New DySrAlO₄ Compound Synthesis and Formation Process Correlations for *Ln*SrAlO₄ (*Ln* = Nd, Gd, Dy) Series

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Abstract For the first time, DySrAlO₄ of K₂NiF₄-type structure was synthesized. The parameters of DySrAlO₄ elementary unit cell are determined as follows: $a = 0.368$ (4) nm, $c = 1.229$ (2) nm, $V = 0.166$ (4) nm³. The research of the complex aluminates *Ln*SrAlO₄ (*Ln* = Nd, Gd, Dy) solid-state process demonstrated the change of the formation mechanism among *Ln*SrAlO₄ (*Ln* = Nd, Gd, Dy) series from DySrAlO₄ oxide. The performed analysis provided a possibility to realize why chemists couldn't get DySrAlO₄ for a long period of time.

KEY WORDS: Rare earths; Oxide materials; K₂NiF₄-type structure; Solid-state reactions; Phase formation

1 Introduction

Materials based on the layered perovskite-like compounds, in particular Ruddlesden–Popper phases (RP), are of interest due to the fact that they possess the unique physical and chemical properties, which may provide wide possibilities for use as catalytic electrodes, ferrites, superconductors, insulators, etc. [1–7]. Recently, *Ln*MAIO₄ (*Ln* = La, Nd, Sm and Y; *M* = Sr, Ca) crystals and ceramics have attracted much scientific attention because of their interesting dielectric characteristics and potential applications as substrates [8, 9]. However, the existence and stability of mixed *Ln*MBO₄ oxides (*M* = alkaline earth metal; *B* is Al or 3*d* metal) of K₂NiF₄-type phases sets the crystal problem of the *MO* rock salt (RS) and *Ln*BO₃ perovskite (P) layer adaptability composing of the 1:1 (P/RS) intergrowth structure [10–12]. Hence, the K₂NiF₄-type

structure peculiarity predetermines apparently the synthetic complexities in *Ln*MBO₄ oxides production [10, 11, 13, 14] and thus resulted in restriction or absence of data on numerous P/RS series formation.

Stability condition of one-layered RS phase existence, in terms of LaCaAlO₄, has been described in [11]. Stabilization of LaCaAlO₄ is possible through replacement of La atoms in RS layer by atoms of any rare earth element and Y. Substitution of calcium atoms by other alkaline earth element in the LaCaAlO₄ structure may stabilize or destabilize the layered structure depending on the sizes of replacing atoms. This is the result of ion adaptation to the volume of oxygen polyhedrons in the course of transition from one crystal (P) structure to other (P/RS), i.e., (La, Ca)–O bond lengths are compared in P and RS blocks at conversion from 12- and 6/8-coordinated states to 9 [11]. So, the existence of the whole *Ln*CaAlO₄ series has been confirmed [11, 12]. Apparently, the analyzed reasons provide a possibility to explain the lack of data on *Ln*MgAlO₄ yield. It is necessary to note that *Ln*BaAlO₄ (*Ln* = rare earth metal) has not been described in the literature, except specific information given in the work [13] devoted to LaBaAlO₄ formation possibility prediction. Up to the present, GdSrAlO₄ is the latest known representative of the compounds with a common formula *Ln*SrAlO₄ [7, 11]. The

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lack of data on the existence of LnSrAlO_4 ($\text{Ln} = \text{Tb, Dy, Ho}$) oxides can occur potentially, which encourages our work in the field of formation process possibility research. Note that apart from geometric factor evaluating the stability of considered phases, it seems to be of importance to analyze the thermodynamic possibility of one-layered RP phase production. In this course, the information on phase equilibria in the $\text{Ln}_2\text{O}_3\text{--SrO--Al}_2\text{O}_3$ ($\text{Ln} = \text{Nd, Gd, Dy}$) systems, where the analyzed complex oxides are localized, is required. Note that data on phase equilibria in the $\text{Ln}_2\text{O}_3\text{--SrO--Al}_2\text{O}_3$ systems are limited enough [4, 15–19]. Therefore, the first step in the poorly developed P/RS compound's technology is the investigation of stability conditions of all complex oxides included into mentioned sections as well as isostructural analogs formation mechanism.

The present research is to investigate the possibility of a new DySrAlO_4 oxide existence and the formation mechanism of NdSrAlO_4 and GdSrAlO_4 .

