



Nanotechnology and the Commonwealth: Use and Implications

Thursday, December 7th 2017
Toxics Use Reduction Institute



Welcome/Webinar Logistics

- Due to the number of participants on the Webinar, all lines will be muted
- If you wish to ask a question, please type your question in the Q&A box located in the drop down control panel at the top of the screen
- All questions will be answered at the end of the presentations
- Call is being recorded

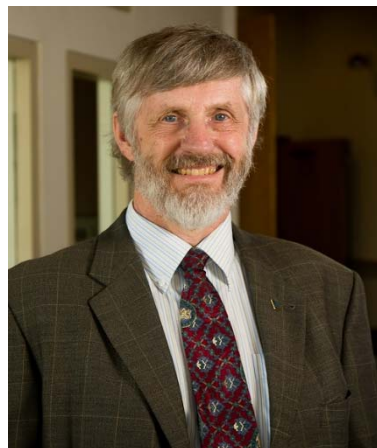
Today's Speakers

Molly Jacobs
LCSP



**Senior
Research
Associate**

Dr. Mike Ellenbecker
TURI



Director

Dr. Gregory Morose
TURI



**Research Program
Manager**

Mary Butow
TURI



**Research &
Reference
Specialist**



Nanotechnology 101

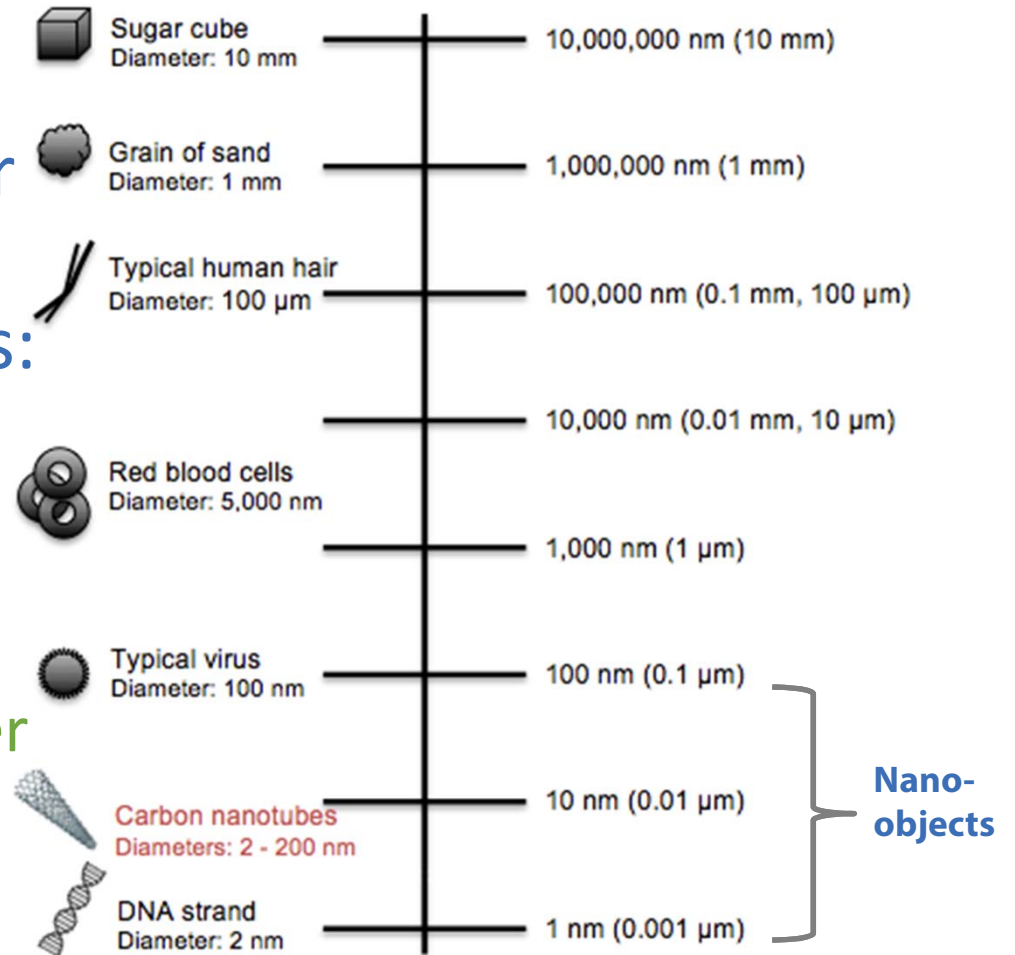
Molly Jacobs

Senior Research Associate, Lowell
