

Nanotechnology

Current NIOSH Activity and Looking to the Future

2018 Pharmaceutical Forum

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Associate Director

Emerging Technologies

National Institute for Occupational Safety and Health

Current State

- Nanotechnology still a NIOSH priority
- Fourteen years: 2004-2018
- Have we made any progress ?
- Beyond “Nano to Advanced”
- Federal priorities

Nanotechnology in 2018-2020

Growth areas as noted by the sectors

- **2D materials:** Graphene, boron nitride, silicene: Energy storage, flexible electronics, supercapacitors, conductive inks
- **Quantum Dots:** manufacturing scalability solved: Flat panel displays 'booming'
- **Carbon Nanotubes:** CNT arrays, batteries, composites, sensors, filters
- **Nano coatings:** Architectural, construction, anti-corrosion,
- **Advanced Materials:** foundation material or activity enhancer/additive
- **Nano Cellulose:** still a promising renewable

Nanotechnology at NIOSH 2018-2020

- Continue to evaluate the toxicology of nanomaterials
 - Deeper evaluation of initial materials: CNT, Titania
 - Evaluate new or emerging nanomaterials
 - Develop a mechanistic approach; look for AOP
- Refine exposure measurement and assessment methods
- Broaden risk assessment to a categorical approach
- Continue Epi, Exposure and Health study of CNT cohort
- Demonstrate effectiveness of engineering controls
- Guidance
- (New) Employer survey

Nano-Bio-Medical Activity at NIOSH?

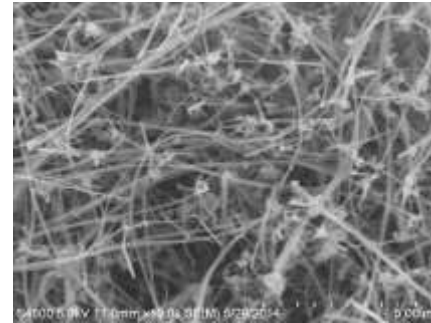
- Nothing specific to Pharma
- A lot of aligned work that applies
- Emission and exposure studies
- Containment and control evaluations

Nanomaterials Investigated at NIOSH

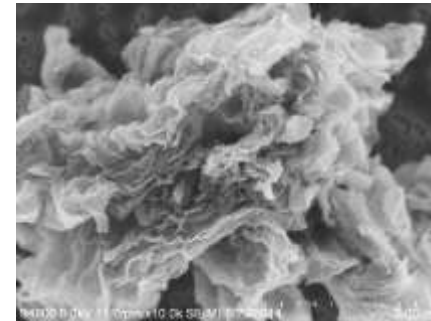
MWCNT – Mitsui 7
DWCNT – double walled CNT
MWCNT – amine and carboxyl functionalized
MWCNT – Doped (Nitrogen, Aluminum)
MWCNT – Heat Treated
Vapor-grown Carbon nanofibers (CNF)
CNT and CNF – 10 US Facilities in Epidemiology Study
SWCNT – single-walled CNT
Carbon Nanodots
Graphite Nanoplatelets or Nanoplates
Graphene
Graphene Oxide

Nanocellulose Nanomaterials

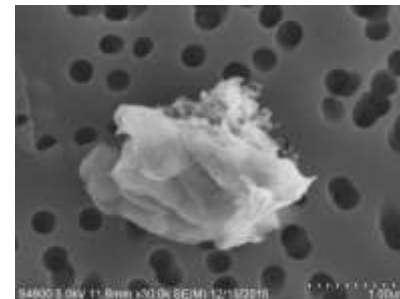
Natural and Organomodified Montmorillonite Nanoclay



MWCNT- Mitsui 7 – Courtesy of Bob Mercer



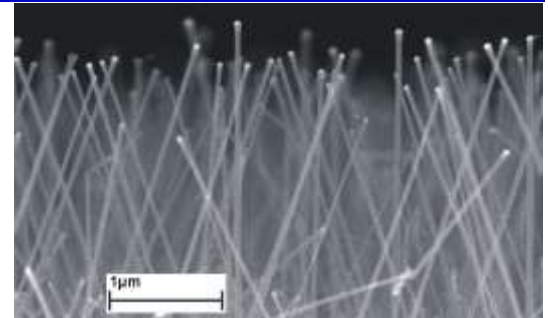
Layered Reduced Graphene Oxide



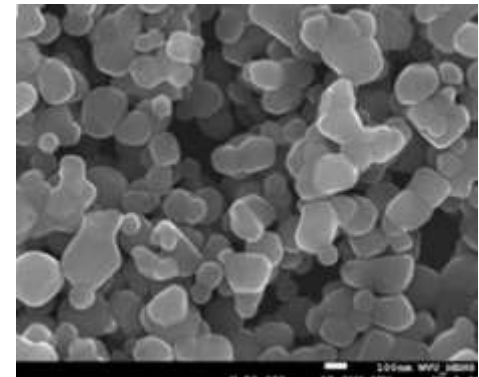
Stacked Plates of Nanoclay – courtesy of Todd Stueckle

