ISSN : 2393-8188 (print)
2393-8196 (online)
www.milliyasrcollege.org.journal.php

ELECTRICAL PROPERTIES OF COMPOSITE MATERIAL

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ABSTRACT:

The magnetoelectric composites with general formula (1-x) $Ni_{0.5}Cu_{0.3}Mg_{0.2}Fe_2O_4$ + (x) $BaTiO_3$ in which x = 0, 0.20, 0.40, 0.60, 0.80 and 1 mol were prepared by conventional solid state reaction. The presence of constituent phases in the composites was confirmed by x-ray diffraction studies. The patterns show well-defined peaks. There is no any intermediate phase formed in the composites. Phase analysis gives the formation of spinel structure for the ferrite phase and tetragonal perovskite structure for the ferroelectric phase. No structural changes are observed for both the phases in composites. The samples were characterized by SEM to study surface morphology**.** The D.C. electrical resistivity was measured using two probe methods in the temperature range 300K to 800 K. The resistance of a sample measured at an interval of 5K while cooling the temperature. Here the electrical resistivity found to be increases with respect to increase in composition of ferroelectric materials in the composites.

KEYWORDS: Composites, ferrite, ferroelectric, Electrical, X-ray diffraction.

INTRODUCTION:

The magnetoelectric (ME) composite possess two coupled order parameters in the same material and gives ME effect with variation of a dielectric/ferroelectric property under magnetic field changes and vice versa [1]. To realize ME effect in the composite it is important to select suitable combination of piezomagnet/ferrite and piezoelectric/ferroelectric phase. A magnetic field induces distortion in magnetostrictive phase which in turn distort piezoelectric phase in which electric field is generated. The composite as a whole can be considered as macroscopically homogeneous new material with product property called ME property and the coupling in this case is of mechanical type. Thus this property facilitates the magnetic-electric energy conversion and thus is attractive for applications as magnetic field probe, transducers, novel actuators, sensors, capacitive/inductive passive filters for telecommunications etc. Due to their multifunctional properties, these systems have attracted in the last years an outstanding interest [2-4].

So many researchers are trying to develop ME effect in composite by using different material, changing their composition in order to get significant properties and better ME effect [5-11]. Nickel-zinc ferrites are widely used as magnetic materials for high frequency applications due to their high electrical resistivity and low losses [12-14]. Recently, the NiCuZn ferrites with high initial permeability have been rapidly developing for electronic applications such as telecommunication [15, 16]. Hence NiCuZn selected as a ferrite phase. Electrical properties of these ferrite materials strongly depend on their chemical composition and additives. Keeping this in mind in the present work an attempt is made to prepare ME composite materials consists ferroelectric phase as a $BaTiO_3$ and ferrite phase as $Ni_{0.5}Cu_{0.3}Mg_{0.2}Fe_2O_4$. These composites prepared by standard ceramic method and studied the structural and electrical properties of composite material having the general formula (1-x) $Ni_{0.5}Cu_{0.3}Zn_{0.2}Fe_2O_4$ + (x) $BaTiO_3$ with x = 0.0, 0.2, 0.4, 0.6, 0.8, and 1.0.

EXPERIMENTAL:

The components of present composites are $BaTiO_3$ as ferroelectric phase and $Ni_{0.5}Cu_{0.3}Mg_{0.2}Fe_2O_4$ as a ferrite phase with general formula (1-x)$Ni_{0.5}Cu_{0.3}Mg_{0.2}Fe_2O_4$+ (x) $BaTiO_3$ in which x = 0, 0.20, 0.40, 0.60, 0.80,1 mol were prepared by conventional solid state reaction. The ferrite phase was prepared by NiO, CuO, MgO, and Fe_2O_3 in required molar proportions. These oxides were mixed and grind in agate mortar for couple of hours. The

ferroelectric phase was prepared by using BaO and TiO_2 as starting materials. These oxides are also mixed and grind in agate mortar. The ME composites were prepared by mixing 0.8,0.6,0.4 and 0.2 mol of ferrite phase with 0.2,0.4,0.6,and 0.8 mol of ferroelectric phase respectively. The required molar proportions were mixed and grind for 3 hour. The grind powder mixture was pressed into pellets using hydraulic press. The pelletized sample was final sintered in programmable furnace and slow cooled to room temperature to yield the final product.The ohmic electrical contacts were established by applying silver paste on both the surfaces of the pellets. The resistivity calculated by using formula,

$$\rho = \frac{RA}{t}$$

Where R= Resistance, A= Area of cross section of pellet, t= thickness of pellet.

RESULT AND DISCUSSION:X-RAY DIFFRACTION:

Fig. 1 show X-ray diffractometer patterns of the samples with composition x = 0.40. The patterns show well-defined peaks. There is no any intermediate phase formed in the composites. The occurrence of spinel structure is for the ferrite phase and tetragonal perovskite structure for the ferroelectric phase. No structural changes are observed for both the phases in composites.

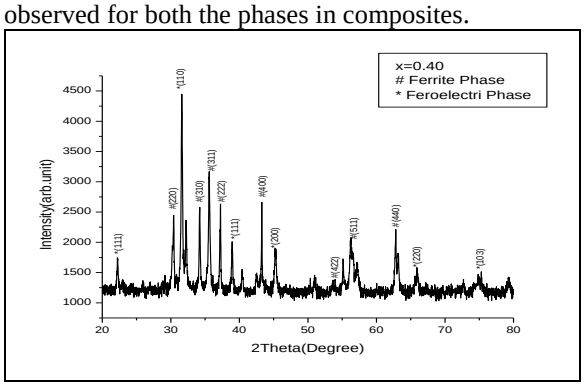

Fig.1: XRD pattern of (1-x) $Ni_{0.5}Cu_{0.3}Mg_{0.2}Fe_2O_4$+(x) $BaTiO_3$ for x=0.4.

