Opportunities in Materials Research at NSF

W. Lance Haworth

Acting Director

Division of Materials Research

University Materials Council

Washington, DC

2 May 2006

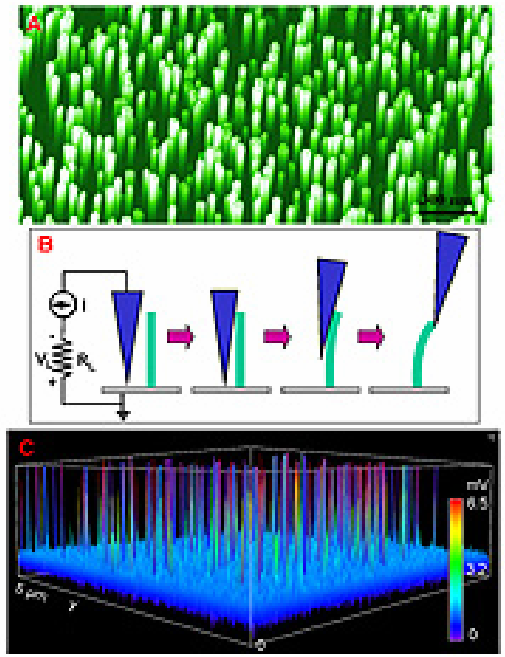
Waterproof Superglue (bacterial adhesive)

Ben Freund, Jay Tang (Brown); Yves Brun (Indiana)

PNAS 11 April 2006

NSF Vision

Enabling the nation's future through discovery,learning and innovation



Piezoelectric nanogenerators – ZL Wang and Jinhui Song, Georgia Tech

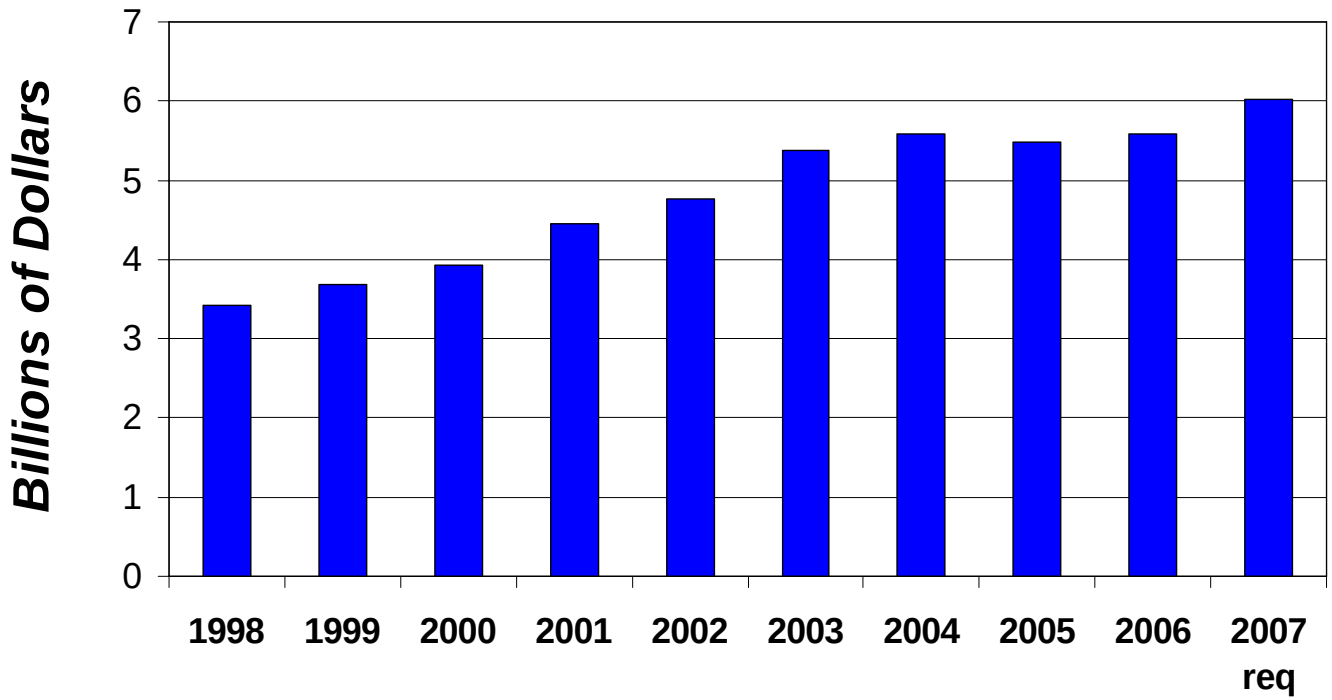
Science, 14 April 2006

NSF invests in the best ideas from the most capable people, determined by competitive merit review

Merit Review Criteria

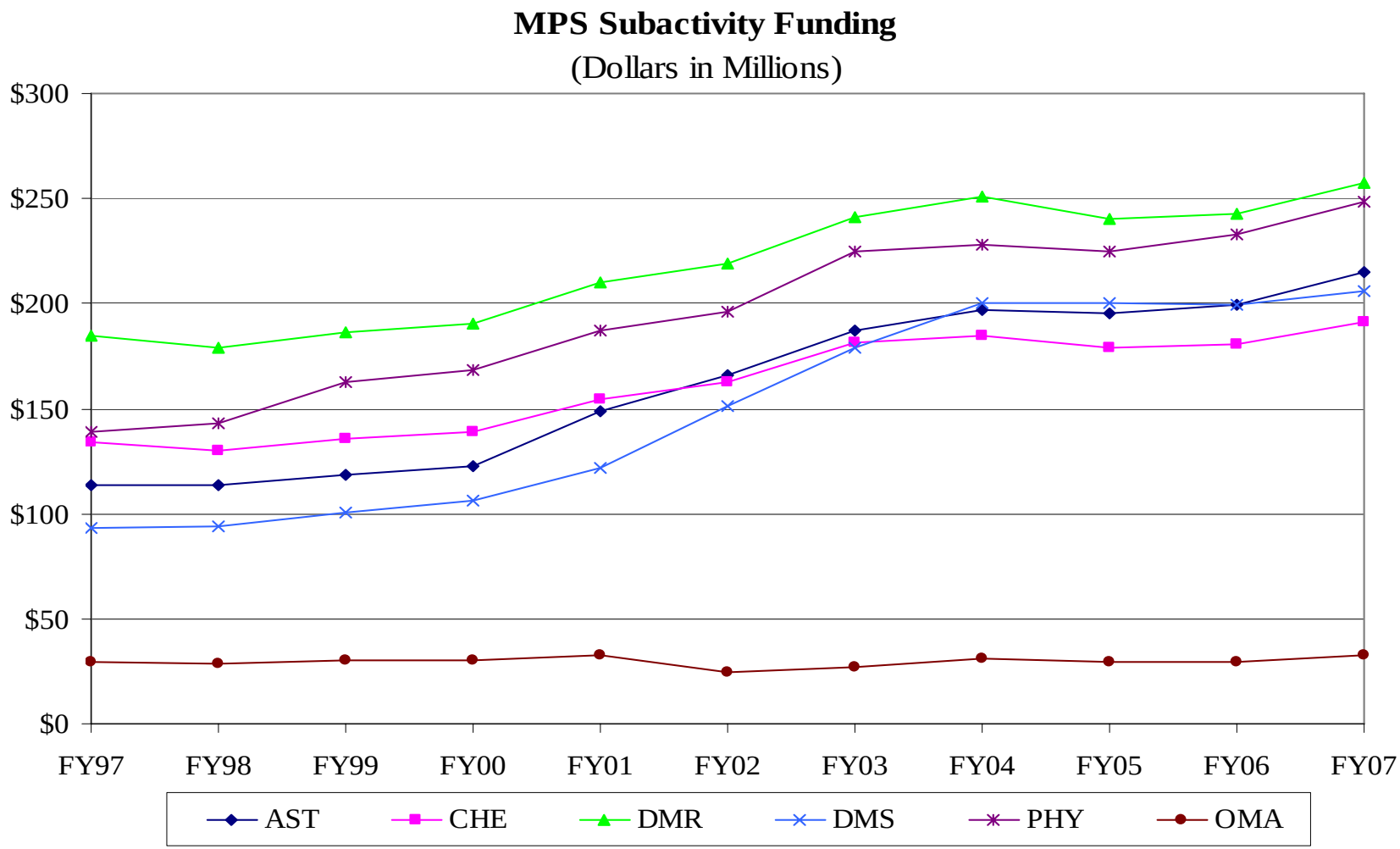
- *What is the intellectual merit of the proposed activity?*
  - ***What projects are most likely to produce new knowledge?***
- *What are the broader impacts of the proposed activity?*
  - ***Education, people, benefit to society, infrastructure, dissemination, impact on science and engineering…***

