Nanomaterial/ Nanotechnology Hazards and Controls

Outline

- What are nanomaterial/nanotechnology
- History
- Types of nanomaterial/nanotechnology
- Industries that use or make nanomaterial
- Agency Overview on Nanomaterial and Technology
  - NIOSH
  - EPA
  - Others
- Type of processes used to make nanomaterial
- Hazards - Toxicity

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Outline

- Exposure routes
  - Inhalation
  - Adsorption
  - Ingestion
  - Injection
- Engineering Controls
- Personal Protective Equipment
- Interactions with the body
- Interactions with the environment
- Hazardous Material Inspection
- Hazards to Fire Departments - Emergencies
- Q&A

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Nanomaterials

- Nanotechnology relies on the ability to design, manipulate, and manufacture particles at the nanoscale.
- These particles are called nanoparticles or nanomaterials.
- Manufactured nanoparticles are now in more than 1,300 commercial products including medical equipment, textiles, fuel additives, cosmetics, plastics and more.
- EPA scientists are researching the most prevalent nanomaterials that have implications toward human and environmental health. That research is presently focused on developing a scientific foundation to better understand, predict and manage the challenges of engineered nanomaterials.

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Size of operations

- Currently, most production facilities are relatively small, with lab, bench, or, at most, pilot plant operations [Genaidy et al. 2009].
- This is also indicative of downstream users (applications and product development). As new manufacturing processes and technologies are developed and introduced, novel materials with unknown toxicological properties will require effective risk management approaches.
- As more of these products enter the market, concern about the health and safety of the workers grows.

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Sector Growth

- In March 2006, the Woodrow Wilson International Center for Scholars created an inventory of 212 consumer products or product lines that incorporate nanomaterials
- As of March 2011, the number of consumer products has increased by 521% (212 to 1,317 nano-enabled products) with products coming from more than 24 nations [WWICS 2011].
  - the largest product category with 738 products was health and fitness.
  - The most common type of nanomaterial used in these products was silver (313 products), followed by carbon (91 products) and titanium dioxide (59 products).
- These products include acne lotions, antimicrobial treatment for socks, sunscreens, food supplements, components for computer hardware (such as processors and video cards), appliance components, coatings, and hockey sticks.

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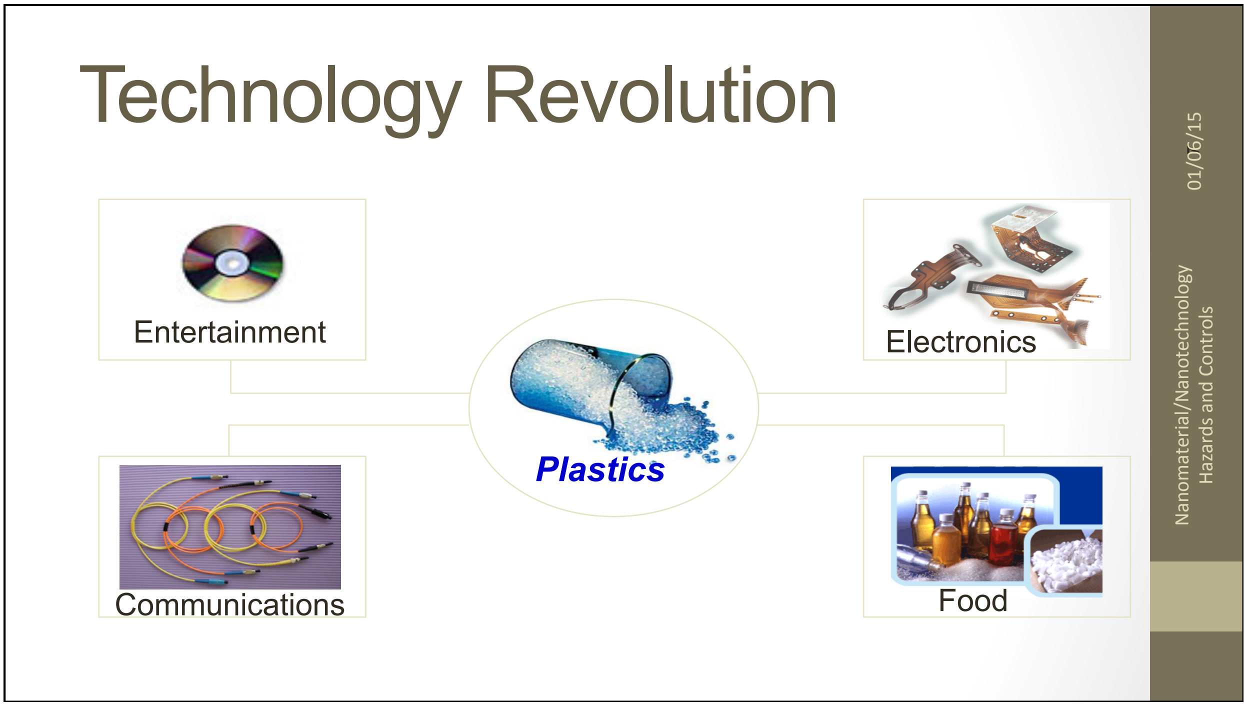
Technology Revolution
Entertainment
Electronics
Plastics
Communications
Food
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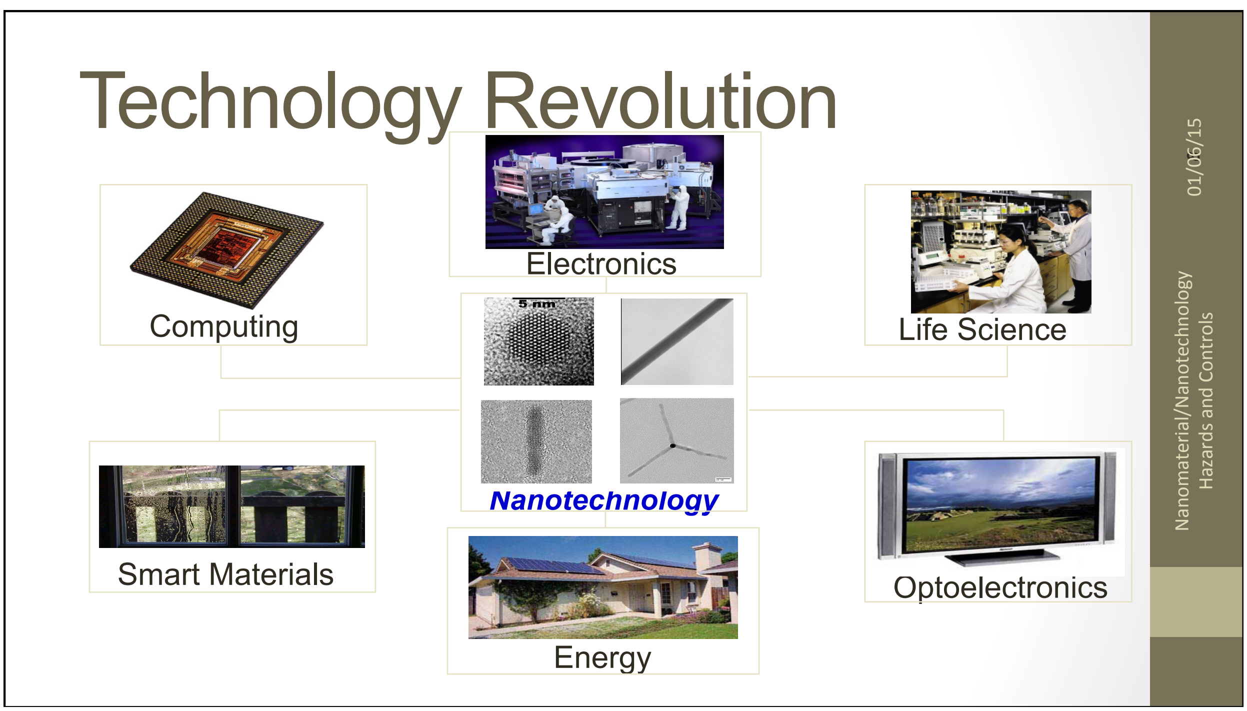
Technology Revolution
Electronics
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Life Science
5 nm
Nanotechnology
Smart Materials
Optoelectronics
Energy
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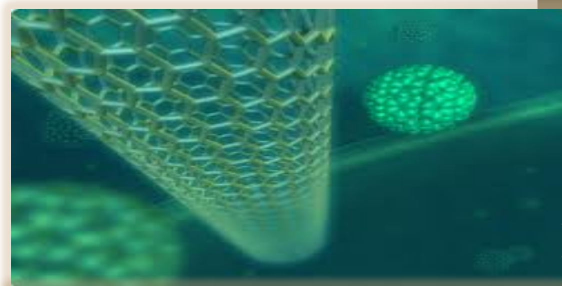
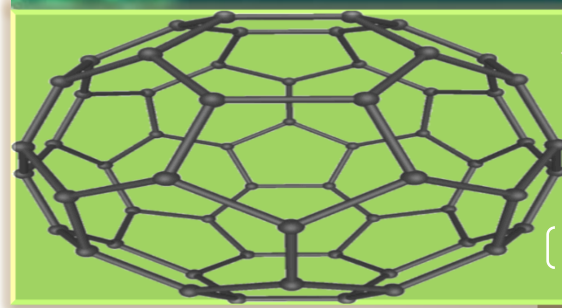
Definition