SEM (Scanning Electron Microscope):

Powder morphology was observed via scanning electron microscopy. Scanning electron microscope (SEM) is one of the most versatile instruments available for the examination and analysis of the micro structural characteristics of materials. The reason for using the SEM is the high resolution and appropriate magnification. The scanning electron micrographs of the all the samples of series under investigation are presented in Fig.2 and Fig. 3. The scanning electron micrographs of samples show that the sample has an agglomerated large grain structure. Heating results in the well-faceted grains to form solid bodies with unregulated shape.

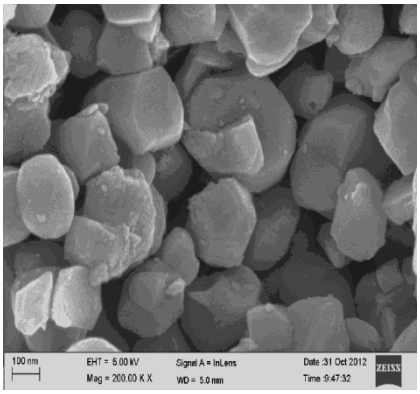

Fig 2: SEM images of (1-x) $Ni_{0.5}Cu_{0.3}Mg_{0.2}Fe_2O_4$+ (x)$BaTiO_3$ for x=0.0

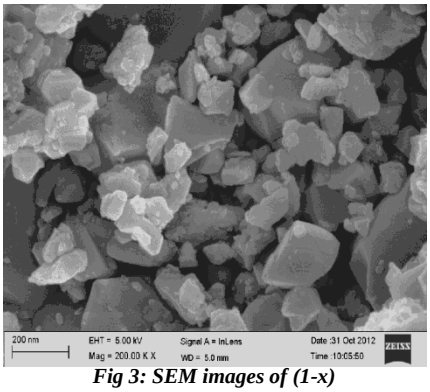

Fig 3: SEM images of (1-x) $Ni_{0.5}Cu_{0.3}Mg_{0.2}Fe_2O_4$+ (x)$BaTiO_3$ for x=0.2

Resistivity:

The variation of resistivity with temperature is shown in Fig. 4. It is clear from the plot that the resistivity of the composites remains constant initially and decreases thereafter. Since ferrites are semiconductors, their resistivity ρ should decrease with increasing temperature. The conduction of ferrite, ferroelectric and their composites results from hopping process of charge carriers. The relationship between resistivity and temperature may be expressed as

$$\rho = \rho_o \exp(\Delta E/KT)$$

Where ρ is the resistivity at temperature T, ρ_o is the temperature independent constant, k the Boltzmann constant and DE is the activation energy for conduction process. The conduction mechanism can be explained with hopping of electrons between Fe^{2+}/Fe^{3+} and Ti^{3+}/Ti^{4+}. There is also contribution by p-type charge carriers by hole hopping between Ni^{2+}/Ni^{3+}, Cu^{2+}/Cu^{3+}, etc. There are two trend observed in fig 4. The first trend observed at low temperature is due to impurities and it is attributed to order ferroelectric phase and the second trend occurs at high temperature this trend is due to the

increase in the thermally activated drift mobility of charge carriers according to the hopping conduction mechanism [17-20]. Also the linear decrease in resistivity with temperature indicates semiconducting nature of the composites. It can be concluded that the dc resistivity of composites depends on the resistivity of the constituent phases. As the mole percent of ferrite in composite increases the resistivity of composite is found to be decreased. The maximum dc resistivity is observed in case of pure ferroelectric for x=1.

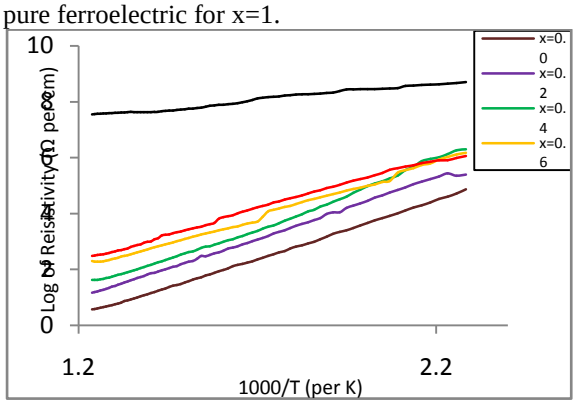

Fig.4 *Variation of dc resistivity (log ρ) with temperature (1000/T) for (1-x) $Ni_{0.5}Cu_{0.3}Mg_{0.2}Fe_2O_4$+ (x) $BaTiO_3$*

CONCLUSION:

The ME composites have been prepared successfully by conventional solid state reaction. The presence of both phase i.e. cubic spinel structure for ferrite phase and tetragonal perovskite structure for ferroelectric phase formation was confirmed by XRD studies. The SEM micrograph shows the formation of unregulated shape of grains. The dc resistivity of composites depends on the resistivity of the constituent phases. As the mole percent of ferrite in composite increases the resistivity of composite is found to be decreased. The maximum dc resistivity is observed in case of composite containing ferroelectric for x=1.

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