



Organising Atoms, Clusters and Proteins on Surfaces

Richard E. Palmer

Nanoscale Physics Research Laboratory, The University of Birmingham, UK

This talk will address two complementary methods to organise many-atom systems on the sub-10 nm scale: room temperature STM manipulation of individual, polyatomic molecules and deposition of size-selected atomic clusters. The common theme will be precision and uncertainty in the organisation of atoms.

Bond-selective molecular manipulation is one of the frontiers of atomic manipulation with the STM. Traditionally such experiments are conducted in the stable, low temperature regime; room temperature manipulation is much more challenging. Here we demonstrate room temperature, bond selective manipulation ("molecular dissection") in a polyatomic molecule, chlorobenzene (C_6H_5Cl), anchored to the Si(111)-7x7 surface by chemisorption. Electron (or hole) injection from the STM tip into the * LUMO (HOMO) orbitals of the benzene ring leads to controlled molecular desorption - a one electron process [1]. We will focus on C-Cl bond dissociation in the chemisorbed chlorobenzene molecule [2]. Detailed STM images identify the azimuthal orientation of the individual chlorobenzene molecules and allow us to correlate the final location of the liberated chlorine "daughter" atoms with their parents. We identify Cl atoms up to 50Å from the parents. We find that dissociation is a two-electron process and propose a vibrationally-mediated electron attachment mechanism.

The controlled deposition of size-selected clusters, assembled in the gas phase, is an alternative route to the fabrication of surface features of size 1-10 nm - also the size scale of biological molecules such as proteins. Scaling relations which describe the implantation [3] and pinning [4] of the clusters enable the preparation of stable, 3D surface features, which can act as protein binding sites. Specifically, we report the pinning of size-selected Au_N clusters ($N = 1-100$) to the (hydrophobic) graphite surface to create films of arbitrary, sub-monolayer density. Gold presents an attractive binding site for sulphur and thus for cysteine residues in protein molecules. AFM measurements in buffer solution show that GroEL chaperonin molecules (15 nm rings), which contain free cysteines, bind to the clusters and are immobilised [5]. Peroxidase [6] and oncostatin molecules behave similarly. By contrast, green fluorescent protein (GFP) does not bind, consistent with detailed analysis of the protein surface; the cysteine residues lie in the interior of the folded protein. The results provide "ground rules" for residue-specific protein immobilisation by clusters and have led to the development of a novel biochip for protein screening by a spin-off company.

The precise control of nanoscale structures paves the way to explore the quantum physics of these "atomic architectures", particularly their excited states. If time allows we will report progress in developing new tools to probe the atomic structure and the excited states of such quantum systems at the single molecule/cluster level, including 3D atom-resolved imaging in the STEM [7] and development of the Scanning Probe Energy Loss Spectrometer [8].

1. P.A. Sloan, M.F.G. Hedouin, R.E. Palmer, M. Persson, Phys. Rev. Lett. **91** 118301 (2003).
2. P.A. Sloan and R.E. Palmer, Nature **434** 367 (2005).
3. S. Pratontep, P. Preece, C. Xirouchaki, R.E. Palmer, C.F. Sanz-Navarro, S.D. Kenny and R. Smith, Phys. Rev. Lett. **90** 055503 (2003).
4. S.J. Carroll, S. Pratontep, M. Streun, R.E. Palmer, S. Hobday and R. Smith, J. Chem. Phys. (Comms) **113** 7723 (2000); M. Helmer, Nature (News & Views) **408** 531 (2000).
5. R.E. Palmer, S. Pratontep and H.-G. Boyen, Nature Materials **2** 443 (2003).
6. C. Leung, C. Xirouchaki, N. Berovic and R.E. Palmer, Advanced Materials **16** 223 (2004).
7. Z.Y. Li, N.P. Young, M. Di Vece, R.E. Palmer, A.L. Bleloch, B.C. Curley, R.L. Johnston, J. Jiang, J. Yuan, Nature **451** 46 (2008).
8. F. Festy and R.E. Palmer, Appl. Phys. Lett. **85** 5034 (2004); J.L. Yin, A. Pulisciano and R.E. Palmer, Small **2** 744 (2006).

www.nprl.bham.ac.uk

DATE: April 29, 2008

TIME: 12:00

PLACE: IFAE