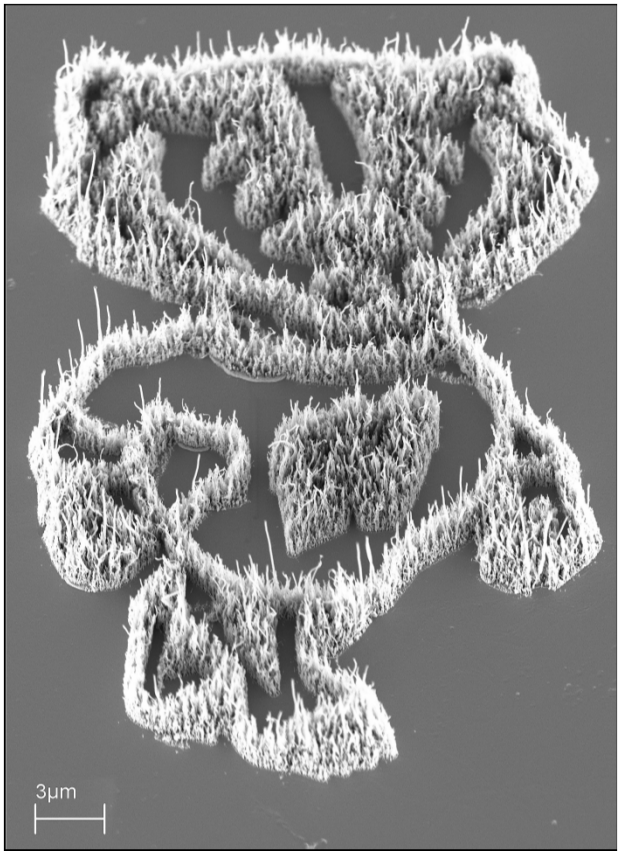
Nanoscale Science and Engineering Center
on
Templated Synthesis and Assembly at the Nanoscale

Padma Gopalan, Director
Robert Hamers, Associate Director
Paul F. Nealey, Founding Director

Reverse Site Visit for the Class of 2004 NSECs, June 10th, 2013

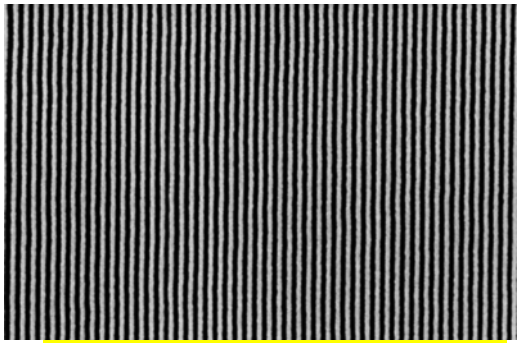
Mission

The University of Wisconsin Nanoscale Science and Engineering Center (NSEC) addresses grand challenges associated with directed assembly of nanoscale materials into functional systems and architectures through the use of self-assembly, chemical patterning, and external fields. Science-media-public interactions, and environmental health and safety research are integral components of the Center. The NSEC operates an ambitious and unique education and outreach program aimed at cultivating the next generation of nanoscale science and engineering experts with diverse and interdisciplinary backgrounds.

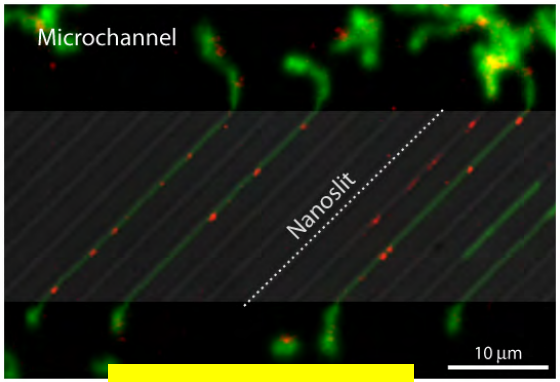


Vision of Outcomes

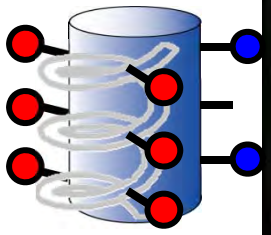
Foster transformative and interdisciplinary research in directed assembly to revolutionize nanomanufacturing and the discovery and control of new materials and material architectures. Investigate the interaction between science, the media, and the public, and incorporate societal and environmental implications into the research enterprise. Educate teachers, students, and the general public about and increase the diversity of participants in nanoscale science and engineering.

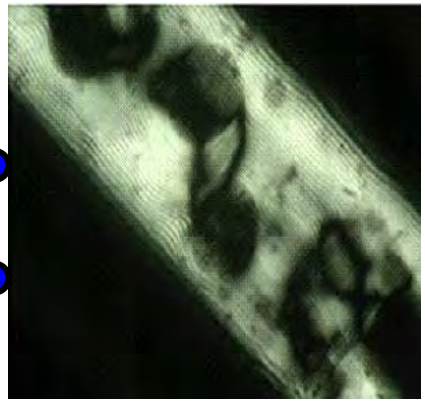


"material architectures"



"revolutionize"





"new materials"

SOCIAL SCIENCE

Science, New Media, and the Public

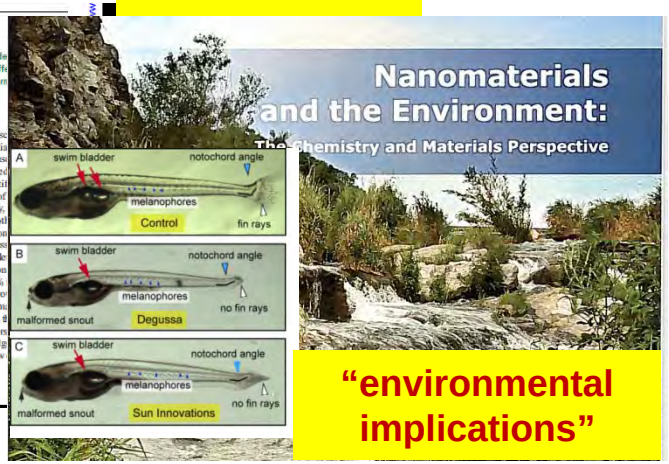
Dominique Brossard and Dietram A. Scheufele

Nine in 10 internet users in the United States turn to search engines to find information (1), and 60% of the U.S. public seeking information about specific scientific issues lists the Internet as their primary source of information (2). This has created a new urgency for scientists to pay attention to these trends and to the emerging scholarly literature about communicating science in this brave new "online" world.

Among the U.S. public, time spent on the World Wide Web has been linked to more positive attitudes toward science, even when controlling for use of traditional mass media such as newspapers and television (3). For instance, frequent Web users are more likely to report in surveys that they support basic scientific research even if it may not have immediate societal benefits. Research suggests that the availability of science news from the Internet may inform U.S. audiences with different educational backgrounds. In other words, online science sources may be helping to narrow knowledge gaps caused partly by science coverage in traditional media that tends to be tailored to highly educated audiences (4). Unfortunately, equivalent data for other countries is not available yet.

Recent communication research, however, has also identified at least three areas in which the new realities of an online information environment will increasingly force

"societal implications"



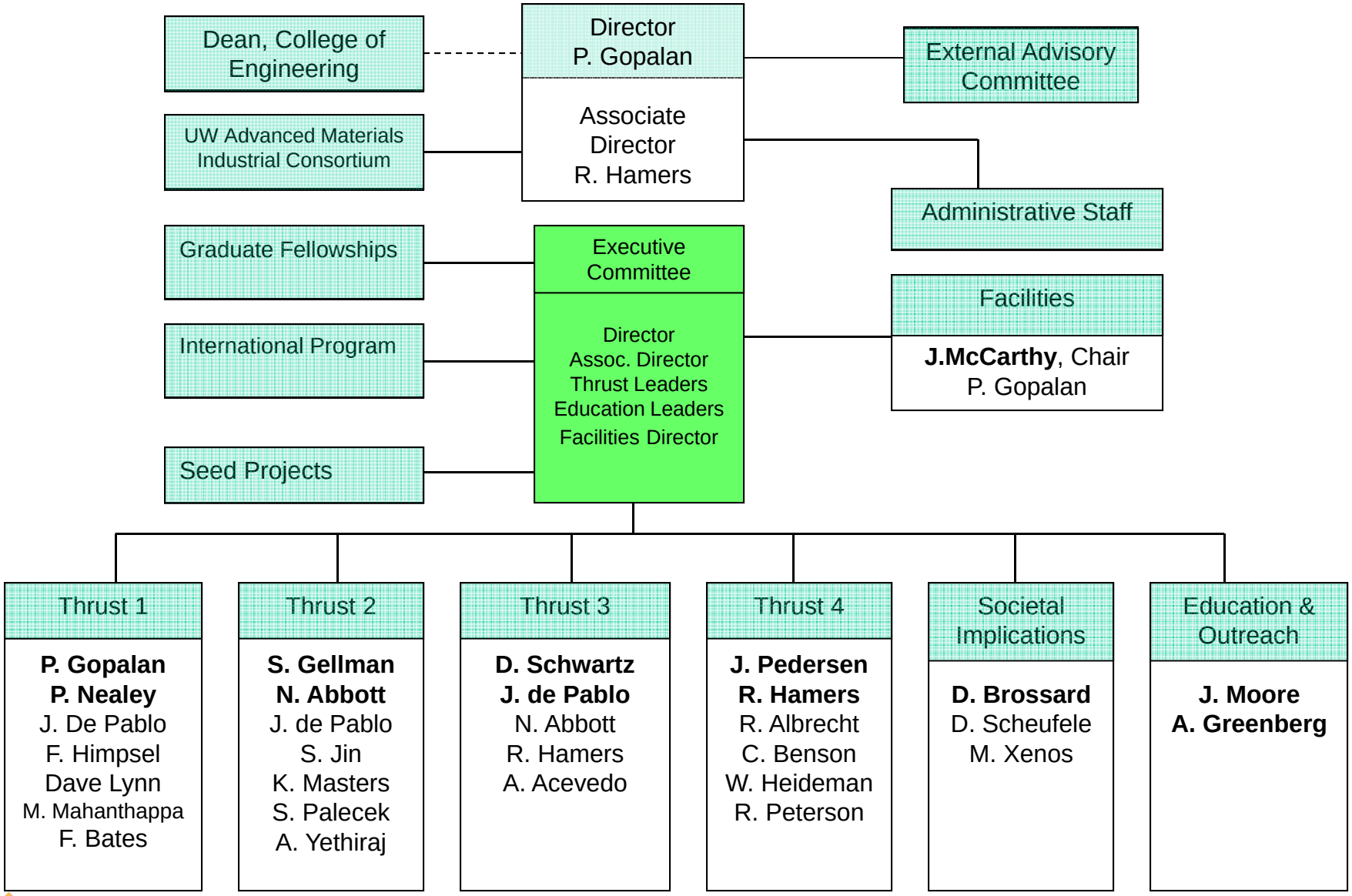
"environmental implications"

SCIEN*Count*Ers

"diversity"

University of Wisconsin-Madison NSEC Nanoscale Science & Engineering Center

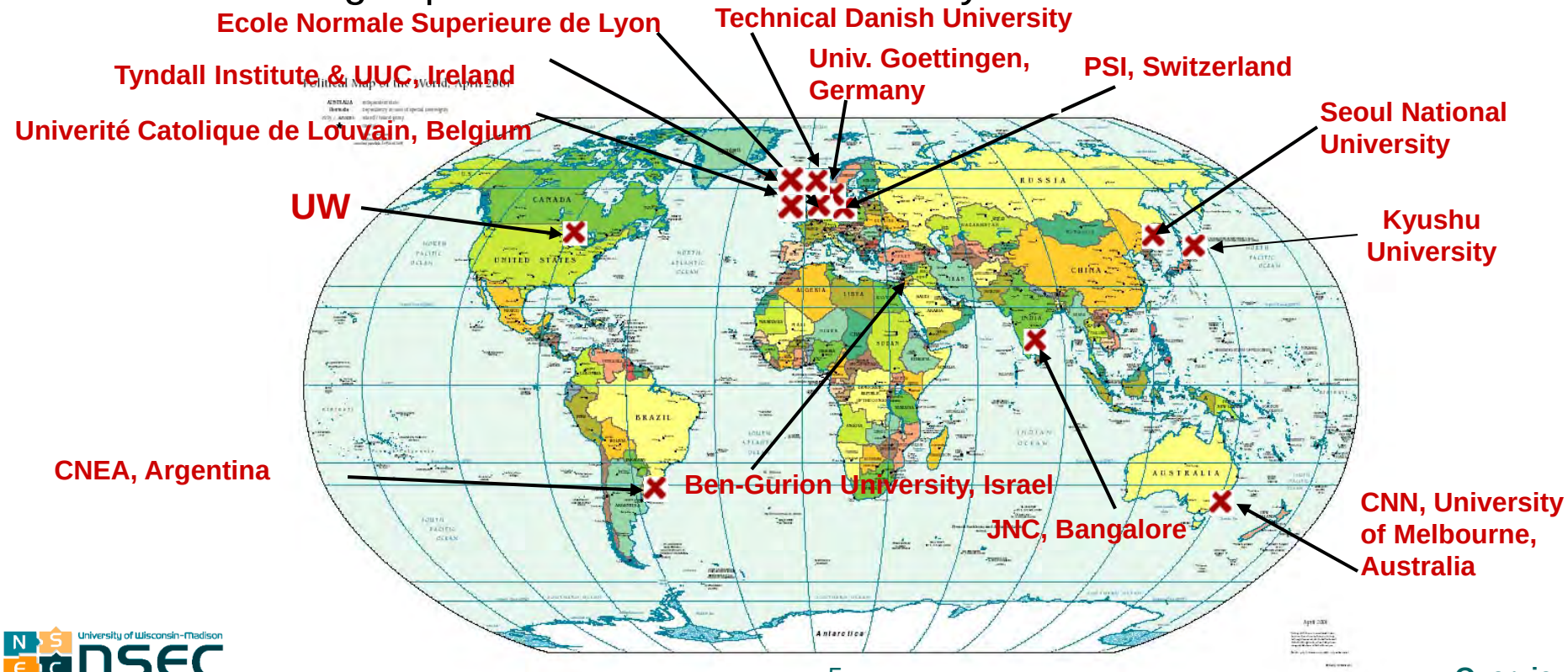
University of Wisconsin – Nanoscale Science and Engineering Center



International Research Experiences for Graduate Students

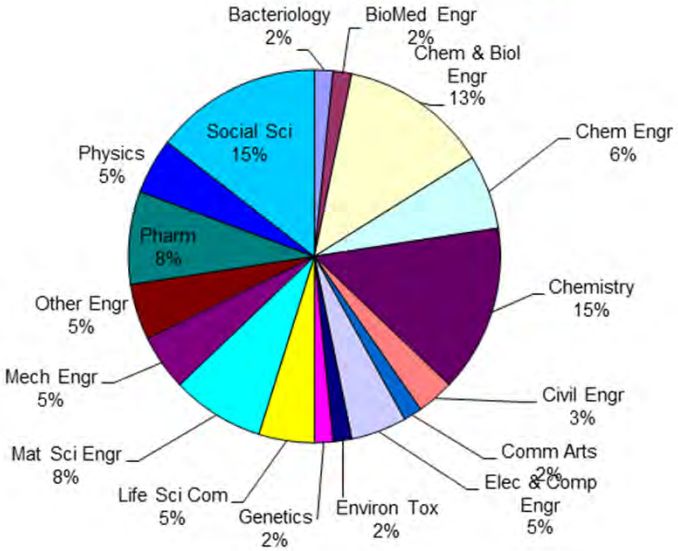
- Cultivate substantive collaborations through exchange of personnel and co-supervised personnel
- Long-term internships for students at international locations, >5 students per year
- Research interests of international partners must heavily overlap with NSEC activities for effective co-advising of students and to ensure mutual benefit
- Students' living expenses abroad are funded by international labs

