

# The Factory of Tomorrow

**How advances in material science and manufacturing technology are shaping the factory of tomorrow and the challenge to the Industrial Hygienist**

Yuma Pacific-Southwest Section  
40<sup>th</sup> Annual Meeting  
January 22, 2015

**Charles L. Geraci, Ph.D., CIH**

Associate Director for Nanotechnology  
Centers for Disease Control and Prevention  
National Institute for Occupational Safety and Health

# Objectives

## Understanding Two Key National Initiatives

- Nanotechnology
  - An overview of the key components of nanomaterial science
  - Benefits and concerns
  - Overview key EHS issues
  - Current state of knowledge
  - Summarize the risk management approaches being used today

# Objectives

## Understanding Two Key National Initiatives

- Advanced Manufacturing
  - What is 'Advanced Manufacturing'
  - Key drivers
  - Benefits and concerns
  - OS&H issues?
  - Current state of adoption
  - How will it change the workplace?

# Nanotechnology

the WHITE HOUSE PRESIDENT BARACK OBAMA

★★★★



★★★★

[Get Email Updates](#) | [Contact Us](#)


BLOG

PHOTOS &amp; VIDEO

BRIEFING ROOM

ISSUES

the ADMINISTRATION

the WHITE HOUSE

our GOVERNMENT

[Home](#) • [The Administration](#) • [National Economic Council](#)
 Search NEC



## National Economic Council

[NEC Home](#) | [NEC Director](#) | [Speeches](#) | [Reports](#)

### A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality Jobs

*"History should be our guide. The United States led the world's economies in the 20th century because we led the world in innovation. Today, the competition is keener; the challenge is tougher; and that is why innovation is more important than ever. It is the key to good, new jobs for the 21st century. That's how we will ensure a high quality of life for this generation and future generations. With these investments, we're planting the seeds of progress for our country, and good-paying, private-sector jobs for the American people."*

*-PRESIDENT BARACK OBAMA, AUGUST 5, 2009*

The Administration is committed to strengthening and focusing investments in our world-class nanotechnology research and development pipeline; targeting support for nanotechnology transfer and facilitating commercial start-ups; and cross-disciplinary training and education of scientists and engineers in the new-generation workforce. This will enable us to capitalize on our investments and stay at the cutting edge of this rapidly growing technology.



# What is the US Investment?

The cumulative investment of NNI agencies since fiscal year 2001, including the 2015 request of \$1.5 Billion, now totals almost \$21 Billion.

Is EHS important?

Cumulative investments in nanotechnology-related environmental, health, and safety research since 2005 now total nearly \$900 million.

## Key Findings of the Review of NNI

- The US is the world leader in nanotechnology R&D and commercialization, but its lead may be transient
- The NNI has had catalytic and substantial impact on the field of nanotechnology
- The program management of NNI is effective but opportunities for improvement exist
- Economic competition from other countries has dramatically increased
- Commercial activities have gained momentum as the field has evolved
- The scarcity of standardized commercialization data challenges the tracking of benefits of nanotechnology
- The identification and management of risks for environment, health and safety are crucial to the responsible commercialization of nanotechnology-related products
- The lack of an American skilled workforce presents a significant challenge to the nanotechnology-related business community.



President's Council of Advisors for Science and Technology



# Easy summary of current state

- **Congress:** Where are the new products and jobs?
- **Industry:** Innovation and commercialization must come closer
- **EHS:** We have some knowledge but a lot of unknowns

**Challenge:** move nanotechnology to market quickly and safely



# Nanotechnology

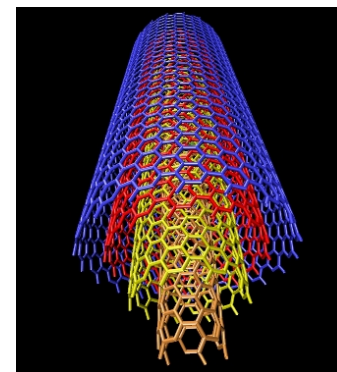
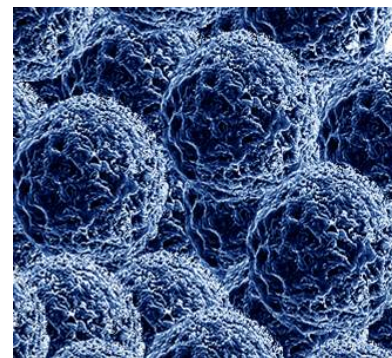
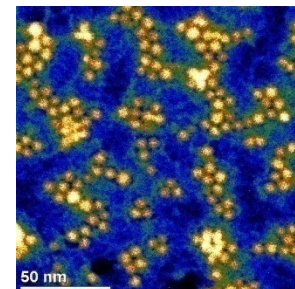
- It is a priority: got it.
- What is it and how will it affect me as an Industrial Hygienist?
- Nanotechnology is a huge collection of scientific disciplines. We will focus on the materials.
- Focus: Nanomaterials that are created by nanoscale science and engineering

# Nanotechnology is Everywhere

- Not a matter of ‘if’, but of ‘when’
- It is the new material science
- Boundaries between materials have been erased to exploit new activity
- Moving into the manufacturing workplace as ‘new and improved’ products are created
- Moving into established and advanced manufacturing processes.

# Nanotechnology: A Review

# Nanoparticles: Some Old, Some New



Naturally occurring

Man-made  
by-product

Engineered  
Nanomaterials (ENM)

# Nanotechnology: The Fast Definition

- Manipulating matter at the atomic level
- Creating materials that have **new and unique properties** because of their size.
- Creating structure and function at nanoscale

**Richard Smalley**

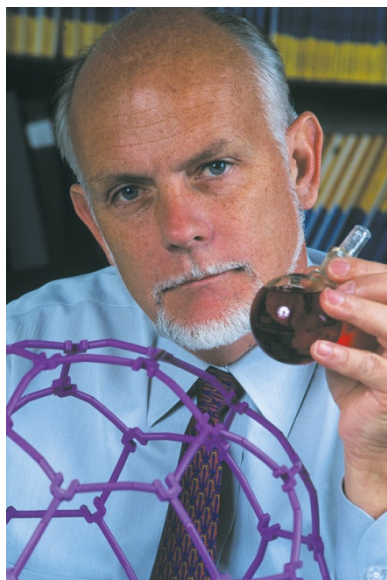
Nobel Prize Winner, Chemistry (1996)

**Nanotechnology:**

“The art and science of building stuff that does stuff at the nanometer scale”

AKA: Material science, one molecule at a time.  
(1943 - 2005)

“Just about anything can be made faster, stronger, smarter, smaller, better, etc., using nanomaterial science”