Center for Sustainable Production

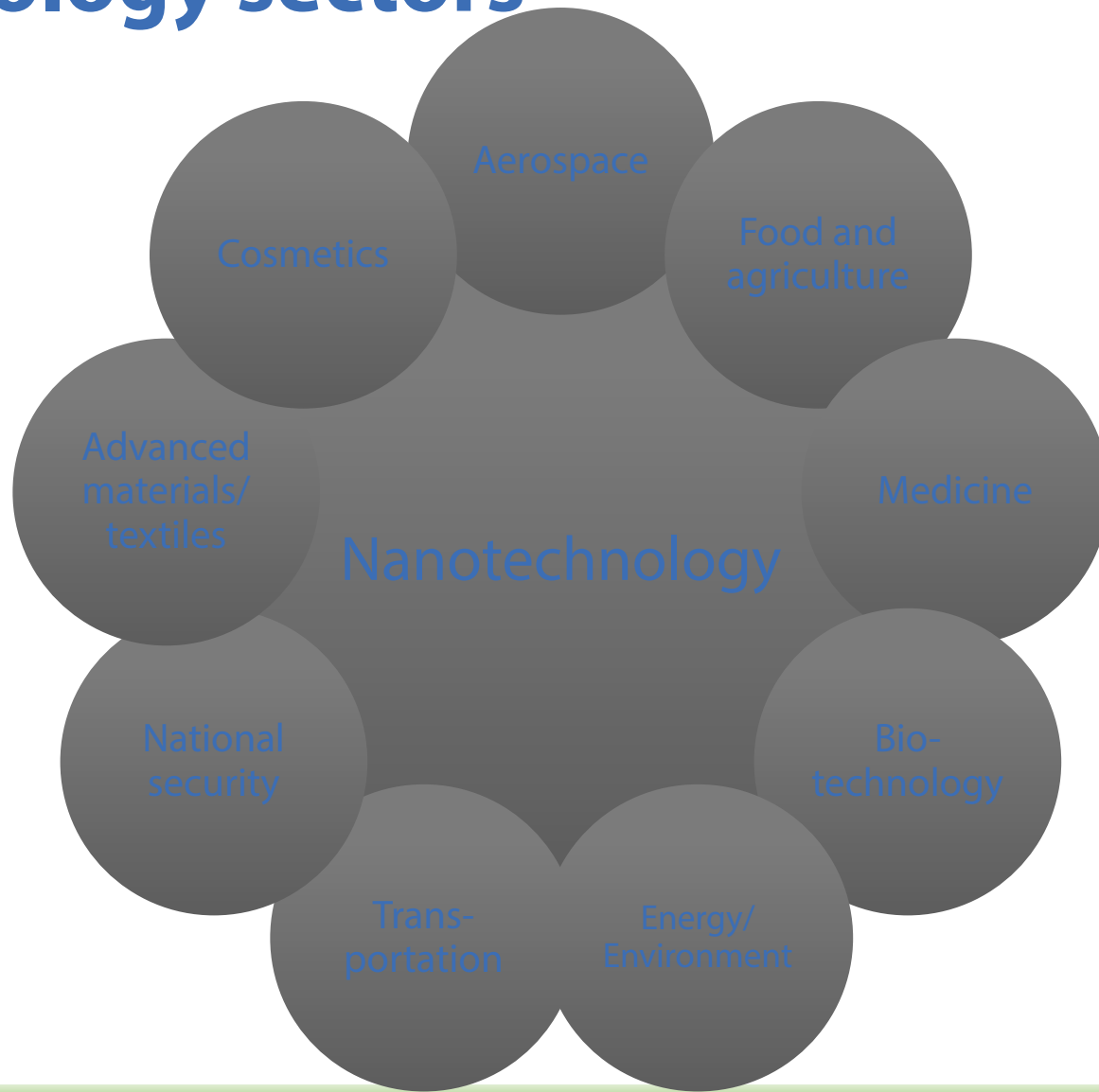


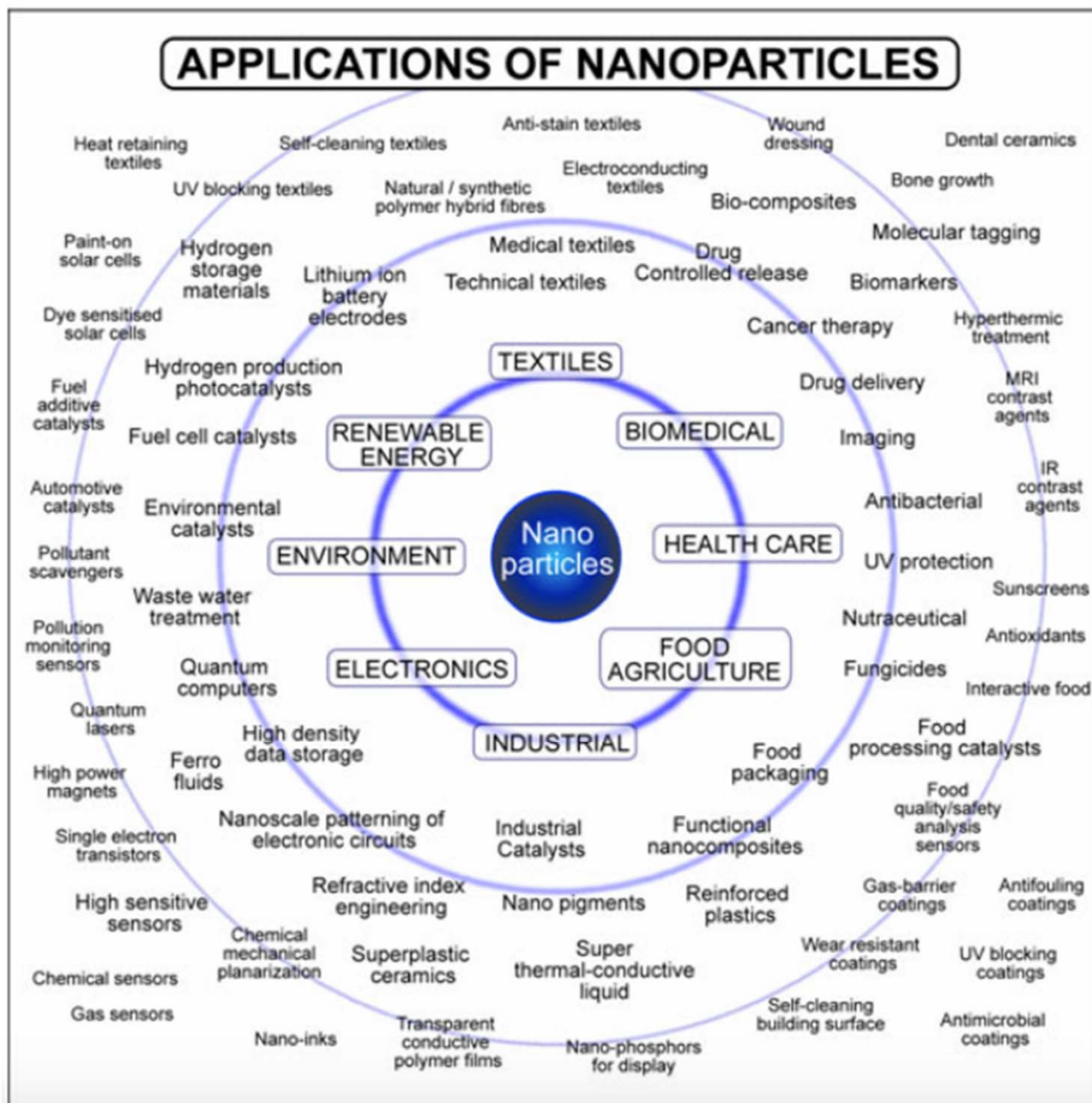
What is Nanotechnology

- The study of the controlling of matter on an atomic and molecular scale
- Engineered nano objects: at least one dimension between 1 to 100 nanometers (nm)
 - roughly 100,000 times smaller than the diameter of a human hair



R&D and Use – Spanning multiple technology sectors

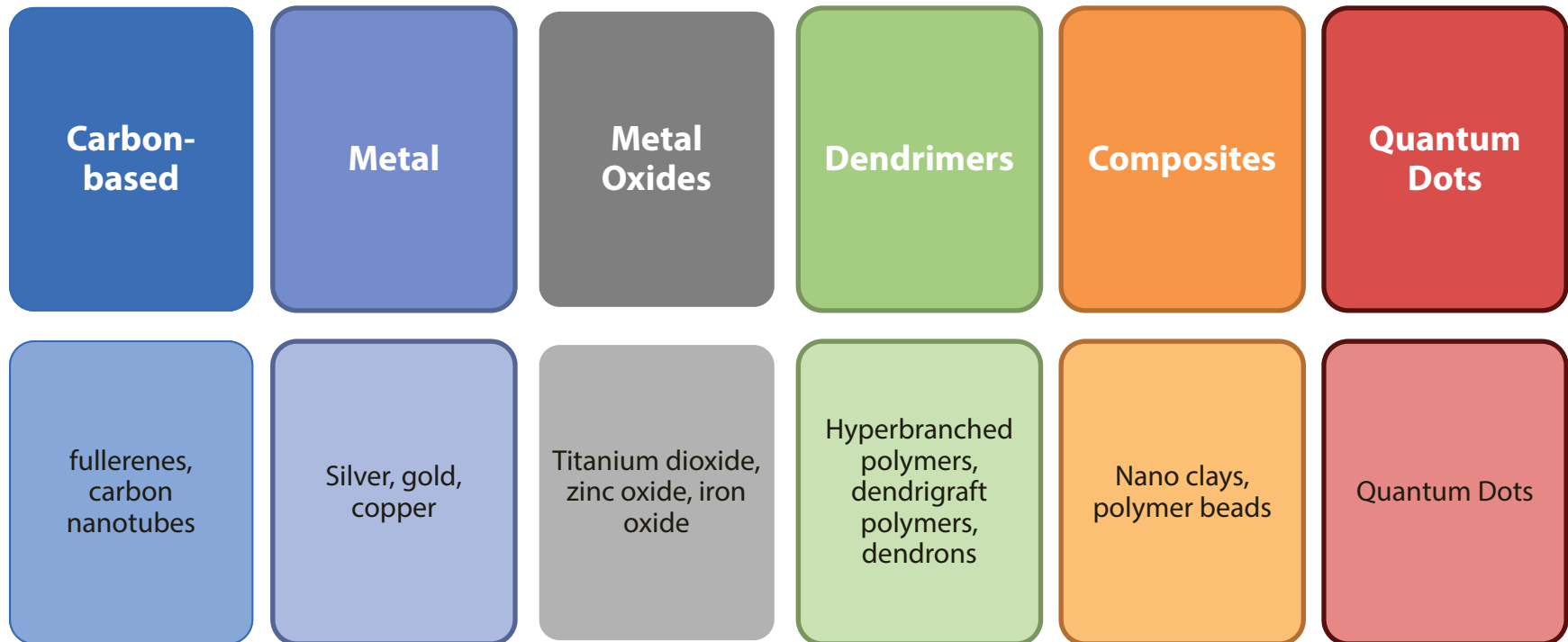




Source: Takuya Tsuzuk. [International Journal of Nanotechnology \(IJNT\)](#), Vol. 6, No. 5/6, 2009 as cited by Nanowerk

Types of Engineered Nanomaterials

Broad Categories: Engineered Nanomaterials



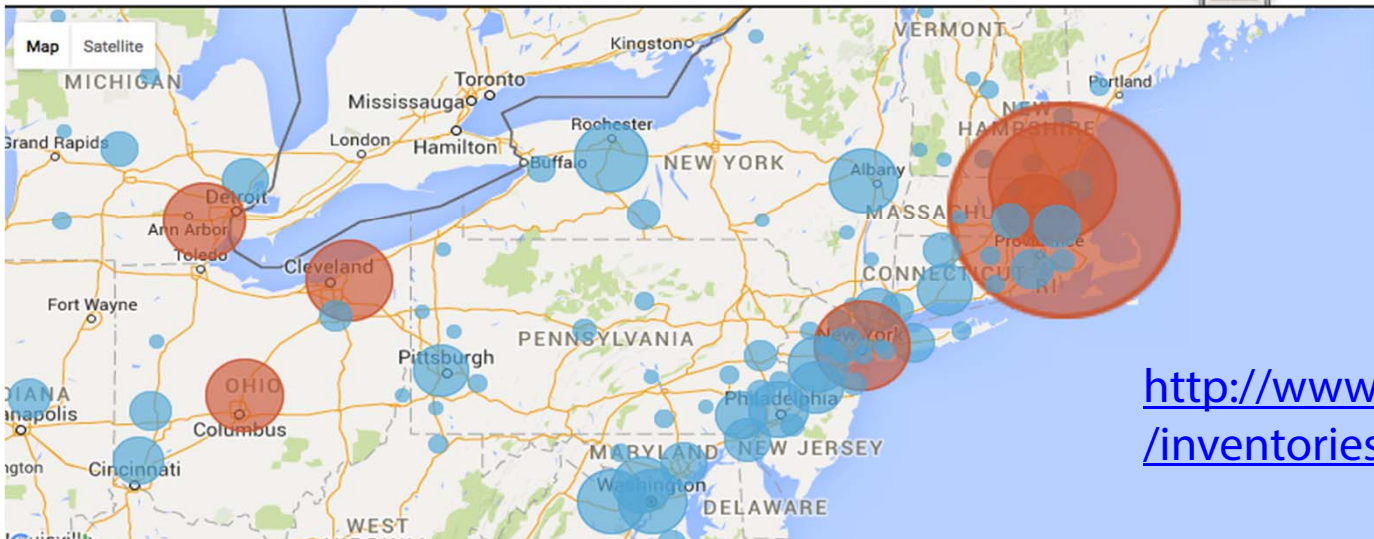
Nanotechnology in the Commonwealth



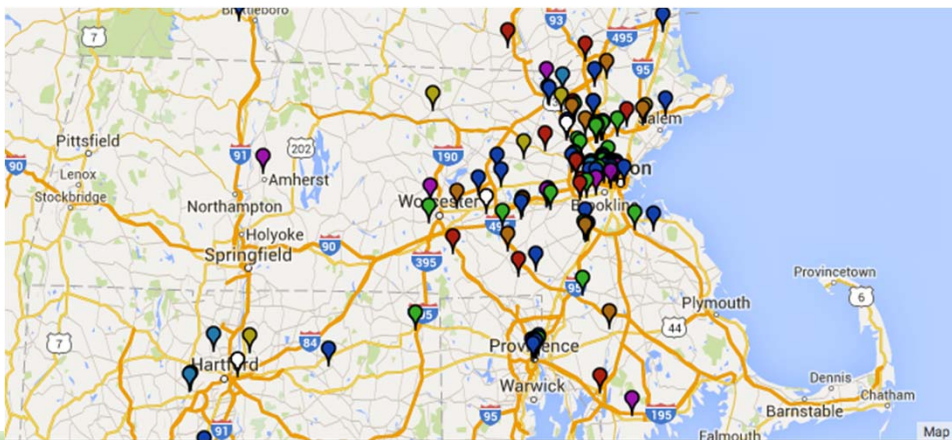
The Project on Emerging Nanotechnologies



