Prospects in molecular electronics devices based on supramolecular chemistry

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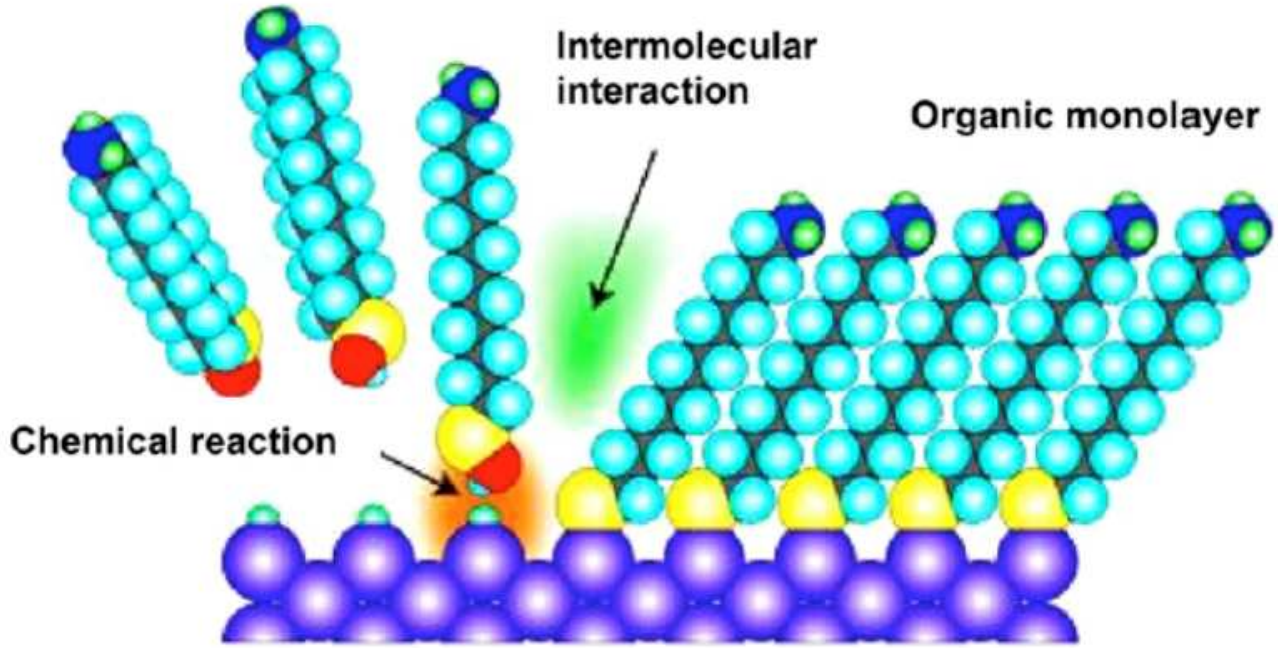
- What is "supramolecular chemistry" relevant to this talk?
- Nanodielectrics
- Monolayer transistors
- Monolayer memories and switches

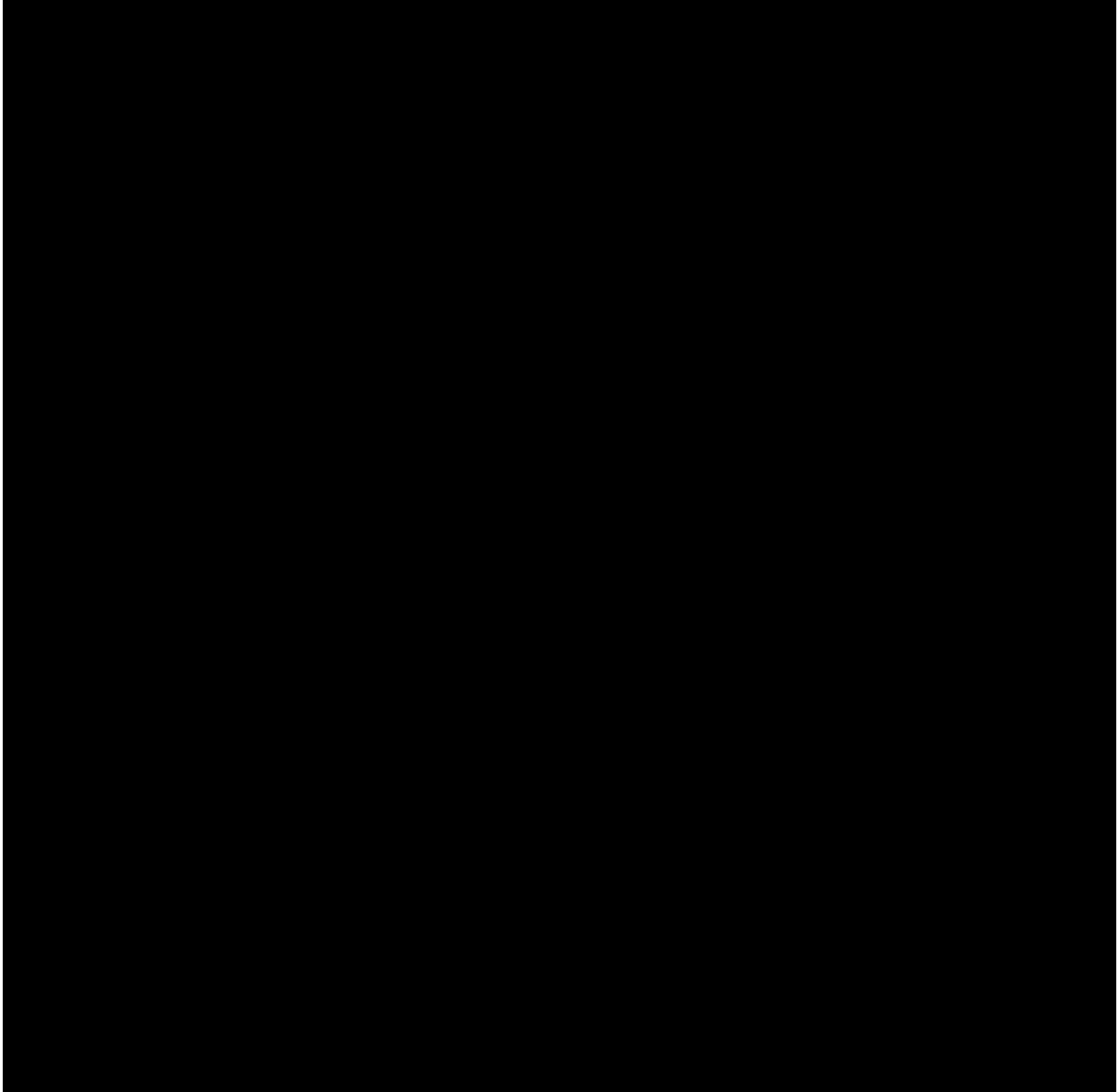
# of supramolecular chemsitry

- "... consists in the design of systems undergoing self-organization, that is, systems capable of spontaneously generating a well-defined supramolecular architecture by self-assembling from their components under a given set of conditions."

J.M. Lehn, Angew. Chem. Int. Ed. (19

SAM : self-assembled mono- or multi-layers

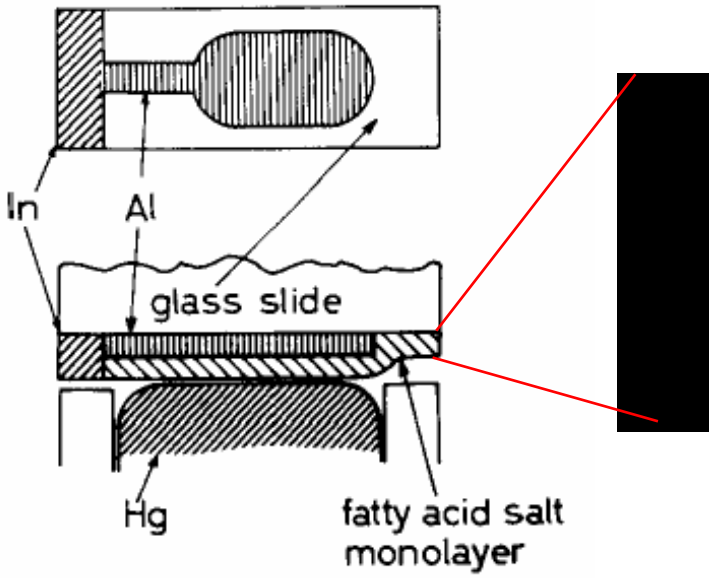


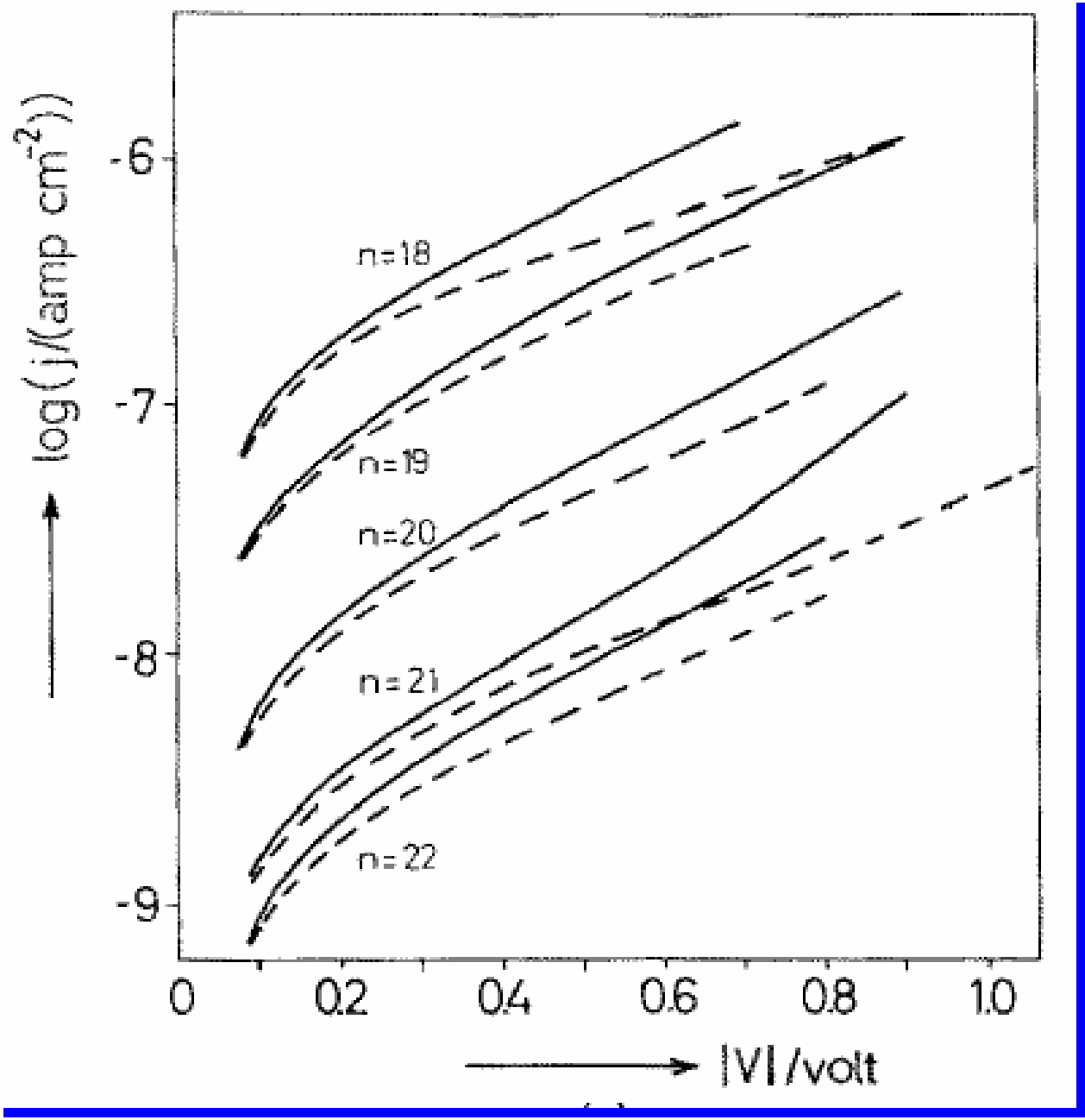


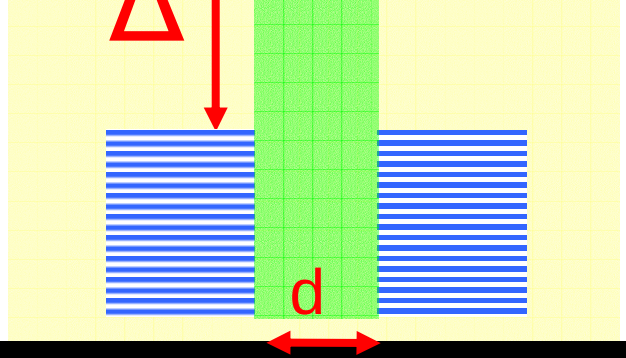
Not a recent story

Mann & Kuhn, J. Appl. Phys. (1971)

1rst evidence of tunneling through a fatty acid LB monolayer sandwiched between metal electrodes



