Nanotechnology and a Sustainable Environment

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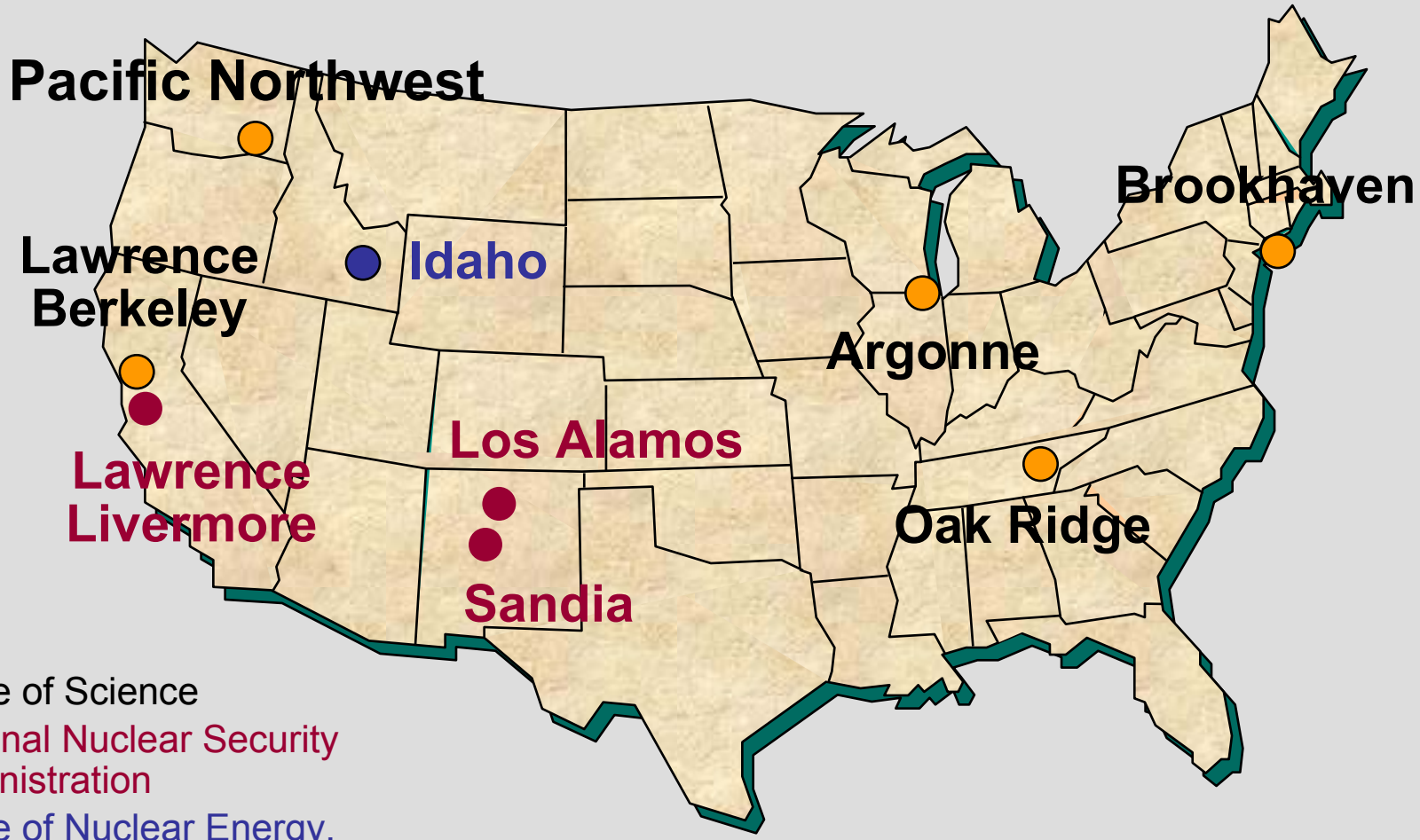
Seoul Korea
April 3-5, 2006

Three Main Messages

- Nanoscience and nanotechnology offer important new tools to work toward a sustainable environment
  - Environmental Remediation
  - Energy Production
  - Environmental Security
- Because nanotechnology is a reality in the market place and will have increasing importance, we need to understand how these powerful material behave in the environment.
  - This need is not unique to nanotechnology, but relevant to any new material, chemical or technology
- In my view many nanomaterials systems are not as well characterized and understood as appropriate.
  - Such factors include: Contamination, environmental effects, time effects, stability, processing history

PNNL in the US Department of Energy National Laboratory System



Pacific Northwest National Laboratory

Sometimes called DOE's environmental laboratory

Mission: Perform basic and applied research to deliver energy, environmental, and national security for our Nation.

