USIC United States Industry Coalition, Inc.

Partnerships for Prosperity Nov 5 – 6, 2003

Nanotechnology-
Catalyzing New Directions
In Electronics and Photonics

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Nano Electronics & Photonics Forum

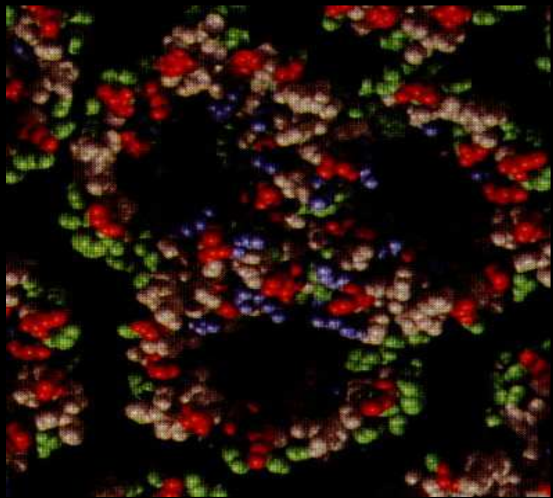
NANOSIG

SSG THE STRATEGIC SYNERGY GROUP

INSTITUTE FOR GLOBAL FUTURES

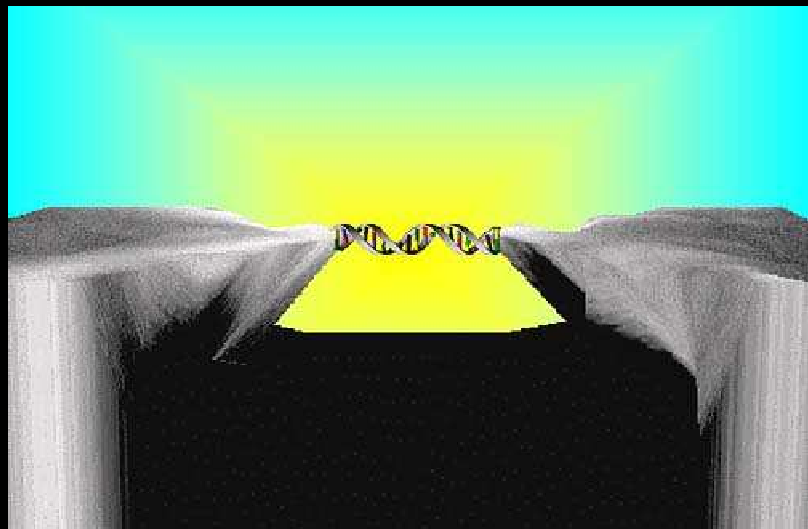
Current Developments and Future Trends
Materials and Processes in Electronics and Photonics

- Market Models, Economic Considerations
- Example Technology Developments
- Future Trends – Near & Far Term
- Conclusions

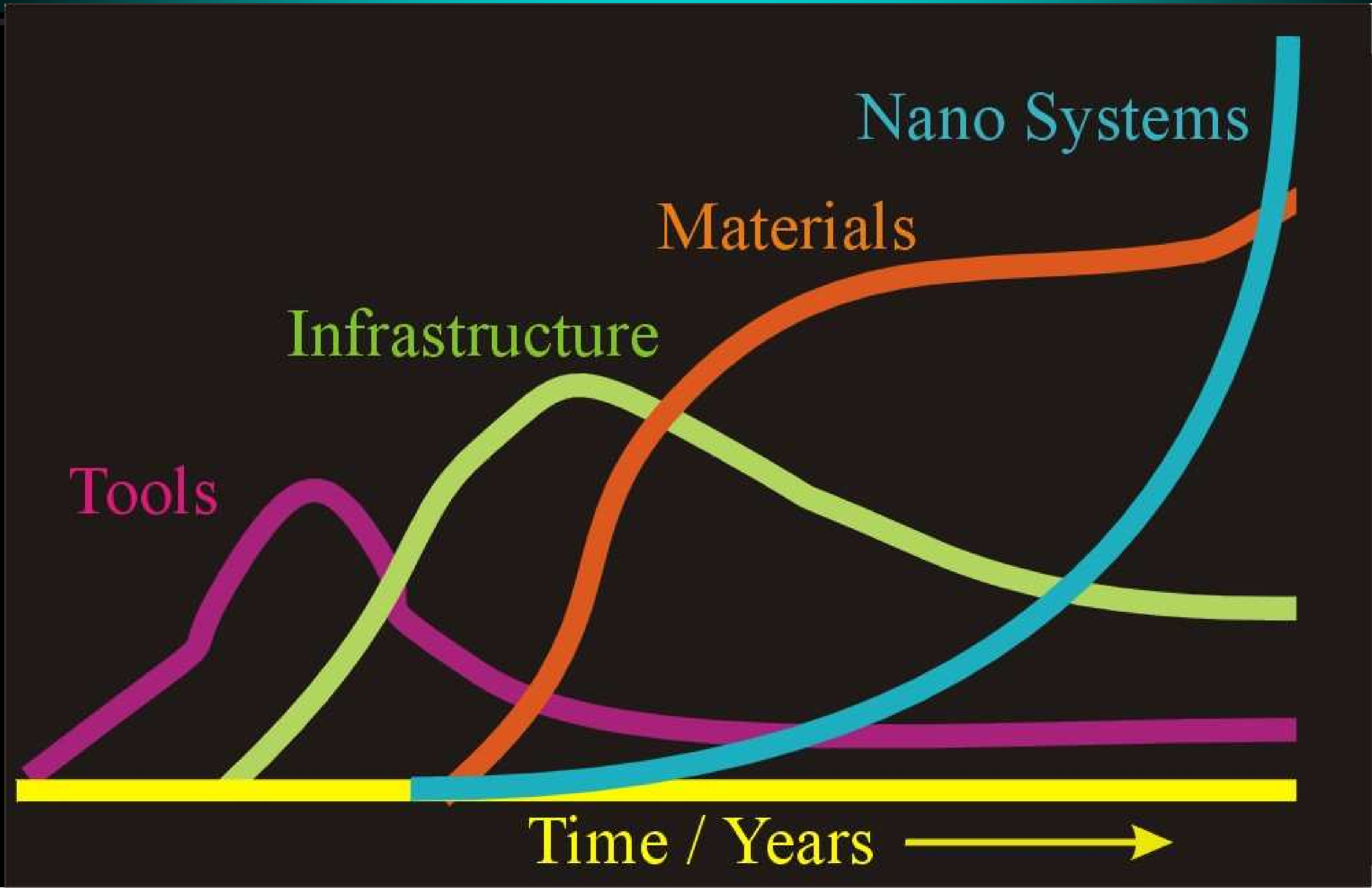


Development Domains

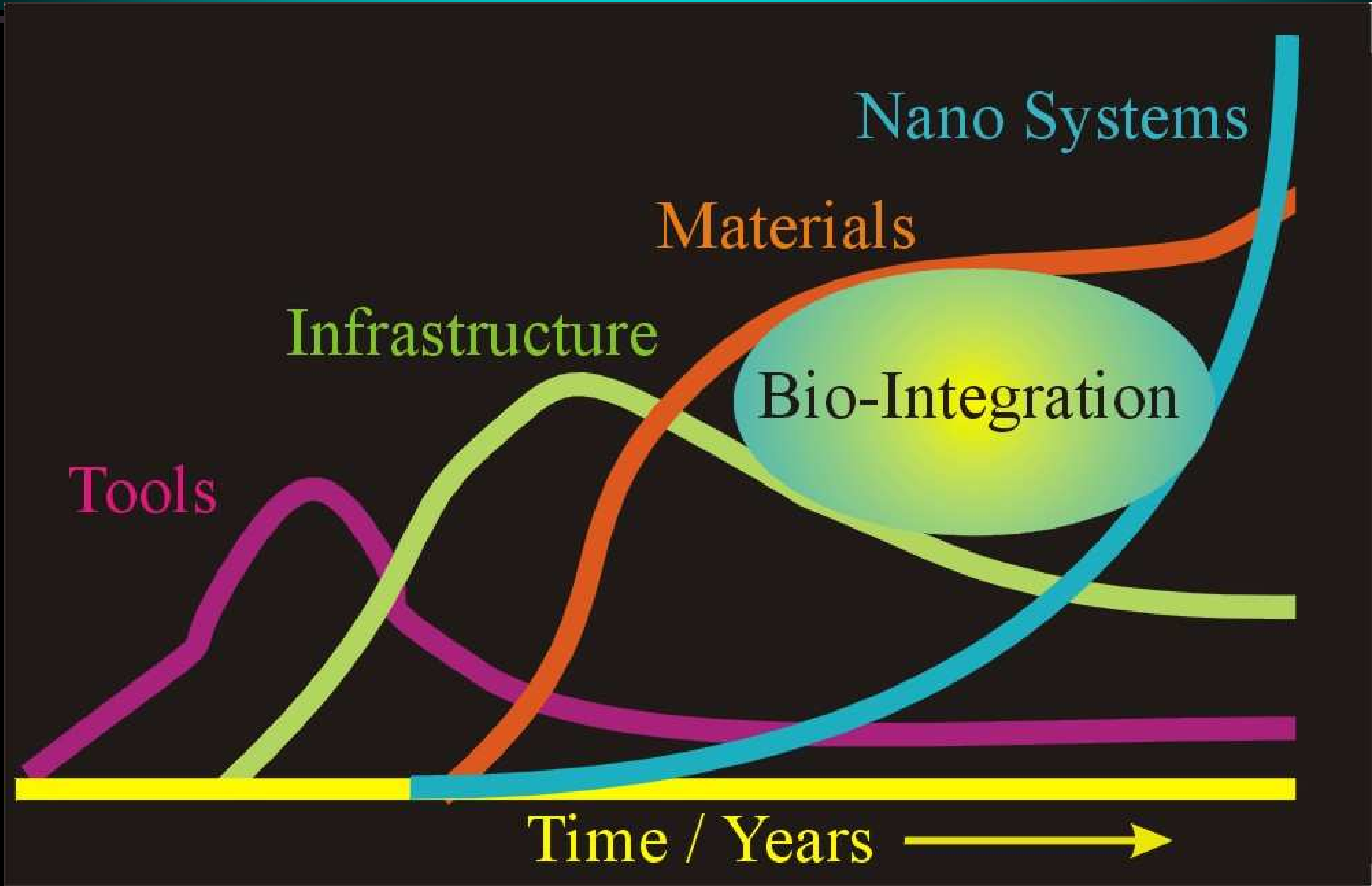
- Tools
- Materials
- Processes
- Infrastructure
- Devices / Products



The Nano-Industrial Infrastructure Development Stream



The Nano-Industrial Infrastructure Development Stream

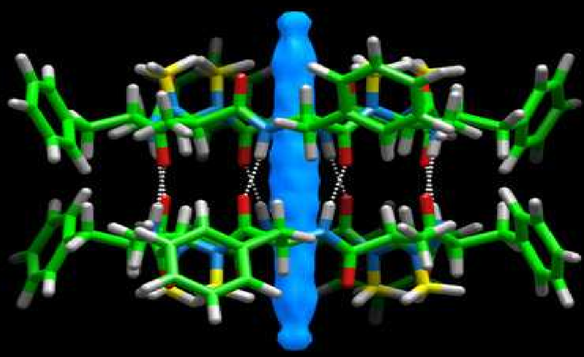


Foundries of the Future
Implementation Goals

- Diverse Methods for Patterning Matter
- Conjunction of Hard and Soft Matter
- Implementation of “Bioconjugates” as an Assembly System
- Whitney’s Interchangable Parts Paradigm Applied to Materials Creation
- Merging of Materials, Devices, Circuits

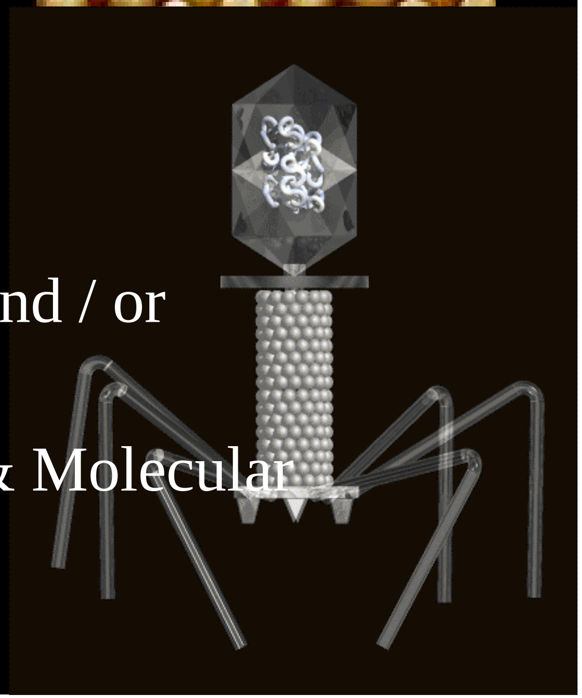
Example Nanofabrication Materials and Systems Enabled by Biological Materials and Processes

- “Printable” chemistries on diverse materials sensors, energy conversion, circuitry, displays
- SAM (Self Assembled Monolayers) reconfigurable logic arrays, memory fabrics
- Integrated 2D and 3D photonic and electronic structures
- Genetic “magnification” of biological materials with electronic and photonic properties
- Living organisms as biofoundries and nanomechanical systems



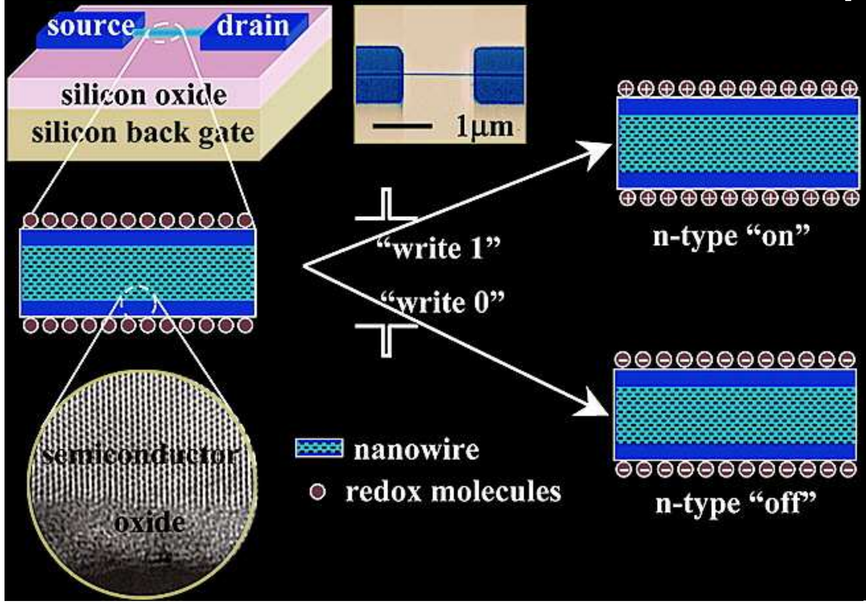
Primary Areas of Interest – Nano Electronics and Photonics

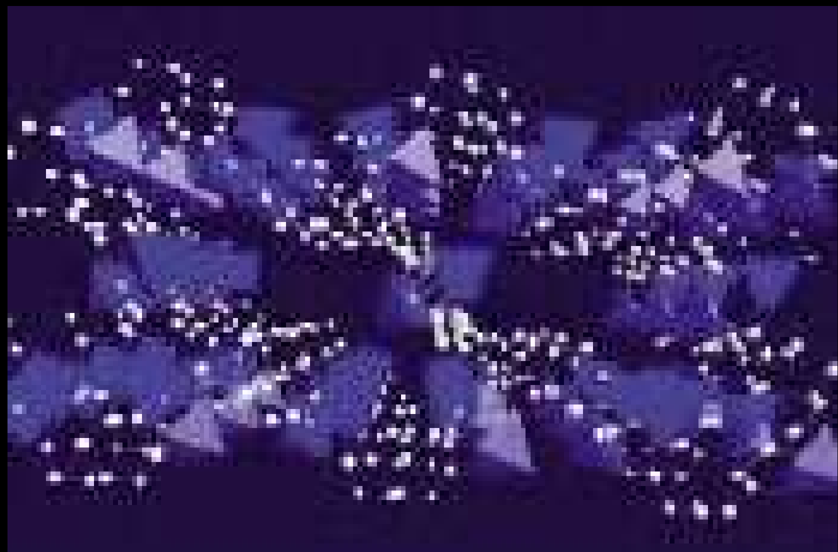
- Molecular Switches, Gates, Sensors
- Nanowires and Interconnect Systems
- Nanobiological Materials and Processes
- Memory and Reconfigurable Architectures
- Electro-Optical Materials and Nanostructures
- Bandgap, Nonlinear, & Other Photonic Systems
- Quantum Devices & Spintronics
- Nanostructured materials with Novel Photonic and / or Electronic Properties
- Nanoprinting, Imprinting, "Soft" Lithography, & Molecular Deposition



