

# Nanoscience Environment, Safety, and Health at the Center for Functional Nanomaterials

**Charles (Chuck) Black**

Director

**Wai-Lin Ng**

Environment, Safety, and  
Health Coordinator



Community Advisory Council Meeting  
October 13, 2016

Center for Functional Nanomaterials



U.S. DEPARTMENT OF  
**ENERGY**

Office of  
Science

**BROOKHAVEN**  
NATIONAL LABORATORY

Center for Functional  
Nanomaterials

# Outline

- What is the CFN mission and how are we doing?



Chuck Black, CFN Director

- How does the CFN accomplish its mission safely?
  - Fostering a positive safety culture
  - ES&H regulatory drivers
  - Safe lab practices when working with nanomaterials



Wai-Lin Ng, ES&H Coordinator

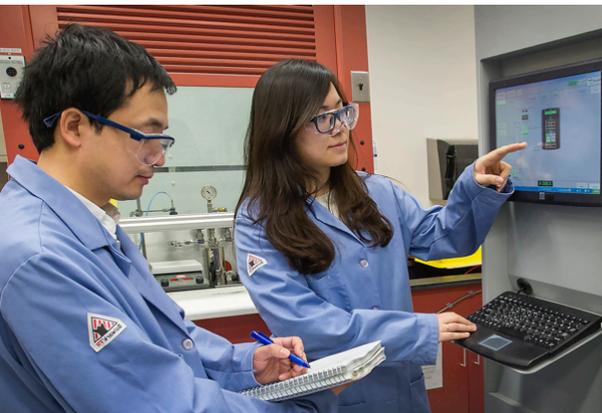
# The CFN mission is advancing nanoscience to impact society

- Operated as a national user facility
- One of five DOE Nanoscale Science Research Centers



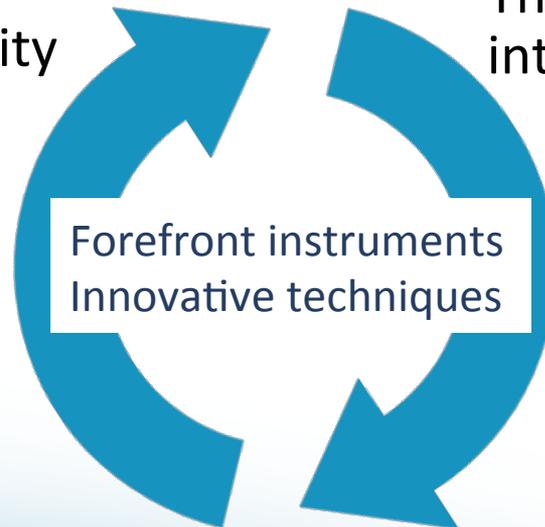
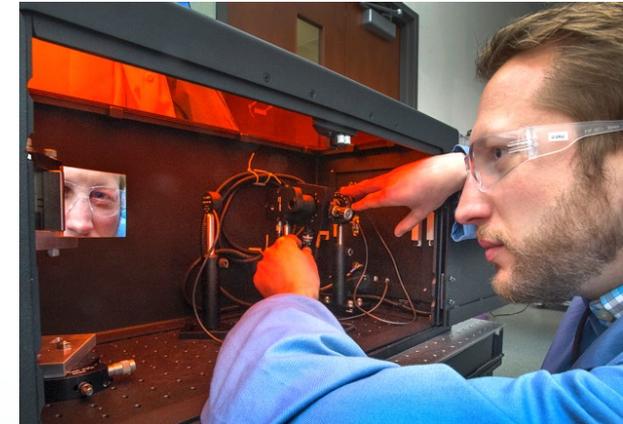
## User program

The CFN is an essential resource for the community



## Internal research

The CFN carries out impactful internal nanoscience research



# The CFN offers Users a research experience supported by top-caliber scientists and using state-of-the-art capabilities for nanoscience

## We are:

28 Scientific Staff

2 Technical Support Staff

5 Operations/Safety Staff

6 Admin/User Staff

21 Postdoctoral Staff

(7 externally supported)



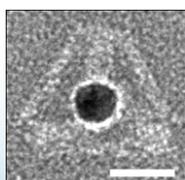
Between 2013–15, 925 unique Users came from universities, government laboratories, and companies