NSF Appropriations 1998-2006



"First, I propose to double the federal commitment to the most critical basic research programs in the physical sciences over the next ten years." – President George W. Bush, January 31, 2006.

Ten-Year Funding History



NSF and the American Competitiveness Initiative

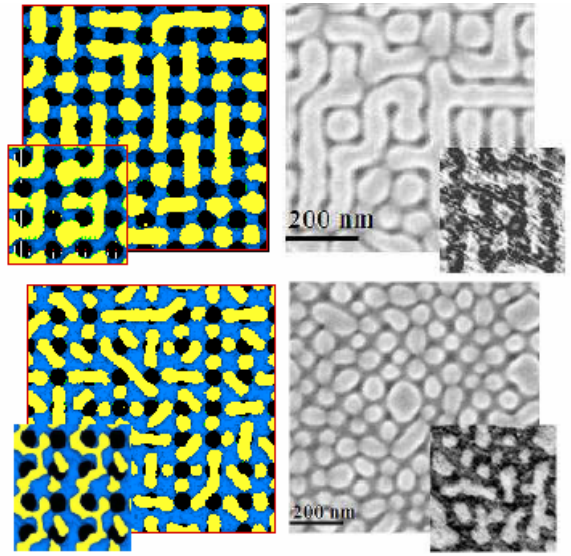
NSF is a Driving Force Behind American Innovation

- NSF funds basic research at the frontier – from fundamental discoveries about Nature to breakthroughs that are almost ready for the marketplace

- NSF-funded research inspires and provides training for the next generation of scientists and engineers

… this motivates doubling NSF's investment in the Physical Sciences over the next ten years

NSF Support for Materials Research



Self-assembly on patterned substrates – Paul Nealey & colleagues, U Wisconsin NSEC

- **From fundamental condensed-matter phenomena to functional materials …devices, and systems**
  - **“from FQH to TBC” in DMR**
- **Phenomena, synthesis, processing, properties, theory and modeling, characterization … devices, manufacturing**
- ***Basic research*, but often with potential future application**
- **Our ‘community’ includes *physicists, chemists, materials scientists, engineers*, biologists, mathematicians, computer scientists, educators…**

Division of Materials Research

Focus for Diverse Communities and Funding Modes

NSF support for materials research is not limited to DMR

- *Individual Investigators and Groups*
  - **Condensed Matter and Materials Theory, Condensed Matter Physics**
  - **Solid State Chemistry, Polymers, Biomaterials**
  - **Metals, Ceramics, Electronic Materials**
- *Cross-cutting Programs in DMR*
  - **Centers *(MRSECs, NSECs, STCs) and PREMs***
  - **User Facilities (synchrotrons, neutrons, high magnetic fields)**
  - **Instrumentation**
  - **Office of Special Programs (International Cooperation)**
- *Distributed Mechanisms*
  - ***Focused Research Groups***
  - **Workshops, Conferences, Educational Partnerships**
  - **NSF-wide programs – *REU/RET, CAREER, EPSCoR, GOALI, MRI …***
  - **NSF priority areas – *DMR is a major partner in NANO***
- *Connections*
  - **Other parts of NSF, other federal agencies, international, industry**

