Coupling and anisotropy of magnetic nano-objects

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Magnetic nano-objects are studied in many reseach fields from physics to biology. Their field of application is very wide as well : they can be used as magnetic media, in catalysis or in medicine…In order to improve the efficiency of these magnetic objects, their size tends to become smaller and smaller, approaching the superparamagnetic limit at room temperature: the thermal excitations become high enough to reverse the magnetization of a nano-object. As a consequence in many applications it is of prime importance to stabilise their magnetization. To achieve this goal understanding the magnetic coupling mechanism between nanoparticles and the effect of the shape/crystallographic anisotropy becomes crucial.

The aim of this thesis will be to study the magnetic properties of nanostructures (Co-Ni nanothumbells and Fe-Co nanocubes…) and to correlate these magnetic behaviours to the shape, the crystallography and the concentration distributions in the nanostructures. The nano-objects will be prepared by chemist collaborators using a polyol process for example. The interest of such a chemical route is the possibility to attach ligands to the objects that allow protecting them from oxidation and in addition allow tuning the distance of nearest neighbours through the length of the ligands. A study as a function of the distance of the nano-objects is then possible in order to disentangle the different magnetic effects.

This thesis will be performed in IPCMS with mainly two types of techniques: transmission electron microscopies (TEM) and magnetic nuclear resonance on the Co nucleus (NMR). In addition to state of the art electron microscopy (high resolution TEM, energy loss spectroscopy and energy dispersive X-ray spectrometry), which will give access to the shape, the crystallography and the concentration maps, some magnetic microscopies (holography and Lorentz microscopies) will be used to get information on the individual magnetic configurations. While TEM techniques will allow detailed investigation of limited numbers of objects, ensemble averaging will be investigated by NMR. The set up consists in a unique, state of the art, NMR spectrometer that has been especially designed for studying ferromagnetic systems.

The project will give to the PhD student a large range of scientific and technical competences.