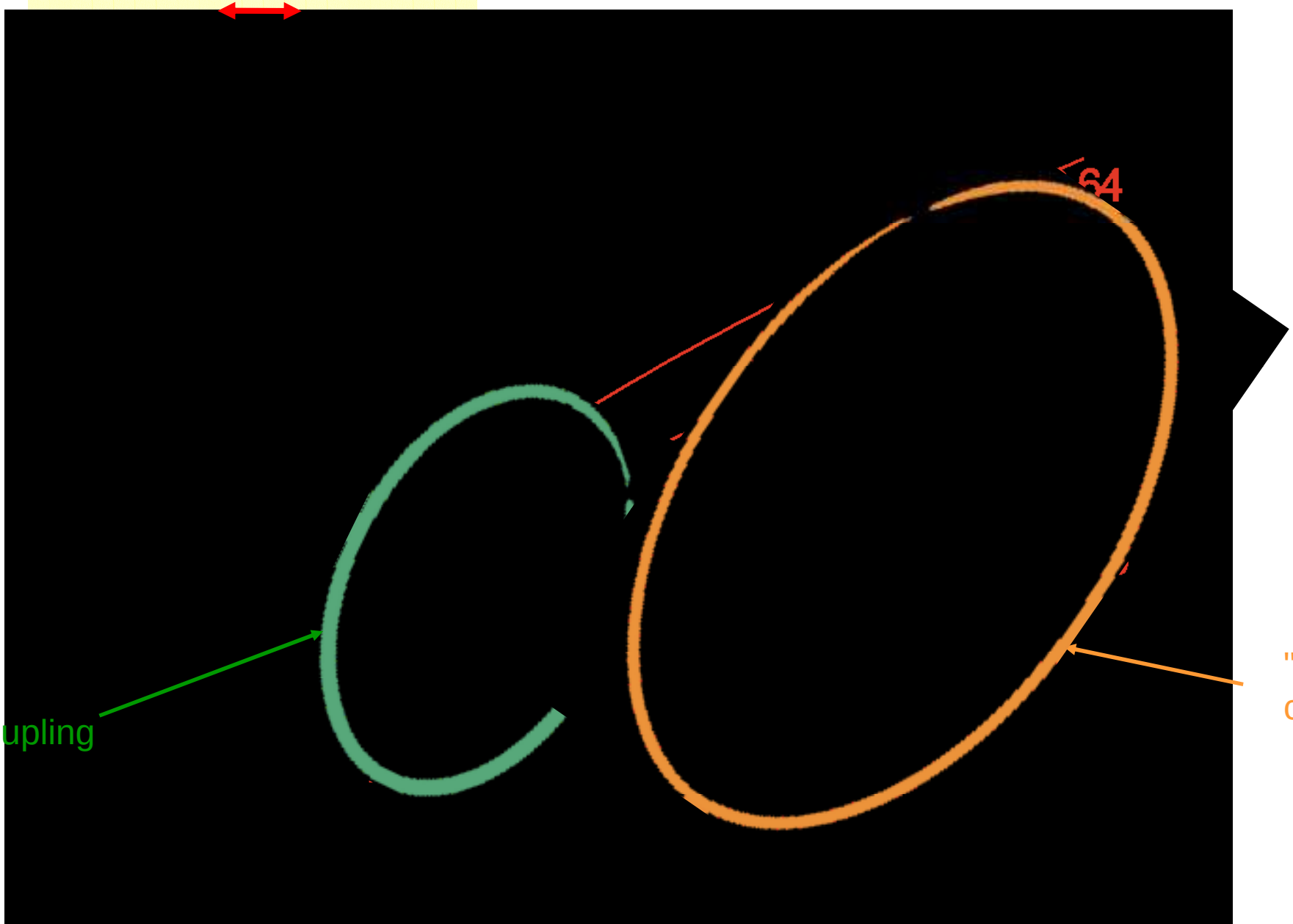




$$J = J_0 e^{\beta d}$$

$$R = R_0 e^{\beta d}$$

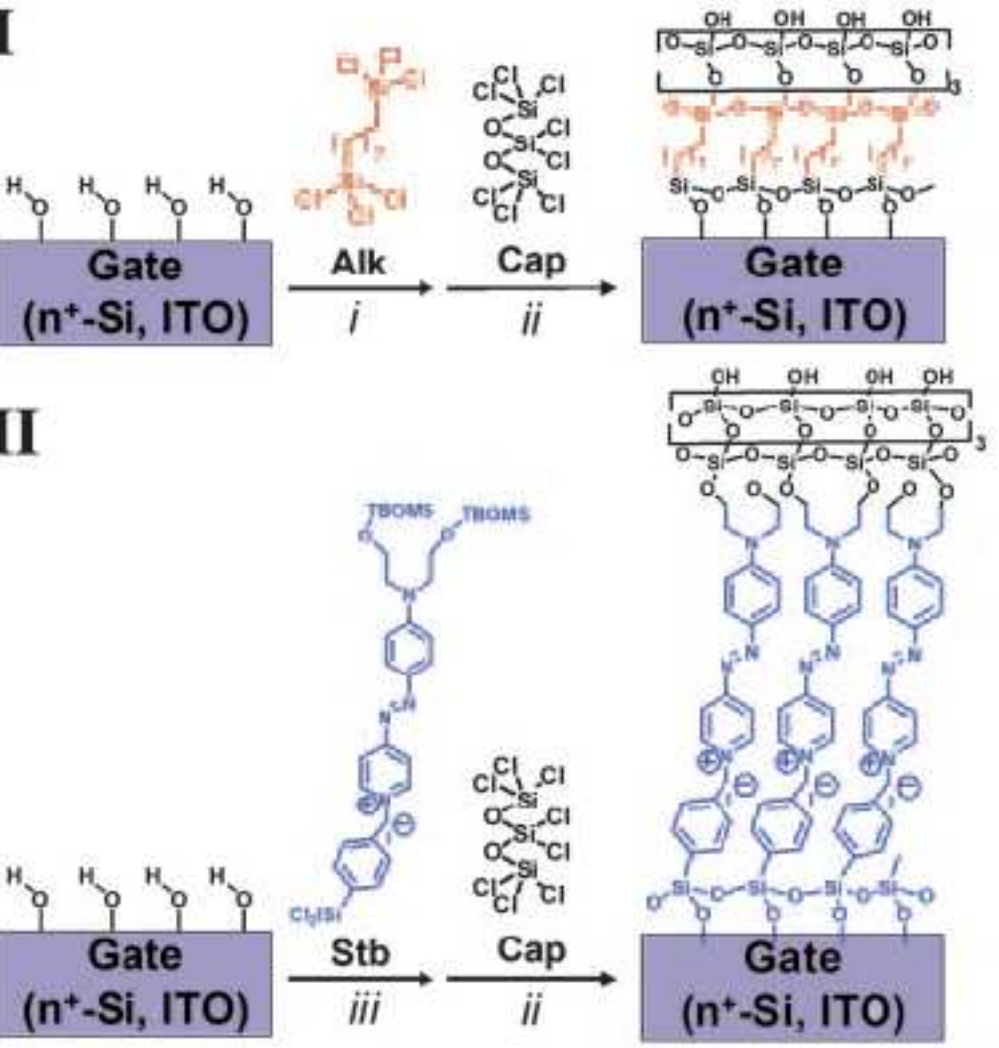
$$\beta = \alpha \sqrt{m^*/m_0} \sqrt{\Delta}$$

