ABSTRACT

The objects of this paper are oxyborate samples substituted by the series of transition cations. These materials represent a wide class of strongly correlated oxide systems that demonstrate effects of magnetic frustrations, charge ordering and multistage magnetic transitions. These lead to a number of unusual magnetic phenomena. Oxyborates show a rich spectrum of magnetic states (spin glass, random magnetic chains, quantum entanglement, two-dimensional Sastri-Sutherland lattice, long-range magnetic order). In this work, we consider an interesting orthorhombic oxyborates of the structural type ludwigite: $Fe_3O_2BO_3$, $Co_3O_2BO_3$, $Co_{2.25}Fe_{0.75}O_2BO_3$, $Co_{2.88}Cu_{0.12}O_2BO_3$ и $Co_{1.7}Mn_{1.3}O_2BO_3$. The crystal structure of the ludwigites is represented by zigzag-like walls formed by oxygen octahedra with metallic ions inside. Magnetic ions form a distorted triangular structure. Thus, magnetic ions form a three-dimensional framework of exchange bonds. Geometric factors associated with the crystal structure lead to a situation where the interactions between magnetic nearest neighbors along one of the crystallographic directions are substantially weakened, in comparison with interactions in other directions. Therefore, the experimental observation of quasi-low-dimensional magnetic behavior in ludwigites is possible. The chains of magnetic ions belonging to one crystallographic position are actually equivalent to one-dimensional chains. Three chains are combined to quasi-two-dimensional three-pillar spin stairs (*Three spin-leg ladders, 3LL*). In this paper, the considered samples characterized by magnetic and Mössbauer measurements, X-ray diffraction and theoretical calculations of indirect exchange interactions. The effect of substitution on anisotropic properties has also been studied.

We studied the crystal structure of $Co_{2,25}Fe_{0,75}O_2BO_3$, $Co_{2,88}Cu_{0,12}O_2BO_3$, and $Co_{1,7}Mn_{1,3}O_2BO_3$ single crystals by X-ray diffraction. It allowed us to defined structural parameters and analyzed the cation distribution by position, as well as the effect of cation substitution on structural parameters. The distribution of Fe ions over nonequivalent positions, as well as a charge and magnetic states measured by

Mössbauer spectroscopy on the $Co_{2,25}Fe_{0,75}O_2BO_3$. Mössbauer spectroscopy also measured the temperature of magnetic ordering in this compound.

We obtained the field, temperature and angular dependences of the static magnetization and the dynamic magnetic susceptibility for all series of the ludwigite single crystals. Using magnetic data, the magnetic characteristics: the temperature of the magnetic ordering, magnetic moments were calculated. Investigations of the effect of cation substitution on the magnetic properties of $Co_{2,25}Fe_{0,75}O_2BO_3$, $Co_{2,88}Cu_{0,12}O_2BO_3$, and $Co_{1,7}Mn_{1,3}O_2BO_3$ samples were carried out. We have calculated integrals of indirect exchange interactions in the framework of the indirect exchange coupling model. Using this model, the effect of cation substitution on the magnitude and sign of the integrals of indirect exchange interactions and the role of frustrating exchange interactions in the formation of the magnetic state of cobalt ludwigites were studied.