33 Papers
(PRL, Nano Lett., ACS Nano, Macromolecules)
4 Manuscripts
APS, MRS Presentations



Cross-Disciplinary Research and Education Programs*

*(Cumulative through 2/29/2013)



6% faculty were from underrepresented groups

25% Female Faculty

25% Untenured faculty

Affiliated Faculty

Ben-Gurion University, Israel
Brown University
CNEA Argentina
Ecole Normale Superieure de Lyon
Eindhoven University of Technology
Kanagawa University
Kyoto University
Kyushu University
McGill University
McMaster University
Rice University
Seoul National University
Stellenbosch University, South Africa
Tokyo Institute of Technology
Université Catholique de Louvain, Belgium
University of Bremen, Germany
University of Göttingen
University of Lyon
University of Melbourne
UP Madrid
Jwaharlal Nehru Institute for Advanced Scientific Research, Bangalore, India
UW-Milwaukee
Biology
UW-Madison
Graduate School
Population Health Sciences
History of Science
Engineering Dean's Office

Affiliated Members

Discovery Museum
ETH – Zurich
Hitachi Global Storage Technologies
Hitachi Limited
IBM
Paul Scherrer Institute
Wis. Department of Natural Resources
National Institute of Occupational Safety & Health
National Institute of Standards & Technology
Dept. of Health & Family Services

Center Scope

- 71 faculty from 28 departments
- 41 affiliate participants
- 125 graduate students
- 46 postdoctoral associates
- 35 undergraduate students
- 63 academic partners
- 40 industry partners
- 13 federal lab partners
- 8 international lab partners

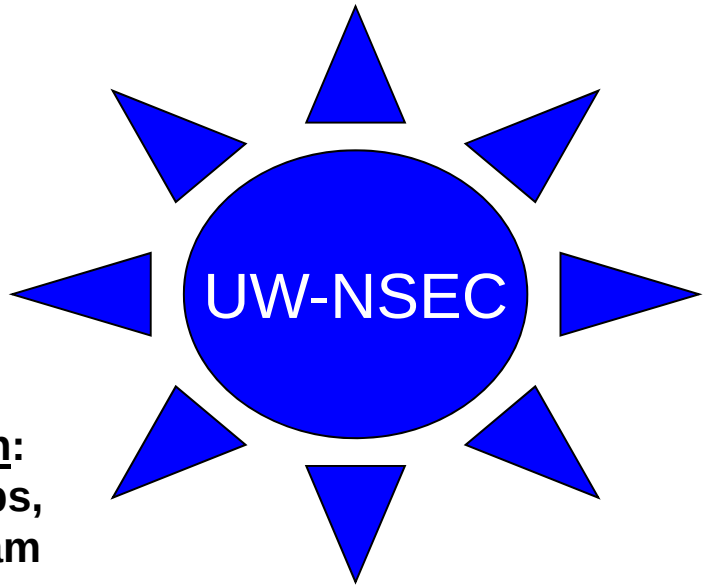
Templated Synthesis and Assembly at the Nanoscale

Industrial Outreach

Thrust 2: Sequence-Directed Assembly of Organic Nanostructures

Seed Program

Thrust 1: Directed Assembly of Block Copolymer Materials



Thrust 3: Driven Assembly at the Nanoscale

International Program

Shared Facilities

Education and Outreach: Underrepresented Groups, NSEC Fellowship Program REU, RET Programs

Thrust 4: Environmental Health and Safety Implications of Nanomaterials

Societal Implications: Science-Media-Public Interactions

Synthesis+theory+processing+characterization+applications

Thrust 1: Directed Assembly of Block Copolymer Materials

Paul Nealey

Padma Gopalan

Nanoscale Object	Medium
- Spherical, homogeneous	- Simple solvent
- Asymmetric, homogeneous	- Simple solvent, confined
- Spherical, inhomogeneous	- Structured solvent
- Asymmetric, inhomogeneous	- Structured solvent, confined
- Flexible, homogeneous	- Dense melt, disordered
- Flexible, heterogeneous	- Dense melt, structured, confined

Fields

Flow

Electric

Nematic

Surface

Well understood

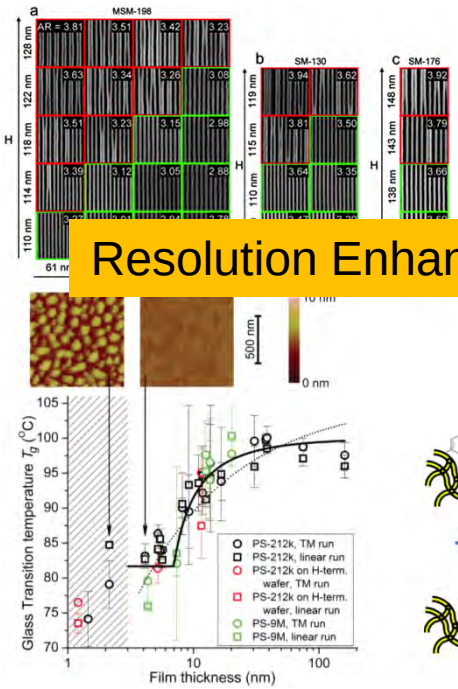
Partially understood

Not understood

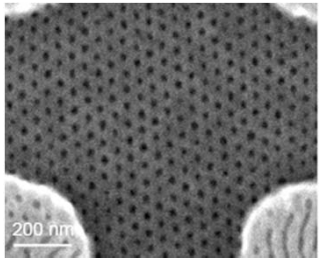
- Principles of thermodynamic equilibrium to direct the assembly of block copolymer materials
- New materials, new materials architectures, functional materials
- Evaluation of near-term technological impact in nanomanufacturing

Thrust 1 : Directed Assembly of Block Copolymer Materials

Triblock copolymer assembly
JVST B 2012, 30(6), 06F204

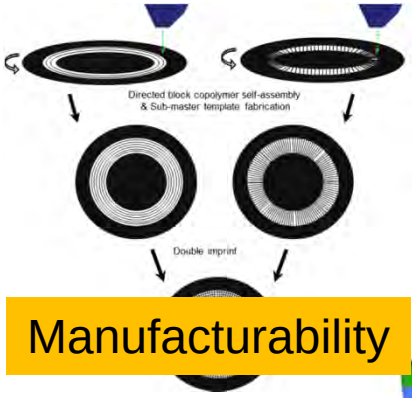


Effect of feature dimensions on Tg
Phys. Rev. E **2012**, 86(2), 021501

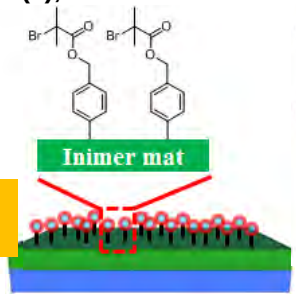


Graphoepitaxial assembly of PTMSI
Poly. Sci. A, Polym. Chem. 2013, 51(2), 290

Resolution Enhancement

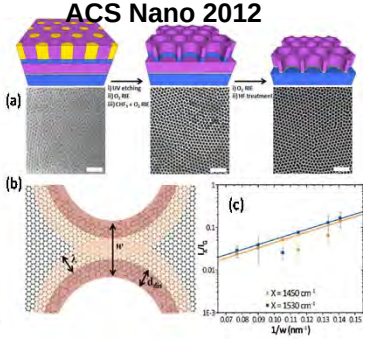


Micro/Nanolithography, MEMS, and MOEMS, 2012, 11, (3), 031405

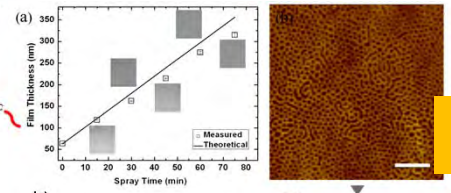


Manufacturability

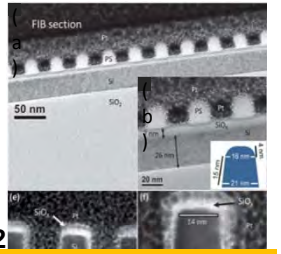
Graphene electronics
ACS Nano 2012



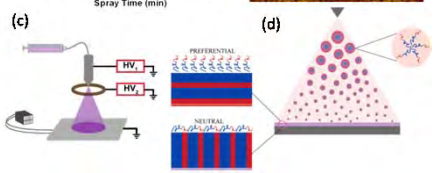
Epitaxial deposition of block copolymers
ACS Nano 2013



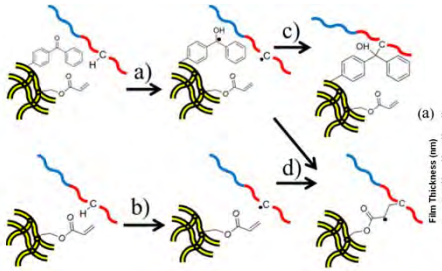
Universal coating for nanopatterning
Langmuir 2013



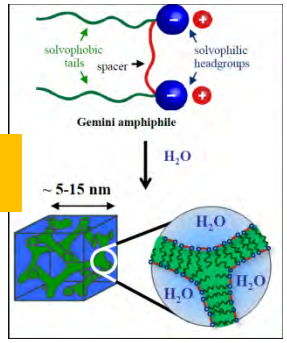
finFETs
ACS Nano 2012



Functional Nanostructures



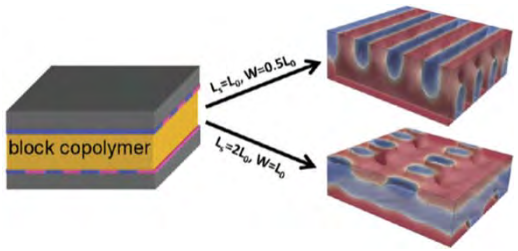
Light activated replication of pattern
Macromolecules 2013



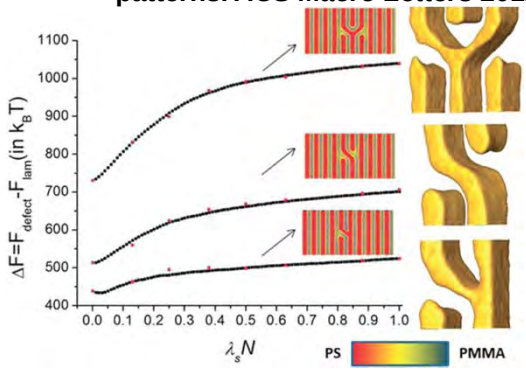
Gemini surfactants self-assemble in water to form cylindrical, lamellar, and gyroid phases. ***The Journal of Physical Chemistry B*****, 2013**

Theory and Modeling

3D structures
***Macromolecules* 2012, 45(5), 2588**



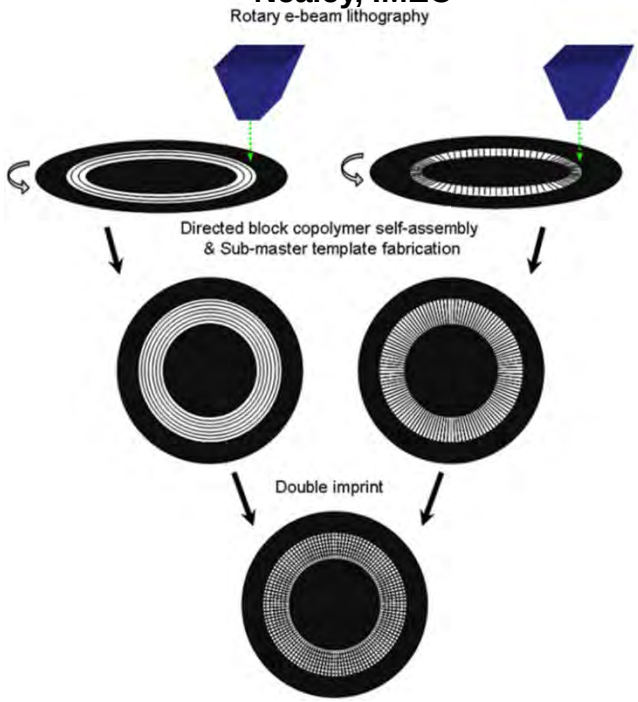
Theoretically informed 3D coarse grain modeling of defects in block copolymer thin films on chemically patterns. ***ACS Macro Letters*** **2012**



Thrust 1 Highlights: Directed Assembly of Block Copolymer Materials

First "full-disc" demonstration of bit patterned media

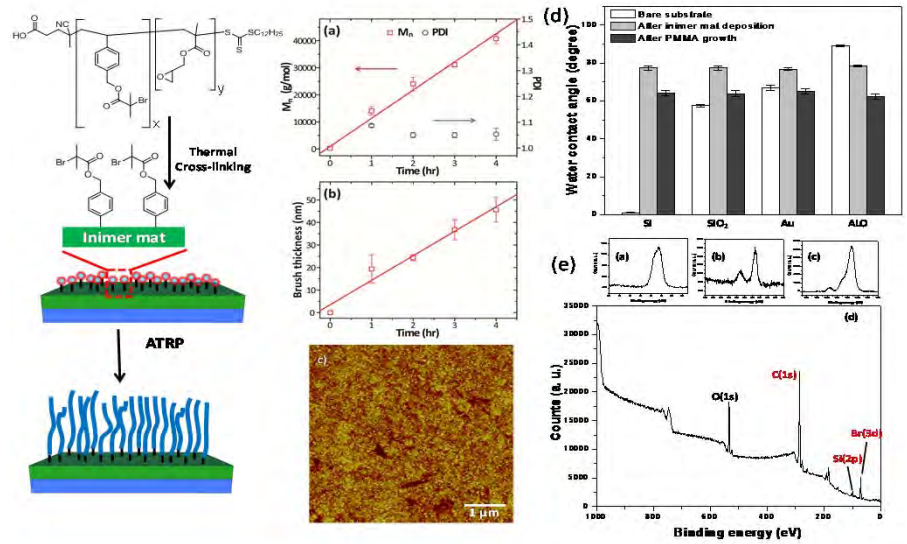
Nealey, IMEC



Overview schematic of the fabrication of nanoimprint templates with rectangular patterns using directed assembly with block copolymers and double nanoimprint.