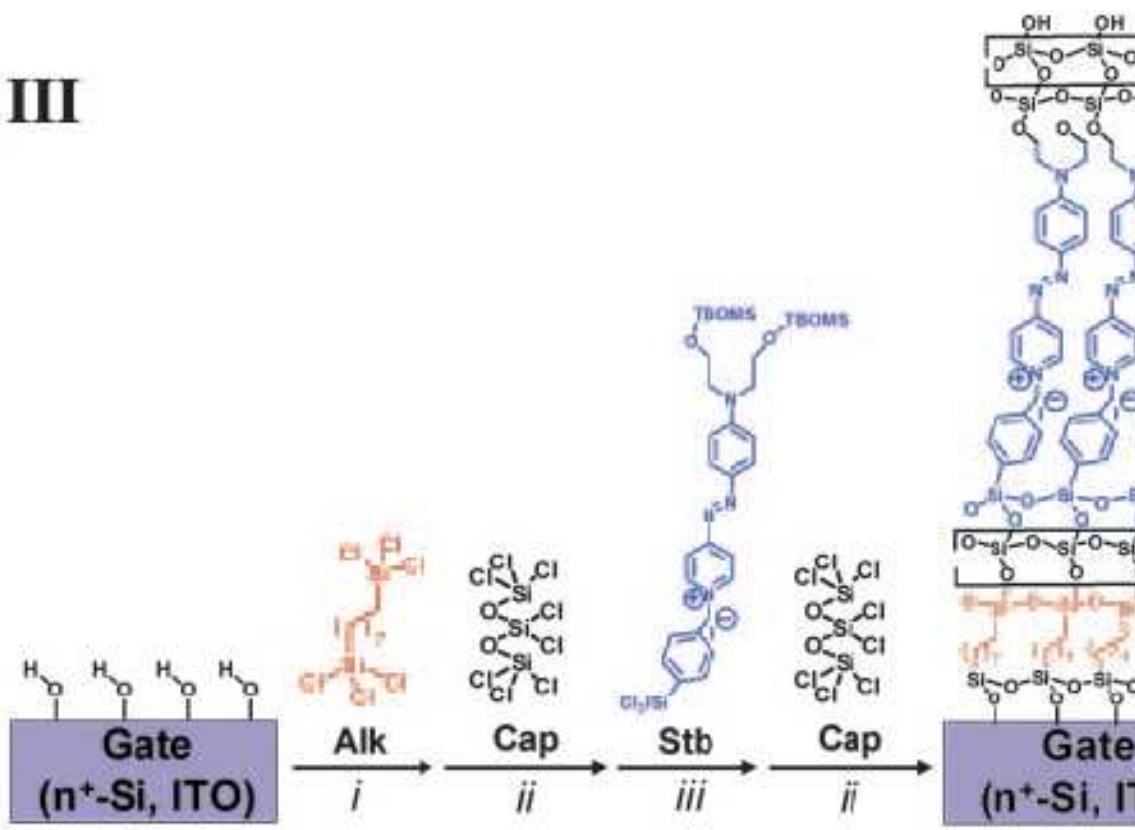


high-k SANDs : $\varepsilon_R \approx 5\text{-}10$

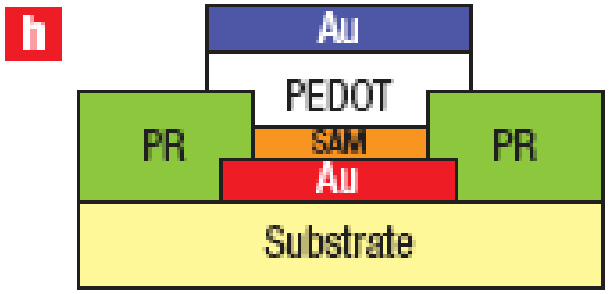
$I_{leak} \approx 10^{-7}$ A/cm^1 @ 1V

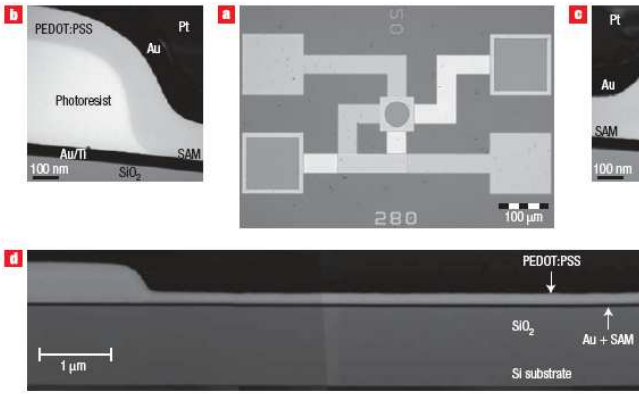
$E_{BD} \approx 7$ - 10 MV/cm

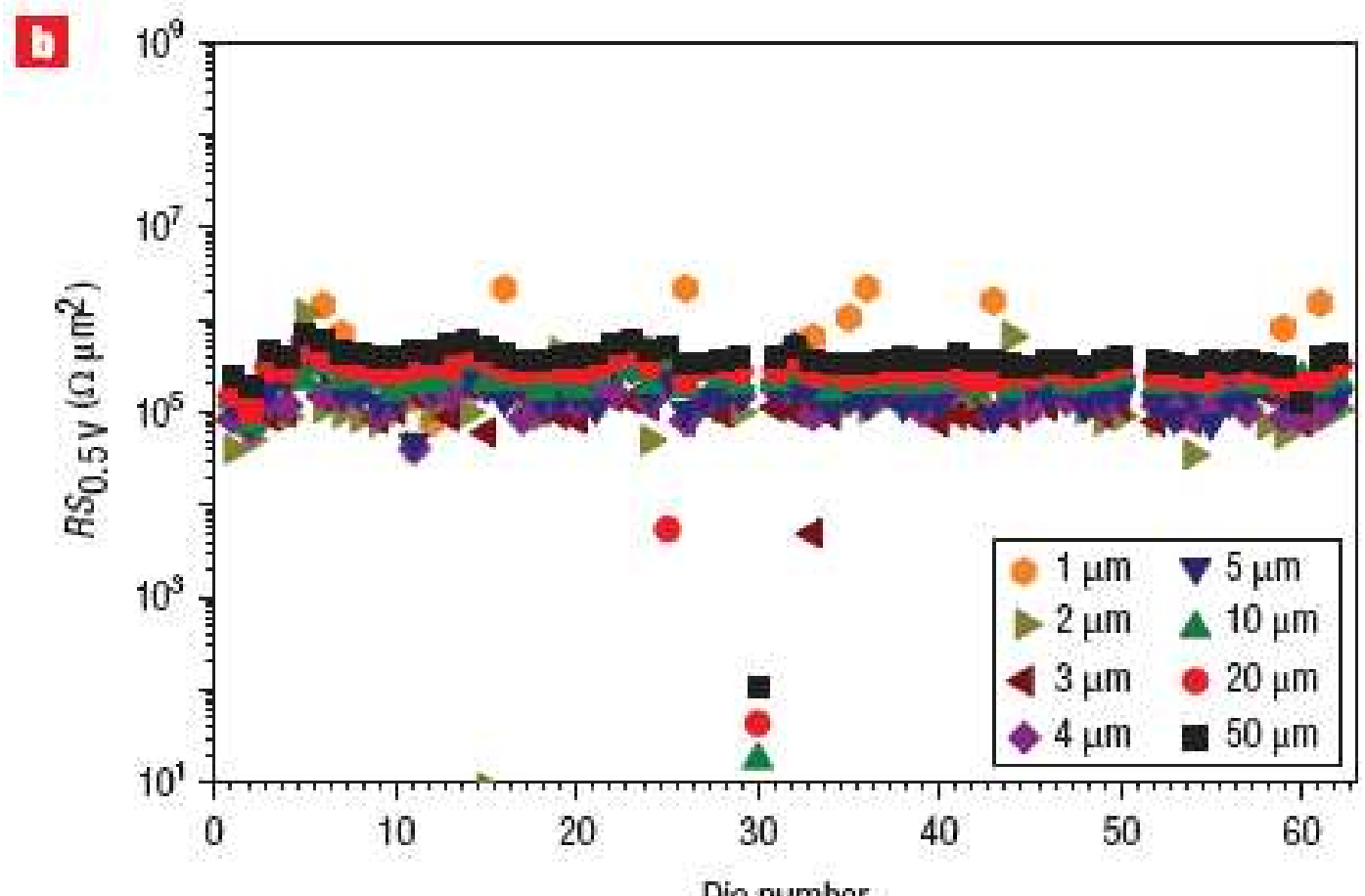


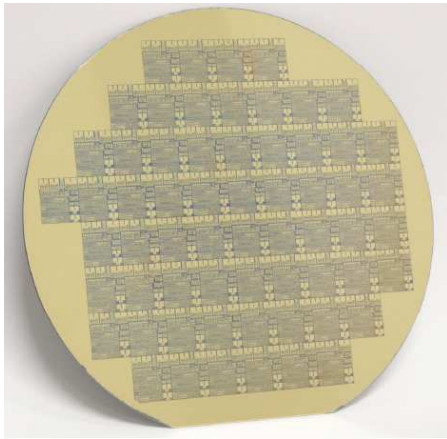


large area capacitors @ wafer level

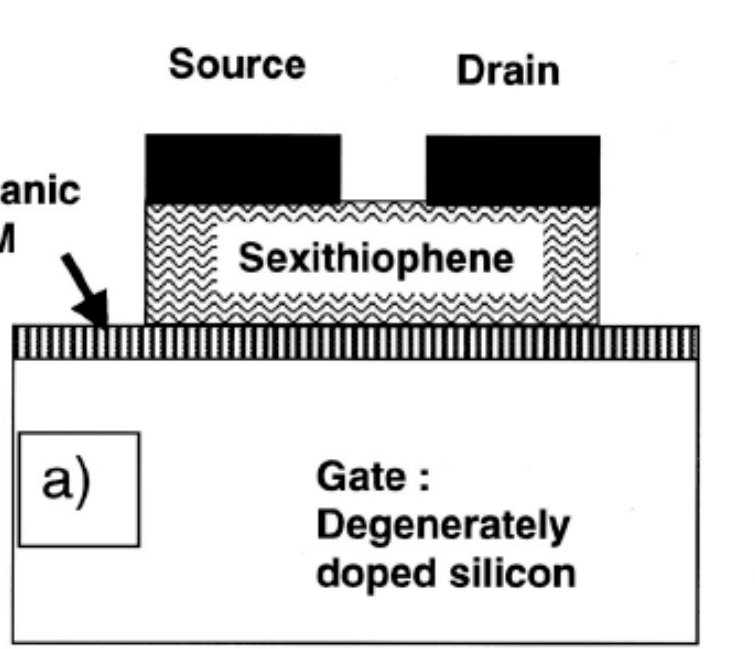


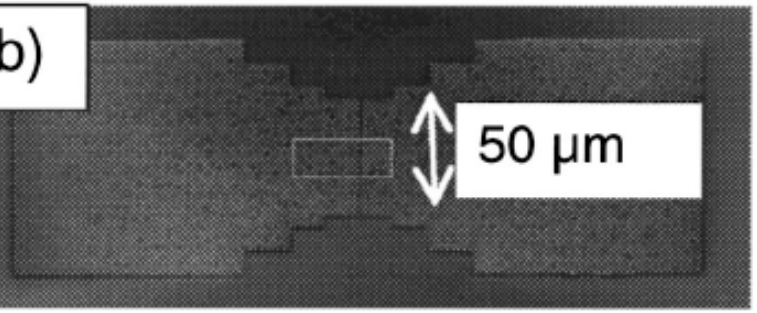


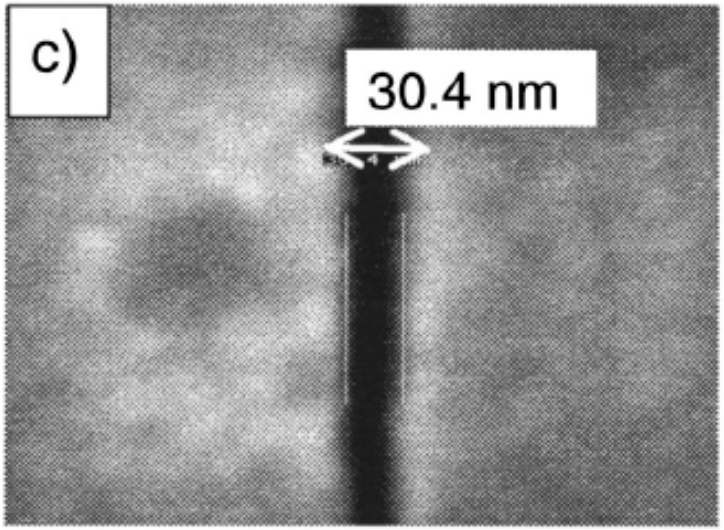




top S-D contacts