Integrating Current Technology and Fabrication Infrastructure Commitments with Emergent Nanofoundry Capacities

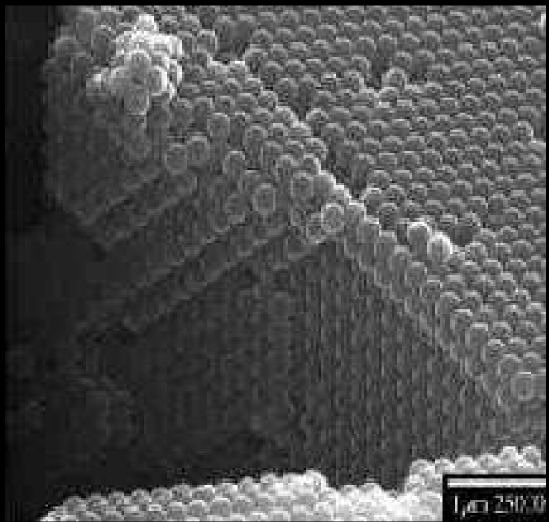
- Microscale top down silicon becomes the "circuit board" for bottom up nanostructured systems
- Integrated "operational ecologies" of fluidics, optics, mechanical, electrical, chemical modalities
- Transition from 2D platforms to 3D manifolds

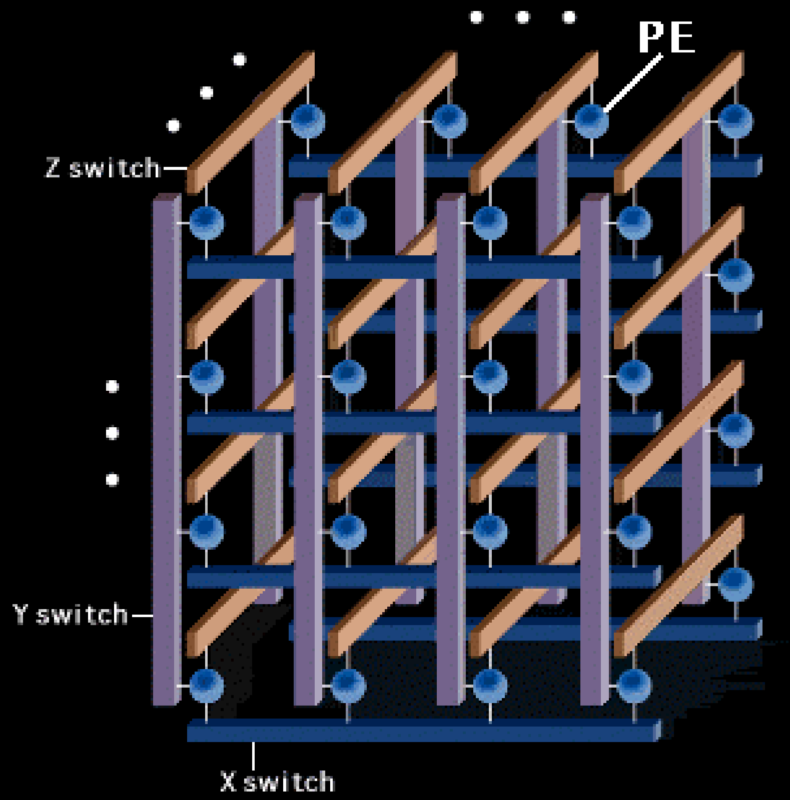




Transition to 3D Structural and Functional Systems

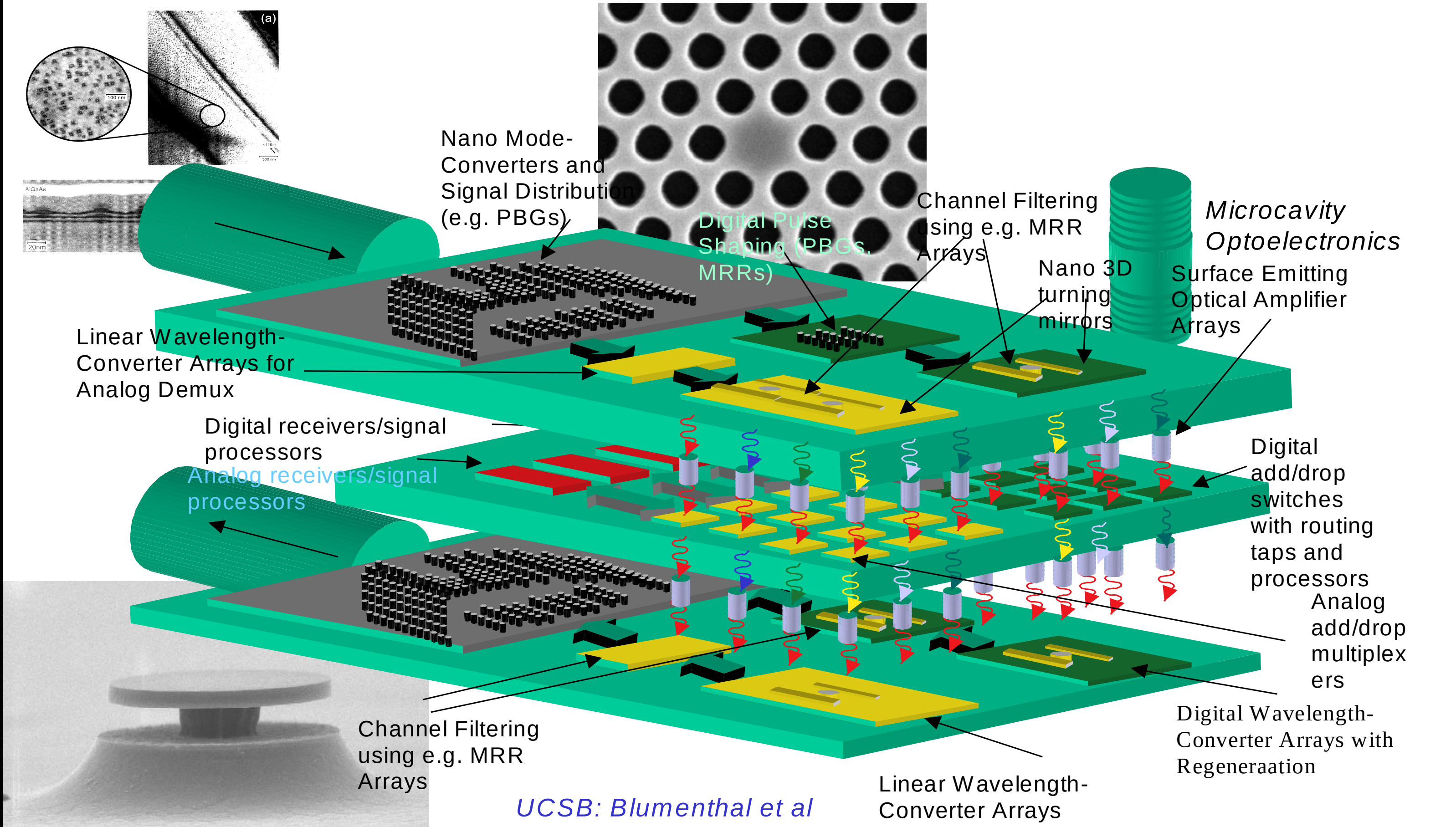
- Interconnect Systems, Scaffolds
- Photonic Band Gap Materials
- MEMs > NEMs
- Switch Fabrics





Nanotechnology Value Proposition - Integration is the Key

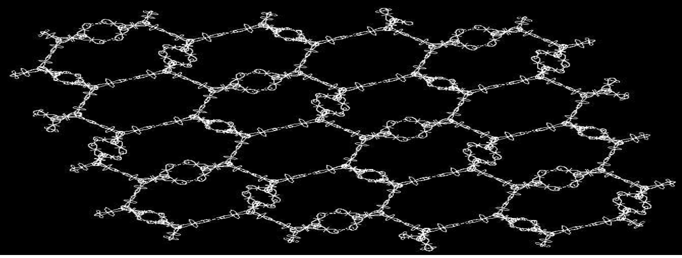
Integrated NanoPhotonics Systems

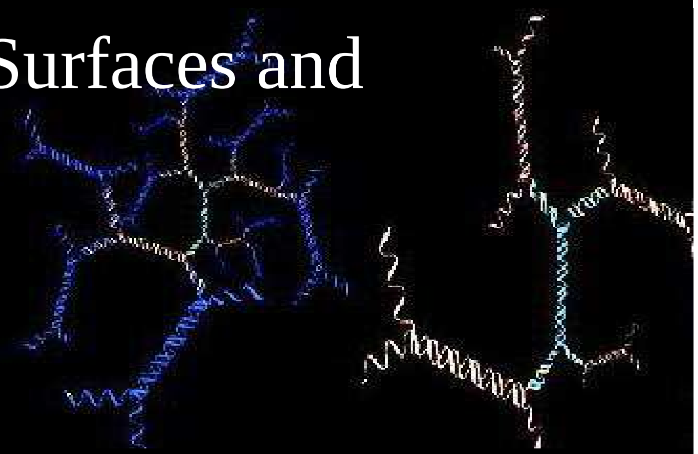


UCSB: Blumenthal et al

Enabling Development Paths

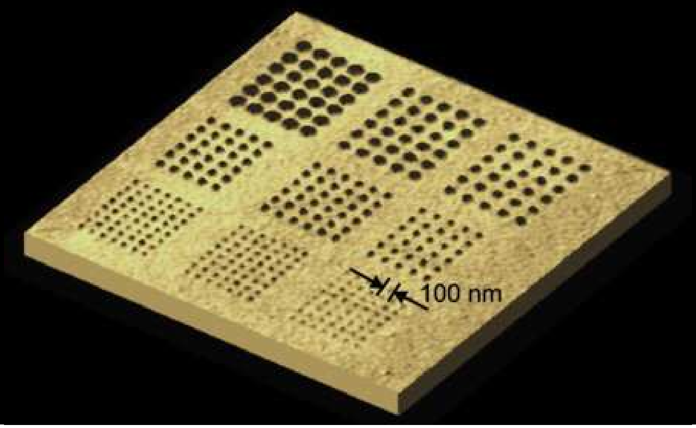
- Enhance “Friendliness” to Novel Materials in “Traditional” Micro-litho Fab Facilities
- Not Necessarily Top / Down vs. Bottom / Up
- Integrated Biological and Non-Biological NanoStructures
- Supra-molecular Synthesis
- Integrated / Inter-related Techniques for Patterning Matter
- Chemical Handles for Attachment to Surfaces and
- Utilizing Biology as a Foundry





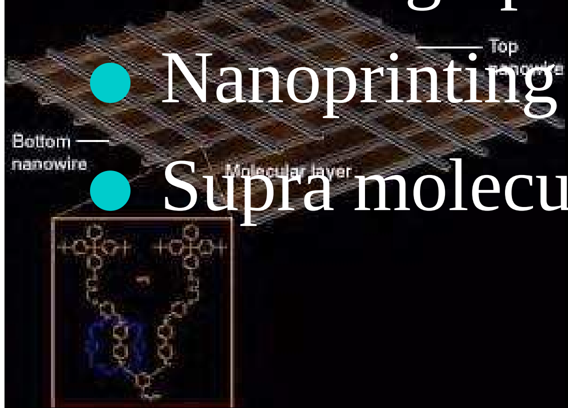
Important Key Features of Nanotechnology – Definitions that are "accurate" vs definitions that are relevant

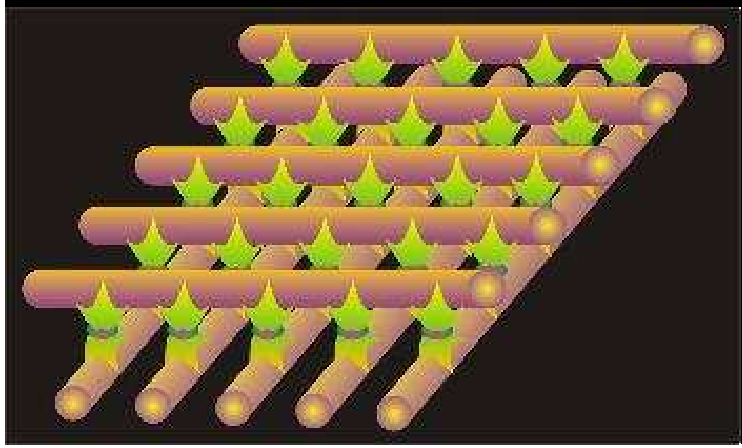
- It's not just about "little things" . . . it's about fabrication **processes**
- Synergistically interrelated chemistries, materials systems and fabrication processes enabling a new type of industrial infrastructure.
- Self assembling and self organizing material systems enable de-dentralized, granular, **Just As Needed** manufacturing modalities
- Nano-industrial infrastructure development represents a gateway to products, processes, and applications that are **not economically or technically feasible via other manufacturing means.**

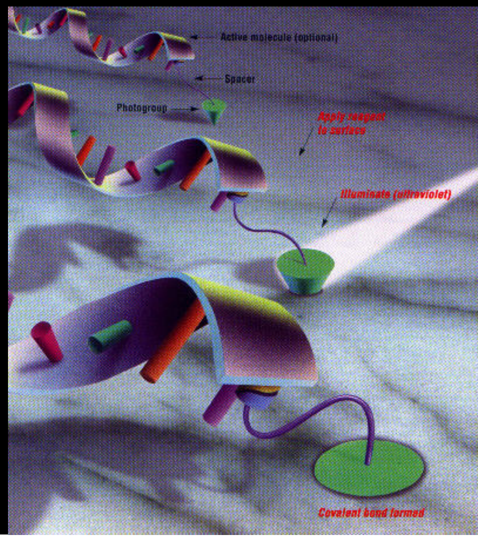


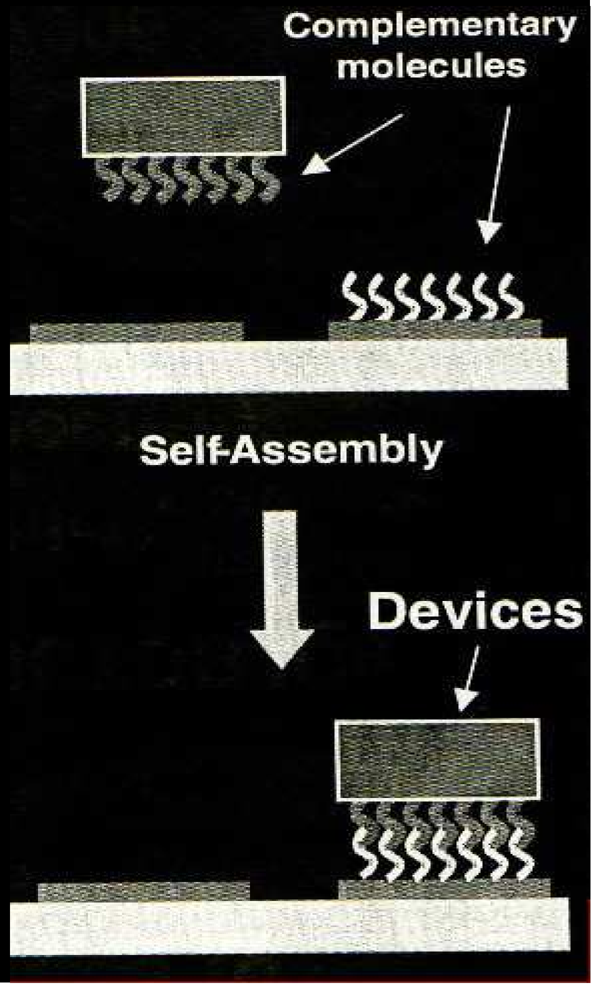
Functional Diversity
Low cost
Highly adaptable

- Self Assembly / Self Organization
- Biolithography / “Soft” lithography
- Nanoprinting & Nanoimprinting
- Supra molecular manipulation



