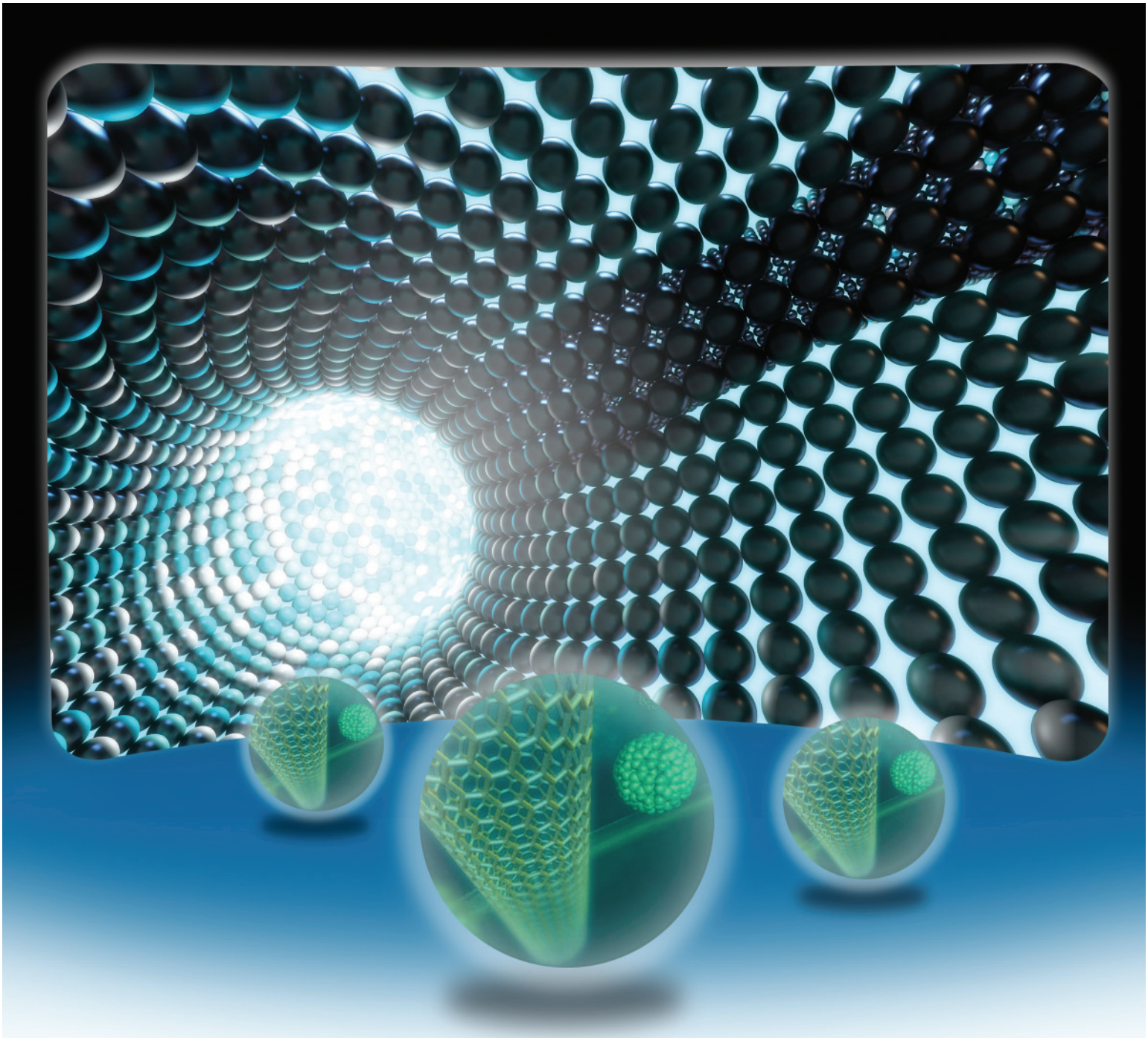

Pollution Prevention through Nanotechnology Conference

September 25-26, 2007

P2 Through Nanotechnology
September 25-26, 2007

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September 25-26, 2007

Sponsored by:

U.S. Environmental Protection Agency's
Office of Prevention, Pesticides, and Toxic Substances &
Office of Research and Development

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In collaboration with the National Science and Technology Council's (NSTC)
Subcommittee on Nanoscale Science, Engineering, and Technology (NSET)

EPA would like to acknowledge and thank the following Pollution Prevention through Nanotechnology Conference Steering Committee members for their insight and leadership in working with EPA to develop this conference.

Steering Committee Members

Lynn Bergeson, Bergeson & Campbell, P.C.

David Berube, University of South Carolina

Jeffrey Burke, National Pollution Prevention Roundtable

Ken Geiser, University of Massachusetts, Lowell

Michael Gorman, University of Virginia

James Hutchison, University of Oregon

Terry Medley, DuPont

Sean Murdock, NanoBusiness Alliance

David Rejeski, Woodrow Wilson International Center

Jennifer Sass, Natural Resources Defense Council

Jeffery Steevens, U.S. Corps of Engineers

Beverley Thorpe, Clean Production Action

Acronyms for U.S. Environmental Protection Agency Programs

CCD – Chemical Control Division

DfE – Design for the Environment

EPA – Environmental Protection Agency

OPPT – Office of Pollution Prevention and Toxics

OPPTS – Office of Prevention, Pesticides, and Toxic Substances

ORD – Office of Research and Development

OSP – Office of Science Policy

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Day One – Tuesday, September 25, 2007

9:00 AM **Registration**

9:30 AM **Introductions and Setting the Stage**
Moderator: Clive Davies, *Chief, DfE Branch, OPPT, OPPTS, U.S. EPA*

Priorities and Perspectives
James Gulliford, *Assistant Administrator*
OPPTS, U.S. EPA

Science and Research
Dr. George Gray, *Assistant Administrator*
ORD, U.S. EPA

Nanotechnology and Pollution Prevention Overview
Dr. Clayton Teague, *Director*
National Nanotechnology Coordination Office

Conference Framework, Goals, and Desired Outcomes
Charles Auer, *Director*
OPPT, OPPTS, U.S. EPA

Discussion

10:55 AM **Break**

11:15 AM **Nanotechnology Life-Cycle Considerations**
Moderator: Jeff Morris, *Associate Director for Science, OSP, ORD, U.S. EPA*

Life-Cycle Thinking for Sustainable Nanotechnology
Dr. Lauren Heine, *Director of Applied Science*
GreenBlue

Identifying Life-Cycle Issues for Nanotechnologies
David Rejeski, *Director, Project on Emerging Nanotechnologies*
Woodrow Wilson International Center

Applying Green Chemistry Principles to Nanotechnology
Professor James Hutchison, *Department of Chemistry, University of Oregon and Director, ONAMI Safer Nanomaterials and Nanomanufacturing Initiative (SNNI)*

Discussion

12:15 PM **Lunch**

1:15 PM **Nanotechnology Products**
Moderator: Dr. Jeffery Steevens, *Research Toxicologist, U.S. Army Corps of Engineers*

Alternatives to Chrome VI Coatings
Dr. Greg Engleman, *Coating Technologies*
Powdermet, Inc.

Easy-to-Clean Surfaces and the Underlying Nanoscale Materials
Dr. Fred Klaessig, *Business Director, Aerosil Business Line*
Degussa Corporation

Energetics, Including Safer Non-Lead Primers to Prevent Pollution
Professor Shubhra Gangopadhyay, *LaPierre Chair Professor*
Department of Electrical and Computer Engineering,
University of Missouri at Columbia

Nanoscale Thermoelectric Materials and Devices
Dr. Rama Venkatasubramanian, *Senior Research Director*
Center for Solid State Energetics, RTI International

2:40 PM **Break**

3:00 PM **Nanotechnology Processes**
Moderator: Dr. Dennis Utterback, *OSP, ORD, U.S. EPA*

Nanoengineering Materials for Pollution Prevention: Concrete and Reduced CO_2 Emissions
Professor Franz-Josef Ulm, *Department of Civil and Environmental Engineering, Massachusetts Institute of Technology*

Stereoselective Green Chemistry Strategies Using Crystal-to-Crystal Reactions: The Advantages of Molecular Nanocrystals
Professor Miguel Garcia-Garibay, *Department of Chemistry and Biochemistry*
University of California, Los Angeles

Nanotechnology as a Tool to Advance Pollution Prevention in the Semiconductor/IT Industry
Dr. Arthur Fong, *Corporate Environmental Affairs, IBM Corporation*

4:05 PM **Energy or Resource Efficiency**
Moderator: Jeffrey Burke, *Executive Director, National Pollution Prevention Roundtable*

Nanomaterials for Low-Cost, High-Efficiency Solar Cells for Clean Energy Production
Professor Peter Peumans, *Department of Electrical Engineering*
Stanford University

Pores Without Walls for Clean Energy
Professor Omar Yaghi, *Department of Chemistry and Biochemistry*
University of California, Los Angeles

Nanotechnology Enabled Materials for Energy Conservation
Dr. Daniel Rardon, *Manager Advanced Technologies*
PPG Industries

5:10 PM **Adjourn**

5:30 PM **Reception and Poster Session**

Day Two – Wednesday, September 26, 2007

8:45 AM **Day Two Welcome**
Clive Davies, *Chief, DfE Branch, OPPT, OPPTS, U.S. EPA*

9:00 AM **Case Study #1: Nanotechnology Processes – Catalysts**
Moderator: Dr. Jeremiah Duncan, *Amercian Association for the Advancement of Science (AAAS) Environmental Fellow, U.S. EPA*

Green Catalytic Processes: Substitution of Volatile Liquid Acids with Solid Acids
Professor Israel Wachs, *G. Whitney Snyder Professor*
Rossin College of Engineering & Applied Science, Lehigh University

Business Potential of Nano Catalysts for Clean Energy
Pankaj Dhingra, *President and Chief Executive Officer*
Nanostellar, Inc.

Nano-Enabled Catalysts for the Commercially Viable Production of H_2O_2
Dr. Bing Zhou, *Vice President and Chief Technology Officer*
Headwaters Technology Innovation Group

Green Chemistry and Life-Cycle Thinking
Professor Terrence Collins, *Thomas Lord Professor of Chemistry and Director, Institute for Green Oxidation Chemistry, Carnegie Mellon University*

Discussion

10:20 AM **Break**

10:40 AM **Case Study #2: Nanotechnology Products – Flame Retardants**
Moderator: Lynn L. Bergeson, *Esquire, Managing Director, Bergeson & Campbell, P.C.*

Nanocomposite-Based Flame Retardants Research at NIST
Dr. Jeffrey W. Gilman, *Leader, Materials and Products Group, Fire Research Division*
National Institute of Standards and Technology

Environmentally Friendly, Nano-Based Polyurethane Fire Retardant Systems
Professor Richard A. Pethrick, *Department of Pure and Applied Chemistry*
University of Strathclyde

Commercialization of Nanoclays for Use as Fire Retardants
Dr. Tie Lan, *General Manager*
Nanocor, Inc.

Learning From Chemical Flame Retardants: The Life-Cycle Questions We Need to Answer
Dr. Mark Rossi, *Research Director*
Clean Production Action

Discussion

12:00 PM **Lunch**

1:00 PM **Case Study #3: Energy / Resource Efficiency – Lithium-Ion Batteries**
Moderator: Kathleen Vokes, *DfE Branch, OPPT, OPPTS, U.S. EPA*

The Enabling Role of Nanomaterials in Lithium Battery Technology for Improved Energy Utilization and Conservation
Professor Yet-Ming Chiang, *Department of Materials Science*
Massachusetts Institute of Technology and Co-Founder of A123 Systems

Nano-Based Lithium-Ion Batteries for Electric Vehicles
Dr. Evan House, *Director, Lithium Titanate Battery Program*
Altair Nanotechnologies, Inc.

Keeping Pace with Nanotechnology: A Proposal for a New Approach to Environmental Accountability
Lee Paddock, *Associate Dean for Environmental Law Studies*
The George Washington University Law School

Discussion

2:15 PM **Break**

2:30 PM **Perspectives and Next Steps**
Moderator: Dr. Ken Geiser, *Co-Director, Lowell Center for Sustainable Production*
University of Massachusetts Lowell

Terry Medley, *Global Director of Corporate Regulatory Affairs*
DuPont Environmental and Sustainable Growth Center

Beverley Thorpe, *International Director*
Clean Production Action

David Rejeski, *Director*
Project on Emerging Nanotechnologies,
Woodrow Wilson International Center

3:15 PM **EPA Perspectives and Closing Remarks**

Jeff Morris, *Associate Director for Science*
OSP, ORD, U.S. EPA

Jim Willis, *Director*
CCD, OPPT, OPPTS, U.S. EPA

3:30 PM **Adjourn**

Pollution Prevention through Nanotechnology Conference Scoping Paper

The purpose of this paper is to explain the scope of EPA's Pollution Prevention through Nanotechnology Conference, including the need for responsible attainment of the pollution prevention benefits that can result from nanotechnologies.

Background

The National Nanotechnology Initiative (NNI) is a federal research and development program established to coordinate efforts in nanoscale science, engineering, and technology. As a participant in the NNI, the U.S. Environmental Protection Agency (EPA) is supporting research in this technology, while evaluating its regulatory responsibility to protect the environment and human health. In February 2007, EPA published the "Nanotechnology White Paper," which described EPA's science needs associated with nanotechnology. One of the recommendations of the document addresses the potential for pollution prevention through nanotechnology innovation. The Pollution Prevention through Nanotechnology Conference will: (1) improve understanding of the potential for pollution prevention benefits through nanotechnology; (2) aid understanding of the life-cycle considerations associated with the responsible development of nanotechnology; and (3) inform the development of EPA's program for nanoscale materials under the Toxic Substances Control Act (TSCA), including the development of a Stewardship Program for nanoscale materials.

