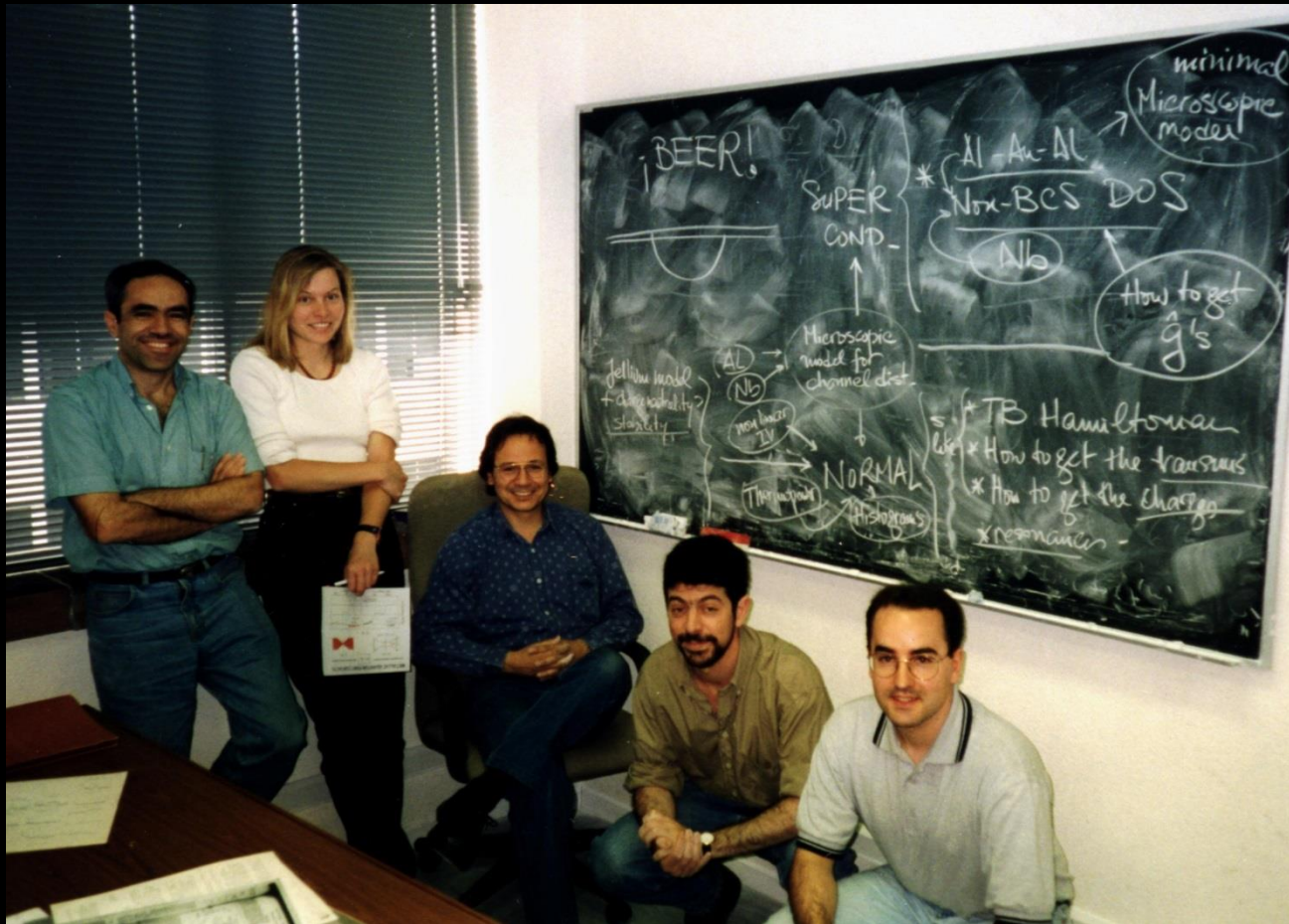
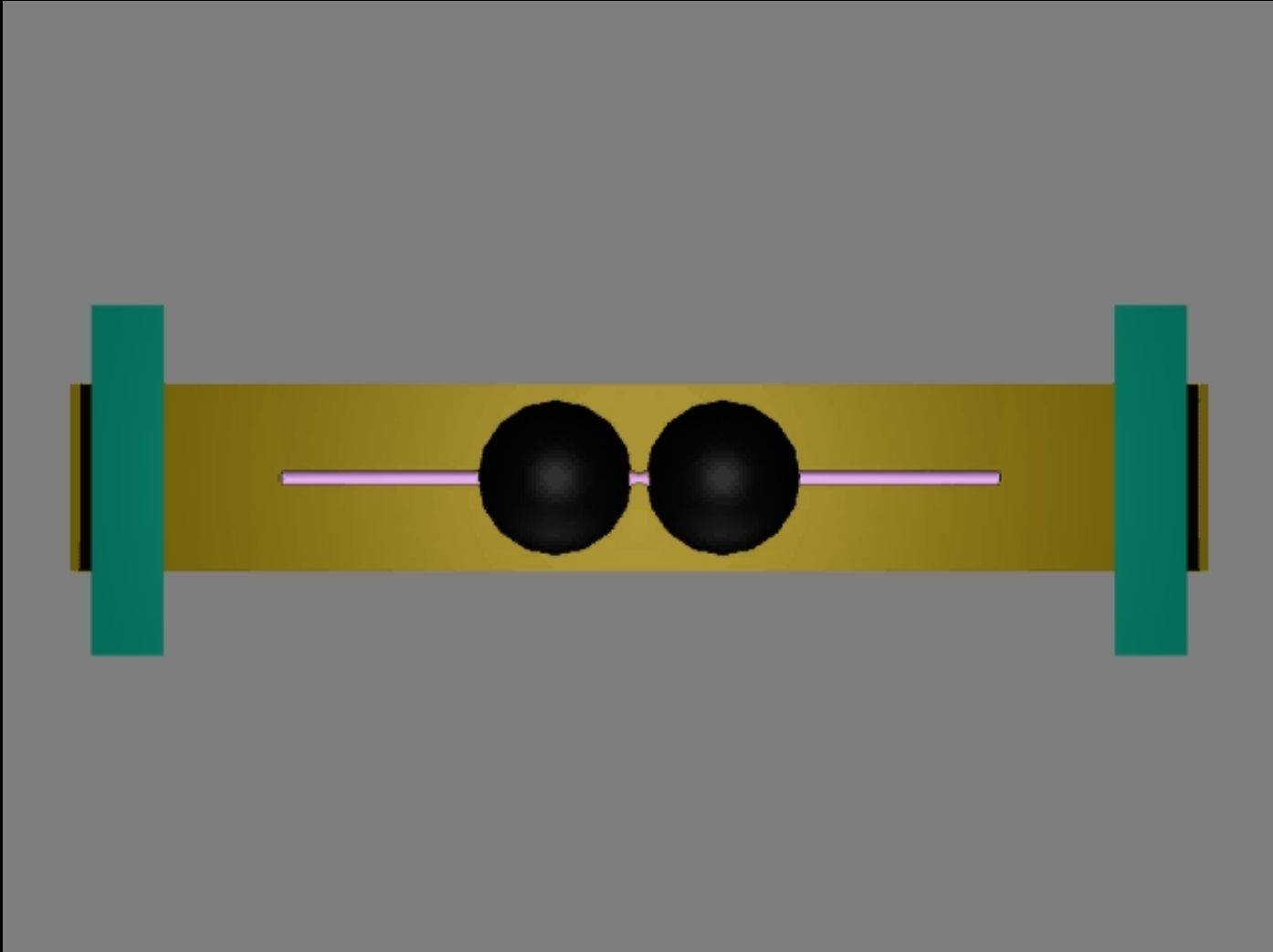


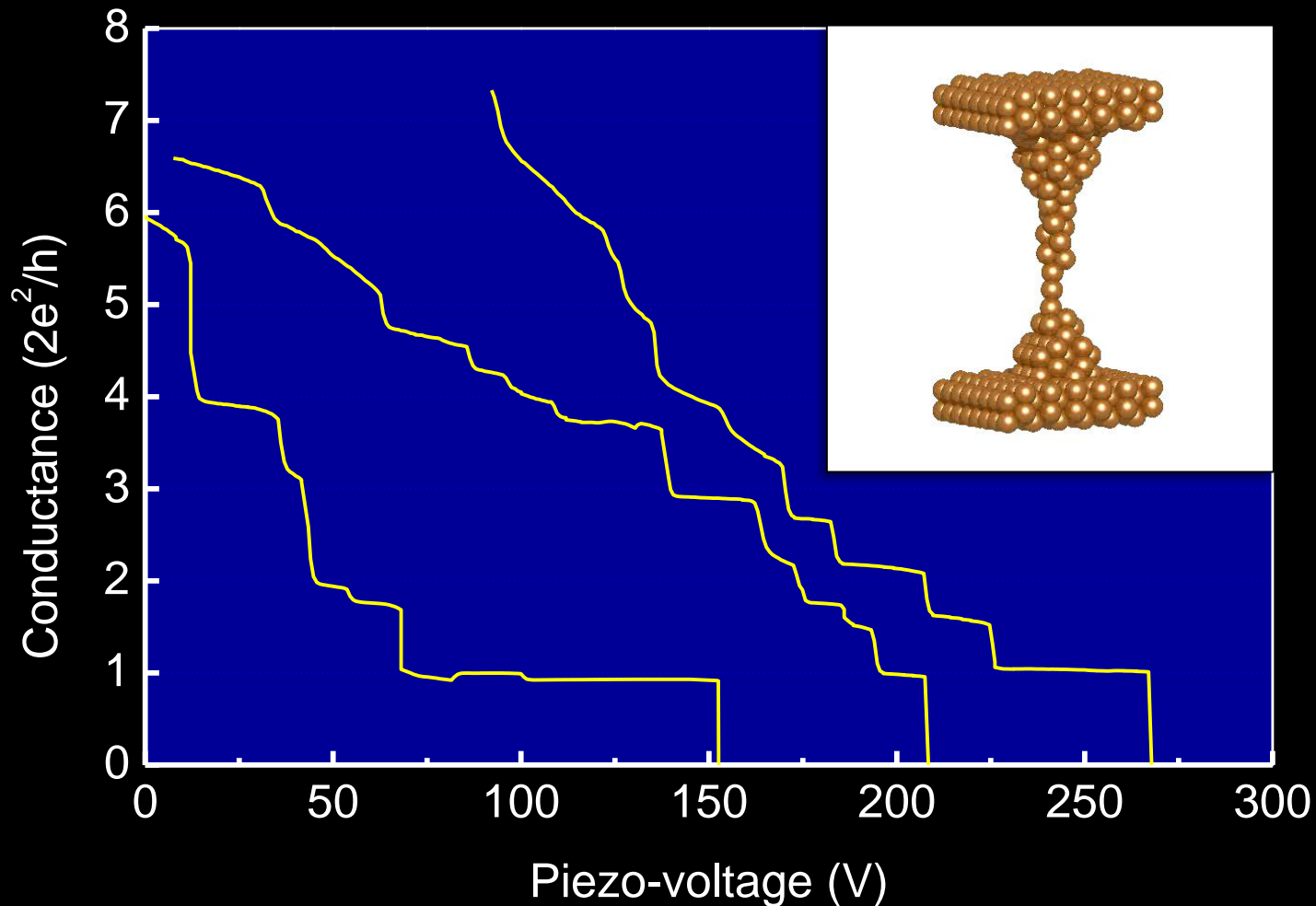
The fun of breaking things



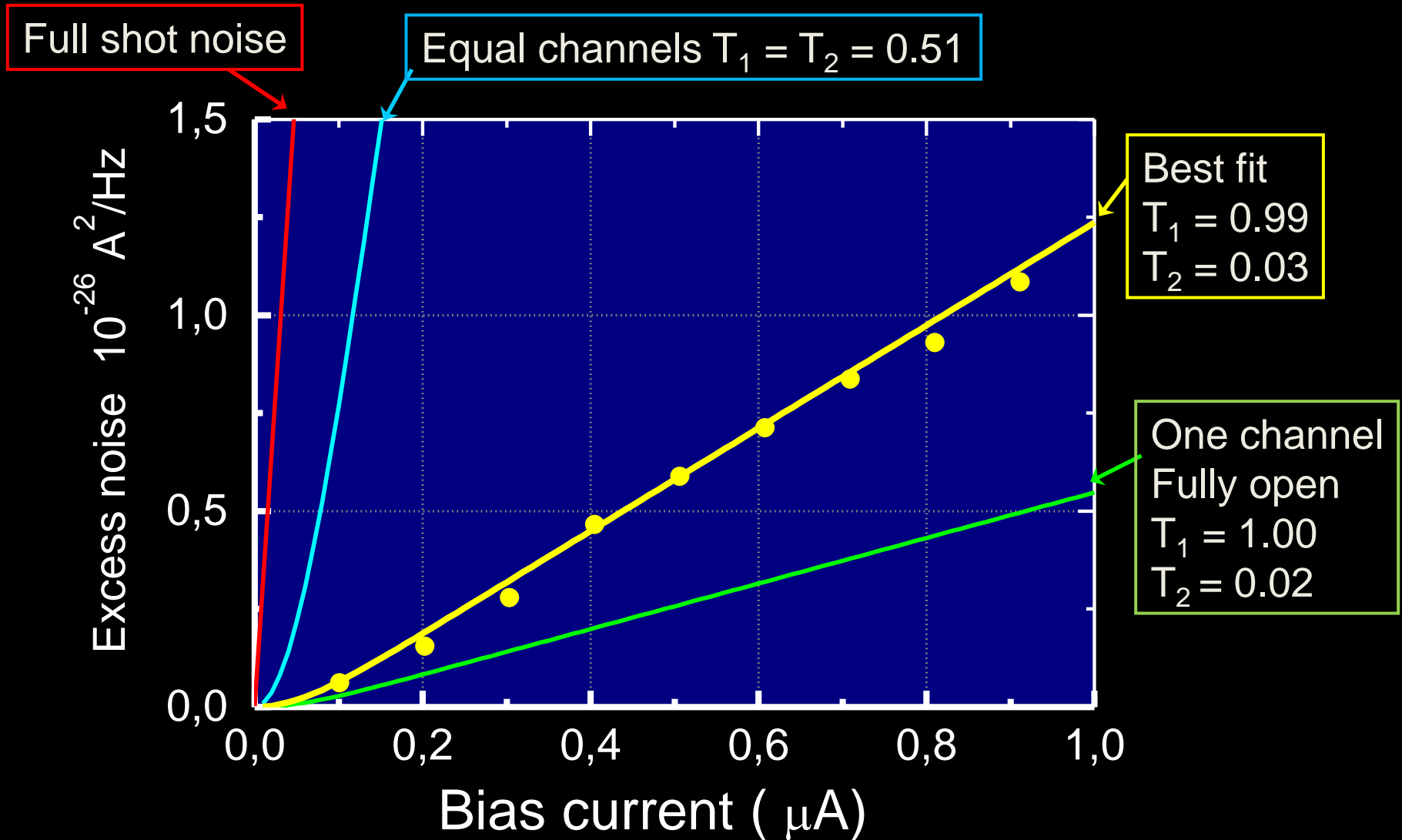
Mechanically Controllable Break Junction