New Methodology for Dense Brush Growth

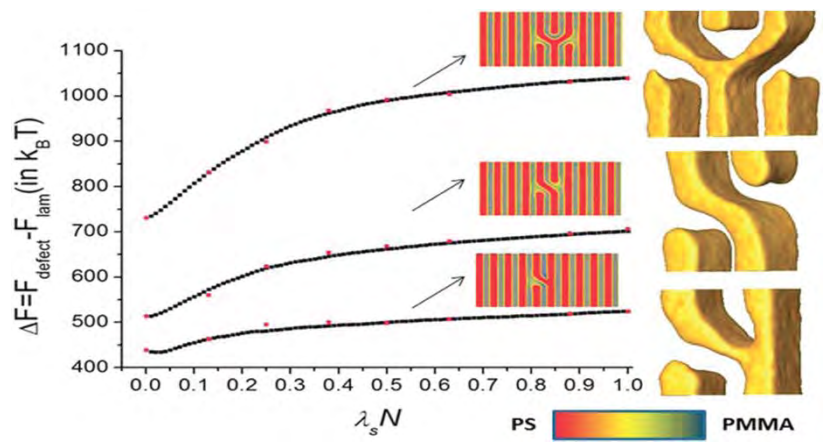
Gopalan, Langmuir 2013



Single component coating; High chain density; Nano-patterned brushes; Chemical patterns for wide range of functional BCPs; Coating material for applications beyond lithography

3D Coarse Grain Model of Defects

Müller, de Pablo, and Nealey (*ACS Macro Letters* 2012, 1(3), 418)



Thrust 2: Sequence-Directed Assembly of Organic Nanostructures

Gellman

Nanoscale Object

- Spherical, homogeneous
- Asymmetric, homogeneous
- Spherical, inhomogeneous
- Asymmetric, inhomogeneous
- Flexible, homogeneous
- Flexible, heterogeneous

Medium

- Simple solvent
- Simple solvent, confined
- Structured solvent
- Structured solvent, confined
- Dense melt, disordered
- Dense melt, structured, confined

Fields

- Flow
- Electric
- Nematic
- Surface

Well understood

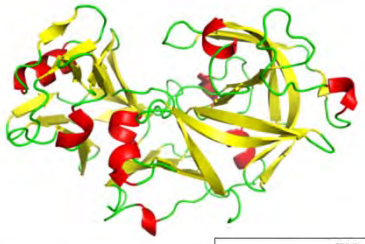
Partially understood

Not understood

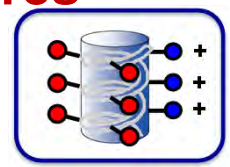
Abbott

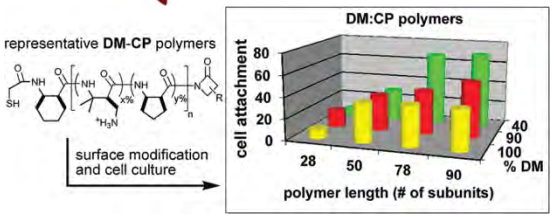
- Precise chemical patterning of nanoscale rods by designing sequence-controlled molecules with folded equilibrium structures
- Properties and assembly of organic nanostructure, driven by surface nanopatterns, in simple and complex media

Thrust 2: Sequence-Directed Assembly of Organic Nanostructures



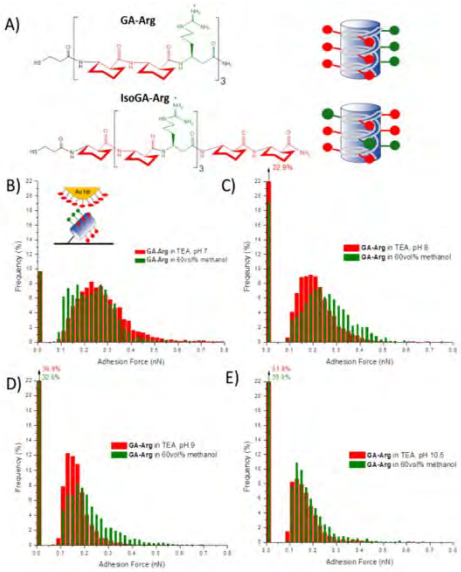
Extrapolating from Biopolymers…
Non-natural oligomers of β amino acids ("*β peptides*")
Organic nanostructures with control over shape and complex surface nanopatterns of chemical groups.



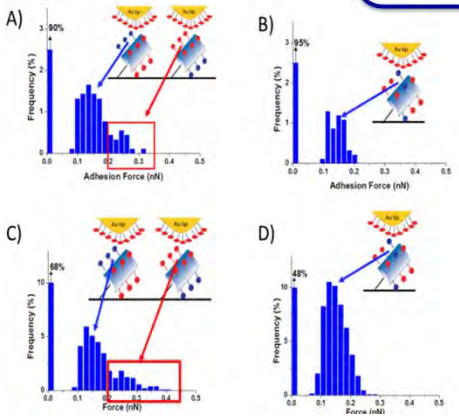


Tissue Engineering with nylon-3 polymers

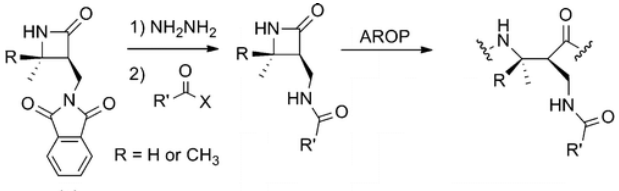
***Biomacromolecules* 2012,*13*, 1100.**
***J. Biomed. Materials Res. A* 2012, *100*, 2750.**

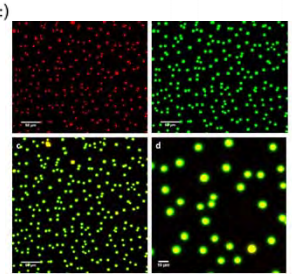


Probing the hydrophobic effect with β-peptides

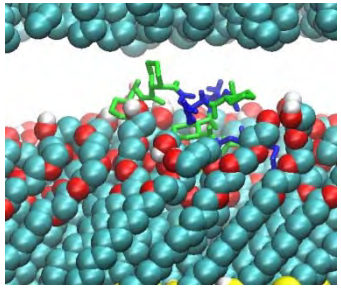


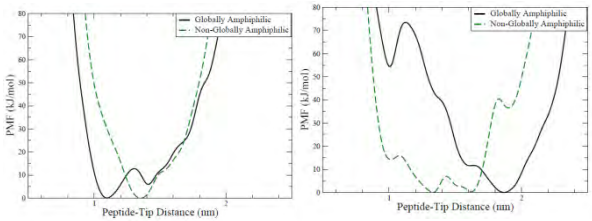
Single-Molecule AFM with β-peptides
***J. Am. Chem. Soc.* 2011, *133*, 3981.**



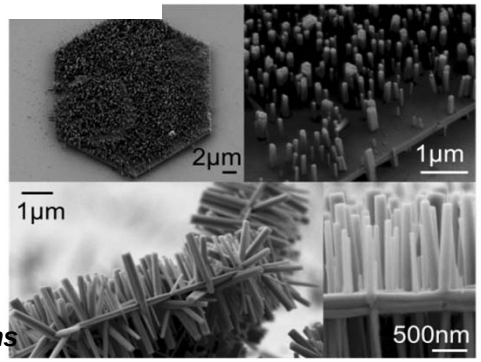


Self-assembling nylon-3 Block co-polymers from β-lactams
***ACS Macro Lett.* 2012, *1*, 714.**





β-pepide attached to a self-assembled monolayer in the presence of a hydrophobic surface (top) that models an AFM tip.

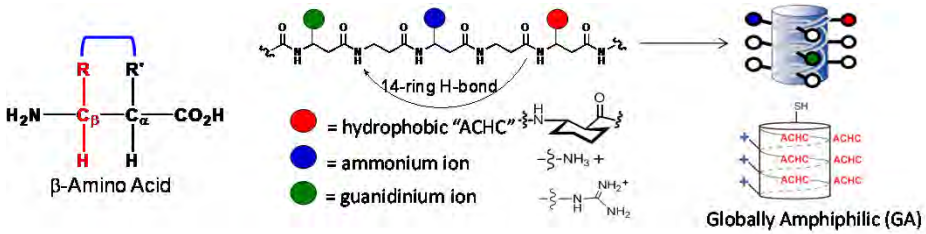


3D assembly of ZnO nanowires heteroepitaxially grown on CuGaO2 nanoplates. ***(ms. in preparation)***

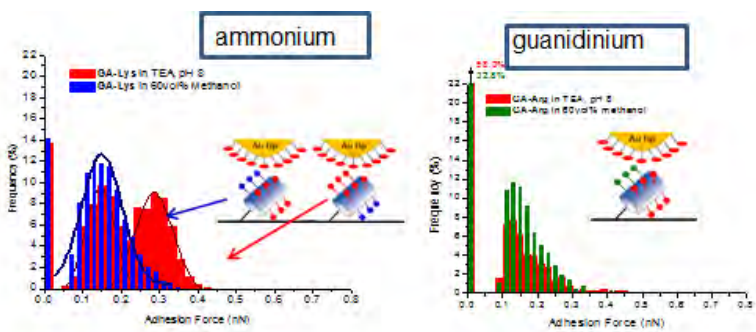
University of Wisconsin-Madison
NSEC
Nanoscale Science & Engineering Center

Thrust 2 Highlights: Sequence-Directed Assembly of Organic Nanostructures

Goal: To use oligomers of β-peptides to generate precise chemical patterns at the nano-scale to understand the origins of intermolecular forces that direct self-assembly.



Elucidation of effects of proximal charge on hydrophobic interactions using single molecule force spectroscopy:

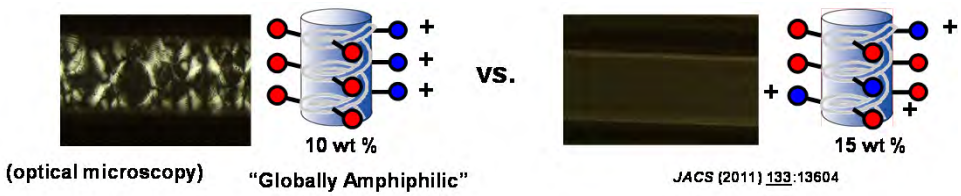


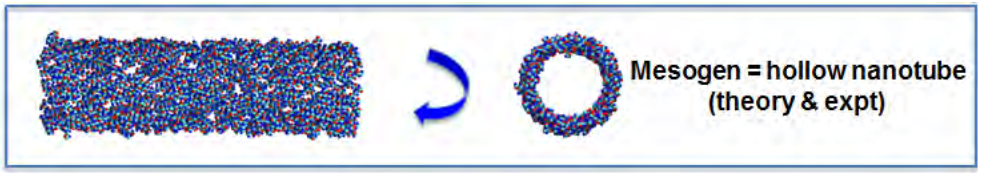
Effect of addition of methanol on force histograms

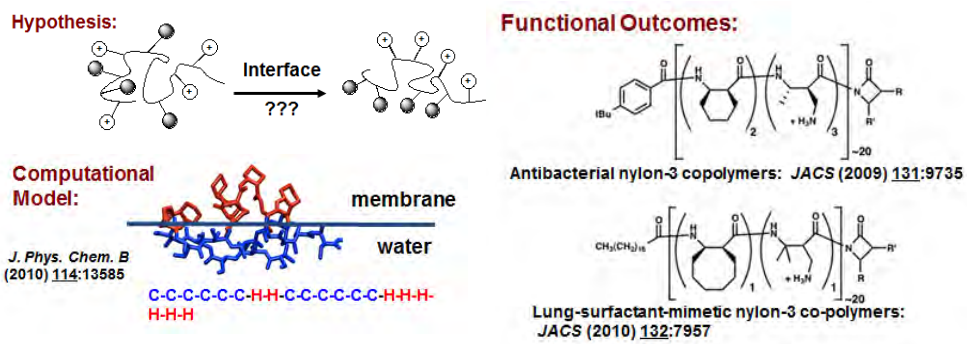
JACS (2011)133, 3981-3988.

Proximal ammonium ions strengthen hydrophobic interactions mediated by ACHC nanodomains while adjacent guanidinium ions abolish hydrophobic interactions.

Goal: Sub-unit sequence-directed assembly of β-peptide nanorods and effect on mesogenic properties.







Formation of lyotropic liquid crystalline phase depends entirely on hydrophobic-hydrophilic nanopatterning.

Nanopatterning of functionality induced by the interface: Interfacial activities such as bacterial membrane disruption and lung-surfactant mimicry.

Thrust 3: Driven Assembly at the Nanoscale

Nanoscale Object	Medium
- Spherical, homogeneous	- Simple solvent
- Asymmetric, homogeneous	- Simple solvent, confined
- Spherical, inhomogeneous	- Structured solvent
- Asymmetric, inhomogeneous	- Structured solvent, confined
- Flexible, homogeneous	- Dense melt, disordered
- Flexible, heterogeneous	- Dense melt, structured, confined

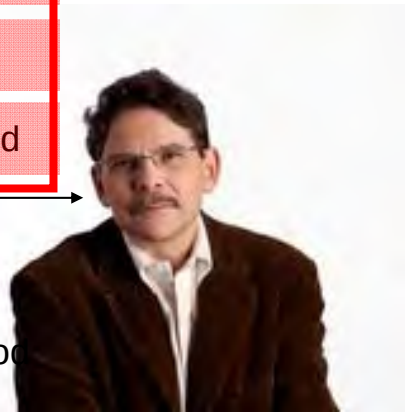
Fields

- Flow
- Electric
- Nematic
- Surface

Well understood

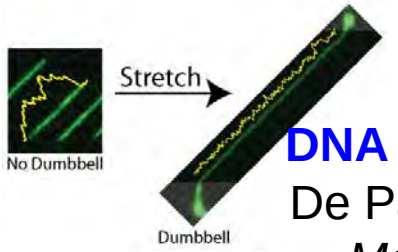
Partially understood

Not understood

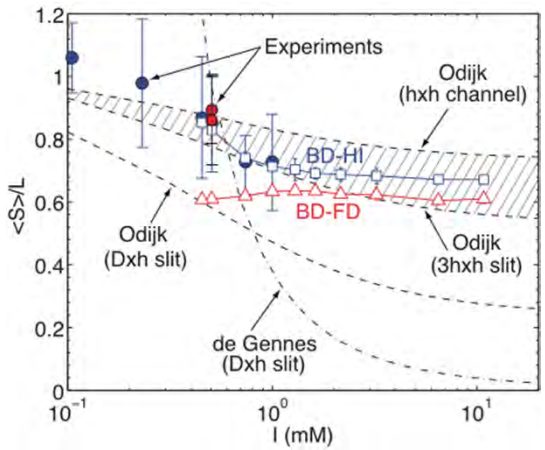


- Develop, implement and validate computational and theoretical formalisms required to harness and predict driven assembly at equilibrium and beyond equilibrium.
- Concerted intra- and inter-thrust experimental and theoretical approach.

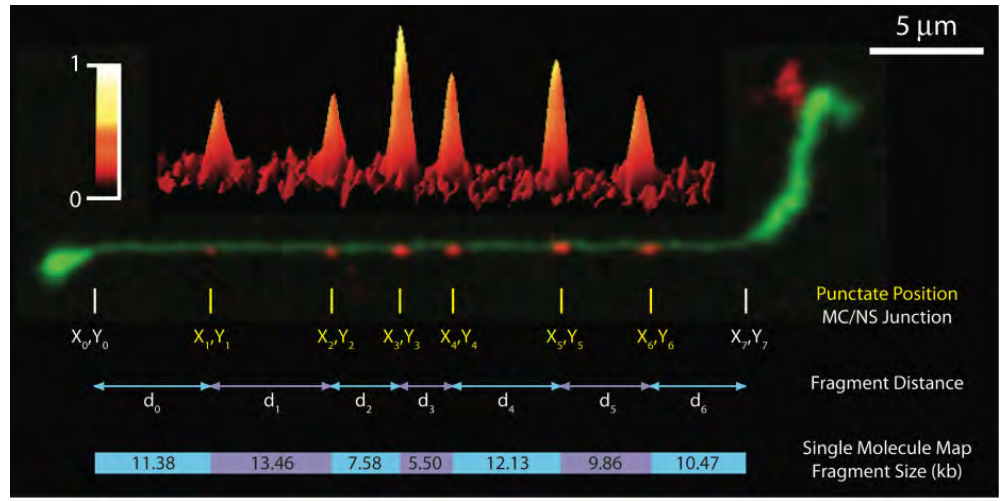
Thrust 3: Driven Assembly at the Nanoscale

