Controlling the molecular switch

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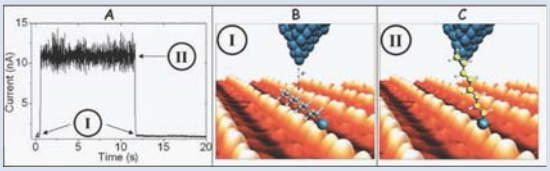
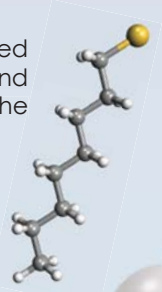
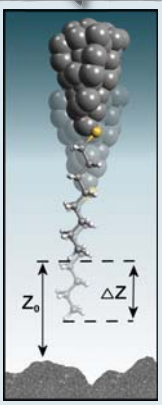
Introduction

In 1974, Aviram and Ratner put forward the idea of molecular electronics where single molecules can be used as functional electronic components [1].
Previously, a single octanethiol molecule was trapped between Scanning Tunneling Microscope (STM) tip and substrate to measure the conductance [2]. Contact of the molecule with the tip was observed.





Building a switch

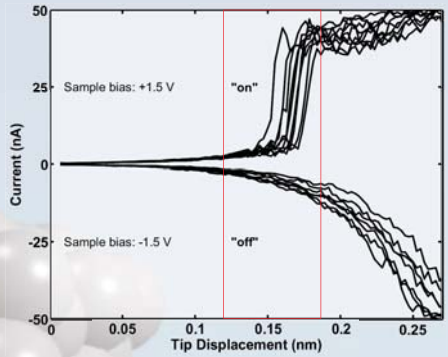


To achieve control over the tip - molecule - surface contact we attached the octanethiol molecule to the tip of the STM.

The system was controlled by changing:

- The distance ΔZ with respect to the initial tip height Z_0
- The applied bias voltage

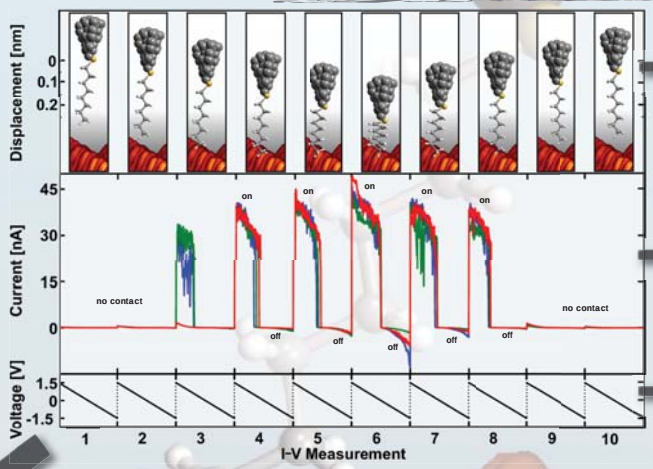
Distance-current behavior



"on"-state: At positive bias, the current jumps to a high value once the tip is brought close enough to the surface.

"off"-state: At negative bias, the current remains at a low value.

Distance-dependent current-voltage spectroscopy



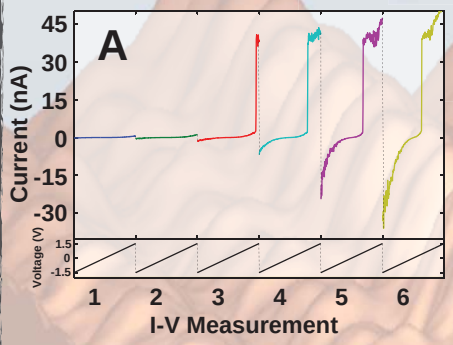
Tip was moved closer to (1-6) and away from (7-10) the surface in steps of 0.05 nm.

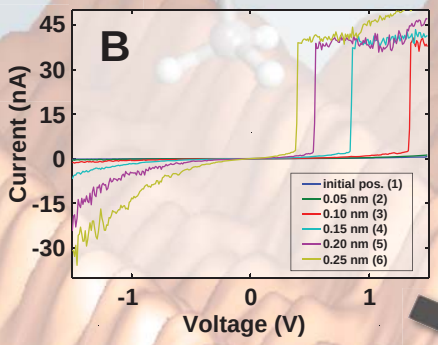
I-V Measurements were consecutively recorded after each step.
Once the molecule is close enough (3-8), switching is achieved by ramping the voltage.

Voltage was ramped from +1.5 V to -1.5 V for each measurement.

Threshold for switching

- Inverse voltage ramping leads to inverse switching sequence (A).
- Threshold for turning on the switch is lowered the closer the tip gets to the surface (B).

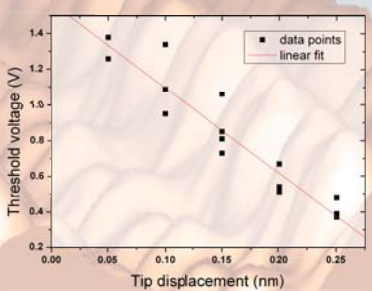




Pushing the button: electric field

- The switching is governed by the applied electric field.
- Threshold for switching lies at:

$$4\text{-}6 \cdot 10^9 \frac{V}{m}$$



Summary

An octanethiol molecule, attached to the apex of an STM tip, is used to controllably bridge the gap between the probe and the surface.
This acts as a switch on the single molecular level, controlled by only the applied electric field.

References

[1] A. Avaram and M. Ratner, Chem. Phys. Lett. **29**, 277(1974)
[2] D. Kockmann et al., Nano Lett. **9**, 1147 (2009)