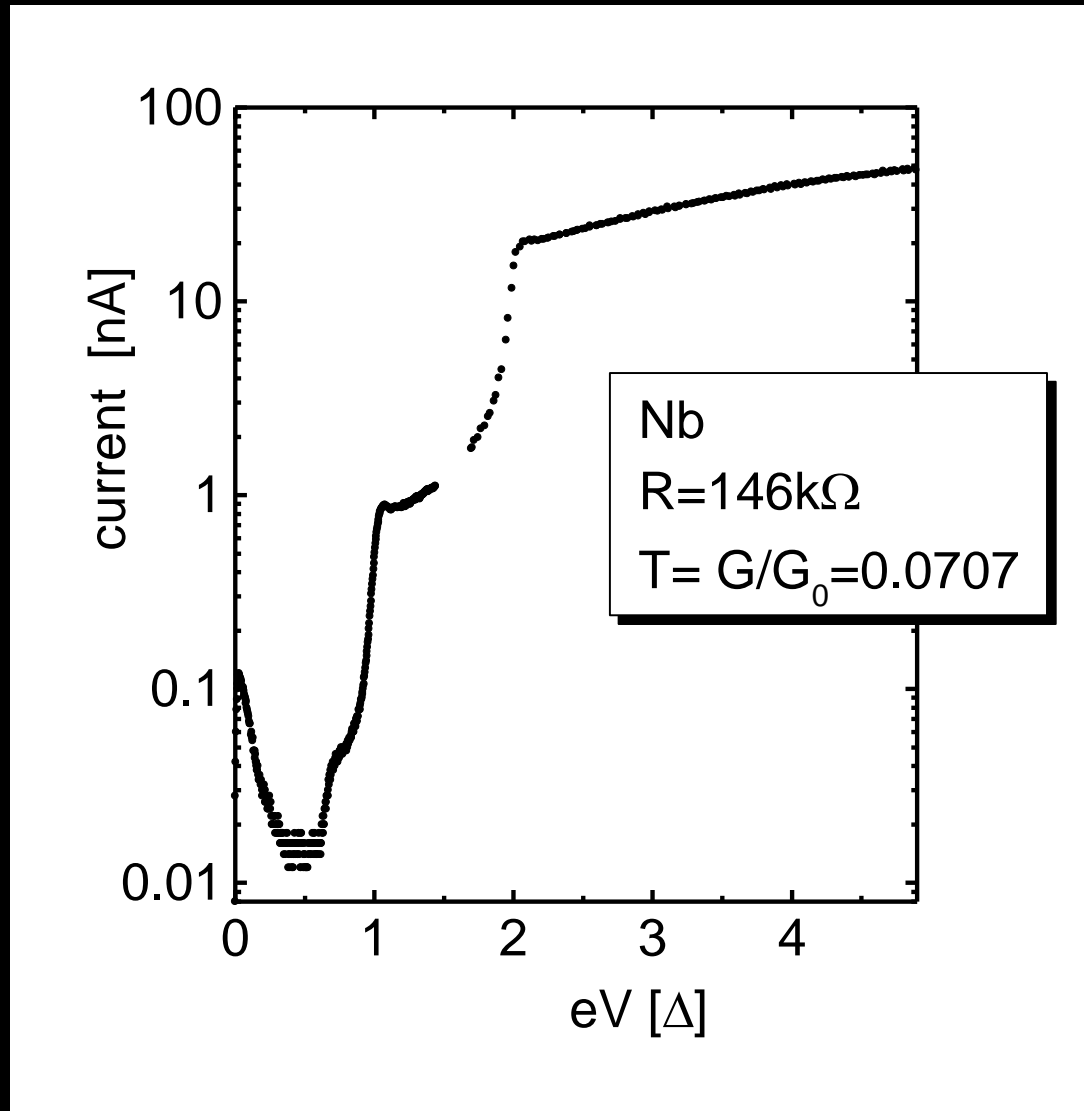
Conductance for Au contacts at 4.2 K



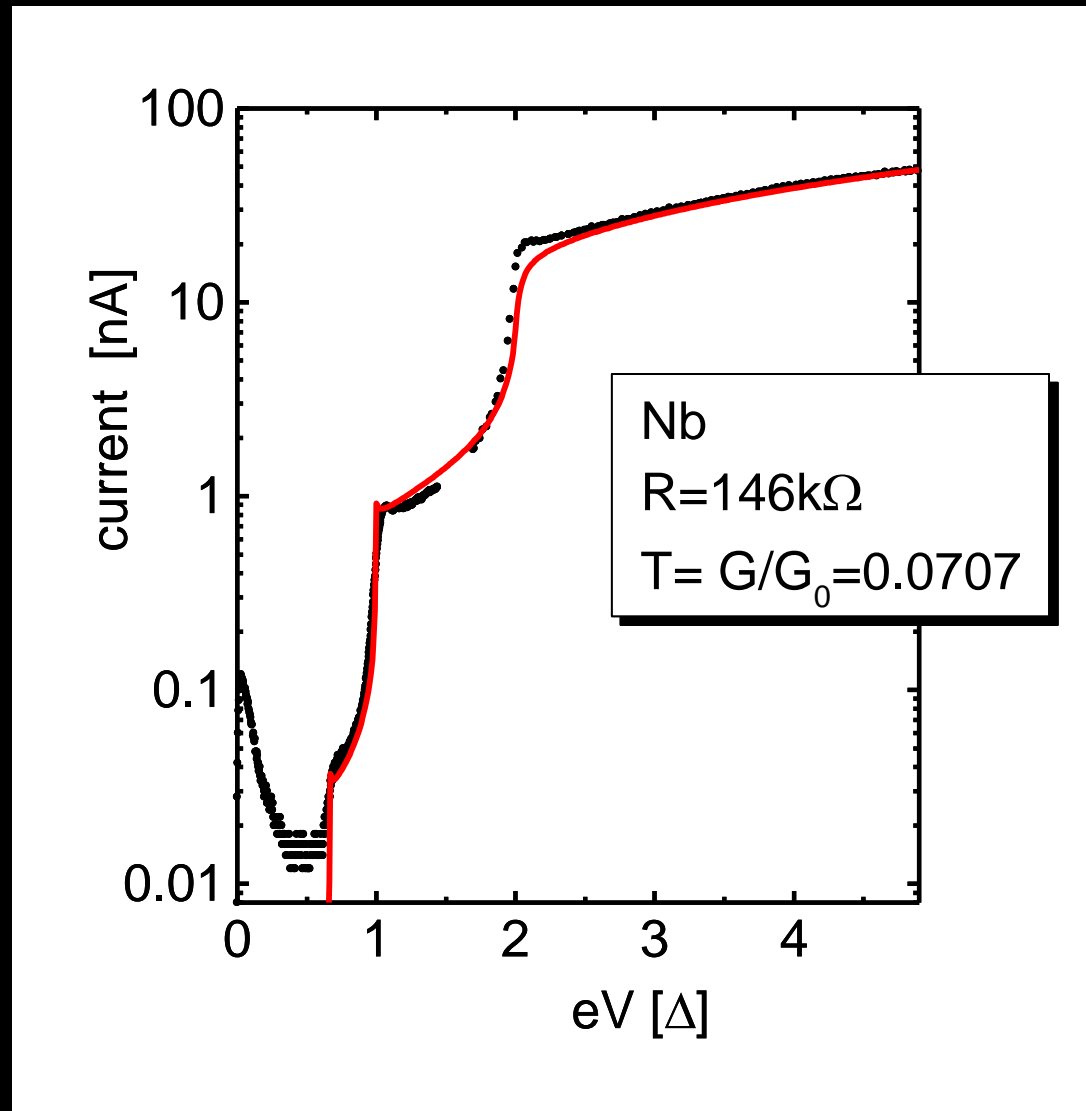
Shot noise as a function of current, Au atomic contact at $G=1.02 G_0$



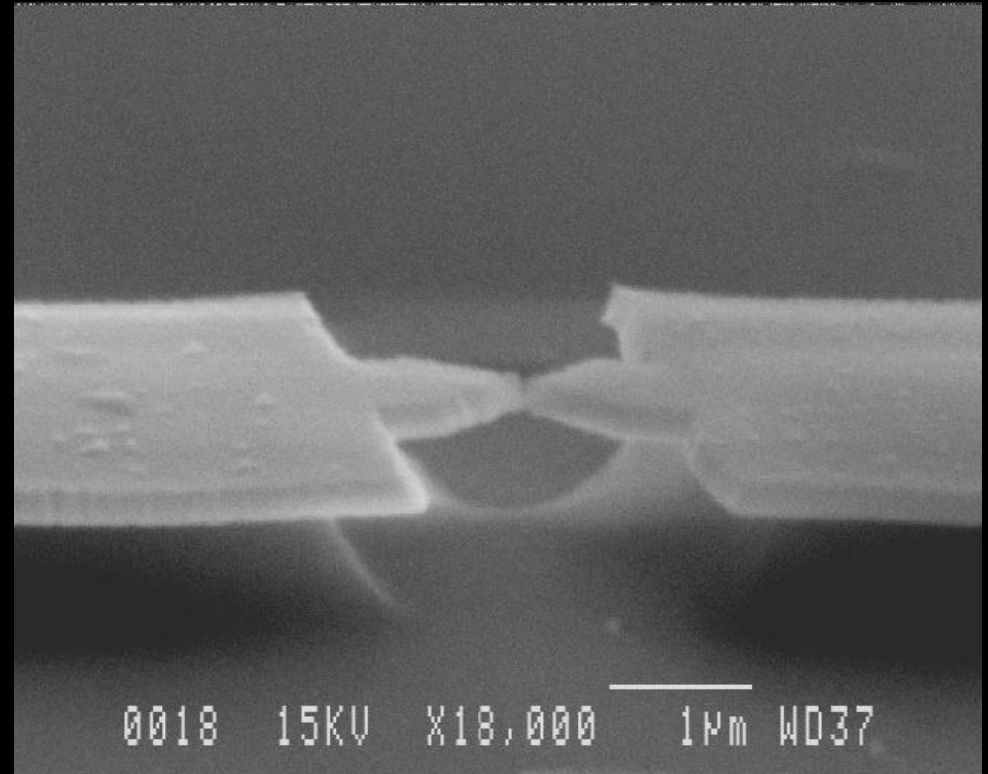
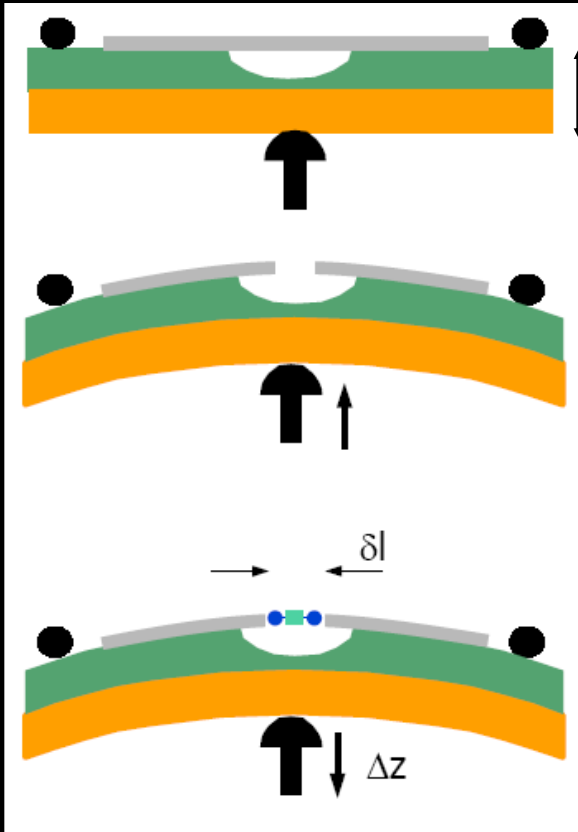
IV-curve for Nb vacuum tunnel junction



IV-curve for Nb vacuum tunnel junction

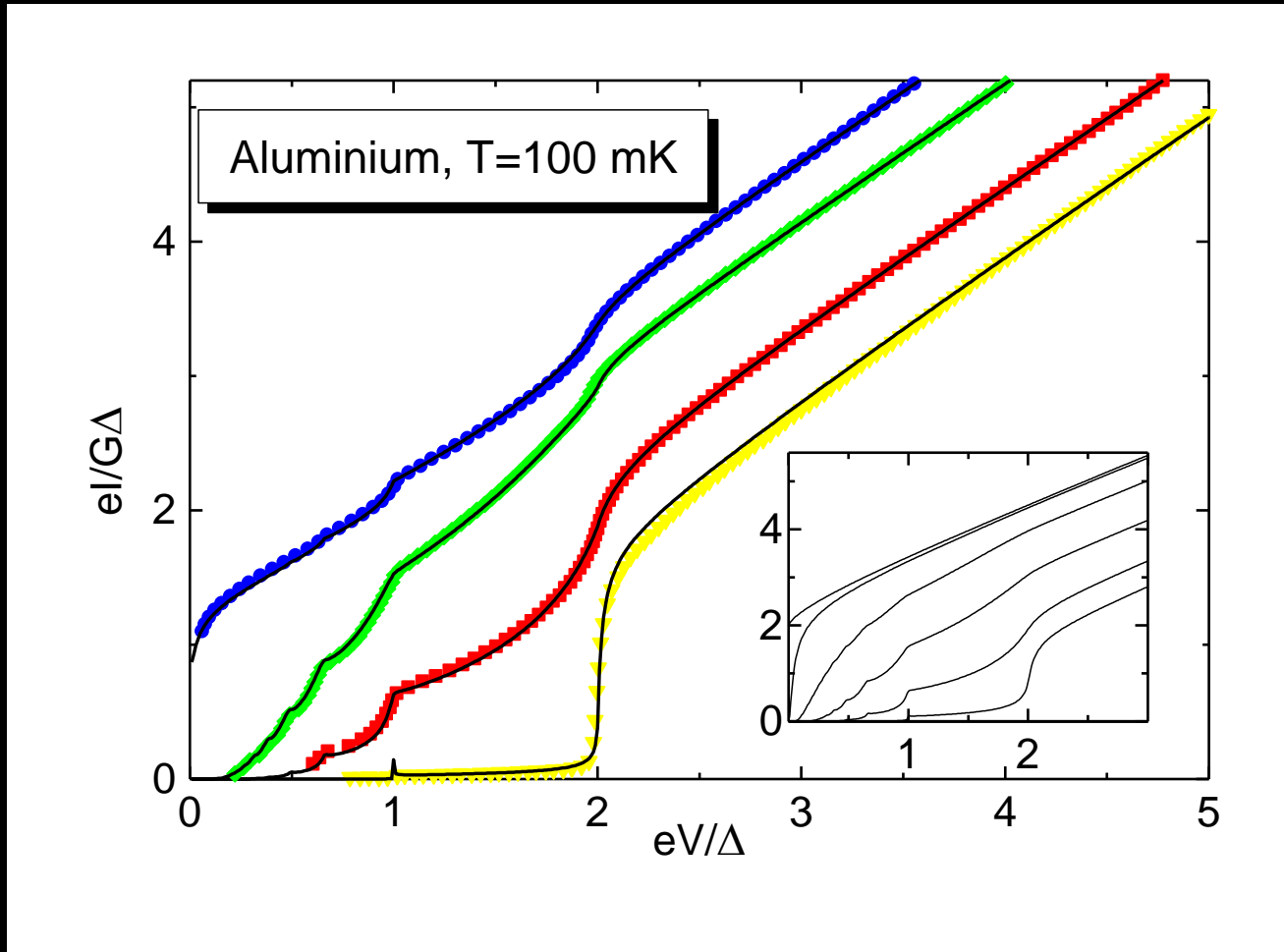


Lithographically fabricated MCBJ



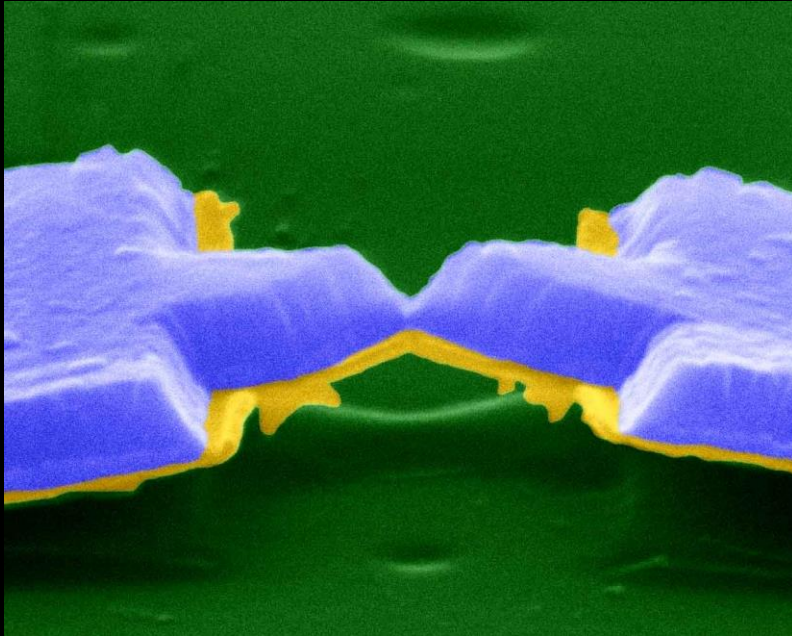
JMvR, Alvarez, Piñeyro, Grahmann, Joyez, Devoret, Esteve, Urbina, Rev. Sci. Instrum. **67** (1995) 108

