

# STUDY OF THE SYSTEMS



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## Abstract

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# STUDY OF THE SYSTEMS $Gd_2O_3-Al_2O_3$ AND $Sm_2O_3-Al_2O_3$

The interaction of aluminum oxide with gadolinium and samarium oxides has been studied repeatedly (<sup>1-4</sup>). According to these investigations, in each system one chemical compound is formed ( $GdAlO_3$  or  $SmAlO_3$ ), possessing the perovskite structure. However, aluminum oxide with other rare-earth oxides and yttrium oxide forms a whole series of new chemical compounds:  $2Y_2O_3 \cdot Al_2O_3$ ,  $3Y_2O_3 \cdot 5Al_2O_3$  (<sup>5</sup>),  $La_2O_3 \cdot 12Al_2O_3$  (<sup>6</sup>). In this connection, investigations were carried out to study the interaction of aluminum oxide with samarium and gadolinium oxides below the solidus temperature. The oxide melts obtained earlier (<sup>4</sup>) and coprecipitated mixtures were subjected to investigation. After thermal treatment, the mixtures were subjected to microscopic and X-ray analysis.

**Table 1**

Phase composition of oxide mixtures calcined at various temperatures

Composition	880°, 55 h	930°, 1 h	1380°, 1 h
Sm : Al = 1 :	$SmAlO_3$ unknown	$SmAlO_3$ unknown	$SmAlO_3 GdAlO_3$
1Gd : Al = 1 : 1	phase	phase ++ $GdAlO_3$	+ unknown phase

The mixtures were prepared by coprecipitation with ammonia from a nitric-acid solution of aluminum and gadolinium (samarium) hydroxides, followed by calcination of the precipitates obtained at various temperatures. The results of the phase X-ray analysis of the mixtures are given in Table 1. As follows from the data presented in Table 1, the reaction of formation of  $SmAlO_3$  is completed at 880°. In the  $Gd_2O_3-Al_2O_3$  system, formation of the compound  $GdAlO_3$  proceeds through a new phase of unknown structure, traces of which are retained even after calcination at 1380°.

Melted specimens were obtained by thermal analysis, which was used to determine the melting temperatures (<sup>4</sup>). In studying the interaction between

Fig. 1. Microstructure of an alloy containing 66 mol.% gadolinium oxide, 200×. Left—before annealing; right—after annealing at ~1900°

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aluminum oxide and the corresponding compound ( $\text{GdAlO}_3$  or  $\text{SmAlO}_3$ ), the melts were annealed at 1700°. No interaction between the components was detected. Microscopically, only coarsening of the eutectic structure was observed. The interplanar spacings of the aluminum oxide lattice and the lattice periods of the compounds  $\text{GdAlO}_3$  and  $\text{SmAlO}_3$  in the melts remained practically unchanged. The lattice period of  $\text{GdAlO}_3$  in annealed specimens containing 40 and 50 mol.%  $\text{Gd}_2\text{O}_3$  was, respectively,  $3.732 \pm 0.005$  kX and  $3.736 \pm 0.005$  kX, while the lattice period of  $\text{SmAlO}_3$  in analogous specimens was  $3.727 \pm 0.005$  kX and  $3.728 \pm 0.005$  kX, which indicates the absence of noticeable solubility of aluminum oxide in  $\text{GdAlO}_3$  and  $\text{SmAlO}_3$ . In the study of annealed melts containing more than 50 mol.% rare-earth oxides, it was found—

the formation of new chemical compounds was established. According to microstructural studies, a single-phase structure arose in compositions containing about 66 mol.% rare-earth oxide. Figure 1 shows the microstructure of specimens before and after annealing.

**Fig. 1.** Microstructure of an alloy containing 66 mol.% gadolinium oxide, 200×. Left—before annealing; right—after annealing at ~1900°.