- Managed by **Battelle** since 1965
- $638 million FY04 business volume for government and private industry
- Steward: Office of Biological and Environmental Research
- 3,900 staff
- National user facilities
- More than 1,200 patents and 200 active licenses

Battelle Helped Found KRIST

Battelle-Korea Office

Established January 13, 2006

Three business models:
Contract R&D
Laboratory Management
Technology Commercialization

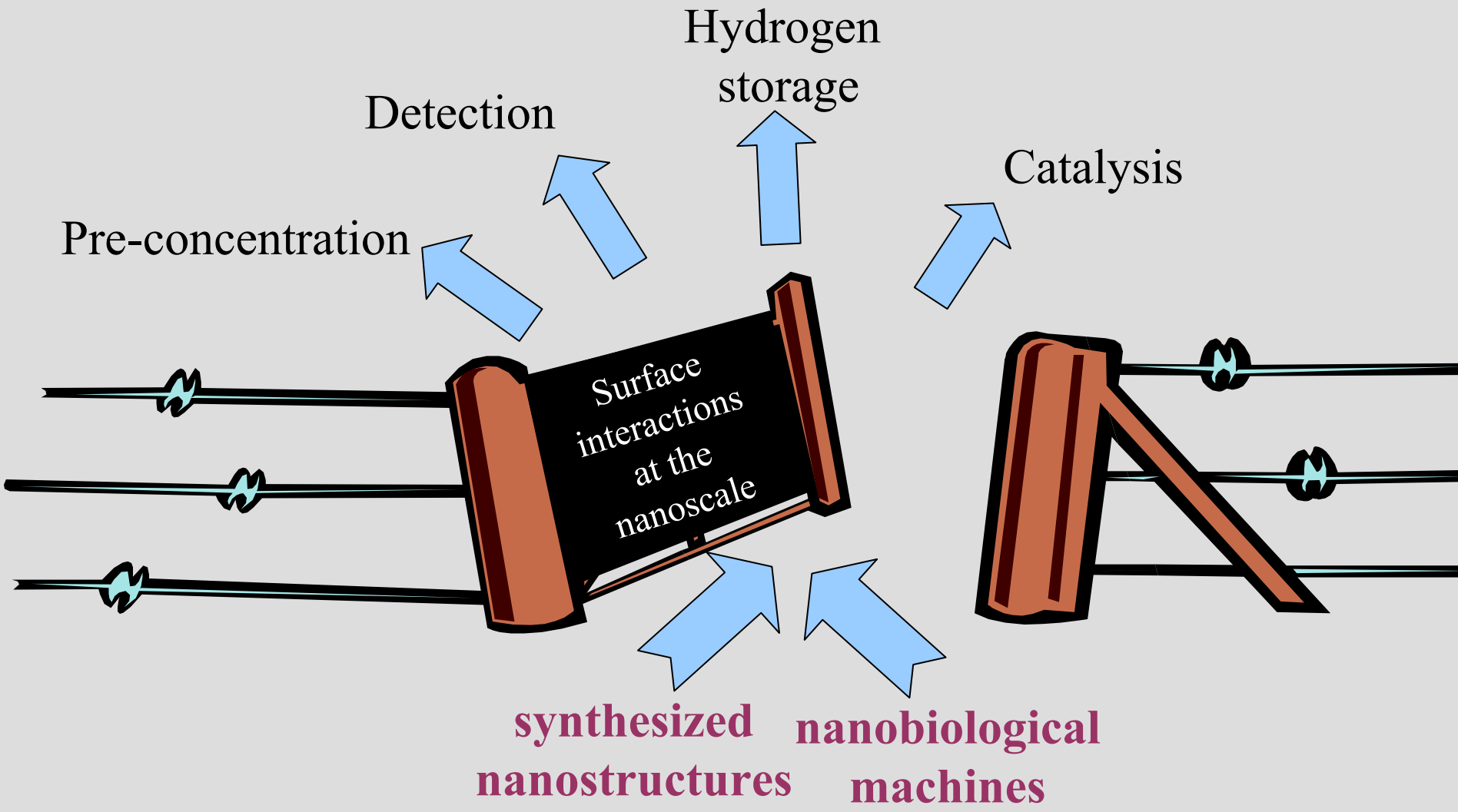
www.battelle-korea.com (active mid-April)