Reading the transmission probabilities



Scheer, Joyez, Esteve, Urbina, Devoret, *Phys. Rev. Lett.* **78**, 3535 (1997)

The modes determined by valence orbitals

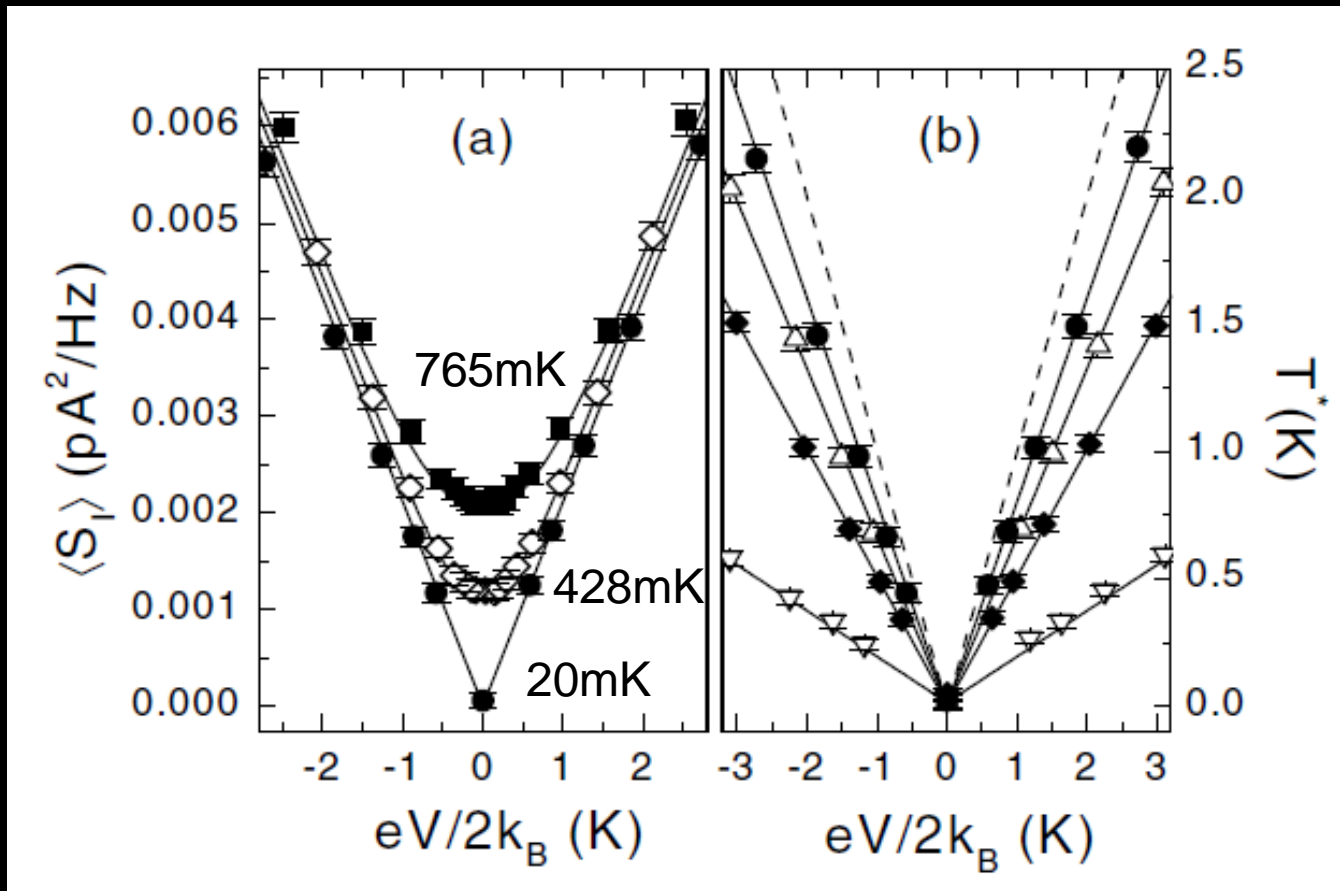


<i>Element</i>	<i>Type of atom</i>	<i>Number of modes</i>	<i>Conductance for one atom</i>
Au	<i>s</i>	1	1 G_0
Al	<i>s-p</i>	3	~0.8-1.2 G
Pb	<i>s-p</i>	3	~2.5-3 G
Nb	<i>s-d</i>	5	~2.5-3 G

Cuevas, Levy Yeyati, Martin-Rodero, Phys. Rev. Lett. **80** (1998) 1066

Scheer, Agraït, Cuevas, Levy Yeyati, Ludoph, Martin-Rodero, Rubio-Bollinger, JMvR, Urbina, Nature **394** (1998) 154

The PIN code is all you need to know



{0.21;0.20;0.20}

{0.40;0.27;0.03}

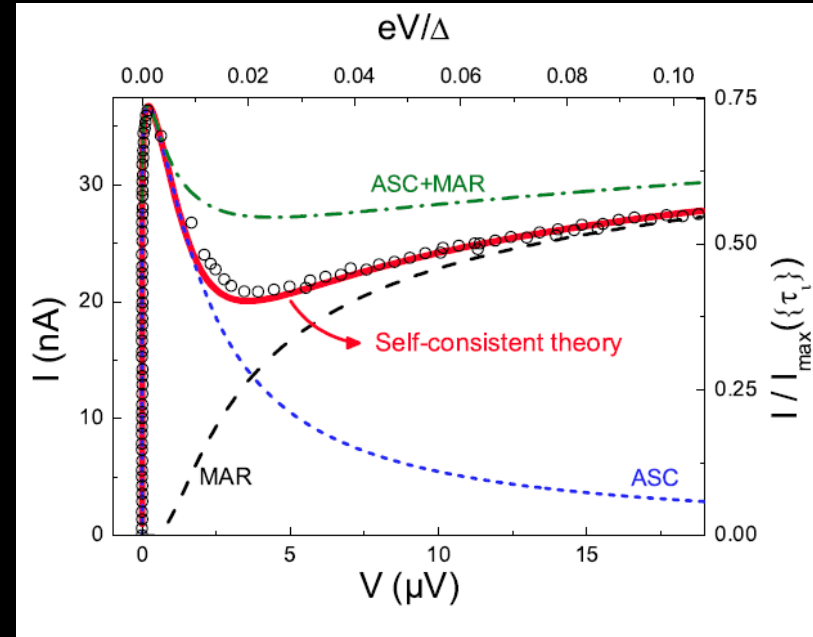
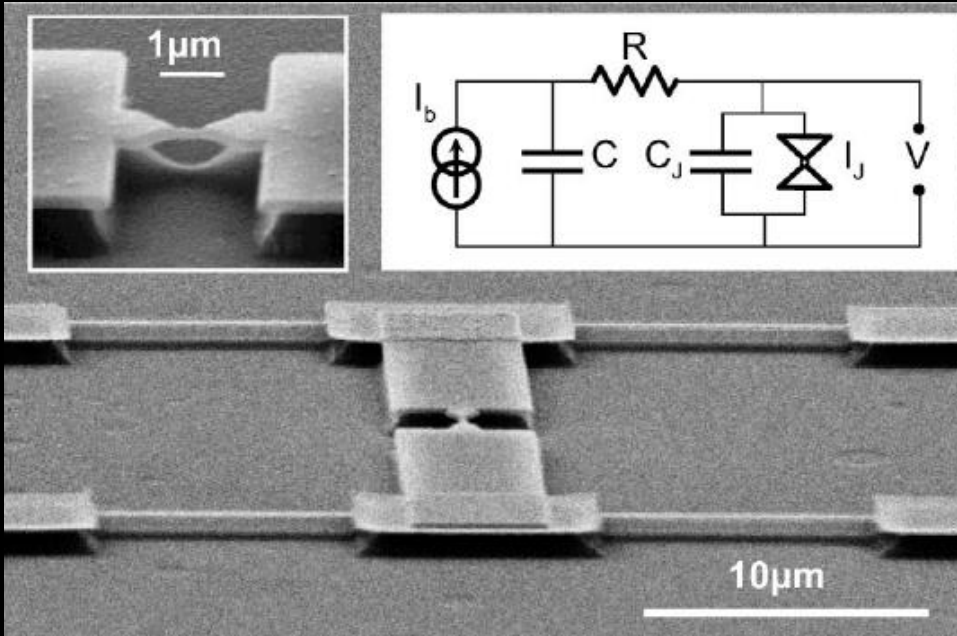
{0.68;0.25;0.22}

{0.996;0.26}

{0.21;0.20;0.20}

Cron, Goffman, Esteve, Urbina, Phys. Rev. Lett. 86, 4104 (2001)

Supercurrent



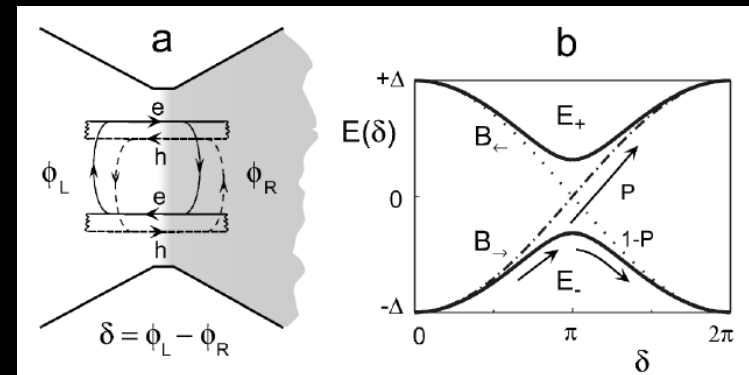
{0.995; 0.372; 0.174; 0.022}

ASC = Adiabatic Super Current

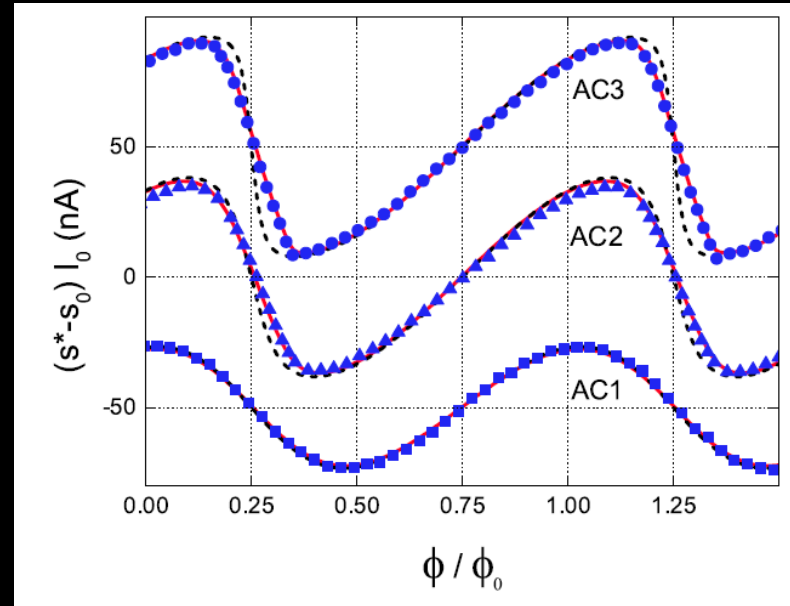
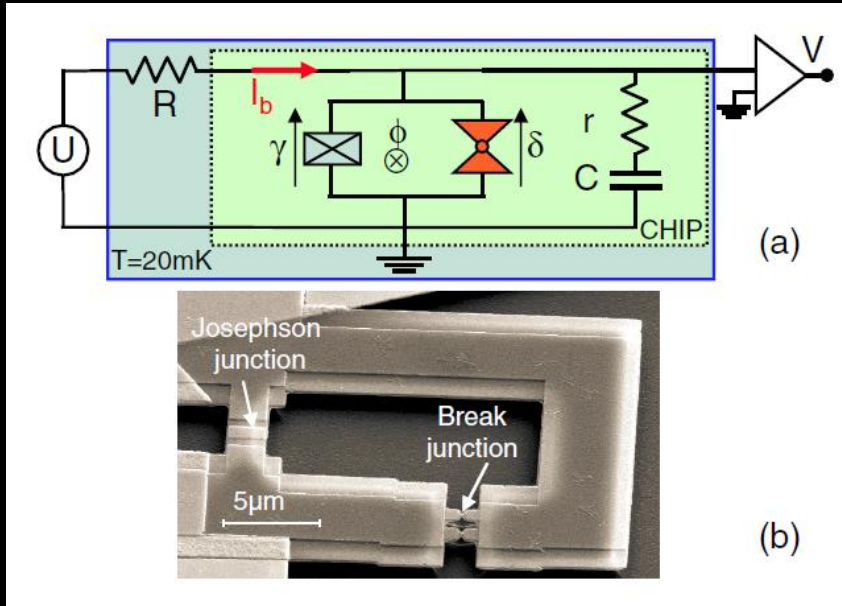
MAR = Multiple Andreev Refelction

Goffman, Cron, Levy Yeyati, Joyez, Devoret, Esteve, Urbina, Phys. Rev. Lett. **85**, 170 (2000)

Chauvin, vom Stein, Esteve, Urbina, Cuevas, Levy yeyati, Phys. Rev. Lett. **99**, 067008 (2007)

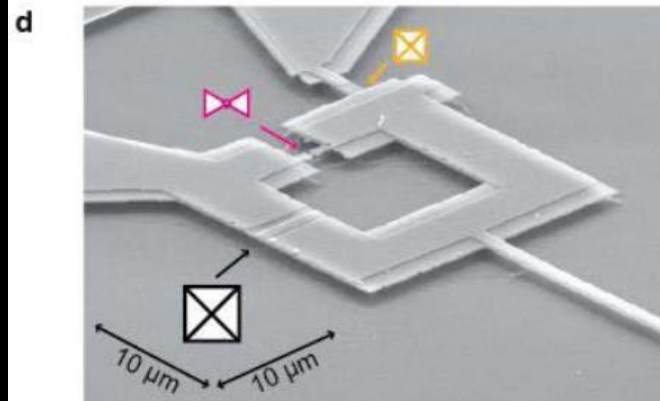
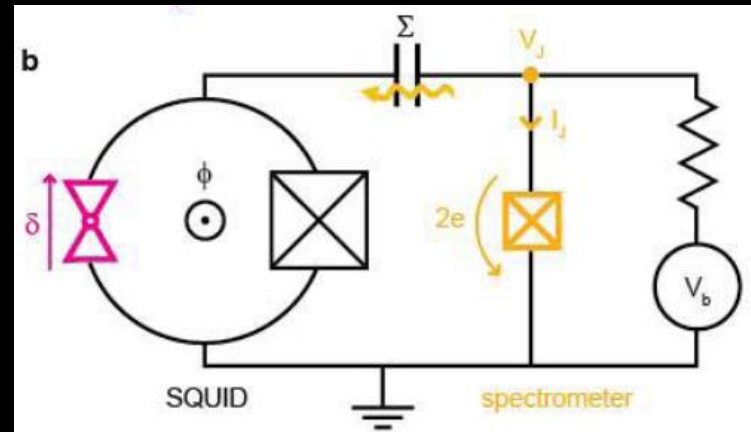
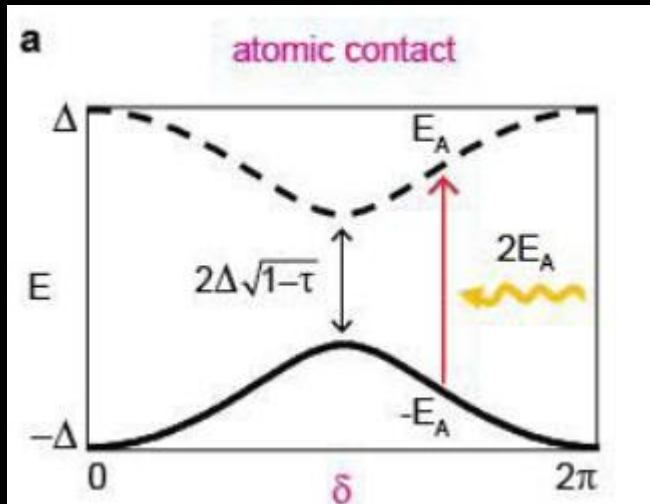