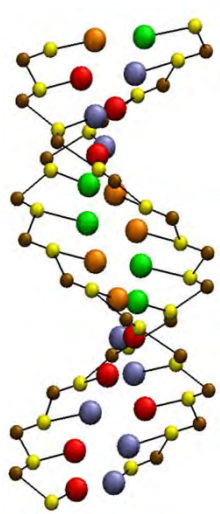


DNA Hyperstretching
De Pablo – Schwartz,
Macromol., 2013



DNA Nanocoding
Schwartz - De Pablo,
Nature Biotech, 2013





3SPN Model of DNA
De Pablo – Schwartz

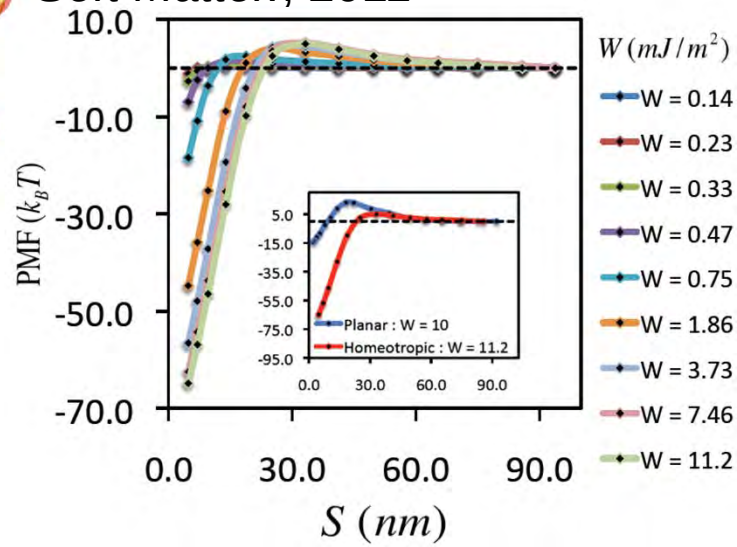
Knotts et al., *JCP*, 2007
Sambriski et al., *JPCM*, 2009
Sambriski et al., *PNAS*, 2010
Ortiz et al., *PRL*, 2011
Freeman et al., *JCP*, 2011

Thrust 3: Driven Assembly at the Nanoscale

Liquid Crystal Nanosuspensions

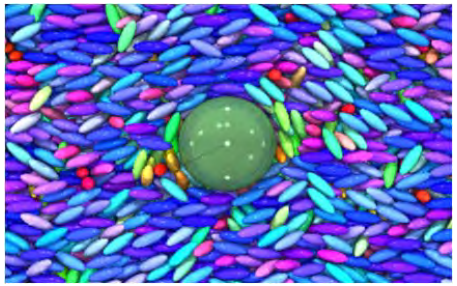
De Pablo – Abbott, *Soft Matter.*, 2011

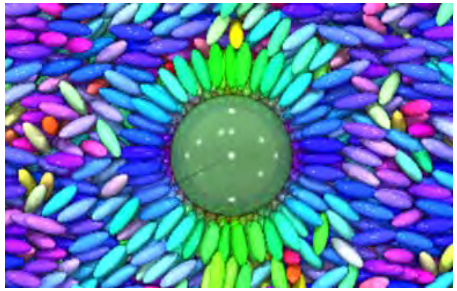
S = 0.40



Curvature Induced Anchoring at LC Interfaces

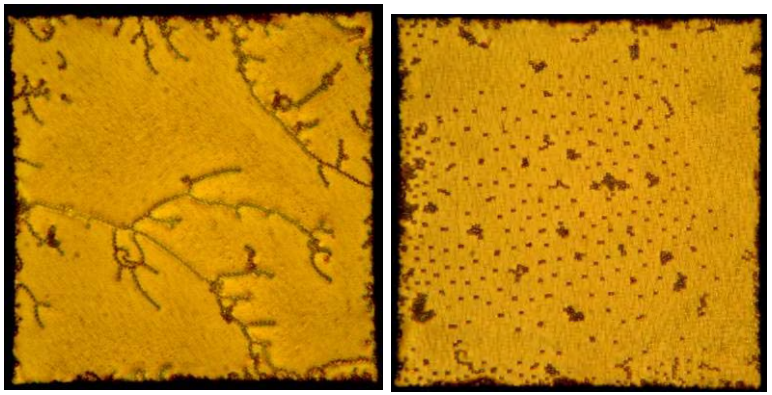
de Pablo - Abbott, *Soft Matter,* 2011





Nanoparticle Assembly at LC Interfaces

Abbott – de Pablo, *PNAS*, 2010, Langmuir 2011



Thrust 4: Environmental Implications of Nanomaterials

Joel Pedersen

Nanoscale Object

- Spherical, homogeneous
- Asymmetric, homogeneous
- Spherical, inhomogeneous
- Asymmetric, inhomogeneous
- Flexible, homogeneous
- Flexible, heterogeneous

Medium

- Simple solvent
- Simple solvent, confined
- Structured solvent
- Structured solvent, confined
- Dense melt, disordered
- Dense melt, structured, confined

Fields

Flow

Electric

Nematic

Surface

Well understood

Partially understood

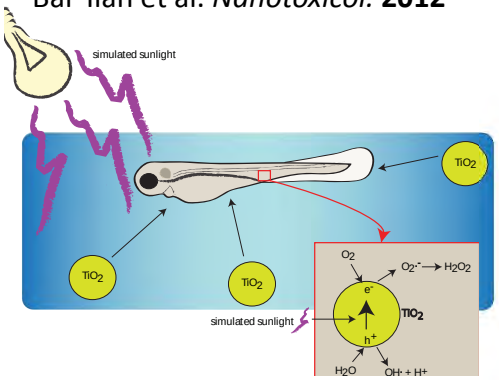
Not understood

Robert Hamers

- Toxicology and environmental fate of nanoengineered materials
- Facilitate development in an environmentally benign or beneficial manner
- Societal implications of nanotechnology

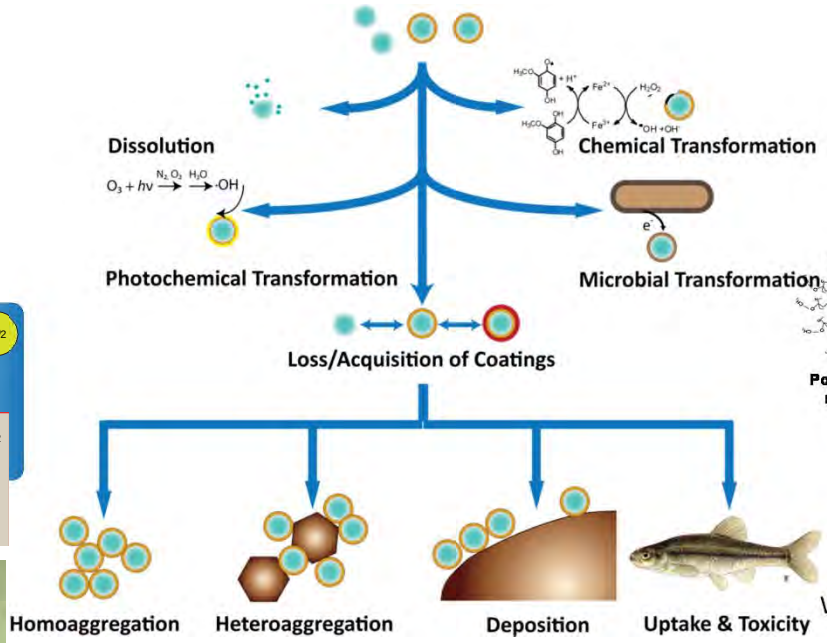
Environmental Weathering and Developmental Toxicity of Engineered Nanomaterials

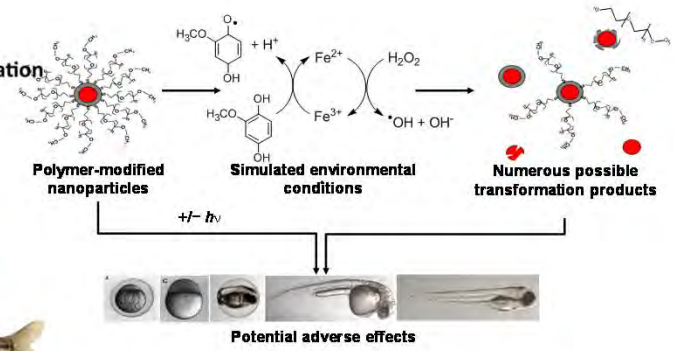
Bar-Ilan et al. *Nanotoxicol.* **2012**



23 day-old zebrafish exposed to titanium dioxide nanoparticles.

Bar-Ilan et al. (in review)





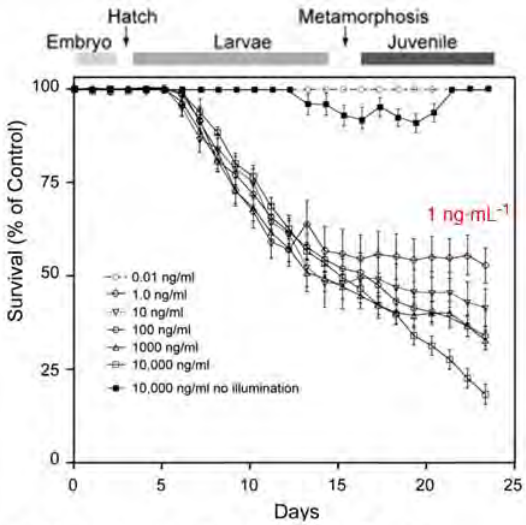
Wiecinski et al. *Environ. Sci. Technol.* (in review)

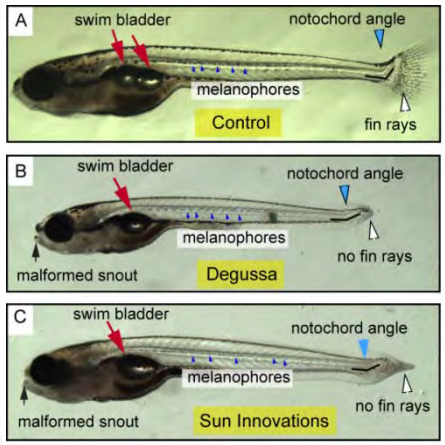
Bishop et al. *Langmuir* **2012**

Yang et al. *Environ. Sci. Technol.* **2013** (in press)

Thrust 4: Environmental Implications of Nanomaterials

Photo-Enhanced Toxicity: Subchronic Exposures





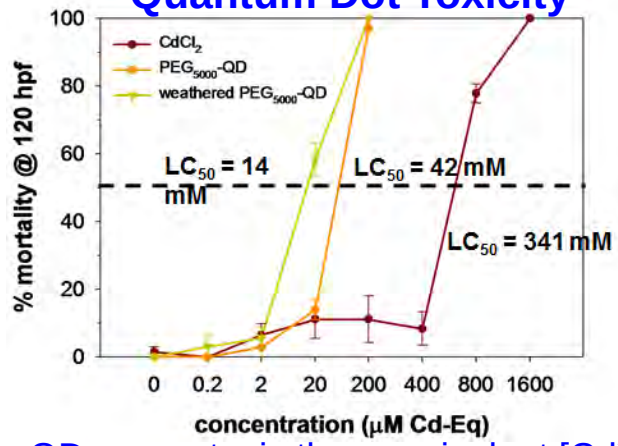
3:1 anatase:rutile, d_p = 23 ± 9.8 nm

Photo-enhanced toxicity at concentrations approaching those expected to be in the environment. TiO_2NP exposure produced significant mortality at 1 ng/mL

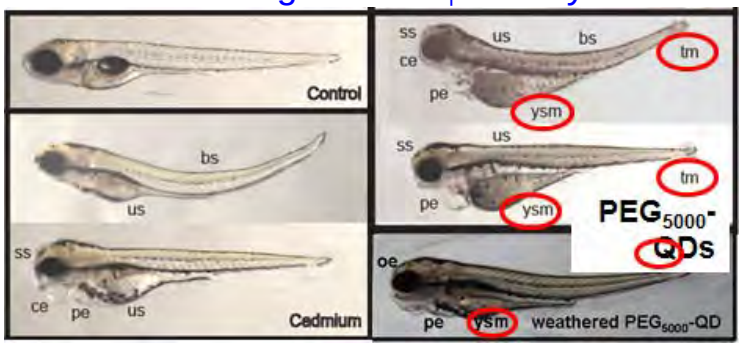
Bar-Ilan et al. *Environ. Sci. Technol.* **2013**, *47*, 4726-4733)

King Heiden et al. *Environ. Sci. Technol.* **2009**, *43*, 1605-1611; Wiecinski et al. (2013 in review)

Oxidatively Weathering Increases Quantum Dot Toxicity



QDs more toxic than equivalent [Cd^{2+}]
Oxidative degradation ↑ toxicity.



Morphological end points of Cd toxicity and some unrelated to Cd.

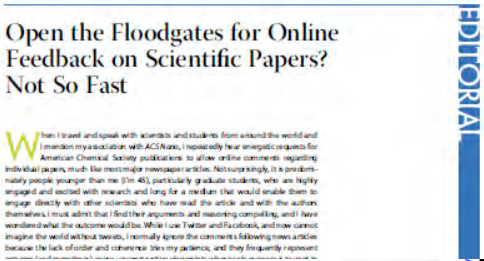
Co-exposure to Se NPs + $CdCl_2$ recapitulates weathered QD toxicity due to selenium modulation of cadmium toxicity.

Societal Implications Research Program

Dominique Brossard

- **The group has established itself as the leader in research on online communication about emerging technologies**
- **Innovative research areas:**
  - Analyses of online public discourse about nanotechnology
  - Understanding of the mechanisms through which different lay publics make sense of information in an online environment and form attitudes and risk perceptions (with clear policy recommendations)
  - Investigation of public engagement mechanisms (with Education and Thrust 4)
  - Analysis of linkages between social media activity and academic impact (with Thrust 1)
- **Emphasis on outreach (research reported on NPR Science Friday, the *NY Times*, WSJ, *Chronicle of Higher Education*, etc.) has initiated a national debate about online communication among science communicators**

ACS Nano editorial 2013



EDITORIAL

Open the Floodgates for Online Feedback on Scientific Papers? Not So Fast

When I travel and speak with scientists and students from around the world and I mention my association with ACSNano, I repeatedly hear energetic requests for American Chemical Society publications to allow online comments regarding individual papers, much like most major newspaper articles. Not surprisingly, it is predominately people younger than me (I'm 46), particularly graduate students, who are highly engaged and excited with research and long for a medium that would enable them to engage directly with other scientists who have read the article and with the authors themselves. I must admit that I find their arguments and reasoning compelling, and I have wondered what the outcome would be. While I use Twitter and Facebook, and now cannot imagine the world without tweets, I normally ignore the comments following news articles because the lack of order and coherence tries my patience, and they frequently represent

Science 2013

SOCIAL SCIENCE

Science, New Media, and the Public

A better understanding is needed about how the online environment affects the communication of science information to the public.

Dominique Brossard and Dietram A. Scheufele

Nine in 10 internet users in the United States turn to search engines to find information (1), and 60% of the U.S. public seeking information about specific scientific issues lists the Internet as their primary source of information (2). This has created a new urgency for scientists to pay attention to these trends and to the emerging scholarly literature about communicating science in this brave new "online" world.

Among the U.S. public, time spent on the World Wide Web has been linked to more positive attitudes toward science, even when controlling for use of traditional mass media such as newspapers and television (3). For instance, frequent Web users are more likely to report in surveys that they support basic scientific research even if it may not have immediate societal benefits. Research suggests that the availability of science news from the Internet may inform U.S. audiences with different educational backgrounds. In other words, online science sources may be helping to narrow knowledge gaps caused partly by science coverage in traditional media that tends to be tailored to highly educated audiences (4). Unfortunately, equivalent data for other countries is not available yet.

Recent communication research, however, has also identified at least three areas in which the new realities of an online information environment will increasingly force scientists and social scientists to rethink the interface between the science community and the public. One area is science journalism. The rise of online media since the late 1990s has come at the expense of traditional mass print and broadcast media. Less space has been allocated for scientific issues, even to the complete elimination of science coverage in some outlets (5). Today, audiences turn more and more to blogs and other online-only media sources for information about specific scientific issues and much less to online versions of traditional news outlets. Almost half of Americans currently rely on nontraditional online sources, and only 12% turn to science news from online content provided by traditional print newspapers and magazines (2).