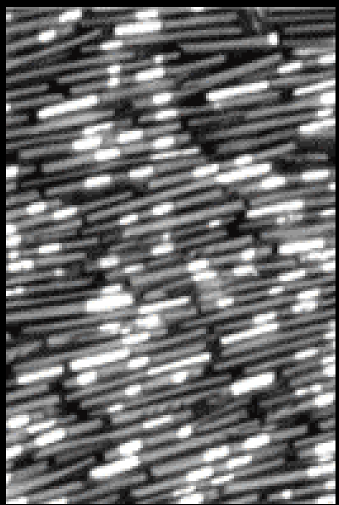


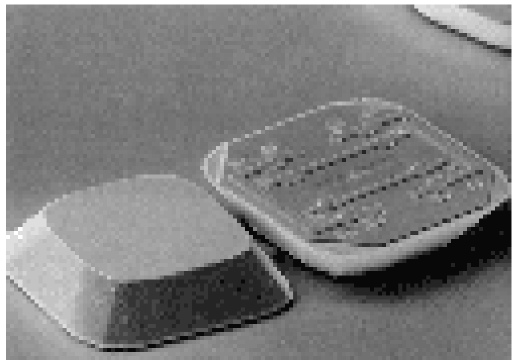




Application Domain Example - Ubiquitous Object Interface

- Nano Bar Codes
- Micro / Nano RFT devices
- Printable Nano-circuitry

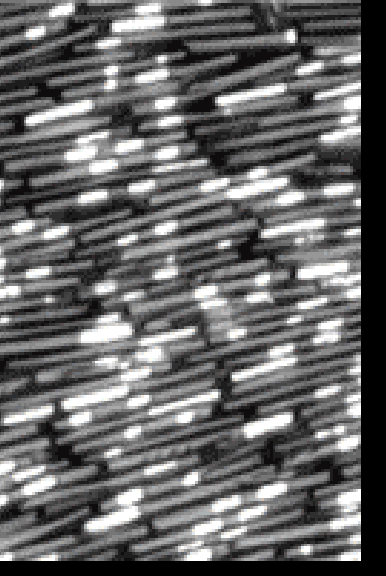


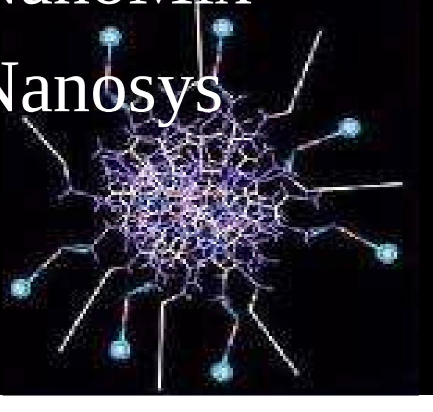


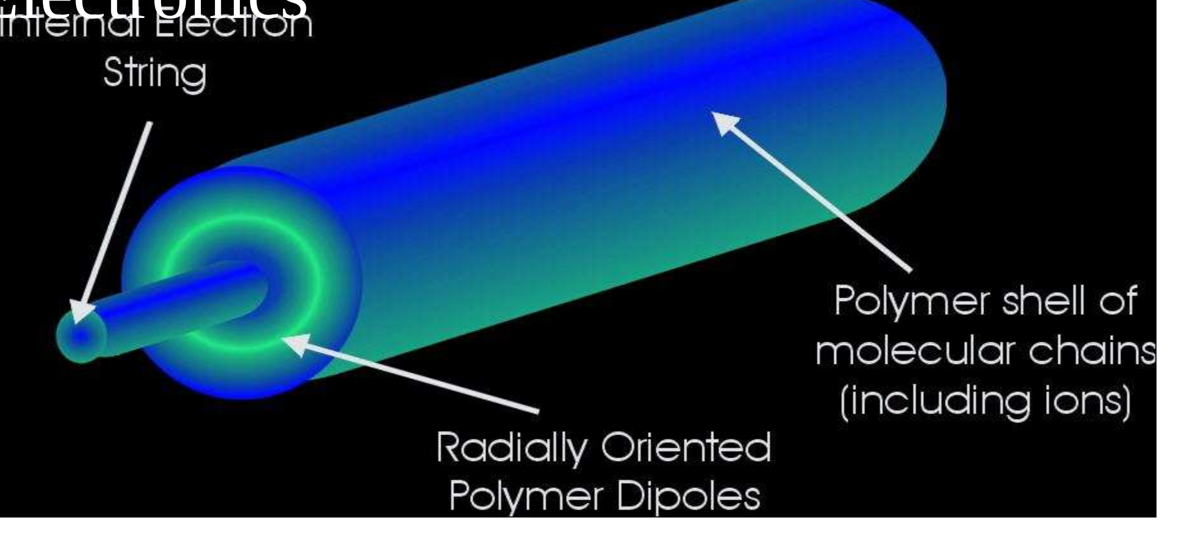
SEM Photograph of
185 Micron NanoBlocks

Example Start-up Ventures

- NanoInk
- Quantum Polymers
- Optiva
- Dendritic Nanosciences
- Nanoplex
- California Molecular Electronics
- NanoMix
- Nanosys

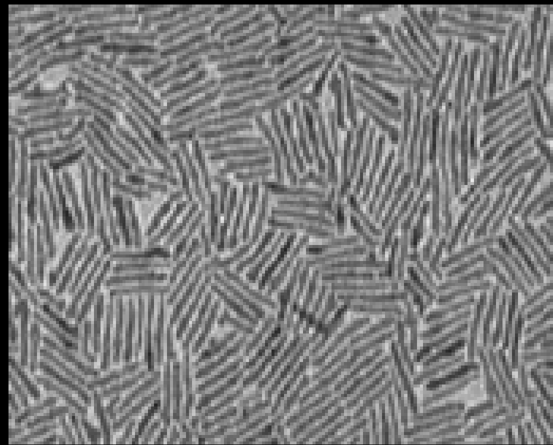


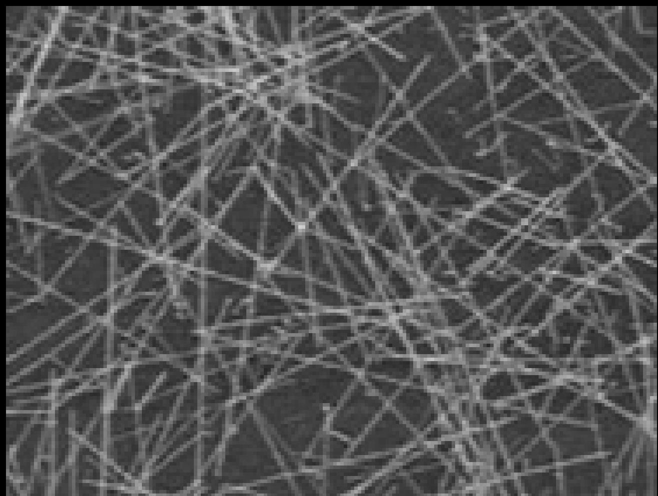


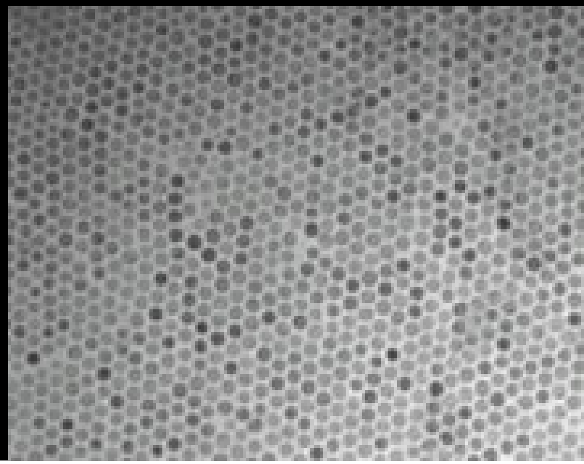


Nanostructured Materials – Wires, Rods, Dots . . .

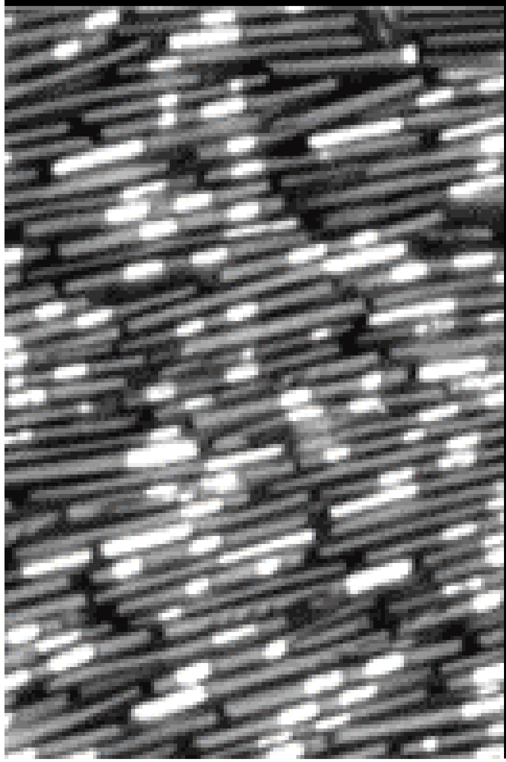
- Foundry processes / fabrication techniques enabling mass production of nanoparticles
- Broad range of functionality

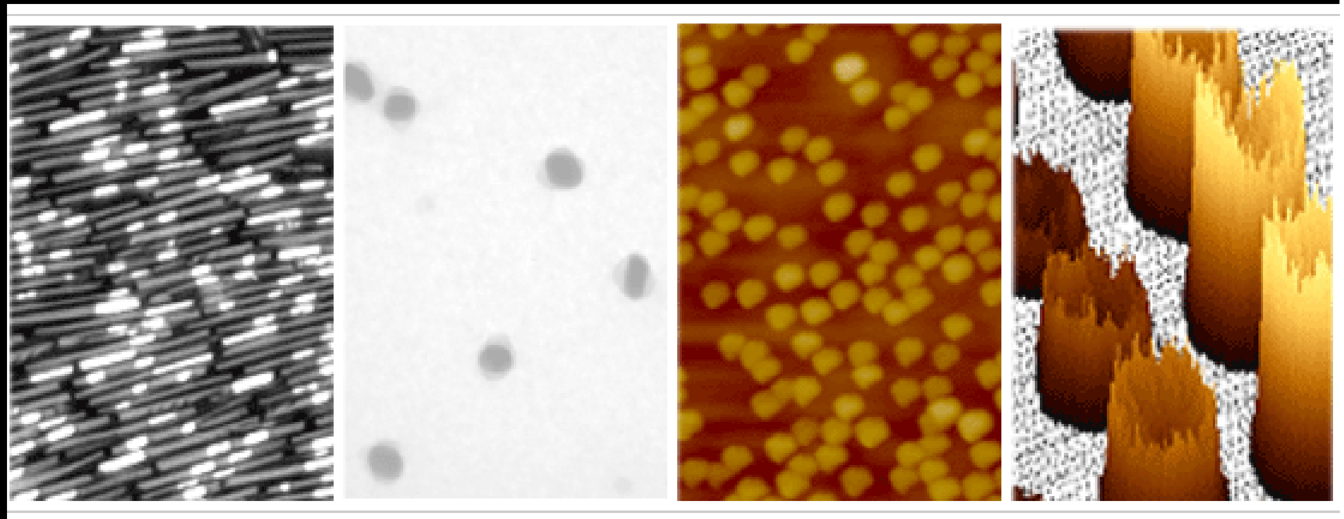






Periodic Nanostructured Materials

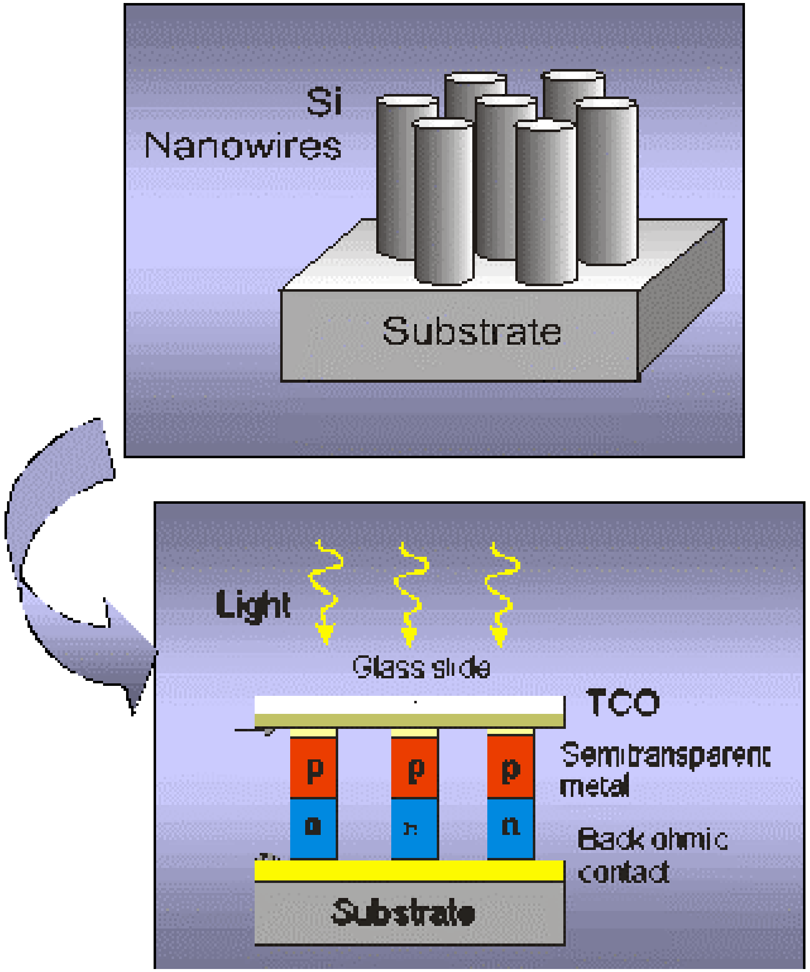


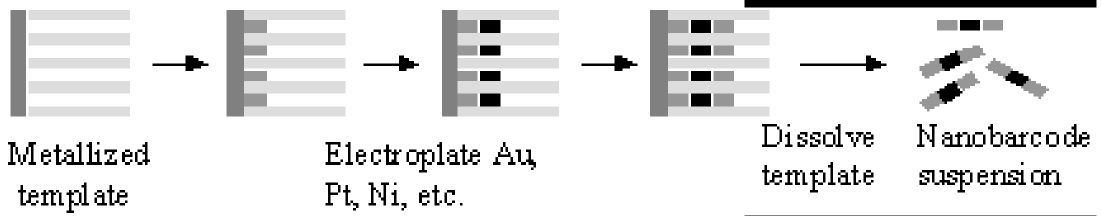


Periodic Nanostructures

Some of the potential applications of periodic nanostructures are:

- Quantum effect dots
- Resonant tunneling diodes
- Single-domain/bit magnetic storage media
- Single electron transistors (SETs)
- Light-emitting diodes (LEDs)
- Photodetectors
- Quantum well optoelectronic devices
- Quantum cellular automata
- High-density memory

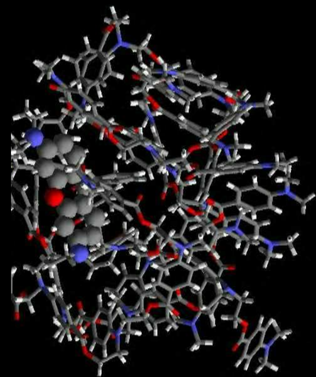


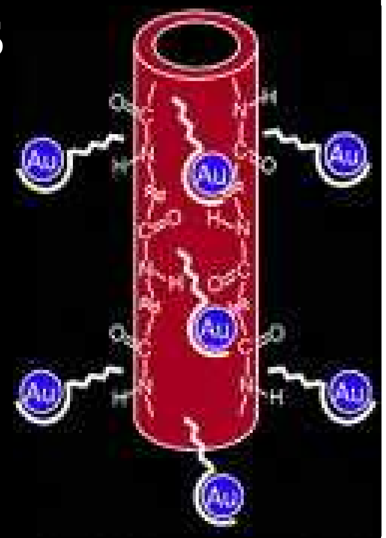


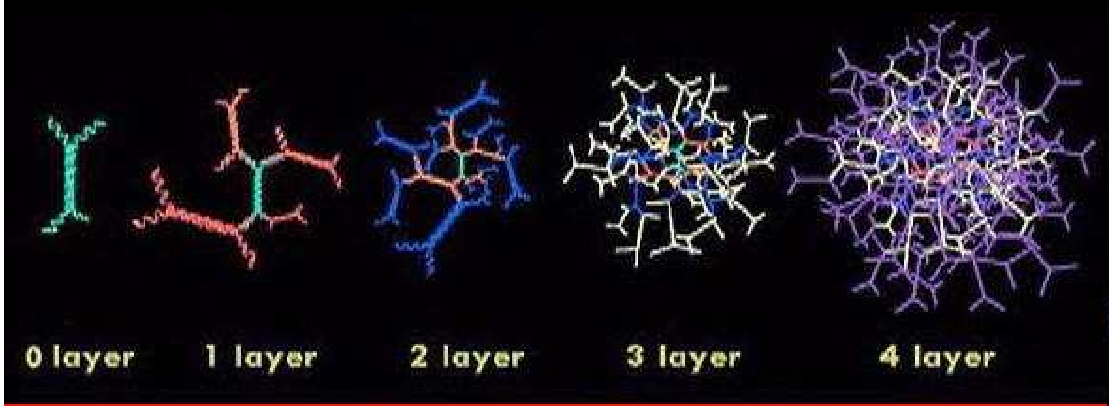
Schematic of a Si photodetector array fabricated on periodic Si nanowires