Current-phase relation



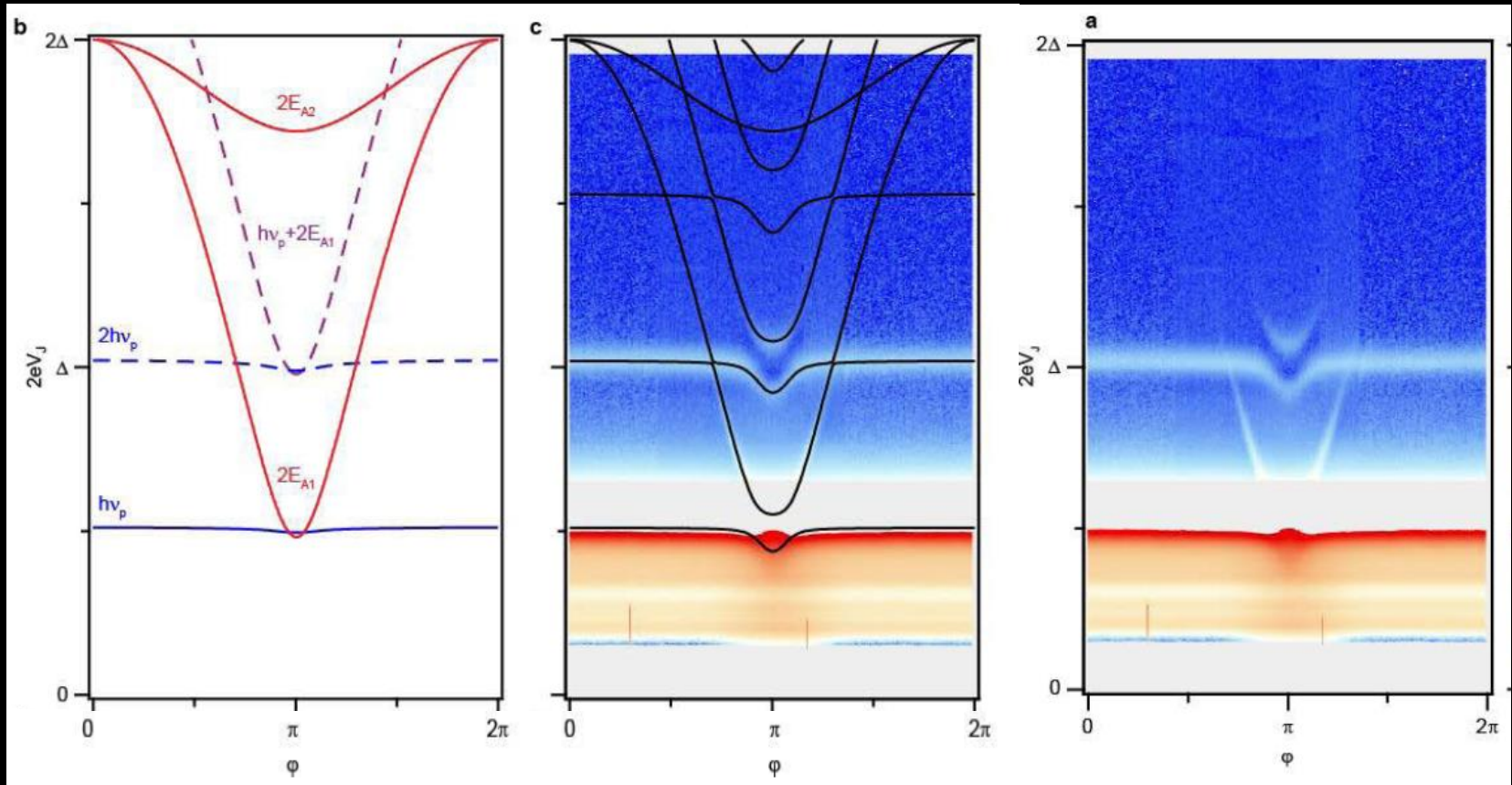
Della Rocca, Chauvin, Huard, Pothier, Esteve, Urbina, Phys. Rev. Lett. **99**, 127005 (2007)

Andreev level spectroscopy



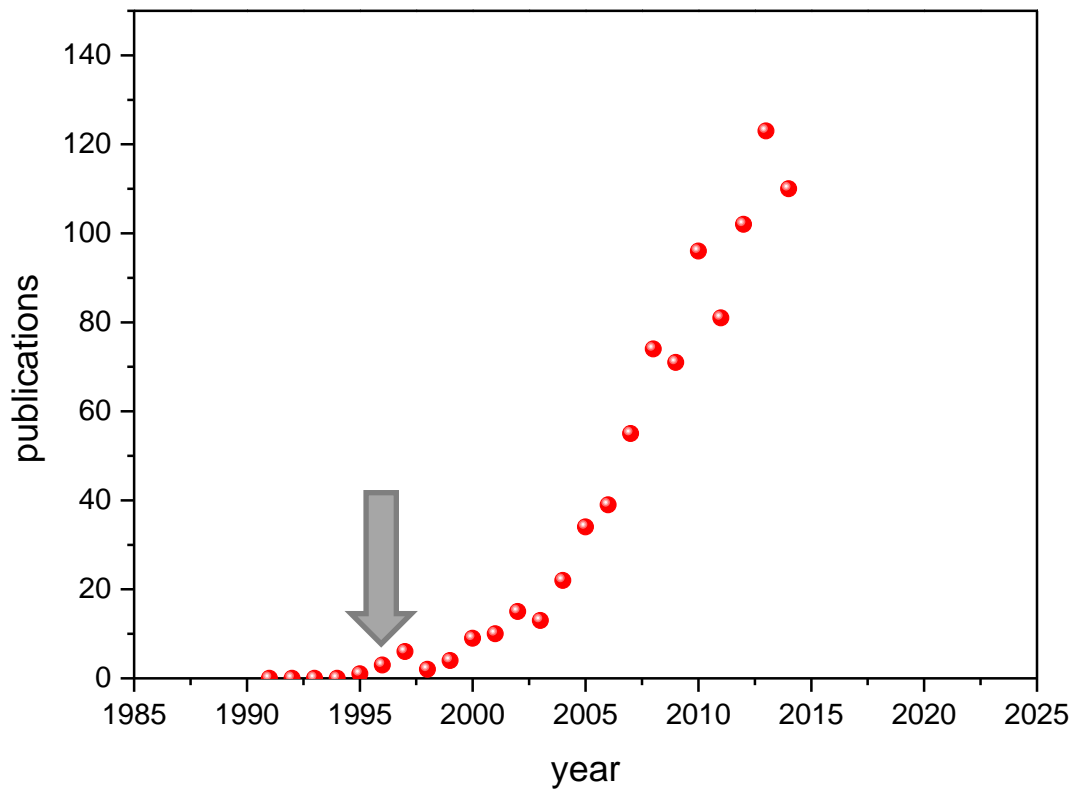
Brethau, Girit, Pothier, Esteve, Urbina, Nature. **499**, 312 (2013)

Andreev level spectroscopy

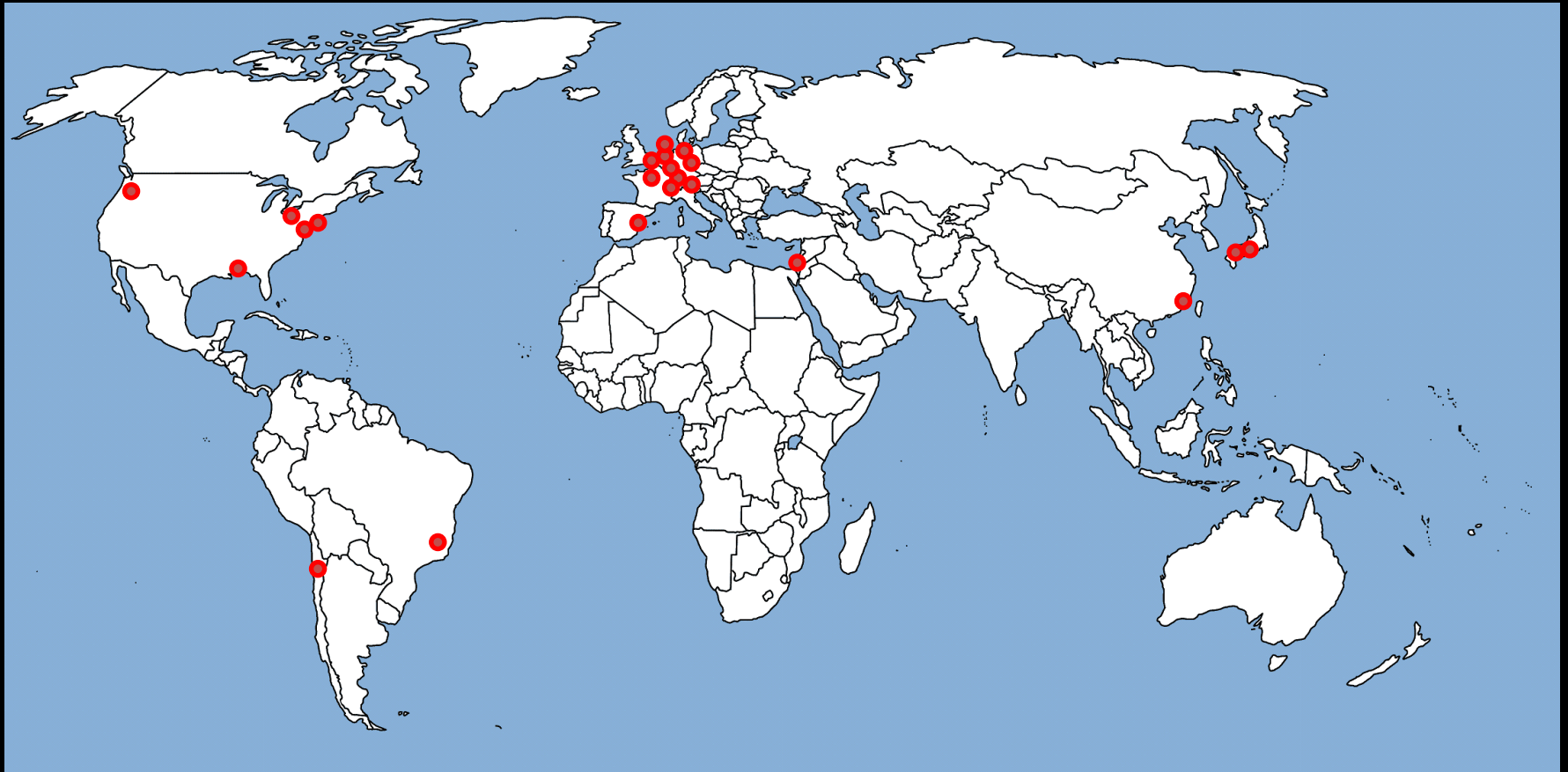


Bretheau, Girit, Pothier, Esteve, Urbina, Nature. **499**, 312 (2013)

Publications based on MCBJ



MCBJ in labs around the world



MCBJ based circuits in labs around the world



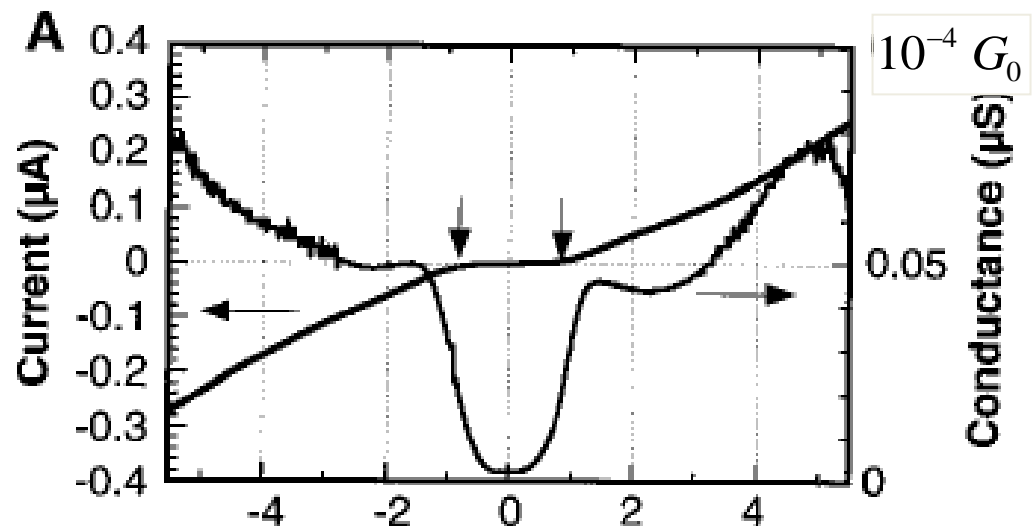
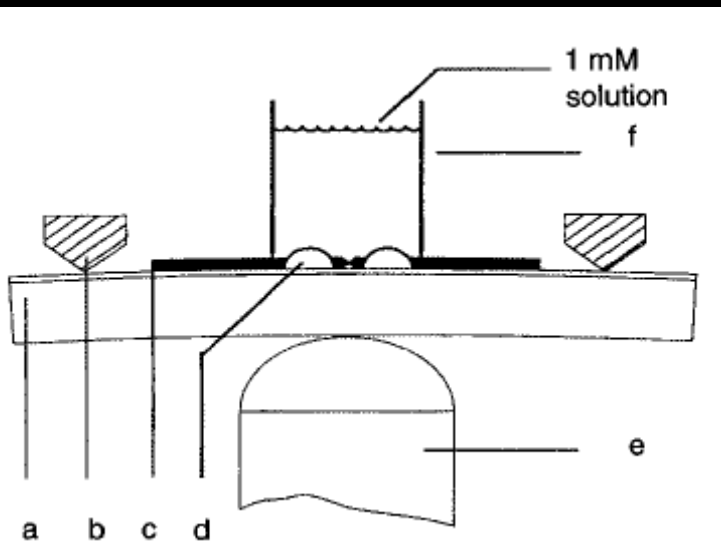
Towards single molecule junctions

