Available online at www.sciencedirect.com
ScienceDirect
Ceramics International 42 (2016) 2289–2298
CERAMICS INTERNATIONAL
www.elsevier.com/locate/ceramint

Structural phases and Maxwell–Wagner relaxation in magnetically soft-$ZnFe_2O_4$ and hard-$Sr_2Cu_2Fe_{12}O_{22}$ nanocomposites

Rajshree B. Jotania[a,*], Reshma A. Nandotaria[a], Chetna C. Chauhan[b], Mohd. Hashim[c], Sher Singh Meena[d], Sagar E. Shirsath[e]

[a]Department of Physics, Gujarat University, Ahmedabad 380009, Gujarat, India
[b]Institute of Technology, Nirma University, Ahmedabad 382481, Gujarat, India
[c]Department of Physics, Aligarh Muslim University, Aligarh 202002, UP, India
[d]Solid State Physics Division, Bhabha Atomic Research Centre, Mumbai 400085, MS, India
[e]Department of Physics, Vivekanand College, Aurangabad 431001, MS, India

Received 29 July 2015; received in revised form 15 September 2015; accepted 6 October 2015
Available online 17 October 2015

Abstract

In the present investigation magnetically soft-$ZnFe_2O_4$ (S-spinel) and hard-$Sr_2Cu_2Fe_{12}O_{22}$ (Y type) mixed ferrite nano-composites (S:Y as 1:0, 1:0, 1:1, 1:2, 1:4, 1:8 and 0:1) were synthesized by using chemical co-precipitation technique. X-ray diffraction analysis revealed the formation of mixed ferrite phases containing Y-type hexaferrite and spinel ferrite phases. The particle size of the prepared samples was estimated from transmission electron microscopy and it lies within the nanometer range. Fourier transform infrared spectroscopy was employed to determine the local symmetry in the crystalline solids and to shed light on the ordering phenomenon of ferrite nano-composite. Curie temperature of all the samples was evaluated using AC susceptibility measurements. Dielectric constant and loss factor was studied as a function of frequency and it is found to be minimum for pure soft ferrite and increased with increase in the concentration of hard ferrite. The results were interpreted in terms of the two-layer model that conducting grains partitioned from each other by poorly conducting grain boundaries. This dielectric dispersion was well explained in terms of Maxwell–Wagner relaxation.

Keywords: C. Dielectric properties; C. Magnetic properties; Ferrite nanocomposites; Structural properties

1. Introduction

In the last decade there is a continuous increasing attention has been devoted to a new class of materials that called nanocomposites; comprising multicomponent hybrid nanostructures containing two or more nanosized components assembled in a controlled way [1,2]. Nanocomposite materials can achieve enhanced properties and provides novel functionalities those are not available in the single-phased nanostructures due to the synergistic properties usually induced by the intimate contact and interaction between the different components [3]. Scientists have explored various types of materials such as dielectric and magnetic conducting polymer or their composites to achieve desired properties.

Ferrites are important class of magnetic materials that exhibits various interesting structural, electrical and magnetic properties. However, a single material cannot fulfill the requirements of desired application. Nanocomposites consisting of hard- and soft-ferrite phases, could offer to construct a unified systems whose properties are complimentary or even mutually exclusive [4]. There has been a growing interest on the materials having good spring exchange coupling behavior. According to the exchange spring theory proposed by Kneller and Hawig [5], the nanocomposite magnets consisting of soft and hard phases, are known as exchange spring magnet when both the phases are sufficiently exchanged coupled with each other. The exchange spring magnets possess high saturation

*Corresponding author: Tel.: +91 79 26303041.
E-mail address: rbjotania@gmail.com (R.B. Jotania).

http://dx.doi.org/10.1016/j.ceramint.2015.10.023
0272-8842/

Table 1
Compositions of spinel/hexaferrite with sample code.

Sr. No.	Sample code S:Y	Ratios of spinel to hexaferrite	
		Weight % of $ZnFe_2O_4$ spinel ferrite	Weight % of $Sr_2Cu_2Fe_{12}O_{22}$ hexaferrite
1	1:0	100	0
2	1:1	50	50
3	1:2	40	60
4	1:4	20	80
5	1:8	10	90
6	0:1	0	100

magnetization of soft phase and high coercivity of hard phase, which leads to produce large energy product value [6]. These materials also exhibit improved microwave absorbing property [7]. According to Maeda et al. [8] the exchange interaction between hard- and soft-ferrite phases can enhance the microwave absorption properties. In comparison to the metallic systems, the nanocomposites composed of soft spinel ferrite and hard hexagonal ferrite (S:Y) have shown great potential to be advanced permanent magnet, because of their low cost, excellent corrosion resistance behavior and high electrical resistivity. However, reports on the hard- and soft-ferrite nanocomposites in the literature are very limited due to the lack of availability of easy preparation technique for this type of nanocomposites [6,9–11]. Ferrites have attracted much attention, not only because of their numerous potential technological applications, but also because of the origin of the high dielectric constant. The high dielectric constant in the present S:Y composite can be interpret by using Maxwell–Wagner relaxation [12,13], which generally refers to interfacial polarization occurring in electrically inhomogeneous systems. When an electric current passes through interfaces between two different dielectric media, because of their different conductivities, surface charges pile up at the interfaces, and give rise to a Debye-like relaxation process under an external alternating voltage.