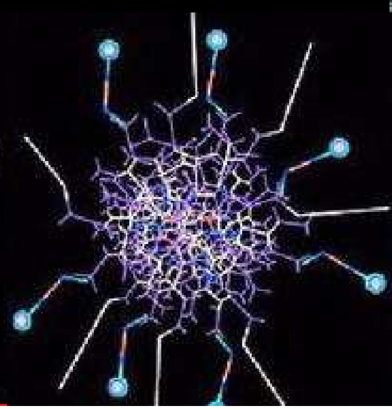
Molecules as Tools – Not Just Endproducts

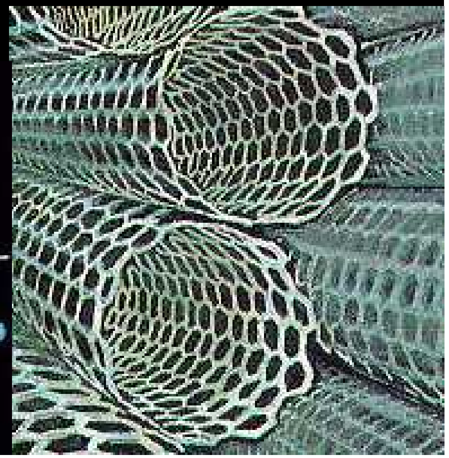
- Nanotubes – Carbon, Polymer, various materials
- Dendrimers
- Zeolites
- Organo-metallics
- Structural Proteomics





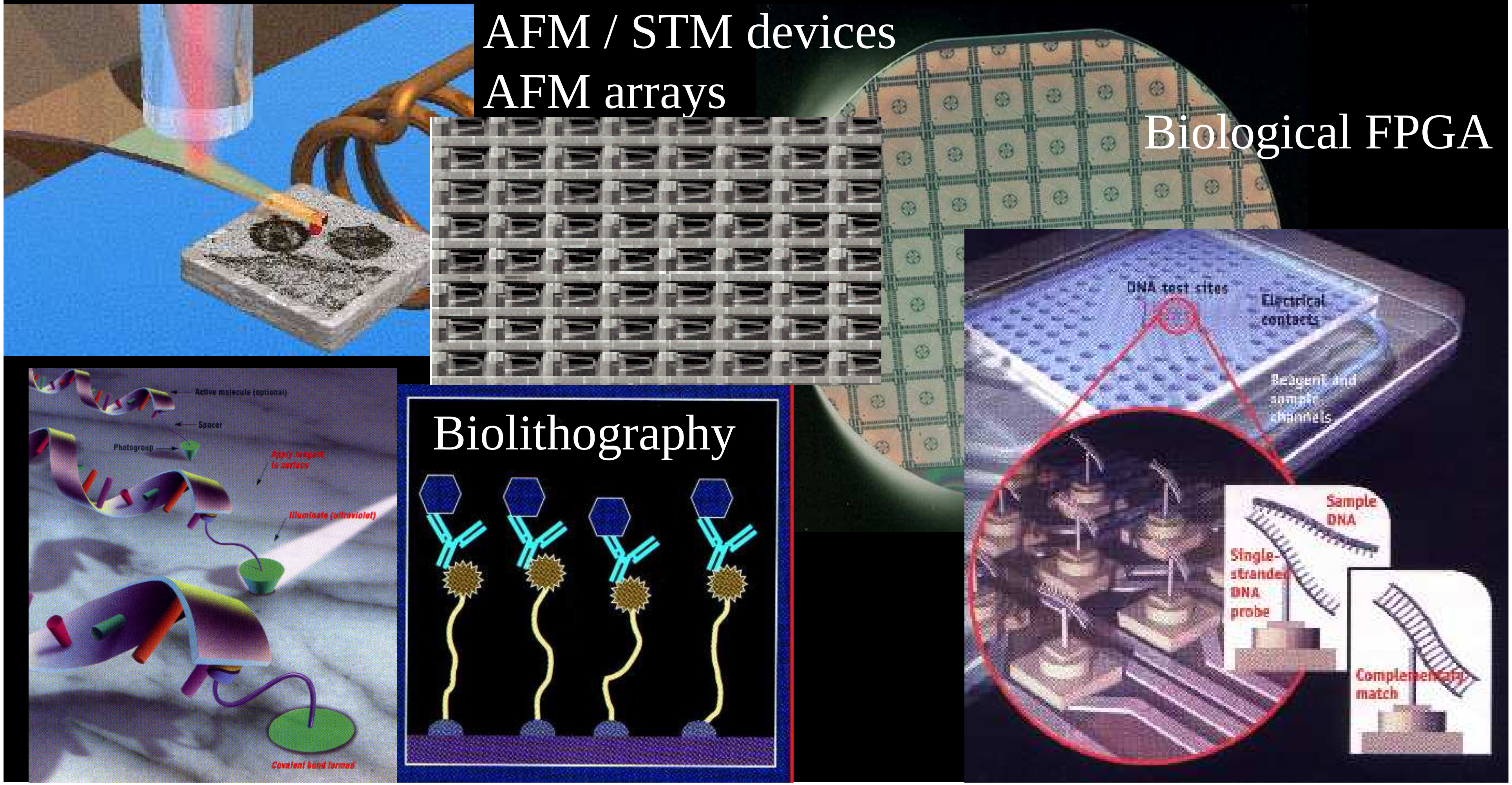






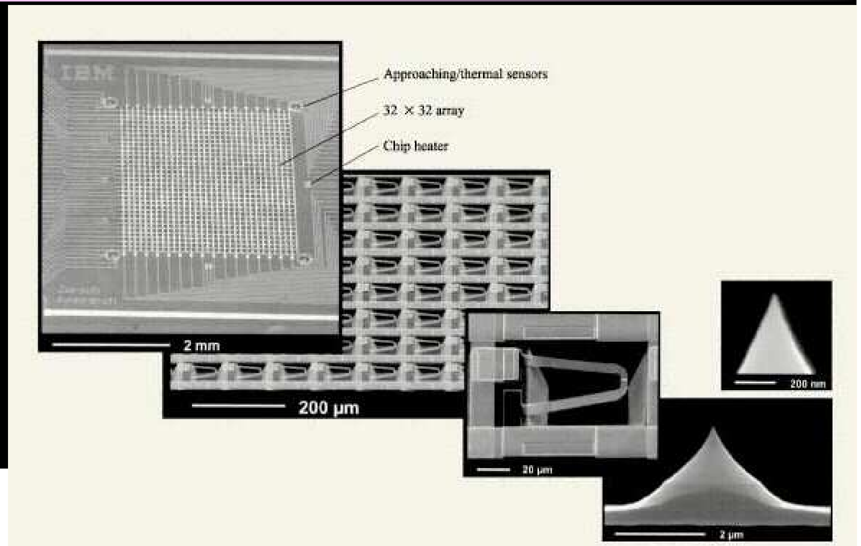
Define “Tools”

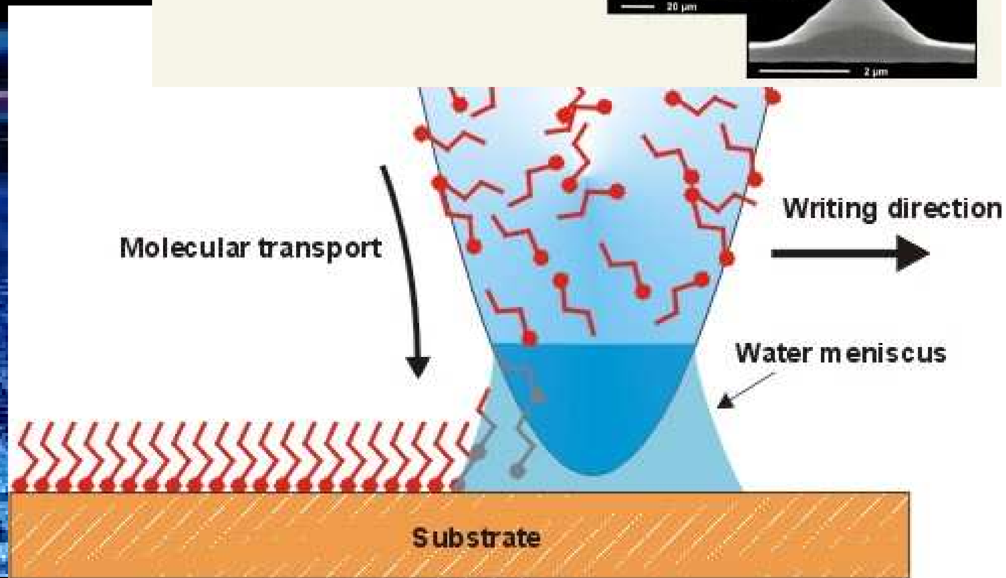
- Goal of the tool is to manipulate molecules



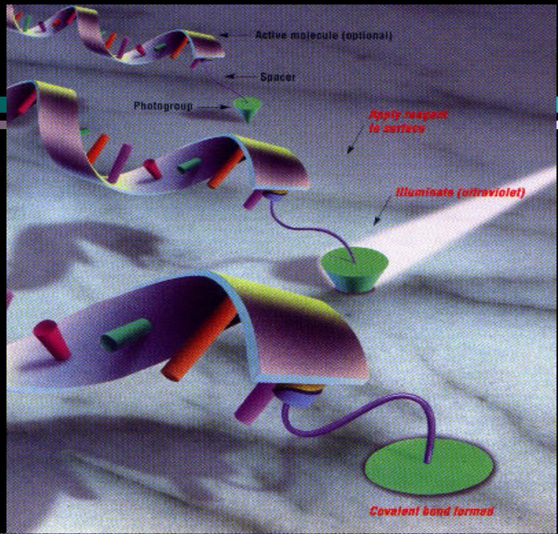
Value Proposition is in Synergistic Opportunity Example - AFM arrays

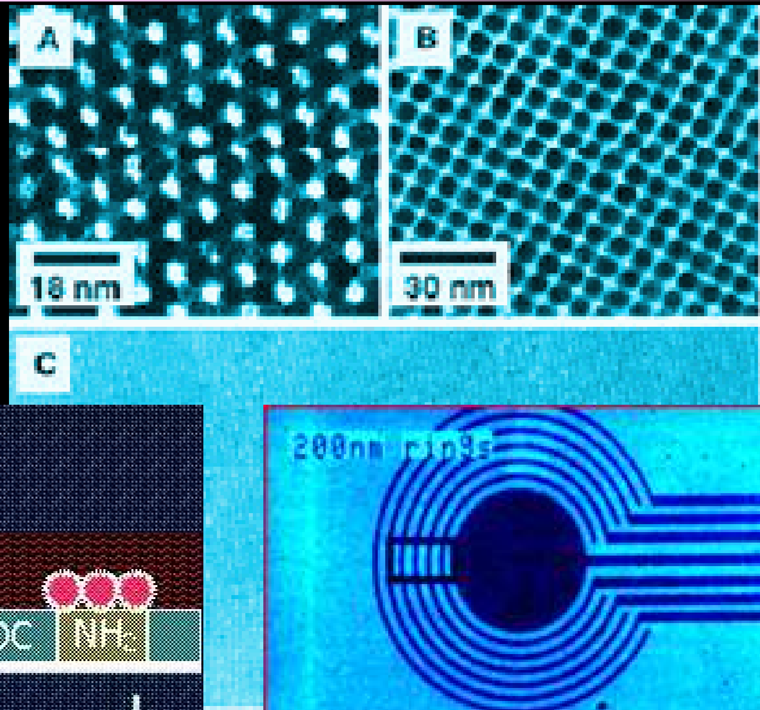
- Enabling platform for data storage
- Massively parallel molecular deposition