Pollution prevention

Pollution prevention is reducing or eliminating waste at the source by modifying production processes, promoting the use of non-toxic or less-toxic substances, implementing conservation techniques, and re-using materials rather than putting them into the waste stream.

Beneficial characteristics

The unique and potentially useful properties of nanomaterials include dramatically increased surface areas and reactivities, improved strength-weight ratios, increased electrical conductivity, and changes in color and opacity. Materials designed to take advantage of these properties are finding application in a variety of areas, such as electronics, medicine, and environmental protection.

This conference is focused on three major areas of pollution prevention:

- Products – Products that are less toxic, less polluting, and wear-resistant;
- Processes – Processes that are more efficient and waste-reducing;
- Energy and Resource Efficiency – Processes or products that use less energy and fewer raw materials because of greater efficiency.

Products

Examples of products with potential for preventing pollution include coatings that are free of volatile organic compounds and diisocyanates, safer surfactants, and self-cleaning surfaces. Nanotechnology and nanomaterials can help create alternatives to light-emitting or absorbing applications that previously relied upon heavy metal-based semiconductors. Nanocomposites may be used in a variety of products, resulting in reduced need for addition of flame retardant chemicals. In addition, products including a variety of tools, automobile and airplane components, and coatings can be made harder and more wear-, erosion-, and fatigue-resistant than conventional counterparts.

Processes

Processes that could prevent pollution include more efficient industrial chemical production through the use of nanoscale catalysts, and the bottom-up self-assembly of materials, resulting in processing efficiency, reduction of waste in manufacturing, and stronger materials with fewer defects. In addition, the ability to enhance and tune chemical activity can result in catalysts that improve the efficiency of chemical reactions in automobile catalytic converters, power generation plants, and manufacturing facilities.

Energy and Resource Efficiency

Efficiency of resource use could be improved through nanotechnologies such as light-emitting diodes. Nanocomposites are valued in automotive applications for their improved physical properties and their ability to produce parts with reduced weight (leading to improved fuel efficiency). Carbon nanotubes added to inherently non-conductive polymers allow nanocomposite parts to be painted using electrostatic methods, significantly reducing paint emissions. Conventional and rechargeable batteries are used in a growing number of portable electronic devices, and nanomaterials are beginning to make an impact by enabling batteries to last longer and withstand an increased number of charging cycles. In addition, nanomaterials can be used to make aerogels: porous and extremely lightweight materials that can save energy when used as insulation.

Responsible development

While nanomaterials have beneficial applications, they also raise concerns over potential implications for human health and the environment. Bioaccumulation potential, toxicity, worker and community exposure, and ultimate fate are among the concerns that merit consideration. The pursuit of pollution prevention applications of nanotechnology should be undertaken with consideration of the potential impacts across the entire life cycle of the nanomaterials, including production, use, and end-of-life disposition. A broad consideration of the benefits and potential impacts can help to ensure that economic and environmental benefits are maximized, while minimizing the likelihood of unintended adverse consequences.

Pollution Prevention through Nanotechnology Conference Charge to Participants

Background

To better understand the benefits that nanotechnology can offer by preventing pollution, and to encourage development of nanotechnology that offers such benefits, EPA convened a multi-stakeholder Steering Committee to plan a *Pollution Prevention through Nanotechnology Conference*. The Steering Committee helped refine goals and set the content for the conference.

To emphasize the importance of the responsible development of nanotechnology, conference speakers and attendees are encouraged to apply "life-cycle thinking" as they make presentations or participate in conference sessions. Life-cycle thinking involves consideration of environmental and human health endpoints such as toxicity and exposure that occur over the material's life cycle. Design, production, use, and disposal are all relevant to life-cycle thinking. While these aspects may not be specifically identified in each conference session, they will be considered throughout.

Questions

The questions below are intended to focus presentations and discussions at the conference. Answers to these questions could help guide subsequent work in P2 through nanotechnology.

1. Which nanotechnologies show the greatest promise for preventing pollution?

   Considerations:
   - This question should be viewed through the lens of life-cycle thinking to minimize the possibility of unintended consequences.
   - Which pollution prevention applications are the most likely to find real-world applications?
   - What barriers exist to the adoption of nanotechnology-enabled pollution prevention applications?

2. What are the most promising areas of research on pollution prevention applications of nanotechnologies?

   Considerations:
   - Which research areas could improve our understanding of the full life cycle of nanomaterials?
   - How can the beneficial properties of engineered products of nanotechnology such as increased surface activity, greater conductivity, improved strength-weight ratio, altered optical properties (changes in color or opacity), and flame retardancy be used to improve materials and products and reduce the production of pollutants at their source?

3. What recommendations do conference participants have for promoting and encouraging pollution prevention in the development and application of nanotechnology?

   Considerations:
   - What actions could be taken, and by whom?
   - What mechanisms, programs, or associations could promote the research, development, and adoption of such applications?
   - What role can EPA programs play?

Pollution Prevention through Nanotechnology Conference Presentation Abstracts

DAY ONE – TUESDAY, SEPTEMBER 25, 2007

Nanotechnology Life-Cycle Considerations

Life-Cycle Thinking for Sustainable Nanotechnology

Dr. Lauren Heine, *Director of Applied Science, GreenBlue*

The value of life cycle thinking is that it can support sustainable product development and sustainable material flows, which includes the protection of human and environmental health and ecosystems. While a focus on hazard (and risk) during the use phase is critical to public acceptance of nano-based products, manufacturers and consumers should not forget that earlier and later stages of the life cycle are points of potential exposure and unintended consequences.

How might industry demonstrate due diligence in the design, development, and deployment of nanotechnologies so that society may reap the benefits of these technologies? This will require industry to address well-founded concerns, based on the historical impact of conventional chemicals.

Identifying Life-Cycle Issues for Nanotechnologies

David Rejeski, *Director, Project on Emerging Nanotechnologies, Woodrow Wilson International Center*

This presentation will examine the life-cycle of nanomaterials from multiple perspectives: physical, biological, regulatory, and user/consumer perception. The purpose is to develop a fuller understanding of barriers to the application of pollution prevention approaches to nanotechnologies, both existing and emerging, and identify possible solutions. The talk will also include the results of new survey work that examined barriers to implementing green approaches to nanotech.

Applying Green Chemistry Principles to Nanotechnology

Professor James Hutchison, *Department of Chemistry, University of Oregon and Director, ONAMI Safer Nanomaterials and Nanomanufacturing Initiative (SNNI)*

Nanotechnology promises considerable benefit to society and the environment. However, the products of nanotechnology and the manufacturing processes used to produce these products may pose threats to human health, the environment, worker safety, and security. The challenge will be to develop nanotechnology to provide maximum benefit, while minimizing the hazards. Green chemistry and engineering principles can be adopted to guide the early stages of product and process development to meet this challenge. Discoveries in nanoscience will provide new opportunities for the development of sustainable technologies. This presentation will discuss how green chemistry principles guide the responsible development of nanotechnology and how nanoscience can enable the discovery of greener products and processes. Specific examples of greener syntheses, purification strategies and nanofabrication methods will be presented.

Nanotechnology Products

Alternatives to Chrome VI Coatings

Dr. Greg Engleman, *Coating Technologies, Powdermet, Inc.*

Chrome and cadmium plating provide very effective surface treatments for wear and corrosion reduction. In use for more than 70 years, they have proven to be a relatively inexpensive, effective solution. Electrolytic Hard Chrome (EHC) is applied using the reduction of hexavalent chrome in a solution of chromic acid. The EHC plating process is a low efficiency process which results in vigorous gas evolution at the electrode. This results in airborne mist which contains hexavalent chrome, a known carcinogen. Several alternative technologies exist to coat a substrate with metal without using electrolytic solutions or plating baths. These technologies do not eliminate the use of metal coatings, but they do eliminate the use of non-metal toxic components such as cyanide from the plating process. They can also reduce the amount of metal-contaminated wastewater and sludge that is generated from plating. These alternative technologies include thermal spray coating, vapor deposition, and chemical vapor deposition, and can be used to apply alternate materials. Powdermet, Inc. has developed a combined top-down/bottom-up approach to this problem, utilizing a novel process for producing nano-featured feedstock materials for the alternative technologies mentioned above. This approach both reduces the amount of waste produced and the amount of post plating processing required resulting in a hard, corrosion resistant coating.

Easy-to-Clean Surfaces and the Underlying Nanoscale Materials

Dr. Fred Klaessig, *Business Director, Aerosil Business Line, Degussa Corporation*

The ability to control surface roughness reproducibly at the nanoscale, combined with surface reaction kinetics and spreading of liquids has led to many descriptive terms such as easy-to-clean, self-cleaning, anti-fouling, dirt resistant and anti-graffiti. These capabilities are extensions of traditional concepts behind matte, semi-gloss and glossy finishes, but with the added functionality of phenomena that are enhanced at the nanoscale. In the presentation, examples will be provided using Lotus Effect®, AEROXIDE® P25 (nanostructured titania) and Protectosil® Anti-Graffiti products.

Energetics, Including Safer Non-Lead Primers to Prevent Pollution

Professor Shubhra Gangopadhyay, *LaPierre Chair Professor,*
Department of Electrical and Computer Engineering, University of Missouri at Columbia

The Gangopadhyay Research Group is currently developing nanoengineered thermites (nanothermite) with tailored properties that are expected to replace lead azide and lead styphnate primers in the near future. Nanothermites are comprised of a mixture of fuel and oxidizer nanostructures. Typically Al nanoparticles are used as fuel and metal oxides like CuO, MoO_3, Bi_2O_3 are used as oxidizers. Environmentally safe chemicals are utilized for the preparation of these materials. Nanothermite are self-assembled and coated with polymers or explosives in nanoscale for applications such as primers, reactive materials, propellant initiators etc. These materials are also integrated with microdevices for various applications such as micro-thrusters, power generators, micro-shock generators for drug delivery and microinitiators.

Nanoscale Thermoelectric Materials and Devices

Dr. Rama Venkatasubramanian, *Senior Research Director,*
Center for Solid State Energetics, RTI International

Increasingly, the ability to provide power and cooling are major factors in how large scale computer systems, as in internet data centers, are designed and managed. This stems from the fact that advanced high-performance electronics in many situations are currently limited by the ability to remove heat from the operating chip. This heat is typically concentrated in hot spots in the chip, experiencing very high heat fluxes. Such thermal problems are also relevant to small-scale computationally intense, wireless and

communication devices that rely on advanced algorithms for voice, video and error-free data operations. Component and system level heat flux densities are projected to increase as computers and other digital devices add increased functionality. Strategies to manage these problems will have a profound impact on future technology and economic growth. Concomitant with these technology issues- are the emerging problems of rising energy costs that is demanding higher efficiency in automobiles to cooling systems, as well as in other energy-intensive industries. It is worth noting that nearly 60% of the world's useful energy is wasted as heat. Thus it is worth considering the recovery of even a fraction of this heat by converting to useful electric power. Complicating this mix is the urgent need for limiting CO_2 levels in the atmosphere to contain global warming and minimizing ozone-depleting refrigerants. This presentation will demonstrate how nanoscale thermoelectric materials and device technology can have an impact on such a broad spectrum of emerging technological, energy and environmental issues.

Nanotechnology Processes

Nanoengineering Materials for Pollution Prevention: Concrete and Reduced CO_2 Emissions

Professor Franz-Josef Ulm, *Department of Civil and Environmental Engineering, Massachusetts Institute of Technology*

Protecting the built environment from the forces of the natural world with dams and seawalls is important work, as is protecting the natural environment from the engineered world. But the 21st-century engineer should also look to the natural world as a powerful design partner and a source of sustainable solutions. A good place to begin is by studying the way natural materials are constructed at the nanoscale and drawing inspiration from them as we engineer our own materials. Take, for example, the civil engineer's construction material of choice: concrete, the oldest engineered building material and one of the most widely consumed materials on earth, second only to water. Each year, 2.1 billion tons of cement—the primary component of concrete—are manufactured, enough to produce one cubic meter of concrete for every person alive. Unfortunately, cement is a major source of atmospheric carbon dioxide—largely because it's made by burning fossil fuel to heat a limestone and clay powder to 1,500 °C, which changes its molecular structure. When the cement powder is later mixed with water and gravel, the invested energy is released into chemical bonds that form calcium silicate hydrates--the glue that binds the gravel to make concrete. The production of cement accounts for 7 to 8 percent of all human-generated carbon dioxide emissions. If novel cement can be engineered, whose manufacture produces only half as much CO_2, a significant reduction in total CO_2 emissions will be achieved. This presentation will discuss most recent results of the application of nanotechnology that may make all this happen.

Stereoselective Green Chemistry Strategies Using Crystal-to-Crystal Reactions: The Advantages of Molecular Nanocrystals

Professor Miguel Garcia-Garibay, *Department of Chemistry and Biochemistry, University of California, Los Angeles*

It has recently been shown that photochemical excitation of crystalline ketones bearing radical-stabilizing substituents on their two α-positions leads to efficient photodecarbonylation reactions. Experiments with crystals of carefully designed carbonyl compounds can be used to accomplish the formation of sigma bonds between adjacent quaternary stereogenic centers in good chemical yields and with remarkable chemical control. The exceptional simplicity, chemoselectivity, and stereospecificity of the solid state reactions has been combined with well-developed ketone chemistry for the preparation of several natural products, including the sesquiterpenes cuparenone, herbertenolide and touchuinyl acetate. Simple scale up strategies based on nanocrystals and the use of sunlight suggest a remarkable potential for specialty chemicals applications for these crystal-to-crystal reactions.

