NanoElectronics and Photonics Forum™ Roadmap of Convergent Development and Synergistic Opportunity

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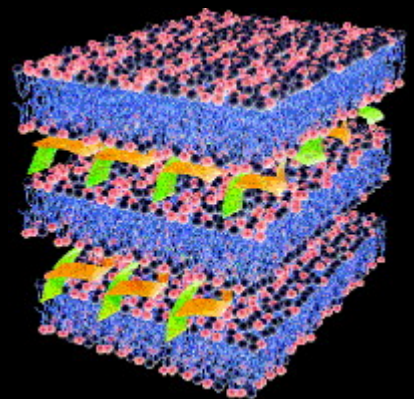
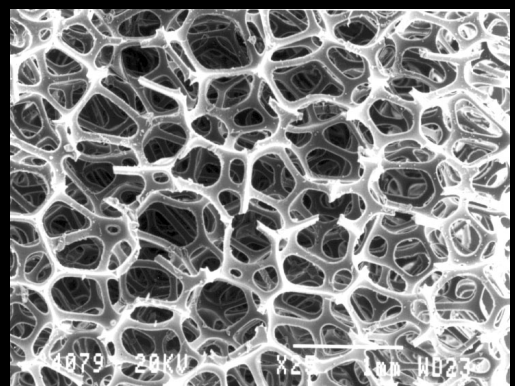
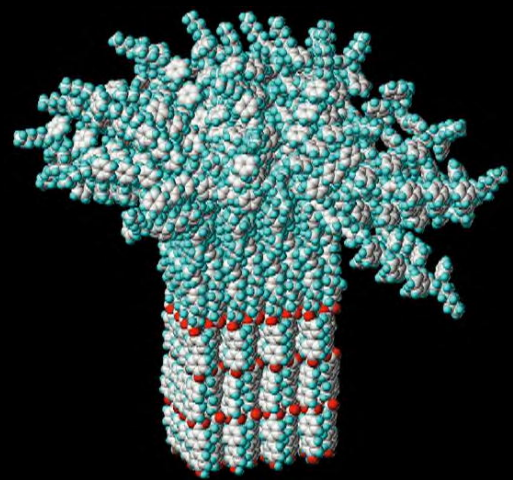
NanoElectronics and Photonics Forum™ Mission

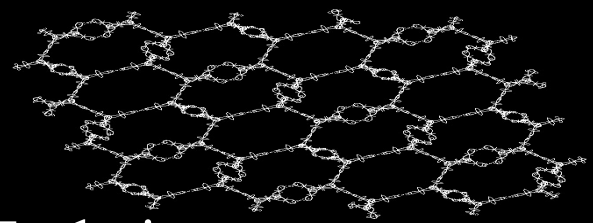
- Our mission is to provide our members and sponsors with a key competitive advantage in the next industrial revolution spawned by the convergence of interrelated domains of applied nanotechnology in electronics and photonics.
- Through our forums you will be able to participate in information exchange and networking activities & accelerate your learning and connections in the nano Electronics & Photonics arena



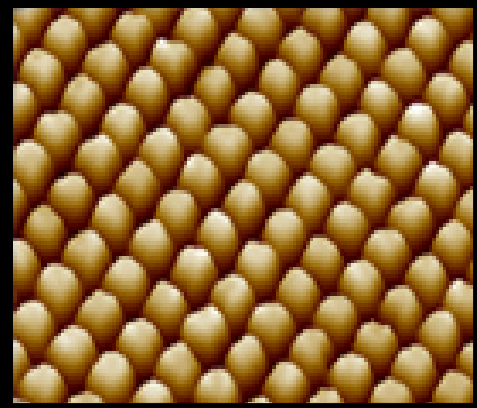




Primary Areas of Interest



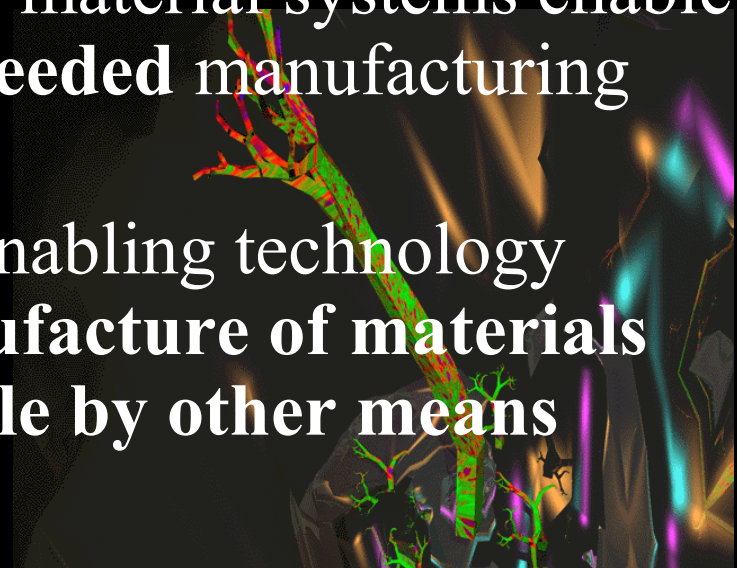
- Molecular Switches, Gates, Sensors
- Nanowires and Interconnect Systems
- Nanobiological & Self-Assembling Materials, Techniques and Processes



- 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

Important Key Features of Nanotechnology in Electronics and Photonics

- It is not necessarily about nano-widgets or “little things”
- It consists of an ever expanding collection of interrelated manufacturing modalities that operate with the controlled manipulation and patterning of atoms and molecules.
- It is the gateway to an evolving industrial infrastructure
- Self assembling and self organizing material systems enable de-dentralized, granular, **Just As Needed** manufacturing modalities
- Nanotechnology is a fundamental enabling technology domain **which allows for the manufacture of materials and products not viable or possible by other means**

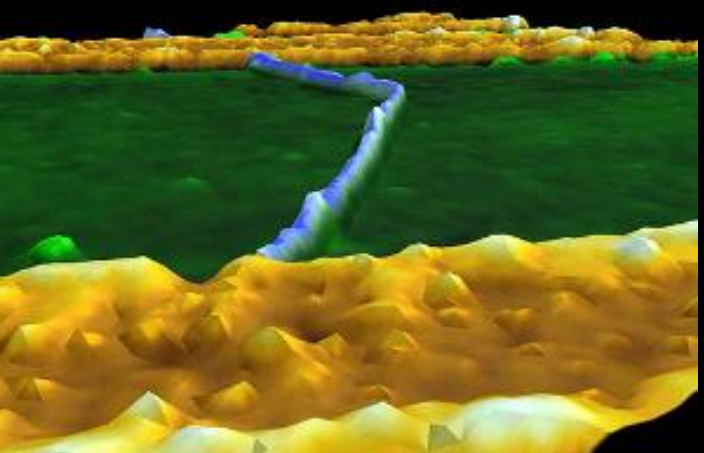


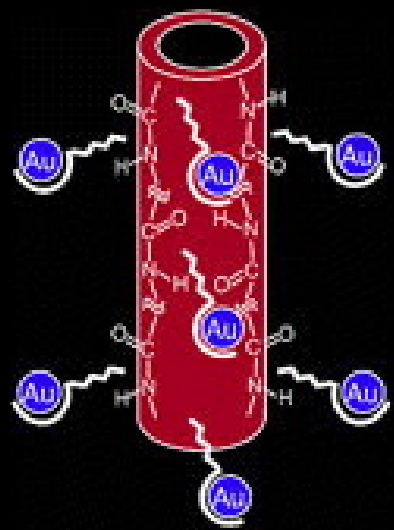
Example Enabling Development Paths

- 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

The Emergent NanoEconomy

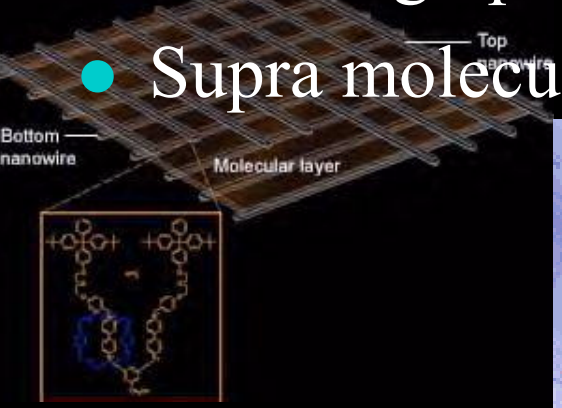
- Moore's 1st Law is Not Relevant, Moore's 2nd Law is
- Economies of Scale, New Value Chain Models
- Systems Approach to an Emergent Industrial Infrastructure
- Enabling Access to New Markets that Could Not Exist Without Nanotechnology

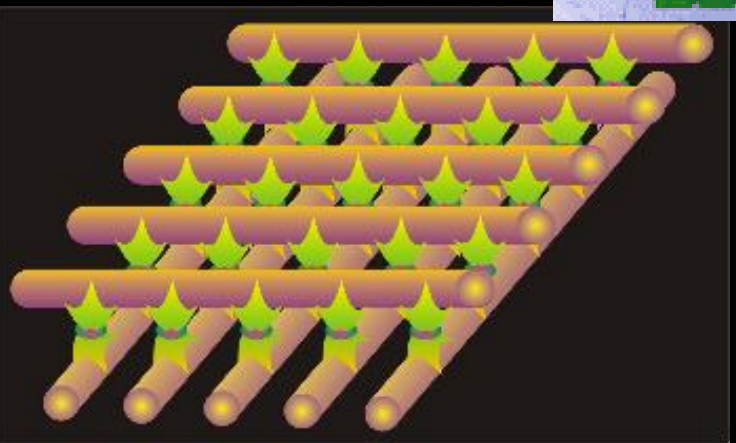


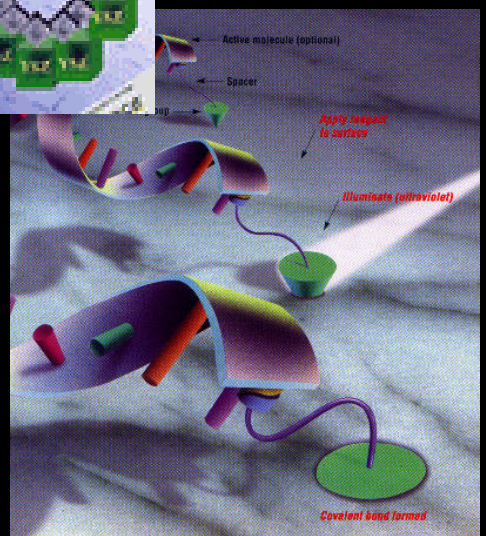


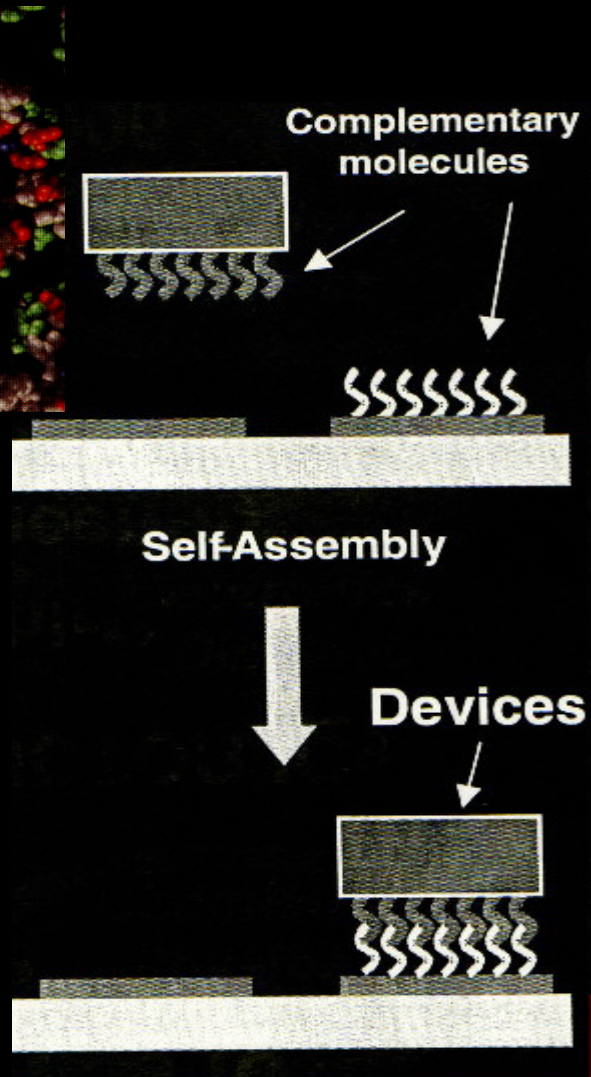
The goal is not just “little things”, but system integration

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







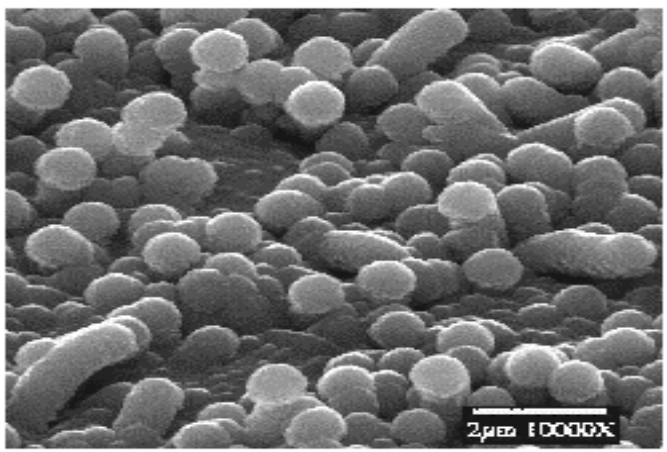


Self Assembly as a Foundry Process

Self-assembly is the most practical and realizable approach to fabricate arrays of nanodevices with the sub-100nm size features in short-term (the conventional lithographic methods of microsystem processing offer very limited control over the fabrication on the sub-100 nm scale)

Spontaneous self-assembly

This approach relies on structural disorder at the interface between the two materials with different physical properties (heteroepitaxy, fluctuations of the dopant concentration, etc.)

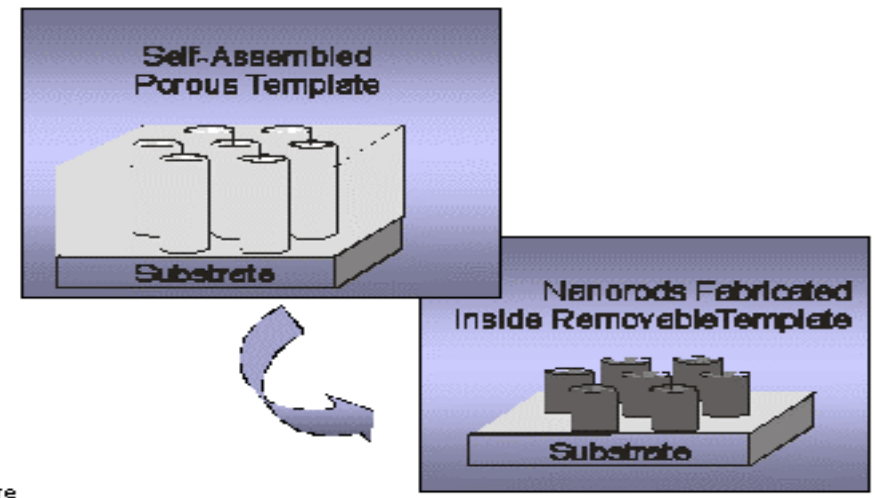


Self-assembled Si nanowires grown by magnetron sputtering

(E.A. Guliants and W.A. Anderson, "A Novel Method of Structure Control in Si Thin Film Technology" *197th Meeting of The Electrochemical Society* Toronto, ON, May 2000)

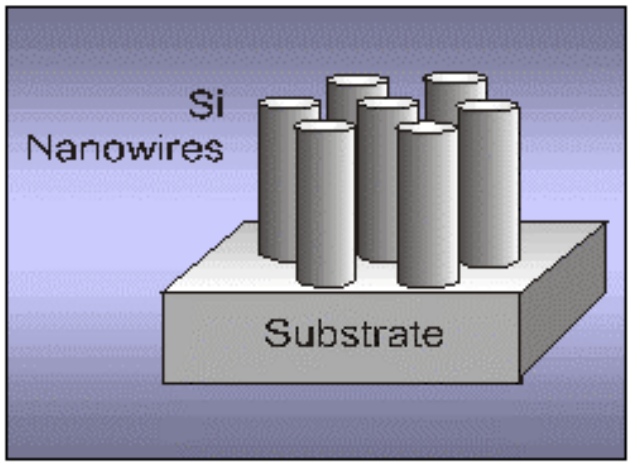
Controllable self-assembly

Involves self-assembly of the tools for fabrication of nanostructures and nanodevices, such as masks or templates.