Conductance of a Molecular Junction

M. A. Reed,* C. Zhou, C. J. Muller, T. P. Burgin,
J. M. Tour*

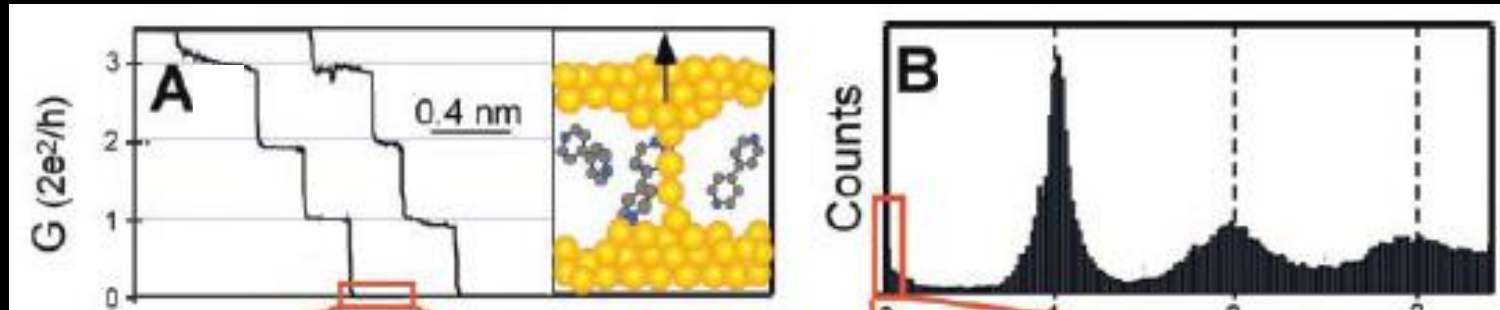
252

SCIENCE • VOL. 278 • 10 OCTOBER 1997



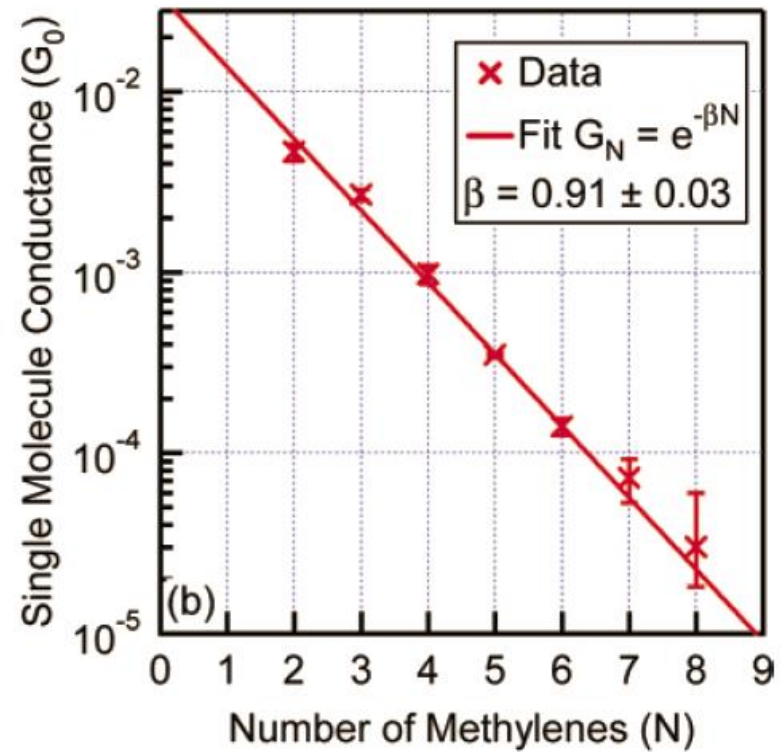
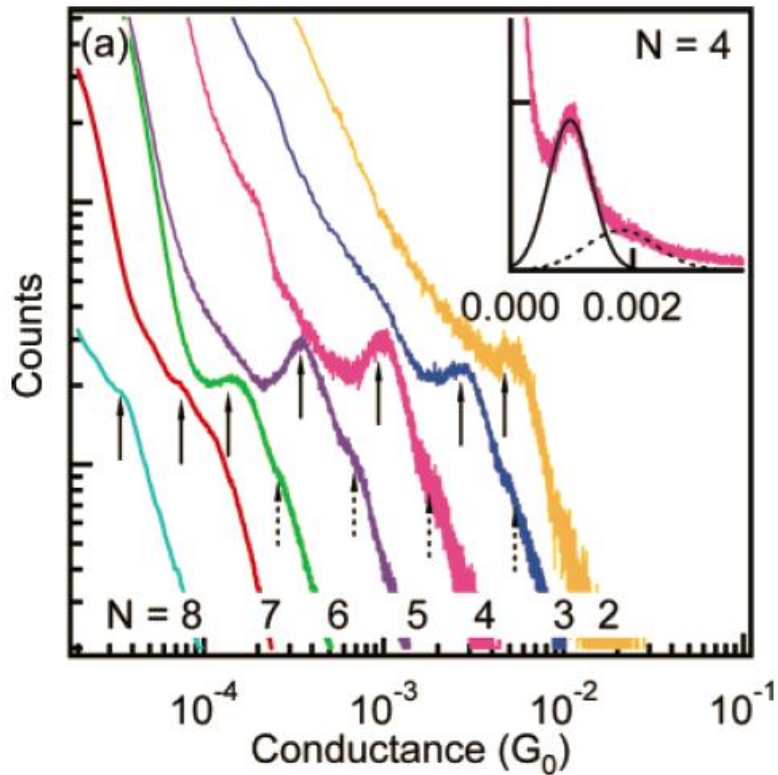
Benzenedithiol (BDT)

Larger molecules; off-resonant transport



Systematic dependence

alkanediamines

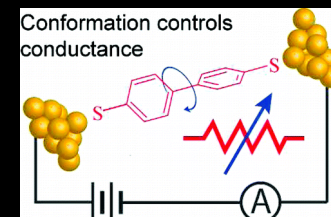
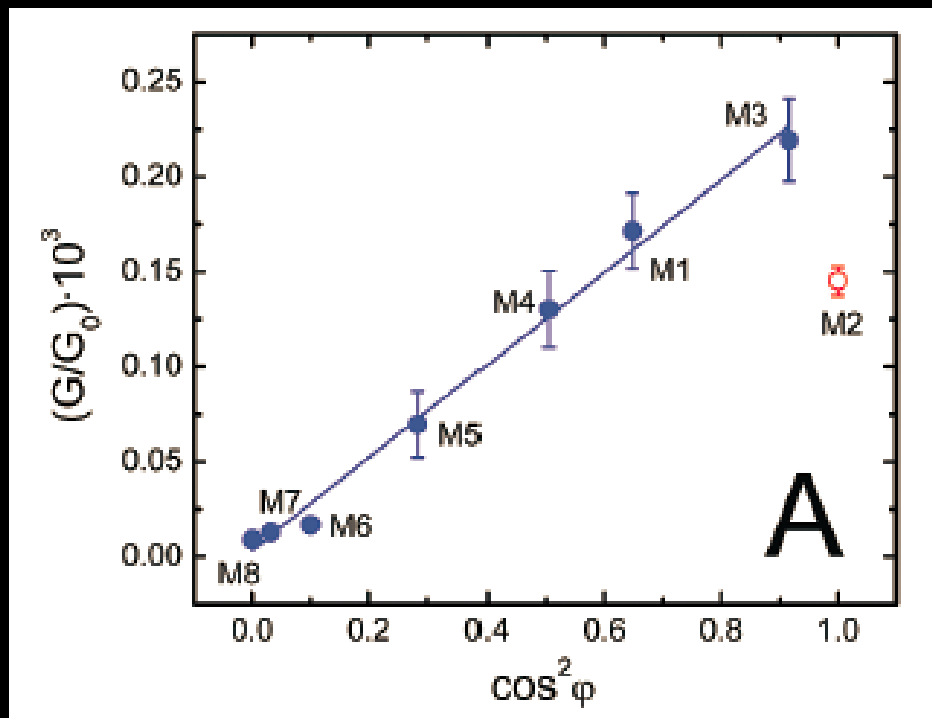


Venkataraman, Klare, Tam, Nuckolls, Hybertsen, and Steigerwald, Nano Letters 6, 458 (2006)

30 years Quantronics

Angle of two porpheringes

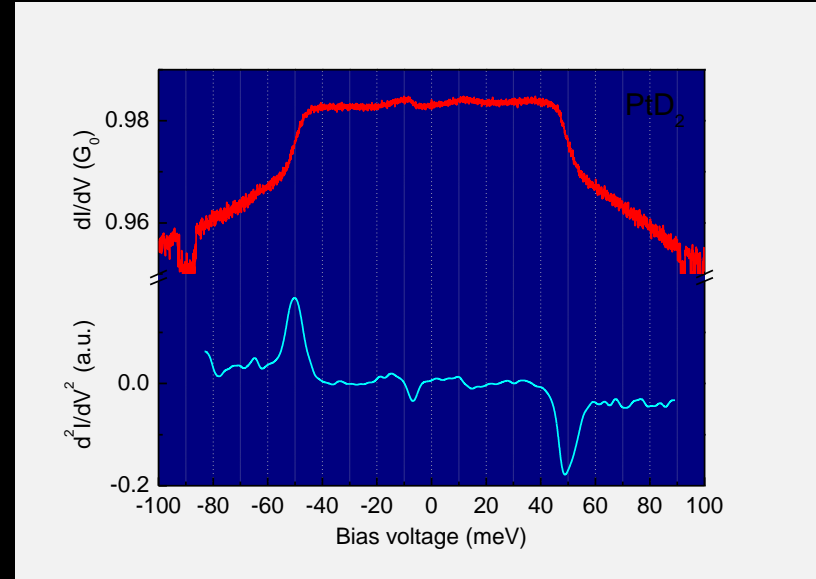
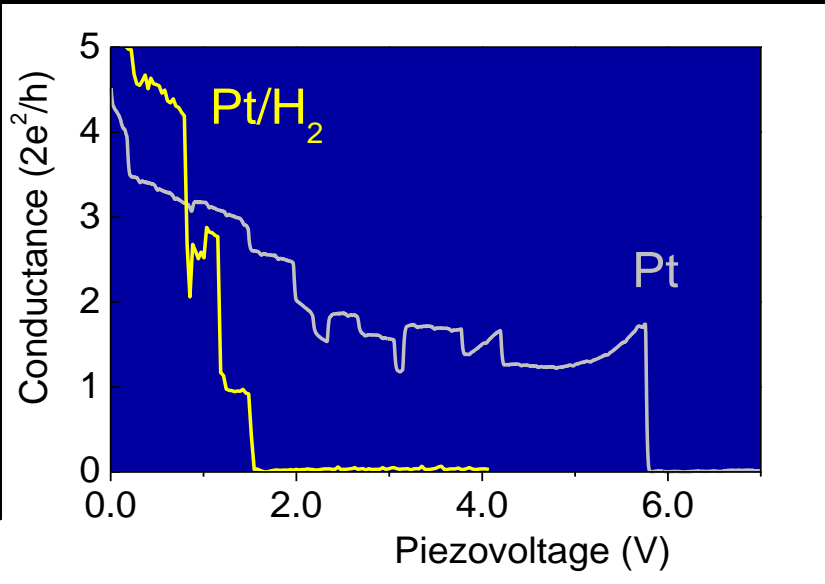
structure	Torsion angle φ x-ray (DFT SH-terminated)
	36.4° ²⁹ (44.9°)
	1.1° (2.4°)
	16.8° (20.3°)
	44.7° (46.7°)
	57.8° (61.3°)
	71.5° (70.5°)
	79.7° (89.7°)
	89.0° (89.6°)



Michenko, Vonlanthen, Meded, Bürkle, Li, Pobelov, Bagrets, Viljas, Pauly, Evers, Mayor, Wandlowski, *Nano Letters* **10**, 156 (2010).

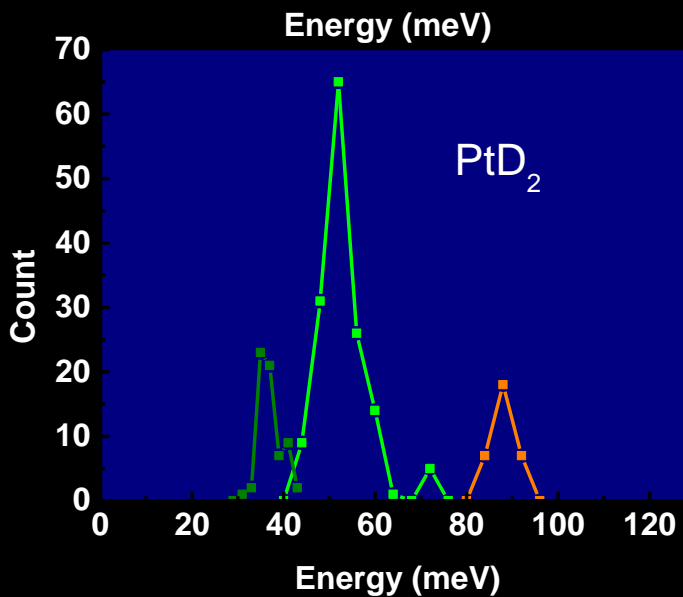
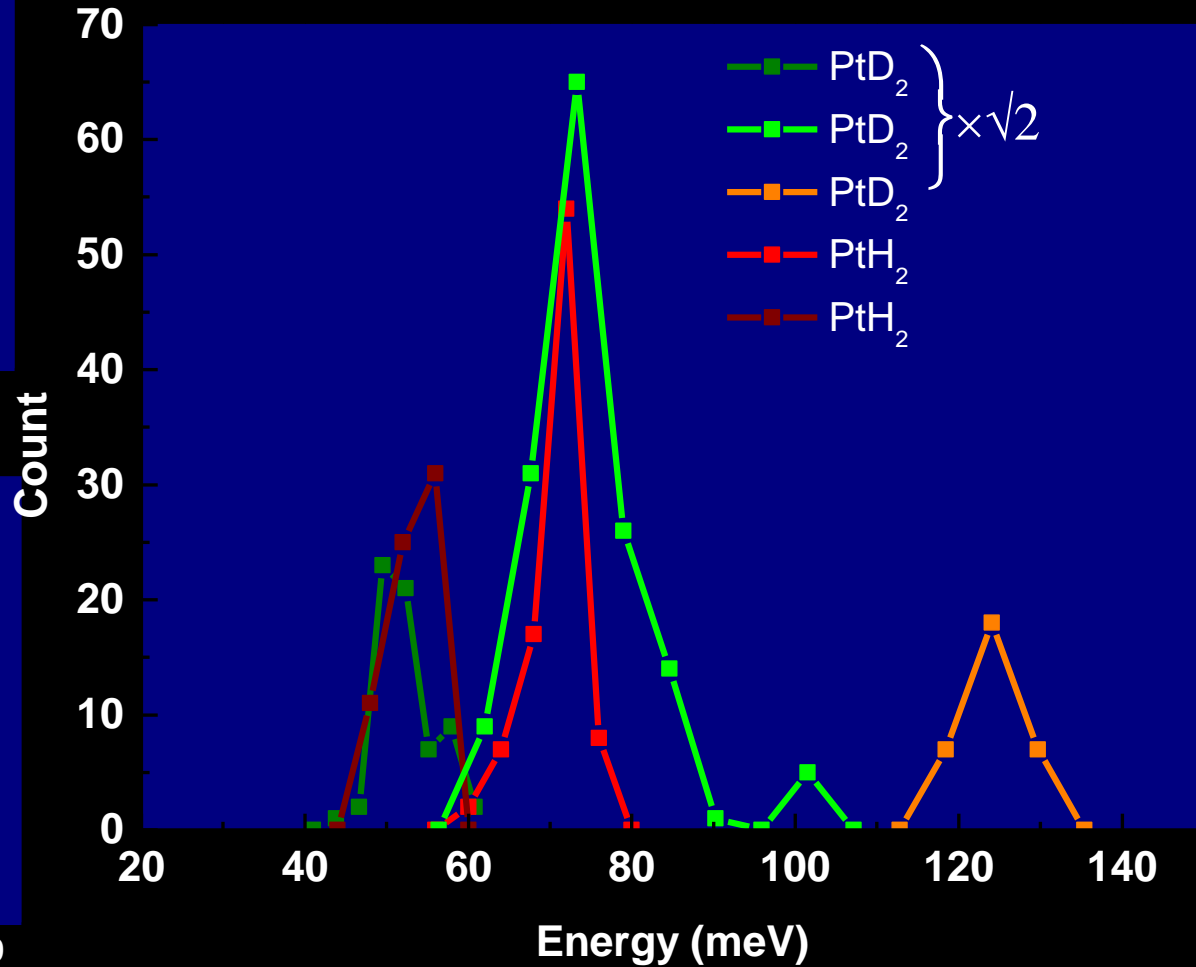
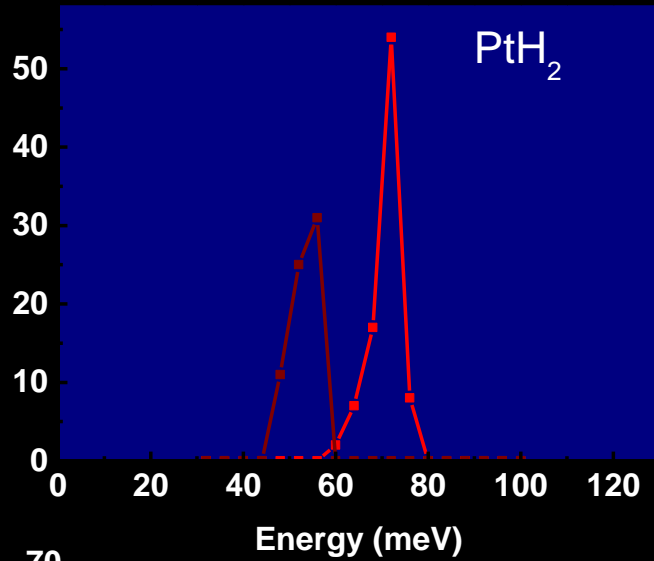
See also: Venkataraman, Klare, Nuckolls, Hybertsen, Steigerwald, *Nature* **442**, 904 (2006).