Nanomaterials Investigated at NIOSH

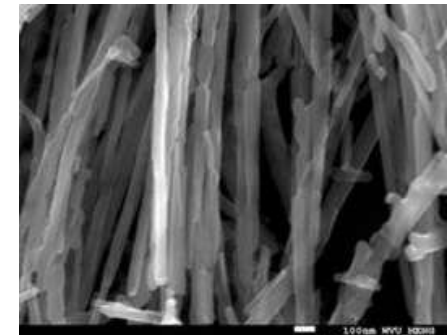
Boron Nitride Nanotubes
Boron Nitride Nanopowder
Silicon nanowires
Elemental nano-silver
Cerium Dioxide
Lanthium Oxide
Cobalt Oxides
Nickel Oxide
Iron Oxides – SiO₂ coated and uncoated
Zinc Oxide Spheres and Nanowires
Elemental Zn
Titanium Dioxide Nanorods, nanowires, nanobelts
SiO₂ – amorphous and crystalline
Tungstate (particles and rods) CaWO₄, SrWO₄, BaWO₄
Tungsten carbide-cobalt
Tungstate (particles and rods)
 CaWO₄
 SrWO₄
 BaWO₄
Copper Oxide
Quantum Dots – ZnS/CdSe



Si nanowires: Roberts et al., 2012



TiO₂ nanospheres: courtesy of Dale Porter

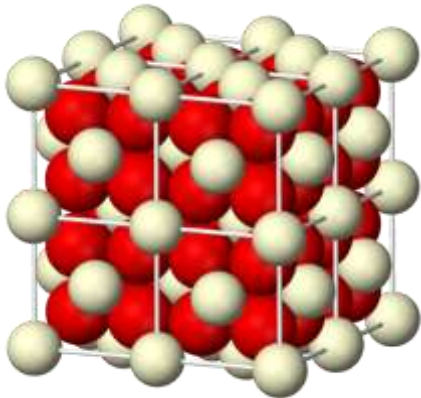


TiO₂ nanobelts: courtesy of Dale Porter

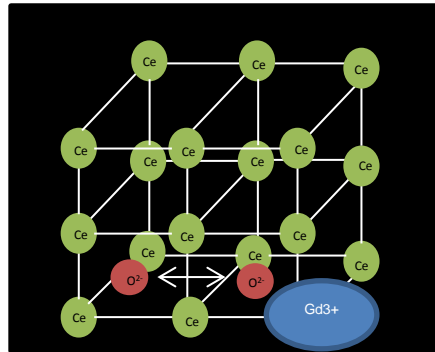
Nanomaterials Investigated at NIOSH

Functionally Modified Nanoparticles – Prevention through Design:

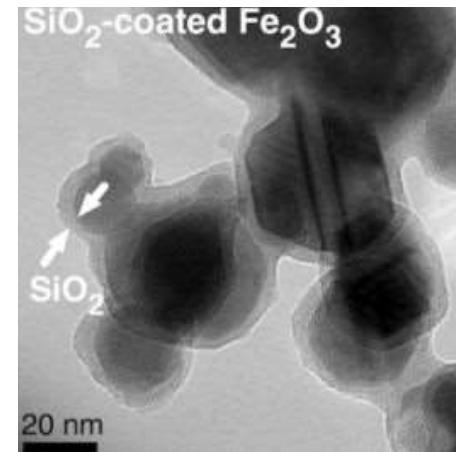
- Carboxylated and Humics Acid Titanium Nanobelts
- Nitrogen-doped MWCNT
- Carboxylated MWCNT
- Amine Functionalized MWCNT
- Heat-Treated MWCNT
- Amorphous silica coated Iron Oxide and Cerium Oxide
- Gadolinium-doped and SiO₂ coated cerium oxide



<http://goo.gl/vWa6HO>



Courtesy of Stephen Leonard



Gass et al., 2013

NIOSH Nanotoxicology Program Directions

- Generating Occupationally Relevant Aerosols for In Vivo Studies
- CNT – A Model Toxicity Assessment
- Into the Future with a life cycle approach

'NanoProducts' Investigated at NIOSH

Exposure with Nanoparticle Components – NanoRelease/Life Cycle:

Crushed Preparation MWCNT

CNT Polymer Composites – Construction operations – Sanding/Sawing

Printer-Emitted Particles – Toners and Inks (CPSC and Harvard University)

Three Dimensional Printing Emissions (CPSC and West Virginia university)

Copper-Treated Wood – Dust from Construction Operations (CPSC)