# The CFN operates productively, efficiently, and safely

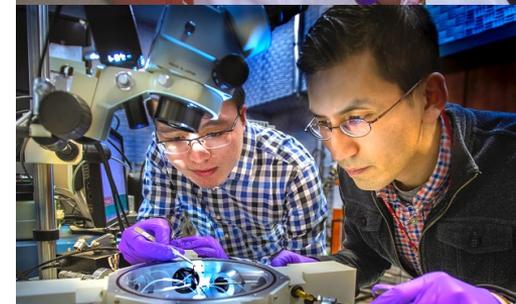
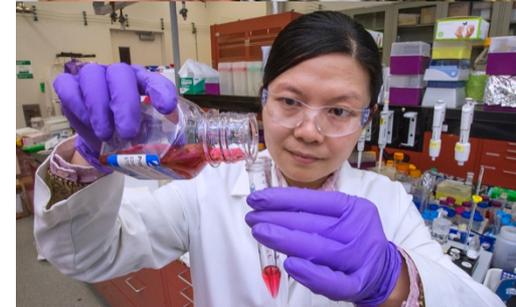
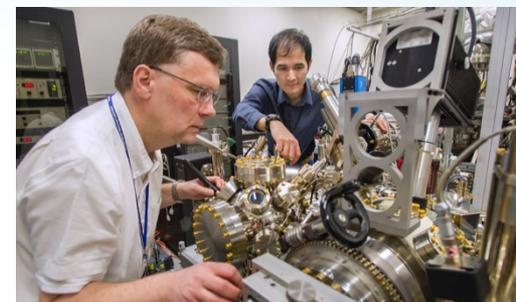
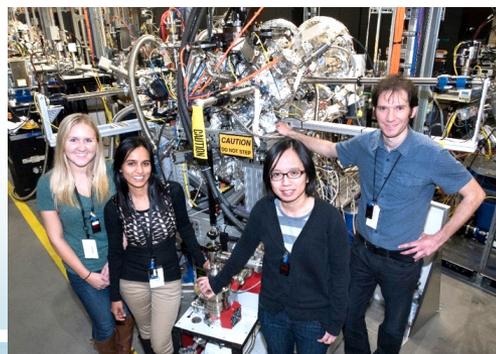
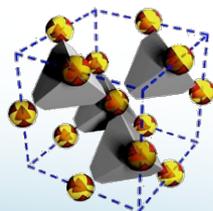
- Three **Themes** provide us identity, direction, and focus
- We support seven state-of-the-art **Facilities** for User and staff nanoscience
- We run a highly-successful **User Program** supporting >500 scientists/year from around the world
- We have an accomplished scientific staff and a leading program of internal **Research**
- We work together as a team to ensure health and environmentally **Safe** laboratory operations



20 nm



20 nm



# Three strategic themes have emerged from CFN facility strengths and our science accomplishments



Self-Assembled  
Nanomaterials by Design

We understand complex self assembly processes, for constructing ***Nanomaterials by Design***

*“Discovering new ways to make materials with new properties”*



Nano-Architectures for  
Energy Solutions

We design ***Nano-Architectures*** to improve the performance of energy materials

*“Putting nanomaterials to work to improve the quality of life”*



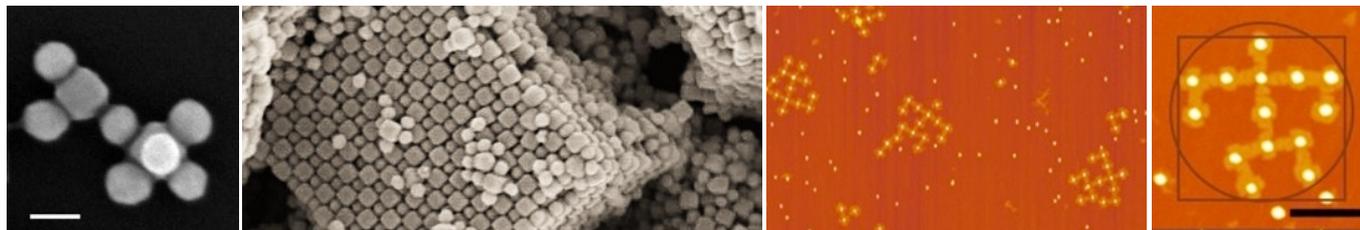
Nanomaterials in  
Operando Conditions

We advance characterization of ***Nanomaterials in Operando***, in real-world environments

*“Watching nanomaterials work, to understand how to make them work better”*

# Three strategic themes have emerged from CFN facility strengths and our science accomplishments

  
Self-Assembled  
Nanomaterials by Design

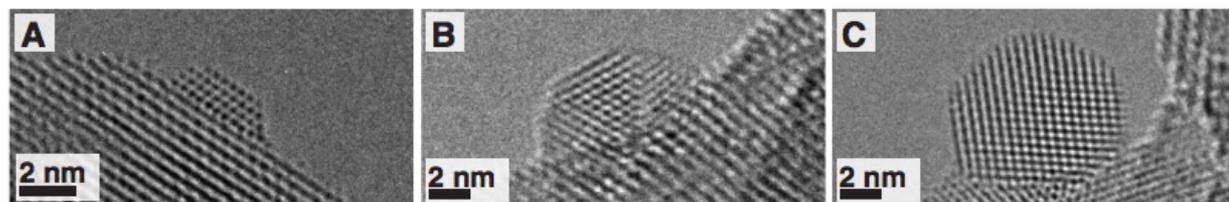


World-leadership in self-assembly of nanomaterials

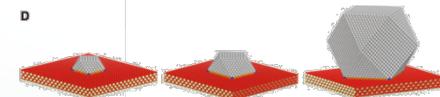
  
  
Nano-Architectures for  
Energy Solutions



  
  
