

Molecular Electronic Building Blocks: Functional Metal Nanowires

Theresa S. Mayer¹, Seth Goldstein³, Thomas Mallouk²,
Christine Keating², and Thomas Jackson¹

¹Department of Electrical Engineering,

²Department of Chemistry

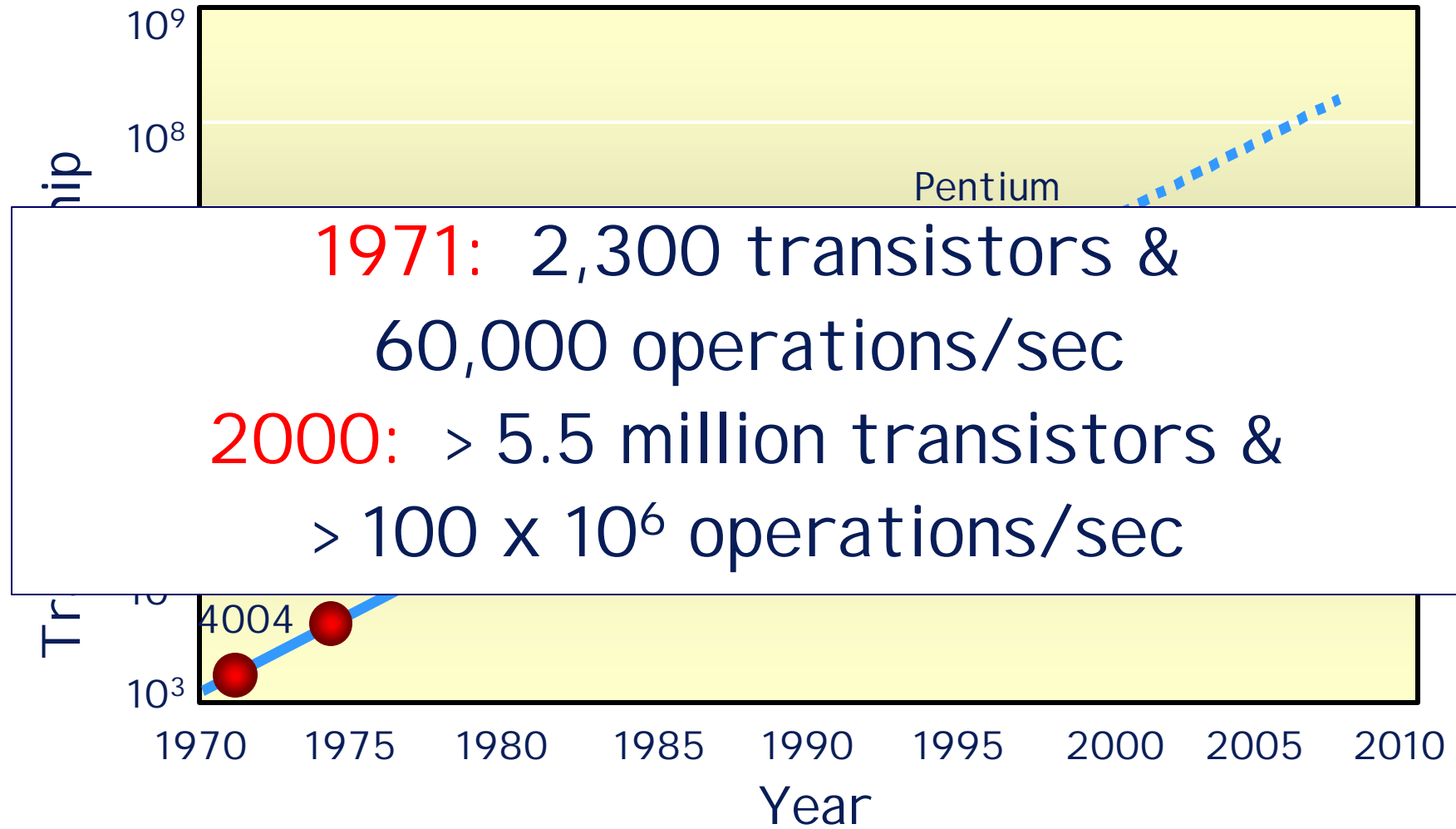
The Pennsylvania State University, University Park, PA

³Department of Computer Science

Carnegie Mellon University, Pittsburgh, PA

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Moore's First Law

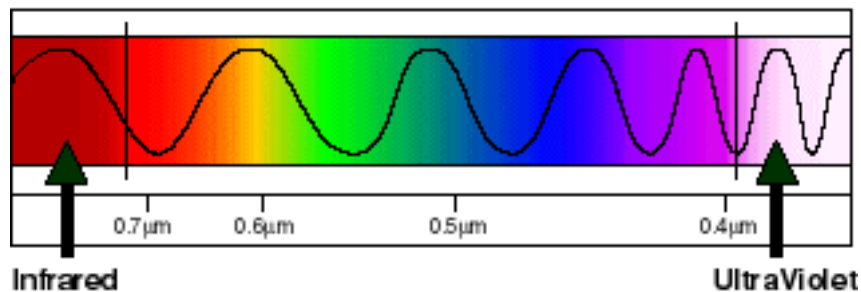


❖ <http://www.physicstoday.com/vol-53/iss-1/p38.html>

Fundamental Limits?

Today: Optical Lithography

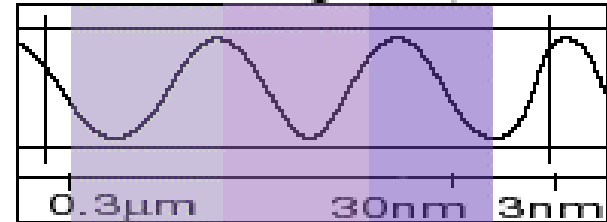
Visible Light Region
of the Electromagnetic Spectrum



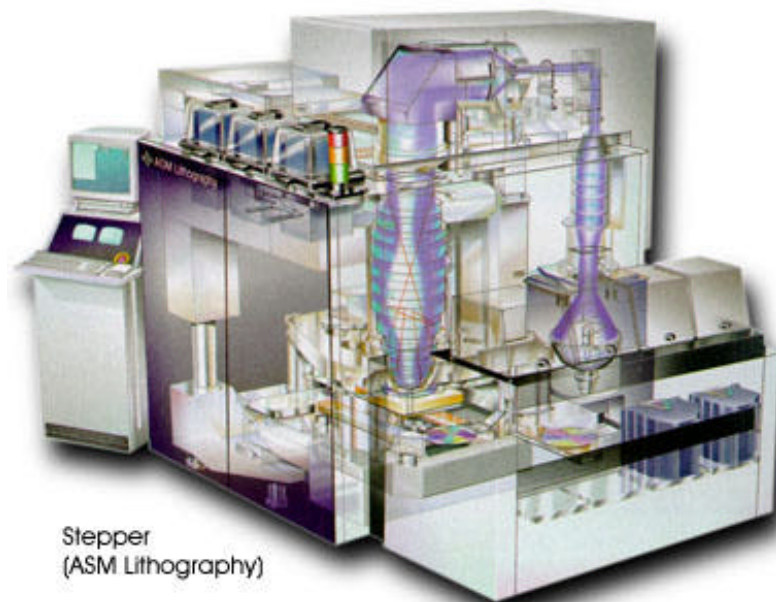
Today: SiO₂ Gate Dielectric

➔ Sub 1 nm with high-K

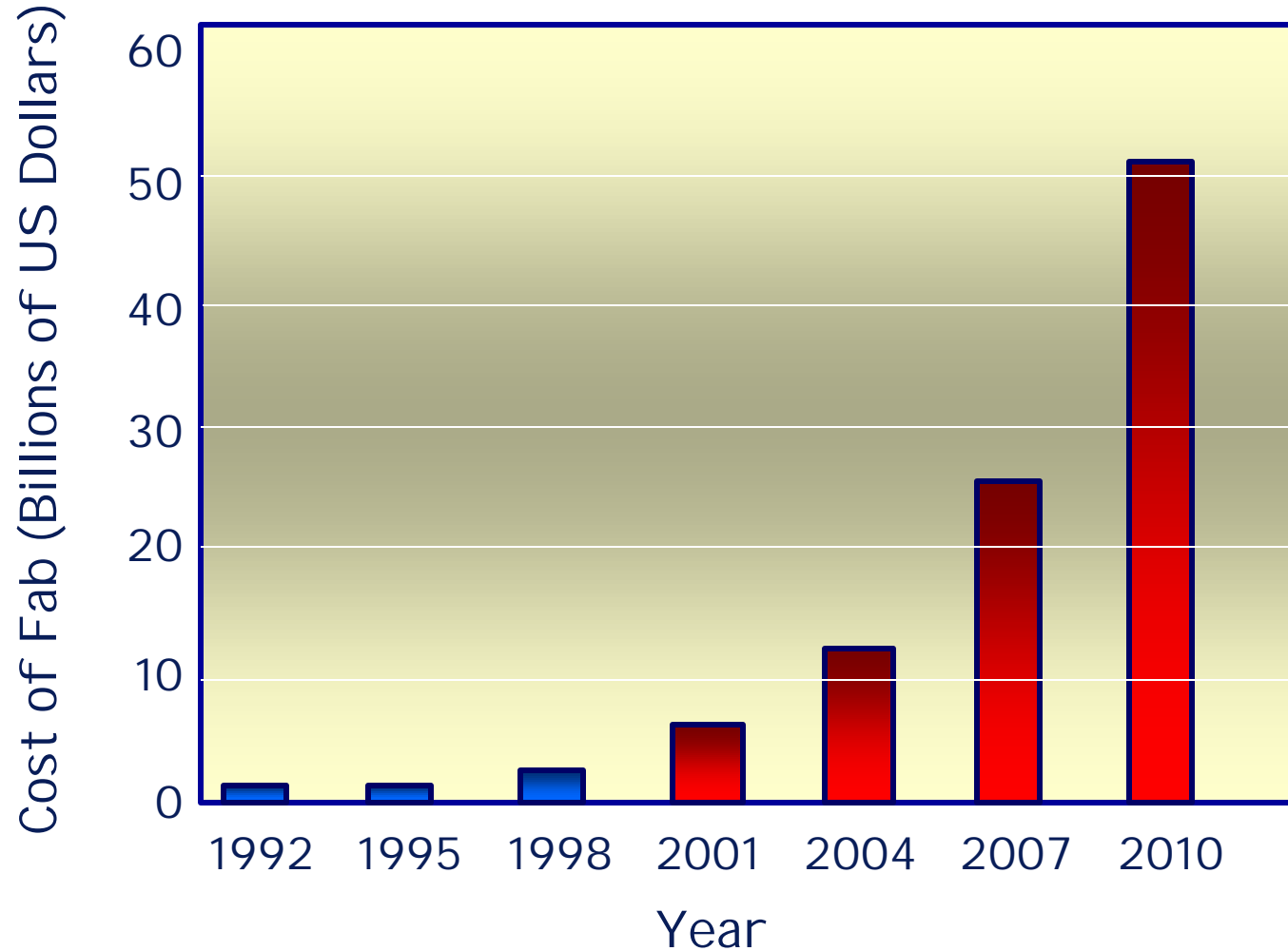
Ultra Violet Region
of the Electromagnetic Spectrum