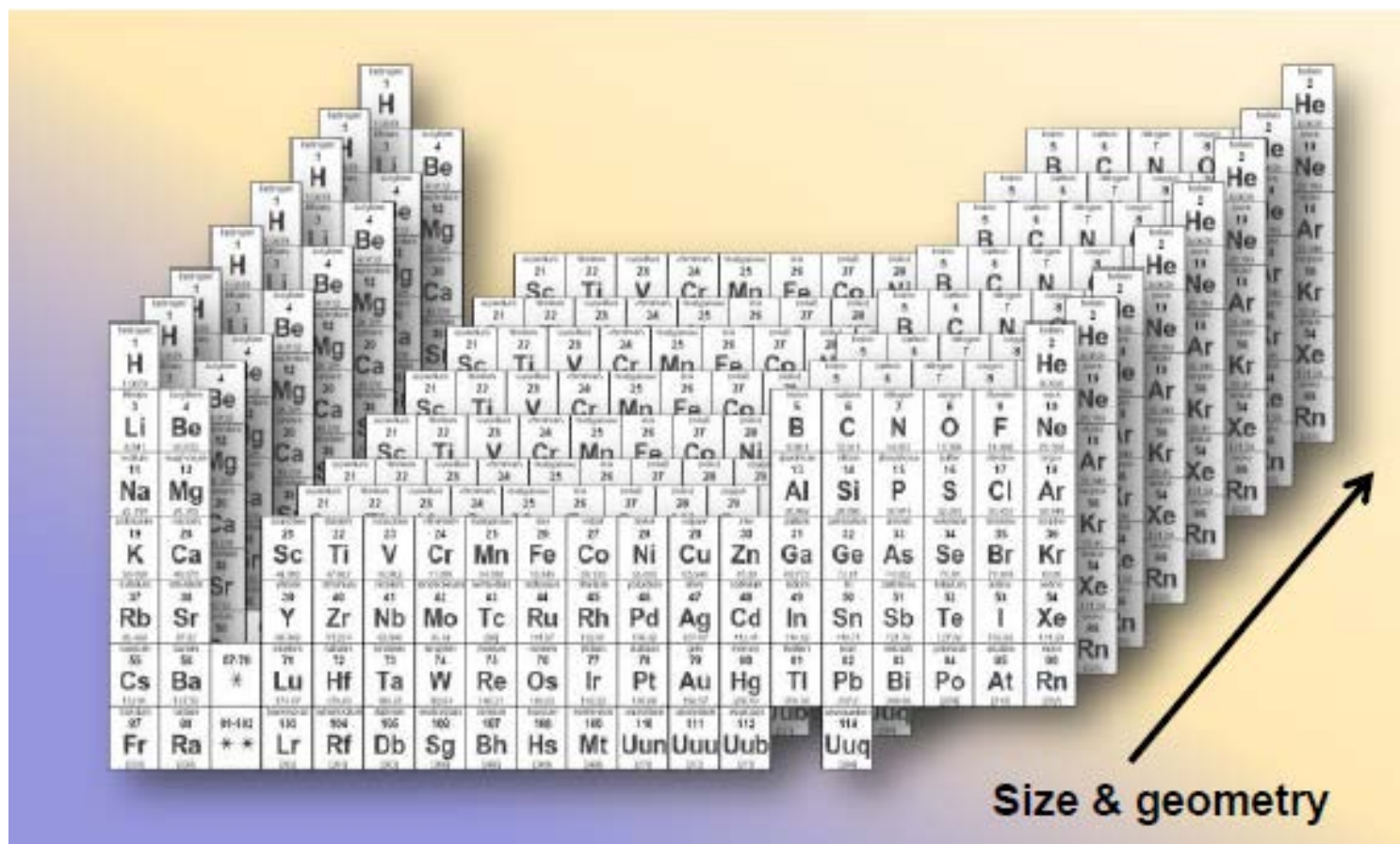
# A 'Flat Earth' View of the Elements

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra																

La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr



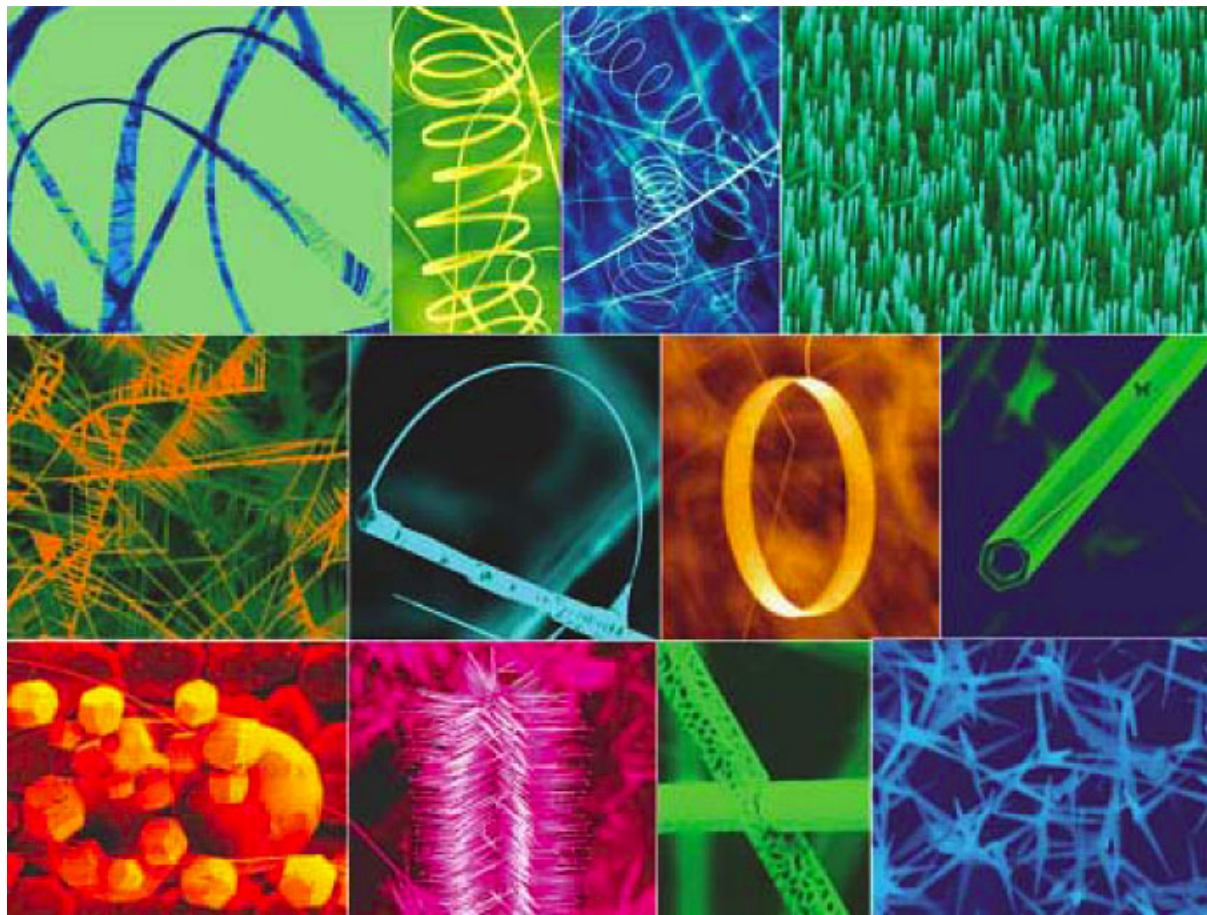
# Nanomaterial Science: Opening the 3<sup>rd</sup> Dimension of the Periodic Table



“Carbon just isn’t carbon anymore”

# Zinc oxide nanoparticles

**Same composition: different shapes and different chemical and biological activities**



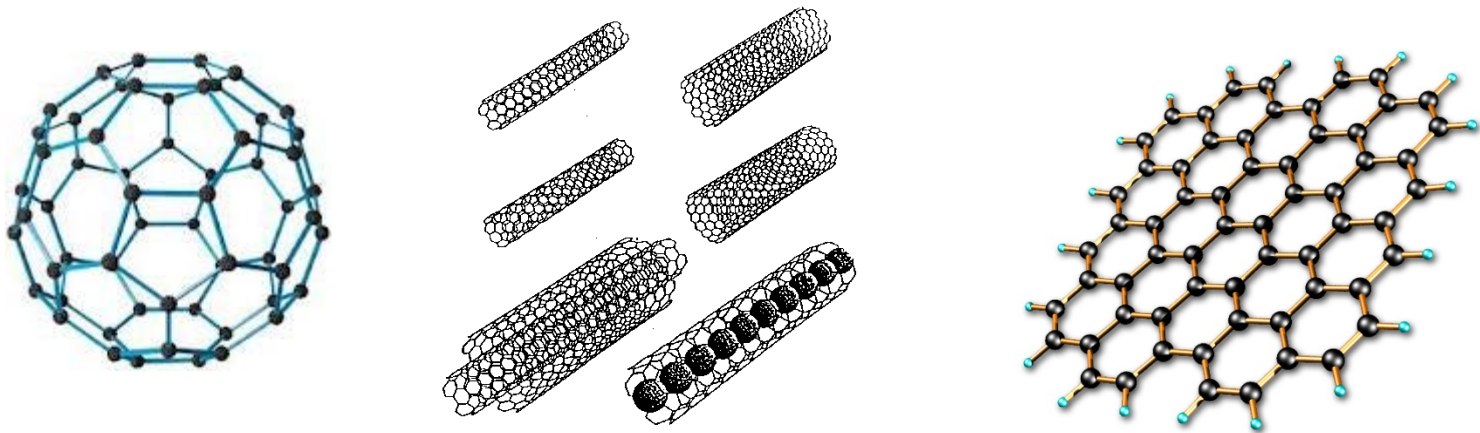
Source: Materials Today June 2004. Zhong Lin Wang, Georgia Institute of Technology





← Old

# Your Grandfather's Carbon

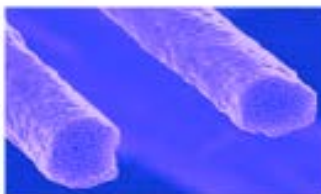


# The Nanomaterial designer's carbon

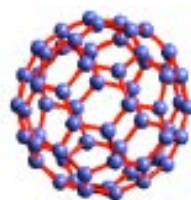
← Built in the nm range

# Nanoparticles: Many shapes, many chemistries

Single and multi walled nanotubes



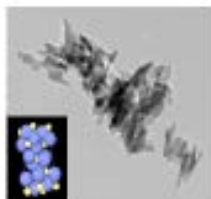
Fullerenes



Nanoshells



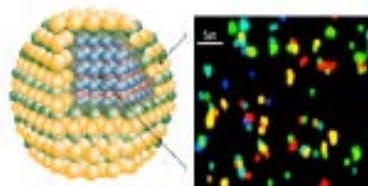
Metal oxides



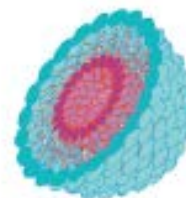
Dendrimers



Quantum dots



Nanosomes



N. Walker, National Toxicology Program

Not all nanoparticles are the same

# Nanotechnology: 30 Second Review

Old: Material behavior driven by chemistry and making things from big pieces

Nanoscale Science: making materials one molecule at a time at the nano scale

New: Material behavior driven by size, shape, surface chemistry. More active and efficient

Result: New material properties and behavior:

**Higher or newer hazard?**

# Challenges of Nanotechnology for the Industrial Hygienist

# Challenges of Nanotechnology

- Few 'new-to-the-world' materials, but many new forms of familiar materials
- Beneficial properties associated with the technology and the materials – highly promoted
- Potential hazards have been identified
- Action needed in an environment of uncertainty
- Potential for many 'generations' of the technology and the materials
- **Moving into every sector**

# Applications of nanotechnology

<b>Agriculture</b>	More efficient, targeted delivery of plant nutrients, pesticides
<b>Aerospace and Automotive</b>	Lighter, stronger, self-healing materials
<b>Medical</b>	Targeted therapeutics, enhanced detection, new structural materials
<b>Energy</b>	More efficient fuel cells, solar collectors, transmission, storage
<b>Environmental</b>	New pollution control and remediation tools, sensors
<b>Food</b>	New safety sensors, food preservatives, nutrient additives, packaging
<b>Materials</b>	Self-cleaning glass, stain resistance, stronger materials, body armor
<b>Water</b>	New purification approaches, wastewater treatment

# ***NANOTECHNOLOGY: In the Balance***

## ***THE PROMISE!***

***and***

## ***THE CONCERN?***

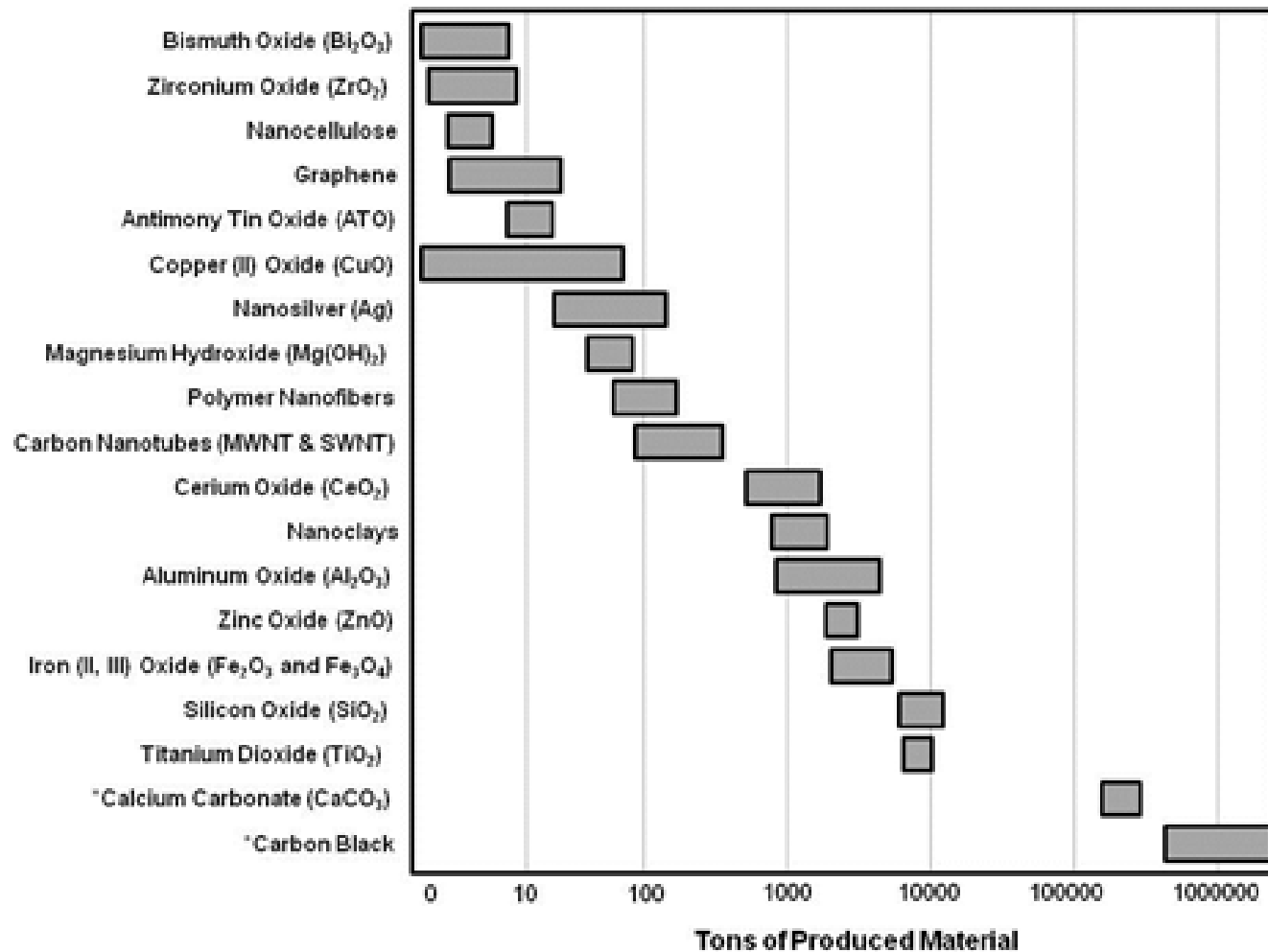
### **Multiple Applications/Benefits**

- Structural Engineering
- Electronics, Optics
- Food and Feed Industry
- Consumer Products
- Alternative Energy
- Soil/Water Remediation
- Nanomedicine:
  - *therapeutic*
  - *diagnostic*
  - *drug delivery*
  - *cancer*
  - *nanosensors*
  - *nanorobotics*