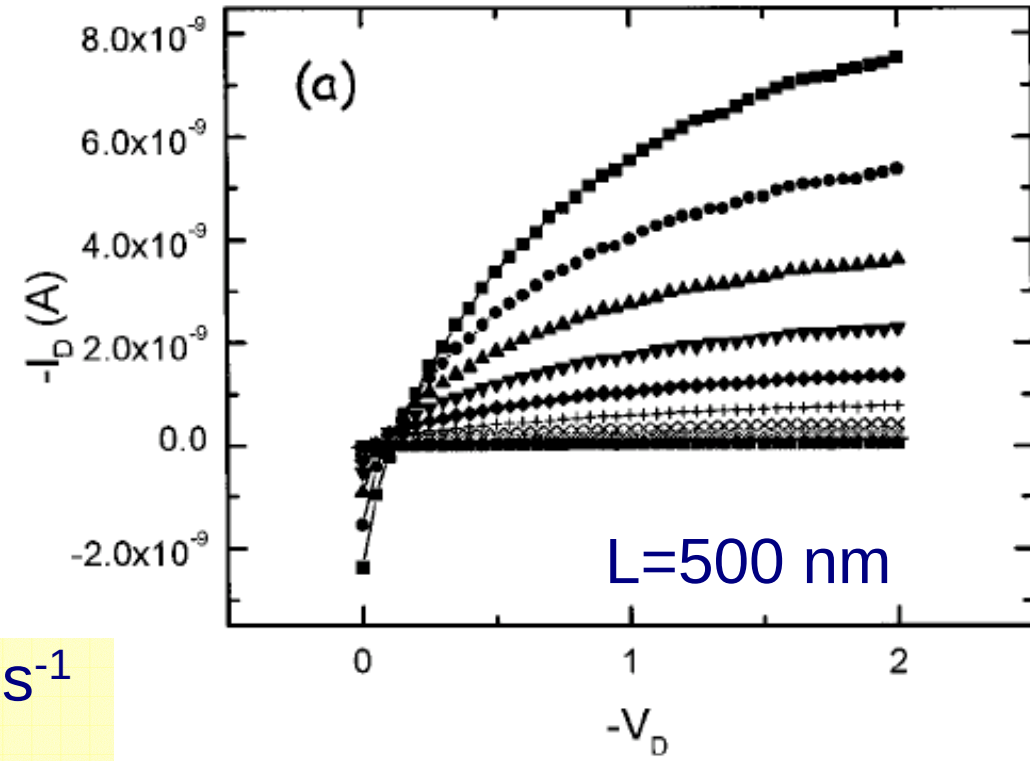


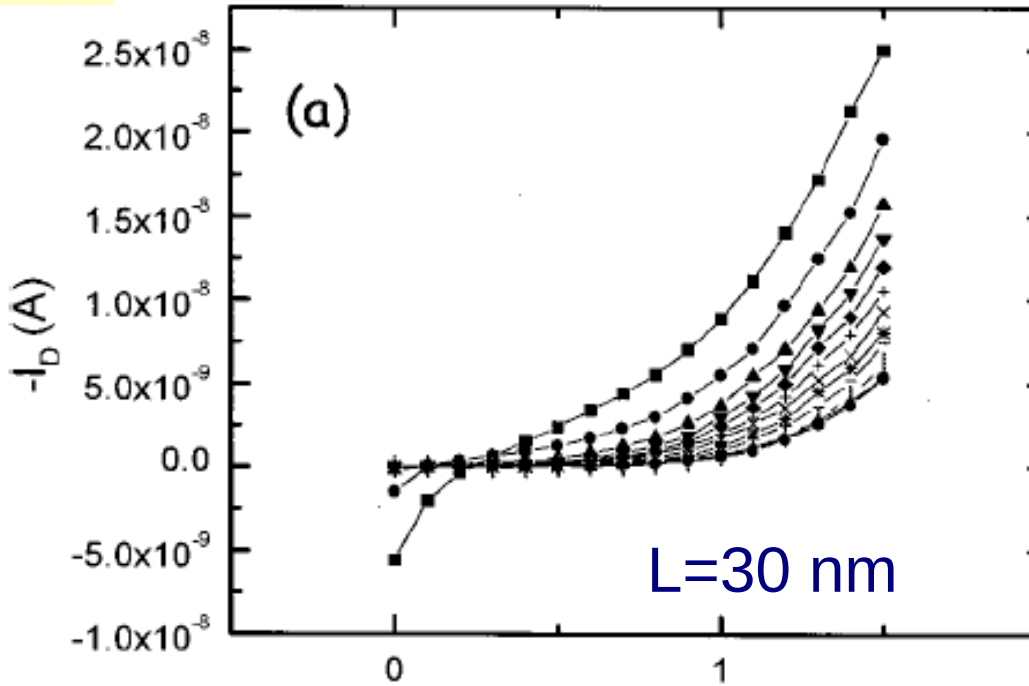


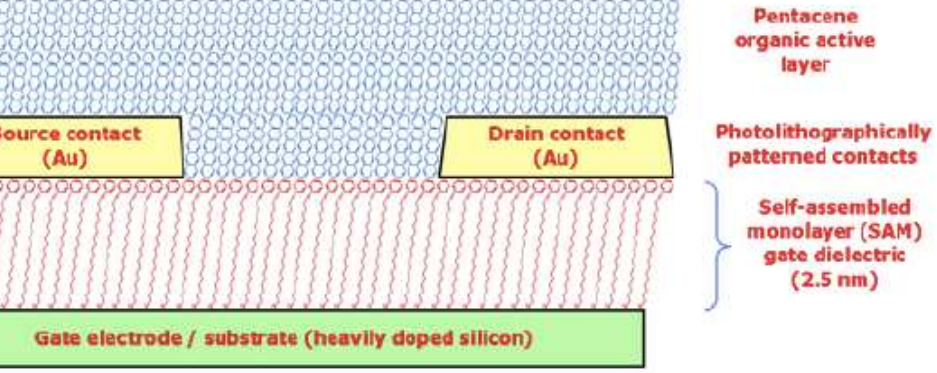


$\mu \approx 10^{-3}\ cm^2V^{-1}s^{-1}$

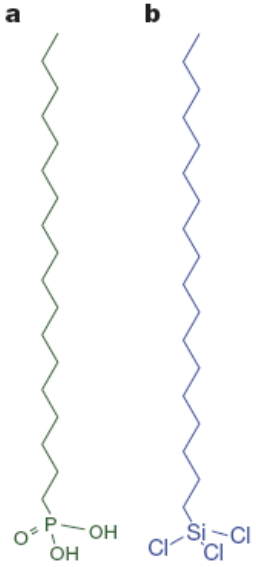
$on/off \approx 10^4$

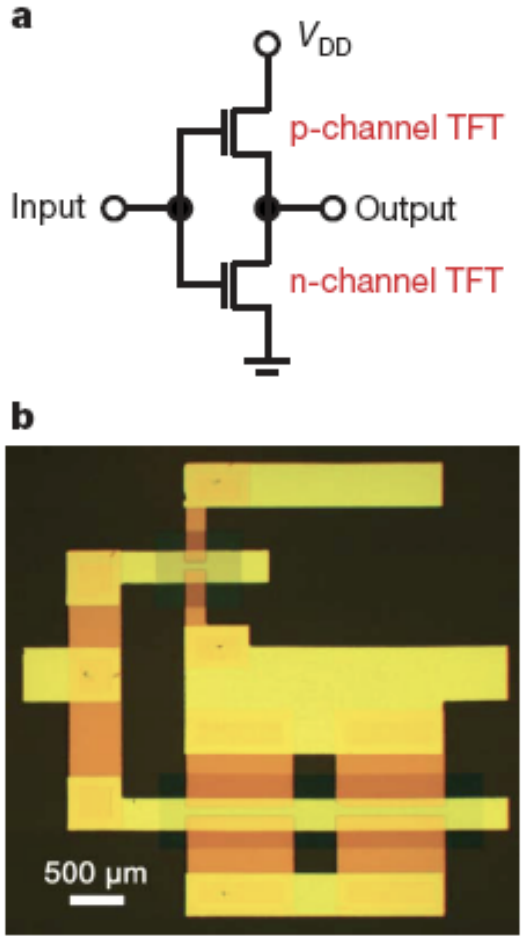


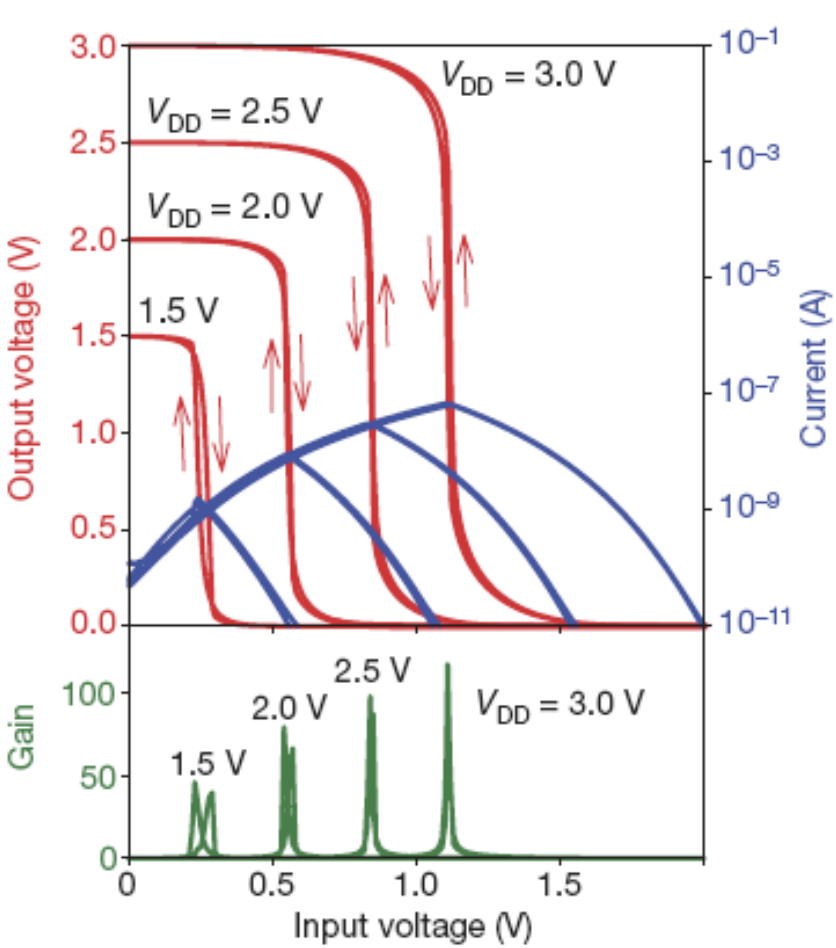


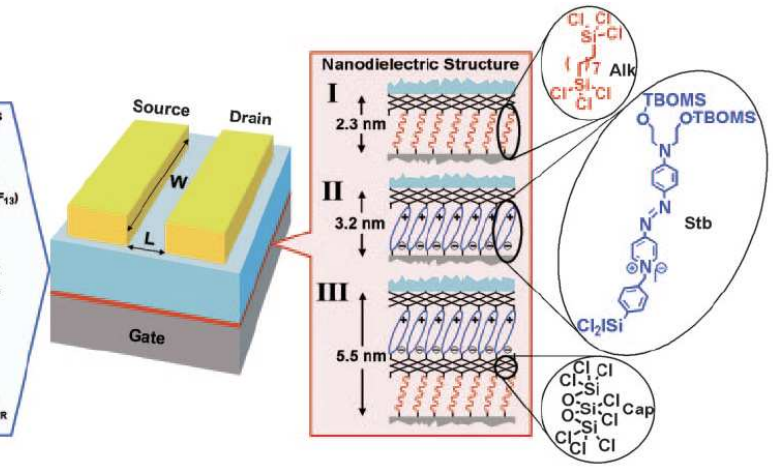


bottom S-D contacts







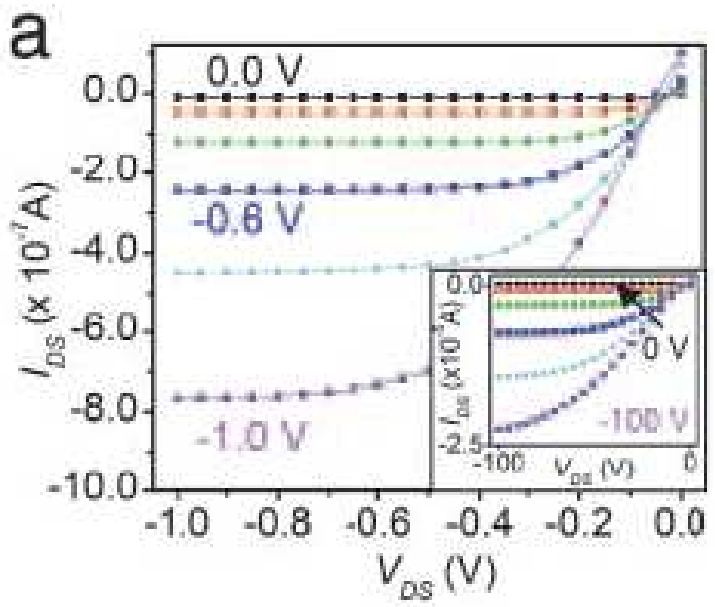


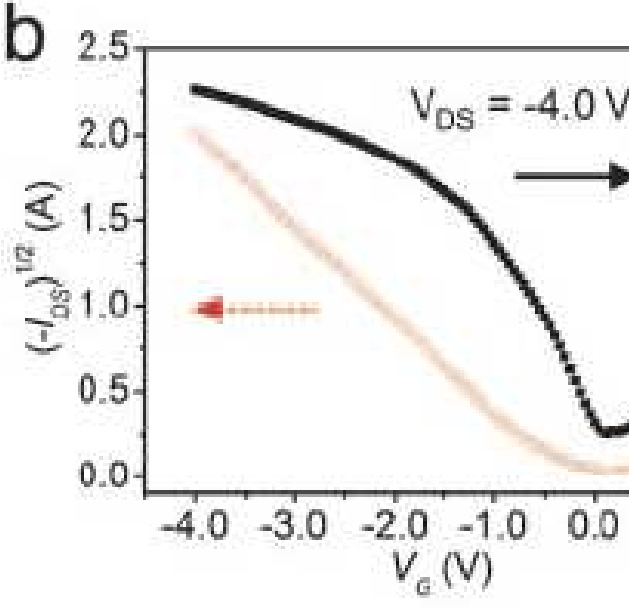
n- and p-type OSC

