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Manipulation of single molecules at surfaces: switches, wires and motors

Molecular nanotechnology aims to use functional molecules as individual machines or electronic devices. Hence, their self-assembly into pre-defined architectures and the full control over each individual molecule are key objectives. Various examples of functional molecules, ranging from molecular wires to molecular switches and machines that are studied and manipulated at the single-molecule level by scanning tunneling microscopy (STM) under ultrahigh vacuum conditions, will be discussed in this presentation. Molecular wires or molecular nodes with different conjugation pathways can be fabricated from specifically designed molecular building blocks that are connected to two-dimensional networks or one-dimensional chains. In the case of molecular switches, the switching rate can be tuned up and down by only one single atom in the vicinity of the molecule. The same effect is then extended to molecular assemblies where cooperative effects in single molecules are directly observed. The switching process can also be used to trigger a molecular motor where the lateral translation of molecular machines on a surface can be enhanced by light of specific wavelengths that match the absorption properties of the molecule. By comparing molecules with and without a motor unit, the enhanced motion can be directly assigned to the motor that is incorporated in the molecules. STM manipulation gives detailed insight into the physical and chemical processes at the single-molecule level by varying the relevant parameters as tip height over the surface, bias voltage or tunneling current. While the speed is typically of minor importance in these experiments, it becomes crucial when studying so-called nanocars. By implementing a dipole moment into the molecular structure, we could show that very efficient and therefore fast manipulation can be realized. The key property is that no continuous imaging is required, rendering the manipulation fast enough to win the first nanocars race.

Recent Publications:

1. C Nacci et al. (2015) Conductance of a single flexible molecular wire composed of alternating donor and acceptor units. Nature Comm. 6:7397.
2. C Nacci et al. (2016) Covalent assembly and characterization of non-symmetrical single-molecule nodes. Angew. Chem. Int. Ed. 55(44):13724.
3. T Kumagai et al. (2014) Controlling intramolecular hydrogen transfer in a porphycene molecule with single atoms or molecules located nearby. Nature Chem. 6(1):41-46.
4. A Saywell et al. (2016) Light-induced translation of motorized molecules on a surface. ACS Nano. 10(12):10945-10952.
5. G J Simpson et al. (2017) How to build and race a fast nanocar, Nature Nanotech. 12(7):604-606.

Biography

Leonhard Grill is currently a Professor of Physical Chemistry at the University of Graz, Austria, since 2013. He studied physics at the University of Graz and did his PhD thesis at the Laboratorio TASC in Trieste (Italy) in experimental surface physics on electron scattering in ultrathin metal films (group of Silvio Modesti). He is an experimental physicist specialized in the study of single functional molecules. By using scanning probe microscopy, his group is able to image and manipulate individual atoms and molecules adsorbed at surfaces and to characterize specific molecular functions. In this way electronic, electrical, optical or mechanical properties of individual molecules are controlled with the goal to obtain fundamental physical and chemical understanding of these processes. He received the Feynman Prize in Nanotechnology (2011).

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