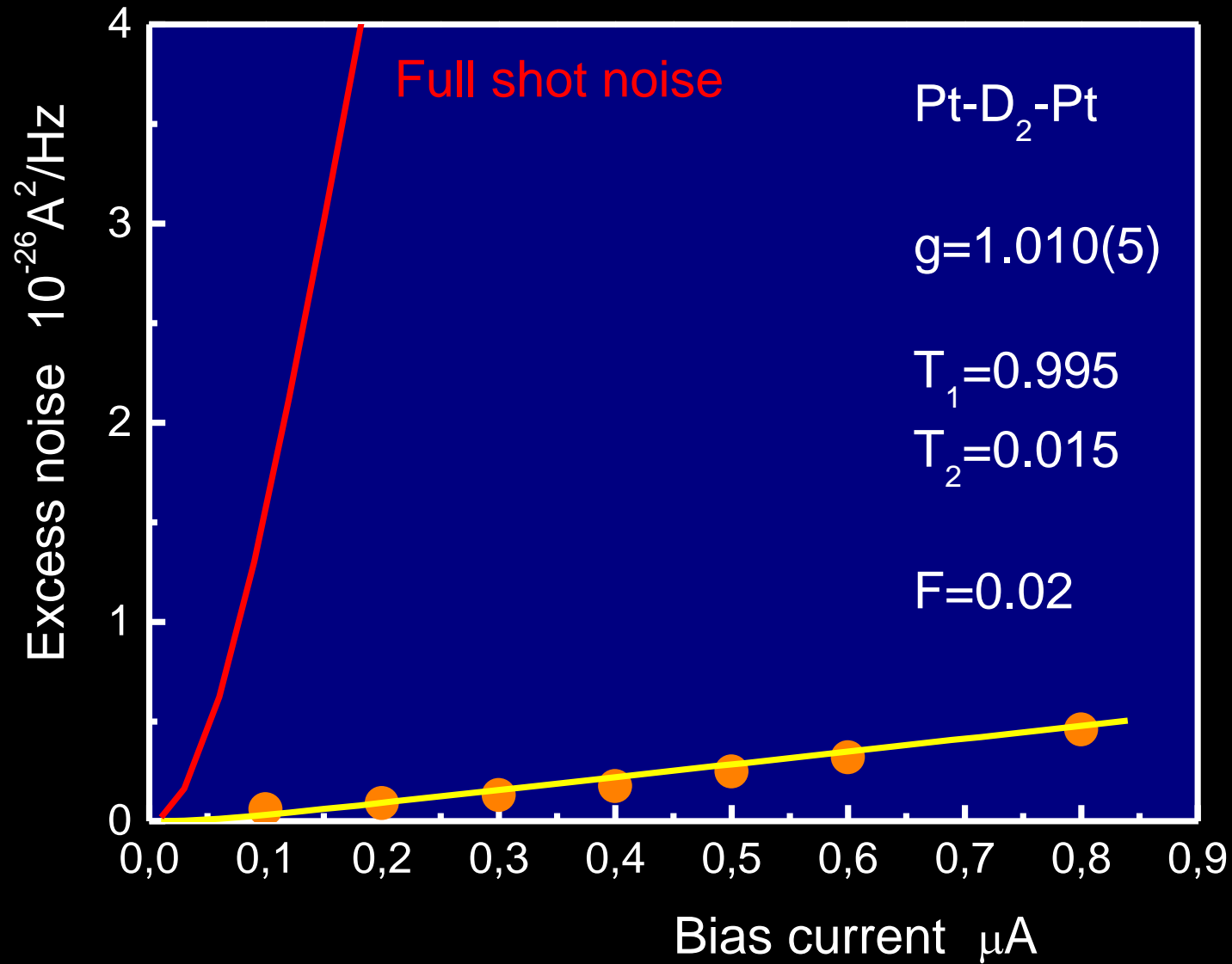
Conductance curve for Pt/H₂



Smit, Noat Untiedt, Lang, van Hemert, JMV_R, Nature 419, 906 (2002)

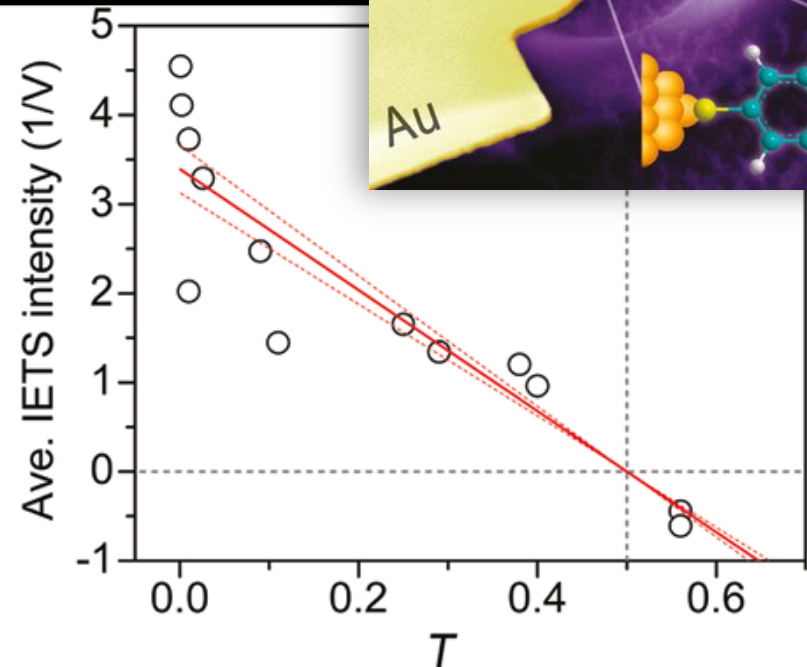
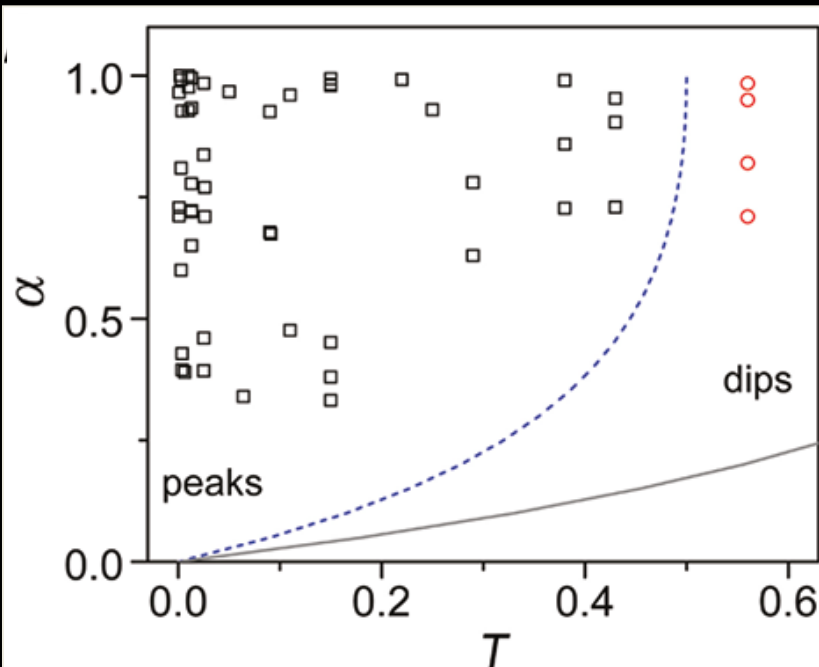
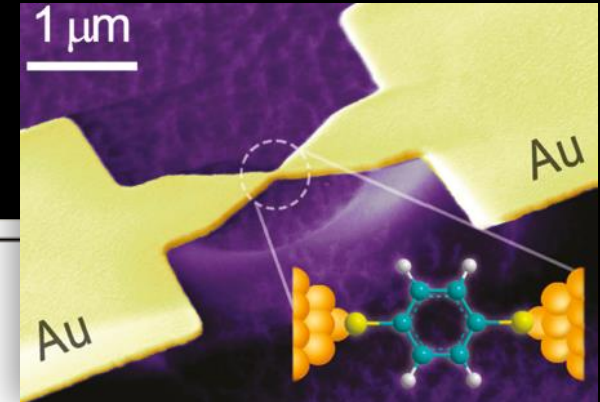
Comparison H₂ and D₂



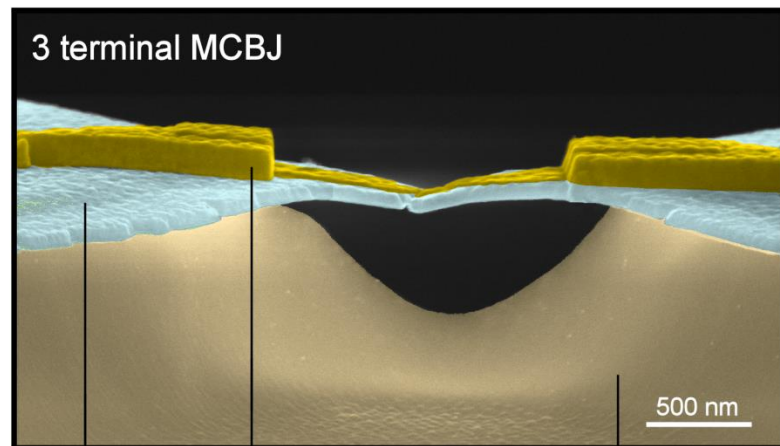
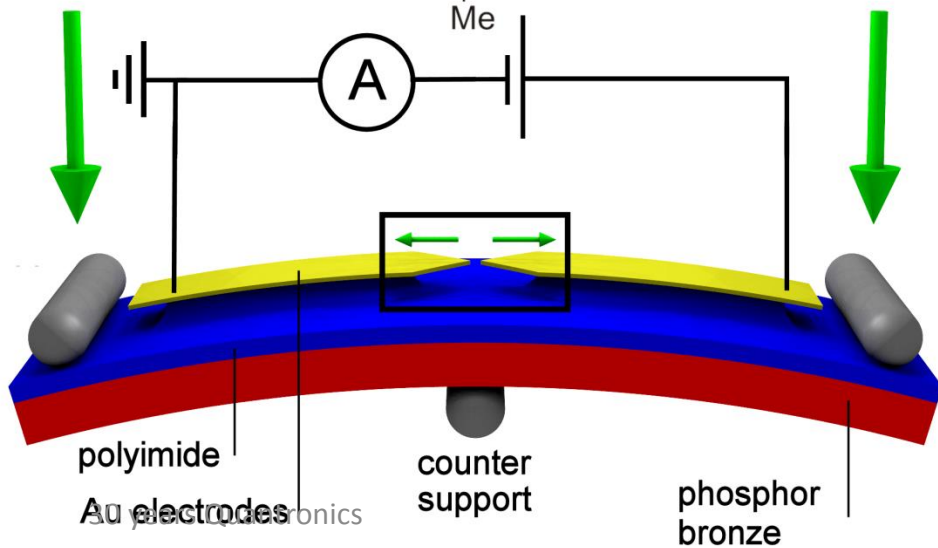
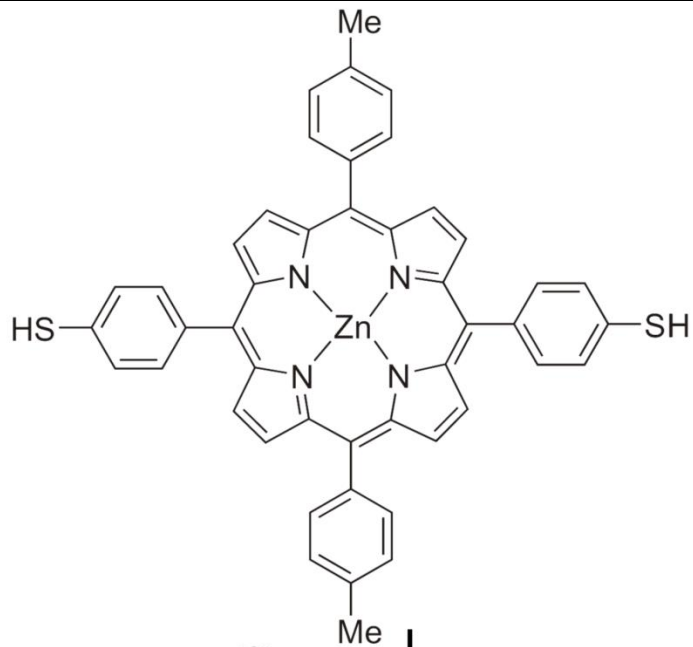


Benzenedithiol-Au junctions

Y Kim, T Pietsch, A. Erbe, W Belzig & E. Scheer,
Nano Lett 11, 3734 (2011)



