Molecular electronics

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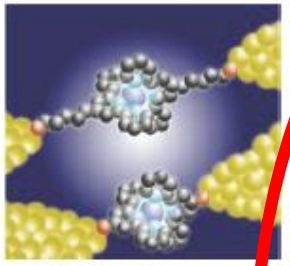
What is molecular electronics?

single molecule electronics

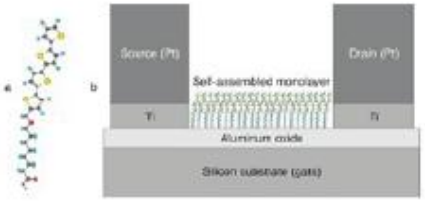


L < a few nm
t < a few nm

basic science
knowledge development

no foreseen applications
in a reasonable time-scale

self-assembled molecular electronics



L ~ hundred nm - µm
t < a few nm

basic science
knowledge development

possible applications
foreseen

thin-film molecular electronics

L > µm
t > few 10 nm

plastic electronics
(OLED, OFET, OPV)

some products already
commercialized

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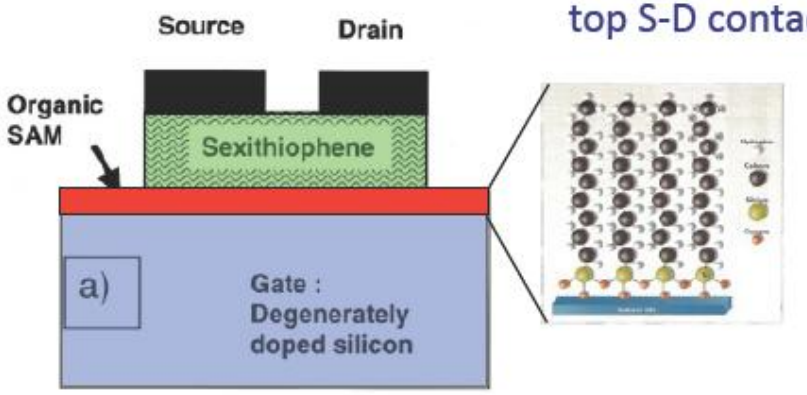
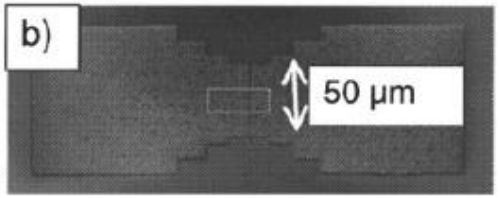
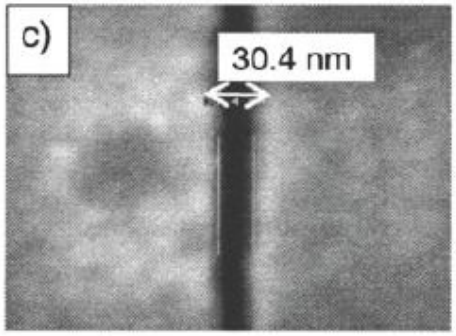
nano-scale organic transistors

