NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

NTRC | NANOTECHNOLOGY RESEARCH CENTER

Nanotechnology: Where is it Today and Is EHS an Element of Success?

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National Institute for Occupational Safety and Health

CDC Workplace Safety and Health | NIOSH

Key Components of the Discussion

- Nanotechnology is Alive and doing well
- Responsible development is still a priority
- Twelve years and $11Billion in EHS: Any Progress?
- Rapid move from Nano to ‘Advanced’
- Path forward

Nanotechnology in 2018-2020

Building on the growth of 2006 to 2016 with focus on key areas

2D Materials

Graphene, Boron Nitride, Silicene. Energy, flexible electronics, conductive inks

Quantum Dots

Scalability issues solved. Organic QD breakthroughs. Flat panel displays, lighting, etc. "Booming business".

Carbon Nanotubes

CNT arrays, functional CNT, hybrid forms. Batteries, sensors, composites, filters.

Nano Coatings

Metal and ceramic nanomaterials, Wear and corrosion resistance, 'smart', sensing, self-healing.

Advanced Materials

Foundation in Nano. Enhanced activity or performance. Still size mediated but >100 nm.

Nano Cellulose

Still promising. Crystal and Fibril forms. Element of the Green Economy?

All are contributing to Industry 4.0

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Nanotechnology: Impacts on Products and Industry

Agriculture	More efficient and lower volumes through targeted delivery of plant nutrients, pesticides.
Automotive	Lighter, stronger materials; body panels as sensors
Health Care	New nanoparticle based therapeutics, advanced sensors, more sensitive imaging and diagnostics.
Energy	Better conductors for transmission lines, higher efficiency in solar generation, advanced insulation
Environmental	New pollution control and remediation tools, sensors, water treatment
Food	Safety sensors, preservatives, nutrient additives, smart packaging
Materials	Lighter, stronger composites and metals. More efficient catalysts. Pollution and corrosion fighting finishes.
Electronics	Smaller, faster computers

Reality

Films and Coatings

Nanofilm

http://www.techandinnovationdaily.com/2013/06/05/p2i-water-repellent-nano-coating/

NanoMech

GM

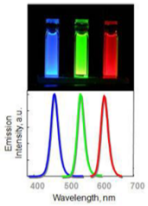
Zyvex Marine

Nano Electronics

Quantum Dots now in Mass Market Applications

Consumer electronics already 'nano'

QD Vision's Color IQ Technology



CdSe quantum dots

Sony Bravia LED TV

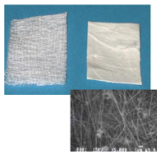
Nanosys

Samsung SUHD TV using Nanosys quantum dots

Food, Health Care and Medical

RipeSense.co.nz

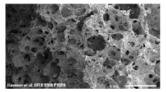
timestrip.com



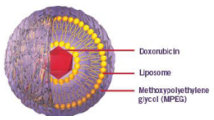
Nanofiber Wound Dressings
Bowlin, VCU
FASTCLOT

3M's FilTek® restorative dental

Acute lymphoblastic leukemia (ALL)
Sigma-Tau Pharmaceuticals

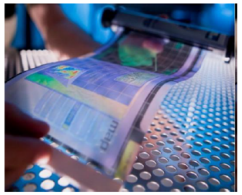


Stryker's Vitoss Bone Graft Substitute

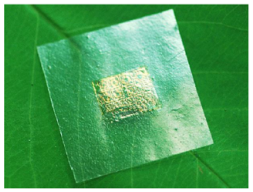


Nanosphere

Flexible Electronics and Sensors

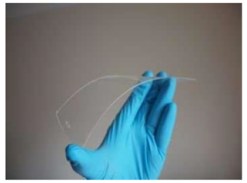


Flexible Electronics (HP&ASU)
http://memebox.com/



Ma, Wisconsin-Madison
http://spectrum.ieee.org/tech-talk/consumer-electronics/portable-devices/green-microchips-created-on-cellulose-nanofibril-paper

http://www.labmanager.com/news/2018/01/engineers-make-wearable-sensors-for-plants-enabling-measurements-of-water-use-in-crops#.WlPaqd-nE2w



https://phys.org/news/2017-10-physicists-breakthrough-brittle-smartphone-screens.html