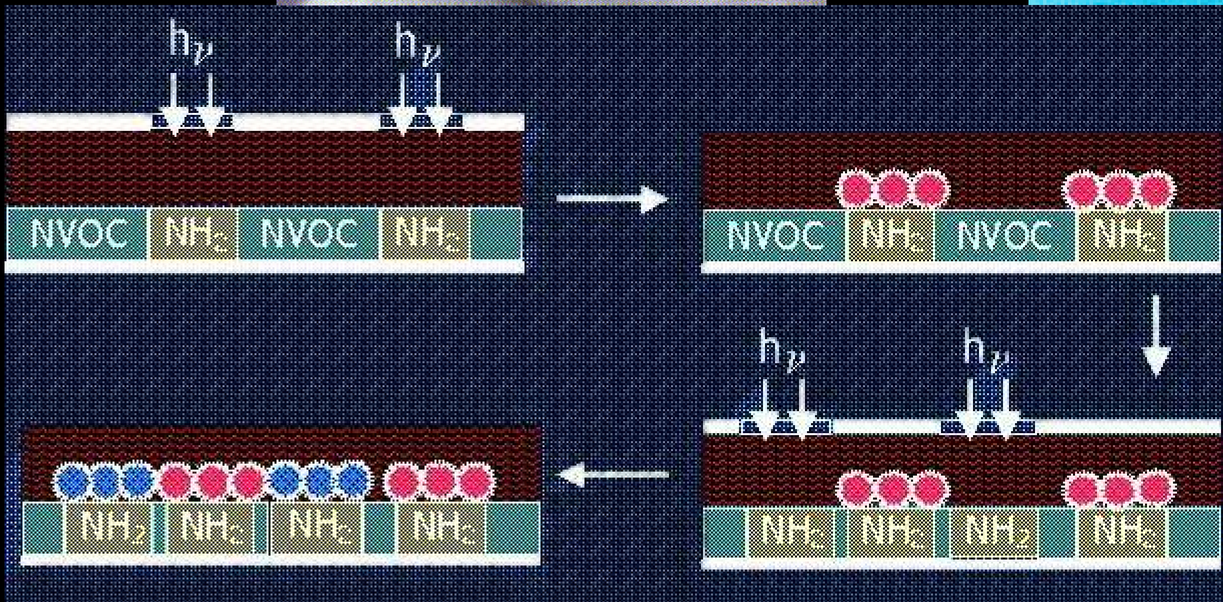


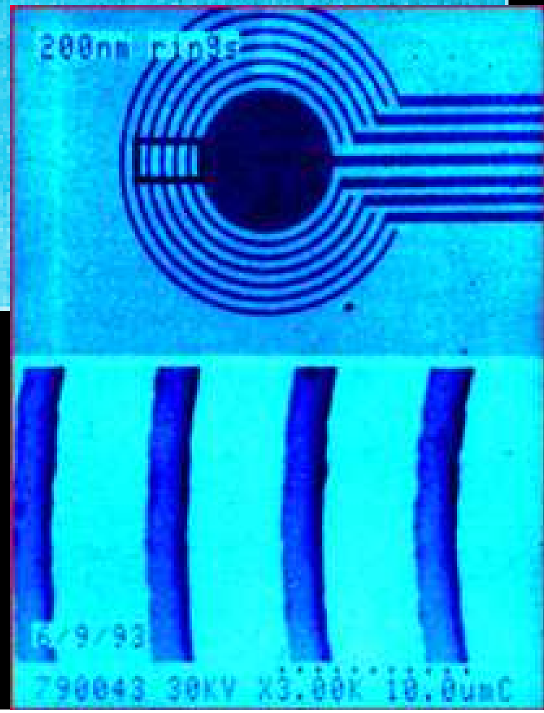


Biolithography – Directed Biochemical Assembly

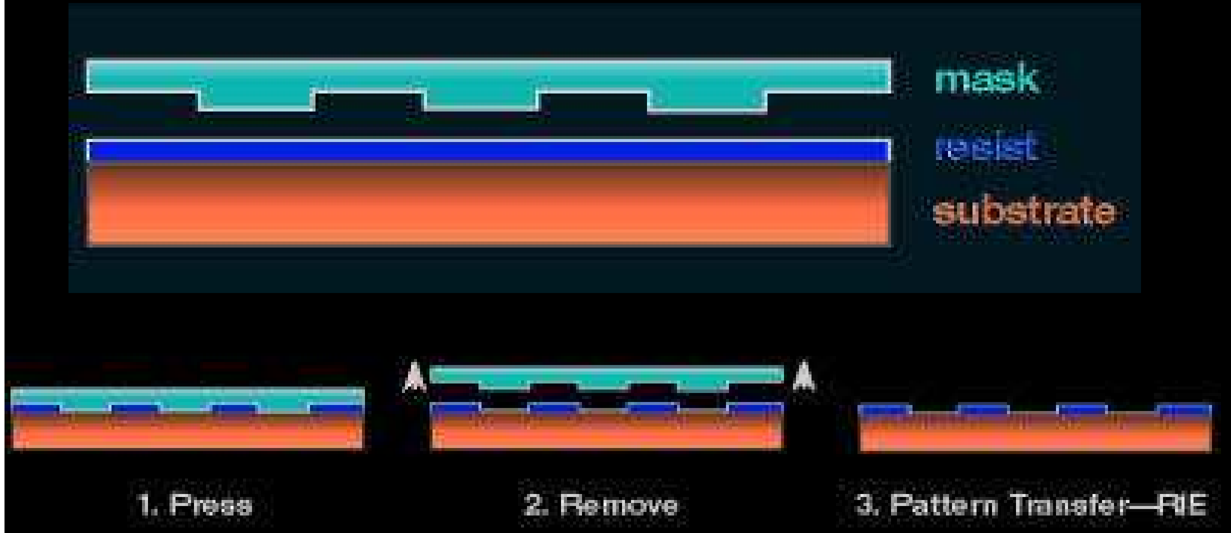


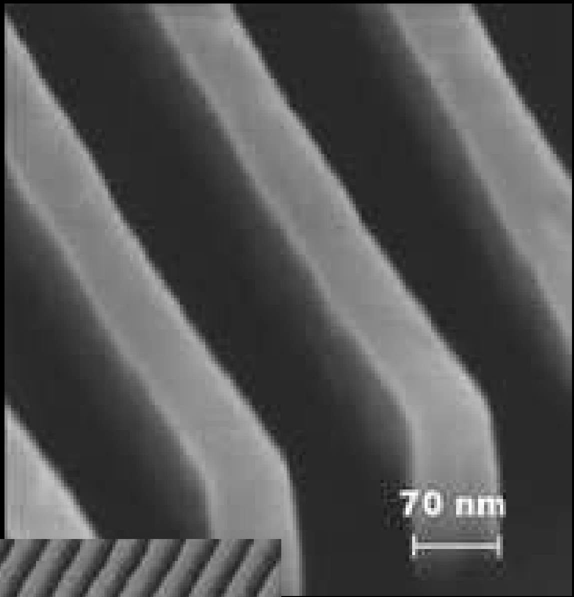


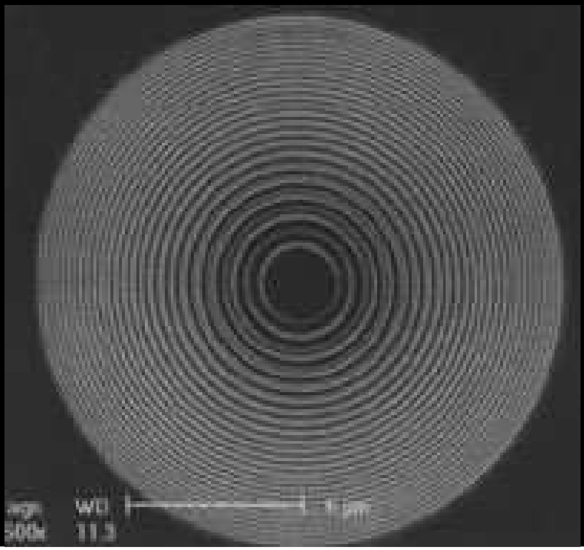


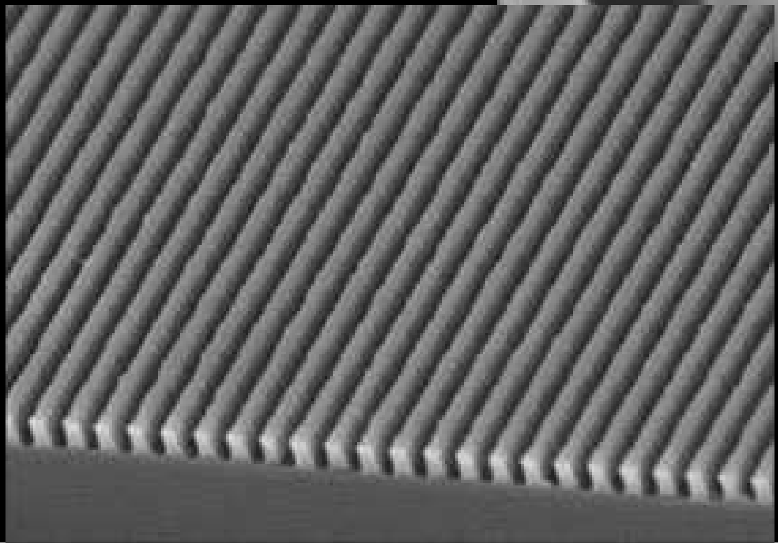


NanoImprinting Foundry Processes in Photonics, Electronics, Fluidics – Integrated Systems



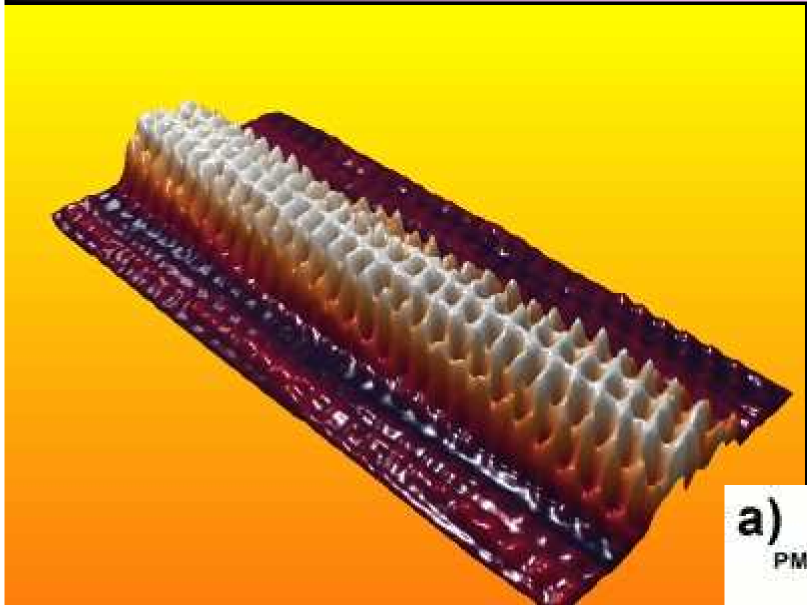


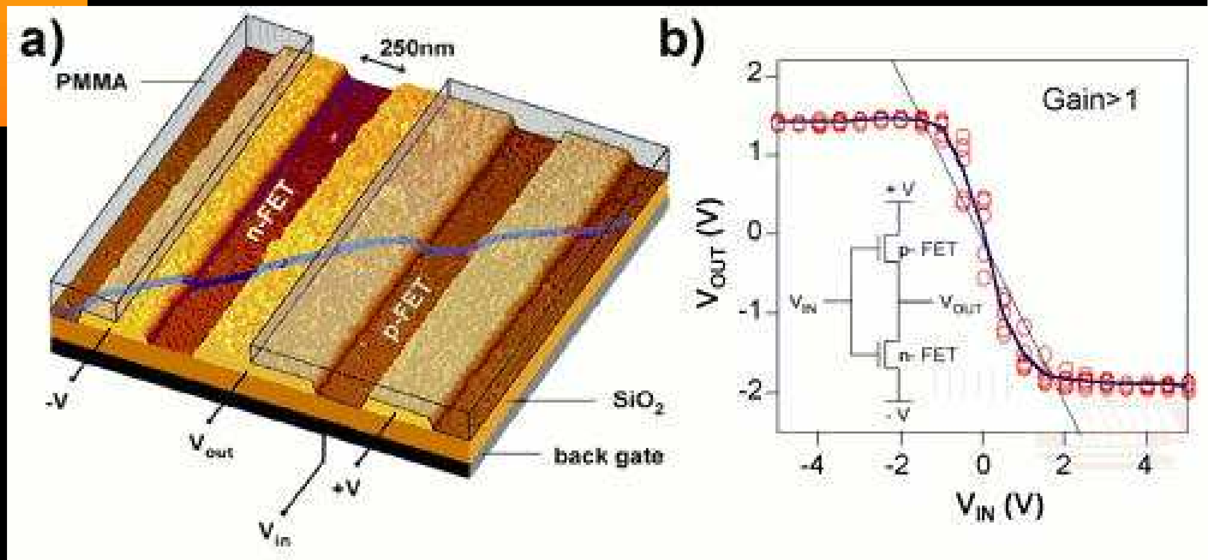




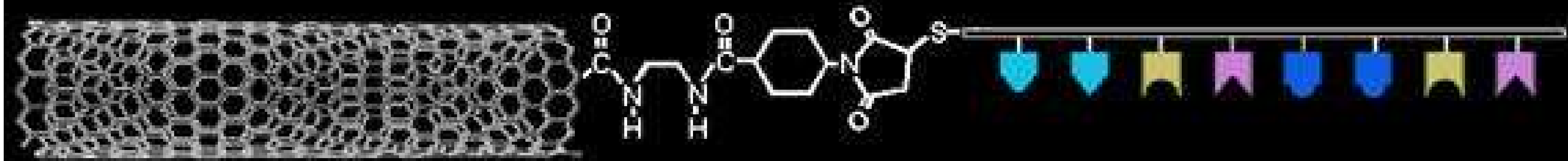
Nanowires in Nanoelectronics / Molectronics

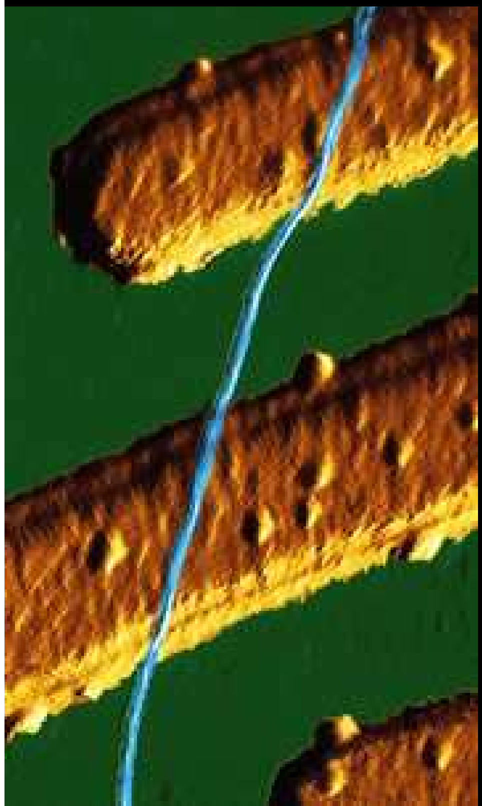
- Interconnections
- Dynamic Devices

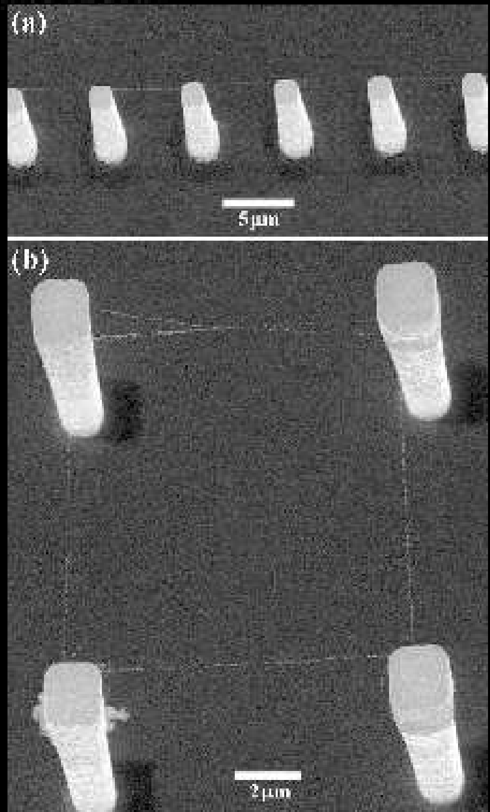


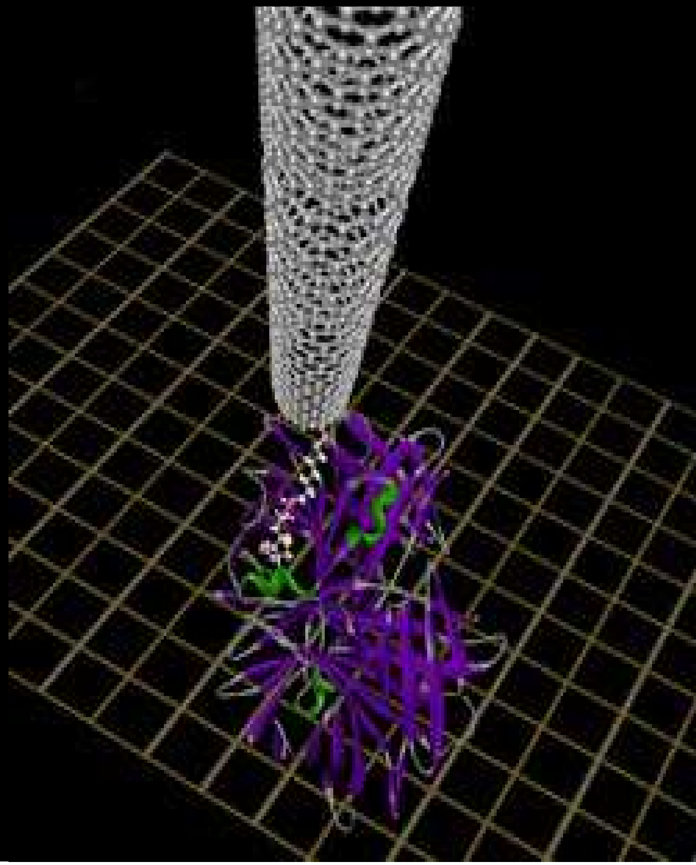


Example – Carbon Nanotubes Integrated with Organic Molecules / Biological Materials

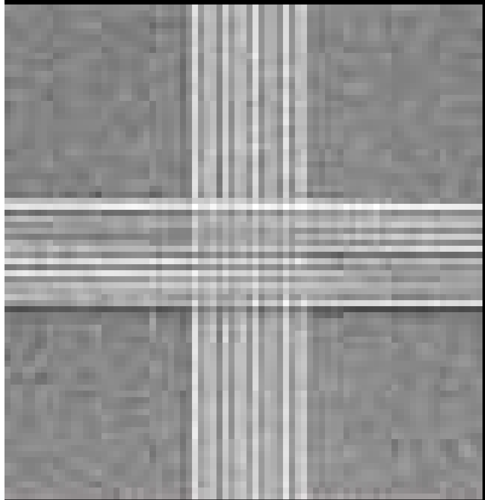




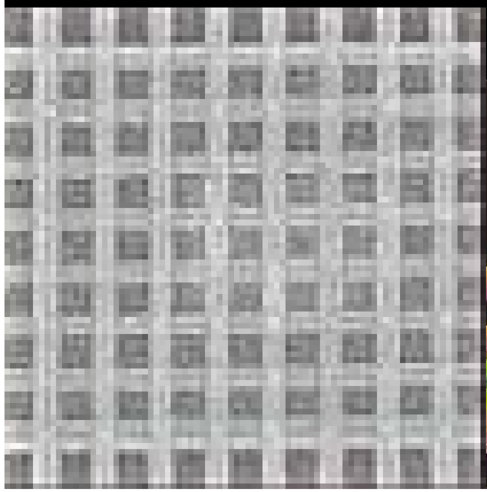


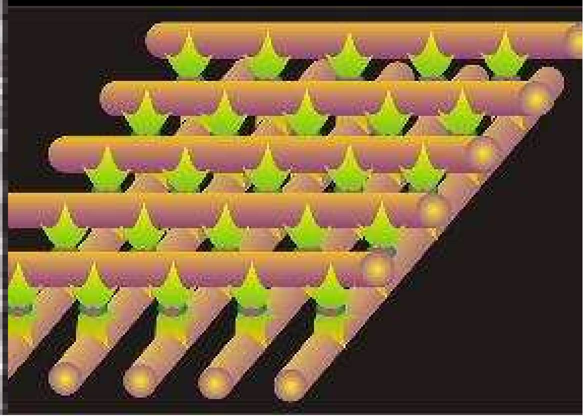


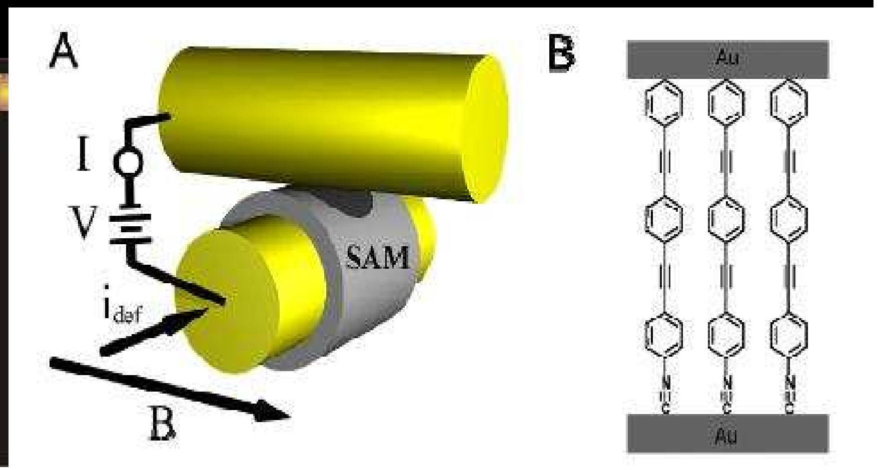
Nanoelectronics / Molectronics



- Interconnects for memory, FPGA (reconfigurable logic) array fabrics
- Interconnection between the nano / micro / meso domains

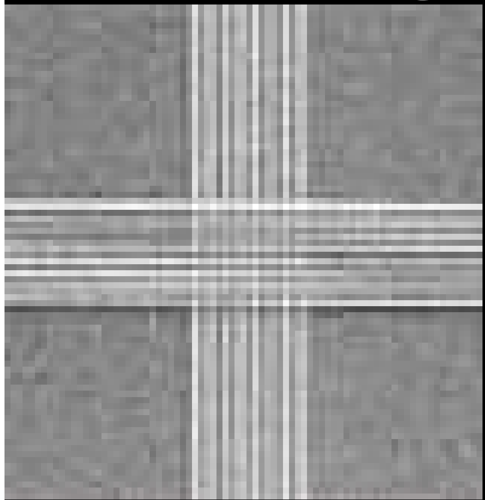


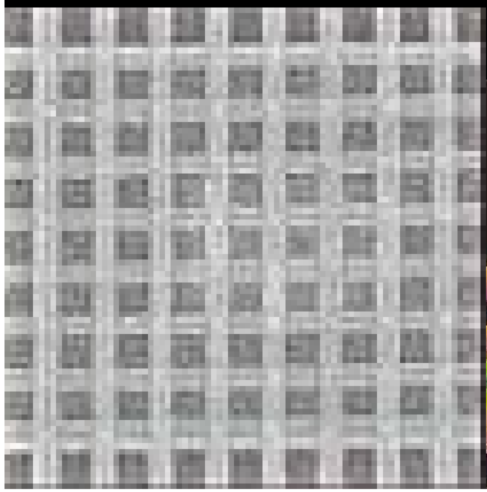


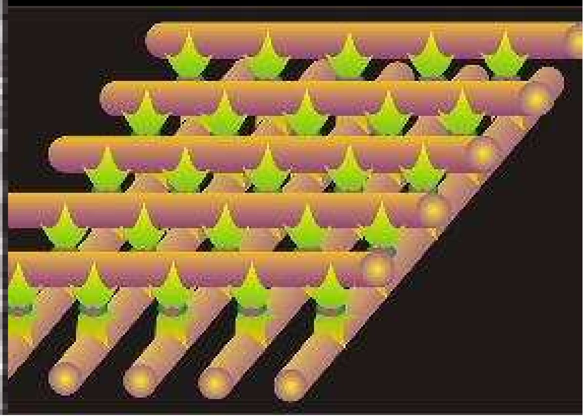


Nanoelectronics / Molectronics
It’s not just about “little devices” . . .