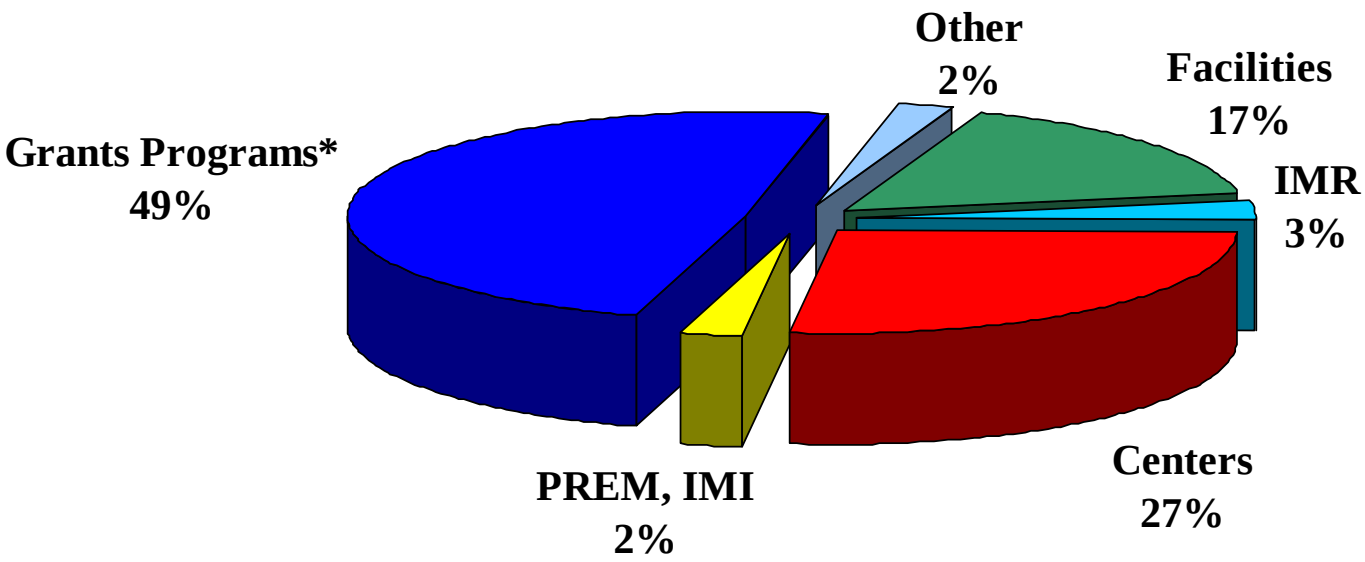
DMR Scientific Staff

*** Acting** **Visiting or Temporary Appt (Full Time)** ***Part Time***

Division Director	Lance Haworth*
Executive Officer	Ulrich Strom*
Sr Staff Associate	Lorretta Hopkins
CMP	Wendy Fuller-Mora, Roy Goodrich, Satyen Kumar
CMMT	Bruce Taggart, Daryl Hess
MET	Harsh Chopra
CER	Lynnette Madsen
EM	Verne Hess, *Bruce MacDonald,* Vacant
POL	Andy Lovinger, *Freddy Khoury*
SSC	David Nelson, *Akbar Montaser*
BMAT	Vacant
OSP	Carmen Huber
IMR	Chuck Bouldin
NAF	G.X. Tessema
MRSEC	Maija Kukla, Tom Rieker, Joe Akkara*
Volunteers	*Udo Pernisz (CMP), Michael Owen (SSC)*

DMR Support for Materials

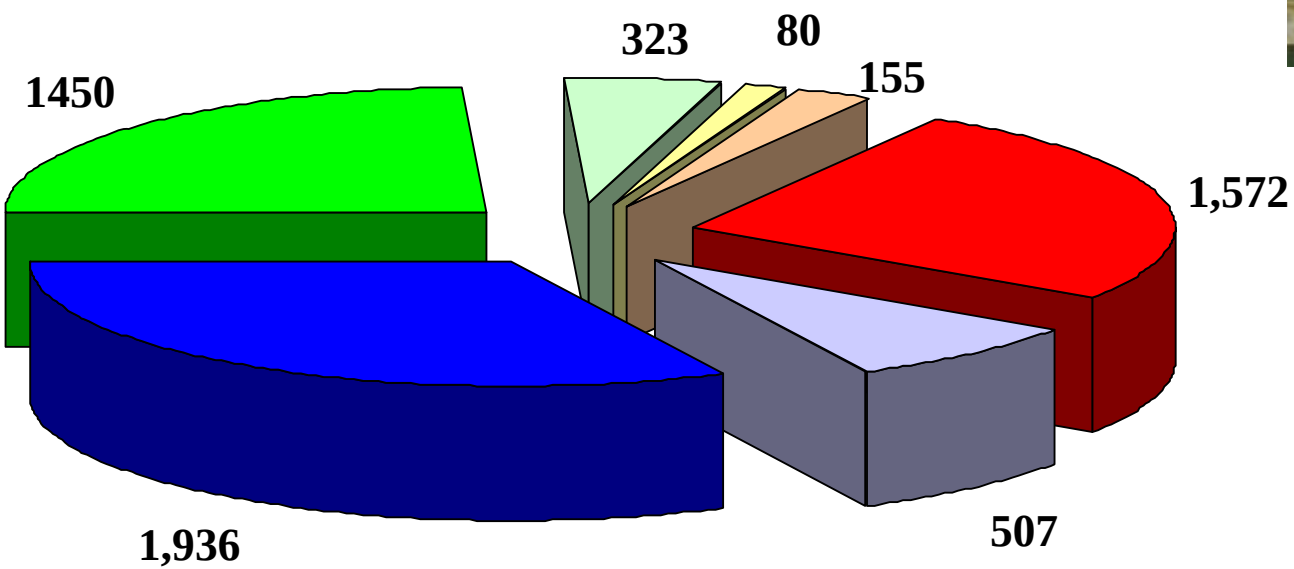
$240M in FY 2005



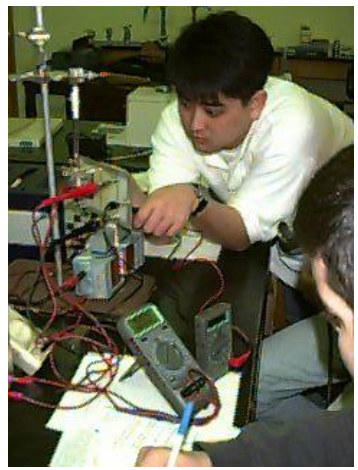
***Total* NSF support for materials is over $400M annually**

(including support from CHE, ENG, and others)

The DMR Community
FY 2005

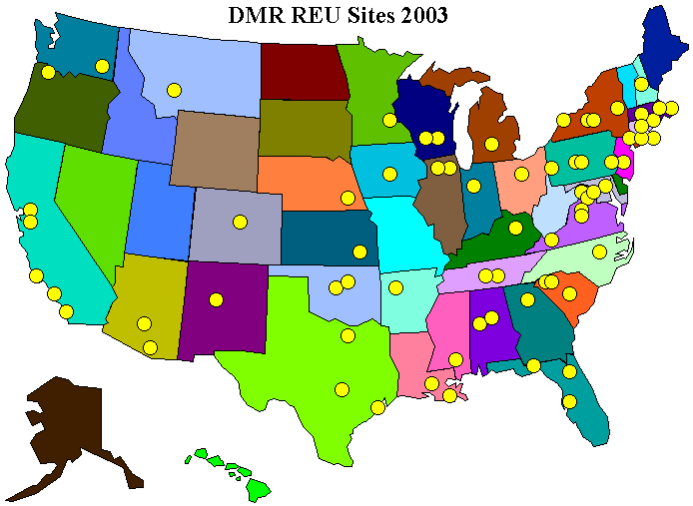


- Faculty
- Post Doc
- Graduate Student
- Undergrad
- Other Prof
- Sec-Clerical
- Other



In addition, more than **5000** investigators used DMR-supported facilities in 2005

Research Experience for Undergraduates and for Teachers



DMR supported 73 REU sites and 21 RET sites in summer 2003 - more than 1000 undergraduates and more than 100 pre-college teachers participated.

