HIGH-ENTROPY OXIDE SYSTEMS BASED ON RARE-EARTH ELEMENTS: SYNTHESIS AND PROPERTIES

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ВЫСОКОЭНТРОПИЙНЫЕ ОКСИДНЫЕ СИСТЕМЫ НА ОСНОВЕ РЕДКОЗЕМЕЛЬНЫХ ЭЛЕМЕНТОВ: СИНТЕЗ И СВОЙСТВА

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Аннотация. *В данной работе проведен синтез высокоэнтропийных оксидных систем на основе редкоземельных элементов путем осаждения гидроксидов и последующего отжига смеси. Исследованы морфология частиц, их фазовый и химический состав. Изучены магнитные свойства материала.*

Introduction. High-entropy oxide systems (HEOS) are systems that contain more than three components with a uniform distribution of ions in crystal lattice [1-4]. The possibility of synthesizing these oxide systems containing rare earth elements (REE) in one phase is prospective because some binary oxides of these elements have different crystal structures in their pure form. Stabilization of the structure in such systems is achieved due to the high mixing entropy. The main idea of obtaining HEOS comes from the field of high-entropy alloys (HEA). HEAs have a number of important mechanical (strength, hardness, plasticity, wear resistance), physical (magnetic, conductivity) and chemical (corrosion resistance) properties compared to conventional alloys with one or two basic elements. In such metal systems, high mixing entropy thermodynamically stabilizes a single-phase solid solution by reducing the Gibbs free energy [5]. By analogy with HEAs, it can be expected a similar entropy mixing effect in oxide systems.

Research methods. In the work $(Sm_{0,2}Ce_{0,2}Gd_{0,2}Sc_{0,2}Yb_{0,2})_2O_{3\pm\delta}$. was obtained. The characteristics of the starting materials are listed in table 1. Nitrates solutions of REE were mixed in an equal molar ratio for an hour on a magnetic stirrer. The resulting mixture was precipitated with a 0.05-molar solution of NaOH. Precipitation process may be described by the chemical reaction:

$$R(NO_3)_3 + 3NaOH \rightarrow R(OH)_3\downarrow + 3HNO_3,$$

where R = Sm, Ce, Gd, Sc, Yb.

The required volume of NaOH was calculated based on maximum pH of precipitation of hydroxides from the REE nitrates solution in the system.

The gel mixture of REE hydroxides was rinsed with distilled water in a volume of 500 ml. The presence of nitrate ions was determined by qualitative reaction with diphenylamine. The resulting precipitate was filtered on a Buchner funnel, dried in cupboards at a temperature of 60 □ for 8 hours and annealed in furnaces at a temperature of 800 □ for 1 hour. Phase composition was studied by X-ray diffraction analysis (XRD) "DRON-3M diffractometer". Magnetic properties were investigated on an induction magnetometer "HB1200.4B".

Table 1

Purity grades of reagents

Chemical formula	Purity grade
$Sm(NO_3)_3*5H_2O$	«99,99»
$Ce(NO_3)_3*5H_2O$	«99,99»
$Gd(NO_3)_3*5H_2O$	«99,99»
$Sc(NO_3)_3*5H_2O$	«99,99»
$Yb(NO_3)_3*5H_2O$	«99,99»
HF	«p.a.»
H_2O	Distillate

Results. Figure. 1 shows the X-ray diffraction pattern of $(Sm_{0,2}Ce_{0,2}Gd_{0,2}Sc_{0,2}Yb_{0,2})_2O_{3\pm\delta}$. It was found that this material contains one cubic crystal phase – Sc_2O_3 type. This indicates the packaging of REE oxides in a single crystal lattice.