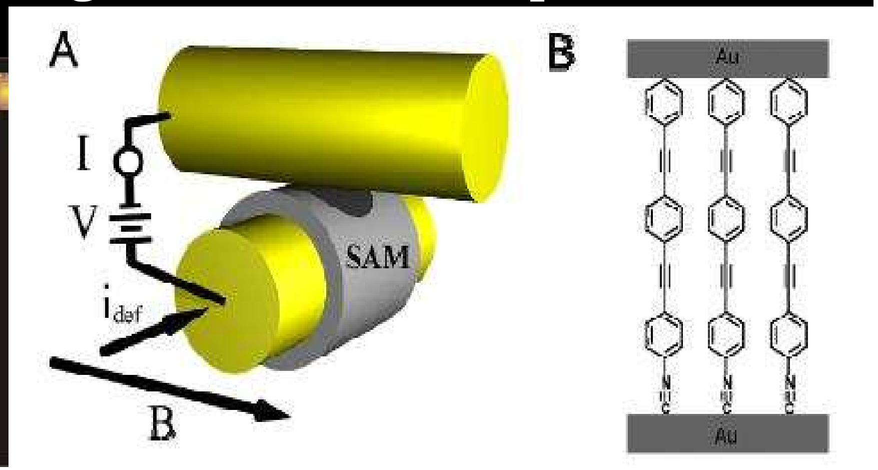
- Reconfigurable logic arrays, memory fabrics





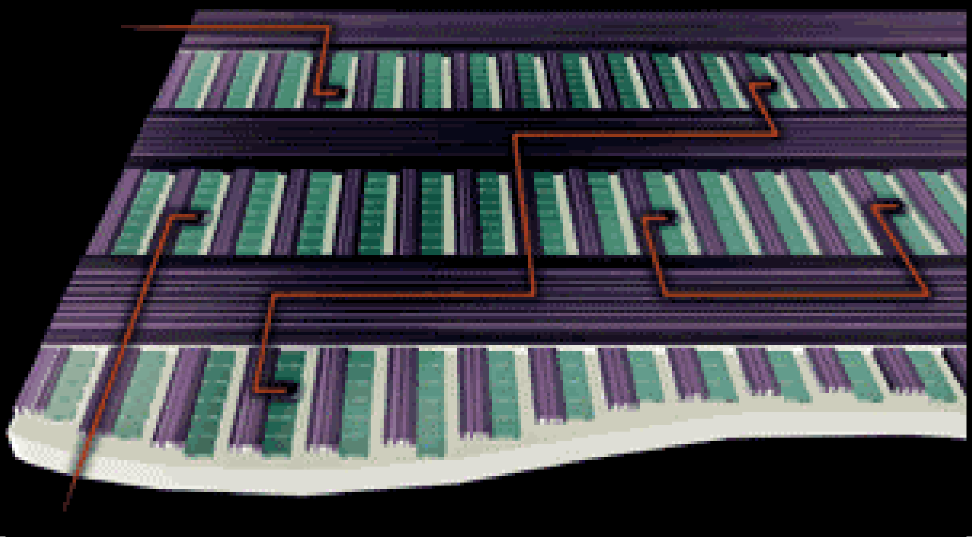


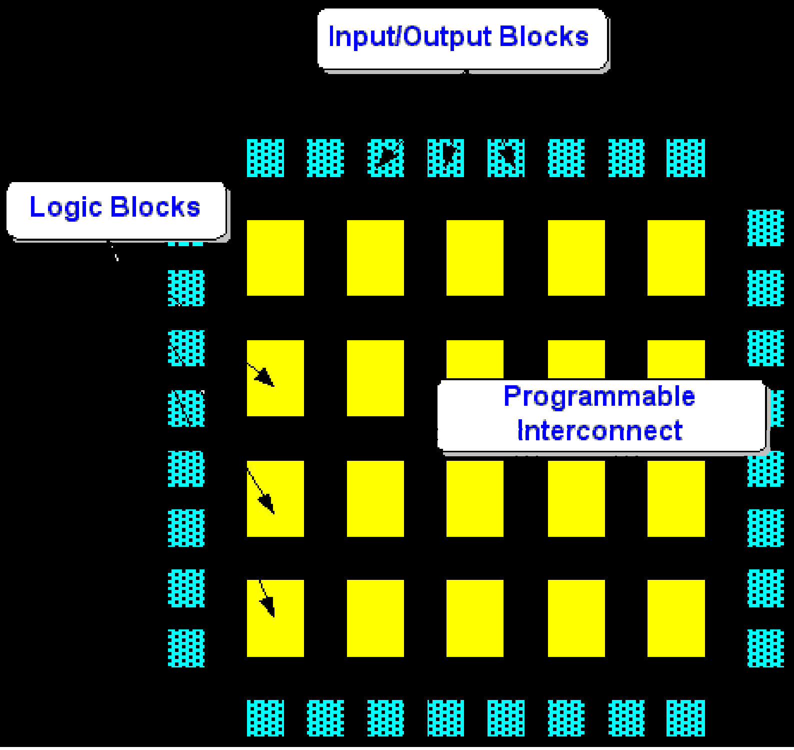
  - FPGA Architecture is asyncrhonous (not confined by Finn’s Law
  - Extremely fault tolerant
  - Functional identity is in the software, not the hardware
  - Well suited for contiguous fabrication processes



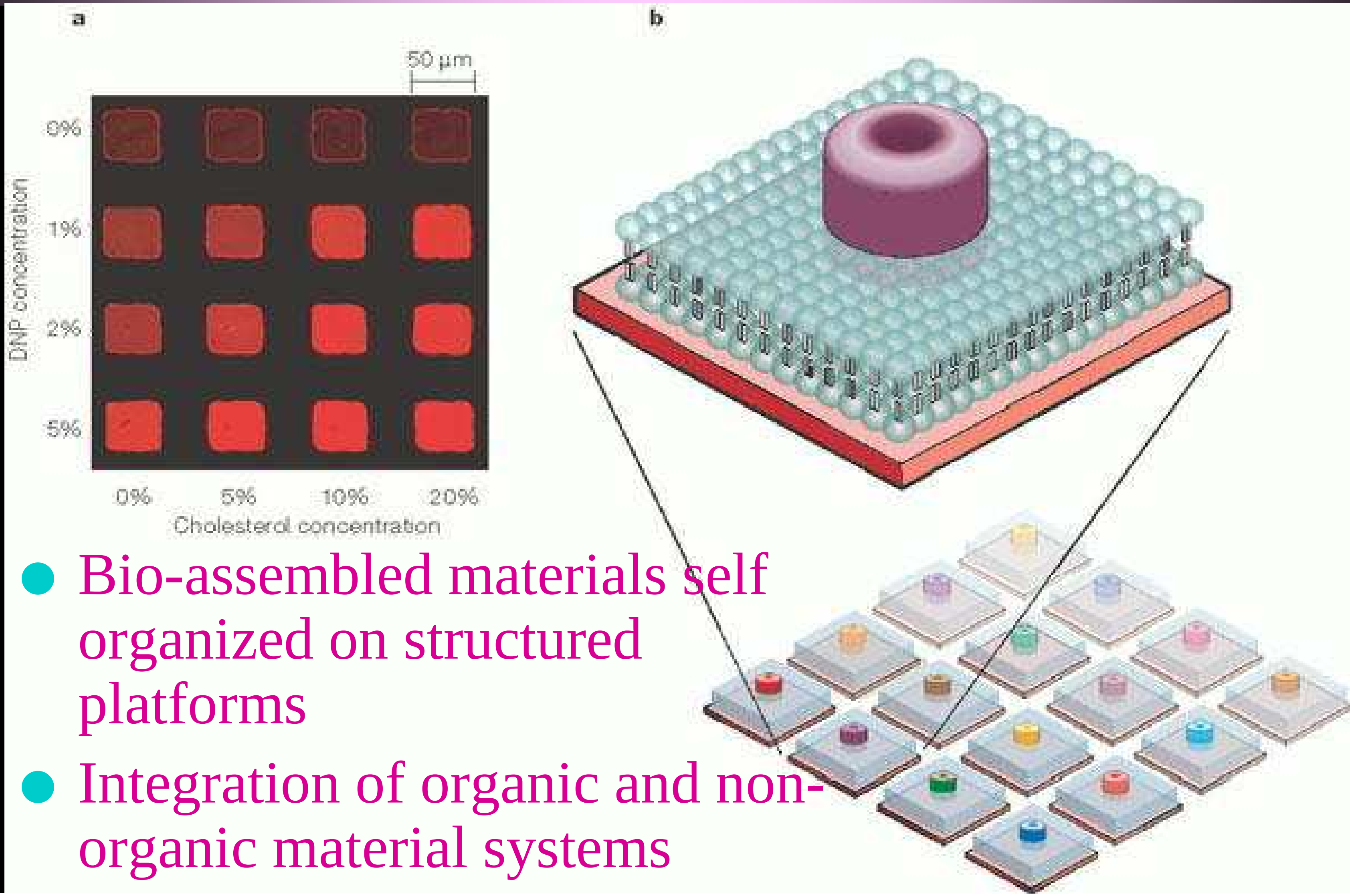
Reconfigurable Computing Architectures – Gateway to Unique Computational Resources

- Extreme Parallelism – speed not the real issue
- Enables evolutionary and biological metaphors in computing
- Extreme process morphology





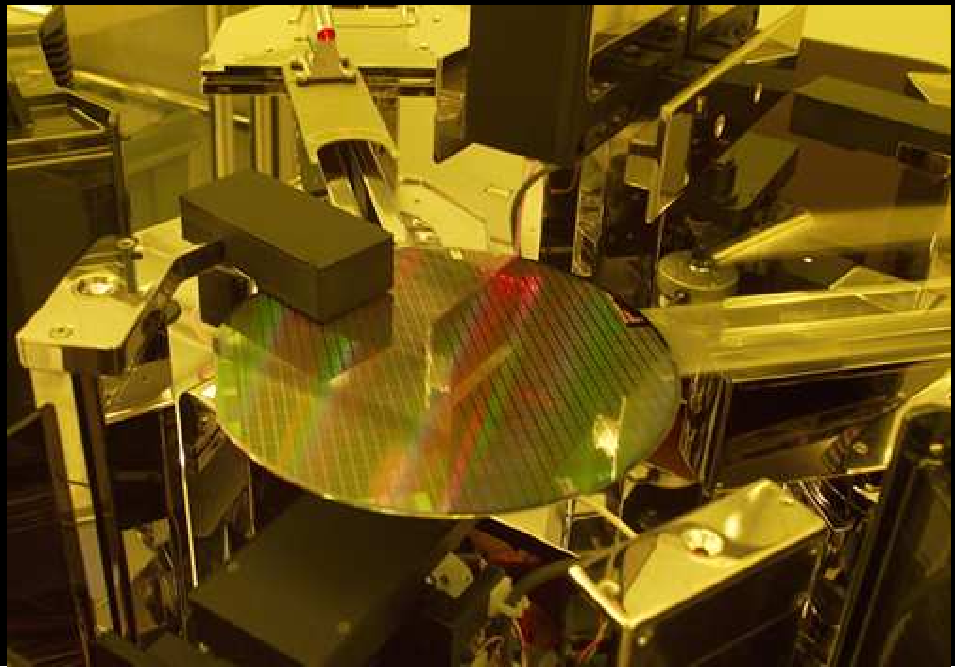
Future “Foundry” Models - Integrated Biofoundry Processes



- Bio-assembled materials self organized on structured platforms
- Integration of organic and non-organic material systems

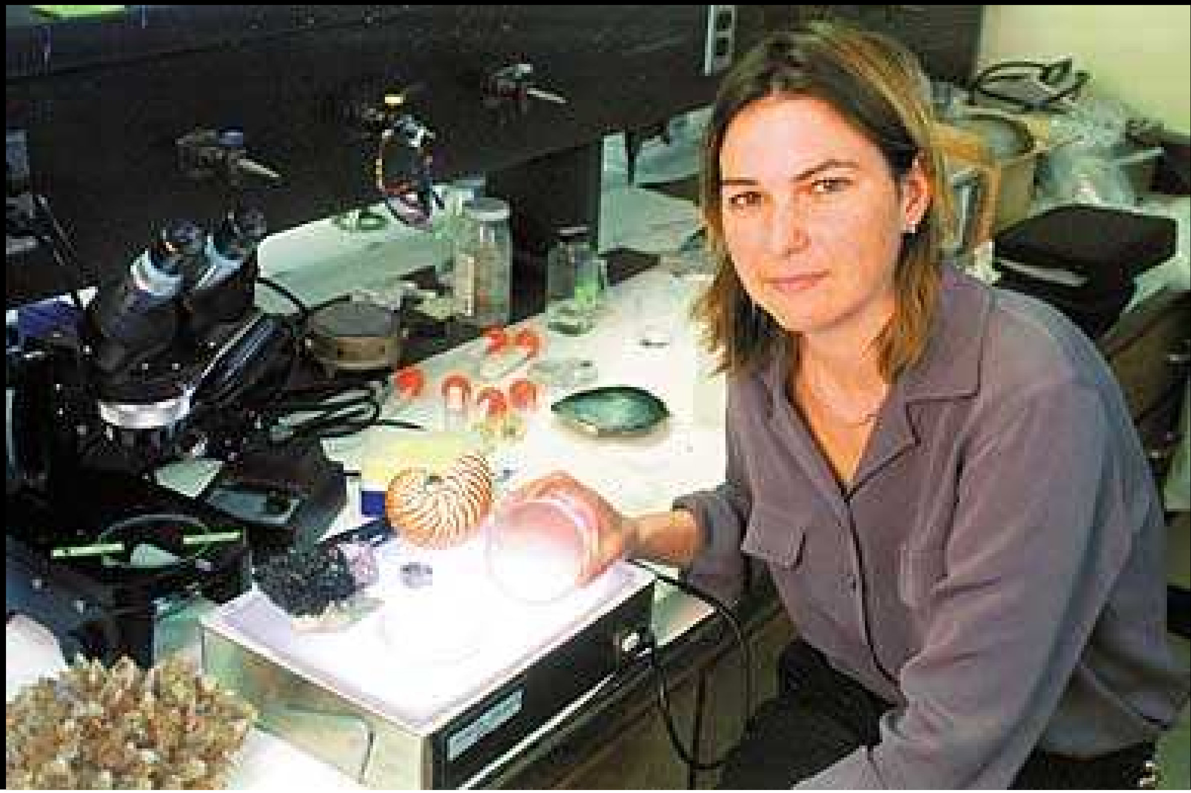
Define Foundry - Current

- Monolithic, Centralized
- Volume Dependant Amortization
- Rigid Fabrication Parameters
- Highly confined range of materials