### **Consumer Fears/Perceived Risks**

- Safety: Potential adverse effects
- Environmental Contamination
- Inadvertent Exposure  
*(inhalation, dermal, ingestion)*
- Susceptible Subpopulation
- Societal Implications
- Nanotoxicology:  
*Safety Assessment of  
engineered Nanomaterials  
and of Nanotechnology  
enabled Applications*

# Commonly Produced and Used NM



Draft NIOSH Contract Report (C. Sayes, 2014)



NCI Alliance for  
**Nanotechnology**  
in Cancer

## Developing Small Tools with a Big Impact on Cancer

Search

## Learn About Nanotechnology

## Collaborate

## Alliance in Action



## News Spotlight

**NEW ROUND OF ALLIANCE FUNDING  
WITH APPLICATION SUBMISSIONS DUE  
FALL 2014!**

Application announcements for NCI's Cancer Nanotechnology Program are now published. Opening dates for the CCNEs (U54) and IRCNs (U01) are listed below with initial awards to begin September 2015. A

## Understanding the Potential



## News &amp;

## ANNUAL

The National Cancer Institute's annual report outlines the Alliance's research and community outreach efforts, and features numerous articles, a community advisory board, and a section on advancing nanotechnology.

Read the |

## REQUEST SUMMARY

The Nation  
of Cancer  
published



U.S. Department of Health and Human Services


**U.S. Food and Drug Administration**  
Protecting and Promoting *Your* Health

[A to Z Index](#) | [Follow FDA](#) | [En Español](#)

Search FDA

[Home](#)[Food](#)[Drugs](#)[Medical Devices](#)[Radiation-Emitting Products](#)[Vaccines, Blood & Biologics](#)[Animal & Veterinary](#)[Cosmetics](#)[Tobacco Products](#)

## Science & Research


[Home](#) > [Science & Research](#) > [Science and Research Special Topics](#) > [Nanotechnology](#)

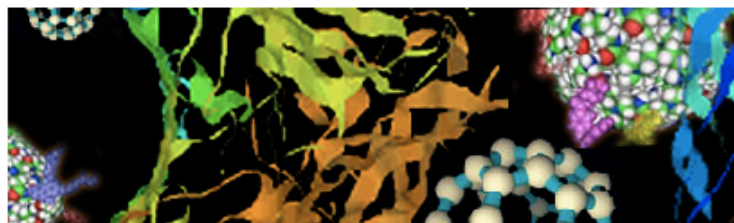
### Science and Research Special Topics

[▶ Nanotechnology](#)
[Current Nanotechnology Programs at FDA](#)

### Resources for You

- [FDA Publications](#)

## Nanotechnology



The U.S. Food and Drug Administration (FDA) regulates a wide range of products, including foods, cosmetics, drugs, devices, veterinary products, and tobacco products some of which may utilize nanotechnology or contain nanomaterials. Nanotechnology allows scientists to create, explore, and manipulate materials measured in nanometers (billionths of a meter). Such materials can have chemical, physical, and biological properties that differ from those of their larger counterparts.

### Spotlight

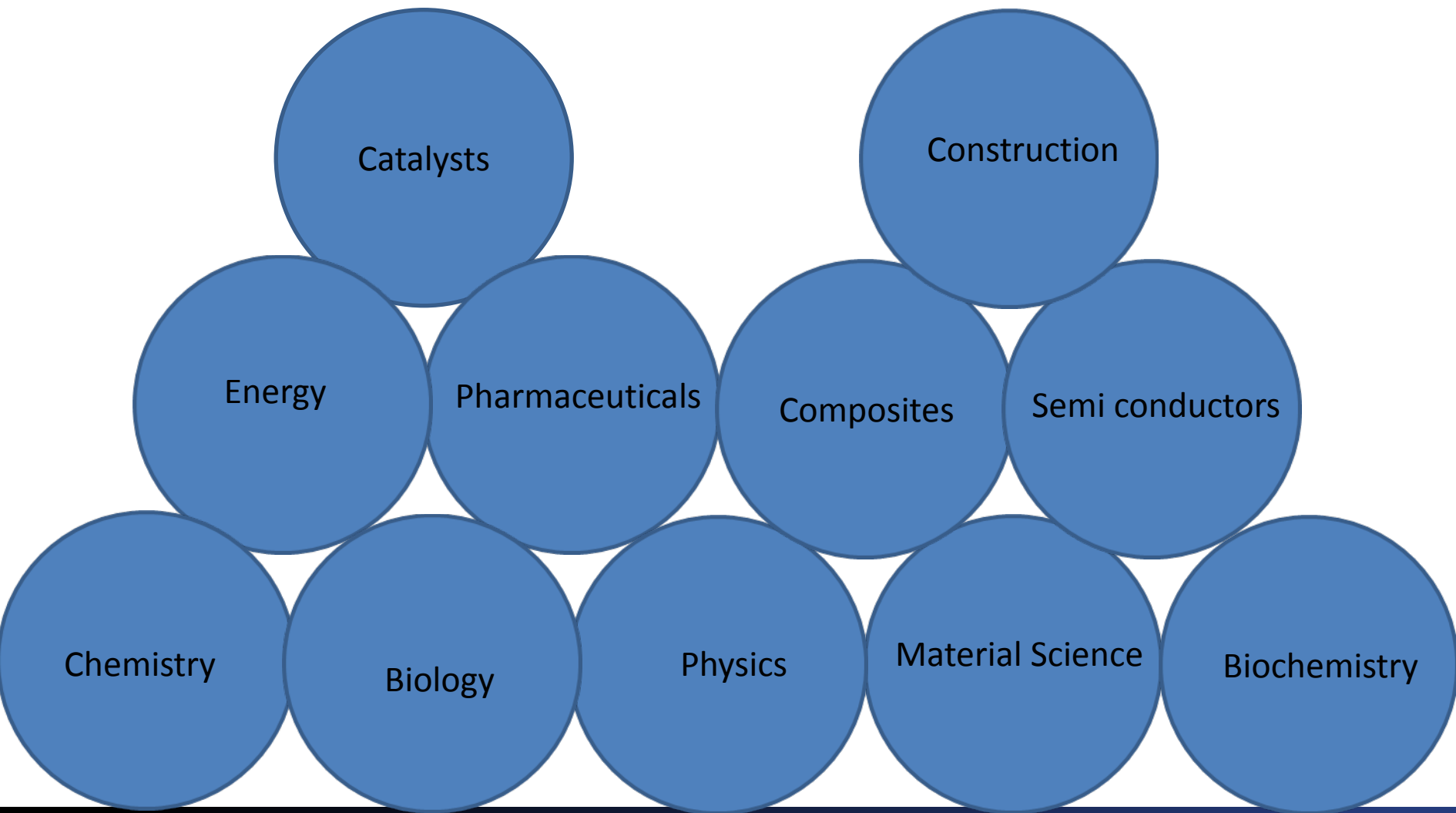
- [FDA's Approach to Regulation of Nanotechnology Products](#)
- [Article by FDA Commissioner Margaret A. Hamburg in Science, April 2012](#)
- [2013 Nanotechnology Regulatory Science Research Plan](#)

### Related Links

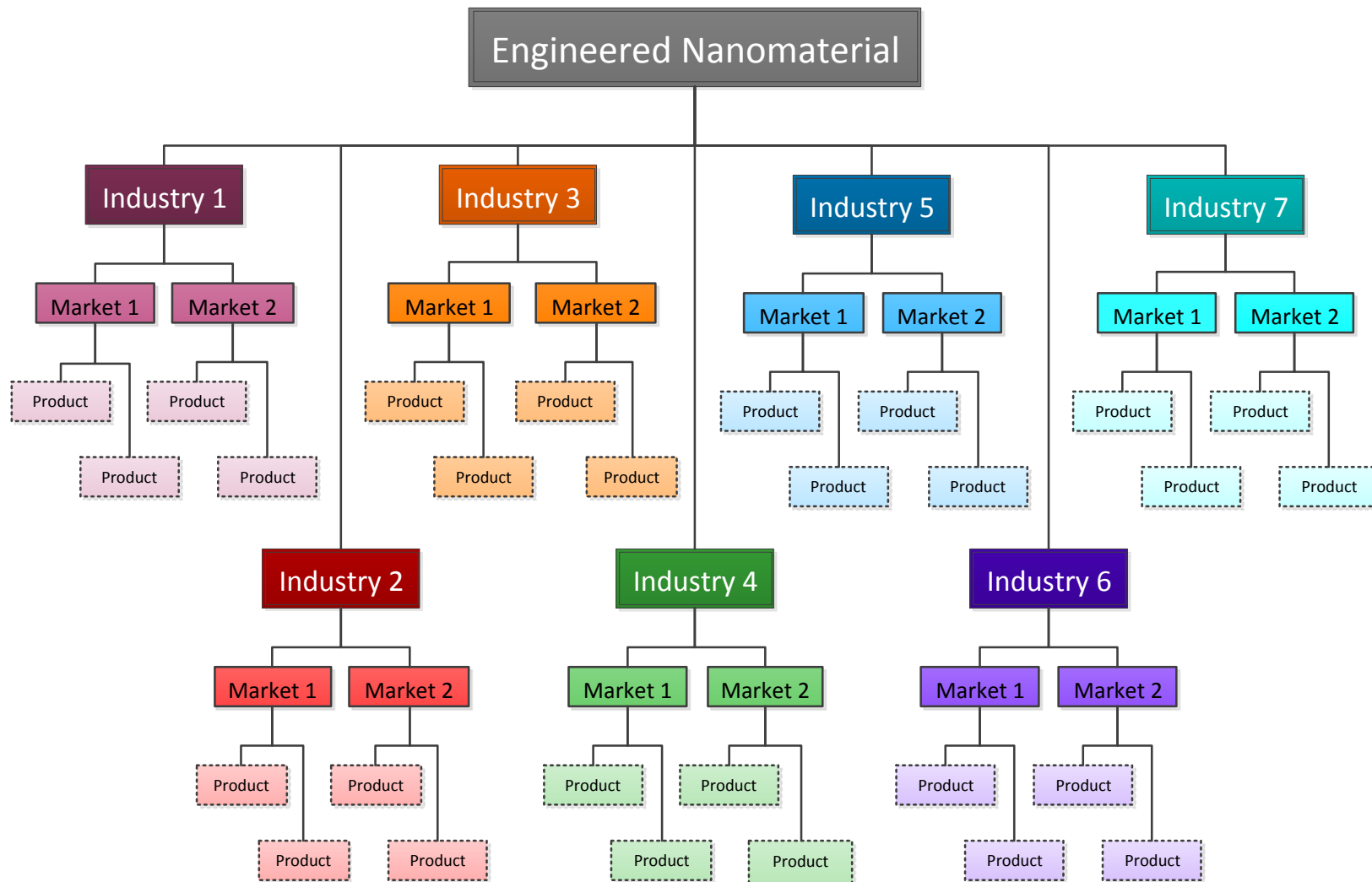
- [National Activities](#)
- [International Activities](#)
- [Nanotechnology Partnerships](#)