Nanomaterials in  
Operando Conditions



Identifying catalyst active sites



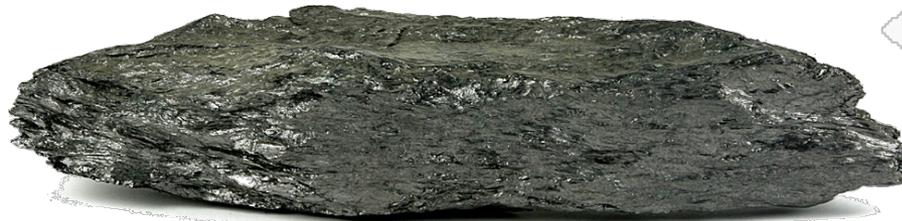
# A material's properties are determined by how its atoms are assembled



Self-Assembled  
Nanomaterials by Design



Coal

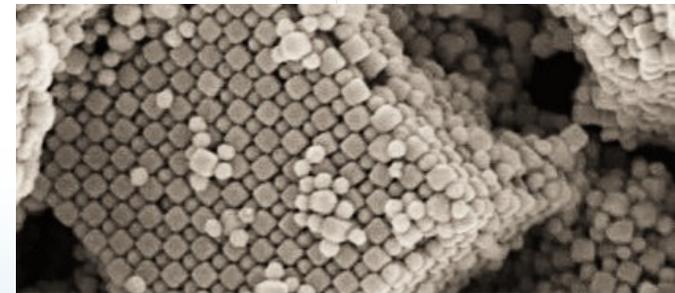


Graphite

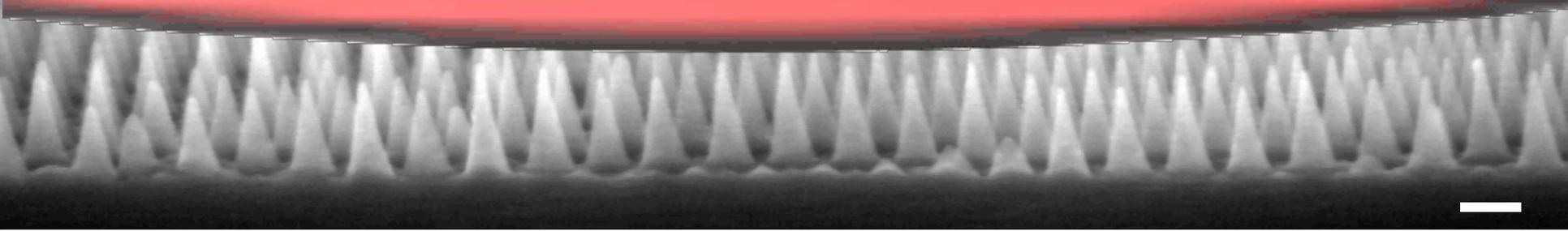


Diamond

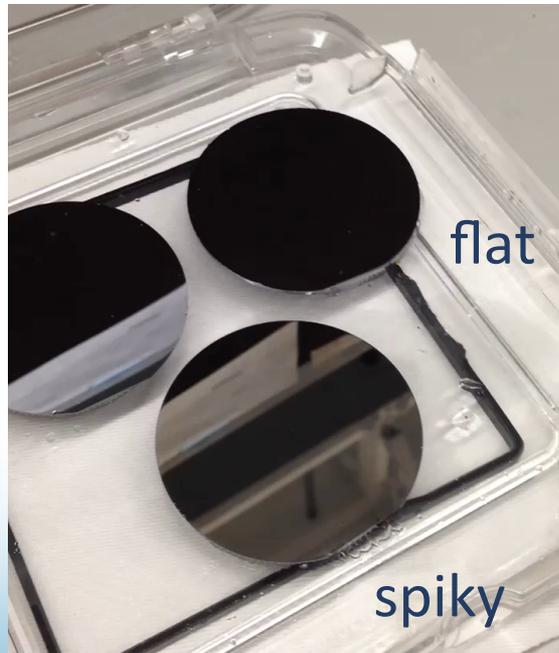
**Goal:** Use nanoscience to make materials with new arrangements of atoms, for materials with new properties



Talcum dust particle (~10 micron diameter)

