Comparison of Structural and Transport Properties of Zirconia Single-crystals Stabilized by Yttria and Gadolinia

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The results of the study of the crystal structure, ionic conductivity and local structure of $(ZrO_2)_{1-x}(Gd_2O_3)_x$ and $(ZrO_2)_{1-x}(Y_2O_3)_x$ solid solutions in a wide range of compositions (x = 0.04-0.38) are given. Studies were performed on crystals obtained by the method of directional crystallization of the melt in a cold crucible. The results of the study of the local structure of the solid solutions of the ZrO₂-Y₂O₃ and ZrO₂-Gd₂O₃ systems revealed the formation of optical centers, which reflect the localization of oxygen vacancies in the crystal lattice depending on the concentration of the stabilizing oxide. It was shown that the local crystalline environment of Eu^{3+} ions in solid solutions $(ZrO_2)_{1-x}(Y_2O_3)_x$ and $(ZrO_2)_{1-x}(Gd_2O_3)_x$ is determined by the concentration of the stabilizing oxide and practically does not depend in this case on the type of the stabilizing oxide. The maximum conductivity of ZrO₂-Gd₂O₃ solid solutions is shifted to higher concentrations relative to the maximum conductivity of ZrO₂-Y₂O₃ solid solutions and was observed on crystals corresponding to the t'' phase. The results of the study of the crystal and local structure of solid solutions of the ZrO₂-Gd₂O₃ and ZrO₂-Y₂O₃ systems allowed us to isolate the concentration regions of stabilizing oxides in which the ionic conductivity is determined mainly by the phase composition or localization of oxygen vacancies in the crystal lattice.

Introduction

Solid solutions based on ZrO_2 doped with trivalent cations possess high ionic conductivity at temperatures of 800–1000°C and are widely used as solid electrolytes in SOFC (1–3). A systematic study of the dependence of the conductivity of ceramic solid solutions on the type and concentration of the doping oxide was carried out in (4). It was shown that an increase in the ionic radius of the stabilizing cation leads to a decrease in the maximum value of ionic conductivity. In this case, the concentration of the stabilizing

oxide corresponding to the maximum conductivity decreases with an increase in the ionic radius of the stabilizing cation (4). It is detected that the closer the ionic radius of the doping cation is to the radius of Zr^{4+} , the higher the conductivity. This behavior is usually explained in terms of elastic deformation, which is associated with the size mismatch between the cation matrix and the dopant. The higher the elastic deformation, the stronger the tendency of complex formation of oxygen vacancy is a cation (5). These complexes reduce conductivity, since they limit the number of mobile vacancies and increase the enthalpy of ion migration (4).

The study of defects in the crystal lattice of the $(ZrO_2)_{1-x}$ - $(Y_2O_3)_x$ solid solutions showed the presence of three different types of defects inside the fluorite lattice (6). At low yttrium oxide concentrations (x < 0.15), there are regions containing relatively few oxygen vacancies, which introduces a small tetragonal distortion into the lattice. The second type of defect is isolated oxygen vacancies that sometimes form vapors along the <111> directions. As the yttria content increases, these pairs of vacancies are ordered in the <112> direction, forming a third type of defect, the local structure of which is similar to the crystal structure of the ordered compound $Zr_3Y_4O_7$. The authors believe that a decrease in ionic conductivity with increasing yttria concentration is a consequence of a decrease in the mobility of isolated defects, that is, in this case, it is assumed that the decrease in conductivity in these materials is due to the vacancy-vacancy interaction.

Currently, there are quite a large number of works devoted to computer simulation of local structural defects and their interaction in oxide solid electrolytes using different approaches (7–12). One of the experimental methods for studying the local structure of crystals is optical spectroscopy. This method, using the Eu^{3+} ion as a spectroscopic probe, is widely used to study the local structure of crystals, including solid solutions based on zirconia (13–16).

It should be noted that the data available in the literature for the investigation of the ZrO_2 - Y_2O_3 and ZrO_2 - Gd_2O_3 systems relate mainly to the study of samples obtained by various methods of ceramic technology and for a limited range of compositions. As is known, the phase composition and properties of solid electrolytes strongly depend on the methods used to synthesize the material (17). In particular, the phase composition of the melted materials can differ greatly from the phase composition of materials obtained at lower synthesis temperatures.

This paper presents the results of a comparative study of the electrical conductivity, phase composition and local crystal structure of $ZrO_2-Y_2O_3$ and $ZrO_2-Gd_2O_3$ solid solutions in a wide range of compositions obtained by directional crystallization of the melt in order to identify the main factors affecting the concentration dependence of ionic conductivity.

