Magnetization switching of elliptical magnetic nanoparticle by ultashort 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). 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 ~1% [1].

We investigate the magnetization switching in a polycrystalline Ni nanoparticle, induced by ultrashort pulses of SAW. We modelize the Ni nanoparticle 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 >> c). If we consider that the XY plane corresponds to the Ni surface, and the axis b is parallel to the Y axis, then the easy magnetization axis is also parallel to this axis. By applying a relatively weak external magnetic field H along the X axis, the free energy density will have two in-plane minima symmetric with respect to this axis. Increasing H, we will make the stable orientations of the magnetization closer to the X axis and 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 H, two minima merge into one and the magnetization becomes parallel to the X axis. Using previously characterized magnetoelastic interactions [2] we achieve the switching of the magnetization between two free energy minima. Variations of three parameters a/b, c/b and H allow us to get optimal conditions for the acoustically induced magnetization switching.

We determined the mechanisms responsible for the acoustically induced magnetization switching. Its threshold depends on the acoustic pulse’s parameters, the magnetic shape anisotropy and H. 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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