The NSF and the Structural Materials and Mechanics (SMM) Program

Lawrence C. Bank
Structural Materials and Mechanics

NATIONAL SCIENCE FOUNDATION

Outline

- NSF Mission and Vision
- Organization
- Budget Trends
- Current NSF Initiatives
- Proposal writing and review process
- Examples of Current Awards

NSF – Where Discoveries Begin

Mission – *Encourage & develop a national policy for the promotion of basic research and education in the math, physical, medical, biological, engineering and other sciences*

(NSF Act of 1950)

Vision – *Advancing discovery, innovation and education beyond the frontiers of current knowledge, and empowering future generations in science and engineering*

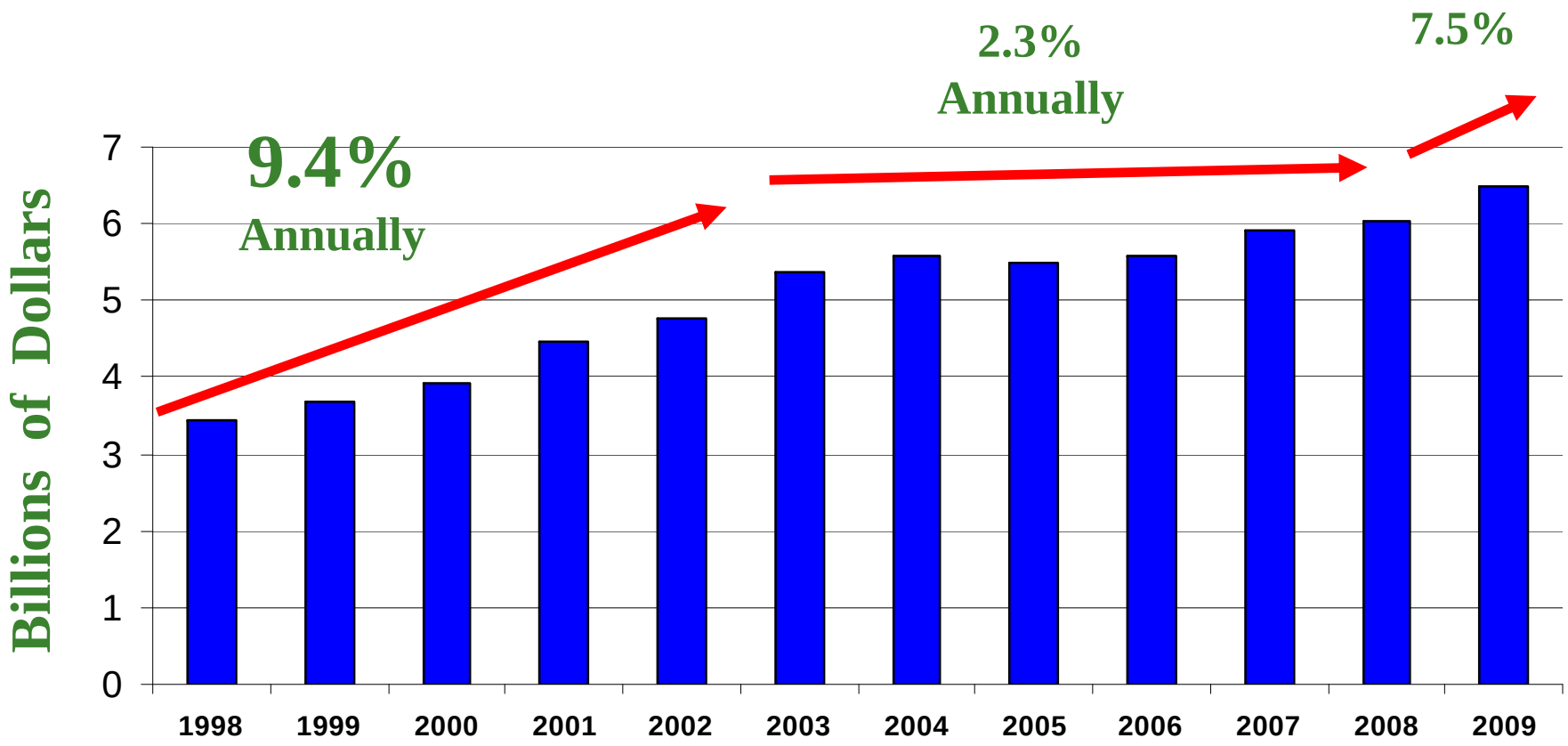
(NSF 06-48 Strategic Plan 2006-2011).

National Science Foundation

- Directorates
  - Biological Sciences (BIO)
  - Computer and Information Science and Engineering (CISE)
  - Education and Human Resources (EHR)
  - **Engineering (ENG)**
  - Geosciences (GEO)
  - Mathematical and Physical Sciences (MPS)
  - Social Behavioral and Economic Sciences (SBE)

- Offices
  - Office of Cyberinfrastructure (OCI)
  - Office of International Science and Engineering (OISE)
  - Office of Polar Programs (OPP)
  - Office of Integrative Activities (OIA)

NSF – Budgets


9.4%
Annually
2.3%
Annually
7.5%
Billions of Dollars
0
1
2
3
4
5
6
7
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009

NSF 2009 Budget by Research Directorate

Dollars in Millions

Mathematical & Physical Sciences (MPS)	**$1,276**
Social, Behavioral & Economic Sciences (SBE)	**$242**
Computer & Information Science & Engineering (CISE)	**$575**
Geosciences (GEO)	**$808**
Engineering (ENG)	**$708**
Biological Sciences (BIO)	**$667**
Total Research and Research Admin	**$4,711**

FY 2009 Budget by ENG Division

Dollars in Millions

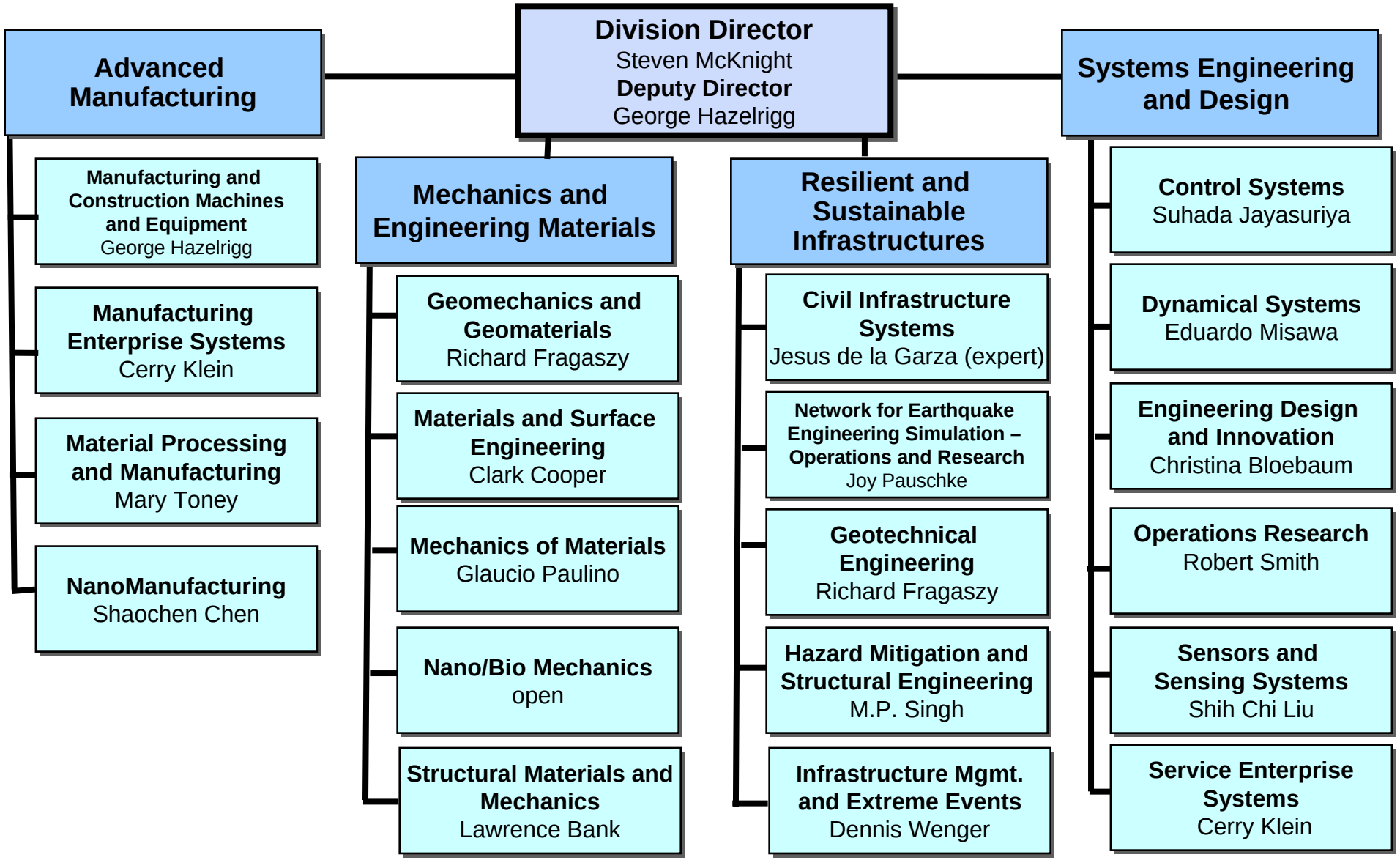
Electrical, Communications and Cyber Systems (ECCS)	**$93**
Chemical, Bioengineering, Environmental, and Transport Systems (CBET)	**$151**
Civil, Mechanical and Manufacturing Innovation (CMMI)	**$176**
Emerging Frontiers in Research and Innovation (EFRI)	**$27**
Engineering Education and Centers (EEC)	**$115**
Industrial Innovation and Partnerships (IIP)	**$141**
Grand Total	**$708**