Samples and Experimental Techniques

Crystals of solid solutions $(ZrO_2)_{1-x}(Y_2O_3)_x$ and $(ZrO_2)_{1-x}(Gd_2O_3)_x$ in a wide range of compositions (x = 0.04–0.38) were grown by the method of directional crystallization of the melt in a cold container (18). The process was carried out in a water-cooled copper crucible with a diameter of 130 mm at a crystallization rate of growth of 10 mm/h. All

solid solutions were additionally doped with 0.1 mol% of Eu_2O_3 . Eu^{3+} ions were used as a spectroscopic probe to study the local crystal structure using optical spectroscopy. The growth of crystals was carried out on the setup "Crystal-407" (frequency of 5.28 MHz, maximum output power 60 kW). The loading weight was 6 kg. To prepare the mixture, ZrO_2 , Y_2O_3 , Gd_2O_3 and Eu_2O_3 powders with a purity of at least 99.99% were used.

The phase composition of the crystals was analyzed using X-ray diffraction on a Bruker D8 instrument in CuK α radiation and using Raman spectroscopy. The excitation source was a 532 nm laser. The Raman spectra were recorded at multiple points along the crystal for phase composition homogeneity assessment.

Studies of the transport characteristics of crystals were carried out in the temperature range of 450–900°C with a step of 50°C on a Solartron SI 1260 analyzer, in the frequency range from 1 Hz to 5 MHz. The measurements were performed on crystal plates with the size of 7x7 mm² and thickness of 0.5 mm with symmetric platinum electrodes. To do this, platinum paste was applied to the plates, after which annealing was performed at a temperature of 950°C for one hour in air. The amplitude of the applied alternative signal to the sample was 24 mV. A detailed analysis of the frequency spectrum of the impedance was carried out using the ZView program. The electrolyte resistances were calculated from the obtained impedance spectra, then the specific electrical conductivity of the crystals was calculated.

The luminescence spectra were recorded at 300 and 77 K using a Horiba FHR 1000 spectrometer. As a radiation detector, a Hamamatsu R928 PMT was used. The luminescence was excited to the ⁵D₁ level by the emission of the second harmonic of YVO₄:Nd lasers ($\lambda_{exc} = 532$ nm). The luminescence was excited to the ⁵L₆ level of Eu³⁺ ions using the third harmonic of the LiYF₄:Nd laser with a wavelength of 351 nm.

Results and Discussion

The compositions of the grown crystals, the corresponding designations and the density values of the crystals are presented in table 1.

ZrO ₂ -Y ₂ O ₃			ZrO ₂ -Gd ₂ O ₃			
Crystal Composition	Designat ion	Density, g/cm ³	Crystal Designat Composition ion		Density, g/cm ³	
$(ZrO_2)_{0.96}(Y_2O_3)_{0.04}$	4YSZ	6.020(2)	$(ZrO_2)_{0.96}(Gd_2O_3)_{0.04}$	4GdSZ	6.251(2)	
$(ZrO_2)_{0.92}(Y_2O_3)_{0.08}$	8YSZ	6.010(2)	$(ZrO_2)_{0.92}(Gd_2O_3)_{0.08}$	8GdSZ	6.394(2)	
$(ZrO_2)_{0.90}(Y_2O_3)_{0.10}$	10YSZ	5.950(2)	$(ZrO_2)_{0.90}(Gd_2O_3)_{0.10}$	10GdSZ	6.481(2)	
$(ZrO_2)_{0.88}(Y_2O_3)_{0.12}$	12YSZ	5.928(2)	$(ZrO_2)_{0.88}(Gd_2O_3)_{0.12}$	12GdSZ	6.533(2)	
$(ZrO_2)_{0.86}(Y_2O_3)_{0.14}$	14YSZ	5.882(2)	$(ZrO_2)_{0.86}(Gd_2O_3)_{0.14}$	14GdSZ	6.586(2)	
$(ZrO_2)_{0.84}(Y_2O_3)_{0.16}$	16YSZ	5.861(2)	$(ZrO_2)_{0.84}(Gd_2O_3)_{0.16}$	16GdSZ	6.634(2)	
(ZrO ₂) _{0.80} (Y ₂ O ₃) _{0.20}	20YSZ	5.797(2)	$(ZrO_2)_{0.80}(Gd_2O_3)_{0.20}$	20GdSZ	6.702(2)	
$(ZrO_2)_{0.62}(Y_2O_3)_{0.38}$	38YSZ	5.507(2)	$(ZrO_2)_{0.77}(Gd_2O_3)_{0.33}$	33GdSZ	6.863(2)	