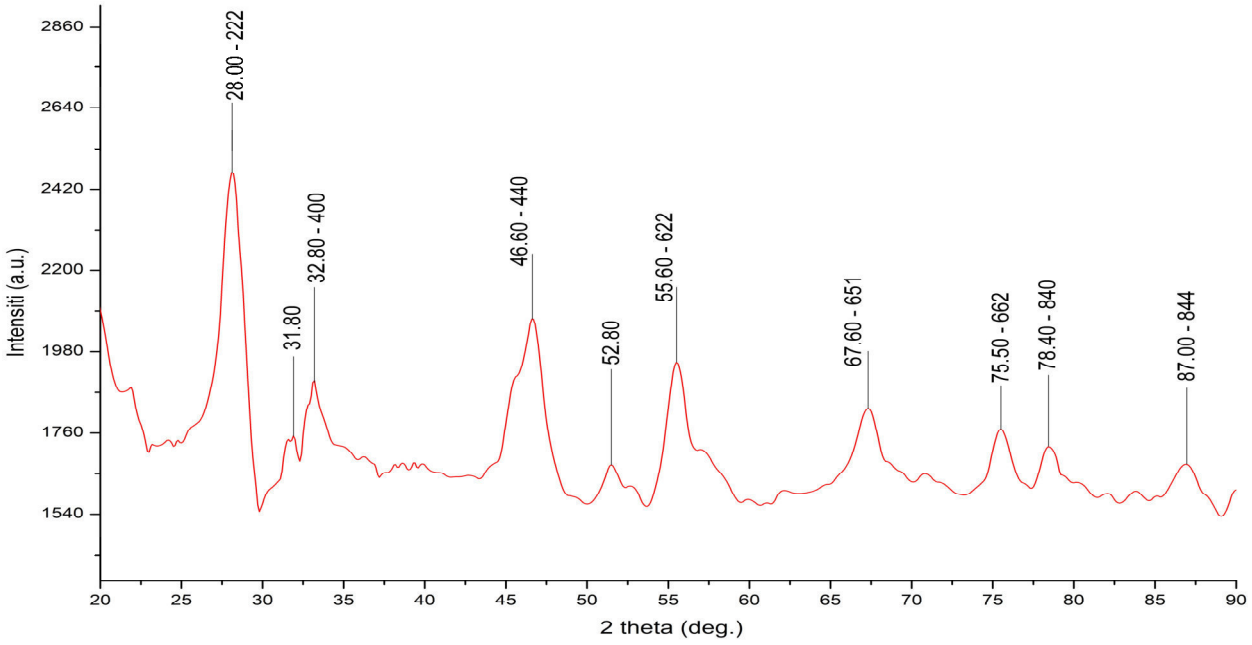

Fig. 1. XRD-spectrum of HEOS $(Sm_{0,2}Ce_{0,2}Gd_{0,2}Sc_{0,2}Yb_{0,2})_2O_{3\pm\delta}$

The evaluation of magnetic properties was carried out by magnetization curves (fig. 2).

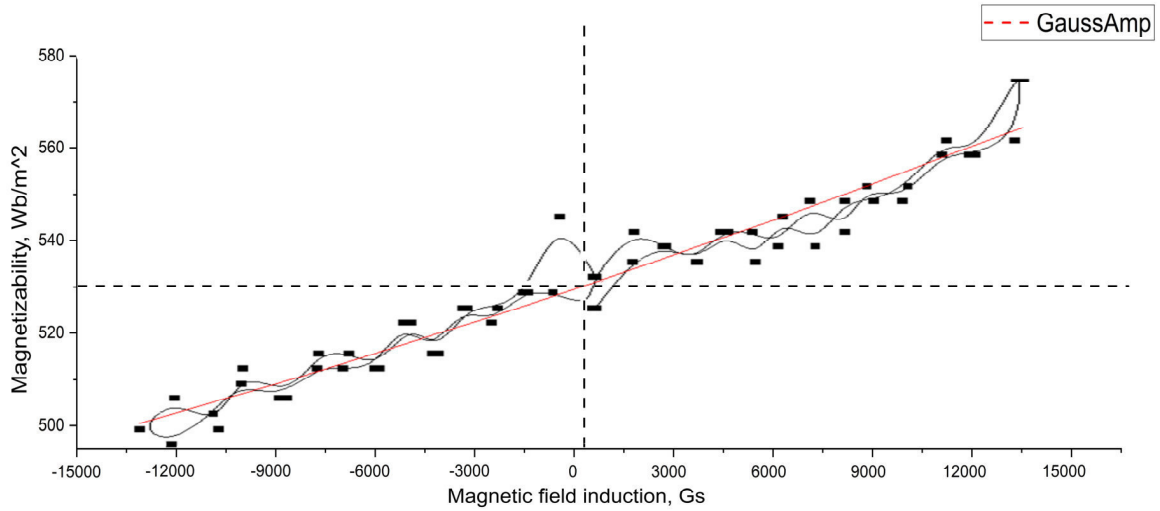

Fig. 2. Magnetization curve of HEOS ($Sm_{0,2}Ce_{0,2}Gd_{0,2}Sc_{0,2}Yb_{0,2})_2O_{3\pm\delta}$

Figure 2 shows that the obtained sample of HEOS $(Sm_{0,2}Ce_{0,2}Gd_{0,2}Sc_{0,2}Yb_{0,2})_2O_{3\pm\delta}$ has paramagnetic properties. Magnetization in such substances is achieved by the ordered arrangement of electrons and atoms.

Conclusion. High-entropy oxide systems based on rare-earth elements were successfully synthesized. The phase composition, structure, and surface morphology of the obtained powders were established by XDA methods. The magnetic properties of the material were studied.

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