Flexible Tablet concept, Samsung

http://news.softpedia.com/news/Samsung-Flexible-Tablets-Might-Become-a-Reality-Soon-Thanks-to-Graphene-Breakthrough-435805.shtml

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Federal Funding for EHS

6% of FY 2018 Investment.
($91.8M of $1,558M)

Healthy growth from an initial funding level of 2.7%in 2007

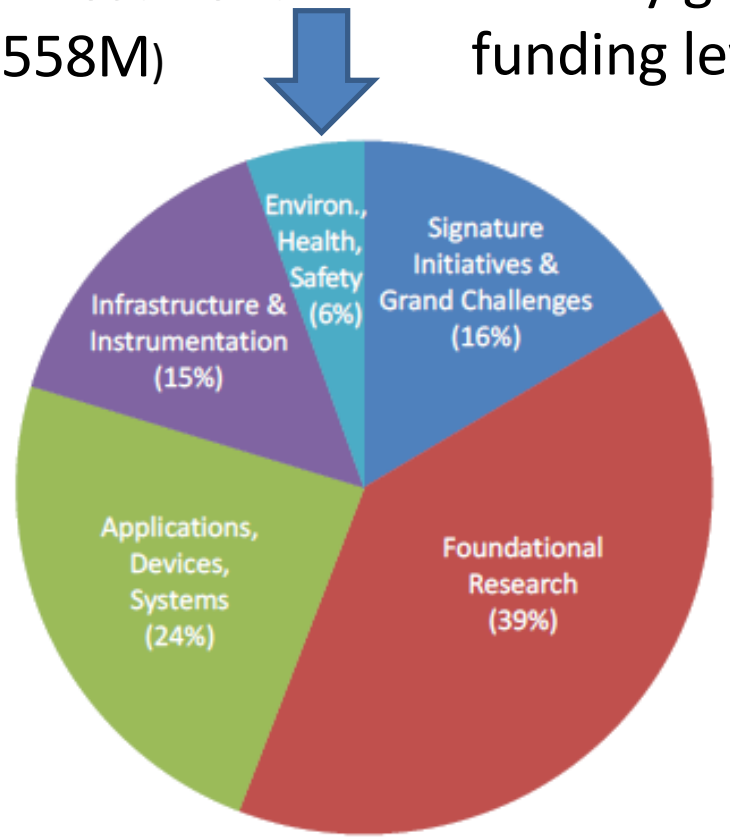

Figure 2. Breakout of NNI Funding by Program Component Area In the 2018 Budget.

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EHS Directions

- Basic research is continuing
- Applied research in occupational settings
- Moving along the value chain/life cycle
- Broader awareness and adoption of good practices
- Risk governance versus regulation
- Public-Private partnerships
- Evolving regulatory landscape

Are we Making any Progress?

Overall awareness has been raised across the value chain

R&D: Continued work to develop good practices for Nano and Advanced

Occupational: Adoption of proactive practices to minimize exposures and releases

Commercial Use: High-volume applications being identified and precautionary practices being developed

Environmental: Better understanding of fate and effects

Consumer Products: Still a challenge but awareness and response growing

Movement?

From

"There are too many unknowns"

To

"A lot of progress has been made"

To

"There are good lessons learned that can be reapplied"

To

"Consensus best practices meet EHS needs"

The View from NIOSH

In the Occupational Element of EHS

- Investigate specific materials and types
- Move hazard assessment along the value chain
- Assess and control exposure
- Use exposure data to evaluate risk
- Issue good practice guidelines