TABLE I. The compositions of the grown crystals, their designations and density

The crystals stabilized with gadolinium oxide in form, color, and size were not fundamentally different from crystals stabilized with yttrium oxide. All crystals had a columnar shape typical of this growing method. In the investigated composition range, homogeneous, transparent single crystals of $(ZrO_2)_{1-x}(Y_2O_3)_x$ solid solutions were obtained at $x \ge 0.08$, and solid solutions $(ZrO_2)_{1-x}(Gd_2O_3)_x$ at $x \ge 0.10$. Unlike homogeneous transparent single crystals of 8YSZ, 8GdSZ crystals were semi-transparent, but without visible defects in the ingot volume. The 4YSZ and 4GdSZ crystals were white and opaque.

With an increase in the concentration of Y_2O_3 in solid solutions based on $ZrO_2-Y_2O_3$, the density of crystals decreases, since the density of Y_2O_3 (4.850 g/cm³) is less than the density of ZrO_2 (5.68 g/cm³). The density of Gd_2O_3 (7.407 g/cm³) is greater than the density of ZrO_2 , therefore the density of $ZrO_2-Gd_2O_3$ crystals increases with increasing concentration of Gd_2O_3 .

In figure 1, in Arrhenius coordinates, the temperature dependences of the specific conductivity of the investigated crystals $(ZrO_2)_{1-x}(Y_2O_3)_x$ and $(ZrO_2)_{1-x}(Gd_2O_3)_x$ are shown. As can be seen from figure 1 temperature dependences are linear in the entire temperature range under study.



Figure 1. Temperature dependences of the specific conductivity of the investigated crystals (a) $-(ZrO_2)_{1-x}(Y_2O_3)_x$ and (b) $-(ZrO_2)_{1-x}(Gd_2O_3)_x$.

In figure 2 the electrical conductivity of the crystals $(ZrO_2)_{1-x}(Y_2O_3)_x$ and $(ZrO_2)_{1-x}(Gd_2O_3)_x$ at a temperature of 900°C is presented.



Figure 2. Electrical conductivity of the crystals $(ZrO_2)_{1-x}(Y_2O_3)_x$ and $(ZrO_2)_{1-x}(Gd_2O_3)_x$ at a temperature of 900°C.

One can see from figure 2 that the concentration dependences of the conductivity, both in the case of Y_2O_3 and in the case of Gd_2O_3 , have a similar type. However, the maximum conductivity of ZrO_2 - Gd_2O_3 solid solutions is shifted to higher concentrations relative to the maximum conductivity of ZrO_2 - Y_2O_3 solid solutions. Thus, the maximum conductivity of the ZrO_2 - Y_2O_3 solid solution was observed at a content of 8–10 mol% of Y_2O_3 , while for the ZrO_2 - Gd_2O_3 solid solution this concentration was 10-12 mol% of Gd_2O_3 . Note that the maximum conductivity in the ZrO_2 - Y_2O_3 system was higher than the analogous value for the ZrO_2 - Gd_2O_3 system. An increase in the concentration of Y_2O_3 above 10 mol% and Gd_2O_3 above 12 mol% led to a decrease in conductivity. The conductivity of crystals at x ~ 14 mol% in the case of stabilization by Gd_2O_3 is slightly higher than for Y_2O_3 at comparable concentrations.

To explain the non-monotonic dependence of conductivity on the concentration of a stabilizing oxide, as well as the position of the maximum of conductivity on the type of stabilizing oxide, an investigation was made of the phase composition and local structure of crystals.

Data in table 2 shows the phase composition and lattice parameters for ZrO_2 crystals stabilized with Y_2O_3 or Gd_2O_3 .

