

## AN ABSTRACT OF DOCTORAL DISSERTATION

**The influence of the crystal structure on the physicochemical properties  
of M-hexaferrite and selected coordination polymers  
- potential multiferroic materials**

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The PhD dissertation presents a description of the synthesis, structural, magnetic, dielectric and spectroscopic properties of two classes of materials. The first of these are strontium M-hexaferrites with the formula  $\text{SrFe}_{12}\text{O}_{19}$  (**SrM**) pure and doped with  $\text{Nd}^{3+}$ ,  $\text{Al}^{3+}$ ,  $\text{Sc}^{3+}$  ions. The second group of compounds are ferroelectric metal oxalates:  $[\text{H}_2\text{dabco}][\text{M}(\text{C}_2\text{O}_4)_2]\cdot 3\text{H}_2\text{O}$  (where:  $M(\text{II})$ : Mg, Co, Zn). Additionally, the cobalt(II) oxalate exhibits magnetic ordering and, by extension, is the first multiferroic homometallic 1D oxalato-bridged coordination polymer.

**SrM** and **SrM: Nd<sup>3+</sup>, Al<sup>3+</sup>** hexaferrites were obtained in a nanocrystalline form using the microwave-assisted hydrothermal method, **SrM: Nd<sup>3+</sup>** was obtained by the co-precipitation method, while **SrM: Nd<sup>3+</sup>, Sc<sup>3+</sup>** by the sol-gel method. The sufficient selection of synthesis methods allowed us to obtain a material with a different shape and size of crystallites, which made it possible to determine the effect of morphology and crystallite size, doping, and defects of the crystal structure on the physicochemical properties of M-hexaferrites. The samples were

characterized by X-ray diffraction (XRD) and scanning electron microscopy (SEM). Dielectric and magnetic properties were analyzed in a wide range of fields and temperatures. In all samples, the doping disturbs the magnetic order, locally changes the crystal field, and strengthens the displacement of iron ions from the center of the trigonal bipyramid, inducing local electric dipoles. In contrast, morphology affects the size of the magnetic anisotropy, surface spins, and the magnetic domain structure.

Hexaferrites belong to the group of multiferroic transition metal oxides. The search for new magnetoelectric materials in the group of organic-inorganic compounds has been carried out for over a decade. The main advantage of organic-inorganic hybrids is the unique variety of crystal structures they can form, which increases the likelihood of obtaining functional phases, and relatively simple synthesis at significantly lower temperatures compared to oxide materials.

Metal oxalates presented in the dissertation:  $[H_2dabco][M(C_2O_4)_2] \cdot 3H_2O$  were obtained in a monocrystalline form by crystallization from a gel medium. The series of compounds display a phase transition from a paraelectric phase ( $P2_1/n$ ) to a ferroelectric phase ( $P2_1$ ). Based on the analysis of the X-ray diffraction, calorimetric and dielectric results it was found that the microscopic mechanism of the phase transition is related with the change in the order of crystal water and the reorganization of the O-H $\cdots$ O hydrogen bonds. Moreover, in cobalt(II) oxalate,  $[H_2dabco][Co(C_2O_4)_2] \cdot 3H_2O$ , a paramagnetic-antiferromagnetic phase transition was identified, which arises from super-exchange interactions between  $Co^{2+}$  ions in the coordination polymer chain. Due to the coexistence of ferroelectricity and antiferromagnetism,  $[H_2dabco][Co(C_2O_4)_2] \cdot 3H_2O$  is the first multiferroic homometallic 1D coordination polymer in the family of organic-inorganic metal oxalates.