INSTITUT LUMIÈRE MATIÈRE

"Magnetic Nanostructures" group

Master 2 research internship / PhD research subject

Superconducting clusters and hybrid superconducting/ferromagnetic nanosystems: an experimental study

More than a century after the discovery of superconductivity (SC), theoretical as well as experimental research in this field remains very active. Due to its remarkable properties (quantum coherence, electron pairing, absence of electrical resistance, perfect dia-magnetism...), SC is a fascinating area of physics with ongoing new findings and discoveries of exotic features (unconventional and high-T_C SC, iron-based superconductors, interface and dimensionality effects…). Ferromagnetism and SC are a priori not compatible: for a s-wave superconductor, Cooper pairs are made with electrons of opposite wave vector and spin (singlet state), while exchange interaction in a ferromagnet tends to align the spins in a given direction (spin polarization), which induces a pair-breaking effect. Moreover, with exchange splitting the two electronic wave vectors are different, thus resulting in a spatial modulation of the superconducting order parameter. This gives rise to interesting effects, often subtle and exotic, where both magnetism and superconductivity can be modified at the nanoscale. The interplay between magnetism and SC still need to be investigated, especially in systems involving nanoparticles (NPs), as opposed to thin films, where additional size-reduction effects can be involved.

An interest in small-scale SC is also coming from cluster science, with recent results on free clusters, as well as on nanoparticle assemblies. Such nanomaterials have shown interesting behaviours, despite the fact that the structure is often poorly known and that the properties of the individual objects are not well understood. Moreover, in recent years, hybrid ferromagnetic/superconducting systems based on NPs (in a matrix) have attracted attention with the idea of combining magnetism and SC in a single nanomaterial and inducing novel properties. A few interesting results have been reported with very specific features, such as magnetic history effects on the SC properties. Additional investigations (with a precise study of the nanostructure effect, and more elaborate theoretical analysis) are needed to go further in this direction.

We want to study model systems prepared by low energy cluster beam deposition, where nanoparticles (obtained by laser vaporization) are soft-landed under ultrahigh vacuum (UHV) conditions on a surface and/or diluted in a matrix. This is a powerful and original approach because the particle size can be controlled (mass-selection, between 2 and 10 nm diameter, which is a perfect length-scale for confinement and proximity effects), as well as their concentration (i.e. the interparticle separation) in a matrix, and we can choose the material for the NPs (including alloys) and the matrix We aim at putting into evidence unusual properties (combination and interplay between magnetism and SC) of hybrid nanosystems. The internship will involve sample preparation by cluster deposition followed by magnetic (and electronic transport) characterization.

Contact:
Florent Tournus (florent.tournus@univ-lyon1.fr)