Nara Tower, Floor 7, Cheongdam Dong, Seoul

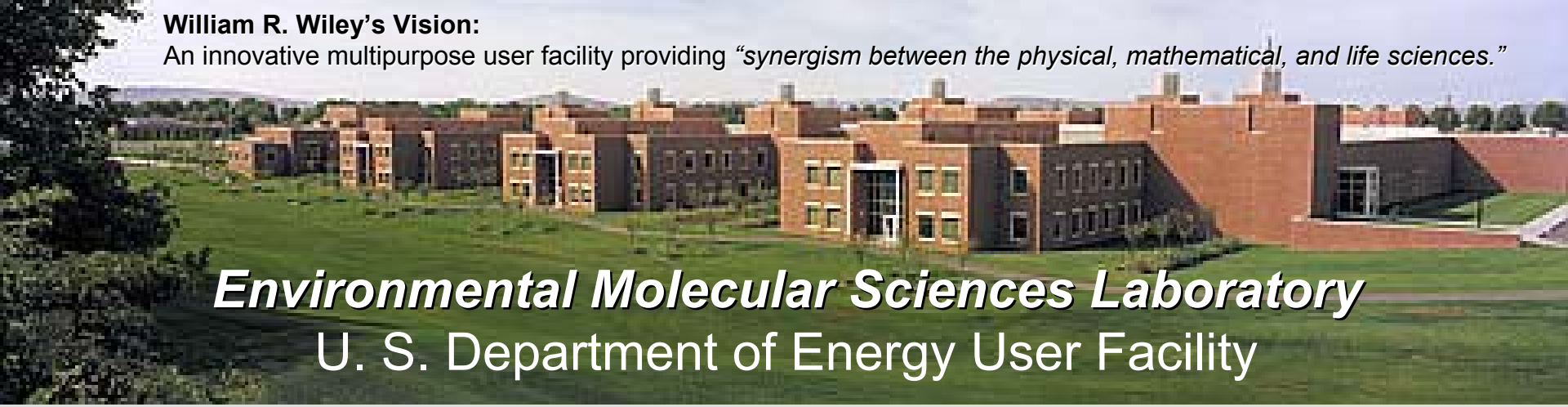
Nanoscience and Nanotechnology are integral parts of the major business activities at Pacific Northwest National Laboratory

- Fundamental and applied research relating nanoscience and nanotechnology concepts to a sustainable environment
  - Homeland security
  - Energy
  - Environmental cleanup
- World-class user facilities and multidisciplinary teams
- Collaborating with others throughout the World, e.g.,
  - Courses in Nanostructured Materials
  - Joint Institute of Nanotechnology
  - Microproducts Breakthrough Institute
  - Oregon Nanoscience and Microtechnologies Institute

Control of the nanostructure is a gateway to solving environmental problems



Nanoscience is a collaborative field requiring the formation of unique teams and access to state of the art tools



William R. Wiley's Vision:
An innovative multipurpose user facility providing *"synergism between the physical, mathematical, and life sciences."*

Environmental Molecular Sciences Laboratory
U. S. Department of Energy User Facility

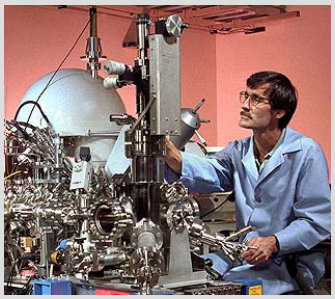
EMSL is a U.S. scientific user facility provides integrated experimental and computational resources for discovery and technological innovation in the **environmental molecular sciences** to support the needs of DOE, the nation, and the world.