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

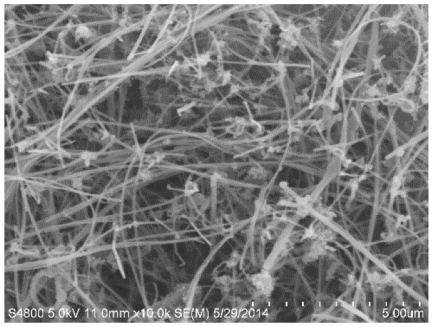
Graphite Nanoplatelets or Nanoplates

Graphene

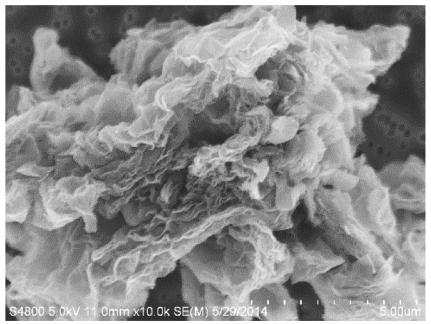
Graphene Oxide

Nanocellulose Nanomaterials

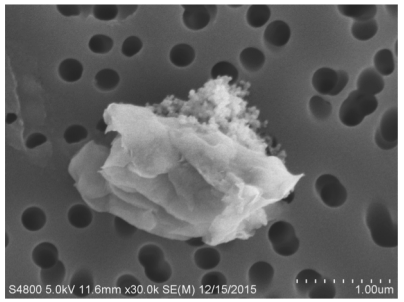
Natural and Organomodified Montmorillonite Nanoclay



MWCNT- Mitsui 7 – Courtesy of Bob Mercer



Layered Reduced Graphene Oxide



Stacked Plates of Nanoclay – courtesy of Todd Stueckle

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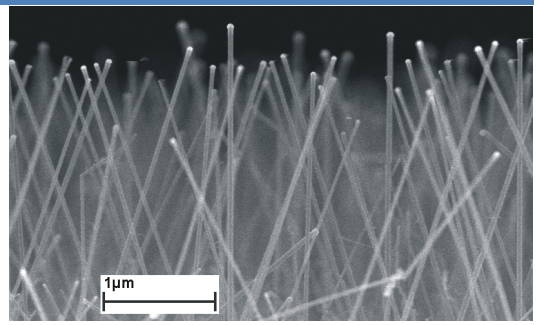
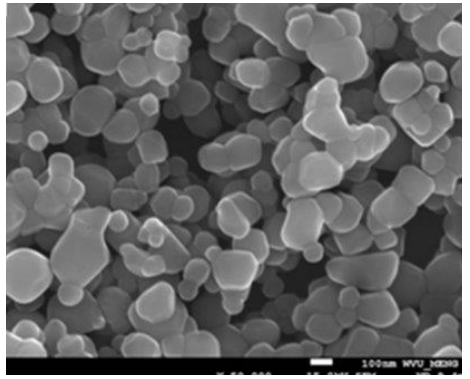
Nanomaterials Investigated at NIOSH

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
SiO_2 – amorphous and crystalline
Tungstate (particles and rods) CaWO4, SrWO4, BaWO4
Tungsten carbide-cobalt
Tungstate (particles and rods)
- CaWO4
- SrWO4
- BaWO4

