Magnetization switching of elliptical magnetic nanoparticle by ultashort pulses of surface acoustic waves

V.S. Vlasov,1\* A.M. Lomonosov, 2 A.V. Golov,1 V. Besse,2 A. Alekhin,2 D.A. Kuzmin,3,4 L.N. Kotov,1 I.V. Bychkov,3,4 R.I. Tobey5 and V.V. Temnov2

1 *Syktyvkar State University named after Pitirim Sorokin, 167001, Syktyvkar, Russian Federation*

2 *IMMM UMR CNRS 6283, Le Mans Université, 72085 Le Mans Cedex, France*

3*Chelyabinsk State University, 454001 Chelyabinsk, Russian Federation*

4*South Ural State University (National Research University),454080 Chelyabinsk, Russian Federation*

5*Zernike Institute for Advanced Materials, University of Groningen, 9747AG Groningen, The Netherlands*

\**vlasovv78@mail.ru*

This work is devoted to the magnetization switching in magnetic nanoparticles (NPs) by short pulses of surface acoustic waves (SAW). Magneto-acoustic interactions in all-optical transient grating experiments provide a detailed picture of elastically driven small-angle ferromagnetic resonance precession [1]. We extend our previous work on the acoustically induced magnetization switching, where the magnetization in a Terfenol thin film is characterized by four metastable in-plane minima of the free energy density. It has been demonstrated that the magnetization can be switched to one of the four energetically stable orientations by a single acoustic pulse with relatively large strain amplitude ~1% [2].

In present work, we investigate the magnetization switching in a polycrystalline Ni NP, induced by ultrashort pulses of SAW. In our model, a Ni NP is an ellipsoidal disc deposited on a dielectric substrate. This disc is characterized by a small thickness c, minor and major axes a and b, respectively (b > a >> c). If the XY plane corresponds to the substrate surface, and the major axis b of the Ni nanoparticle is parallel to the Y axis, then the easy magnetization axis is also parallel to the Y axis. In relatively weak external magnetic field H along the X axis, the free energy density has two in-plane minima symmetric with respect to the X axis. Increasing H makes the stable magnetization states closer to the X axis and decreases the energy barrier between them. If H is sufficiently large, two minima merge into one, where the magnetization is parallel to the X axis. An ultrashort SAW pulse can be launched by an impulsive laser heating of a stripe acoustic transducer (oriented along the Y-axis). It will propagate in the dielectric substrate along the X axis and interact with the Ni NP. We demonstrate switching of the magnetization between two free energy minima. Since the NP dimensions determine the demagnetizing tensor components, adjustment of three parameters a/b, c/b and H makes it possible to achieve optimal conditions for the magnetization switching.

Our study reveals the mechanisms of the acoustically induced magnetization switching. Despite smaller magnetostriction coefficient in Ni, the elastic strains required for the magnetization switching in Ni NP can be several orders of magnitude smaller than in a highly magnetostrictive Terfenol thin film. Thus, it opens a door for real applications of the magneto-elastic switching at the nano-scale.

Funding through Nouvelle équipe, nouvelle thématique ”Ultrafast acoustics in hybrid magnetic nanostructures”, Strategie internationale NNN-Telecom and the Acoustic HUB de la Region Pays de La Loire, Alexander von Humboldt Stiftung, ANR-DFG “PPMI-NANO”, PRC CNRS-RFBR ”Acousto-magneto-plasmonics” (grant number 1757 150001) is greatfully acknowledged.

[1] C.L. Chang et al., Phys. Rev. B **95**, 060409(R) (2017).

[2] O. Kovalenko, T. Pezeril, and V. V. Temnov, Phys. Rev. Lett. **110**, 266602 (2013).