get
findNano



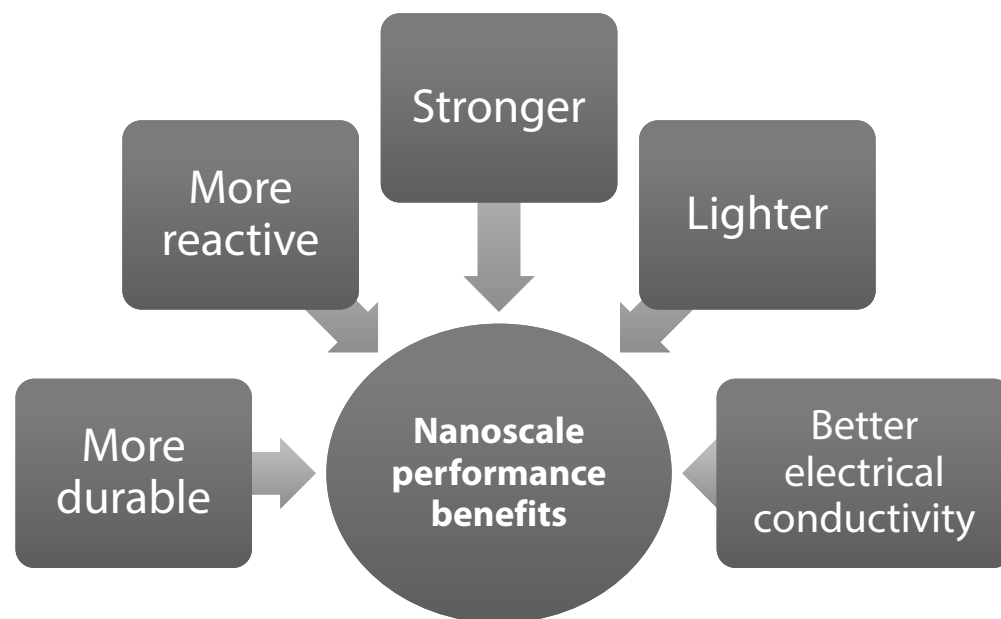
<http://www.nanotechproject.org/inventories/map/>



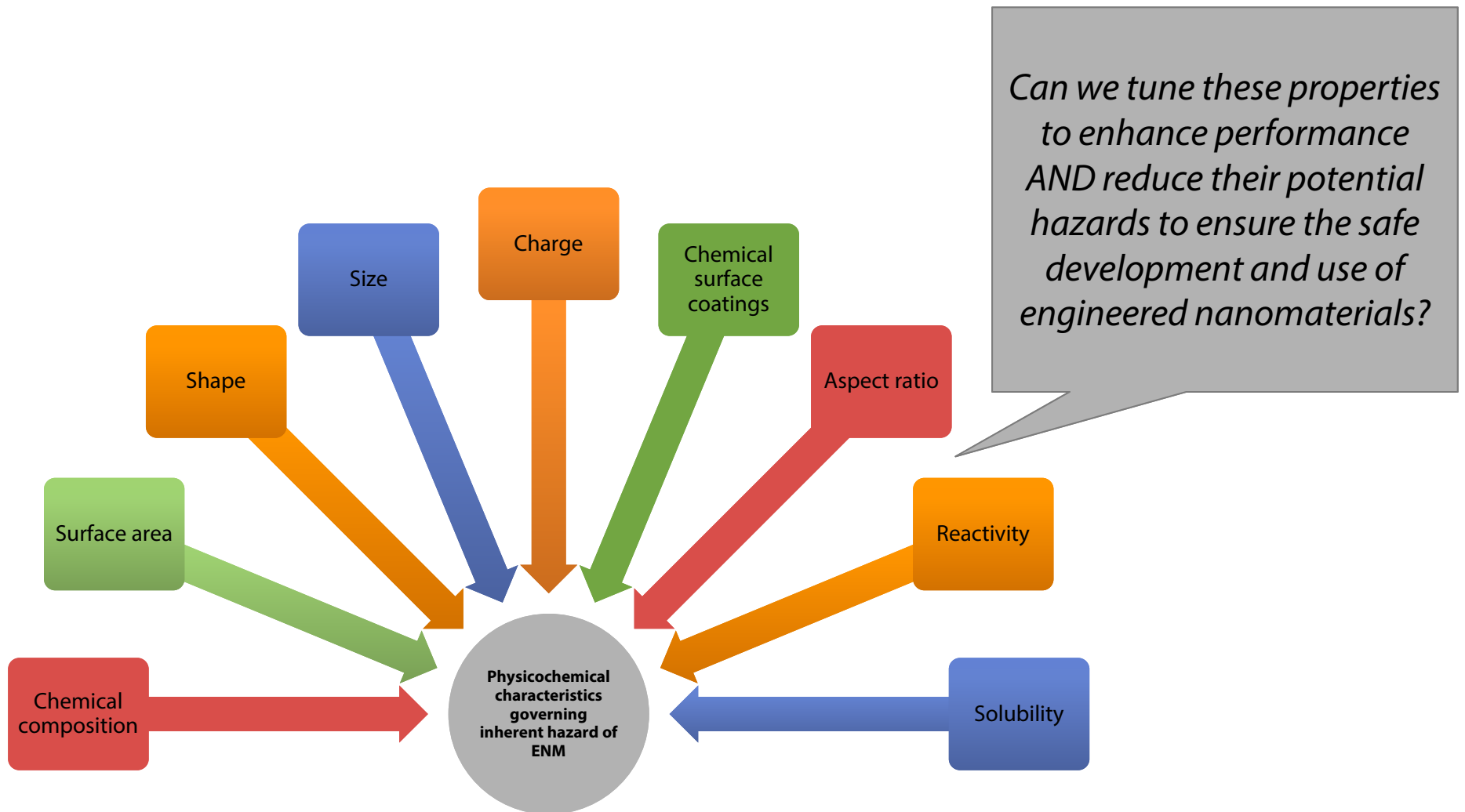
MA is among the top 5 in the country for commercial and R&D activity on nanomaterials/nanotechnology

Engineered nanomaterials: enhanced performance compared to their bulk counterparts

- At nano-scale:
 - material **properties change** - melting point, fluorescence, electrical conductivity, and chemical reactivity
 - **Surface size is larger** - more material comes into contact with surrounding materials and increases reactivity



Physical-chemical properties: key to performance AND inherent hazard



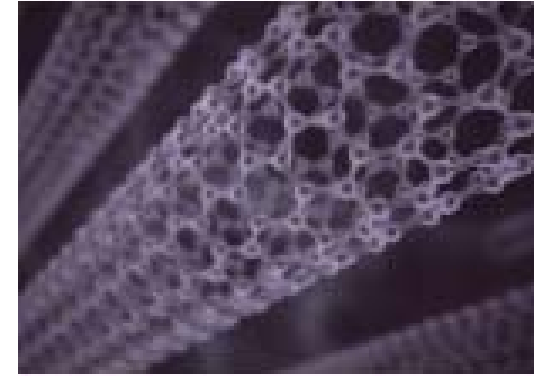


A deep dive on environmental safety and health aspects of one engineered nanomaterial: Carbon Nanotubes

Dr. Michael Ellenbecker
Director, Massachusetts Toxics Use
Reduction Institute



Engineered Carbon Nanotubes – What are They?

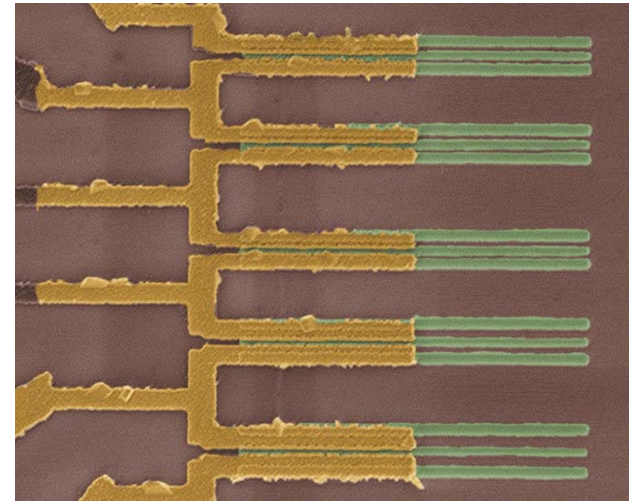


- Discovered in 1991
- Divided into 2 broad categories:
 - Single-walled CNTs (SWCNTs)
 - Multi-walled CNTs (MWCNTs)
- **Important:** CNTs are not a single material.
~50,000 SWCNTs and likely even more potential combinations of MWCNTs
 - Vary based on size, shape, chemical composition, reactivity, etc.

New York Times, 1 Oct 2015

“IBM Scientists Find New Way to Shrink Transistors”

- CNT field effect transistors
- Increase speed and/or reduce power use by a factor of 7



Emerging as substitutes for chemical toxicants



BIOCYL™ X1

Fouling release coatings

Anti-fouling marine paints
[substitutes for tributyltin, copper boat paints, etc]



THERMOCYL™ X1

Flame retardant coatings for non-metallic substrates

Flame retardants for electronics, wire/cable, textiles, foams [substitutes for halogenated flame retardants]

CNT Toxicity

- Many studies published in the last 10 years
- Primary end points of concern:
 - Pulmonary fibrosis
 - Inflammation
 - Lung tissue
- Cancer
 - Lung tumor promoter
 - Mesothelioma

Current Intelligence Bulletin 65, Occupational Exposure to Carbon Nanotubes and Nanofibers.
Available at: <http://www.cdc.gov/niosh/docs/2013-145/pdfs/2013-145.pdf>.