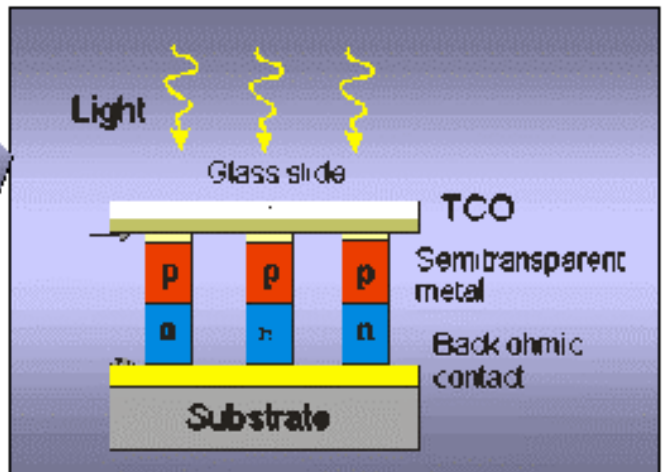


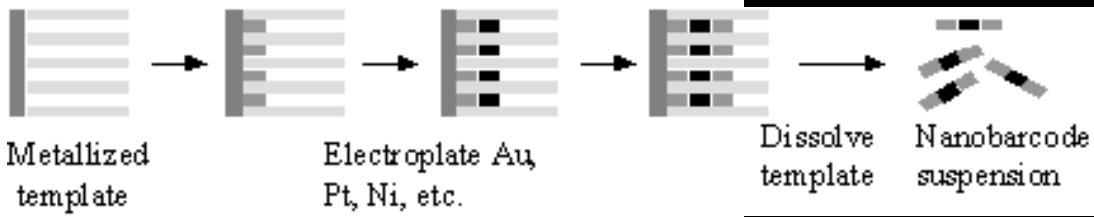
Periodic Nanostructures

Some of the potential applications of periodic nanostructures are:



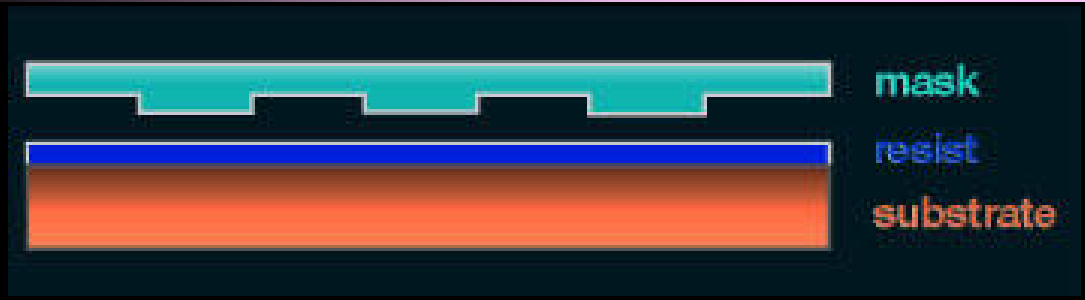
- Quantum effect dots
- Resonant tunneling diodes
- Single-domain/bit magnetic storage media
- Single electron transistors (SETs)
- Light-emitting diodes (LEDs)
- Photodetectors
- Quantum well optoelectronic devices
- Quantum cellular automata
- High-density memory

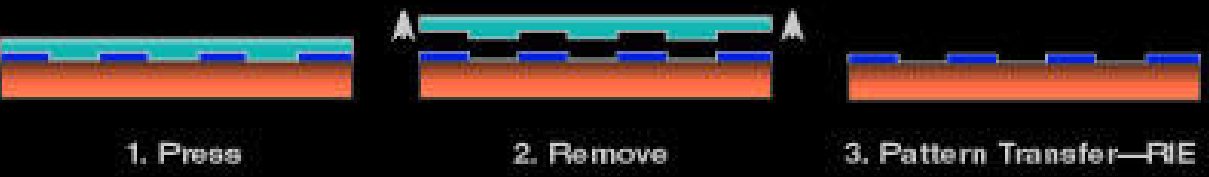


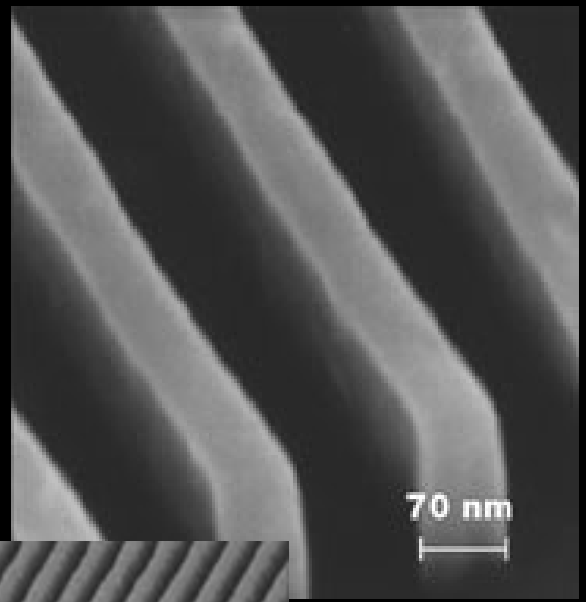


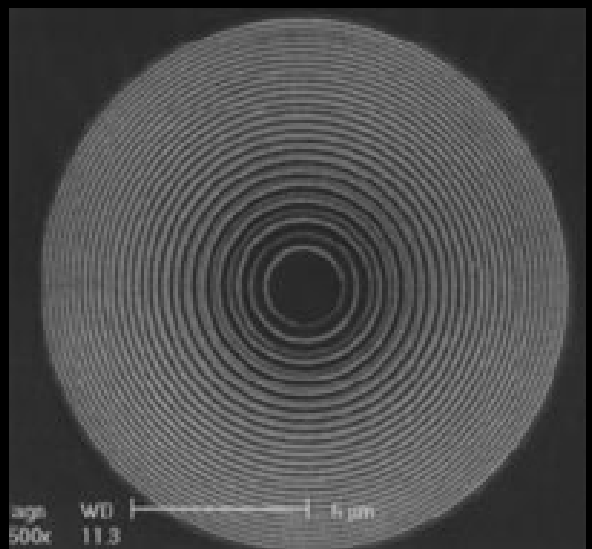
Schematic of aSi photodetectorarray fabricated on periodicSi nanowires

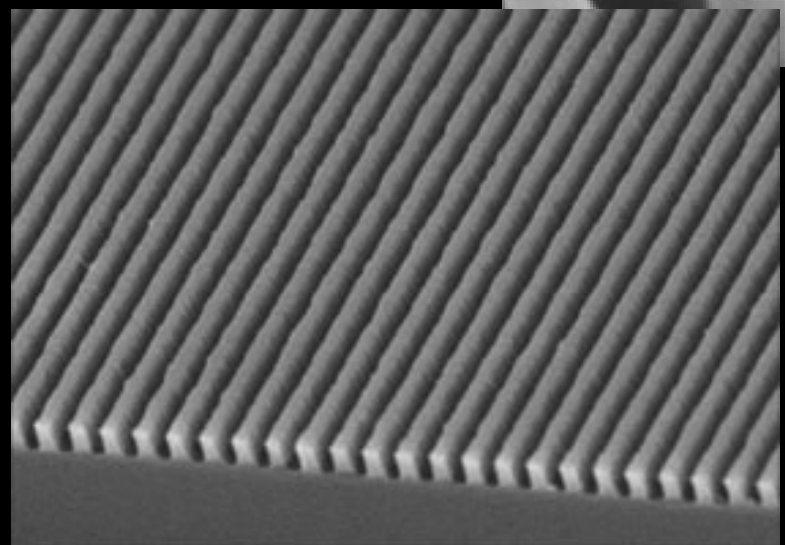
NanoImprinting Foundry Processes in Photonics, Electronics, Fluidics – Integrated Systems





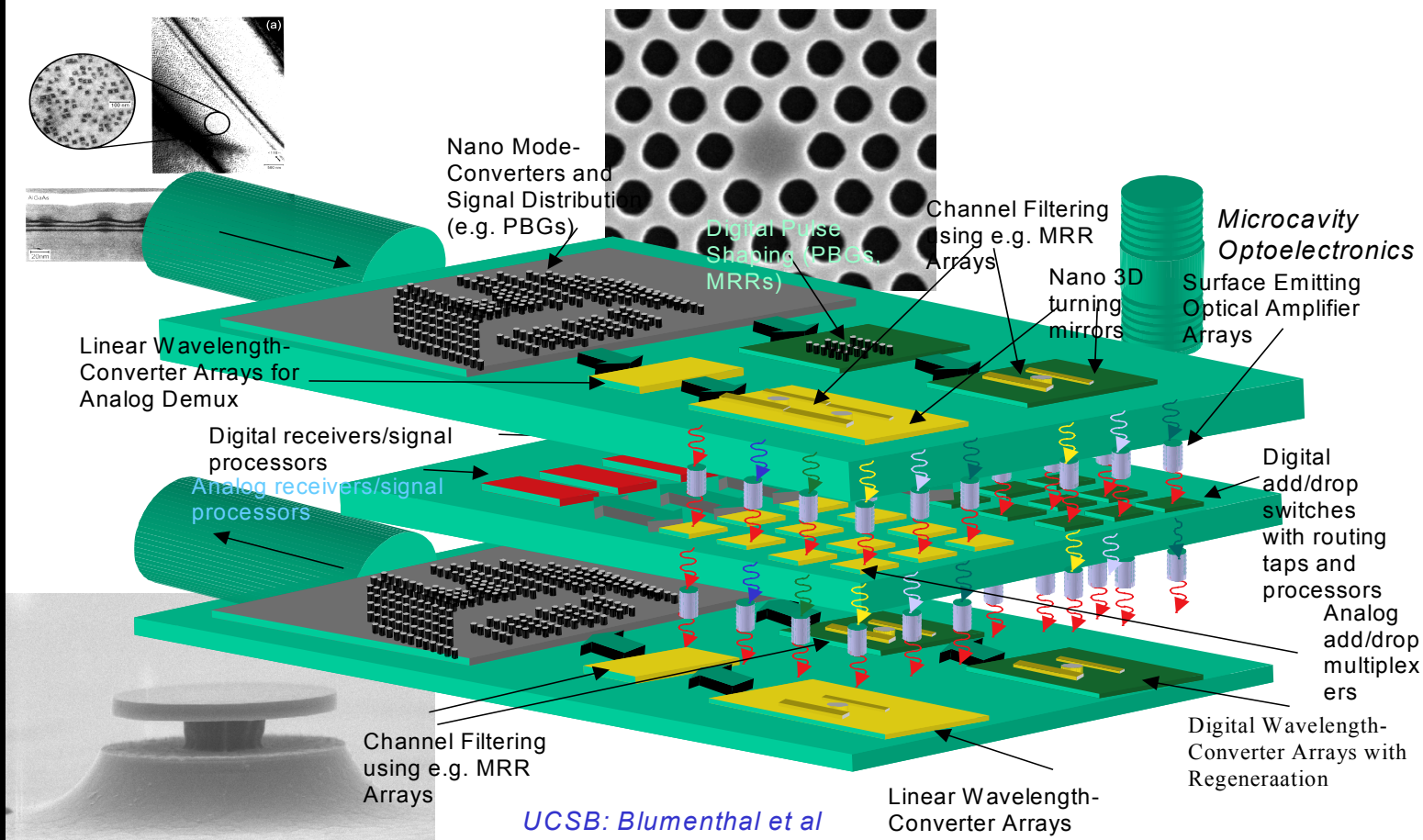






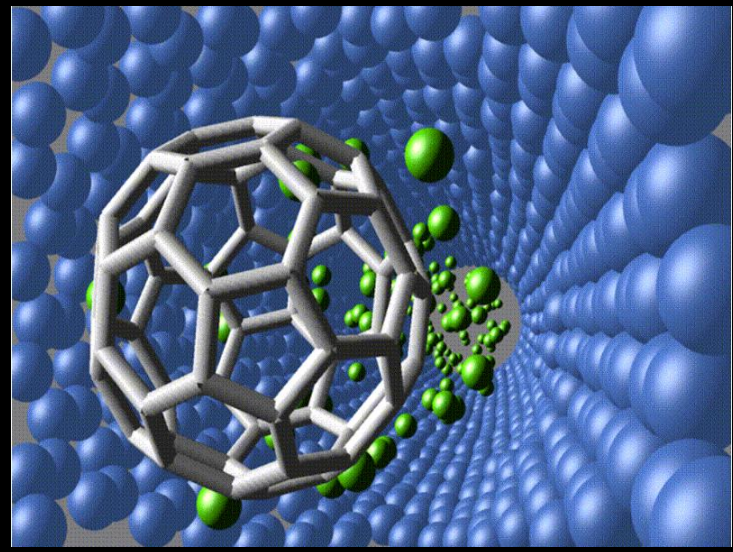
Nanotechnology Value Proposition - Integration is the Key

Integrated NanoPhotonics Systems



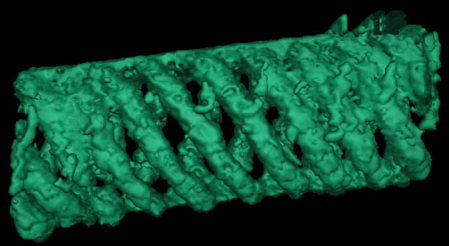
Nano Electronic and Photonic Industrial Development Domains

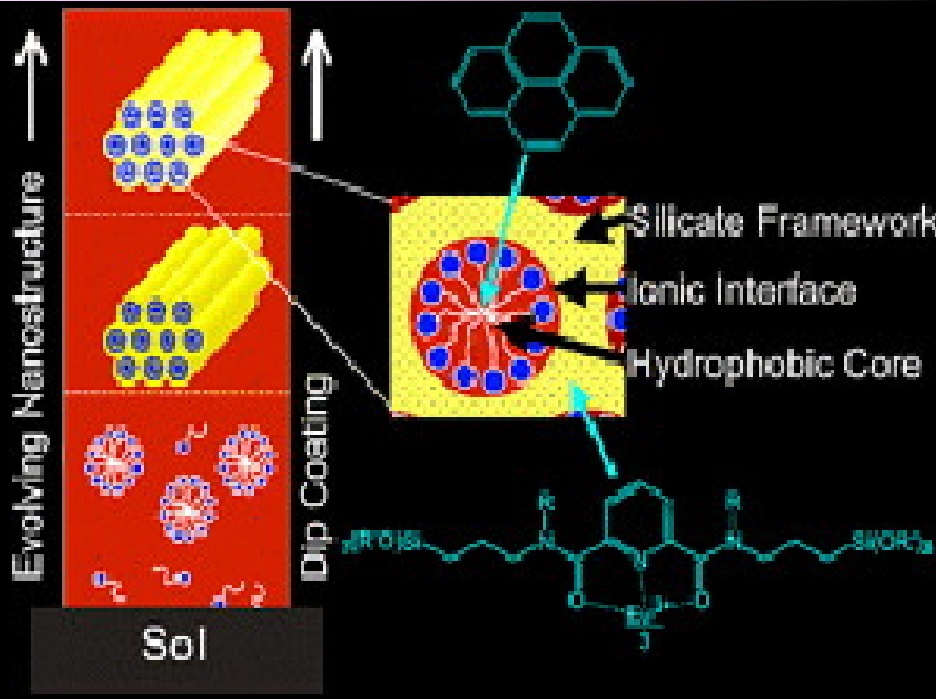
- Tools
- Devices
- Processes
- Infrastructure