Near UV Far UV Extreme UV



Financial Limits ? Moore's Second Law



❖ <http://www.physicstoday.com/vol-53/iss-1/p38.html>

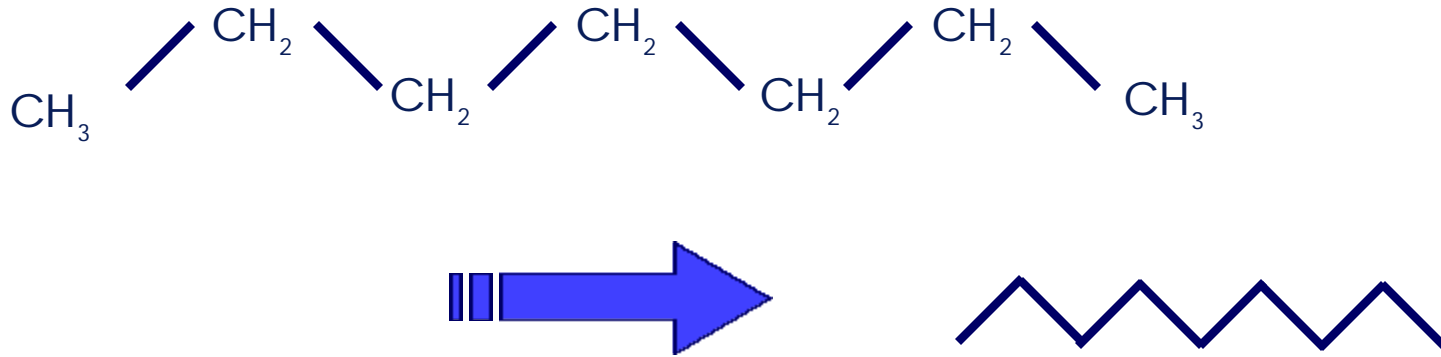
What's needed for logic ?

- Robust Molecular Devices
- Nanoscale Wires
- Directed Assembly Approach
- New Logic Architecture

Functional Nanoelectronic

Building Blocks

Electrical Properties of Molecules

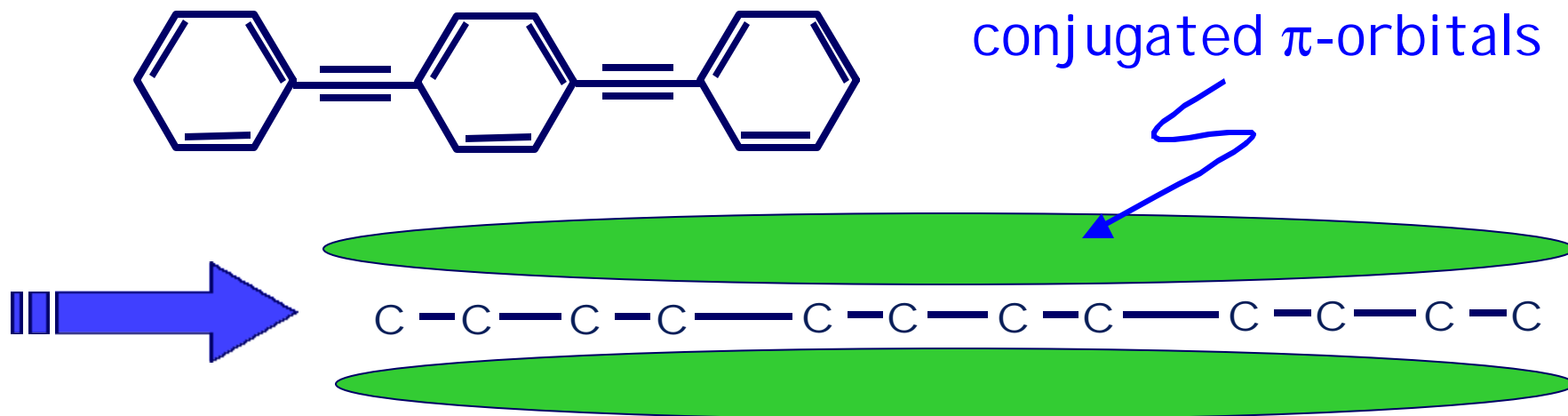


Alkyl Chains → “electrical insulator”

Contain σ -bonds that don't form uninterrupted “electrical” channel

❖ After Ellenbogen, et. al. Proceedings of IEEE, Vol 88 No 3, 2000

Electrical Properties of Molecules

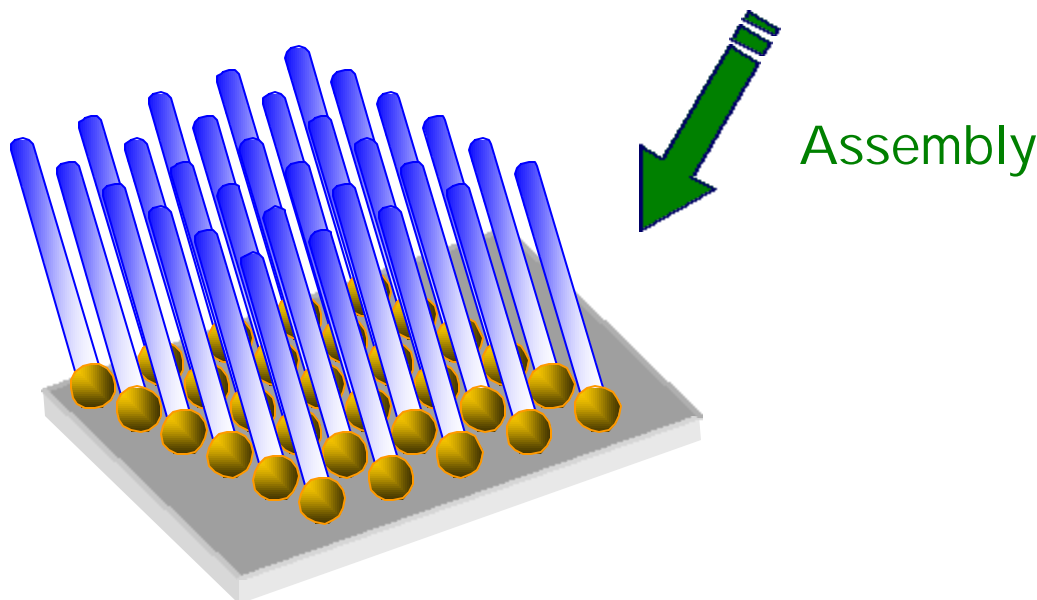
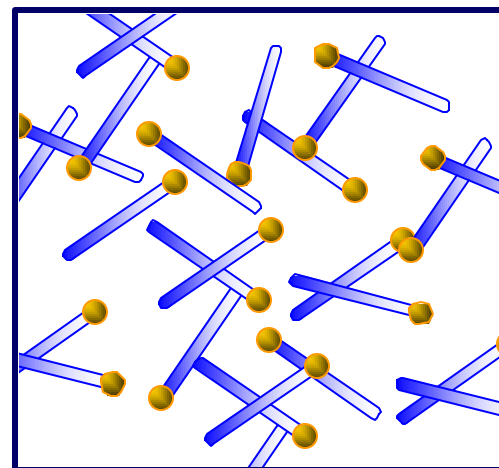
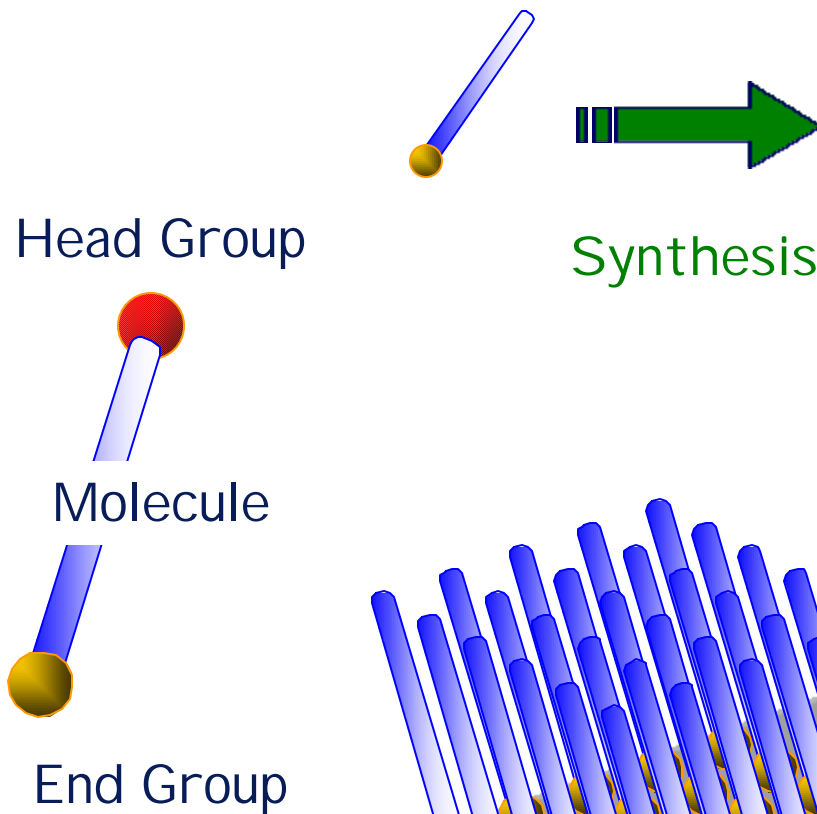
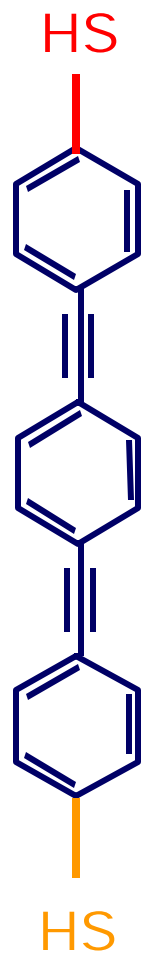