Directorate for Engineering

Research and Education Themes

- Energy, Water and the Environment
- Complexity in Engineered and Natural Systems
- Cognitive Engineering: Intersection of Engineering and Cognitive Sciences
- Competitive Manufacturing and Service Enterprise
- Systems Nanotechnology

Civil, Mechanical, and Manufacturing Innovation (CMMI)



Funding Opportunities

- Individual projects
- Instrumentation
- Large-scale facilities
- Fellowships, traineeships, research assistantships, post-doctoral funding
- Centers
  - Research (e.g. ERC, STC, I/UCRC)
  - Science and engineering education
- Small Business Innovation
- International Collaboration
- Workshops, Conferences

Individual Program Projects

- Unsolicited Proposals
  - CMMI Division
    - Jan 15 to Feb 15
    - Sept 1 to Oct 1
  - CBET Division
    - Feb 1 to Mar 1
    - Aug 15 to Sept 15
  - ECCS Division
    - Jan 7 to Feb 7
    - Sept 7 to Oct 7

Specific Solicitations

- ADVANCE: Increasing the Participation of Women in Academic Science and Engineering Careers
- BRIGE: Broadening Participation Research Initiation Grants in Engineering
- GOALI: Grant Opportunities for Academic Liaison with Industry
- RET and REU (Research Experiences for Teachers, Undergraduates)

Specific Solicitations

- CDI: Cyber-Enabled Discovery and Innovation
  - **Letter of Intent**: Not required
  - **Preliminary Proposal**: November - December, 2009
  - **Full Proposal**: April – May, 2010
  - **Type I**: 2 PIs, 2 two graduate students; 3 yrs.
  - **Type II**: 3 PIs, 3 graduate students; 1-2 senior personnel, 4 yrs.
  - **Funds**: $26 M in FY 09
- EFRI: Emerging Frontiers in Research and Innovation
  - **Letter of Intent:** October 9, 2009
  - **Preliminary Proposal:** November 13, 2009
  - **Full Proposal:** March 31, 2010
  - **Funds**: $22-29 M in FY 09 (11 grants expected)

Cyber-Enabled Discovery and Innovation (CDI)

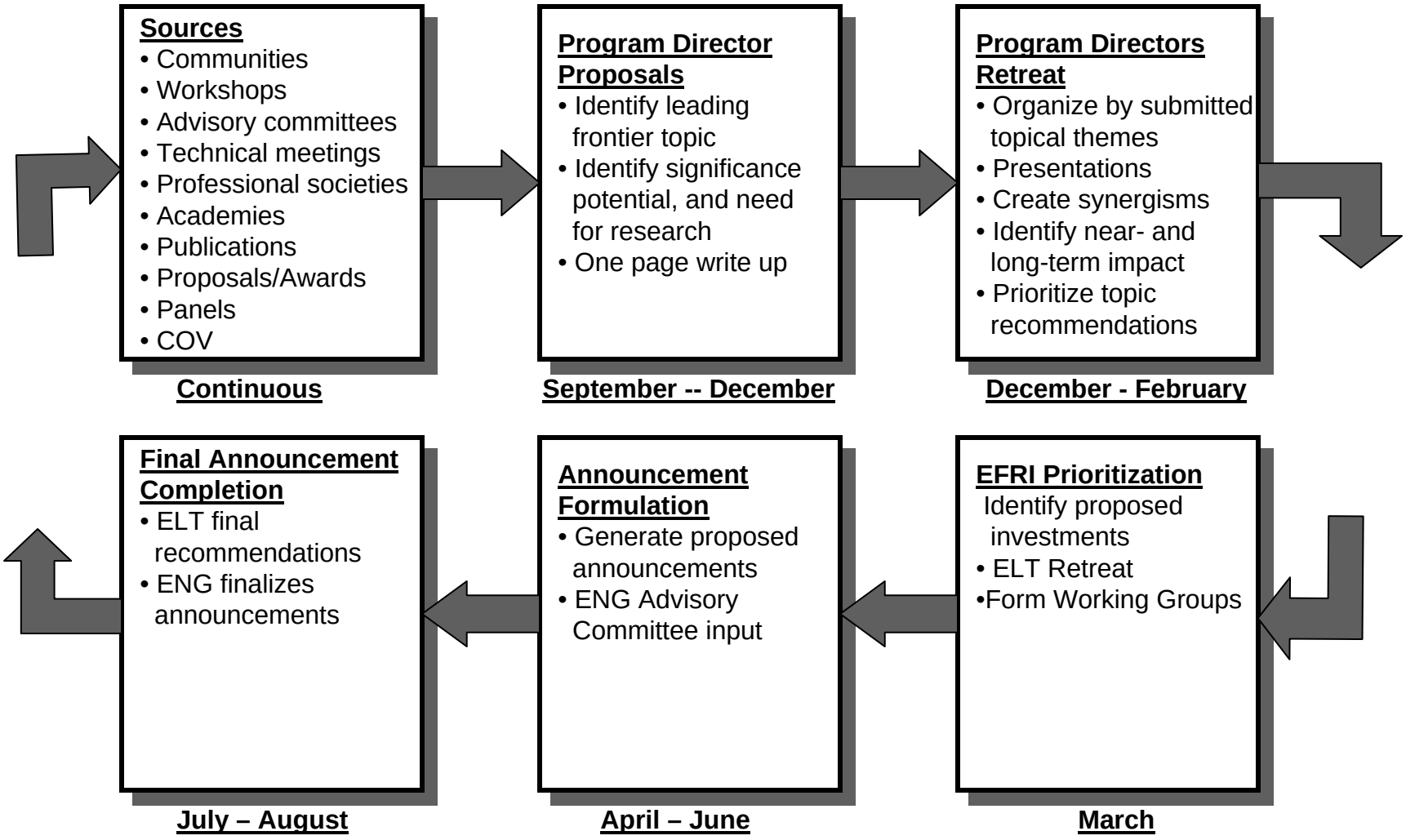
- five-year initiative to create revolutionary science and engineering research outcomes
- made possible by innovations and advances in computational thinking
- emphasis on bold, multidisciplinary activities
- radical, paradigm-changing science and engineering outcomes through computational thinking

Emerging Frontiers in Research and Innovation (EFRI) NSF 09-606

- Funding for interdisciplinary initiatives at the frontier of engineering research and education

- Transformative opportunities that lead to
  - New research areas for NSF, ENG and other agencies
  - New industries or capabilities for our country
  - Significant progress on a recognized national need

EFRI Annual Process



EFRI – Community Input

- **EFRI 2011 Topic Suggestions**
- DEADLINE: SEPTEMBER 15, 2009

  Dear Colleagues:

  The Office of Emerging Frontiers in Research and Innovation (EFRI) invites you to submit your suggestions for frontier ideas for possible consideration as topics for the FY 2011 EFRI Program Solicitation.
  http://www.nsf.gov/eng/efri/efri2011/

Emerging Frontiers in Research and Innovation (EFRI) – FY 2010

- **Renewable Energy Storage (RESTOR)**
- **Science in Energy and Environmental Design (SEED): Engineering Sustainable Buildings**

Science in Energy and Environmental Design (SEED): Engineering Sustainable Buildings

Emerging Frontiers in Research and Innovation (EFRI)
FY 2010 Solicitation

Introduction

1. **New and existing buildings have a significant impact on our economy, non-renewable resources, fossil fuels, and health.**

2. **Engineering and science research in building performance in US universities engineering schools is negligible.**

3. **Current initiatives in "High Performance Green Buildings" have a near-term focus (1-5 yrs) – this initiative takes a longer term view (10-20 yrs) and looks at systems level research on buildings.**

Key Idea

Breakthrough multidisciplinary engineering research is needed to move the building industry beyond the qualitative and prescriptive design philosophy of "Leadership in Energy and Environmental Design (LEED)" towards a quantitative and science-based design philosophy "Science in Energy and Environmental Design (SEED)" for sustainable green buildings.