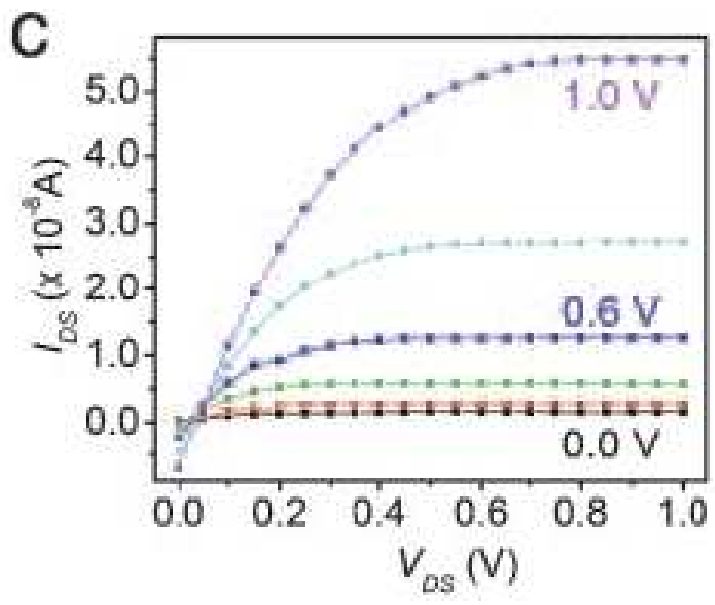
μ : up to 10^{-2} $cm^2V^{-1}s^{-1}$

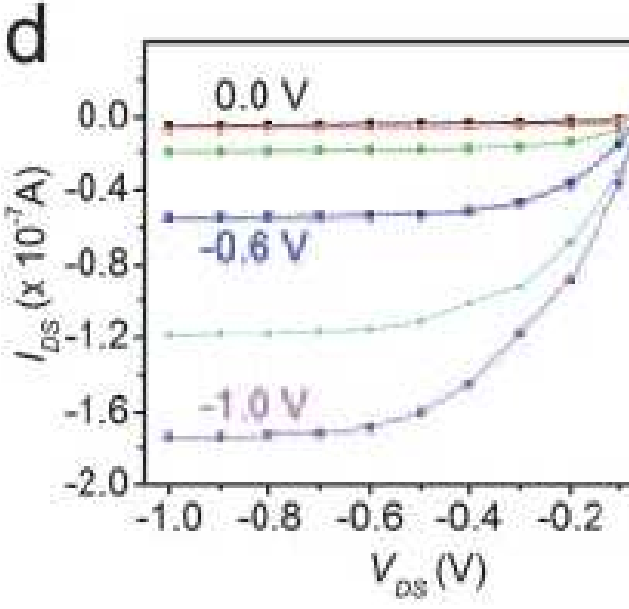
on/off : up to 10^5

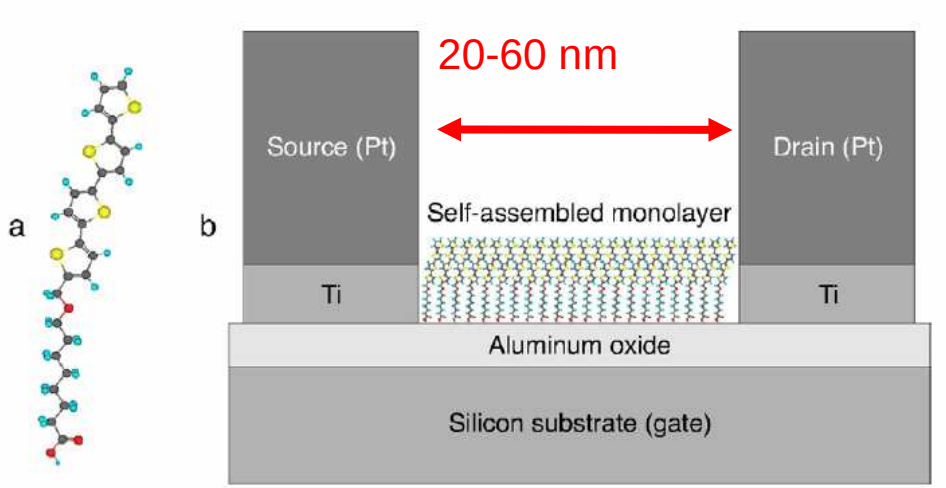
with CNT 2D network FET

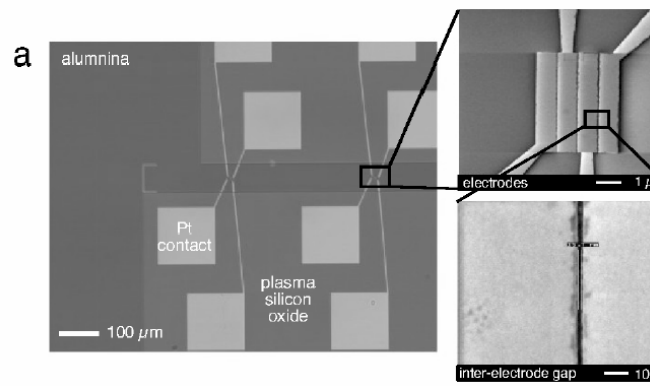


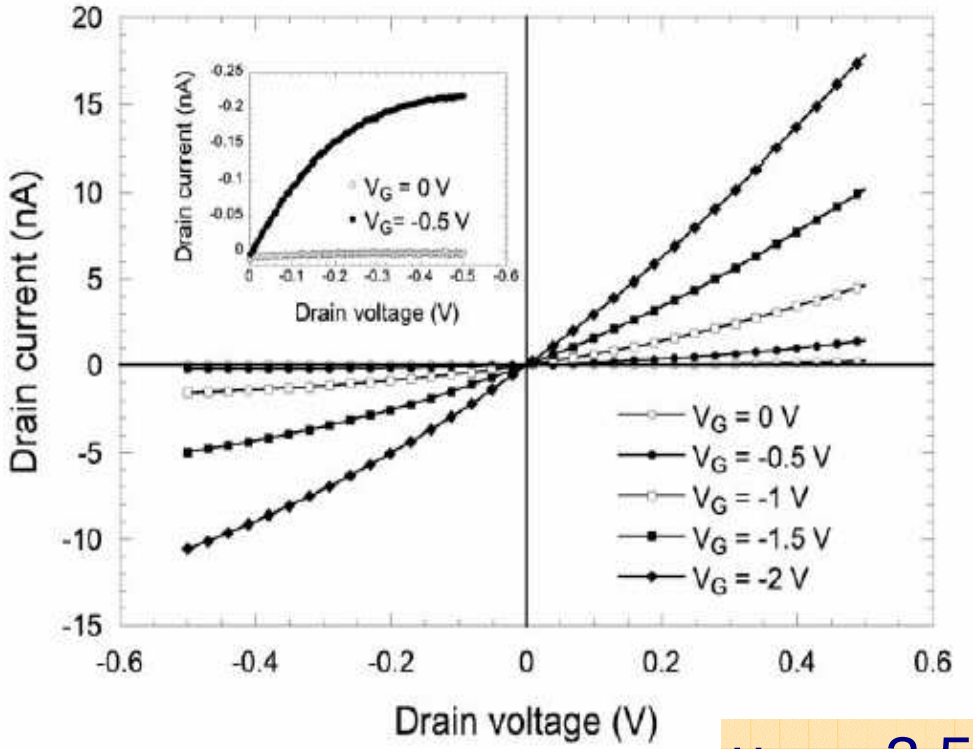


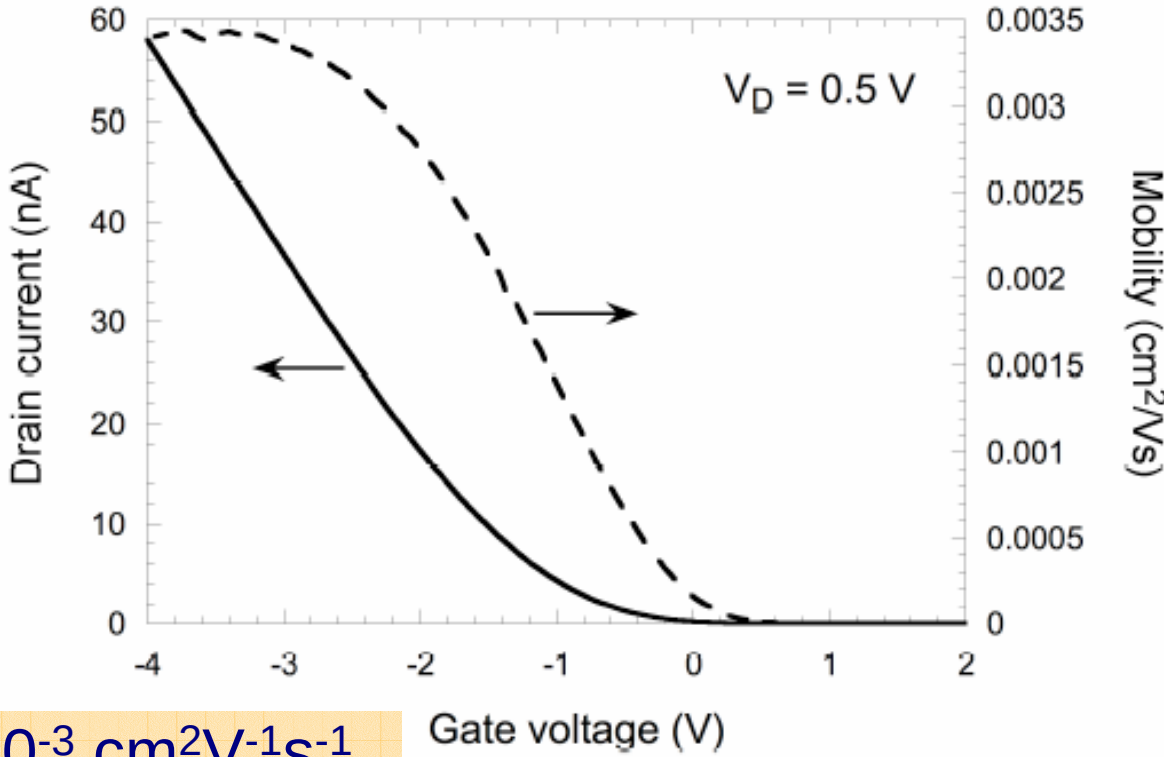




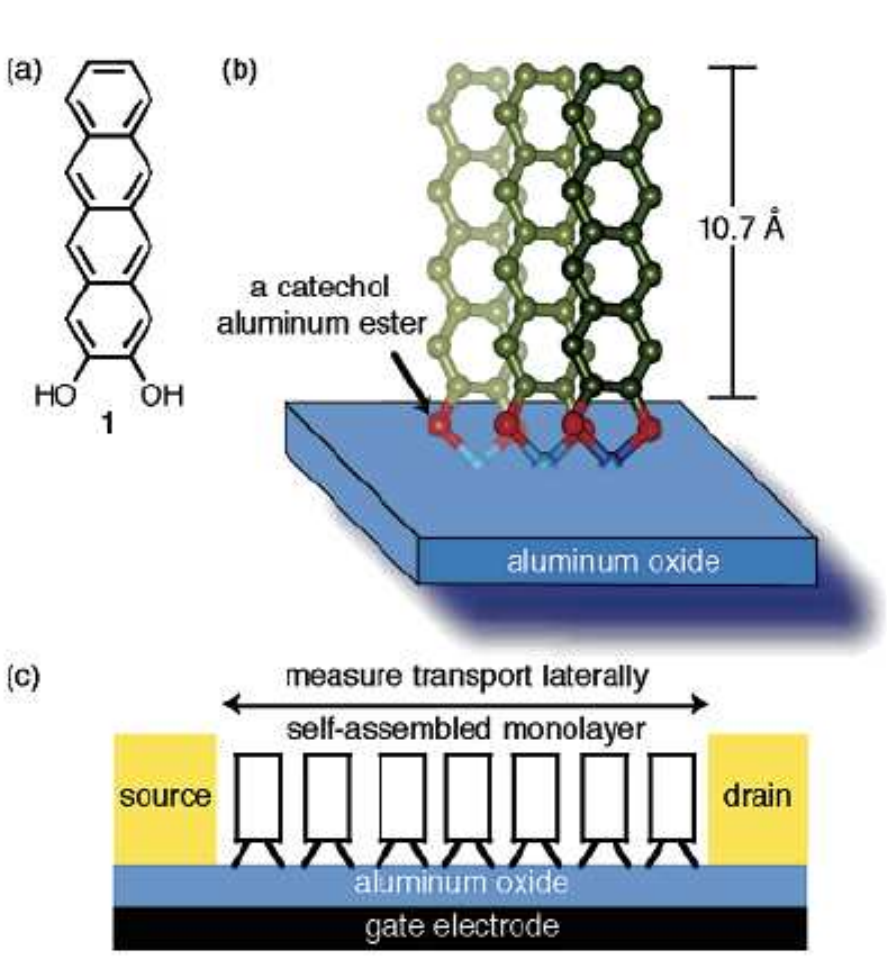


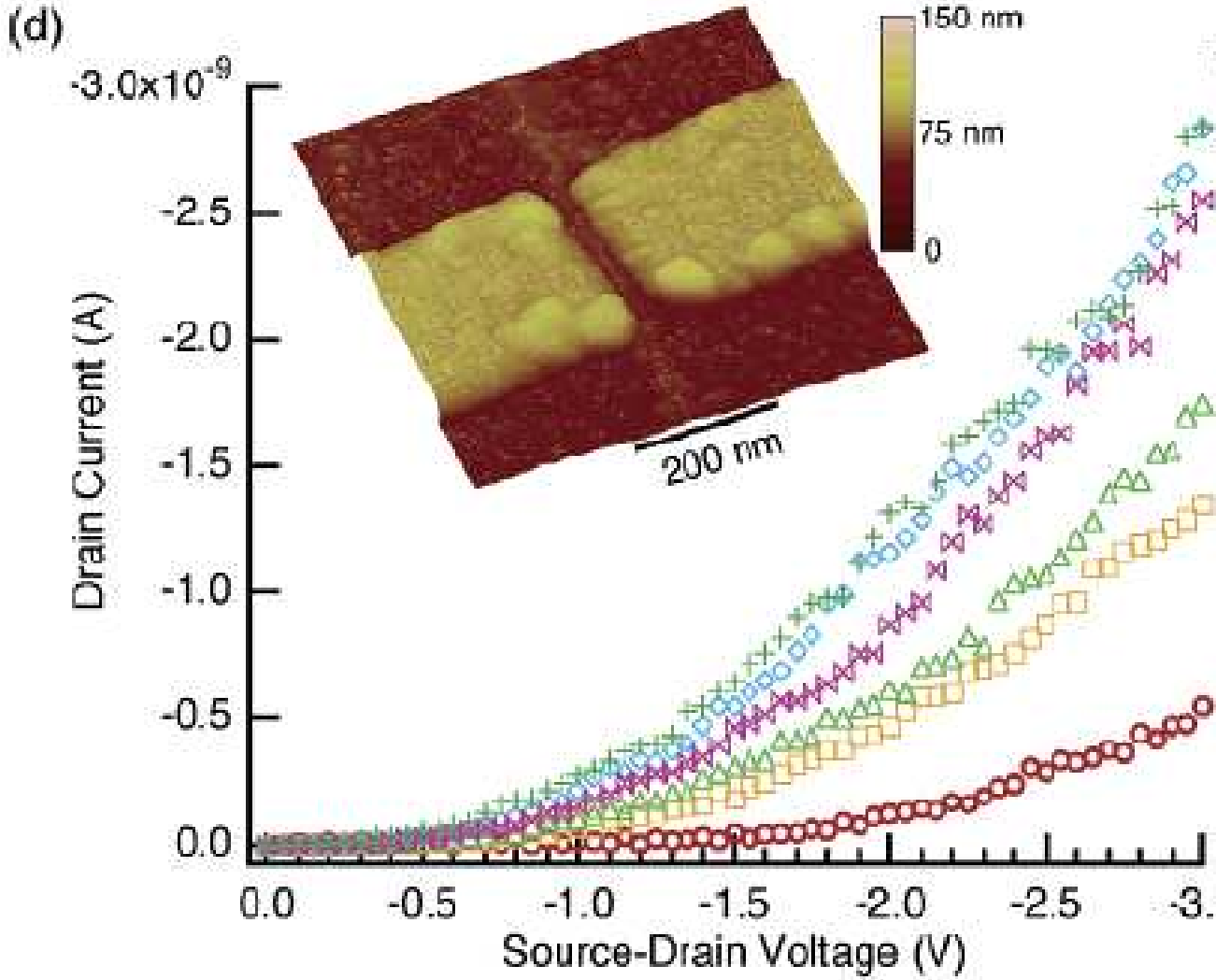




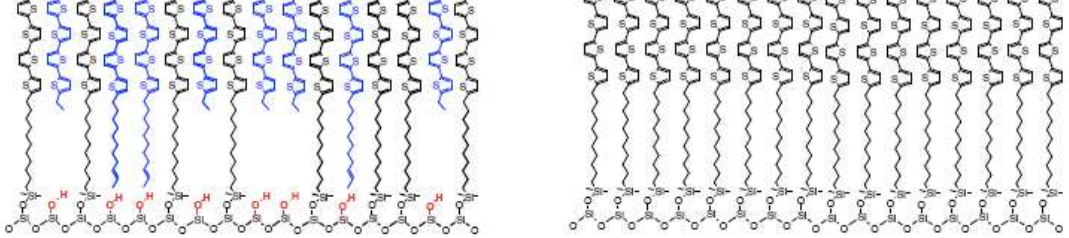


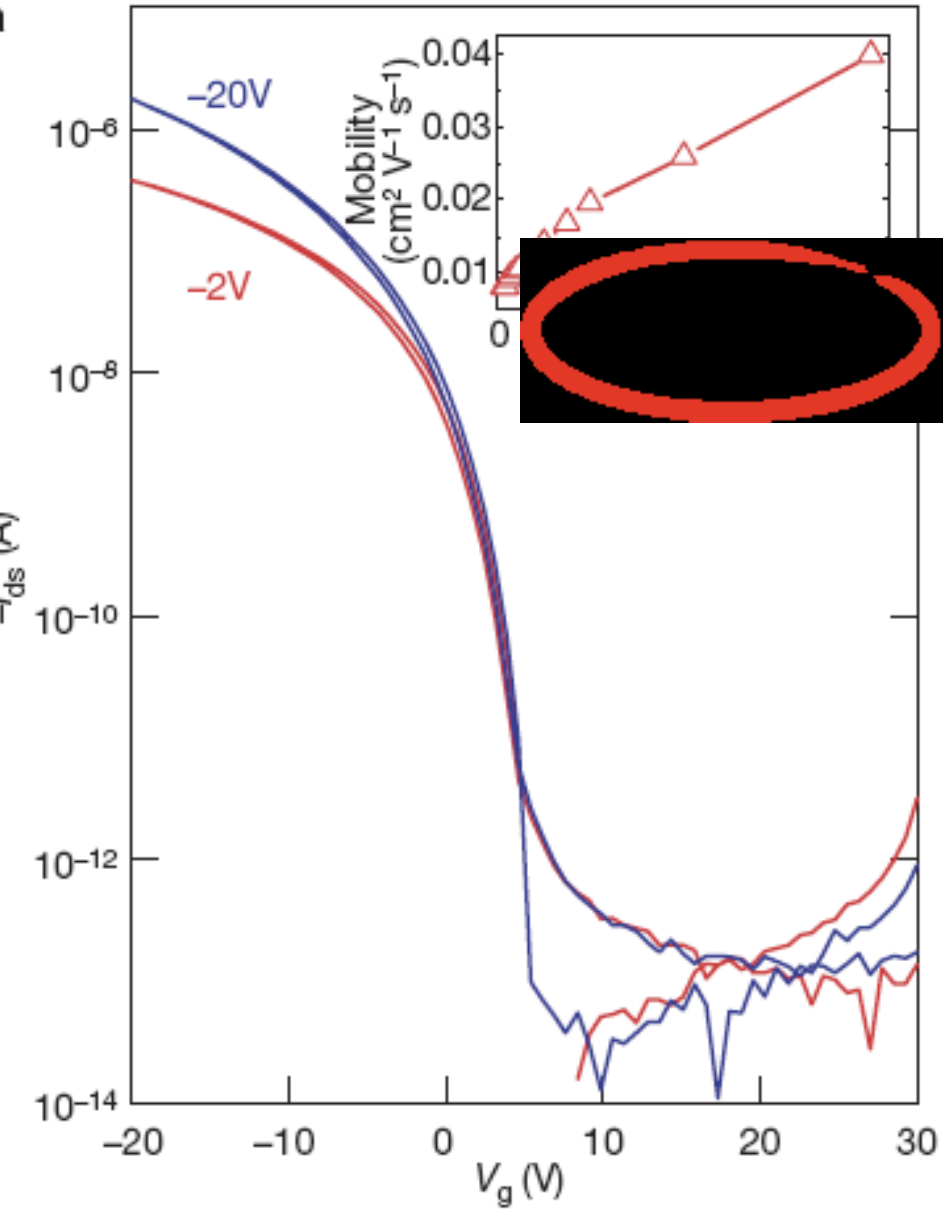