Another area of concern is the trend among online information providers to select and prioritize content by using algorithms and/or audience metrics, such as how often an online

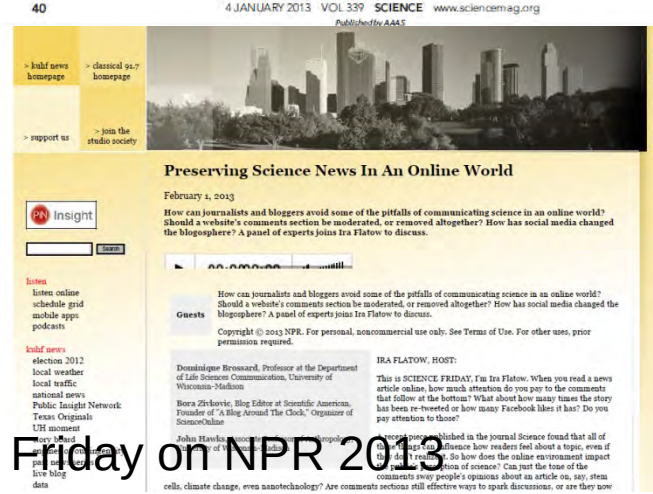
Department of Life Sciences Communication, University of Wisconsin–Madison, 1545 Observatory Drive, Madison, WI 53706–1215, USA. E-mail: dbrossard@wisc.edu

40 4 JANUARY 2013 VOL 339 SCIENCE www.sciencemag.org

Published by AAAS

Downloaded from www

Science Friday on NPR 2013



> kuhf news homepage
> classical 91.7 homepage
> support us
> join the studio society

Preserving Science News In An Online World

February 1, 2013

How can journalists and bloggers avoid some of the pitfalls of communicating science in an online world? Should a website's comments section be moderated, or removed altogether? How has social media changed the blogosphere? A panel of experts joins Ira Flatow to discuss.

Insight

Search

listen
listen online
schedule grid
mobile apps
podcasts

kuhf news
election 2012
local weather
local traffic
national news
Public Insight Network
Texas Originals
UH moment
live blog
data

Guests

How can journalists and bloggers avoid some of the pitfalls of communicating science in an online world? Should a website's comments section be moderated, or removed altogether? How has social media changed the blogosphere? A panel of experts joins Ira Flatow to discuss.

Copyright © 2013 NPR. For personal, noncommercial use only. See Terms of Use. For other uses, prior permission required.

Dominique Brossard, Professor at the Department of Life Sciences Communication, University of Wisconsin-Madison

Bora Zivkovic, Blog Editor at Scientific American, Founder of "A Blog Around The Clock," Organizer of ScienceOnline

IRA FLATOW, HOST:

This is SCIENCE FRIDAY, I'm Ira Flatow. When you read a news article online, how much attention do you pay to the comments that follow at the bottom? What about how many times the story has been re-tweeted or how many Facebook likes it has? Do you pay attention to those?

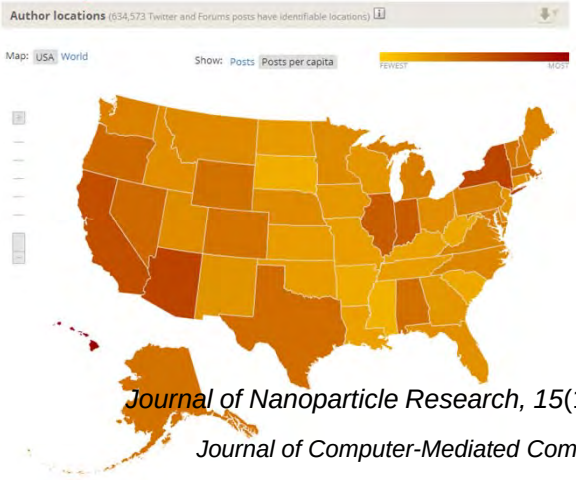
cells, climate change, even nanotechnology? Are comments sections still effective ways to spark discussions, or are they now

Societal Implications Research Program

Tweeting nano: How public discourses about nanotechnology develop in social media environments

Kristin K. Runge, Sara K. Yeo, Michael A. Cacciatore, *et al.*

- **This study maps the landscape of social media discourse about nanotechnology using sophisticated computational linguistic software to analyze a census of all nanotechnology-related tweets expressing opinions on Twitter between September 1, 2010 and August 31, 2011.**
- **Results:** 55% of tweets expressed certainty, 45% expressed uncertainty. 27% percent of tweets expressed optimistic outlooks, 32% expressed neutral outlooks, and 41% expressed pessimistic outlooks. Tweets were more likely to originate from states with a federally-funded National Nanotechnology Initiative center or network.
- The trend toward certainty in opinion coupled with distinct geographic origins of much of the social media traffic on Twitter has significant implications for understanding how key online influencers are debating and positioning the issue of nanotechnology for lay and policy audiences.
- **First published map of social media discourse on nano.**



Journal of Nanoparticle Research, 15(1381). doi: 10.1007/s11051-012-1381-8

The "nasty effect:" Online incivility and risk perceptions of emerging technologies

Ashley A. Anderson, Dominique Brossard, Dietram A. Scheufele, *et al.*

- **This study examines how the effects of uncivil online interpersonal discussion may polarize risk perceptions of nanotechnology.**
- **Results:** Among people supportive of nano, those exposed to uncivil comments following an objective news story perceived more risks in the technology than those exposed to civil comments following the exact same article. Those exposed to uncivil comments were also more likely to perceive bias in the news story compared to those exposed to civil comments.
- A well-written, balanced news story about a nanotechnology can be interpreted differently because of the comments that follow it. This has important implications for science communication online and points to the importance of carefully evaluating how information about nano is presented, under which format, and with what type of contextualization.
- **First empirical study on comments and risk perceptions of new technologies.** Reported in over 20 national and international media outlets.

Journal of Computer-Mediated Communication. doi: 10.1111/jcc4.12009.

Center Achievements: September 1, 2009 to February 1, 2013

Publications

- Primarily NSEC Funded - 143
- Partially NSEC Funded - 69
- Shared Facilities - 86
- Including:
  - PNAS
  - Science
  - Environmental Science and Technology
  - Physical Review Letters
  - Advanced Materials
  - Nano Letters
  - Soft Matter
  - JACS Commun.
  - Journal of computer mediated communication

NSEC Influences on Curriculum

- New courses based on NSEC Research – 4
- Modified Courses to include NSEC Research – 22
- New Textbooks Based on NSEC Research - 1
- Workshops, Short Courses to Industry/others - 46
- World Wide Web Courses - 2

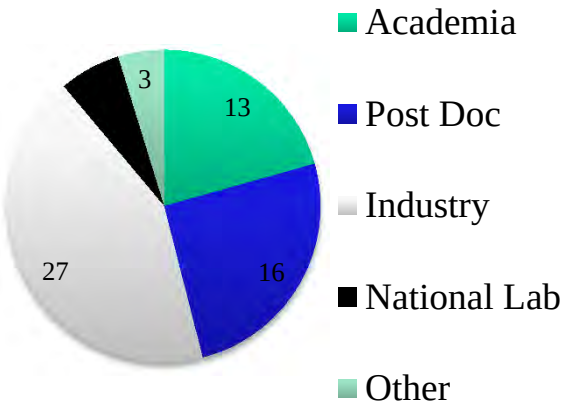
Invited Talks

- Workshops, Seminars – 383

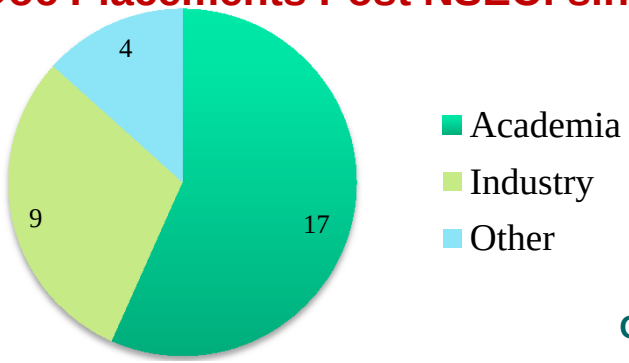
NSEC Graduates

- PhD Degrees Granted – 23
- MS Degrees Granted - 1

Graduate Student Placements Post NSEC: since 2004



Post Doc Placements Post NSEC: since 2004



NSEC Shared Facilities

Jon McCarthy

Goal: Provide state-of-the art instrument capabilities and new facilities in NSEC laboratories and College Shared Instrument Facilities.

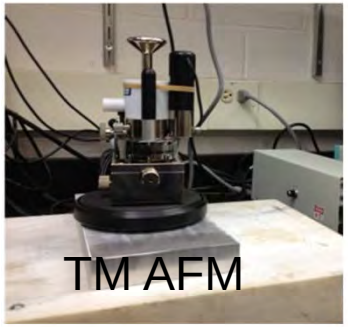
Major NSEC focussed Initiatives:

- **Soft Materials Laboratory**
  - Added 6 instruments this year
  - Users up 15% yr/yr
- New NanoPatterning Facility in use!
  - Full nanolithography

NPL:
Spinners,
EB Litho
Processing
Metrology

NSEC Investment shared Centers:

Since renewal: Cryo TEMs now at >50% utilization in 1.5 years



NSEC Supported Shared Facilities

Materials Science Center (MSC) 395 users

- Electron microscopy, surface analysis, X-ray diffraction, Micro Raman and Micro FT-IR, UV/VIS/NIR spectroscopy, AFM and Confocal Laser Scanner, Bio AFM, SAXS, Crossbeam FIB, FEI 200KV Titan, CryoTEM and Cryo Sample Prep.

Wisconsin Center for Advanced Microelectronics (WCAM) 173 users

- Seven Bay, 10,000 Square foot clean room Facility
  - CMOS devices, MEMS, soft lithography, DC/RF sputter deposition tool.
- Nano-Imprinter, 2 RIE etchers,

Soft Materials Laboratory (SML) 90 Users

- Driven by NSEC initiative and funding (matched by college and MRSEC)
  - Addressed critical need of campus soft materials researchers!
- Rheometry, chromatography, TGA, DSC, contact angle, Ellipsometry, Nanopatterning VPSEM, TM AFM with Thermal Probe, New FT-IR PM IRRAS, and micro-FT-IR
- SML staff are supported by NSEC and recharge funds.

Instruments in Blue are NSEC leveraged purchases or NSEC supported.

Education and Outreach

Andrew Greenberg

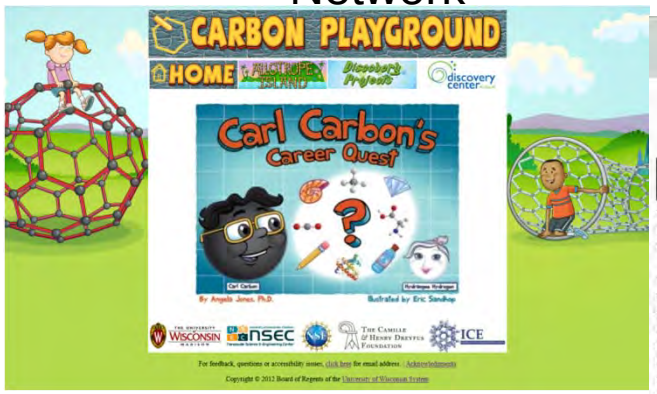
John Moore

Expansion of SCI ENCountErs to four additional sites in four states. Program meeting at six clubs weekly

SCIENCountErs

Completed Small Science Big Decisions project and disseminated nationally through the NISE Network

Outreach activity designed to engage adults in a discussion on nanotechnology



Installation and grand opening of the Carbon Playground at the Discovery Center Museum in Rockford, IL.

newscripts

CARBON-INSPIRED PLAYGROUND, NOBEL-WORTHY PATIO

Forget the slide and swing set. Children visiting the Discovery Center Museum, in Rockford, Ill., can now frolic on chemistry-inspired **PLAYGROUND** equipment, including a model of a C_{60} buckyball molecule and a carbon nanotube.

"We built our equipment not only to exact molecular specification but to also hold up to the rigorous playground standards that the discovery center uses," says Jim Maynard, lecture demonstrator in the chemistry department at the University of Wisconsin, Madison. Maynard conceived of and helped design the equipment along with Andrew Greenberg, codirector of outreach for the

"We hope the playground equipment is a hook that gets children interested in nanoscience," Moore says. "There is no question that this is a fruitful frontier for science and engineering. It's the shape of tomorrow."

When Michael Fricke, a Ph.D. chemist at Boehringer Ingelheim's Ben Venue Laboratories, in Ohio, set out to find inspiration for a new **PATIO** for his house, he also turned to chemistry.

In November, Fricke completed a year-long project in which he constructed a patio with 1,200 custom-molded concrete paver stones laid out in a quasicrystal pattern.

Fricke says the unusual design came to him late last year after he learned of the research of 2011 Chemistry Nobel Laureate Dan Shechtman. The Nobel Prize winner discovered quasicrystals, which contain an orderly pattern of atoms that doesn't repeat.

To construct the patio, Fricke created rhombus-shaped wooden molds in two different sizes. Using the molds, he was able to cast 15 concrete pavers per day, and after 10 months of production, he began assembling them into a pattern called Penrose aperiodic tiling.

Despite gaining a more in-depth understanding of Shechtman's research,

COURTESY OF JOHN MOORE

Carbon curiosities: State-of-the-art playground equipment.

Playground structures built with x-ray crystallography data as blueprints

Education and Outreach

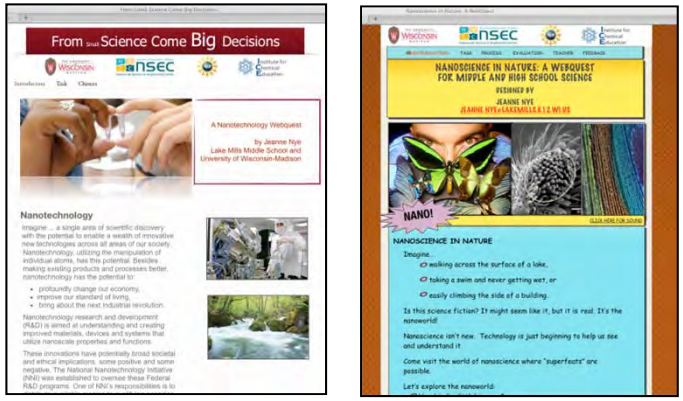
Making Nanoscience Larger than Life

Mission: **The education and outreach group is developing new scalable teaching and learning programs, methodologies, and communities aimed at cultivating a diverse next generation of nanoscientists and engineers. We seek to excite and educate underrepresented groups, build communities of nanoscience and engineering educators through teacher professional development, foster new means of communicating science and engineering research accomplishments to the K-12 community, and design new teaching models to make nanoscience and engineering more inclusive for students with physical and learning disabilities.**

University of Wisconsin-Madison NSEC Nanoscale Science & Engineering Center

Vision of Outcomes

The efforts of the education and outreach group will create <u>innovative</u> and scalable teaching methodologies, build new learning communities, broaden interest in nanoscience and engineering, increase the percentage of students pursuing science and engineering careers, build a more <u>diverse</u> science and engineering workforce, and train a future generation of engaged faculty.