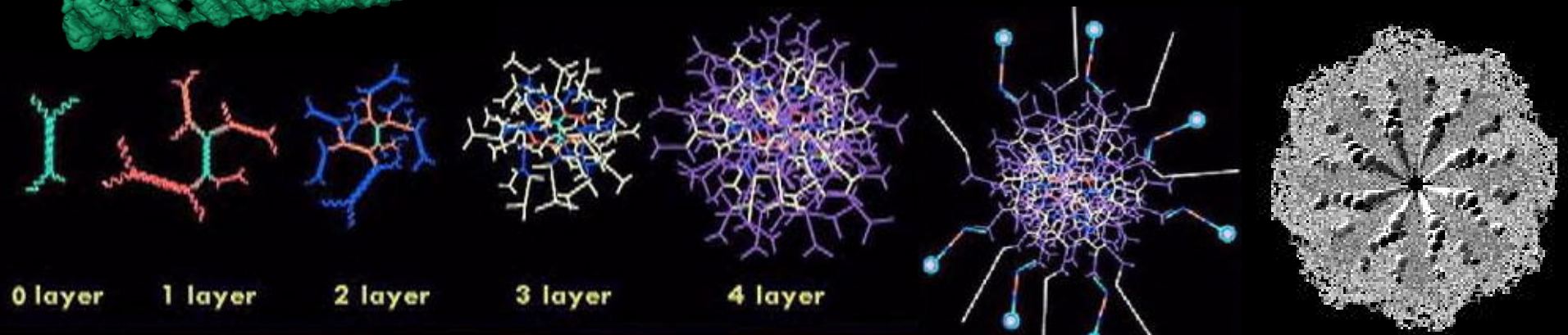


Molecules as Tools – Not Just Endproducts

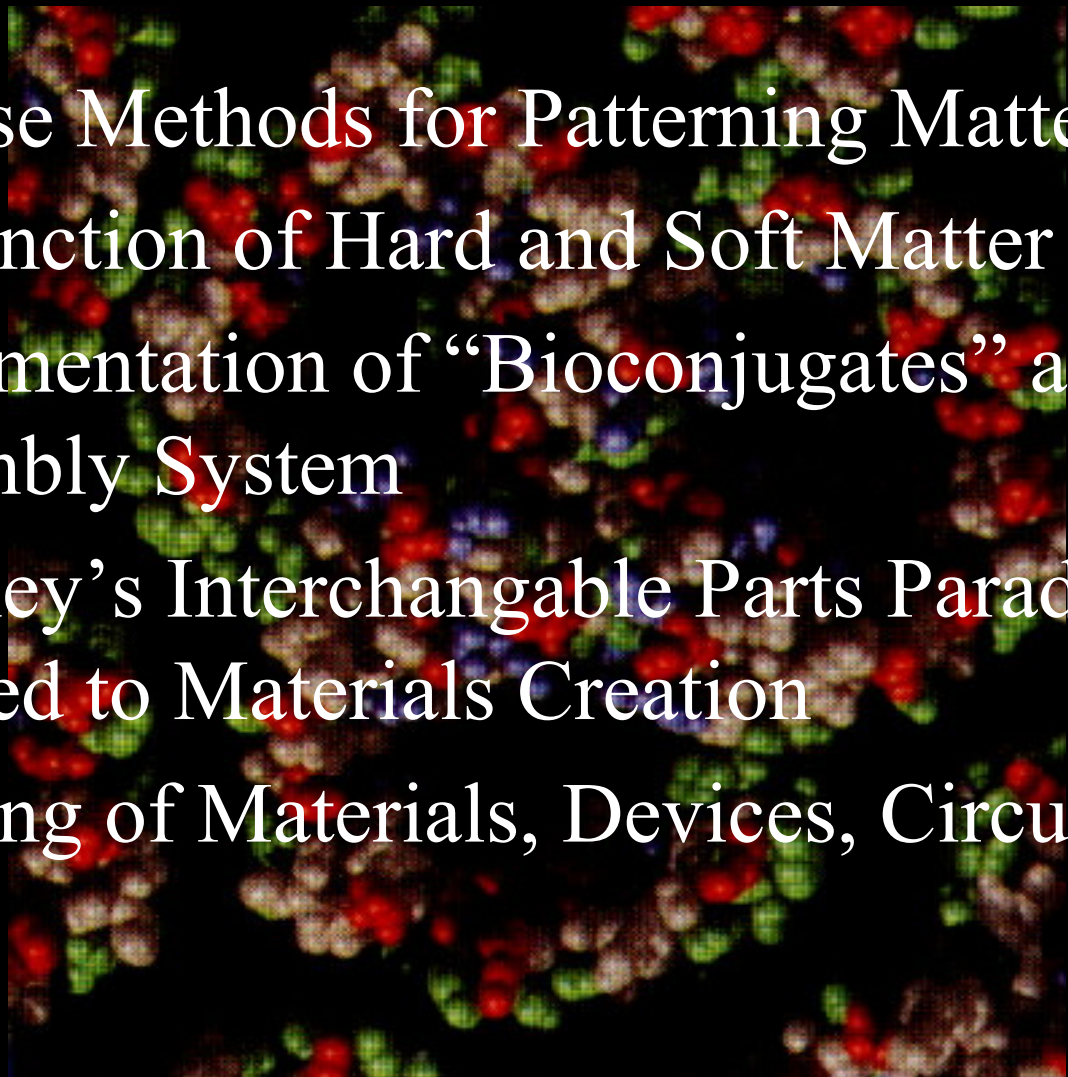
- Nanotubes - carbon, polymer, protein, etc.
- Structural proteomics
- Dendrimers
- Organometallics







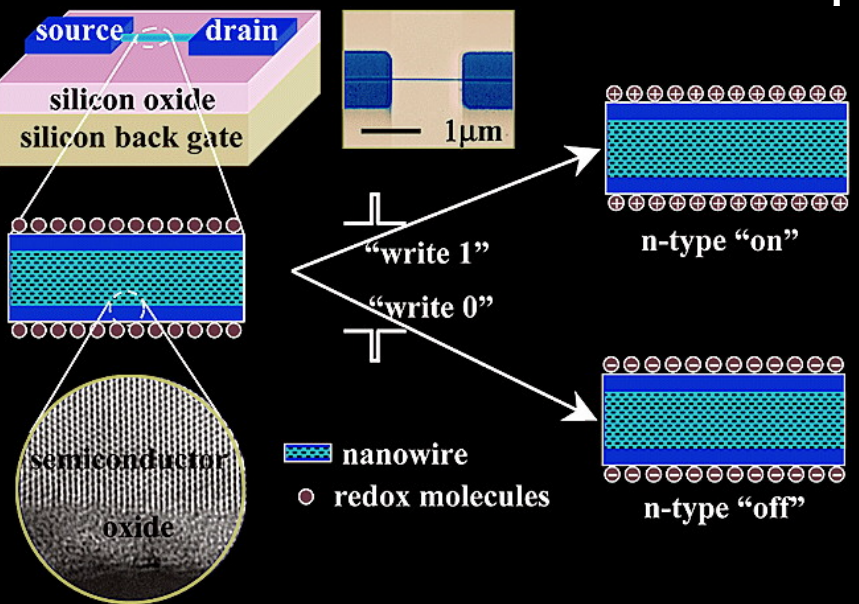
Key Industrial Infrastructure Development Indicators

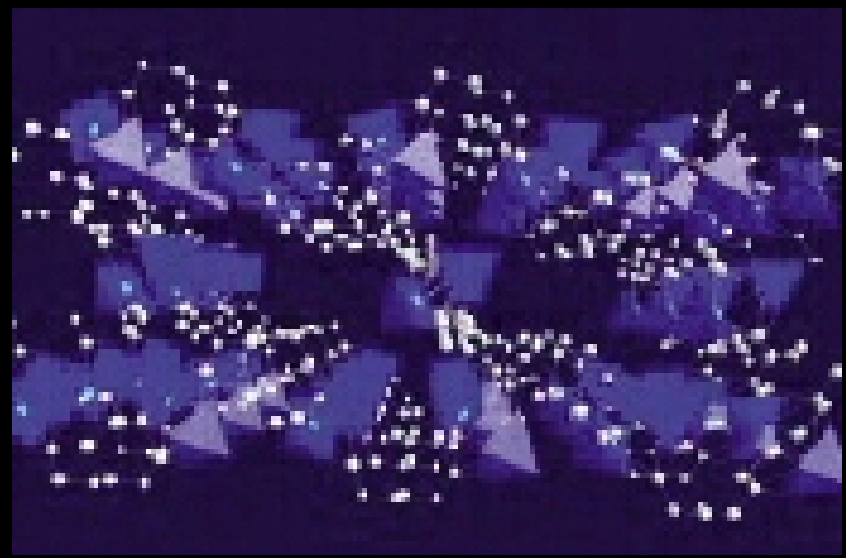


- Diverse Methods for Patterning Matter
- Conjunction of Hard and Soft Matter
- Implementation of "Bioconjugates" as an Assembly System
- Whitney's Interchangable Parts Paradigm Applied to Materials Creation
- Merging of Materials, Devices, Circuits

Integrating Current Technology and Fabrication Infrastructure Commitments with Emergent Nanofoundry Capacity

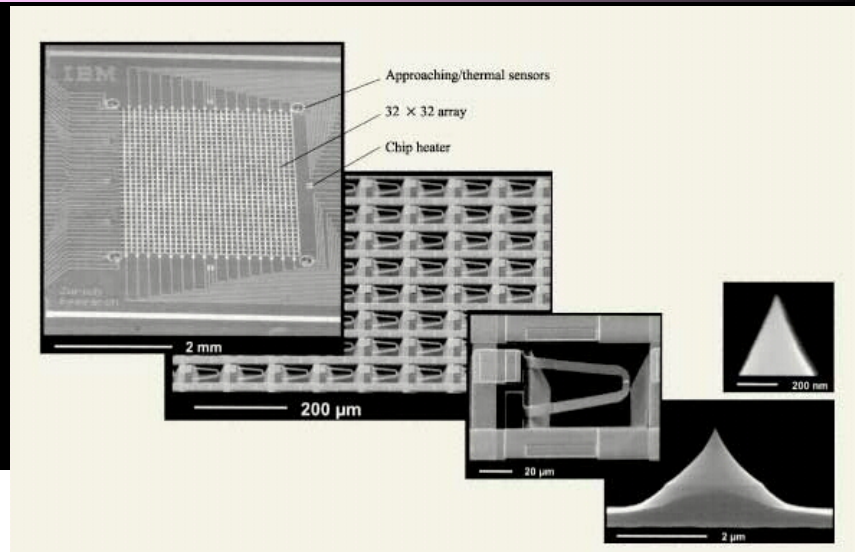
- Microscale top down silicon becomes the "circuit board" for bottom up nanostructured systems
- Integrated "operational ecologies" of fluidics, optics, mechanical, electrical, chemical modalities
- Transition from 2D platforms to 3D manifolds

