Finite Elements Micromagnetic Simulation of the domain wall resonance

N. Ntallis, K.G. Efthimiadis,
Department of Physics, Aristotle University, 54124 Thessaloniki, Greece

In this work simulations of the domain wall oscillations under the influence of alternating external magnetic fieldswere performed.

The simulation method is based theoretically on Brown's classical micromagnetic approach and computationally on the finite element method.The magnetization dynamics is not simply described by the classical Landau – Lifshitz – Gilbert equation, but it is generalized in order to include, besides the precession, the nutation of the magnetizationvector as well.In a compact vector form with respect to the magnetization vector, $\vec{M}$, the used partial differential equation is

$$\frac{\partial \vec{M}}{\partial t} = \gamma \vec{M} \times \left(\mu_o \vec{\mathcal{H}} - \eta \frac{\partial \vec{M}}{\partial t} - \frac{\mathcal{I}}{M_s^2} \frac{\partial^2 \vec{M}}{\partial t^2} \right),$$

where γ is the gyromagnetic ratio, η is the Gilbert damping parameter, $\mathcal{I}$ is the moment of inertia regarding the magnetization nutation and $\vec{\mathcal{H}}$is a local effective field acting on the magnetization. The last onewas defined by the variational derivative of the free micromagnetic energy, in which the main contributions arise from exchange, magnetocrystalline, magnetostatic and Zeeman energies. In this context, assuming a uniaxial anisotropy

$$\vec{\mathcal{H}} = \ell^2 \nabla^2 \vec{M} + \kappa^2 \left(\hat{k} \cdot \vec{M} \right) \hat{k} + \vec{H}_d + \vec{H},$$

where $\ell = \sqrt{2\,A/\mu_o M_s^2}$ is the exchange length with A the exchange stiffness constant and $\kappa = \sqrt{2K/\mu_o M_s^2}$ is the hardness parameter with K the first order anisotropy constant and $\hat{k}$ the direction of the anisotropy axis, i.e. the easy magnetization axis. In the absence of conducting media, the demagnetizing field, $\vec{H}_d$, was calculated from the gradient of a magnetic scalar potential φ, which obeys the Poisson equation $\nabla^2 \varphi = -\nabla \vec{M}$. The last term, $\vec{H}$, is the external field, which is parallel to the easy axis. The governing equations was supplemented with the boundary condition $\partial \vec{M} / \partial \hat{n} = 0$, where $\hat{n}$ represents the unit vector normal to the surface of the particle.

The simulations were performed for soft ferromagnetic spherical particles of uniaxial magnetocrystalline anisotropy, in which the magnetic domains were created during the demagnetization from saturation (figure 1).

The simulation results indicate multiple resonances in different points of the susceptibility spectrum, due to different oscillation modes of the domain wall (figure 2).