Polyphenylene-based molecules

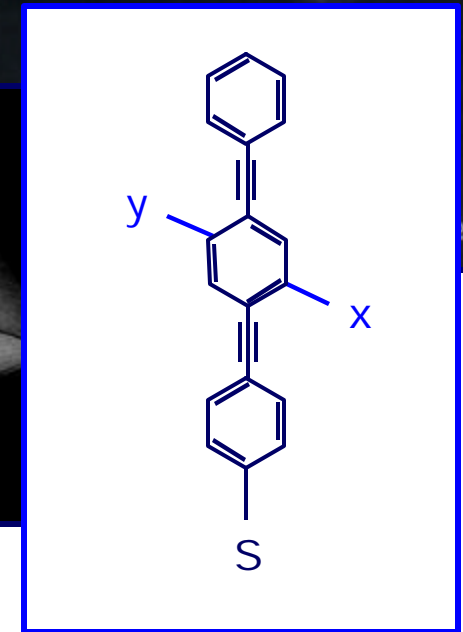
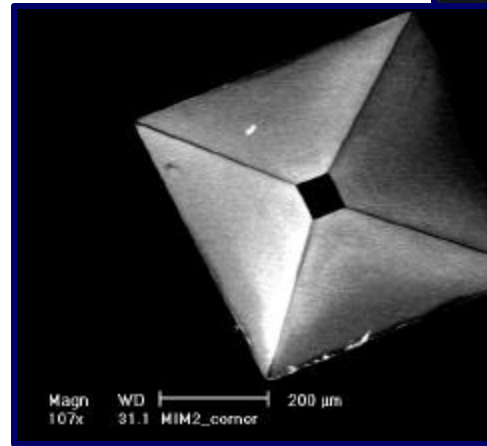
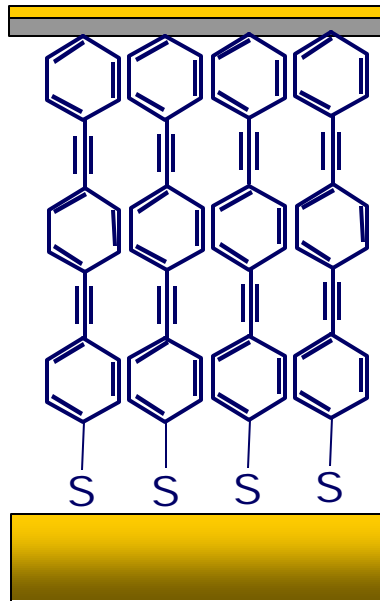
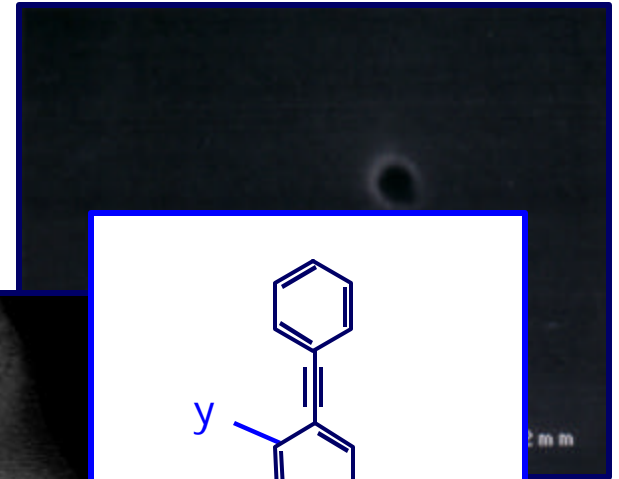
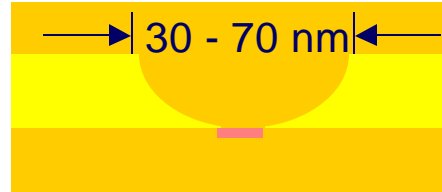
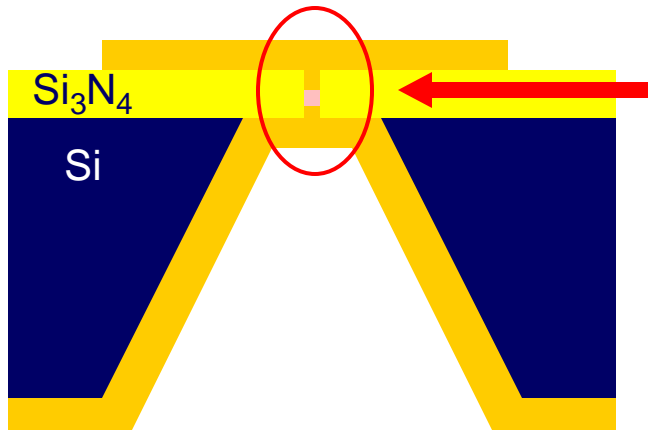
→ “electrical wires”

Molecular wires contain conjugated π -orbitals that form uninterrupted “electrical” channel

Molecular Self Assembly



Molecular Device Testbed



Memory Effect
Negative Differential Resistance

❖ Zhou, C., M. R. Deshpande, M. A. Reed, L. Jones, and J. M. Tour, *Appl. Phys. Lett.*, 71 (5) 1997

