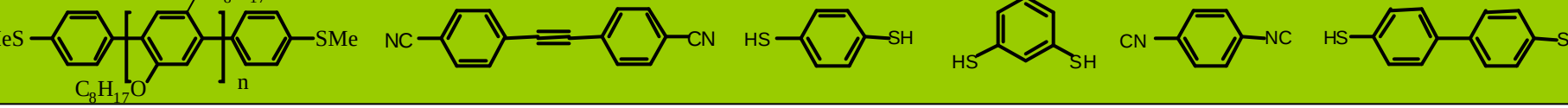
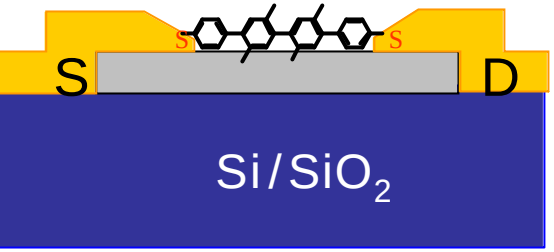
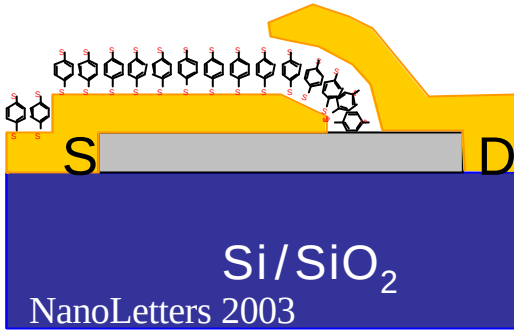


Electrical measurements on phenylene-based conjugated molecules



Günther Lientschnig
Department of NanoScience and DIMES
TU Delft



Jeong-O Lee, Frank Wiertz, Peter Hadley, Cees Dekker
Department of NanoScience and DIMES, TU Delft

Richard Egberingk, David Reinhoudt
University of Twente

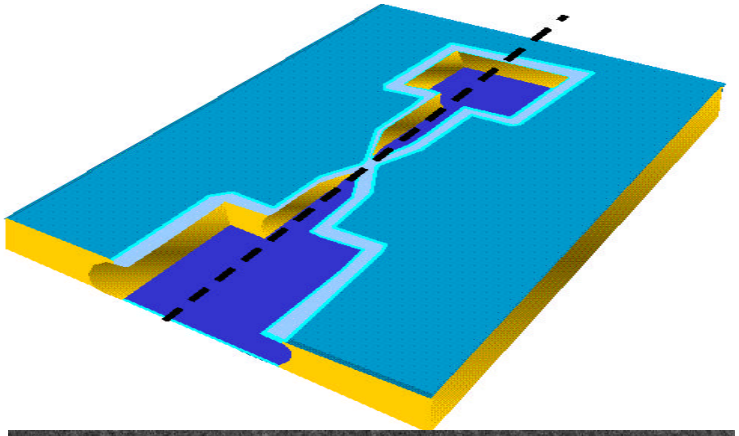
Martin Struijk, René Janssen
TU Eindhoven

Andrew Grimsdale
MPIP Mainz

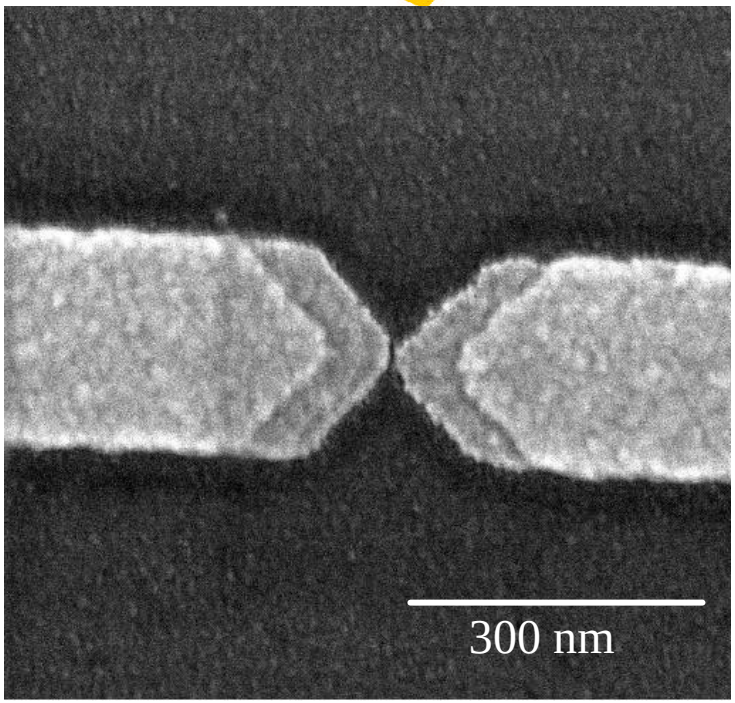
TU Delft
Delft University of Technology

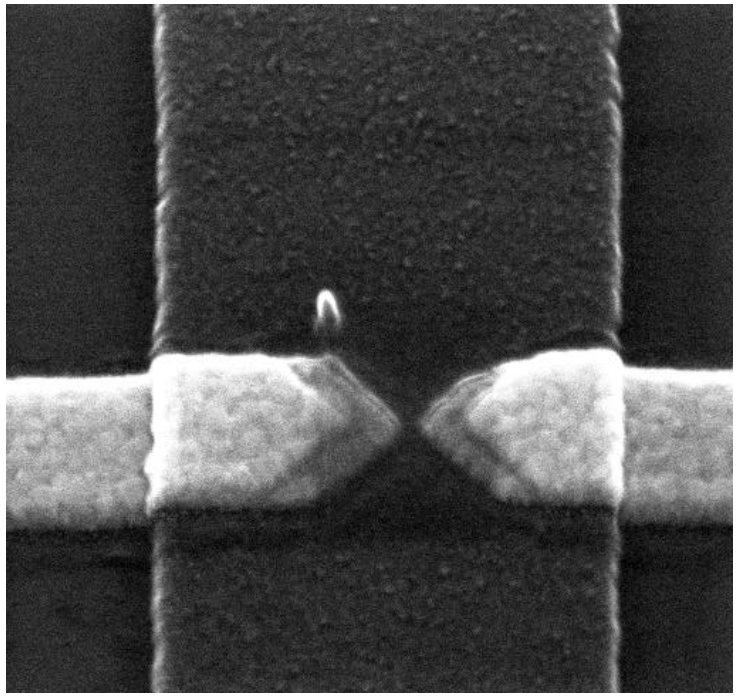
DIMES
Delft Institute of Microelectroni
and Submicrontechnology

Long Molecules: Device Fabrication



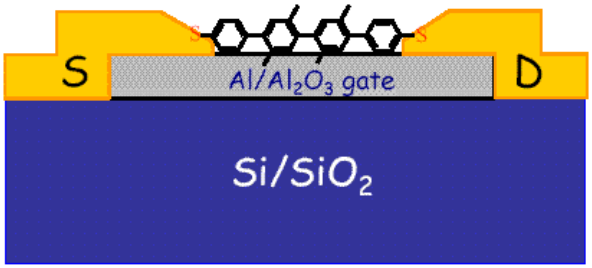
- Al Gate
- Double layer resist
- Shadow evaporation
- Liftoff

