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Lanthanide Atoms on Surfaces:

From Single Atom Magnets to Spin Qubit Candidates

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Abstract

As the global demand for sustainable technologies rises, reducing the amount of lanthanide elements in future devices becomes imperative to mitigate environmental impacts. A viable way to achieve this goal is through the miniaturization of logic units down to the level of single atoms. Lanthanide atoms on surfaces have been proven to be a potential platform for storing and manipulating classical binary information due to their very long magnetic lifetime [Science 352, 318 (2016), Nat. Comm. 12, 4179 (2021)], representing the ultimate limit of downscaling for magnetic storage devices [Appl. Phys. Lett. 119, 160503 (2021)]. The current challenge is to utilize these elements to realize atomic-scale quantum logic units, or qubits.

In this talk, I will discuss the potential of lanthanide atoms on surfaces as a platform for demonstrating quantum coherent operations. An atom should have a suitable ground state that can efficiently interact with microwave fields. Combining X-ray magnetic circular dichroism and density functional theory, we found that erbium (Er) and thulium (Tm) atoms on MgO/Ag(100) possess these characteristics [Phys. Rev. B 107, 045427 (2023)]. Using scanning tunneling microscopy, we demonstrated the drive and detection of electron-spin resonance in an all-electrical fashion, a necessary condition to achieve quantum coherent control of their spin states [arXiv:2309.02348].

Finally, I will present the development of a novel instrument to characterize the quantum coherence of surface adsorbed atoms. The setup allows performing ensemble averaged continuous-wave and pulsed X-band electron spin resonance (ESR) spectrometer down to 10 K and in ultra-high vacuum. The use of a half-wavelength microstrip line resonator made of epitaxially grown copper films on single crystal sapphire allows achieving a sensitivity below a single molecular layer. By demonstrating advanced pulsed ESR experimental capabilities, including dynamical decoupling and electron-nuclear double resonance, we showcase the potential of this instrument to explore novel low-dimensional spin arrangements [arXiv:2312.00459].

The speaker

Fabio Donai is Associate Professor of Physics at Ewha Womans University and a Research Fellow at the Center for Quantum Nano Science in Seoul. He holds a Ph.D. in Radiation Science and Technology from Politecnico di Milano, Italy, with part of his research conducted at the Max Planck Institute in Halle, Germany. Previously, he worked as a post-doc researcher at EPFL in Switzerland. In 2018, he received the Max Auwärter award for his achievements in the physics of surfaces and interfaces. His research focuses on the magnetism and quantum coherence properties of atomic-scale strcutures at surfaces.