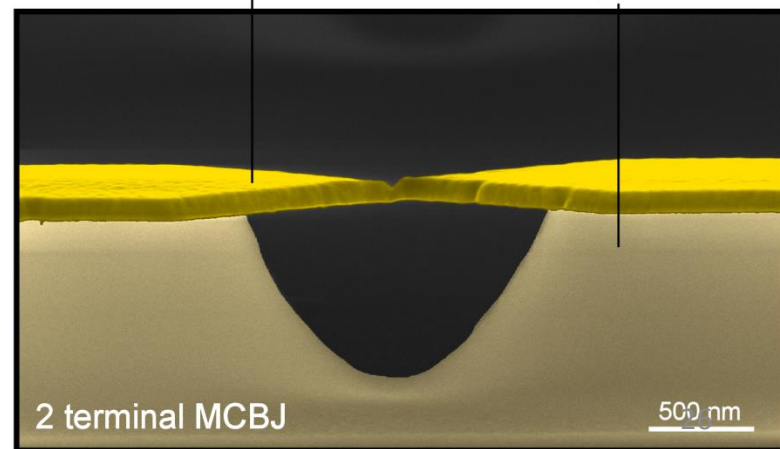
Thiol-terminated Zn-porphyrin molecules



Al gate electrode

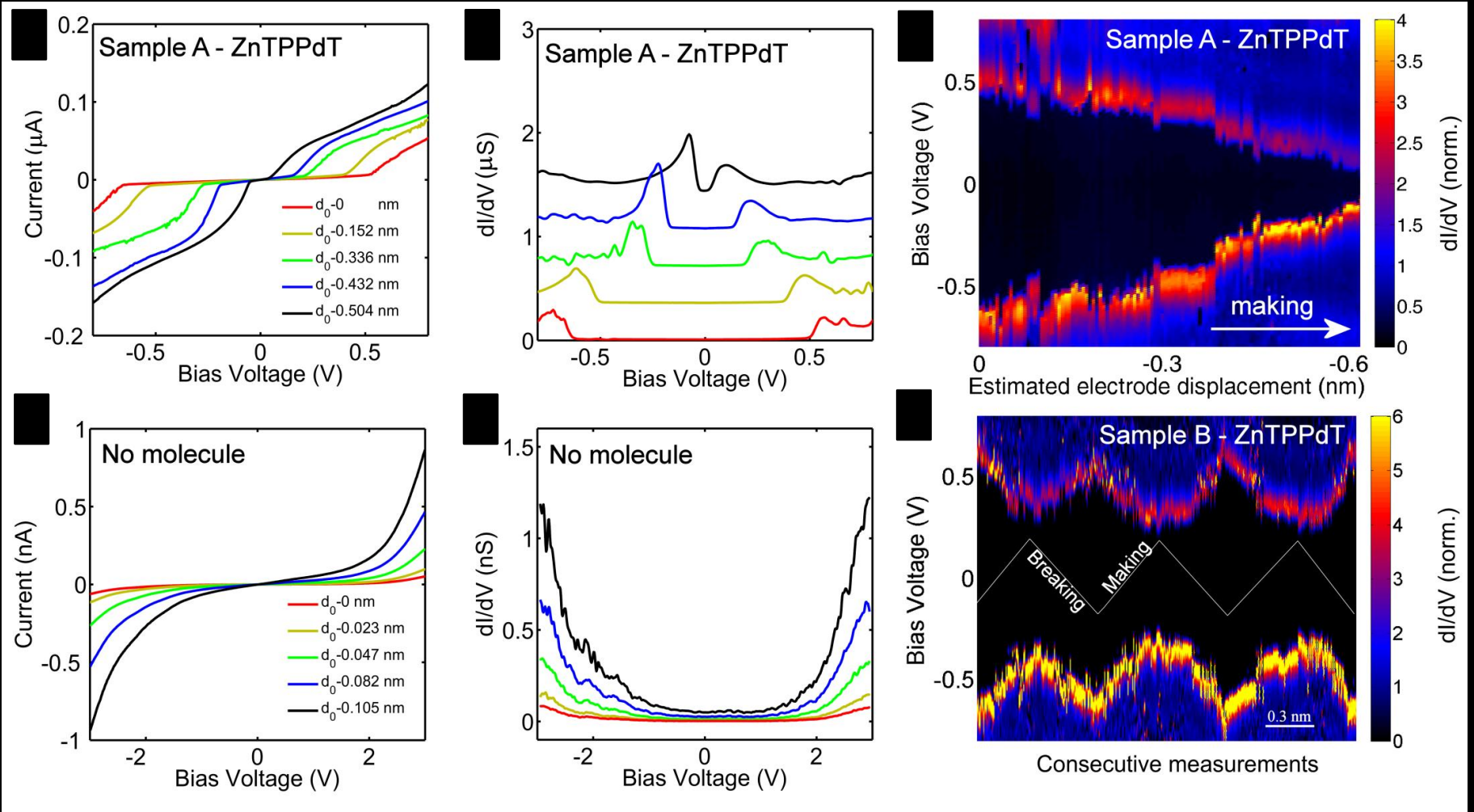
Au electrodes

polyimide



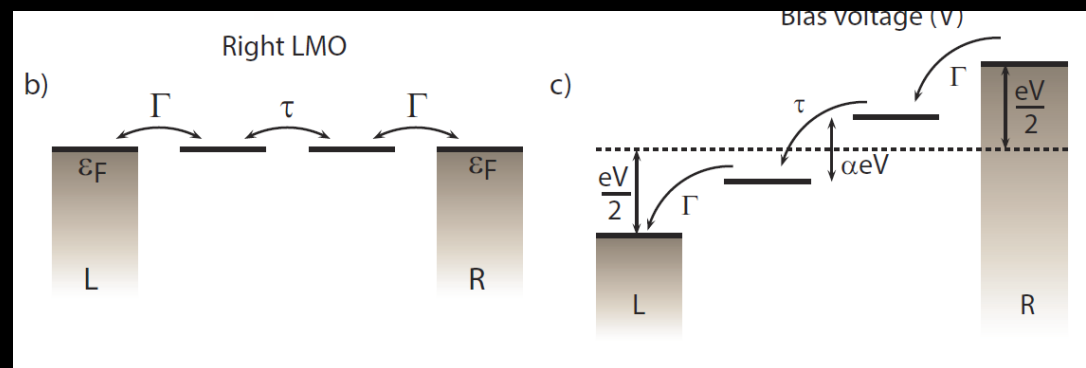
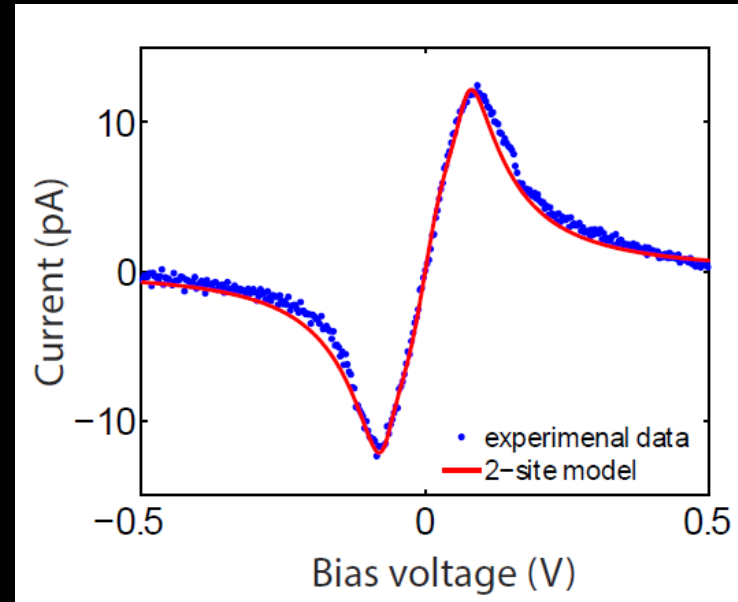
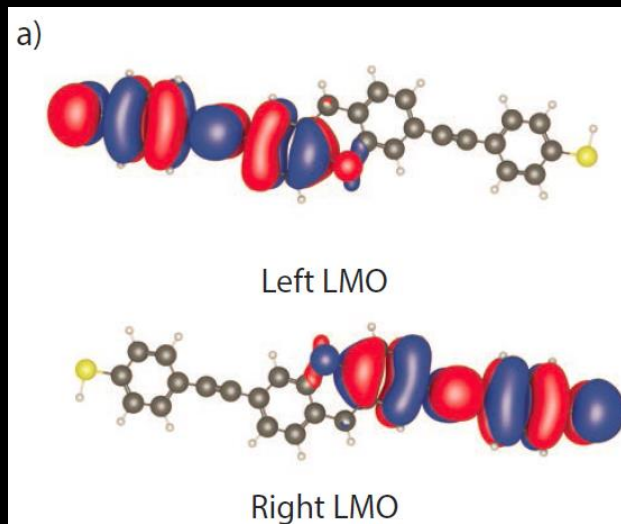
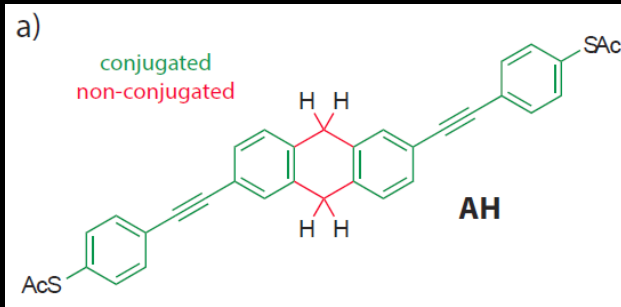
2 terminal MCBJ

Observation of “Mechanical Gating”



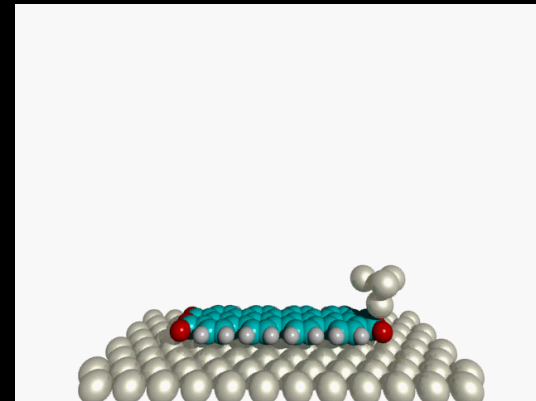
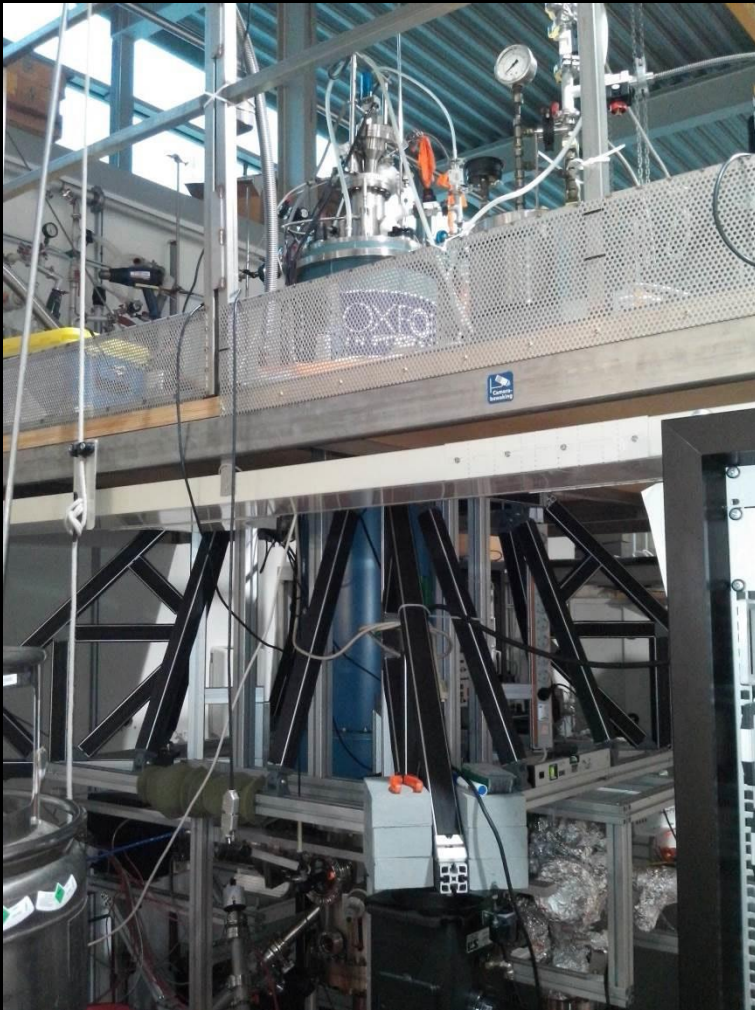
Perrin, Verzijl, Martin, Shaikh, Eelkema, van Esch, JMvR, Thijssen, van der Zant & Dulic, Nature Nanotechnology 8, 282 (2013)

Negative differential conductance



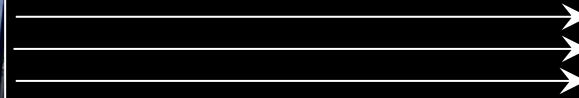
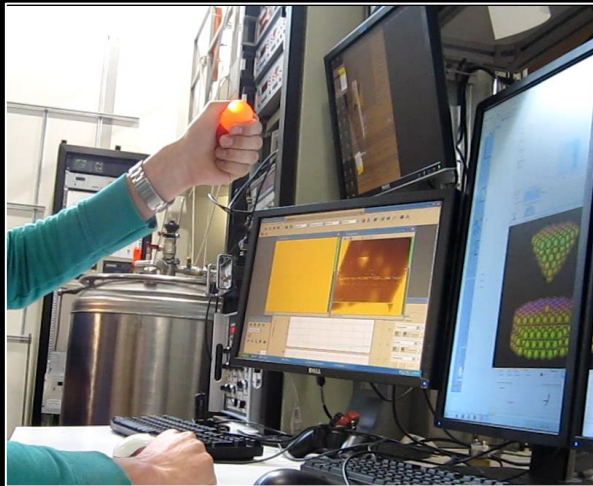
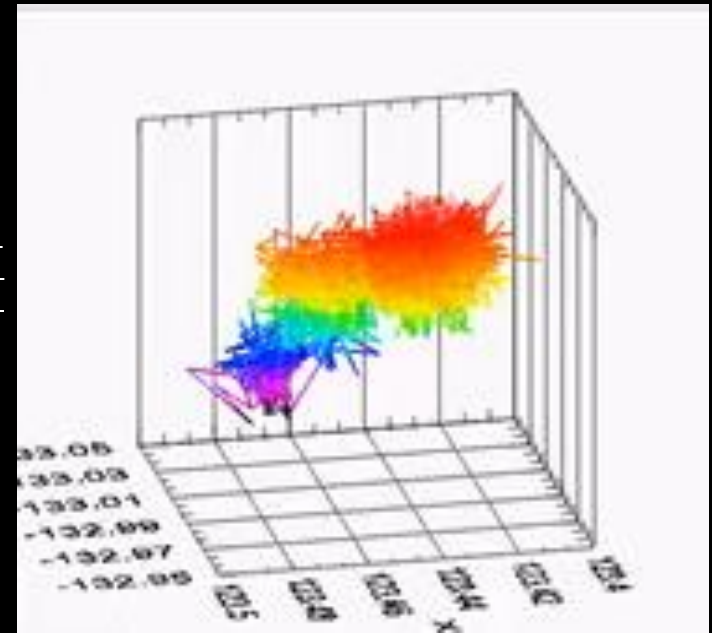
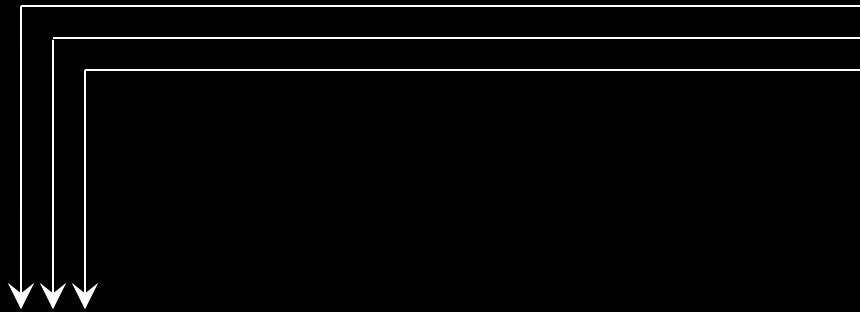
Perrin, Frisenda, Koole, Seldenthuis, Celis Gil, Valkenier, Hummelen, Renaud, Grozema, Thijssen, Dulic & van der Zant, Nature Nanotechnology 9, 380 (2014)

Low-temperature STM

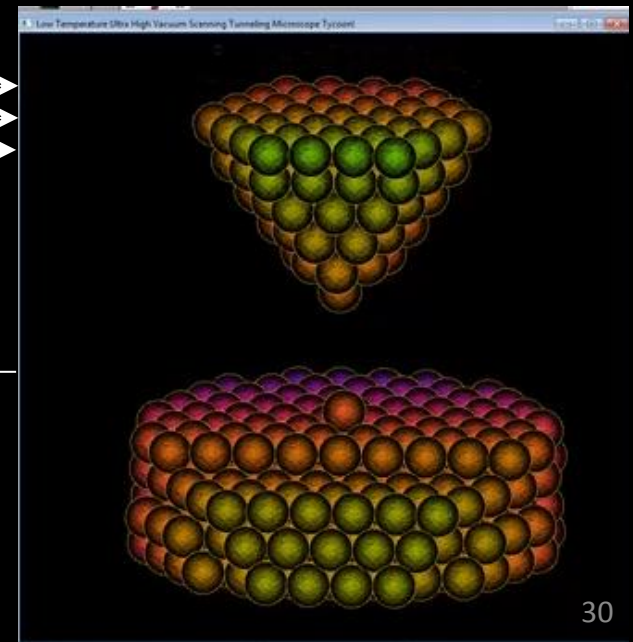


STM control: The game

x
y
z

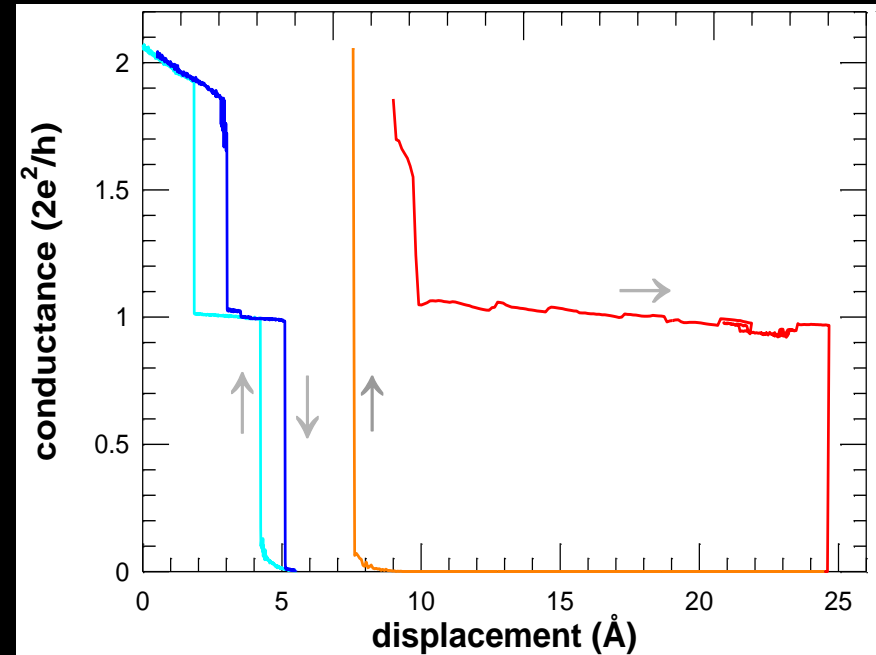
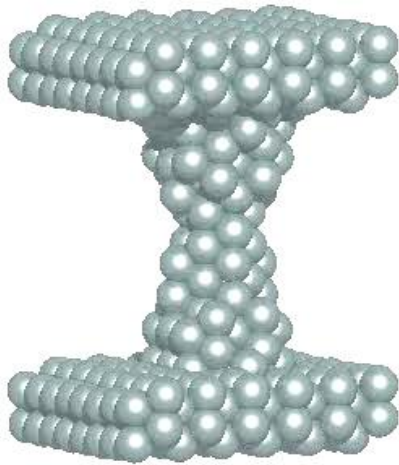


feedback





A chain of metal atoms



Molecular dynamics simulation
Sørensen, Brandbyge and Jacobsen, PRB
57, 3283 (1998)

