
NATIONAL NANOTECHNOLOGY INITIATIVE

FROM VISION TO IMPLEMENTATION

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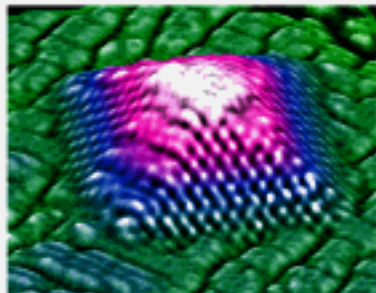
Topics to be addressed

- R&D themes and potential impact
- Science and engineering research priorities
- International perspective
- Activities of the IWGN/NSET:
NNI concept, approval PCAST, OMB, Congress
- "Nanoscale Science and Engineering"
FY 2001 solicitation

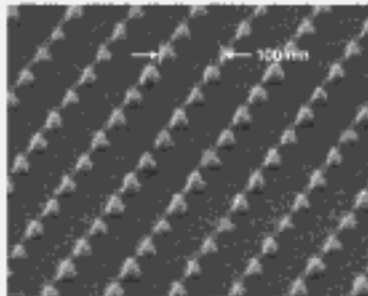
HISTORY - NNI Timeline

- November 1996 Nanotechnology Group (bottom-up)
- September 1998 NSTC establishes IWGN
- January 1999 Workshop on research priorities
- March 1999 OSTP/CT presentation on NNI
- May-June 1999 Congress hearings
- July-Sept. 1999 Three background publications
- August 1999 First draft of the IWGN Plan
- Oct. - Nov. 1999 PCAST Nanotech Panel Review
- December 1999 PCAST Full Committee Consent
- December 1999 OMB Review
- January 2000 OSTP and WH Approval
- February 2000 WH Release of NNI Initiative

Arrays of Quantum Dots



Self-assembled Germanium pyramid
Size 10 nm (1999)

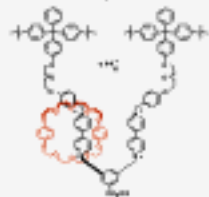


Ni-alloy evaporated pyramids
Size 30 nm (1999)

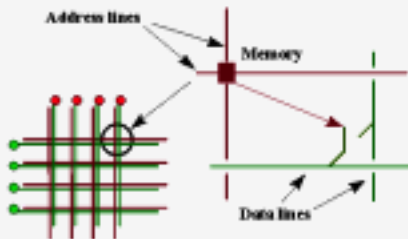
Integration of New Nanodevices in Systems

GOALI project (first in 1993), UCLA and HP

Molecular logic:
switches (size ~ 1 nm)



New architectures: the crossbar



Nanobiomotors (Cornell U., C. Montemagno)

Dynein-controlled Cilia

~10 pN
~14 % efficient

Kinesin

45 pN nm
~60 % efficient



Bacterial Flagellar Motor

4600 pN nm
unknown efficiency

F₁F₀-ATPase

60 pN nm
50 % efficient

Myosin

15 - 40 pN nm
20 - 50 % efficient

Neal Lane

Testimony in Congress on April 1, 1998

"If I were asked for an area of science and engineering that will most likely produce the breakthroughs of tomorrow, I would point to nanoscale science and engineering often called simply "nanotechnology"; . . . only recently have scientists been able glimpse Feynman's vision by creating rudimentary nanostructures."

Examples of Nanotechnology Applications

- Giant magnetoresistance in magnetic storage applications
- Nanostructured catalysts
- Drug delivery systems
- Nanocomposites: nanoparticle reinforced polymers
- Two examples of nanoelectronic devices
- LED lighting breakthroughs from nanotechnology
- National security: Bio detection
- Water purification and desalinization

Nanotechnology in the world

Comparison for industrialized countries

Estimated government sponsored R&D in \$ millions/year

	1997	2000	2001
W . Europe	126	184	
Japan	120	245	
USA	116	270	423
Total	362	624	

Nanoscale Science, Engineering and Technology (NSET)

