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**ELECTROPHYSICAL PROPERTIES OF NANOSTRUCTURED
COMPOSITIONS OF (1-x)AF₁₂O₁₉ - xBTiO₃(A-Ba,Pb,Cd;B-Ba,Pb)**

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Abstract: In this work, the electrophysical properties of nanostructured compositions of (1-x)AF₁₂O₁₉ - xBTiO₃(A-Ba,Pb,Cd;B-Ba,Pb) ceramics in the range of x=0.0–1.0 with a concentration step Δx=0.1 were studied by complex methods. X-ray diffraction revealed that the YbMF compositions in the range of x=0.1–0.5 were hexagonal (H) phase solid solutions. In the concentration range of x=0.6–0.8, the hexagonal and orthorhombic (O) systems coexist, and the unit cell parameters of these phases rise with increasing x. The study of the lattice parameters, bond lengths, bond angles and the main parameters of the magnetic hysteresis loop of the H-phase revealed the presence of a singular point x=0.5 in the concentration range, where extrema of the corresponding parameters were observed.

Key words: electrophysical, spintronics, magnetoelectric sensors, multiferroic, Néel temperature, ferroelectric, antiferromagnet.

Introduction. Rare-earth multiferroic (1-x)AF₁₂O₁₉ - xBTiO₃(A-Ba,Pb,Cd;B-Ba,Pb) is interesting because it is a potential candidate for use as a functional element in information storage devices, spintronics, magnetoelectric sensors, etc. Such applications are based on the presence of magnetic and ferroelectric sublattices in YbMF and the possibility of cross-influence on them by electric and magnetic fields, respectively. The initial (1-x)AF₁₂O₁₉ - xBTiO₃(A-Ba,Pb,Cd;B-Ba,Pb) component crystallizes in the hexagonal syngony (hereinafter h-YbMO), while the second YbFeO₃ component crystallizes in the hexagonal (hereinafter h-YbFO) and orthorhombic (hereinafter o-YbFO) syngonies. Hexagonal h-YbMO is a multiferroic with a ferroelectric phase transition temperature T_c≈993 K. The temperature of the antiferromagnetic phase transition differs in different works: According to, the antiferromagnetic transition in these manganites occurs at TN ≈ 70–130 K,

according to other sources, TN is 81 K and 82 K, respectively. The stable orthorhombic phase o-YbMO can be obtained by heating the hexagonal h-YbMO under a pressure of 5 GPa and a temperature of 1100 °C [14] or by quenching under high pressure. According to, the magnetic phase transition occurs at TN =43 K. Hexagonal h-YbFO is also multiferroic. At room temperature, its symmetry space group is P63cm, and it is characterized by two ferroelectric phase transitions. The transition temperature from the paraelectric to ferroelectric phase is T_{c1}=470 K, and the transition between the ferroelectric phases occurs at a temperature of T_{c2}=225 K. The Néel temperature is TN =120 K. The symmetry above 470 K is described by the space group P63cm. At temperatures below 1000 K, ferroelectricity in h-RMnO₃ and h-RFeO₃ is induced by lattice distortion with a tilt angle (θ) of the FeO₅ (or MnO₅) trigonal bipyramid. In the orthorhombic phase, o-YbFO is an antiferromagnet with a Néel temperature TN =627 K and is described by the symmetry space group Pbnm. According to, no ferroelectric properties were found in o-(1-x)AF₁₂O₁₉ - xBTiO₃(A-Ba,Pb,Cd;B-Ba,Pb). At room temperature, the structure and physical properties of rare-earth manganites (ReMnO₃) and rare-earth orthoferrites (ReFeO₃) change depending on the radius of Re³⁺ ions. ReMnO₃ compositions with a greater Re³⁺ ionic radius than Dy (1.05 Å) have an orthorhombic distorted perovskite-type crystal structure, whereas those with a smaller Re³⁺ ionic radius than Dy have a hexagonal crystal structure. (1-x)AF₁₂O₁₉ - xBTiO₃(A-Ba,Pb,Cd;B-Ba,Pb) can crystallize in different space symmetry groups depending on the Fe/Mn molar ratios; therefore, the physical properties of (1-x)AF₁₂O₁₉ - xBTiO₃(A-Ba,Pb,Cd;B-Ba,Pb) can be purposefully changed over a wide range. It was discovered that the Néel temperature TN of hexagonal YbMnO₃ manganites doped with Fe³⁺ ions increases from 81 to 116 K (for YbMn_{0.45}Fe_{0.55}O₃), and YbMn_{0.45}Fe_{0.55}O₃ crystals exhibit antiferromagnetic properties. In addition, its magnetization M(H) is more than 100 times higher than that of YbMnO₃. The Mössbauer spectra of the hexagonal and orthorhombic phases of the YbMn_{1-x}Fe_xO₃ compounds were studied in, and the magnetic susceptibility was studied during zero field cooling (ZFC). However, YbMn_{1-x}Fe_xO₃ compositions have not been studied by dielectric, FTIR and optical absorption spectroscopy over the entire concentration range; and there is practically no data on their magnetodielectric properties. There are no data on the morphotropic region (MR) of these compositions. In order to fill this gap, such measurements are carried out for the first time. The aim of this work was to study the structural-phase state and physical properties of the YbMn_{1-x}Fe_xO₃ compositions, as well as establish the “structure–property” relationship using complex physical methods[1-5].