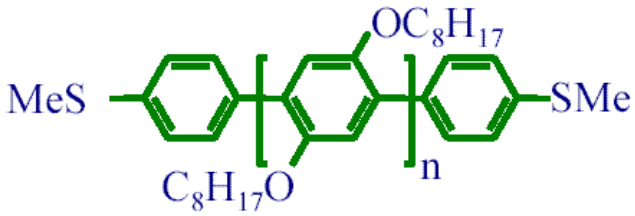




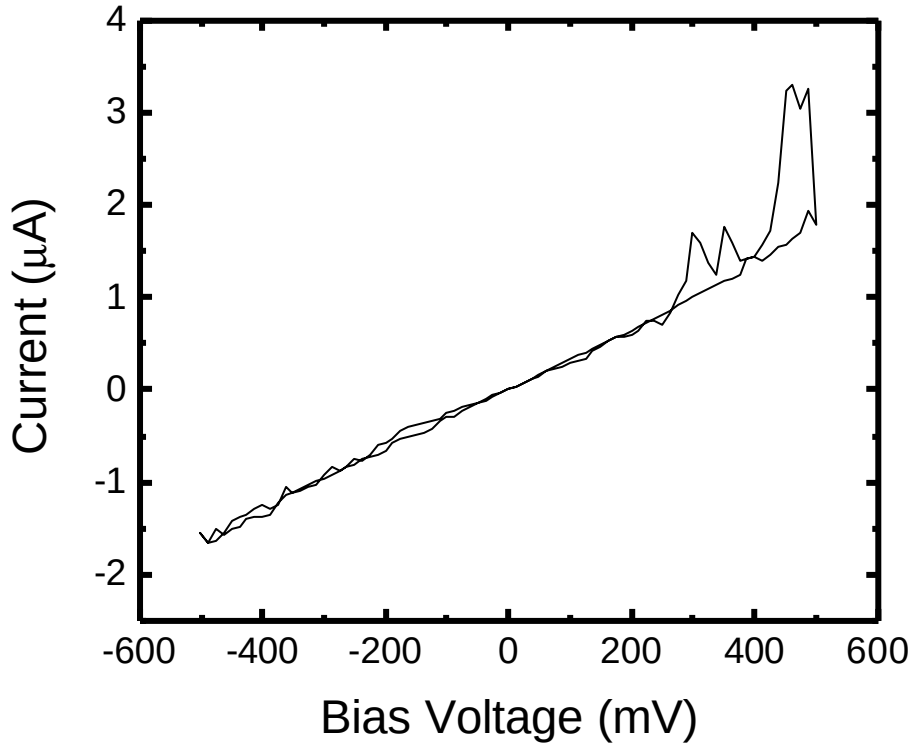
Long Molecules: Device Fabrication

- Self assembly in solution





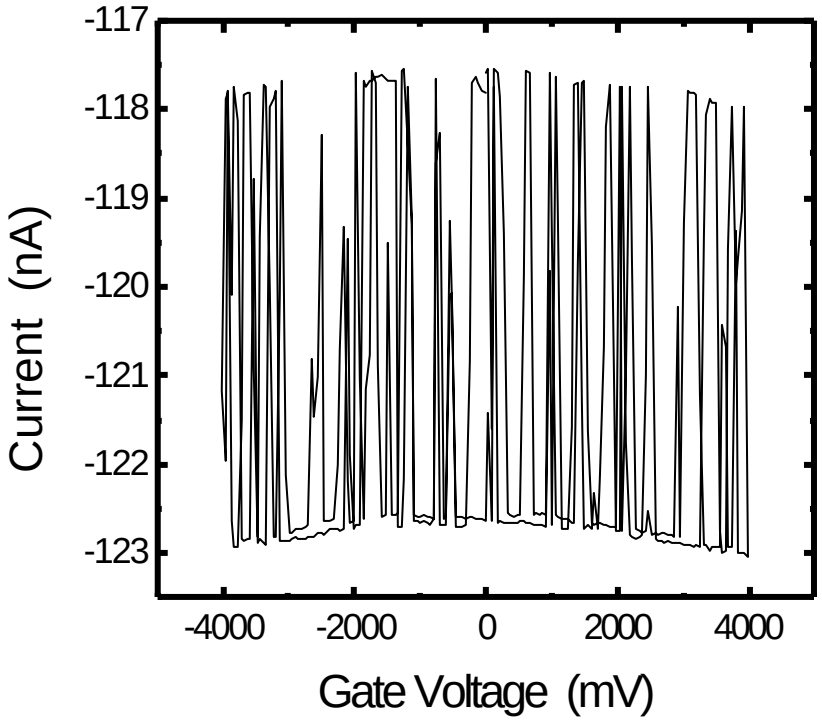
AG180(~8nm)