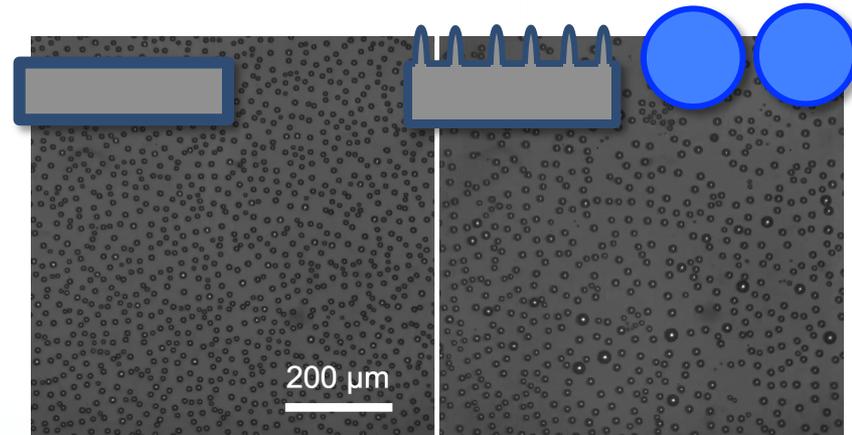


Nano-Architectures for Energy Solutions



flat

spiky



Fog condensing on water-repellent surfaces

CFN User: D. Quéré

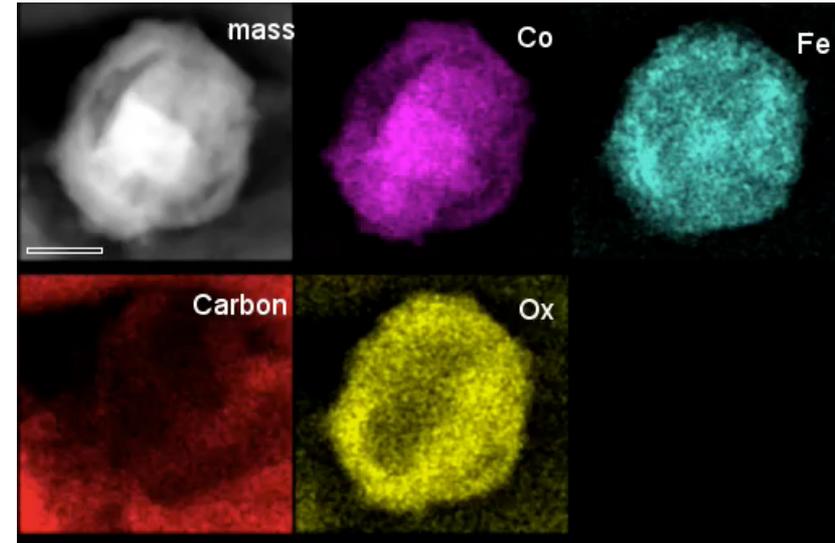
Water-repellent surfaces  
CFN User: A. Checco

# Nanomaterials in *operando* conditions



Nanomaterials in  
Operando Conditions

- Capabilities for watching materials while they work – in real time and in functioning environments
  - Positions and type of every atom
  - During all steps of a chemical reaction
  - Electron motion or electronic structure
  - In harsh environments (corrosive (e.g., batteries), or high T (e.g., catalysts))

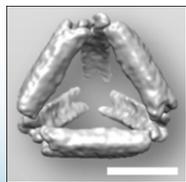


3D image showing the element distributions in a FeCoOx fuel cell electrocatalyst (acquired in < 20 min)

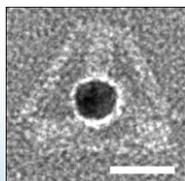
FEI Talos “Operando TEM/STEM”

# The CFN operates productively, efficiently, and safely

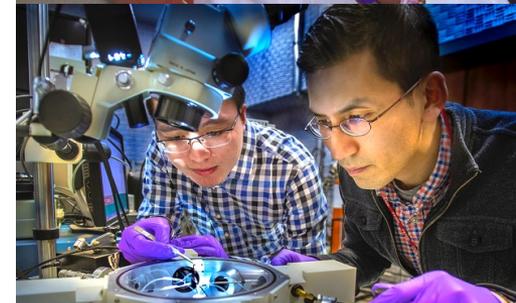
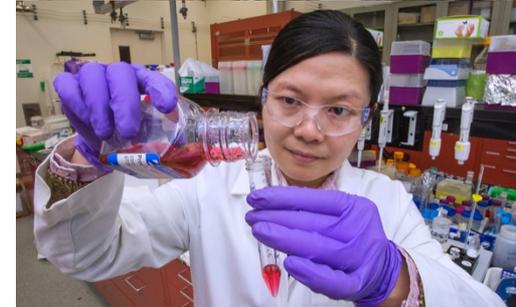
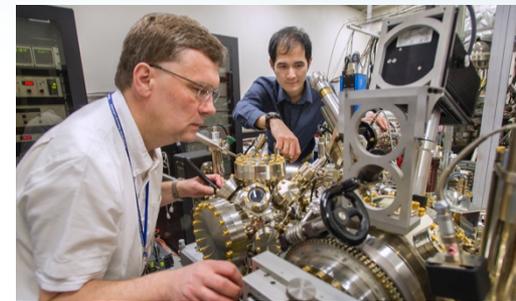
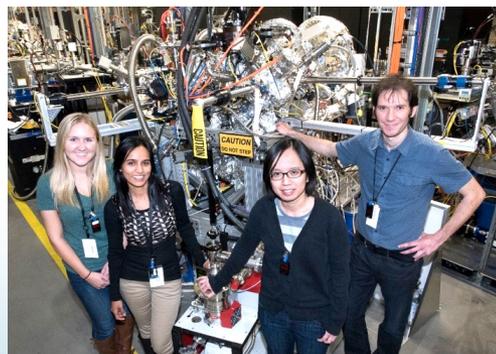
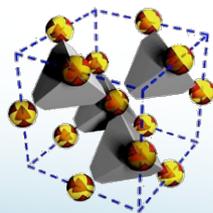
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20 nm