2 Experimental

2.1 Sample Preparation

LnSrAlO_4 ($\text{Ln} = \text{Nd, Gd, Dy}$) phases were synthesized by solid-state reaction route of stoichiometric amounts of SrCO_3 (special purity grade 7-2), Ln_2O_3 ($\text{Ln} = \text{Nd, Gd, Dy}$) (99.99%) and Al_2O_3 (Johnson Matthey 99.99%, 1–15 μm). The lanthanide oxides were dried in air at 1000 °C for 2 h prior to use. The correction for the decarbonization of SrCO_3 first dehumidified at 300 °C for 2 h was calculated on the thermogravimetric data, performed by MOM 52 Q-1500C Paulik–Paulik–Erdey derivatograph (Hungary) [17]. After mechanical stirring with water and compaction, the mixtures were heat-treated in the isothermal annealing–quenching mode at 700–1500 °C in air under oxygen partial pressure of 21.3 kPa. Thermal exposures were ranged from 5 to 15 h.

2.2 Characterization Techniques

The phase composition and sequence of phase transformations of LnSrAlO_4 samples were characterized by powder X-ray diffraction (PXD). PXD data were initially collected at room temperature using Shimadzu XRD-7000 operating with CuK_α radiation ($\lambda = 0.154178 \text{ nm}$). Calculation of elementary unit cell parameters is executed by the software package of PDWin 4.0. The angular amendment was carried out by internal standard method. As the standard, the $\alpha\text{-Si}$ was used.

As starting points for DySrAlO_4 theoretical diffraction plotting, the data on type and atomic coordinates (x ,

y, z) in the GdSrAlO_4 as an example [20, 21], isotropic thermal factors (B) and occupancy G were taken into consideration (Table 1).

The file received as a result of theoretical diffractogram construction contained information on interplanar distance d (Å), angle 2θ (°), reflection index hkl and intensities I_c (%) for all reflexes in 2θ range of 20°–70°.

The microstructure of the specimen and elemental composition of coexisting phases were analyzed by scanning electron microscopy (SEM) and energy-dispersive X-ray spectrometry (EDX) using the CamScan MV2300 coupled with the Oxford Link microprobe analyzer. The error in determining the elements content by this method varies with the atomic number and equals $\pm 0.3 \text{ mass\%}$ on average.

3 Results

3.1 Formation Mechanism of NdSrAlO_4 and GdSrAlO_4

The X-ray analysis data (Fig. 1a) show that after calcination of Nd_2O_3 , Al_2O_3 SrCO_3 oxide mixture, corresponding stoichiometry of NdSrAlO_4 , at 700 °C for 5 h, only initial components are fixed. Increasing treatment temperature up to 900 °C in 5 h both $\text{Sr}_3\text{Al}_2\text{O}_6$ and SrAl_2O_4 (trace amounts) yields (Fig. 1a). Formation of aluminate–strontium oxides took place by interaction of SrO with Al_2O_3 after SrCO_3 decarbonization process. It is worth mentioning that decarbonization of SrCO_3 , according to the results obtained in [17], starts from the polymorphous transition from orthorhombic to hexagonal modification at 920 °C, and it is over the temperature of 1100 °C. Nd_2O_3 reflexes (Fig. 1a) are also registered in the reaction mixture. NdSrAlO_4 existence is fixed during thermal treatment of initial mixture at 1050 °C (Fig. 1a). The received results correlate well with the data of the works [7, 19], where the kinetics of NdSrAlO_4 formation was considered. The yield of homogeneous NdSrAlO_4 was registered by Zvereva et al. [19] at 1300–1500 °C. So, an interaction of Nd_2O_3 with SrAl_2O_4 and $\text{Sr}_3\text{Al}_2\text{O}_6$ results in NdSrAlO_4 production.