Long Molecules: Results

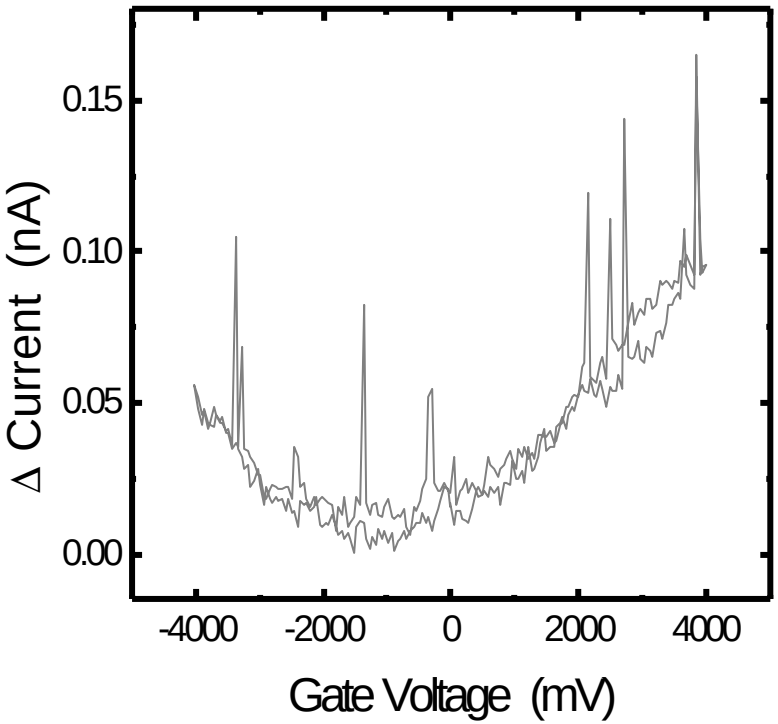
Switching

Bias Voltage: -100 mV



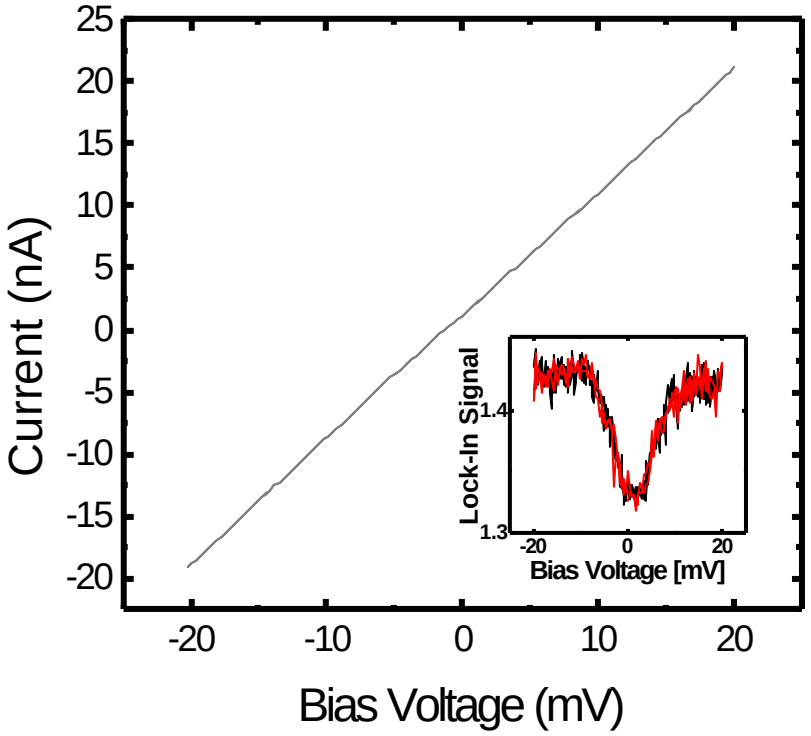
Gate dependance

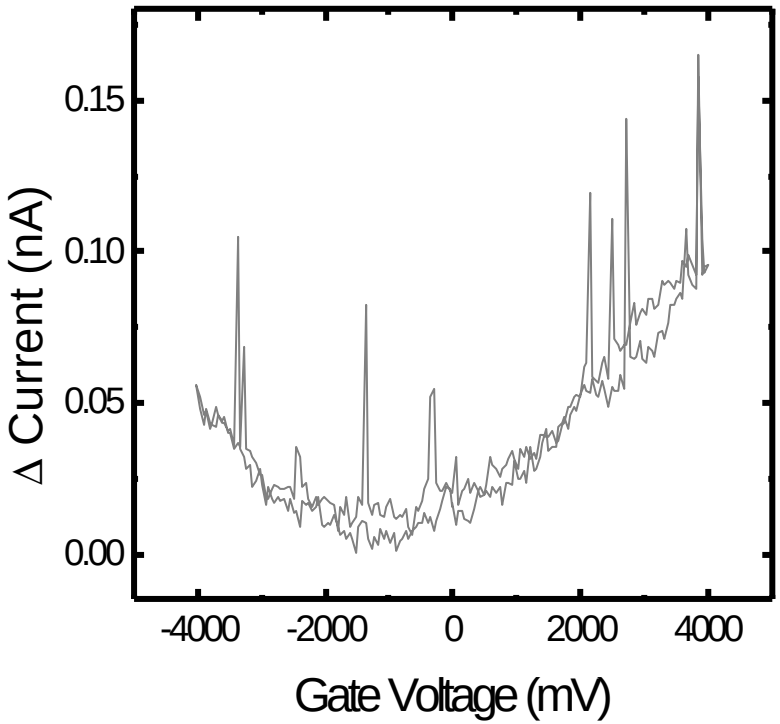
Bias Voltage: 20 mV



Long Molecules: Results

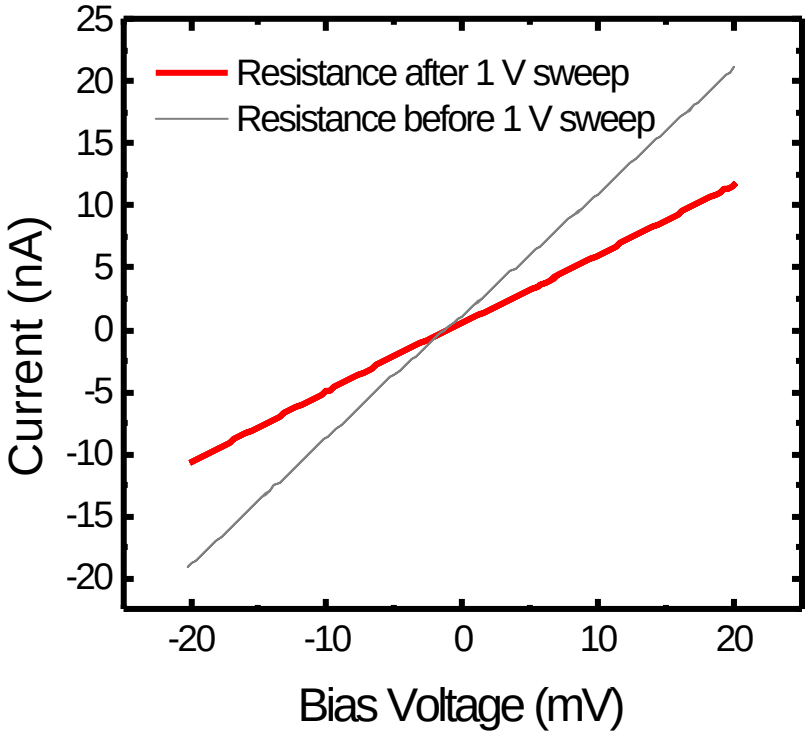
- Gate dependance, conductance

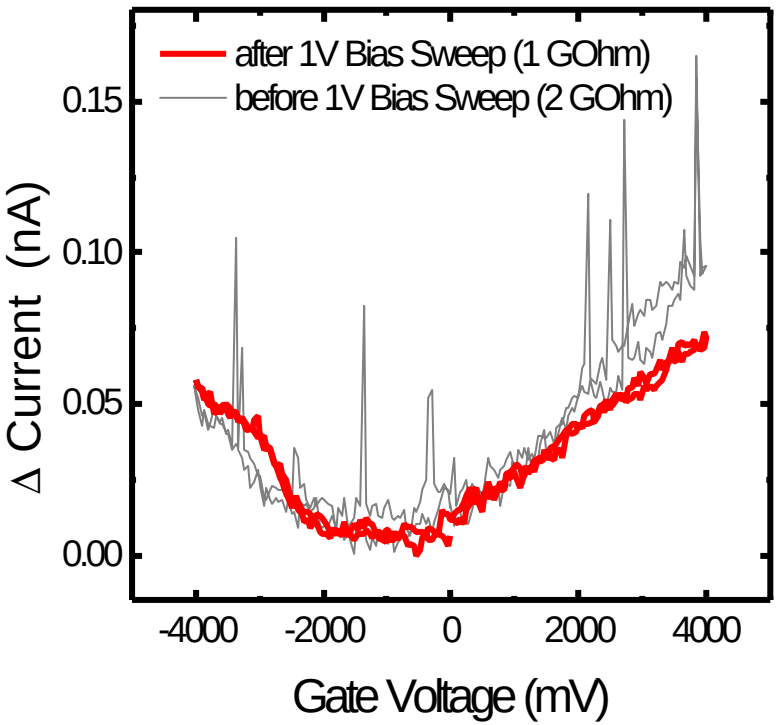




Long Molecules: Results

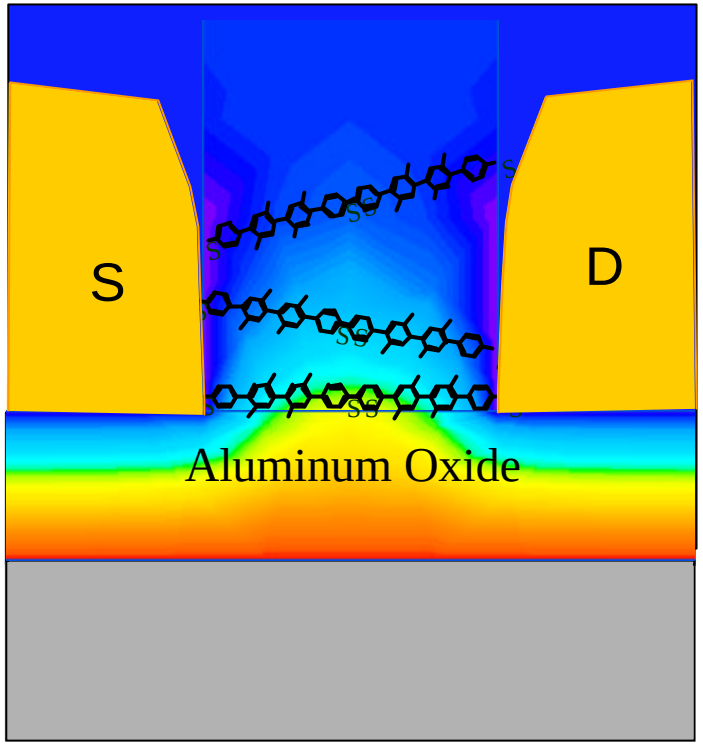
- Gate dependance, conductance
- “Electrical annealing”