# Challenge: There is no single nanomaterial industry



# The ENM value chain gets complex quickly



## Example consumer products that contain nanomaterials

[www.nanotechproject.org/cpi/products](http://www.nanotechproject.org/cpi/products)

### 260 Den Nano Silver Far Infrared Anti-odor Healthy Socks

**Company:** TSUNG-HAU Technology

**Category:** Health and Fitness > Clothing

**Origin:** Taiwan

**Nanomaterial:** Silver



### 2C Auto Sealant PRO

**Company:** Nanosafeguard

**Category:** Automotive > Maintenance & Accessories

**Origin:** USA

**Nanomaterial:** Silicon dioxide

**How much we know:** Category 4 (Unsupported claim)



### 928 Carbon/SL Record

**Company:** Bianchi

**Category:** Health and Fitness > Sporting Goods

**Origin:** Italy

**Nanomaterial:** Carbon



### A La Mode Performance Long Sleeve Mock Neck

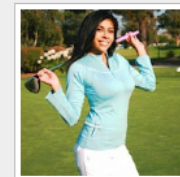
**Company:** Green Tee Apparel

**Category:** Health and Fitness > Clothing

**Origin:** USA

**Nanomaterial:** Polymer

**How much we know:** Category 4 (Unsupported claim)



### AccuFlex® Evolution Golf Shaft

**Category:** Health and Fitness > Sporting Goods

**Origin:** USA

**Nanomaterial:** Carbon



### Ace Casual White Paint

**Company:** Ace

**Category:** Home and Garden > Paint

**Origin:** USA

**Nanomaterial:** Titanium dioxide

**How much we know:** Category 5 (Not advertised by manufacturer)



Workers: Make NM, formulate products

Consumers: use products

Public: Possible releases

Environment: Mfg emissions, waste,  
weathering

# Nanotechnology

Illustrates the challenges to society of a new technology

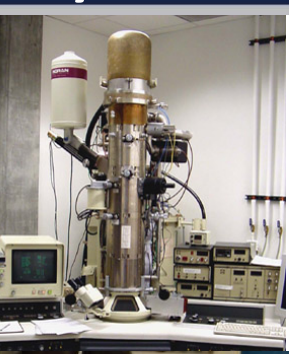
Beneficial properties ↔ Potential hazards

What to do when information is lacking or uncertain





# Reality !



It's not all clean rooms and  
electron microscopes



# The Classic Risk Model

## Hazard Identification

Is there reason to believe this could be harmful?



## Exposure Assessment

Will there be exposure in real-world conditions?



## Risk Characterization

Is substance hazardous and will there be exposure?

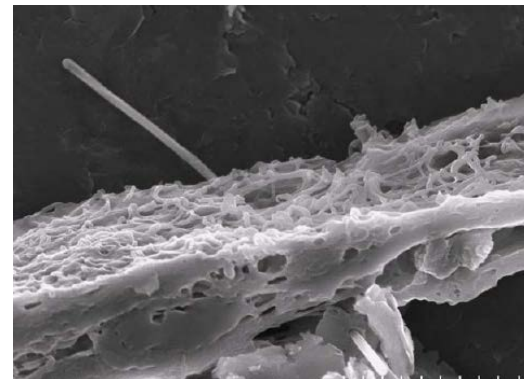


## Risk Management

Develop procedures to minimize exposures



## Lab and Field Investigations are Underway



# Health Hazard Research for ultrafine (<100 nm) TiO<sub>2</sub>

- **Weight of evidence suggests tumor response**
  - Results from secondary genotoxic mechanism
  - Related to physical form of inhaled particle
  - Rat tumorigenic data are sufficient and appropriate for making preventive recommendations
- ***In vivo* studies indicate NanoTiO<sub>2</sub> causes:**
  - pulmonary inflammation
  - lung tissue damage
- **Concern: Existing OELs for larger TiO<sub>2</sub> may not be protective for Nano TiO<sub>2</sub>**

# Health Hazard Research - Carbon Nanotubes

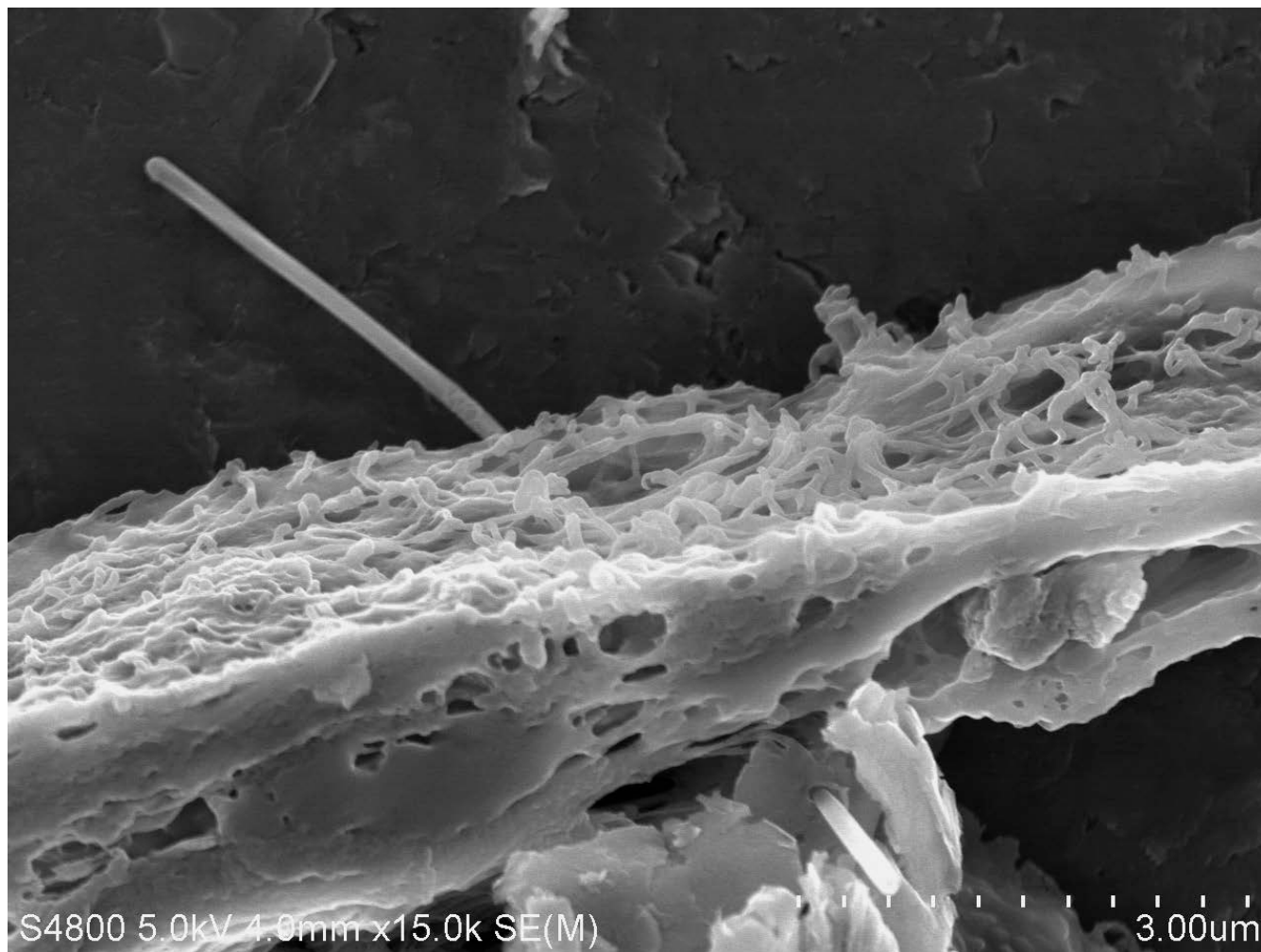
## Aspiration of SWCNT resulted in:

- Rapid but transient inflammation and damage
- Granulomas and fibrosis
- Rapid and progressive interstitial fibrosis
- SWCNTs more fibrogenic than an equal mass of ultrafine carbon black or fine quartz

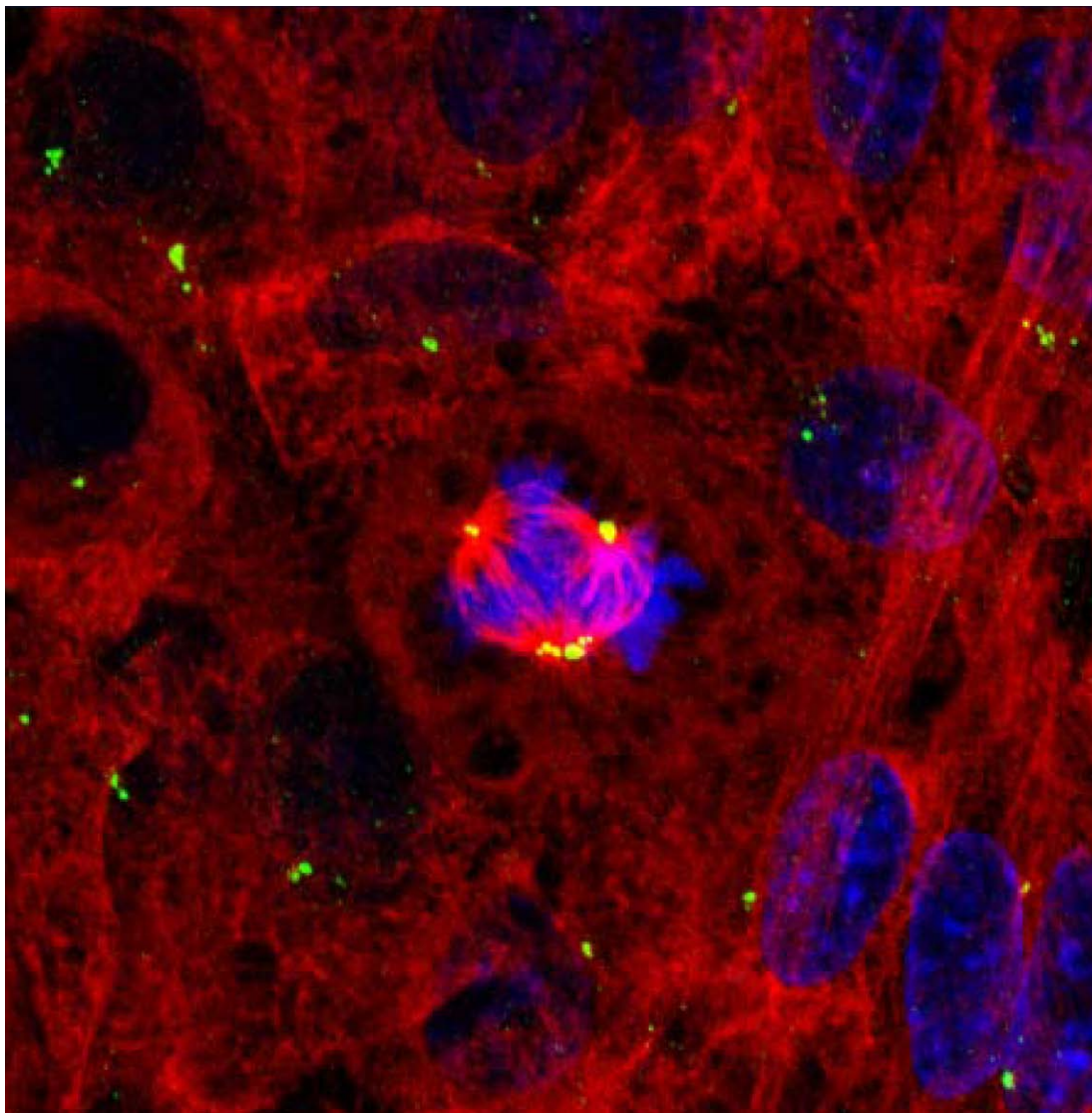
## Inhalation of SWCNT and MWCNT

- Similar results using less mass: inflammation and fibrosis
- Evidence of migration of MWCNT to pleura
- Evidence of cell division disruption