Nanotechnology as a Tool to Advance Pollution Prevention in the Semiconductor/IT Industry

Dr. Arthur Fong, *Corporate Environmental Affairs, IBM Corporation*

Nanotechnology is not new to the semiconductor/IT (information technology) industry. Many features in semiconductors and integrated circuits have been at the nanoscale for decades. The International Technology Roadmap for Semiconductors identifies nanotechnology, both traditional semiconductor nanotechnology and novel nanomaterials, as a critical key to the future development of the industry, both in extending the current CMOS (complimentary metal oxide semiconductor) scaling and in positioning beyond the current CMOS platform. The expanded use of nanotechnology and the incorporation of nanomaterials into semiconductor/IT processes and products not only provide potential solutions to many technical and business challenges facing the industry, but they also offer a tremendous opportunity to advance pollution prevention. Examples of nano-applications in semiconductor/IT processes and products that may result in energy and resource conservation, waste minimization, and energy efficient products include bottom-up self assembly, nanoarchitecture, and nanophotonics.

Energy or Resource Efficiency

Nanomaterials for Low-Cost, High-Efficiency Solar Cells

Professor Peter Peumans, *Department of Electrical Engineering, Stanford University*

Materials structured on the nanoscale offer new opportunities to engineer solar cells that are both cheap and efficient. This presentation will focus on the use of nanostructured metals to guide optical energy on the nanoscale and to make electrodes that are very conductive yet also extraordinarily transparent. It will be demonstrated how micro- and nanostructuring of conventional materials such as silicon can lead to new paradigms for solar cell manufacturing that could lead to solar cells that are an order of magnitude cheaper.

Pores Without Walls for Clean Energy

Professor Omar Yaghi, *Department of Chemistry and Biochemistry, University of California, Los Angeles*

Reticular chemistry concerns the linking of molecular building blocks into predetermined structures using strong bonds. We have been working on developing the conceptual and practical basis of this new area of research. As a result, new classes of crystalline porous materials have been designed and synthesized: metal-organic frameworks, covalent organic frameworks, and zeolitic imidazolate frameworks. Crystals of this type have exceptional surface areas (2,000-6,000 m^2/g) and take up voluminous amounts of hydrogen (7.5 wt% at 77 K and 30-40 bar), methane (50% at 298K and 25 bar), and carbon dioxide (140 wt% at 298 K and 30 bar); the first is considered the clean fuel of the future and the latter two are considered green house gases. This presentation will outline the design concepts of these materials, their synthesis and applications.

Nanotechnology-Enabled Materials for Energy Conservation

Dr. Daniel Rardon, *Manager Advanced Technologies, PPG Industries*

Nanotechnology offers the promise for new solutions and product improvements to a variety of market sectors including materials, electronics, energy, bio-medical, and consumer goods. A great deal of emphasis is placed on the real societal benefits around nanotechnology for energy efficiency, renewable resources, environmental remediation, and pollution prevention. Examples include more efficient solar and wind energy technologies, better batteries and fuel cells, heat recovery, water and air treatment, and carbon sequestration solutions. While all of these initiatives are critical to the future of the global society and economy, most are forward-looking, coming to fruition over the coming years and decades. Often overlooked are the currently available technologies, made possible by nanotechnology, which can provide immediate benefit for energy conservation if more widely adopted.

DAY TWO – WEDNESDAY, SEPTEMBER 26, 2007

Case Study #1: Nanotechnology Processes – Catalysts

Green Catalytic Processes: Substitution of Volatile Liquid Acids with Solid Acids

Professor Israel Wachs, *G. Whitney Snyder Professor,*
Rossin College of Engineering & Applied Science, Lehigh University

Catalysts are chemical agents that selectively accelerate molecular transformations. Catalytic materials are extensively employed by the petroleum, chemical, plastics, pharmaceutical, food, energy and environmental industries. Catalysis has become indispensable for the existence of modern society and is related to industrial production responsible for ~20% of USA's GNP. Approximately 25% of catalytic applications are related to environmental applications and environmental catalysis represents the fastest growing market for catalysts.

Liquid acids such as sulfuric acid (H_2SO_4) and hydrofluoric acid (HF) are employed by the petroleum and chemical industry to catalyze numerous molecular transformation reactions. Evaporation of these liquid acids contributes to acid rain and accidental spills can contribute to groundwater contamination. Thus, there is a strong incentive to develop solid acid catalysts that would replace these liquid acid catalysts.

Solid tungstated zirconia (WO_3/ZrO_2) catalysts have found application in the petroleum industry to increase fuel octane number by isomerizing long chain alkanes to branched alkanes (e.g., n-pentane to isobutene). The nature of the catalytic active site in the solid tungstated zirconia catalytic material is not well understood and, consequently, has hampered further performance improvements.

Cutting edge molecular and electronic characterization of tungstated zirconia solid acid catalysts has identified the nature of the specific catalytic acid site: ~1 nm sized crystalline tungsten oxide (WO_3) nanoparticles (~1 nm) that are stabilized by zirconia impurities. These new fundamental insights have lead to a new synthesis for the preparation of tungstated zirconia solid acid catalysts based on ~1 nm crystalline tungsten oxide nanoparticles.

Business Potential of Nano Catalysts for Clean Energy

Pankaj Dhingra, *President and Chief Executive Officer, Nanostellar, Inc.*

Pankaj Dhingra from Nanostellar will discuss an innovative methodology that Nanostellar is developing and implementing for designing high-performance catalyst materials. Rational Catalyst Design methodology uses quantum physics based models to develop a fundamental understanding of the chemical reactions and material properties and uses this knowledge to design new materials. This process substitutes fast and inexpensive computational cycles for tedious lab-work and enables design of better targeted materials.

Within three years of its inception, Nanostellar introduced NS Gold™, a diesel emissions control material that independent testing has determined to be 15%-20% better than the most advanced materials being readied by the industry for 2010 introduction. The industry participants in this case are all large companies such as BASF, Johnson Matthey and Umicore – each with over $100m in annual R&D budgets and over 30 years of automotive emissions control experience.

Although, until recently, Nanostellar has focused its efforts on developing catalyst materials for automotive emissions control, the Rational Design methodology is generic and Nanostellar plans to use this approach to develop catalysts for biofuels, solar cells and other clean-technology applications in the near future.

Nano-Enabled Catalysts for the Commercially Viable Production of H_2O_2

Dr. Bing Zhou, *Vice President and Chief Technology Officer, Headwaters Technology Innovation Group*

Hydrogen peroxide (H_2O_2) is a clean, versatile, environmentally friendly oxidant that can substitute for environmentally harmful chlorinated oxidants in many manufacturing operations. However, the current manufacturing process for H_2O_2 is complex, high cost, and energy-intensive. This process uses an anthraquinone working solution, containing several toxic chemicals, which requires additional and complex equipment to control exposure. The solution is reduced by hydrogen in the presence of a catalyst, forming anthrahydroquinone, which then reacts with oxygen to release H_2O_2. The H_2O_2 is removed from the solution with an energy-intensive stripping column and then concentrated by vacuum distillation. While the bulk of the working solution is recycled, the balance is a waste stream of quinone-derived byproducts that requires environmentally acceptable disposal.

Headwaters Technology Innovation (HTI) has produced a robust nanocatalyst technology that enables the synthesis of H_2O_2 directly from hydrogen and oxygen. This breakthrough technology, called NxCat™, is a palladium-platinum catalyst that eliminates all the hazardous reaction conditions and chemicals of the existing process, along with its undesirable byproducts. It produces H_2O_2 more efficiently, cutting both energy use and costs. It uses innocuous, renewable feedstocks and generates no toxic waste.

NxCat™ catalysts work because of their precisely controlled surface morphology. HTI has engineered a set of molecular templates and substrates that maintain control of the catalyst's crystal structure, particle size, composition, dispersion, and stability. This catalyst has a uniform 4-nanometer feature size that safely enables a high rate of production with a hydrogen gas concentration below 4 percent in air (i.e., below the flammability limit of hydrogen). It also maximizes the selectivity for H_2O_2 up to 100 percent.

The NxCat™ technology enables a simple, environmentally friendly, commercially viable H_2O_2 manufacturing process. In partnership with Degussa AG (a major H_2O_2 manufacturer), HTI successfully demonstrated its technology in a miniplant over the last 3 years. The partnership completed the construction of a demonstration plant in 2006, is preparing to run the plant for collection of data necessary to design a full-scale commercial plant, and is planning to begin commercial production in 2009. The NxCat™ process has the potential to significantly cut the cost of H_2O_2, generating a more competitively priced supply of H_2O_2 and increasing its market acceptance as an oxidant for chemical synthesis. Except for its historically higher price, H_2O_2 is an excellent substitute for the more frequently used—and far more deleterious—chlorinated oxidants. The NxCat™ technology has the benefit of producing a cost effective, environmentally preferable oxidant (H_2O_2), and is expected to be the oxidant of choice for synthesis of major industrial chemicals.

Green Chemistry and Life-Cycle Thinking

Professor Terrence Collins, *Thomas Lord Professor of Chemistry and Director, Institute for Green Oxidation Chemistry, Carnegie Mellon University*

Since William Henry Perkin accidentally synthesized in 1856 the first synthetic dye, more than 80,000 chemicals have been commercialized. In this building of the chemical enterprise, an unspoken premise has been that useful chemicals cause no harm. This premise is profoundly wrong. Because there was little or no idea of the dangers involved, hazardous chemicals made their way into the economy often to cause harm for decades until their problems were discovered and for additional decades while there were excruciating societal journeys undertaken to remove them from the economy.

In our laissez faire building of the chemical enterprise a great deal has been learned about chemical hazards. This knowledge can now serve as roadmap for guiding us away from the known hazards. In general, chemicals produce three catastrophic toxicological endpoints: cell death; DNA-damage/mutagenesis; and epigenetic alteration of gene expression. This can be roughly translated by saying that chemicals

can devastate living things by killing them, by giving them cancer, or by impairing their offspring. Green chemistry is the design of chemical products and processes to reduce or eliminate the use and generation of hazardous substances. This lecture will focus on the classes of green chemistry problems where, if strategic research were conducted, immense progress in reducing and eliminating pollutants can be made. The lecture will especially focus on problems associated with chemicals that disrupt cellular development, the so-called endocrine disrupting chemicals (EDCs), as these are often viewed as our greatest challenge in developing a sustainable chemistry. The lecture will also explore how to better avoid the extremely serious hazards EDCs represent and focus on structural elements of the chemical enterprise that must be changed if there is to be any hope of success.

Case Study #2: Nanotechnology Products – Flame Retardants

Nanocomposite-Based Flame Retardants Research at NIST

Dr. Jeffrey W. Gilman, *Leader, Materials and Products Group, Fire Research Division, National Institute of Standards and Technology*

For the last several decades halogen-free flame retardant approaches for polymeric materials have been under investigation. Currently, considerable attention has been focused on flame retardant approaches which include nanocomposites as one of the components. NIST has pioneered this field; first focusing on studying the mechanism of nanocomposite flame retardants in thermoplastics and more recently applying it to crosslinked systems such as polyureas and polyurethane foams. This presentation will review some of these results, present the current mechanistic understanding of this flame retardant system and some of the new characterization tools, such as confocal microscopy, TEM image analysis and rheology, which have been developed for measuring nano-particle polymer mixing at several length scales.

Environmentally Friendly, Nano-Based Polyurethane Fire Retardant Systems

Professor Richard A. Pethrick, *Department of Pure and Applied Chemistry, University of Strathclyde*

Current flexible foams are protected against fire by the use of a range of additives, some of which have unfortunate potential toxicological side effects. Polyurethane foams are used extensively in a wide range of applications. Flexible foams are found in furniture; cushions, upholstery, curtain linings, mattresses in bedding, under carpet protection and similar applications. Rigid foams are to be found in sound damping applications in white goods, cars, a variety of transportation including aircraft, and in buildings. In all these applications a reasonable level of fire resistance is desirable and in certain situations required by law. Because of the open cell structure of flexible foams fire retardancy is difficult to achieve. Currently a number of additive are used which rely on their volatility in a fire situation. The compounds used have therefore the potentially of being slowly released into the environment and consequently have the potential of being slowly released during the life of the foam. Some of the most efficient additives are organic compounds which contain either halogens or phosphorous compounds or both. The release of halogen containing organics into the atmosphere is not desirable and some compounds have been shown to have the potential of initiating asthmatic reactions and other medical conditions. It is therefore desirable to where possible remove potentially volatile materials form the system. A further problem with most fire situations is that the heat can cause the foam to melt and drip into the fire and hence fuel the combustion process.

As a consequence of systematic studies of the processes which lead to the creation of a fire it has been possible to identify various types of additives which should be added to the foam to achieve fire resistance. Several factors are worth highlighting:

1. Before a fire is established the polymer melts and chain scission occurs with the creation of low molar mass fragments which will often be close to their spontaneous ignition temperature and hence can create a flame.

2. Subsequent decomposition will feed the flame and establish the fire.
3. The spread of the fire can be reduced by stopping the molten polymer falling into the source of the fire – rheology modification
4. The production of molten polymer can be suppressed by the creation of a char on the surface of the foam – char promotion.
5. The spread of the flame can be influenced by the volatile entities and their ability to sustain the radical chemistry associated with combustion – flame retardants.