Science Themes

- Science of Interfacial Phenomena: (Tailored Interfacial Structures for Dynamics, Reactivity and Transport)
  - "New" energy development (H2 economy, solar, catalysis)
- Biogeochemistry and Subsurface Science
  - Environmental remediation, geochemical cycling
- Atmospheric Aerosol Chemistry
  - Climate change impacts
- Biological Interactions and Interfaces
  - Bioremediation, alternative energy (biomass), geochemical cycling

EMSL Facilities

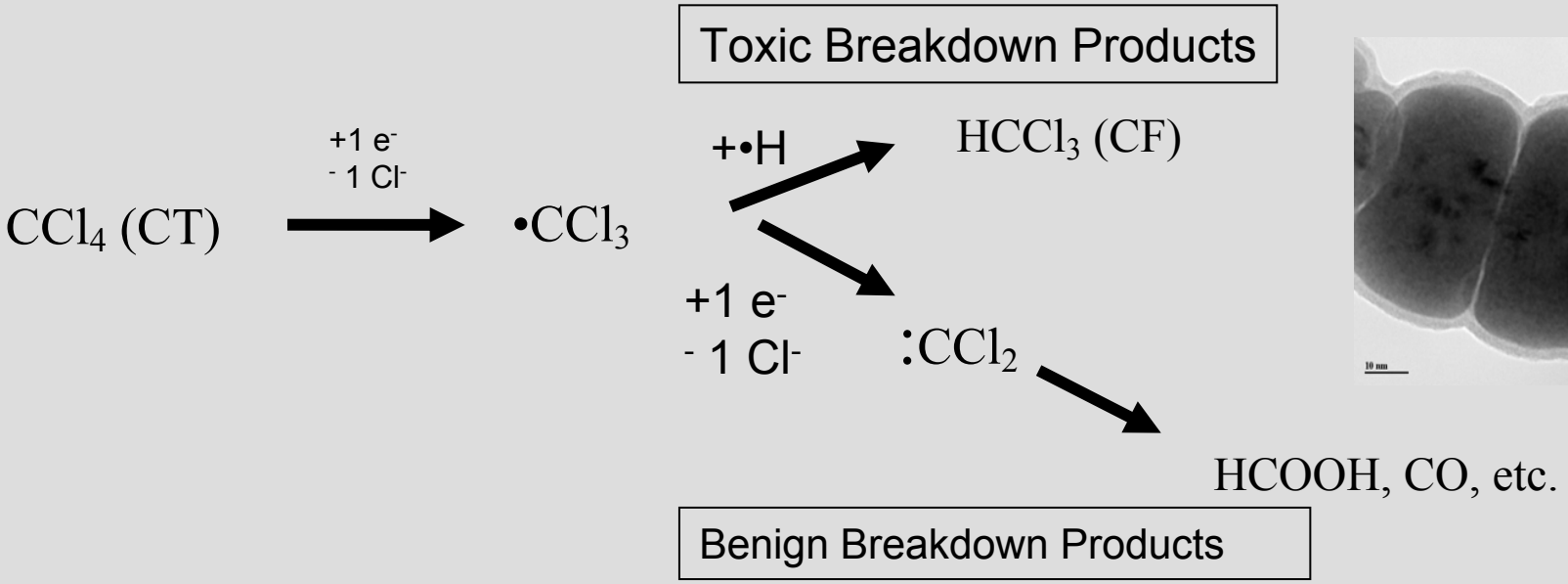
All EMSL Facilities have important tools that are being applied to address problems that have nanoscience and nanotechnology components



- Interfacial & Nanoscale Science
- Molecular Science Computing
- Proteomics and High Performance Mass Spectrometry
- Chemistry & Physics of Complex Systems
- Environmental Spectroscopy & Biogeochemistry
- High Field Magnetic Resonance

www.emsl.pnl.gov

Possible use of iron nanoparticles to assist environmental remediation one research area driving analysis needs



- Transmission Electron Microscopy – Size, structure, shape
- X-ray Photoelectron Spectroscopy – Surface Chemistry; Composition; Contamination
- Surface Area – Gas Adsorption - BET
- XRD – Structure, Grain Size
- Reaction Studies and Electrochemical Measurements
- X-ray adsorption Spectroscopy - electronic structure, oxidation state, property variation
- Modeling – Structure, Transport Properties

The Secret Life of Nanoparticles:

characteristics of nanoparticles and nanostructured materials that are frequently forgotten or ignored

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Pacific Northwest National Laboratory

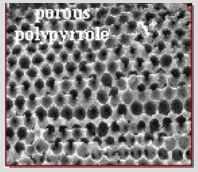
A. A. El-Azab
Florida State University

S. Kuchibhatla and S. Seal
University of Central Florida

TMS 2006
San Antonio Texas

Importance of Understanding Nano-Structured Materials

Increasingly we need analyze nano-structured materials. Frequently we find that analysis of nano-structured materials involves a variety of different surprises. This talk has evolved from those surprises.