Cancer & MWCNTs

- Tumor promotion [high aspect ratio MWCNTs]:
 - mouse inhalation study, first exposed to methylcholanthrene (MCA) via intraperitoneal injection.
 - Strong promotion of lung tumors [pulmonary adenomas and adenocarcinomas]
 - Strong promotion of malignant serosal tumors consistent with sarcomatous mesothelioma

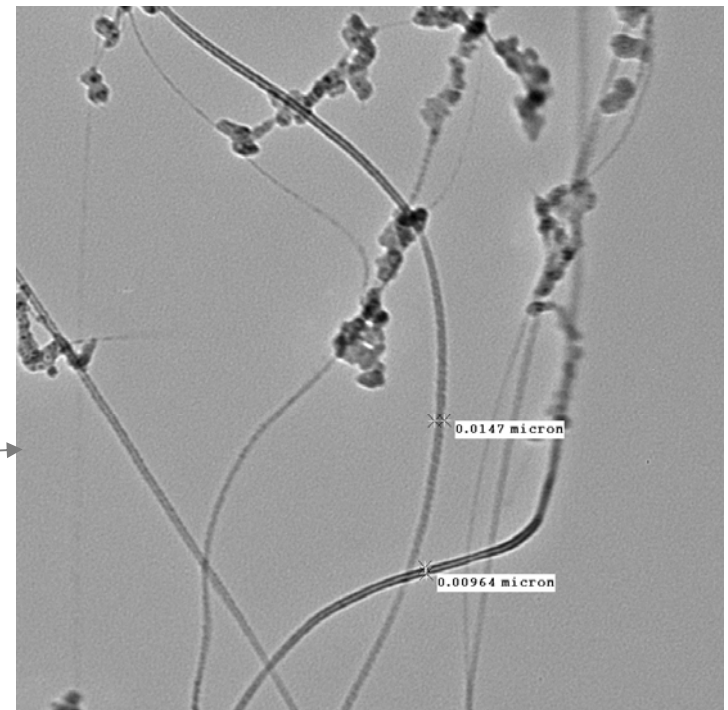
Sargent LM, et al. *Part Fibre Toxicol.* 2014 Jan 9;**11**:3. doi: 10.1186/1743-8977-11-3.



Asbestos



CNTs



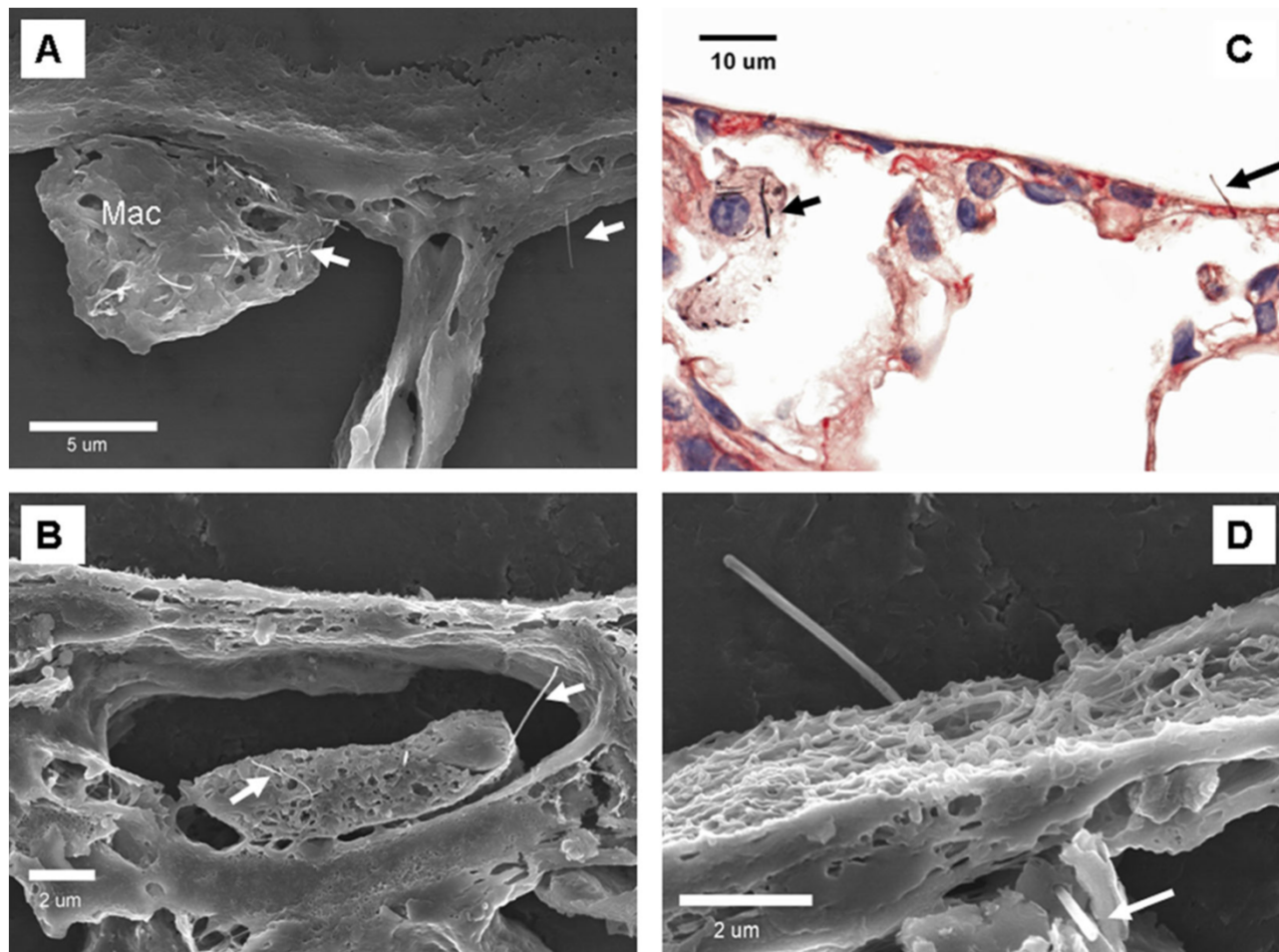
nanocomp source-4-1 0608.tif
CNT source 0608-4-1
Cal: 955.975pix/micron
TEM Mode: Imaging
Microscopist: Candace

100 nm
HV=100kV
Direct Mag: 20000x

CNTs cause Mesothelioma?

- Carbon nanotubes introduced into the abdominal cavity of mice show asbestos-like pathogenicity in a pilot study, Poland, et al., *Nature Nano.*, 2008.
- Induction of mesothelioma in p53+/- mouse by intraperitoneal application of multi-wall carbon nanotube, Takagi, et al., *J. Toxicol. Sci.*, 2008.

Mercer, et al., Distribution and persistence of pleural penetrations by multi-walled carbon nanotubes, *Part. Fibre Tox.*, 2010.



CNTs cause Mesothelioma?, Cont.

Poland: “Here we show that exposing the mesothelial lining of the body cavity of mice, as a surrogate for the mesothelial lining of the chest cavity, to long multiwalled carbon nanotubes results in asbestos-like, length-dependent, pathogenic behaviour... Our results suggest the need for further research and great caution before introducing such products into the market if long-term harm is to be avoided.”

Dec 2014 – IARC designates “certain MWCNTs” as 2B, Possible Human Carcinogen

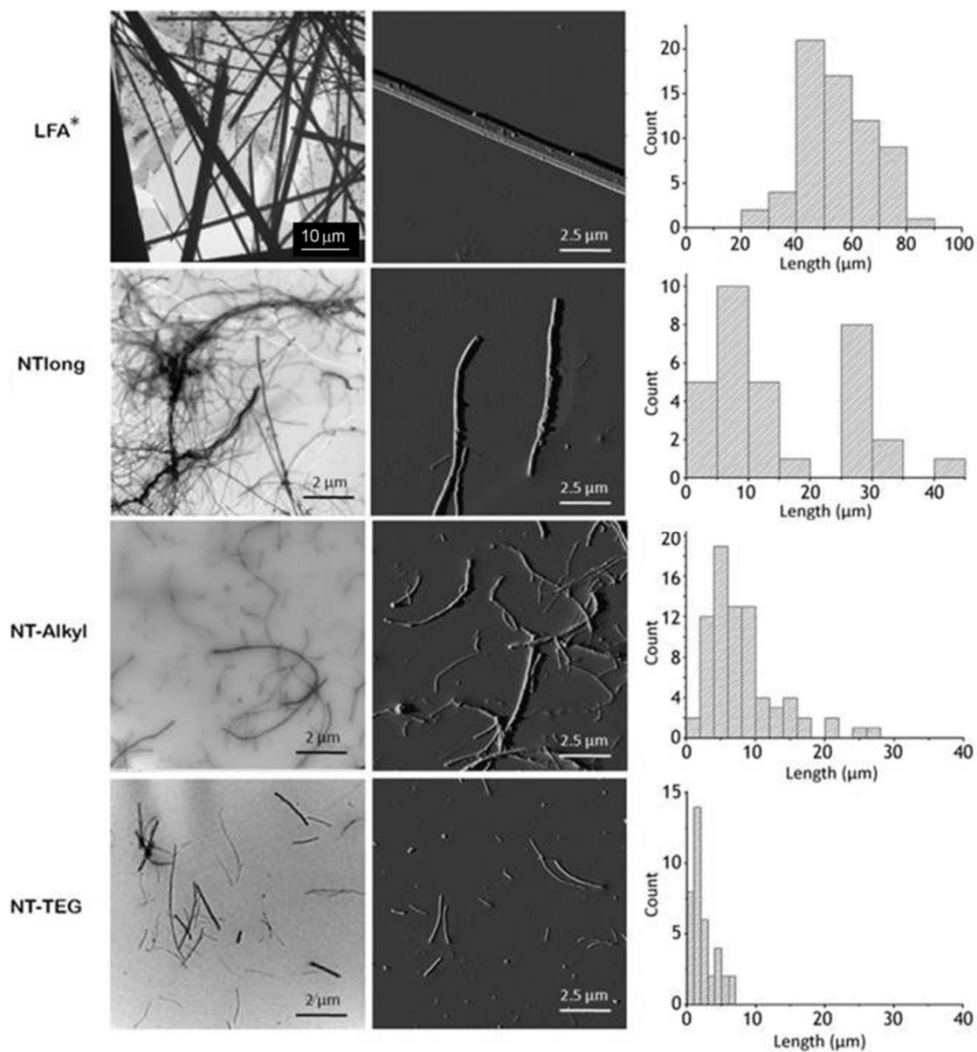
Grosse Y et al. *Lancet Oncol.* 2014;**15(13)**: 1427-28.

Fiber Morphology Important

- In animal studies thus far:
 - SWCNTs do not cause mesothelioma
 - Thin ($d < 15$ nm) MWCNTs – ditto
 - Thick ($d > 150$ nm) MWCNTs – ditto
- But – all commercially available MWCNTs :
 $15 \text{ nm} < d < 150 \text{ nm}$
- Short ($L < 1\text{-}5 \text{ }\mu\text{m}$) MWCNTs – ditto

Can we make them all short?