Molecular Logic Array

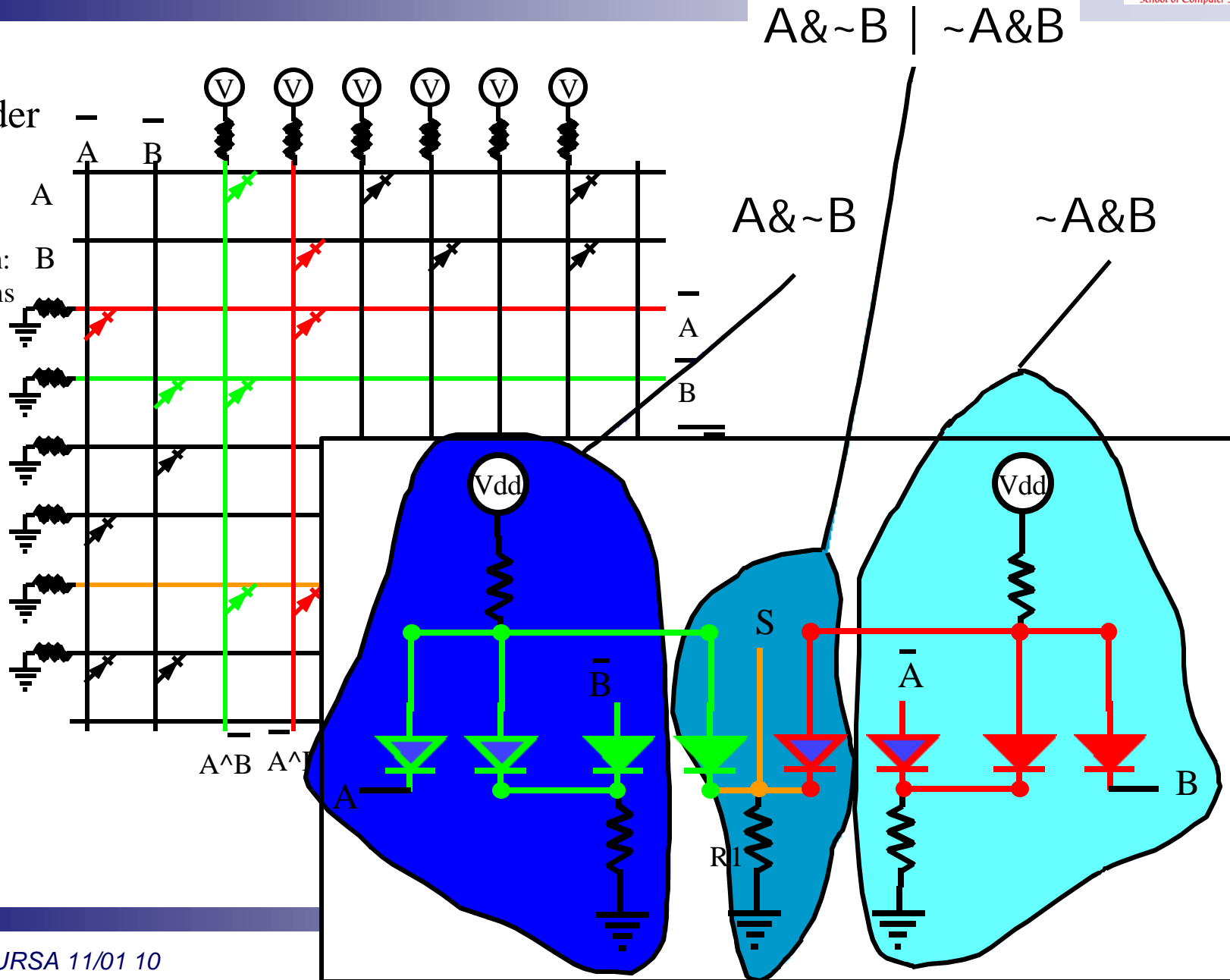
Half adder

$$S = A \oplus B$$

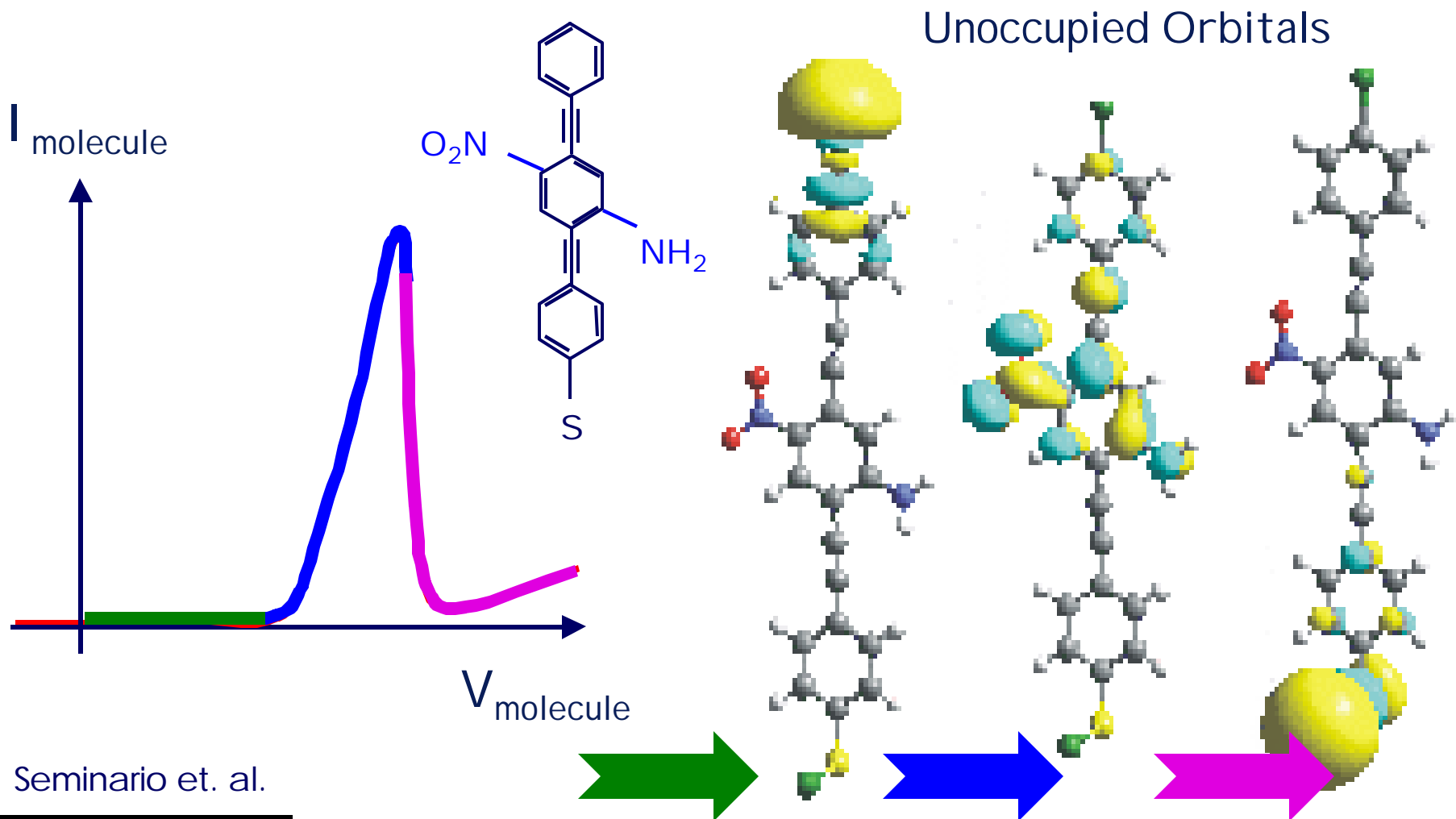
$$C = A \wedge B$$

critical path: B

S has 3 turns



Molecular Negative Differential Resistance

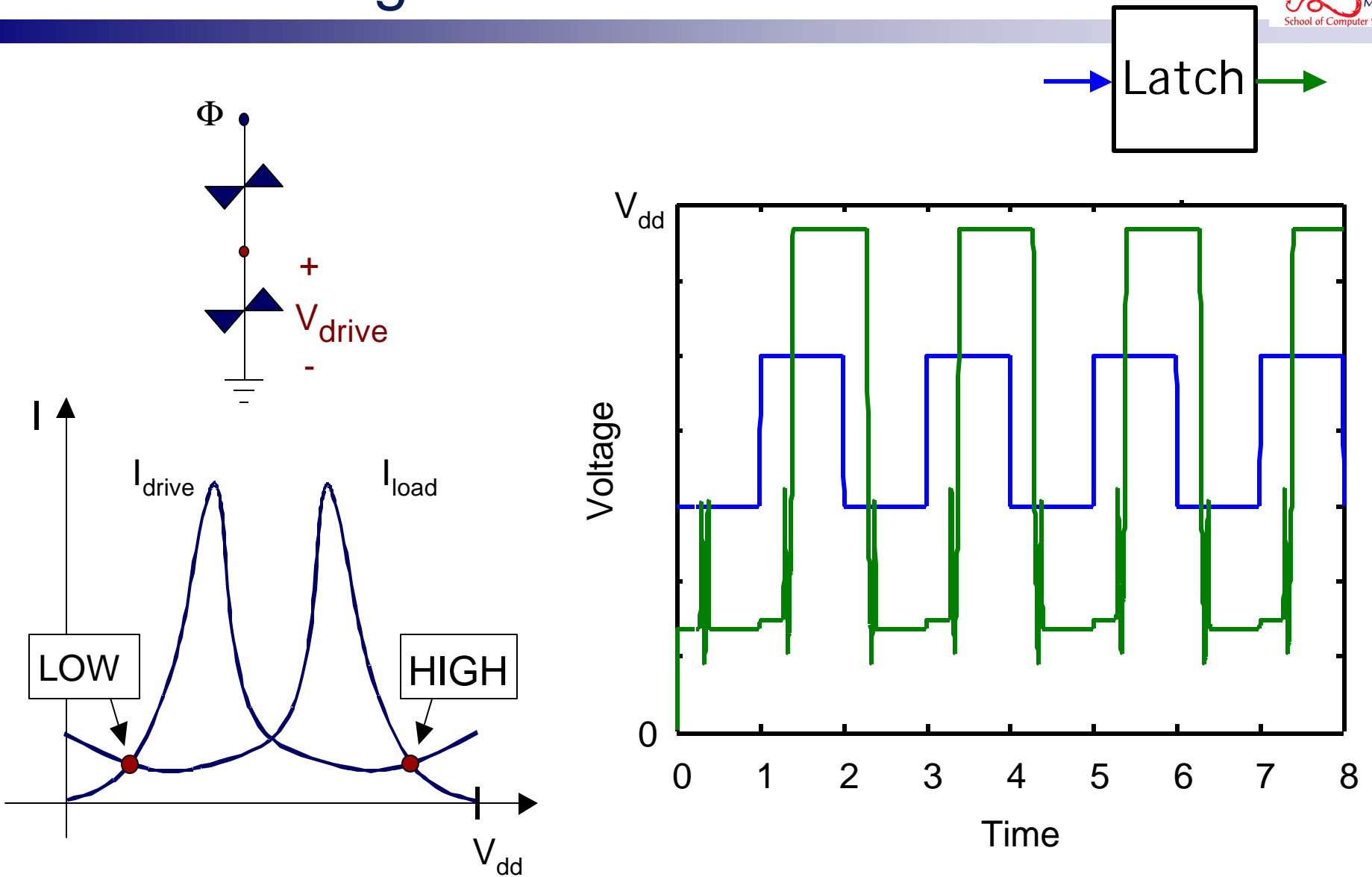


Seminario et. al.



❖ <http://www.cosm.sc.edu/~jorgemgr/research/ppt/>

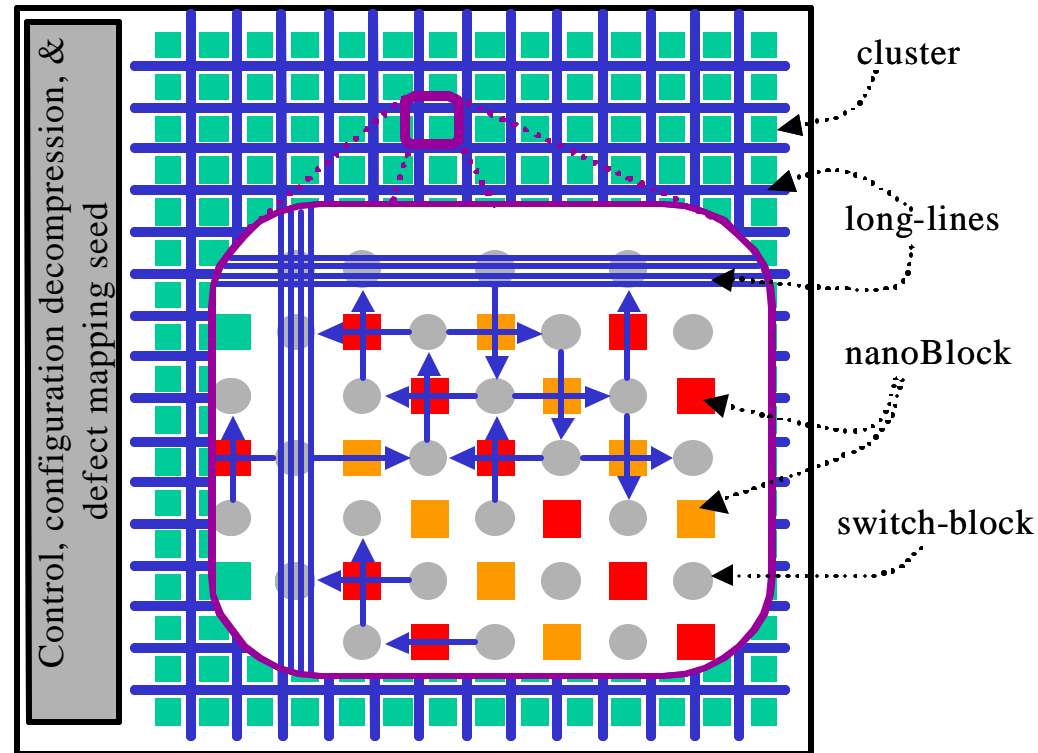
Molecular Logic Restoration



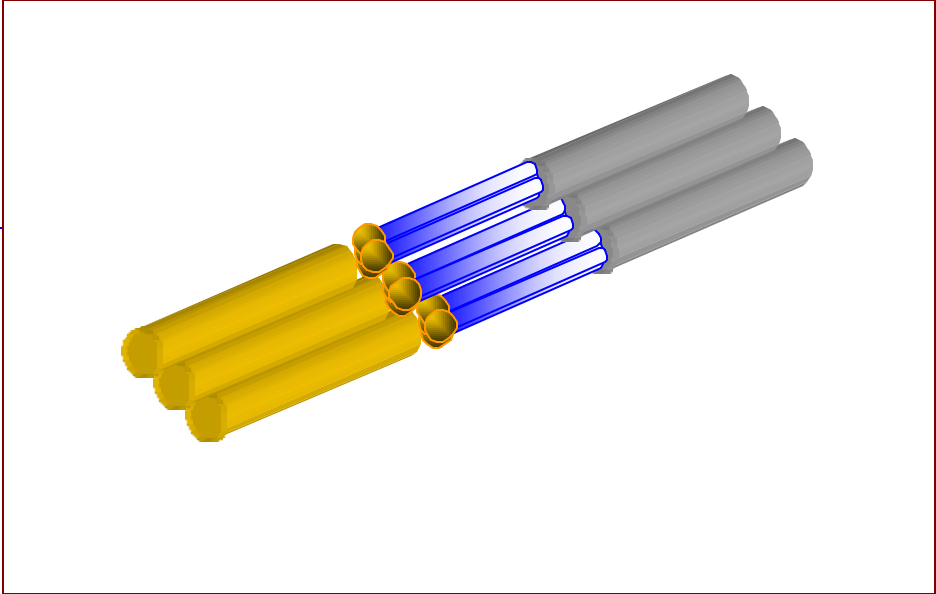
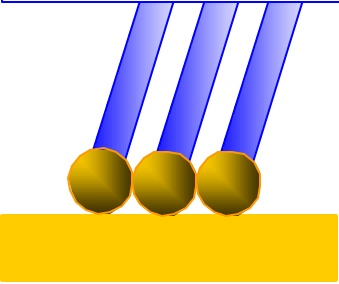
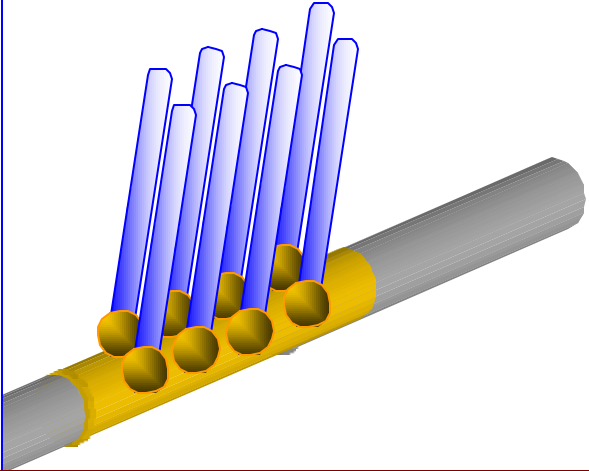
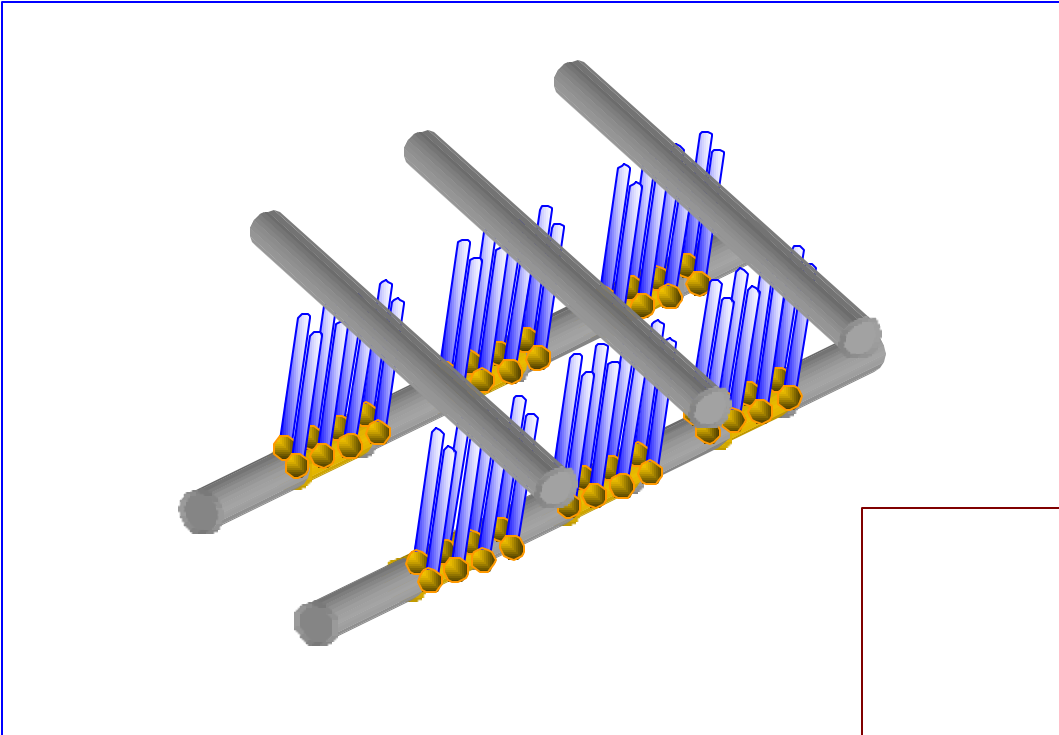
Compatible Architecture