I have come to believe that:

- Some of the issues are intrinsic to the nature of nano-materials and that these materials present a variety of challenges for understanding and characterization that are often not acknowledged.
- Many studies of nano-sized materials involve incomplete description of sample history and inadequate characterization. *Contamination and uncharacterized coatings are a dirty secret of nanotechnology*
- Surface analysis methods are underused in the study of nano-materials.

Information needed about nano-structured materials?

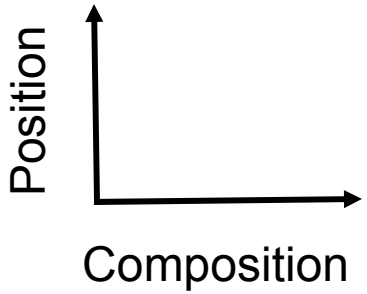
Results of Synthesis or Processing:

size and size distribution
composition and structure
component segregation
surface contamination
defect concentration
shape

Experimental Axes

• Energy; Composition; Spectroscopy; Structure
• Resolution; Dimension; Position

2 Dimensional Analysis



Information needed about nano-structured materials?

Results of Synthesis or Processing:

- size and size distribution
- composition and structure
- component segregation
- surface contamination
- defect concentration
- shape

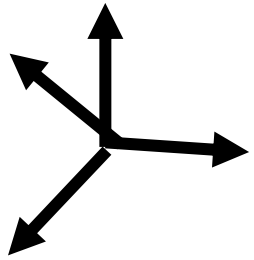
Influence of History, Aging (Time) and Environment:

- processing
- aggregation and growth
- environmental interactions
- reactive layer formation
- structure changes with time

Analyses are usually done assuming that the properties are independent of time and environment.

Experimental Axes Change to Multi Dimensional Analysis

- Energy/composition
- Resolution/Dimension
- Time
- Environment



Multi Axis Analysis from Bob Hwang BNL

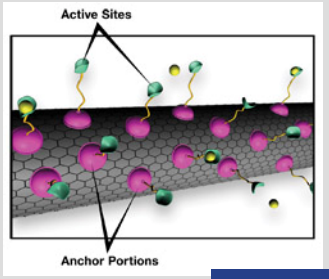
Advanced Nanoscale Materials Research

From cosmetics to hydrogen storage—nanoscale materials push the frontier

Thin films enable next-generation displays
Flexible and highly portable displays

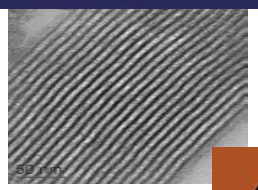
Nanoparticles may mean longer life for enzymes
Biosensors, waste destruction, medicine