"It was the sharing of ideas and information that made the biggest impression on me. This is the feeling I want to bring back to my students, that science is interesting, challenging and exciting."
Dara Stone, Teacher
Chestnut Middle School, Springfield, MA

REU Site – Eric Kvam, Purdue Univ

27 University-Based Centers, $1M - $4M per year

6-year awards with open competition every 3 years

68 Interdisciplinary Groups address almost all areas of materials research

Biomolecular and biomimetic materials, self-assembly

Coatings, ceramics

Condensed matter phenomena, highly correlated systems

Electronic and photonic materials

Magnetic materials, ferroelectrics

Nanostructured / mesostructured materials

Nonequilibrium phenomena

Organic systems, colloids, polymers, soft materials

Structural materials, metals, mechanics of materials

Surfaces and interfaces

Synthesis and processing

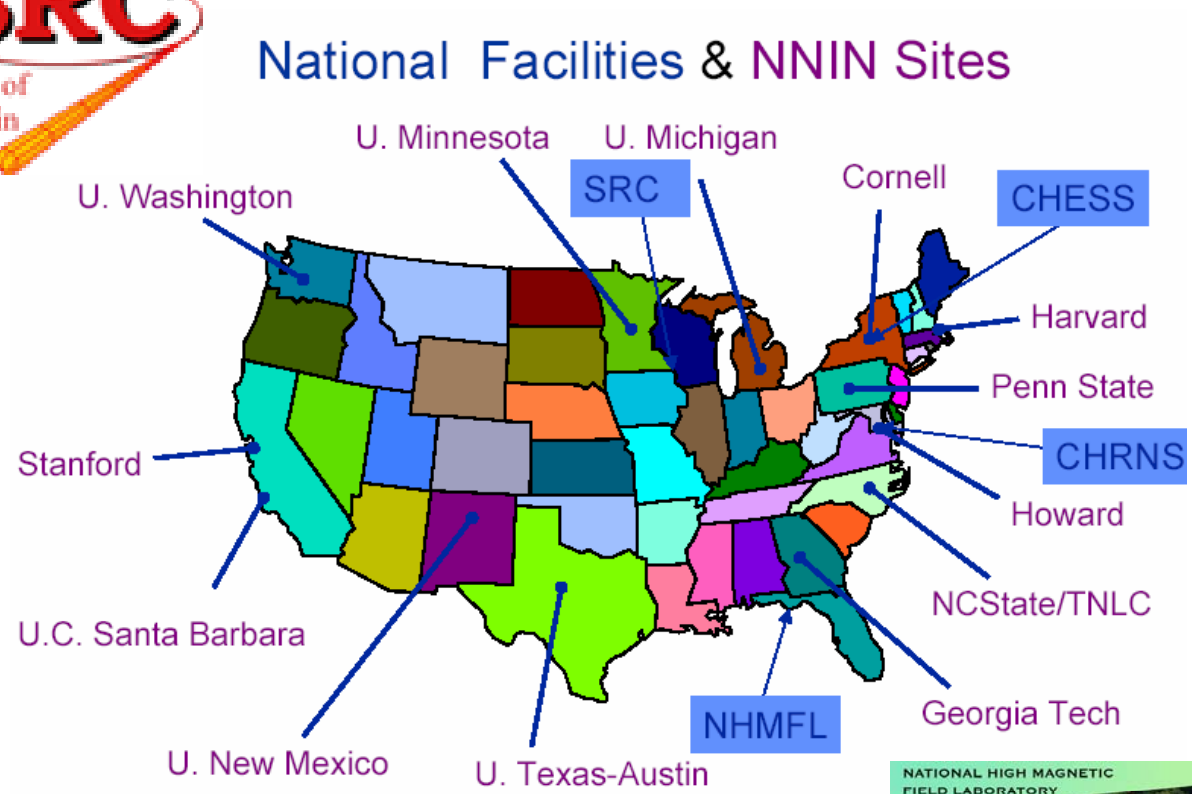
www.mrsec.org

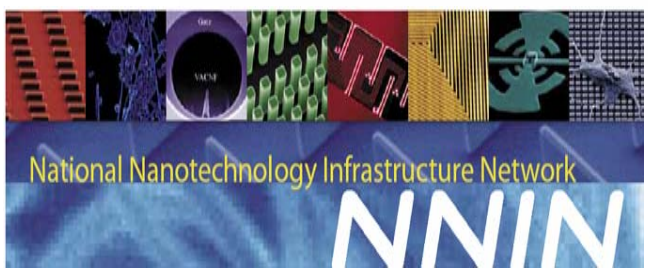
More than half the IRGs address nano

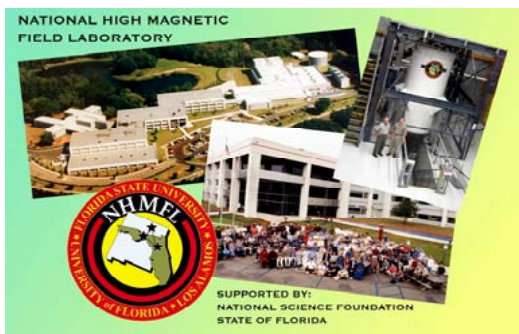
DMR National User Facilities

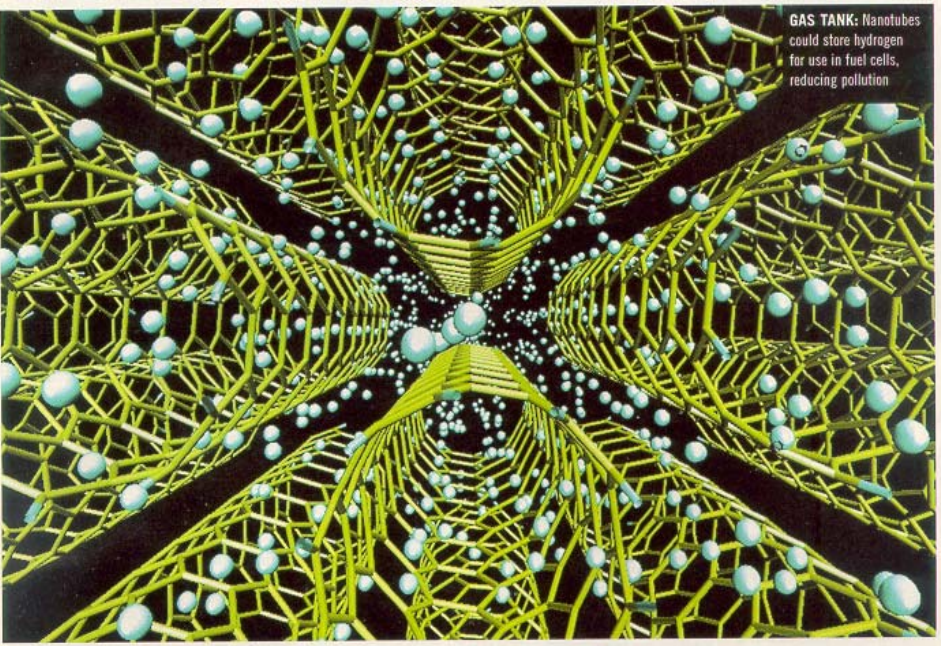
- National High Magnetic Field Laboratory
  - Florida State University, University of Florida, Los Alamos NL
  - Partnership between NSF and the State of Florida
- Neutron Facility
  - CHRNS at the National Center for Neutron Science, NIST
- Synchrotron Facilities
  - CHESS at Cornell University (NSF-PHY supports CESR)
  - SRC at the University of Wisconsin
  - *CHEM/MAT/CARS beamline at APS (NSF-CHE lead)*
- Nanotechnology Facilities
  - National Nanotechnology Infrastructure Network
    - 13 Universities
    - **NSF-ENG lead**, plus DMR, CHE, BIO co-funding

DMR NATIONAL FACILITIES









GAS TANK: Nanotubes could store hydrogen for use in fuel cells, reducing pollution

NANO TECHNOLOGY

NO, IT'S NOT ALL HYPE: THESE SUPERTINY GIZMOS WILL TRANSFORM OUR WAY OF LIFE

There isn't a nano-name company among this year's BW50 companies, and there won't be next year, either. But there are plenty of hopefuls. With all the hype about nanotechnology now swirling around Wall Street, you have no doubt already encountered some nanonewcomer with a catchy name like Nanogram, NanoOpto, Nanophase, NanoProducts, Nanosphere, or Technanogy.