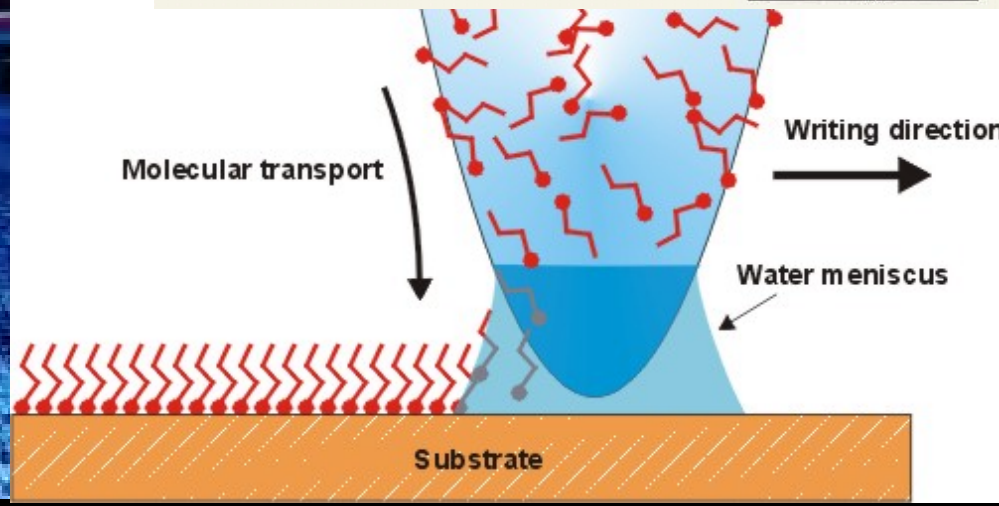




Value Proposition is in Synergistic Opportunity Example - AFM arrays

- Enabling platform for data storage
- Massively parallel molecular deposition





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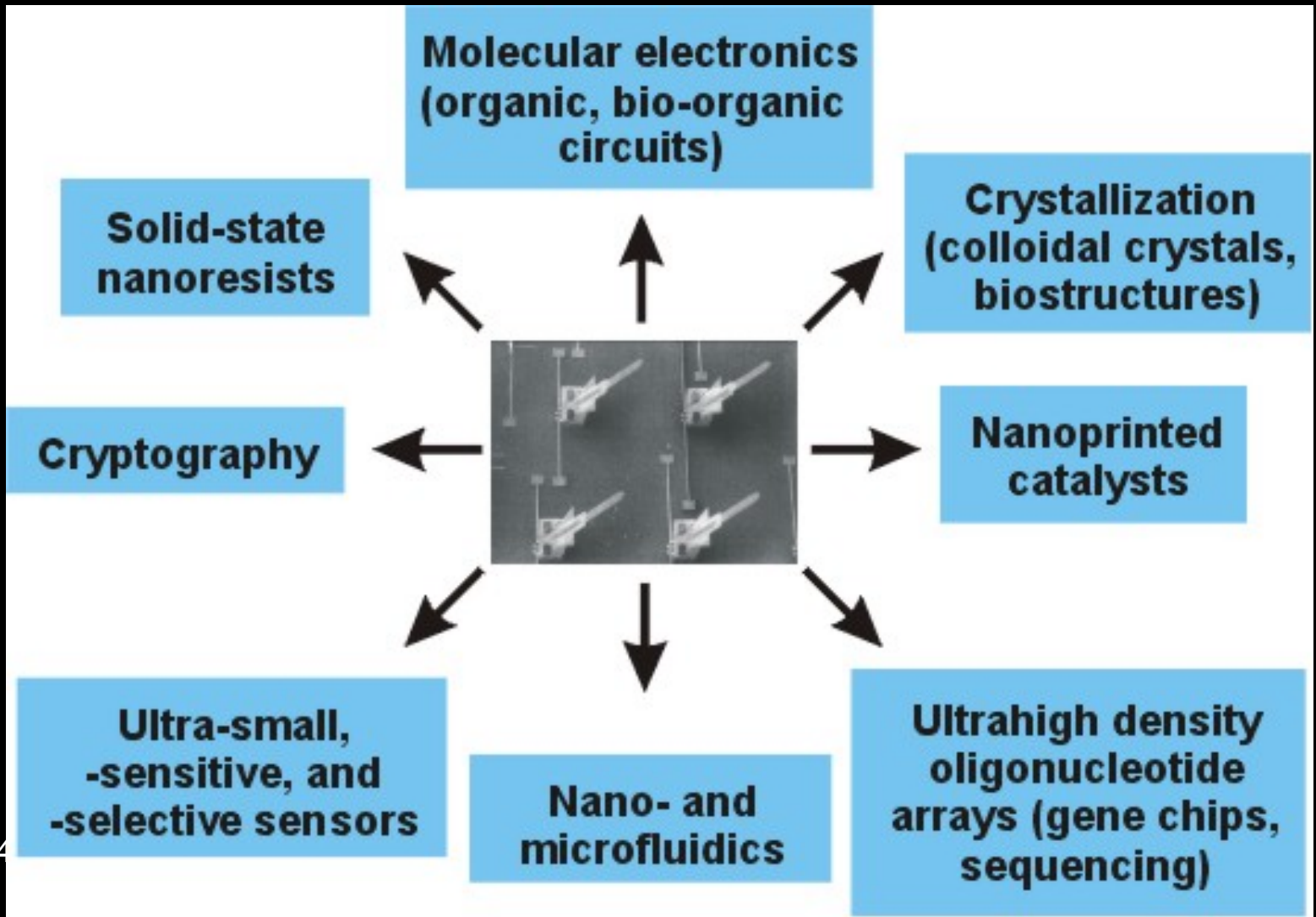
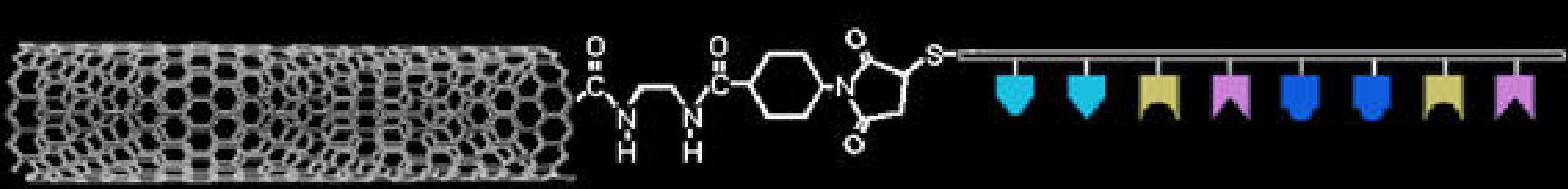
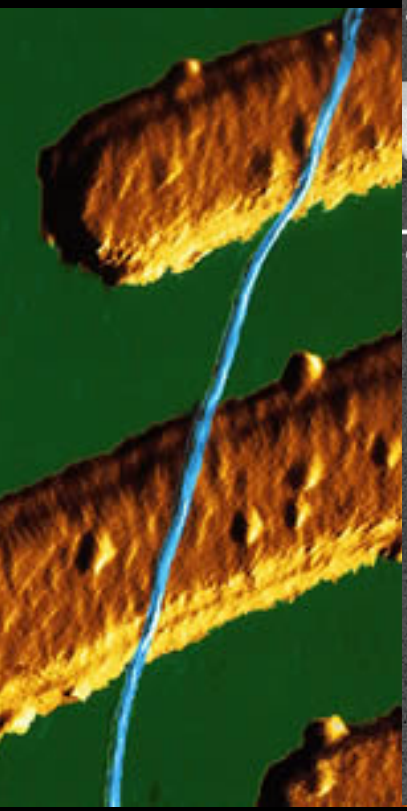
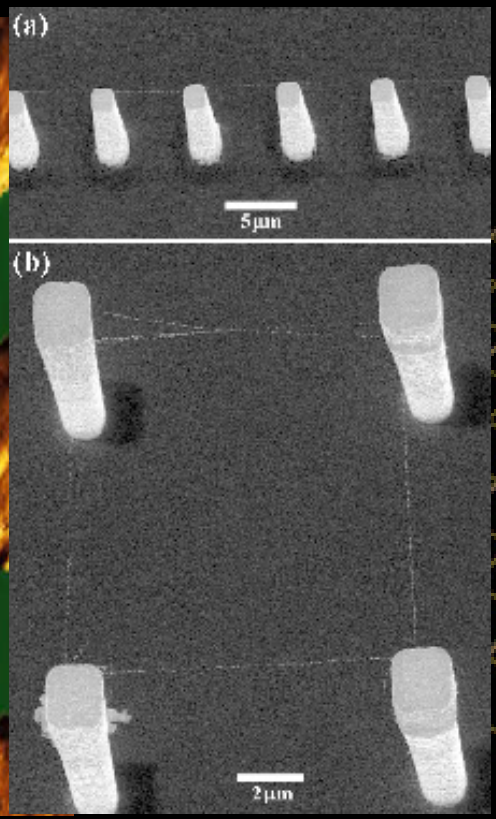
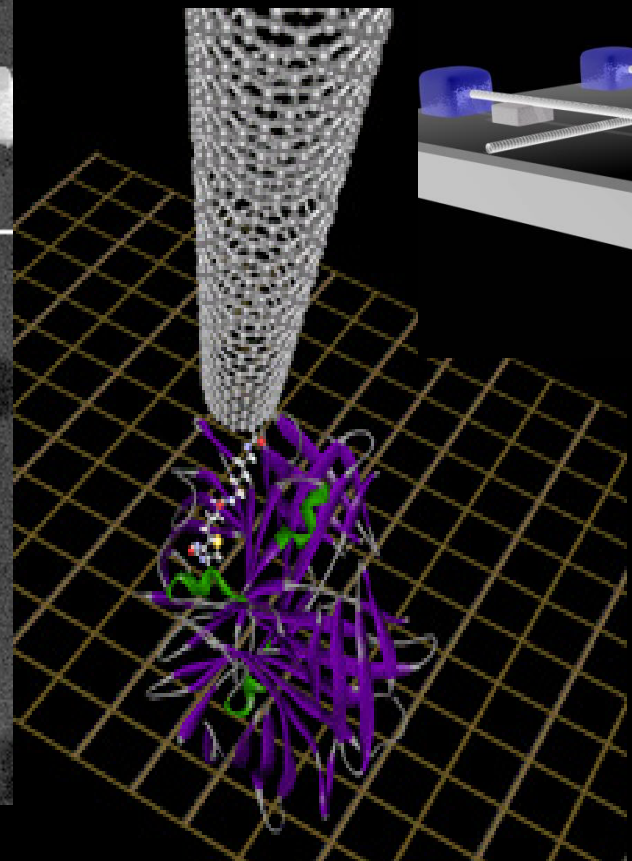


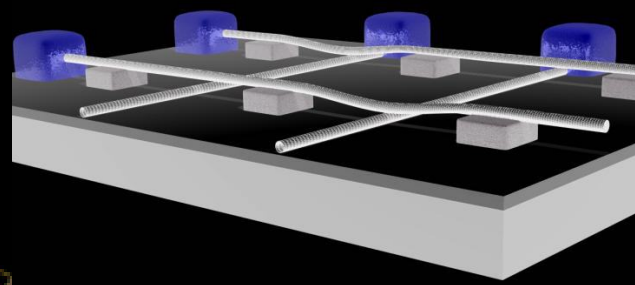
Value Proposition is in Synergistic Opportunity Example – Carbon Nanotubes





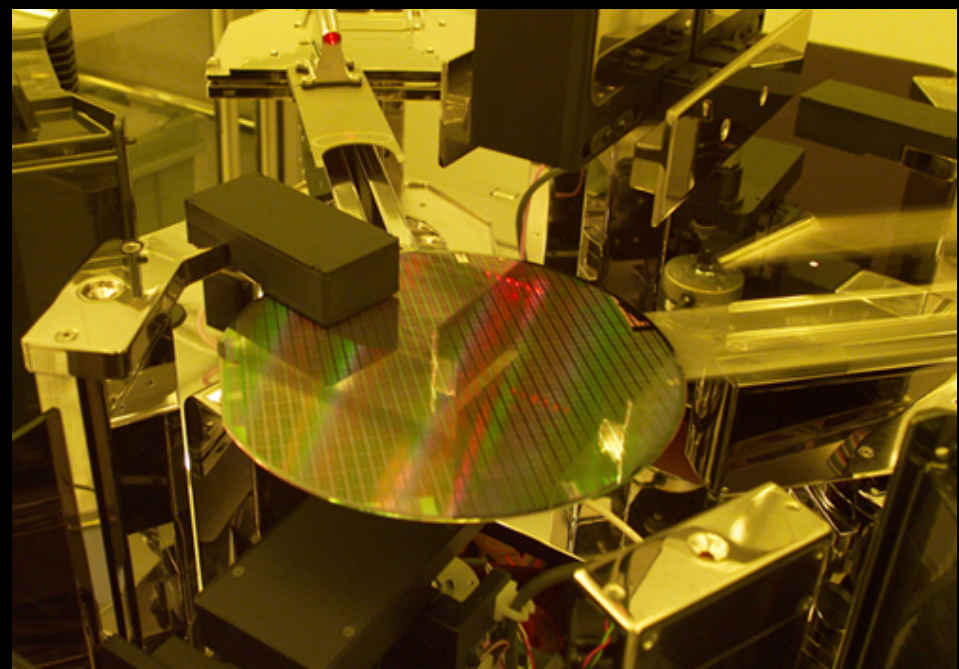






Define Foundry - Current

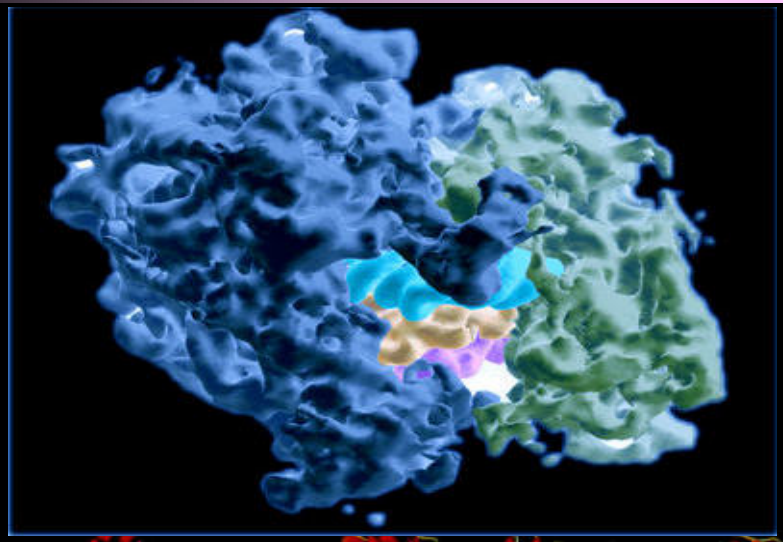
- Monolithic, Centralized
- Volume Dependant Amortization
- Rigid Fabrication Parameters
- Highly confined range of materials

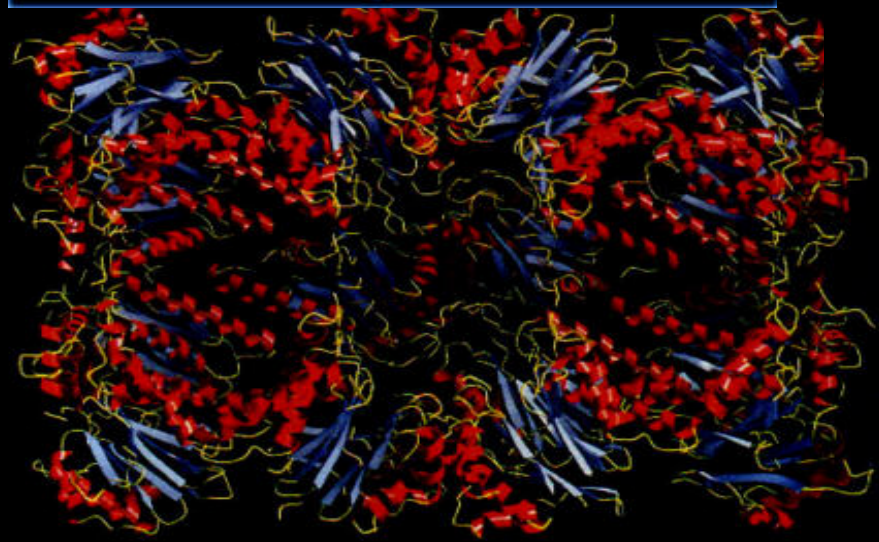


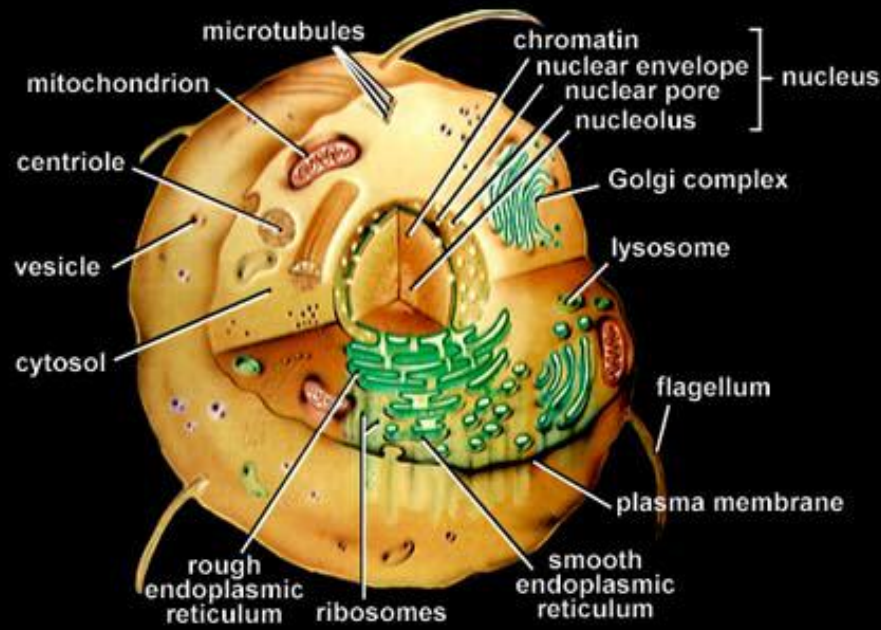
Define Foundry - Future

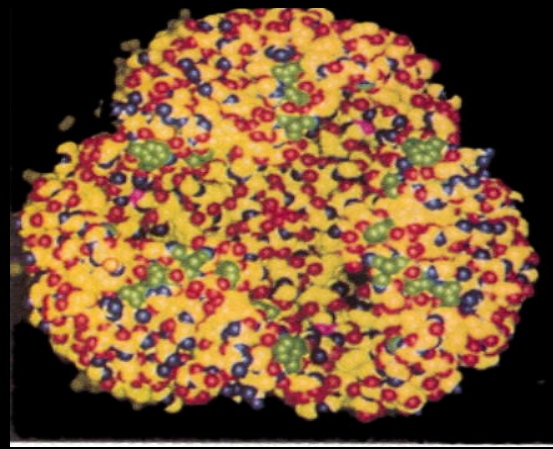
- Extremely diverse range of materials
- Highly adaptive, polymorphic
- Just as Needed Fabrication