Figures 1b, 2a, a' and Table 2 show PXD, scanning electron microscopy (SEM) and elemental analysis data of GdSrAlO_4 sample received during thermal treatment of Gd_2O_3 , SrCO_3 and Al_2O_3 mixture at 1400 °C for 5 h (synthesis conditions selection is based on NdSrAlO_4 formation mechanism results presented above). Together with the yield of GdSrAlO_4 , we observed the occurrence of SrAl_2O_4 , $\text{Sr}_3\text{Al}_2\text{O}_6$ and monoclinic modification of Gd_2O_3 (Table 2; Figs. 1b, 2a, a'). Formation of homogeneous GdSrAlO_4 for the simple Gd_2O_3 , SrCO_3 and Al_2O_3 oxides

Table 1 Basic data, chemical composition and atomic parameters for DySrAlO₄

Phase: DySrAlO ₄									
Chemical structure: DySrAlO ₄									
Chemical composition per unit [Dy ³⁺] 2 [Sr ²⁺] 2 [Al ³⁺] 2 [O ²⁻] 8									
Sys: Tetragonal; Space group symmetry: I4/mmm (139)									
Z = 2									
Atom	El ₁	El ₂	G ₁	G ₂	x/a	y/b	z/c	B _{is} (Å ²)	Site
<i>Atomic parameters</i>									
Dy	Dy ³⁺	Sr ²⁺	0.50	0.50	0.0000	0.0000	0.3643	0.4000	4
Al	Al ³⁺		1.00		0.0000	0.0000	0.0000	0.6000	2
O ₁	O ²⁻		1.00		0.5000	0.0000	0.0000	0.8000	4
O ₂	O ²⁻		1.00		0.0000	0.0000	0.1680	0.8000	4

Fig. 1 X-ray diffraction patterns of initial mixtures corresponding stoichiometry of **a** NdSrAlO₄ after sintering in air at 700, 900, 1050 °C for 5 h; **b** GdSrAlO₄ after sintering in air at 1400 °C for 5 (1) and 15 (2) h

took place at 1400 °C and thermal exposure within 15 h (Fig. 1b).

3.2 Formation Mechanism of DySrAlO₄

Based on PXD data, DySrAlO₄ samples heat-treated at 1300 °C for 5 h contain the required synthesis product, SrAl₂O₄, DySr₃Al₂O₇ and Dy₂O₃ (Fig. 3). Increase in synthesis temperature up to 1400 °C results in the

occurrence of SrAl₄O₇ and Sr₄Al₁₄O₂₅ (Figs. 2b, 3; Table 2). DySrAl₃O₇ formation is confirmed by SEM/EDX data (see Table 2; Figs. 2b, 3). In addition to considered oxides, the DySrAlO₄, Dy₂O₃, Sr₃Al₂O₆ and DySr₃Al₂O_{7.5} phases are fixed in the mixture. DySrAlO₄ and Dy₂O₃ DySr₃Al₂O_{7.5} oxides are registered after thermal treatment at 1500 °C (Figs. 2, 3; Table 2). Determination of DySrAlO₄ elementary cell parameters ($a = 0.368$ (4) nm, $c = 1.229$ (2) nm, $V = 0.166$ (4) nm³) has been done in the course of model described in experimental part by comparison with structural data [20, 21]. For confirmation of DySrAlO₄ formation, we proposed an approach based on construction of theoretical X-ray diffractogram, in which elementary cell parameters for DySrAlO₄ as initial detailed information as well as atomic parameters (see Table 1) were used. Table 3 summarizes the data on interplane distance d (Å), angle 2θ (°), reflection index hkl and integral intensity I_c (%), received in the course of DySrAlO₄ theoretical diffractogram construction. According to theoretical calculation data (Table 3) in comparison with experimental results of X-ray phase analysis of DySrAlO₄ samples thermally treated in the temperature interval 1300–1500 °C (Fig. 3), the complete correspondence of reflexes on the set of characteristic lines is observed. The mentioned result once again proves the existence of the new DySrAlO₄ oxide belonging to RP series.

4 Discussion

To illustrate the processes of LnSrAlO₄ ($Ln = \text{Nd, Gd}$) formation from simple oxides of neodymium/gadolinium, aluminum and strontium carbonate, we analyzed the scheme demonstrated in Fig. 4a, which indicates that the basic stages result in the yield of target products, using GdSrAlO₄ as an example. The first stage of GdSrAlO₄ synthesis is connected with the formation of Sr₃Al₂O₆, SrAl₂O₄ through interaction of SrO with Al₂O₃. Following

Fig. 2 SEM photographs of initial mixtures corresponding stoichiometry of GdSrAlO_4 after sintering at 1400 °C **a, a'**; DySrAlO_4 after sintering at 1400 °C **b**; 1500 °C **c** in air for 5 h

reaction of Gd_2O_3 with SrAl_2O_4 and $\text{Sr}_3\text{Al}_2\text{O}_6$ results in the formation of GdSrAlO_4 (see Fig. 4a).