$\mu_{max}=3.5x10^{-3}\ cm^2V^{-1}s^{-1}$





in the two cases, $L \leq 200$ nm





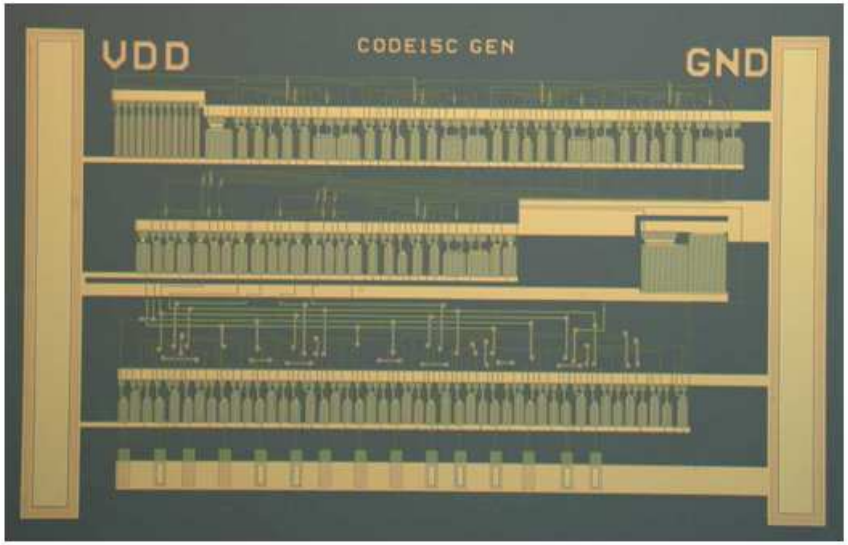
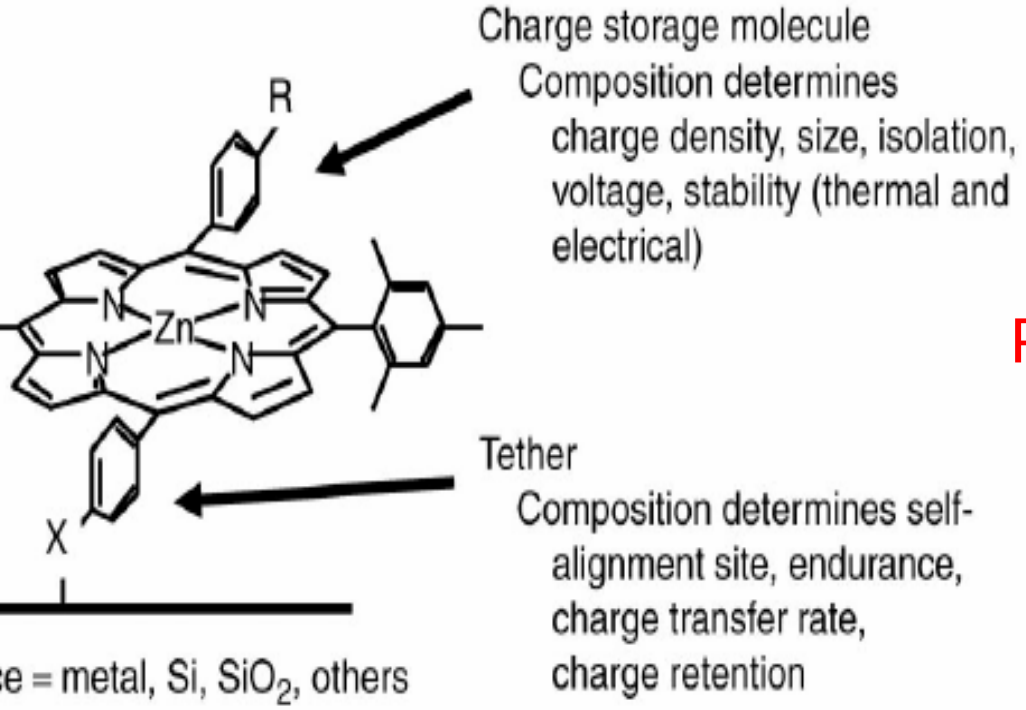


Fig. S31. Optical photograph of a functional 15-bit SAMFET code generato circuit combines over 300 SAMFETs.

15-bit code generator
300 SAMFETs



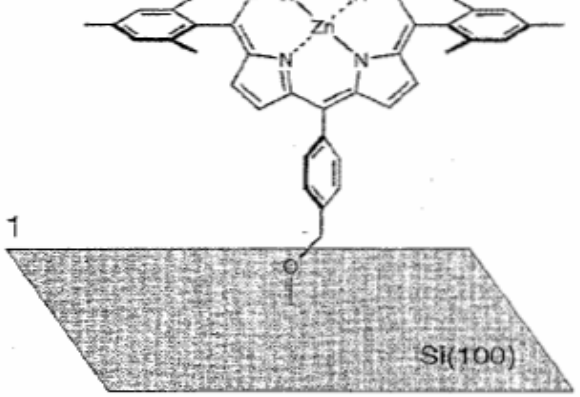
Principle 1 : charge storage on a redox mole

porphyrins

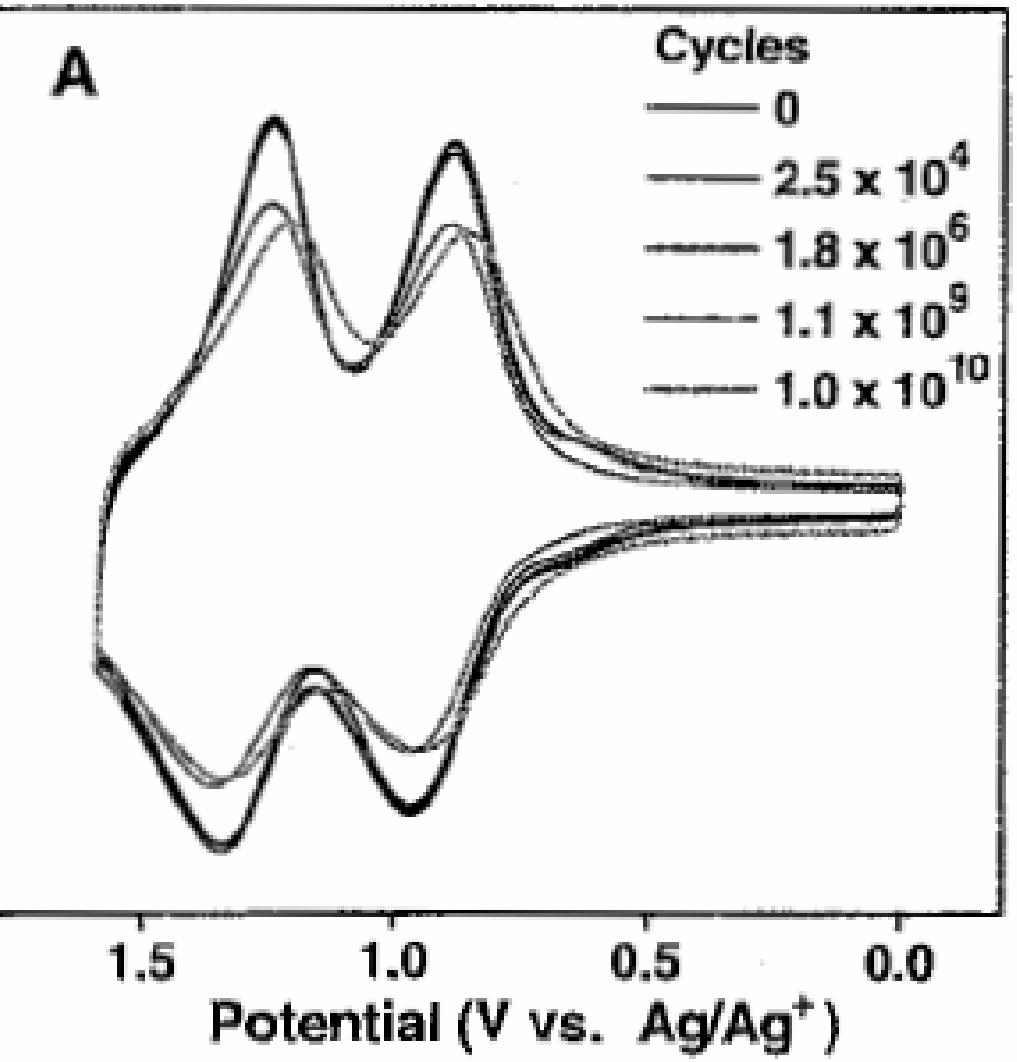
Table I: Criteria for Incorporation of Molecules in CMOS Storage Devices.

