COMPOSITION, STRUCTURE AND DIELECTRIC PROPERTIES OF MULTIFUNCTIONAL SINGLE-PHASE $Bi_{1-x}La_xFeO_3$ CERAMICS

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OBJECTIVES

Partial replacement of the *A*-cation bismuth by lanthanum in the $Bi_{1-x}La_xFeO_3$ composition leads to changing its structural, microstructural and dielectric properties [1-5]. The sintering possibility of the multiferroics with definite functional properties by the changing of composition, structure and its defects determines the objectives of the researching $Bi_{1-x}La_xFeO_3$ (x = 0 - 0.5).

MATERIALS

The $Bi_{1-x}La_xFeO_3$ (x = 0, 0.1, 0.3 and 0.5) samples were prepared by the rapid liquid-phase sintering method from stoichiometric mixtures of La_2O_3, Bi_2O_3 and Fe_2O_3 powders. The initial mixture was calcined at 180 °C (4 h), then it was pressed into pellets (Ø = 8 mm, h = 3 mm) under pressure of 0.2 GPa and sintered at t_{ann} = 880 °C (8 min).

METHODS

- X-ray diffraction method (a, $\Delta a/a$);
- Thermogravimetric method ($\Delta m/m$);
- Dielectric spectroscopy method ($\varepsilon/\varepsilon_0$, $\tan\delta$);
- Scanning electron microscopy (SEM) method

TABLE

Molar formulas of defective perovskite structure $Bi_{1-x}La_xFeO_{3-\delta}$ (x = 0 – 0.5), concentration of anionic vacancies $V^{(a)}$, tolerant factor t and relative changes of samples mass $\Delta m/m$

x	Molar formulas of real perovskite structure	$V^{(a)}$, %	t	$\Delta m/m$, %
0	$\{Bi^{3+}_{0.96}V^{(c)}_{0.04}\}_A[Fe^{3+}_{0.98}V^{(c)}_{0.02}]_BO^{2-}_{2.91}V^{(a)}_{0.09}$	3.0	0.968	-1.477
0.1	$\{Bi^{3+}_{0.88}La^{3+}_{0.10}V^{(c)}_{0.02}\}_A[Fe^{3+}_{0.94}Fe^{2+}_{0.01}V^{(c)}_{0.05}]_BO^{2-}_{2.89}V^{(a)}_{0.11}$	3.7	0.946	-1.518
0.3	$\{Bi^{3+}_{0.69}La^{3+}_{0.30}V^{(c)}_{0.01}\}_A[Fe^{3+}_{0.77}Fe^{2+}_{0.21}V^{(c)}_{0.02}]_BO^{2-}_{2.85}V^{(a)}_{0.15}$	5.0	0.939	-3.189
0.5	$\{Bi^{3+}_{0.50}La^{3+}_{0.50}\}_A[Fe^{3+}_{0.74}Fe^{2+}_{0.26}]_BO^{2-}_{2.87}V^{(a)}_{0.13}$	4.3	0.938	-3.131

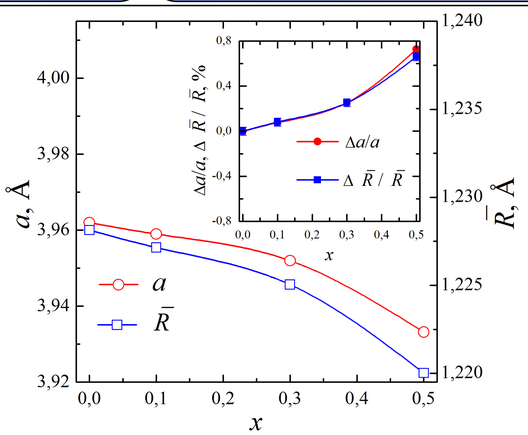

Fig. 1. Concentration changes of the lattice parameter a and the average ionic radius $\bar{R}$ of the $Bi_{1-x}La_xFeO_{3-\delta}$ perovskite structure. The inset shows the correlation of the relative parameter changes $\Delta a/a$ and the average ionic radius $\Delta\bar{R}/\bar{R}$.

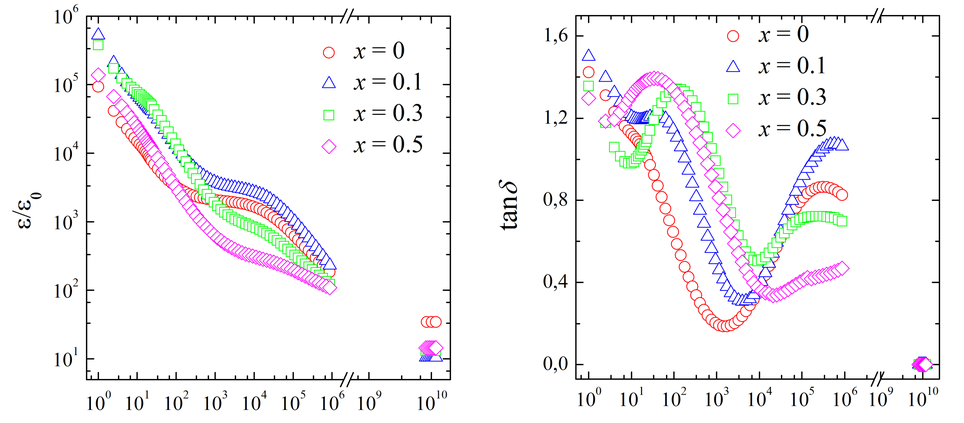

Fig 2. Frequency dependences of the relative permittivity $\varepsilon/\varepsilon_0(f)$ and dielectric loss tangent $\tan\delta(f)$ of the $Bi_{1-x}La_xFeO_{3-\delta}$ ceramics.