Using the above approach a framework was developed which creates an environmentally friendly flexible foam package which meets the Crib 5 tests for industrial foams. In the talk, the fire tests on these foams will be demonstrated and the viability of achieving fire retarded flexible foams without the use of some of the potentially toxic additives will be demonstrated.

Commercialization of Nanoclays for Use as Fire Retardants

Dr. Tie Lan, *General Manager, Nanocor, Inc.*

Nanoclays have been used as plastic flame retardant additives for several years. The unique nature of nanoclay reduces the burning rate of plastics, it also enhances the char forming and anti-dripping of the burning plastics. Combination of nanoclay with regular flame retardant compounds allow reduction of regular FR agents, provide better processability of the FR compounds. Reduction of FR agents, particularly the halogen containing compounds, marks the new FR compound environmentally friendly. The combination of nanoclay with FR agents is applicable to most of the currently commercially available flame retardants.

Learning From Chemical Flame Retardants: The Life-Cycle Questions We Need to Answer

Dr. Mark Rossi, *Research Director, Clean Production Action*

Chemical flame retardants, especially the brominated flame retardants (BFRs), have been the subject of intensive scrutiny for human health and environmental concerns across their life cycle. When considering the use of nanomaterials as flame retardants or additives to flame retardants it is important to learn from the experiences with BFRs and ask the hard life cycle questions now before releasing these materials into the environment. Here are many of the questions that are being asked of flame retardants:

- Extraction: Environmental concerns from extraction have not been raised during discussions of environmental concerns with flame retardants (yet, it is known that the environmental impacts of mining, drilling, and agriculture need to be minimized).
- Manufacturing: Is the nanomaterial reactive or additive in polymers? How is worker exposure to nanomaterials minimized? What are the emissions to the environment?
- Use: What happens to nanomaterials during use? Will exposure to light, heat, or abrasion release nanomaterials into household or office dust? Will nanomaterials collect in dust, to be picked up by babies and toddlers crawling on floors?
- End of Life: What happens to nanomaterials in polymers/textiles when recycled? How will recycling workers be protected? What happens to nanomaterials during combustion? Will nanomaterials alter the formation of combustion byproducts from other chemicals in the product?
- Environmental Fate and Transport: What happens to nanomaterials in the environment? Are they persistent and/or bioaccumulative? Are they capable of long range transport? Or do they safely degrade?
- Toxicological Characteristics: What are the potential toxic effects from exposure to nanomaterials?

Case Study #3: Energy / Resource Efficiency – Lithium-Ion Batteries

The Enabling Role of Nanomaterials in Lithium Battery Technology for Improved Energy Utilization and Conservation

Professor Yet-Ming Chiang, *Department of Materials Science, Massachusetts Institute of Technology and Co-Founder of A123 Systems*

Advanced rechargeable batteries are considered to be a critical and enabling storage technology for the full range of electrified vehicles from hybrid electric (HEVs) to plug-in hybrid electric (PHEVs) to all-electric vehicles (EVs), as well as other large-scale energy systems. Amongst various approaches, a new generation of lithium-ion batteries with improved power, energy, safety, and life, compared to previous lithium-ion batteries developed primarily for portable electronics, has recently reached the commercial marketplace in power tool applications and now is poised for deployment in vehicles. Nanomaterials lie at the heart of these recent advances. This talk will discuss the ability of developing battery technologies to meet performance metrics for automotive and large scale storage applications, and the key underlying scientific issues on which progress will rely.

Nano-Based Lithium-Ion Batteries for Electric Vehicles

Dr. Evan House, Director, *Lithium Titanate Battery Program, Altair Nanotechnologies, Inc.*

Success in the transportation market for EVs, HEVs, and PHEVs is dependant upon a significant improvement in battery technology. Popularity of electric vehicles is a step in the right direction toward a more efficient fuel-based economy, and major automotive manufacturers have embraced this technology. The only thing holding the market back is the battery technology.

Nickel metal hydride batteries, primarily used in the HEV market, are expensive and self-discharge at a fast rate. Traditional lithium ion batteries exhibit safety problems and are intolerant of temperature extremes. Clearly, a new, next-generation, disruptive technology is needed.

Using nano materials, Altairnano has created an environmentally friendly new battery - NanoSafeT. Manufactured in-house, NanoSafe batteries are a rechargeable, nano-titanate battery system that provides fundamental advantages over existing battery solutions. With a very fast charge, long life, high power, an extremely wide operating temperature range, and inherent safety, NanoSafe batteries have what it takes to transform the alternative fuel marketplace and ultimately assist with the prevention of pollution.

Keeping Pace with Nanotechnology: A Proposal for a New Approach to Environmental Accountability

Lee Paddock, *Associate Dean for Environmental Law Studies, The George Washington University Law School*

The rapid growth of the nanotechnology industry that challenges traditional governance structures also calls for new approaches to accountability. Accountability mechanisms would help avoid adverse effects of the evolving technologies, foster public confidence in nanotechnology, and encourage the development of new, beneficial technologies. Prof. Lee Paddock will illustrate some of the tools of environmental accountability that may be employed in the context of nanotechnology. He will discuss how traditional accountability mechanisms already inherent in the federal environmental statutes may be applied, and emphasizes the need for flexibility in permitting, public involvement, voluntary accountability programs, and opportunities for industry self-regulation. He will suggest the creation of a nanotechnology Council to bring stakeholders together to address accountability issues.

Pollution Prevention through Nanotechnology Conference Presenters

Charles Auer, Director
Office of Pollution Prevention and Toxics (OPPT), OPPTS
U.S. Environmental Protection Agency

Mr. Charles M. Auer is the Director of EPA's Office of Pollution Prevention and Toxics (OPPT). OPPT manages this country's new and existing chemicals programs, chemical testing, and efforts to address national priority chemicals such as asbestos, lead, and mercury. OPPT is responsible for oversight of new and existing chemical nanomaterials. OPPT has a lead role in promoting pollution prevention both within the agency and with States, tribes, communities, industry, and environmental communities. The Office is also responsible for numerous successful collaborative, voluntary efforts such as the High Production Volume (HPV) Challenge Program, Green Chemistry, Design for the Environment, and the PFOA Stewardship Program.

Mr. Auer also has broad international experience with the Organization for Economic Cooperation and Development and has had extensive bilateral interaction with the European Union, Canada, Japan, and other major U.S. trading partners. Mr. Auer played a major role in representing the U.S. in the successful negotiation of the Stockholm Convention on Persistent Organic Pollutants (POPs).

Lynn Bergeson, Esquire, Managing Director,
Bergeson & Campbell, P.C.

Lynn L. Bergeson is Managing Director of Bergeson & Campbell, P.C. (B&C), a Washington, D.C. law firm concentrating on conventional and engineered nanoscale chemical, pesticide, and other specialty chemical product regulation and approval matters, domestic and foreign chemical classification, chemical product litigation, Food and Drug Administration (FDA)-regulated product approval, and associated business issues. Ms. Bergeson is also President of The Acta Group, L.L.C. and The Acta Group EU, Ltd., B&C's consulting affiliates, with offices in Washington, D.C. and Manchester, U.K., respectively.

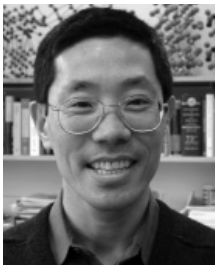
Ms. Bergeson counsels clients on health, safety, science policy, and related legal and regulatory aspects of traditional domestic chemical regulatory programs under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Toxic Substances Control Act (TSCA), as well as on issues pertinent to nanotechnology and other emerging transformative technologies. Ms. Bergeson serves on the President's Council of Advisors on Science and Technology (PCAST) Nanotechnology Technical Advisory Group (PCAST nTAG), and served on the U.S. Environmental Protection Agency's (EPA) Steering Committee for the Pollution Prevention through Nanotechnology Conference. Ms. Bergeson served in 2004 and 2005 on the American National Standards Institute (ANSI) Nanotechnology Standards Panel (NSP) Steering Committee and is now a member of the ISO Technical Committee 229 on Nanotechnologies. Ms. Bergeson also serves on the Board of Directors of Earth Day Network and the Converging Technologies Bar Association (CTBA), and is Chair of the CTBA Environmental, Health, and Safety Committee. She was Chair of the American Bar Association (ABA) Section of Environment, Energy, and Resources (SEER) (2005-2006), is current Chair of the SEER Pesticides, Chemical Regulation, and Right-to-Know Committee, and serves in other ABA leadership positions. Ms. Bergeson is also a member of the ALI-ABA Environmental Law Advisory Panel. Ms. Bergeson serves on the Editorial Board of the Environmental Law Institute's (ELI) *The Environmental Forum*, 2004—; *Pesticide & Toxic Chemical News*, 2002--; *EPA Administrative Law Reporter*, 1996--; *Environmental Quality Management*, 2002--; *Chemical Processing Magazine*, 2002—; and *Pollution Engineering*, 1990—, among other publications. Ms. Bergeson is a member of The District

of Columbia Bar; Bar Association of the District of Columbia; ABA (Section of Environment, Energy, and Resources); Women's Bar Association of the District of Columbia; and the Women's Council on Energy and the Environment.

Ms. Bergeson is listed in *The International Who's Who of Business Lawyers* (2006 and 2007), and *The Chambers USA: America's Leading Lawyers for Business* (2005 and 2006). Ms. Bergeson is a graduate of Michigan State University (B.A., magna cum laude), and the Columbus School of Law, Catholic University of America, where she was a member of the Law Review. She is admitted to the bar of the District of Columbia and several federal circuit courts.

Jeffrey Burke, Executive Director
National Pollution Prevention Roundtable

Jeffrey J. Burke has been the Executive Director of the National Pollution Prevention Roundtable (NPPR) since August 2003. He is responsible for oversight of NPPR's activities, workgroup coordination, and promoting pollution prevention (P2). He retired from EPA in January 2004 after twenty-four years of service, the last ten as the Regional P2 Coordinator in Philadelphia. He was responsible for the National Environmental Performance Track program, development of the Region's Environmental Management System, and P2 training. He has been a speaker at conferences and training workshops throughout the U.S. as well as in China, Dubai, South Africa, Switzerland and Thailand.



Professor Yet-Ming Chiang
Department of Materials Science
Massachusetts Institute of Technology and Co-Founder of A123 Systems

Yet-Ming Chiang is Kyocera Professor in the Department of Materials Science and Engineering at MIT. He received his S.B. degree in 1980 and Sc.D. in 1985, both from MIT, and has been a faculty member at MIT since 1985 with occasional leaves for outside experience including a research appointment at DuPont Central Research in 1992-93. His research focuses on advanced inorganic materials and their applications in energy storage and generation, mechanical actuation, and micro/nano electronic devices. Current projects include advanced rechargeable batteries of various size scales, interfacial thermodynamics and kinetics, self-organizing colloids and related devices, and solid-state electrochemistry-based mechanical actuators for morphing structures.

Professor Chiang is a Fellow of the American Ceramic Society and recipient of its Ross Coffin Purdy, R.M. Fulrath and F.H. Norton Awards, and a recipient of the ONR Young Investigator award. Basic research from his laboratory recently enabled new battery technology that was honored in 2006 with an R&D 100 Award and the R&D 100 Editor's Choice Award. He serves or has served on the editorial boards of Journal of the American Ceramic Society, Journal of Electroceramics, Materials Science and Engineering Reports, and Current Opinion in Materials Science and Engineering. He is a founding scientist of two companies, American Superconductor Corporation (Westboro, Mass.) and A123 Systems, Inc. (Watertown, Mass).

Professor Terrence Collins
Thomas Lord Professor of Chemistry and
Director, Institute for Green Oxidation Chemistry, Carnegie Mellon University

Terry Collins was born in New Zealand in 1952. He received his B.Sc. (1973), M.Sc. (1975) and Ph.D. (1978) degrees from the University of Auckland where his research advisor was Warren R. Roper, FRS. He conducted postdoctoral studies with James P. Collman at Stanford University (1978-80). He is the Thomas Lord Professor of Chemistry at Carnegie Mellon University where he directs the Institute for Green Oxidation Chemistry, a research, education and development center focused upon developing a holistic approach to sustainability science. He is also an Honorary Professor at the University of Auckland. Professor Collins taught the first university course in green chemistry at Carnegie Mellon, starting in 1992. He writes and lectures widely on how chemists can promote sustainability and has delivered over 400 public lectures. Professor Collins' research is focused on greening the historically dirty area of oxidation chemistry by designing nontoxic catalysts for activating the natural oxidants, hydrogen peroxide and oxygen. His widely patented, commercializing TAML activators promise to transform industrial peroxide chemistry, allowing it to substitute more effectively for chlorine- and metal-based processes and to enable much more effective processes for destroying in water recalcitrant pollutants and hardy pathogens.

Clive Davies, Chief
Design for the Environment Branch, OPPT, OPPTS
U.S. Environmental Protection Agency

Clive Davies has served as Chief of the Design for the Environment Program (DfE) in the Office of Pollution Prevention and Toxics at the U.S. Environmental Protection Agency (EPA) since 2003. DfE partnerships offer special advantages to partners and help those partners distinguish themselves as environmental stewards. DfE accesses the unique tools and experts in EPA's new chemicals review program to ensure the technical soundness of DfE partnerships.

DfE recognizes products with environmental and human health profiles that are safer than those for other products with similar uses. DfE also helps industries that are considering alternatives to chemicals of concern. While industry examines cost and performance, DfE partnerships make it possible to cost-effectively account for environmental and human health considerations. DfE partners, including industry, States, and environmental groups, promote DfE Programs and protect the environment and human health through actions they take based on DfE partnerships.

In his 17 years at EPA, Clive has worked in water and air programs and conducted the first national survey of drinking water infrastructure needs.