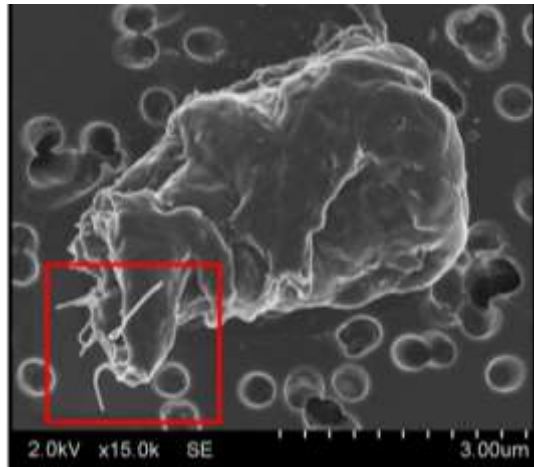
Sunscreen Spray – ZnO nanoparticles (FDA)

Disinfectant Sprays – ZnO or Silver Nanoparticles

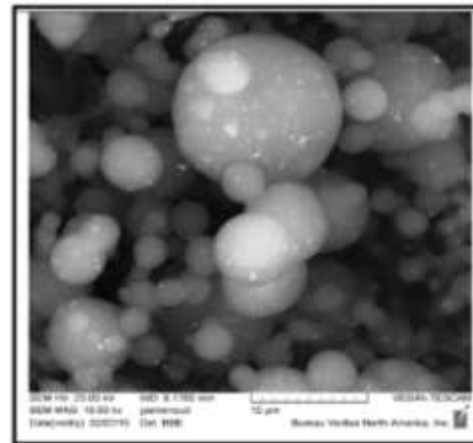
Wood Sealant/Stain Aerosol – Spraying Operations – ZnO Nanoparticles (CPWR)

Stain-Treated Wood Dust – Construction Operations – ZnO Nanoparticles (CPWR)

