# Atomic-scale magnetometry with a mobile molecular quantum sensor

Léo Garnier[a*], Benjamin Verlhac,[a] Nicolas Bachelier,[a] Maider Ormaza,[a] Paula Abufager,[b] Nicolás Lorente,[c,d] Markus Ternes[e], Marie-Laure Bocquet,[f] et Laurent Limot[a]

a. Université de Strasbourg, CNRS, IPCMS, UMR 7504, F-67000 Strasbourg, France
b. Instituto de Física de Rosario-CONICET-Universidad Nacional de Rosario,Rosario, Argentina
c. Donostia International Physics Center (DIPC), 20018 Donostia-San Sebastián, Spain
d. Centro de Física de Materiales (CFM), 20018 Donostia-San Sebastián, Spain
e. Max Planck Institute for Solid State Research, Heisenbergstrasse 1, 70569 Stuttgart, Germany
f. PASTEUR, Département de Chimie, Ecole Normale Supérieure, PSL Research University, Sorbonne Universités, UPMC Univ. Paris 06, CNRS, 75005 Paris, France

∗ leo.garnier@ipcms.unistra.fr, ≪ Léo Garnier ≫

Recent advances in scanning probe techniques rely on the chemical passivation of the probe-tip termination with single molecules weakly connected to the metallic apex. Valuable information, otherwise unaccessible with a metallic tip, can then be gathered, notably offering to image the skeletal structure and bonding of single molecules. The undeniable success of this approach opens the tantalizing prospect of introducing spin sensitivity through the probe-tip termination with a magnetic molecule. Here, we use a tip decorated by a single nickelocene molecule [1,2] and exploit it as a spin-sensitive mobile sensor. Nickelocene behaves as a two-level spin system where the uniaxial magnetic anisotropy (noted $D$) separates the magnetic ground state $|S = 1, M = 0 >$ from the excited state $|S = 1, M = \pm 1 >$. This nickelocene-terminated tip, or Nc-tip, offers the unique possibility of producing electrically-driven spin excitations on the tip apex. We show that when the Nc-tip is within $150$ pm from a magnetic object, its spin excited spectrum is modified by the presence of an exchange interaction. Magnetic information may be probed with lateral and vertical atomic-scale resolution. Virtually all systems may be addressed with this detection scheme, including ferromagnetic surfaces, as we exemplify for a single Fe atom on Cu(100) and for surface atoms within a cobalt island grown on Cu(111).

[1] M. Ormaza *et al.*, Nat. Commun. **8**, 1974 (2017)
[2] M. Ormaza *et al.*, Nano Lett. **17**, 1877 (2017)