NanoFabric: 2-D mesh of interconnected nanoBlocks

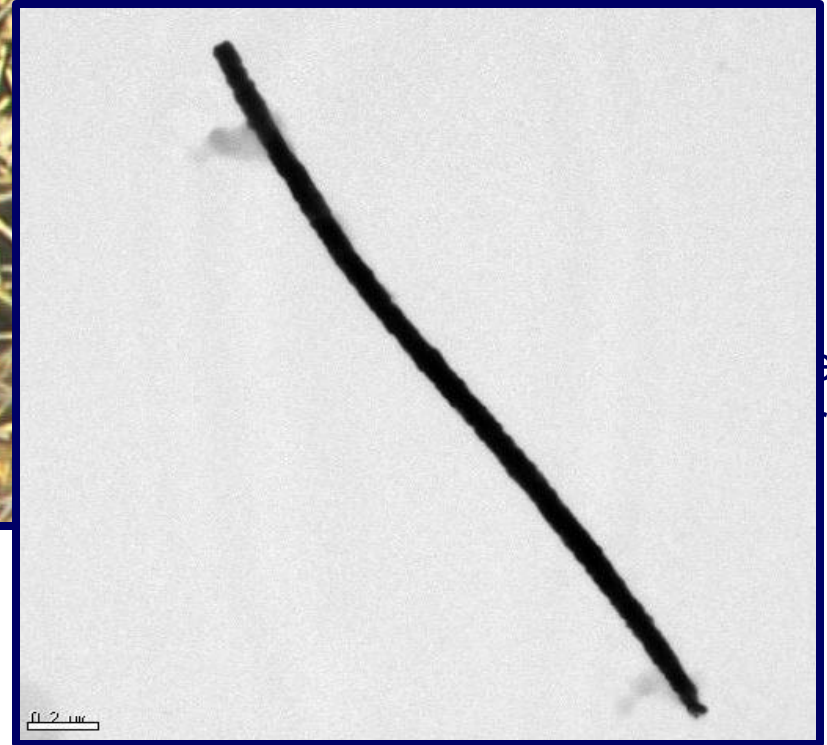
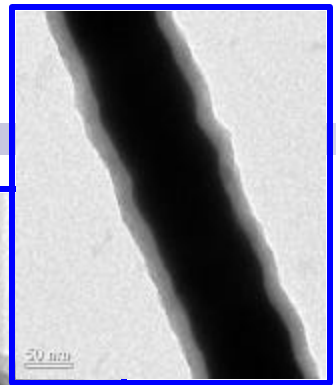
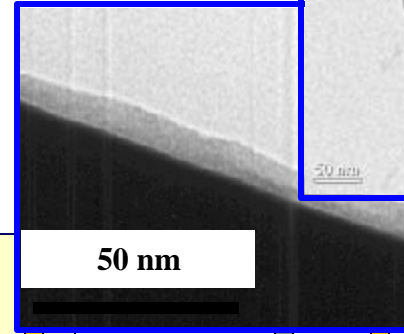
- Simple geometry compatible with directed assembly
- Defect tolerance and circuit complexity via configuration



Nanoscale Building Blocks

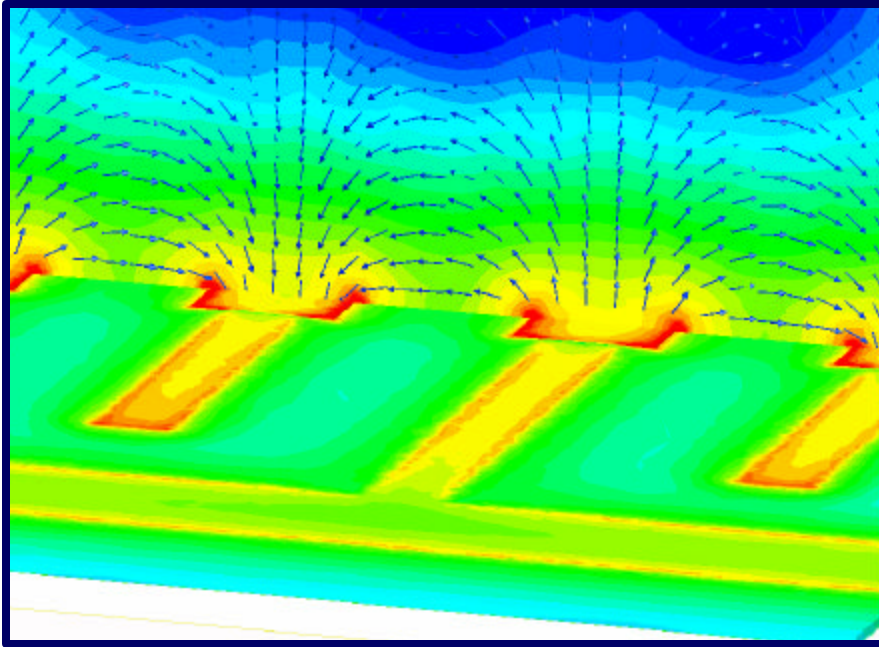


Good Old Metal Wires ...



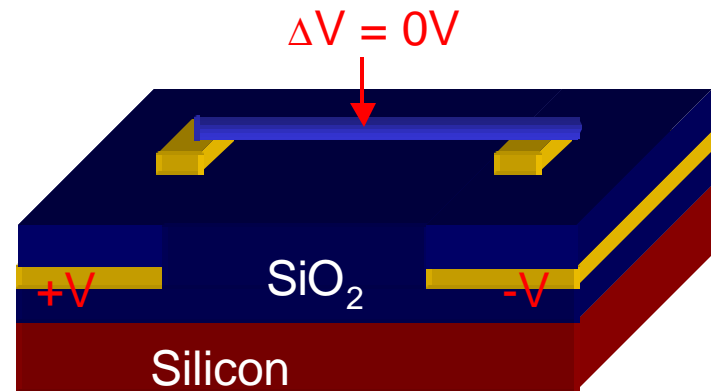
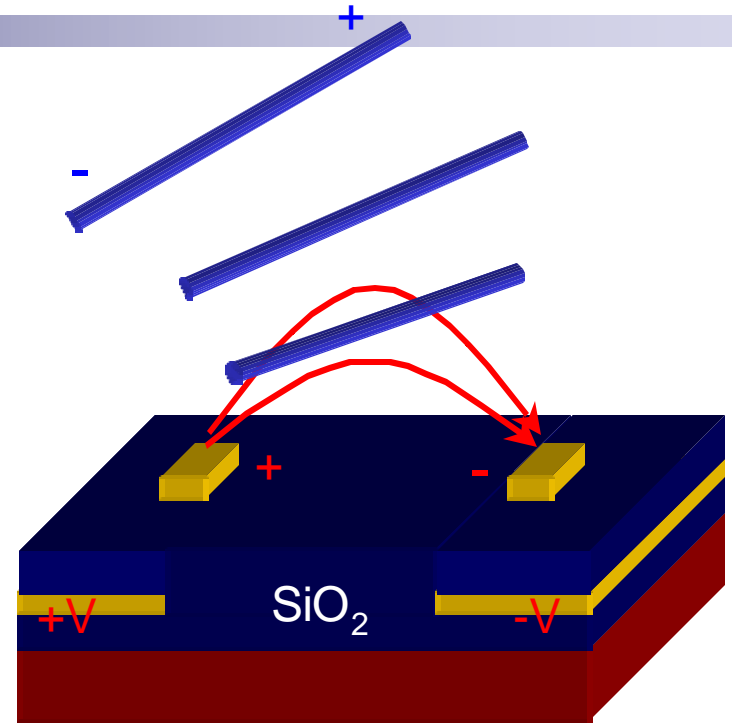
metal
ane