- Nanotechnology is the study of manipulating matter on an atomic scale.
- Nanotechnology refers to the constructing and engineering of the functional systems at very micro level or we can say at atomic level.
- A Nanometer is one billionth of a meter, roughly the width of three or four atoms. The average human hair is about 75-100,000 nanometers wide.





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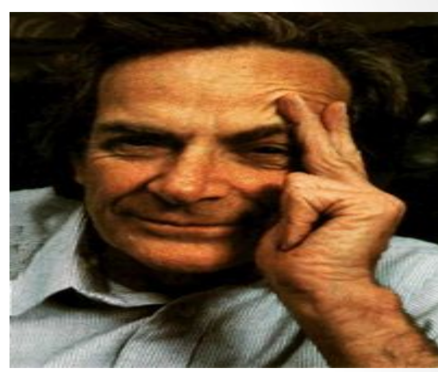
History

- The first ever concept was presented in 1959 by the famous professor of physics Dr. Richard P.Feynman.
- Invention of the scanning tunneling microscope in 1981 and the discovery of fullerene(C60) in 1985 lead to the emergence of nanotechnology.
- The term “Nano-technology" had been coined by Norio Taniguchi in 1974



THERE’S PLENTY OF ROOM AT THE BOTTOM

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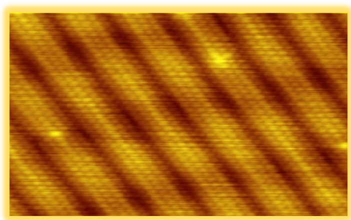

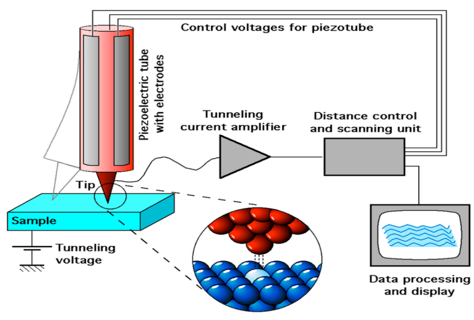

- The early 2000s saw the beginnings of commercial applications of nanotechnology, although these were limited to bulk application of nanomaterials.
- Silver nano platform for using silver-nanoparticles as an antibacterial agent , nanoparticle-based transparent sunscreens, and carbon nanotubes for stain-resistant textiles.

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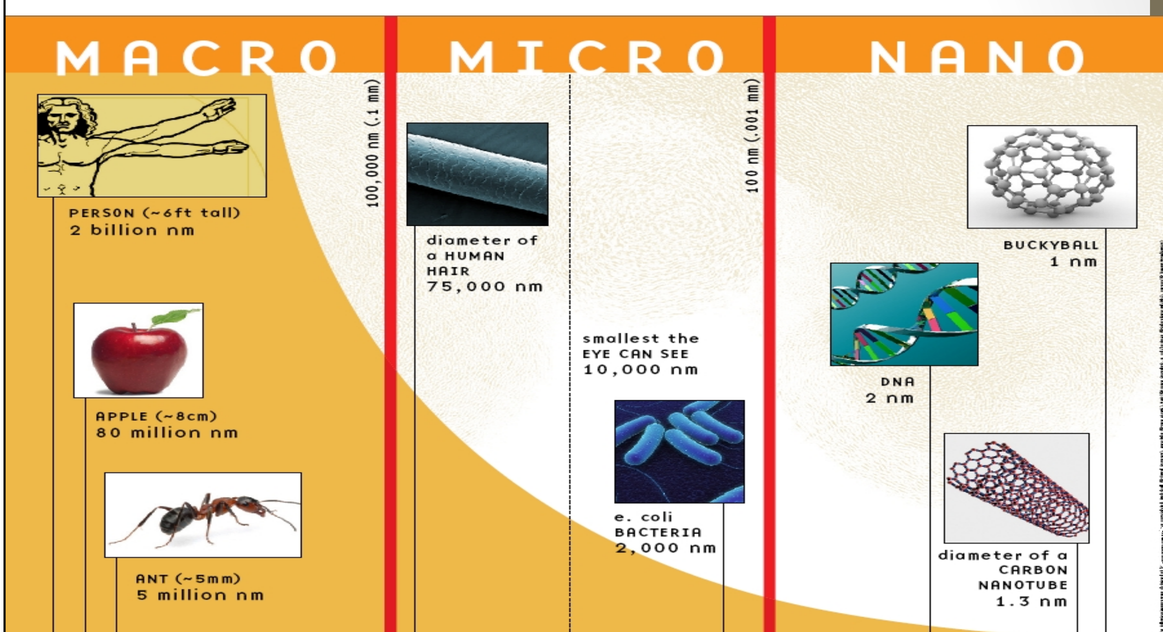