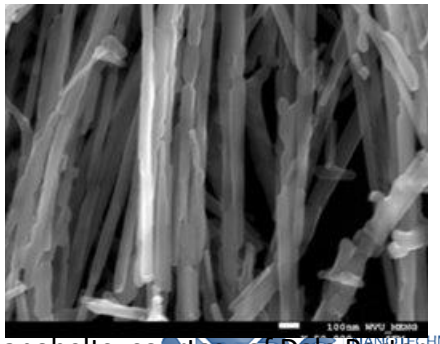
Copper Oxide
Quantum Dots – ZnS/CdSe



Si nanowires: Roberts et al., 2012



TiO2 nanospheres: courtesy of Dale Porter

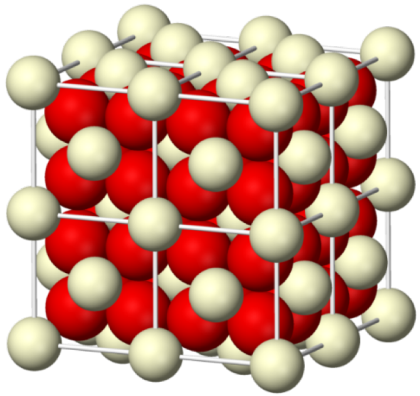


TiO2 nanobelts: courtesy of Dale Porter

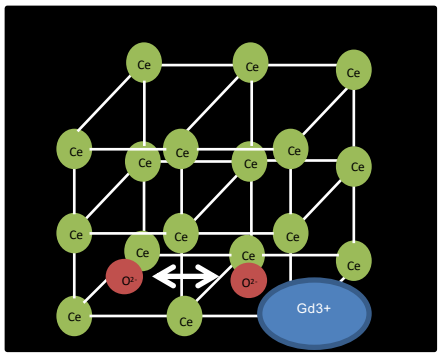
Nanomaterials Investigated at NIOSH

Functionally Modified Nanoparticles – Prevention through Design:

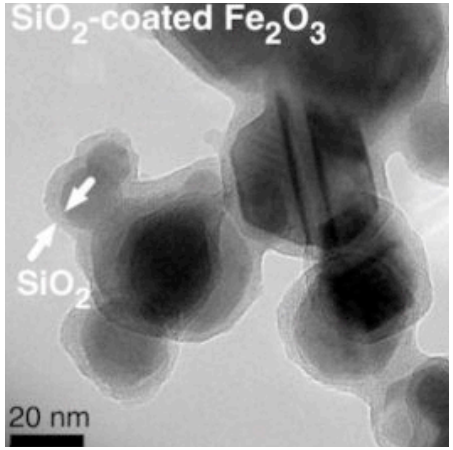
- Carboxylated and Humics Acid Titanium Nanobelts
- Nitrogen-doped MWCNT
- Carboxylated MWCNT
- Amine Functionalized MWCNT
- Heat-Treated MWCNT
- Amorphous silica coated Iron Oxide and Cerium Oxide
- Gadolidium-doped and SiO2 coated cerium oxide



http://goo.gl/vWa6HO



Courtesy of Stephen Leonard



Gass et al., 2013

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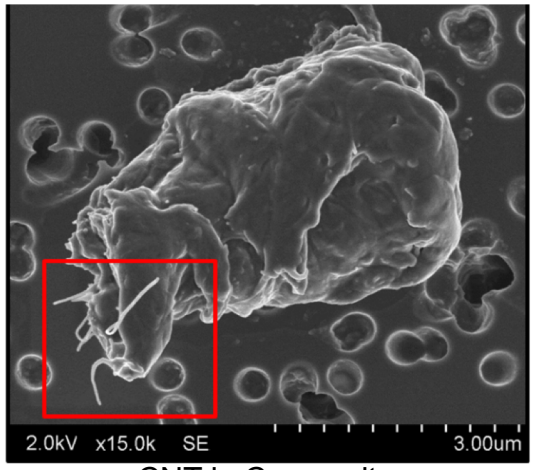
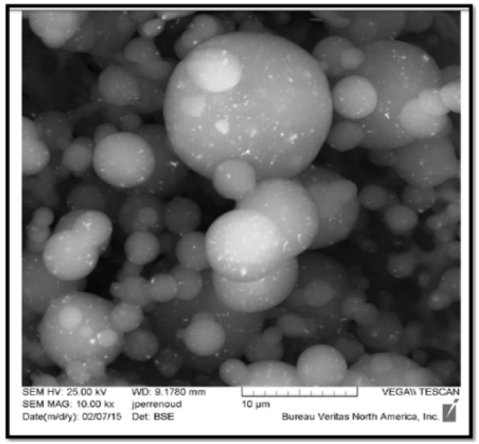
‘NanoProducts’ Investigated at NIOSH

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)
Suncreen 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