Chair: M.C. Roco, NSF ; Executive Secretary: J. Murday, NRL/DOD

- IWGN established in August 1998; proposed and planned NNI in 1999; it has become a top priority of WH in 2000
- August 2000: NSTC (WH) has established NSET
 - **Goal:** NNI implementation, facilitate interagency collaboration for nanoscale R&D including NNI, develop vision for nanotechnology, identify provide a framework for establishing federal R&D priorities and budget.
 - **Participants:** DOC, DOD, DOE, DOT, EPA, NASA, NIH and NSF; since 10/00 USDA, DOJ, DOTREAS, DOS (observer); open to others.
 - **Expected outcomes:** Development of the field; Collaborations; Prioritization of R&D themes; Balanced infrastructure; Budget requests; Investment strategy.
- For current technical and administrative support of NSET:
National Nanotechnology Coordination Office

2001

Request by the President - \$495 million (see nano.gov)

- **Fundamental Research - \$170 million** (NSF: \$122 million)
Provides sustained support to individual investigators and small groups doing fundamental, innovative research
- **Grand Challenges - \$140 million** (\$12M)
for research on major, long-term objectives
- **Centers and Networks of Excellence - \$77 million** (\$37M)
for interdisciplinary research, networking, industry partnerships
- **Research Infrastructure - \$80 million** (\$24.7M)
metrology, instrumentation, modeling/simulation, user facilities
- **Societal Implications and Workforce Education and Training - \$28 million** (\$21M)
for a new generation of skilled workers; the impact of nanotechnology on society (legal, ethical, social, economic)

Nanotechnology R&D Funding by Agency

(FY 2001 budget enacted by Congress)

	FY 2000 (\$M)	FY 2001 (\$M)	% Increase
National Science Foundation	\$97M	\$150M	55%
Department of Defense	\$70M	\$110M	57%
Department of Energy	\$58M	\$93M	60%
NASA	\$5M	\$21M	320%
Department of Commerce	\$8M	\$10M	25%
<u>National Institutes of Health</u>	<u>\$32M</u>	<u>\$39M</u>	<u>22%</u>
TOTAL	\$270M	\$423M	57%

Grand Challenges

- Nanostructured materials "by design" - stronger, lighter, harder, self-repairing, and safer
- Nanoelectronics, optoelectronics and magnetics
- Advanced healthcare, therapeutics and diagnostics
- Nanoscale processes for environmental improvement
- Efficient energy conversion and storage
- Microcraft space exploration and industrialization
- Bio-nanosensors for communicable disease and biological threat detection
- Application to economical and safe transportation
- National security



IWGN Publications (see nano.gov)

- *National Nanotechnology Initiative -
Leading to the Next Industrial Revolution*
Supplement to the President's FY 2001 Budget, 2/2000
- *Nanotechnology - Shaping the World Atom by Atom*
Brochure for the public
- *Nanostructure Science and Technology*
Worldwide study
- *Nanotechnology Research Directions*
Vision to the future
- 15 supporting publications/proceedings by agencies for
 - specific scientific topics (modeling, selfassembling, macromolecules)
 - technological issues (synthesis, processing, nanofabrication)
 - areas of relevance (energy, space, biomedicine, biotech, others)

Sampling the Programs at NSF

Mainly seed funds:

- Synthesis and Processing of Nanoparticles (since 1991)
- National Nanofabrication User Network (since 1994)
- Nanoscale Instrumentation (1995)

Larger investments:

- Functional Nanostructures (1998)
- Biotechnology at Nanoscale (1999 / 00, exploratory),
Nanoscale Modeling and Simulation; Centers; (2000)
- STTR& SBIR Solicitations on Nanotechnology (1999 / 00)

Nanoscale Science and Engineering

NSF areas of focus in FY 2001

- Nano-Biotechnology
- New Phenomena and Structures, Quantum Control
- Integration at the Nanoscale: Systems and Architectures
- Interfaces in Environment at Nanoscale
- Nanoscale Theory, Modeling and Simulations
- Education and Society Implications

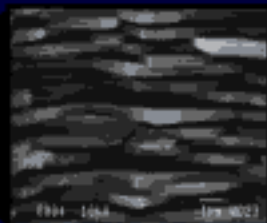
Using Nature's Tools to Synthesize Nanoelectronic Materials