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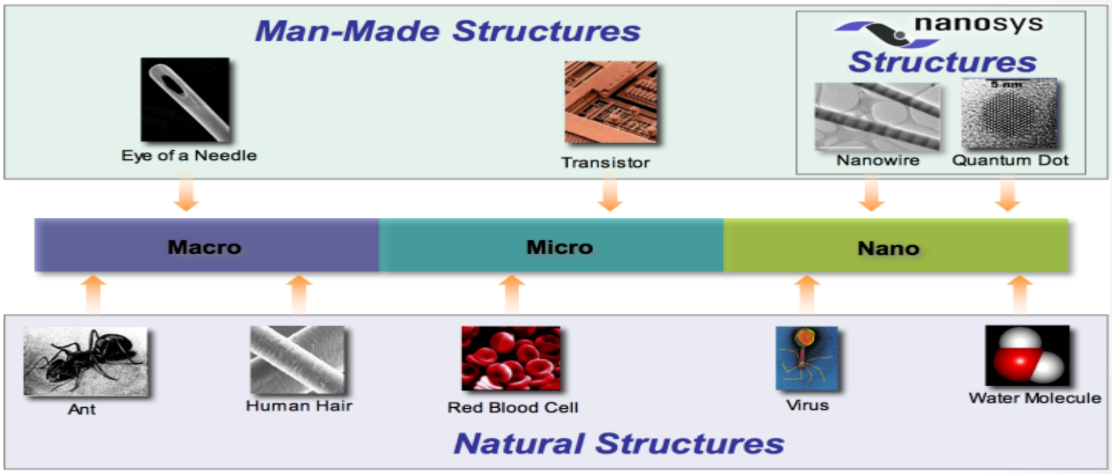
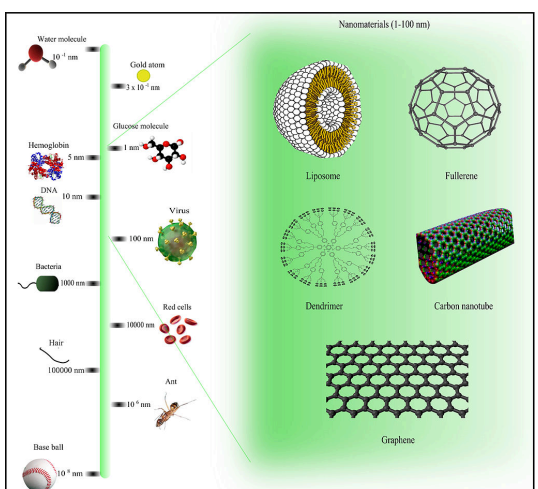


Size Comparison



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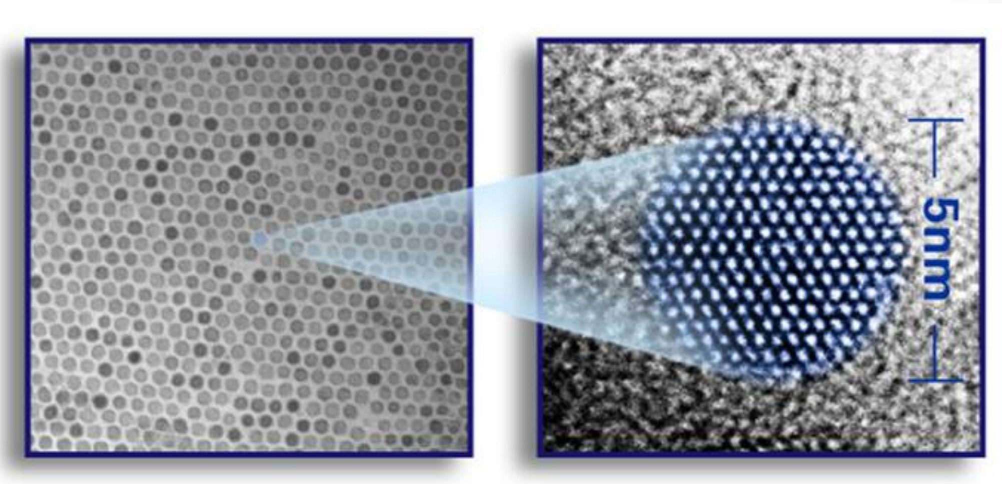
Perfectly Small Structures



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Recent Nanotechnology

- The first integrated circuits using three-dimensional carbon nanotubes. These could be vital in maintaining the growth of computer power, allowing Moore's Law to continue.
- Solar panels with greater efficiency through the use of nanotechnology materials.
- Water purification bottles, with filters only 15 nanometers in width, allowing military personnel and also civilians hit by disasters to create safe drinking water (even if that water comes from a filthy source).
- Military equipment made lighter and stronger through the use of nanomaterial composites.
- Nanostructured polymers in display technologies allowing brighter images, lighter weight, less power consumption and wider viewing angles.

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Recent Nanotechnology

- Nanotechnology surfaces which are highly resistant to bacteria, dirt and scratches.
- New fabrics that are highly resistant to liquid, causing it to simply fall off without leaving any dampness or stains.
- Nanostructured catalysts used to make chemical manufacturing processes more efficient, saving energy and reducing waste products.
- Pharmaceutical products reformulated with nanosized particles to improve their absorption and make them easier to administer.
- There are many other applications and the list is growing all the time.