Nature's Nanofoundries



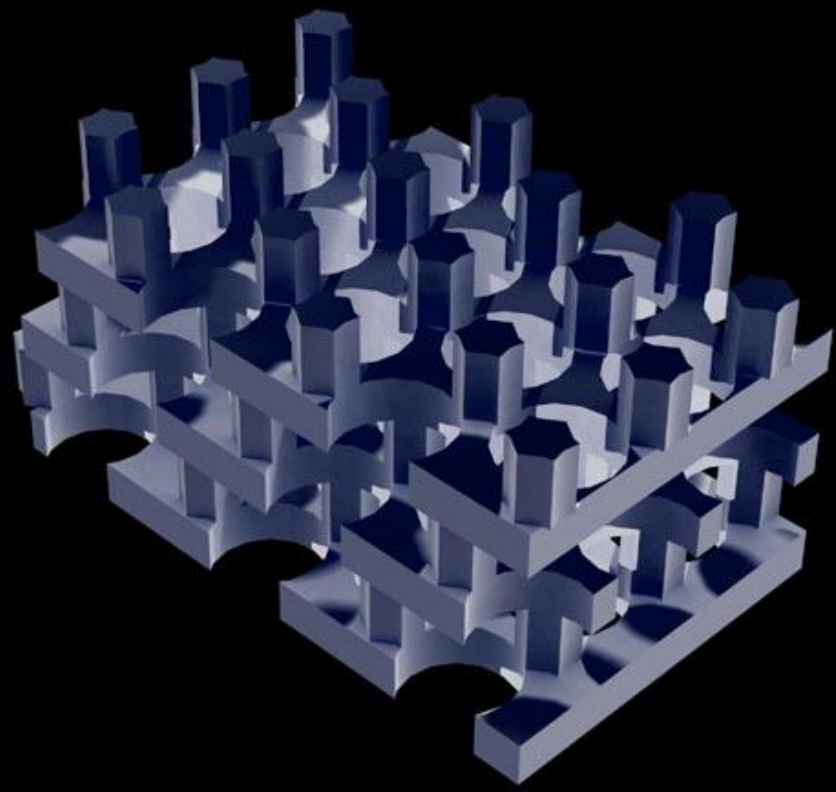






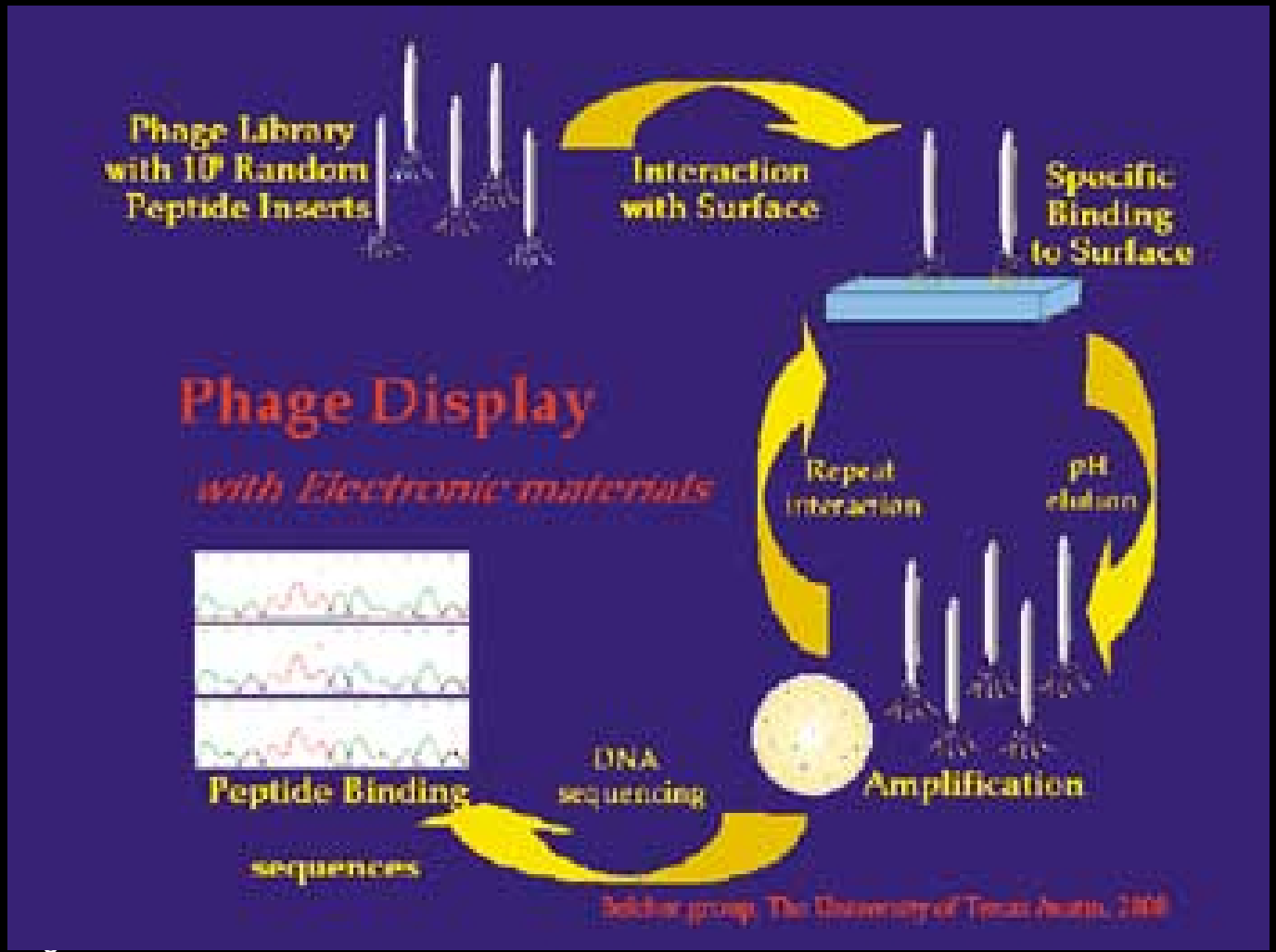
Value Proposition is in Synergistic Opportunity Integrated Nanophotonics

- ***Nature's Nanofoundry*** vs. mechano-chemistry, nanolithograpy, directed self-assembly

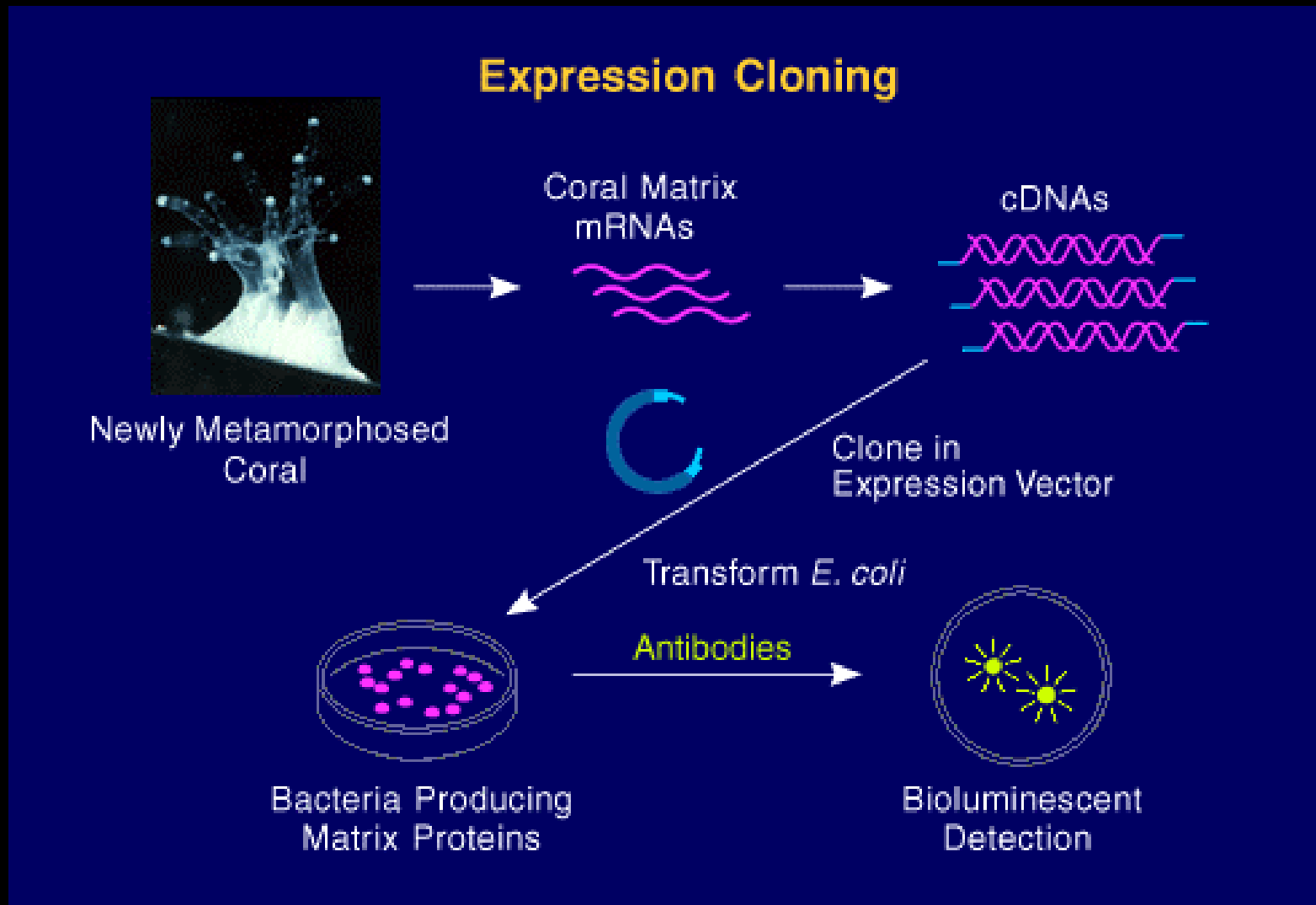


Define Foundry - Future

Define Foundry - Future

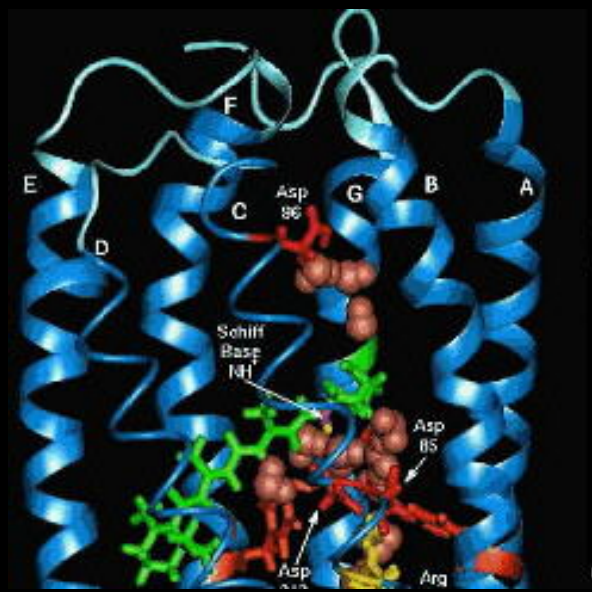


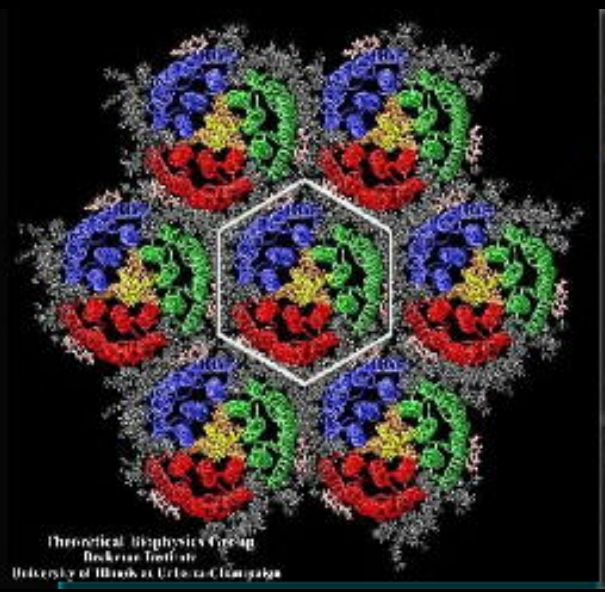
Define Foundry - Future

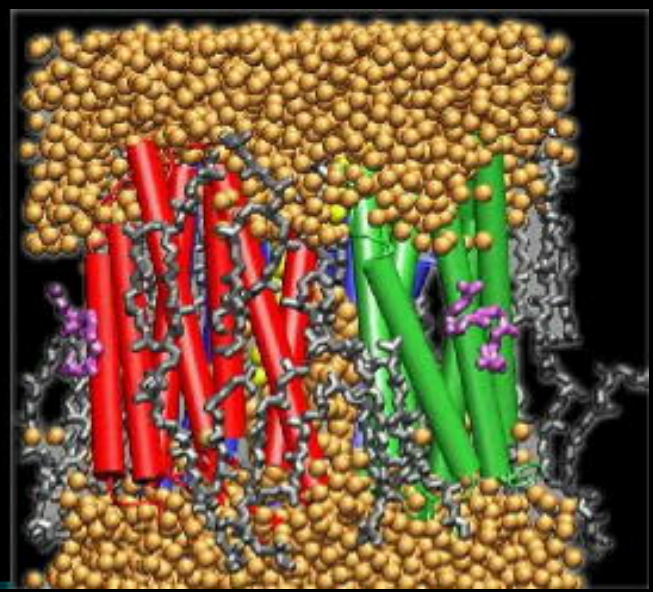


Nanobiology meets Nanophotonics

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







Holographic Storage and Computing

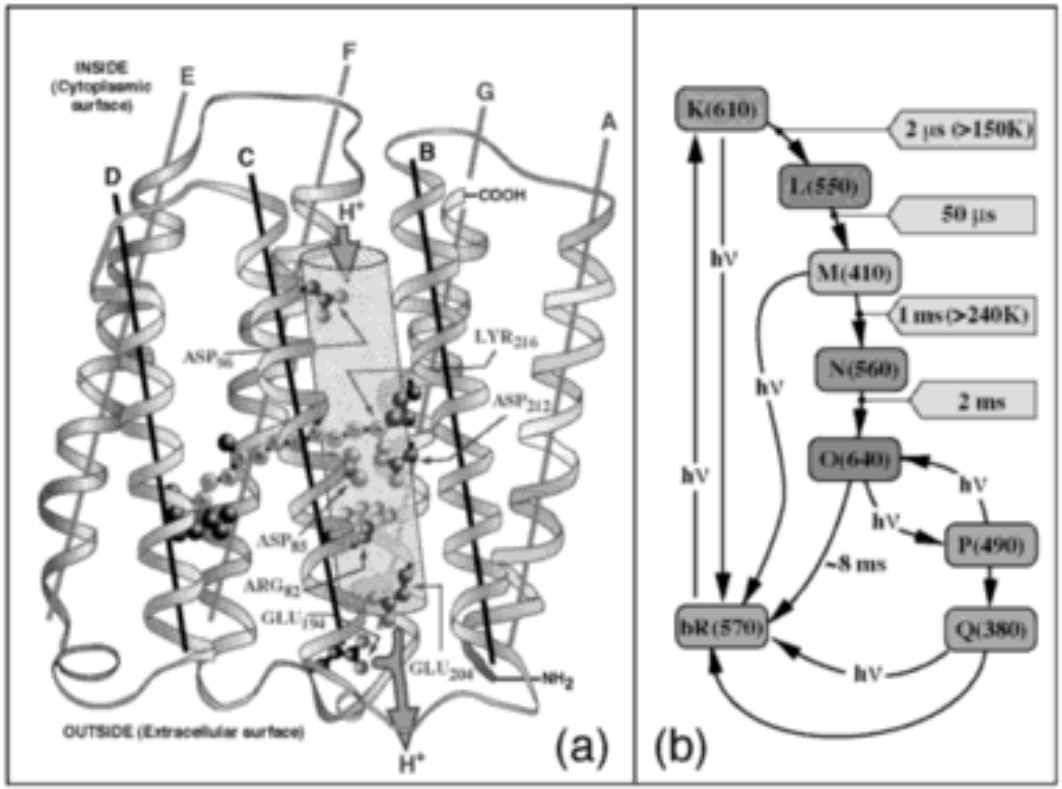
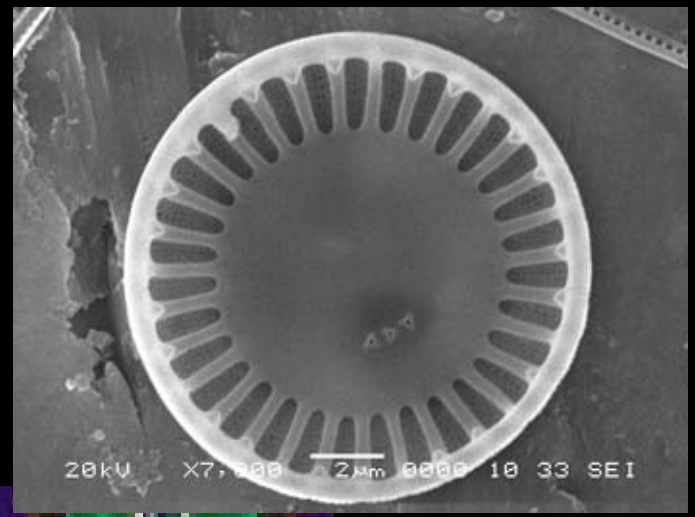


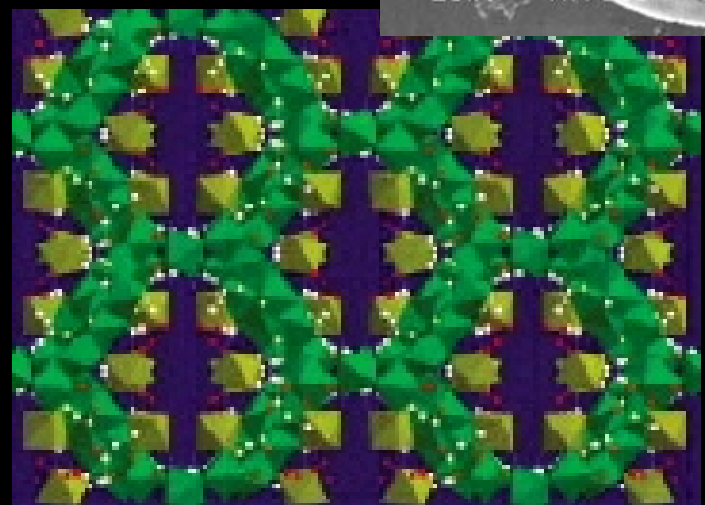
FIGURE 4-1 Simplified protein structures. 4-1a Structure and key intermediates in primary and branched photocycles. 4-1b Structure and key intermediates of bacteriorhodopsin. Note: Maximum wavelengths in parentheses are in nanometers (nm). Lifetimes and temperatures apply to the wild-type proteins only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

Source: Reprinted with permission from Birge et al., 1999. Copyright 1999, American Chemical Society.