Motivation – Critical National Need

1. Commercial and residential building construction constitutes $805 billion of our GDP (6.1% of $13.2 trillion).

2. According to the US Green Building Council/EPA, in the United States, buildings account for:

- 72% of electricity consumption,
- 39% of energy use,
- 38% of all carbon dioxide (CO_2) emissions,
- 40% of raw materials use,
- 30% of waste output (136 million tons annually),
- 14% of potable water consumption.

Transformative Characteristics

At present, the green building "movement" is focused on rating buildings using prescriptive metrics (LEED).

The engineering academic research and education community is not sufficiently involved in this movement. The current situation is inadequate to meet the future building performance objectives which requires a science-based approach.

Transformative Characteristics

The **three interrelated research thrusts for integrated** multidisciplinary science, engineering and systems research for innovative, transformative buildings research are:

- **Materials and Sensing**
- **Modeling and Simulation**
- **Concepts for Autonomy and Interdependence**

Research Thrusts

Materials and Sensing - New synthetic multifunctional materials and sensors for intelligent building envelopes; adaptive, phase-changing curtain walls; multifunctional glazing (optical, thermal and moisture transport); multifunctional flooring, ceilings, partitions walls; biodegradable building materials; self-cleaning materials; multifunctional utility networks (conduits, wires, cables, pipes, ducts, vents); water and waste reuse and recirculation; human-scale light sensing; intelligent motion and indoor-air-quality sensors; waste recycling; "cogeneration" capabilities for buildings, on-site energy production, harvesting and storage.

Research Thrusts

Modeling and Simulation - New interoperable computational platforms for simulation and animation of energy, power, air, water and occupant systems and the complex interactions between them; design integration with real-time monitoring and adaptive control; lean construction management and contracting models; building information modeling (BIM); life-cycle assessment (LCA); decision making visualization; design optimization; system dynamics (SD), agent-based modeling (ABM), and triple-bottom-line (economic, environmental, social) modeling; sociological and psychological modeling; productivity modeling.

Research Thrusts

Concepts for Autonomy and Interdependence - New engineering concepts and design paradigms for "off-grid" self-powering (local wind and solar energy harvesting and storage), self-ventilating, self-heating, self-cooling (natural ventilation, geothermal), self-hydrating (closed-loop water systems), self-sensing, super-insulated, climate-controlled buildings; reconfigurable systems for rapid construction, deconstruction, disassembly; reliability and resiliency; disaster recovery; reducing complexity of building subsystems; interaction of sustainable buildings and infrastructure systems.

Key Questions

QUESTION 1

How do we model and control, in real-time, the critical flows (e.g., energy, heat, water, light, sound, air and occupants) through the building materials and the building spaces?

QUESTION 2

How do we create new paradigms for designing, constructing, operating, maintaining, and retiring buildings that will minimize fossil fuel consumption and adverse environmental effects?

Possible Research Topics

1. **Materials that can change phase and transport properties on demand or autonomously.**

2. **Mathematical theories and computational algorithms to predict and control steady state and transient flows though adaptive building materials**

3. **Compressive sensing and distributed control systems to monitor and optimize energy usage and detect pollutants in real-time.**

4. **Methods for integrating analysis and design software for rapid information delivery to diverse stakeholders throughout the building life-cycle.**

Research Topics

5. **New concepts for buildings that are manufactured off-site, self-sustaining and autonomous.**

6. **Theories on energy-consumption patterns of building occupants as a function of their for socio-economic characteristics.**

7. **Rigorous, real-time, life-cycle assessment (LCA) methods that continuously optimize building performance as a function of key economic, environmental and social metrics.**

Management Plan

- $500k for 4 years = $2M each award
- 5-7 grants in 2010 ($10 - $14M)
- Min 3 co-PIs
- PI must be faculty member.
- Co-PIs - architect and engineer required.
- Co-PI from physical/biological/social sciences encouraged.

RENEWABLE ENERGY STORAGE (RESTOR)

NEED: Renewable sources, such as solar or wind, offer great promise for meeting future clean energy and environmental demands.

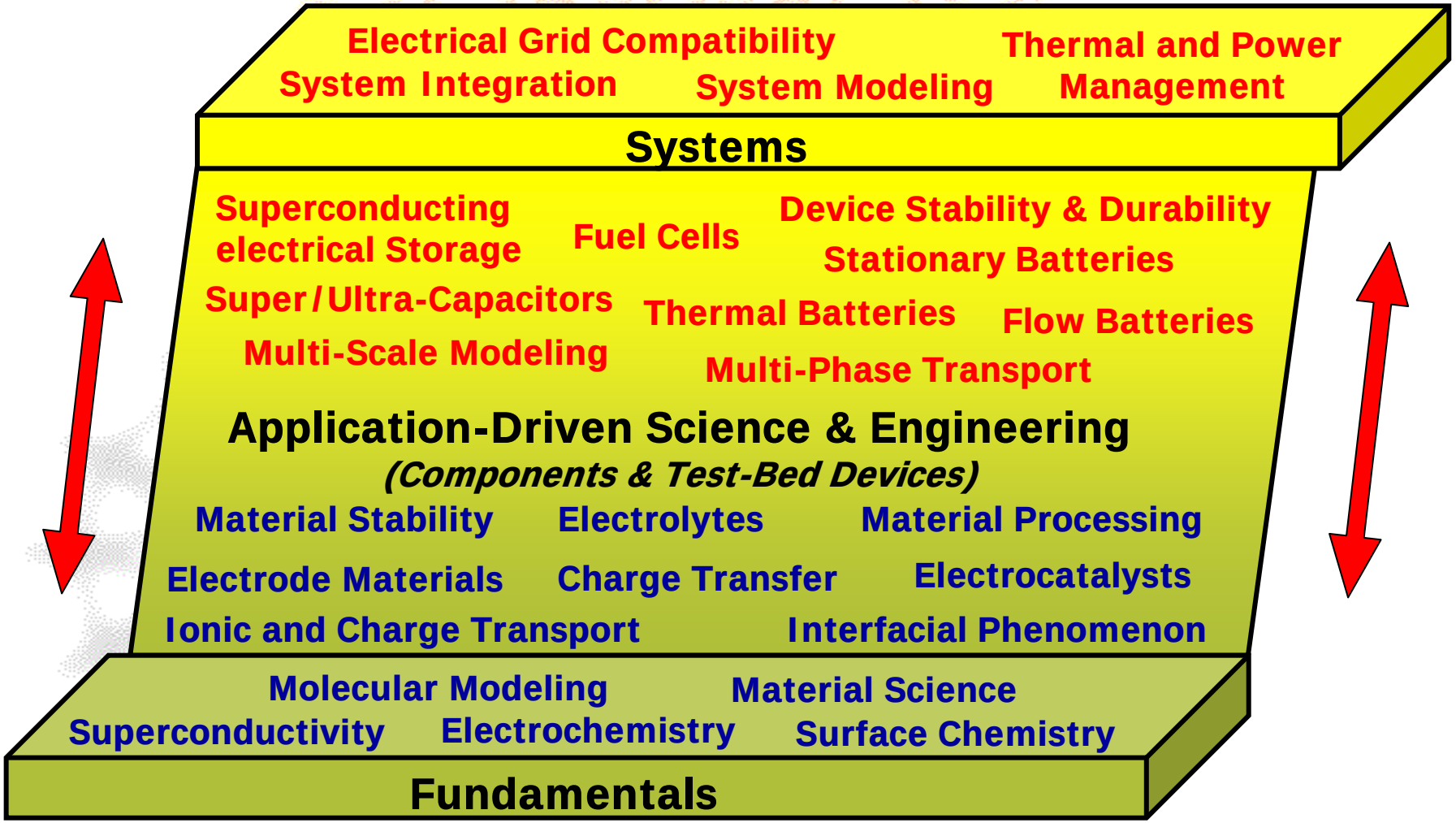
MAJOR ISSUE: These distributed energy sources require energy storage systems to regulate and smooth out their intermittent power generation

Transformational Aspect

- Need breakthroughs beyond current state-of-the-art

- Fundamental research needed for a transformative understanding of (a) Employing new electrode materials capable of multi-electron transfer, (b) Transport and reaction mechanisms, (c) Interrelated mechanisms of electron and ion transfer influencing material decomposition and energy conversion processes for large scale storage

RENEWABLE ENERGY STORAGE (RESTOR)



Structural Materials and Mechanics Program (PD 08-1635)

The SMM program supports fundamental research on the behavior of civil infrastructure materials and the mechanics of structural components in the built environment. Of particular interest is novel research on structural components consisting of natural and synthetic materials, their response to mechanical, hygrothermal and time-dependent loads, and their impact on life-cycle performance and sustainable development of the civil infrastructure.

