Ph.D. Description

Title:
Hard magnetic nanomaterials based on iron anisotropic magnetic nanoparticles obtained by magnetic field assisted soft chemistry route

Scientific keywords:
Micromagnetic simulation, nanomagnetism, soft chemistry, polyol synthesis, magnetic nanoparticles, microsctructure, metal, iron oxide

Hosting laboratory:
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Context:

Nowadays Nd-Fe-B [1] and Sm-Co [2] systems are the most used materials in the field of permanent magnetism and magnetic recording. This is mainly due to their very high magneto-crystalline anisotropy. However, because of the scarcity of rare earths and their high price, a major effort is being made in terms of research to develop new materials as an alternative.
In this context, several works in the recent years have shown that the anisotropic nanoparticles have proven their interest. Indeed these particles show high remanence and high coercivity. Such characteristics are mainly governed by three parameters (i) the ratio aspect defined by the ratio L/D, (ii) the mono-domain character of the nanoparticle and (iii) the good crystallinity and thus the absence of defects [3]. We have also recently demonstrated by micromagnetic simulation [4-5] and static magnetic measurements [6] that a judicious well-organized dispersed assembly of these anisotropic nanoparticles can bring to very interesting magnetic properties (high magnetic anisotropy and tunable magnetic energies).
Two main chemical methods have been developed to synthesize anisotropic ferromagnetic nanoparticles. The first method consists of conducting chemical or electrochemical reduction in the pores of inorganic or organic templates such as alumina, polycarbonate membranes [7]. The second method consists of reduction in solution without the presence of a template agent. This method is more difficult to conduct because of the high surface tension of metals, which leads generally to spherical particles. Among these approaches, one can find the organometallic route which consists of the reduction by hydrogen gas or strong reducing agent in the presence of a surfactant [8]. We have recently reported on an alternative and friendly environmental approach for the fabrication of Ni nanofibers and nanowires in the absence of any template, substrate, surfactant, or strong reducing agent such as hydrazine. It consists on conducting reducing chemical reaction in a polyol medium under applied external field [9]. It takes benefit from the properties of polyol which act as solvent,

complexing and reducing agents to produce a great variety of inorganic materials (oxides, metals, layered hydroxyl salts). The external applied field likely controls the nucleation and growth processes.

Goals:

The aim of this project is double: The first goal is to extend this friendly environmental approach to elaborate anisotropic nanoparticles for various systems which may be an alternative to rare earth based alloys. In this context several systems will be investigated: Cobalt and iron based alloys, iron oxides. Preliminary explorations show promising results. Indeed Cobalt Nano rods with very high ratio L/D were obtained (L up to 1 μm). The second goal is to take profit of the external field to elaborate well organized composite magnetic materials based mainly on iron oxides. The first system explored will be iron oxide nanoparticles embedded in silica. The strategy will be as follows: First iron oxide nanoparticles will be elaborated by hydrolysis in polyol medium under the applied field. Then the as-obtained sol will be subject to sol-gel reaction in presence of silane alkoxides. Such strategy will likely stabilize well-organized very fine iron oxide nanoparticles and particularly corresponding the ε- Fe_2O_3 which present a very high coercivity. Stabilizing this iron oxide variety is a challenge since classical heat treatment allows only the formation of stable iron oxide varieties α-Fe_2O_3 and γ-Fe_2O_3. Static magnetic measurements along with micromagnetic simulations will be thus performed as a demonstration of our approach.

Several characterization techniques will be used during this work: X-ray diffraction, magnetism (standard SQUID measurements and Vectorial VSM magnetometry), SEM, TEM, TGA-TD techniques, Spectroscopic methods (IR, UV, Raman).

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Student profile:

Student applying for this subject should possess a good background in material science and in the physico-chemistry properties of inorganic magnetic materials. He/She should also present experimental skills and a scientific interest in the academic studies on the elaboration and characterization of nanomaterials. All these skills as well as human qualities allowing the student to integrate easily a new team, will be very useful in order to manage the multidisciplinary thematic of the PhD thesis.