Assembling Metal Nanowires

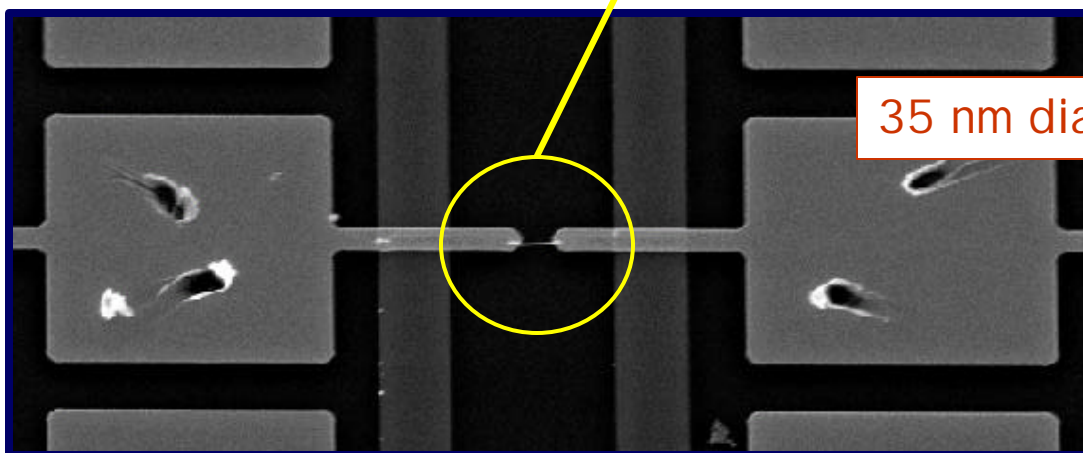
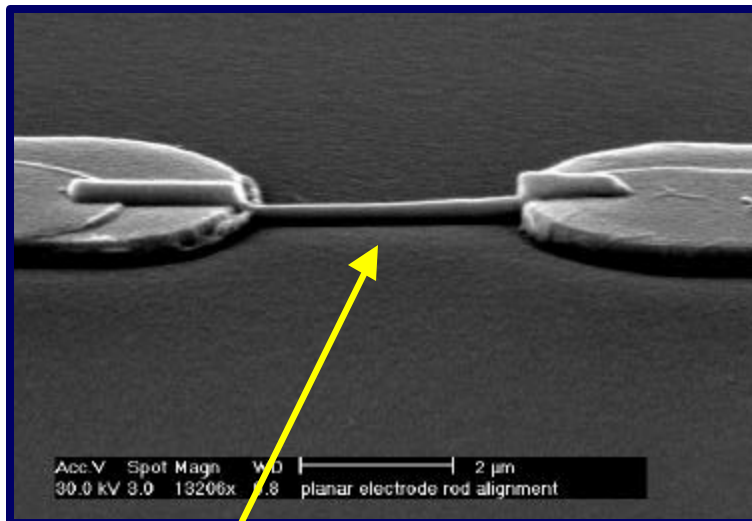
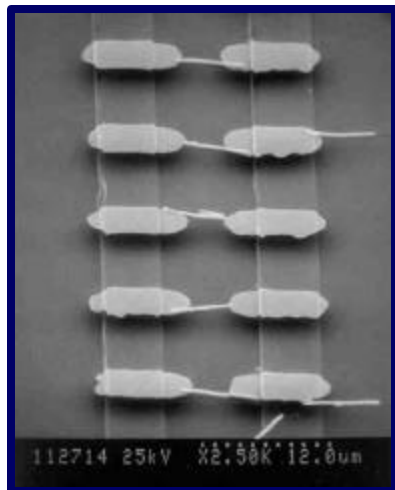


Nanowires attracted and aligned to top electrodes

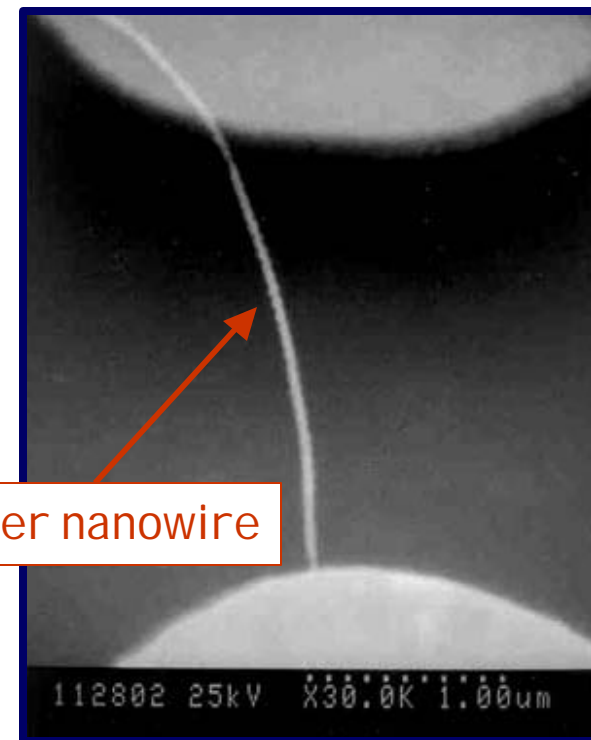
Alignment process is self limiting



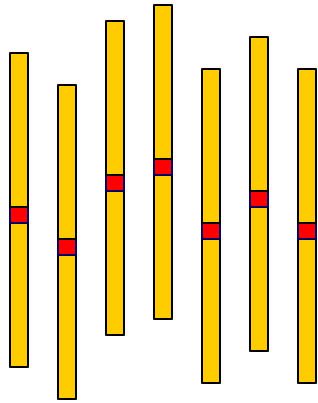
Characterizing Nanowires



35 nm diameter nanowire

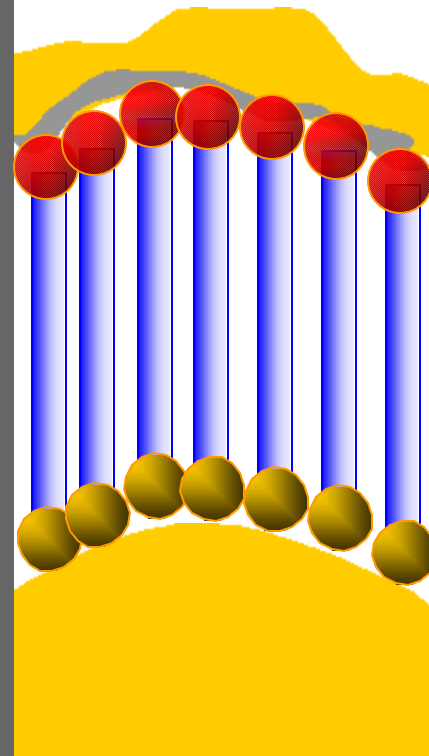


Functional Nanowires

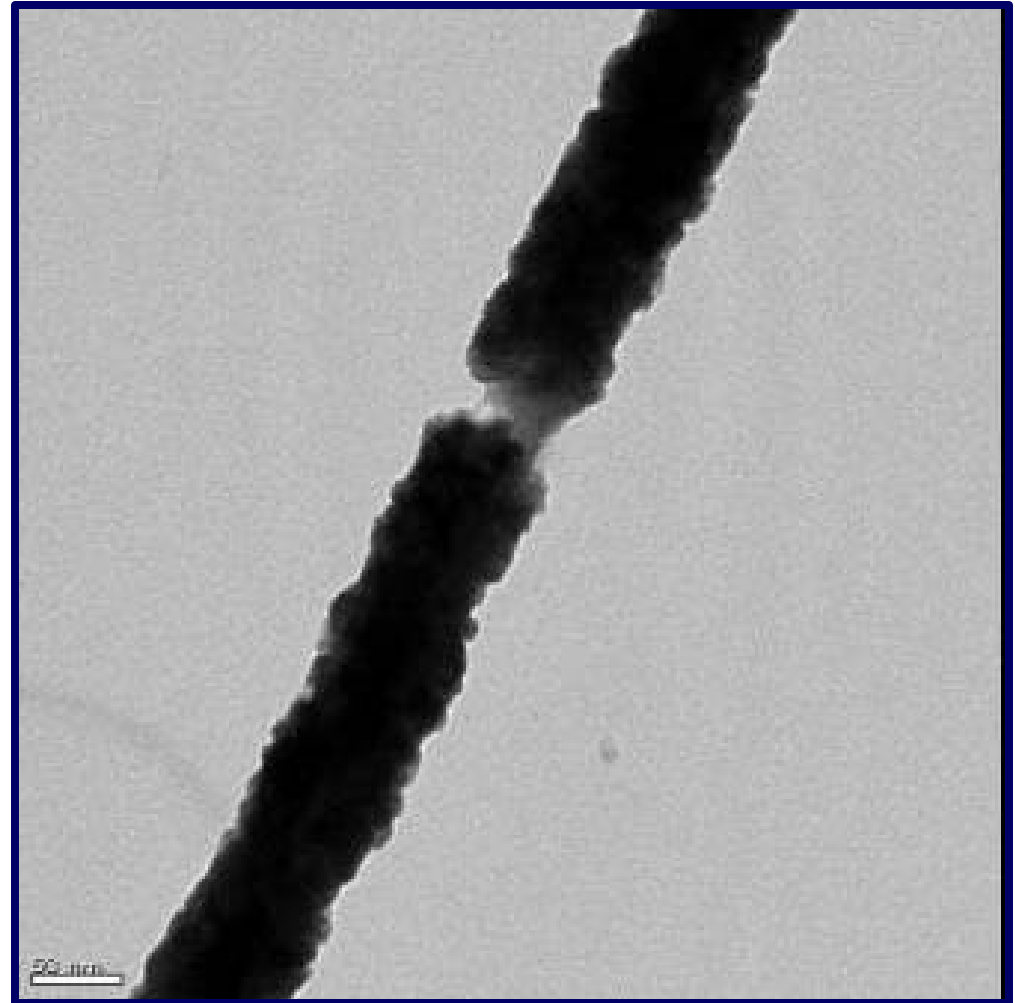
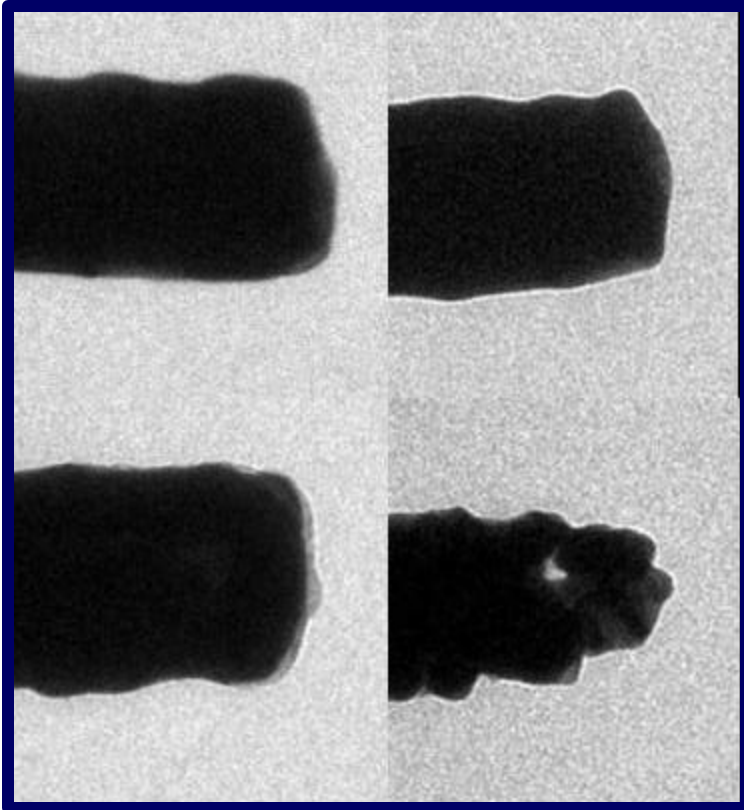