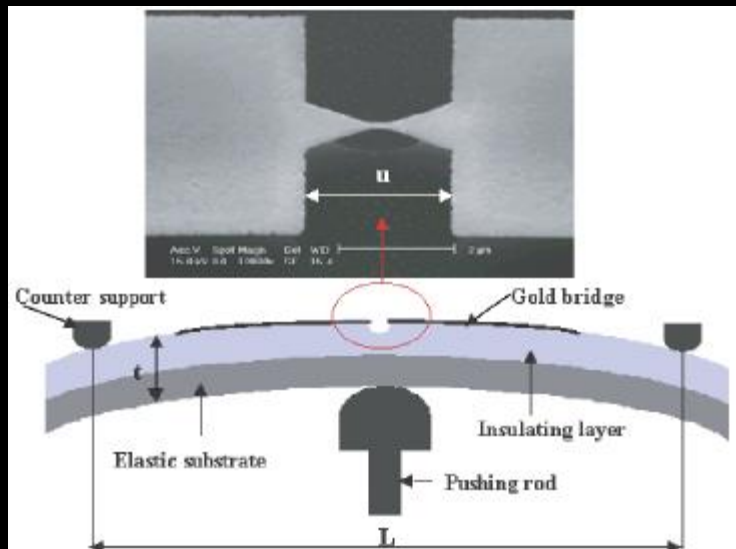
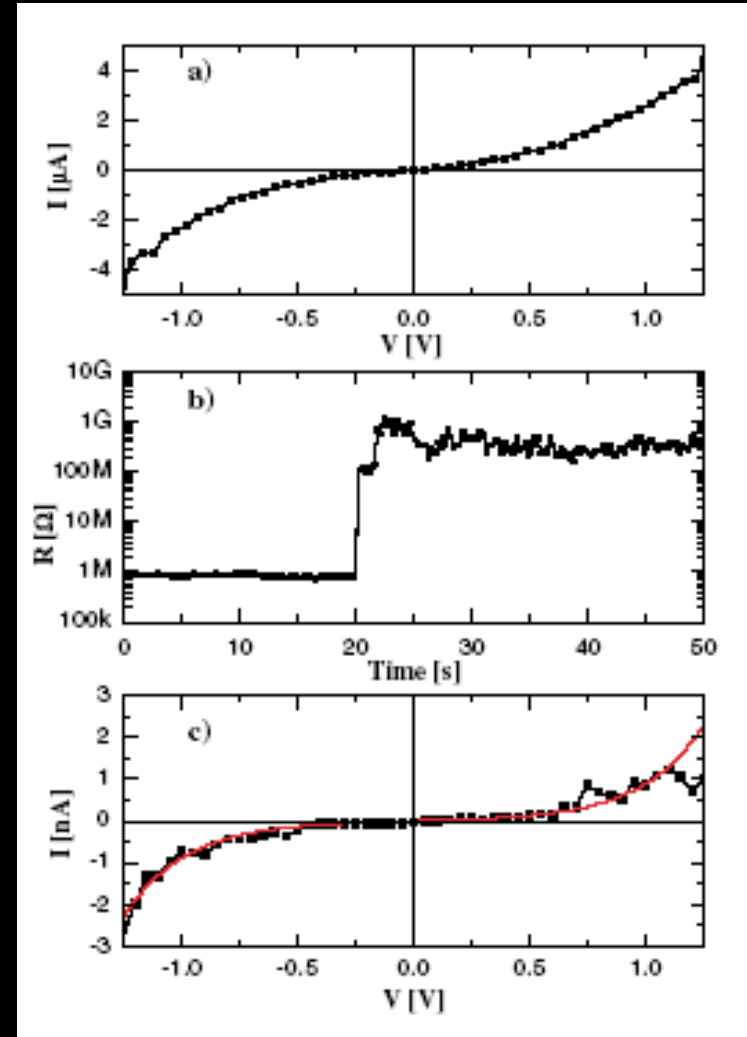
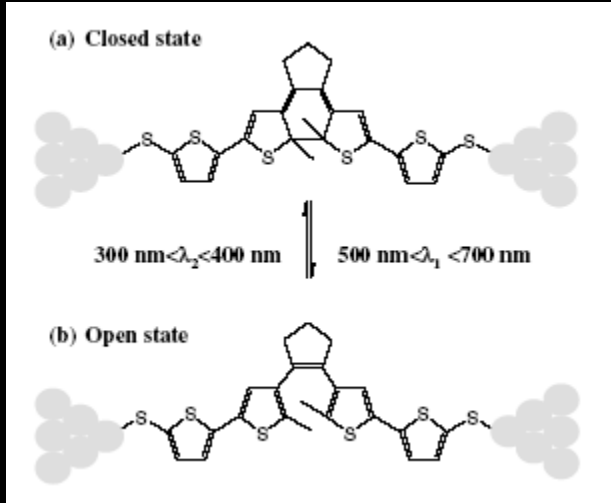
Relativity builds nanowires

Fe Co Ni Cu Zn

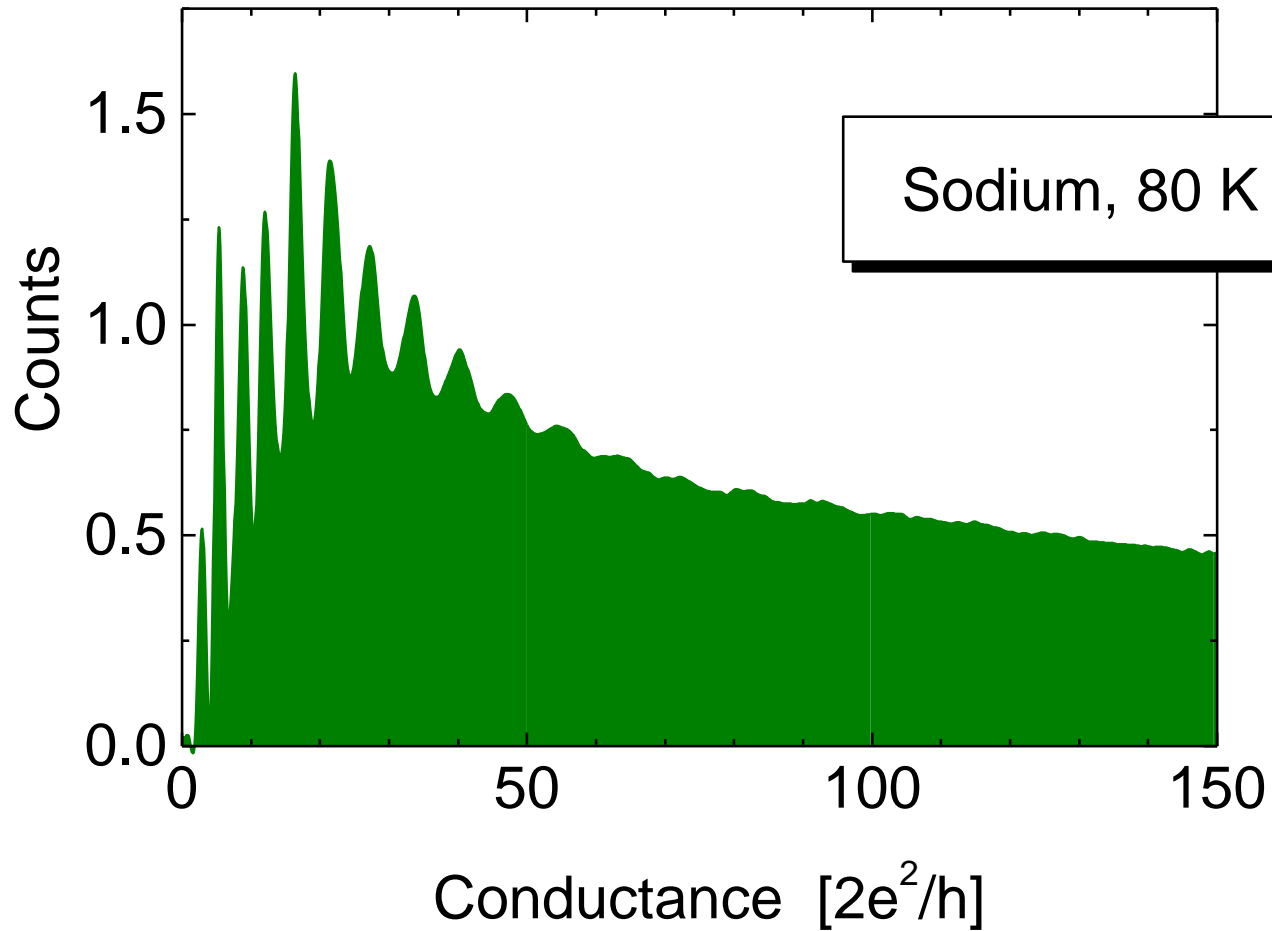
Pd Ag Cd

Os Ir Pt Au Hg

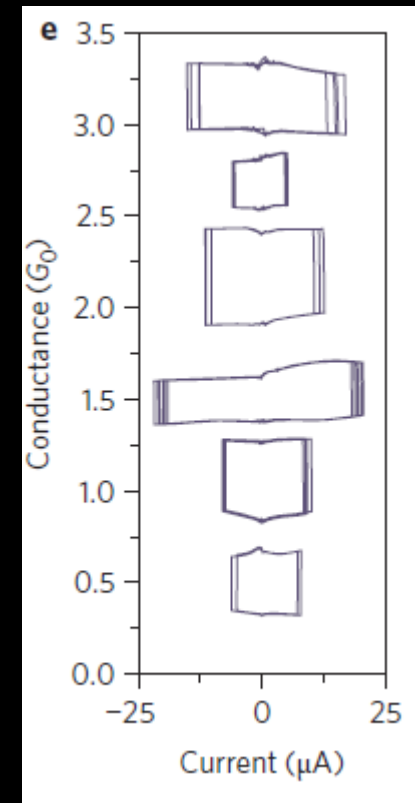
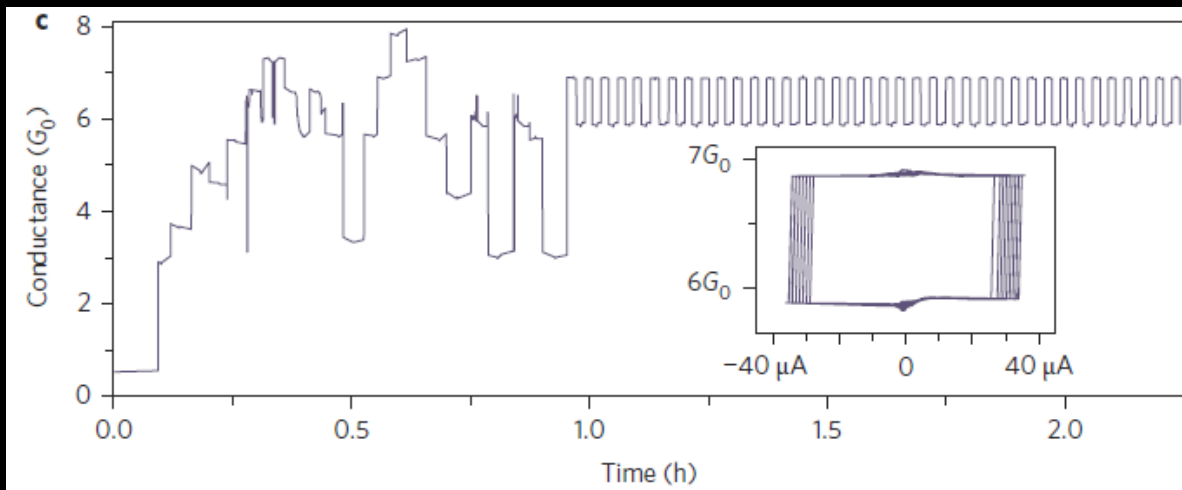
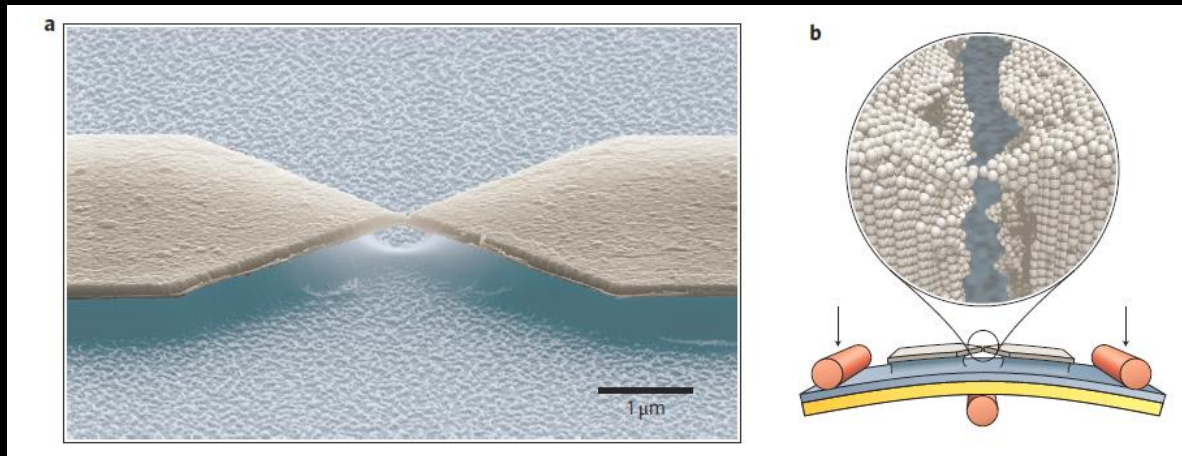
Foton-gestuurd schakelen van één molecuul



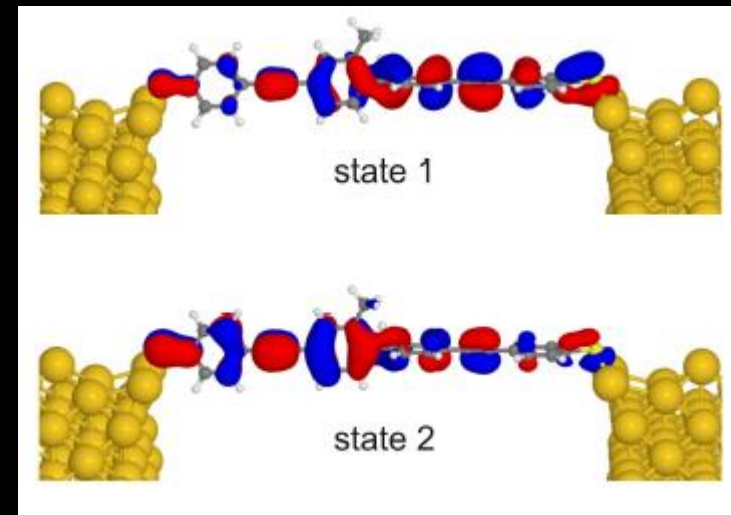
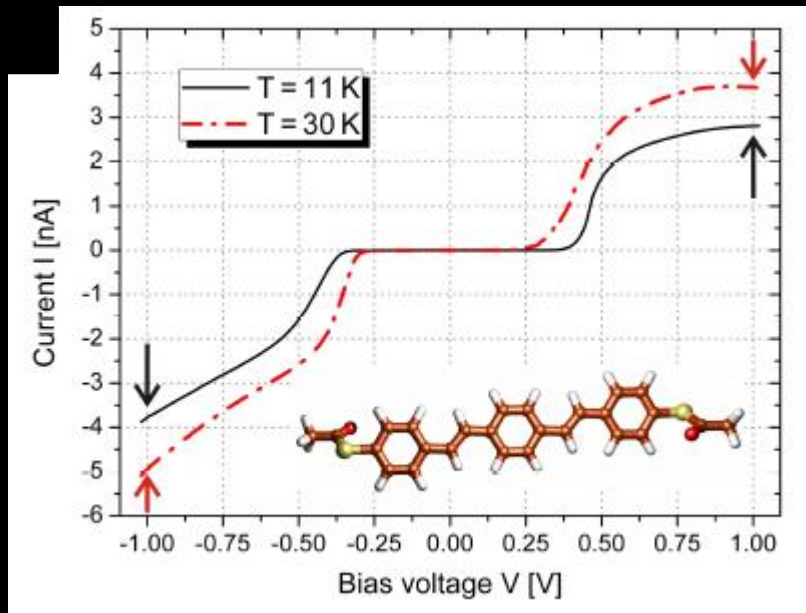
Shell structure in atomic nanowires



Current induced single-atom switching



Destruction of quantum interference by current heating



Ballmann, ..., Weber, Phys. Rev. Lett. **109**, 056801 (2012)

Comparison of conductance of alkanes with theory