# MWCNT Penetration of Pleura



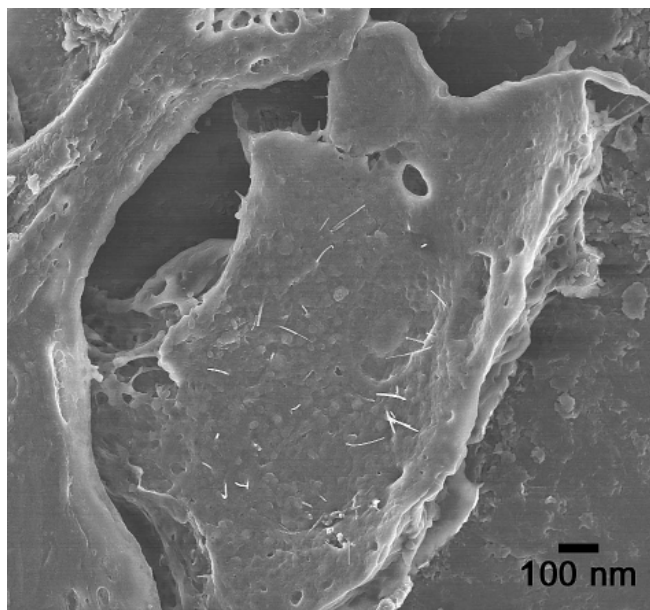




Tripolar mitosis  
following  
exposure to .024  
 $\mu\text{g}/\text{cm}^2$  SWCNT

# Toxicology Take-Home Message

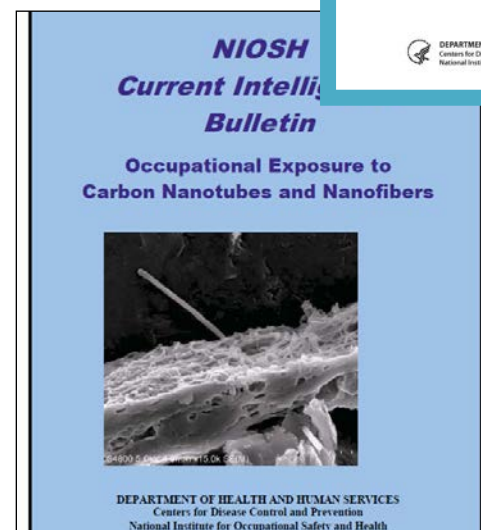
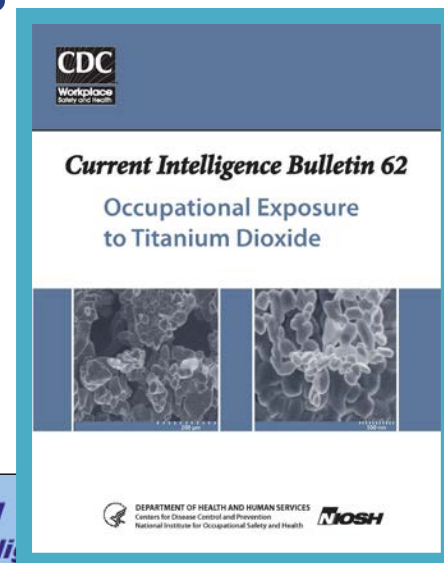
Exposure limits for the large form of the material may not be protective for the nano size.



# Closing Risk Management Gaps

## Current Intelligence Bulletins

- Describe the hazards
  - Set exposure limits
- NIOSH RELs:**
- 300  $\mu\text{g}/\text{m}^3$  for Nano  $\text{TiO}_2$
  - 2.4  $\text{mg}/\text{m}^3$  for fine  $\text{TiO}_2$
  - 1  $\mu\text{g}/\text{m}^3$  for CNT and CNF
- How and where to measure exposures
  - Limits of controls
  - Research needs



# The Classic Risk Model

## Hazard Identification

Is there reason to believe this could be harmful?



## Exposure Assessment

Will there be exposure in real-world conditions?



## Risk Characterization

Is substance hazardous and will there be exposure?



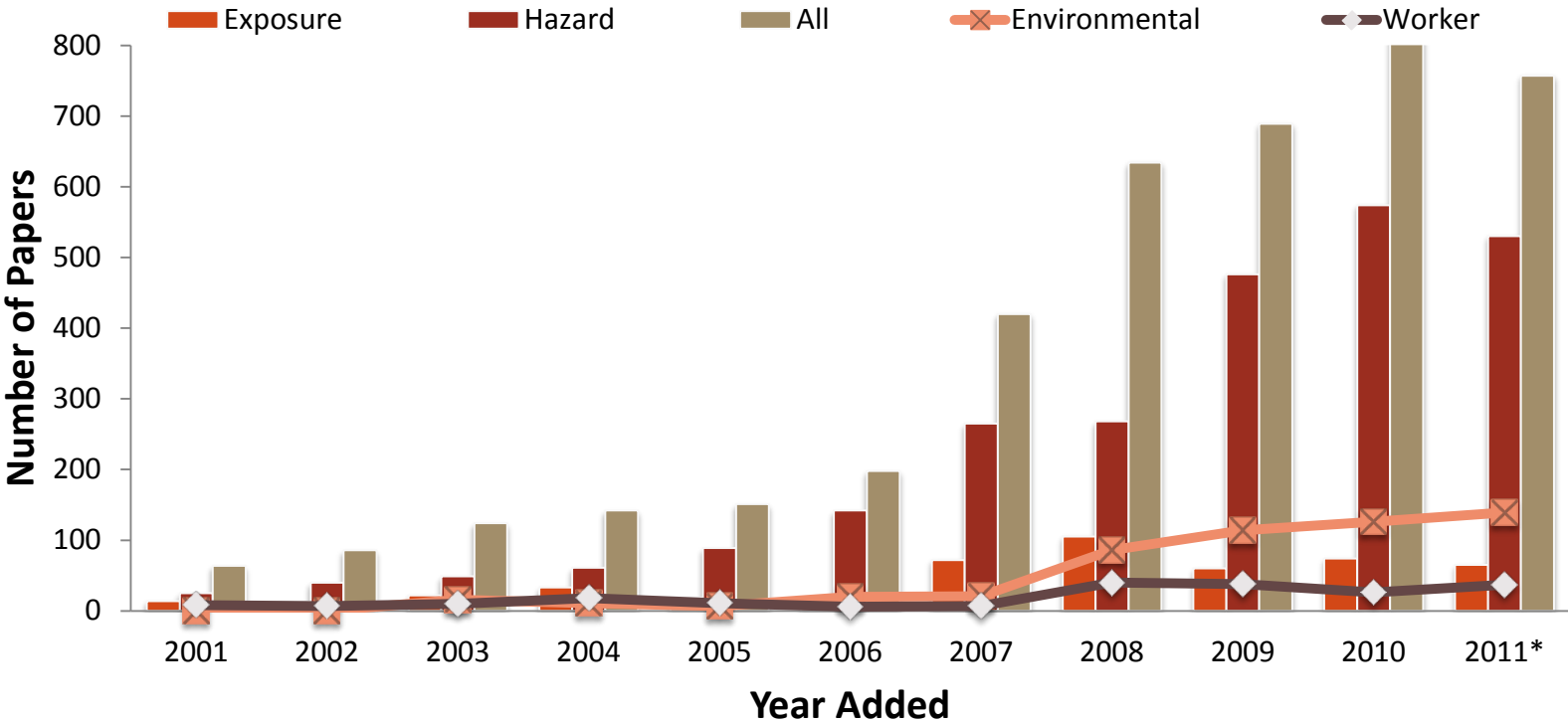
## Risk Management

Develop procedures to minimize exposures



# Do we have exposure data to mine?

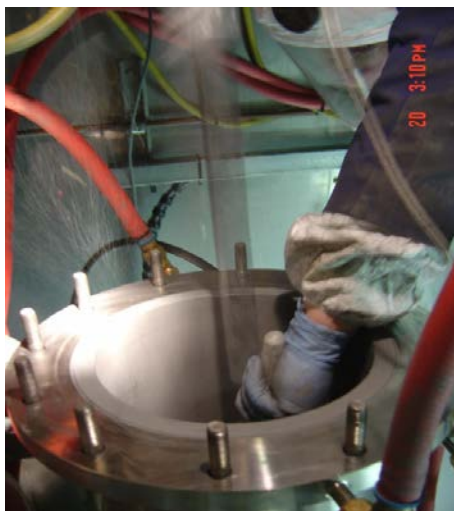
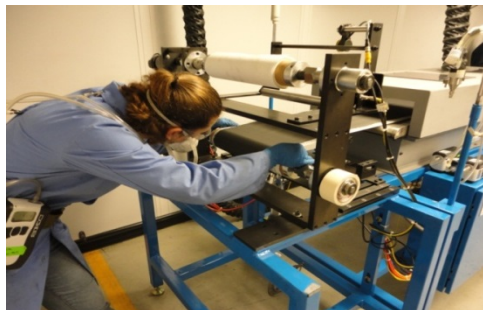
## Peer Reviewed Nano Environment, Health and Safety Journal Articles



<http://icon.rice.edu/research.cfm>

Not really.

## Exposure Assessment in the Real World



# First Generation Products

## Paint containing silver and titanium dioxide acts as a biocide



**BIONI MEDICAL**  
Clinical Coating System

The first clinical interior coating system



**Nature Interior Paint**  
New multi-functional  
interior paint  
based on green  
nanotechnology



**BIONI Perform - Exterior**  
New multi-functional  
energy saving paint for  
exteriors based on green  
nanotechnology



**BIONI Roof**  
New multi-functional  
energy saving roof  
coating based on green  
nanotechnology



**BIONI Grip**  
Special Primer for interior  
and exterior use, free of  
solvents

## Commercial and Consumer Potential



Mixing and applying  
Nanocrete mortar



Applying glass  
coating

## PCI Nanosilent combines leveling, isolating and sound reduction in one step



**BASF**: "Special polymers and rubber granules"

Potential worker exposures can occur during the use of many early product applications of nanomaterials.