Putting carbon nanotubes to work
Functionalized nanotube sensors



Supercritical fluids—making nanoparticles easy
Rapid nanoparticle synthesis

Hydrogen storage for fuel-efficient vehicles
Storing hydrogen in NH_4BH_4

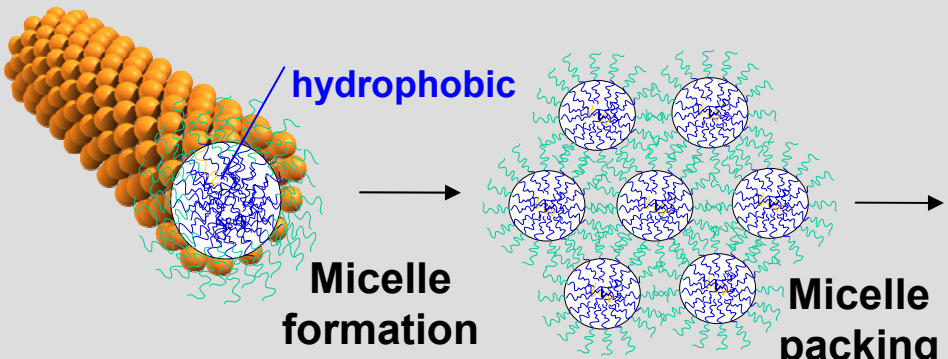


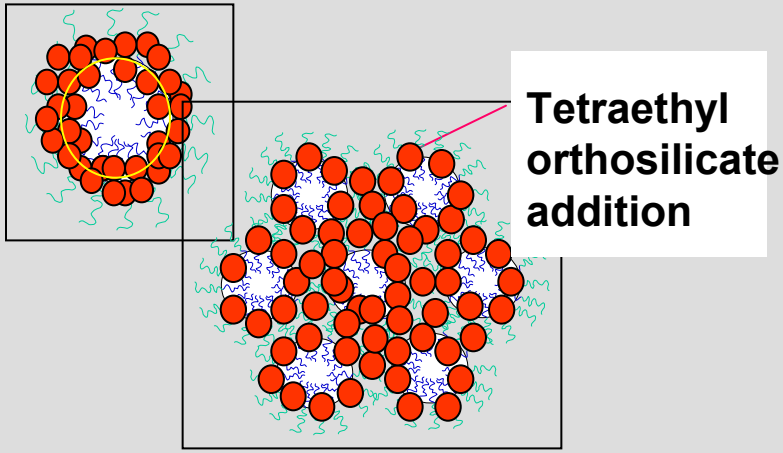
Self-Assembled Monolayers on Mesoporous Supports
Nanosponges with several environmental and energy applications

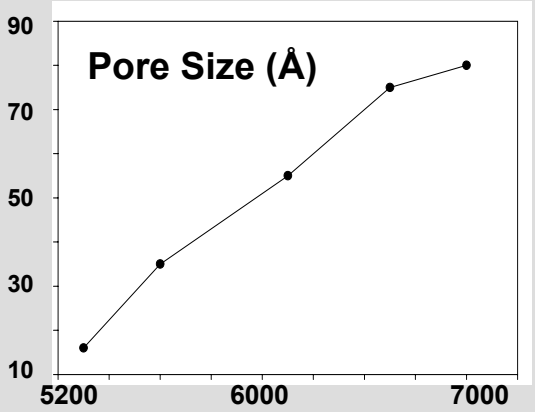
Office of Science
U.S. DEPARTMENT OF ENERGY