Functionalization can affect Length



Ali-Boucetta, *et al.*, *Angew. Chem. Int. Ed.* 2013, **52**, 2274 –2278, DOI: 10.1002/anie.201207664

Human Studies

- Few human studies to date
 - Case reports of CNTs found in the lungs of 911 first responders
 - Recent case-control study revealed MWCNT manufacturing workers (levels 3x above the NIOSH REL) found biomarkers of effect similar to conclusions from tox studies
 - increase in serum & sputum inflammatory & fibrotic biomarkers [IL-1 β , IL6, TNF- α , inflammatory cytokines, KL-6, TGF- β 1]

Wu, M. et al. *Environ. Health Perspect.* 2010; **118**: 499–504.

Fatkhutdinova LM et al. *Toxicol and App Pharmacol.* 2016; **299**: 125–131.

Emerging Ecotoxicity Concerns

- Daphnids (*Daphnia magna*)
 - Interferes with food uptake & movement at low concentrations [MWCNTs & SWCNTs]; More toxic with longer exposures; Impaired growth and reproduction at very low levels
- Juvenile rainbow trout (*Oncorhynchus mykiss*)
 - Systemic toxicity at very low levels (consistent with GHS classification of “extremely toxic to aquatic life”)
- Powerful anti-microbial agent
 - Implications for sewage treatment plants

*variation in findings given differing physicochemical characteristics

Source: Petersen, et al. *Env Sci Technol* 2011; **45(23)**:9837-9856.

CNTS in Products

- If CNTs are bound in a matrix (e.g., incorporated into an epoxy matrix), are they still of concern?
- In normal use, probably not, but cutting, sanding, etc., can release CNT fibers
- A recent study found no difference in pulmonary effects between CNT and non-CNT epoxies, but increased liver function damage with the CNT epoxy

Source: Saber, et al., *Particle and Fiber Toxicology* 2016; **13**:37.

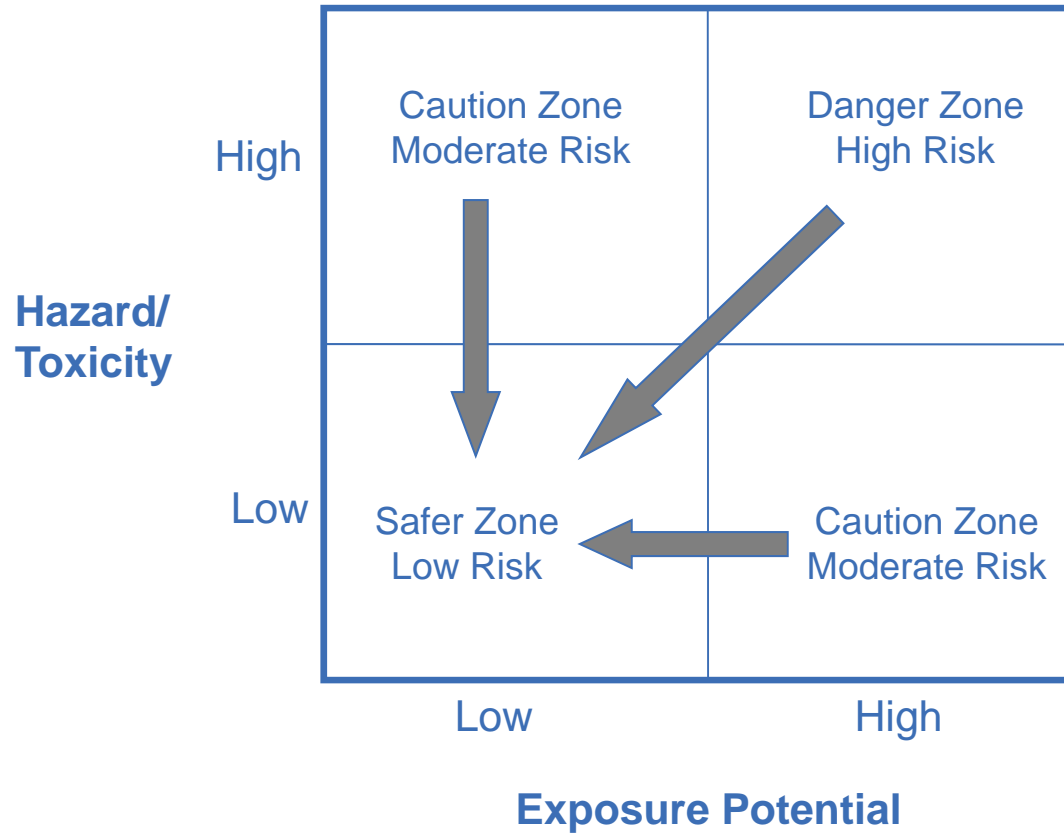


Principles for Safer Nano

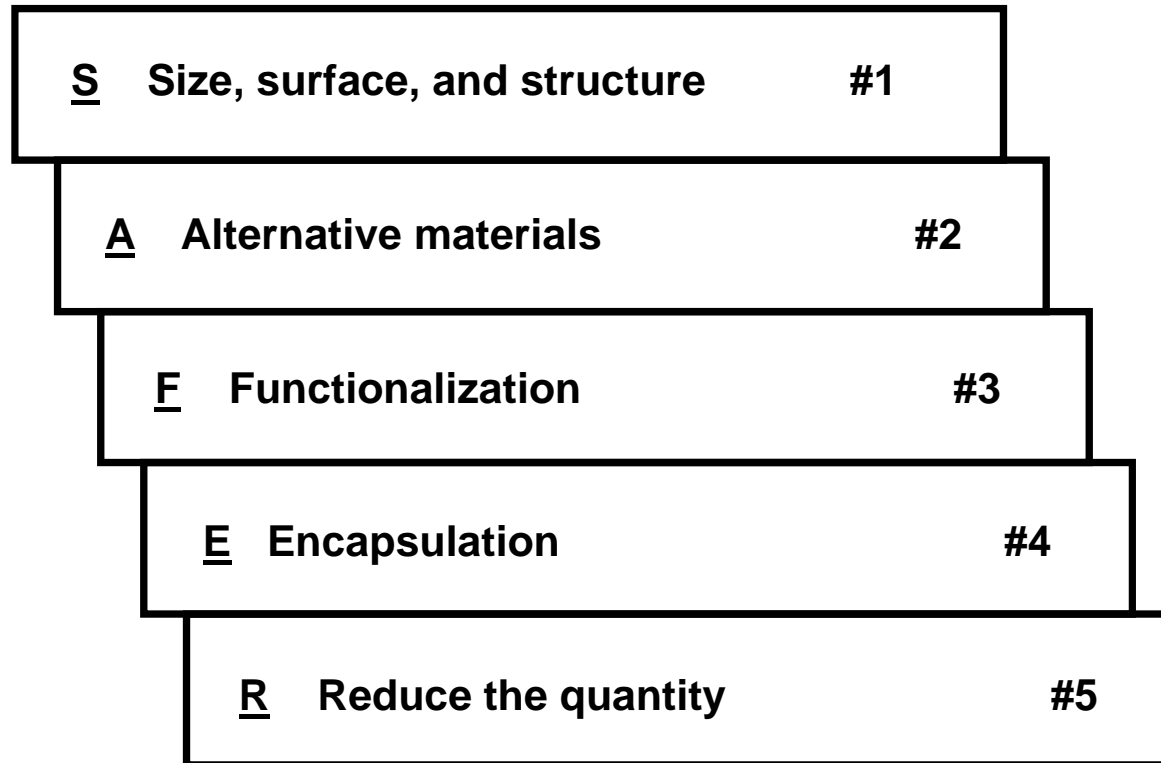
Dr. Gregory Morose
Research Program Manager
Toxics Use Reduction Institute



Risk Mitigation Matrix



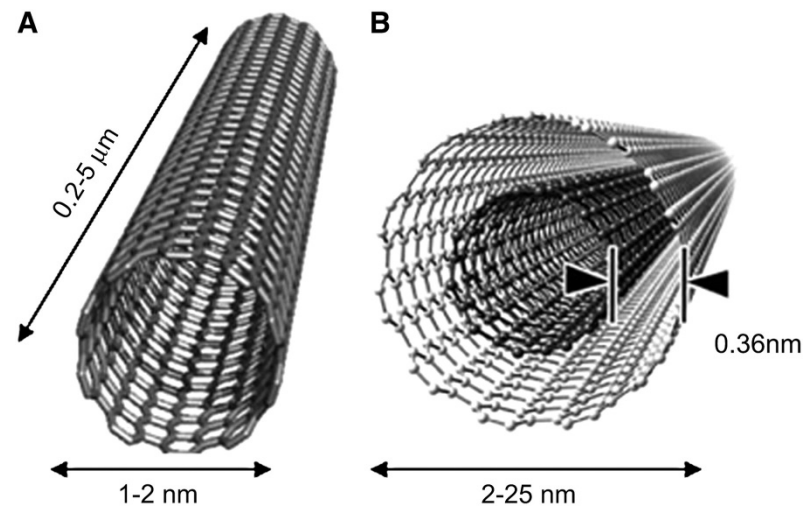
Five Principles of Design for Safer Nanotechnology



Principle 1: Size, Surface, Structure

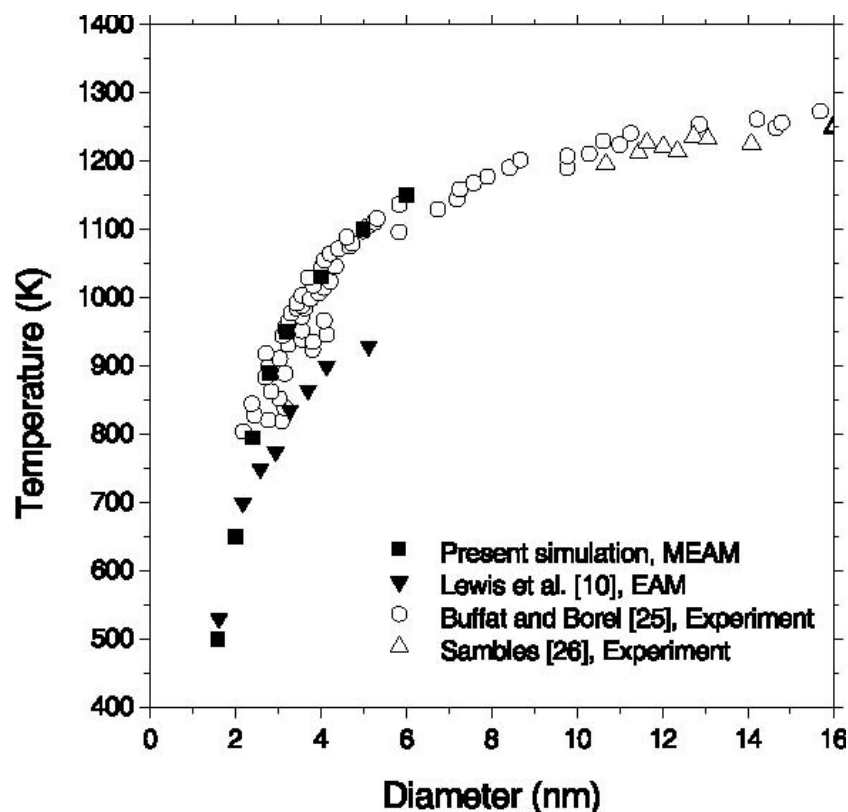
Three major characteristics of nanoparticles (size, surface, and structure).

