Nanotechnology - Catalyzing New Directions In Electronics and Photonics

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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

- Infotech
- Biotech
- Nanotech

[Diagram showing the development of Nano Systems, Materials, Infrastructure, and Tools over time (in years)].

Time / Years
The Nano-Industrial Infrastructure Development Stream

- Infotech
- Biotech
- Nanotech

Nano Systems
Materials
Infrastructure
Bio-Integration

Time / Years
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

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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-centralized, 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
Example Start-up Ventures

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

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

- Foundry processes / fabrication techniques enabling mass production of nanoparticles
- Broad range of functionality
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 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
  - AFM / STM devices
  - AFM arrays
  - Biological FPGA

Biolithography
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 / Moletronics

- Interconnections
- Dynamic Devices
Example – Carbon Nanotubes Integrated with Organic Molecules / Biological Materials
Nanoelectronics / Moletronics

- Interconnects for memory, FPGA (reconfigurable logic) array fabrics
- Interconnection between the nano / micro / meso domains
Nanoelectronics / Moletronics
It’s not just about “little devices” . . .

- Reconfigurable logic arrays, memory fabrics
  - FPGA Architecture is asynchronous (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

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Photonic bandgap crystals – another fabrication option?

*Nature’s Nanofoundry*, directed self-assembly vs “traditional” lithography and microfabrication techniques
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Define Foundry - Future

Using Nature’s Tools to Synthesize Nanoelectronic Materials

- Natural Biological Materials
  - Self Assembly
  - Recognition
  - Nanoscale
  - Self Correcting

Bio-mediated Synthetic Materials & Devices

Abalone Shell CaCO3 Protein Composite

Electron micrograph (20,000X) Protein Controlled Nanostructure

Protein Assisted Magneto-electronic Heterostructure Assembly

Phase bound nanostructure Pynin and Batcher 2000
Nanobiology meets Nanophotonics

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

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
Our mission is to provide our members and sponsors a key competitive advantage in the next industrial revolution spawned by the convergence of interrelated domains of nanotechnology in electronics and photonics.