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

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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
## Nanotechnology: Impacts on Products and Industry

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

Nanomaterials Investigated at NIOSH
‘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

- Nanocomposite Sample
- Constant-Force Feeder
- Sampling Lines
- Filter Sampler
- Boat for Particle Collection
- Sanding Belt
- Respirable Cyclone
- Filter
- Respirable Cyclone

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),

CLGeraci-11/17
Some processes, some products, but all have a Nano element
Response to the need for EHS guidance
Recent Guidance

Practical approaches to evaluating hazards and controlling exposures.

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

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

NNI: [www.nano.gov](http://www.nano.gov)

Good Nano Guide: [www.nanohub.org/groups/gng](http://www.nanohub.org/groups/gng)

ACS: [www.dchas.org](http://www.dchas.org)

SafeNano: [www.safenano.org](http://www.safenano.org)

EHS: Support growth by minimizing risk

Thank You!
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