Structural Materials and Mechanics Program (PD 08-1635)

- Program Funding Objectives:
  - Multifunctional and adaptive construction and building materials for the built environment.
  - Sustainable materials that reduce energy demands and reduce environmental and societal impacts of the built environment.
  - Optimized design of infrastructure materials that includes life-cycle assessment for specific infrastructure systems.

Structural Materials and Mechanics Program (PD 08-1635)

- **Opportunities and Strategic Directions for the Program:**
  - Adaptive energy-efficient building materials for building envelopes.
  - Multifunctional construction materials for Architectural, Mechanical, and Electrical systems.
  - Sustainable cementitious materials with reduced Portland cement content and increased recycled materials content.
  - Sustainable asphalt materials with reduced petroleum products and increase recycled materials content.

Unsolicited Proposals

- Up to three year duration
- Up to $100K per year
- One faculty summer month per year (total)
- One to two graduate students
- Travel funds to attend the CMMI Grantees Conference
- Other expenses

Structural Materials and Mechanics Program (PD 08-1635)

Annual budget of approximately $4.0 – 5.0 M

Approximately 60 current awards (standard 3 year awards)

1-2 ~$400,000 CAREER, 10-15 ~$300,000 Unsolicited, 5-10 ~$30,000 EAGERS, 3-4 ~$40,000Workshops, 10-15 $6,000 REUs

Oct 2007 – 36 proposals, 6 funded
Feb 2008 – 46 proposals, 8 funded
Oct 2008 – 43 proposals, 6 funded + 4 ARRA funded
Feb 2009 – 37 proposals, 6 funded + 1 ARRA CAREER

Success Rate: FY 08 = 17%; FY 09 = 20%; CAREER 09 = 23%

Peer Review Process

- Program director identifies reviewers
- Reviewers perform 9-12 proposal reviews
- Panelists come to NSF for 1-2 days to discuss and rank proposals
- Program director recommends proposals for funding
- Recommendation goes through the approval process
- PIs are notified

Review Criterion: Intellectual Merit
(Thinking - Contribution to "Self")

- How important is the proposed activity to advancing knowledge and understanding within its own field or across different fields?
- How well qualified is the proposer to conduct the project?
- To what extent does the proposed activity suggest and explore creative, original, or potentially transformative concepts?
- How well conceived and organized is the proposed activity?
- Is there sufficient access to resources?

Transformative Research

The term **transformative research** is being used to describe a range of endeavors which promise extraordinary outcomes, such as: revolutionizing entire disciplines; creating entirely new fields; or disrupting accepted theories and perspectives — in other words, those endeavors which have the potential to change the way we address challenges in science, engineering, and innovation.

Review Criterion: Broader Impacts (Enabling - Contribution to Society)

- How well does the activity advance discovery and understanding while promoting teaching, training and learning?
- How well does the activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)?
- To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks and partnerships?
- Will the results be disseminated broadly to enhance scientific and technological understanding?
- What may be the benefits of the proposed activity to society?

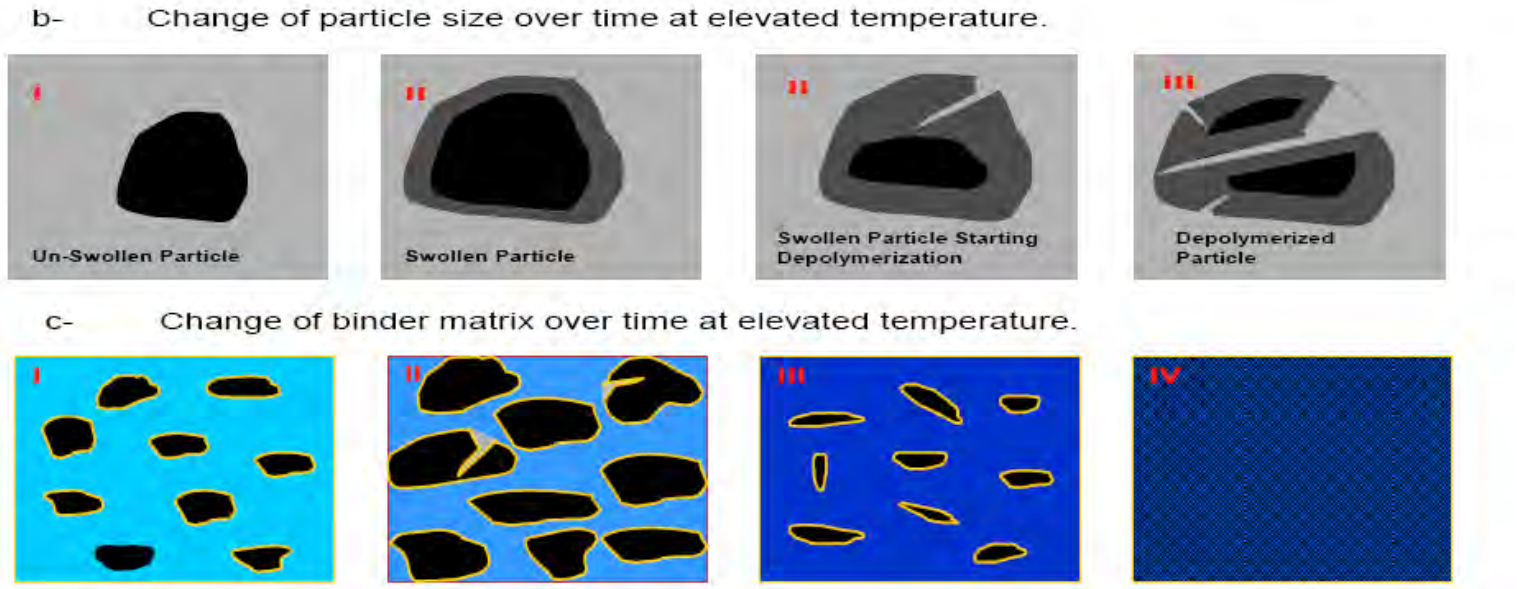
Structural Materials and Mechanics Program (PD 08-1635)

Examples of Current Funded Projects

Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0846861 CAREER: A Program of Research Focused on Understanding of Interaction of Recycled Materials with Asphalt, Outreach, Academic and Engineering Development

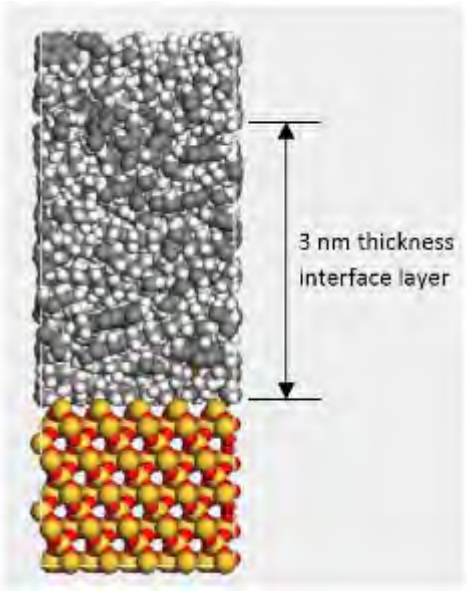
Magdy A. Abdelrahman, North Dakota State University Fargo

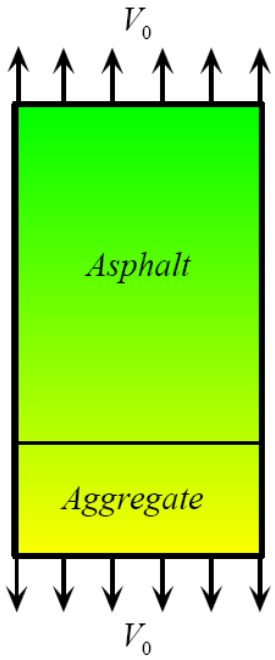


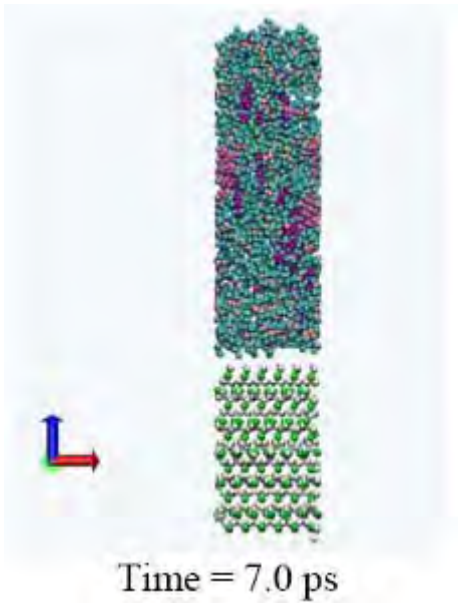
Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0625927 Unified Approach for Multiscale Characterization, Modeling, and Simulation for Stone-based Infrastructure Materials