Welding Fume Exposure – mixture on metal nanoparticles



CNT in Composite
– Courtesy of A. Erdely

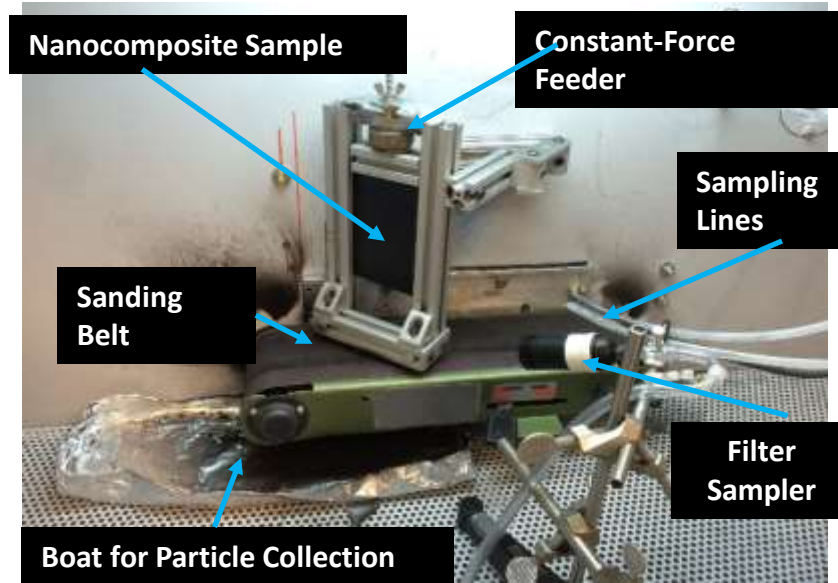


ZnO particles on paint droplets
– Courtesy of CPWR, B. Lippy

Processing and Characterizing Aerosols from Nano-Enabled Materials

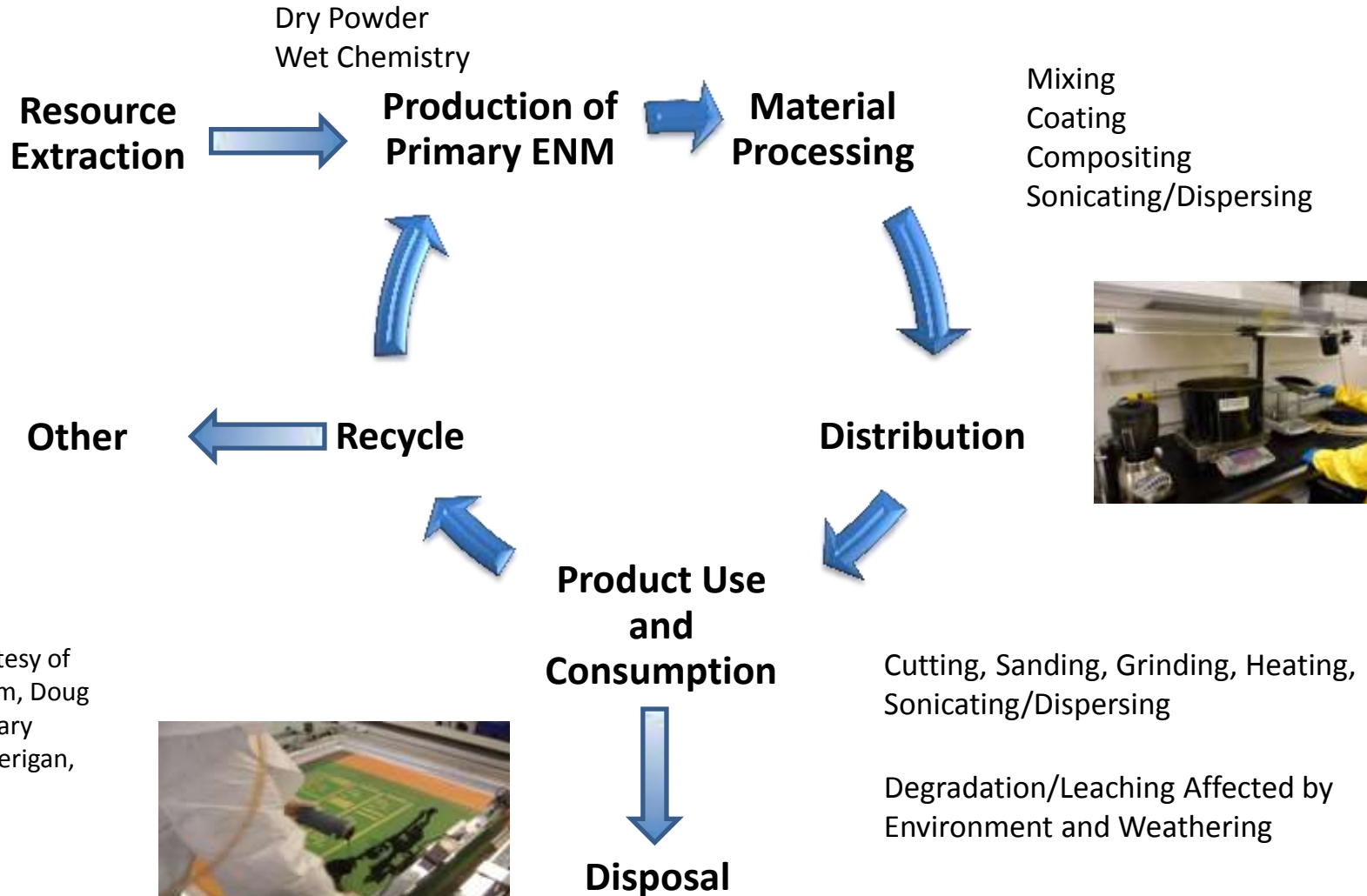


Internal View



Future Directions

Occupational Material Lifecycle



Images courtesy of
Matthew Dahm, Doug
Evans, Mary
Schubauer-Berigan,
NIOSH

Food, Health Care and Medical



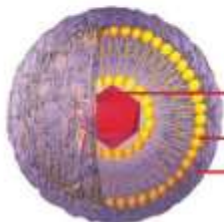
RipeSense.co.nz



timestrip.com



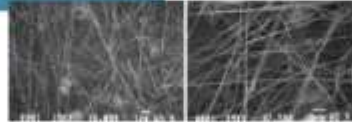
Acute lymphoblastic leukemia (ALL)
Sigma-Tau Pharmaceuticals



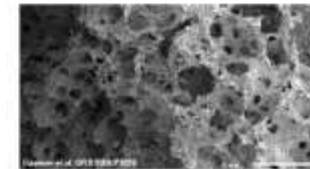
Doxorubicin
Liposome
Methoxy polyethylene glycol (MPEG)



Nanofiber Wound Dressings
Bowlin, VCU
FASTCLOT



3M's FilTek® restorative dental



Stryker's Vitoss Bone Graft Substitute



Nanosphere

Some processes, some products, but all have a Nano element



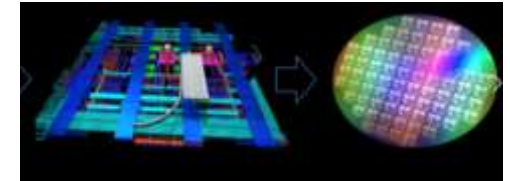
Additive Manufacturing



3D Printing



Functional Fabrics



Photonics



Flexible Sensors

“Advanced Manufacturing”