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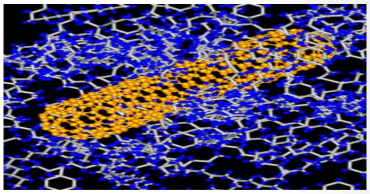
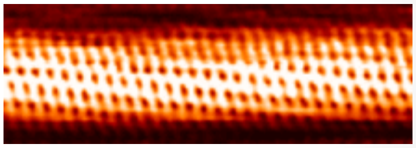
Carbon Nanotube



- Carbon nanotubes are allotropes of carbon with a cylindrical nanostructure.
- They have length-to-diameter ratio of up to 132,000,000:1.
- Nanotubes are members of the fullerene structural family. Their name is derived from their long, hollow structure with the walls formed by one-atom-thick sheets of carbon, called grapheme.
- Properties
  - Highest strength to weight ratio, helps
    - in creating light weight spacecraft (many others).
  - Easily penetrate membranes such as cell walls. Helps in cancer treatment.
  - Electrical resistance changes significantly when other molecules attach themselves to the carbon atoms. Helps in developing sensors that can detect chemical vapors.



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About Nanosys

Nanosys is the premier developer and manufacturer of Quantum Dots, the best emitter material in the world

More compelling and realistic images and video

Missing: London Bus Red

Missing: Pacific Surf Cyan

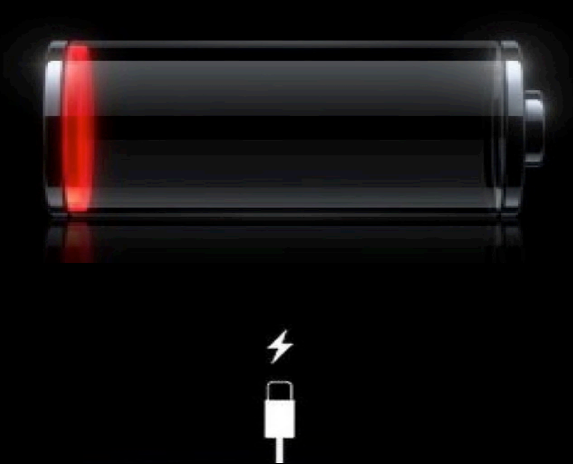
Standard Display

Dolby Vision Display with QD

Why Quantum Dots?

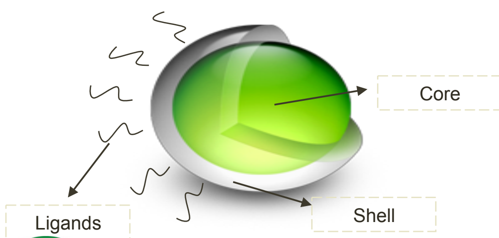
Quantum Dots are **a new advanced materials system** that enables device makers to deliver not just more but better pixels with:

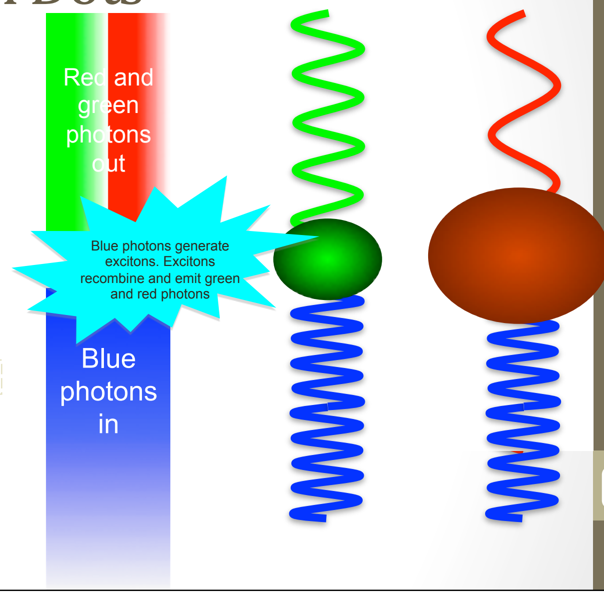
- Lower Power Consumption
- Lifelike Color
- High Brightness



Core Shell Quantum Dots

- Core shell quantum dots are manufactured using a cost effective liquid phase chemistry process
- The size of a core shell quantum dot determines wavelength, and thus color output





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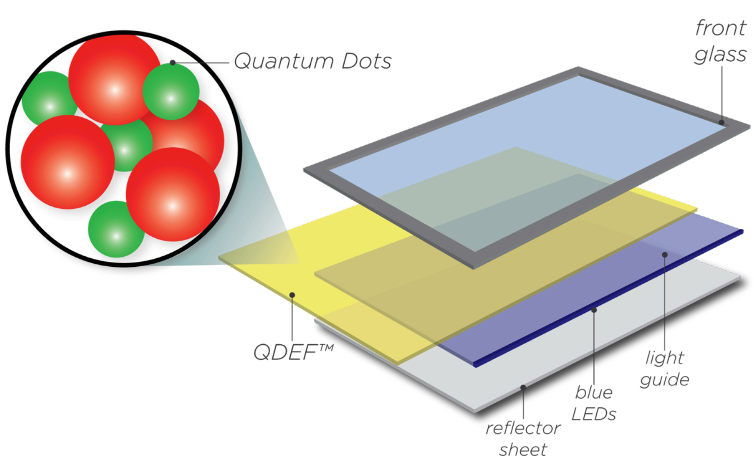
QDEF Optical Film Leveraging LCD Infrastructure with simple "drop-in" design



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Technology

- Oxidation Furnaces
- Sputtering
- Evaporative
- Chemical Vapor Deposition
- Reactor Vessels
- Grinding

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Gas phase processes, including flame pyrolysis, high-temperature evaporation, and plasma synthesis.

- This process involves the growth of nanoparticles by homogenous nucleation of supersaturated vapor. Nanoparticles are formed in a reactor at high temperatures when source material in solid, liquid, or gaseous form is injected into the reactor. These precursors are supersaturated by expansion and cooled prior to the initiation of nucleated growth. The size and composition of the final materials depend on the materials used and process parameters.

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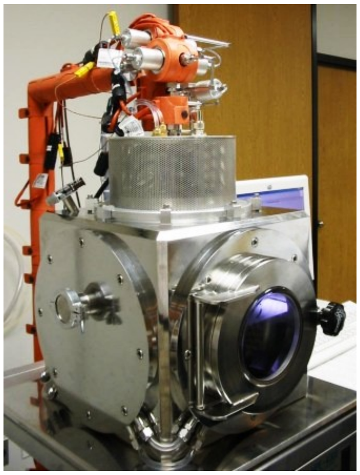
Chemical vapor deposition (CVD).

- This process has been used to deposit thin films of silicon on semiconductor wafers. The chemical vapor is formed in a reactor by pyrolysis, reduction, oxidation, and nitridation and deposited as a film with the nucleation of a few atoms that coalesce into a continuous film. This process has been used to produce many nanomaterials including TiO2, zinc oxide, silicon carbide, and, possibly most importantly, CNTs. The use of fluidized bed technology has been adopted as a way to prepare CNTs on a large scale at low cost [Wang et al. 2002]. This technology fluidizes CNT agglomerates and produces high yields necessary for larger-scale operations.



