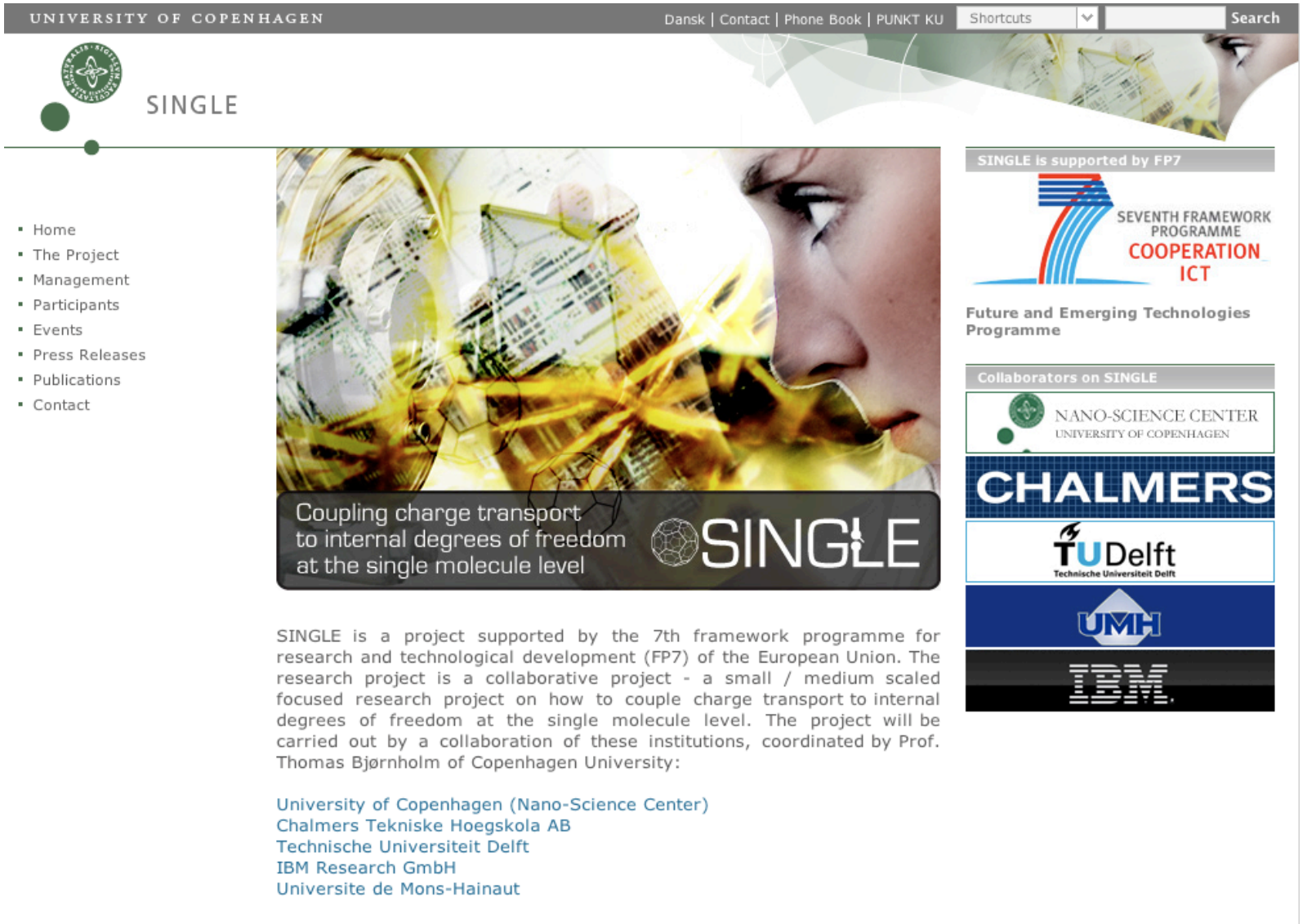
Nano-Science Center, University of Copenhagen

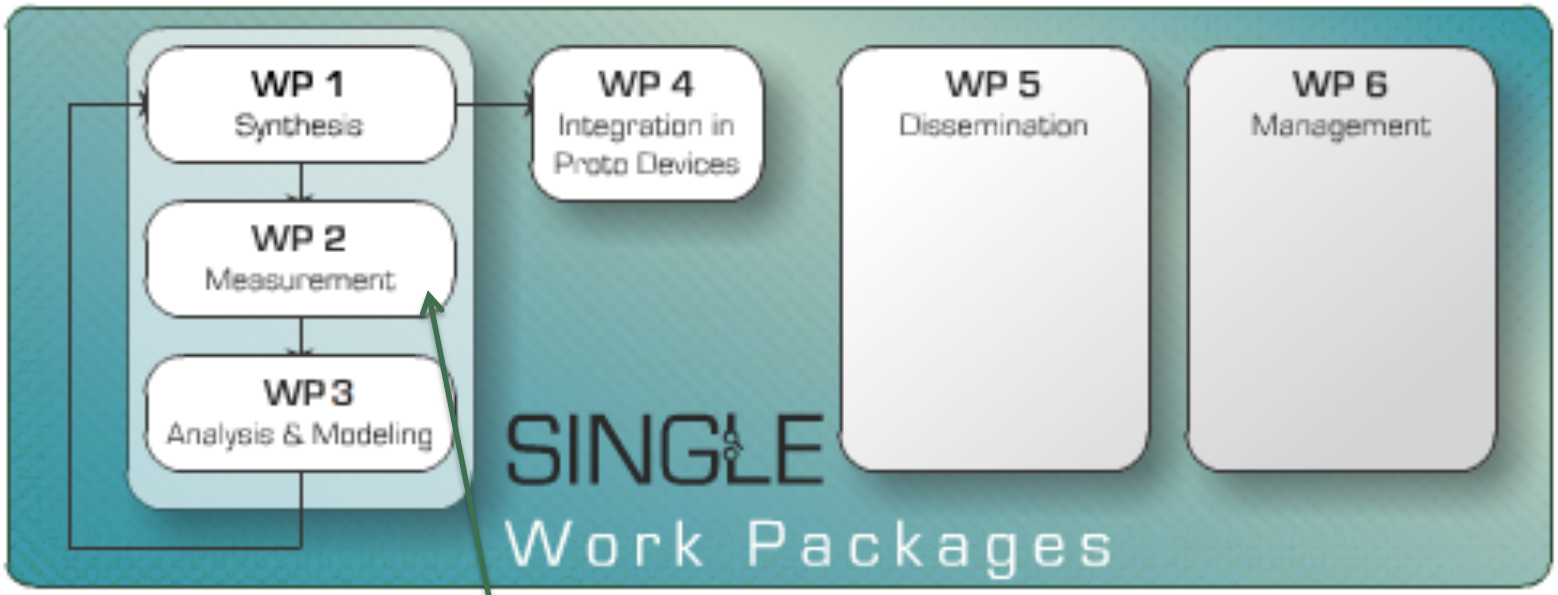
"Single-molecule electron transfer in solid state three-terminal devices: Status and challenges for molecular electronics with single molecules"

Kasper Moth-Poulsen
Post Doc at
Nano-Science Center,
University of Copenhagen



Bjørnholm
Kubatkin
Van der Zant
Cornil
Riel

www.single.ku.dk

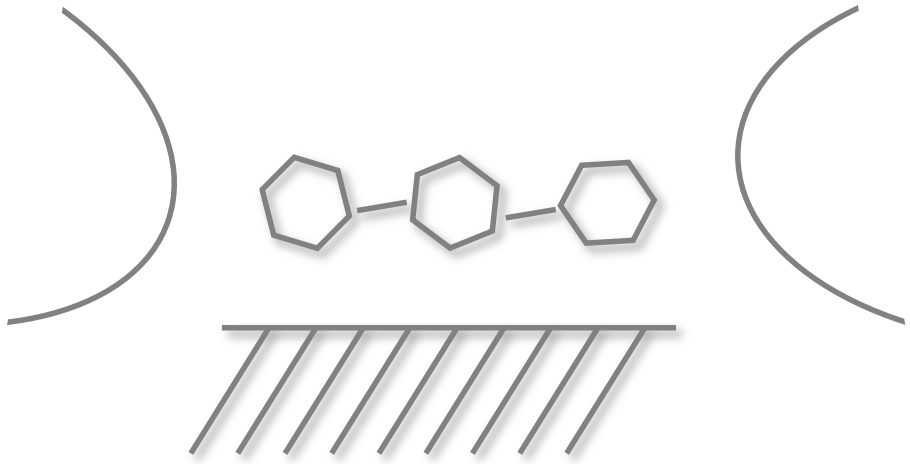


The work is proceeding in iterative cycles of synthesis, measurements, modeling, and eventually integrating the most promising systems in more advanced prototype systems.