## Nano TiO<sub>2</sub> Based Smog Eating Roof Tiles

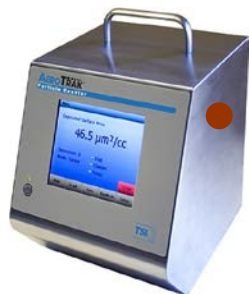


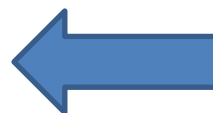


# Exposure and Emission Measurements



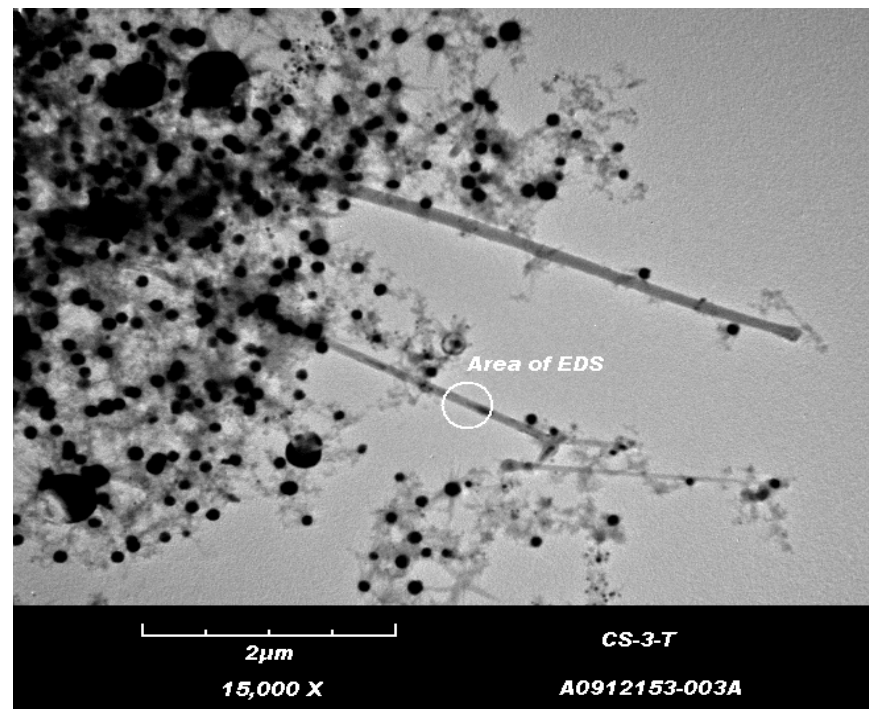
- Qualitative
  - Confirmation: e.g. TEM with elemental analysis
- Mass concentration
- Particle number
- Size distribution (count or mass by size)
- Surface area



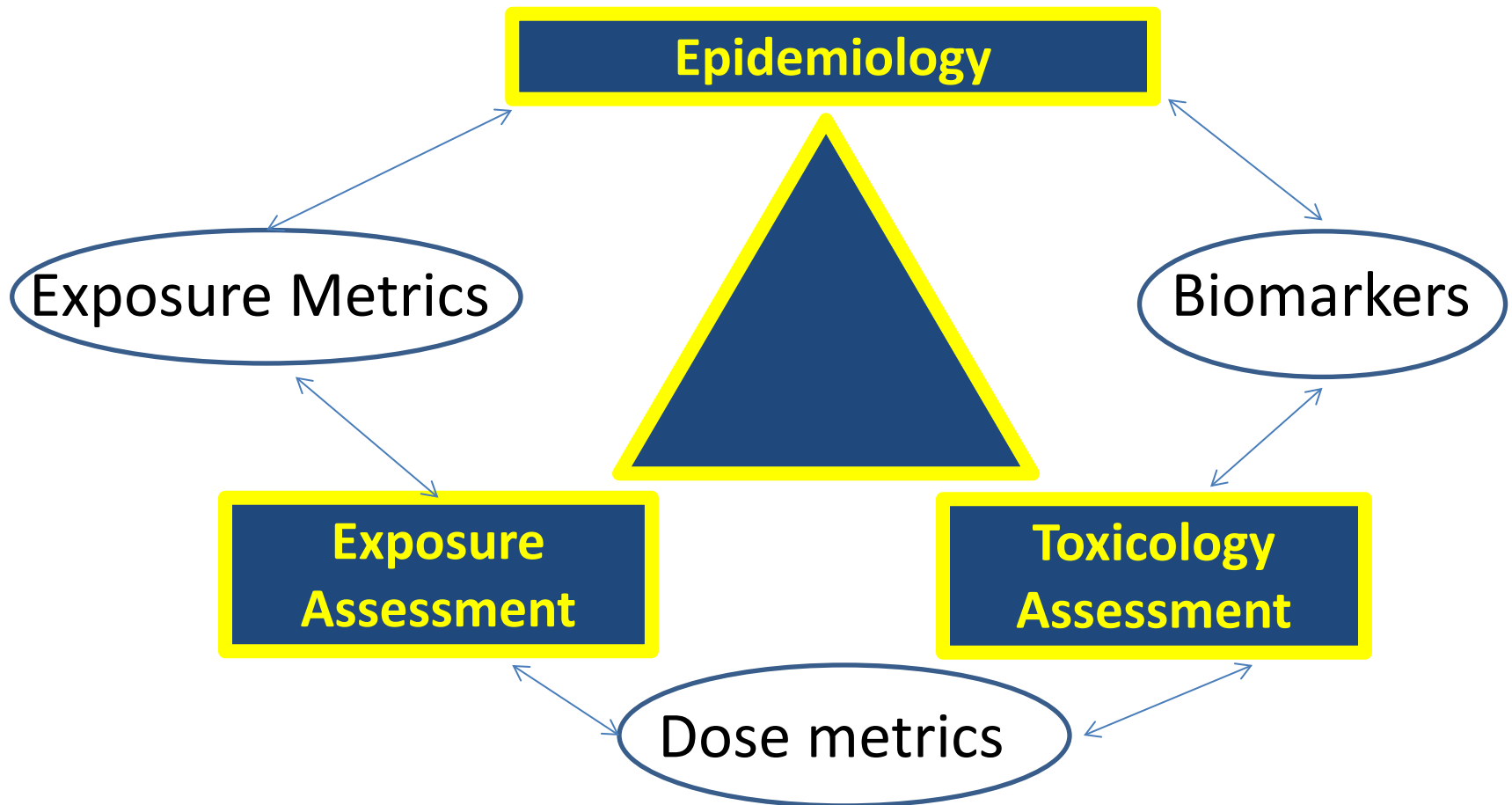


Harvesting SWCNTs from a  
Carbon Arc Reactor

Task-based PBZ air sample  
analyzed via TEM w/ EDS



# Research is underway to Connect the Key Exposure Assessment Elements





# Exposure Data: Conclusions/Challenges

- We have addressed a small piece of the pie
- Exposures do occur in the workplace
- Exposure limits are being developed
- Mass is still the primary metric for exposure
- Direct-reading approaches have a place
- Additional metrics need to be explored: fiber count?
- Confirmatory methods are needed
- Controls can be effective

# The Classic Risk Model

## Hazard Identification

Is there reason to believe this could be harmful?



## Exposure Assessment

Will there be exposure in real-world conditions?



## Risk Characterization

Is substance hazardous and will there be exposure?



## Risk Management

Develop procedures to minimize exposures

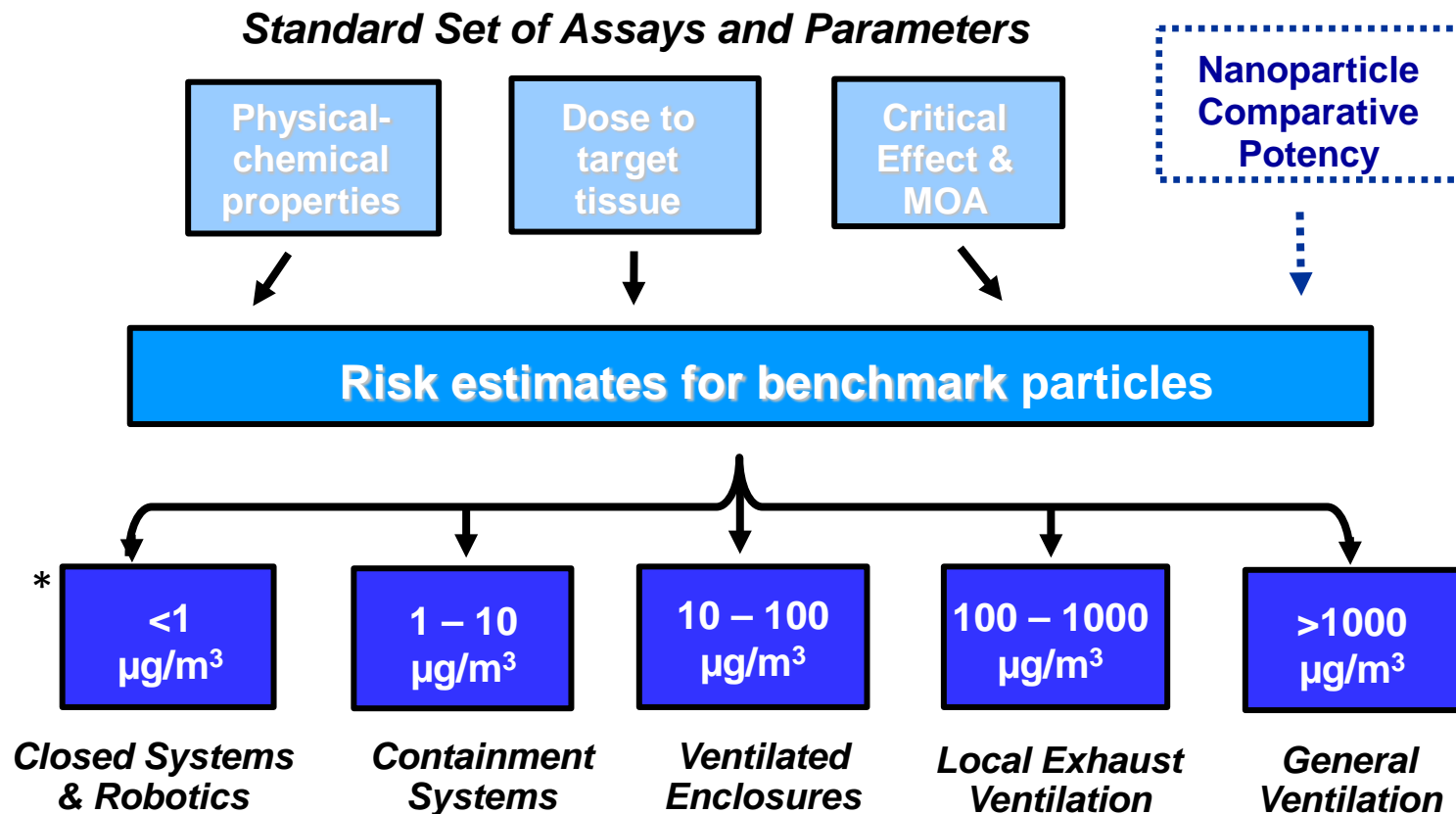
# Benefits of a Categorical Approach

- More efficient use of data
- Reduced costs and animal use
- Increased sample size
- Greater robustness of results
- Increased biological plausibility for other materials in same mode of action (MOA) category

[OECD, Env/JM/MONO(2007)28]

*New guidance on methods for grouping chemicals: OECD, ENV/JM/MONO(2014)4*

# Risk Assessment in Hazard & Control Banding



\* Example of exposure control bins developed in pharmaceutical industry; 8-hr TWA concentrations [Naumann et al. 1996; Ader et al. 2005; Zalk & Nelson 2008];

# The Classic Risk Model

## Hazard Identification

Is there reason to believe this could be harmful?



