Materials Chemistry and Physics 130 (2011) 847–852

Contents lists available at SciVerse ScienceDirect

Materials Chemistry and Physics

journal homepage: www.elsevier.com/locate/matchemphys

Materials science communication

IR spectra and dielectric properties of Cu–Ge ferrite

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ARTICLE INFO

Article history:
Received 4 January 2011
Received in revised form 6 September 2011
Accepted 7 September 2011

Keywords:
IR spectra
Dielectric properties
Cu–Ge ferrite

ABSTRACT

The mixed ferrite $Cu_{1+x}Ge_xFe_{2-2x}O_4$; where $x = 0.0$, 0.05, 0.1, 0.15, 0.2, 0.25 and 0.3; was prepared from high purity oxides using the standard ceramic technique. The IR spectra were recorded on the range from 200 to 1000 cm^{-1}. The two primary bands corresponding to tetrahedral ν_A and octahedral ν_B were observed around 575 cm^{-1} and 400 cm^{-1}, respectively. It was found the threshold frequency ν_{th} for the electronic transition increases with increasing the Ge content. The Debye's temperature θ_D was calculated and it was found dependent on the type of charge carriers. AC conductivity σ_{ac} with dielectric properties (dielectric constant ε', dielectric loss ε'' and loss tangent tan δ) as a function of frequency ($f = 10^2 \rightarrow 10^6$ Hz) at room temperature have been measured. The dispersion of the dielectric properties was discussed in the light of Koop's phenomenological theory.

The phonon frequency ν_{ph} which calculated from IR spectra for each composition of Cu–Ge ferrite was found to be higher than that calculated from the AC conductivity by a factor of about 10^4–10^5 Hz.

1. Introduction

Ferrites are a very well established group of magnetic semiconductor materials. Unlike in semiconductors where the charge carriers occupy states in wide energy band, the charge carriers in ferrites are localized at the magnetic atoms. The electrical behaviour of ferrites depends on the presence of iron ions with different valence states at crystallographically equivalent lattice points. The conduction is due to exchange of the 3d electrons, localized at the metal ions, from Fe^{3+} to Fe^{2+} [1,2]. Many models have been suggested to account for the electrical properties as Heiks [3] and Reslescu et al. [4]. The presence of Fe^{2+} ions results in n-type behaviour and Fe^{3+} ions birth p-type behaviour. The conductivity arises due to the mobility of extra electron (from Fe^{2+}) or the positive hole (Fe^{3+}) through the crystal lattice [5,6]. Recently, we discussed the conduction mechanism of $Cu_{1+x}Ge_xFe_{2-2x}O_4$ through the DC and AC measurements at elevated temperature [7].

The dielectric properties of ferrites are dependent upon several factors including the method of preparation, chemical composition and grain size. Such ferrites in which the individual grains are separated by either air gaps or low conducting layers behave as inhomogeneous dielectric materials. This aroused considerable interest in low frequency (10^2–10^5 Hz) dielectric behaviour of ferrites [2]. These studies have been discussed by many workers [8–16].

The IR spectroscopy was used to determine the local symmetry in crystalline and non-crystalline solids and also to study the ordering phenomenon in ferrites. So, the IR spectra can give an idea about the change in the molecular structure of the ferrite due to the perturbation exerted on Fe–O bonds by introducing Ge^{4+} ions. On the other hand, the electronic distribution of Fe–O bonds will be affected when Ge^{4+} ions are introduced to its neighbourhood.

The aim of the present work is to study the effect of tetravalent germanium ions on the conductivity (DC and AC) besides some information about the ions in the crystal lattice using IR spectra.

2. Experimental

The mixed ferrite $Cu_{1+x}Ge_xFe_{2-2x}O_4$ (where $x = 0.0$, 0.05, 0.1, 0.15, 0.2, 0.25 and 0.3) was prepared by using the standard ceramic technique from mixing the pure oxides in calculated proportions. The IR spectra in the range from 200 to 1000 cm^{-1} were recorded at room temperature using the infrared spectrometer model 1430, Berkin Eloner.

DC and AC electrical conductivity of the investigated samples were studies using AC–DC bridge type Fluke model PM 6306. More details about the preparation and measurements were mentioned in our previous publications [17–19].

3. Results and discussion

3.1. IR Spectra

The IR spectra in the range of 200–1000 cm^{-1} of the above mentioned composition at room temperature are shown in Fig. 1 for $x = 0.0$, 0.15 and 0.3 only. As usual, the band ν_A ($\approx$600 cm^{-1}) arises due to tetrahedral complexes (the stretching vibration of the tetrahedral metal–oxygen bond) and ν_B ($\approx$400 cm^{-1}) is due to

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doi:10.1016/j.matchemphys.2011.09.017