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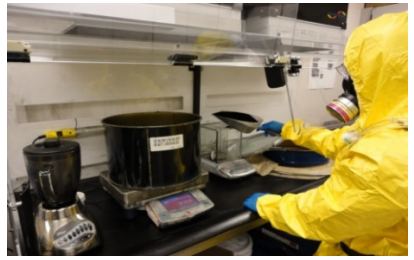
Applied Research Approach

Occupational Material Lifecycle

Dry Powder
Wet Chemistry

Resource Extraction → **Production of Primary ENM** → **Material Processing**

Mixing
Coating
Compositing
Sonicating/Dispersing



Distribution

Product Use and Consumption

Cutting, Sanding, Grinding, Heating, Sonicating/Dispersing

Degradation/Leaching Affected by Environment and Weathering

Disposal

Recycle → **Other**

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

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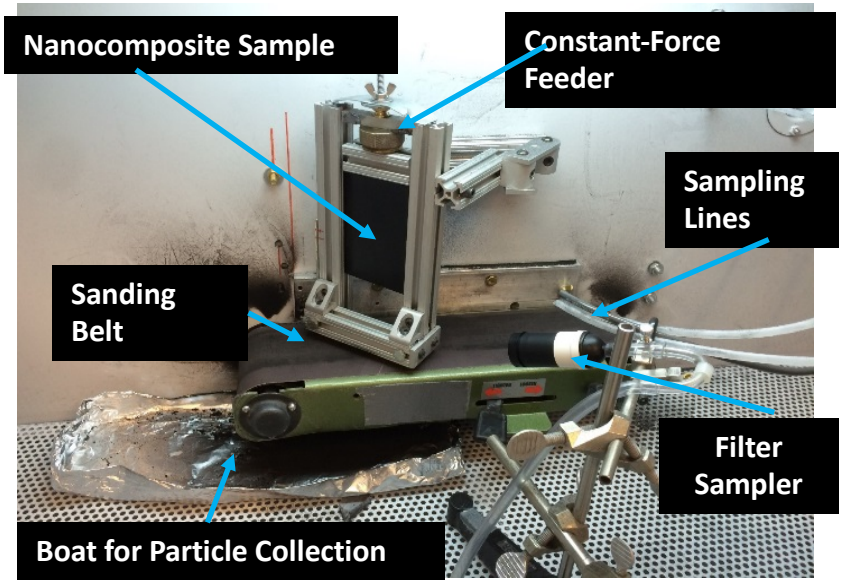
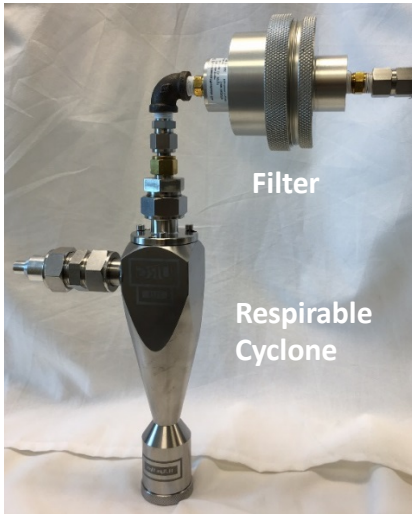
Processing and Characterizing Aerosols from Nano-Enabled Materials

Internal View





Courtesy of A. Erdely, L. Cena and A. Afshari

Moving Forward (2018 and Beyond)

- Focus on commercialization (not new)
- Nano is: mainstream, not a separate theme, stealth
- **Advanced Manufacturing** as a direct outlet for Nano
- Advanced Material quickly displacing Nanomaterial
- Growth in Bio-Manufacturing

Advanced Materials and Manufacturing

Advanced Materials

New materials and modifications to existing materials to obtain superior performance in one or more characteristics

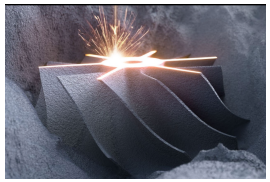
Advanced Manufacturing

Rapid transfer of science and technology into manufacturing products and processes