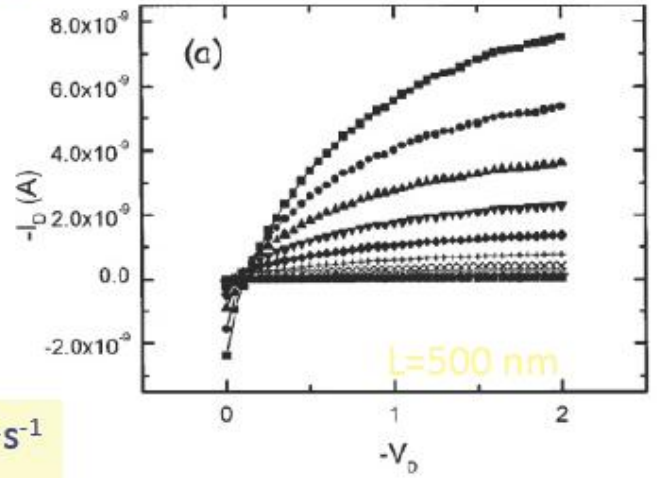
top S-D contacts

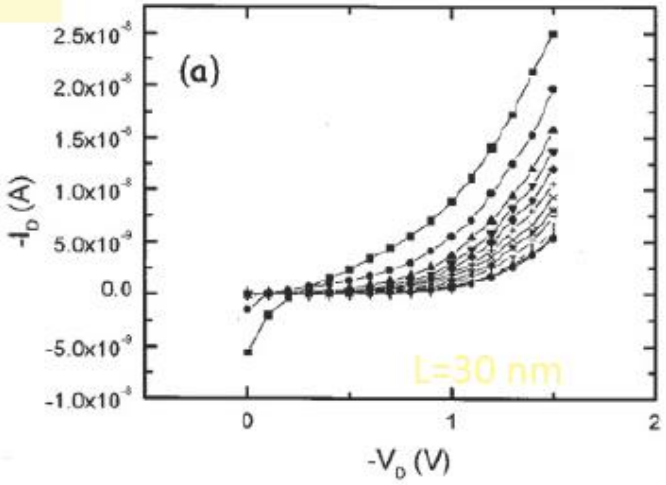






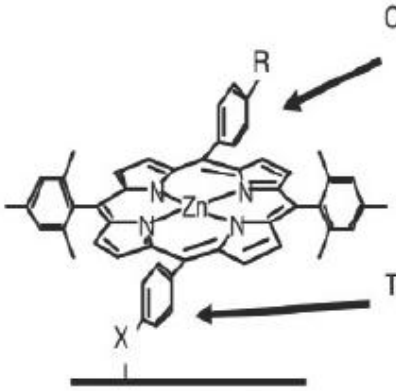
$\mu \approx 10^{-3}\ cm^2V^{-1}s^{-1}$
on/off $\approx 10^4$





Collet, Vuillaume et al., Appl. Phys. Lett. (2000)

Molecular memories & switches



Charge storage molecule
Composition determines
charge density, size, isolation,
voltage, stability (thermal and
electrical)

Tether
Composition determines self-
alignment site, endurance,
charge transfer rate,
charge retention

porphyrins

Principle 1 : charge storage on a redox molecule

Table I: Criteria for Incorporation of Molecules in CMOS Storage Devices.

Property	Implementation
Chemical stability	Delocalized cationic charge
Thermal stability	$T_{decomposition} > 400°C$.
Endurance	$>10^{15}$ cycles
Read/write speed	$t_{R/W} = 1/k_{eff} < 10$ ns
Charge retention half-life	$t_{1/2} > 10$ s
Charge density	$\mu = 10\ \mu C/cm^2$ or higher
Self-assembly and self-alignment	Selective covalent bond formation of molecules to specific substrate

W. Kuhr, Mat Res Soc (2004)

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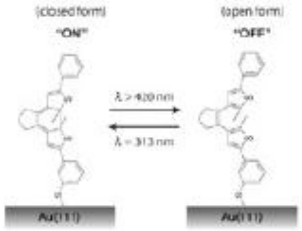
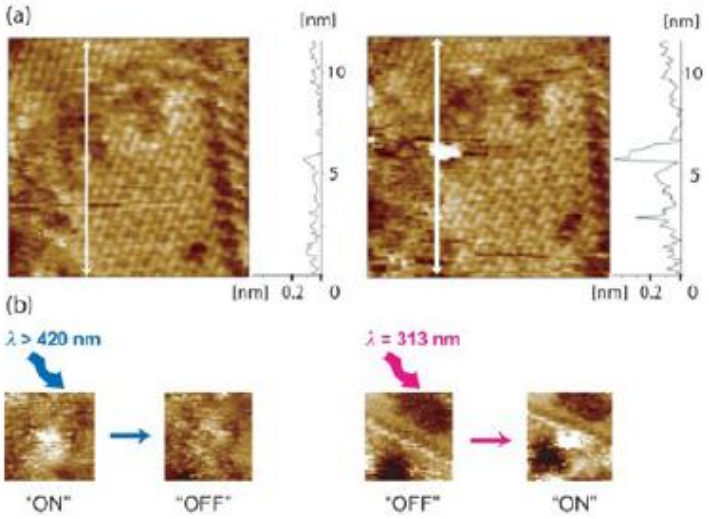
Principle 2 : change of molecular conformation, conductance switching