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Colloidal or liquid phase methods

- Chemical reactions in solvents lead to the formation of colloids. Solutions of different ions are mixed to produce insoluble precipitates. This method is a fairly simple and inexpensive way to produce nanoparticles and is often used for the synthesis of metals (e.g., gold, silver). These nanomaterials may remain in liquid suspension or may be processed into dry powder materials often by spray drying and collection through filtration.

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Mechanical processes including grinding, milling, and alloying.

- These processes create nanomaterials by a "top-down" method that reduces the size of larger bulk materials through the application of energy to break materials into smaller and smaller particles. This technique has been referred to as nanosizing or ultrafine grinding.

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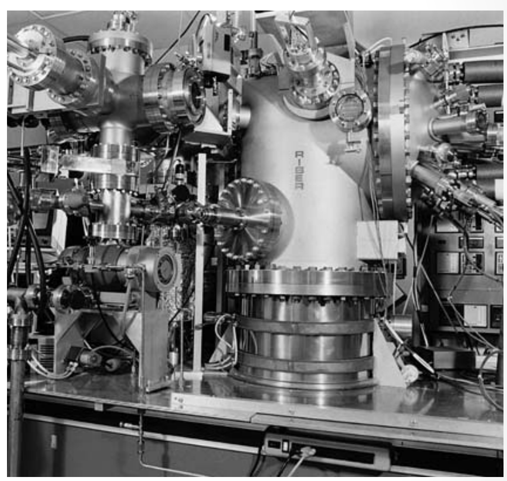
Atomic and molecular beam epitaxy

- Atomic layer epitaxy is the process of depositing monolayers (i.e., layers one molecule thick) of alternating materials and is commonly used in semiconductor fabrication. Molecular beam epitaxy is another process for depositing highly controlled crystalline layers onto a substrate.



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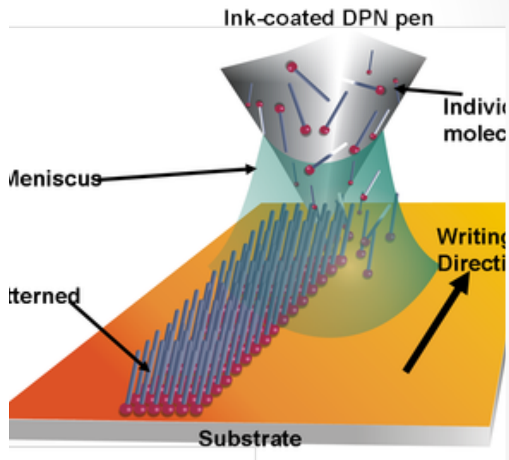
Dip pen lithography

- A “bottom-up” method is a production process that involves depositing a chemical on the surface of a substrate using the tip of an atomic force microscope (AFM). The AFM tips are coated with the chemical, which is directly deposited on a substrate in a specific pattern.



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Gas phase processes, including flame pyrolysis, high-temperature evaporation, and plasma synthesis.

- Downstream processes use engineered nanomaterials for product application and development.
- Examples of these tasks or operations include
  - weighing,
  - dispersion/sonication,
  - mixing,
  - compounding/extrusion,
  - electro-spinning,
  - packaging, and
  - maintenance.
- These activities should be evaluated for potential sources of exposure.

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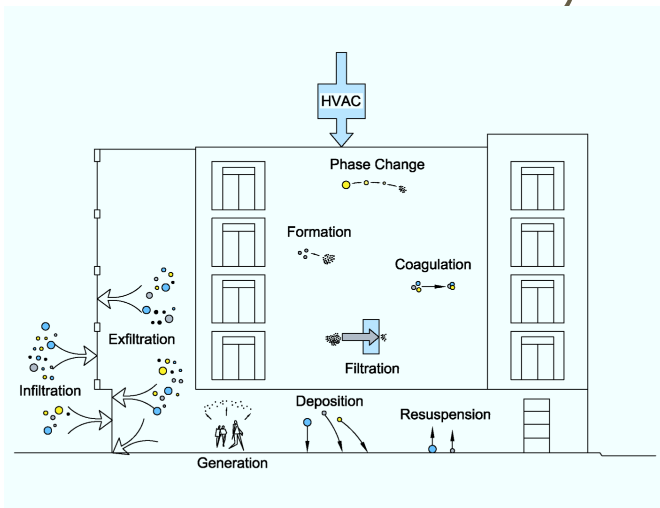
Airborne Particulate Dynamics



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Dimensions

Category of nanomaterials	examples
One-dimensional nanomaterials	layers, multi-layers, thin films, platelets and surface coatings. They have been developed and used for decades, particularly in the electronics industry.
Two-dimensional nanomaterials	nanowires, nanofibers made from a variety of elements other than carbon, nanotubes and, a subset of this group, carbon nanotubes.
Three-dimensional nanomaterials	are known as nanoparticles and include precipitates, colloids and quantum dots (tiny particles of semiconductor materials), and Nanocrystalline materials

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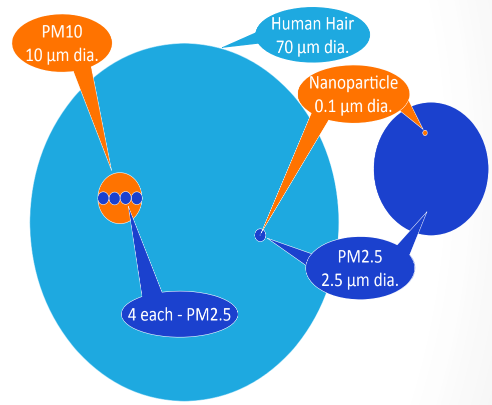
Particulate Matter Types PM10

- PM10 refers to particles with diameters that are less than or equal to 10 µm in size
- Examples – Building demolition, soil activities



Fine Particles (PM2.5)

- Travel into the respiratory tract, and reach deeply into the lungs.
- Cause short-term health effects:
  - eye, nose, throat, and lung irritation,
  - coughing, sneezing, runny nose, and shortness of breath.
  - worsen medical conditions such as asthma and heart disease.
- Children and the elderly may be particularly sensitive.
- Diesel PM is listed TAC (potential to cause cancer, premature death, and other health problems

Fine Particles (PM2.5)

- Exhaust – on-road and off-road vehicles
- Demolition, Soil Activities, Welding, Fueling,
- Burning of fuels – Furnace, Stove, Fireplace
  - Wood smoke from the 1.4 million woodstoves and fireplaces contributes about one-third of the overall PM pollution (Source: BAAQMD)
- Natural sources such as forest and grass fires.