More than 300 nano-whippersnappers in the U.S. and overseas are targeting what promises to be a new Industrial Revolution. Nanotechnology will leave virtually no business untouched—or unscathed. The ability to create materials from building blocks the size of a virus (page 182) will unleash unprecedented capabilities. Autos and airplanes, chemicals and plastics, computers and chips, cosmetics and drugs—all of these industries, and plenty more, are facing upheavals that could make the advent of the Internet seem like a minor adjustment.

Tiny upstarts aren't the only ones noticing that small is beautiful. Nano is receiving enthusiastic scrutiny from some big companies in the Standard & Poor's 500-stock index. Led by IBM, Lucent Technologies, and Hewlett-Packard, along with Samsung and Siemens, industrial heavyweights are pumping significant sums into nanotech research, as are governments around the world. A new study from CMP Cientifica, a market researcher in Madrid, says last year's worldwide government figure topped $1.2 billion (page 184). This year, the private and public sectors will probably spend $2 billion apiece on nano.

For insurance, big-name companies

Business Week

NO, IT'S NOT ALL HYPE. THESE SUPERTINY GIZMOS WILL TRANSFORM OUR WAY OF LIFE

NSF Support for Nano

Wide Spectrum of Topics and Support Modes

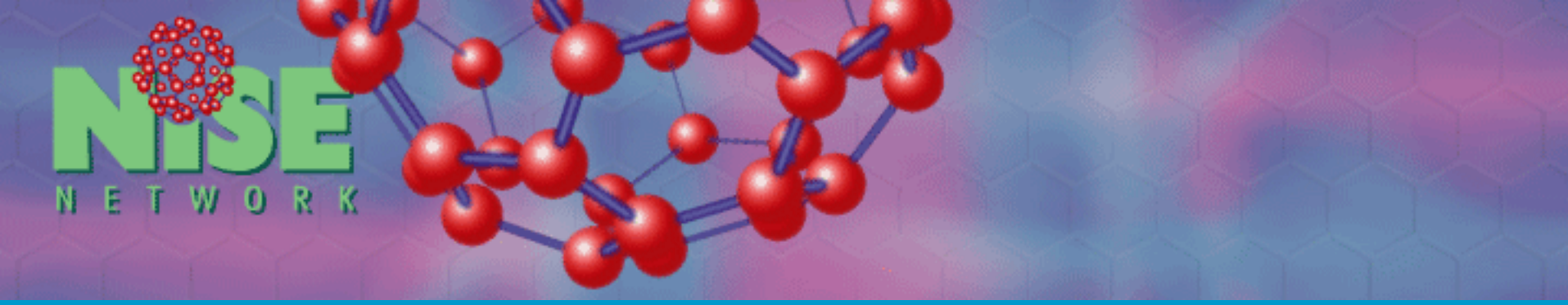
Individuals, Groups, Centers, Networks, Facilities, Education, SBIR…

FY 07 *REQUEST* $373M

includes about $106M in DMR funds

- **Fundamental Phenomena & Processes** **132**
- **Nanomaterials** **58**
- **Devices and Systems** **50**
- **Instrumentation Research** **15**
- **Nanomanufacturing** **27**
- **Facilities & instrument acquisition** **32**
- **Societal dimensions** **59**
  - **Environment/Health/Safety, Education, Implications for Society**

DMR support for nano is now mostly ‘mainstreamed’ via unsolicited proposals (individuals and groups), centers competition, or instrumentation



The Nanoscale Informal Science Education (NISE) Network

Informal Science Education (ISE) people

&

Nanoscale Science, Engineering and Technology (NSET) researchers

working together to foster public awareness, engagement, and understanding of nanoscale science, engineering, and technology.

To learn about a range of new and different ways to enhance the broader impacts of your research and outreach efforts in your area…

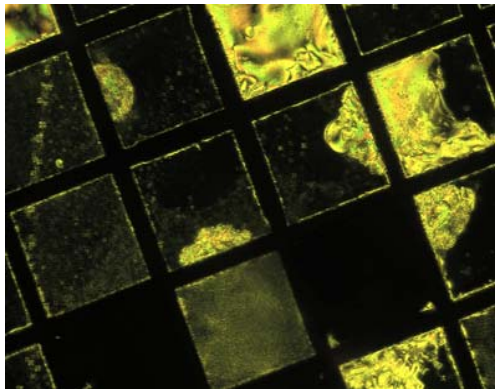
Contact Sheff Baker, MS&E, Cornell University, shefford.baker@cornell.edu

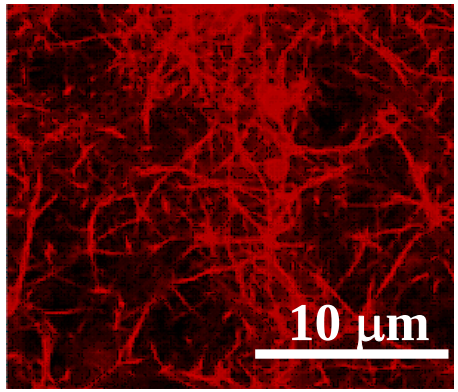
Or google NISE Network for more information

Some New DMR Activities

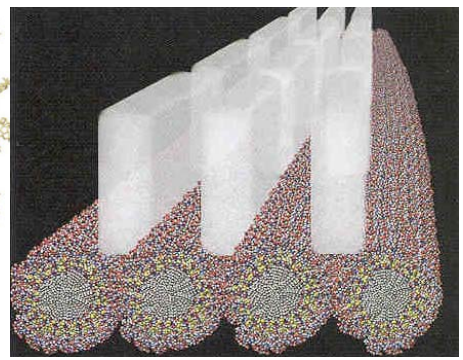
- Biomaterials Program
- Partnerships for Research and Education in Materials (PREM)
- Mid-Scale Instrumentation (IMR-MIP)
- Materials World Network

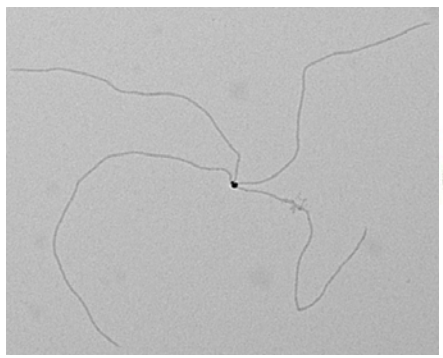
"Strange Matter" at Liberty Science Center

