O 95: Poster Session VII: Poster to Mini-Symposium: Manipulation and control of spins on functional surfaces III

Time: Thursday 10:30–12:30 Location: P

O 95.1 Thu 10:30 P

Single-atom electron paramagnetic resonance in a scanning tunneling microscope driven by a radiofrequency antenna at 4 K — •Stepan Kovarik[1], Tom S. Seifert[1], Dominik Juraschek[2], Nicola A. Spaldin[1], Sebastian Stepanow[1], and Pietro Gambardella[1] — [1]Department of Materials, ETH Zürich, Switzerland — [2]Harvard John A. Paulson School of Engineering and Applied Sciences, Harvard University, USA

Combining electron paramagnetic resonance (EPR) with scanning tunneling microscopy (STM) enables detailed insight into the interactions and magnetic properties of single atoms on surfaces [1]. A requirement for EPR-STM is the efficient coupling of a microwave excitation to the tunnel junction. Here, we present a coupling efficiency of the order of unity by using a radiofrequency (RF) antenna placed parallel to the STM tip [2]. This highly efficient coupling allows us to observe the EPR of individual atoms on an MgO surface routinely at 4 K. Using this technique, we perform a systematic study of the EPR of Fe and hydrogenated Ti atoms on MgO, comparing different tunneling parameters, frequency, and magnetic field sweeps as well as amplitude and frequency modulation in order to maximize the EPR signal. We interpret the data based on density functional theory and charge transfer multiplet calculations, revealing the important role of the tip magnetic field in EPR-STM [3].

[1] S. Baumann, et al., Science 350, 417 (2015).
[2] T. S. Seifert, et al., Phys. Rev. Research 2, 013032 (2020).
[3] T. S. Seifert, et al., Sci. Adv. 6, eabc5511 (2020).

O 95.2 Thu 10:30 P

Exploring inelastic electron tunneling with functionalized STM tip using cluster Hubbard model — •Daria Medvedeva and Jindřich Kolorenč — Institute of Physics, Czech Academy of Sciences, Na Slovance 2, Prague 8, Czech Republic

Inelastic electron tunneling spectroscopy (IETS) is a widely used experimental technique to explore vibrations and magnetic excitations of atoms and molecules adsorbed on metal surfaces [1]. Functionalization of the STM tip, for instance by attaching a magnetic molecule to it, introduces spin sensitivity and expands the possibilities of the scanning-probe technique [2]. We use a co-tunneling theory of STM-IETS [3] to investigate how a nickelocene-terminated tip (Nc-tip) senses excitations in a magnetic system (atom, molecule, cluster of atoms) adsorbed on a surface. In our approximation, the Nc molecule on the tip and the object on the surface are modeled by a cluster Hubbard model (one site for each magnetic atomic shell). We reproduce the spectra measured in STM experiments where the object on the surface was Nc molecule [4] or Fe atom (spin 3/2 with an out-of plane easy axis) [3], and predict spectra for several more complex magnetic systems. In particular, we compare cases with in-plane and out-of-plane easy axis.

[1] J.D.Langan, P.K.Hansma. Surf. Science **52**, Issue 1, pp. 211-216, Sept. (1975).
[2] K.W. Hipps, U. Mazur. *Inelastic Electron Tunneling Spectroscopy* (2006).
[3] B. Verlhac et al. Science **366**, 6465, pp. 623-627 (2019).
[4] F. Delgado and J. Fernández-Rossier. PRB **84**, 045439 (2011).

O 95.3 Thu 10:30 P

Engineering of Fe Spin Excitation on NaCl — •Shinjae Nam[1,2], Jinoh Jung[1,4], Christoph Wolf[1,3], Andreas Heinrich[1,2,3], and Jungseok Chae[1,3] — [1]center for Quantum Nano Science — [2]Physics department, Ewha Womans University — [3]Ewha Womans University — [4]Physics of department, KAIST

For scanning tunneling microscopy (STM) study of single magnetic atoms, a decoupling thin layer of Cu2N and MgO have been widely used to isolate magnetic atoms from the conducting substrate. However, NaCl wasn't commonly used for single magnetic atom even though it has been widely used for decoupling layer of single organic molecules.

Here, we investigated the electronic and magnetic properties of single Fe atoms absorbed on NaCl thin film on the Au (111) substrate depending on its absorption sites using STM. Notably, the Fe atoms are adsorbed on the interstitial bridge site of NaCl after deposition, while density functional theory (DFT) calculations indicate the Cl-top site as a preference absorption site. We confirmed the dynamic absorption process by atomic manipulation and simulation using DFT calculations. Moreover, Fe on the interstitial bridge shows an apparent step-wise increase at 23 meV, as expected for a spin-excitation. The DFT+multiplet calculation reproduces the spin excitation energy of Fe at the interstitial bridge of 3d7 electronic configuration with spin 3/2. Interestingly, the Fe at interstitial bridge has in-plane magnetic anisotropy due to the large transverse crystal field and its ground spin 1/2 two level system might be utilized as a qubit.

