AFM-PM Phase Transitions in nanocomposite materials $(SrFe_{12}O_{19})_x(CaCu_3Ti_4O_{12})_{1-x}$

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Nano-composite materials are multi-constituent combinations of nano-dimensional phases with distinct differences in structures and physical properties, which can be used in variety of applications. These materials typically consist of two or more inorganic phases in some combination and possess unique combinations of magnetic, dielectric, electrical, and other properties compared to those of each individual constituent. Nano-composite dielectrics are promising materials for technical applications such as microelectronics, capacitors, and energy storage systems because they combine the good processability and high breakdown field strength of metal oxides with the high permittivity of ABO_3 type oxides.

One of the components of the composite material that is studied in this work is $CaCu_3Ti_4O_{12}$ (CCTO). The dielectric behavior of calcium copper titanate (CCTO) exhibits an extraordinary high dielectric constant (ε_r~10^4–10^5) and shows good thermal stability in a wide temperature range (100–600K) [1]. Due to the high dielectric constant, it is widely utilized to manufacture electronic components. The only limitation, which restricts the broader applications of this compound, is the dielectric loss. But recently, Singh et al. reported about improvement in both the dielectric constant (ε_r ~7007) and dielectric loss (tan δ~0.2) at 1 kHz, at room temperature for $0.5\cdot Bi_{0.5}Na_{0.5}TiO_3\cdot 0.5CaCu_3Ti_4O_{12}$ nano-composite material [2]. This fact stimulated us to study composite materials based on CCTO. As the second component of the composite material besides CCTO we chose the strontium hexaferrite $SrFe_{12}O_{19}$ (SFO) to modulate the magnetic properties of the composite to get multiferroic material.

The magnetic microstructure of $(SrFe_{12}O_{19})_x(CaCu_3Ti_4O_{12})_{1-x}$ were investigated by the ESR method. ESR measurements of ceramic samples $(SrFe_{12}O_{19})_x(CaCu_3Ti_4O_{12})_{1-x}$ (x=0, 0.05, 0.9, 1) were carried out in the temperature range of 20 - 300K at the frequency of

9.48GHz. Some interesting results were obtained for concentration of the strontium hexaferrite x=0.05.

ESR spectrum of $(SrFe_{12}O_{19})_{0.05}(CaCu_3Ti_4O_{12})_{0.95}$ consists of one superparamagnetic resonance line at room temperature (Fig. 1a), because the ferrimagnetic core of $SrFe_{12}O_{19}$ polarizes the paramagnetic matrix $CaCu_3Ti_4O_{12}$ forming superparamagnetic particle. With decreasing the temperature one of the sublattices of iron ions in $SrFe_{12}O_{19}$ orders antiferromagnetically and ferromagnetic correlations between CCTO and SFO destroy. Thus we observe the phase transition to the phase-separated state in $(SrFe_{12}O_{19})_{0.05}(CaCu_3Ti_4O_{12})_{0.95}$ at T=175 K. This state is characterized by the presence of paramagnetic (CCTO) and ferrimagnetic phases (SFO) that results to the two lines in the ESR spectrum (Fig. 1a). The temperature of the phase transition corresponds to the maximum of the temperature dependence of the integral intensity of the ESR spectrum in $(SrFe_{12}O_{19})_{0.05}(CaCu_3Ti_4O_{12})_{0.95}$ (Fig. 1b). Below T=25K system CCTO is ordered antiferromagnetically. These results are confirmed by the magnetic susceptibility measurements.

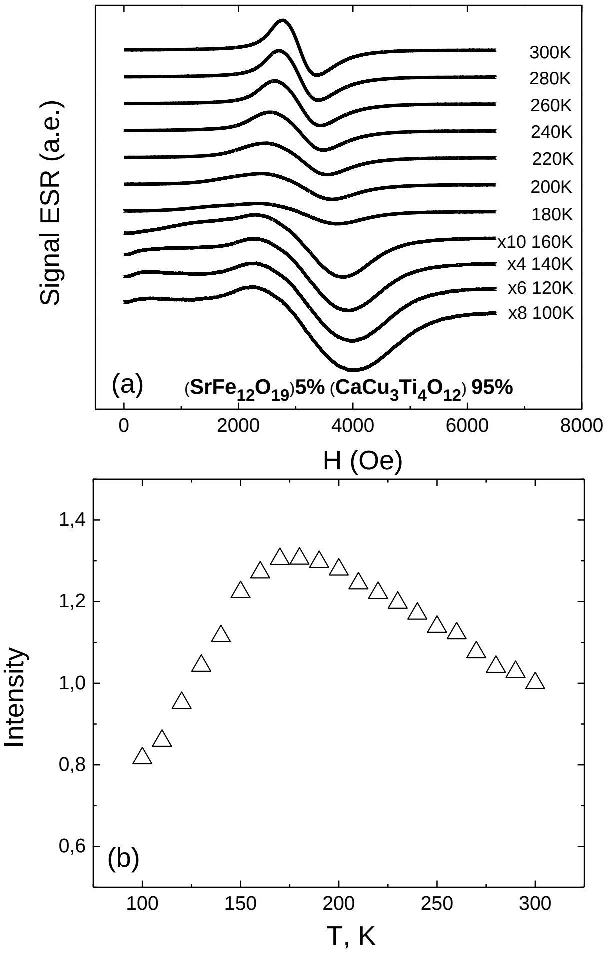

Fig. 1. Temperature dependence of the ESR spectrum – (a) and integral intensity - (b) in $(SrFe_{12}O_{19})_{0.05}(CaCu_3Ti_4O_{12})_{0.95}$

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