Nanoscience Webquests

Informal Science Education Exhibits

Training of the Next Generation

K-16 Curriculum

NSEC Education and Outreach Group

<u>Leaders:</u>

Prof. John Moore — Chemistry

Dr. Andrew Greenberg — Chemical and Biological Engineering

<u>Outreach Specialist:</u>

Francisca Jofre

<u>Post-Doctoral Fellow:</u>

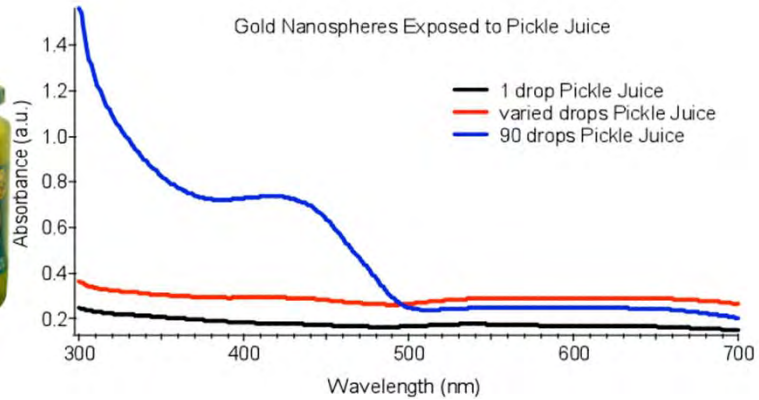
Dr. Angela Jones

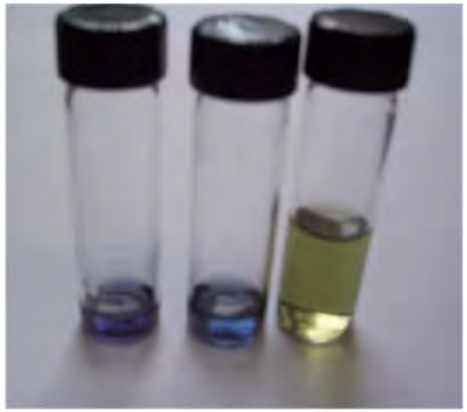
<u>Graduate Students:</u>

Mary Beth Anzovino

Jaccyln Brown

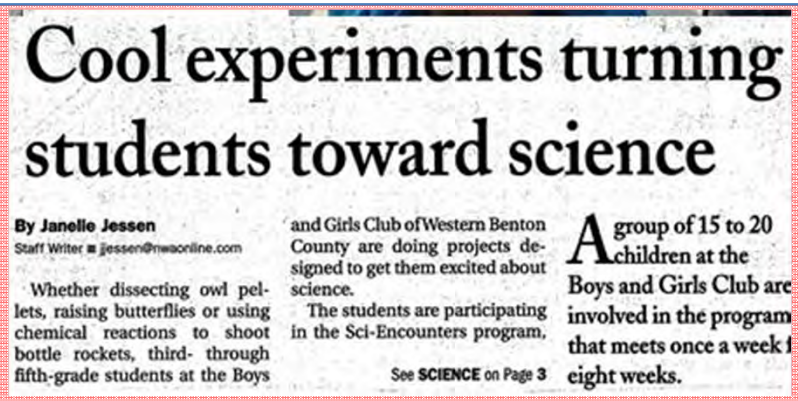
Elvin Morales





Accomplishments

SCIENCountErs



Cool experiments turning students toward science

By Janelle Jessen
Staff Writer ■ jjessen@nwaonline.com

Whether dissecting owl pellets, raising butterflies or using chemical reactions to shoot bottle rockets, third- through fifth-grade students at the Boys and Girls Club of Western Benton County are doing projects designed to get them excited about science.

The students are participating in the Sci-Encounters program,

See SCIENCE on Page 3

A group of 15 to 20 children at the Boys and Girls Club are involved in the program that meets once a week f eight weeks.

Expansion of SCI ENCountErs to four additional sites in four states. Program meeting at six clubs weekly

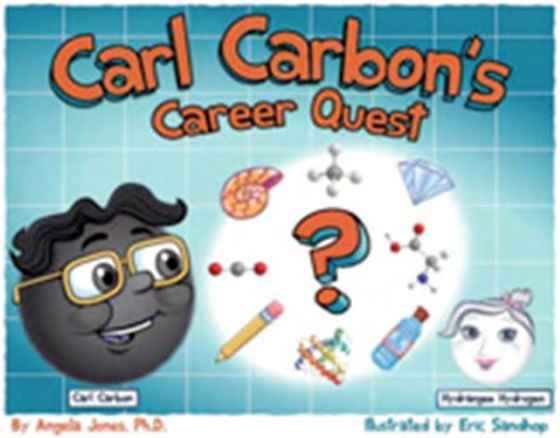
Completed Small Science Big Decisions project and disseminated nationally through the NISE Network

Outreach activity designed to engage adults in a discussion on nanotechnology

Accomplishments: Carbon Playground

Installation and grand opening of the Carbon Playground at the Discovery Center Museum in Rockford, IL.

Playground structures built with x-ray crystallography data as blueprints



Carl Carbon's Career Quest: A Children's Book about Carbon

Carbon Playground Website

newscripts

CARBON-INSPIRED PLAYGROUND, NOBEL-WORTHY PATIO

Forget the slide and swing set. Children visiting the Discovery Center Museum, in Rockford, Ill., can now frolic on chemistry-inspired **PLAYGROUND** equipment, including a model of a C_{60} buckyball molecule and a carbon nanotube.

"We built our equipment not only to exact molecular specification but to also hold up to the rigorous playground standards that the discovery center uses," says Jim Maynard, lecture demonstrator in the chemistry department at the University of Wisconsin, Madison. Maynard conceived of and helped design the equipment along with Andrew Greenberg, codirector of outreach for the

"We hope the playground equipment is a hook that gets children interested in nanoscience," Moore says. "There is no question that this is a fruitful frontier for science and engineering. It's the shape of tomorrow."

When Michael Fricke, a Ph.D. chemist at Boehringer Ingelheim's Ben Venue Laboratories, in Ohio, set out to find inspiration for a new **PATIO** for his house, he also turned to chemistry.

In November, Fricke completed a year-long project in which he constructed a patio with 1,200 custom-molded concrete paver stones laid out in a quasicrystal pattern.

Fricke says the unusual design came to him late last year after he learned of the research of 2011 Chemistry Nobel Laureate Dan Shechtman. The Nobel Prize winner discovered quasicrystals, which contain an orderly pattern of atoms that doesn't repeat.

To construct the patio, Fricke created rhombus-shaped wooden molds in two different sizes. Using the molds, he was able to cast 15 concrete pavers per day, and after 10 months of production, he began assembling them into a pattern called Penrose aperiodic tiling.

Despite gaining a more in-depth understanding of Shechtman's research,

COURTESY OF JOHN MOORE

Carbon curiosities: State-of-the art playground equipment.

Chemical and Engineering News article about the Carbon Playground

SCIENCountErs

A hands-on after school science club for Boys and Girls Clubs

SCIENCountErs Team:

Coordinator: Francisca Jofre
Manual Development: Elvin Morales
Evaluation: Angela Jones, Jacyln Brown
Expansion: Andrew Greenberg

What is SCIENCounters?

- Outreach program from the Nanoscale Science and Engineering Center (NSEC) of the University of Wisconsin-Madison
- Collaboration between Boys and Girls Clubs of Wisconsin and the NSEC
- Established in 2005 to help build a pipeline of STEM students from underrepresented groups
- Serves as an opportunity for graduate student and post docs to meet their NSEC education and outreach requirement

Why The Boys and Girls Clubs of America?

Mission: To enable all young people, especially those who need us most, to reach their full potential as productive, caring, responsible citizens.

Demographics:

- Some 4.8 million boys and girls served
- More than 4,000 Club locations
- Locations in all 50 states, Puerto Rico and the Virgin Islands plus domestic and international military bases

Club Membership:

- 64% are from minority families
- 11% are less than 7 years old
- 26% are 7-9 years old
- 30% are 10-12 years old
- 21% are 13-15 years old
- 11% are 16-18 years old
- 1% are more than 18 years old
- 55% are male
- 45% are female

Program Goals

- To affect participating Boys & Girls Club members by improving their:
  - Attitudes towards science/scientists
  - Perceptions of their scientific ability
  - Ability to communicate science
  - Scale to B&GCs statewide and nationwide

http://www.ice.chem.wisc.edu

SCI EN*Count*Ers: *Evolution*

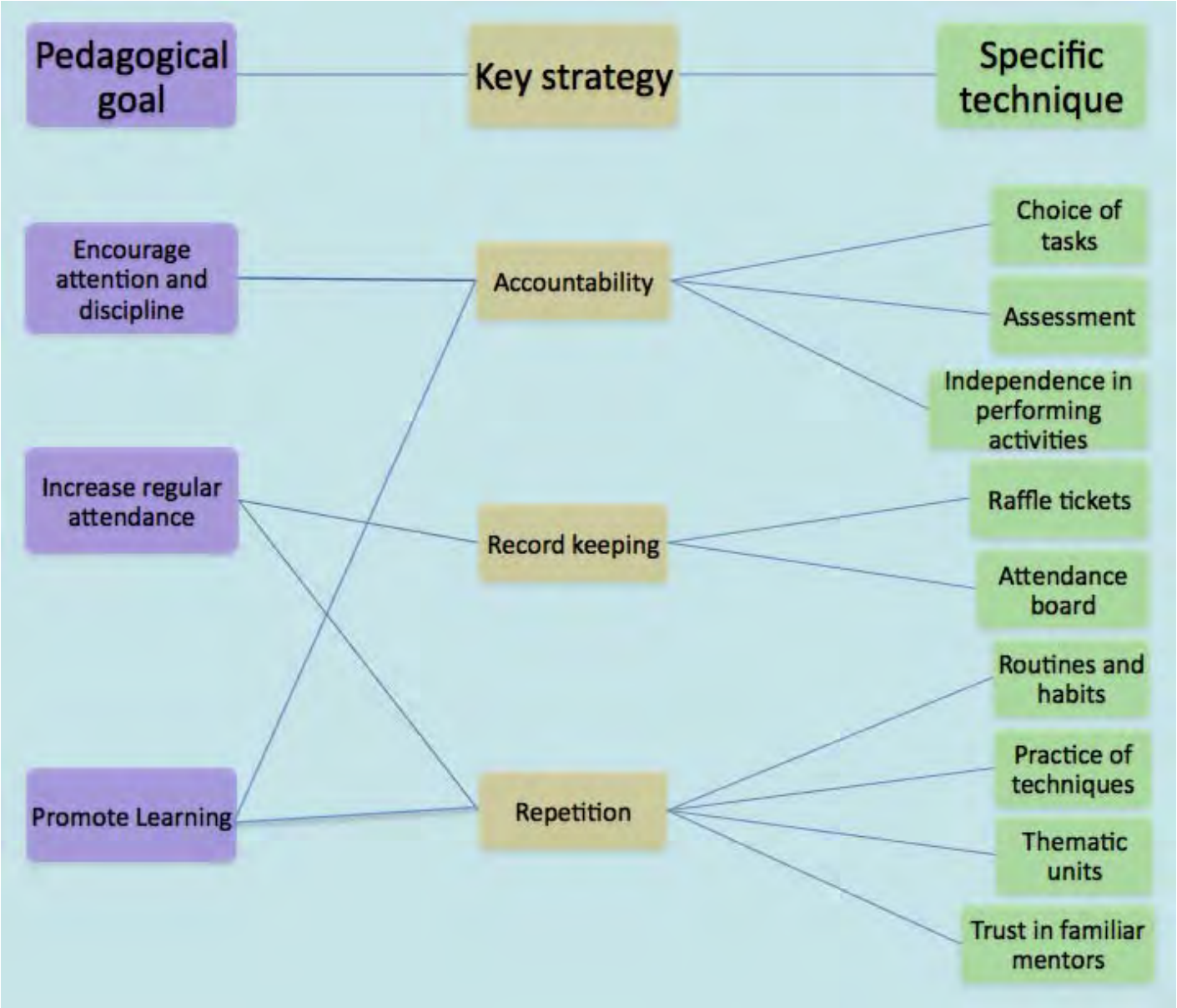
	2005-2006	2006-2007	2007-2009	2009-Present
Target Age group	9-12th graders	1-8th graders	4-8th graders	4-8th graders
Frequency of visits	Bi-Weekly	Bi-Weekly for Each Club Visited	Weekly for Each Club Visited	Weekly for Each Club Visited
Number of Clubs Visited	1	2	2	2
Volunteers	Graduate students	Undergraduates	Undergraduates	Undergraduates
Record Keeping-Attendance	None	None	Volunteer and student participation	Volunteer and student participation
B&GC Staff Member	None	Present	Present	Present
Number Volunteers	3	10-15	27	30+
Average number of B&GC participating per month	3-5	10-15	~ 30 students	~ 30 students
Lesson Style	Staff guided	Staff guided	Staff guided	Student Guided
Thematic Units	No	No	No	Yes
Netbooks	No	No	No	Yes
Program Director	Diane Nutbrown	Ken Robertson	Jenny Powell	Brittland DeKorver and Francisca Jofre

Changes in the program were a result of formative evaluation based on feedback from B&GC staff and students and UW volunteers

SCIENCounterS Pedagogical Goals

- Promote learning
- Encourage attention and discipline
- Increase regular attendance

SCIENCounterS Pedagogical Model



SCIENCounterS Sample Unit

Renewable Energy (Spring 2013)

Concepts	Lessons	Tools and Instruments
Measurement and scale	Energy	Lab glassware
Energy	Renewable vs. Non-renewable Energy	Balance
Renewable	Design	Hot plate
Non-renewable	Types of Biofuels	Stopwatch
Biofuel		Ruler
Solar Energy		Craft and construction materials
Wind Energy		

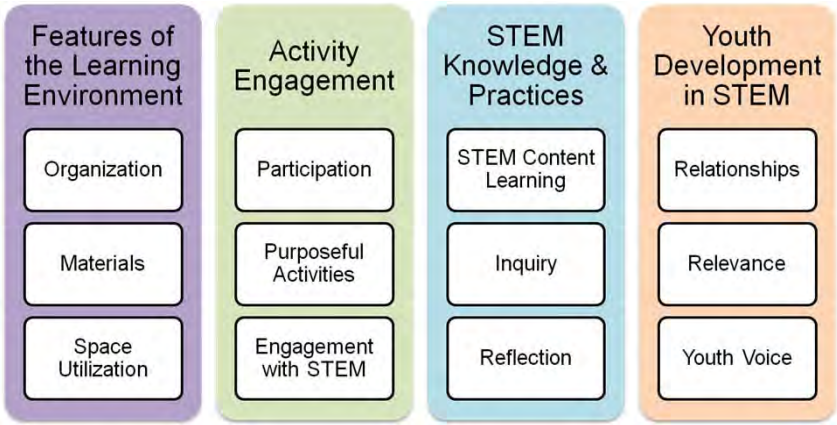
SCIENCounters Impact

- During Fall 2012, 94 students attended 334 times over the course of 24 sessions.
- Since Fall 2008, 512 students have made 1465 visits over the course of 192 sessions.

SCIENCountErs Evaluation

Dimensions of Success

- Developed through collaboration
  - **Program in Education, Afterschool, and Resiliency (PEAR) at McLean Hospital and Harvard University**
  - Educational Testing Services (ETS)
  - Project Liftoff
- Funded through National Science Foundation
- Based on NSF 2008 Evaluation Framework [1]
- Observational tool
  - 12 dimensions divided into 4 domains
  - 4 level rubric with qualitative descriptors for each level [2]



Copyright Program in Education, Afterschool, and Resiliency

References

1. Friedman, A. (Ed.). (March 12, 2008). Framework for Evaluating Impacts of Informal Science Education Projects [On-line]. Retrieved January 18, 2013, from http://informalscience.org/evaluations/eval_framework.pdf
2. Shah, A. (June 4, 2012). Dimensions of Success (DOS) Observation Tool [On-line]. Retrieved February 18, 2013 from http://www.pearweb.org/atis/tools/60

SCIENCountErs Expansion

Goal to be in five additional sites by the end of the NSEC

Provide $1000 and curriculum with each site

Sites required to provide their attendance numbers and feedback on curriculum

Training and curriculum manual underdevelopment will be disseminated to existing and future sites

Science grant brings experiments to kids' club

Laura Roller
News Editor

Thirteen science majors from John Brown University will take science experiments to the children at the Boys and Girls Club in Siloam Springs beginning Feb. 19.

The idea for this began when Carla Swearingen, assistant professor of chemistry, went to a conference on chemical education last year. A professor from the University of Wisconsin spoke about his students who received a grant from the National Science Foundation and were participating in a science education outreach, called SCIENCountEr, at Boys and Girls Clubs in their area.