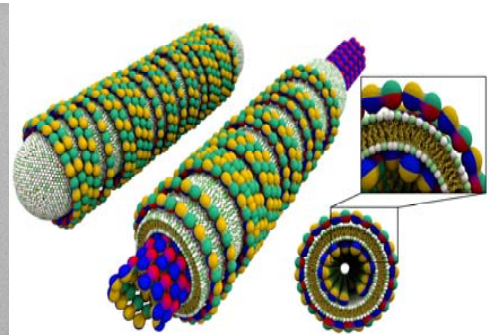




Biomaterials is an increasingly important area for DMR – we plan to provide a clear focus for individual investigator and small group research







Interfaces between Materials and Biology / Bioengineering

New DMR Program in Biomaterials planned for FY 2007

Acting Program Director – David Nelson – dnelson@nsf.gov

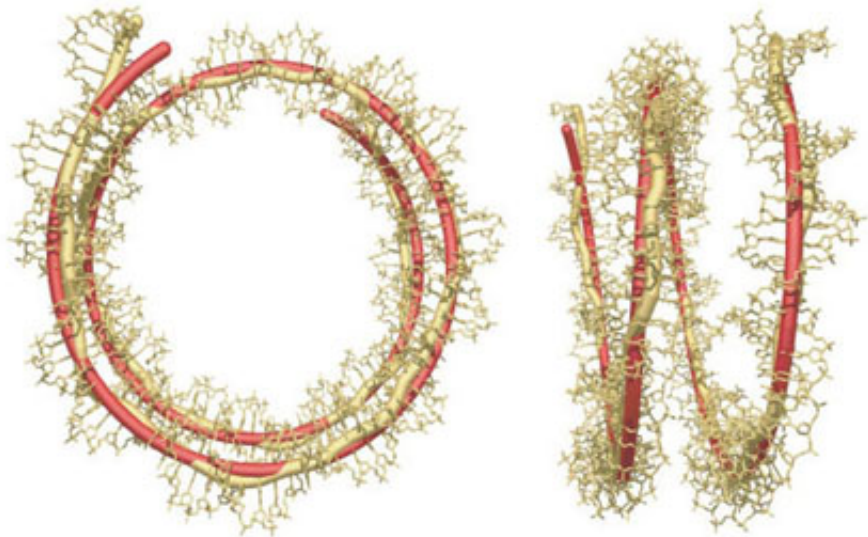
Recruiting for Program Director to start October 2006

The study of biologically-related materials and phenomena, including biological pathways to new materials. Materials and systems of interest include biomolecules, biomolecular assemblies, biomolecular systems (vesicles, membranes, and various other assemblies and networks of biomolecules), and biomimetic, bioinspired, or biocompatible materials. The methods of materials research may be applied to biological systems to discover or understand phenomena and to create or optimize materials.

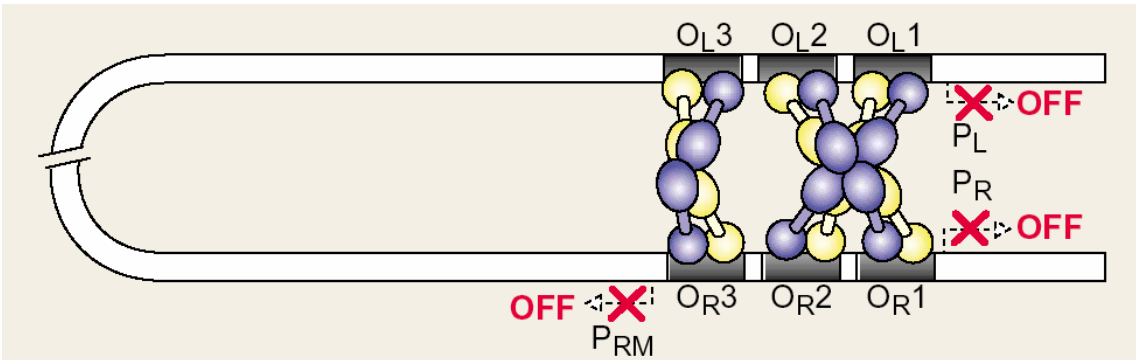
Entropic Forces in Single-Biomolecule Mechanics,

Philip Nelson, University of Pennsylvania, DMR-0404674

Kink formation has recently been documented in a number of protein-DNA complexes, for example the nucleosome core particle (right). For clarity, the proteins making up the core are not shown; only the DNA, with its kinked axis (gold), is shown, compared with the prediction of a simple elastic-rod model (red). [Richmond and Davey,Nature 423 (2003)]



Kink formation can have a significant impact on the ability of DNA to form regulatory loops. For example, physical measurements are starting to document loop formation in the lambda phage regulatory switch system (right). [Hochschild Curr Biol 12(2002)]

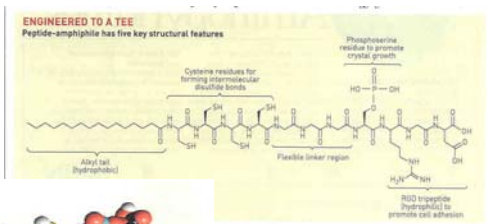


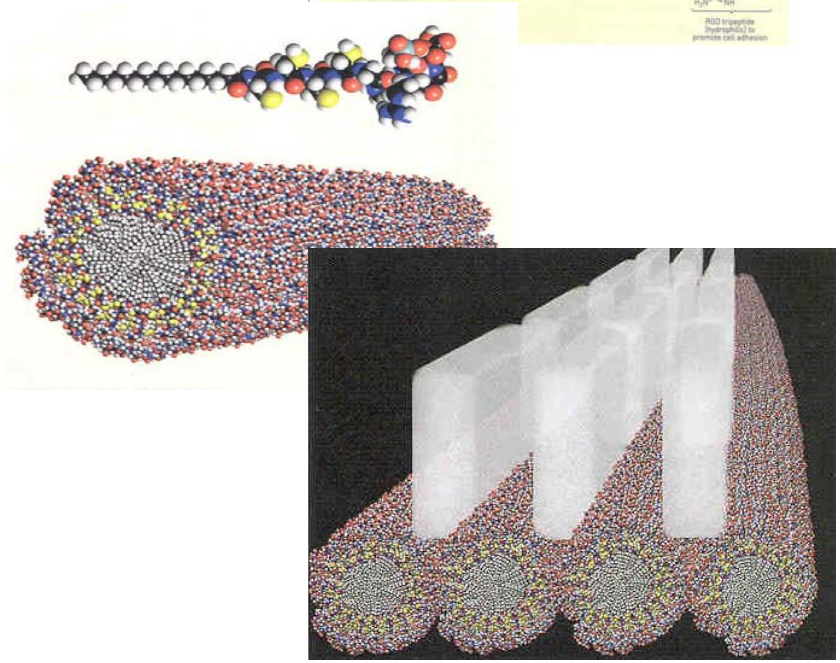
SELF-ASSEMBLED BIOMATERIALS FOR BONE AND NERVE GROWTH