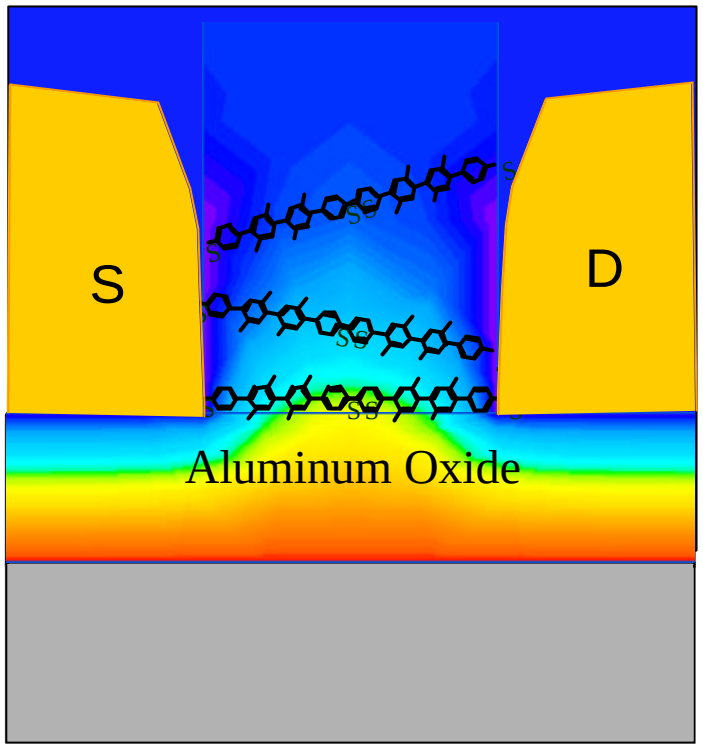
Long and Short Molecules

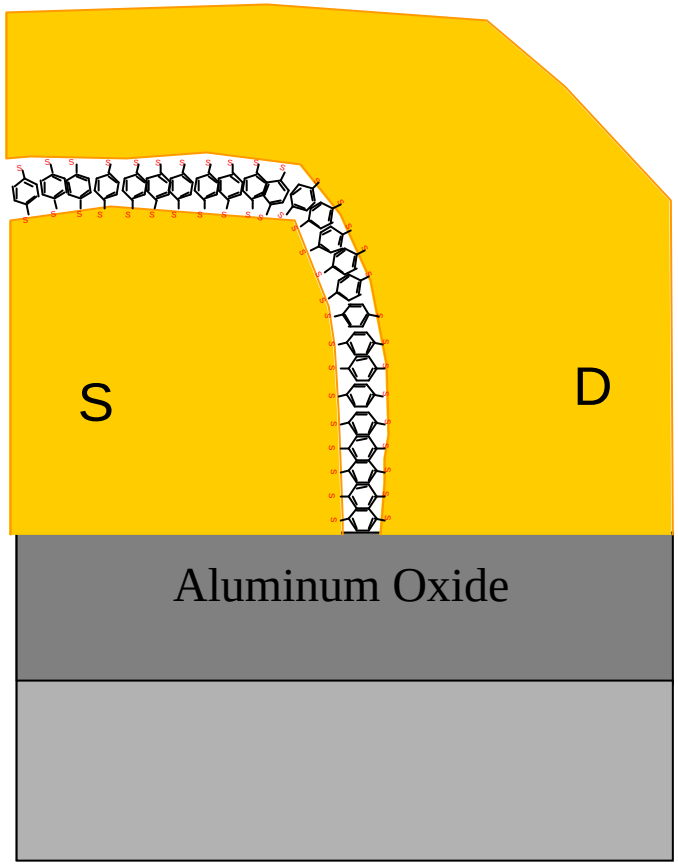
- Expected gate effect



Long and Short Molecules

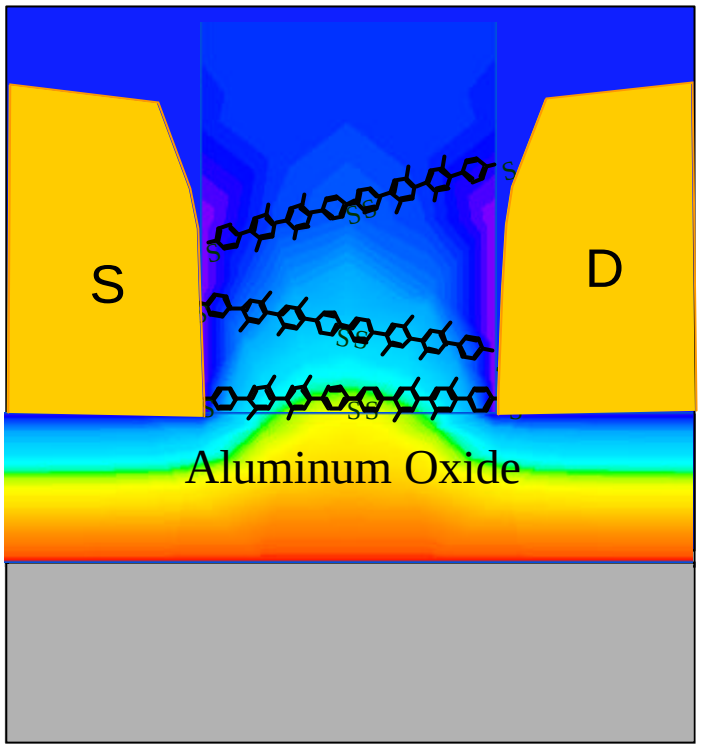
- Expected gate effect

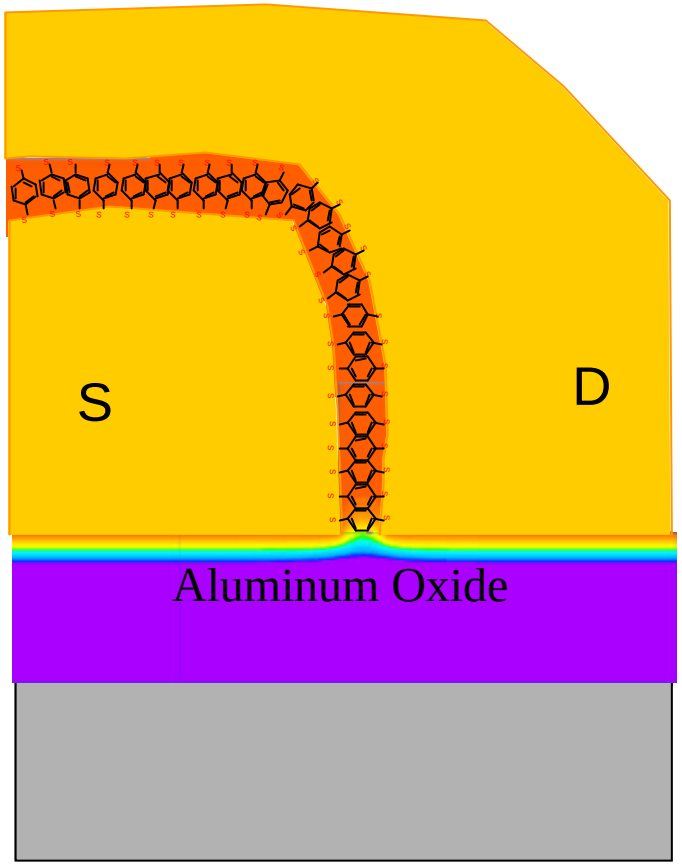




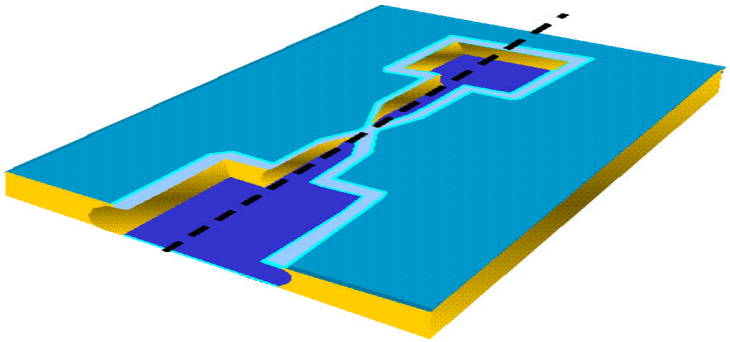
Long and Short Molecules

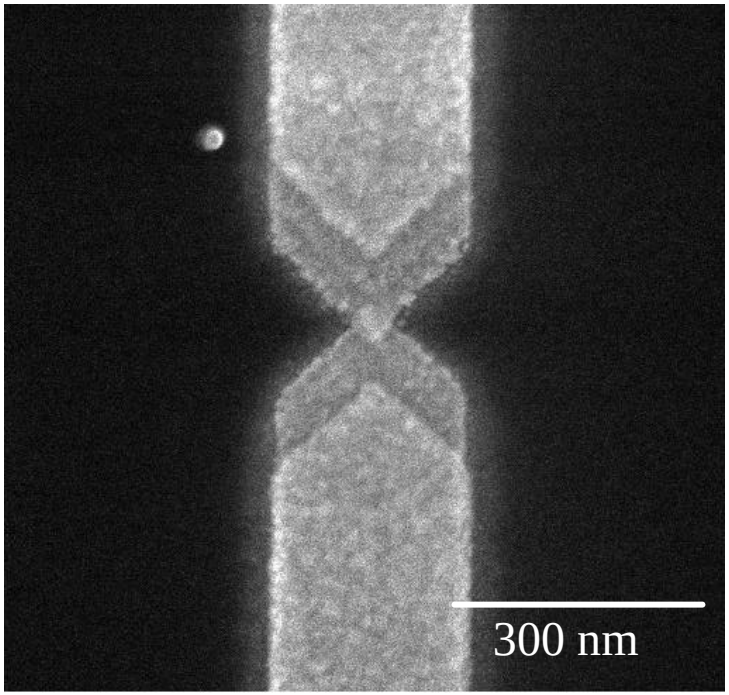
- Expected gate effect