The initial stage in DySrAlO_4 formation may be described as production of several aluminate–strontium oxides SrAl_2O_4 (crystallized in the monoclinic and hexagonal modifications), $\text{Sr}_3\text{Al}_2\text{O}_6$, SrAl_4O_7 and $\text{Sr}_4\text{Al}_{14}\text{O}_{25}$. Appearance of SrAl_4O_7 and $\text{Sr}_4\text{Al}_{14}\text{O}_{25}$ phases, registered by X-ray and elemental phase analysis (Figs. 2b, c, 3, 4b; Table 2), may be explained by kinetic factors as well as by the fact that within the interval of 1300–1500 °C temperatures, SrAl_2O_4 , $\text{Sr}_3\text{Al}_2\text{O}_6$ and SrAl_4O_7 phases are coexisted according to phase equilibrium in $\text{SrO}–\text{Al}_2\text{O}_3$ system data [22, 23]. Appearance of $\text{Sr}_4\text{Al}_{14}\text{O}_{25}$ may be connected with interaction of

SrAl_2O_4 and SrAl_4O_7 [24]. $\text{DySrAl}_3\text{O}_7$ occurrence can be explained by coupling of previously formed $\text{Sr}_4\text{Al}_{14}\text{O}_{25}$ with Dy_2O_3 . The yield of $\text{DySr}_3\text{Al}_2\text{O}_{7.5}$ passes the reaction: $\text{DyO}_{1.5} + \text{Sr}_3\text{Al}_2\text{O}_6 = \text{DySr}_3\text{Al}_2\text{O}_{7.5}$. Note that $\text{DySr}_3\text{Al}_2\text{O}_{7.5}$ phase is not practically described in the literature. The search in the literature for particularities of isostructural compounds formation with a common formula $\text{LnM}_3\text{Al}_2\text{O}_{7.5}$ (Ln = rare earth metal, M = Ca, Sr, Ba) demonstrates that the mentioned phases in two modifications exist and forms even at the temperatures of 1050–1200 °C; moreover, they are known only as the compounds of $\text{LnBa}_3\text{Al}_2\text{O}_{7.5}$. $\text{LnCa}_3\text{Al}_2\text{O}_{7.5}$ oxides are not formed at all, and $\text{LnSr}_3\text{Al}_2\text{O}_{7.5}$ compounds exist only starting from Ln equaling to Dy.

Table 2 Electron probe microanalysis data for the regions indicated in Fig. 2a, a', b, c

Sample (Fig.)	Examined region	Components content (mol%)				Phases
		AlO _{1.5}	SrO	GdO _{1.5}	DyO _{1.5}	
a, a'	P1	61.50	31.63	6.86		SrAl ₂ O ₄
	P2	42.20	34.33	23.47		SrAl ₂ O ₄ + Gd ₂ O ₃
	P3	38.21	29.70	32.09		GdSrAlO ₄
	P4	36.37	30.95	32.68		GdSrAlO ₄
	P5	58.98	32.00	9.02		SrAl ₂ O ₄
	P6	42.84	42.42	14.74		SrAl ₂ O ₄ + Sr ₃ Al ₂ O ₆
	P7	36.38	29.32	34.30		GdSrAlO ₄
	P8	55.75	22.17	22.08		SrAl ₂ O ₄
b	P1	42.32	33.39		24.28	Solid solution based on SrDy ₂ O ₄ , SrAl ₂ O ₄
	P2	37.30	23.73		38.97	Dy ₂ SrAl ₂ O ₇
	P3	61.15	16.22		22.63	DySrAl ₃ O ₇
	P4	57.70	32.55		9.74	SrAl ₂ O ₄
	P5	44.00	36.82		19.17	Solid solution based on SrDy ₂ O ₄ , SrAl ₂ O ₄
	P6	59.15	20.89		19.96	DySrAl ₃ O ₇
	P7	27.54	13.94		58.52	Dy ₂ O ₃
c	P1	34.11	44.90		20.99	DySr ₃ Al ₂ O _{7.5}
	P2	36.02	32.30		30.98	DySrAlO ₄
	P3	37.78	33.45		28.77	DySrAlO ₄
	P4	55.29	31.57		13.14	SrAl ₂ O ₄
	P5	21.79	18.40		59.81	Dy ₂ O ₃
	P6	38.36	32.66		28.98	DySrAlO ₄
	P7	35.89	35.52		28.59	

