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Features of the surface morphology and magnetic properties of $Sm_{0.5}R_{0.5}Fe_2$ (R = Tb, Gd) compounds

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A comprehensive study of the structure and phase composition, magnetostrictive and magnetic properties of the compounds $(Sm_{0.5}R_{0.5})Fe_2$ (R = Gd, Tb) was performed. Using atomic force and magnetic force microscopy, the surface topology at the micro and nanoscale has been established, and information on the magnetic domain structure at room temperature has been obtained. The effect of partial replacement of samarium with gadolinium and terbium on the surface microstructure and domain structure, the temperature of phase transitions, the magnitude of magnetostrictive deformations and magnetization is studied.

The high magnetostrictive Laves phases of the RFe_2 type are of great interest from both the applied and fundamental points of view. SmFe2 and TbFe2 compounds have the highest saturation magnetostriction values at room temperature ($-1.5 \cdot 10^{-3}$ and $+1.7 \cdot 10^{-3}$, respectively), while they are opposite in sign. GdFe2 at room temperature shows an insignificant positive value of magnetostriction. When samarium is partially replaced with terbium, with a terbium content of 0.4–0.5 at/f.u., the sign of magnetostriction changes [1]. In addition, when replacing the light rare-earth ion Sm^{3+} with heavy Tb^{3+} and Gd^{3+}, a composition with magnetic compensation of magnetization can be obtained. The contents of Tb^{3+} and Gd^{3+} in this case, according to calculations, are also close to 0.5 at./f.u.

The aim of this work was a comprehensive study of the structural, magnetic, and magnetostrictive characteristics of $Sm_{0.5}Gd_{0.5}Fe_2$ and $Sm_{0.5}Tb_{0.5}Fe_2$ compounds and their comparison with similar $SmFe_2$ characteristics obtained by us earlier [2,3].

As the initial components, metals of a high degree of purity were used: (99.99%). $Sm_{0.5}Gd_{0.5}Fe_2$ alloy was obtained by high-frequency induction melting in an atmosphere of highly pure argon, while $Sm_{0.5}Tb_{0.5}Fe_2$ was obtained by the arc melting method. In order to equalize the composition of the obtained alloys, homogenizing annealing was performed. As shown by x-ray studies, the content of the main phase with the $MgCu_2$ structure in the compound with gadolinium reaches 97%, while in the compound with Tb - 88%. No significant distortions of the cubic crystal structure at room temperature were detected, the unit cell parameters are 0.7397 and 0.7375 nm, respectively (decreased compared to $SmFe_2$).

The morphology of the surface of the alloys was studied by atomic force microscopy (AFM) using a SMENA-A scanning probe microscope (Solver, NT – MDT Zelenograd, Russia) in the semi-contact mode at room temperature. The obtained AFM images of the surfaces of the chips were processed by the software for visualization and analysis of Nova_873. Studies of the domain structure of the samples were performed on polished thin sections by magnetic force microscopy (MFM) using a two-pass technique. Unlike $SmFe_2$ [3], the studied alloys have a nonuniform and inhomogeneous surface microstructure with large (diameter 5–7 μm, height up to 500 μm) agglomerates in the form of a radially-cellular crystallization front of small particles (50–70 nm). Regions of the cell-like surface, similar to $SmFe_2$, but with large sizes (from 1.2 to 1.4 μm), are unevenly distributed between the agglomerates. The domain structure of the samples is irregular; strip domains with a strip width of 10–20 μm of a cellular shape are observed.

The magnetization of the alloys was measured using induction and vibration magnetometers in the temperature range of 80 - 800 K in magnetic fields up to 1.8 T. Studies have shown that the Curie temperatures of $Sm_{0.5}Gd_{0.5}Fe_2$ and $Sm_{0.5}Tb_{0.5}Fe_2$ compounds have close values (~ 645 K), lower than the initial $SmFe_2$. The magnetization of compounds at room temperature decreased by about 3 times, i.e., partial compensation of magnetization is observed.

Magnetostriction was measured by a strain gage method in magnetic fields up to 1.2 T along the direction of the magnetic field (longitudinal magnetostriction) and perpendicular to it (transverse magnetostriction) in the temperature range from 80 to 360 K. The significant decrease in the anisotropic (difference between longitudinal and transverse magnetostriction) magnetostrictions was established. The peak in the temperature region of the spin reorientation expands significantly, compared with the initial $SmFe_2$ composition, and shifts to the region of low temperatures

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