Probing quantum-coherence in atomic-scale spin systems using ESR-STM

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The development of electron-spin resonance (ESR) spectroscopy in a scanning tunneling microscope (STM) has enabled the quantum-coherent control of electrons localized in single atoms or molecules on surfaces. [1] In such a system, individual atoms can be manipulated using the extreme spatial precision of the STM to engineer the interaction between neighboring spins. Using pulsed ESR the spins can then be individually or collectively driven. This allows for the study of the quantum behavior of spins in the solid state with unprecedented control over the environment. In this talk I will discuss recent developments and insights into quantum state control of atoms and molecules on surfaces from a combined theory and experiment perspective. I will focus on individual titanium atoms [2] and Fe(II)phthalocyanine molecules [3], which are prototypical S=1/2 systems when deposited on ultrathin layers of MgO grown on a silver supporting substrate. I will show our most up-to-date models which provide quantitative and qualitatively predictive results and discuss possible molecular spin qubit and qudit candidates.

References:

[1] Baumann et al., Science 350 (6259) 2015
[2] Yang et al., Science 366 (6464) 2019, Wang et al., Science 382 (6666) 2023
[3] Willke et al., ACS Nano 15 (11) 2021, Zhang et al., Nat. Chem. 14 (1) 2022, Zhang et al., https://arxiv.org/abs/2412.03866 (2025)

This project was funded by IBS-R027-D1