If changed, can affect fundamental nanoparticle properties such as color, conductivity, melting temperature, reactivity etc. as well as alter the hazard and exposure potential of the nanoparticle.



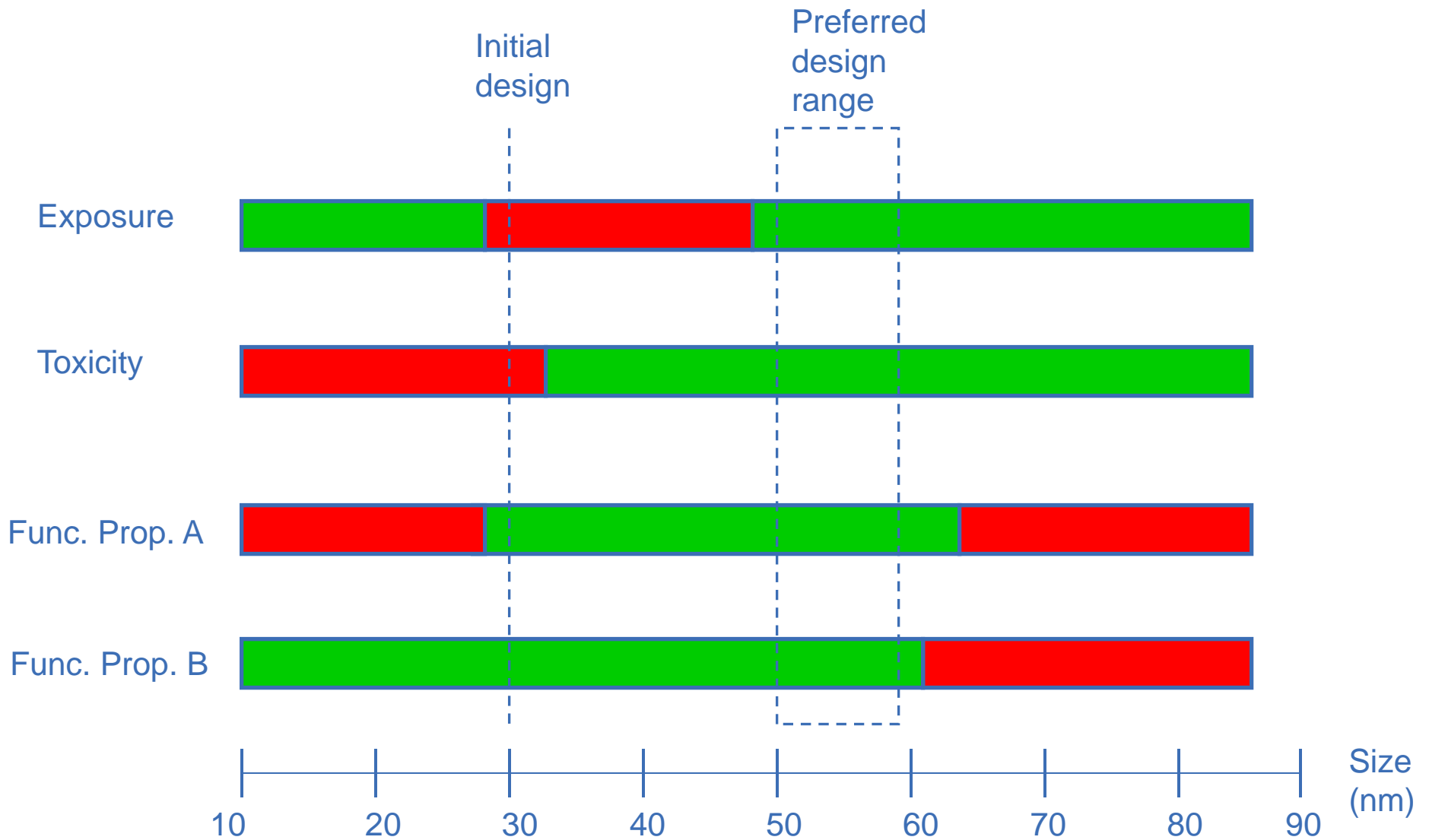
Size: Effect on Properties

The size of a nanoparticle includes the dimensions for diameter, length, width, etc. which affects the fundamental properties of the nanoparticle.



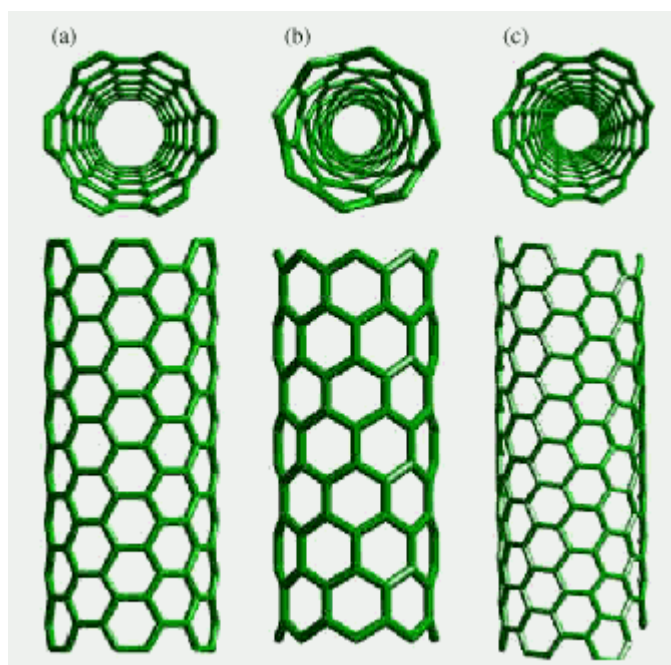
Source: Shim Jae-Hyeok, Lee Byeong-Joo Cho, Young Whan. Thermal stability of unsupported gold nanoparticle: a molecular dynamics study. *Surface Science* 2002;512:262–8.

Size Dependent Properties

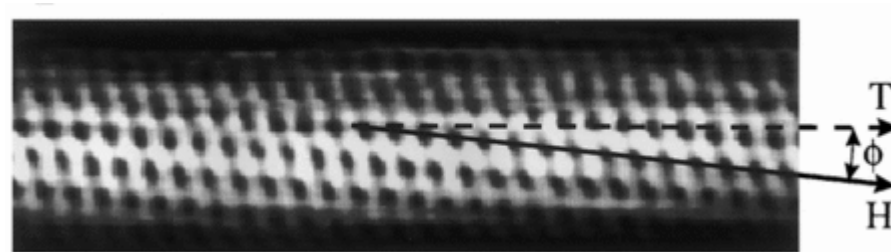


Structure: Effects on Properties

Minor variations of carbon nanotube wrapping angle or diameter affect functional properties.