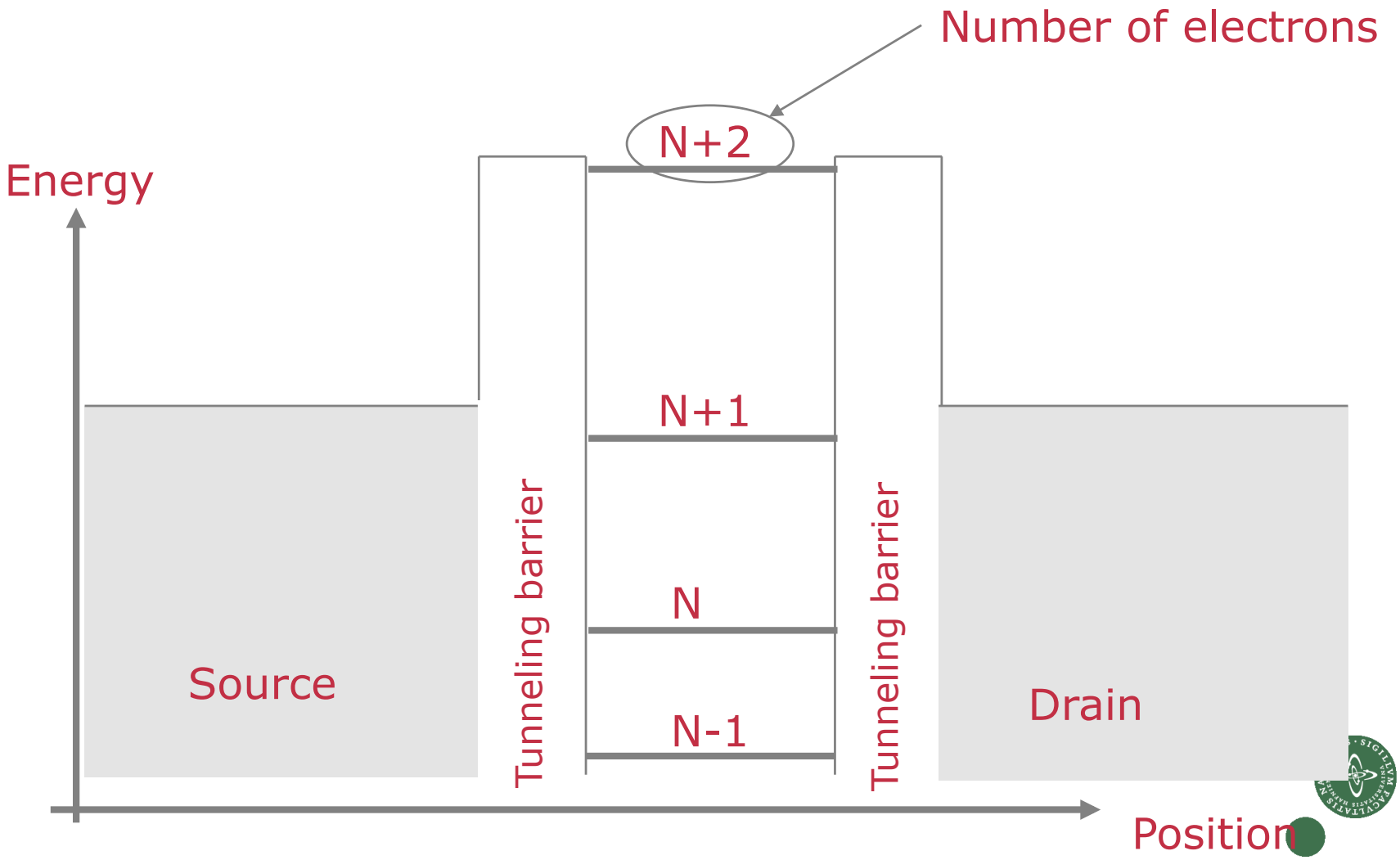
Measurements by 3 different exerimental research groups

Question:

What are the key parameters for electron transport through single molecules?



Energy Levels

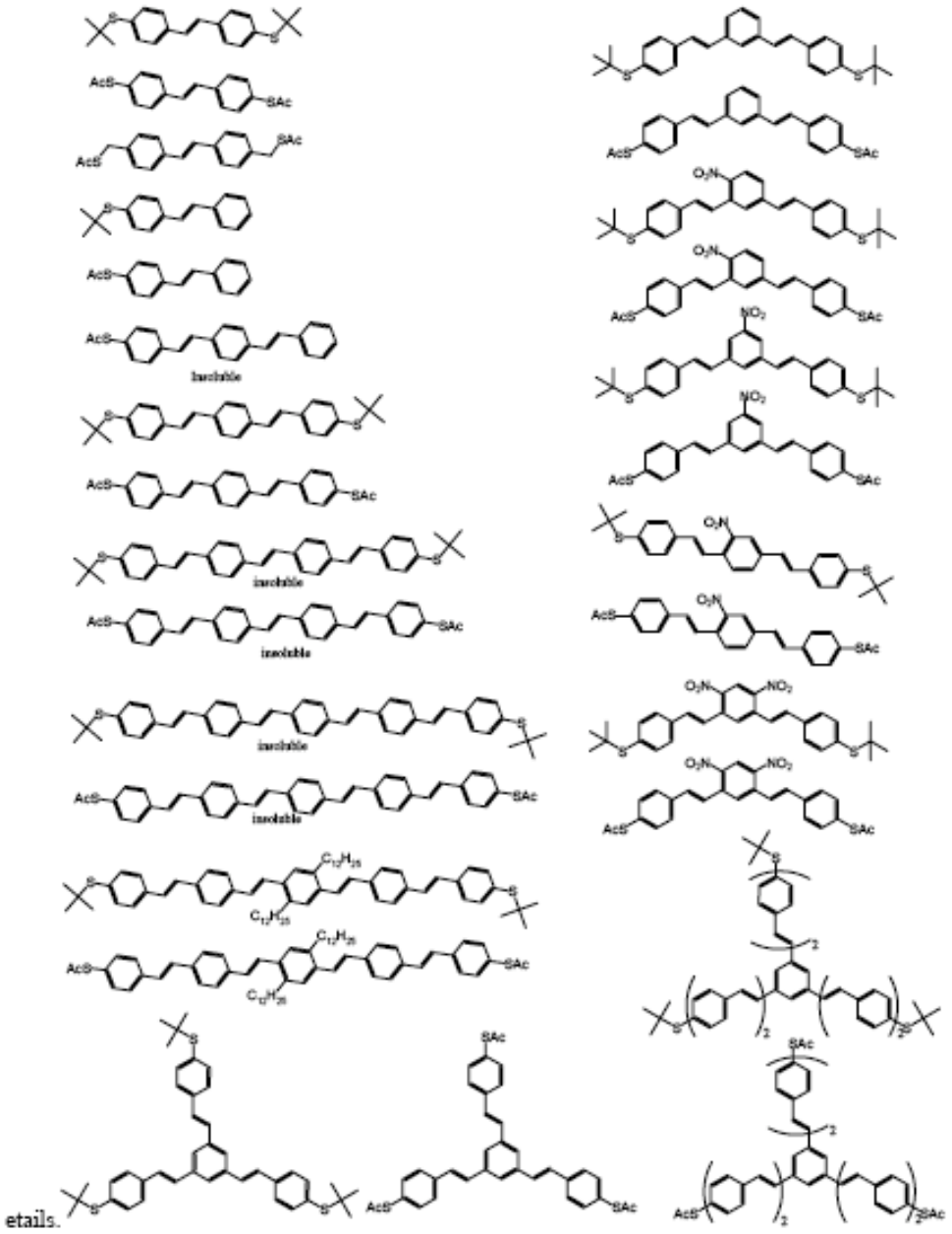


Outline:

1) Measurements on thiol end-capped OPV's

2) *C60*

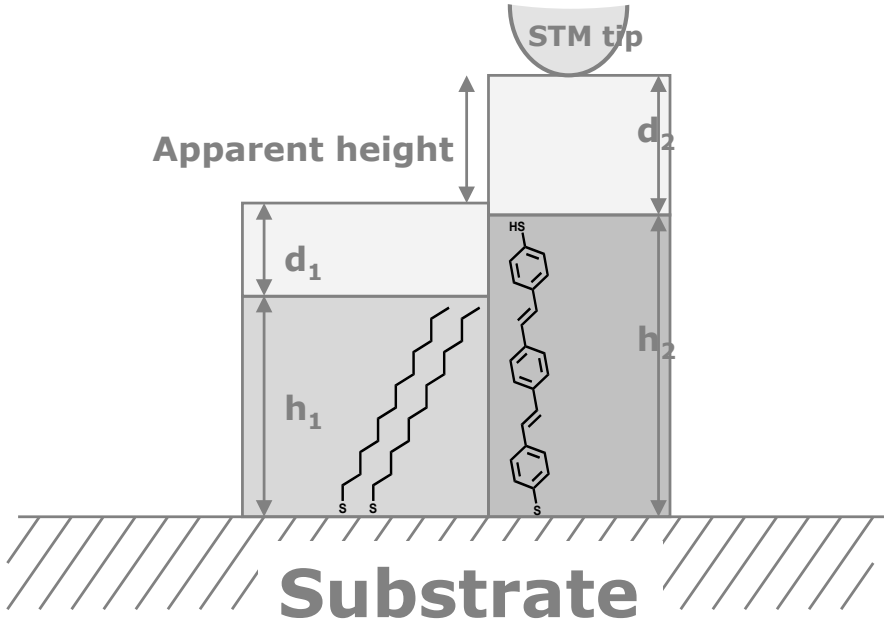
3) C60 as the *"alligator clip"*: a new generation of molecules

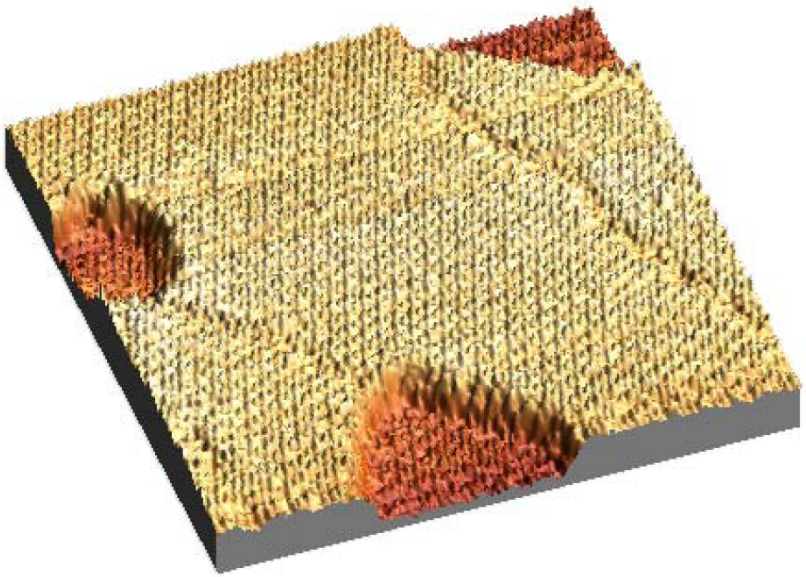


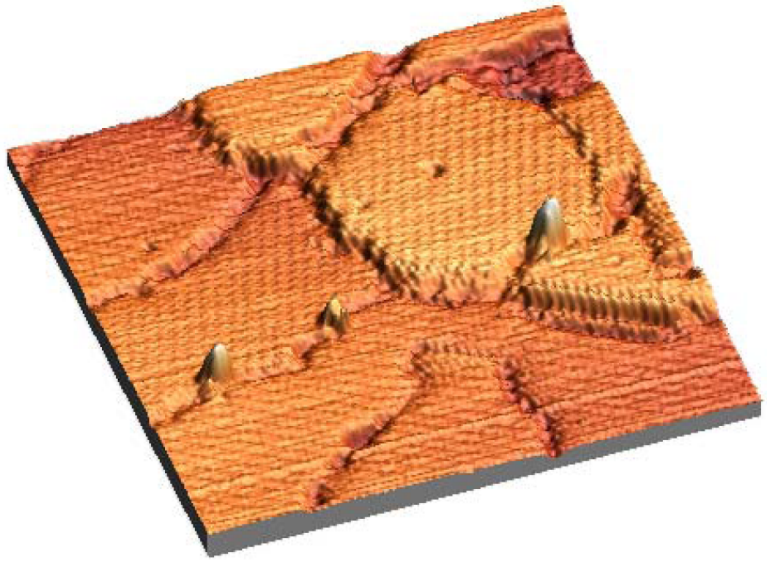
etails.