TABLE II. Phase composition and crystal lattice parameters of $(ZrO_2)_{1-x}(Y_2O_3)_x$ and $(ZrO_2)_{1-x}(Gd_2O_3)_x$ crystals

ZrO ₂ -Y ₂ O ₃			ZrO ₂ -Gd ₂ O ₃			
Sample	Phase	Lattice parameters, Å	Sample	Phase	Lattice parameters, Å	

ECS Transactions,	91	(1)	1173-	1183	(2019)	
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4YSZ	t t´	a = 3.606(1), c = 5.169(1) a = 3.626(1), c = 5.147(2)	4GdSZ	t t´	a = 3.609(1), c = 5.182(1) a = 3.636(1), c = 5.155(2)
8YSZ	с	a = 5.138(1)	8GdSZ	ť	a = 3.641(1), c = 5.155(1)
10YSZ	c	a = 5.144(1)	10GdSZ	c	a = 5.159(1)
12YSZ	c	a = 5.148(1)	12GdSZ	c	a = 5.167(1)
14YSZ	c	a = 5.153(1)	14GdSZ	c	a = 5.175(1)
16YSZ	c	a = 5.159(1)	16GdSZ	c	a = 5.186(1)
20YSZ	c	a = 5.172(1)	20GdSZ	c	a = 5.197(1)
38YSZ	c	a = 5.224(1)	33GdSZ	с	a = 5.246(1)

* t – tetragonal modification of ZrO_2

c – cubic modification of ZrO₂

The 4YSZ and 4GdSZ crystals contained two tetragonal phases of zirconia t and t` with different degrees of tetragonality. The presence of these phases is due to the phase decomposition of the high-temperature cubic solid solution into two metastable tetragonal phases. During the transition from a single-phase cubic region to a two-phase (c + t)region of the equilibrium phase diagram of the ZrO₂-Y₂O₃ and ZrO₂-Gd₂O₃ systems, no decomposition into stable phases occurs. At a certain supercooling critical for a given composition, a first-order phase transition occurs, accompanied by a redistribution of the stabilizing impurity and the formation of two metastable tetragonal phases whose compositions lie inside the two-phase (c + t) region near the equilibrium boundaries. When the concentration of the stabilizing oxide was 8 mol%, the phase composition of the crystals depended on the type of stabilizing oxide: the 8GdSZ crystals had a tetragonal structure, and the 8YSZ had a cubic structure. At a concentration of more than 8 mol% of Y_2O_3 and 10 mol% of Gd_2O_3 , the crystals were single-phase cubic with a fluorite-type structure. In cubic solid solutions, the lattice parameter of the crystals almost linearly increased with an increase in the concentration of the stabilizing oxide. At comparable concentrations, the lattice parameter of cubic crystals stabilized with Y₂O₃ was lower than that of crystals stabilized with Gd₂O₃. It should be noted that the stabilization of the cubic phase in crystals, doped with Y₂O₃, occurs at a lower concentration of Y_2O_3 in the solid solution than in crystals, doped with Gd_2O_3 . This may be due to the dependence of the mechanism for stabilizing the high-temperature phase on the type of stabilizing impurity. In binary systems ZrO₂-R₂O₃ a decrease in the ionic radius reduces the transition temperature from the high-temperature cubic phase to the low-temperature tetragonal phase (19), which will result in the high-temperature cubic phase remaining at room temperature at a lower concentration of stabilizing oxide.

The phase composition was also investigated by Raman spectroscopy. Figure 3 shows the Raman spectra for crystals of the ZrO₂-Y₂O₃ and ZrO₂-Gd₂O₃ solid solutions.



Figure 3. Raman spectra for ZrO₂-Y₂O₃ (a) and ZrO₂-Gd₂O₃ (b) crystals

The Raman spectra of the 4YSZ and 4GdSZ crystals have the shepa characteristic for the tetragonal structure of zirconia (20,21) and contain lines with maxima of 146 cm⁻¹, 262 cm^{-1} , 321 cm^{-1} , 464 cm^{-1} , 608 cm^{-1} , 644 cm^{-1} .

In the spectra of crystals 8YSZ, 10YSZ and 10GdSZ, 12GdSZ, along with the line in the region of 628 cm⁻¹, which corresponds to the F_{2g} vibration for a cubic structure (22), there is a line with a maximum of 480 cm⁻¹ corresponding to the tetragonal t"-phase (21,23). This phase was described as having a degree of tetragonality with c/a = 1, but belonging to the space group of symmetry P4₂/nmc due to the displacement of oxygen atoms in the anion sublattice. In the Raman spectrum of the 8GdSZ crystal, the main lines corresponding to the tetragonal structure of 146 cm⁻¹, 262 cm⁻¹, 321 cm⁻¹, 464 cm⁻¹ of the solid solution are preserved. However, the width of the lines increases and there is a wide line of 628 cm⁻¹, corresponding to the cubic phase. Such a character of the spectrum may indicate the presence of two phases in a crystal. The crystal spectra for (12-20) mol% of Y₂O₃ and (14-20) mol% of Gd₂O₃ correspond to the cubic phase. The shape of the Raman spectra for the 38YSZ and 33GdSZ crystals differs from the Raman spectra of cubic crystals and is similar to the spectrum of the cubic structure of pyrochlore (O^h₇) given in (22). This type of crystal spectra of 38YSZ and 33GdSZ can be associated with partial ordering of the structure with respect to oxygen vacancies.

