Numerical Magnetic Nanocomposites for Microwave Applications

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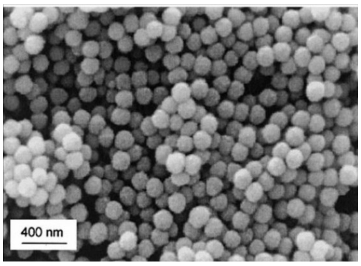
Micro- and nanocomposites, consisting of ferro or ferrimagnetic micro- and nanoparticles embedded in an insulator matrix, are key materials for a broad panel of applications including high-density data storage, spintronics and microwave devices (on-chip inductors, microwave shielding or absorbing materials). For such applications, an in-depth understanding of both the static and dynamic properties of composite materials is required.

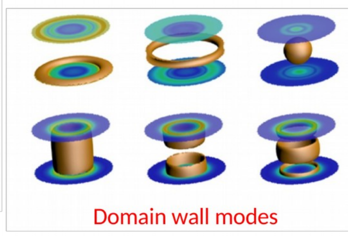
The goal of this PhD thesis project is to build a multi-scale model of the susceptibility spectra of micro- and nanocomposite magnetic materials. At the particle scale, the magnetic structure and the intrinsic susceptibility spectra will be computed using a three-dimensional micromagnetic approach. In a first step, isolated spherical particles with diameter in the (sub-)micron range will be addressed. We will investigate standing-wave modes occurring in such geometries after excitation with a short field pulse. In a second step we will study the impact of interparticle coupling on the magnetic normal modes. The dipolar field coupling is expected to result in new features changes, such as the onset of collective modes.

The study will be performed using a custum-developed finite-element micromagnetic software which combines modern numerical methods and massively parallel GPU computations, making it particularly suited for large-scale simulations involving general geometries. Both directors of this PhD thesis project have ample experience in the simulation of three-dimensional magnetic modes in magnetic nanostructures, and were the first to conduct such studies [1,2]. The project will benefit from the interdisciplinary environment at the IPCMS, as the numerical studies will be compared and possibly combined with experimental ones performed in the framework of a related experimental project which started in 2018 at the neighboring department of inorganic materials chemistry.

(a)



(b)



(a) Quasi-monodisperse CoNi powder synthesized by the polyol process [3].

(b) Various simulated modes of the magnetization for a single cylinder-shaped, sub-micron sized CoPt particle in a bubble state [3].

[1] N. Vukadinovic, F. Boust, Phys. Rev. B 75, 014420 (2007)
[2] M. Yan, R. Hertel & C. Schneider, Phys. Rev. B 76, 094407 (2007)
[3] P. Toneguzzo, G. Viau, O. Acher, F. Fiévet-Vincent, & F. Fiévet, Adv. Mater. 10, 1032 (1998)