STM

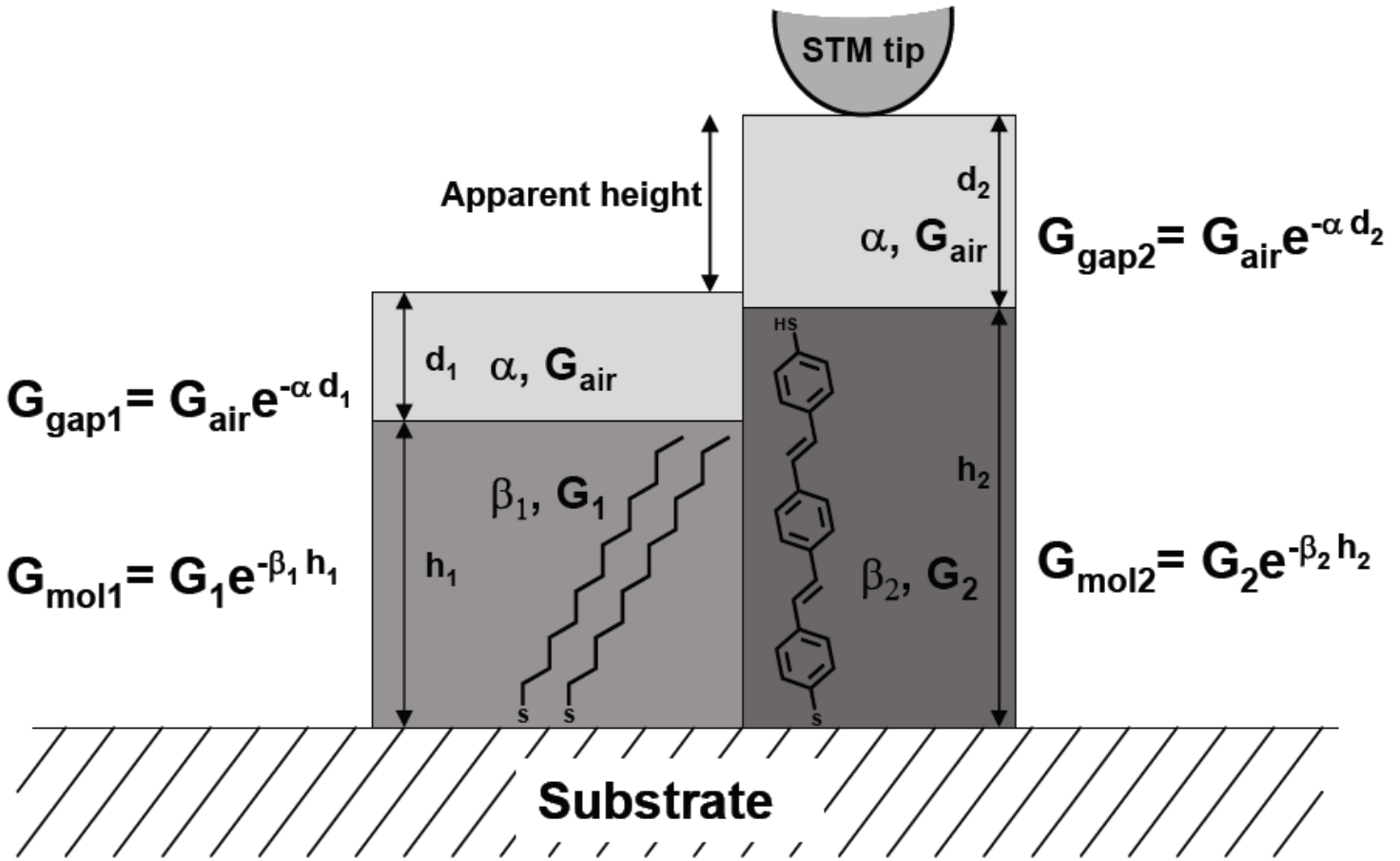
Goal: to compare the tunnelling properties of a series of molecular wires





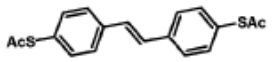
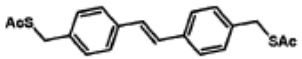
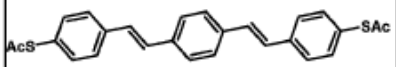
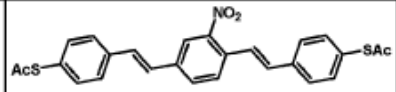
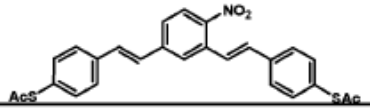
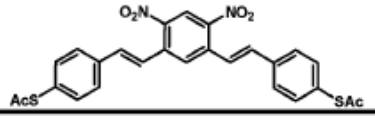
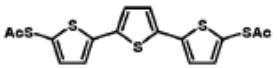
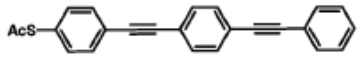
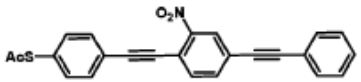
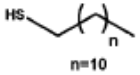


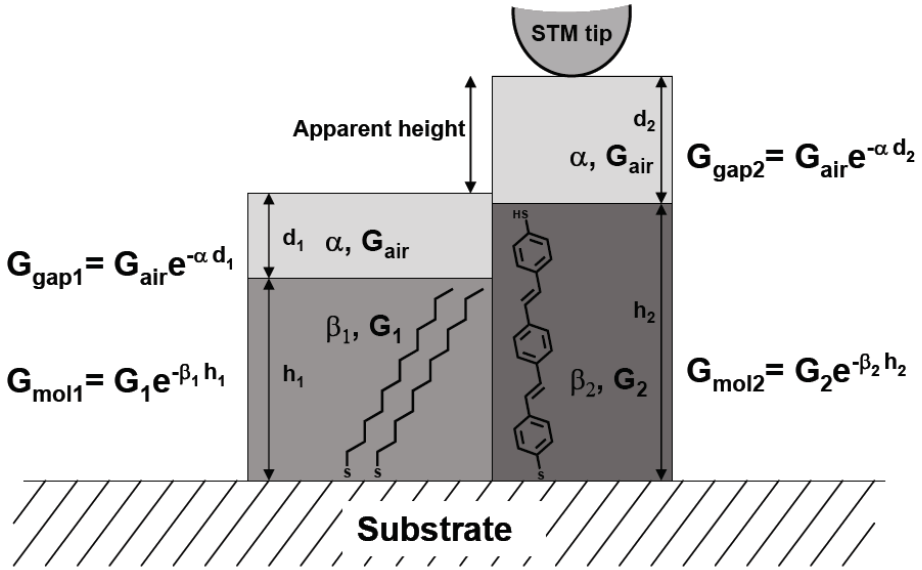
Nano Letters, 5 (4): 783-785 **2005**



Assumption: $G_1 \approx G_2$

Nano Letters, 5 (4): 783-785 **2005**

Entry	Molecule	Length (Å)	Apparent height (Å)
1		13.9	4.0 ±0.7
2		14.2	3.5 ±1.0
3		19.5	7.5 ±1.1
4		19.4	6.1 ±2.0
5		16.5	4.1 ±1.6
6		15.9	4.2 ±0.9
7[6]		13.7	2.0 ±0.9
8[2]		19.3	4.70 ±1.01
9[2]		19.3	4.30 ±0.54
10[12]		14	0.0