Pankaj Dhingra, President and Chief Executive Officer
Nanostellar, Inc.

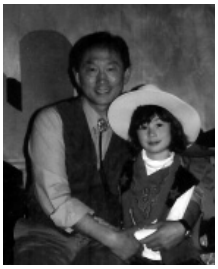
Pankaj Dhingra is president and CEO of Nanostellar, Inc., an emissions control company designing engineered nano-materials to clean diesel automotive exhaust. Pankaj has more than 25 years of experience, including managing a technology startup and a $650 million global automotive components business. His functional experience spans sales, finance, strategic planning and mergers and acquisitions with Delphi, General Motors and Unisys. During his tenure at Delphi, Pankaj managed the company's automotive battery business which he turned around from a $100m loss to significant profits and sold the business for over $200 million. Pankaj has a B.S. in Electrical Engineering from India and MBA in Marketing and Finance from Columbia University.

Dr. Jeremiah Duncan, AAAS Environmental Fellow, OPPT, OPPTS
U.S. Environmental Protection Agency

Dr. Jeremiah Duncan was an Environmental Science Policy Fellow sponsored by the AAAS and placed at the U.S. Environmental Protection Agency in both the Office of Research and Development and the Office of Pollution Prevention and Toxics from September, 2005 to August, 2007. At the EPA, Dr. Duncan worked on issues relating to the environmental applications and implications of nanotechnology. Notable activities included the EPA Nanotechnology White Paper, the development of the Nanoscale Materials Stewardship Program, and the organization of a Pollution Prevention through Nanotechnology Conference. Dr. Duncan received his B.S. in Chemistry (1997) from the University of Missouri at Rolla and his M.A. (2000) and Ph.D. (2003) in Chemistry from Princeton University. His graduate research was in inorganic synthesis of iron-sulfur and iron-sulfur-nitrogen clusters as small molecule models of the nitrogenase enzyme. In 2003-2004 he was a Peace Corps Volunteer in the Republic of Kiribati in the central Pacific, and since 2006 he has been the Nanotechnology Scholar in the Program on Science in the Public Interest at Georgetown University. He currently lives in Madison, WI with his wife, Dr. Kimberly Duncan, and his dog, Dylan.

Dr. Greg Engleman
Coating Technologies
Powdermet, Inc.

Coating Technologies Group Leader, received his B.S. in Physics from Central Washington University in 1998, his M.S. in Materials Science and Engineering, specializing in metallurgical science, from the University of Tennessee in 2003, and his Ph.D. in Materials Science and Engineering from the University of Tennessee, specializing in metallurgical science and processing, in 2007. Greg has 9 years of research and development experience in metals and materials processing working at a national laboratory. His experience includes the development of coatings for wear and corrosion resistance, and materials processing using advanced techniques such as low- and high-density infrared, and laser processing. His other experience includes research on the brazing and joining of difficult to join materials, and research into the prevention of solder in aluminum die-casting dies. Dr. Engleman's achievements include process development for depositing and fusing an iron-based, nano-structured coating to enhance the wear resistance of disc cutters for tunnel boring applications and an R&D 100 award for the *Development of an Advanced Heating System for High-Performance Aluminum Forgings*.



Dr. Arthur Fong
Corporate Environmental Affairs
IBM Corporation

Dr. Fong received a B.S. in Genetics from the University of California, Davis and his Ph.D. in Toxicology at the University of California, Irvine. He then completed his Post-Doctoral Fellow in Marine/Freshwater Biomedical Sciences Center at Oregon State University.

Currently, Dr. Fong is a Senior Scientist in Corporate Environmental Affairs of IBM Corporation. He also participates on the Steering Committee and Technical Committee for the EPA Design for the Environment Flame Retardants in Printed Circuit Boards Partnership. Dr. Fong is the Co-Lead on the Semiconductor Industry Association Nanotechnology ESH Work Group and also participates on the Public Advisory Committee at the University of California's Toxic Substances Research and Teaching Program. Dr. Fong is also a member of the Advisory Committee on the California Office Equipment Emissions Study at Lawrence Berkeley National Laboratory.

Professor Shubhra Gangopadhyay
LaPierre Chair Professor
Department of Electrical and Computer Engineering
University of Missouri at Columbia

The Gangopadhyay Research Group is an electrical engineering and materials science research facility at the University of Missouri Columbia's College of Engineering and is associated with the International Center for Nano/Micro Systems and Nanotechnology. It is dedicated to expanding the realm of science and technology through optimization of existing techniques and exploration of new dimensions of knowledge. The group's research includes discovering, integrating, and optimizing new materials, processing methods, and characterization techniques. By promoting an interdisciplinary approach, our unique and modern research facility was designed to train, educate and prepare students to join and lead the workforce in innovative solutions to scientific challenges.

The group is headed by Dr. Shubhra Gangopadhyay, LaPierre Chair and Joint Professor, Departments of Electrical Engineering, Biological Engineering and Physics, who is an acclaimed researcher in the fields of material science and physics. The group has set up a high class research facility - the first of its kind in Missouri - with plans to upgrade and expand the facilities over the next two years.

Professor Miguel Garcia-Garibay
Department of Chemistry and Biochemistry
University of California, Los Angeles

Miguel A. Garcia-Garibay was born in Morelia, Mexico in 1960. He received his B.S. degree in 1982 from the University of Michoacan, Mexico, and a Ph.D. degree in organic Chemistry from the University of British Columbia in 1988, working with Prof. John R. Scheffer. He was a postdoctoral Fellow at Columbia University with Prof. N.J. Turro before joining the faculty at UCLA in 1992. Dr. Garcia-Garibay was promoted to full professor in the year 2000 and he has served as Vice Chair for Education in the Department of Chemistry and Biochemistry since 2005. He is also a member of the California NanoSystems Institute. During his career, Prof. Garcia-Garibay has achieved international reputation for his work in solid-state organic chemistry, photochemistry and spectroscopy, solid state reaction mechanisms, dynamics in crystals, dipolar lattices and molecular machines. His current research efforts are aimed at the development of artificial molecular machinery in highly organized crystalline media, and to the development of green chemistry by taking advantage of organic reactions in molecular nanocrystals. There are currently four main research thrusts in the Garcia-Garibay group: (I) The design of reactions in crystals for both synthetic and materials applications; (II) The design of solid state materials with functions that rely on the controlled mechanical changes at the molecular level, including electrooptics, ferroelectrics, etc. (III) The use of nanoparticles to control photochemical processes, and (IV) the study of structure-reactivity correlations based on solid-state reactivity and X-ray structural analyses, including the control of reactive intermediates and a better understanding of quantum mechanical tunneling. Prof. Garcia-Garibay has written extensively, authoring or co-authoring over 110 articles published in peer-reviewed Journals, 9 book chapters, and over 150 invited lectures. He is a member of the advisory board of The Journal or Organic Chemistry, The Journal of the American Chemical Society, and the Journal of the Mexican Chemical Society. He has also been guest editor of special issues of the Journal of Physical Chemistry, Tetrahedron, and Molecular Crystals and Liquid Crystals.

Dr. Ken Geiser, Co-Director
Lowell Center for Sustainable Production
University of Massachusetts Lowell

Dr. Kenneth Geiser is Professor of Work Environment and Director of the Lowell Center for Sustainable Production at the University of Massachusetts Lowell. Dr. Geiser is one of the authors of the Massachusetts Toxics Use Reduction Act and served as Director of the Massachusetts Toxics Use Reduction Institute from its founding in 1990 to 2003. His research and writing focus on pollution prevention and cleaner production, toxic chemicals management, international chemicals policy, safer technologies, and green chemistry and, in 2001, he completed a book, *Materials Matter: Towards a Sustainable Materials Policy* published by MIT Press. As a recognized expert on environmental and occupational health policy, he has served on various advisory committees for the U.S. Environmental Protection Agency, and the United Nations Environment Program.

Dr. Jeffrey Gilman
Leader, Materials and Products Group, Fire Research Division
National Institute of Standards and Technology

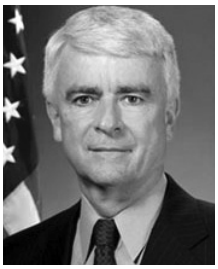
Dr. Jeffrey W. Gilman received his B.A. in chemistry from Ithaca College and his Ph.D. in organic chemistry from the University of California, Irvine. He developed polyoligosilsesquioxane, POSS, hybrid-materials at the Air Force Research Lab from 1986 to 1992. Since he joined NIST in 1994, Dr. Gilman has studied new approaches to flame retarding polymers using non-halogenated nanocomposite materials. He has over 50 peer-reviewed publications, several patents and has authored book chapters on polymer nanocomposites, high throughput materials science, polymer modification and flammability. Dr. Gilman has formed four NIST-Industry Research Consortia during the 13 years at NIST.

Dr. George Gray, Assistant Administrator
Office of Research and Development (ORD)
U.S. Environmental Protection Agency

On November 1, 2005, Dr. Gray was sworn in to serve as the Assistant Administrator for the Office of Research and Development, which is the 1,900-person, $600 million science and technology arm of the U.S. Environmental Protection Agency. Dr. Gray was appointed to this position by President George W. Bush and confirmed—by unanimous consent—by the U.S. Senate.

Prior to joining EPA, George was Executive Director of the Harvard Center for Risk Analysis and a Lecturer in Risk Analysis at the Harvard School of Public Health (HSPH). In 16 years at HSPH, his researched focused on scientific bases of human health risk assessment and its application to risk policy with a focus on risk/risk tradeoffs in risk management. George taught toxicology and risk assessment to both graduate students and participants in the School's Continuing Professional Education program.

George holds a B.S. degree in biology from the University of Michigan, and M.S. and Ph.D. degrees in toxicology from the University of Rochester. He and his wife, Ann, and their two children make their home in McLean, Virginia.



James Gulliford, Assistant Administrator
Office of Prevention, Pesticides, and Toxic Substances (OPPTS)
U.S. Environmental Protection Agency

Jim Gulliford is the Assistant Administrator for the Office of Prevention, Pesticides, and Toxic Substances (OPPTS) and is responsible for managing the Nation's regulatory and scientific programs on pesticides and industrial chemicals, as well as overseeing many collaborative pollution prevention programs. The office has an annual budget of $260 million and more than 1,400 employees.

Prior to being confirmed by the Senate in July 2006 as the Assistant Administrator for OPPTS, Jim served as the Region 7 Administrator for the EPA. Serving as Region 7 Administrator since September 2001, he was responsible for interface between EPA headquarters in Washington and represented EPA in the four-state region including Iowa, Kansas, Missouri, and Nebraska and managed various environmental issues important in that area.

Jim had 25 years of professional experience administering environmental programs in the agricultural and mining areas before he was appointed Regional Administrator. He received a bachelor's degree in forestry management and a master's degree in forestry economics and marketing from Iowa State University. He worked at Iowa State University and Southern Illinois University in mine reclamation and environmental protection program areas until 1982, when he became director of Iowa's Department of Soil Conservation. Jim was named director of the Division of Soil Conservation when the Department of Soil Conservation merged into the Department of Agriculture and Land Stewardship.

Dr. Lauren Heine, Director of Applied Science
GreenBlue

Dr. Lauren Heine's experience and expertise lies in green chemistry, green engineering, sustainable business practices, and multi-stakeholder initiatives. As Principal for the Lauren Heine Group, she advises organizations seeking to integrate green chemistry and engineering into product and process design and development activities – eliminating toxics and the concept of waste, and moving toward economic, environmental and community sustainability. Specific areas of expertise include the development of technical tools and strategies for product assessment, evaluation, design and market recognition; and facilitation of multi-stakeholder initiatives – particularly those that are technically-based. From 2003-2007, Lauren served as Director of Applied Science at Green Blue Institute (GreenBlue) where she continues her association as a Senior Fellow. Lauren initiated and directed the development of CleanGredients™, a unique, web-based information platform, developed in partnership with the U.S. EPA Design for the Environment Program that promotes green chemistry and environmentally preferable product formulation by providing information on key human and environmental health, safety and sustainability attributes of cleaning product chemicals. She is also directing the development of the Standard for Sustainable Contract Furnishing Fabrics, an American National Standards Institute standard, in collaboration with the Association for Contract Textiles and NSF International for GreenBlue.

Lauren publishes on green chemistry metrics, alternatives assessment and multi-stakeholder processes. She was previously Director of Green Chemistry and Engineering at the Portland, OR-based, Zero Waste Alliance (ZWA) and a Fellow with the American Association for the Advancement of Science in the Green Chemistry Program of the Industrial Chemicals Branch of the U.S. EPA in Washington, D.C. Prior to that, Lauren taught Organic Chemistry labs at Bowdoin College in Brunswick, ME where she helped to develop the Microscale Organic Lab program.

Lauren earned her doctorate in Civil and Environmental Engineering from Duke University.

Dr. Evan House, Director
Lithium Titanate Battery Program
Altair Nanotechnologies, Inc.

Dr. House currently leads the program for developing and commercializing Lithium Titanate batteries for EV, HEV, stationary, and military markets. Dr. House comes to Altair from Enerdel in Ft. Lauderdale, Florida where he created and led the product engineering group in lithium metal primary battery development. Prior to Enerdel, Dr. House served as Delphi Corporation's lead on lithium ion polymer cell development. This included heading advancements for Delphi's USABC program developing cells for HEV as well as the cell development for the Segway Human transporter. Dr. House also worked with Energizer Power Systems in NiMH and NiCd research and development, product, and process engineering. During this time, Dr. House created Energizer's HEV battery pack development program where he helped Energizer obtain patents on battery pack, modules, and thermal management systems. Dr. House received his Ph.D. in physical chemistry from the University of Florida.