Value Proposition is in Synergistic Opportunity NanoBiological Synthesis

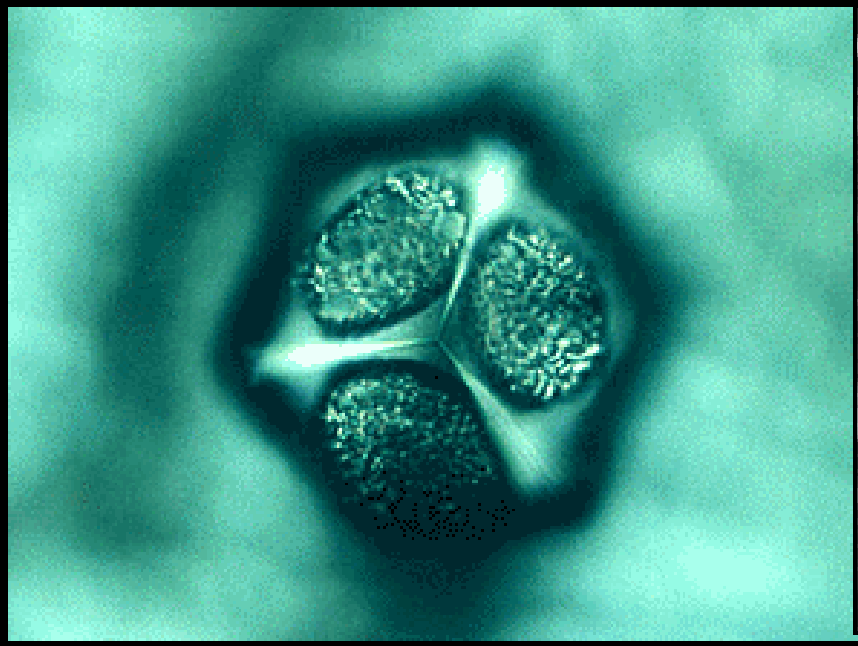
- High energy vs. Low energy synthesis



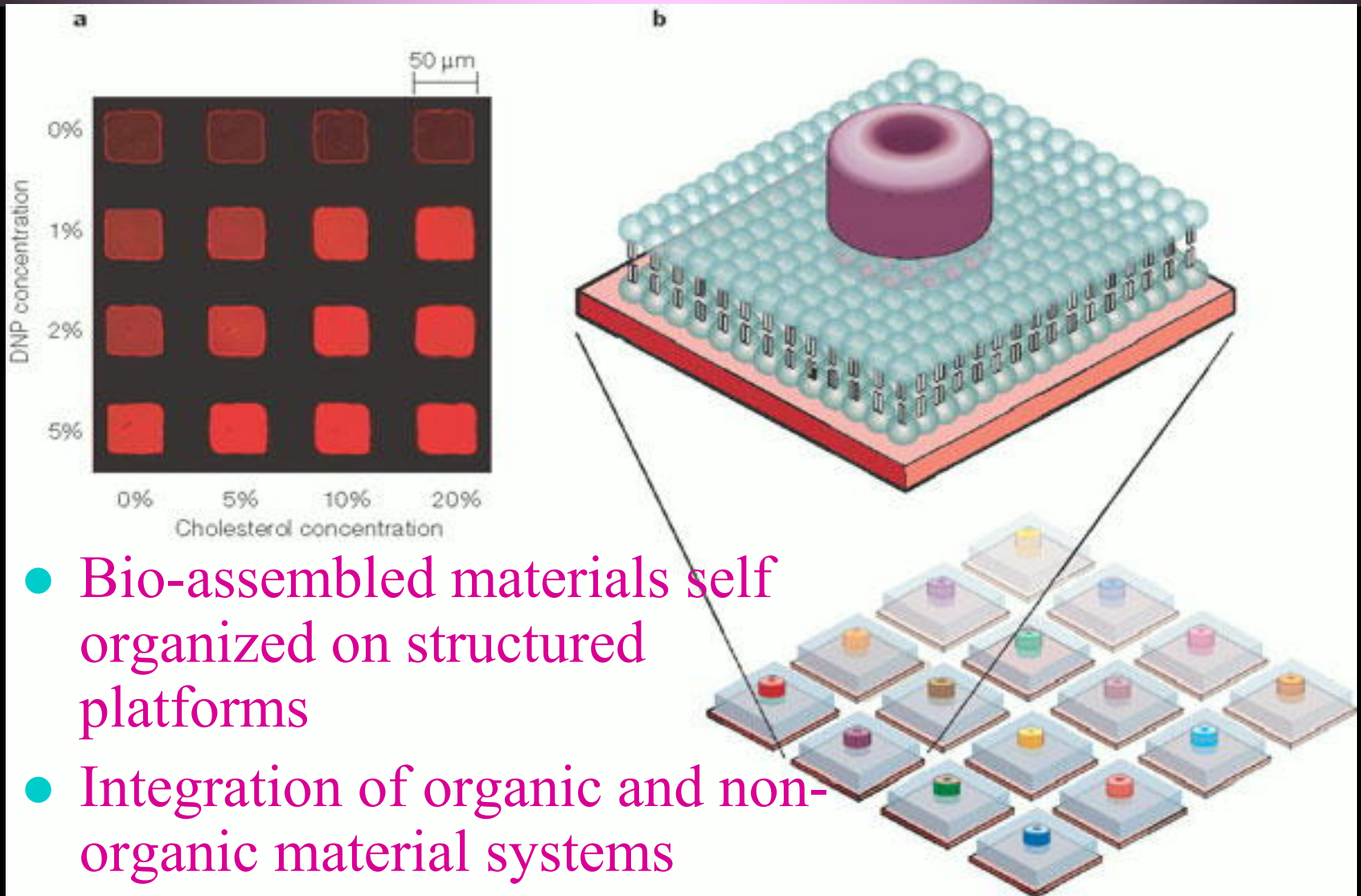


Nanostructured BioMaterials with Special Properties

- Crystallized proteins
- Structural proteomic systems



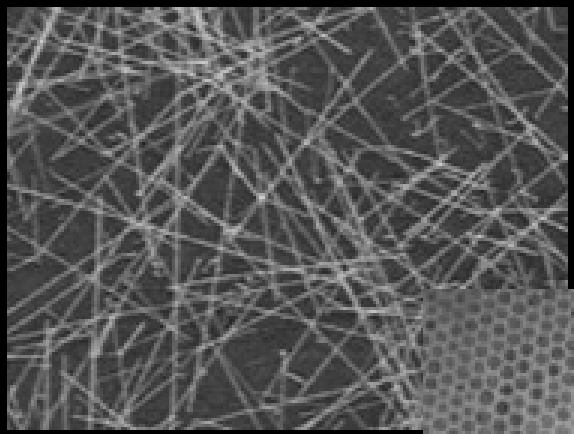
Integrated Biofoundry Processes

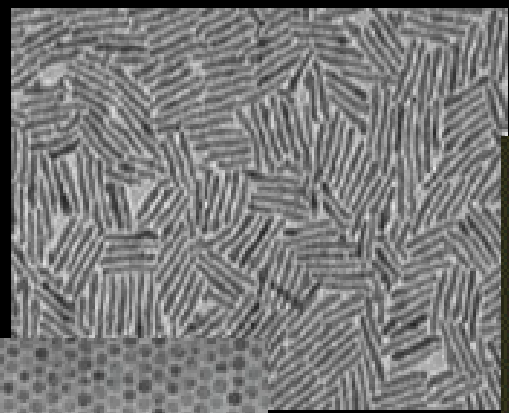


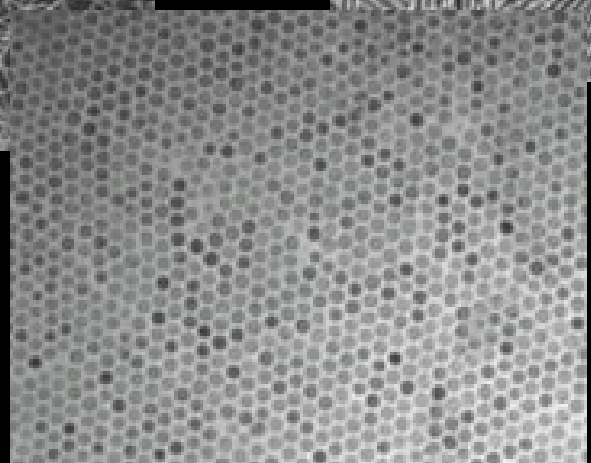
- Bio-assembled materials self organized on structured platforms
- Integration of organic and non-organic material systems

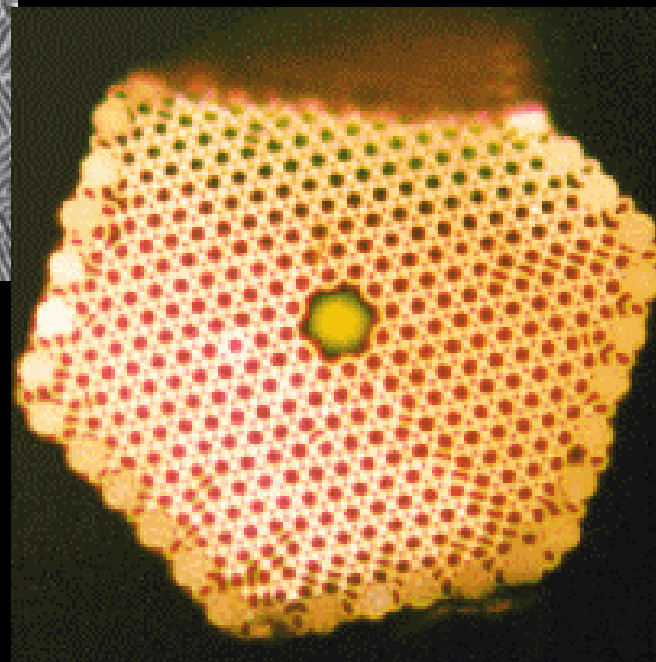
Nanostructured Materials

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



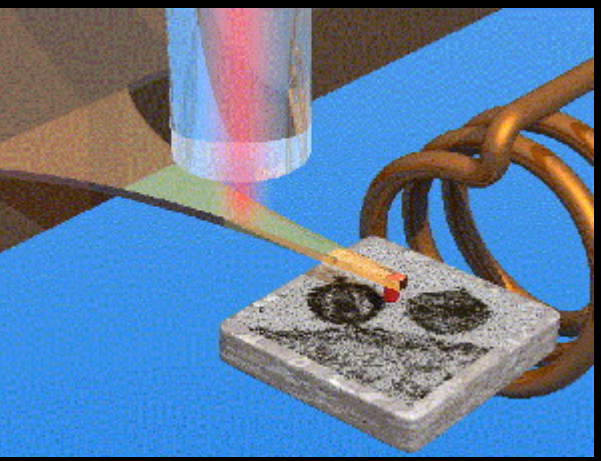






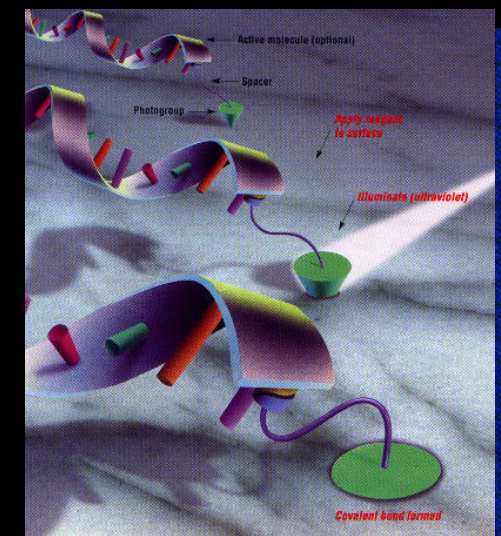
Define “Tools”

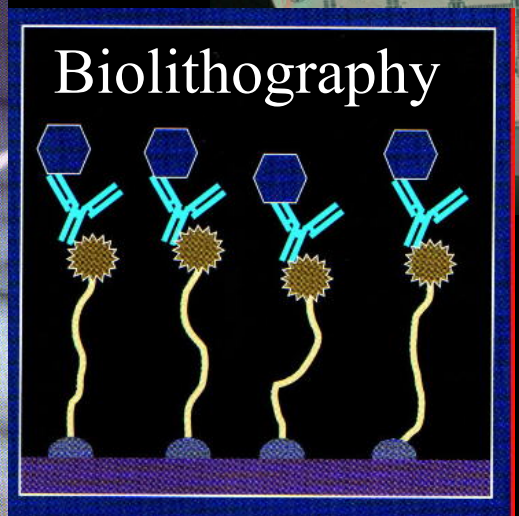
- Goal of the tool is to manipulate molecules