Synthesis, sample preparation and measurement apparatus. The (1-x)AF₁₂O₁₉ - xBTiO₃(A-Ba,Pb,Cd;B-Ba,Pb) compositions studied in this work were obtained by the solid-phase reaction method using the oxides Yb₂O₃, Mn₂O₃ and Fe₂O₃ (Yb₂O₃≥ 99.9%, Mn₂O₃≥ 99.9%, Fe₂O₃≥ 99.9%, Sigma-Aldrich). Eleven different molar fractions (x=0–1 with a step of 0.1) were mixed and ground in an agate mortar for 3 h in the presence of ethanol. After that, each mixture was made into a cylinder of 6 mm in diameter and 1 mm in thickness under a pressure of 120 MPa. The compositions were then placed in a closed platinum crucible. The synthesis was performed in a high-temperature furnace with thermal stabilization at 1250 °C for 4 h in an air atmosphere, after which the furnace was switched off and cooled by inertia to room temperature. To obtain a ceramic sample, each pre-synthesized sample was ground in an agate mortar for 0.5 h in the presence of ethanol, then pressed into a cylinder 6 mm in diameter and 1 mm thick under a pressure of 200 MPa. The sintering of ceramics was carried out in the furnace with thermal stabilization at 1150 °C for 4 h in an air

atmosphere. For electrophysical measurements, silver paste electrodes were applied to both sides of the sample and dried at 750 °C for 10 min. Phase analysis of the as-synthesized samples was performed on an X-ray diffractometer (D2 Phaser, Bruker, Germany) using Cu K α radiation with a step $\Delta 2\theta=0.01^\circ$ and a data acquisition time $\tau=1$ s. The microstructure of the samples was observed and examined by a scanning electron microscope (LEO EVO 40 XVP; Carl Zeiss AG, Germany). Optical absorption spectra were studied on a Shimadzu UV-2600 two-beam spectrophotometer at room temperature. The magnetic properties were studied on a vibrating sample magnetometer (VSM, LakeShore 7404, USA) at room temperature. The dielectric properties were analyzed using a High-Performance Dielectric Analyzer (Alpha-A, Novocontrol Technologies, Germany). The magnetodielectric and magnetoresistive properties were studied under a current magnetic induction field up to 2 T and a laboratory attachment for samples with temperature control from the boiling point of nitrogen to 900 K.