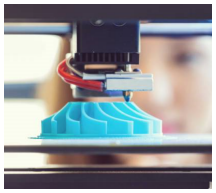
Advanced (Nano) Material

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 are critical for the application under consideration (that allow for novel applications),

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

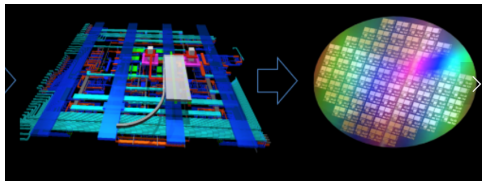


Additive Manufacturing



3D Printing

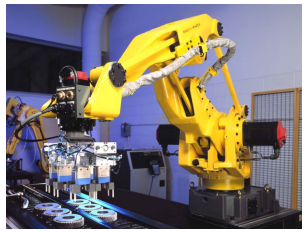
Functional Fabrics



Photonics

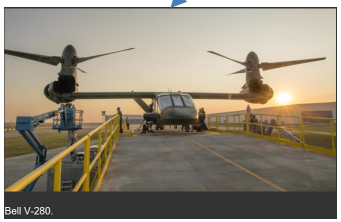
Flexible Sensors

“Advanced Manufacturing”



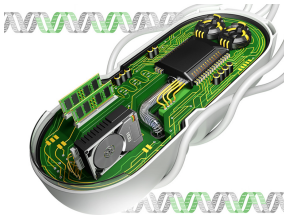
Robotics

Light Weighting



Advanced Composites

Clean Energy



Engineered Biology

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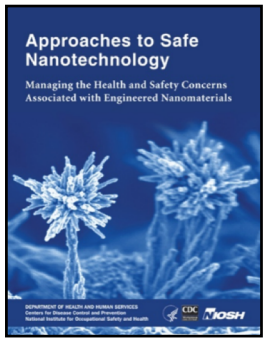
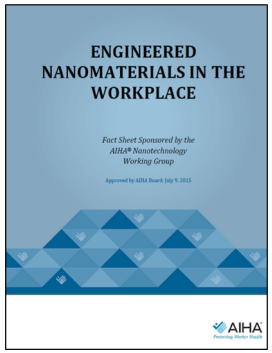
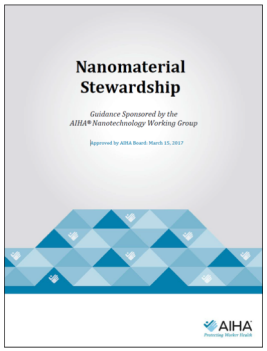
Response to the need for EHS guidance