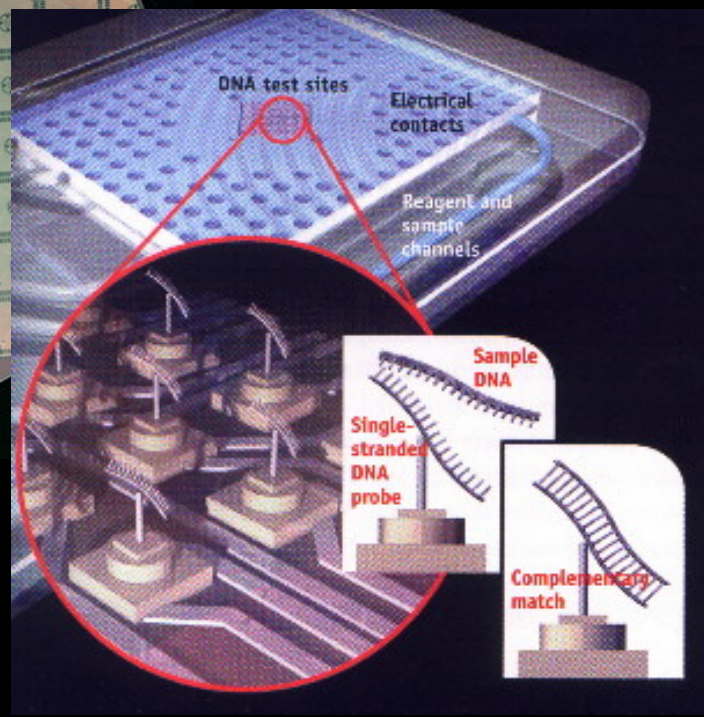


AFM / STM

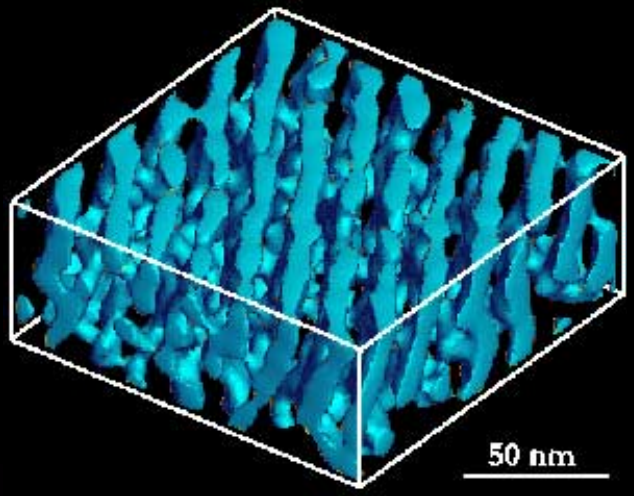
Biological FPGA

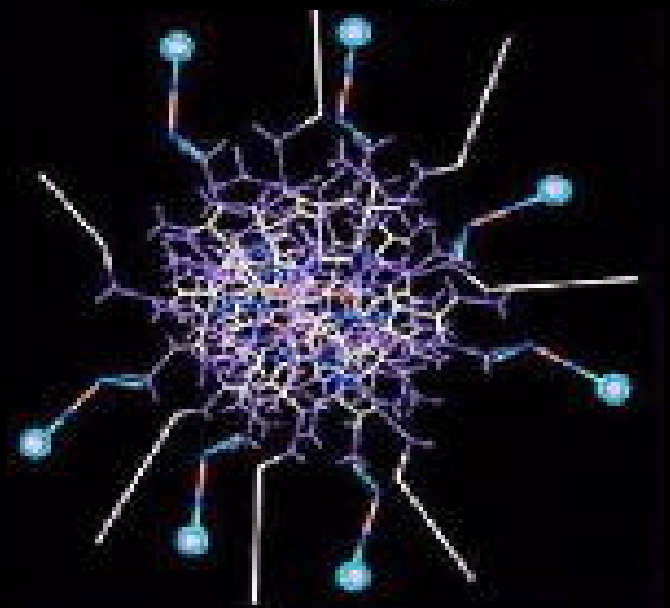


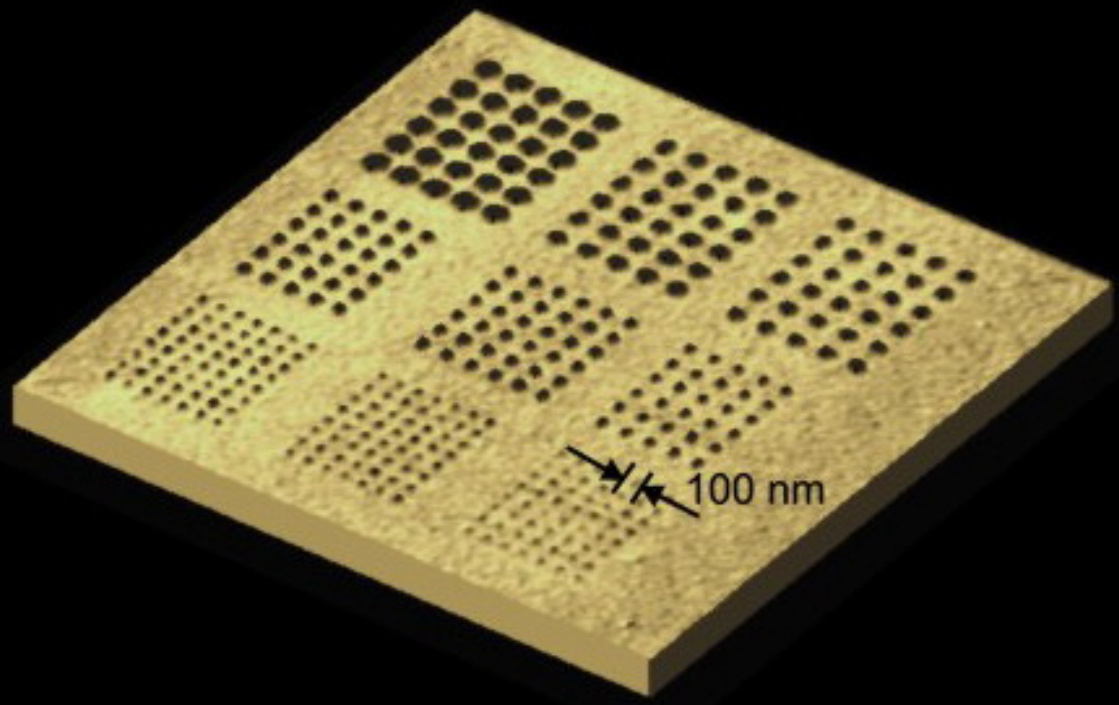




Diversity of Tools – Molecular Integration







Diversity of Tools – Nanoprinting

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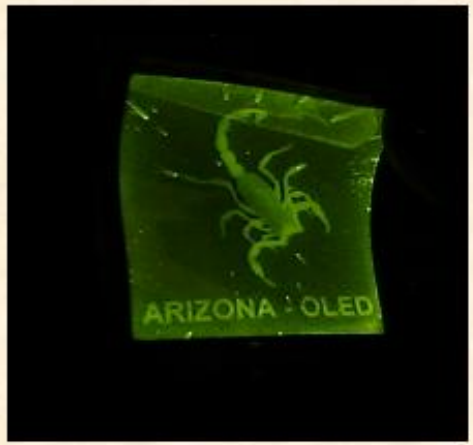
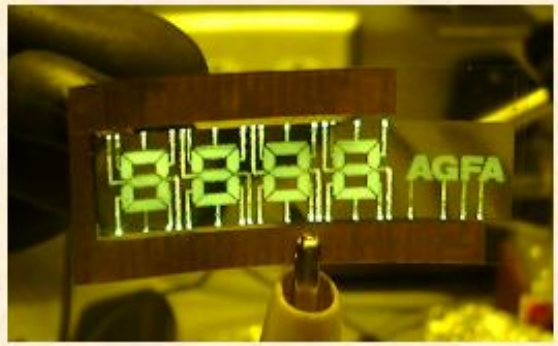
Non-Contact Printing (ink jet conductivity modification)



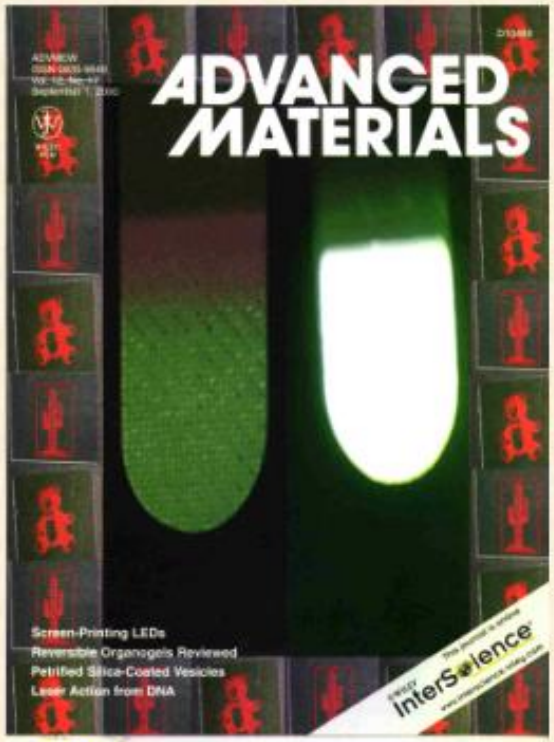


G. E. Jabbour Group
gej@optics.arizona.edu

NanoElectronic, Photovoltaic Circuitry Printed on Paper, Cloth, Plastics

THE UNIVERSITY OF ARIZONA. TUCSON ARIZONA

Screen Printing for OLEDs and Flexible Solar Cells



Sep 2000

Wall-to-wall power
Solar cells printed like wallpaper.
Nature, 6 November 2001

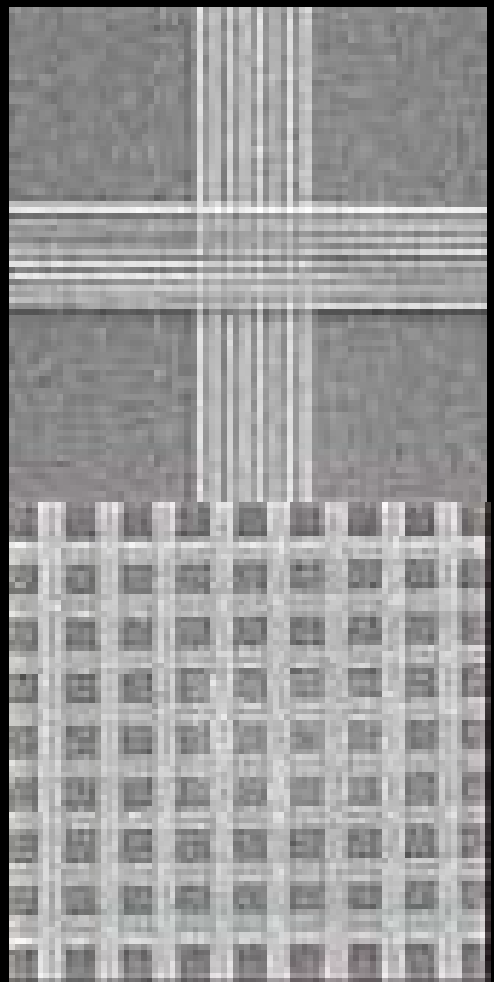
On a roll: solar panels could soon be as cheap and easy to print as wallpaper.

G. E. Jabbour Group
gej@optics.arizona.edu

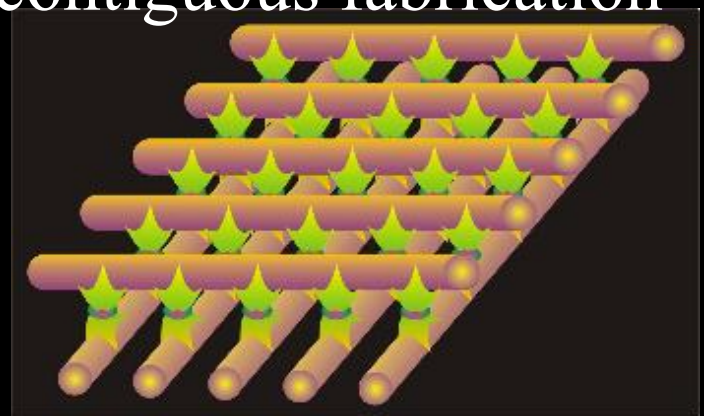
S. E. Shaheen, R. Radspinner, N. Peyghambarian, and G. E. Jabbour, "Fabrication of bulk heterojunction plastic solar cells by screen printing," *Appl. Phys. Lett.*,79, 2996 (2001).

Nanoelectronics / Molectronics
It's not just about "little devices"

- Reconfigurable logic arrays, memory fabrics

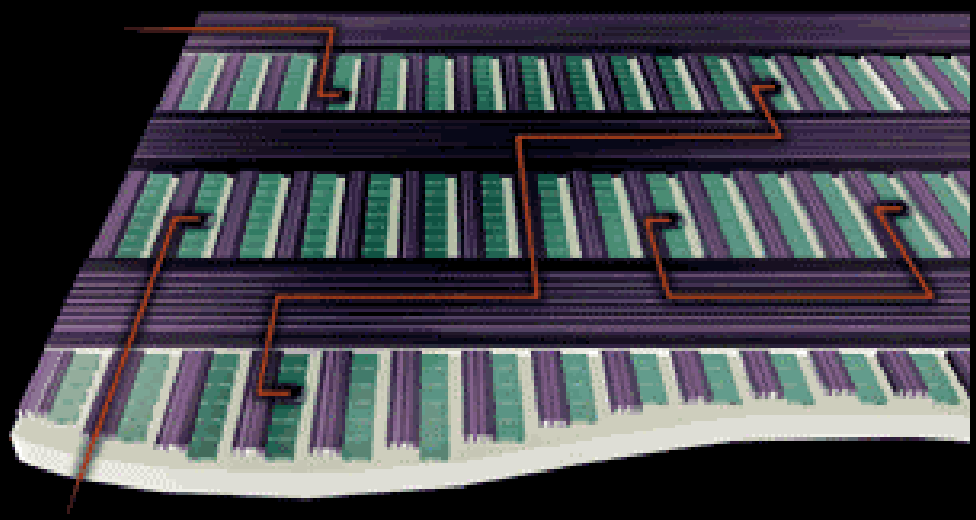


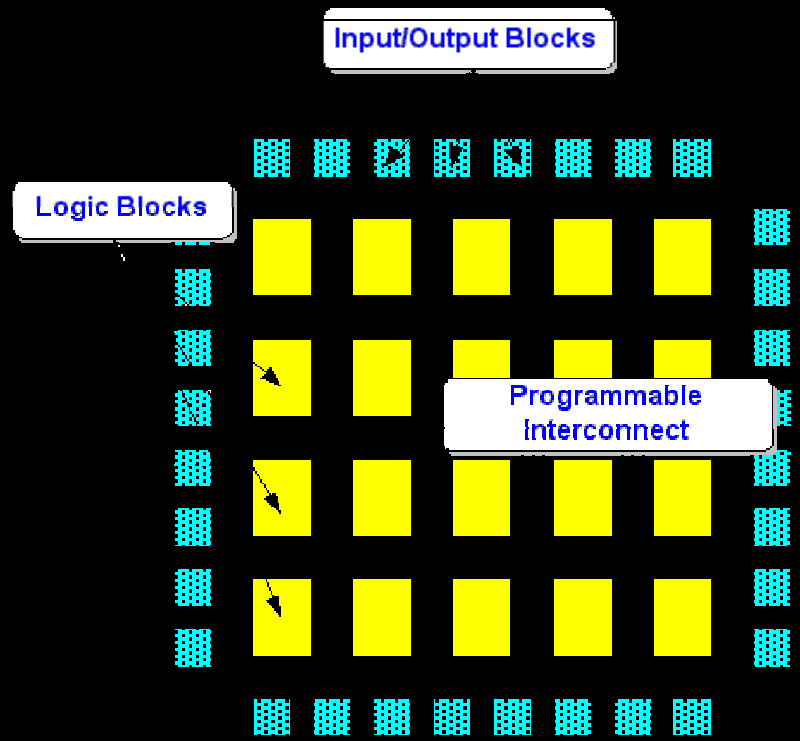
  - FPGA Architecture is asyncrhonous (not confined by Finn's Law
  - Extremely fault tolerant
  - Functional identity is in the software, not the hardware
  - Well suited for contiguous fabrication processes



