New insight into magnetic anisotropy within Ferromagnetic Resonance experiments

Piotr Tomczak[1] and Henryk Puszkarski[1]

[1]*Faculty of Physics, Adam Mickiewicz University, Uniwersytetu Poznańskiego 2, 61-614 Poznań, Poland*

The phenomenon of ferromagnetic resonance (FMR) is still being widely used for determining the magnetocrystalline anisotropy constants of magnetic materials. We show that one can interpret the resonance condition (the Smit-Beljers equation) as the relationship between resonance frequency and curvature of the spatial distribution of free energy at resonance. Subsequently, taking this relationship into account and using cross-validation of numerical solutions of the Smit-Beljers equation [1,2] we show how to determine accurately all the relevant constants (saturation magnetization, g-factor, magnetocrystalline anisotropy constants) entering this equation and related to the tested sample in FMR experiments. Specifically, three examples are given of calculating such constants from FMR data: we use historical Bickford's measurements from 1950 for bulk magnetite [3], Liu's measurements from 2007 for a 500 nm thin film of a weak ferromagnet (Ga, Mn)As [4], and Wang's measurements from 2014 for an ultrathin film of YIG [5]. In all three cases, the constants we have determined are consistent with the results of other measurements. In the fourth numerical example, we show, using Heinrich *et al*. FMR measurements from 1991 for ultrathin Co film [6], that the presented method can also be a test for the correctness of the assumed form of the ferromagnet free energy at resonance. Eventually, in the fifth numerical example, basing on Roemer *et al*. broad-band measurements from 2012 for Fe thin films [7], the unambiguity of the determined parameters in the present approach is briefly discussed.

References:

[1] P. Tomczak and H. Puszkarski, Phys. Rev. **B** 98, 144415 (2018).
[2] P. Tomczak and H. Puszkarski, Journ. Mag. Mag. Mat. 507, 166824 (2020).
[3] L. R. Bickford, Phys. Rev. 78, 449 (1950).
[4] X. Liu, Y. Y. Zhou, and J. K. Furdyna, Phys. Rev. **B** 75, 195220 (2007).
[5] H. Wang, C. Du, P. C. Hammel, and F. Yang, Phys. Rev. **B** 89, 134404 (2014).
[6] B. Heinrich et al., Phys. Rev. **B** 44, 9348 (1991).
[7] F. M. Roemer et al., Appl. Phys. Lett. 100, 092402 (2012).