SCIENCE & TECHNOLOGY

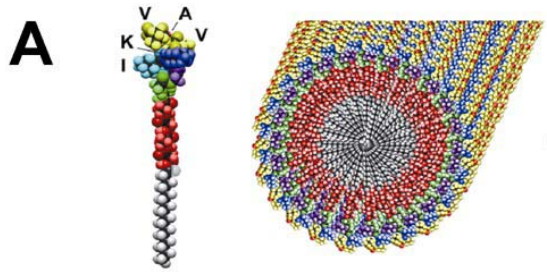
MIMICKING THE WAY NATURE GROWS BONE

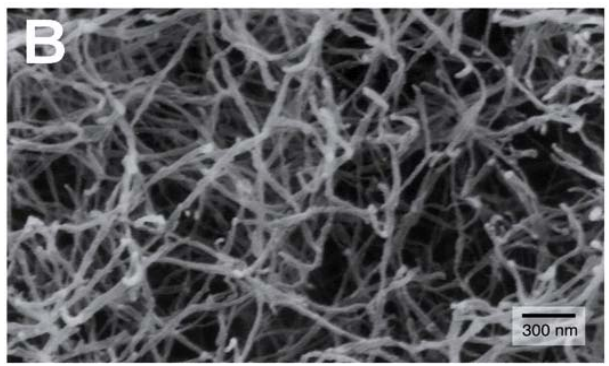
Exquisitely designed molecules assemble into nanofibers that promote the growth of mineral





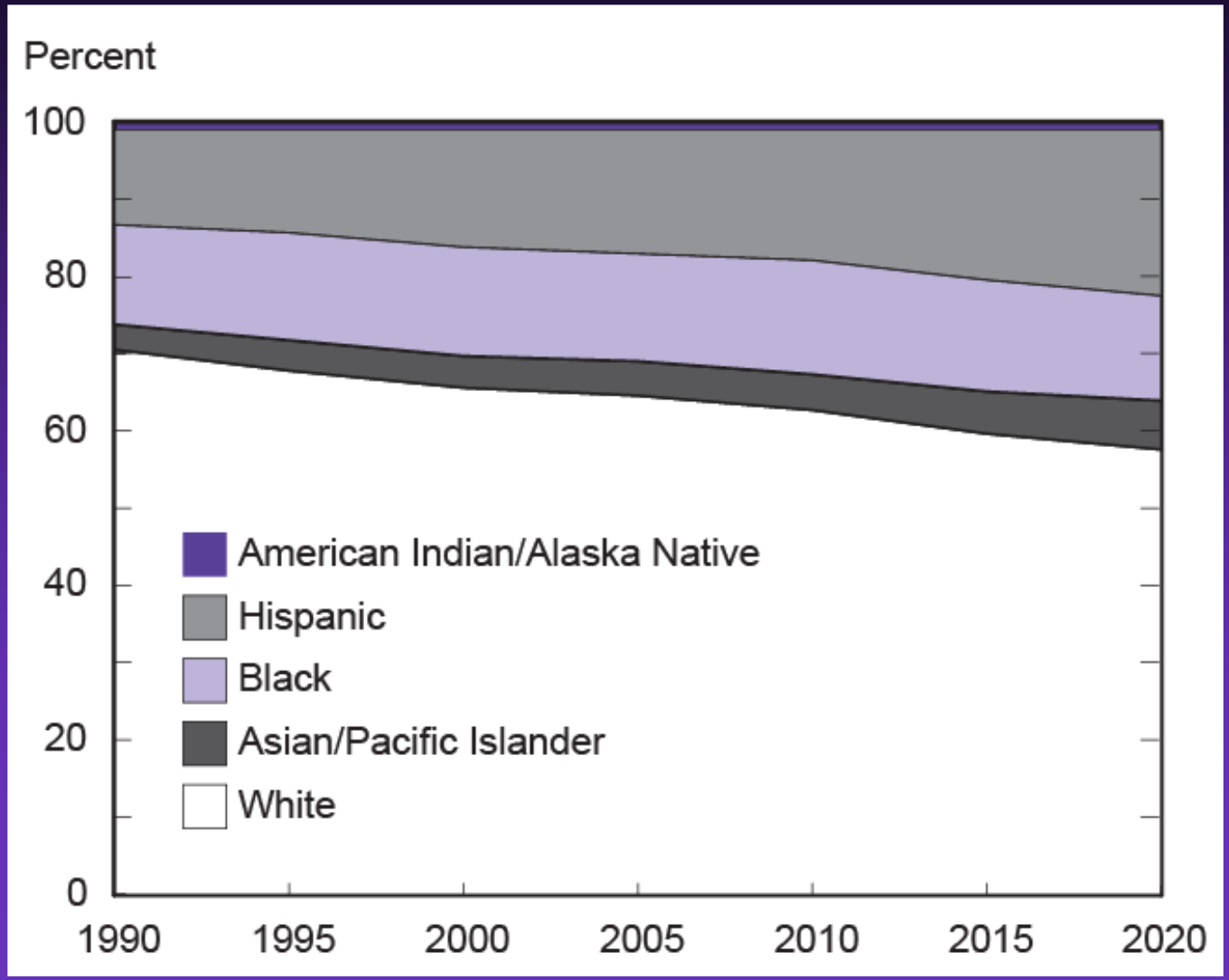
Sam Stupp (Northwestern U.)





Science 303, 1253 (2004)

Composition of U.S. college-age cohort: 1990–2020



SOURCE: National Science Board, *Science and Engineering Indicators 2006*

Partnerships for Research and Education in Materials (PREM)

www.mrsec.org/prem

….broaden participation in materials research and education by stimulating the development of *long-term, collaborative partnerships between minority institutions and DMR-supported groups, centers and facilities*

- **Awards to minority institutions**
- **Up to $750K/year for 5 years**
- **4 awards in FY04**
  - ***CSULA** (Cal Tech MRSEC)*
  - ***FAMU** (Carnegie-Mellon MRSEC)*
  - ***UPR Humacao** (Penn MRSEC)*
  - ***UPR Mayaguez** (Wisconsin MRSEC and NIRT)*
- ***FY06 competition – up to 6 new awards***

Summer 04 - UPR Mayaguez PREM

- **DMR contacts**

Dr. Maija Kukla – mkukla@nsf.gov
Dr. Thomas Rieker – trieker@nsf.gov

New DMR Program began FY04

NSF 05-513 (updated)

Mid-Scale Instrumentation Projects (IMR-MIP)

Instrumentation for Materials Research

- **~$2M - $20M per instrument**
  e.g. beamline instrumentation, high-field magnets, etc.
- **2 types of proposals**
  - Conceptual & Engineering Design
  - Construction
- **6 CED awards made to date**
- **FY 06 competition currently underway**

DMR contact Dr. G.X. Tessema – gtessema@nsf.gov

Separate competition for IMR (Instrument Development) also planned for FY 2007

International Activities in Materials

DMR Office of Special Programs
Dr. Carmen Huber – chuber@nsf.gov

The primary goal is to enhance international collaboration in materials research, education and technology