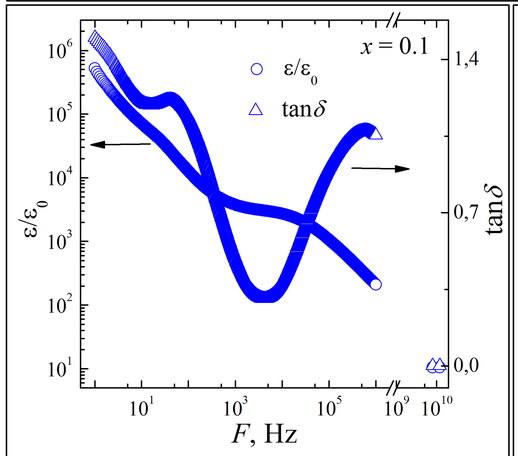

Fig 3. Frequency dependences of the $\varepsilon/\varepsilon_0(f)$ and $\tan\delta(f)$ of the $Bi_{0.9}La_{0.1}FeO_{3-\delta}$ ceramics.

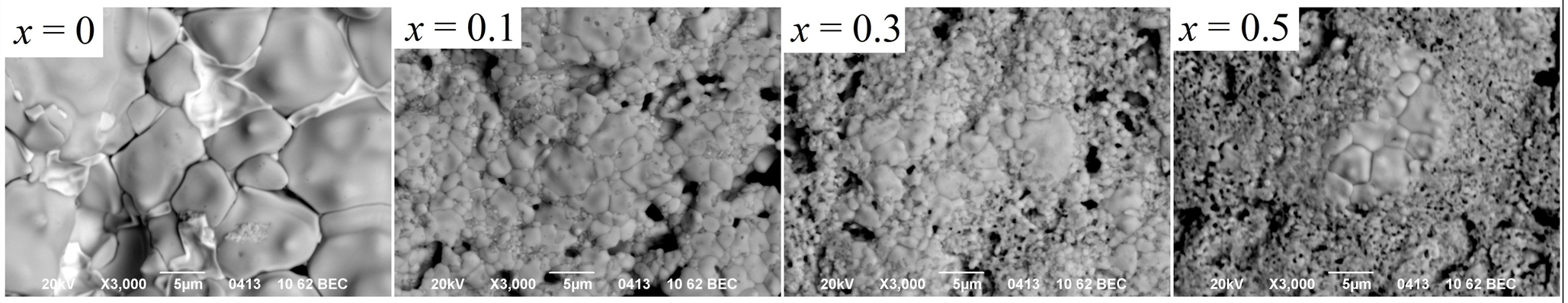

Fig. 4. Microstructure of the $Bi_{1-x}La_xFeO_{3-\delta}$ ceramics prepared by rapid liquid-phase sintering method (SEM-method).

CONCLUSIONS

• The crystal structure has a rhombohedral type of crystal structure distortion with changing of lattice parameters and space group from $R3m$ (x = 0) to $R3c$ (x = 0.1), $R\bar{3}m$ (x = 0.3) and $Pnma$ (x = 0.5).

• The molar formulas of the $Bi_{1-x}La_xFeO_{3-\delta}$ real perovskite structure have been determined. The crystal structure is defective because of the presence of vacancy type point defects $V^{(a)}$ and $V^{(c)}$ there. The correlation between the relative parameter changes $\Delta a/a$ and the average ionic radius $\Delta\bar{R}/\bar{R}$ has been found out.

• The microstructure of the $Bi_{1-x}La_xFeO_{3-\delta}$ ceramics consists of crystallites. Their size reduces from ~ 10 to ~ 1 μm with increasing x from 0 to 0.5.

• The monotone dispersion for relative permittivity $\varepsilon/\varepsilon_0(f)$ and non-monotonic dispersion for the dielectric loss tangent $\tan\delta(f)$ have been observed in the LF range from 1 Hz to 1 MHz. The $Bi_{0.9}La_{0.1}FeO_{3-\delta}$ composition has the greatest value of the dielectric permittivity: $\varepsilon = 5\cdot10^5$ at the 1 Hz and ε = 209 at the 1 MHz. The dispersion $\varepsilon/\varepsilon_0(f)$ and $\tan\delta(f)$ for all compositions is absent in the MW range from 8 to 12 GHz and their values are in the range ε = 10.5…34.5 and $\tan\delta = 10^{-4}…3\cdot10^{-3}$. The appearance of two peaks on the non-monotonic frequency dependencies of the $\tan\delta(f)$ in the LF range is caused by the presence of relaxation polarization processes in the defect structures of $Bi_{1-x}La_xFeO_{3-\delta}$.

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