STM

+ easy comparison of tunnelling through different molecules

- No control of electronic levels in the molecule

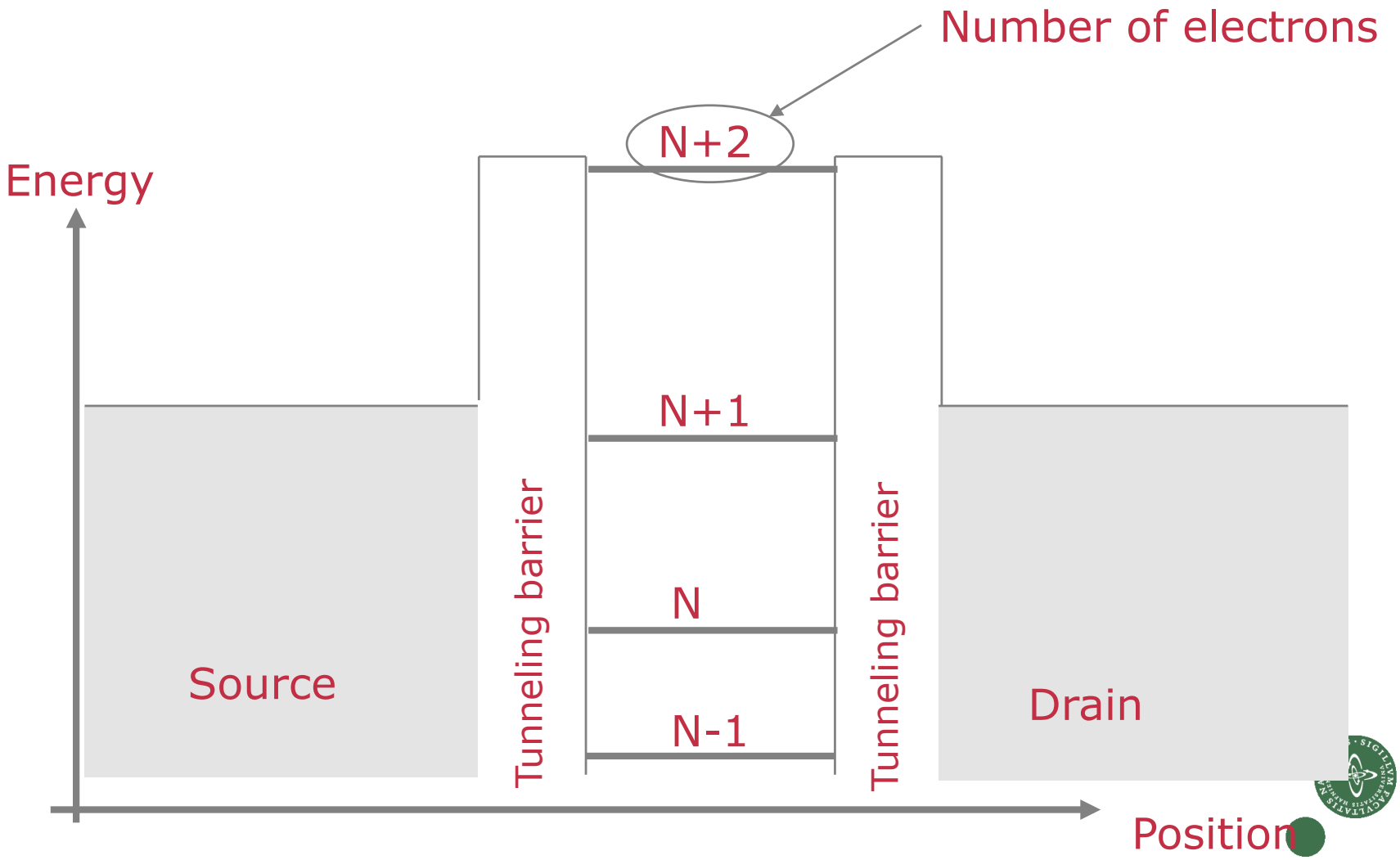
Solid state 3 terminal device

+ detailed spectroscopic characterisation of the molecule

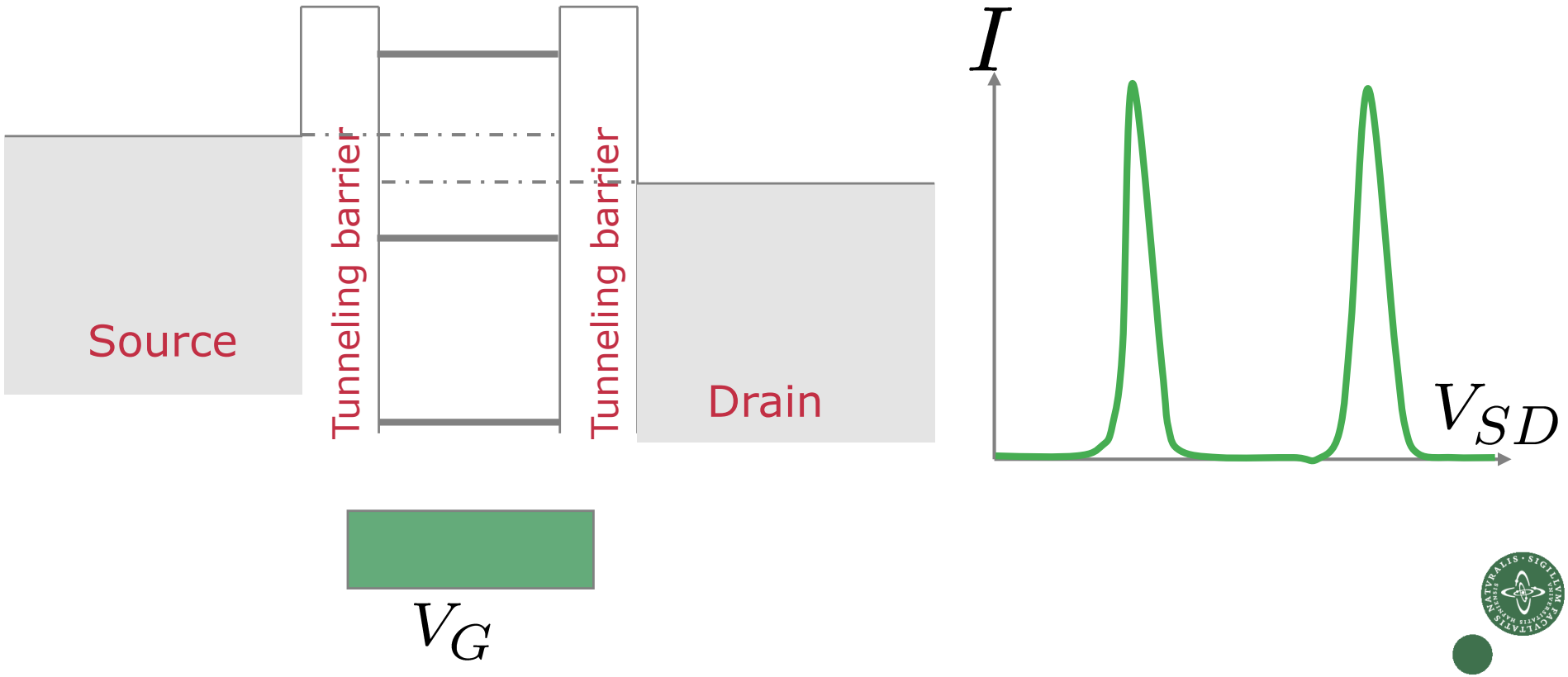
Goal: to study the importance of the contacts between molecule and leads

Faraday Discussions 131: 265-279 **2006**
J. Am. Chem. Soc. 128 (20): 6574-6575 **2006**