Belcher and Korgel - NSF 9986563

Natural
Biological
Materials



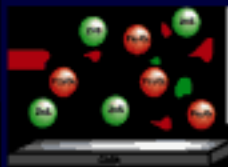
Abalone Shell
 CaCO_3 -Protein
Composite



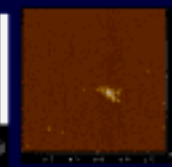
Protein Controlled Nanostructure
3000x Tougher

- Self Assembly
- Recognition
- Nanoscale
- SelfCorrecting

Bio-mediated
Synthetic
Materials &
Devices



Protein Assisted Magneto-electronic
Heterostructure Assembly



Protein Nucleated
ZnS Nanocluster

NANOSCALE SCIENCE AND ENGINEERING (NSF 00-119)

- Part of the National Nanotechnology Initiative
- NSF-wide solicitation
- Six science and engineering research themes
- Three modes of support:
 - interdisciplinary teams
 - nanoscale science and engineering centers
 - exploratory research

NSE Program Goal

- Support research in emerging areas of nanoscale science and technology, including:
 - biosystems at nanoscale levels
 - nanoscale structures, novel phenomena, quantum control
 - device and system architecture; design tools and nanosystems specific software
 - nanoscale processes in the environment
 - multi-scale, multi-phenomena modeling and simulation
 - studies on societal implications of NSE, education and training
- Support collaborative research and educational activities that have less chance of success in exiting programs

Six NSE Research and Education Themes

- *Biosystems at the Nanoscale*

Supports the development of a fundamental understanding of nanobiostructures and processes, nanobiotechnology; and fundamental concepts for novel techniques for a broad range of applications in biomaterials, biosystem-based electronics, agriculture, energy, and health.

- *Nanoscale Structures, Novel Phenomena, Quantum Control*

Explores the novel phenomena and material structures that appear at the nanoscale. Critical to overcoming obstacles to miniaturization as feature sizes in devices reach the nanoscale. Also refers to development of the experimental tools necessary to characterize and measure nanostructures and phenomena, and development of techniques for synthesis and design.

Six NSE Research Themes (cont.)

- *Nanoscale Devices and System Architecture*

New concepts and design methodologies needed to create new nanoscale devices, synthesize nanosystems and their integration into architectures for various operational environments. Requires an understanding of the physical, chemical and biological interactions among nanoscale components.

- *Nanoscale Processes in the Environment*

Research will focus on probing nanostructures and processes of relevance in the environment from the Earth's core to the upper atmosphere and beyond. Emphasis will be on understanding the distribution, composition, origin, and behavior of nanoscale structures under a wide variety of naturally occurring physical/chemical conditions.

Six NSE Research Themes (cont.)

- *Multi-scale, Multi-phenomena Theory, Modeling and Simulation at the Nanoscale*

The emergence of new behaviors and processes in nanostructures, nanodevices and nanosystems creates an urgent need for theory, modeling, large-scale computer simulation and new design tools in order to understand, control and accelerate development in new nanoscale regimes and systems.

- *Societal and Education Implications of Scientific and Technological Advances on the Nanoscale*

Studies might include: economic assessments and business models for nanoscale development and use; knowledge barriers preventing the adoption of nanotechnology by commercial firms; educational needs; life cycle assessment of manufacturing processes; the ethical and legal ramifications of nanotechnology in health, medicine, law, and the environment.

Current Announcements for NNI FY 2001

(see <http://nano.gov>)

- **NSF: Nanoscale Science and Engineering (NSE)**
for interdisciplinary team research, centers and
exploratory research - solicitation \$74M (of total \$217M)
www.nsf.gov/nano
- **DOD: Defense University Research Initiatives on
NanoTechnology (DURINT):**
for research projects and equipment - planned \$23M
www.onr.navy.mil/sci_tech/special/durint/durint01baa.htm
- **DARPA: Simulation of Bio-Molecular Systems**
for R&D projects; Solicitation 01-07, due on January 12
- **NASA: from NASA labs**
- **Other agencies (DOE, NIH, NIST) - pending**