"I'd been looking for a while for some sort of outreach for our students to do service learning," Swearingen said. "I thought this was a great fit because we have a Boys and Girls Club that is so close to the campus, and we have a lot of wonderful students with great hearts who really want to serve."

As Swearingen discussed her interest with the presenter following the session, she found out that the grant included money to fund the start-up of the same project at other universities. Those funds to begin the project at the local Club. Most of the money will go towards supplies for the science experiments, with some leftover for incentives such as an end of the year party to reward the kids.

The eight-week program will be split evenly between life science and physical science. Half the University students will go each time and do experiments with 20 selected elementary students.

If it is successful, Swearingen hopes to continue the project, but she will need to seek out further funding, since the grant from the University of Wisconsin is a one-time thing.

"I don't think we will have a problem finding other sources of funding for it; we'll just have to go out and look," she said.

Late last semester, Swearingen began looking for volunteers. She pitched the experiment project idea to a small group of 21 freshmen and sophomores known as SUCCESS scholars. These students receive scholarship money through another National Science Foundation scholarship grant, and also receive additional benefits such as mentoring, tutoring and faculty support to encourage them to remain biology, chemistry or biochemistry majors.

not the only ones excited about it; Swearingen got all 13 student volunteers she needed from the SUCCESS group.

Bell was asked to help take charge. Now, he is responsible for the 12 student volunteers, including helping facilitate the experiments while at the Club and figuring out scheduling. Swearingen is in charge of developing the content, but while at the Club, the project is completely student-led.

"It's a group of students looking to invest in kids," said Bell. "We get to show them that learning is tangible, not just memorization. We're going to try to turn their lights on to learning and invest in their lives."

Hirsch and Garrison are SUCCESS scholars who work regularly at the Boys and Girls Club. They are excited to be able to combine their love for science with their love for the kids through the program this spring.

Hirsch said, "I already work at the club, so I get to play with the kids a lot. What I am most excited about is the experiments. I haven't done things like that since elementary school."

For example, the curriculum includes dissecting owl pellets, making ice cream to demonstrate phase changes, learning about germs by using powder that glows under UV

Club, she often finds herself attempting to explain and share her love for science.

Hirsch agreed, "Science really can be fun, not just formulas."

J. PAULO GARCIA/The Threshold Advocate

These 13 students will be teaching kids in six science experiments at the Boys and Girls Club beginning in February using grant money from the National Science Foundation. They are excited to share their love of science with children.

Janelle Jessen/Siloam Sunday

Fourth-grade student Abbie Scroggins showed off the bracelet she made out of beads sensitive to ultraviolet light during the Sci-Encounters program last week. The beads are white indoors, but change colors when they are exposed to sunlight.

Cool experiments turning students toward science

By Janelle Jessen
Staff Writer ■ jjessen@nwaonline.com

Whether dissecting owl pellets, raising butterflies or using chemical reactions to shoot bottle rockets, third- through fifth-grade students at the Boys and Girls Club of Western Benton County are doing projects designed to get them excited about science.

The students are participating in the Sci-Encounters program,

See SCIENCE on Page 3

A group of 15 to 20 children at the Boys and Girls Club are involved in the program that meets once a week f eight weeks.

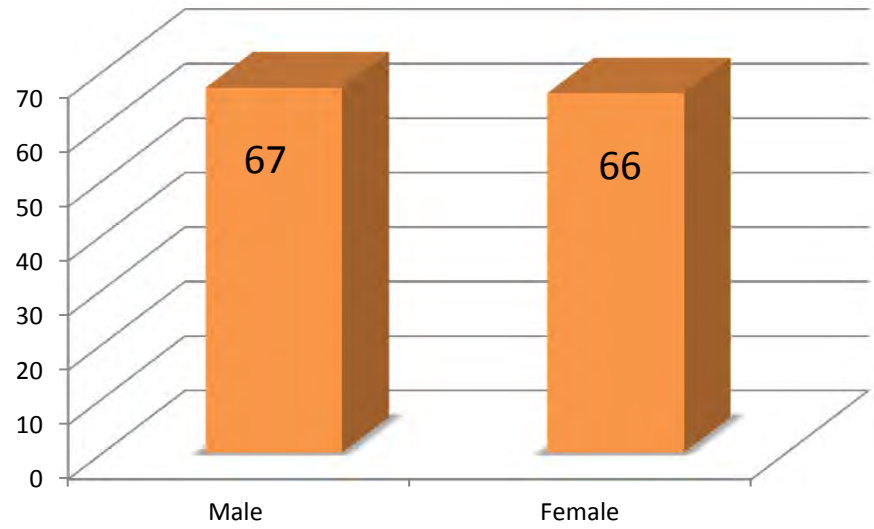
"I would like to say a big thank you to [Dr. Swearingen] and all [her] volunteers. The kids were very excited each and every Tuesday for the SCIENCountErs. It was one of the most successful programs that we have had here at the Boys & Girls Club of Western Benton County. The volunteers did a great job interacting with the kids and the lessons/activities were always well prepared."

Kyle Scoggin, Director of the Western Benton County Boys and Girls Club

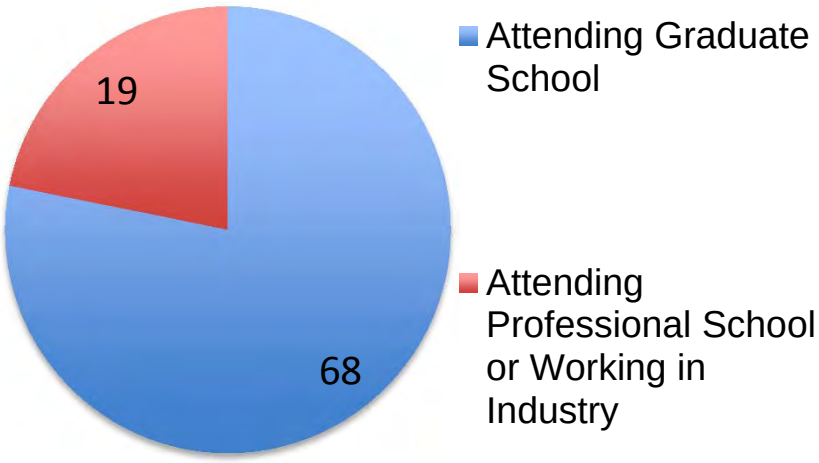
REU Program and Demographics

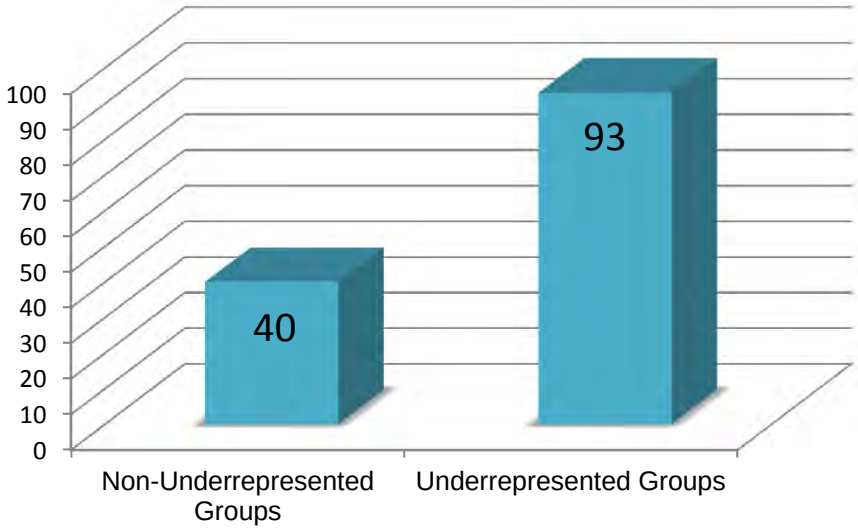
- REU program started in 2005.
- Focus as a diversity program began in 2007.
  - Since 2007 74% from underrepresented groups
- Great impact on encouraging students from underrepresented groups and females to pursue advanced degrees in science and engineering.

REU Participants: 2005-2012



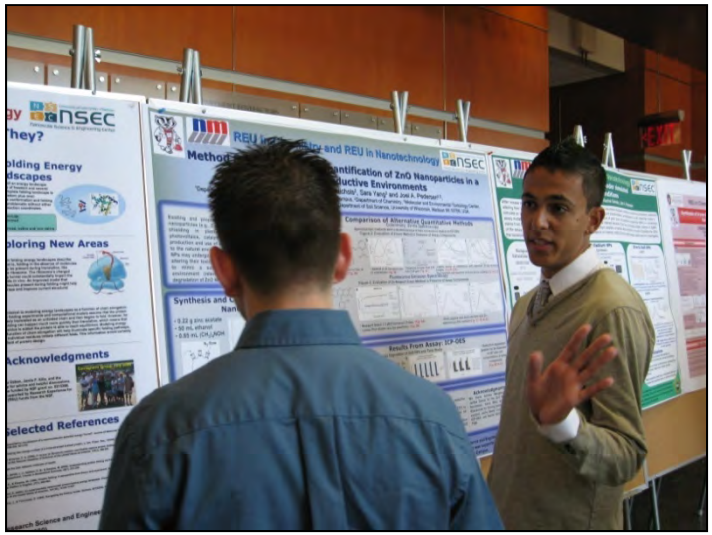
Former REU Participants: 2005-2012
Pursuing Advanced Degrees





REU Program Impact

- Direct impact on Center Diversity
  - Claribel Acevedo- NSEC former graduate student in lab of NSEC faculty member Nick Abbott
  - Miguel Caban 2008 REU in lab of NSEC faculty member Song Jin
  - Mercedes Ruiz 2009 REU in lab of NSEC faculty member Joel Pedersen
  - 85% of 2007-2012 REU students plan to attend PhD programs in science or engineering
  - 78% of eligible students enrolled in advanced degree programs.
  - 19 students from summer 2008 -2012 REU program applied for graduate study at UW-Madison with 10 of these students enrolled.



REU Program Impact

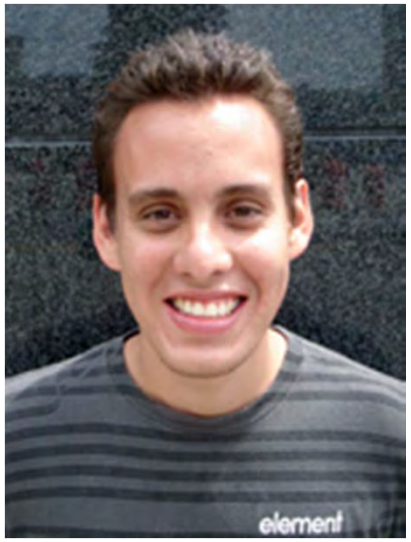
Allie Cardiel: Carlton College
C&E News Highlight

Azide-alkyne cycloaddition chemistry forms nanoparticle junctions that support light-induced (blue arrow) charge transfer and separation.
Credit: ACS Nano

Cardiel, Allison C., Benson Michelle C., Bishop Lee M., Louis Kacie M., Yeager Joseph C., Tan Yizheng, and Hamers Robert J. , ACS Nano, Volume 6, Issue 1, p.310-318.

Jaritza Gomez

2012 NSF GRFP Winner



Miguel Caban

2010 NSF GRFP Winner

Education and Outreach Post NSEC

Maintaining and entire Education and Outreach program without center support is not feasible. We will continue our two most impactful projects through other funding mechanisms.

SCIENCountErs

Inclusion in individual investigator and center proposals

- Recently funded NSF-EFRI grant will fund SCI ENCountErs through 2016
- Expand beyond nanoscience into other STEM areas

Continued curricular and evaluation support for new and existing SCI ENCountErs sites

REU

NSEC provides smallest percentage of REU program support

- Existing NSF REU site award
- Funds from UW-Madison grad school and departments
- Funds from Industry (3M)

Legacy of the Education and Outreach Program

The NSEC Education and Outreach program will have a lasting legacy on the UW-Madison campus and nationwide.

Campus Wide

REU program has served as a key recruitment tool for NSEC supported departments

SCIENCountErs

Campus wide interest in SCIENCountErs program

Nationwide

SCI ENCountErs program has national reach and will live on post NSEC

SCIENCountErs

NSEC developed curriculum and courses have been disseminated and implemented nationwide

Informal science education exhibits will continue to excite and teach visitors long past the end of the NSEC

State of Nano Research < 2004

Status:

Nano research being done on campus, but disorganized

Few if any joint appointments between departments

Single-investigator grants are the "norm" for research and for junior faculty evaluation

Graduate Students Trained by one faculty only

Little organized interaction with industry

Challenges:

Campus administration outside of ENGR not used to dealing with cross-disciplinary grant opportunities

Campus Instrumentation geared toward hard materials
No soft materials characterization

Different cultures: Physics/Chemistry (L&S), CBE/MS&E (ENGR), Bio (CALS), Social Sciences (e.g. Rural Sociology, CALS),

Impact of NSEC on Faculty: Interdisciplinary Science

Cluster Hire program initiated in 1998 to transform hiring in interdisciplinary areas; Competitive proposals, independent search/screen committees formed

Advanced Materials by Design (Proposal/Hiring committee: **DePablo** et al.)

Izabella Szlufarska (Materials Science and Engineering, hired 2004)

Functional Organic Materials (Proposal / Hiring by **Ediger, Abbott, Nealey, Hamers)**

David Lynn (Chemical and Biological Engineering hired ,2002)*
Padma Gopalan (Materials Science & Engineering, hired 2003)* **Center Director**
Mahesh Mahanthappa (Chemistry, hired 2005)

Chemical Genomics

David Schwartz (Genomics, Chemistry ,hired 2002)* **Co-leader, T3 (2009-2014)**

Communication Technologies Research

Dietram Scheufele (Life Sci. Comm.) **Co-leader, SI (2010-2014)**

Chemistry

Shannon Stahl (Chemistry), **Co-leader, T2, 2004-2009**

Nanophase Inorganic Materials and Devices (Proposal/Hiring **Hamers,** et al.)