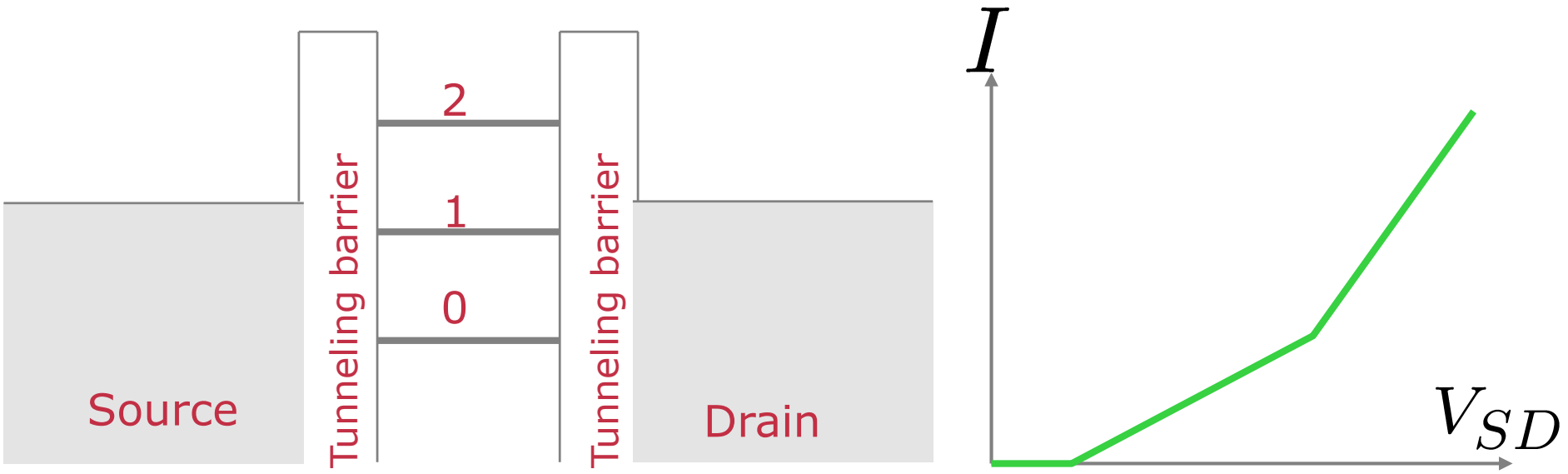
Energy Levels

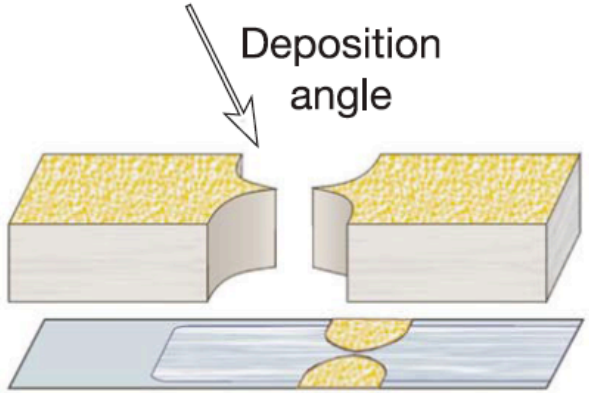


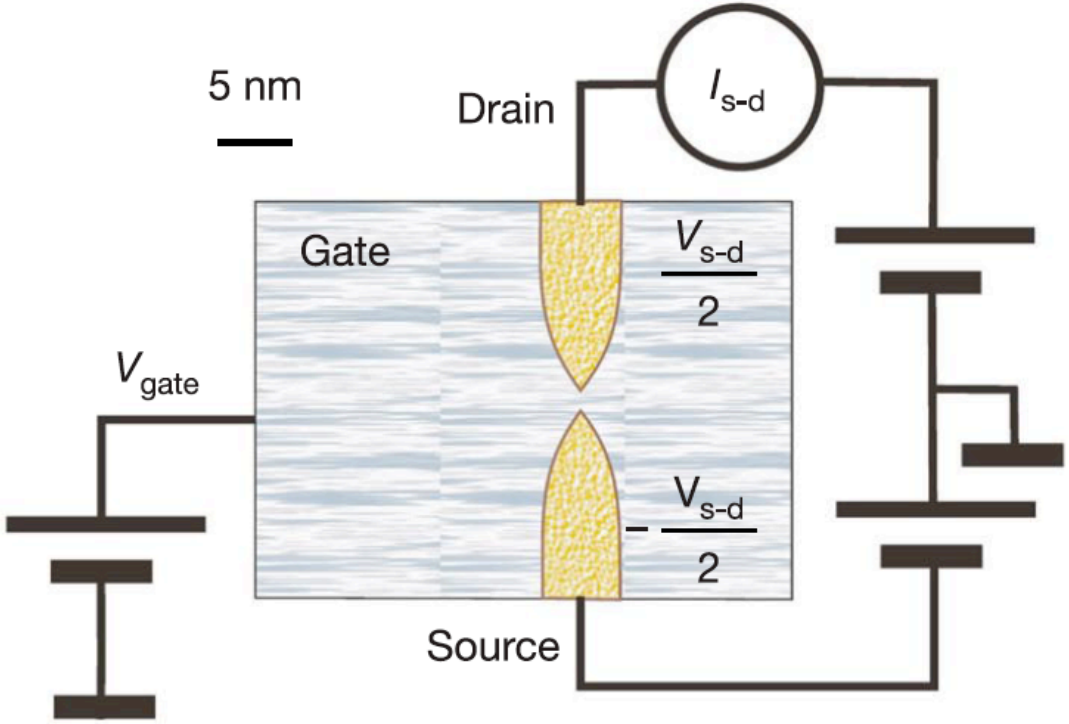
Varying Gate voltage



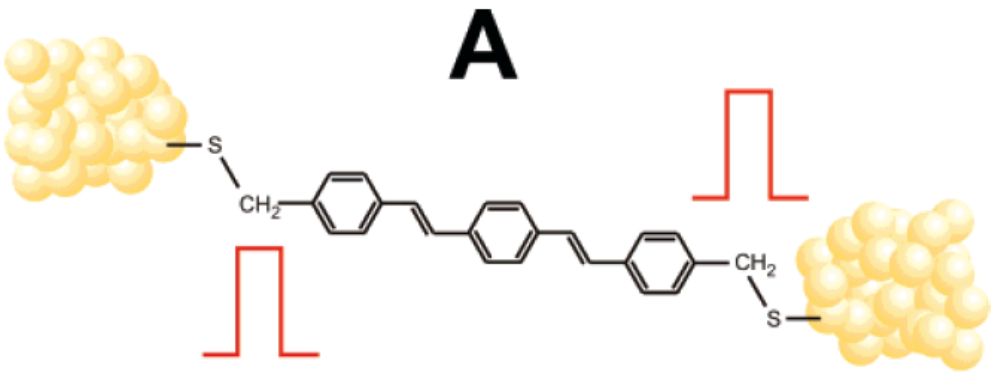
Varying Source-drain voltage







Kubatkin et al. *Nature* 426 (2003)

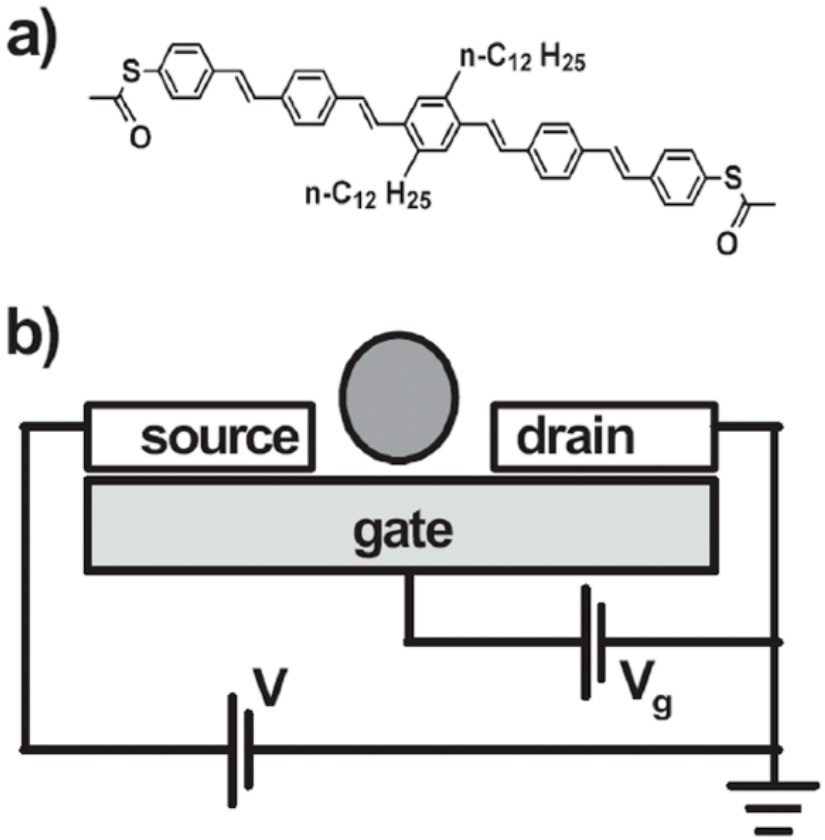


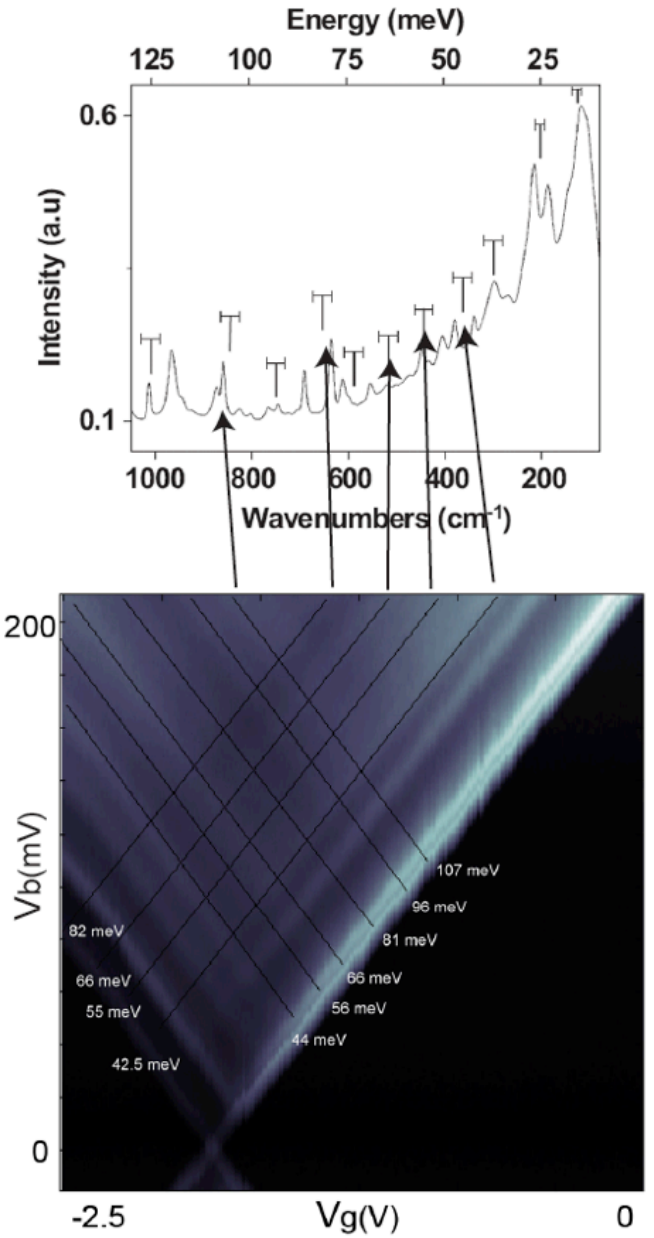
Nano Letters 8 (1) 1-5, **2008**

How can we be sure that we are measuring on a single molecule?

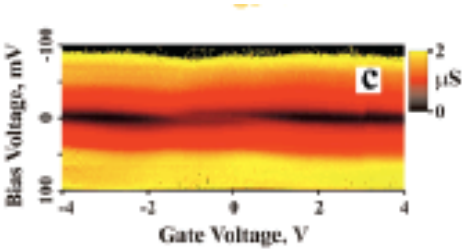
What is special about molecules?

