

Nanotechnology

Nanotechnology - General

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What is nanotechnology?

Nanotechnology is a broad name given to a wide range of technologies and materials that create, manipulate, or use particles that have one thing in common - their size.

Nanotechnology includes the manipulation of extremely small particles to produce new structures, materials, and devices.

Nanotechnology (or nanoscience) involves materials that are extremely small and have dimensions roughly between 1 and 100 nanometres (nm). A nanometre is 1 billionth of a metre. To give you an idea of the scale of nanomaterials:

- A piece of paper is about 100,000 nm thick.
- A human hair is about 70,000 to 80,000 nm.
- A red blood cell is about 7,000 nm.
- A virus is about 10 to 100 nm.

While the exact definition of nanotechnology may vary, most research and studies have concentrated on particles with at least one dimension of less than 100 nm. Health Canada's working definition of nanomaterial is "any manufactured substance or product and any component material, ingredient, device, or structure if:

- it is at or within the nanoscale in at least one external dimension, or has internal or surface structure at the nanoscale
- it is smaller or larger than the nanoscale in all dimensions and exhibits one or more nanoscale properties/phenomena.

For the purposes of this definition:

- The term "nanoscale" means 1 to 100 nanometres, inclusive;
- The term "nanoscale properties/phenomena" means properties which are attributable to size and their effects; these properties are distinguishable from the chemical or physical properties of individual atoms, individual molecules and bulk material; and,
- The term "manufactured" includes engineering processes and the control of matter."

NOTE: There are many types of nanomaterials - they can be particles, tubes, shells, quantum dots, etc. Other terms used are nanoparticles, nanoobjects, or ultrafine particles. For simplicity, we'll use the term nanomaterials to mean any or all of these types.

What does this document cover?

This OSH Answers document provides a brief summary of the research into nanotechnology. It focuses on the health and safety concerns when workers are exposed during the manufacture and use of nanomaterials. It does not summarize concerns for general exposure to consumers (e.g., when an individual uses a product for their personal use).

Nanotechnology is a field that is quickly changing both in terms of how we use it, and in our understanding of it. If you have concerns, you are encouraged to contact the manufacturer or supplier, or look for research in scientific journals for the latest findings.

For more information, please see:

- Nanotechnology – Health and Safety Concerns
 - [Nanotechnology – Controls](#)
 - Nanotechnology - Legislation and Occupational Exposure Limits
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What are nanomaterials?

There are many types of nanomaterials. Nanomaterials can differ by their chemical constituents (e.g., carbon, metal, polymer, etc.), shape, structure (e.g., different dimensions), and physical form (e.g., powder, fibres, tubes, etc.).

They can be particles (zero-dimensional structure), tubes (one-dimensional structure), carbon buckyball (three-dimensional structure), shells, quantum dots (e.g., nanoscale semiconductor materials), fibres, thin films (two-dimensional structure), threads, dendrimers, etc. They can be unbound (i.e., free nanoparticles or not firmly attached to a surface), prepared in solutions, or bound in composite materials or polymeric matrices.

How are nanomaterials made?

Nanomaterials can be naturally occurring, incidental, and man-made.

Nanomaterials can be manufactured intentionally and specifically controlled to be a particular shape, size and functionality. Man-made nanomaterials are created through specific processes that produce purposely built materials with specific properties. These processes can be "top-down" where particles are milled to be smaller by methods such as etching, laser ablation, sputtering or electro-explosion, or "bottom-up" where the atoms and molecules are arranged to create the nanomaterials. In some cases, the nanomaterials can "self-assemble" such as carbon fragments that assemble into nanotubes.

Ultrafine particle is a term sometimes used to describe nanomaterials that were not intentionally produced - these are incidental by-products of processes, or they occur naturally. Sources of ultrafine particles include:

- Combustion by-products, such as from welding, cooking, burning, diesel exhaust, etc.
- DNA, enzymes, antibodies, etc.
- Viruses
- Volcanic ash
- Produced by plants and algae

What makes nanomaterials unique?