Robotics



Light Weighting



Advanced Composites



Clean Energy



Engineered Biology

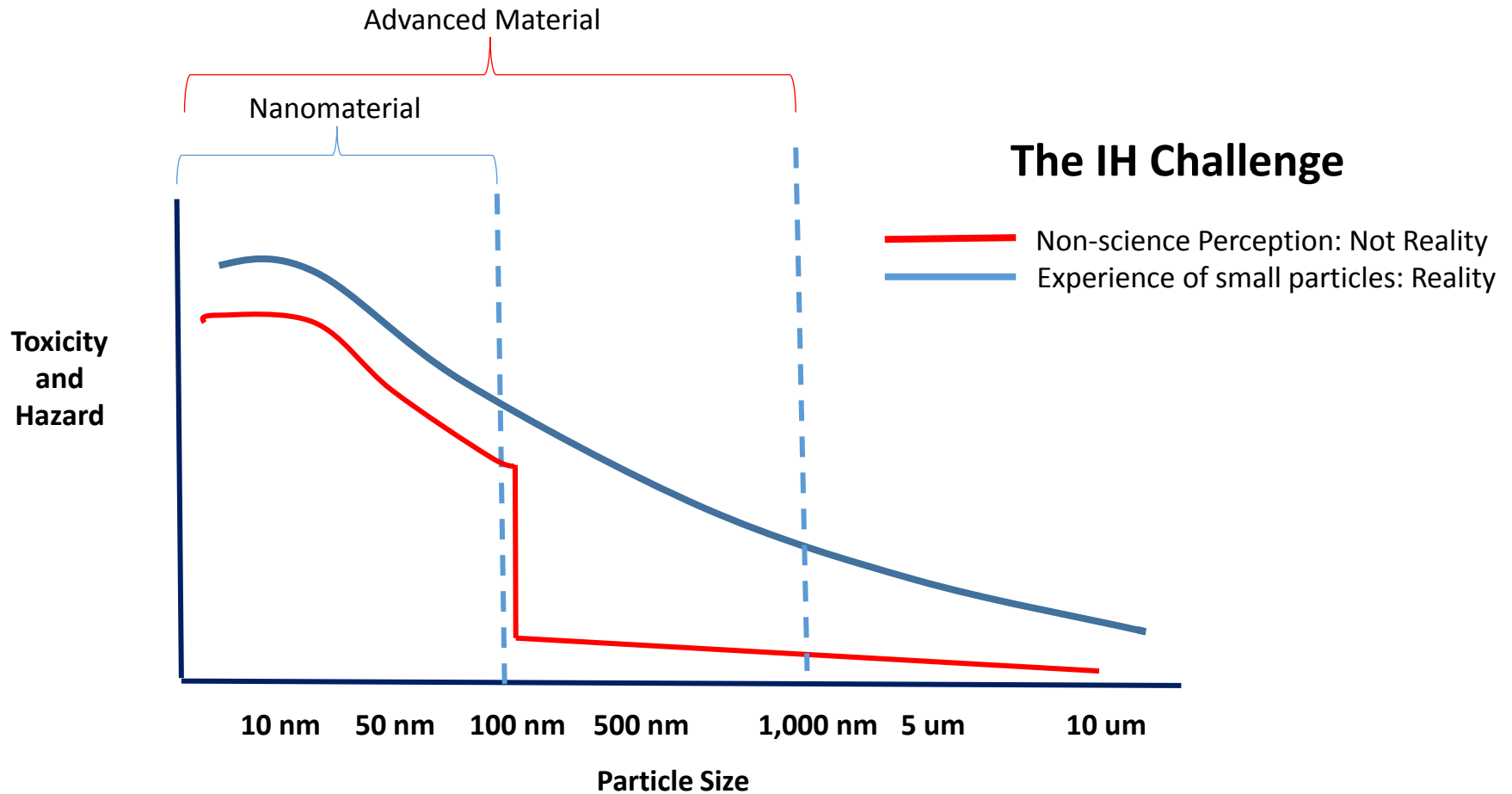
Why the Interest in ‘Advanced Material’?

Advanced Materials refers to all new materials and modifications to existing materials specifically engineered to have novel or enhanced properties for superior performance over conventional materials, critical for the application under consideration.

Nano (Advanced) Material

~~Advanced~~ Nano Materials refers to all new materials and modifications to existing materials that are specifically engineered **in the 1 to 100 nm scale** to have novel or enhanced properties that result in superior performance relative to ~~conventional materials~~ **their bulk counterparts that allow for novel applications**, ~~that are critical for the application under consideration.~~

The IH Challenge



Responsible Practice Needed

NIOSH Site Studies

Exposure characterizations for a wide variety of Nano materials

- Active program since 2006.
- Completed >100 site visits.
- Summary results published.
- Basis for guidance.



Field Measurements

- Filter-cassette based
 - Elements and Electron Microscopy (EM)
 - PBZ, Source/ Area, Background
 - Full shift and task specific
 - With and without cyclones
 - Various filter media
- Data logging with DRI's
 - Source/Area and Background



Direct Reading Instruments (DRIs)

- TSI CPC 3007 (TSI Inc., Shoreview, MN)
 - Condensation Particle Counter
 - Measures particles between 10 nm and $\sim 1 \mu\text{m}$
- TSI OPS 3330 (TSI Inc., Shoreview, MN)
 - Optical Particle Counter with collection filter
 - 16 user defined bins
 - Measures particles between 300 nm -10 μm
- TSI DustTrak DRX (TSI Inc., Shoreview, MN)
 - Optical Particle Counter with collection filter
 - 4 pre-determined size bins (1, 2.5, 4.0, and 10 μm)