1. Sn (II)
2. Ag nanoparticles
3. Au electroless

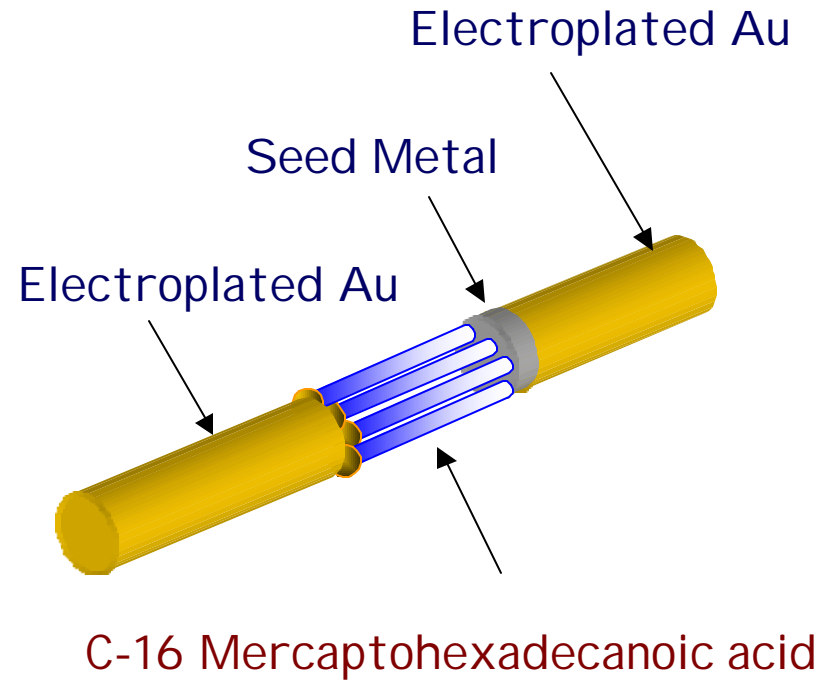
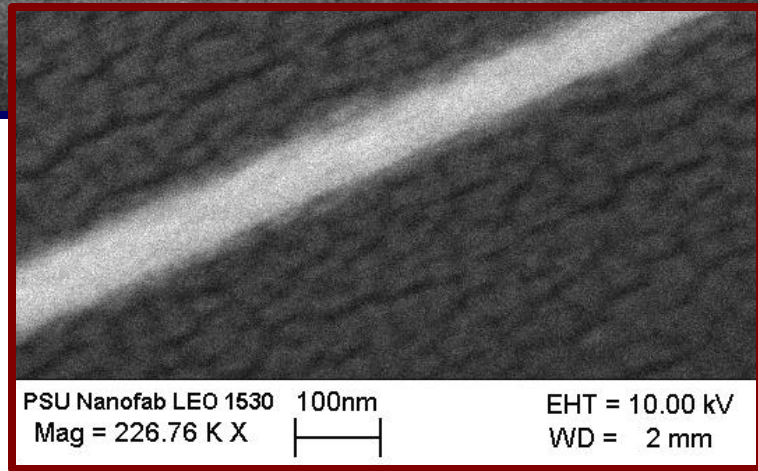
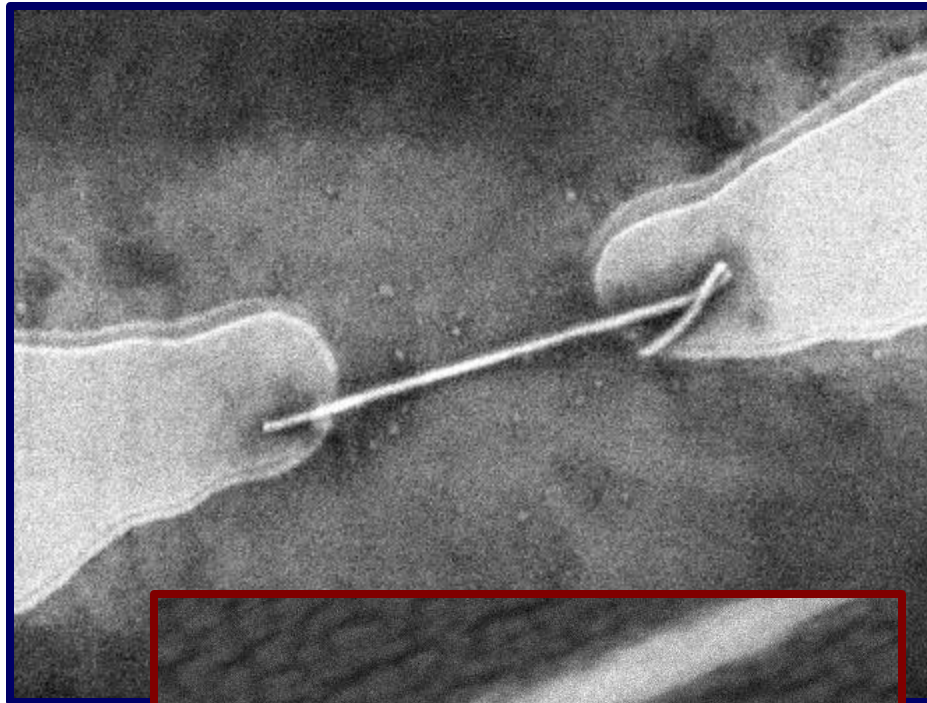
1. Electroplate Au
2. Assemble monolayer
3. Electroless seeding
4. Electroplate Au
5. Dissolve Membrane



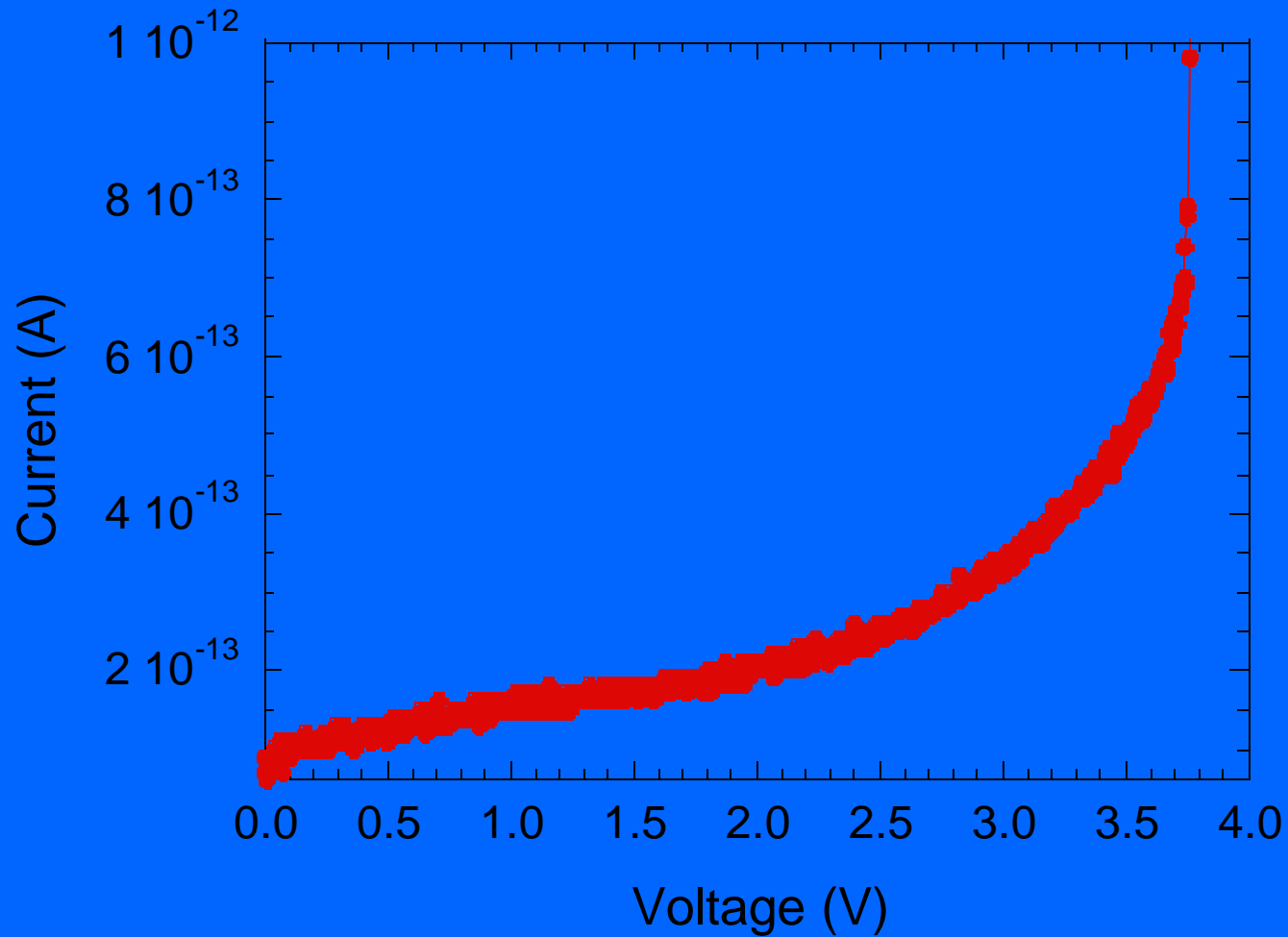
C-16 Mercaptohexadonic acid SAM Nanowires



