

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

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This work is devoted to the magnetization switching in magnetic nanoparticles by short pulses of surface acoustic waves (SAW). Magneto-acoustic interactions in all-optical transient grating (TG) 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 consisting of the magnetocrystalline anisotropy, magnetoelastic and magnetostatic contributions. It has been demonstrated that the magnetization vector can be switched to one of the four energetically stable orientations by a single picosecond acoustic pulse characterized by a relatively large strain amplitude $\sim 1\%$ [2].

In present work we investigate the magnetization switching in a polycrystalline Ni nanoparticle, induced by ultrashort pulses of surface acoustic waves generated in single stripe acoustic transducer. In our numerical experiment, a Ni nanoparticle is modelled as an ellipsoidal disc deposited on a dielectric substrate. This disc is characterized by a small thickness c , minor and major ellipse axes a and b , respectively ($b > a \gg c$). If we consider that the XY plane corresponds to the Ni surface, and the major axis b of the Ni nanoparticle is parallel to the Y axis and larger than the minor axis a , then the easy magnetization axis is also parallel to the Y axis. It should be noted that the nanoparticle dimensions determine the demagnetizing tensor components. If we apply relatively weak external magnetic field H along the X axis, the free energy density will have two in-plane minima symmetric with respect to the X axis. Increasing H , we will make the stable orientations of the magnetization closer to the X axis. Also it will decrease the depth of the free energy minima and the height of the energy barrier between them. In the case of sufficiently strong magnetic field, two minima merge into one, where the magnetization becomes 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) and propagate in the dielectric substrate along the X axis. Using previously characterized magneto-elastic interactions [1] we demonstrate switching of the magnetization between two free energy minima. Variations of three parameters a/b , c/b and c allow us to achieve optimal conditions for the acoustically induced magnetization switching.

Our study reveals the mechanisms responsible for the acoustically induced magnetization switching. Its threshold depends on the parameters of the acoustic pulses, the magnetic shape anisotropy and the magnetic field. Despite of an order-of-magnitude smaller magnetostriction coefficient in Ni, the elastic switching strains for Ni nanoparticles with amplitudes below 0.1% can be orders of magnitude smaller than in the case of a highly magnetostrictive

Terfenol thin film. The use of such small-amplitude elastic perturbations open the door to real-life applications of magneto-elastic switching at the nanoscale.

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[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).

Commenté [A1]: I do not understand what do you mean here. You should use "In spite of" or "Despite" (without "of"). "Despite of" is not grammatically correct. You can also use "Despite that" which is equivalent as "Nevertheless". Also you said "of an order of magnitude smaller magnetostriction in Ni", smaller compare to what? If it is compare to Terfenol, it is not clear (or it is too far away in the sentence). You could say : "Despite that the magnetostriction coefficient in Ni is an order-of-magnitude smaller than the one in Terfenol, the elastic switching strains ...".