Thus, the structure of crystals with a concentration of stabilizing oxide (8-10) mol% of Y_2O_3 and (10-12) mol% of Gd_2O_3 is the structure of the t''-phase, and not cubic as determined by X-ray diffraction data.

The study of the features of the local structure of crystals of ZrO_2 - Y_2O_3 and ZrO_2 - Gd_2O_3 solid solutions, formed with accordance to oxygen vacancies, was carried out by optical spectroscopy. A detailed description of the local structure of ZrO_2 - Y_2O_3 and ZrO_2 - $Gd2O_3$ crystals depending on the concentration of the stabilizing oxide is given in (24,25). This paper presents the main results that are necessary for analyzing the obtained dependence of ionic conductivity on the content of a stabilizing oxide.

Figure 4a shows the luminescence spectra for $(ZrO_2)_{1-x}(Y_2O_3)_x$ crystals (x = 0.04, 0.08, 0.16, 0.20, 0.38), and figure 4b – for $(ZrO_2)_{1-x}(Gd_2O_3)_x$ crystals (x = 0.04, 0.08, 0.16, 0.20, 0.33) doped with Eu³⁺ ions, due to the ${}^5D_0 \rightarrow {}^7F_0$, ${}^5D_0 \rightarrow {}^7F_1$ and ${}^5D_0 \rightarrow {}^7F_2$ transitions of Eu³⁺ ions when excited to the level 5D_1 ($\lambda_{exc} = 532$ nm) at a temperature of 300 K.



Figure 4. luminescence spectra for (a) $- (ZrO_2)_{1-x}(Y_2O_3)_x$ crystals (x = 0.04, 0.08, 0.16, 0.20, 0.38), and (b) $- (ZrO_2)_{1-x}(Gd_2O_3)_x$ crystals (x = 0.04, 0.08, 0.16, 0.20, 0.33) doped with Eu³⁺ ions, due to the ${}^5D_0 \rightarrow {}^7F_0$, ${}^5D_0 \rightarrow {}^7F_1$ and ${}^5D_0 \rightarrow {}^7F_2$ transitions of Eu³⁺ ions when excited to the level 5D_1 ($\lambda_{exc} = 532$ nm) at a temperature of 300 K.

A comparative analysis of the luminescence spectra of ZrO_2 -Gd₂O₃ crystals suggests that, by the shape and position of the lines, they reveal significant similarity with the luminescence spectra of ZrO_2 -Y₂O₃ crystals at comparable concentrations of a stabilizing oxide.

The number I in the luminescence spectra denotes lines belonging to the optical centers of Eu³⁺ ions, in which the oxygen vacancy is located in the first coordination sphere (24,25). The lines belonging to optical centers, in which there is no anion vacancy in the first coordination sphere, but present in the second sphere, are indicated on the spectra by the number II (24,25). From figure 4 it can be seen that as the concentration of the stabilizing oxide increases, the relative intensity of the lines belonging to the optical centers I and II of the Eu³⁺ ions changes. When the concentration of the stabilizing oxide is <8 mol%, the intensity of the lines belonging to centers I. At concentrations of Y_2O_3 , $Gd_2O_3 \ge 8 \mod \%$ the intensity of the lines of optical centers I becomes greater than the intensity of the lines of optical centers I becomes greater than the intensity of the lines of optical centers I becomes greater than the intensity of the lines belonging to stabilizing oxide more than 20 mol% in the luminescence spectra revealed additional lines (III), which were attributed to Eu³⁺ ions having two oxygen vacancies in the diagonal positions of the cubic crystal lattice (24,25). The positions of the optical centers of type III Eu³⁺ ions are similar to the positions of Y³⁺ ions with C₂ point symmetry in the Y₂O₃ structure.