C-16 Nanowire Junctions

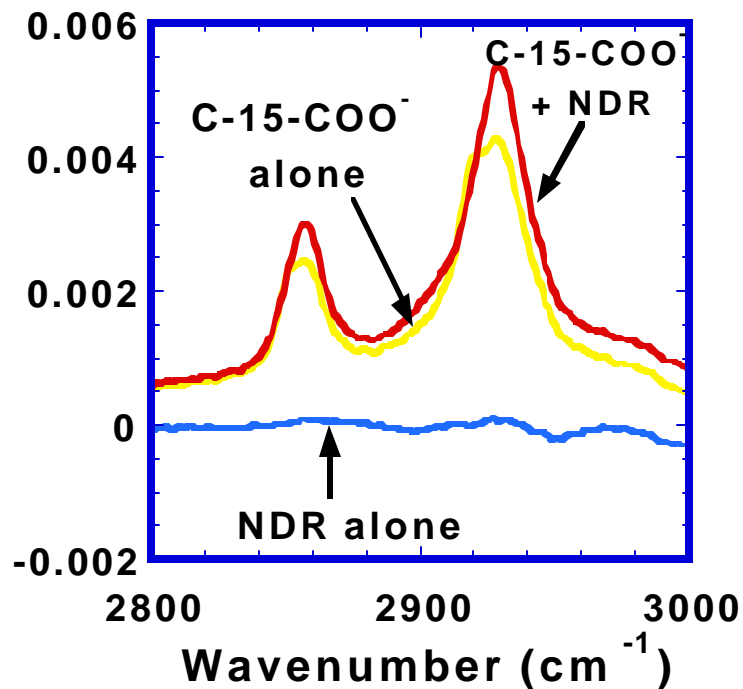


C-16 In-line Nanowire Junction

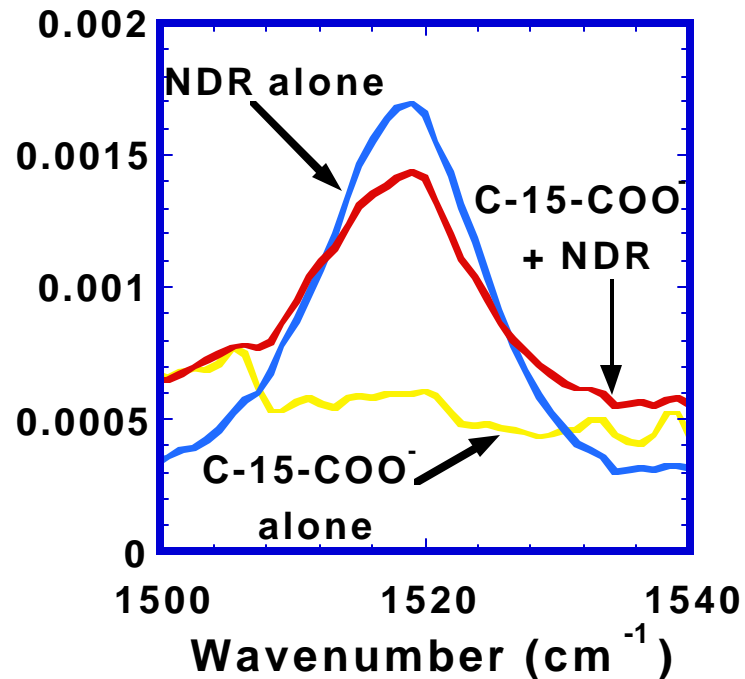


C-16 & Mononitro SAM Nanowires

C-H stretching region

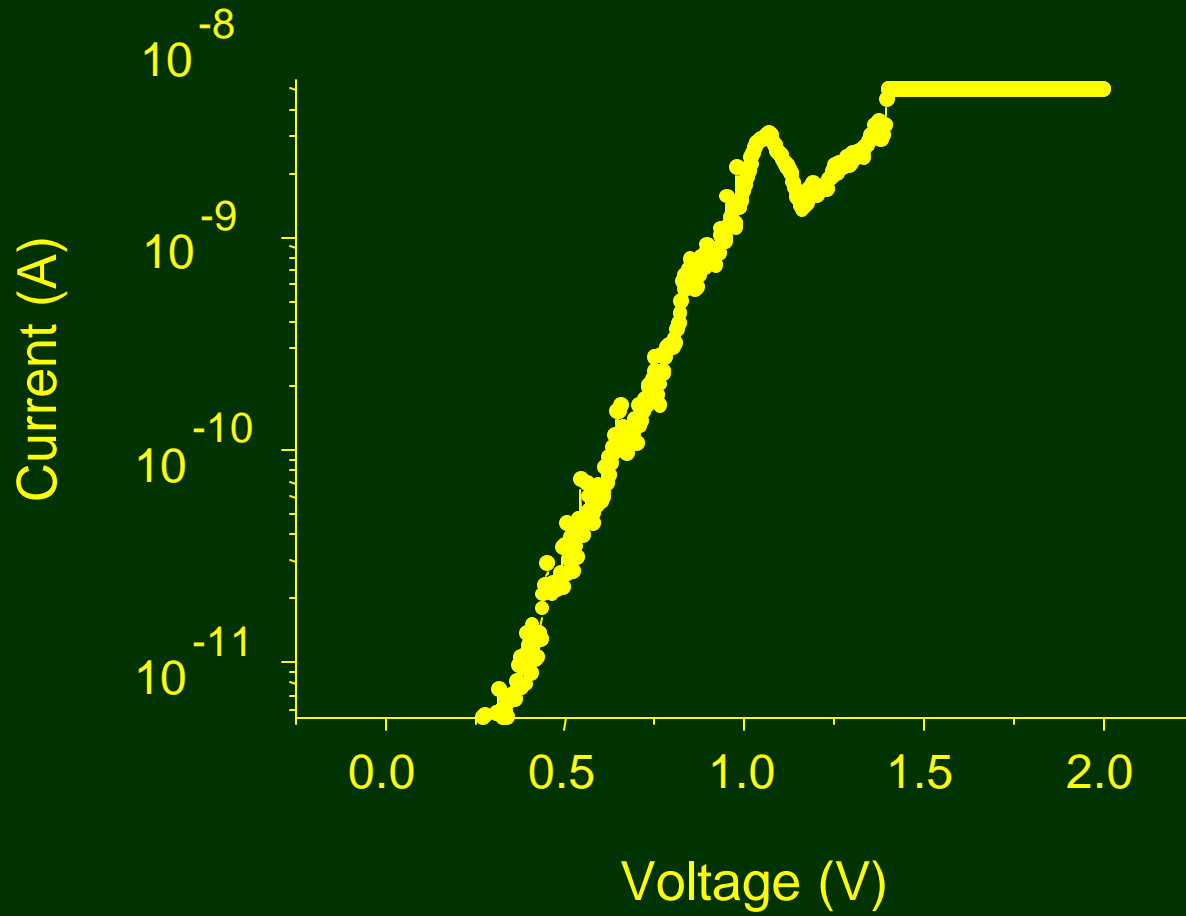
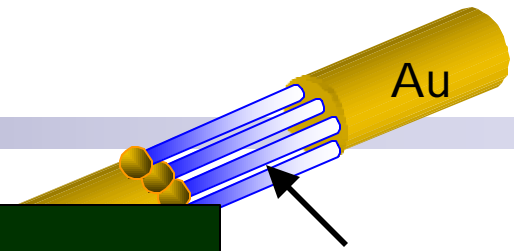


C=C stretching region



3 mM mercaptohexadecanoic acid + 0.3 mM mononitro

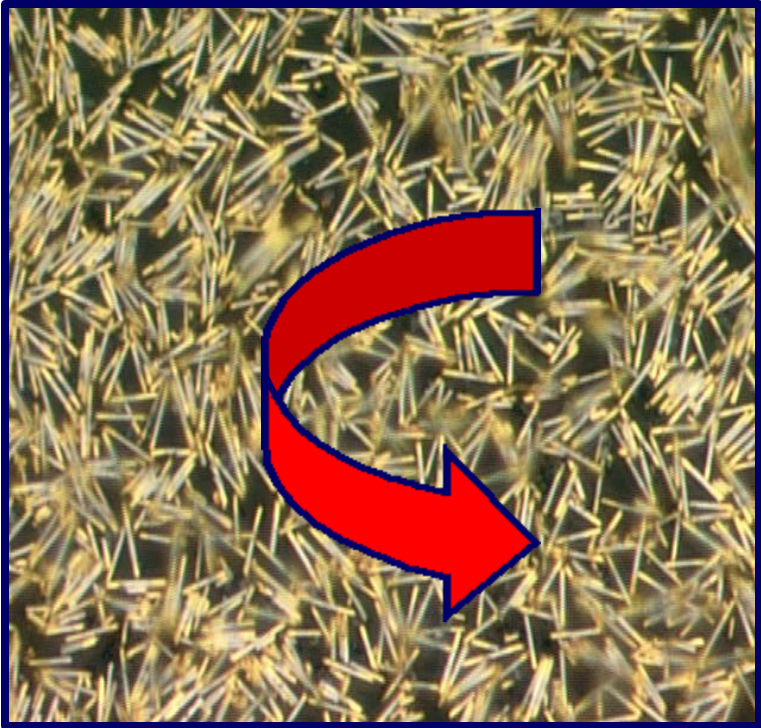
C-16 & Mononitro SAM Nanowires



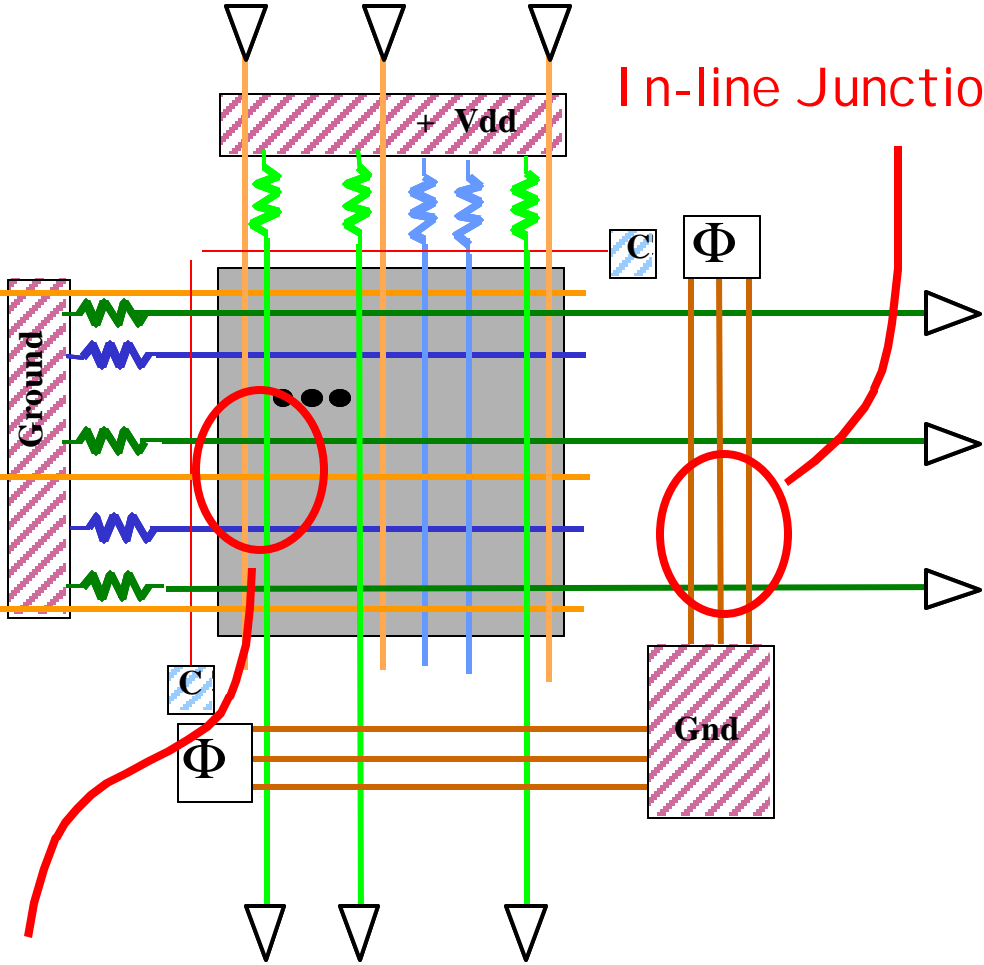
C-16 & NDR

Where Do We Go From Here ?

Individual Metallic Nanowires



In-line Junctions



Crossing Nanowires