Wang, Linbing, Virginia Polytechnic Institute and State University



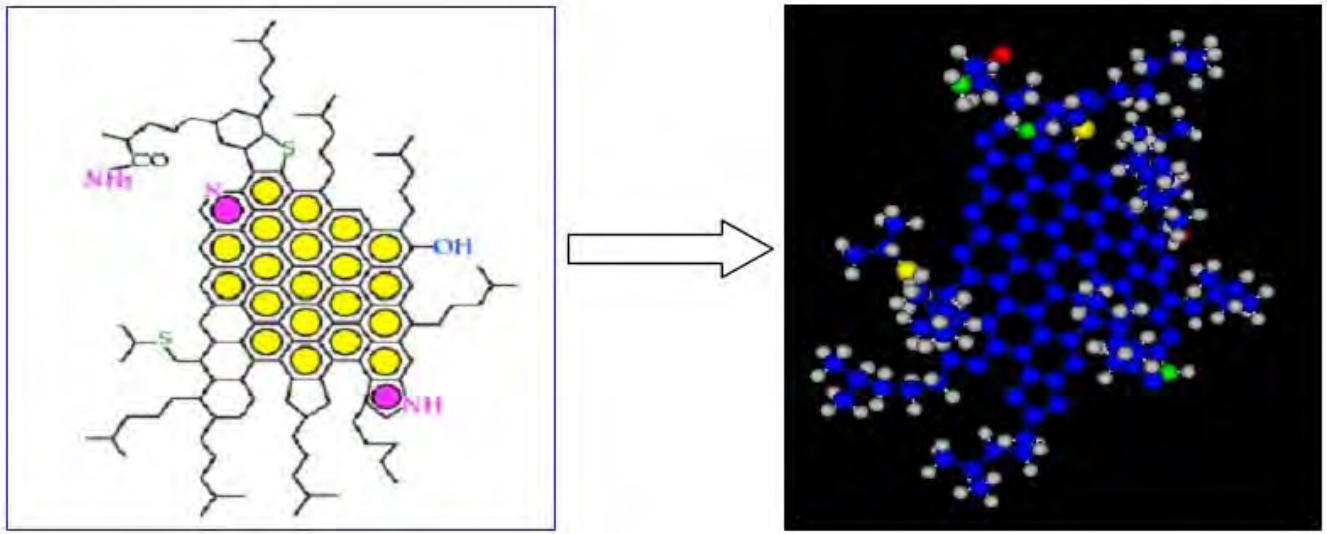




Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0900778 GOALI: Nanoscale Testing and Molecular Modeling of Aging in Asphalt.

Rafiqul A. Tarefder, University of New Mexico



(a) Asphalt Chemical Structure (b) Asphalt Molecular Structure

Figure 15. An all-atom molecular model of asphalt molecule

Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0856477 RUI: Self-sensing Concrete Pavement

Yu, Xun University of Minnesota Duluth

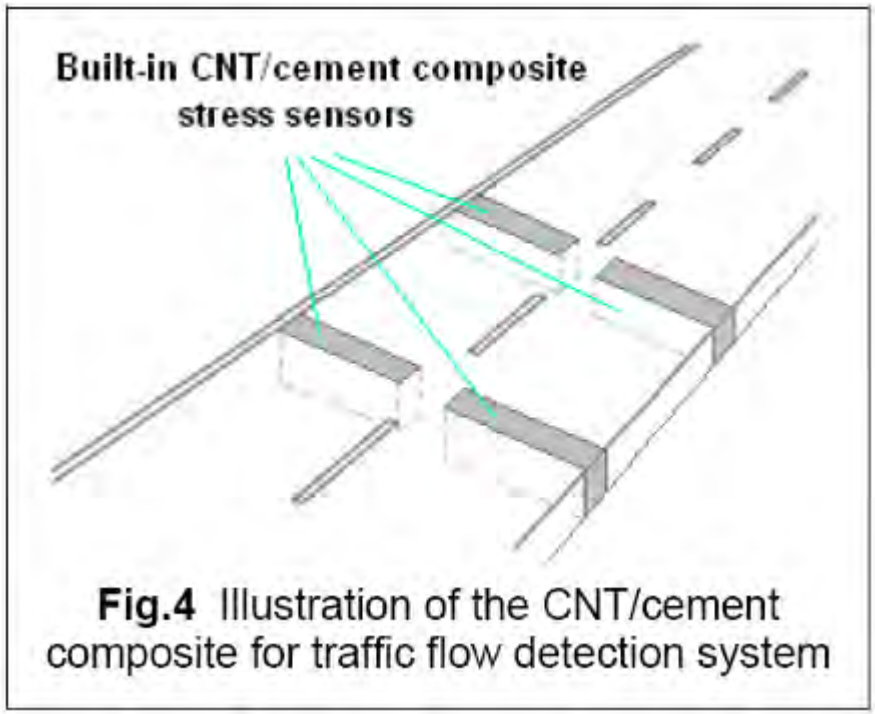


Fig.4 Illustration of the CNT/cement composite for traffic flow detection system

Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0843979 CAREER: Linking Nanoscale and Macroscale Viscoelastic Responses of Cementitious Materials

Zachary Grasley, Texas Engineering Experiment Station

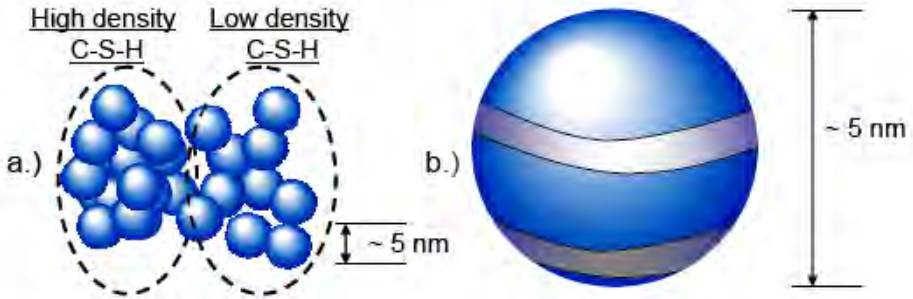


Figure 3. a. Colloidal structure of C-S-H globules depicting low-density and high-density packing. b. Single C-S-H globule indicating crystalline layers of silicate sheets with interlayer space [33-36].

Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0800805 Functionally Graded Concrete for The Civil Infrastructure - A Multifunctional Material System Approach

Roesler, Jeffery R., University of Illinois at Urbana-Champaign

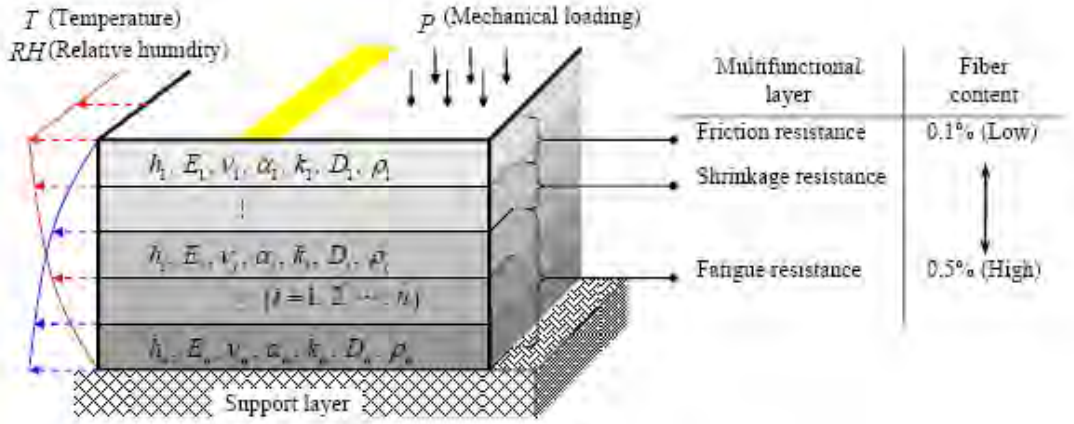
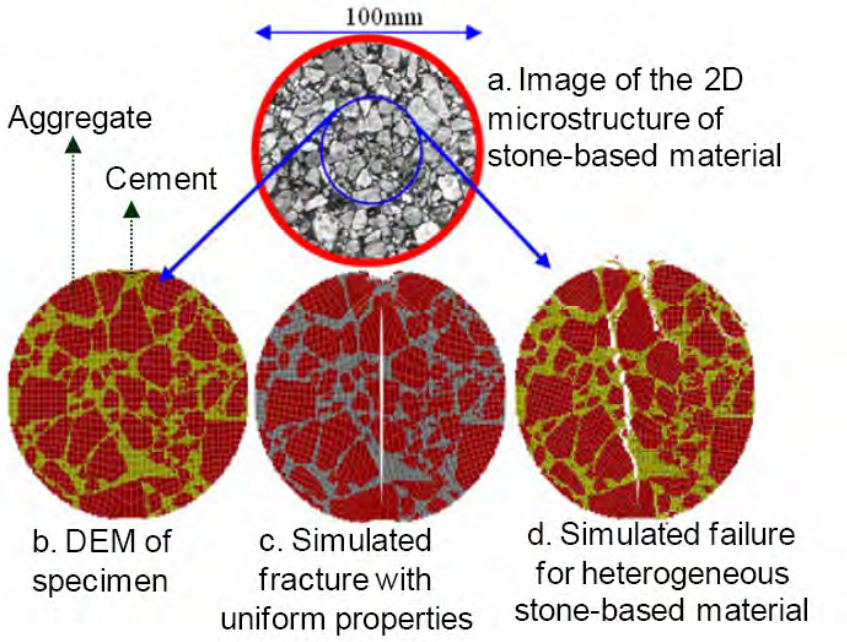