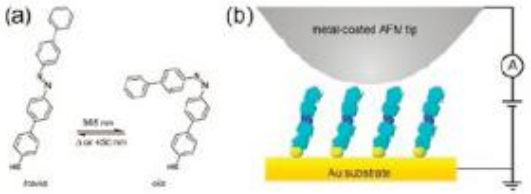
diarylethene

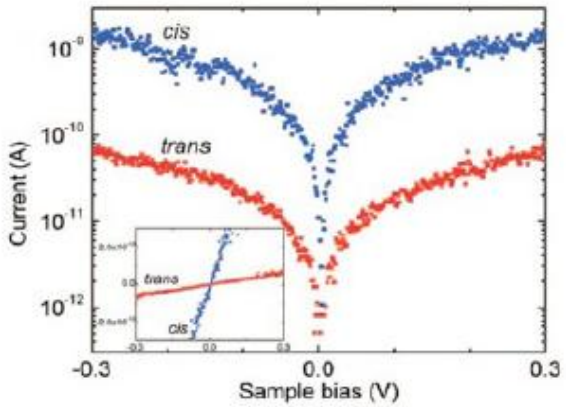




B. Feringa et al., Adv Mater (2006)

azobenzene derivative

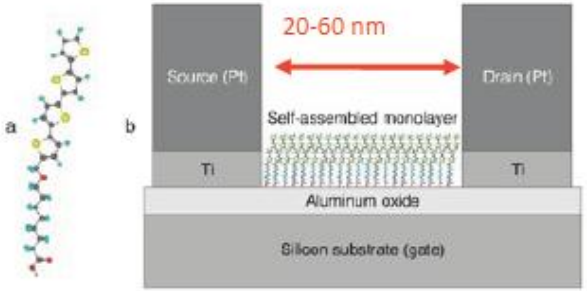


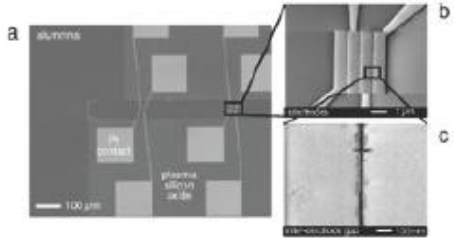


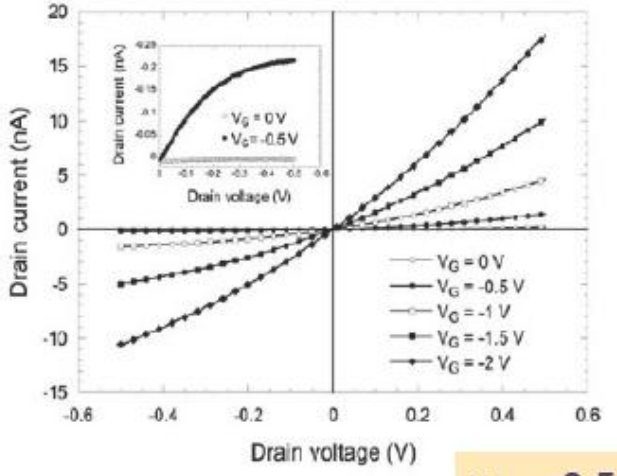
J.M. Mativetsky et al., JACS 2008

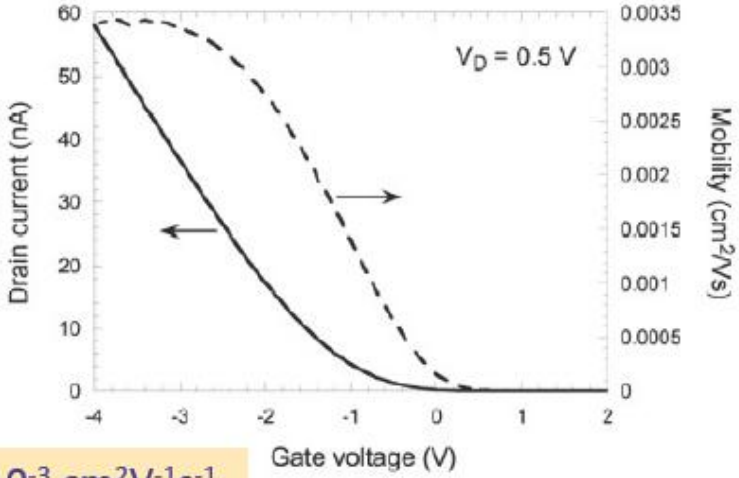
on/off ratio < 100

SAM Field Effect Transistor









$\mu_{max}=3.5x10^{-3}\ cm^2V^{-1}s^{-1}$

$I_{on}/I_{off} \sim 1800\ (V_D=-0.5V)$

Mottaghi et al., Adv. Func. Mater. (2007)