A kind of soft-magnetic material, $ZnFe_2O_4$ has normal spinel structure and extensively used in biomedicine, radar absorbing material due to its various advantages, for instance good chemical stability, corrosion resistivity, and superior magnetic properties. A kind of hard-magnetic material, $Sr_2Cu_2Fe_{12}O_{22}$ could provide various species of non-equivalent sites for various magnetic or non-magnetic cations. $Sr_2Cu_2Fe_{12}O_{22}$ has several merits, such as relatively high saturation magnetization, superior coercivity, high uniaxial magnetic crystalline anisotropy, chemical stability, and corrosion resistivity, which stimulated researchers to appreciate its significance in the electronic components, magnetic memories, biotechnology, and magnetic substrate for magnetic catalysts [14,15].

In view of this, in the present research work, the structural and dielectrical properties of the composite powder consisting the hard magnetic strontium hexaferrite and soft magnetic zinc ferrite are studied. The combination of these two types of

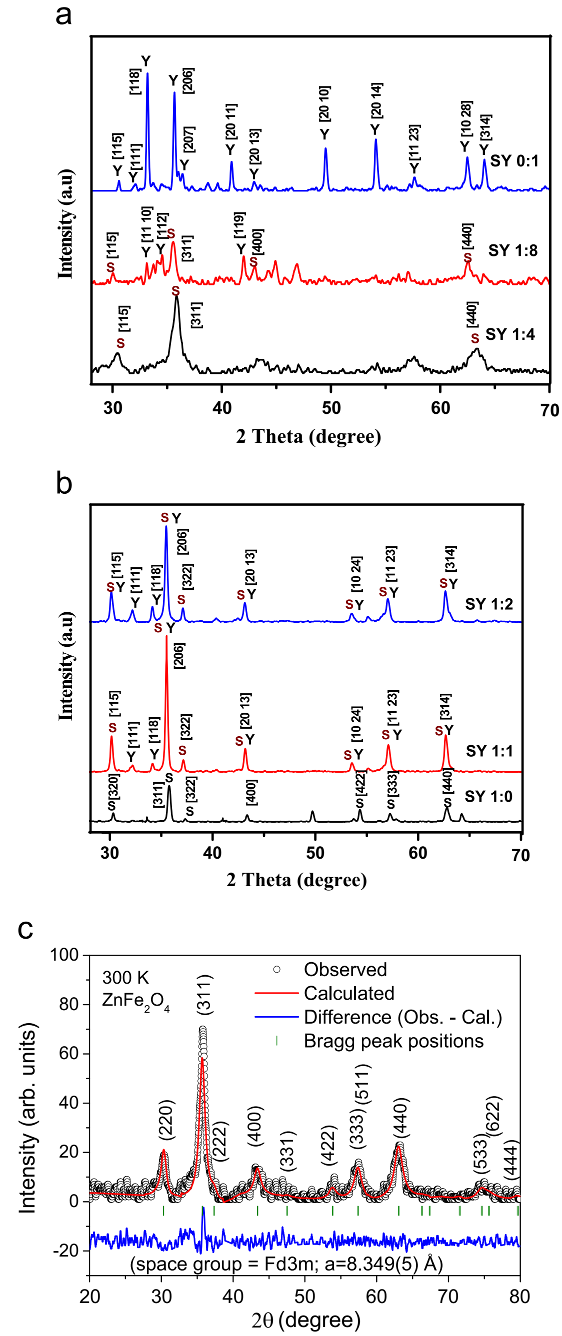

Fig. 1. (a): XRD patterns of soft $ZnFe_2O_4$–hard $Sr_2Cu_2Fe_{12}O_{22}$ ferrite composites (S:Y – 1:0, 1:8, 1:4) samples. (b): XRD patterns of soft $ZnFe_2O_4$–hard $Sr_2Cu_2Fe_{12}O_{22}$ ferrite composites (S:Y – 1:2, 1:1, 1:0) samples. (c): Rietveld refined XRD pattern of soft $ZnFe_2O_4$ ferrite sample (sintered at 950 °C for 4 h.).

ferrites can improve the magnetic and dielectrical properties of materials. The conventional way of synthesizing hexaferrites involves solid state reaction route at high heat treatment temperature (> 1200 °C), which results in powders with limited chemical homogeneity, large and coarse particle size. The chemical co-precipitation method is more suitable method because of its simplicity, low cost and better control over particle size [16–19]. To avoid high temperature synthesis we