Figure 1. Schematic illustration of multifunctional and functionally graded concrete material (FGCM) under temperature (T), relative humidity (RH) and mechanical loading (P), where f_i =fiber type and volume content for layer i. Here h_i=layer thickness, E_i=elastic modulus, υ_i=Poisson's ratio, α_i=coefficient of thermal expansion D_i=diffusivity coefficient, k_i=thermal conductivity, and ρ_i=layer density

Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0900015 Collaborative Research: Understanding Mechanism of Internal Frost-Induced Damage of Concrete from Microstructure Aspects

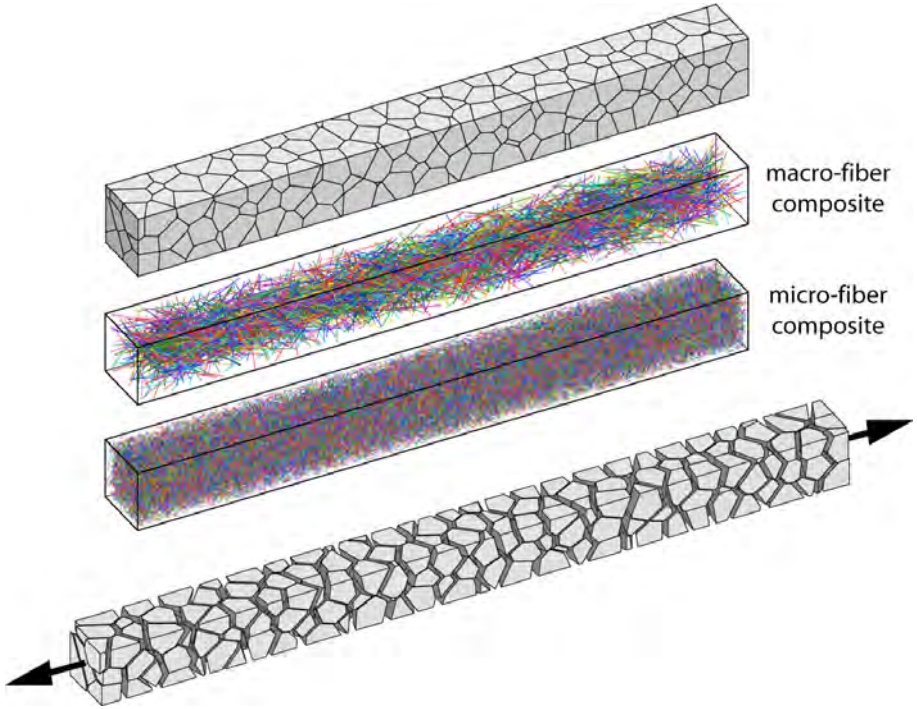
Dai, Qingli, Michigan Technological University; Yu, Xiong, Case Western Reserve University



Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0625593 Collaborative Research: An Integrated Microstructure-Based Approach to Property Prediction for Cement-Based Materials

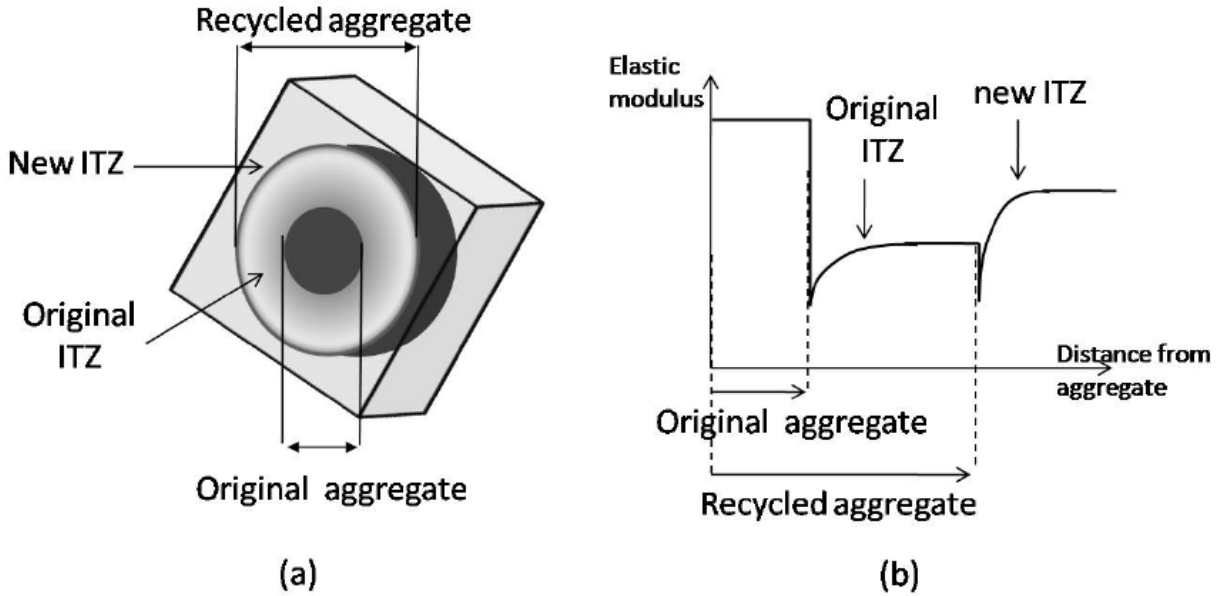
Bolander, John E., University of California-Davis; Landis, Eric N., University of Maine



Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0900607 Experimental Study and Theoretical Modeling of High Performance Recycled Aggregate Concrete

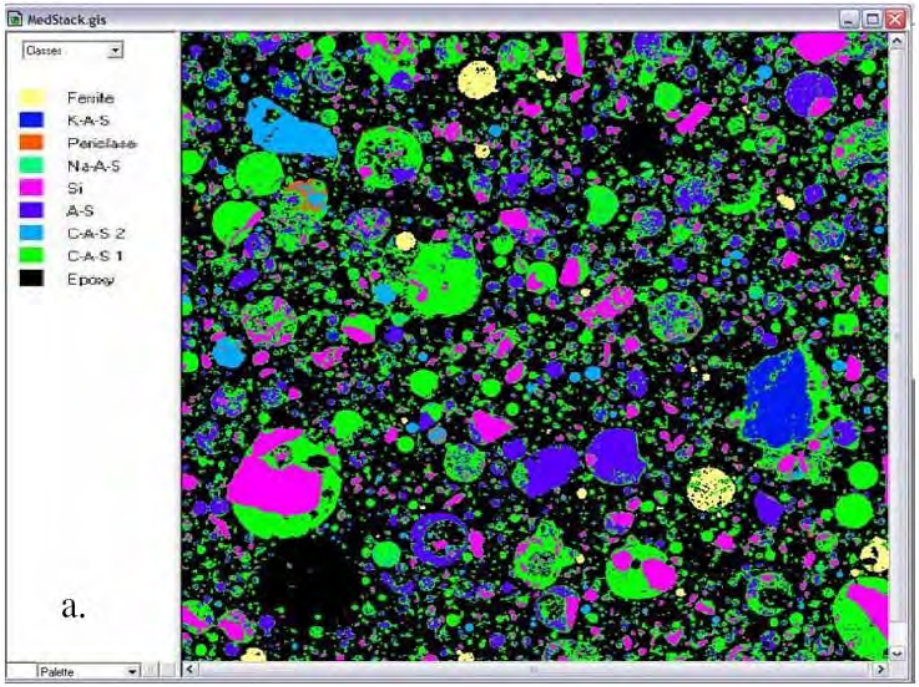
Vernerey, Franck J., University of Colorado at Boulder