20 nm

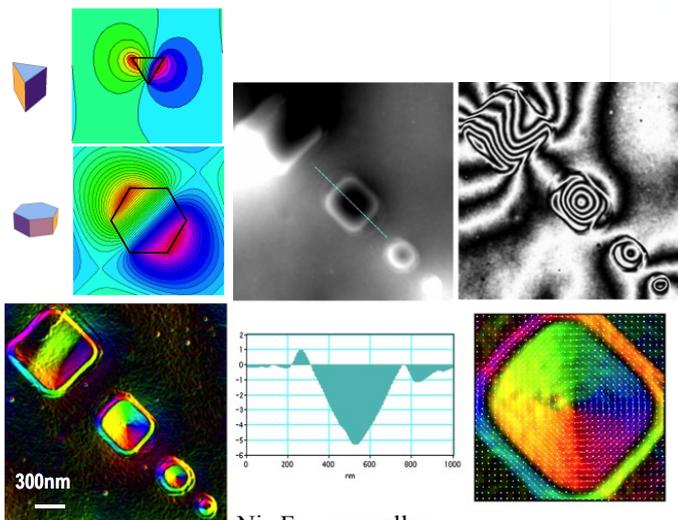


# DOE P 456.1 - SECRETARIAL POLICY STATEMENT ON NANOSCALE SAFETY

DOE requires that all work with nanomaterials be conducted in a safe and responsible manner that protects workers, the public, and the environment.

## BNL PROCEDURES

- The U.S. Department of Energy **Order DOE O 456.1, “The Safe Handling of Unbound Engineered Nanoparticles.”** This policy establishes requirements to ensure that the work involving unbound engineered nanoparticles occurs in a safe and secure manner that protects workers, the public, and the environment.
- BNL’s SBMS Procedure, **“Nanoscale Particle ESH.”** This procedure sets forth practices for managing environmental, safety, and health (ESH) hazards associated with unbound engineered nanoscale particles (UNP).



Ni<sub>20</sub>Fe<sub>80</sub> permalloy

## Working with Nanoparticles at Brookhaven National Laboratory

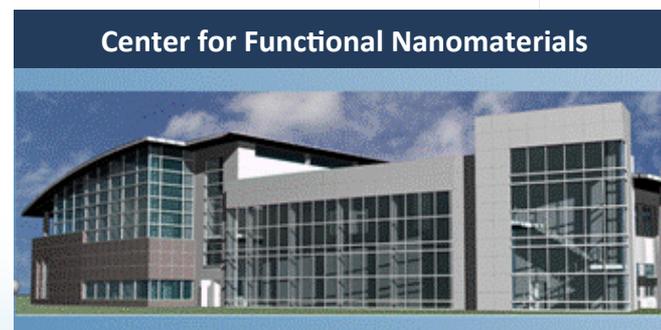
Engineered nanoparticles are intentionally created (in contrast to natural or incidentally formed) and have one or more dimensions that are greater than 1 nanometer (nm) and less than 100 nm.

Unbound engineered nanoparticles (UNP) are particles that are “loose” and that can become airborne such as powders and aerosols. These provide a potential source of exposure. Engineered nanoparticles are designed to have special functions and properties.

# Where is Nanomaterial Work Conducted?

Some work at BNL involves the handling of engineered nanoscale particulate matter such as nanotubes, quantum dots, shell structures, and nanowires.

- The buildings in which nanomaterials work is conducted include:
  - Center for Functional Nanomaterials, Bldg. 735
  - Condensed Matter Physics & Material Science, Bldgs. 480, 703, 510
  - Chemistry, Bldg. 555
  - National Synchrotron Light Source II, Bldg. 740
  - Energy, Environment, and National Security, Bldg. 815
  - Hazardous Waste Management Facility, Bldg. 865 (Waste Storage)



# Working with nanomaterials requires special care

Some engineered nanomaterials may pose ESH concerns:

- Toxicology of materials is not well understood
- Acute and chronic effects in the body are not identified
- Exposure standards do not exist
- Some nanomaterials are very reactive
- Measurement for occupational exposures are limited for nano-sized particles
- Fate of nanomaterials in the environment is not well understood
- There are few product Safety Data Sheets (SDS) available for nanomaterials and the information provided usually is limited to the bulk properties of the materials.



Weighing nanomaterials in a HEPA-filtered balance enclosure

# BNL takes a precautionary approach to handling nanomaterials that have unknown toxicity and reactivity

The properties of nanoscale materials may be fundamentally different from bulk materials of the same composition.