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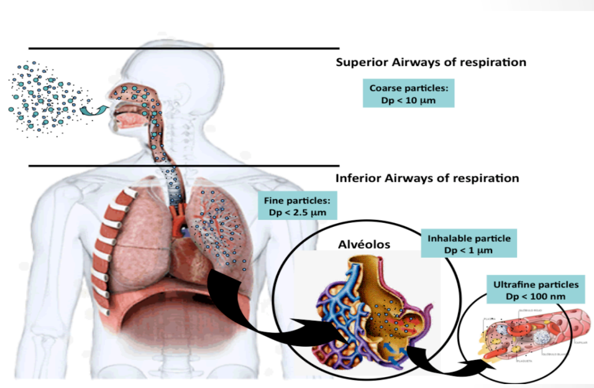
Ultrafine Particles (Nanoparticle)

- Ultrafine particles are defined as having a diameter less than 0.1 µm (or 100 nm).
- The health effects are expected to be similar or worse than that of PM2.5
- Ex: Exhaust, Smoke



Source: Biofuels - Economy, Environment and Sustainability, ISBN 978-953-51-0950-1

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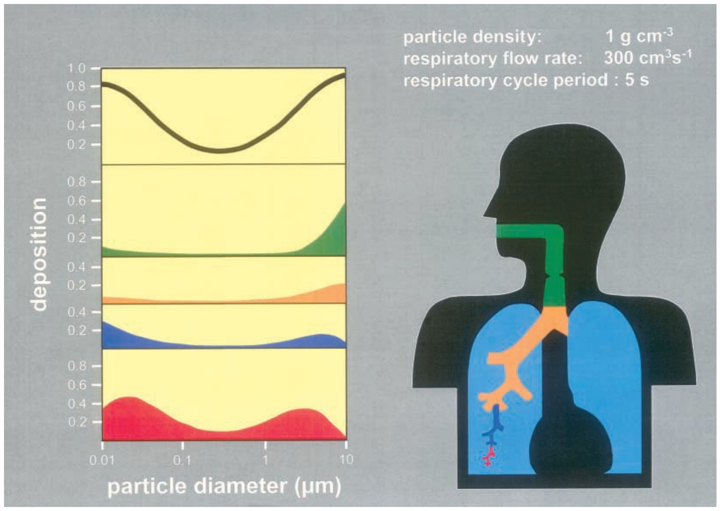

Total and Regional Deposition of Particles in the Human Respiratory Tract

_((ICRP), 1994) (Heyder, 2004)

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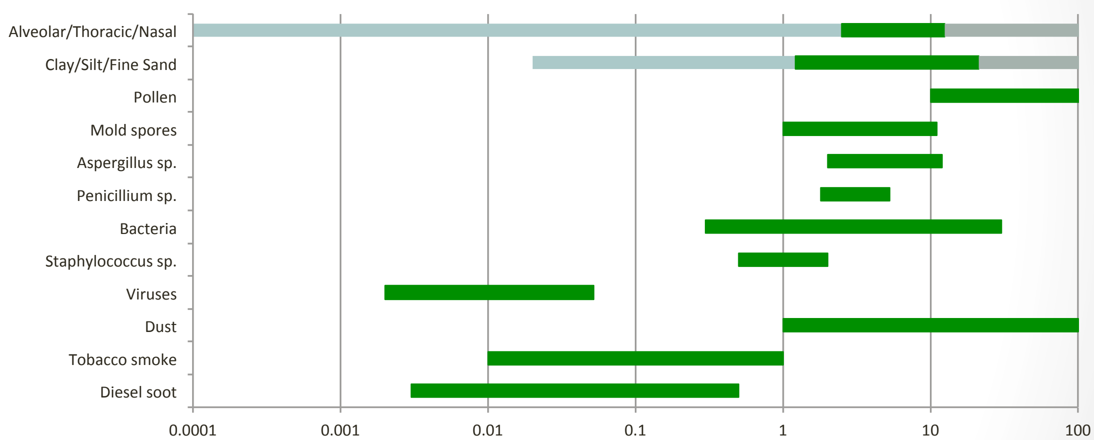
Particle Size Ranges



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Settling Velocities Estimated Using Stokes Equations

Particle Diameter (µm)	Settling Velocity (m/sec)	Time to Fall 1 Meter (minutes)	Comments
1.5	7.5E-05	223	
2	1.3E-04	166	
3	2.9E-04	58	Approx. size of *Penicillium* spores
4	5.0E-04	33	Approx. size of *Aspergillus* spores
5	7.8E-04	21	
6	1.1E-03	15	Approx. size of *Stachbotrys* spores
8	2.0E-03	8	
10	3.2E-03	5	Approx. size of *Alternaria* spores
15	6.8E-03	2	
20	1.2E-02	1	

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Cleanroom Standards

	Particles/0.15 ft³ (cumulative counts)					
Class	> 0.1 µm	> 0.2 µm	> 0.3 µm	> 0.5 µm	> 1.0 µm	> 5.0 µm
ISO 1	0.04	0.01				
ISO 2	0.42	0.1	0.04	0.02		
ISO 3	4.25	1.01	0.43	0.15	0.03	
ISO 4	42.5	10.1	4.33	1.5	0.35	
ISO 5	425	101	43	15	4	0.12
ISO 6	4248	1007	433	150	35	1.24
ISO 7				1495	353	12.4
ISO 8				14953	3534	124
ISO 9				149533	35344	1245

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Agency Overview - NIOSH

- 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.

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NIOSH – 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 chemistry are responsible for observed responses in cell cultures and animals. Studies suggests that some nanoparticles can move from the respiratory system to other organs. Research is continuing to understand how these unique properties may lead to specific health effects.

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The NIOSH Effort

- NIOSH leads the federal government nanotechnology initiative.
- Research and activities are coordinated through the NIOSH Nanotechnology Research Center (NTRC) established in 2004.

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NIOSH Control

- Health and Safety Management System
- Conducting a preliminary hazard assessment (PHA) encompasses a qualitative life cycle analysis of an entire operation, appropriate to the stage of development:
  - Chemicals/materials being used in the process
  - Production methods used during each stage of production
  - Process equipment and engineering controls employed
  - Worker's approach to performing job
  - Exposure potential to the nanomaterials from the task/ operations
  - The facility that houses the operation

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NIOSH NTRC strategic goals

- Increase understanding of new hazards and related health risks to nanomaterial workers.
- Expand understanding of the initial hazard findings of engineered nanomaterials.
- Support the creation of guidance materials to inform nanomaterial workers, employers, health professionals, regulatory agencies, and decision makers about hazards, risks, and risk management approaches.
- Support epidemiologic studies for nanomaterial workers, including medical, cross-sectional, prospective cohort, and exposure studies.
- Assess and promote national and international adherence with risk management guidance.