http://www.pnl.gov/breakthroughs/

SAMMS:
A hierarchical self-assembly process

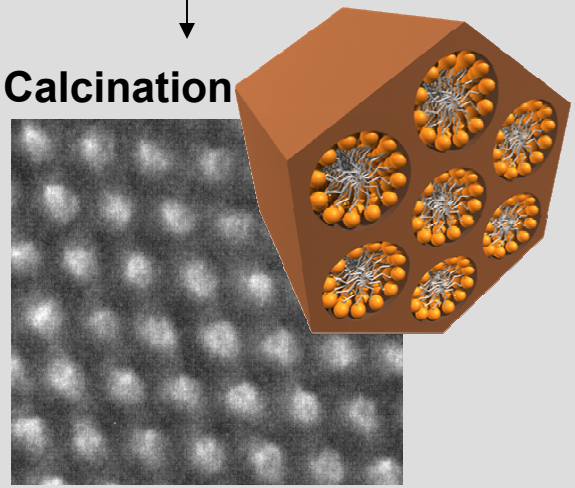






Chain Length —> Pore Size

Calcination



Nanoscience can offer solutions to environmental problems

H… d … up

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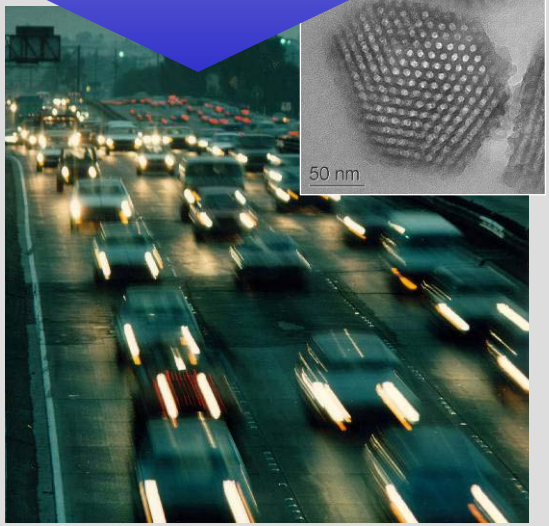
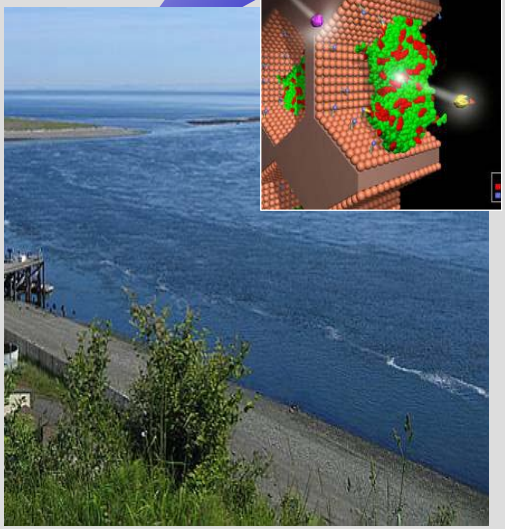
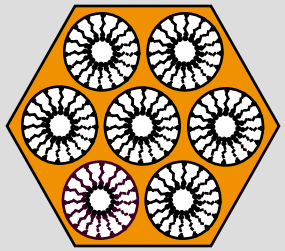
Energy

Hydrogen Storage





Cleaner Water: SAMMS in a Nutshell



- High capacity from high surface area
- Fast sorption from rigid, open pore structure
- Chemical specificity dictated by monolayer interface
- Easily modified for new targets
- Chemically and thermally stable
- Easily regenerated or recycled

SAMMS Removes…

- Mercury
- Arsenic
- Technetium
- Cesium
- Thorium
- Protactinium
- Uranium
- Neptunium
- Plutonium
- Americium
- Selenium
- Bromine
- Iodine
- Palladium
- Silver
- Cadmium
- Platinum
- Gold
- Germanium
- Thallium
- Lead
- Molybdenum
- Vanadium
- Chromium

What's Coming Next…

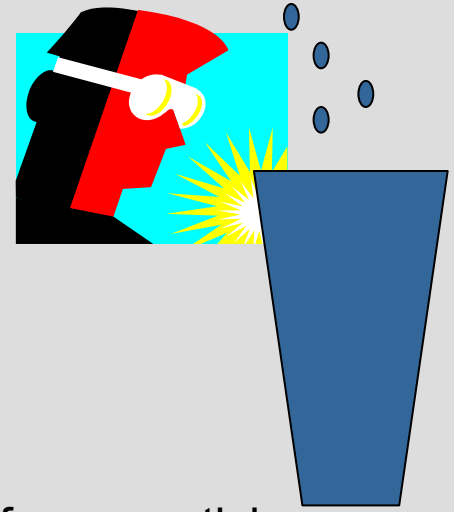
Understanding how the nature of nanoparticles varies with time and environment; examining nanoparticle toxicity

When properties of nanoparticles vary with time and distance, the exposure risk would also vary

100 meter

10-50 meter

1-2 meter



- A DOE Office of science program is looking at the evolution of nanoparticles in the environment
- Northwest Toxicology is working with the National Toxicology Institute to examine inhalation effects of nanoparticles

Nanotechnology Facilitates Development of New Technologies that Have Environmental Benefits

- Many groups around the world are using nanotechnolgy creatively to address interrelated environmental, energy and security issues.
- This presentation highlighted as examples some activities at PNNL. Other related activities include:
  - Sensors – coated Au nanoparticles, Carbon Nanotube Concentrators
  - Energy –
    - Fuel Cells – Catalysts and nanostructured electrodes
    - Hydrogen production – Photocatalysis
  - Institute for Interfacial Catalysis - Energy production and emission control
  - Medical – Nanoparticle Enhance Imaging and Drug Delivery
  - Environmental Remediation – Iron nanoparticles for decontamination

Conclusions

- Nanoscience and nanotechnology are powerful parts of many different technologies and are here to stay.
- They provide critical tools for creating a sustainable environment.
- They are powerful and we need to understand any unique or new toxicology issues.