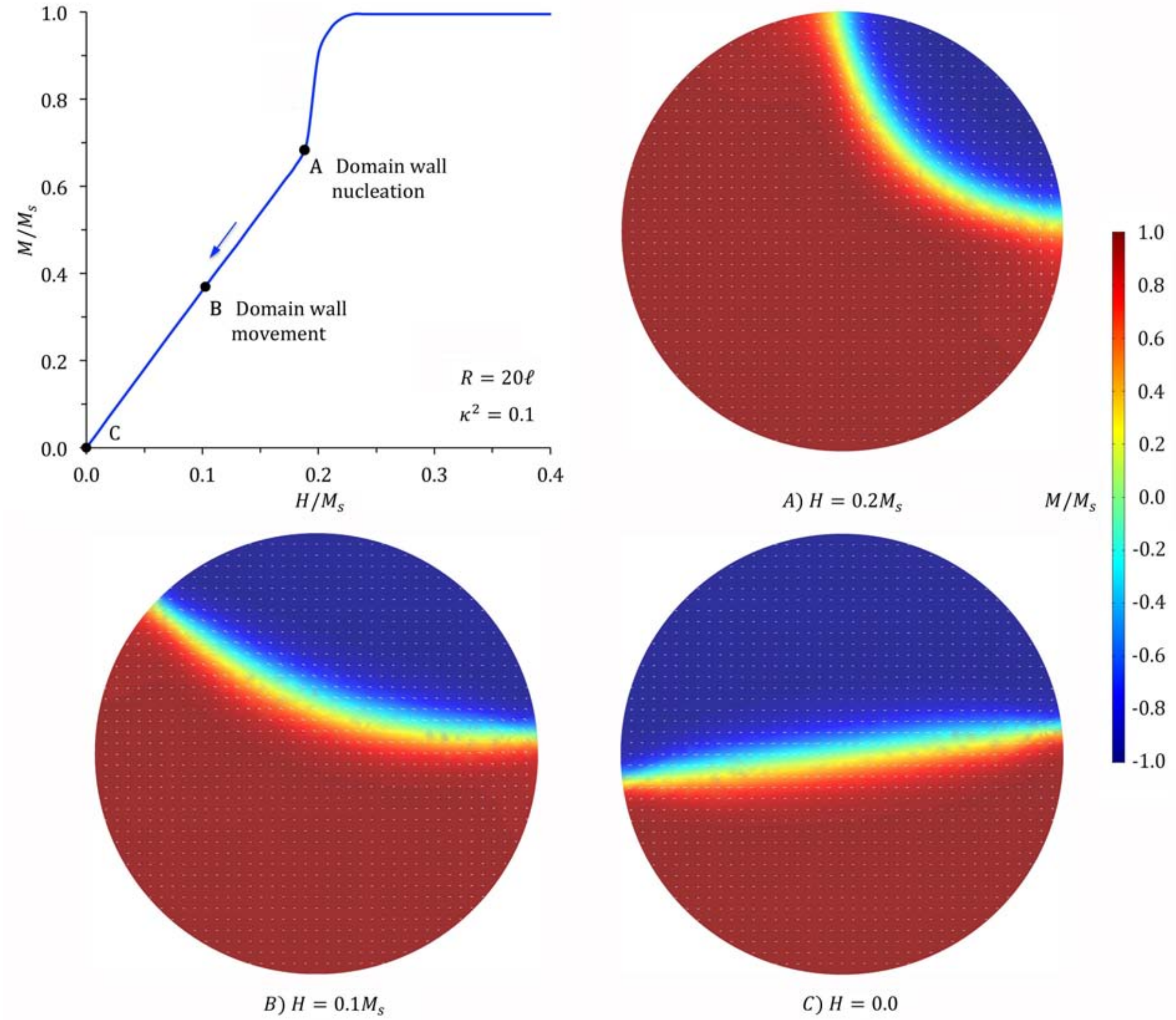

Fig. 1 Nucleation and expansion of a magnetic domain wall during the demagnetization.

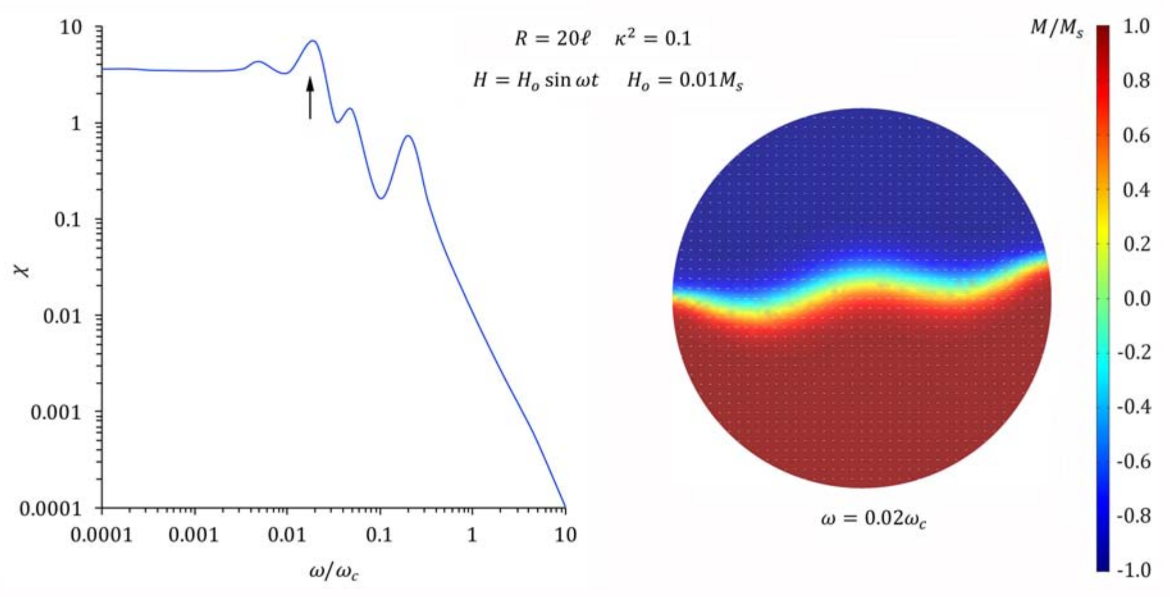

Fig.2 Susceptibility spectrum and a snapshot of domain wall oscillation in one of the resonance frequencies.