- A series of international (regional) workshops was held 1995-2004
- *NSF - **Materials World Network***
  - ***~50 awards since 2000. FY06 competition includes 50 international partner organizations – NSF 05-594***
- *NSF - **International Materials Institutes***
  - ***enhancing US-international collaboration via a network of (6) campus-based nodes***

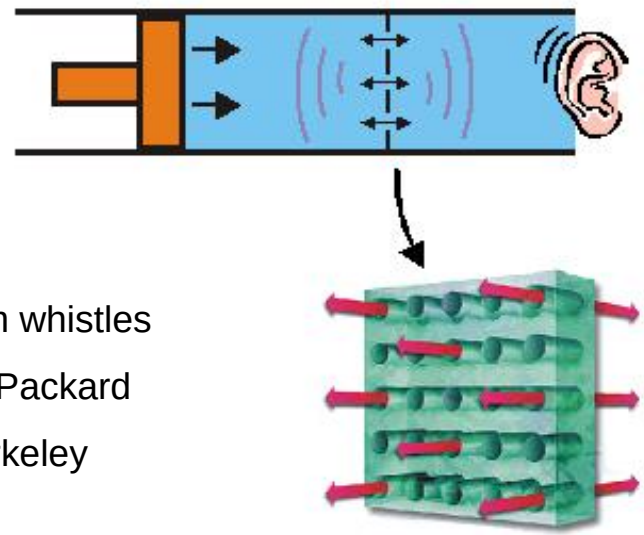
International Materials Institutes

Enhancing international cooperation in materials via a network of US nodes

- ***Princeton*** — ***US/Africa Materials Institute***
- ***U Tennessee*** — ***Neutron Scattering Network***
- ***Iowa State / Maryland/ Florida International University*** — ***Combinatorial Sciences / Materials Informatics***
- ***UC Santa Barbara*** — ***Functional Materials***
- ***U California*** — ***Complex Adaptive Matter (I^2CAM)***
- ***Lehigh / Penn State*** — ***New Functionality in Glass***

NSF Program Officer: Dr. Carmen Huber – chuber@nsf.gov

Materials Research – What's Next?

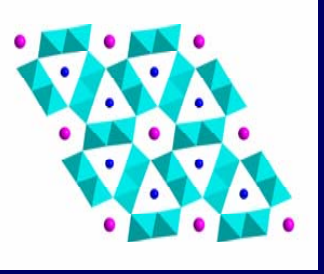


Quantum whistles

Richard Packard

UC - Berkeley

- **'Advancing the Frontier'**
  - **New physics – new phenomena**
  - **Transformational materials**
  - **Functional and engineering materials**
  - **Lots of stuff we haven't thought of yet…**
- **Nanoscale science and engineering – plenty of room at the bottom**
  - **surfaces and interfaces!**
  - **molecular electronics, self & directed assembly, fluctuations**
  - **spintronics, quantum science and engineering**
- **Cyberscience and cyberinfrastructure**
  - **It's a 2-way street**
  - **Computation needs physical foundations ("materials")**
  - **Computation advances condensed matter and materials research**



Ruthenate array

R. Cava, Princeton

Transformational Materials

New Phenomena, New Scientific Frontiers, New Technologies

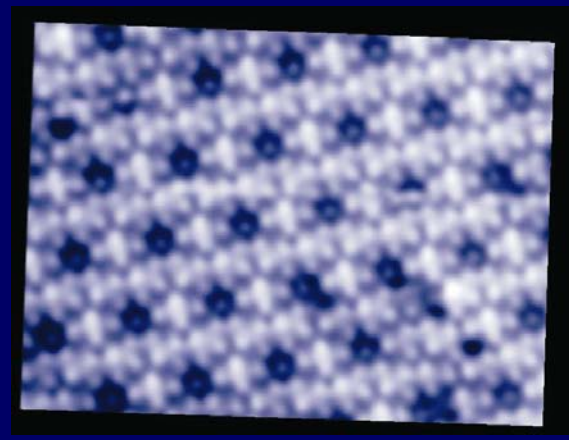
- **How do atoms and molecules become materials?**
- **Creating new materials and integrated materials structures to open new scientific frontiers and advance technology**

Opportunities

- **New Science - *consequences of new ways of ordering atoms!***
  - New principles of order and organization: materials, synthesis and structure
  - New materials => New “universes” for electrons
- **New Technologies**
  - Quantum computing, Spintronics, Multiferroics, Next Generation Electronics, Sensors, Atomtronics ...

Why Now?

- Capitalize on new discoveries and advances in theory, modeling, instrumentation, and new synthetic tools
- Basis for new technologies that meet national and global needs - Energy, Environment, Health, Communications, Transportation…



Self-assembled 2-D Kondo Lattice
Smith, Hla, Sandler, Ulloa – Ohio University

Materials Research – What's Next?

Photonic band-gap mirror fibers -

Joel Fink

MIT MRSEC

- **Frontier with bio – learning from nature**
  - **bio-inspired, biomimetic, and biomolecular materials; condensed-matter bio…**
- **Instrumentation and facilities**
  - **Instrument development**
  - **Mid-scale projects**
  - **Role in major facilities – high magnetic fields, neutrons, light sources**
- **International collaboration**
  - **towards a *Materials World Network***
- **People and education**
  - **Next generation of researchers – disciplinary and interdisciplinary**
  - **Research experience for undergraduates, teachers, pre-college…**
  - **Materials as hands-on learning**
- **We MUST broaden participation in materials research!**

Research grants:
The nightmare before funding

Nature 437

15 September 2005

Asked to name one thing they hate about their jobs, many scientists say grant applications. *Nature*'s reporters have asked researchers just why the process is so frustrating, and what can be done to improve matters.

National Science Foundation
DIRECTORATE FOR
Mathematical & Physical Sciences (MPS)

SEARCH
NSF Web Site

Materials Research (DMR)

Programs and Funding Opportunities

Key: C Crosscutting | N NSF-wide

Ceramics

Condensed Matter Physics

Electronic Materials

Instrumentation for Materials Research
- Instrumentation for Materials Research - Major Instrumentation Projects

Materials Research Science and Engineering Centers C
- Partnerships for Research and Education in Materials

Materials Theory

Metals

National Facilities

Finally

Combining microelectronics with optical fibers – John Badding et al, Penn State – Science, 17 March 06

- ***The next DMR Submission Window for <u>Unsolicited</u> Proposals is 18 Sept – 3 Nov 2006***
- ***Look for CAREER, MRI, IMR and Materials World Network solicitations***
- **Contact us *before* you send us a proposal**
- **Volunteer as a reviewer or panelist**
- **Current Vacancies for DMR Program Directors – see DMR web page**
  - **Biomaterials**
  - **Condensed Matter and Materials Theory**
  - **Ceramics**
- **“Nuggets” – tell us about your achievements!**

Thank you!

http://www.nsf.gov/materials

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