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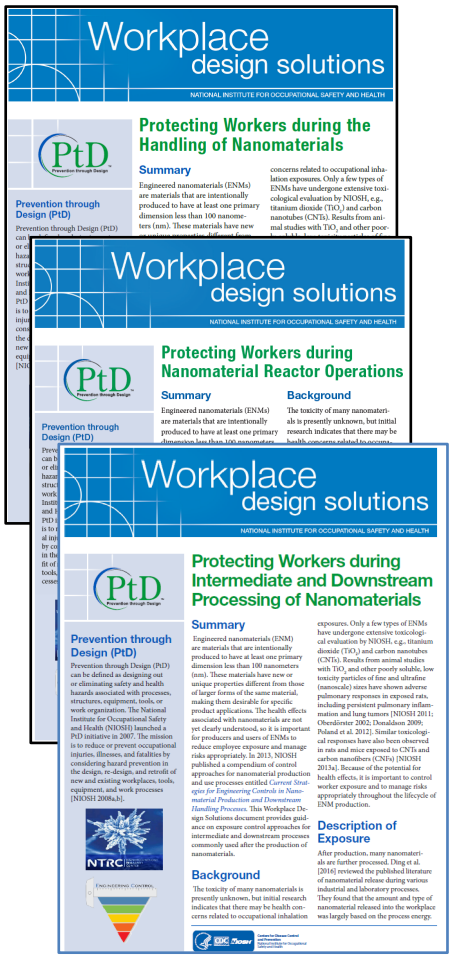
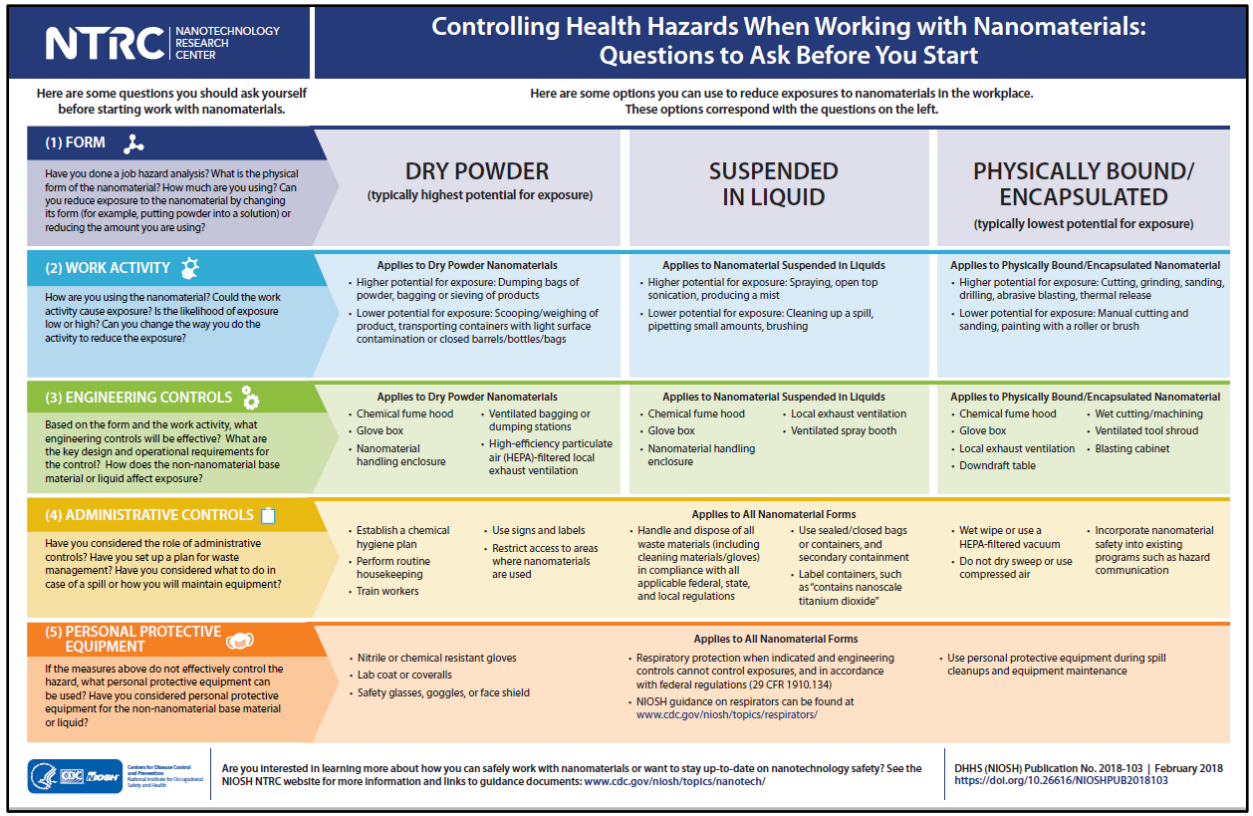
Recent Guidance





Practical approaches to evaluating hazards and controlling exposures.
https://www.cdc.gov/niosh/topics/nanotech/pubs.html