- Nanoscale materials may have new toxicological properties not seen in bulk material.
- Variables that may affect toxicity include: size, shape, chemical composition, crystal structure, water solubility, surface area, dispersability, surface charge, and conductivity.
- Some nanoparticles may be pyrophoric or readily combustible, and therefore very reactive, making fire and explosion a safety hazard in the workplace.

# Unusual Exposure Routes and Transport

- From animal studies, there is some evidence to suggest that some nanoparticles can distribute across anatomical barriers such as through the gastrointestinal epithelium, respiratory tract epithelium, the placenta, through the blood-brain barrier, and along the nerve axons from the nose to the brain.
- The toxic effects of nanoparticles may occur remote from the site of exposure through transport within the body.
- **Precautionary Approach:** Use best laboratory practices when working with nanomaterials based on risk of exposure. Working with dispersible UNP poses the highest risk, UNP in liquids is considered a moderate risk, and working with UNP fixed to substrates presents the lowest risk.
- These features allow researchers to design nanoparticles that specifically target cancer cells to deliver drugs.\*

Organizations like the National Institute for Occupational Safety and Health (NIOSH) are conducting research to determine hazards of nanoparticles in the workplace.

# Required ESH Controls for UNP Work

- **Engineering Controls**

**High Efficiency Particulate Air (HEPA) filtered hoods, balance enclosures, local exhaust ventilation.** Working in the lab hood reduces worker exposure to fine particles. HEPA filtration of the exhaust protects the environment.

*Note: Current data shows that HEPA filtration is capable of removing more than 99.97% of particles down to the range of 2-4 nm.*

**Contained systems** such as gloveboxes

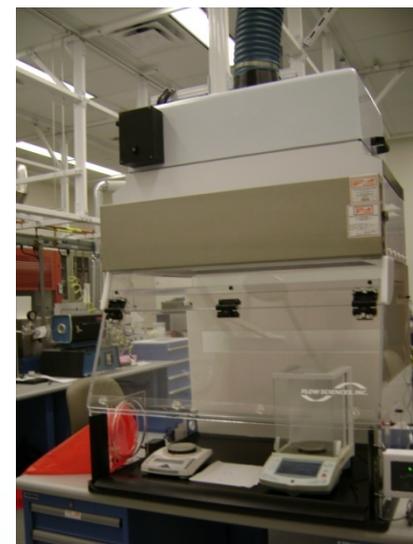
- **Administrative Control**

**Good housekeeping practices.** Wet-wiping of surfaces for minor spills and keeping workspaces clean help to reduce contamination and tracking material out of the work area.

- **Personal Protective Equipment**

**Minimize contact** to skin and eyes.

HEPA Hood



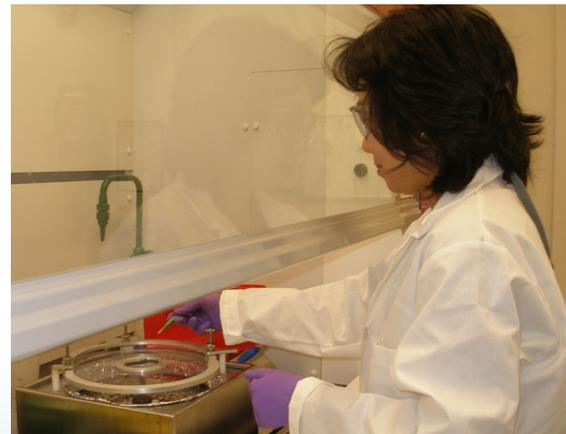
HEPA-filtered balance enclosure

# Personal Protective Equipment (PPE)

At a minimum, laboratory personnel working with nanomaterials will wear:

- Clothing that covers legs
- Enclosed shoes
- Safety glasses with side shields
- Lab coats or gauntlet-style gloves when handling UNP
- Chemical resistant/impermeable gloves

Additional PPE may be specified under Work Planning and Control.



# How is Worker Exposure Determined?

At BNL we monitor to screen and verify controls work.

- Condensation Particle Counter (TSI shown) is one device used to measure particle concentrations in the nano-size range.
- This is used to screen for suspect emissions and atypical conditions that warrant further investigation.
- Limitations: It cannot distinguish engineered nanoparticles from naturally occurring nanoparticles.

Scientists are developing more sensitive and specific sampling techniques to evaluate exposures to nanoparticles in the workplace.



# Posting and Labeling

- Post a sign at the entrance of locations or areas where nanomaterials are stored or used. A designated area may be an entire laboratory, a specific area in a lab, a fume hood or a glovebox.
- Label storage and transfer containers with the following wording and identify the contents, e.g., nano-scale zinc oxide.