Professor James Hutchison
Department of Chemistry
University of Oregon
Director, ONAMI Safer Nanomaterials and Nanomanufacturing Initiative (SNNI)

Dr. Jim Hutchison joined the faculty at the University of Oregon (UO) in the fall of 1994 where he is now a Professor of chemistry. His research interests are in materials chemistry and nanoscience. He co-developed the UO's nation-leading program in "green" (environmentally-benign) organic chemistry and launched the university's pioneering Center in Green Nanoscience. He is a member of the leadership team for the Oregon Nanoscience and Microtechnologies Institute (ONAMI) and founded, and now directs, the ONAMI's Safer Nanomaterials and Nanomanufacturing Initiative. He has won a number of awards, including an NSF-CAREER award and the 2003 Oregon Academy of Science Outstanding Teacher of Science and Math in Higher Education. Hutchison is an Alfred P. Sloan research fellow and a Camille Dreyfus teacher-scholar. He is the author of over 85 refereed publications, three book chapters and a text book ("Green Organic Chemistry: Strategies, Tools and Laboratory Experiments"). He is a member of the Governing Board of the ACS Green Chemistry Institute and a member of the ACS Committee on Environmental Improvement.

Dr. Fred Klaessig, Business Director, Aerosil Business Line
Degussa Corporation

Fred Klaessig is currently the Business Director of the Aerosil Business Line at Degussa Corporation, a subsidiary of Degussa AG. For the past ten years, he was the Technical Director for the Aerosil & Silanes Business Unit, where his responsibilities ranged from technical service to new product introduction to liaison with the R&D Department in Germany to regulatory matters. Aerosil is a trade name for fumed silica, which the company has manufactured for 60 years and which is often cited as an example of a nanoparticle. Fumed silica, fumed alumina and other fumed metal oxides are utilized for reinforcement, rheology control, abrasion and UV absorption. In the recent years, the great interest in nanotechnology has raised safety and registration concerns about materials of this class. These issues, both everyday technology and EHS concerns, has led to greater involvement in ASTM (E56), ISO (TC229) and industry organizations focusing on this subject area.

Dr. Klaessig has a B.Sc. in Chemistry from the University of California, Berkeley and a Ph.D. in Physical Chemistry from Rensselaer Polytechnic Institute. His industrial experience has been with Bio Rad Laboratories as a Quality Control Chemist and various management positions at Betz Laboratories, now a division of GE Water Services, where his responsibilities involved scale and corrosion control in many chemical industrial processes.

Dr. Tie Lan, General Manager
Nanocor, Inc.

Dr. Lan serves as the General Manager at Nanocor, Inc., a wholly own subsidiary of Amcol International Corporation.

Dr. Lan received his Ph.D. in Chemistry from Michigan State University under the guidance of Prof. Tom Pinnavaia in 1995. He was one of the first Ph. D. degreed chemists specialized in polymer-clay nanocomposite materials. He joined Nanocor as a research scientist in 1996 and started his journey in commercializing nanocomposite technologies. In 2002, he was promoted to technical director. He holds nearly three dozen patents in the polymer-clay nanocomposite technology areas. He also published more than 20 papers in nanocomposite research from his academic work at Michigan State University. In 2006, Dr. Lan took the General Manager position and led the company to a new era.

Terry Medley, Global Director of Corporate Regulatory Affairs
DuPont Environmental and Sustainable Growth Center

Terry Medley is Global Director of Corporate Regulatory Affairs, DuPont Environmental and Sustainable Growth Center.

Prior to joining DuPont in May of 1998, Mr. Medley was Administrator of the Animal and Plant Health Inspection Service (APHIS) at U.S. Department of Agriculture (USDA)- a 6,000-person science and regulatory agency charged with protecting the health of the U.S. plant and animal resources. He also served as Acting Administrator of USDA's Food Safety and Inspection service. He began his career as an attorney in USDA's office of the General Counsel. In 1987, he became the first Director of the USDA- APHIS Biotechnology, Biologics and Environmental Protection Division. At USDA, he played a central role in the development of the U.S. federal regulatory biotechnology policy. Under his leadership, APHIS became the first federal agency to implement final regulations for the field-testing and development of genetically engineered plants and microorganisms.

In 1997, he was conferred the rank of Distinguished Executive in the U.S. Senior Executive Service. He is recognized internationally as an expert on biotechnology and environmental regulatory matters. He has served on numerous international steering committees, advisory committees and expert working groups, reviewing the biosafety of biotechnology products. He has served two three-year terms as a member of the U.S. National Academies, National Research Council's Board on Agriculture and Natural Resources. He is an Executive Committee member and chair of the Advisory Board for the International Society for Biosafety Research.

His current responsibilities include leading the DuPont Nanotechnologies Safety Health and Environment Advisory Team. He is the Vice-Chair of the American Chemistry Council's Nanotechnology Panel; the Co-leader of the Business Industry Advisory Committee (BIAC) delegation to the Organization for Economic Co-operation and Development (OECD)'s Working Party on Manufactured Nanomaterials; Co-chair of the International Council of Chemical Associations (ICCA)'s Task Force on Nanomaterials; a member of the International Council on Nanotechnology (ICON)'s Steering Committee; a member of the Meridian Institute's Global Dialogue on Nanotechnology and the Poor Critical Connection Group; and he participated in the U.S. Environmental Protection Agency (EPA)'s National Pollution Prevention and Toxics Advisory Committee (NPPTAC) Interim Ad Hoc Work Group on Nanoscale Materials. He serves as the DuPont lead for the DuPont/Environmental Defense partnership for the responsible development of nanomaterials.

He graduated cum laude from Amherst College and received a Doctor of Jurisprudence degree from the University of Virginia.

Jeff Morris, Associate Director for Science
Office of Science Policy, ORD
U.S. Environmental Protection Agency

Jeff Morris is Associate Director of the EPA's Office of Science Policy. His office's principal role is to ensure that environmental decisions made at EPA are informed by the best available scientific information, and that such information is appropriately characterized in those decisions. Jeff co-chairs EPA's Nanotechnology Coordinating Committee, which issued EPA's Nanotechnology White Paper in February 2007. Jeff is also a member of the U.S. delegation to the Organization of Economic Cooperation and Development's working party on manufactured nanomaterials, and he co-chairs the Working Party's test guidelines steering group. All of the several positions Jeff has held during his 15 years at EPA have focused on either regulatory issues or science policy.

Lee Paddock, Associate Dean, Environmental Law Studies
George Washington University

Lee Paddock is Associate Dean for Environmental Law Studies. He Chairs the Committee for Innovations, Management Systems and Trading for the American Bar Association's Section on Environment, Energy and Resources.

Prior to coming to George Washington, he was the Director of Environmental Legal Studies at Pace University School of Law from 2002-2007. Lee has served as a Senior Consultant for the National Academy of Public Administration on several projects since 1999. He was also a Visiting Scholar at the Environmental Law Institute between 1999 and 2002, focusing on clean air act, state-federal relationship and enforcement issues.

From 1978 until 1999, Lee was an Assistant Attorney General with the Minnesota Attorney General's Office where he served as Director of Environmental Policy for 13 years, as manager of the Office's Agriculture and Natural Resources Division and a member of its Executive Committee. He has served on numerous national panels including the Aspen Institute's Series on Environment in the 21st Century and the American National Standard Institute's ISO 14000 Environmental Management Systems Council.

Lee graduated from the University of Iowa Law School with High Honors and served as a law clerk to Judge Donald Lay of the U.S. Eighth Circuit Court of Appeals.

Professor Richard Pethrick
Department of Pure and Applied Chemistry
University of Strathclyde

Professor Richard Pethrick has been Professor in the Department of Pure and Applied Chemistry since 1982. His area of expertise is in structure property relationships in polymer and small molecule chemistry and has published over 400 papers in this area. He has worked in polymer urethane chemistry for over twenty years and designed and developed materials for arrange of applications. In the last ten years he has focused on the area of nano composites and in particular the issues surrounding the control of dispersion and understanding the effects of concentration on physical property enhancement. Using nano particles the research group has demonstrated the ability to modify the glass transition temperature, the creation of barrier properties, improvement of impact properties and fire retardant characteristics. His work over the years has been funded by a number of government and industrial agencies. He has had a programme of research funded for about twelve years by AFSOR on adhesive bond ageing in metal and composite structures and has developed a new non destructive test method for the monitoring of ageing. He has

been involved with number of industrial projects and carried out the characterization of the cure kinetics and the property –morphology correlations for the thermoplastic toughened resin used in the Boeing 777 aircraft, designed the polyurethane materials used by Xerox as doctor blades in their reprographic equipment, helped develop the adhesives used in the computer printable luggage labels and a number of other applications.

Professor Peter Peumans
Department of Electrical Engineering
Stanford University

Peter Peumans is an assistant professor of Electrical Engineering and is an expert in organic device modeling and characterization. He has developed several efficient solar cell device architectures and has contributed to today's understanding of the mechanisms that play a role in organic solar cells. Peumans also contributed to the development of vapor phase deposition techniques that lend themselves to reel-to-reel processing of organic and organic/inorganic nanocomposite solar cells. Two of Dr. Peumans' publications are in the top-20 cited papers in the field of solar cells. He holds 10 patents and has 5 or more pending. He is a co-founder and the Chief Scientific Officer of NetCrystal, a Silicon Valley startup focusing on low-cost microconcentrator solar cells using a technology developed by Peumans' group at Stanford. Dr. Peumans is on the advisory board of Soltaix and Innovalight. Prof. Peumans is the recipient of an NSF CAREER award.

Dr. Daniel Rardon, Manager, Advanced Technologies
PPG Industries

Daniel Rardon is currently a Senior Scientist and Manager Advanced Technologies within the Office of Science & Technology at PPG Industries. In this role, he coordinates PPG's emerging materials technology programs spanning across the corporation and defines and sets strategic direction in areas including nanotechnology, ceramics, and composite technology. Much of his focus is external to the corporation, looking for collaborative R&D programs and partners that fit with PPG's strategic direction. Prior to this role, Dr. Rardon spent 15 years in the coatings field in various research, development, and management assignments. His technical experience includes polymer, monomer, and cross-linker synthesis; reaction kinetics and coating stabilization and degradation; as well as waterborne coating and color development. Dr. Rardon currently serves on the Board of Directors for the Pennsylvania NanoMaterials Commercialization Center and the Advisory Board for the Nanofabrication Manufacturing Technology Partnership out of Penn State. He received his Ph.D. in Organic Chemistry from the University of Cincinnati, his B.S. in Chemistry from Miami University, and has some 20 patents and numerous publications to his name.

David Rejeski, Director
Project on Emerging Nanotechnologies, Woodrow Wilson International Center

David Rejeski directs the Project on Emerging Nanotechnologies and Foresight and Governance Project at the Woodrow Wilson International Center for Scholars. He was a Visiting Fellow at Yale University's School of Forestry and Environmental Studies and an agency representative (from EPA) to the White House Council on Environmental Quality (CEQ). Before moving to CEQ, he worked at the White House Office of Science and Technology (OSTP) on a variety of technology and R&D issues, including the development and implementation of the National Environmental Technology Initiative.

Before moving to OSTP, he was head of the Future Studies Unit at the Environmental Protection Agency. He spent four years in Hamburg, Germany, working for the Environmental Agency, Department of Public Health, and Department of Urban Renewal and, in the late 1970's, founded and co-directed a non-profit involved in energy conservation and renewable energy technologies.

He has written extensively on science, technology, and policy issues, in areas ranging from genetics to electronic commerce and pervasive computing and is the co-editor of the recent book: Environmentalism and the Technologies of Tomorrow: Shaping the Next Industrial Revolution, Island Press 2004.

He sits on the advisory boards of a number of organizations, including the Environmental Protection Agency's Science Advisory Board; the Committee on Science, Engineering and Public Policy of the American Association for the Advancement of Science (AAAS); the Advisory Committee for Environmental Research and Education of the National Science Foundation; the Journal of Industrial Ecology, the Greening of Industry Network, and the University of Michigan's Corporate Environmental Management Program. He has graduate degrees in public administration and environmental design from Harvard and Yale.

Dr. Mark Rossi, Research Director
Clean Production Action

Dr. Mark Rossi is the Research Director of Clean Production Action. He is co-author of *The Green Screen for Safer Chemicals: Evaluating Flame Retardants for TV Enclosures*. The Green Screen is an open source and transparent method for evaluating progress to green chemicals. Dr. Rossi also serves on the steering committee of Health Care Without Harm and is a Research Fellow at the Lowell Center for Sustainable Production. His doctorate is in Environmental Policy from the Massachusetts Institute of Technology.

Dr. Jeffery Steevens, Research Toxicologist
U.S. Army Corps of Engineers

Dr. Steevens is a research toxicologist and team leader of the Environmental Risk Assessment Team at the U.S. Army Engineer Research and Development Center in Vicksburg, MS. He obtained his bachelors degree in biochemistry from the University of Missouri at Columbia and his doctorate degree in pharmacology and toxicology from the University of Mississippi. Currently his research activities are in the area of contaminated sediments risk assessment and the ecological risk of engineered nanomaterials. His current responsibilities include leading several projects focusing on the fate, transport, and ecotoxicology of military relevant nanomaterials. In addition, Dr. Steevens is involved in studies focusing on the toxicity and bioaccumulation of contaminants from sediments. He supports the military by conducting studies focusing on the toxicology of explosive compounds including trinitrotoluene, RDX, and HMX. Dr. Steevens is also a technical advisor to the military by providing expertise for the risk assessment of contaminated military facilities. He is a member of several national organizations including the Society

of Environmental Toxicology and Chemistry, American Chemical Society, and Society of Toxicology. Dr. Steevens is a Technical Advisor for nanomaterials work group for the Materials of Evolving Regulatory Interest Team (MERIT), Office of Secretary of Defense.

