Neutron scattering studies of multiferroics. A review

I. Sosnowska

[1] *Institute of Experimental Physics, University of Warsaw, 00-691 Warsaw, Hoza 69, Poland*

Multiferroics belong to a class of materials that show at the same time an ferroelectric and magnetic ordering. They exhibit a magnetoelectric (ME) effect which is the results of coupling between the spontaneous electric polarization, and the spontaneous magnetization. Multiferroics are recently the object of intensive investigations, in view of their potential technical applications. ME coupling allows to tune electrical processes in multiferroics with a magnetic field and magnetic properties with an electric field. Multiferroics can be used in the future in electronic devices which will take advantage of this unique ME effect. Thin $BiFeO_3$ multiferroic layers already find application in electronic devices. So far $BiFeO_3$ is the only substance found which shows the ME effect at room temperature. This substance serves as a model substance for experimental and theoretical studies of ME coupling in solids. Other multiferroics such as, e.g., $TbMnO_3$ or $DyMnO_3$ show the ME effect only at low temperatures.

In this review, the role of the neutron scattering techniques in investigations of multiferroics is presented. The effect of the doping process, as well as of the size of the sample (bulk, thin layers, and nano-powder) on the ME effect in multiferroic materials is reported. The main problem in the practical application of this most promising material, $BiFeO_3$, is its magnetic structure discovered and described almost 30 years ago [1]. This magnetic ordering, ie. a long period magnetic cycloid (620 Å), causes that the linear ME effect does not appear in $BiFeO_3$. This finding was the reason why $BiFeO_3$ was forgotten for almost three decades as a technically useless material. In the mean time it was found that doping (e.g with La, Mn ions) and a size effect (thin layers) can lead to the restoring of the linear ME effect in $BiFeO_3$. Some of these findings were obtained by using the neutron scattering technique.

The role of neutron scattering in these studies of multiferroics is crucial. The most successful neutron scattering technique for studding the magnetic structure, especially the magnetic structure of multiferroics, is very high resolution Time-of-Flight (TOF) neutron diffraction. All substances with perovskite-like structure having multiferroic properties reveal a complicated domain structure when they appear in a single crystal form. Polycrystalline materials do not show this effect. However, neutron diffraction studies of these compounds require a good quality powder (no strain, proper grain size). The above mentioned TOF technique is the best tool to determine magnetic ordering in multiferroics. To date the TOF technique used in 1982 gives the richest information on the complicated magnetic structure of $BiFeO_3$ [1]. Neutron scattering from $BiFeO_3$a multidomain single crystal was recently obtained [2]. The Authors confirm the main result of paper [1], ie. the long period magnetic cycloid ordering in $BiFeO_3$.

In the review the current situation and the perspectives of studies of ME coupling in multiferroics by the neutron scattering technique are presented.

References

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2. D. Lebeugle, D. Colson, A. Forget, M. Viret, A. M. Bataille, A. Gurkasov, Phys. Rev. Letters **100,** 227602 (2008).