Nanomaterials can have characteristics that are very different from when they are in their larger micro or macro (or "normal") form. Often, nanomaterials will be stronger, lighter, more reactive, or conduct electricity differently. For example:

- Nanomaterials have a higher surface area in proportion to their mass. An increased surface area typically means the particle will be more reactive (such as having an increased biological activity by mass when compared to larger particles). This effect can be either a positive or negative quality. It is a positive quality when the particle displays antioxidant activity or can carry drugs to specific organs or cells. But it can be a negative quality when the effect can increase toxicity, increase the oxidative stress of a cell, or destroy the cell or when it increases the risk of a safety hazard such as explosibility.
- The magnetic behaviour of some nanomaterials changes.
- Macro non-metallic substances (e.g., boron) can exhibit metallic properties in nano form (e.g., borophene).
- Nanomaterials can increase the mechanical strength of materials.
- Electrical properties such as electrical conductivity may change.

- Optical properties include when solutions change colour when in nano forms. For example, the macro form of gold in solution is yellow, compared to the nano form which is purple or red.
 - Enhanced catalytic activity or it becomes a catalyst in nanoform.
 - Nanomaterials have different ways of interacting with each other. They can remain free or group together, aggregate, dissolve, or react with other materials.
 - The material may have a higher permeability through biological barriers.
 - Melting temperature changes.
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How is nanotechnology used?

- Common uses currently include:
- Computer hard drives which use the magnetic properties of nanomaterials to store more data on much smaller devices.
- Automotive applications such as rechargeable battery systems, sensors, or catalytic converters on cars.
- Lightweight ballistic energy deflection for personal body armour.
- Medical applications such as:
 - "Smart fabrics" that can be equipped with nanoscale sensors for health monitoring, and treatments such as burn and wound dressings, or dental bonding agents.
 - Use of nanomaterials that target specific organs or can deliver medicine to exact locations within the body (such as drugs directly to cancer cells).
 - Lipid nanoparticle-based mRNA vaccines.
 - Use of DNA technology instead of conventional electronics for data storage and computing functions.
- Transportation, aviation and space travel, especially the ability to create lighter-weight materials.
- Agriculture and nutrition systems. For example, carbon nanotube sensors are used to detect plant signals when plants are experiencing stresses such as heat, light, or infestation from insects or bacteria.
- Water filtration systems.
- Coatings for easier cleaning, anti-glare, anti-reflective, antifog, antimicrobial, scratch-resistance for eyeglasses, computer screens, camera displays, glass, etc.
- Sunscreens and cosmetics.

- Sports equipment such as longer-lasting tennis balls or lightweight, stronger baseball bats.
- Treatments to create resistance to stains, wrinkling, and bacterial growth in clothing and mattresses.

What are some examples of classes of nanomaterials and their use?

Below are some common examples of nanomaterials and how they can be used.

Table 1: Classes of nanomaterials and examples of use

Classes of nanomaterials	Chemical composition	Examples of Use or Application
Carbon nanotubes	Carbon	Anti-static fabrics Lithium-ion batteries Drug delivery and cancer therapy
Inorganic carbon	Carbon atomic scale, carbon black, carbon dots	Electrolyte additive High-efficiency catalysis Thermal stability of materials Memory devices High-strength composites Biosensors Cosmetics
Metals, metal salts, and metalloids	Silver, gold, iron, copper	Anti-microbial wound dressings Imaging Solar cells Nanosilver use - water treatment devices, food storage containers, cosmetic products, and disinfectant sprays.
Metal oxides (e.g., ceramics) and metalloids oxides	Titanium dioxide, zinc oxide, cerium oxide	Sunscreen filters Self-cleaning glass Fertilizer developer Nanocerium oxide is used as a catalyst in diesel fuel to increase combustion efficiency
Semiconductor quantum dots	Cadmium selenide, cadmium telluride	Medical imaging agents Light-emitting diodes

		Solar panes
Organics (e.g., polymeric)	Carbon, hydrogen, and sometimes other atoms such as oxygen and nitrogen. (e.g., hydrocarbon polymers, layered biopolymer)	Drug delivery devices
Other classes E.g., metal alloys, nanoclays, tubes of metals/metalloids, and	Zinc selenide, cadmium sulfide, zinc sulfide	High sensitivity sensors Car manufacturing industry

Where can I get more information?

More information is available from:

- [Engineered nanoparticles: Health and safety consideration](#) – Employment and Social Development Canada
- [Nanomaterials](#) – Health Canada
- [Nanotechnology Frequently Asked Questions](#) – National Institute for Occupational Safety and Health (NIOSH)

(*We have mentioned these organizations as a means of providing a potentially useful referral. You should contact the organization(s) directly for more information about their services. Please note that mention of these organizations does not represent a recommendation or endorsement by CCOHS of these organizations over others of which you may be aware.)

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