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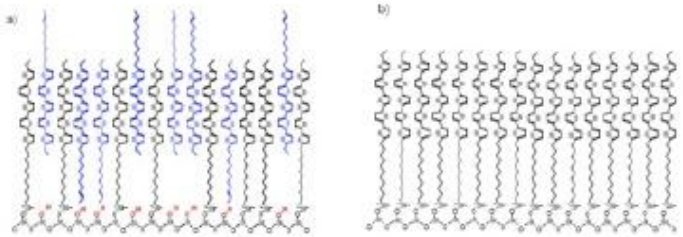

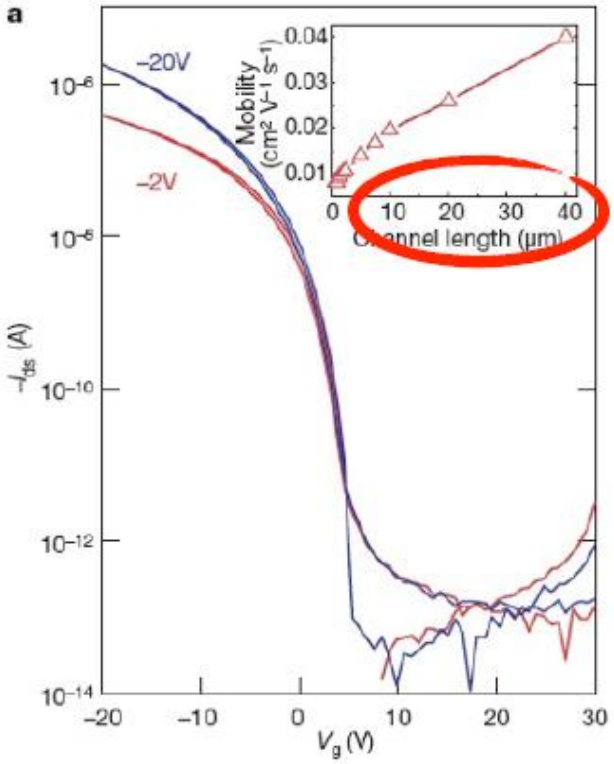

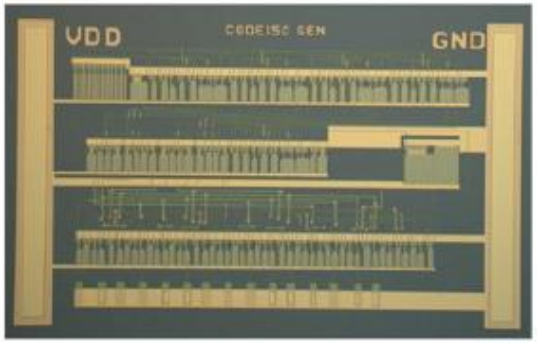

Fig. S31. Optical photograph of a functional 15-bit SAMFET code generator. The circuit combines over 300 SAMFETs.

15-bit code generator
300 SAMFETs

Smits et al., Nature (2008)

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Comments/Discussion:

- So far driven by academic push
- Industrial pull? Philips active on FETs
- Fexible electronics
- Integration? Several different molecules needed, connection..?
- Design related issues?