

# **Magnetic excitations in individual metal-porphyrins: manipulation of oxidation states, spin states and magnetic anisotropy**

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The magnetic properties of atoms and molecules on a surface are significantly affected by details in the atomic-scale surrounding. Manipulation of this surrounding provides the possibility to tune the electronic and magnetic functionality of surfaces on the nanometer scale. Here, we use scanning tunneling spectroscopy to resolve the magnetic properties of individual paramagnetic metal-organic complexes on normal metal and superconducting surfaces.

Fe-octaethylporphyrin-Cl (FeOEP-Cl) is a paramagnetic complex with ethyl groups, which lift the Fe core from the surface and render the molecule flexible. When these molecules are adsorbed on a Pb(111) surface, they retain their magnetic moment with an  $S=5/2$  state and exhibit magnetic anisotropy as evidenced by inelastic spin excitations [1].

We show that the magnetic anisotropy of the individual molecules can be varied by the proximity of the STM tip. Approaching the tip to FeOEP-Cl leads to an increase in the axial anisotropy. We ascribe this behavior to a modification of the crystal field resulting in a shift of the d-level energies [2]. Eventually, the proximity of the tip leads to a change in the oxidation state of the Fe center, which is accompanied by a change of the spin state from half-integer to integer [3].

[1] B. W. Heinrich, L. Braun, J. I. Pascual, K. J. Franke, *Nature Physics* 9, 765 (2013).

[2] B. W. Heinrich, L. Braun, J. I. Pascual, K. J. Franke, *Nano Lett.* 15, 4024 (2015).

[3] B. W. Heinrich, C. Ehlert, N. Hatter, L. Braun, C. Lotze, P. Saalfrank, K. J. Franke, *ACS Nano* 12, 3172 (2018).