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Resources

NIOSH: www.cdc.gov/niosh/topics.nanotech

NNI: www.nano.gov

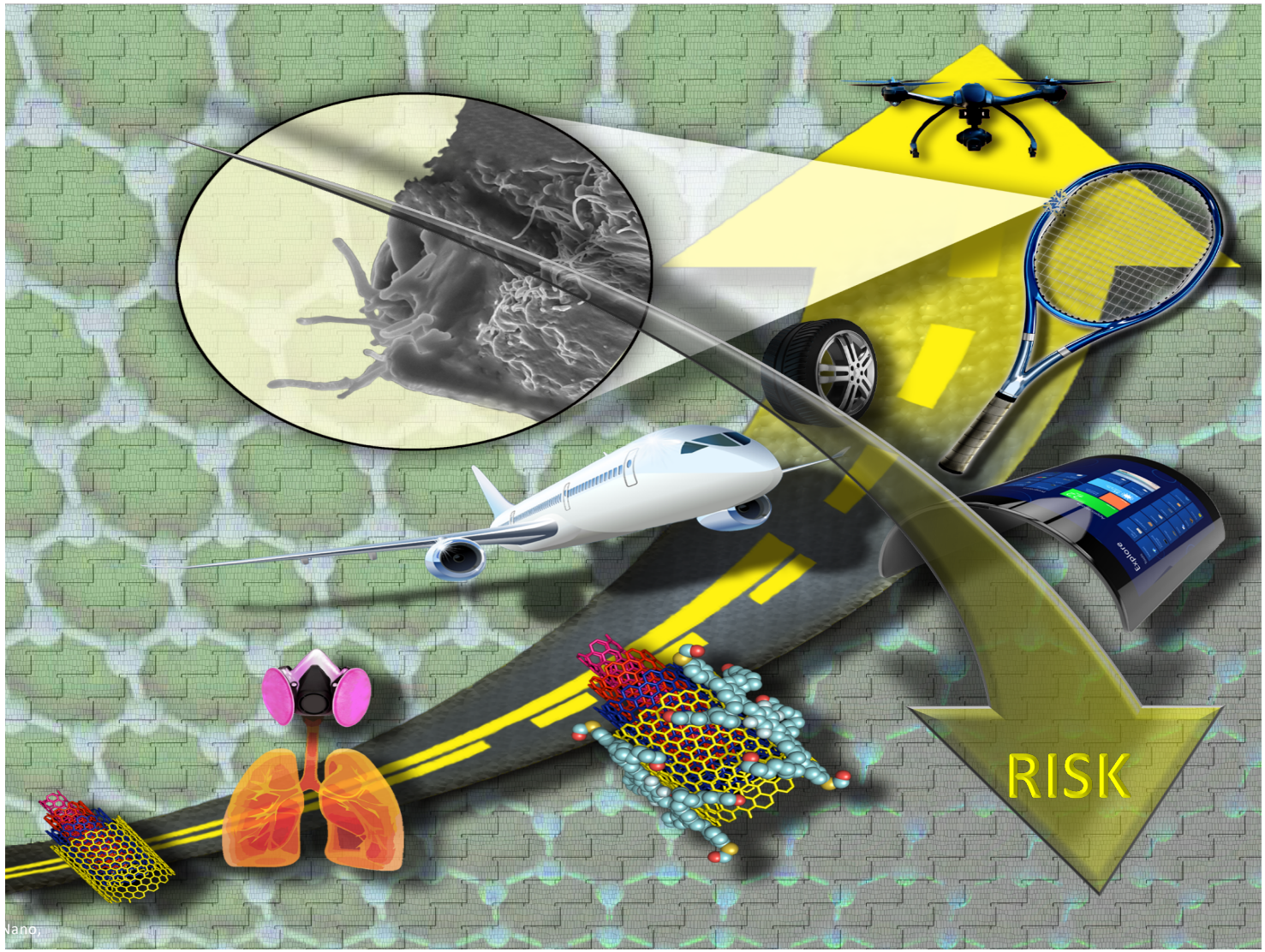
Good Nano Guide: www.nanohub.org/groups/gng

ACS: www.dchas.org

SafeNano: www.safenano.org

AIHA Nano Working group: www.aiha.org/get-involved/VolunteerGroups/Pages/Nanotechnology-Working-Group.aspx

EHS : Support growth by minimizing risk



Thank You!

cgeraci@cdc.gov