Mark Eriksson (Physics)

8 NSEC faculty hired via cluster hire initiative

Impact of NSEC on Faculty: Interdisciplinary Participation

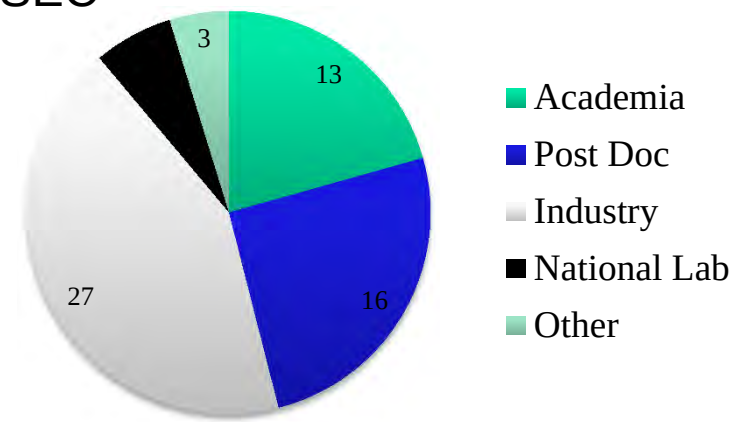
Some selected examples:

MS&E	Padma Gopalan	T1, Director	**20 total faculty 20%**
	Xudong Wang	Seed	
	Mike Arnold	Seed	
	Izabella Szlufarska	Seed	
Chemistry	Robert Hamers	T1, T4 Co-leader, Assoc. Dir.	**40 total faculty 23%**
	Mahesh Mahanthappa	T1	
	Sam Gellman	T2 Co-leader	
	Song Jin	T2	
	Arun Yethiraj	T2	
	David Schwartz	T3 Co-leader	
	Martin Zanni	Seed	
	James Skinner	Seed	
	Shannon Stahl	T2	
Chemical and Biological Engineering	Paul Nealey	T1, Founding Director	**18 total faculty 33%**
	Juan dePablo	T3	
	Michael Graham	T3	
	Nick Abbott,	T2	
	Dave Lynn	Seed	
	Tom Kuech	Seed	

NSEC facilitates the hiring/ training of faculty in interdisciplinary areas

Impact on Academia and Industry

Graduate Student Placements Post NSEC



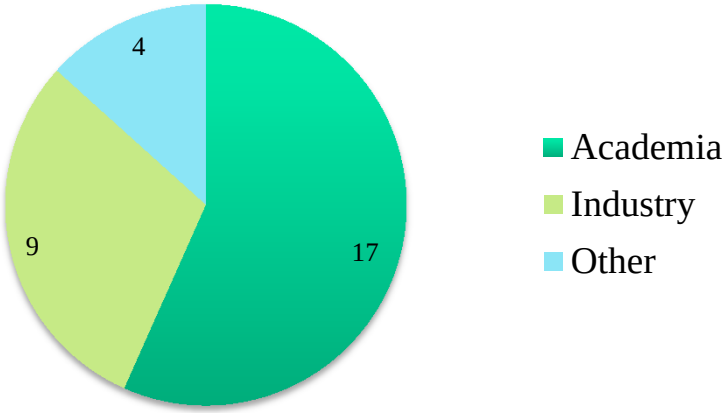
Paige Wiecinski,
Lancaster Labs

Will Pomerantz
Assistant Professor
University of Minnesota

Academia: Ex. University of Minnesota, Louisiana State University, University of Nebraska-Kearny, Emporia State University, Tufts University

Industry: Ex. Intel, Brady Corporation, , Proctor and Gamble, IBM, Amgen, Dow Chemical, Seagate, Air Products, 3M

Post Doc Placements Post NSEC



NSEC Students, postdocs are particularly sought-after candidates for employment in academia, industry, and national labs

Advanced Materials Industrial Consortium - UWAMIC

Provides **Industrial Partners**

- **Access to students and faculty** performing advanced materials and nanotechnology research
- **Access to facilities and expertise** to solve problems that can not be done with in-house industrial resources.
- **Defined research collaboration** and tech transfer routes

UW participation is more than 60 faculty members and 90 students and Post-Docs from 15 departments and three colleges at UW-Madison.

UWAMIC Consortium Annual Meeting Participation

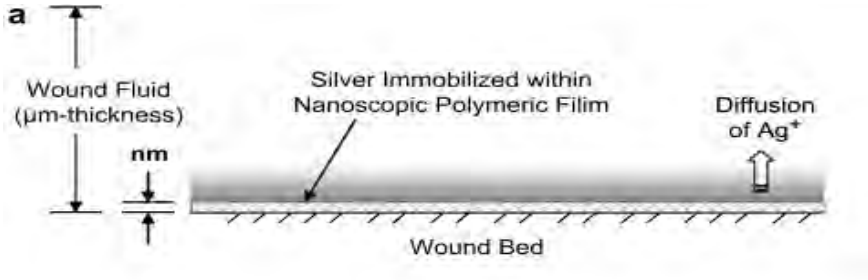
2012 Annual Meeting

- Largest attendance ever! 70 registered participants, 25 from industry
  - Member Presentations and Posters
    - company-to-company collaborations
    - Greater participation from UW-Madison researchers

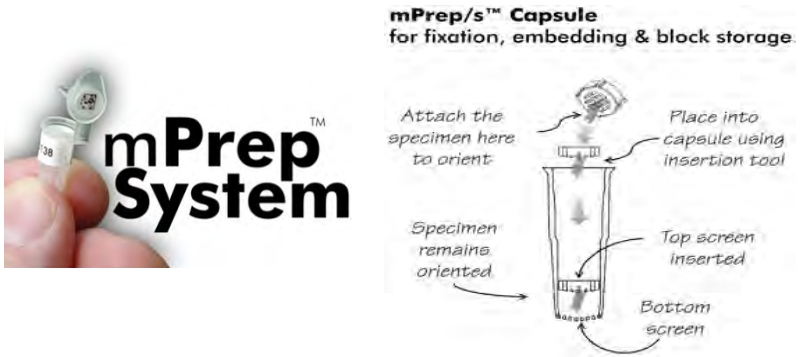
Consortium Industrial Collaborations:

- **Four companies have Industrial associates on Campus**
  - **Cameca** –Biological Atom Probe
  - **Imbed Biosciences** – wound dressings and surgical implants
  - **Microscopy Innovations** – new Sample Preparation
  - **Platypus Technologies** – LC sensors

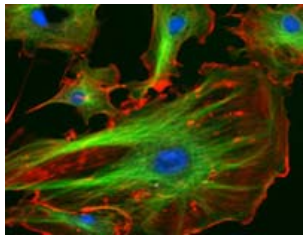
Imbed Biosciences

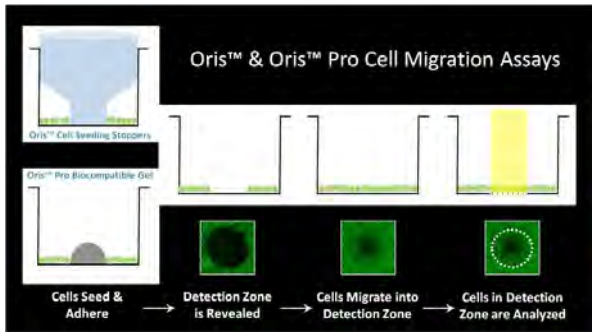


Microscopy Innovations



Platypus Technologies





Impact on the state: NSEC impacts state legislation

2009: Legislation introduced to regulate the use of nanomaterials within Wisconsin

Wisconsin State Legislature
Legislative Council

20010-11: Legislative Study Committee appointed to examine issue and work with legislators to develop recommendations to legislature

Peterson (T4) and Hamers (T4), public member, Scheufele (SI) testified (presentation)

Public Members act as expert witnesses and are asked to inform, but are not asked to advocate any particular position

2012: Legislation introduced based on informed discussion (2011 Senate Bill 533)

PART III - RECOMMENDATIONS INTRODUCED BY THE JOINT LEGISLATIVE COUNCIL 9

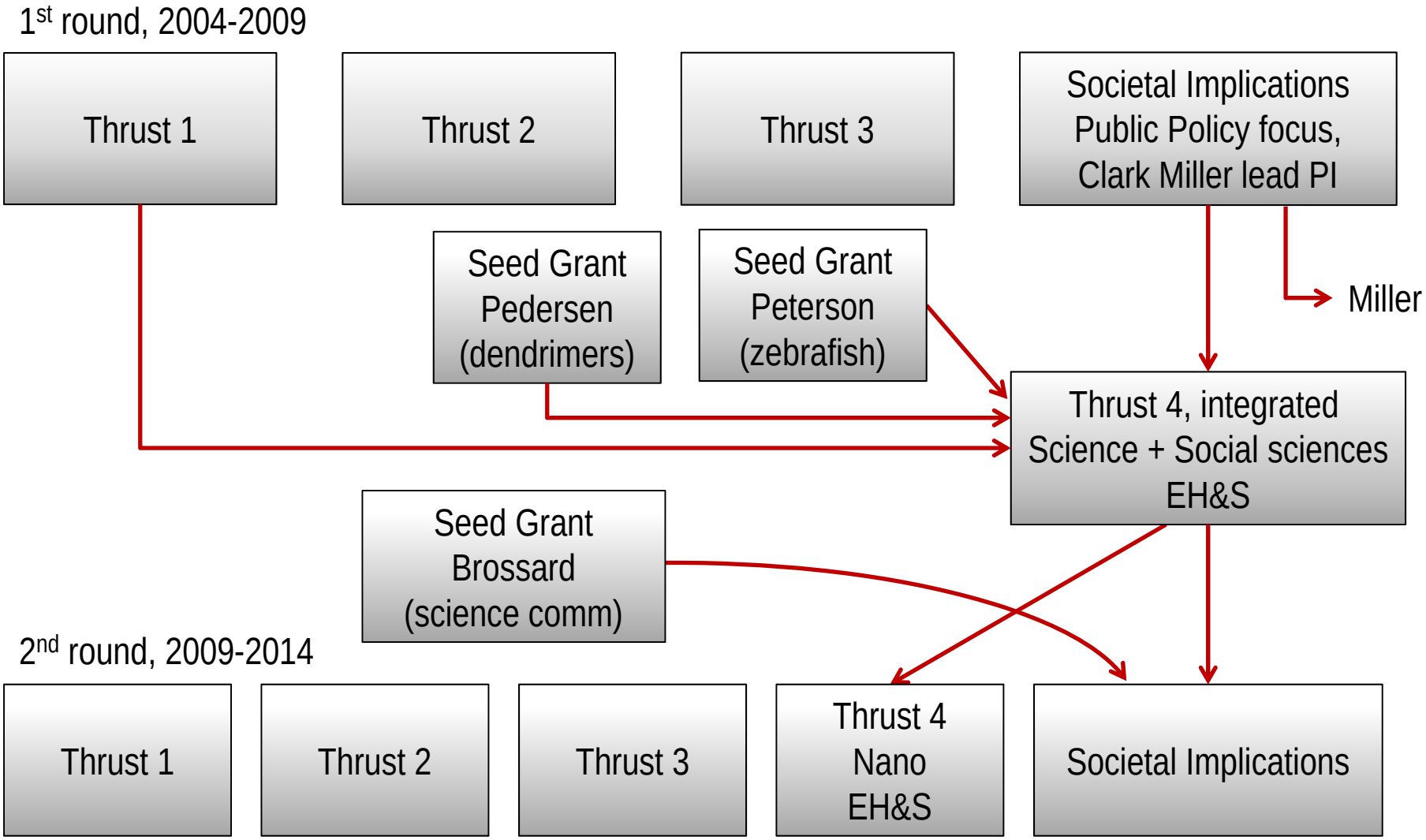
WLC: 0037/3, Relating to Establishing a Nanotechnology Information Hub and a Nanotechnology Council 9

WLC: 0101/2, Relating to a Wisconsin Interagency Nanotechnology Council 11

PART IV - OTHER ACTION OF THE COMMITTEE 15

Initial proposal to regulate nanotechnology was transformed into submitted legislation to innovate by providing EH&S information to state businesses and Enhance safe use of nanomaterials within the state (But bill eventually died without a vote….)

Evolution of NSEC Structure 2003-2013

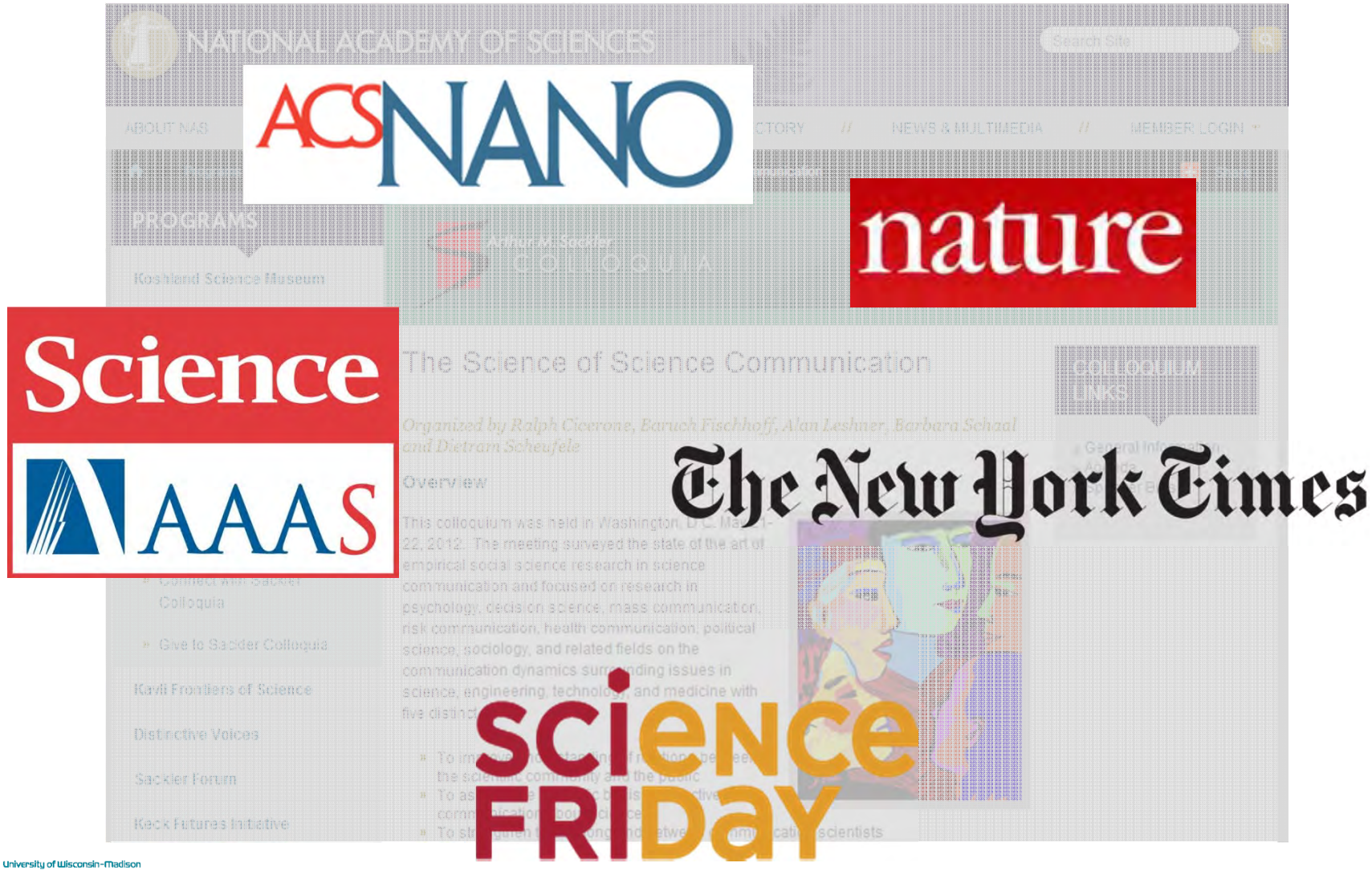


Legacy:

Creation of a new science-based thrust (Thrust 4) with strong SI connection

SI group focusing on science-based approach to science communication

NSEC Informing the Debate on Science Communication



Forward Looking
Training The Scientists of Tomorrow

Franci, M. (2011). *Nature Chemistry 3*, 183-184

Tweeting to the top?

By Sara K. Yeo, Dominique Brossard, Dietram A. Scheufele, Paul Nealy, Elizabeth Corley

Upcoming Opinion Article, *The Scientist*

Social media is blurring the lines between scholarly and traditional forms of popular communication, and scientists need to take advantage.

Outlook > 2014

- Much better organization across multiple colleges for handling multidisciplinary grants
(e.g., CCI Phase I Center → 6 institutions)

- Soft Materials Laboratory poises group to seek external funding from NSF and other agencies, also improves new and emerging links to industry

- Many new joint appointments

- Junior faculty hiring and tenure now encourages collaboration within and across disciplines

- Large number of faculty participate in collaborative research

- Shared graduate students are common

- UW-Advanced Materials Consortium provides infrastructure for engaging with industry and establishing university-industry partnerships

Legacy of NSEC

- The NSEC has gelled into a highly productive interdisciplinary center.
- NSEC has brought in fundamental cultural changes on campus by bringing in physical sciences and social sciences to interact with the engineering college.
- Infrastructure for nanoscience research on campus has evolved to be world class.
- Fundamental research with an impact in transformative technologies.
- The NSEC is educating and training large numbers of sought-after (both industry and academia), uniquely skilled scientists and engineers.
- The NSEC has established a high impact education program.
- The NSEC has become a focal point for increasing the diversity of the UW and creating programs for improved diversity in science and engineering nationally.
- The NSEC has enthusiastically and proactively embraced the incorporation of environmental health and safety and societal implications of nanotechnology.