Structure and magnetic properties of superparamagnetic $La_{0.8-x}Gd_xNa_{0.2}MnO_3$ nanoparticles

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Methods of Investigation

- X-ray diffraction method using Shimadzu LabX XRD-6000 diffractometer in $Cu_{K\alpha 1}$-radiation (λ = 0.15418 nm) at room temperature
- Transition electron microscopy (TEM) method using JEM-2200FS Transmission Electron Microscope
- Magnetic method using LDJ-9500 magnetometer in the temperature T = 90 – 350 K and magnetic field H = 0 – 1 T ranges

Motivation

Magnetic metal oxides based on the manganites with a perovskite structure belong to multifunctional materials which demonstrate colossal magnetoresistance effect, magnetocaloric effect, etc [1-3]. They are perspective and topical materials which are actively used in various fields of science and technology as ultra-high density magnetic recording and data storage, highly sensitive magnetic sensors, permanent magnets, as well as for magnetic cooling systems and in biomedicine for treating cancer by local hyperthermia method [4-6].

Objects of Investigation

The rare-earth $La_{0.8-x}Gd_xNa_{0.2}MnO_3$ manganites with x = 0 and 0.05 were prepared using a sol-gel auto-combustion method at different additional synthesizing temperatures of t_{synth} = 500 °C (20 h), 700 °C (20 h) and 900 °C (20 h).