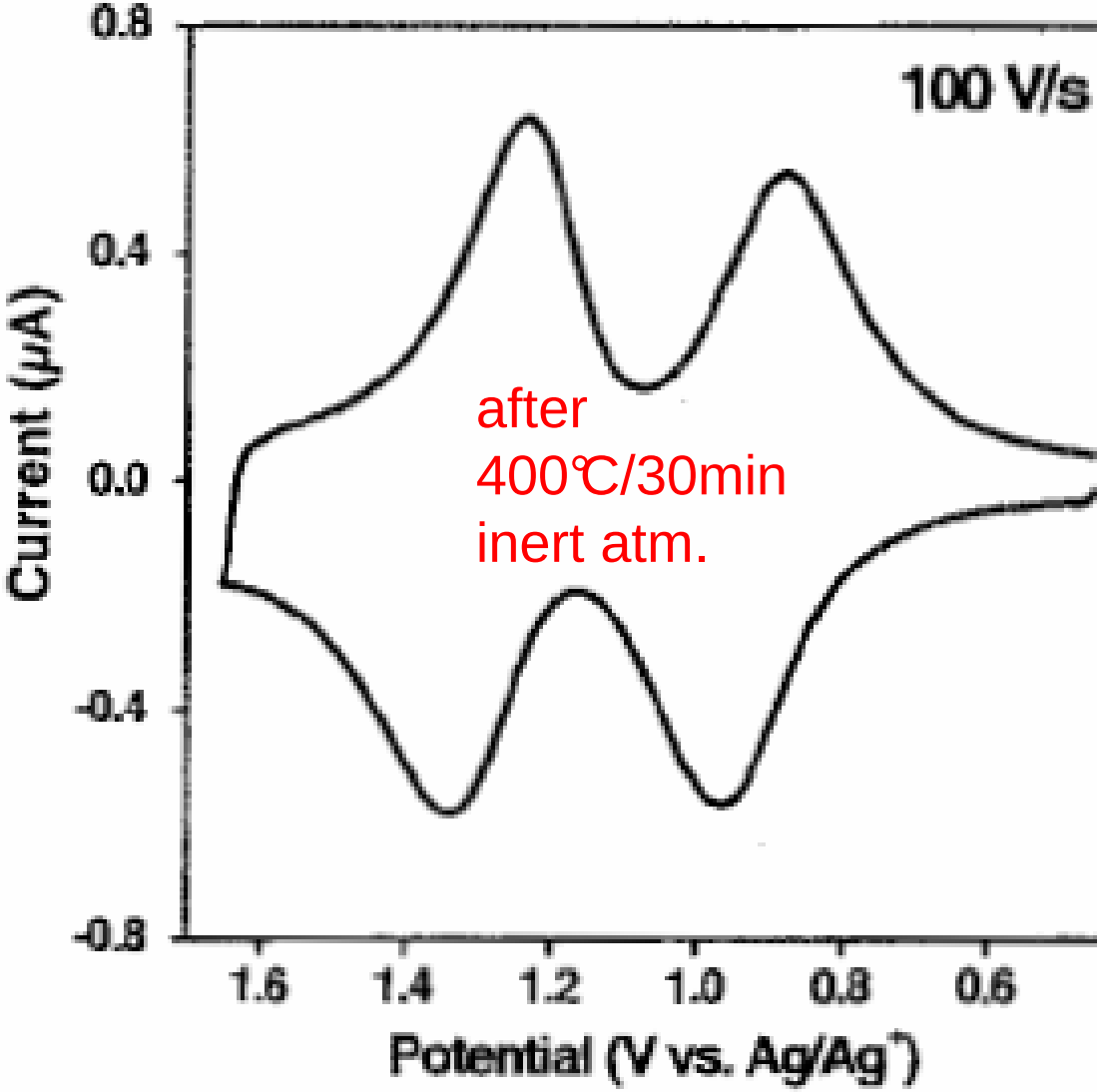
Property	Implementation
Chemical stability	Delocalized cationic charge
Thermal stability	$T_{decomposition} > 400°C$.
Endurance	$>10^{15}$ cycles
Read/write speed	$t_{R/W} = 1/k_{eff} < 10$ ns
Charge retention half-life	
Charge density	
Self-assembly and self-alignment	molecules to specific substrate

direct grafting on Si-H
CMOS compatible



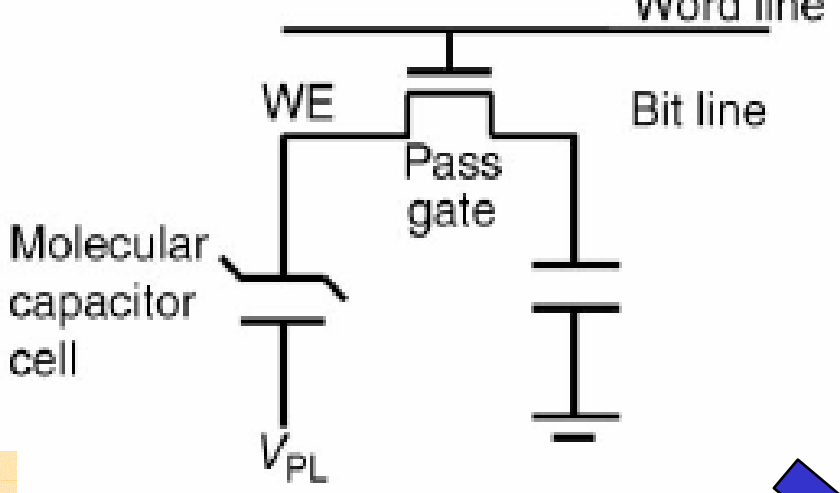
survive a 400℃ process





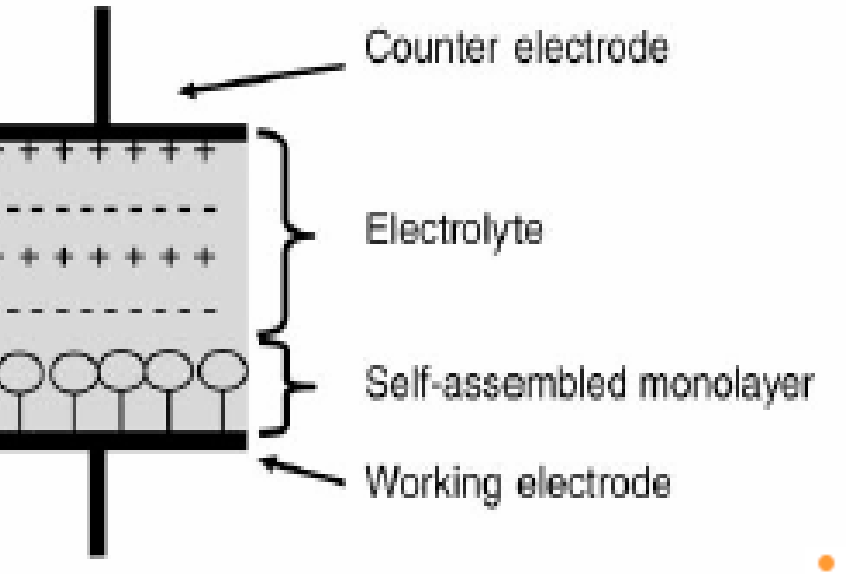
working stability: up to 10^{12} cycles

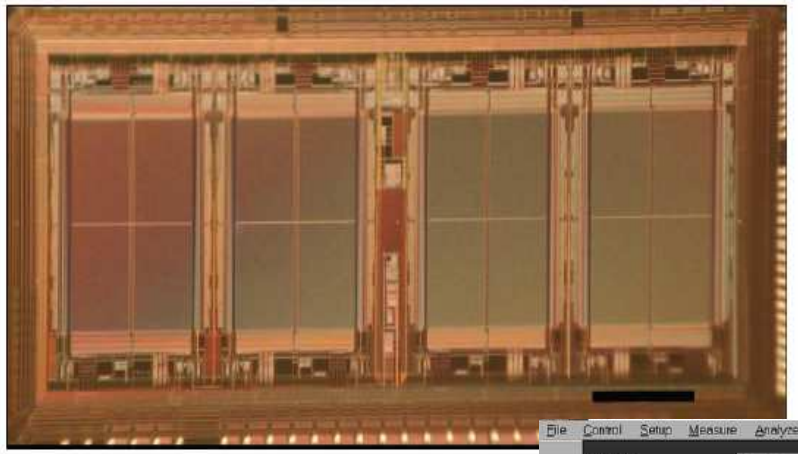
1Mbit / molDRAM
Zettacore

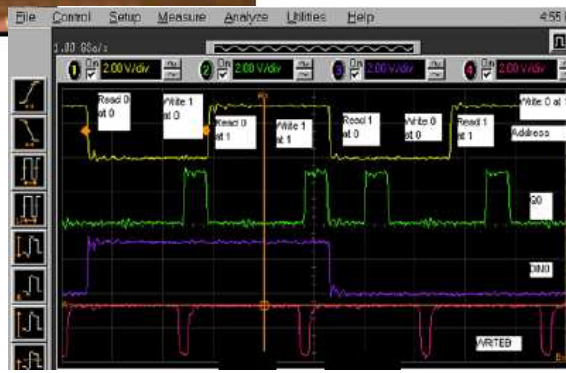


planar (no trench, no stac
10% steps/Si DRAM

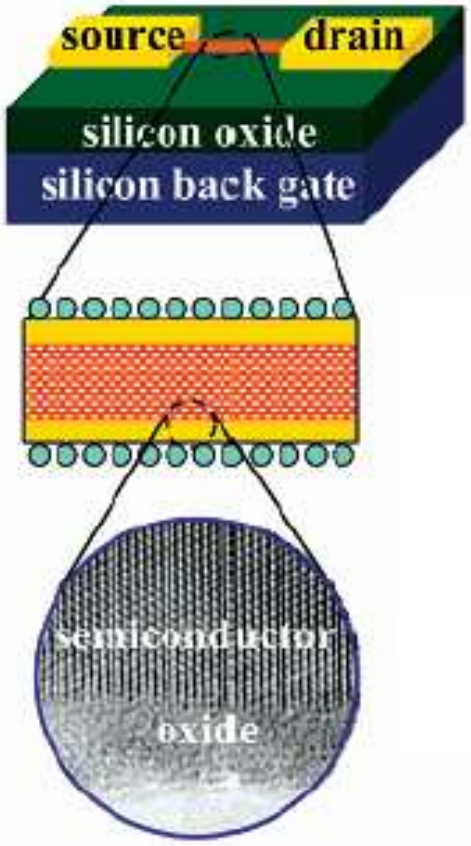
10 µs (theory: 10 ns)
on : few hundred sec

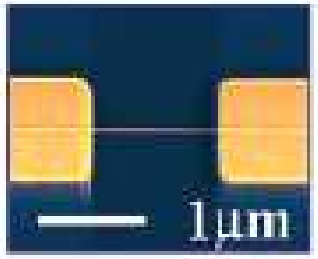


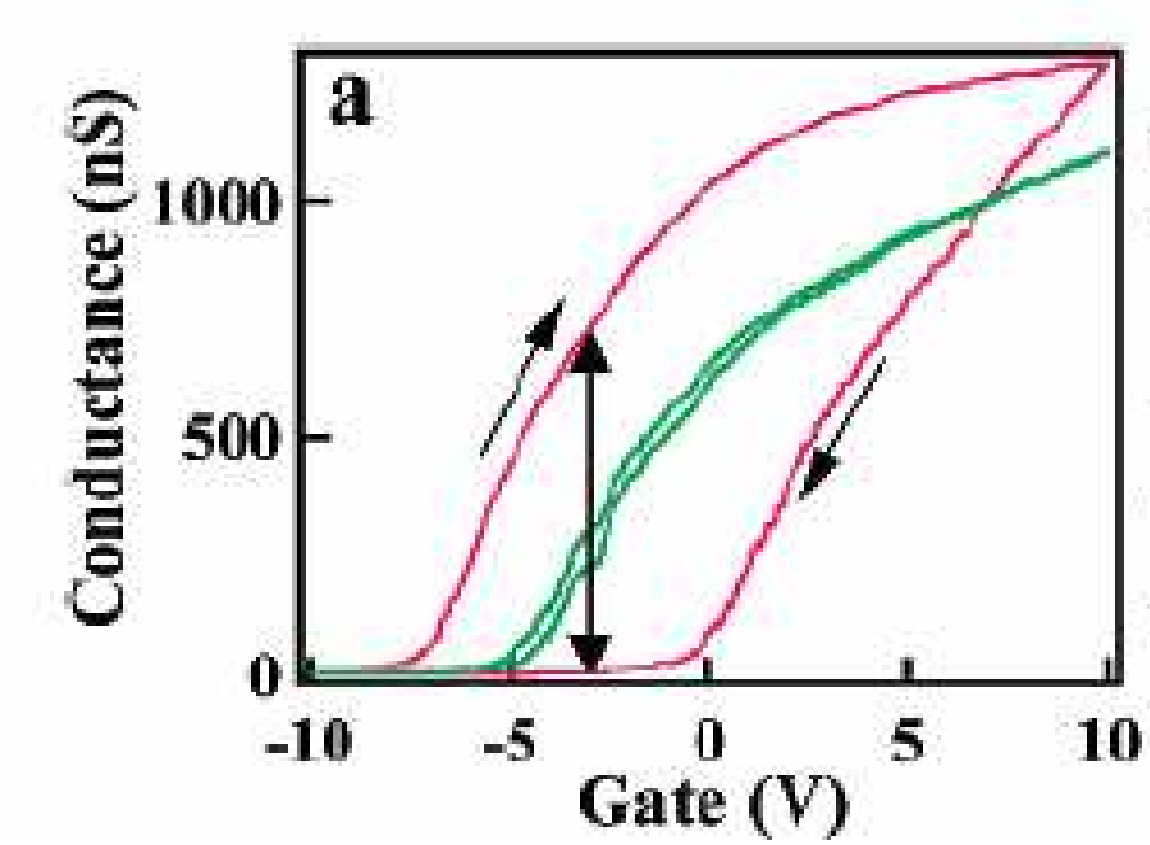




- Evaluations performed to confirm circuit functionality
- Write, read, addressing capability