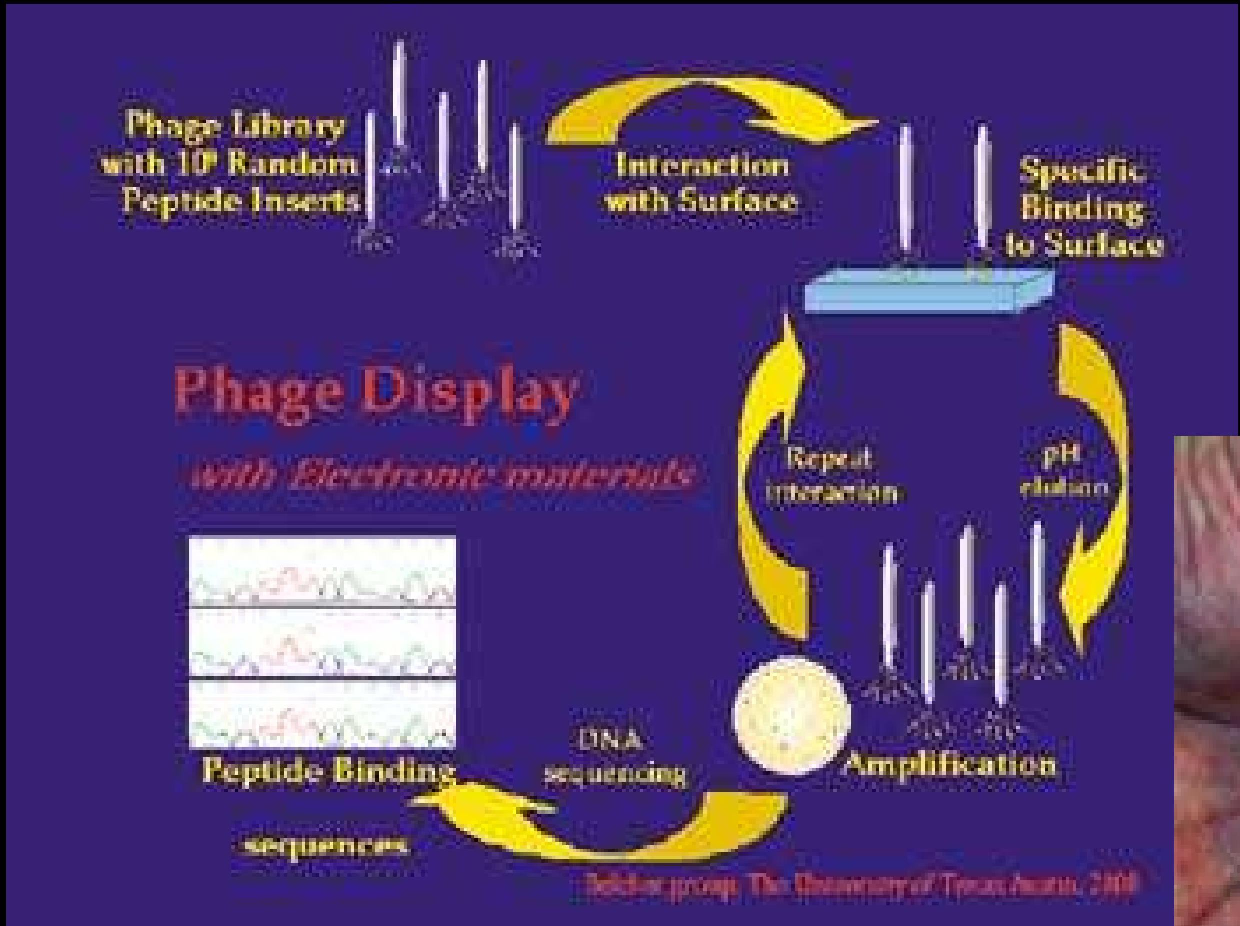


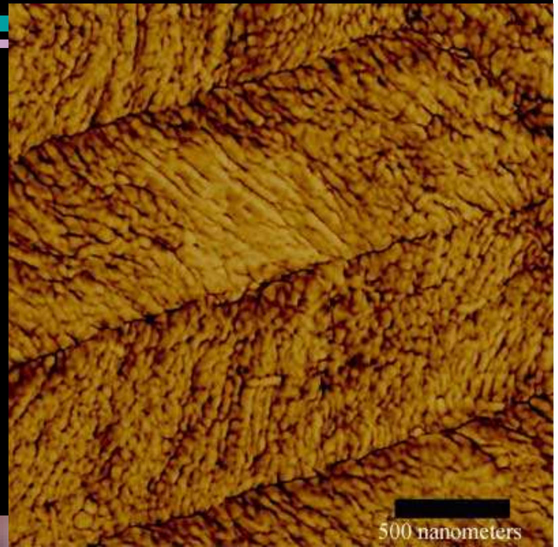
Define Foundry - Future

- Extremely diverse range of materials
- Highly adaptive, polymorphic
- Just as Needed Fabrication

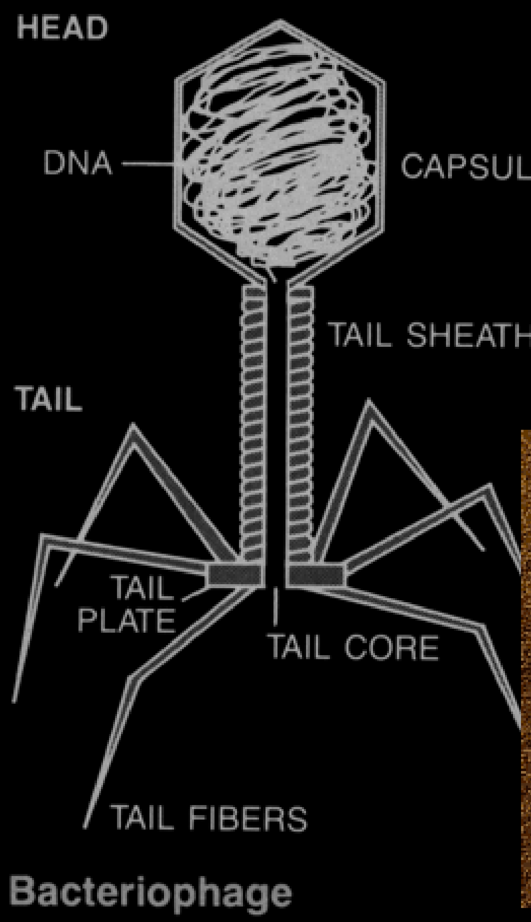


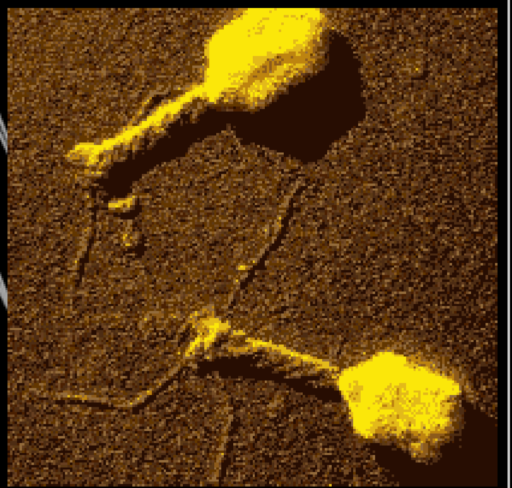
Define Foundry
Living Systems as BioFoundries

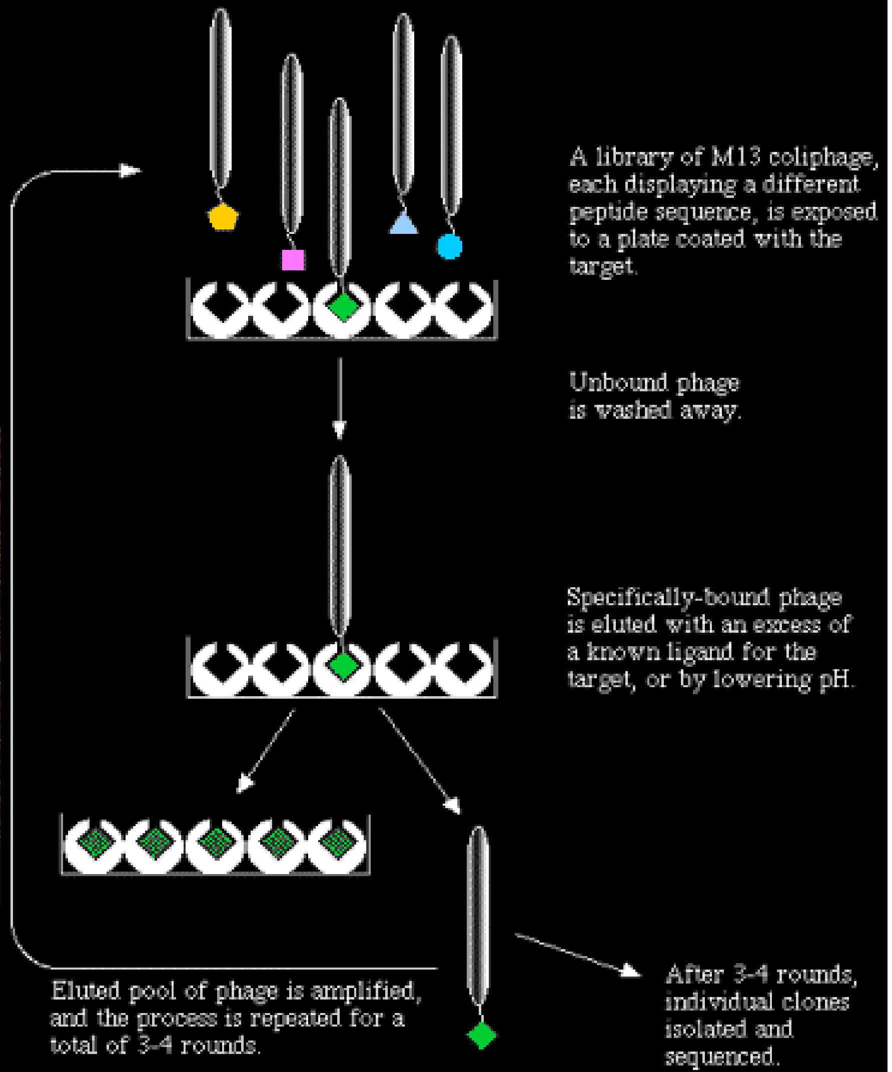




Define Foundry
Living Systems as BioFoundries

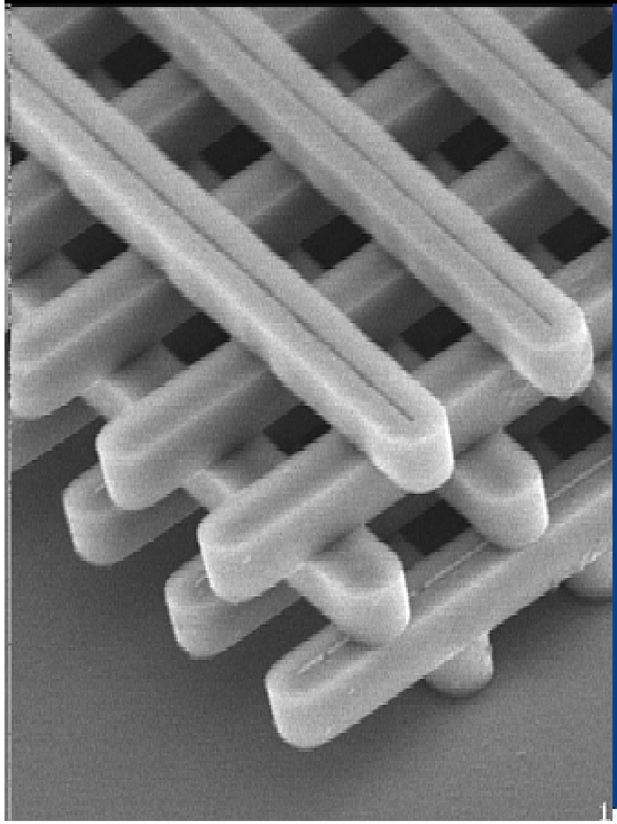
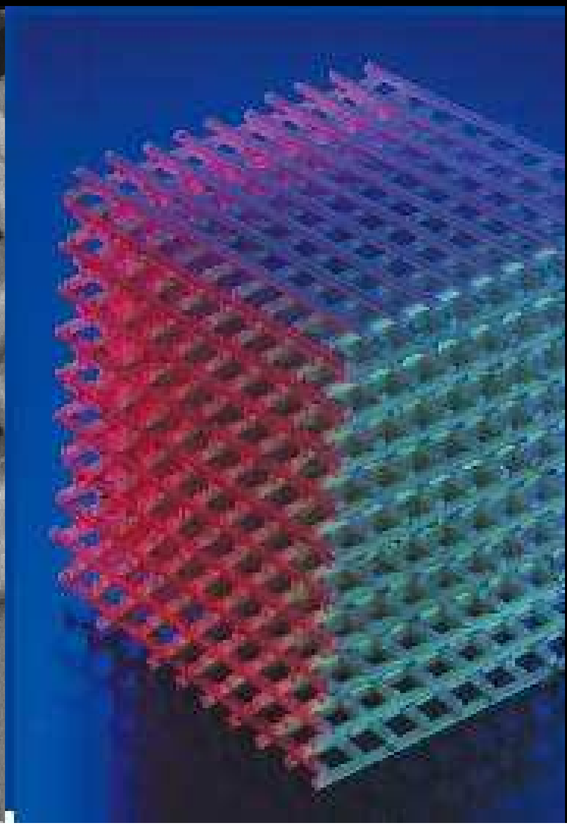
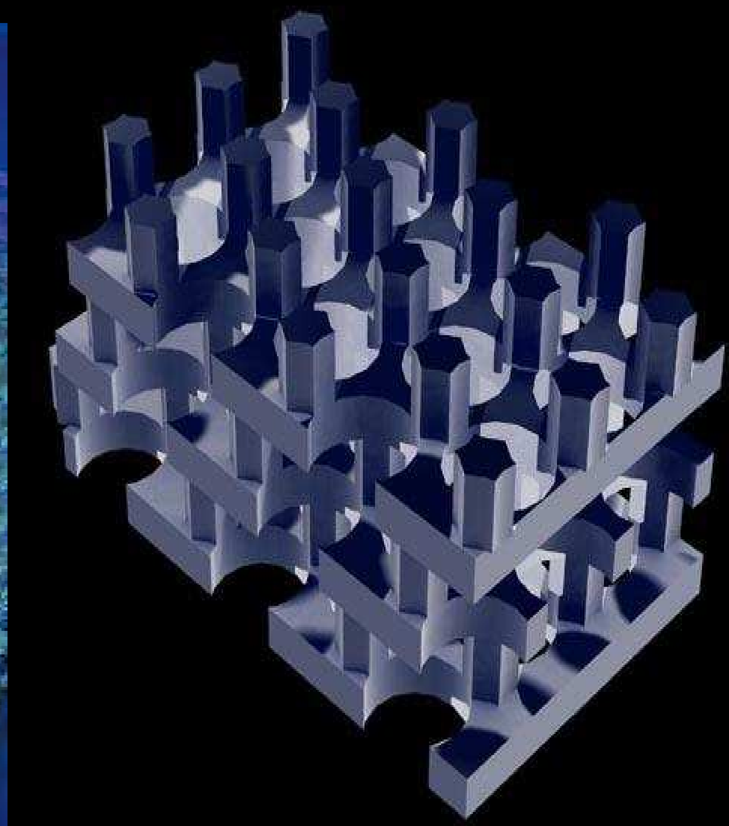






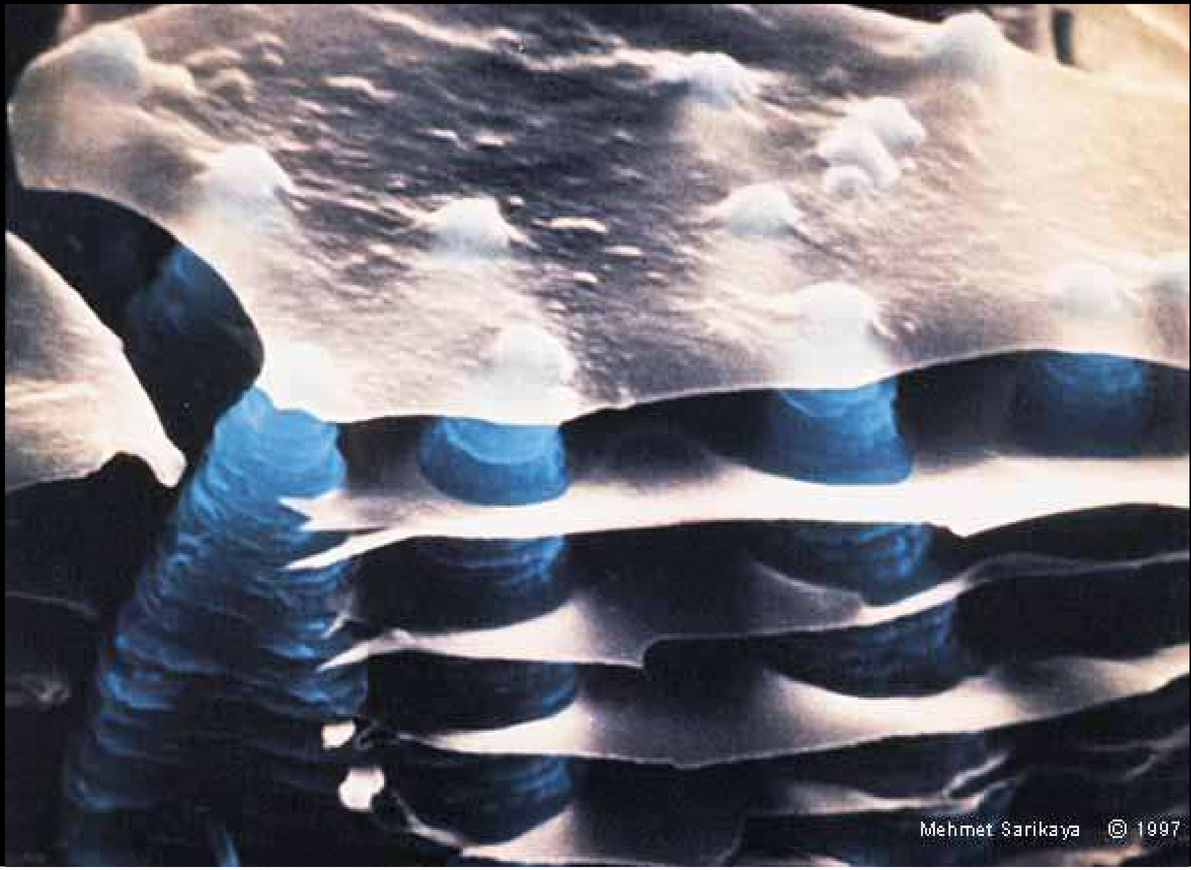
Photonic bandgap crystals – another fabrication option?