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Why is EPA studying nanomaterials?

- Currently, knowledge of the unique features of nanomaterials that influence their behavior in environmental and biological systems is inadequate for predicting potential impacts across the materials' lifecycle.
- We need new models and data to support the development of more efficient and comprehensive engineered nanomaterials (ENM) testing procedures.

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What are the unique characteristics of nanomaterials?

- The rapid and diverse growth of engineered nanomaterials presents a challenge for regulators and risk assessors to understand potential for exposure causing adverse health effects and whether methods used for assessing conventional chemicals can be applied for these novel materials.
- Identification and characterization of the role that key chemical and physical features of nanomaterials play in the behavior of engineered nanomaterials will enable the development of predictive models that can be used to differentiate between the nanomaterials that may pose a higher probability of risk and those expected to have little impact.

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What nanomaterials are EPA studying?

- Nanoparticles are produced from a variety of materials including metals such as copper, silver, and iron, metal oxides including titanium dioxide, cerium dioxide, and carbon-based materials such as carbon nanotubes and grapheme.
- Materials are selected for study based on their prevalence in the marketplace, and the ability to reveal the role of physical and chemical properties of nanomaterials in determining their behavior in environment.

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Nano Silver:

- Because silver nanoparticles have antibacterial, antifungal and antiviral properties, they are used in medical equipment, textiles and cosmetics, fabrics, plastics and other consumer products.
- EPA is researching the fate and transport of silver nanoparticles and how they interact with the environment.
- EPA is developing methods to measure Nano silver concentration and characteristics such as size, shape, surface charge, and surface chemistry to better understand the role of these physical and chemical properties.

Carbon Nanotubes:

- Are one of the most abundant classes of nanomaterials, and come in a variety of shapes and sizes.
- Carbon materials have a wide range of uses, including structural composites for vehicles or sports equipment, coatings, textiles, polymers, plastics and integrated circuits for electronic components.
- The interactions between carbon nanotubes and natural organic matter strongly affect their transport, transformation and exposure in aquatic environments.
- EPA research will evaluate the physical and chemical properties of carbon nanotubes that influence their behavior in the environment and in biological systems.

Cerium dioxide:

- Nanoscale cerium dioxide is used in electronics, plastics, biomedical supplies, energy, fuel additives, and other consumer products.
- One application of cerium dioxide nanoparticles, in particular, leads to dispersion in the environment, which is the use as a fuel-borne catalyst in diesel engines.
- There is ongoing research to evaluate exposure to cerium dioxide from diesel emissions and the potential for environmental and public health impacts.
- Researchers Examine Nanoparticles' Impact on Fuel Emissions and Air Pollution

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Titanium dioxide:

- Nano titanium dioxide is currently used in many products. Depending on the type of particle, it may be found in sunscreens, cosmetics, paints and coatings, photovoltaic and other electronic devices.
- Titanium dioxide may become activated by ultraviolet radiation, a normal component of sunlight, to catalyze reactions that can be toxic to fish and other aquatic species under certain conditions.
- EPA is researching the potential for titanium dioxide nanoparticles to be released from consumer products and enter the environment, to be transformed in the environment, and to become toxic to sensitive environmental species or to humans

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Iron:

- Nano-scale iron is being investigated for many uses, including "smart fluids" for uses such as optics polishing and as a better-absorbed iron nutrient supplement.
- One important use of nano zero-valent iron particles is to catalyze the breakdown of chlorinated hydrocarbon compounds that are among the most common toxic contaminants in hazardous waste sites.
- The injection of zerovalent iron into such sites is a relatively inexpensive and rapid way to reduce the presence of these otherwise persistent hazardous environmental pollutants.
- EPA research is being conducted to assure that this beneficial use of nanotechnology is not associated with unwanted or unexpected adverse side effects on human health or the environment.
- This research will help assure the safe and beneficial use of nanotechnology for environmental remediation

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Micronized Copper:

- Micron sized and nanometer sized copper particles are used as preservatives in pressure treated lumber and in anti-fouling paints and coatings.
- EPA is working with the Consumer Product Safety Commission to evaluate if there is a potential for release of copper particles or copper ions from such products under normal use and wear.
- If copper is released into the environment, research will assess the potential for exposure and adverse effects on human or the ecosystem.

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How will EPA use this research?

- EPA will use this research to develop research protocols for characterizing engineered nanomaterials (ENMs) and for evaluating exposure and toxicity in complex biological or environmental systems.
- This research will allow EPA scientists to evaluate the relationships between the physical and chemical properties of ENMs and their fate, transport, and effects which could lead to safer and more sustainable ENMs.

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OSHA – Cal/OSHA

- The General Duty Clause, Section 5(a)(1) of the Occupational Safety and Health Act, also may apply in situations where workers handle or are exposed to nanomaterials.
- States with OSHA-approved state plans may have additional standards that apply to nanotechnology.
  - Injury and Illness Prevention Program

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Exposure Routes

- Inhalation
- Adsorption
- Ingestion
- Injection

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Methods Employers Can Use to Reduce Worker Exposure to Nanomaterials

- Because the research and use of nanomaterials continues to expand and information about potential health effects and exposure limits for these nanomaterials is still being developed, employers should use a combination of the following measures and best practices to control potential exposures:

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Methods Employers Can Use to Reduce Worker Exposure to Nanomaterials

- The hierarchy of controls should be followed when controlling potential occupational hazards from nanoparticles. Elimination and substitution are at the top of the hierarchy. However, eliminating nanomaterials may not be possible as the nanomaterials were likely chosen because of their unique properties. The manner in which these materials are handled and processed can largely affect the overall safety of the process.
- The substitution of less hazardous materials for those that are a higher hazard should be considered to reduce the risk to workers. Substitution also applies to the form of the product used; for example, a slurry with less exposure potential could be used to replace a dry powder.

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Engineering Controls

- Preventative maintenance schedules should be developed to ensure that engineering controls are operating at design conditions.
- Work with nanomaterials in ventilated enclosures (e.g., glove box, laboratory hood, process chamber) equipped with high-efficiency particulate air (HEPA) filters.
- Where operations cannot be enclosed, provide local exhaust ventilation (e.g., capture hood, enclosing hood) equipped with HEPA filters and designed to capture the contaminant at the point of generation or release.

