°C.

CONCLUSIONS

Effect on the structural and electrical properties of Holmium doped Strontium hexaferrite was investigated. Pure phase Strontium hexaferrite and Holmium doped $SrFe_{12-x}Ho_xO_{19}$ samples were prepared with WOWS sol-gel method. The powder obtained was pelletized for further characterization through XRD and electrical analysis. Hexagonal pure phases were confirmed for all the samples. The ac conductivity increased for all the samples at higher frequencies. Increase in dc conductivity with temperature was also recorded for the samples under investigation. This material may be used for the fabrication for the antenna.

ACKNOWLEDGEMENTS

Pakistan Academy of Sciences is acknowledged for the grant of Research fund for this project.

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