Example label or posting

## Hazard Information Placard

HAZARD INFORMATION PLACARD-EMERGENCY INFORMATION						
Safety, Health & Environmental Information						
Bldg: 0735 M1 Room: 1-1L26		Contact Information				
Dept: NC Center for Functional Nanomaterials	Name: Kim Kasilinger	Work #	Cell/Home			
NO FOOD OR DRINK ALLOWED	Nov. Date: 06/19/10 12:23 PM	5174	408-691-7881			
ESR / SWP / RWP / PI ESR NC-19	Dr: Dr. Eric Black	2818	715-349-3450			
	Dr: Dr. Ng, Wall Lin	7153	631457-3824			
PROTECTIVE EQUIPMENT REQUIRED FOR AREA Area Designation: Unbound Nanomaterial Laboratory						
SAFETY GLASSES	LAB COAT	LONG PANTS	FULLY ENCLOSED SHOE			
HAZARDS OF THE AREA						
FLAMMABLE	SELF REACTIVE	CARCINOGEN	RESPIRATORY SENSITIZER	DERMAL SENSITIZER	HIGHLY ACUTE TOXIN	OXIDIZER
WATER REACTIVE	REACTIVE	REPRODUCTIVE TOXICITY				
CORROSIVE	GAS UNDER PRESSURE	NANOMATERIAL	CRYOGENS	NO OPEN FLAME		
Health Hazards: Acids (nitric, hydrochloric, acetic, sulfuric) Fire Hazards: Solvents (Methanol, Ethanol)						
ADDITIONAL INFORMATION						
Water, Air and Vacuum Cutoffs in Service Gallery Access Requirements: Listed in the ESR, SAF, authorized, or escorted. Training Requirements: CFN JTA NC-09 for Staff, Work Permit for Vendors, Users per ESR and COSA.						
UTILITY ISOLATION - CRITICAL EQUIPMENT						
Electric: Power panel LL1K09; SL1K09; LL1K05; SL1K05; LL1K03; SL1K03 (Service Gallery)						

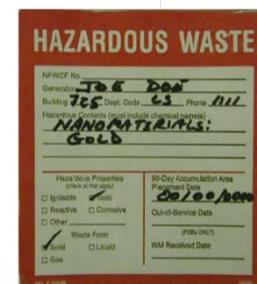


Nanomaterial samples in storage

# Managing Nanomaterials Waste

**All materials to be disposed that have come in contact with nanomaterials must be disposed as Hazardous Waste.**

- Chemicals containing nanomaterials must NOT be released to the sink or disposed in the regular trash.
- All waste containers are kept in a tray within the designated Satellite Accumulation Area.
- Liquids must be stored in rigid leak-proof containers, solids may be stored in plastic bags (>6 mil thick).
- Label containers with a red Hazardous Waste label and with wording "Contains Nanomaterials."

A red-bordered hazardous waste label with the following handwritten information:  
**HAZARDOUS WASTE**  
NPWT No. \_\_\_\_\_  
Gen. No. 785 Dept. Code 63 Proj. No. 011  
Hazardous Constituents (list individual chemical species)  
NANOMATERIALS:  
Gold  
Hazardous Properties (check all that apply)  
 Irritant  Ac  
 Reactive  Corrosive  
 Other \_\_\_\_\_  
Waste Form  
 Solid  Liquid  Gas  
90-Day Accumulation Area  
Placement Date 02/06/09  
Out-of-Site Date \_\_\_\_\_  
P&H (3037)  
WM Received Date \_\_\_\_\_