Dr. Clayton Teague, Director
National Nanotechnology Coordination Office

Clayton Teague is Director of the federal National Nanotechnology Coordination Office (NNCO) since April 2003. Established in 2001, the NNCO is the secretariat to the Nanoscale Science, Engineering and Technology Subcommittee of the NSTC. As such, the NNCO provides day-to-day technical and administrative support to the NSET Subcommittee and assists in the preparation of multi-agency planning, budget and assessment documents. The NNCO is the point of contact on federal Nanotechnology activities for government organizations, academia, industry, professional societies, foreign organizations, and others to exchange technical and programmatic information. In addition, the NNCO develops and makes available printed and other materials as directed by the NSET Subcommittee as well as maintains the NNI Web site.

Dr. Teague was previously Chief of the Manufacturing Metrology Division in the Manufacturing Engineering Laboratory of the National Institute of Standards and Technology (NIST).

At NIST since 1972, Dr. Teague has designed, constructed, and used precision instrumentation for ultra-high accuracy dimensional metrology of surfaces and micrometer to nanometer-scale features. Beginning with his metal-vacuum-metal tunneling work in the 1970's, he continued to work with such precision instrumentation as scanning tunneling microscopes, atomic force microscopes, displacement and phase-measuring interferometry, stylus instruments, flexure stages, and light scattering apparatus. Because the laboratory and building environments were always factors in the ultimate performance of these instruments, the subject of this workshop has been an ongoing topic of great interest.

Dr. Teague is a member of the American Society for Precision Engineering, has served twice as the Society's President, and is a fellow of the UK Institute of Physics. He served as Editor-in-Chief of the international journal Nanotechnology for ten years and is currently a member of the Editorial Board of the journal. He holds a B.S. and M.S. in physics from the Georgia Institute of Technology and a PhD in physics from the University of North Texas. He has authored or coauthored 70 papers, has presented 50 invited talks in the technical fields described, and jointly with colleagues, has six patents. Dr. Teague has received the Gold Medal, Silver Medal, and Allen V. Astin Measurement Science Award from the Department of Commerce, the Kilby International Award by the Kilby Awards Foundation, and an IR-100 Industrial Research and Development Award for his work.

Beverley Thorpe, International Director
Clean Production Action

Beverley Thorpe has researched and promoted clean production strategies internationally for over fifteen years and in 1990 was a co-founder of the first UNEP Cleaner Production Programme as well as clean production coordinator for Greenpeace International. As International Director of Clean Production Action she networks with progressive businesses, academics, governments and advocacy groups round the world to advance a variety of clean production strategies. Her current focus is the promotion of Green Chemistry practices in business and government policy. She has produced documentaries on the effects of genetically engineered crops to U.S. farmers and is working to promote sustainable biomaterials in commerce. She has also written extensively on the benefits of producer responsibility for electronic product take-back and recycling.

Professor Franz-Josef Ulm
Department of Civil and Environmental Engineering
Massachusetts Institute of Technology

Franz-Josef Ulm is a Professor of Civil & Environmental Engineering at the Massachusetts Institute of Technology. He received his engineering degree from the Technical University Munich, Germany, in 1990, his Ph.D. from the Ecole nationale des ponts et chaussées, France, in 1994; and his Habilitation Degree from the Ecole Normale Supérieure de Cachan, France in 1998. Prior to joining MIT, he was research engineer at the Laboratoire Central des Ponts et Chaussées of the French Department of Transportation and Public Works. He joined MIT in January 1999, where he is responsible for mechanics of materials, with a current focus on experimental and theoretical nanomechanics of natural composites (concrete, soil, rock, bone), microporomechanics and biochemomechanics. He has published over 80 scientific papers in peer-reviewed mechanics, materials science and biomechanics journals, and 4 books; most recently Microporomechanics(co-authored with L. Dormieux and D. Kondo) published by J. Wiley & Sons in 2006.

Dr. Dennis Utterback
Office of Science Policy, ORD
U.S. Environmental Protection Agency

Dennis Utterback is policy analyst in EPA's Office of Science Policy, Office of Research and Development, specializing in toxics, pesticides, and nanotechnology issues. He co-chaired a subcommittee in developing EPA's White Paper on Nanotechnology, and is a member of a new OECD Working Party on Nanotechnology. Prior to this position he worked for several years in EPA's Office of Pesticide Programs as a risk manager. Dennis has a Ph.D. in Public Administration from Syracuse University.

Dr. Rama Venkatasubramanian
Senior Research Director, Center for Solid State Energetics
RTI International

Dr. Rama Venkatasubramanian is the Director of the Center for Solid State Energetics at RTI International in Research Triangle Park, North Carolina, USA and is also the Founder of Nextreme Thermal Solutions, a company that has been spun off from RTI to commercialize its unique thin-film superlattice thermoelectric technology. After serving as the CTO and Strategist of Nextreme in its first two years, Dr. Venkatasubramanian currently serves on the Technical Advisory Board of Nextreme. Dr. Venkatasubramanian is well known for pioneering thermoelectric superlattice materials and device developments. Dr. Venkatasubramanian's work on superlattices was recognized as the first significant breakthrough in nearly 40 years in Thermoelectrics in 2001. This technology has won an R&D 100 Award (2002) and the Technology of the Year Award (2005) by the Council for Entrepreneurial Development in North Carolina and the Nano 50 Award (2006) of NASA's Nanotech Briefs. Dr. Venkatasubramanian is the recipient of several awards and honors including the Allen B. Dumont Prize at Rensselaer Polytechnic Institute, RTI's Margaret Knox Excellence Award in Research (2002) and the IEEE Eastern North Carolina Inventor of the Year (2003). He has seven patents issued in thermoelectrics, has over 100 refereed publications and has contributed to two book chapters. Dr. Venkatasubramanian obtained his Ph.D. in Electrical Engineering from Rensselaer. He is a National Talent Scholar and a graduate of the Indian Institute of Technology, Madras, India. Dr. Venkatasubramanian's interests and contributions have been in photovoltaics, hetero-epitaxy of novel materials, photonic materials, metamaterials, study of nanoscale thermal physics and more recently in the areas of high-performance electronics thermal management, direct thermal-to-electric power conversion and energy harvesting concepts.

Kathleen Vokes
Design for the Environment Branch, OPPT, OPPTS
U.S. Environmental Protection Agency

Kathleen Vokes is Project Manager in the Design for the Environment (DfE) Program at the U.S. Environmental Protection Agency (EPA). Ms. Vokes focuses on alternatives assessments, and was responsible for completing an evaluation of flame retardants in low-density furniture foam through the Furniture Flame Retardancy partnership. She is now focusing on flame retardants in printed circuit boards. Other projects include the Safer Detergents Stewardship Initiative (SDSI) and a Sustainability Standard for Office Furniture. SDSI is a voluntary program to encourage the use of safer surfactants in detergents. The common objective of these partnerships is to integrate health and environmental considerations into business decision cycles. Prior to joining DfE, Ms. Vokes worked in EPA's Office of Water on the implementation of drinking water regulations pertaining to small water systems. Ms. Vokes holds a Bachelor of Science in Chemical Engineering from the Massachusetts Institute of Technology.

Professor Israel Wachs
G. Whitney Snyder Professor, Rossin College of Engineering & Applied Science
Lehigh University

Israel E. Wachs received his undergraduate education at The City College of The City University of New York where he graduated with a B.E. (ChE) in June, 1973. He stood out among his ChE classmates and received several recognitions upon graduation (AIChE Award for Outstanding Senior, Heller Memorial Award for Outstanding Scholastic Achievement, and White ChE Alumni Award). He continued his graduate ChE education at Stanford University under the mentorship of Professor Robert J. Madix in the area of surface science, and graduated with a PhD (ChE) in 1978. His research findings are considered the first application of surface science to catalysis, and his thesis publications are extensively cited in the surface science and catalysis literature.

He joined Exxon Research & Engineering Company in their Corporate Research Labs towards the end of 1977. At Exxon, he was involved with many different catalytic technologies over the year (selective oxidation, synthesis of synthetic fuels, hydrodesulfurization (HDS) and hydrocarbon conversion). He obtained 100 patents during his industrial career. One of his inventions on the selective oxidation of o-xylene to phthalic anhydride became the leading international industrial catalyst for this technology and is still used around the world. At Exxon, he received the Research Incentive Award for one of his inventions on the synthesis of synthetic fuels and was also selected to be an Exxon Fellow for a semester at California Institute of Technology (CalTech).

He joined the Chemical Engineering Department at Lehigh University at the beginning of 1987. At Lehigh, he taught many different courses over the years: Heterogeneous Catalysis, Reactor Engineering, Fluid Mechanics, Professional Development, Unit Operations, Environmental Catalysis, and Air Pollution Control. He set up a world-class catalysis research laboratory focusing on mixed metal oxide catalytic materials and their characterization under reaction conditions. These studies have established the foundation for the molecular/electronic structure – activity/selectivity relationships and the molecular engineering of mixed metal oxide catalysts. The research performed by Wachs and his students is well known around the world. This is reflected in the many national and international honors he has received over the years as well as the 10,000+ citations to his publications with an H-factor of ~60.

Jim Willis, Director
Chemical Control Division, OPPT, OPPTS
U.S. Environmental Protection Agency

Since October 2004, Jim Willis has been Director the Chemical Control Division (CCD) in EPA's Office of Pollution Prevention and Toxics (OPPT). CCD is responsible for the implementation of EPA's new and existing chemicals programs, the chemical testing program, and special projects such as the Nanoscale Materials Stewardship Program, the HPV Challenge and the PFOA Stewardship program. Jim co-chaired EPA's nanotechnology white paper development and, since 2006, has chaired the OECD Working Party on Manufactured Nanomaterials. Prior to his return to EPA, he was Director of Chemicals for the United Nations Environment Programme, a position he held since November, 1995, where he also facilitated the negotiations of, and served as Executive Secretary of the Rotterdam Convention on Prior Informed Consent and the Stockholm Convention on Persistent Organic Pollutants. He also directed UNEP's mercury program, its chemical safety capacity building program, and its efforts to develop a "Strategic Approach to International Chemicals Management". Jim joined EPA in 1984 and served in a variety of staff and management roles in OPPT before transferring to UNEP.

Professor Omar Yaghi
Department of Chemistry and Biochemistry
University of California, Los Angeles

Omar M. Yaghi was born in Amman, Jordan (1965). He received his B.S. in chemistry from the State University of New York-Albany (1985) and his Ph.D. from the University of Illinois-Urbana (1990) with Professor Walter G. Klemperer. From 1990-92, he was an NSF Postdoctoral Fellow at Harvard University with Professor Richard H. Holm. He joined the faculty at Arizona State University in 1992 and was awarded the ACS-Exxon Solid-State Chemistry Award in 1998. In June 1999, he moved to the University of Michigan as a Professor of Chemistry and was awarded the Robert W. Parry Collegiate Chair by the Chemistry Department at UM, and the Sacconi Medal by the Inorganic Division of the Italian Chemical Society in 2005. Since January 2006 he has been the Christopher S. Foote Professor of Chemistry and Biochemistry at UCLA and the Director of the Center for Reticular Chemistry at the California NanoSystems Institute, UCLA. Recently he has been named as one of Popular Science Magazine "Brilliant 10" scientists and engineers in the nation. He is one of the most highly cited chemists in the world with over 100 citations per paper for over 100 scientific papers. He has established several research programs dealing with the reticular synthesis of discrete polyhedra and extended frameworks from purely organic, inorganic, and metal-organic building blocks for their applications in clean energy, catalysis, gas storage and separation technologies.

Dr. Bing Zhou, Vice President and Chief Technology Officer
Headwaters Technology Innovation Group

Dr. Bing Zhou, a leading scientist in nanocatalyst field, has more than 20 years experience in design and synthesis of catalysts at nanometer scale. His contribution to nanotechnology is well recognized internationally. The American Chemical Society (ACS) appointed him three times to organize and chair symposia on Nanotechnology in Catalysis, which were attended by well-known scholars from academic and researchers from industry around the world. An authority in nanotechnology and nanomaterials, as an editor and author Dr. Zhou initiated a book series entitled "Nanotechnology in Catalysis" and has served as a "member of judge" for several peer reviewed world-class publications in nanoscience and nanomaterials.

The platform technology NxCat™ developed by Dr. Zhou has a potential to change the catalysis industry. The nanocatalysts synthesized by this technology outperform many existing commercial catalysts that have been improved and perfected over many years. It is a technology that catalysis industry has desired for last thirty years. The high efficiency and selectivity catalysts developed by NxCat™ technology save significant capital and operation costs, eliminate the production of by-products usually being treated as waste; and make the chemical and petrochemical industrial processes clean (*Green Chemistry*). Based on such contribution, Dr. Zhou has won numerous awards including the Presidential Award for Green Chemistry, the Innovative Research Awards from the National Science Foundation and the Department of Energy. In 2003, Dr. Zhou was selected by the Chinese Academy of Science to receive the "Outstanding Overseas Scholar Award". He is active in various professional associations and societies, including serving as chair and board member for ACS Catalysis Secretariat, ACS Trenton Section and member of the Catalysis Society of Metropolitan New York.

Dr. Zhou received a Ph.D. degree in Materials Science and a M.Sc. from Catholic University of Louvain, Belgium, and a B.Sc. degree from Jilin University, China.