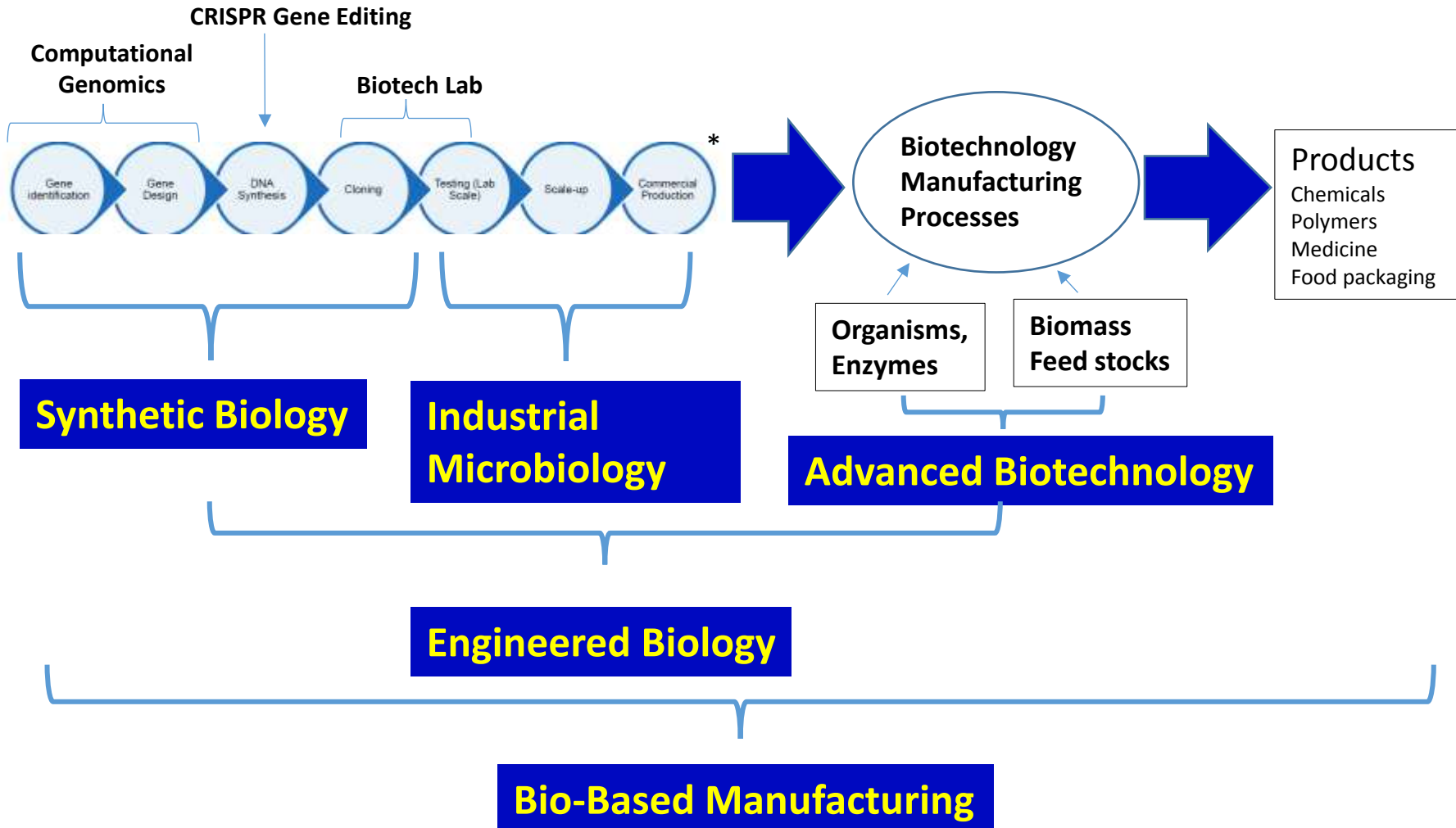


Bio-Based Manufacturing

A new area of interest?

- Maybe for NIOSH
- Maybe not for Pharma

Elements of Biology – Based Manufacturing



Recent Guidance

Workplace design solutions

Protecting Workers during the Handling of Nanomaterials

Summary

Engineered nanomaterials (ENMs) are materials that are intentionally produced to have at least one primary dimension less than 100 nanometers (nm). These materials have unique properties that differ from their bulk counterparts. They are used in a wide range of consumer products, including cosmetics, food, and pharmaceuticals. ENMs are also used in research and development, and in the manufacturing of new products. The handling of ENMs in the workplace can pose health risks to workers. This document provides guidance on how to protect workers during the handling of ENMs in the workplace.

Background

The National Institute for Occupational Safety and Health (NIOSH) is the lead agency for research on the health effects of ENMs. NIOSH has conducted a number of studies on the health effects of ENMs, and has published a number of documents on this topic. This document is one of the most recent publications from NIOSH on this topic. It provides guidance on how to protect workers during the handling of ENMs in the workplace.