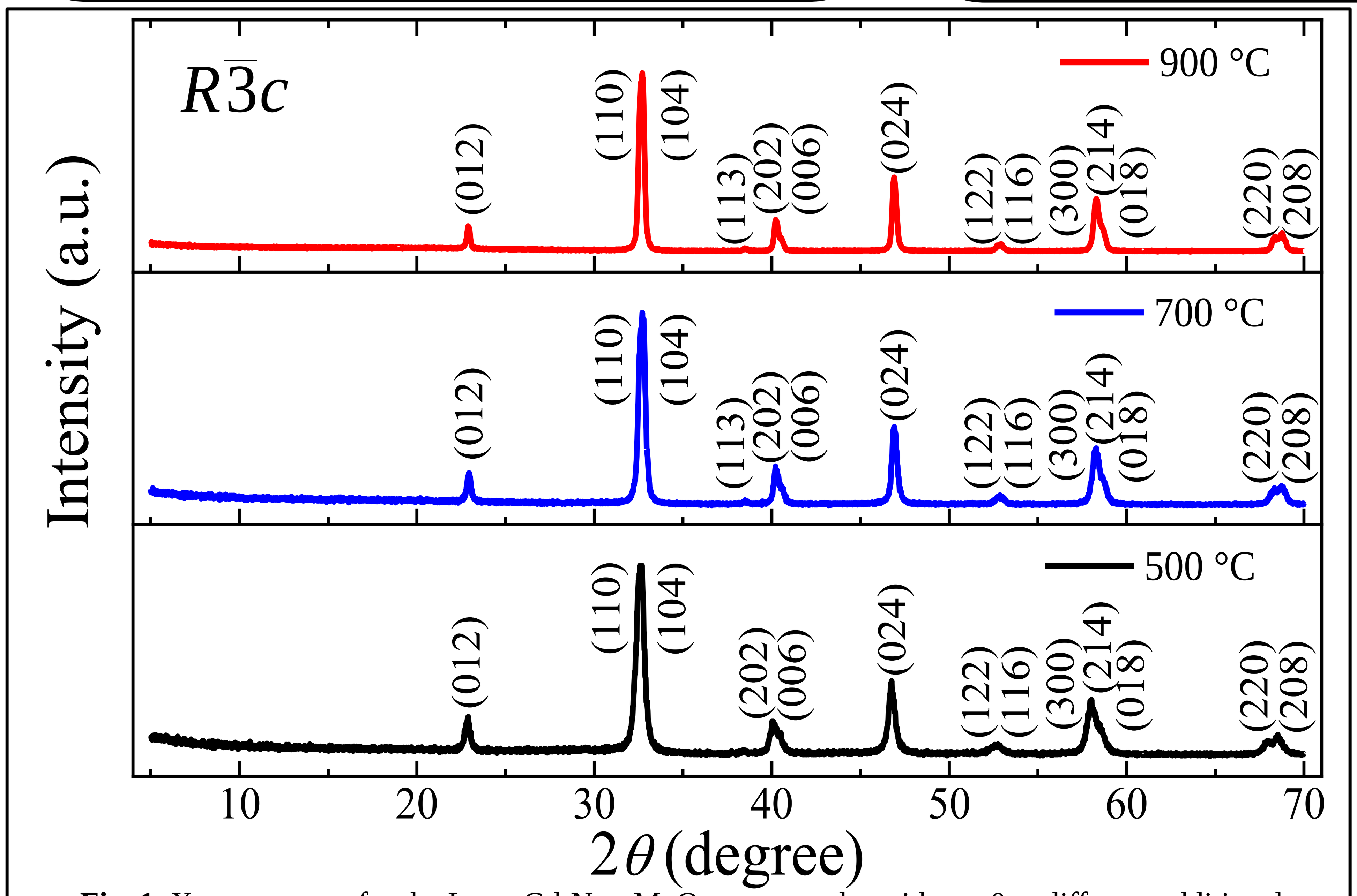

Fig. 1. X-ray patterns for the $La_{0.8-x}Gd_xNa_{0.2}MnO_3$ nanopowder with x = 0 at different additional synthesizing temperatures of t_{synth} = 500 °C (20 h), 700 °C (20 h) and 900 °C (20 h).

Lattice parameters (a, c, V) and coherent scattering region (D) for the $La_{0.8-x}Gd_xNa_{0.2}MnO_3$ nanopowder (x = 0) with t_{synth} = 500, 700 and 900 °C

x	t_{synth} (°C)	a (Å)	c (Å)	V (Å³)	D (nm)
0	500	5.513(2)	13.362(8)	351.7(5)	35
	700	5.495(1)	13.336(3)	348.7(2)	63
	900	5.489(1)	13.346(4)	348.3(2)	97