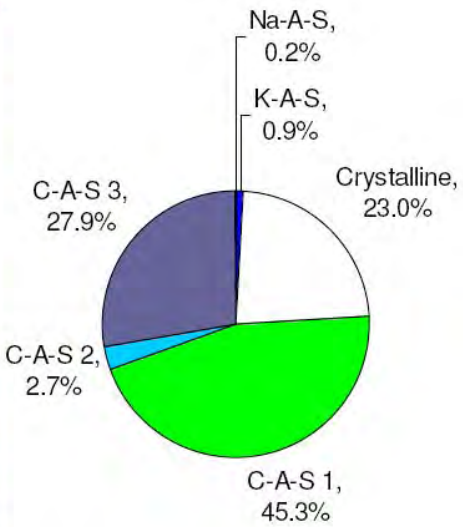


Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0926627 Inorganic Polymers for Sustainable Civil Infrastructure

Juenger, Maria G., University of Texas at Austin





Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0825373 Understanding the Structure and Durability of Nano-Anatase TiO_2 Cement-Based Materials

Kimberly E. Kurtis, Georgia Institute of Technology

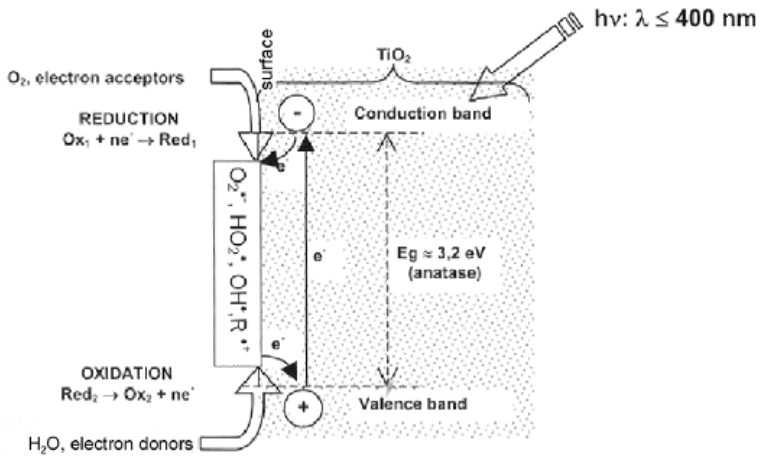


Figure 1 Schematic of the photocatalytic process, based upon [Hermann et al., 2007]

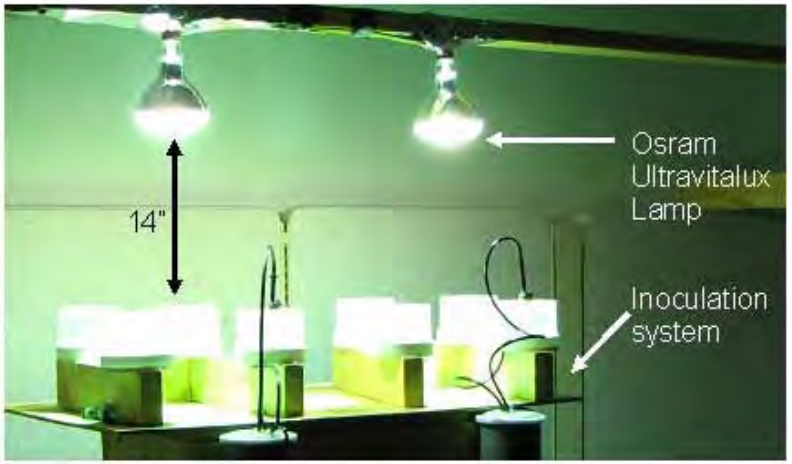


Figure 3 Photocatalytic test set-up developed by research team

Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0856325 Debonding in Bi-layer Material Systems under Moisture Effects : A Multi-scale Fracture Approach

Oral Buyukozturk, Massachusetts Institute of Technology

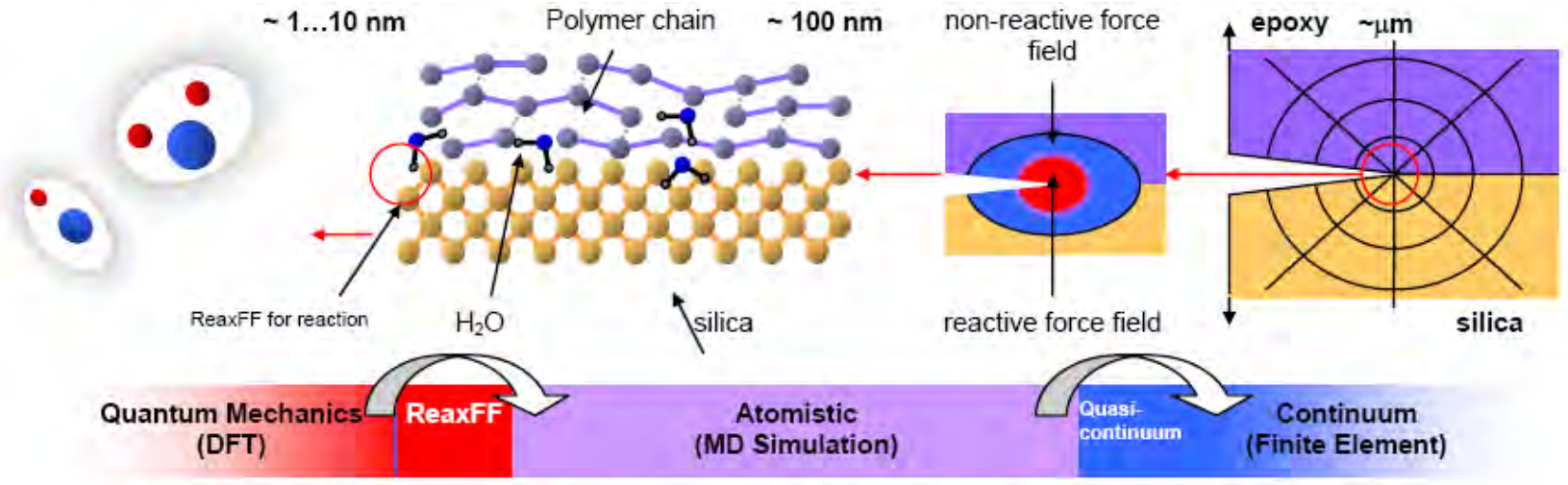


Figure 4: Multi-scale Simulation of Silica and Epoxy Bi-layer System under Moisture Effect

Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0928835 Hybrid Nanostructured Material Systems for Tailored Stress-Wave Mitigation of Impact and Blast Effects

Burgueno, Rigoberto, Michigan State University

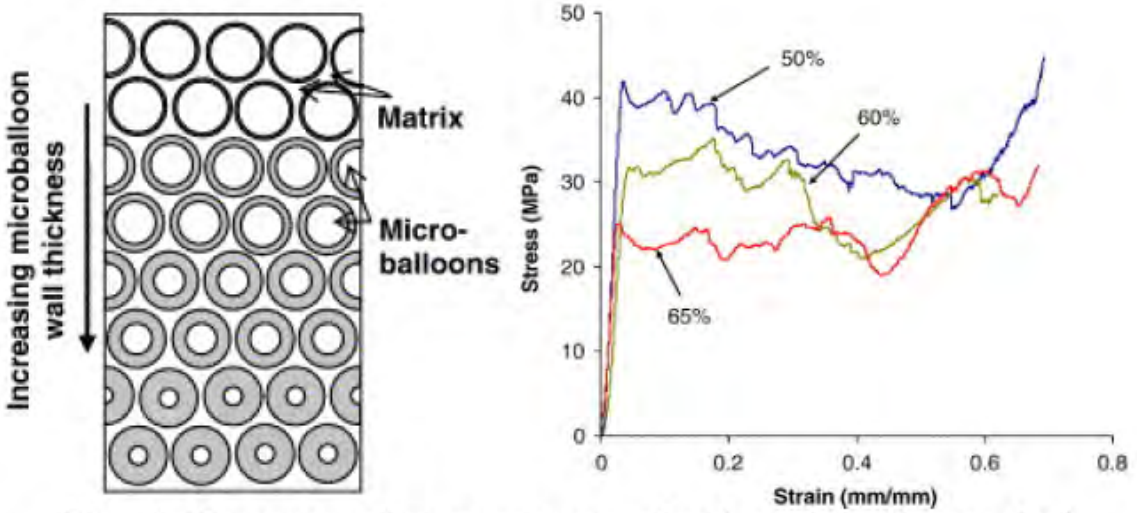
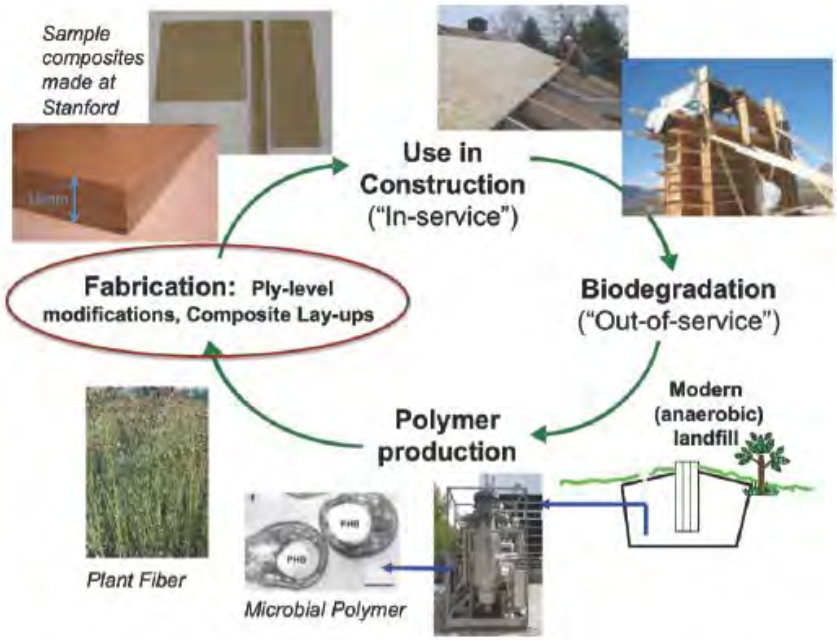


Fig. 4. Compressive response of a functionally graded syntactic foam [22]

Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0900325 Engineering Bio-based Composites for In-Service and Out-of-Service Performance.