Note Sign of sample correlates with the number of SEM images, presented in Fig. 2

Fig. 3 X-ray diffraction patterns of initial mixtures corresponding stoichiometry of DySrAlO₄ after sintering in air at 1300–1500 °C for 5 h as well as theoretical diffractogram

To explain the common mechanisms in the formation processes of complex aluminates of K₂NiF₄-type structure, we compared the information from experiments and literature [4, 6, 15–19] on complex compounds existing in Ln₂O₃–SrO–Al₂O₃ systems (Ln = Nd, Gd, Dy).

According to provided [16–19, 25–27], we may point out that Ln₂O₃–SrO–Al₂O₃ systems (Ln = Nd, Gd) are

Table 3 Calculated interplanar distance *d* (Å), angle *2θ* (°) and integral intensity *I_c* (%) for polycrystalline DySrAlO₄ sample in comparison with experimental *d* and *2θ* data (see Fig. 3)

No.	<i>2θ_c</i>	<i>2θ_{obs}</i>	<i>d_c</i>	<i>d_{obs}</i>	<i>hkl</i>	<i>I_c</i>
1	14.40	–	6.144	–	002	2
2	25.25	25.28	3.523	3.521	011	60
3	29.04	29.04	3.072	3.072	004	30
4	32.70	32.71	2.736	2.736	013	100
5	34.46	34.46	2.600	2.600	110	89
6	37.52	37.52	2.395	2.395	112	7
7	44.18	44.22	2.048	2.047	006	12
8	44.29	44.34	2.043	2.042	015	31
9	45.67	45.67	1.985	1.985	114	77
10	49.53	49.50	1.839	1.839	020	55
11	51.85	–	1.761	–	022	<1
12	56.39	56.34	1.630	1.631	121	18
13	57.20	57.17	1.609	1.609	116	10
14	58.18	58.21	1.584	1.584	017	22
15	58.44	58.44	1.578	1.578	024	22
16	60.19	60.22	1.536	1.535	008	9
17	60.62	60.58	1.526	1.527	123	48
18	68.52	68.52	1.368	1.368	026	13
19	68.60	68.60	1.367	1.367	125	19

Very weak intensities reflexes *I_c* < 2% in the powder diffraction experimental patterns could not be assigned to calculated; c—calculated data; obs—experimental data

Fig. 4 Phase formation schemes, describing processes which are taken place under heat treatment of initial mixture of: **a** SrO:Gd₂O₃:Al₂O₃ = 1:0.5:0.5; **b** SrO:Dy₂O₃:Al₂O₃ = 1:0.5:0.5 at 1400 °C. Notes asterisks The compositions of determined phases are put according to data: opened diamond fixed by X-ray analysis; closed circle fixed by SEM/EDX method and reflected in Table 2; closed square the nominal composition of synthesis target product: **a** GdSrAlO₄, **b** DySrAlO₄

Fig. 5 Schematic illustration of the Gibbs energy of **a** equilibrium state of compound C in pseudo-binary system A–B; **b** metastable state of compound C in pseudo-binary system A–B in the case of stable compound D formation

distinguished by the formation of $\text{Ln}_2\text{SrAl}_2\text{O}_7$, LnSrAlO_4 , $\text{LnSr}_2\text{AlO}_5$, $\text{LnSrAl}_3\text{O}_7$ and the absence of $\text{LnSr}_3\text{Al}_2\text{O}_{7.5}$ phases.

According to [26], $\text{LnSr}_2\text{AlO}_5$ crystallized in the tetragonal system is synthesized by calcination with intermediate grindings of stoichiometric amounts of SrCO_3 , Ln_2O_3 and Al_2O_3 mixture at 1400 °C. To perform synthesis of $\text{LnSrAl}_3\text{O}_7$ phases from simple oxides using solid-phase technique, it is required to achieve higher temperatures of 1650–1700 °C [27]. $\text{DySrAl}_3\text{O}_7$ is received from stoichiometric amounts of SrCO_3 , Dy_2O_3 and Al_2O_3 , thermally treated at 1500 °C for 48 h. The former is described in [28], as crystallizing in the tetragonal system with the parameters of elementary unit cell: $a = 0.776$ nm, $c = 0.509$ nm, $d_{\text{calc}} = 4.84$ g/cm³. So, note the existence of $\text{Dy}_2\text{SrAl}_2\text{O}_7$, $\text{DySrAl}_3\text{O}_7$ in the Dy_2O_3 –SrO– Al_2O_3 system as well as $\text{DySr}_3\text{Al}_2\text{O}_{7.5}$ which is absent in the

corresponding composition in the Ln_2O_3 –SrO– Al_2O_3 ($\text{Ln} = \text{Nd}, \text{Gd}$) systems.