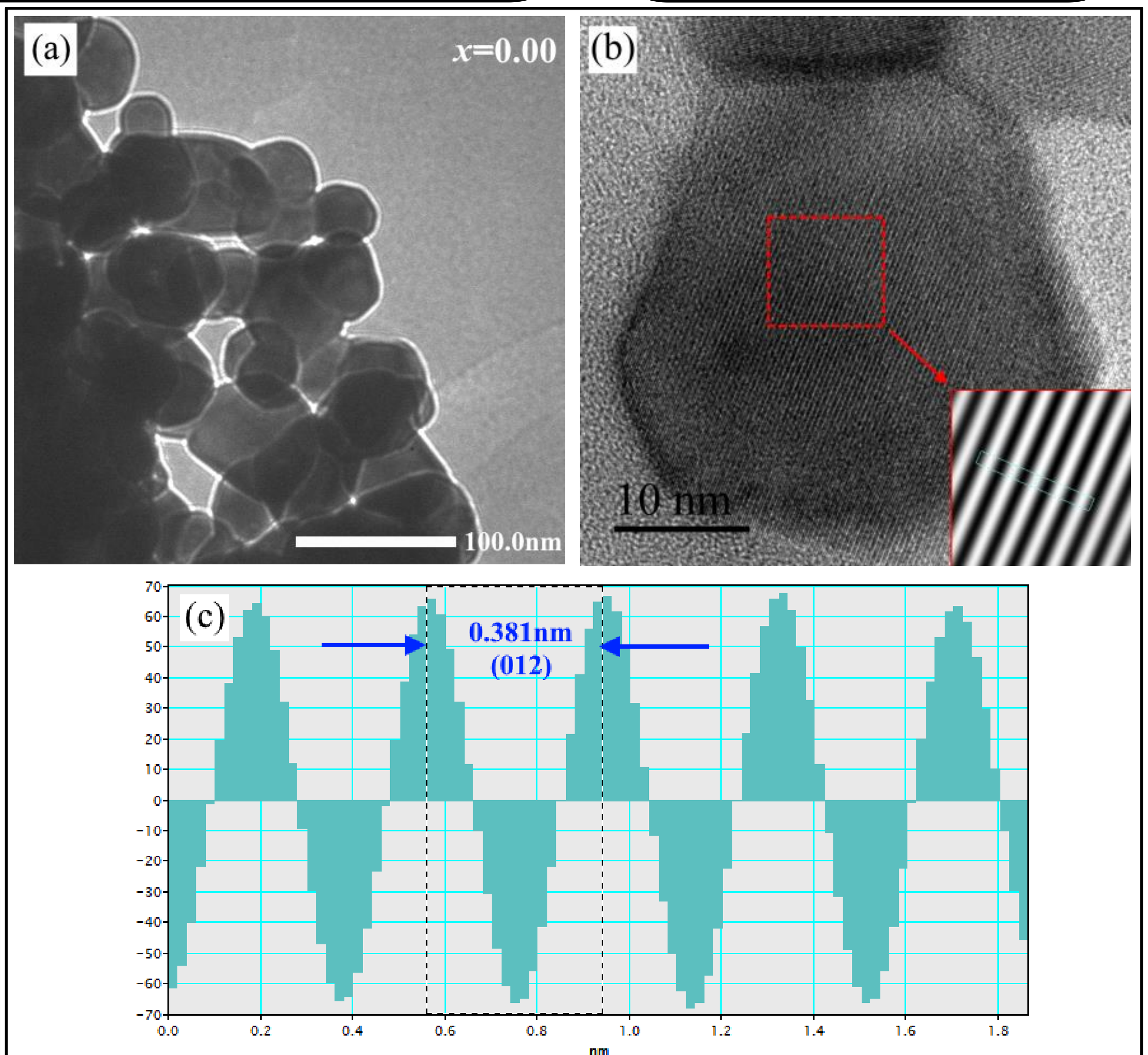

Fig. 2. TEM (a), HRTEM (the inset shows the FFT) (b), and the lattice plane intensity profile corresponding to (012) plane (c) for the $La_{0.8}Na_{0.2}MnO_3$ nanopowder with t_{synth} = 900 °C.

