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Impact of spatially inhomogeneous macroscopic uniaxial magnetic anisotropy on the small-angle neutron scattering cross-sections

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Small-angle neutron scattering (SANS) is a particularly powerful method that makes it possible to study inhomogeneities in the volume of macroscopic samples at scales from several to several hundreds of nanometers. Magnetic SANS is used to study a wide range of magnetic materials, including amorphous metals, nanocrystalline hard and soft magnetic materials [1]. Scattering occurs due to the interaction of the magnetic moment of neutrons with the distribution of internal magnetic field, created by the spatially inhomogeneous magnetization in the material. Thus, to interpret the scattering cross sections, it is necessary to understand formation of the magnetic structure and its dependence on the inhomogeneity of the material and the external magnetic field. The distribution of magnetization on such a scale is described by the theory of micromagnetism, which is the main tool for interpreting SANS cross sections. Such a combination of neutron scattering theory and micromagnetism, called the micromagnetic SANS theory, has already shown its effectiveness in explaining the magnetic properties of macroscopically anisotropic multiphase magnetic systems with weak inhomogeneity of saturation magnetization and magnetic anisotropy [2]. An example of such a system could be a macroscopically anisotropic (e.g. subjected to field annealing) nanocrystalline ferromagnet. In such materials, in addition to local (random) magnetic anisotropy, there is a global (macroscopic) anisotropy, which may be due to mechanical stresses caused by external pressure, or internal stresses arising from the inhomogeneity of the structure, chemical or phase composition of the material. The report presents several examples of successful application of this theory to various nanocrystalline systems, as well as an extension of the theory taking into account possible inhomogeneity of macroscopic uniaxial anisotropy. It is shown that in high magnetic fields the inhomogeneity of the global anisotropy affects the scattering pattern only when the anisotropy direction vector has a component along the axis of the applied external field.

1. Michels, A., Weissmüller, J. (2008). Rep. Prog. Phys. 71(6), 066501.
2. Zaporozhets V., Oba, Y., Michels A., Metlov K. (2022). J. Appl. Cryst. 55. 592-600.

Primary author: Mr ZAPOROZHETS, Vladislav (Galkin Donetsk Institute for Physics and Engineering)

Co-author: Mr METLOV, Konstantin (Galkin Donetsk Institute for Physics and Engineering)

Presenter: Mr ZAPOROZHETS, Vladislav (Galkin Donetsk Institute for Physics and Engineering)

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