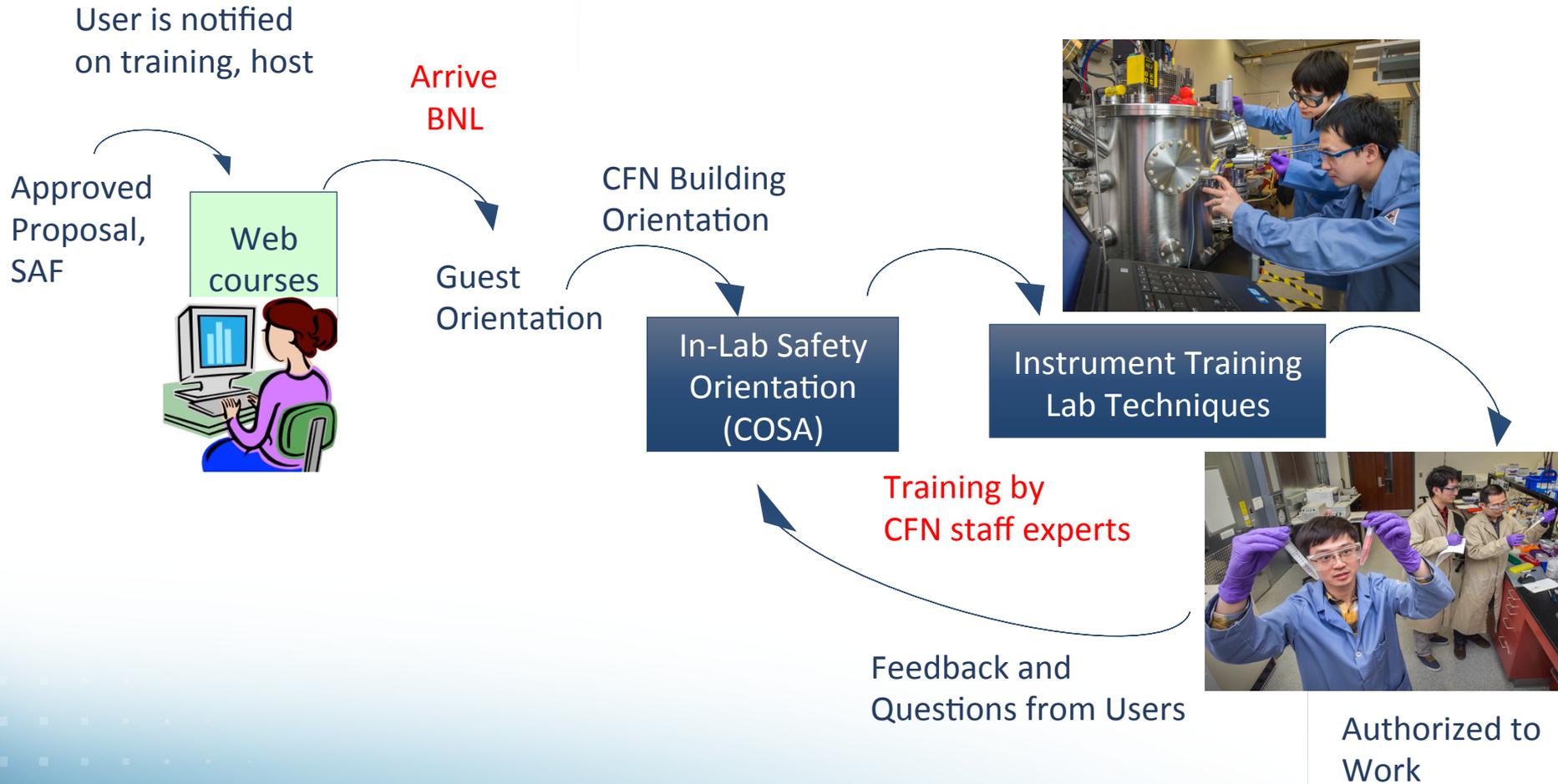
# Fostering a positive safety culture at the CFN: All CFN staff are active safety practitioners, effective safety teachers, and vigilant observers

- Safe CFN operation requires active participation by all staff
  - Users arrive with a diverse backgrounds and experience
  - Many activities; distinct hazards (e.g., chemicals, lasers, unbound nanoparticles)
- Training stresses communication, encourages questions
- Awareness training provided on nano hazards to support staff (non-research)



# Preparing Users to work safely

All Work is planned, hazards identified and controls are put in place.



# Communicating ES&H expectations is done at all levels

- *Safety Observations* (monthly). Managers engage researchers regarding their work, discuss safety concerns and receive feedback.
- *All-Hands Safety* module (bimonthly). Safety topics and lessons learned are presented to all CFN staff as part of Director's message.
- *Student Safety Orientation* (annual). Classroom instruction on the importance of a questioning attitude and adherence to safe lab practices.
- *Cleanroom Safety Tips* (weekly) notes from CFN staff to current Users addressing questions and protocols for working in the Nanofabrication Facility.
- *Facility inspections* (quarterly). ESH and research staff walk through laboratories, machines shops and storage areas to assess hazards, housekeeping concerns.

# Community Outreach: Summer Sunday at CFN, July 17, 2016

Estimated ~800 people attended

## Comments:

- Great presentations and very interesting. Good/excellent use of our tax dollars!
- I love Summer Sundays!
- Great for kids and adults. A wonderful experience
- Thanks so much for doing this! We learned a lot!
- This was a great event for kids and family
- Absolutely perfect, especially on a hot day. Educational and entertaining. Wonderful
- It was exciting to meet scientists. When you think of scientists, you think of mad scientist that are not so friendly, but everyone was friendly at BNL.
- Excellent. People are very welcoming and excited to show science to everyone.
- Fun stuff. Should do Saturday and Sunday
- I intend to write the Dept. of Energy to urge them to continue funding BNL after meeting young people from around the world. We really are a science world-leader.



# Acknowledgments

- Deborah Bauer (BNL), Environmental Compliance
- Bruce C. Stockmeier (ANL) ES&H Coordinator
- John Peters (BNL), Nanoscale Subject Matter Expert

The Center for Functional Nanomaterials is one of the five DOE Nanoscale Science Research Centers, premier national user facilities for interdisciplinary research at the nanoscale supported by the DOE Office of Science. Together the NSRCs comprise a suite of complementary facilities that provide researchers with state-of-the-art capabilities to fabricate, process, characterize and model nanoscale materials, and constitute the largest infrastructure investment of the National Nanotechnology Initiative. The NSRCs are located at DOE's Argonne, Brookhaven, Lawrence Berkeley, Oak Ridge, Sandia and Los Alamos National Laboratories. For more information about the DOE NSRCs, please visit

<http://science.energy.gov/bes/suf/user-facilities/nanoscale-science-rese...>