Description of Exposure

ENMs can be inhaled, ingested, or absorbed through the skin. The most common route of exposure is inhalation. ENMs can be inhaled as dusts, fumes, or mists. The size of the ENMs and the way they are handled in the workplace can affect the route of exposure. For example, ENMs that are inhaled as dusts are more likely to reach the lungs than ENMs that are inhaled as fumes or mists. The way ENMs are handled in the workplace can also affect the route of exposure. For example, ENMs that are handled in a way that creates dusts, fumes, or mists are more likely to be inhaled than ENMs that are handled in a way that does not create dusts, fumes, or mists.

Prevention through Design (PTD)

PTD is a process that involves identifying and eliminating or minimizing hazards and risks before they are introduced into a product or process. PTD is a key element of a comprehensive safety and health program. PTD can be used to protect workers during the handling of ENMs in the workplace. PTD can be used to identify and eliminate or minimize hazards and risks associated with the handling of ENMs in the workplace. PTD can be used to design products and processes that are safer and healthier for workers.

Workplace design solutions

Protecting Workers during Nanomaterial Reactor Operations

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Workplace design solutions

Protecting Workers during Intermediate and Downstream Processing of Nanomaterials

Summary

Engineered nanomaterials (ENMs) are materials that are intentionally produced to have at least one primary dimension less than 100 nanometers (nm). These materials have unique properties that differ from their bulk counterparts. They are used in a wide range of consumer products, including cosmetics, food, and pharmaceuticals. ENMs are also used in research and development, and in the manufacturing of new products. The handling of ENMs in the workplace can pose health risks to workers. This document provides guidance on how to protect workers during the handling of ENMs in the workplace.

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Prevention through Design (PTD)

PTD is a process that involves identifying and eliminating or minimizing hazards and risks before they are introduced into a product or process. PTD is a key element of a comprehensive safety and health program. PTD can be used to protect workers during the handling of ENMs in the workplace. PTD can be used to identify and eliminate or minimize hazards and risks associated with the handling of ENMs in the workplace. PTD can be used to design products and processes that are safer and healthier for workers.

NTRC NANOTECHNOLOGY RESEARCH CENTER

Controlling Health Hazards When Working with Nanomaterials: Questions to Ask Before You Start

Here are some questions you should ask yourself before starting work with nanomaterials.

Here are some options you can use to reduce exposures to nanomaterials in the workplace. These options correspond with the questions on the left.

(1) FORM	DRY POWDER (typically highest potential for exposure)	SUSPENDED IN LIQUID	PHYSICALLY BOUND/ ENCAPSULATED (typically lowest potential for exposure)
(1) FORM Have you done a job hazard analysis? What is the physical form of the nanomaterial? How much are you using? Can you reduce exposure to the nanomaterial by changing its form (for example, putting powder into a solution or reducing the amount you are using)?	Applies to Dry Powder Nanomaterials • Higher potential for exposure: Dumping bags of powder, tugging or sieving of products • Lower potential for exposure: Scooping/weighing of product, transporting containers with tight surface contamination or closed tanks/bottles/bags	Applies to Nanomaterial Suspended in Liquids • Higher potential for exposure: Spraying, open top containers, producing a mist • Lower potential for exposure: Cleaning up a spill, spattering small amounts, brushing	Applies to Physically Bound/Encapsulated Nanomaterial • Higher potential for exposure: Cutting, grinding, sanding, drilling, abrasive blasting, thermal release • Lower potential for exposure: Manual cutting and sanding, parking with a roller or brush
(2) WORK ACTIVITY How are you using the nanomaterial? Could the work activity cause exposure? Is the likelihood of exposure low or high? Can you change the way you do the activity to reduce the exposure?	Applies to Dry Powder Nanomaterials • Chemical fume hood • Glove box • Nanomaterial handling enclosure • Ventilated bagging or dumping stations • High-efficiency particulate air (HEPA)-filtered local exhaust ventilation	Applies to Nanomaterial Suspended in Liquids • Chemical fume hood • Glove box • Nanomaterial handling enclosure • Local exhaust ventilation • Ventilated spray booth	Applies to Physically Bound/Encapsulated Nanomaterial • Chemical fume hood • Glove box • Local exhaust ventilation • Downdraft table • Wet cutting/machining • Ventilated tool shed • Blasting cabinet
(3) ENGINEERING CONTROLS Based on the form and the work activity, what engineering controls will be effective? What are the key design and operational requirements for the control? How does the non-nanomaterial base material or liquid affect exposure?	(4) ADMINISTRATIVE CONTROLS Have you considered the role of administrative controls? Have you set up a plan for waste management? Have you considered what to do in case of a spill or how you will maintain equipment?	(5) PERSONAL PROTECTIVE EQUIPMENT If the mistakes above do not effectively control the hazard, what personal protective equipment can be used? Have you considered personal protective equipment for the non-nanomaterial base material or liquid?	Applies to All Nanomaterial Forms • Handle and dispose of all waste materials (including cleaning materials/gloves) in compliance with all applicable federal, state, and local regulations • Use sealed/closed bags or containers, and secondary containment • Label containers, such as "CONTAINS NANOSCALE MATERIAL (S)" • Use signs and labels • Restrict access to areas where nanomaterials are used • Train workers • Respiratory protection when indicated and engineering controls cannot control exposures, and in accordance with federal regulations (29 CFR 1910.134) • NIOSH guidance on respirators can be found at www.cdc.gov/niosh/topics/respirators/ • Use personal protective equipment during spill cleanups and equipment maintenance