On the basis of given above data, $\text{DySr}_3\text{Al}_2\text{O}_{7.5}$ appearance in the reaction mixture may be described by the fact that under mentioned conditions of DySrAlO_4 synthesis, the most stable phase is $\text{DySr}_3\text{Al}_2\text{O}_{7.5}$. The scheme illustrating the stable state of C compound in the pseudo-binary system A–B may explain the analyzed situation (Fig. 5). If formation of the compound, for example D, is thermodynamically possible, the state of C compound in the analyzed section becomes less stable in comparison with coexistence of A and D compounds. It is worth mentioning that the described situation is not unique. The same phenomena were observed under perovskite-like oxides synthesis, for instance, in the case of BiFeO_3 production [29–33] as well as layered Aurivillius phases' synthesis [34].

Therefore, formation of DySrAlO_4 may be imagined according to two mechanisms. The first way is an interaction between Dy_2O_3 with SrAl_2O_4 and $\text{Sr}_3\text{Al}_2\text{O}_6$, resulting in the formation of DySrAlO_4 , i.e., passing the similar mechanism as for the first half of LnSrAlO_4 ($\text{Ln} = \text{Nd}, \text{Gd}$) series. It is confirmed by comparison of reflexes registered by X-ray analysis of the sample heat-treated at 1300 °C with theoretical diffractogram peaks (see Fig. 3). The second mechanism is connected with the interaction stage of $\text{DySrAl}_3\text{O}_7 + 2\text{DySr}_3\text{Al}_2\text{O}_{7.5} + 2\text{Dy}_2\text{O}_3 = 7 \text{DySrAlO}_4$.

5 Conclusions

1. This research presents the results connected with possibility of a new DySrAlO_4 compound, related to the K_2NiF_4 -type structure, formation. The parameters of DySrAlO_4 elementary cell were determined as follows: $a = 0.368(4)$ nm, $c = 1.229(2)$ nm, $V = 0.166(4)$ nm³. The comparative analysis was performed, and the schemes of phase transformations reflecting the stages of LnSrAlO_4 ($\text{Ln} = \text{Nd}, \text{Gd}, \text{Dy}$) formation processes are constructed. It is determined that LnSrAlO_4 ($\text{Ln} = \text{Nd}, \text{Gd}, \text{Dy}$) production takes place through the interaction of Ln_2O_3 , SrAl_2O_4 and $\text{Sr}_3\text{Al}_2\text{O}_6$.
2. LnSrAlO_4 ($\text{Ln} = \text{Nd}, \text{Gd}, \text{Dy}$) solid-state synthesis process demonstrated the change of the formation mechanism among LnSrAlO_4 ($\text{Ln} = \text{Nd}, \text{Gd}, \text{Dy}$) series from DySrAlO_4 oxide. The change of DySrAlO_4 formation mechanism is connected with a possibility of occurrence of $\text{DySr}_3\text{Al}_2\text{O}_{7.5}$ phase, which does not exist in the $\text{Ln}_2\text{O}_3\text{--SrO--Al}_2\text{O}_3$ ($\text{Ln} = \text{Nd}, \text{Gd}$) systems in the corresponding composition. DySrAlO_4 existence according to the second way is related to the stage of $\text{DySrAl}_3\text{O}_7$, $\text{DySr}_3\text{Al}_2\text{O}_{7.5}$ interaction with Dy_2O_3 .
3. $\text{DySr}_3\text{Al}_2\text{O}_{7.5}$ formation at the initial stages of DySrAlO_4 synthesis in the $\text{Dy}_2\text{O}_3\text{--SrO--Al}_2\text{O}_3$ system is one of the reasons of synthetic difficulty in DySrAlO_4 .

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