Nature's Nanofoundry, directed self-assembly vs "traditional" lithography and microfabrication techniques

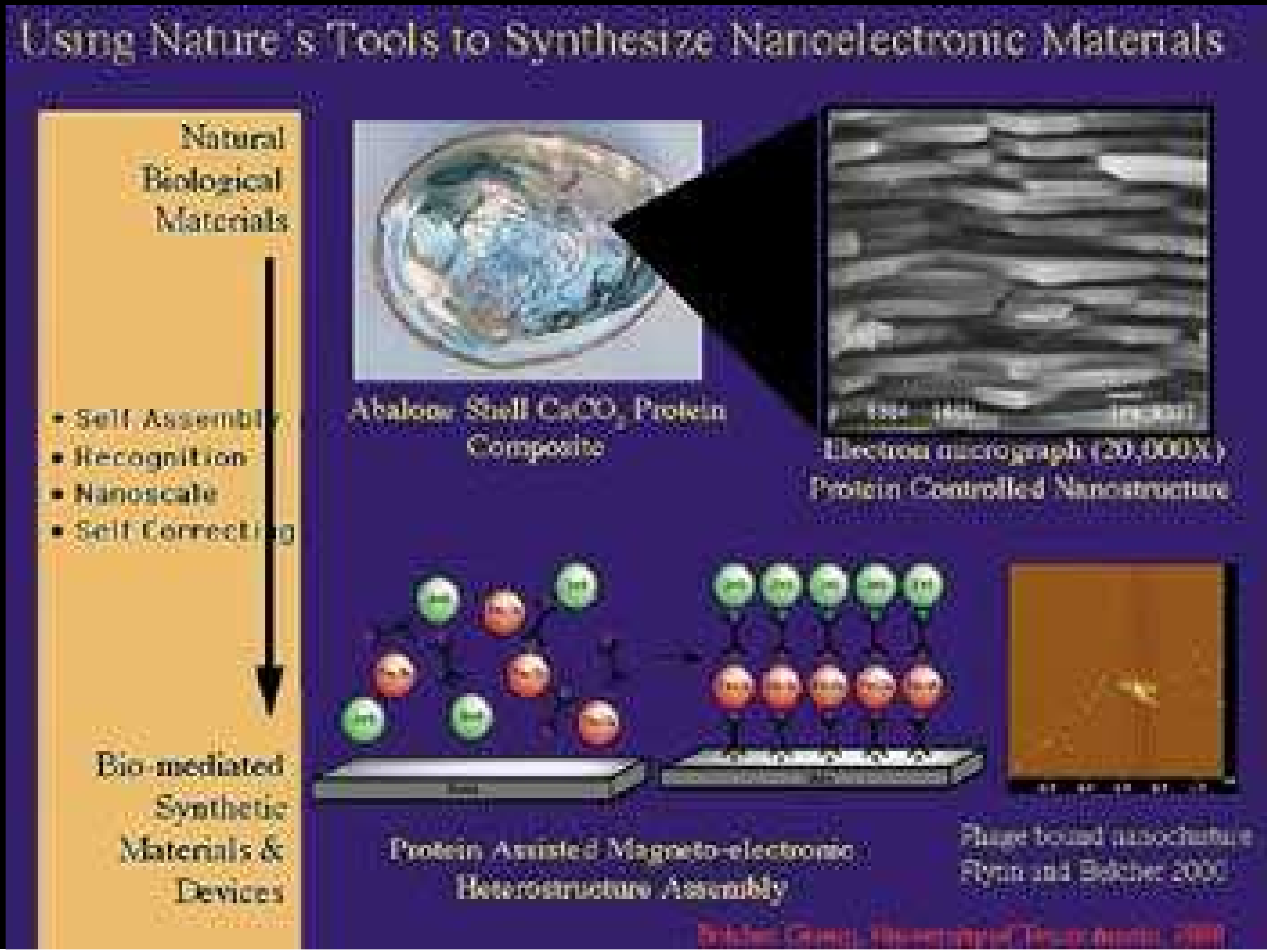




Photonic bandgap crystals – another fabrication option?

Nature's Nanofoundry, directed self-assembly vs "traditional" lithography and microfabrication techniques

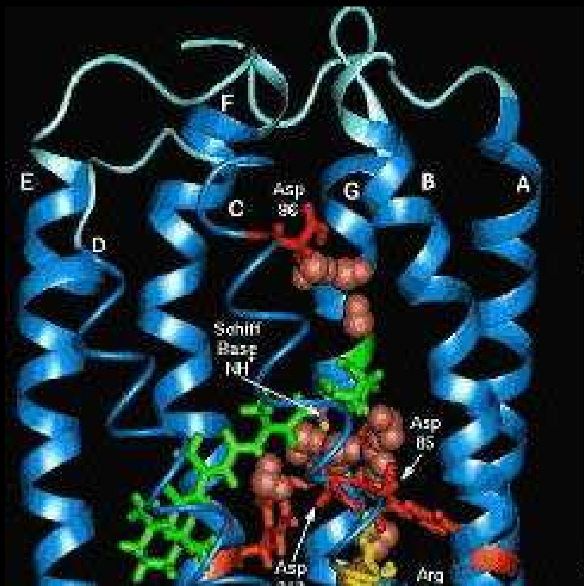


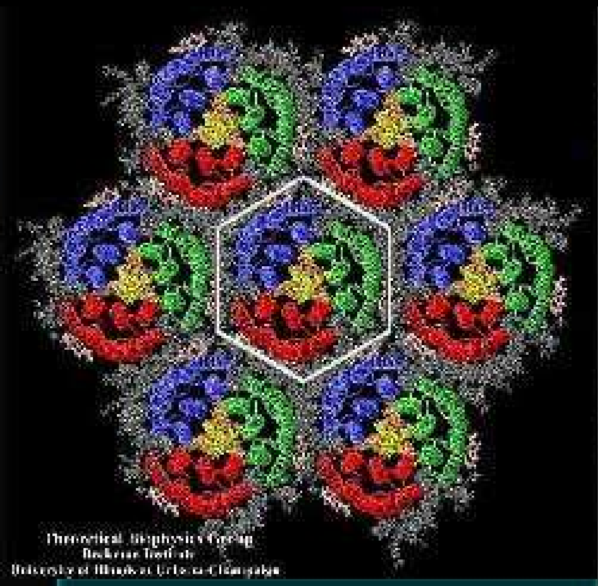
Define Foundry - Future



Nanobiology meets Nanophotonics

- Rhodopsins, other bio-organic materials
- Nano patterned environments to enable “optical fabrics”
- Engineered bandgap, electro-photonic transition properties





Holographic Storage and Computing

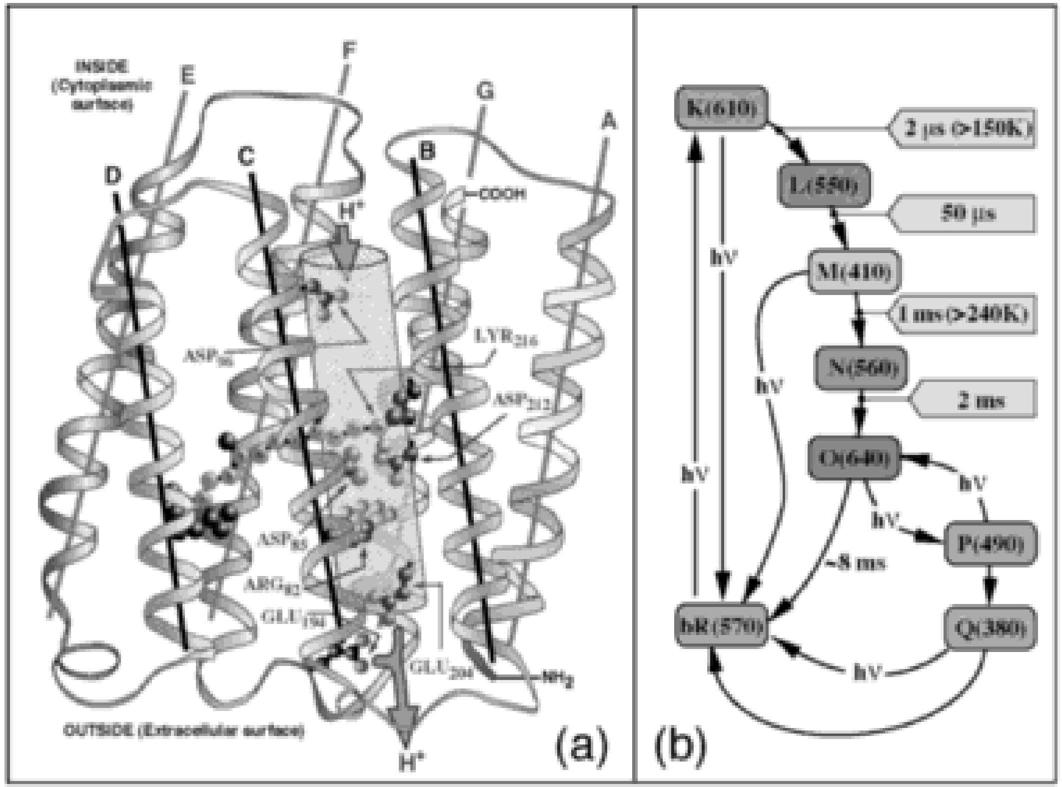


FIGURE 4-1 Simplified protein structures. 4-1a Structure and key intermediates in primary and branched photocycles. 4-1b Structure and key intermediates of bacteriorhodopsin. Note: Maximum wavelengths in parentheses are in nanometers (nm). Lifetimes and temperatures apply to the wild-type proteins only and are approximate.

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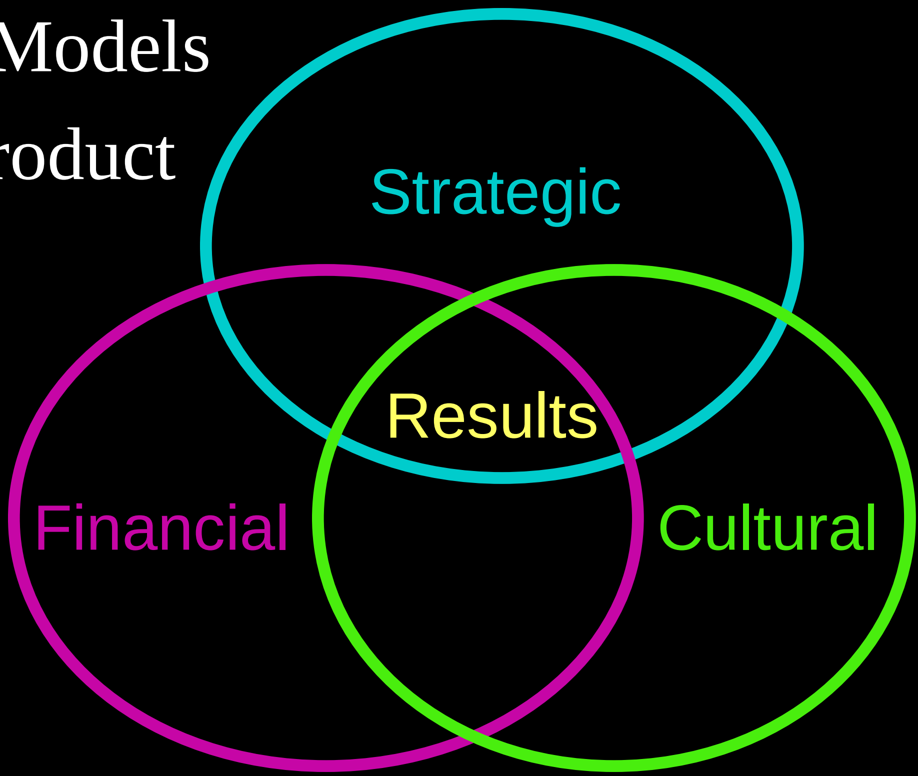
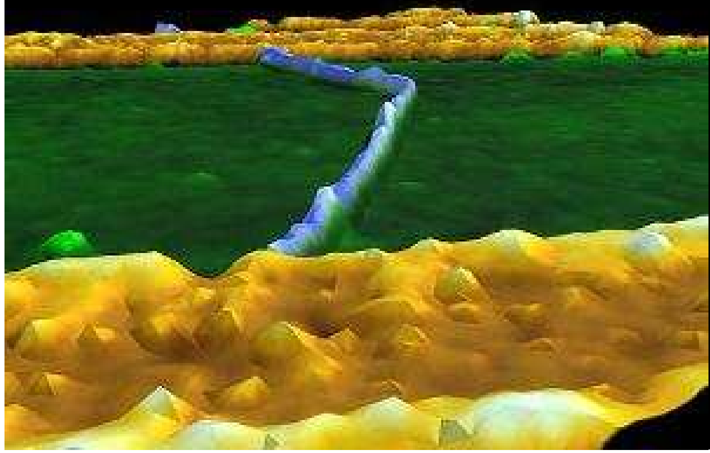
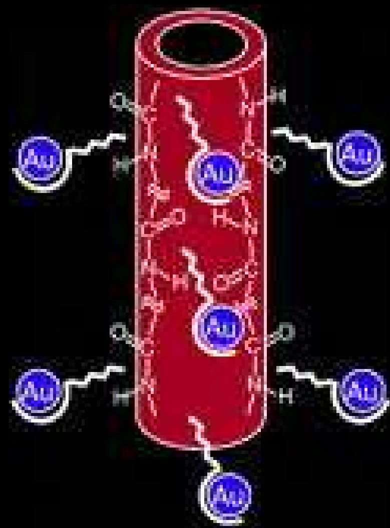
Key Factors in Nanotechnology Business Implementation

- Converging Technologies, Synergistic Interdependence
- Critical Mass Infrastructure Development
- Emergent IP Models
- Process vs. Product



Conclusion:
Key Features of the Emergent NanoEconomy

- Moore's 1st Law is Not Relevant, Moore's 2nd Law is
- Economies of Scale, New Value Chain Models
- Systems Approach to an Emergent Industrial Infrastructure
- Enabling Access to New Markets that Could Not Exist Without Nanotechnology

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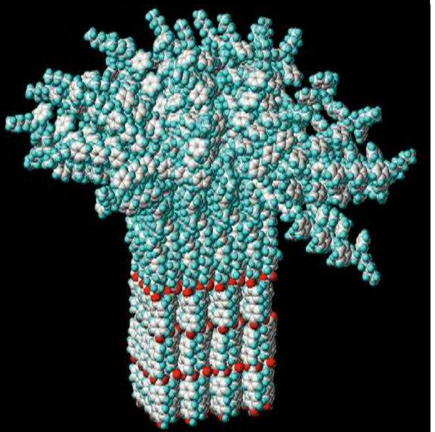

Our mission is to provide our members and sponsor key competitive advantage in the next industrial rev spawned by the convergence of interrelated domain nanotechnology in electronics and photonics.