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Engineering Controls

- Non-ventilation engineering controls cover a range of controls (e.g., guards and barricades, material treatment, or additives). These controls should be used in conjunction with ventilation measures to provide an enhanced level of protection for workers. Many devices developed for the pharmaceutical industry, including isolation containment systems, may be suitable for the nanotechnology industry.
  - a. The continuous liner system allows filling product containers while enclosing the material in a polypropylene bag. This system should be considered for off-loading materials when the powders are to be packed into drums.
  - b. Water sprays may reduce respirable dust concentrations generated from processes such as machining (e.g., cutting, grinding). Machines and tooling, as well as the material being cut or formed, must be compatible with water. If a fluid other than water is used, attention should be given to the fluid being applied to avoid creating a health hazard to workers.

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Standard 52.5 Minimum Efficiency Reporting Value	Dust Spot Efficiency	Arrestance	Typical Controlled Contaminant	Typical Applications and Limitations	Typical Air Filter/Cleaner Type
20	n/a	n/a	< 0.30 pm particle size	Cleanrooms	≥99.999% eff. On .10-.20 pm Particles
19	n/a	n/a	Virus (unattached)	Radioactive Materials	Particles
18	n/a	n/a	Carbon Dust	Pharmaceutical Man.	Particulates
17	n/a	n/a	All Combustion smoke	Carcinogenetic Materials	≥99.97% eff. On .30 pm Particles
16	n/a	n/a	.30-1.0 pm Particle Size	General Surgery	**Bag Filter**- Nonsupported
15	>95%	n/a	All Bacteria	Hospital Inpatient Care	microfine fiberglass or
14	90-95%	>98%	Most Tobacco Smoke	Smoking Lunges	synthetic media, 12-36 in. deep, 6-12 pockets
13	89-90%	>98%	Proplet Nuceli (Sneeze)	Superior Commercial Buildings	**Box Filter**- Rigid Style Cartridge Filters 6 to 12" deep m ay use lofted or paper media.
12	70-75%	>95%	1.0-3.0 pm Particle Size	Superior Residential	**Bag Filter**- Nonsupported
			Legionella		microfine fiberglass or
11	60-65%	>95%	Humidifier Dust	Better Commercial Buildings	synthetic media, 12-36 in. deep, 6-12 pockets
			Lead Dust		
10	50-55%	>95%	Milled Flour		**Box Filter**- Rigid Style Cartridge Filters 6 to 12" deep m ay use lofted or paper media.
			Auto Emissions	Hospital Laboratories	
9	40-45%	>90%	Welding Fumes		
8	30-35%	>90%	3.0-10.0 pm Particle Size	Commercial Buildings	**Pleated Filters**- Disposable, extended surface area, thick with cotton-polyester blend media, cardboard frame
			Mold Spores		
7	25-30%	>90%	Hair Spray	Better Residential	**Cartridge Filters**- Graded density viscous coated cube or pocket filters, synthetic media
			Fabric Protector		
6	<20%	85-90%	Dusting Aids	Industrial Workplace	**Throwaway**- Disposable synthetic panel filter.
			Cement Dust		
5	<20%	80-85%	Pudding Mix	Paint Booth Inlet	

MERV Filter

- Need to verify that Manufacture is doing all rating test not just one
- Tested per Standard 52.2-2012?

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Administrative Controls

- Provide hand washing facilities and information that encourages the use of good hygiene practices.
- Establish procedures to address cleanup of nanomaterial spills and decontamination of surfaces to minimize worker exposure.
  - For example, prohibit dry sweeping or use of compressed air for cleanup of dusts containing nanomaterials, use wet wiping and vacuum cleaners equipped with HEPA filters.

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Personal Protective Equipment (PPE)

- Provide workers with appropriate personal protective equipment such as respirators, gloves and protective clothing.

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Medical Screening and Surveillance

- Make available medical screening and surveillance for workers exposed to nanomaterials if appropriate.
- Review medical surveillance requirements under OSHA standards (e.g., Cadmium, Respiratory Protection).

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What We Know About Exposure to Nanomaterials

- Information from research and animal studies on nanomaterials has identified some potential safety hazards and health effects.
- Because nanotechnology is a rapidly emerging field, more information will likely become available about potential health and safety hazards associated with some nanomaterials.
- The health hazard potential depends on the particular nanomaterial and a person's exposure level.

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What We Know About Exposure to Nanomaterials

- Certain inhaled nanoparticles may be deposited in the respiratory tract and may cause inflammation and damage to lung cells and tissues; e.g., carbon nanotubes and nanofibers may be capable of causing pulmonary inflammation and fibrosis.
- Titanium dioxide ($TiO2$), which has many commercial applications (e.g., paint, paper, cosmetics, food), can be produced and used in varying particle sizes, including the nanoscale particle sizes (< 100 nm). NIOSH has determined that nanoscale $TiO2$ particles have higher mass-based potency than larger particles, and that occupational exposure (by inhalation) to nanoscale $TiO2$ particles should be considered a potential occupational carcinogen.

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Environmental Exposure

- Center for the Environmental Implications of NanoTechnology The Center for the Environmental Implications of NanoTechnology (CEINT) is exploring the relationship between a vast array of nanomaterials— from natural, to manufactured, to those produced incidentally by human activities— and their potential environmental exposure, biological effects, and ecological impacts.

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Hazardous Material Inspection

- Chemicals Used
- Process Used
- Verify that no additional hazards exist
- Incompatibility
- Separation
- Waste Streams

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Hazards to Fire Departments - Emergencies

- Nanoparticles – Once in the air it takes a long time to settle out
- Reacts faster and can have different properties than it's larger particle counterparts
- Explosive Hazard (Explosive/Combustible Dust)
  - Smaller Particle

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Q&A

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Bio

- Troy Christensen's 25 years of expertise spans through all aspects of sustainability, product stewardship, environmental, health and safety, civil and environmental engineering, operations, management system evaluation and implementation.
- Mr. Christensen has worked with hospitals, high technology, solar, LED, retail, office/consumer products, petrochemical, chemical, manufacturing, biotechnology, transportation, power production, and food and beverage industries, as well as universities and government agencies.

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Bio

- Nanomaterial and Nanotechnology projects: Job Hazard Analysis, Nanoparticle Occupational Exposure Limit Evaluation and Determination, Occupational Exposure Monitoring for Nanoparticles and Nanotubes, Engineering Control Design, Standard Operating Procedure Development, Process Hazard Analysis, Environmental Fate Evaluations, Air Risk Assessments, Personal Protective Equipment Evaluations, Safety Data Sheet Development, New Chemical Pre-manufacture Notice (PMN, LVE, and LOREX) for EPA Toxic Substance Control Act.

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THANK YOU