Pollution Prevention through Nanotechnology Conference Posters

Poster #1: Green Fabrication of 3D Architectures Composed of Nanospheres Through Ice Templating

Presenter: Michael Clark
Authors: Jia Yan*, Michael Clark** and Li Tan*
Affiliations: *Department of Engineering Mechanics and Nebraska Center for Energy Science Research, University of Nebraska, Lincoln, NE; **Creighton Prep High School, Omaha, NE

Abstract: Over the last years, Nanoscience and Nanotechnology has been relatively mature to reveal variety of objects at tiny scale. These objects often possess a large ratio of surface area vs. weight and were utilized as building blocks for micro- or macroscopic subjects. However, formidable challenges remain in the efforts to assemble these tiny blocks into complex and ordered architectures. Inspired by a recent discovery in sea shells, we utilize controlled formation of ice platelets to generate highly sophisticated 3D assemblies.

In this ice templating process, the role of ice is two-fold. On one side, freezing repels tiny nanostructures in an aqueous suspension and makes them self-assembled among ice channels; on the other side, ice crystals function as a strong mechanic support to the final lamellar architecture. Notably, this ice templating process can be used to host variety of nanostructures. Accordingly, complex 3D microstructures of inorganic, organic or hybrid species can be fabricated in a high throughput fashion.

Poster #2: Conserve More Resources in Nanofabrication: A Seeding Methodology

Presenter: Michael Clark
Authors: Michael Clark*, Jakeb Riggle**, Haojing Lin**, Biqing Sheng***, Zhaoyan Zhang*** and Li Tan**
Affiliations: *Creighton Preparatory High School, Omaha, NE; ** Department of Engineering Mechanics and Nebraska Center for Energy Science Research, University of Nebraska, Lincoln, NE; ***Department of Mechanical Engineering, University of Nebraska, Lincoln, NE

Abstract: Leaping from nanoscience to nanotechnology requests an engineering level optimization on multiple parameters like production yield, precision, and throughput. Such goals are often in contradictory with demands to save our resource and environment, for instance, less material consumption, reduced processing time, and others.

We demonstrate a novel and simple approach, called seeding methodology to promote nanofabrication while conserving more resource. In one demonstration to form closely packed breath figures, such seeds trigger an early formation of polymeric nanostructures. Accordingly, nanofabrication process is accelerated; both the size and surface coverage of those tiny structures are regulated dramatically. The accelerated kinetics even leads to "freeze" of a few new phenomena that not discovered before, helping to elucidate the role of moist air in the nanofabrication process. Since the methodology is easy to implement, a positive environmental impact is also expected.

Poster #3: Practical Pollution Protection Applications of Nanomaterials

Author and Presenter: Alan Rae
Affiliation: Nanodynamics

Abstract: Nanomaterials show a surprisingly diverse potential for pollution protection. This poster illustrates this range through specific practical examples, including nano-solder (low temperature lead-free soldering), nano-cement (reduced greenhouse gas emission), nano enabled high volume water filtration (removal of heavy metals from drinking water and problem chemicals from effluent) as well as solid oxide fuel cells for portable power (high efficiency use of low greenhouse-gas fuels).

Poster #4: Paradigm Shifts Using Nanotechnology
Presenter: Thomas Maganas
Authors: Thomas C. Maganas and George E. Nelson
Affiliation: The Maganas Group

Abstract: Nanotechnology Products: A Maganas Method produces an unbroken film, comprised of carbon nanotubes that can be deposited on most any surface, including machine shop cutting tools. This unbroken film provides a tremendous increase in cutting ability on difficult to machine materials. It also extends the tool life on all cutting tools and eliminates surface oxidation on all coated surfaces.

Nanotechnology Energy/Resource Efficiency: The Maganas Complete Combustion System presents the greatest promise for preventing pollution by eliminating all toxic emissions from hydrocarbon engines. It also drastically reduces both CO_2 emissions and fuel consumption. In addition it produces an abundant stream of high quality nano particles/nanotubes from its Complete Combustion System.

Poster #5: Delivering the Power of Nanotechnology in UV-Curable Coatings
Author and Presenter: F. Thomas Krotine
Affiliation: Ecology Coatings, Inc.

Abstract: The demand from businesses around the world for low-energy processing and non-polluting manufacturing is driving much of the innovative research and technological development within the nanomaterials sector. The highly polluting coatings industry is often overlooked in an environmental regard, but has immense opportunities to reduce energy usage while eliminating volatile organic compounds and hazardous air particle emissions. Thomas Krotine will present a coating design process that leverages the power of nanotechnology for ultra violet light curable coatings. The novel design paradigm uses acrylic-functional epoxy, urethane and acrylate monomers in conjunction with nanoparticle additions. This combination yields unique film properties such as scratch resistance on clear plastics or gas and fluid barrier capacity on paper or plastic. These properties are achieved in an environmentally friendly coating process that emits no VOCs or HAPs and requires up to 75 percent less energy than solvent-borne or powder coatings.

Poster #6: Use of Multi Criteria Decision Analysis to Prioritize Nanotechnology Research and Application Project Portfolio for Pollution Prevention
Presenter: Igor Linkov
Authors: Igor Linkov*, Matthew Hull**, Jeff Steevens***
Affiliations: *Intertox, Inc., **Virginia Polytechnic Institute, ***U.S. Army Corps of Engineers

Abstract: Even though nanotechnology application is widespread, understanding of the environmental effects and risks associated with nanomaterial use is very limited and often contradictory. Nevertheless, pollution prevention through nanotechnology requires consideration of the product life-cycle to select nanotechnologies with the greatest promise for preventing pollution as well as to focus research on the most advantageous areas. An additional challenge is balancing environmental and societal benefits and risks associated with nanomaterial applications. Many of the challenges posed by the uncertainties in the field of nanotechnology and immediate research and technology needs are characteristic of the types of problems that multi-criteria decision analysis (MCDA) is appropriate for. We propose an MCDA framework to prioritize nanotechnology research and application portfolios and illustrate its applications to pollution prevention through two case studies. The first case study illustrates prioritization of a portfolio consisting of several nanotechnologies potentially useful for pollution prevention but with varying life-cycle impacts. This example shows how MCDA application can balance societal benefits versus unintended side effects and risks, and how it can also bring together multiple lines of evidence to decide on the likely toxicity of nanomaterial given limited information on physical and chemical properties. The second example illustrates MCDA use to identify suitable management options for nanomanufacturing wastes. Alternative

options include landfilling, disposing as hazardous waste, waste integration into alternative products and recover/reuse of waste components. Each option is accompanied by a unique set of pros and cons, which are largely based on potential public health risks and processing costs. The key advantage of the proposed MCDA framework is the visualization and quantification of the uncertainties involved in planning or decision-making processes and the potential to model multiple stakeholder responses.

Poster # 7: Application of NanoScale's Technology Utilizing Chemically Reactive Nanocrystalline Metal Oxide Materials

Author and Presenter: David Jones
Affiliation: NanoScale Corporation

Abstract: The poster discusses NanoScale's unique technology which is based on its chemically reactive nanocrystalline metal oxide materials and end user products and applications that utilize them. Several of these products and applications have already been commercialized and others are currently under development. NanoScale is currently working with EPA and other governmental agencies as well as commercial entities on applications that utilize this technology. The poster will address the following three questions:

1. Which nanotechnologies show the greatest promise for preventing pollution?
2. What are the most promising areas of research on pollution prevention applications of nanotechnologies?
3. What recommendations do conference participants have for promoting and encouraging pollution prevention in the development and application of nanotechnology?

Poster #8: Stewardship with Nanotechnology Public Private Partnerships (P3s)

Author and Presenter: Will Gibson
Affiliation: ICF International

Abstract: The poster presents the results of work on the environmental, health, and safety (EHS) impacts of nanotechnology (NT) and how a management systems framework can be tailored to specific industries and companies to reduce risk. This work, sponsored by the Woodrow Wilson International Center for Scholars and U.S. EPA's Performance Track Program, is part of making a material and proactive federal contribution to addressing the EHS implications of emerging nanotechnologies.

Using a case study of how to reduce EHS impacts of the NT manufacturing process as a basis, we describe a potential strategy for developing an industry-specific voluntary program with one or more federal agencies or trade associations. In lieu of complex regulatory approaches, or in the interim before one is established, such an NT Voluntary Performance Standards Program (NVPSP) could be a compelling avenue for effectively reducing risk on national scale. It would also offer industry a leadership role in setting the EHS standards to which it will be held. The NVPSP would involve commitments from members, such as:

- Adoption of prescribed methods, procedures, or technologies that lead to better EHS protection; or
- Improvements in the process by which EHS protection is planned and implemented.

The poster explores the advantages and disadvantages of each and presents ideas to help develop a member commitment framework that could become part of an NVPSP, including:

- A list of some potential prescriptive commitments;
- A set of suggested processed-based, management systems requirements;
- A discussion of balancing risk assessment rigor with ease of entry and program performance; and
- An example of combining prescriptive and process-based commitments.

Poster #9: Greener Production of Noble Metal Nanostructures and Nanocomposites: Risk Reduction and Applications

Presenter: Carlos Nunez
Authors: Dr. Mallikarjuna N. Nadagouda and Dr. Rajender S. Varma
Affiliation: Clean Processes Branch, Sustainable Technology Division, NRMRL, U.S. Environmental Protection Agency

Abstract: The synthesis of nanometal/nano metal oxide/nanostructured polymer and their stabilization (through dispersant, biodegradable polymer) involves the use of natural renewable resources such plant material extract, biodegradable polymers, sugars, vitamins and finally efficient and selective mode of activation microwave (MW) irradiation. The main objectives are of this research are to:

- Synthesize nanomaterials and enable their characterization (analysis) through 'greener' and optimized preparation,
- Use nanomaterials safely in appropriate formulations e.g. nanocomposites, and
- Demonstrate production approaches of in-situ generated nanomaterials in the media of choice where they can be used without much handling/manipulation thus reducing the risk.

Recent results from our laboratory have shown that vitamin C, B1 and B2 or related benign and renewable materials such as carboxymethyl cellulose (CMC) can function both as a reducing and capping agent and provide an extremely simple, one-pot greener method to synthesize bulk quantities of nanospheres, nanorods, nanowires, nanoballs of aligned nanobelts and nanoplates of the metals in water without the need of capping or surfactant agents, and/or large amounts of insoluble templates. We have extended this non-conventional MW route to make these nanostructures via spontaneous reduction of gold, silver, platinum and palladium nanostrutures with sugar solutions such as alpha-D-glucose, sucrose and maltose; newer form of porous titania has been also prepared using dextron that can be coated with a carbon as well useful for visible-light induced photodegradation of pollutants. The safer preparation of these nanostructured materials can open myriad of applications, such as energy storage system, catalysis, fuel cell membranes, and nanodevices.

Poster #10: Application of P2 Framework Exposure and Release Models to Nanomaterials

Authors and Presenters: Peter B. Ranslow, Ph.D. and David Brandwene, M.S., DABT
Affiliation: Consortium for Environmental Risk Management, LLC (CERM)

Abstract: Environmental Health and Safety professionals are often called upon to assess the risks involved with chemicals in the absence of thorough test data. In such cases, alternative tools and approaches are needed to develop exposure assessments. One such set of tools and methods is the Pollution Prevention (P2) Framework, applied as part of U.S. EPA's Sustainable Futures™ Initiative - a voluntary program with the goal of encouraging application of pollution prevention principles and the development of inherently safer new chemicals. These tools, developed over the past 25 years by the U.S. EPA, provide an efficient and proven method for the assessment of chemical hazard and risk in the absence of data.

Although many of the current software based methodologies for assessing hazard and fate may not be immediately applicable to nanomaterials, existing P2 exposure assessment models, such as ChemSTEER and E-FAST, can be used without modification. Both of these are mass balance models that estimate the releases and exposures of a chemical during manufacturing and use. ChemSTEER uses conservative default release and exposure models based on monitoring data collected by EPA, focusing on workplace exposures and releases of a chemical. E-FAST estimates non-workplace human and aquatic exposures due to industrial releases, which can be those estimated by ChemSTEER, and the use and disposal of consumer products. These validated models can provide information to chemical companies leading to safer and environmentally friendly processes and products, and can be explored as additional tools to aid in reducing the environmental impact of chemicals, including nanomaterials.

Poster #11: Nano Risk Framework

Presenters: Terry Medley* and Scott Walsh**
Authors: Caroline Baier-Anderson**, John Balbus**, John Carberry*, Richard Denison**, Krish Doraiswamy*, John Gannon*, Terry Medley*, Gwen Ruta**, Keith Swain*, Scott Walsh**, David Warheit*, and Gary Whiting*
Affiliations: *DuPont and **Environmental Defense

Abstract: Environmental Defense, an environmental advocacy organization, and DuPont, a science-based products and services company, have developed a comprehensive, practical, and flexible framework for evaluating and addressing the potential risks of nanoscale materials. The intent of this framework is to define a systematic and disciplined process for identifying, managing, and reducing any environmental, health, and safety risks of engineered nanomaterials across all stages of a product's lifecycle. Our framework offers guidance on the key questions an organization should consider in developing applications of such materials, and on the key information needed to make sound risk-evaluation and risk-management decisions. The framework allows users to move ahead despite areas of incomplete or uncertain information, by using reasonable assumptions and by compensating for knowledge gaps with appropriate risk-management practices. Further, the framework describes a system to guide information generation and update assumptions, decisions, and practices with new information as it becomes available. The framework also offers guidance on how to communicate information and decisions to key stakeholders.