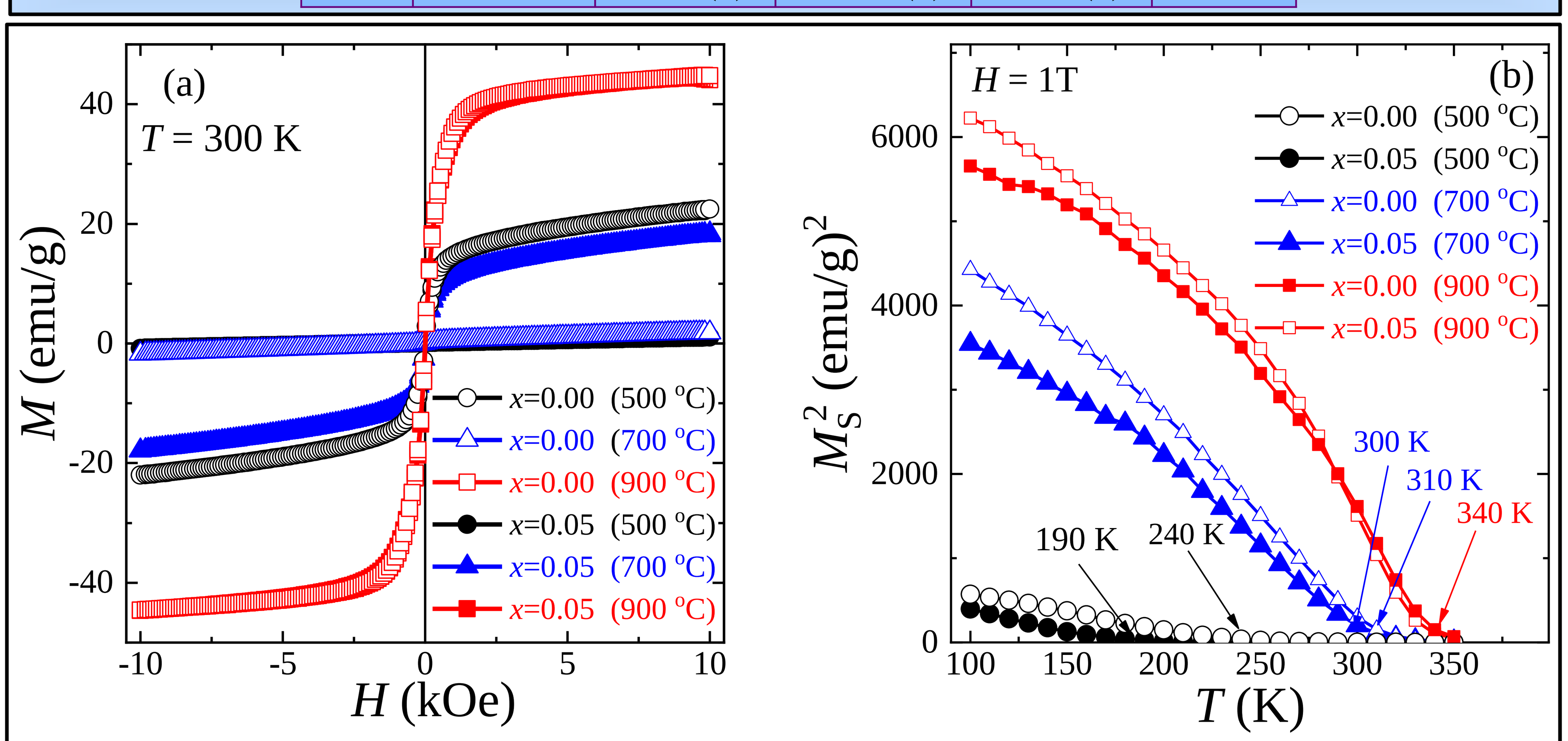

Fig. 3. Field dependences of magnetization (a) and temperature dependences of square magnetization (b) for the $La_{0.8-x}Gd_xNa_{0.2}MnO_3$ nanopowder (x = 0 and 0.05) with t_{synth} = 500, 700 and 900 °C.

Magnetic parameters (T_C, M_S, M_R, H_C) for the $La_{0.8-x}Gd_xNa_{0.2}MnO_3$ nanopowder (x = 0 and 0.05) with t_{synth} = 500, 700 and 900 °C

x	t_{synth} (°C)	T_C (K)	M_S (emu/g)	M_R (emu/g)	H_C (Oe)
0	500	240	1,04	0,065	1,12
	700	300	22,48	0,016	10,7
	900	320	44,75	0,35	10,45
0.05	500	170	1,046	0	0
	700	300	18,38	0,04	0,4
	900	320	44,31	0,618	5,9

Conclusions

- The studied $La_{0.8-x}Gd_xNa_{0.2}MnO_3$ nanopowders have single-phase $R3$-c perovskite structure with an average particle size of D = 35 (t_{synth} = 500 °C) – 97 nm (t_{synth} = 900 °C) for x = 0. At the same time, the lattice parameters decrease slightly with increase in t_{synth} that is in a good agreement with HRTEM data.
- It has been found out that $La_{0.8-x}Gd_xNa_{0.2}MnO_3$ nanopowders demonstrate the typical behavior of an ensemble of superparamagnetic nanoparticles at room temperature with a small coercivity of H_C ~ 20 Oe.
- It has been show that with increase in doping level x, synthesizing temperature t_{synth}, and, as a consequence, size of nanoparticles, the Curie temperature and ferromagnetic phase increase in the $La_{0.8-x}Gd_xNa_{0.2}MnO_3$ nanopowders. It allows to control magnetic properties of the studied composition that can useful for biomedical and refrigerator applications.

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