The composition of the new compounds corresponds to the formulas  $2\text{Gd}_2\text{O}_3 \cdot \text{Al}_2\text{O}_3$  and  $2\text{Sm}_2\text{O}_3 \cdot \text{Al}_2\text{O}_3$ . The compounds melt with decomposition at 1950° and 1920°, respectively.

**Table 2**

**X-ray patterns of synthesized chemical compounds  $2\text{Gd}_2\text{O}_3 \cdot \text{Al}_2\text{O}_3$  and  $2\text{Sm}_2\text{O}_3 \cdot \text{Al}_2\text{O}_3$**

$2\text{Gd}_2\text{O}_3 \cdot \text{Al}_2\text{O}_3$ , 880°, 55 h		$2\text{Gd}_2\text{O}_3 \cdot \text{Al}_2\text{O}_3$ , 1900°		$2\text{Sm}_2\text{O}_3 \cdot \text{Al}_2\text{O}_3^*$ , 1850°	
<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>
3.31	1	3.30	1		
3.05	10	3.03	10	3.06	6
2.92	10	2.90	10	2.94	10
2.56	4	2.55	2		
2.32	3	2.31	1		
2.07	6	2.05	8	2.08	3
1.88	3	1.87	2	1.86	5
1.84	5	1.83	3		

Fig. 2. Phase diagram of the systems  $Gd_2O_3-Al_2O_3$  (A) and  $Sm_2O_3-Al_2O_3$  (B)

Figure 2: Fig. 2. Phase diagram of the systems  $Gd_2O_3-Al_2O_3$  (A) and  $Sm_2O_3-Al_2O_3$  (B)

$2Gd_2O_3 \cdot Al_2O_3$ , 880°, 55 h		$2Gd_2O_3 \cdot Al_2O_3$ , 1900°		$2Sm_2O_3 \cdot Al_2O_3^*$ , 1850°	
1.80	1	1.79	1		
1.74	7	1.73	6	1.76	3
1.63	2	1.62	2		
1.58	8	1.57	5	1.63	4
1.49	2	1.49	2		

\* Apparently, the most intense lines were obtained on the X-ray pattern.

Table 2 gives the X-ray patterns of the new synthesized compounds. The agreement of the X-ray pattern of the chemical compound  $2Gd_2O_3 \cdot Al_2O_3$ , synthesized at high temperatures, with the X-ray pattern of the compound found upon calcination of coprecipitated mixtures indicates that the formation of perovskite  $GdAlO_3$  at low temperatures proceeds through the 2 : 1 phase.

According to microstructural studies, the new compounds do not have a noticeable region of homogeneity. In the interval 50-66 mol.% rare-earth oxide, two phases, 1 : 1 and 2 : 1, coexist in equilibrium. Identification of the phases was carried out by X-ray and microscopic methods and by determination of microhardness. The microhardness of the compound  $GdAlO_3$  was found to be  $1700 \pm 100$  kg/cm<sup>2</sup>, and that of the compound  $2Gd_2O_3 \cdot Al_2O_3$  was  $1100 \pm 100$  kg/cm<sup>2</sup>. For the compounds  $SmAlO_3$  and  $2Sm_2O_3 \cdot Al_2O_3$ , the microhardness is respectively  $1500 \pm 100$  and  $1000 \pm$

$\pm 100$  kg/mm<sup>2</sup>. In alloys containing more than 66 mol.% rare-earth oxides, at high temperatures the 2 : 1 compound and the rare-earth oxide, whose structure corresponds to the B-form, are in equilibrium. On the basis of the investigations carried out, phase diagrams were constructed for the systems

**Fig. 2.** Phase diagram of the systems  $Gd_2O_3-Al_2O_3$  (A) and  $Sm_2O_3-Al_2O_3$  (B)

$Gd_2O_3-Al_2O_3$  and  $Sm_2O_3-Al_2O_3$ , shown in Fig. 2. Low-temperature equilibrium in the indicated systems was not investigated.

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