Physica B xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Physica B

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

Structural and magnetic properties of nanostructured composites $(SrFe_{12}O_{19})_x(CaCu_3Ti_4O_{12})_{1-x}$

T.P. Gavrilova[a,b,*], J.A. Deeva[c], I.V. Yatsyk[a,b], A.R. Yagfarova[b], I.F. Gilmutdinov[b], N.M. Lyadov[a,b], F.O. Milovich[d,e], T.I. Chupakhina[c], R.M. Eremina[a,b]

[a] Kazan E. K. Zavoisky Physical-Technical Institute (KPhTI) of the Kazan Scientific Center of the Russian Academy of Sciences, Sibirsky tract, 10/7, Kazan 420029, Russia
[b] Kazan (Volga Region) Federal University, Kremlevskaya st., 18, Kazan 420008, Russia
[c] Institute of Solid State Chemistry of the Russian Academy of Sciences (UB), Pervomaiskaya St., 91, Ekaterinburg 620990, Russia
[d] National University of Science and Technology, Leninskii pr. 4, Moscow 119991, Russia
[e] Fiber Optics Research Center, Russian Academy of Sciences, ul. Vavilova 38, Moscow 119333, Russia

ARTICLE INFO

Keywords:
$CaCu_3Ti_4O_{12}$
$SrFe_{12}O_{19}$
Composite
Magnetization
Magnetic resonance

ABSTRACT

$(SrFe_{12}O_{19})_x(CaCu_3Ti_4O_{12})_{1-x}$ (x = 0.01, 0.03, 0.07, 0.1) composites were synthesized using a solid state method, while the pre-synthesized strontium hexaferrite $SrFe_{12}O_{19}$ (SFO) was added to the stoichiometric amount of CaO, CuO and TiO oxides to form the $CaCu_3Ti_4O_{12}$ (CCTO) structure around SFO microinclusions. The structural and microstructural properties of obtained composites were studied by X-ray diffraction, scanning electron microscopy and transmission electron microscopy techniques. The magnetic properties were studied by electron spin resonance and magnetometry methods. Based on all experimental data we can conclude, that SFO_xCCTO_{1-x} nanostructured composites were formed only for concentrations x = 0.03 and x = 0.07, where SFO nanoinclusions are inside CCTO matrix, that leads to the strong mutual influence of the magnetic properties of both component.

1. Introduction

Composite materials attract much attention due to the possibility to create the new structure combining the components with high values of the magnetic susceptibility and dielectric permittivity in different component proportions, because they can be used in variety of applications. They exhibit unexpected new physical properties, which can depend on the synthesis method and the internal structure of the composite. The ideal dual-phase $(Bi_4Ti_3O_{12})_x(CaCu_3Ti_4O_{12})_{1-x}$ (x = 0–1.0) composite system with separate orthorhombic and cubic phases gives a high dielectric constant ($\varepsilon' > 3000$) at 100 Hz at room temperature for x = 0.8, that makes these composites applicable for the fabrication of miniaturized global positioning system (GPS) patch antennas [1]. The excellent absorption properties of $SrFe_{12}O_{19}$-based materials indicated their great potential as microwave-absorbing materials. So the microwave absorption results for $SrFe_{12}O_{19}$-TiO_2 indicated that the minimum reflection loss for a specimen with 4.2 mm thickness reached up to −33 dB [2]. The reduced graphene oxide/strontium ferrite/polyaniline ternary nanocomposites exhibited the best absorption property (−45.00 dB) at 16.08 GHz with the 5.48 GHz bandwidth with the optimum matching thickness of the sample 1.5 mm [3]. Special attention is paid to the core-shell structured composites. The excellent review about the applications of exchange coupled bi-magnetic hard/soft and soft/hard ferromagnetic core/shell nanoparticles in the field of permanent magnets, recording media, microwave absorption, biomedical applications was published earlier [4].

Here we investigate the magnetic properties of the composite materials which consist of two inorganic components. One of the components is $CaCu_3Ti_4O_{12}$ (CCTO) which has the perovskite-type structure (space group $Im\bar{3}$, a = 7.391 Å) [5,6] and undergoes the phase transition into the antiferromagnetically ordered phase below T_N = 25 K and a Weiss constant of $\Theta_W \sim -30$ K [7]. The dielectric constant of CCTO has a high value $\varepsilon = 10^3 - 10^5$ in a wide temperature range (40–450 K) for frequencies up to 10 MHz [8,9]. As the second component of the composite material besides CCTO we chose the strontium hexaferrite $SrFe_{12}O_{19}$ (SFO) with ferromagnetic properties to modulate the magnetic properties of the composite. The crystal structure of SFO belongs to the space group $P6_3/mmc$ with the cell parameters a = b = 5.89 Å and c = 23.1 Å [10,11], and the temperature

* Corresponding author at: Kazan E. K. Zavoisky Physical-Technical Institute of the Kazan Scientific Center of the Russian Academy of Sciences (KPhTI), Sibirsky tract, 10/7, Kazan 420029, Russia.
E-mail address: tatyana.gavrilova@gmail.com (T.P. Gavrilova).

http://dx.doi.org/10.1016/j.physb.2017.09.095
Received 28 June 2017; Received in revised form 18 September 2017; Accepted 22 September 2017