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ScienceDirect
Ceramics International 36 (2010) 1339–1346
CERAMICS INTERNATIONAL
www.elsevier.com/locate/ceramint

Structural, magnetic and electrical properties of Ga-substituted NiCuZn nanocrystalline ferrite

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Received 1 June 2009; received in revised form 9 November 2009; accepted 4 January 2010
Available online 29 January 2010

Abstract

In this work, we studied the substitution effect of iron by gallium on the structural, magnetic and electrical properties of the ferrite system; $Ni_{0.5}Cu_{0.25}Zn_{0.25}Fe_{2-x}Ga_xO_4$ (x = 0–1.0), synthesized by using the urea combustion method. XRD patterns of the samples calcined at 700 °C show only cubic spinel ferrite with an average crystallite sizes in the range of 40–54 nm. The lattice parameters were slightly changed with increasing Ga content which can be explained on the basis of the relative ionic radii of Ga^{3+} and Fe^{3+} ions. FT-IR measurements show two fundamental absorption bands, assigned to the vibration of tetrahedral and octahedral complexes, which were slightly changed with increasing Ga content. Mössbauer measurements enable us to predict the possible cation distribution of the system. It was found that Ga^{3+} ion prefer to substitute Fe^{3+} ions located in the octahedral site. Superparamagnetic state was observed in the Mössbauer spectra of the samples with Ga content >0.5. The decrease of the magnetic hyperfine field with gallium concentration was explained on the basis of supertransferred hyperfine interaction. A semiconducting behavior was inferred for all samples and the conductivity values were found to decrease with increasing the Ga content. The conduction mechanism in the spinel ferrite compounds was explained in terms of the hopping conduction process. The dielectric constant measured as a function of frequency and temperature was found to be dependent on the Ga concentration. The determined transition temperature was found to decrease with increasing Ga content.

Keywords: NiCuZn ferrite; Ga substitution; Urea combustion; XRD; Mössbauer; Conductivity; Dielectric

1. Introduction

Synthesis and application of magnetic nanoparticles with diameters of a few nanometers is a subject of intense research because of their unique properties that make them attractive, both from the scientific value of understanding their properties, and the technological significance of enhancing the performance of the existing materials [1]. In this regard, spinel ferrites, which can widely used in computer peripherals, telecommunication equipments, permanent magnets, electronic and microwave devices, are particularly important because of their thermodynamic stability, electrical conductivity, electro-catalytic activity, corrosion resistance and excellent magnetic properties which can be tailored by chemical manipulations to meet stringent requirements in various applications [2].

Up till now, Ni–Cu–Zn ferrites have been the dominant materials for multi-layer chips inductors (MLCI) due to its better electromagnetic properties at high frequency and low sintering temperature. MLCIs have recently been developed as a surface mounting device (SMT) for miniaturization of electronic devices. They are important components for the electronics products, such as cellular phone, notebook computer, video camera, etc. [3].

In MLCI applications, silver (Ag) is generally used as an internal conductor of the multi-layer ferrite chip, but as its melting point is 960.5 °C, developing a ferrite material which can be sintered at a temperature less than 950 °C and establishing a sintering technology are necessary [4].

Fu et al. [5] have been synthesized Ni–Cu–Zn ferrite powders by microwave-induced combustion process. The resultant powders, annealed at different temperature, were investigated by DTA-TG, XRD, TEM, SEM, and VSM. The as-received

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0272-8842/$36.00
doi:10.1016/j.ceramint.2010.01.021