Structural characterization. Electron micrographs of the cleavages of $(1-x)\text{AFe}_{12}\text{O}_{19} - x\text{BTiO}_3(\text{A-Ba,Pb,Cd};\text{B-Ba,Pb})$ ($x=0.0-1.0$) ceramics are shown in Fig. 1. As shown in Fig. 1, the ceramics are rather porous, and there are no visual differences in the habits of crystallites of different compositions; they have rounded shapes. The average size distribution of crystallites is in the range of 1–2 μm . The density of the ceramics was evaluated by hydrostatic weighing, and the pore concentration was determined from the difference between the x-ray density and the density obtained by hydrostatic weighing. We obtained at room temperature for each concentration of the $(1-x)\text{AFe}_{12}\text{O}_{19} - x\text{BTiO}_3(\text{A-Ba,Pb,Cd};\text{B-Ba,Pb})$ ceramics. Rietveld full-profile analysis was used to process the diffraction profiles. As shown in Fig. 1 (a), increasing the molar concentration of Fe $^{3+}$ to $x=0.5$ leads to a decrease in the parameter a_h , and the parameter c_h increases in the concentration range $x=0.0-0.8$. X-ray diffraction patterns show that Yb(Mn,Fe) O $_3$ solid solutions of hexagonal syngony form in the range $x=0.1-0.5$, with a general trend in D and $\Delta d/d$ (see Fig. 3(b)). At the point $x=0.5$, the crystal lattice is deformed due to the formation of an additional phase of a different system. Starting from $x=0.5$, not only a_h increases, but also the parameters of the orthorhombic phase. Apparently, the concentration of the second phase at the point $x=0.5$ is low, and it is not X-ray resolved under our conditions. Therefore, we called the interval $x=0.6-0.8$ the morphotropic region (MR), as in ferroelectrics. Although it would be more correct to start this interval with $x=0.5$. In the MR region, there is a coordinated change in the parameters of coexisting phases. As can be seen, in the region where solid solutions are formed, D and $\Delta d/d$ decrease. This situation is possible if the ionic radii of the substituted ion and the substituent are approximately equal.

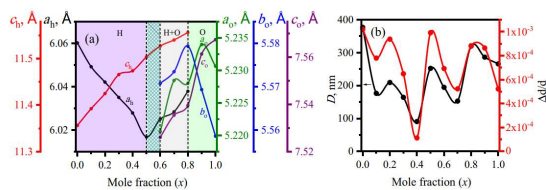


Fig. 1. Dependencies of the unit cell parameters of the hexagonal and orthorhombic phases (a), the sizes D and the microstrains $\Delta d/d$ (b) of the

In our case, this condition is met. The linear parameters of unit cells in the two phases increasing with x is a characteristic of the two phases coexistence region ($x=0.6-0.8$). In the orthorhombic phase, the parameters b_o and a_o that decrease as $x \rightarrow 1.0$ and increase as x increases. In this phase, the changes in D and $\Delta d/d$ have a general trend.

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ТЕМПЕРАТУРНЫЕ ЗАВИСИМОСТИ ХОЛЛОВСКОЙ ПОДВИЖНОСТИ И КОНЦЕНТРАЦИИ НОСИТЕЛЕЙ В ПЛЕНКАХ $\text{CdSe}_{0.8}\text{S}_{0.2}$

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Аннотация. Представлены результаты холловских измерений в темноте подвижности и концентрации электронов в зависимости от температуры. пленок $\text{CdSe}_{0.8}\text{S}_{0.2}$, полученных с помощью метода термического испарения в вакууме. Экспериментальные результаты интерпретированы на основе модели полупроводниковой пленки с межгранульными потенциальными барьерами.

Ключевые слова: твердые растворы $\text{CdSe}_{1-x}\text{S}_x$ поликристаллическая пленка, температурное и инфракрасное гашение темновой проводимости.

Ранее авторами работы [1] впервые обнаружена инфракрасное (ИК) и температурное гашение (ТГ) темновой проводимости (ТП) в диапазоне 77-523 К для пленочных образцов CdSe , обусловленные перезарядкой объемных глубоких центров рекомбинации в области пространственного заряда и модуляцией, как этой области, так и дрейфовых барьеров на границах кристаллитов при нагревании или под действием инфракрасного излучения.

Для выяснения природы наблюдаемых явлений ТГТП и ИКТП в исследованных нами пленках $\text{CdSe}_{0.8}\text{S}_{0.2}$ проводились холловские измерения в темноте средних значений подвижности μ_H и концентрации электронов n в зависимости от температуры T.

На рисунке 1 показаны температурные зависимости $\mu_H(T)$ и $n(T)$. Экспериментальные кривые 1-3 коррелируют кривым работы [1], а кривые 1'-3' рассчитывались с помощью соотношения $-\mu_H = R_H \sigma_d / (R_H - \text{коэффициент Холла})$.