Summarizing the features of the local structure of ZrO_2 -Gd₂O₃ and ZrO_2 -Y₂O₃ crystals, we can conclude that the local crystalline environment of Eu³⁺ ions in solid solutions $(ZrO_2)_{1-x}(Y_2O_3)_x$ and $(ZrO_2)_{1-x}(Gd_2O_3)_x$ formed with the participation of oxygen vacancies is determined by the concentration of the stabilizing oxide and is practically independent in this case of the type of the stabilizing oxide (Y₂O₃ or Gd₂O₃). The relative part of the positions of the Eu³⁺ ions (Y³⁺, Gd³⁺) in which the oxygen vacancy is located in the nearest coordination sphere increases with concentrations of the stabilizing oxide (Y₂O₃, Gd₂O₃) above 8 mol%. For the solid solutions ZrO_2 -Y₂O₃ and ZrO_2 -Gd₂O₃ in the

1180 Downloaded on 2019-09-01 to IP 128.59.222.107 address. Redistribution subject to ECS terms of use (see ecsdl.org/site/terms_use) unless CC License in place (see abstract). concentration range above 20 mol% of the stabilizing oxide (Y_2O_3, Gd_2O_3) , 6coordinated positions of Eu^{3+} ions (Y^{3+}, Gd^{3+}) are observed with two oxygen vacancies in the nearest coordination sphere located along the diagonal on the face of cubic crystal cell, similar in local environment to the positions of Eu^{3+} ions in crystals of sesquioxides (Y_2O_3, Gd_2O_3) , as well as cation positions characterized by the presence of a vacancy in both the first and the nearest coordination spheres.

Comparison of data on the ionic conductivity of crystals with data on the phase composition and local structure of crystals shows that crystals with 10–12 mol% of Gd₂O₃ and 8–10 mol% of Y₂O₃, containing the t' phase, have the highest conductivity. On going from the t' phase to the cubic phase, a decrease in the ionic conductivity with an increase in the concentration of Gd₂O₃ or Y₂O₃ is observed. The conductivity values of single-phase cubic crystals $(ZrO_2)_{1-x}(Y_2O_3)_x$ and $(ZrO_2)_{1-x}(Gd_2O_3)_x$ at $x \ge 14$ mol% are close at comparable concentrations and are determined mainly by the local structure of the crystals.

Conclusion

Crystals of solid solutions $(ZrO_2)_{1-x}(Gd_2O_3)_x$ and $(ZrO_2)_{1-x}(Y_2O_3)_x$ are grown by the method of directional crystallization of the melt in a cold crucible (x = 0.04, 0.08, 0.10, 0.12, 0.14, 0.16, 0.20, 0.33, 0.38). It was shown that in the investigated composition range, homogeneous, transparent single crystals of $(ZrO_2)_{1-x}(Y_2O_3)_x$ solid solutions were obtained at x \ge 0.08, and solid solutions $(ZrO_2)_{1-x}(Gd_2O_3)_x$ at x \ge 0.10.

It has been detected that stabilization of the cubic phase in crystals, co-doped with Y_2O_3 , occurs at a lower concentration of Y_2O_3 in the solid solution than in crystals, doped with Gd_2O_3 .

It was shown that the local crystalline environment of Eu³⁺ ions in solid solutions $(ZrO_2)_{1-x}(Y_2O_3)_x$ and $(ZrO_2)_{1-x}(Gd_2O_3)_x$ is determined by the concentration of the stabilizing oxide and in this case does not depend on the type of the stabilizing oxide $(Y_2O_3 \text{ or } Gd_2O_3)$. The conductivity values of single-phase cubic crystals at $x \ge 14 \text{ mol}\%$ in the case of stabilization by Gd_2O_3 are slightly higher than for Y_2O_3 at comparable concentrations and are determined mainly by the local structure of the crystals. The maximum conductivity at a temperature of 900°C was observed in crystals containing 10 mol% of Gd_2O_3 and 8 mol% of Y_2O_3 . These compositions correspond to the t''-phase and are close to the boundary between the regions of the cubic and tetragonal phases. Thus, the results of a study of the crystal and local structure of solid solutions of the ZrO_2 -Gd₂O₃ and ZrO_2 -Y₂O₃ systems make it possible to detect concentration regions of stabilizing oxides, in which the ionic conductivity is determined mainly by the phase composition or localization of oxygen vacancies in the crystal lattice.

Acknowledgments

This work was supported by the grants of the Russian Science Foundation 18-79-00323 and 17-79-30071. Synthesis, study of the structure and transport characteristics of ZrO_2 -Gd₂O₃ system crystals was carried out with the financial support of the grant 18-79-

00323, and for system ZrO_2 - Y_2O_3 with the financial support of the grant 17-79-30071. Raman spectroscopy technique was developed with the financial support of State Task of Institute of Solid State Physics RAS.

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