Short Molecules: Device Fabrication

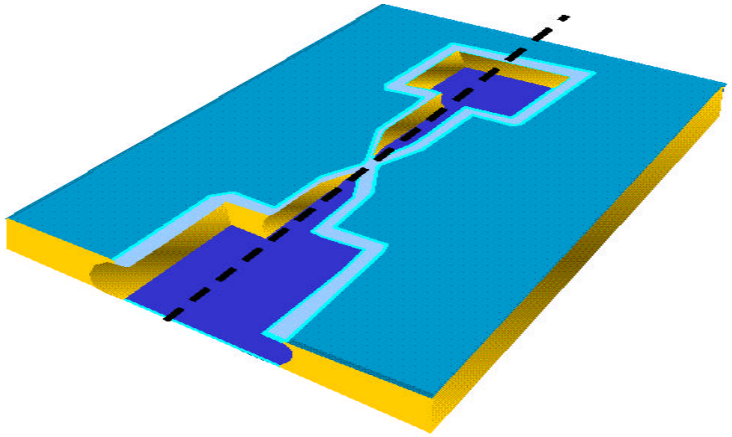


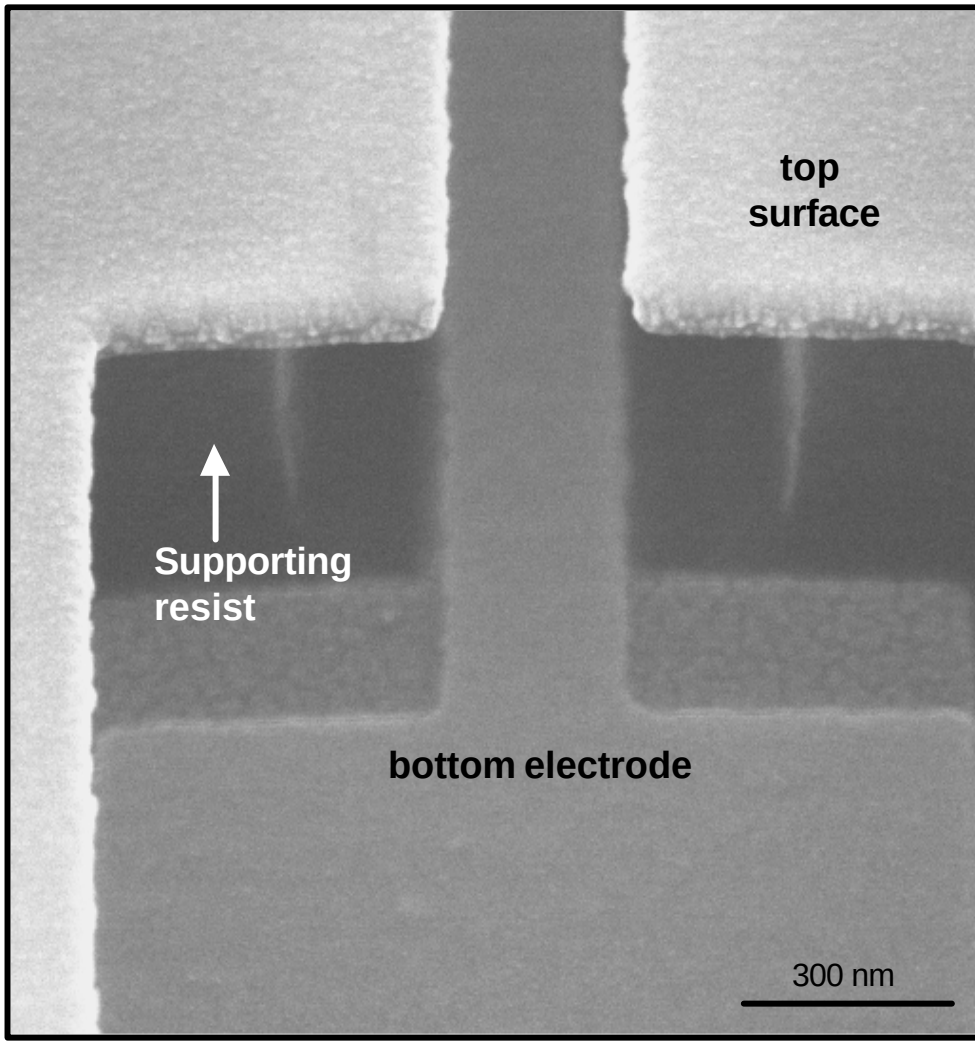


- Evaporation of first electrode
- **Formation of SAM**
- Evaporation of the second electrode
- Varying overlap sizes

Short Molecules: Device Fabrication

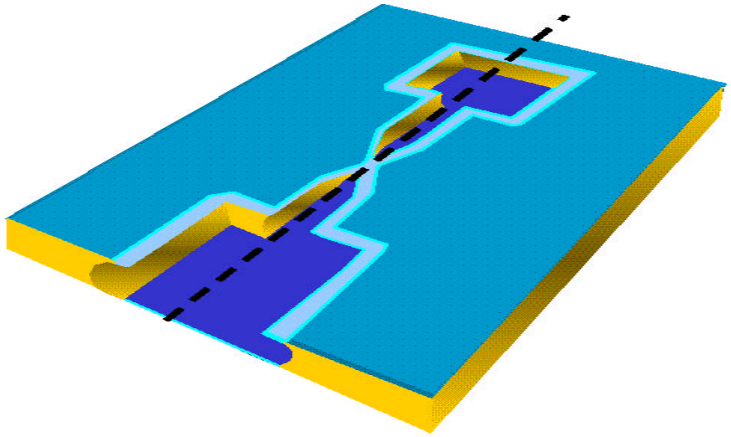
- New resist technique
  - PMMA
  - Si or SiN
  - Photoresist or SiO_2
- SF_6 and O_2 etching
- No lift-off