O 95.4 Thu 10:30 P

Electronic property of organic multilayers: Vanadyl phthalocyanine on Titanyl phthalocyanine monolayer/Ag(001) — Kyungju Noh[1,2], Luciano Colazzo[2], Andreas Heinrich[1,2], Fabio Donati[1,2], and •Yujeong Bae[1,2] — [1]Department of Physics, Ewha Womans University, Seoul, Republic of Korea — [2]Center for Quantum Nanoscience, Institute for Basic Science, Seoul, Republic of Korea

In this study, we identify orbital energy levels of Vanadyl phthalocyanine (VOPc) on Ag(001) with Titanyl phthalocyanine (TiOPc) interlayer by scanning tunneling microscopy (STM). Comparative research of single VOPc with and without molecular interlayer showed decoupling effect of the TiOPc monolayer. Using conductance measurement, we resolved HOMO and LUMO of individual VOPc molecules regularly spaced on one monolayer of TiOPc, whereas VOPc on bare metal substrate was strongly coupled with the metal substrate. Moreover, VOPc on TiOPc molecular layer has consistent adsorption direction. In this highly organized structure, the VOPc molecules presumably preserve the spin, hence representing a potential surface-absorbed molecular qubit.

O 95.5 Thu 10:30 P

Probing the anisotropy of g-factor of a single atom on a surface in vector magnetic fields — •Thi Hong Bui[1,2], Jinkyung Kim[1,2], Won-jun Jang[3], Denis Krylov[1], Soonhyeong Lee[1], Sangwon Yoon[1], Deung-jang Choi[4], Christoph Wolf[1], Fernando Delgado[5], Chris P. Lutz[6], Andreas J. Heinrich[1,2], and Yujeong Bae[1,2] — [1]Center for Quantum Nanoscience, Institute for Basic Science, Seoul, South Korea — [2]Department of Physics, Ewha Womans University, Seoul, South Korea — [3]Nano Electronics Lab, Samsung Advanced Institute of Technology, Suwon 13595, South Korea — [4]Material Physics Center (UPV/EHU), 20018 Donostia-San Sebastian, Spain Donostia International Physics Center (DIPC), Spain — [5]Instituto de estudios avanzados IUDEA, Departamento de Fisica, Universidad de La Laguna, 38203, Tenerife, Spain — [6]IBM Almaden Research Center, San Jose, CA 95120, USA

Combining the electron spin resonance with the scanning tunneling microscope enables us to approach to the quantum states of single atoms on a surface with the energy resolution of sub-nano electron volts [1]. Here, we report the huge anisotropy of a hydrogenated titanium (Ti) atom at a lower symmetry binding site on MgO/Ag(100) studied using a mK ESR-STM in a vector magnetic field. We were able to determine the three components of g-factor. Interestingly, we observed the magnitude of the ESR signal significantly changes depending on the angle of the external magnetic vector, which can be attributed to the correlation between the relative orientation of the tip spin and the Ti spin. [1] S. Baumann et al., Science 350, 417 (2015)

O 95.6 Thu 10:30 P

Probing magnetic excitation of a spin spiral — •Hung-Hsiang Yang[1], Masayuki Hamada[2], Yasuo Yoshida[3], and Yukio Hasegawa[2] — [1]Physikalisches Institut, Karlsruhe Institute of Technology, Wolfgang-Gaede-Str. 1, Karlsruhe, 76131, Germany — [2]Institute for Solid State Physics, University of Tokyo, 5-1-5, Kashiwano-ha, Kashiwa, Chiba 277-8581, Japan — [3]Department of Physics, Kanazawa University, Kakuma-machi, Kanazawa 920-1192, Japan

Magnetic excitation due to inelastic electron scattering plays a crucial role in spintronics devices concerning the spin lifetime of polarized electrons and the amount of spin transfer torque for switching magnetic configurations in magnetic tunnel junctions. One of the fundamental processes is magnon creation, which occurs when injected hot electrons induce spin-flip scattering of the magnetic material. To image and address the magnetic origin of the excitations, we have performed low-temperature spin-polarized inelastic electron tunneling spectroscopy (IETS) on double layer Mn thin films formed on W(110) substrate.

The atomically-thin magnetic layer exhibits a homogeneous spin spiral with antiferromagnetic coupling, which provides a good reference for spin-polarized scanning tunneling microscopy (STM). Characteristic peak-dip features in IETS, as well as their correlation with the spin spiral, are acquired. Additionally, we have observed contrast reversal in the IETS intensity when the tip magnetization direction is flipped, indicating that the excitation is spin-dependent and thus presumably due to magnon creation.