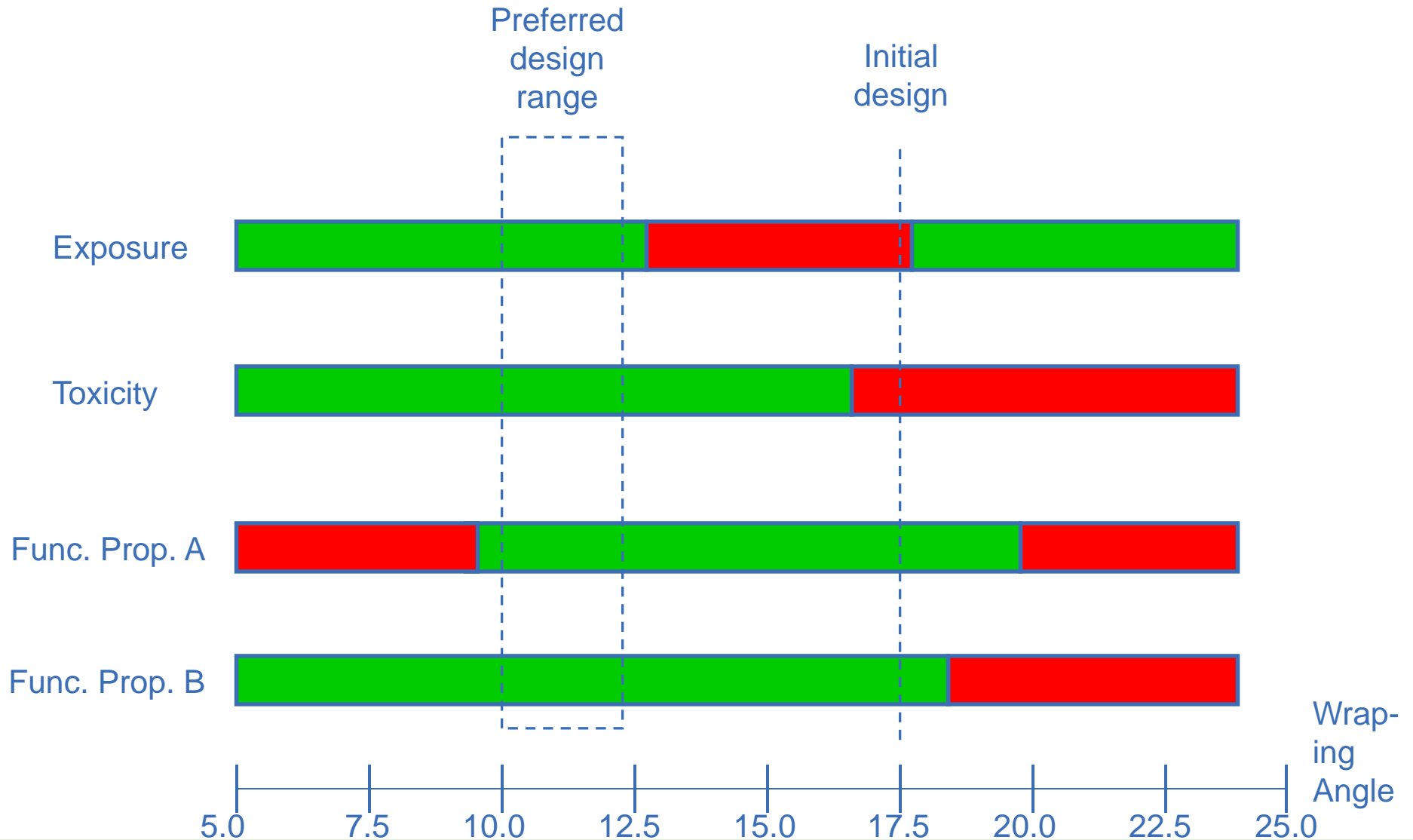
a) armchair, (b) zigzag, (c) chiral



Chiral, wrapping angle 7°

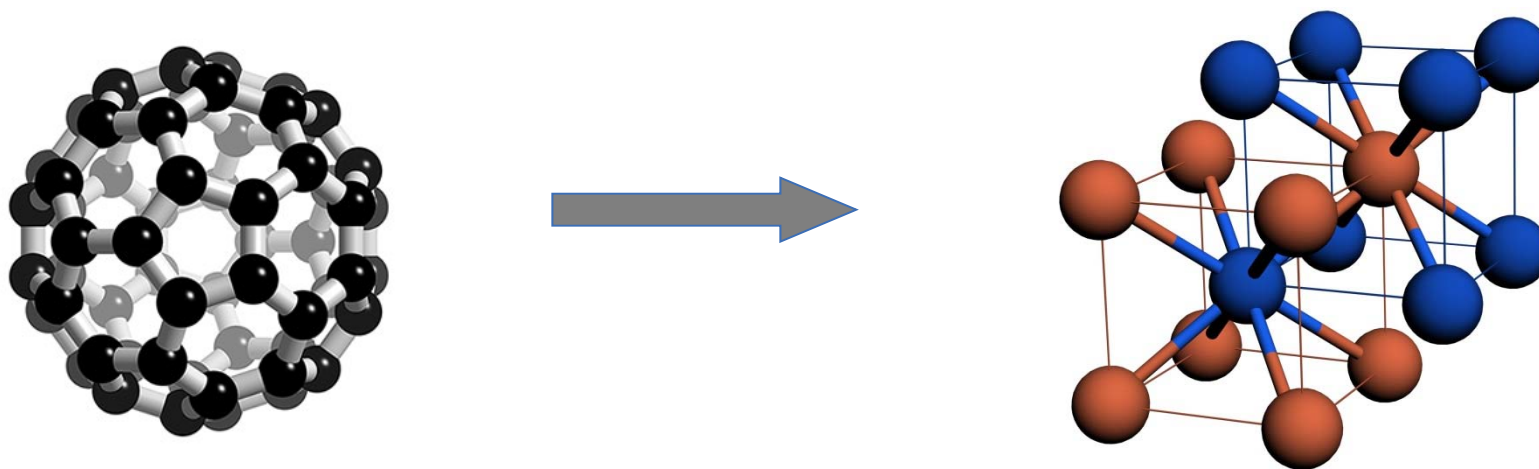
Source: Wildoer Jeroen WG, Venema, Liesbeth C, Rinzler Andrew G, Smalley Richard E, Dekker Cees. Electronic structure of atomically resolved carbon nanotubes. *Nature* 1998;January; **391**:59–62.

Structure Dependent Properties



Principle 2: Alternative Materials

This approach involves identifying an alternative material (nano or bulk), that can be used to replace the hazardous nanoparticle.

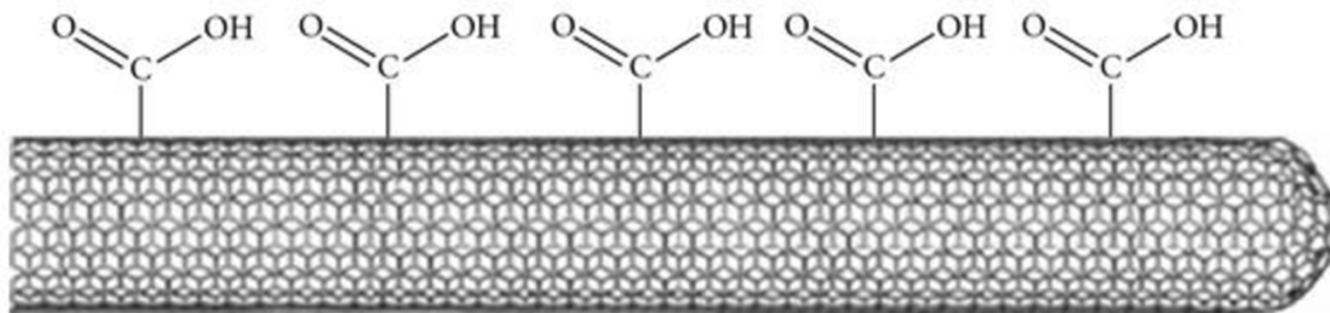


Principle 3: Functionalization

Functionalization is the intentional bonding of atoms or molecules to nanoparticles to change the properties of the nanoparticles.

Functionalize the nanoparticle in a manner such that the desired product properties are preserved, but the hazard and/or exposure potential of the nanoparticle is reduced or eliminated.

For example, functionalization to promote excretion of nanomaterials.



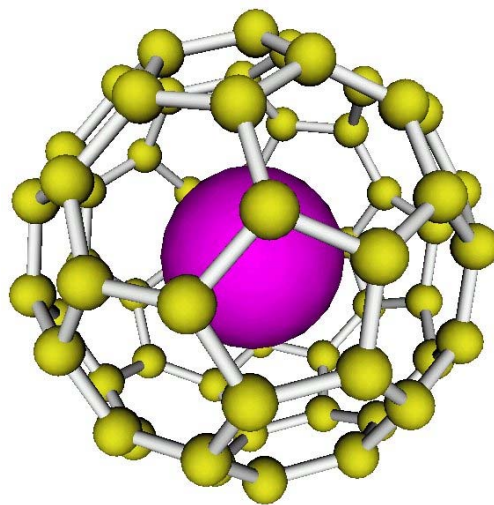
Source: Lara Lacerda, Anuradha Soundararajan, Singh Ravi, Pastorin Giorgia, Al-Jamal Khuloud T, John Turton. Dynamic imaging of functionalized multi-walled carbon nanotube systemic circulation and urinary excretion. *Advanced Materials* 2008;**20**:225–30.

Principle 4: Encapsulation

Encapsulation is a method used to completely enclose a nanoparticle within another material.

The intent of this principle is to enclose a potentially hazardous nanoparticle within a material that is less hazardous.

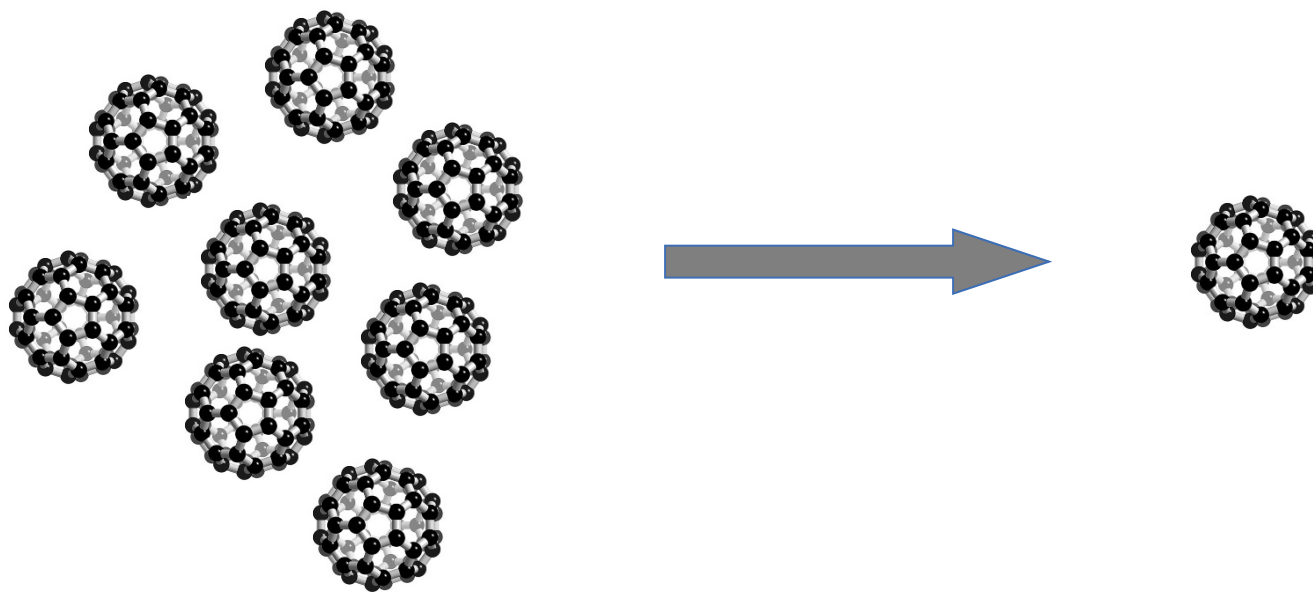
For example, functionalize nanomaterials (dyes) used in two-photon photodynamic therapy.