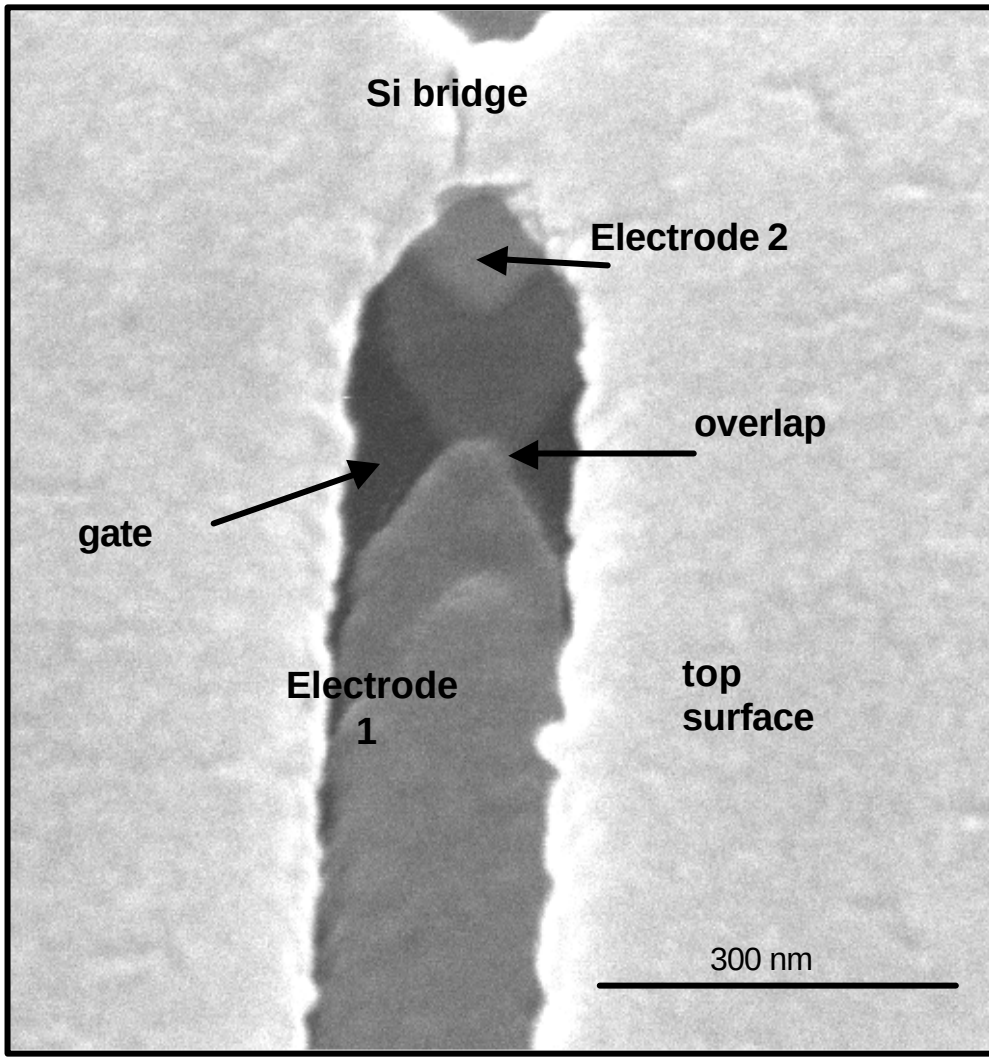




Short Molecules: Device Fabrication

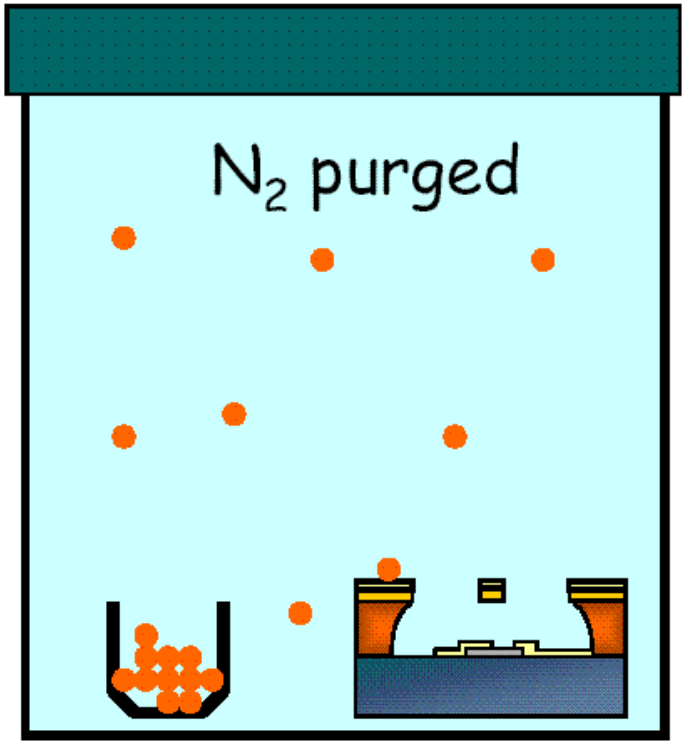
- New resist technique
  - PMMA
  - Si or SiN
  - Photoresist or SiO_2
- SF_6 and O_2 etching
- No lift-off



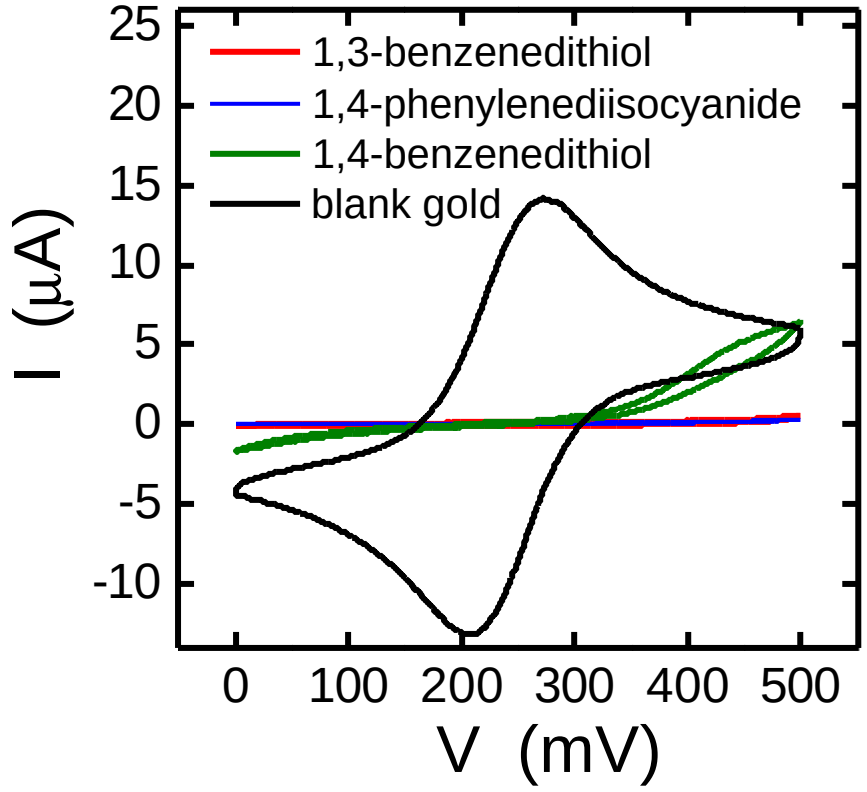


Short Molecules: Device Fabrication

- Growth of SAM
  - Liquid
  - Gas

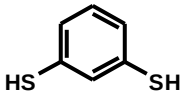
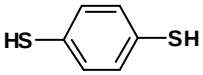
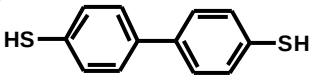
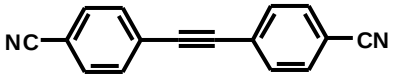