## Exposure Assessment

Will there be exposure in real-world conditions?



## Risk Characterization

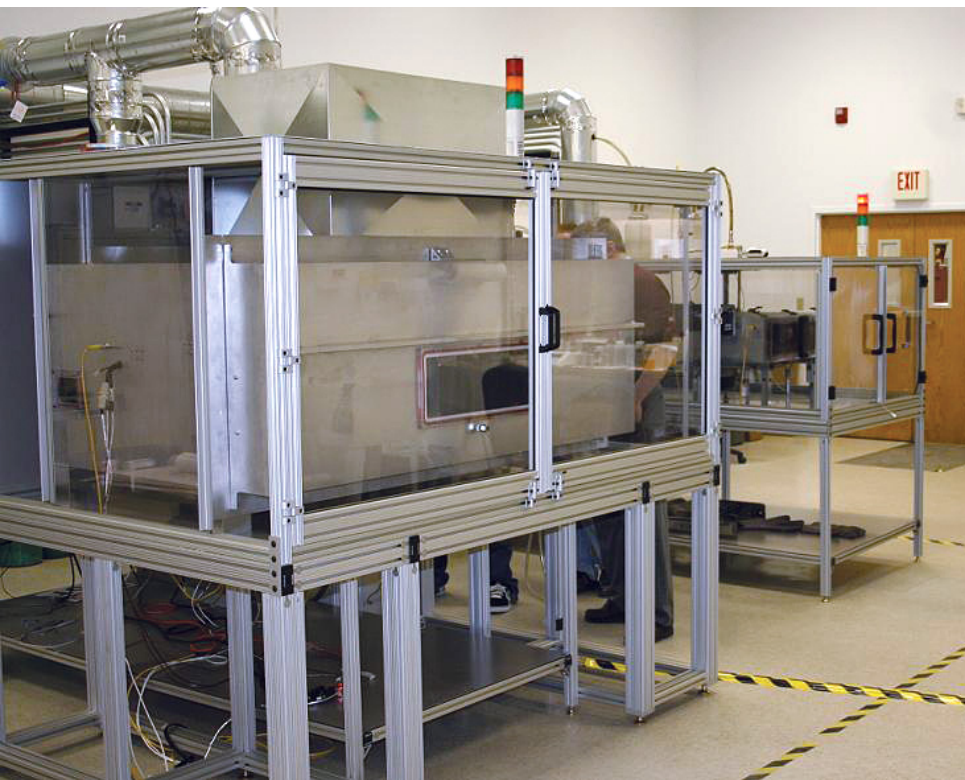
Is substance hazardous and will there be exposure?



## Risk Management

Develop procedures to minimize exposures

# Manufacturing Containment

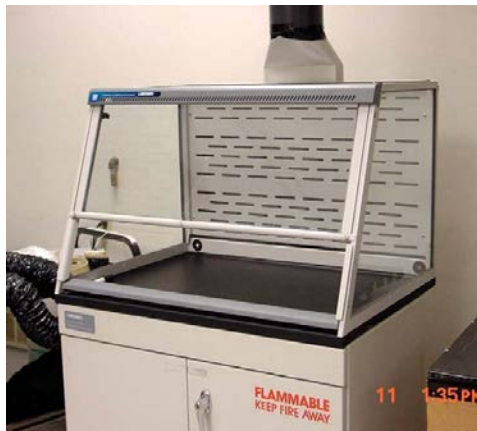


Photos courtesy Nanocomp Technologies, Inc.

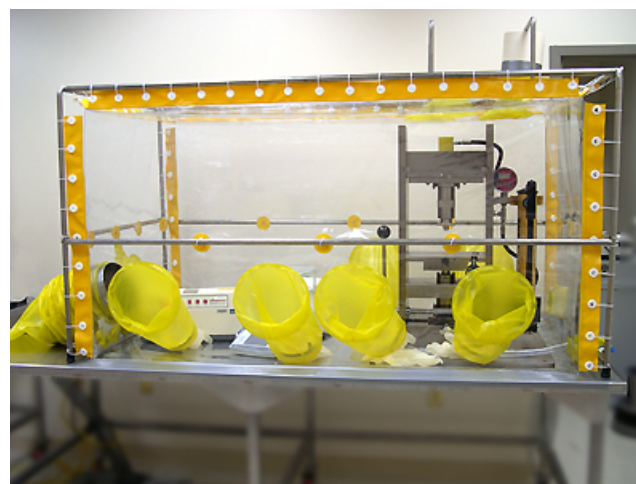
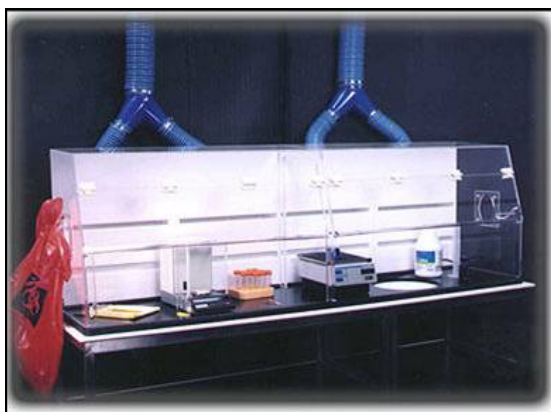




# Controls for Laboratory-Scale Work



- Effective controls that factor budget and space limitations are available
- Select controls based on task-based exposure risks



# Case study: use of LEV during reactor cleanout



Average percent reduction from the use of a local exhaust ventilation unit

**96 +/- 6%** based on **particle counts**

**88 +/- 12%** based on **mass**

Next version...

Methner, JOEH June 2008

# Recommendations

## Personal Protective Equipment

- Provide respiratory protection when exposures can't be controlled below the REL
- Provide protective clothing and gloves when there is potential for contact contaminated surfaces (i.e., when technical methods to control exposure are unsuccessful)

# Regulatory Agency Activity

- OSHA
  - Use existing regulatory framework
  - Advised to work more with NIOSH
- EPA (TSCA)
  - Pre-Manufacturing Notice actions (consent orders)
  - Significant New Use Rules (TSCA)
  - Pesticide registration (FIFRA)
- FDA
  - Recent guidance for food and cosmetics
- CPSC
  - Nanomaterial position statement



# Nanotechnology Guidance Documents





<http://www.cdc.gov/niosh/topics/nanotech/>



**Centers for Disease Control and Prevention**  
CDC 24/7: Saving Lives. Protecting People.™

NIOSH  
All CDC Topics

A-Z Index for All CDC Topics

## Workplace Safety & Health Topics

**Workplace Safety and Health Topics**

Industries & Occupations

**Nanotechnology**

- Nanotechnology Research Center
- Guidance & Publications
- Field Studies Effort
- 10 Critical Topic Areas
- News & Events
- Partnerships & Collaborations
- Frequently Asked Questions
- Other Resources

Hazards & Exposures

Diseases & Injuries

Safety & Prevention

Chemicals

Emergency Preparedness & Response

**NIOSH Homepage**

NIOSH A-Z

Workplace Safety & Health Topics

Publications and Products

**Workplace Safety & Health Topics**

[NIOSH](#) > [Workplace Safety and Health Topics](#) > [Industries & Occupations](#)

[Recommend](#) 56 [Tweet](#) 159 [Share](#)

## NANOTECHNOLOGY

### Overview

#### Defining Nanotechnology

Nanotechnology is the manipulation of matter on a near-atomic scale to produce new structures, materials and devices. The technology promises scientific advancement in many sectors such as medicine, consumer products, energy, materials and manufacturing. Nanotechnology is generally defined as engineered structures, devices, and systems. Nanomaterials are defined as those things that have a length scale between 1 and 100 nanometers. At this size, materials begin to exhibit unique properties that affect physical, chemical, and biological behavior. Researching, developing, and utilizing these properties is at the heart of new technology.

#### Worker Risks

Workers within nanotechnology-related industries have the potential to be exposed to uniquely engineered materials with novel sizes, shapes, and physical and chemical properties. Occupational health risks associated with manufacturing and using nanomaterials are not yet clearly understood. Minimal information is currently available on dominant exposure routes, potential exposure levels, and material toxicity of nanomaterials.

#### Current Research

Studies have indicated that low solubility nanoparticles are more toxic than larger particles on a mass for mass basis. There are strong indications that particle surface area and surface



**NTRC** NANOTECHNOLOGY  
RESEARCH  
CENTER

**Featured Publications**



CURRENT RESEARCH FOR UNDERSTANDING CONTROLS IN  
Nanomaterial Production and  
Downstream Handling Processes

**NIOSH Home**

Email page link

Print page

Get email updates

Subscribe to RSS

Listen to audio/Podcast

**View Related Topic in**  
Español (Spanish)

**Contact Us:**

[National Institute for Occupational Safety and Health \(NIOSH\)](#)  
Centers for Disease Control and Prevention

800-CDC-INFO  
(800-232-4636)

TTY:  
(888) 232-6348

New Hours of Operation  
8am-8pm ET/Monday-Friday  
Closed Holidays

[Contact CDC-INFO](#)



## GoodNanoGuide

**GoodNanoGuide**

Home Sponsors How to Help Protocols About Us Resources

**NIOSH** National Institute for Occupational Safety and Health

**ONAMI** OREGON NANOSCIENCE AND MICROTECHNOLOGIES INSTITUTE

**Oregon State UNIVERSITY OSU**

**Welcome to the GoodNanoGuide!**

The mission of the GoodNanoGuide is to provide an Internet-based collaboration platform specially designed to enhance the ability of experts to exchange ideas on how best to handle **nanomaterials** in an occupational setting. It is meant to be an interactive forum that fills the need for up-to-date information about current good practices for managing **nanomaterials** in a work-related environment, highlighting new practices as they develop.

The goal of the GoodNanoGuide is to create a central repository for good practices for safely handling nanomaterials that can be used and contributed to by people from all over the world.