Sarah L. Billington, Stanford University



Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0826265 Modeling the Design Limit States of Structural Composite Lumber

Clouston, Peggi L., University of Massachusetts Amherst

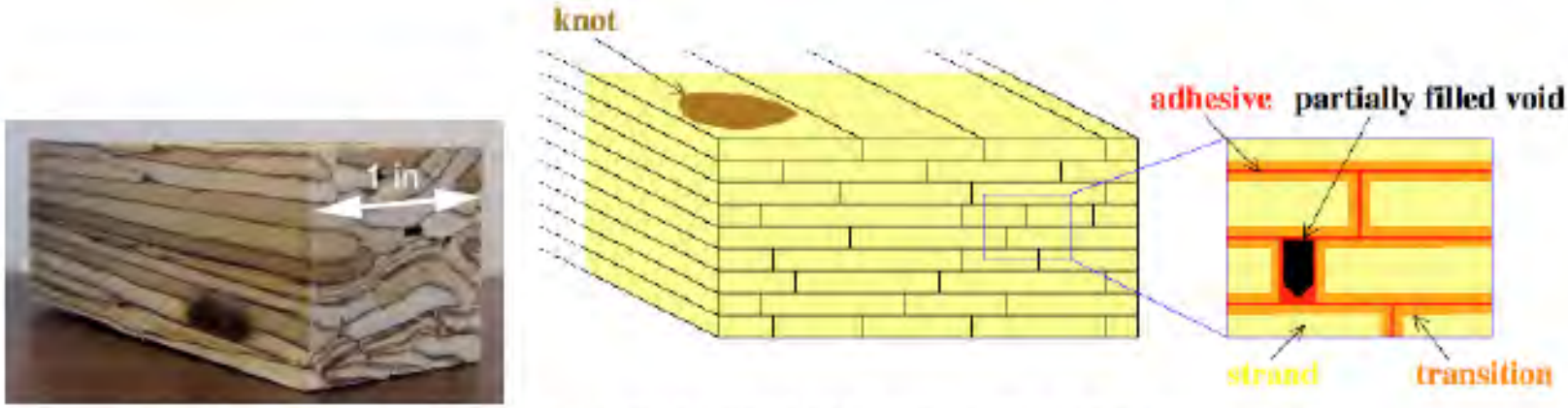


Fig. 4: PSL mesostructure and schematic of idealized SCL cross section showing strand, transition,adhesive, void, and knot phases.

Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0900486 Modeling of Natural Plant Materials to Enable Performance Evaluation of Environmentally Friendly Buildings

Jelena Srebric, Pennsylvania State Univ University Park

Figure 1: Photos of the PI's experimental setup
(a) the environmental chamber, and (b) a green roof sample

Structural Materials and Mechanics Program (PD 08-1635)

CMMI - 0900542 Energy-Efficient, Optoelectronic Smart Window Technology

Kanti Jain, University of Illinois at Urbana-Champaign

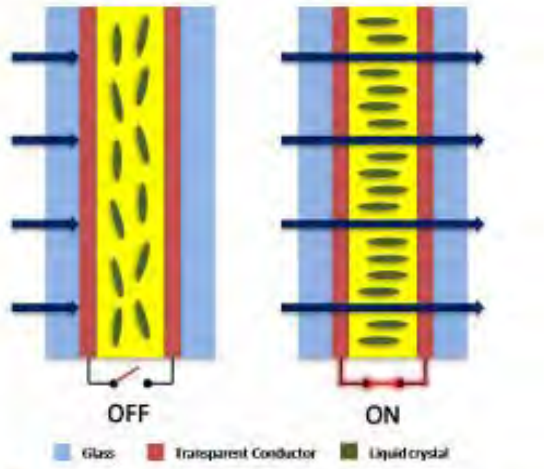


Fig. 3. The on and off states of a polymer dispersed liquid crystal (PDLC) window.

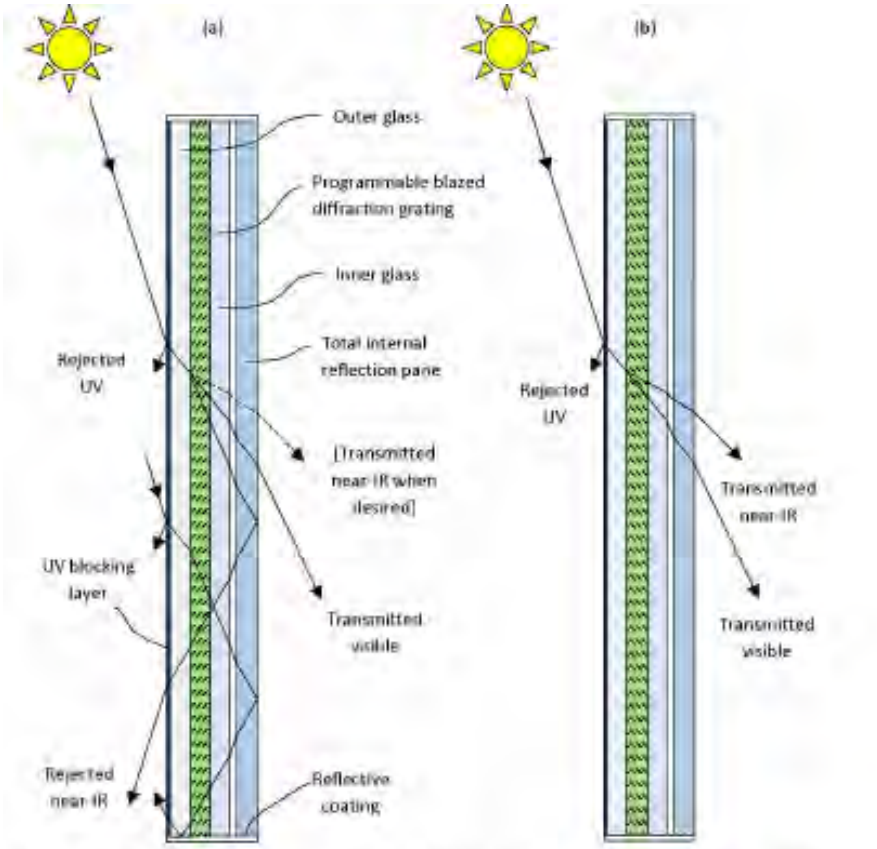
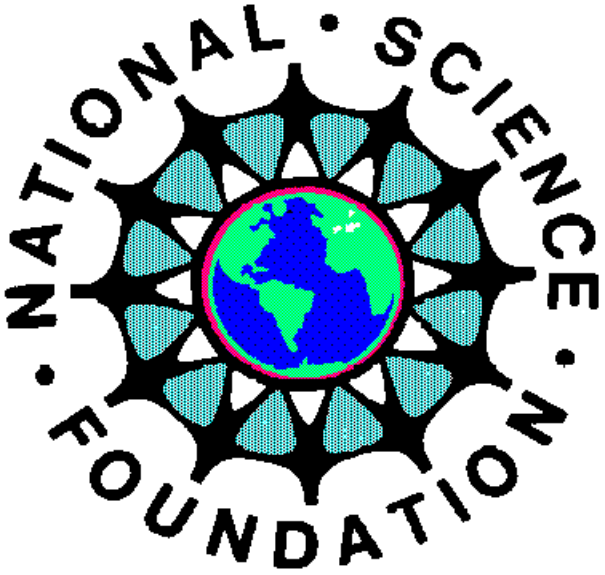


Fig. 5. Fig. 1. Dynamic, energy-efficient, optoelectronic smart window based on programmable blazed diffraction grating: (a) near IR radiation rejected, visible accepted; (b) both near IR and visible accepted.



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Larry Bank
lbank@nsf.gov
703-292-2162