- Cyclic voltammetry
  - 1 mM $K_4[Fe(CN)_6]$, 0.5 M KCl



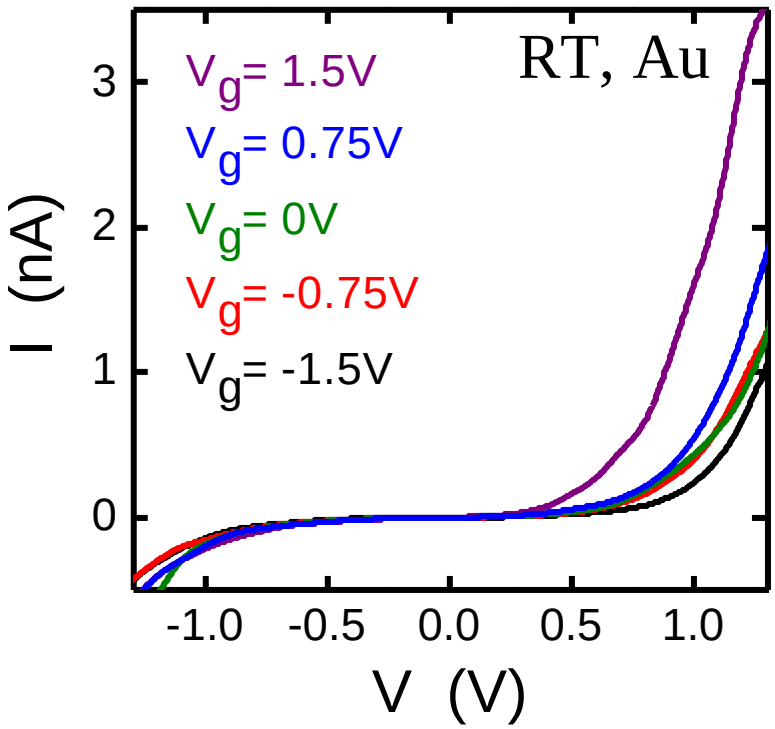
Short Molecules: Device Fabrication

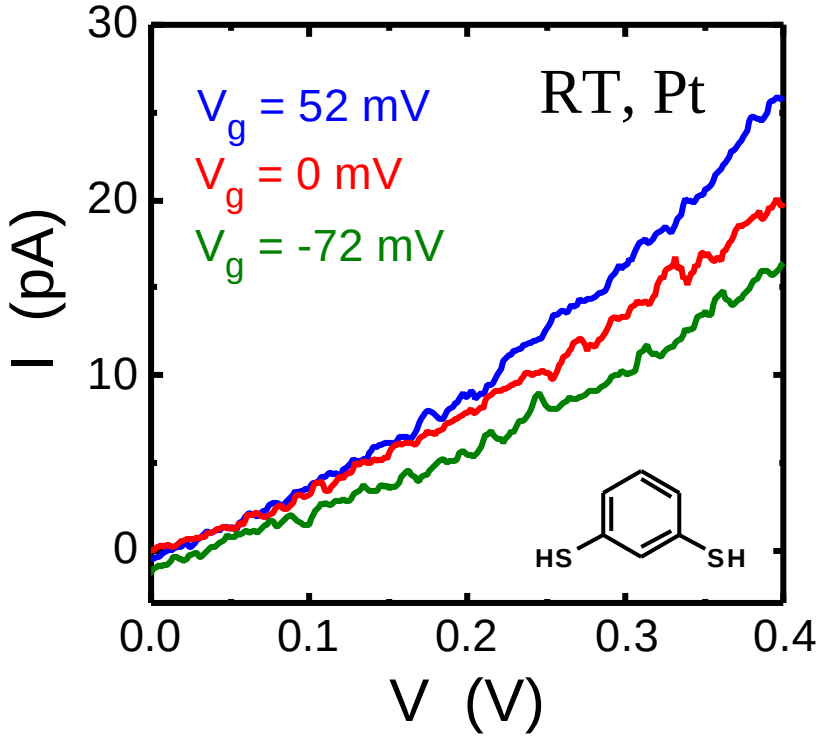
- Device yield

Molecules	Yield (%)	Total # of fabricated samples	Gate dependent samples	Liquid growth	Gas phase SAM growth	characteristics
1 	7.8	256	2	Y	Y	Asymmetric *I-V*
2 	0	216	0	Y	Y	
3 	16	236	0	Y	Y	NDC
4 	5	108	0	Y	N	NDC
5 	0	72	0	Y	N	

Short Molecules: Results

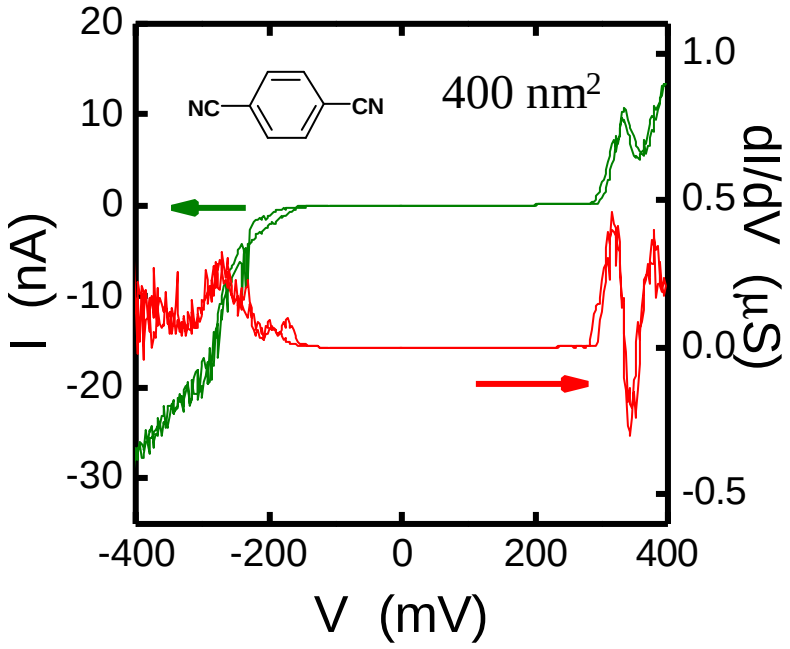
- No gate effect
- Only two exceptions (out of 20) with 1,3 benzenedithiol
- Asymmetric IV courves