**New to nanotechnology?**  
Learn about nanomaterials and efforts to develop good workplace practices.  
[Learn the Basics](#)

**Need nanomaterial specific information?**  
Find good workplace practices for classifying and handling specific types of nanomaterials.  
[Material Guidelines](#)

**Concerned about general workplace practices?**  
Our expert matrix provides information on good practices for handling nanomaterials.  
[OHS Expert Matrix](#)

Training Resources  
Nomenclature & Glossary  
OHS Reference Manual  
Fact Sheet

Login  
Join this group

# Communications on Case Reports

## NIOSH Science Blog

Safer Healthier Workers

[NIOSH](#) > [NIOSH Science Blog](#)

 Recommend 77
  Tweet 44
  Share

## Nickel Nanoparticles: A Case of Sensitization Associated with Occupational Exposure

**Categories:** [Nanotechnology](#)

May 28th, 2014 8:17 am ET - **Charles L Geraci, PhD; Paul Schulte, PhD; Vladimir Murashov, PhD**

In an article published online May 8, 2014 by the [American Journal of Industrial Medicine](#), researchers W. Shane Journeay, Ph.D., M.D., and Rose H. Goldman, M.D., MPH, report the case of a worker who developed sensitization to nickel when working with nickel nanoparticle powder.

According to the details of the case presented by Journeay and Goldman: "A 26-year-old female chemist formulated polymers and coatings usually using silver ink particles. When she later began working with nickel nanoparticle powder weighed out and handled on a lab bench with no protective measures, she developed throat irritation, nasal congestion, 'post nasal drip,' facial flushing, and new skin reactions to her earrings and belt buckle which were temporally related to working with the nanoparticles." The abstract continues, "Subsequently she was found to have a positive reaction to nickel on the T.R.U.E. patch test, and a normal range FEV1 that increased by 16% post bronchodilator."<sup>1</sup>

Journeay and Goldman add valuable new scientific evidence to the ongoing base of knowledge about the need for a proactive approach to addressing potential occupational health and safety implications of nanomaterials in the burgeoning global nanotechnology industry. Case studies by alert clinicians are important to NIOSH and its partners in assessing risks posed by occupational exposure to nanomaterials, and in making recommendations for appropriate risk-management practices.

The basic association between exposure to nickel and the worker's symptoms is not surprising. An ample body of scientific evidence associates exposure to nickel in traditional forms with risk of respiratory and skin sensitization. The immediate question raised by the case study is this:



# Complicating the Task

- Applications research is moving faster than EHS research
- No overt cases of injury or illness reported
- “Nano has gone stealth”
- Reporting and tracking requirements are minimal
- A precautionary approach, though warranted, is difficult to sell

# Take Home Message

- Nanotechnology is here to stay
- It will be integrated onto multiple ‘sectors’
- There are OS&H issues, and they are real
- The OS&H issues can be managed
- Effective risk management now is good for:
  - Workers and the modern workplace
  - Public trust and societal benefit
  - Business and a competitive advantage



# Advanced Manufacturing

# Objectives

- Advanced Manufacturing
  - What is 'Advanced Manufacturing'
  - Key drivers
  - Benefits and concerns
  - OS&H issues?
  - Current state of adoption
  - How will it change the workplace?

# Defining Advanced Manufacturing

We are moving from the Industrial Age to the Information Age, but we still need to make things.

How we make things is evolving from mechanical processes (traditional manufacturing) to information and technology based processes (advanced manufacturing).

# Attributes of Advanced Manufacturing

- Heavy and increasing use of information technology
- Modeling and simulations in manufacturing processes
- Closing the innovation to commercialization gap
- Flexibility to meet customer need
- Sustainable manufacturing (including worker safety)

# Trends, Examples?

- Semiconductors
  - Foundation of information technology applications
  - Rapid research to improve performance
  - New materials and structural technology
- Advanced (Nano) Materials
  - Superior performance properties tuned needs
  - Enhanced performance; reduced quantities
  - Computational engineering



# More Trends, Examples?

- Additive manufacturing
  - 3D Printing
  - Direct write
- Synthetic Biology
  - Manufacture biological substances from engineered biological systems
  - Biomanufacturing: using biological templates or processes for manufacture of materials systems

# The US Landscape

- Advanced Manufacturing Partnership Steering Committee
  - Build public-private partnership environment
- National Network of Manufacturing Innovation (NNMI)
  - Requested \$1 Billion investment matched by private sector
  - Create 15 Manufacturing Innovation centers over the next 5 years, as many as 45 in 10 years



REPORT TO THE PRESIDENT  
ACCELERATING U.S. ADVANCED  
MANUFACTURING

Executive Office of the President  
President's Council of Advisors on  
Science and Technology

October 2014



Reviews significant actions of the  
Advanced Manufacturing  
Partnership (AMP)

Recommendations on:

- Enabling innovation in emerging manufacturing technologies;
- Additional investments in innovation
- Securing the talent (worker) pipeline
- Improving business climate for innovative manufacturing firms.

“ A broad public-private coalition involving business, labor, academia, government, and the community”.

# NNMI

America Makes: National Additive  
Manufacturing Innovation Institute

Digital Manufacturing & Design  
Innovation Institute

Lightweight & Modern Metals  
Manufacturing Innovation Institute

Next Generation Power Electronics  
Manufacturing Innovation Institute

Integrated Photonics Institute for  
Manufacturing Innovation (IP-IMI)

Institute for Advanced Composites  
Manufacturing Innovation (IACMI)

# NNMI Highlights

- National Additive Manufacturing Innovation Institute (now known as *America Makes*)
  - Launched in 2012 in Youngstown, OH
  - A 94-member consortium of business, academia and non-profits
  - Focus on grow of additive, AKA, 3D Printing

**A key activity for the Industrial Hygienist because additive manufacturing is happening now!**



# NNMI Highlights (Cont.)

- Digital Manufacturing & Design Innovation (DMDII) Institute
  - Established February 2014 in Chicago
  - will address the life cycle of digital data interchanged among design, engineering, manufacturing and maintenance systems, and flowing across a networked supply chain

**How will the digital interface between the worker and the process impact or benefit OS&H?**

# NNMI Highlights (Cont.)

- Lightweight & Modern Metals Manufacturing Innovation (LM3I) Institute
  - Established February 2014 in Detroit
  - Transition of advanced lightweight and modern metals manufacturing capabilities and new technologies to the industrial base

**Transportation/Aerospace industries are already engaged.**

## NNMI (Cont.)

- Next Generation Power Electronics National Manufacturing Innovation Institute
  - Established in 2014 in North Carolina
  - Enabling the next generation of energy-efficient, high-power electronic chips and devices by making wide bandgap semiconductor technologies

**The semiconductor alternative. Spawning an entire new industry!**

# NNMI

- Integrated Photonics Institute for Manufacturing Innovation (IP-IMI)
    - Funding opportunity announced in 2014
    - Ari Force major funder
    - Establish a state-of-the-art in the design, manufacture, testing, assembly, and packaging of complex photonic integrated circuits
- Still too new to evaluate OS&H impact.**

# NNMI

- Institute for Advanced Composites Manufacturing Innovation (IACMI)
  - Established January 09, 2015, at the University of Tennessee, Knoxville
  - develop lower-cost, higher-speed, and more efficient manufacturing and recycling processes for advanced composites.

**Nanocomposites are already poised for high-volume application. This accelerates the process!**



# Additive Manufacturing: a simple view

## Traditional

Billet



Subtractive

Machining



Part



Scrap



## Additive Manufacturing

Foil/Powder



Additive

AM



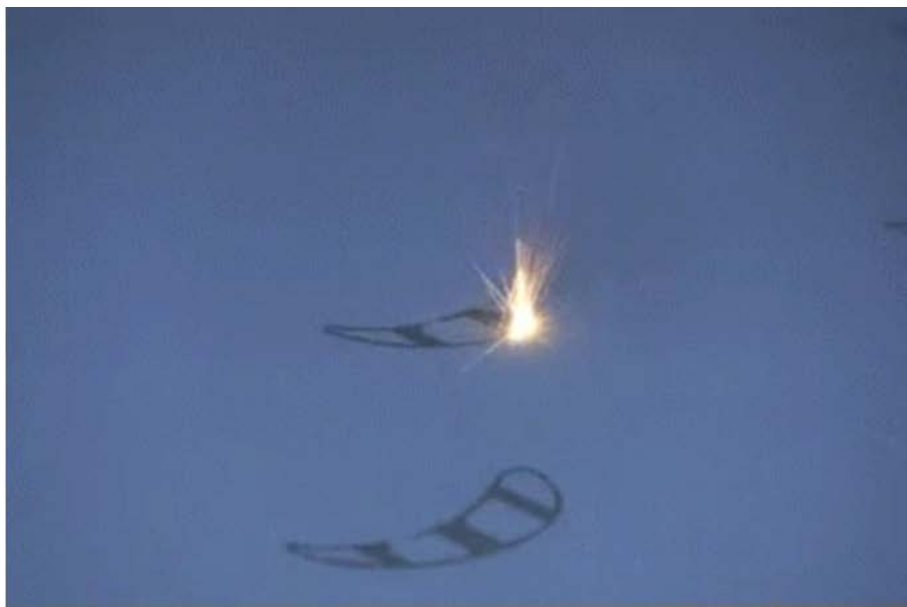
Part



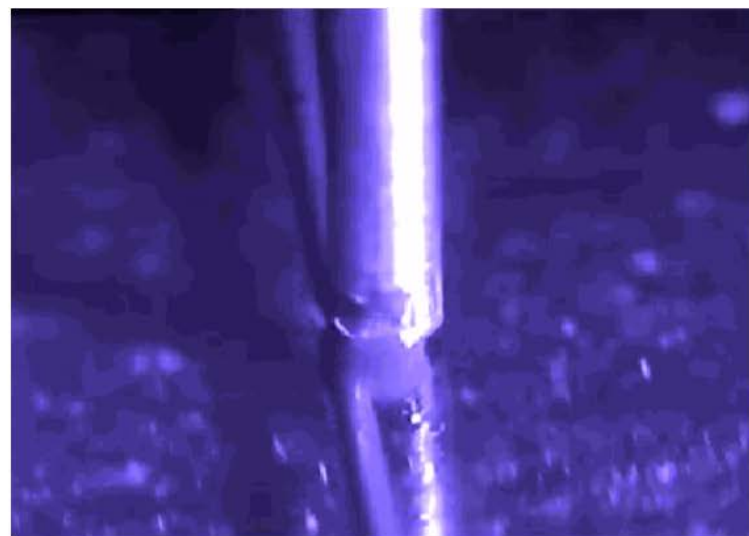
Scrap



# Additive Manufacturing: Now



GE scientists are devising new ways to put sensors in hard-to-reach places through Direct Write technology.



GE Aviation was looking for alloys to 3-D print jet engine parts. They found them in alloys that are used for joint replacements and dental implants.

# The Nano-NNMI Link

- Nearly every process uses advanced materials
- Manufacture of a material or a product is the final output
- Skilled workers are needed
- Occupational safety and health approaches will need to mature with the technologies

# Special thanks to the NIOSH Nanotechnology Research Center



2010



2012



2014

[www.cdc.gov/niosh/topics/nanotech/](http://www.cdc.gov/niosh/topics/nanotech/)

# Thank you!



Charles L. Geraci, Jr, Ph.D., CIH

Associate Director for Nanotechnology

CGeraci@cdc.gov

[www.cdc.gov/niosh/topics/nanotech](http://www.cdc.gov/niosh/topics/nanotech)