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



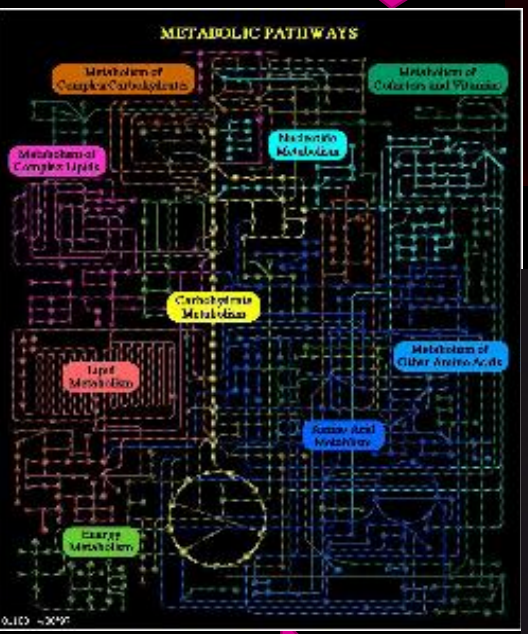


Infotech / Biotech / Nanotech Development Stream Example

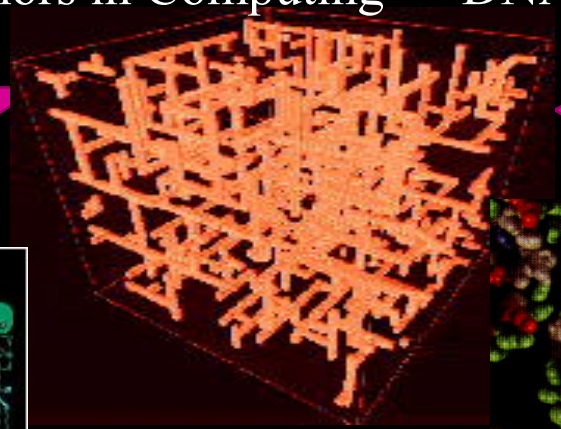
Biological Metaphors in Computing

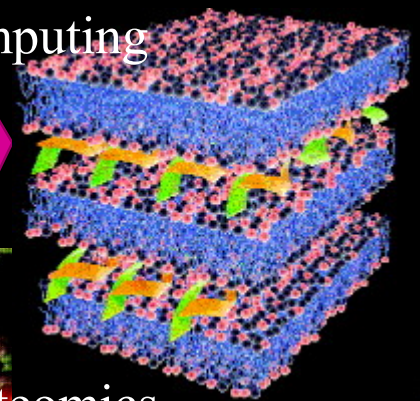
Bioinfomatics

In Silico Biology

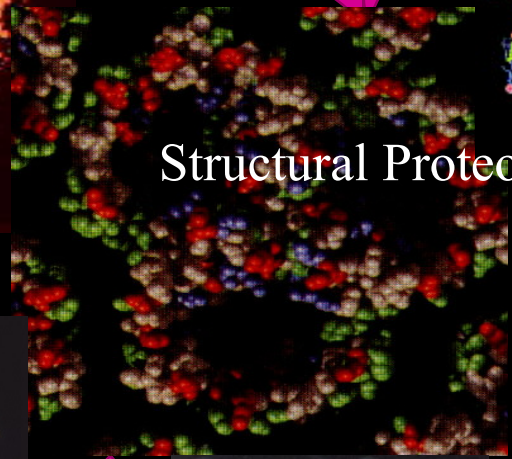


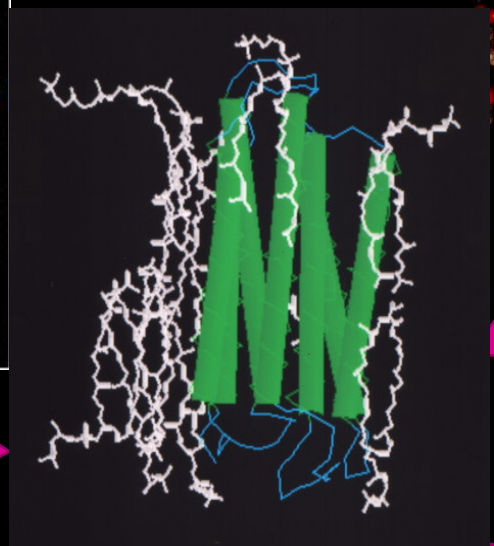
DNA / Proteomic Computing

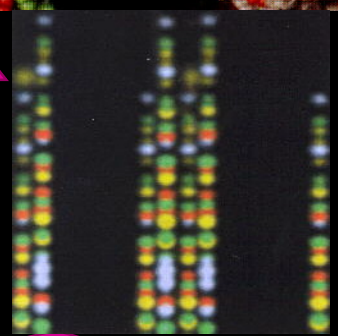


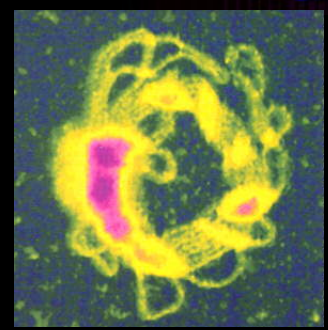


Structural Proteomics





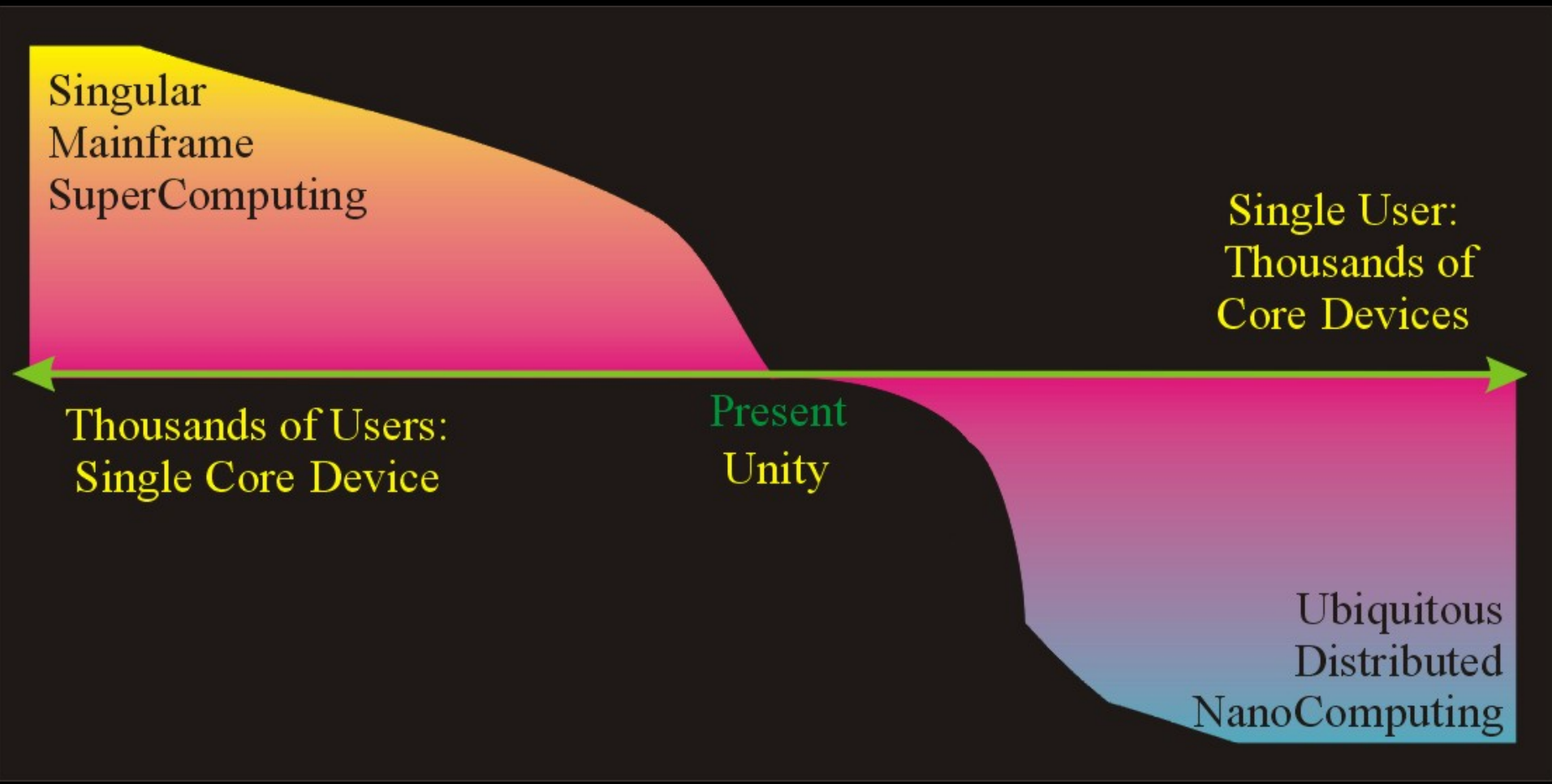




Genetic / BioMed Proteomics

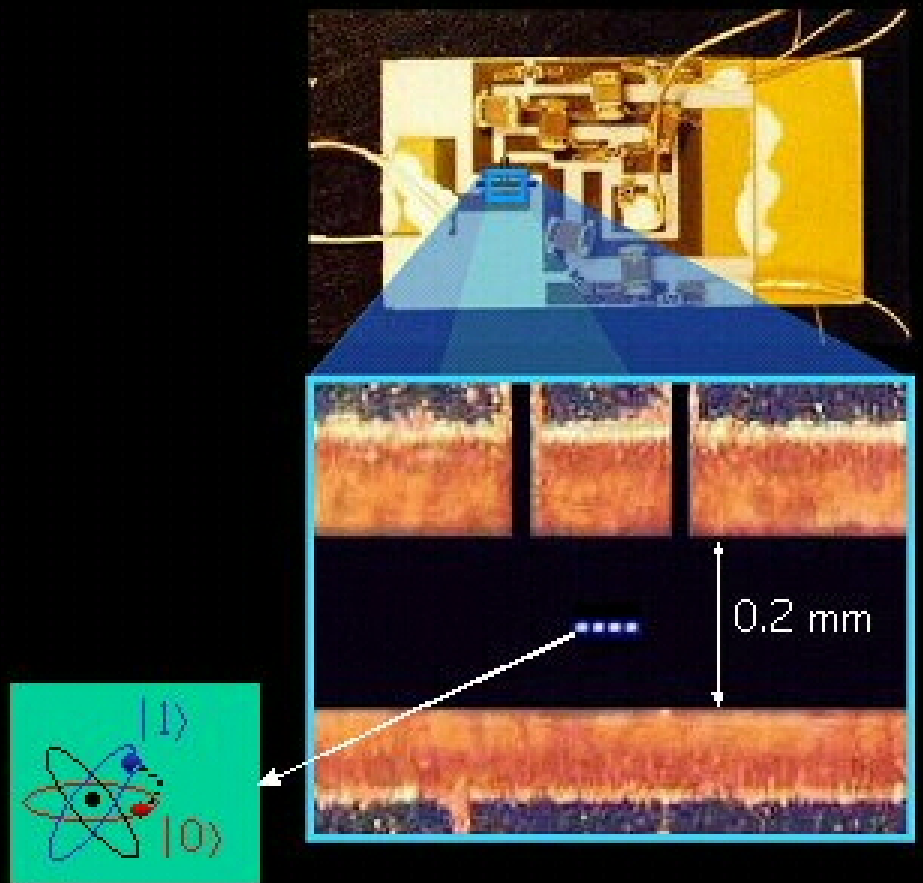
4/23/2010

The Ubiquitous NanoComputing Paradigm – Interconnect Saturation



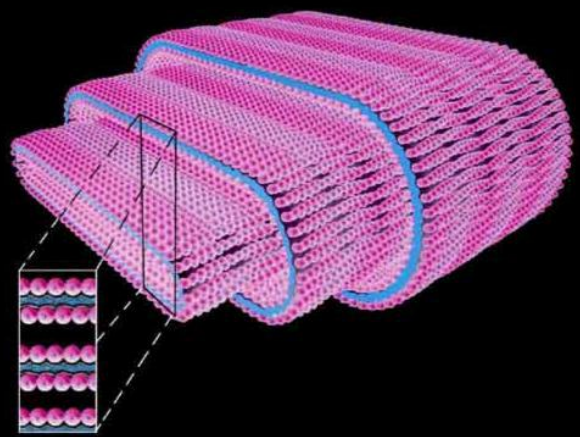
On the horizon – Quantum Computing, Encryption

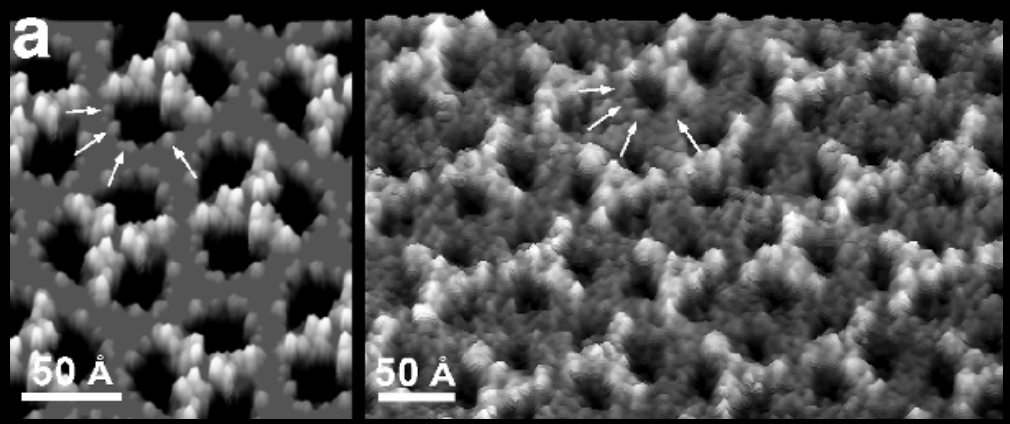
- Quantum devices, spintronics, photonics



Over 500 companies worldwide engaged in nanotechnology related development and business

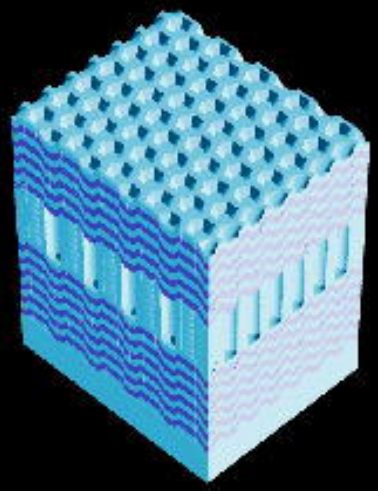
- http://www.nanotechweb.org
- http://www.nanobusiness.org/
- http://www.nanoinvestornews.com/
- http://www.nanotechnews.com/nano
- http://nanotech-now.com/business.htm

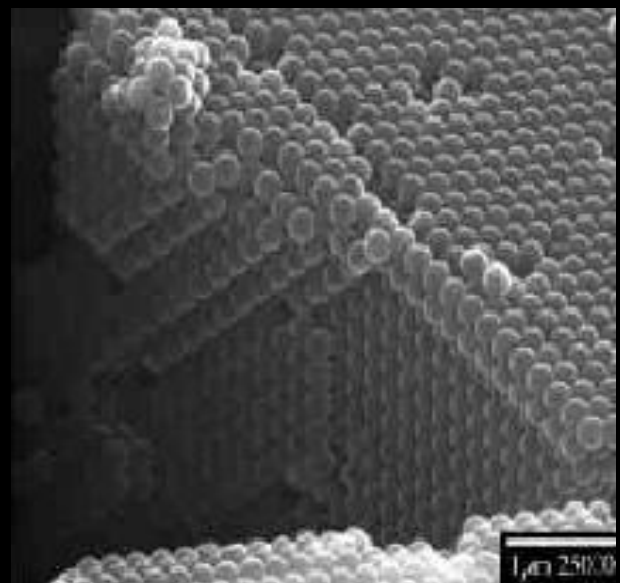


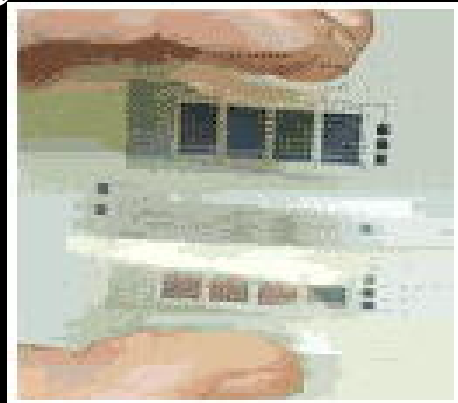


The Big Picture – *Think Different*

- It's not just about "little things" . . . it's about ***processes***
- Synergistically interrelated technologies and fabrication processes enabling a new type of industrial infrastructure.
- Nano-industrial infrastructure development represents a gateway to products, processes, and applications that are ***not economically feasible or technically possible via any other manufacturing means.***







Flexible PET substrate using single crystal silicon NanoBlocks and sputtered aluminum interconnects