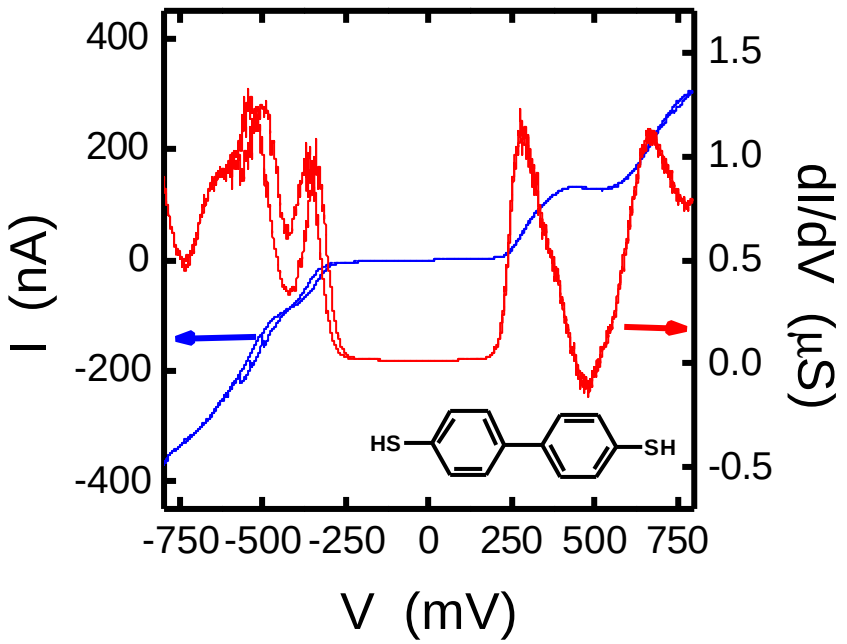




Short Molecules: Results

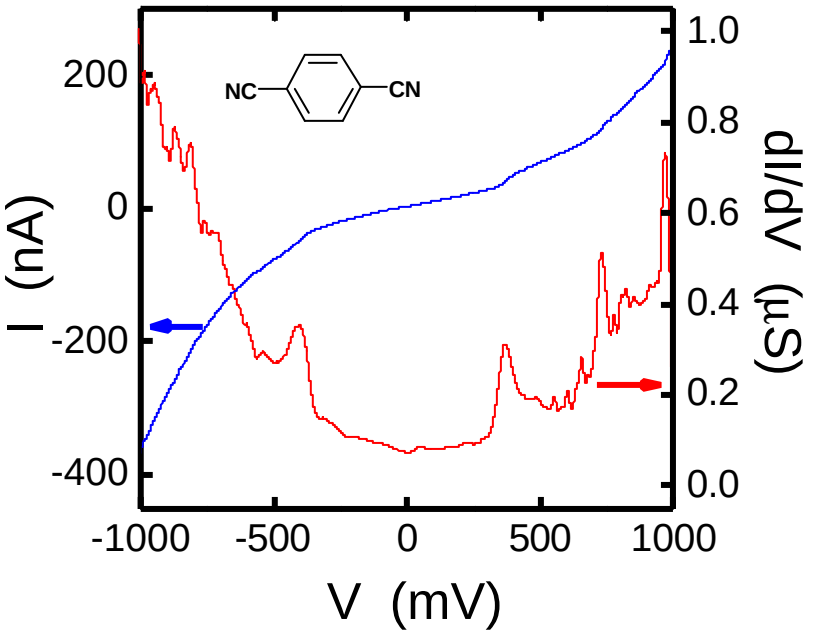
- Negative-differential resistance
  - 1,4-phenylenediisocyanide at 2 K for small overlap
  - 4,4′-biphenyldithiol

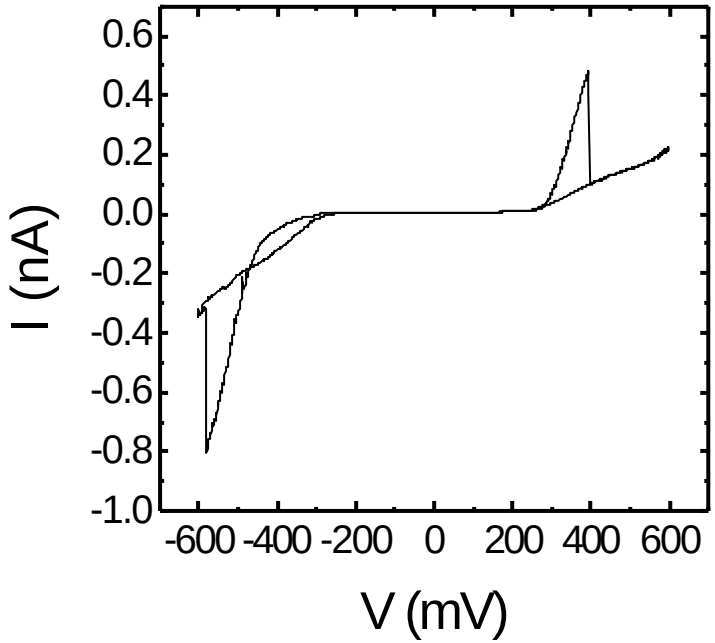




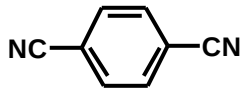
Short Molecules: Results

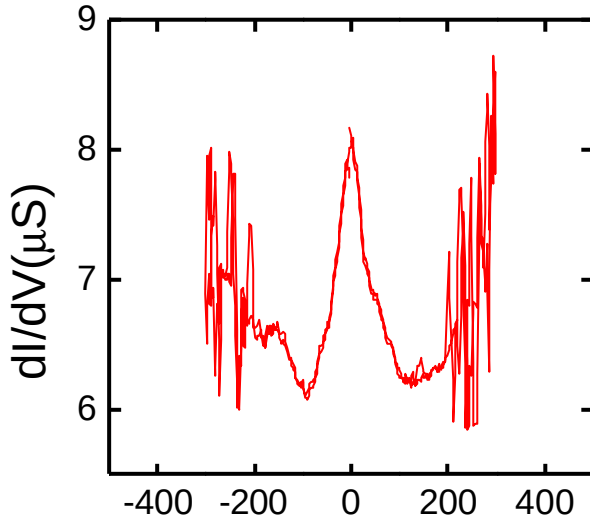
- Switching with all molecules and overlap sizes
  - Switching behaviour for big overlap sample 1,4-phenylenediisocyanide at 4.2 K
  - Discrete even though many 1000s of molecules in parallel

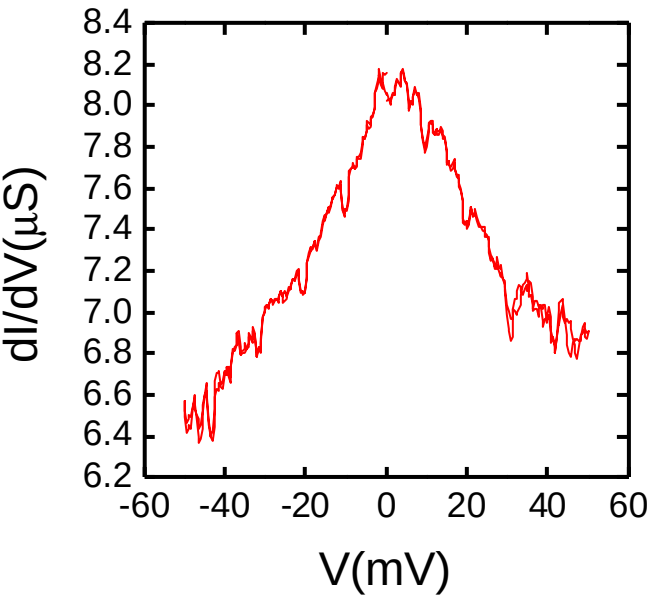


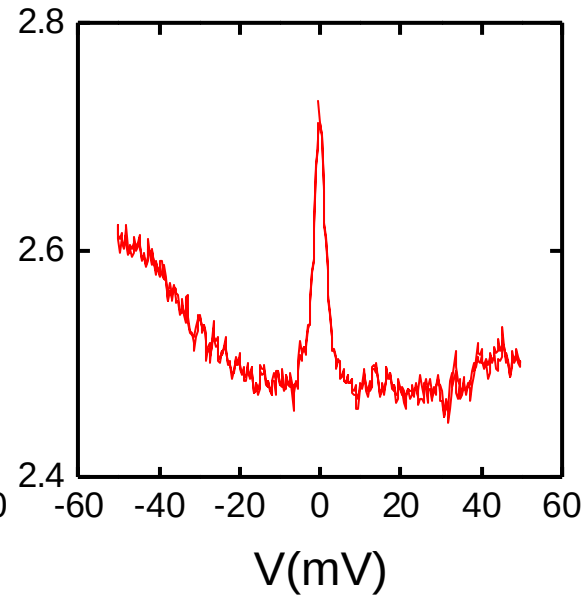


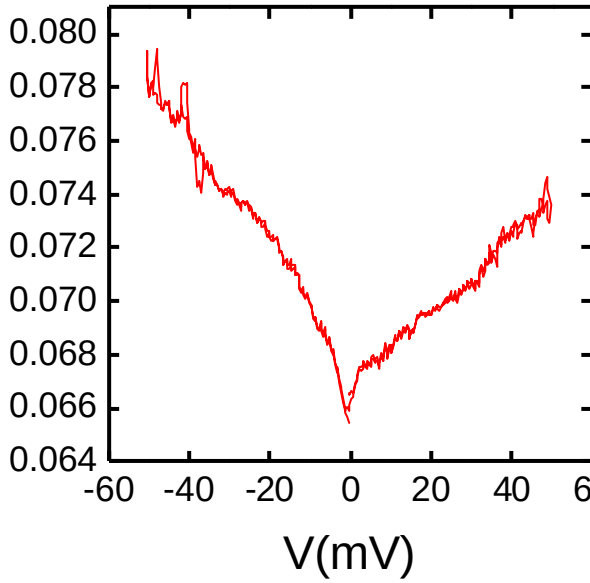
Short Molecules: Zero-Bias Peak

- Occasional anomalies in zero-bias conductance
- 









Conclusions

- Long molecules are more promising
  - Gate effect for long (8nm) molecules
  - No prospect for “SAMFET’s”
- Interesting nonlinear transport characteristics
  - NDR
- “Electrical annealing”