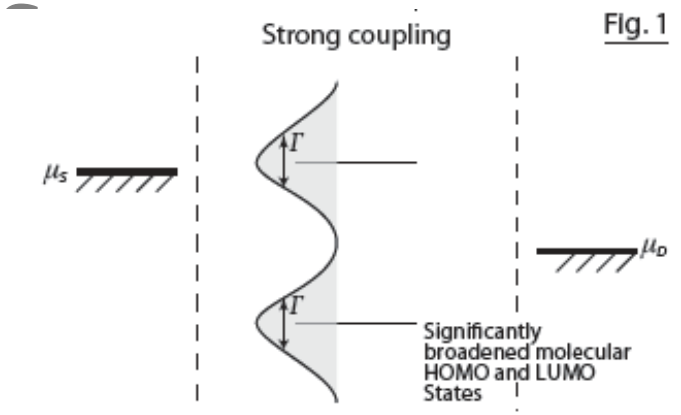
- Molecular vibrations

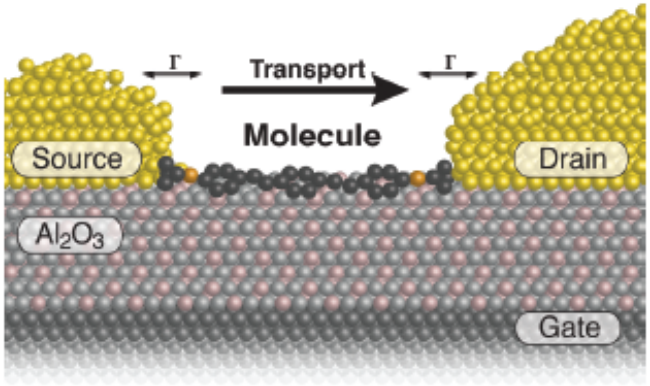


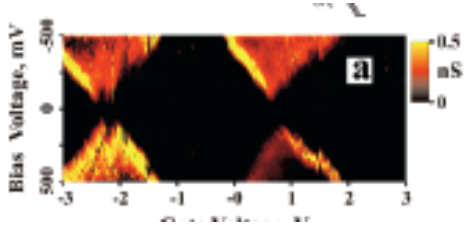


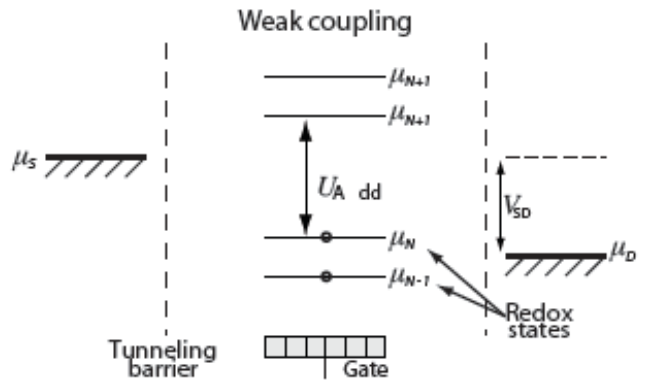
Osorio, van der Zant and co-workers *Adv. Mater*. 19, 281 (2007)











Nano Letters 8 (1) 1-5, **2008**

Outline:

1) Measurements on thiol end-capped OPV's

2) *C60*

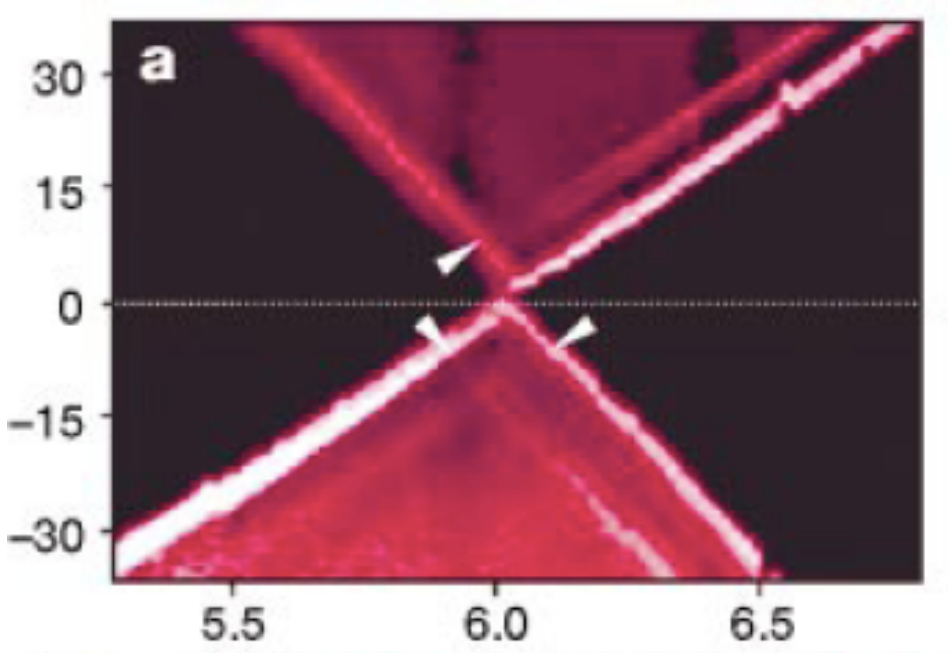
3) C60 as the *"alligator clip"*: a new generation of molecules

Nanomechanical oscillations in a single-C_{60} transistor

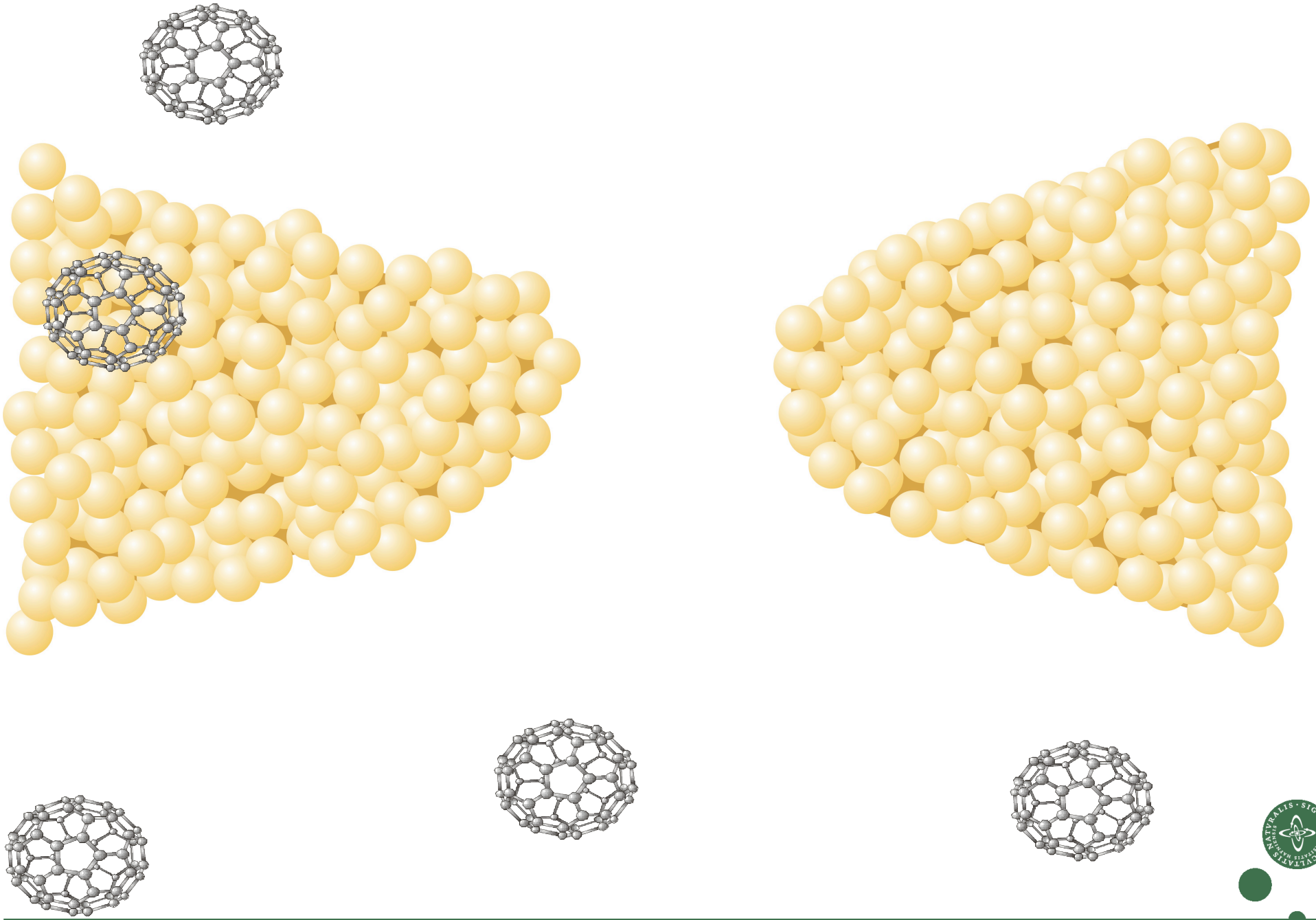
Hongkun Park*‡§, Jiwoong Park†, Andrew K. L. Lim*, Erik H. Anderson‡, A. Paul Alivisatos*‡ & Paul L. McEuen†‡

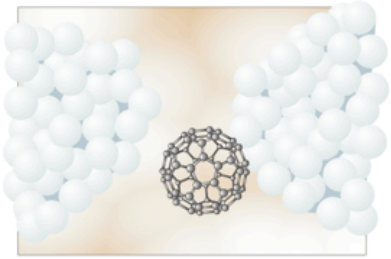
** Department of Chemistry and † Department of Physics, University of California at Berkeley and ‡ Materials Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA*

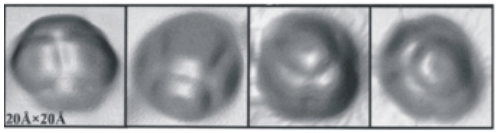
C60 as a model system, *Nature* (2000)