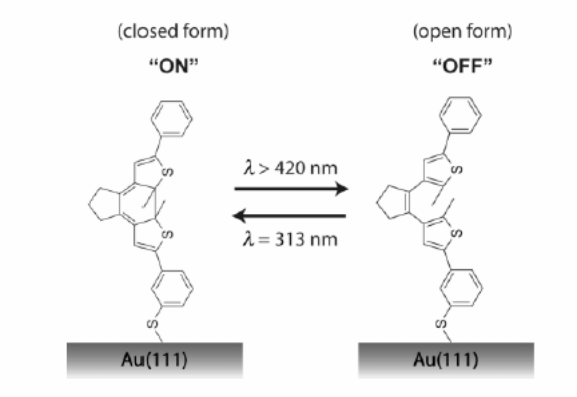


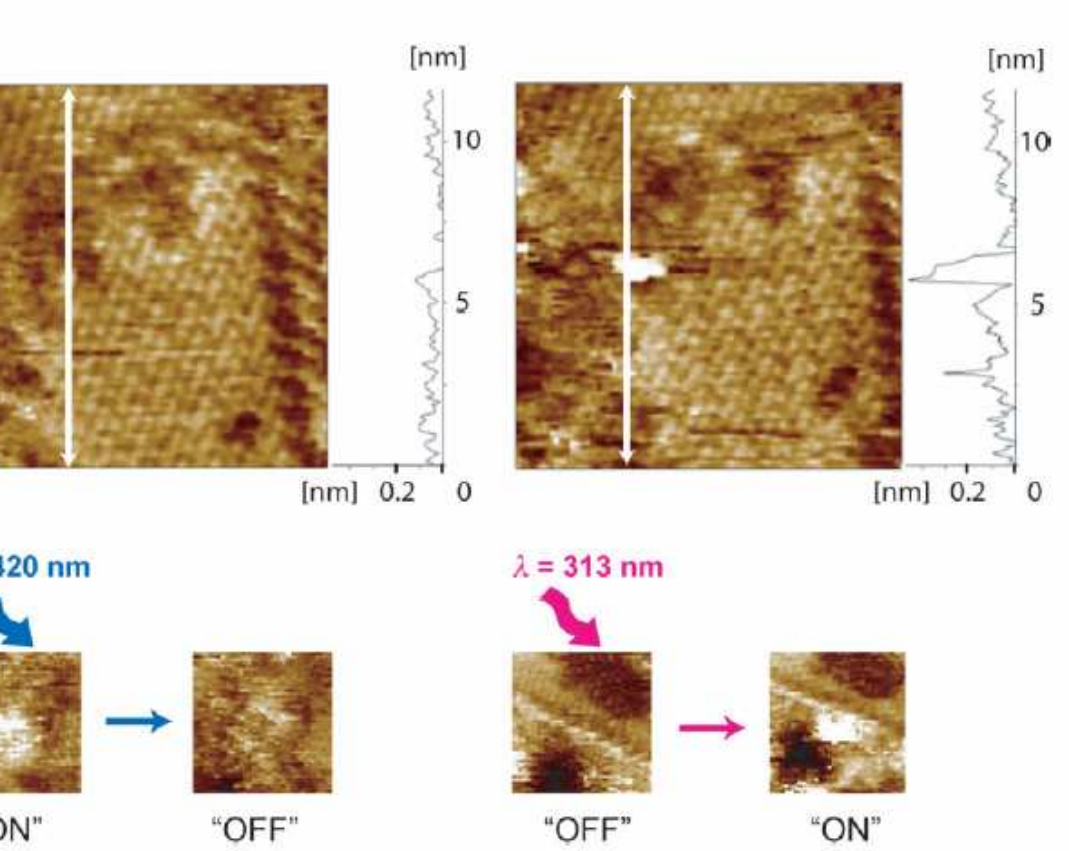


InP (10-30 nm)
molecules = Co phthalocyanine

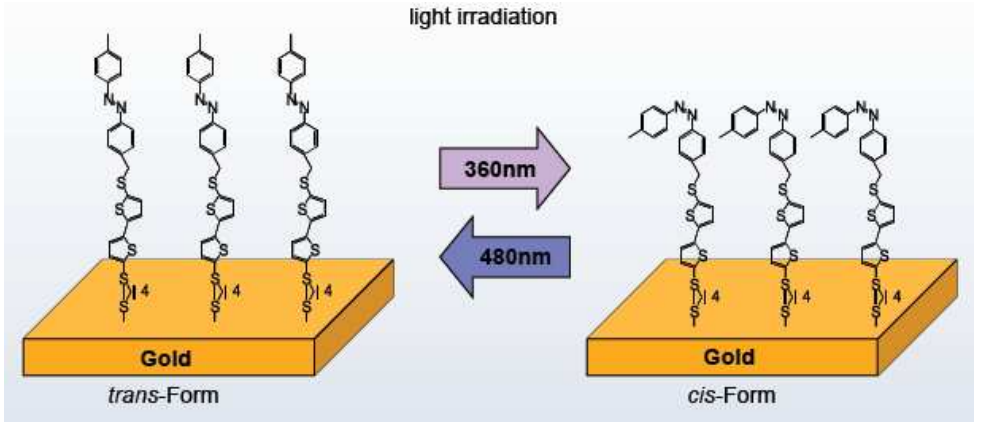
on/off ≈ 10^4
retention time ≈ 10^4 s

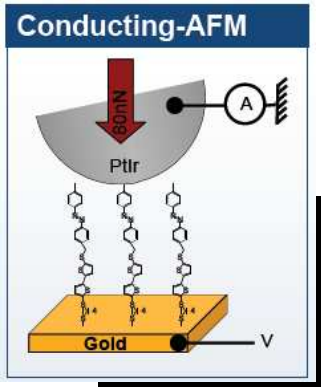
diarylethene



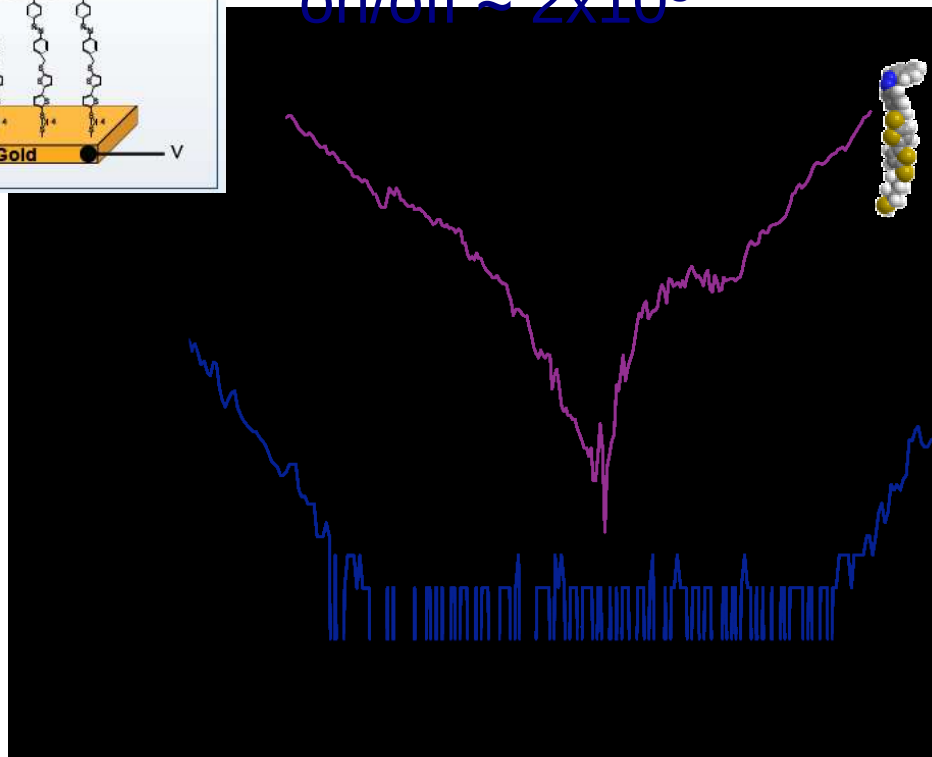


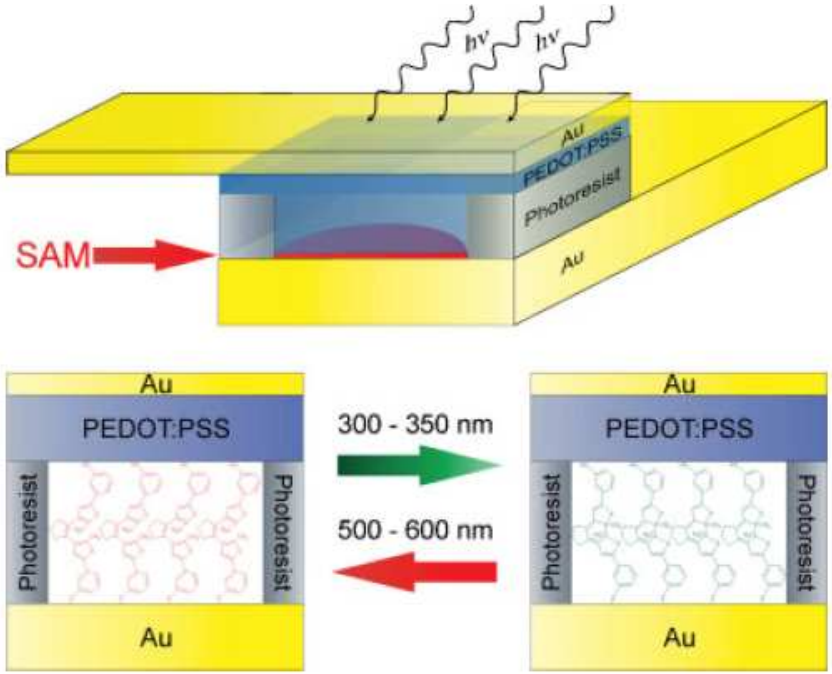
azobenzene derivative



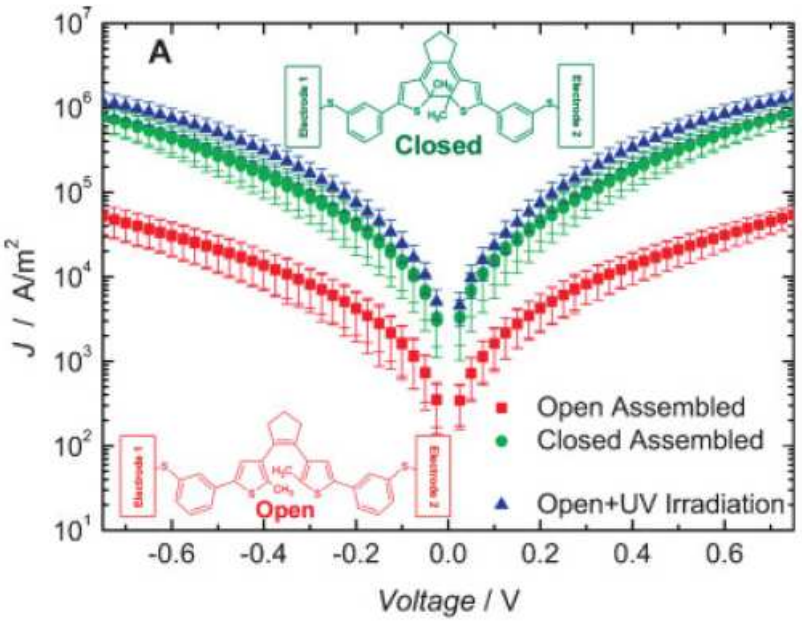


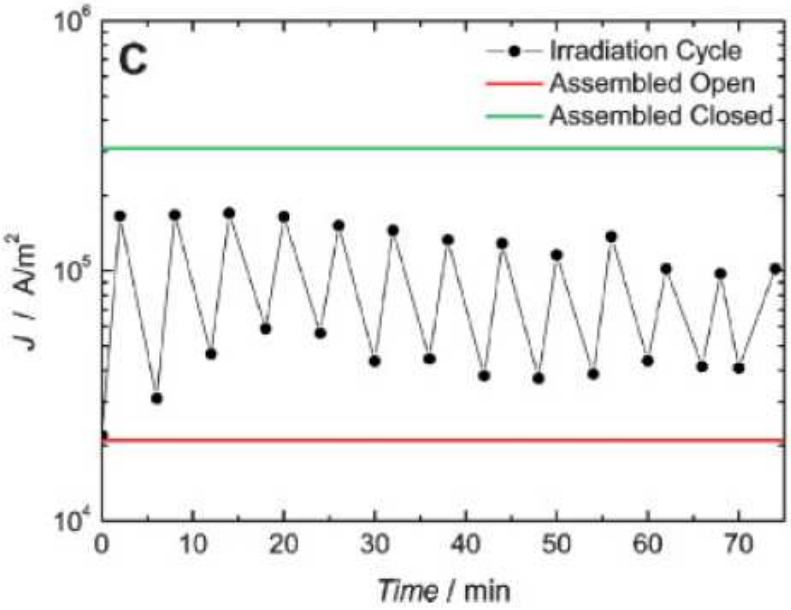
on/off ≈ 2×10^3





suitable for large-area electronics





Thank you for your attention