# PhD position 2019

# Electronic transport properties in individual metallic nano-objects synthesized by chemical routes

**Laboratory :** Laboratoire de Physique et Chimie des Nano-Objets (LPCNO-UMR 5215 INSA-CNRS-UPS)

**Team :** Nanomagnetism

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For several decades already, the study of the electronic transport properties of nano-objects (NO) connected to metallic macro-electrodes allowed to measure a diversity of electronic conduction regimes very fascinating. For instance, the study of the transport properties of individual semi-conducing quantum dots or metallic nano-islands allowed to highlight Coulomb blockade regimes which are a signature of the electron corpuscular nature [1]. In this kind of regime, the current flow is blocked over a large range of polarisation voltages because of the Coulomb electron repulsion. Beyond a threshold voltage, electron injection is possible and electrons flow one by one through the dot. The technological potential of such a device to build very fast single electron transistors is huge. On the contrary, the highlight of ballistic transport regimes in individual carbon nanotubes allows to demonstrate experimentally the conductance quantification [2]. This phenomenon is directly related to the wave nature of electrons. The nanotube behaves like an electronic wave guide within it electrons interact very weakly and where the current flow does not dissipate energy in the form of heat. Such devices could be used as interconnections in the future processors and could solve several problems observed in current processors. Just as fascinating, giant magnetoresistance effects have been measured in magnetic nano-junctions as well as networks of magnetic NO [3]. This effect is directly related to the modulation of the tunnel effect by the electron spin. This spin dependent charge transport is already used for the realisation of fast and non-volatile magnetic memories, the MRAMS.

At the LPCNO, we have access to a great variety of metallic NO synthesized by chemical routes like iron nano-cubes and nano-spheres, platinum nano-stars, gold nano-spheres and nanowires or cobalt nano-rods. Those different kinds of NO have already demonstrated a huge potential in chemical catalysis, in tumour treatments by magnetic hyperthermia or in high density data storage. Now we want to focus on the studies of the NO electronic transport properties, and more specifically on those of gold nanowires (diameter of 1,5 nm and length of few microns) as well as those of magnetic NO based on iron (nano-cubes of 10nm) or cobalt (nano-rods with a diameter of 10nm). Those three kinds of NO appear very interesting both from a fundamental point of view and technological point of view. Indeed, we expect to measure ballistic like behaviour in the gold nano-wires as it has been observed with carbon nanotubes. Concerning the magnetic NO we expect to measure strong coupling between the spin and the charge transport, especially if Coulomb blockage regimes are observed. Measuring such Magneto-Coulomb couplings could allow to deeply probe the magnetic properties of the NO. Beyond the fundamental aspect of those studies, such magnetic nano-devices could constitute the building blocks of artificial neuron networks as demonstrated recently [4].

The main goal of this PhD will be to investigate the electronic transport properties under magnetic field and down too very low temperature (2K) of individual gold nanowires and/or magnetic NO such as iron nano-cubes and cobalt nano-rods. Few studies, or even none, of individual objects have been performed because of the connection of those different NO is non trivial. Thus, it is a real challenge to measure their transport properties. To ease these future studies we have developed at the LPCNO a unique system able to depose in a control manner NO into a surface. The system is based on an electrospray source [5]. It allows to depose individual NO inside nano-gaps (≥10nm) realized with electron beam lithography.

The work done in this PhD will be multidisciplinary and it will consist in:

(i) Realising and optimizing the nano-gap devices using electron beam lithography.
(ii) Deposing into the nano-gap devices the NO using the electrospray system.
(iii) Carrying out the measurements and the studies of the electronic transport properties at low temperature and under magnetic field of the connected NO.

**Require profile:**

Master or Engineering degree (Ecole d'Ingénieur) with a major in condensed matter physics, nano-physics and nanotechnology. The candidate will have to be interested by experimentation and multidisciplinary project. He/She will be meticulous, organized and autonomous. He/she will have to take initiatives.

**Bibliography**

[1] L.P Kouwenhoven & al, Rep. Prog. Phys. 64, (2001) 701–736.
[2] W. Liang & al Nature. 411, (2001) 455.
[3] J. S. Moodera & al Phys. Rev. Lett. 74, (1995) 3273; J. Dugay & al, Nanoletters. 11 (2011) 5128
[4] A. Mizrahi & al, Nature Communications 9 (2018) 1
[5] P. Agostini & al, J Nanopart Res, 18 (2016) 11