Study of the magnetoelectric effect in multiferroic ferrite-perovskite composite ceramics

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Currently, multiferroic materials are considered as potential candidates for developing room temperature sensors for low magnetic fields, memory elements, electromagnetic energy harvesters, and cooling systems. In the multiferroics two ferroic order parameters of different nature: e.g. magnetization and ferroelectric polarization coexist. Of particular interest, is the coupling between these order parameters, the so called magnetoelectric (ME) effect. In single-phase multiferroics the ME effect is weak and usually occurs at cryogenic temperatures, which limits their applications. However, composite multiferroics show strong magnetoelectric effect at room temperature. Typically, the composite multiferroics combine separate ferroelectric and magnetic phases that are mechanically coupled. The applied magnetic field induces magnetostriction, which results in a mechanical stress at the interface to the ferroelectric phase. This stress will induce a change of polarization of due to direct piezoelectric effect. In a similar way application of the electric field will results in change of the magnetization. The ME effect depends not only on properties the constituents, but also on microstructure (the type of connectivity, grain size, etc.) [1].

Here we report on study of the ME effect in several multiferroic composite systems. The $CoFe_2O_4$-$BaTiO_3$ (CFO-BT) composite is a classic example that profits from the large magnetostriction of CFO, large piezoelectric coefficient of BT, and spinodal decomposition of this system, that allows to avoid chemical reaction between the constituents at high temperature ceramic sintering. The microstructure was controlled by the synthesis conditions. The sample prepared by conventional sintering shows a 0-3 connectivity with the coarse micron-size CFO grains distributed in the BT matrix. While, the sample sintered by spark plasma sintering consists on the nanosized BT grains distributed in the CFO matrix. The samples with different microstructure showed the different magnetoelectric effect [2].

The magnetoelectric coupling in the composites was improved by replacing $BaTiO_3$ with $(Ba,Ca)(Ti,Zr)O_3$ (BCZT) with thee larger piezoelectric coefficient and by replacing of CFO with $NiFe_2O_4$ that has a large magnetic field derivative of magnetostriction. More than a twofold increase in the magnetoelectric effect was achieved in the NFO-BCZT composites in comparison with the CFO-BT composites [3].

Along with macroscopic measurements, the magnetoelectric effect was studied on meso- and microscopic scales. In particular, the displacement of the titanium ions of the $BaTiO_3$ phase under the action of a magnetic field was investigated by X-ray absorption spectroscopy. The spatial distribution of the ME effect depending on the distance to the interface with the ferrite phase was studied by piezoreponse force microscopy.

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