Are you interested in learning more about how you can safely work with nanomaterials or want to stay up-to-date on nanotechnology safety? See the [MOSH NTRC website](http://www.cdc.gov/niosh/topics/nanotech/) for more information and links to guidance documents: www.cdc.gov/niosh/topics/nanotech/

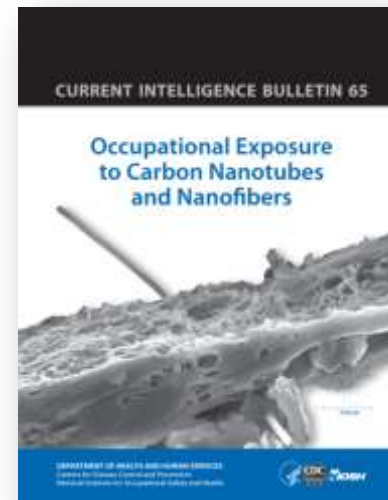
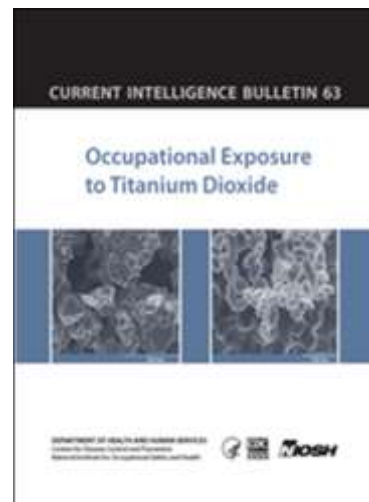
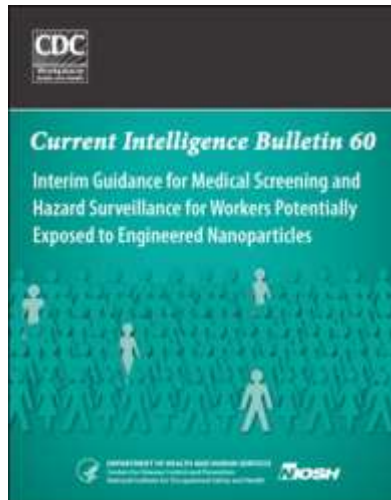
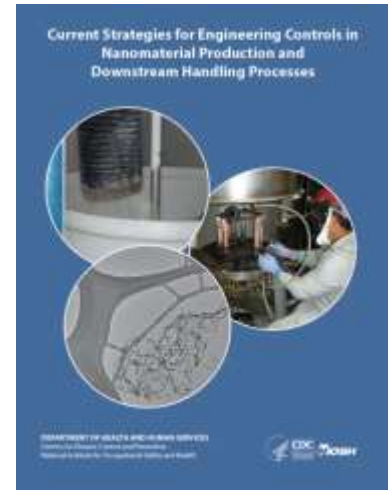
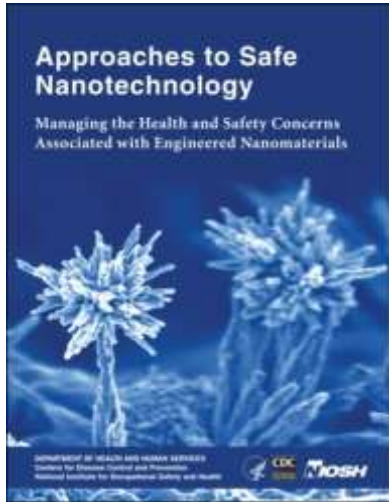
NIOSH (NIOSH) Publication No. 2018-103 | February 2018
<https://doi.org/10.26103/NIOSH.PUB2018103>

Practical approaches to evaluating hazards and controlling exposures.

<https://www.cdc.gov/niosh/topics/nanotech/pubs.html>

Key Communication Products

www.cdc.gov/niosh/topics/nanotech



NIOSH Nanotechnology Topic Page

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

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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.

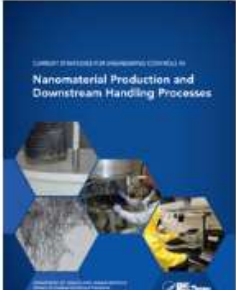
Current Research

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



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Featured Publications



COVER DEVELOPED FOR OCCUPATIONAL SAFETY AND HEALTH BY
Nanomaterial Production and Downstream Handling Processes

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Centers for Disease Control and Prevention

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

TTY:
(888) 232-6348

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

[Contact CDC-INFO](#)

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