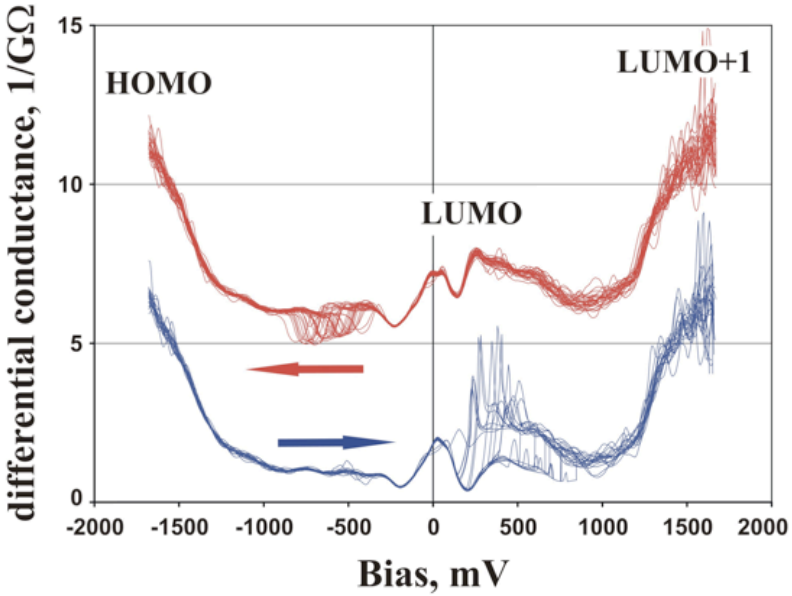


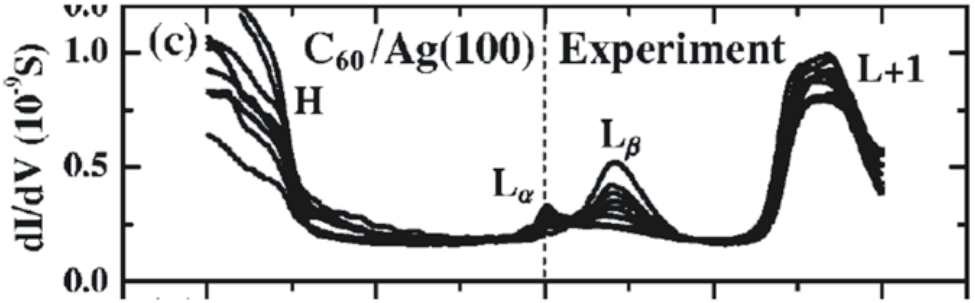
Nanofabrication: catching a single molecule











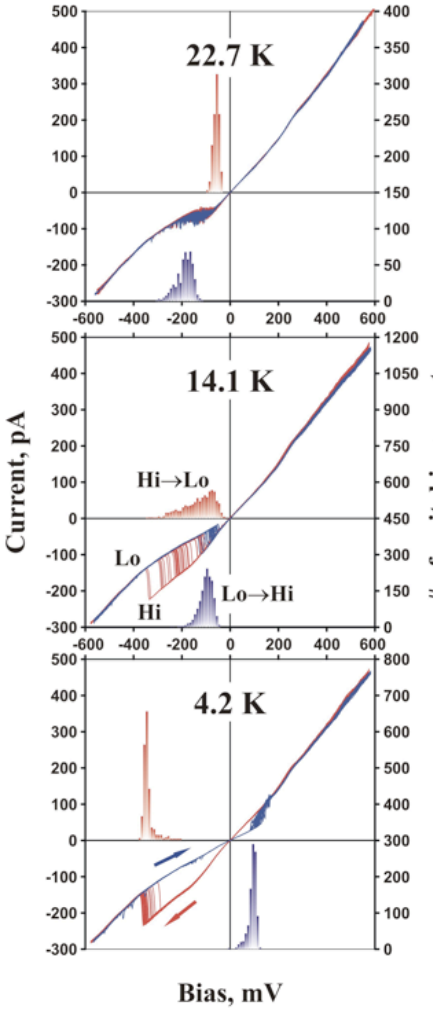
VOLUME 90, NUMBER 9 PHYSICAL REVIEW LETTERS week ending 7 MARCH 2003

Spatially Mapping the Spectral Density of a Single C_{60} Molecule

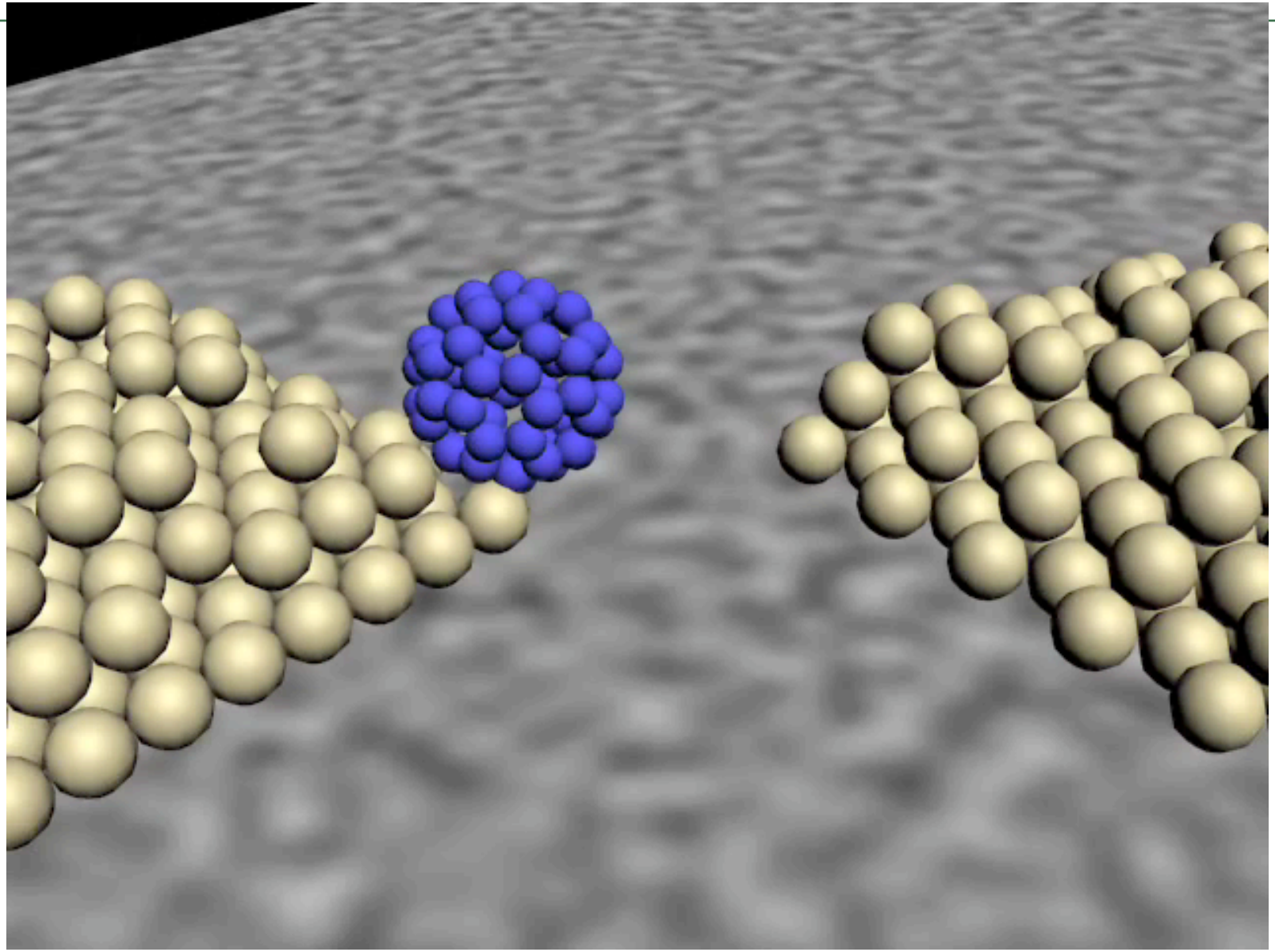
Xinghua Lu, M. Grobis, K. H. Khoo, Steven G. Louie, and M. F. Crommie

Danilov/Kubatkin

Dripling C_{60} for six weeks

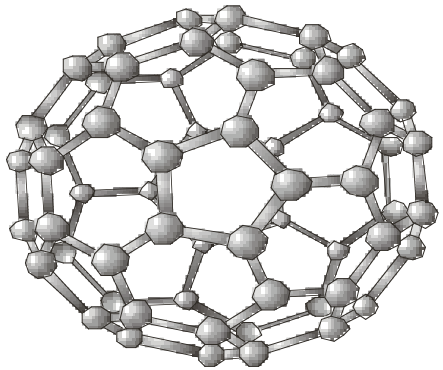


Faraday Discuss., 131, 337–345 (2006)
Nano Lett. 8, 2393-2398 (2008)
Nanotechnology 18, 165501 (2007)



Danilov, Kubatkin Nano Lett 2008

Summary C60:



- In this experimental setup, C60 is strongly coupled to the electrodes*

-The C60 switches between 2 different states, the system is stable for more than 6 weeks
-The two states might be attachment via 5 or 6 fold symmetry possitions

* In contrast to measurements by Park and McEuen *Nature* 2000

Faraday Discuss. 131, 337–345 (2006)
Nano Lett. 8, 2393-2398 (2008)
Nanotechnology 18, 165501 (2007)

Outline:

1) Measurements on thiol end-capped OPV's

2) *C60*

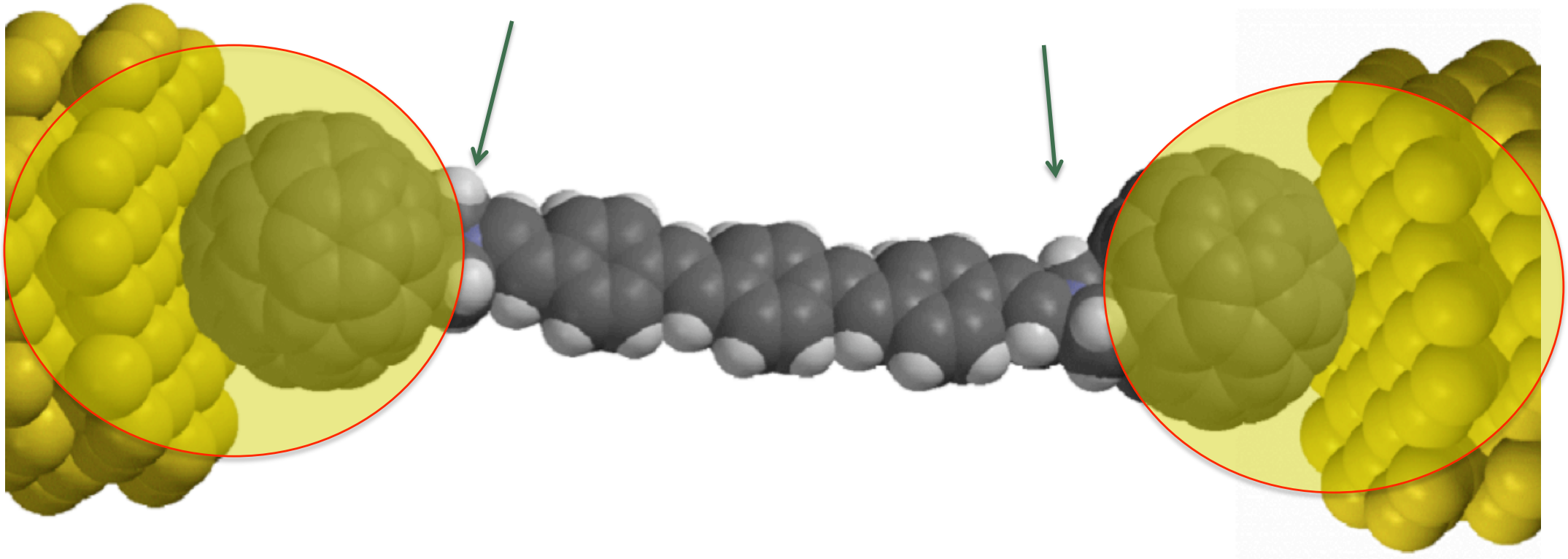
3) C60 as the *"alligator clip"*: a new generation of molecules