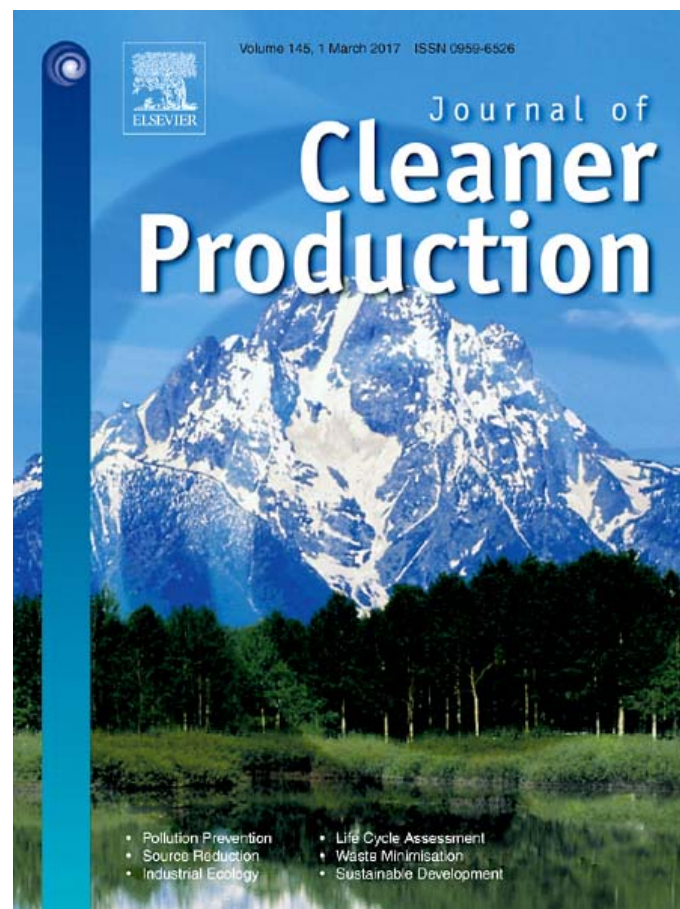
Source: Gao De, Agayan Rodney R, Xu Hao, Philbert Martin A, Kopelman Raoul. Nanoparticles for two-photon photodynamic therapy in living cells. *Nano Letters*, November, 2006;**6(11)**; 2383–2386.

Principle 5: Reduce the Quantity

There may be situations where applying the above design principles cannot reduce or eliminate the nanoparticle hazard while maintaining the desired product functionality.



SAFER Article



Morose, Gregory, “The 5 Principles of Design for Safer Nanotechnology”, *Journal of Cleaner Production*, **Volume 18**, February 2010, pp. 285 – 289.



TURI and Engineered Nanomaterials: Programs and Resources

Mary Butow

Research & Reference Specialist,
Toxics Use Reduction Institute



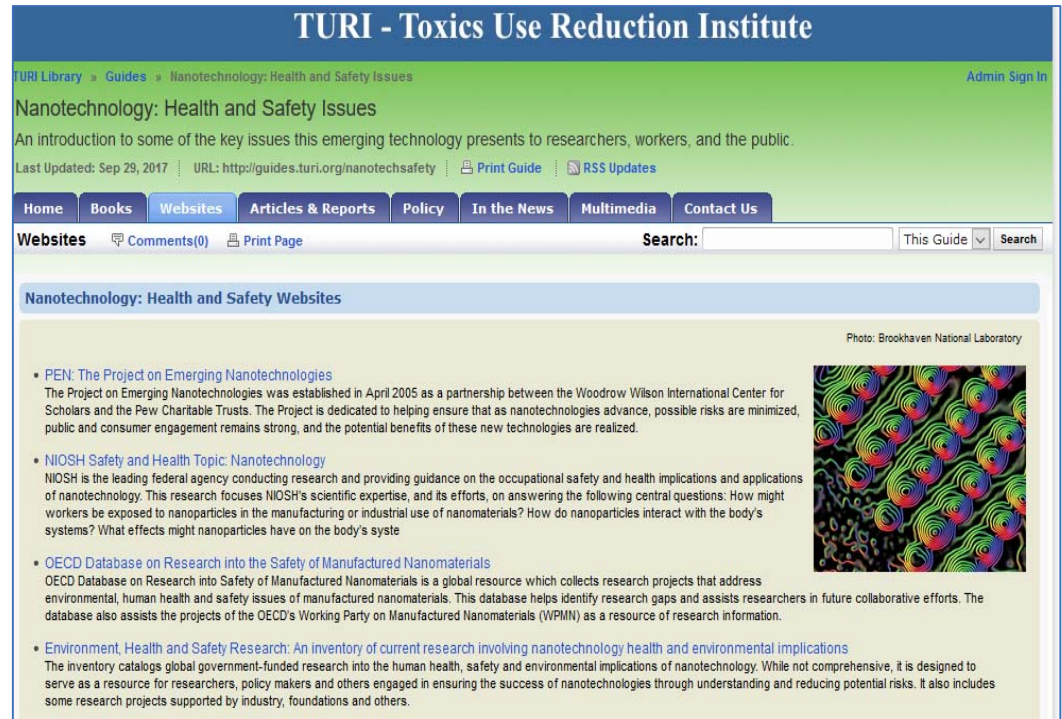
Resources

- Nanomaterials Fact Sheet (www.turi.org/nano)
- TURI Webpage on Engineered Nanomaterials (https://www.turi.org/Our_Work/Policy/Policy_Resources/Engineered_Nanomaterials)

The screenshot shows the TURI website interface. At the top, there is a navigation bar with 'UMass Lowell', 'Site Map', and 'Contact Us'. Below this is the TURI logo and the tagline 'Making Massachusetts a Safer Place to Live and Work'. A search bar is also present. The main navigation menu includes 'ABOUT', 'OUR WORK', 'LIBRARY', 'PUBLICATIONS', and 'NEWS'. The current page is 'TURI » Our Work » Policy » Policy Resources » Engineered Nanomaterials'. On the left, a sidebar lists 'Policy Resources' including REACH, WEEE and RoHS Directives, and 'Engineered Nanomaterials' with a link to 'The Toxic Substances Control Act (TSCA)'. The main content area is titled 'Engineered Nanomaterials' and contains a detailed paragraph about engineered nanomaterials, a section on 'TURI's activities on nanomaterials', and a list of 'Additional resources' with links to NIOSH, the Woodrow Wilson International Center for Scholars, and the OECD. On the right, there are two columns: 'Publications' listing 'Nanomaterials Fact Sheet', 'Nanoscale Lead-free Solders', 'SAFER: Design Principles for Nanotechnology', 'Engineered Nanoparticles: Safer Substitutes for Toxic Materials, or a New Hazard?', 'Precarious Promise: A Case Study of Carbon Nanotubes', and 'Exposure Assessment and Safety Consideration for Working Safely with Engineered Nanoparticles'; and 'Recent Nanomaterials Presentations' listing 'Toxicology and Health Effects Associated with Engineered Nanoparticles', 'Update on Engineered Nanomaterials', and 'Update on Nanotechnology EHS'.

More Resources

- TURI Library
 - Books
 - Reports
 - Databases
- Nanomaterials EH&S Library Guide



The screenshot displays the TURI (Toxics Use Reduction Institute) website. The header includes the TURI logo and navigation links for Home, Books, Websites, Articles & Reports, Policy, In the News, Multimedia, and Contact Us. The main content area is titled "Nanotechnology: Health and Safety Issues" and provides an introduction to the key issues this emerging technology presents. It includes a "Last Updated" date of Sep 29, 2017, and a URL: <http://guides.turi.org/nanotechsafety>. Below the header, there is a search bar and a "This Guide" dropdown menu. The main content area features a section titled "Nanotechnology: Health and Safety Websites" with a list of resources:

- [PEN: The Project on Emerging Nanotechnologies](#)
The Project on Emerging Nanotechnologies was established in April 2005 as a partnership between the Woodrow Wilson International Center for Scholars and the Pew Charitable Trusts. The Project is dedicated to helping ensure that as nanotechnologies advance, possible risks are minimized, public and consumer engagement remains strong, and the potential benefits of these new technologies are realized.
- [NIOSH Safety and Health Topic: Nanotechnology](#)
NIOSH is the leading federal agency conducting research and providing guidance on the occupational safety and health implications and applications of nanotechnology. This research focuses NIOSH's scientific expertise, and its efforts, on answering the following central questions: How might workers be exposed to nanoparticles in the manufacturing or industrial use of nanomaterials? How do nanoparticles interact with the body's systems? What effects might nanoparticles have on the body's systems?
- [OECD Database on Research into the Safety of Manufactured Nanomaterials](#)
OECD Database on Research into Safety of Manufactured Nanomaterials is a global resource which collects research projects that address environmental, human health and safety issues of manufactured nanomaterials. This database helps identify research gaps and assists researchers in future collaborative efforts. The database also assists the projects of the OECD's Working Party on Manufactured Nanomaterials (WPMN) as a resource of research information.
- [Environment, Health and Safety Research: An inventory of current research involving nanotechnology health and environmental implications](#)
The inventory catalogs global government-funded research into the human health, safety and environmental implications of nanotechnology. While not comprehensive, it is designed to serve as a resource for researchers, policy makers and others engaged in ensuring the success of nanotechnologies through understanding and reducing potential risks. It also includes some research projects supported by industry, foundations and others.

A photo of a colorful, textured surface, likely a nanomaterial, is shown on the right side of the page, credited to Brookhaven National Laboratory.

Questions?

- Contact us:

Molly Jacobs



Molly_Jacobs@uml.edu
978-934-4943

Dr. Mike Ellenbecker



Mike@turi.org
978-934-3272

Dr. Gregory Morose



Gregory_Morose@uml.edu
978-934-2954

Mary Butow



Mary@turi.org
978-934-4365