Adsorption Sites of Individual Metal Atoms on Ionic Surface with Use of Scanning Tunneling Microscopy

Edgar Fernandes, Fabio Donati, François Patthey and Harald Brune

Institute of Physics (IPHYS), Ecole Polytechnique Fédérale de Lausanne (EPFL),
Station 3, CH-1015 Lausanne, Switzerland

edgar.fernandes@epfl.ch

Magnetic properties of individual surface-adsorbed atoms are intimately related to the symmetry and chemistry of the adsorption site. A recent example is given by Ho atoms adsorbed on MgO(100) thin films grown on Ag(100). These atoms show long magnetic relaxation times due to a ground state that is protected from quantum fluctuations by the symmetry of the adsorption site [1]. For surfaces made of a single element, the adsorption site of adatoms can be determined by means of atomically resolved scanning tunnelling microscopy (STM) images. However, on MgO the atomic protrusions cannot unequivocally be attributed to either of the two atomic species. In addition, the tunnel parameters required for atomic resolution on MgO imply small tip-sample distances where the adatoms are frequently displaced, thus preventing a clear identification of their adsorption site. Hereafter we present a method that solves these issues.

We grow MgO thin films on Ag(100) and use 0.5% doping with Ca, which substitutes Mg. Ca has different STM contrast than Mg and thereby serves as marker for the Mg positions. The adsorption sites of adsorbed Ho atoms, and of any other atoms, are determined by extrapolating the MgO lattice from images with atomic resolution of an adsorbate-free surface spot onto an area where the adsorbates are.

After Ho deposition, we observe that two species, with different apparent heights, coexist on 1 and 2 ML MgO. Using the method described above, we find that Ho atoms adsorb on on-top of O atoms and on bridge sites between two O atoms. We can reversibly switch between these two sites by STM manipulation. In addition, a third Ho species, adsorbed on top of the Mg atom, can be created. This species does not naturally exist upon Ho evaporation, however, it is the most stable adsorption site of the three. Ho atoms on the two natural sites are immobile up to 50 K and therefore their magnetic properties can be studied up to that temperature without ripening.

Finally, we determined the adsorption site of Au and Co on MgO by comparing their position relative to the Ho atoms using the method described above. We confirm the on-top O site for Co that was found in density functional theory [2]. The adsorption site of Au on 1 and 2 ML thick MgO films is the bridge site. This settles a controversy in literature [3–5].

References

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