-In molecules, the atoms are placed in a well defined way with respect to eachother

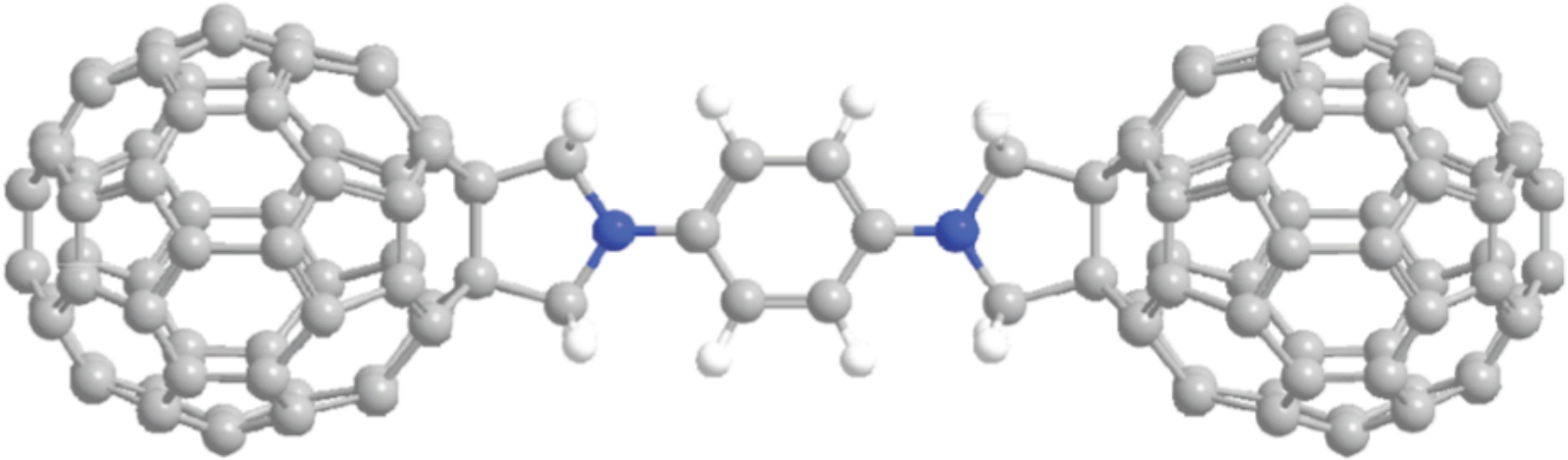
- The problem is the electrodes, and the interface between molecule and electrode

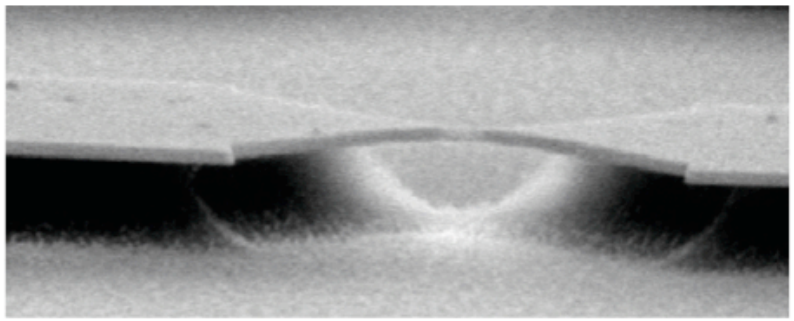
- Since C60 couples strongly to electrodes we might be able to use it to contact a molecule!

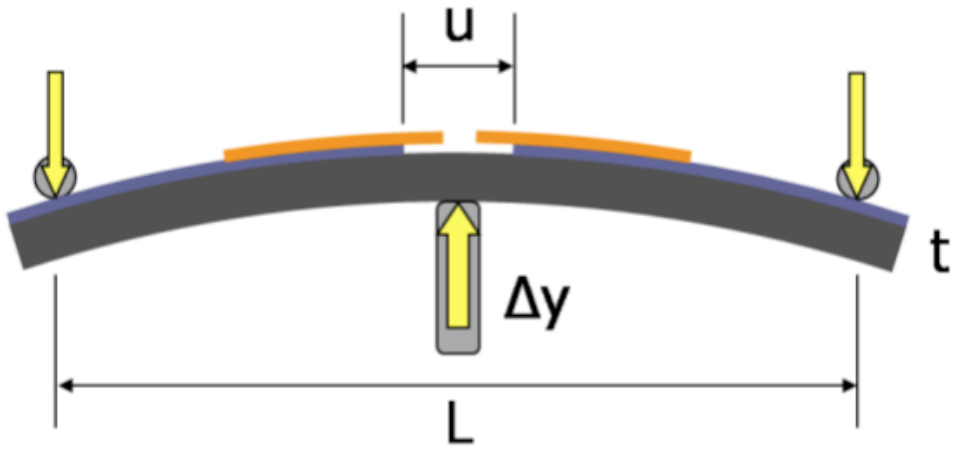
Covalent defined interface



(not yet gated) mechanical break junctions





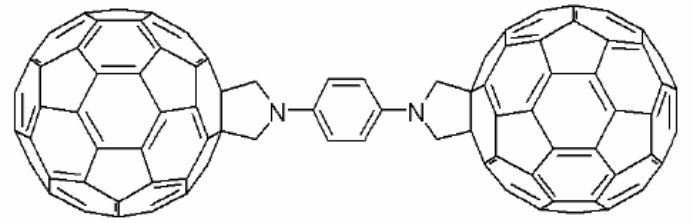


January 25, 2008

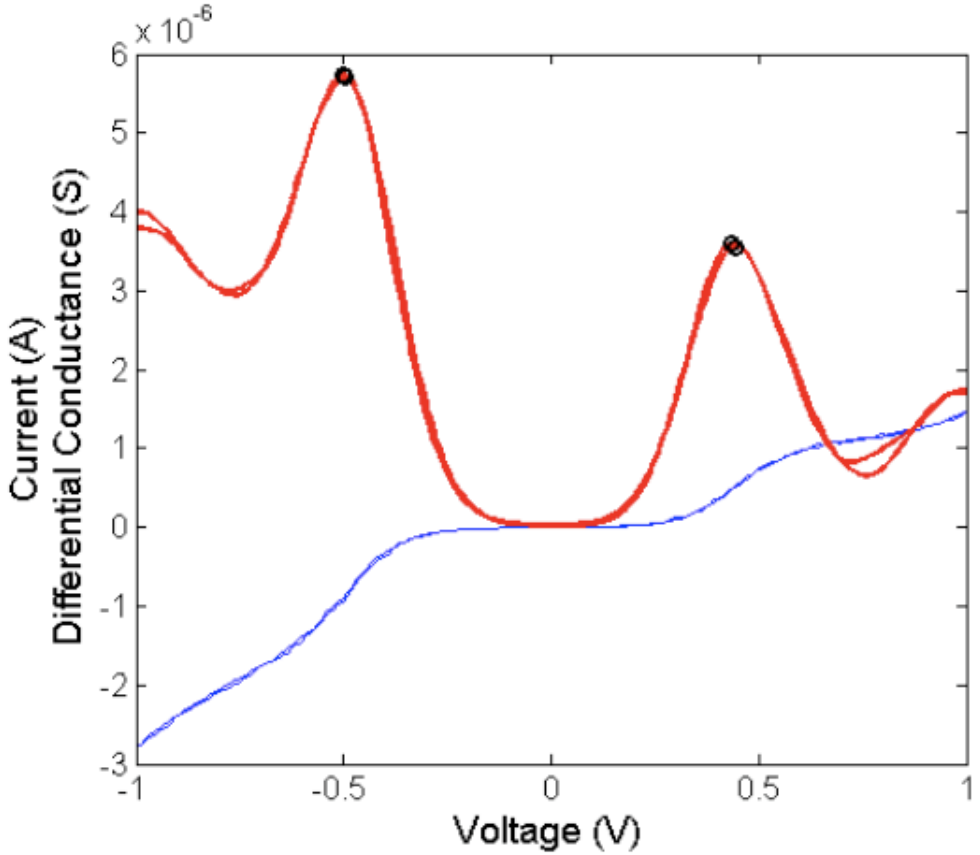
Christian Martin
Work done in collaboration with Jan van Ruitenbeek

TU Delft

Very stable current-voltage characteristics



Room temperature measurements.



Martin, Ruitenbeek, van der Zant JACS 2008 (accepted)

TU Delft

Summary:

- We have used STM to compare the tunnelling through different molecules

-We have used *three terminal measurements* to reveal details about the electron transport through single molecules

-We have tested C60 as a new type of alligator clip, and thereby defining the important interface between molecule and electrodes by covalent chemistry

Thank you!