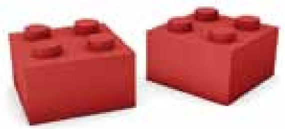
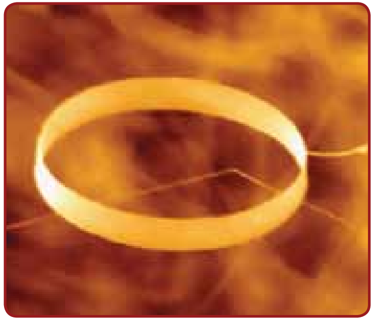
nanotechnology in electronics: The Risks to Humans and the Environment

SVTC

what is nanotechnology?



Most people have heard the term nanotechnology, but many of us are unfamiliar with what nanotechnology actually means. What is it used for? Why is it so important?



ZINC OXIDE NANOSTRUCTURE synthesized by a vapor-solid process.
(Image courtesy of Prof. Zhong Lin Wang, Georgia Tech)

Nanotechnology is the term given to the field of science that manipulates and produces materials at the nanoscale (less than 1 nanometer to greater than 100 nanometers). In the simplest terms, nanotechnology is constructive; it snaps atoms together like Lego building blocks using materials such as carbon and iron in order to build unique molecular structures that have special qualities.[1] The term "engineered nanoparticles" (ENPs) refers to particle structures that have been engineered to the nanoscale size range of approximately 1-100 nanometers.

Unique things happen when particles are changed or manipulated at the nanoscale. Size, shape, and surface area can make a big difference in how particles behave. For example, by arranging carbon (like that used in a pencil) into precise nanoscale structures, a new material can be made that is much stronger than steel, yet only one-sixth its weight.

1: B.C. Crandall, ed., Nanotechnology: Molecular Speculations on Global Abundance (MIT Press, 1996), 6.

GLOSSARY

BROMINATED FLAME RETARDANTS: Organobromide compounds that have an inhibitory effect on the ignition of combustible materials. They are used in plastics and textile applications, e.g. electronics, clothes and furniture. Concentrations of BFRs have been measured in humans extensively. They have been shown to have detrimental effects on both human and environmental health.

ENGINEERED NANOPARTICLES (ENPs): Purposefully made free standing nano-sized material, consisting of a few to thousands of atoms. ENPs are approximately 1 - 100 nanometers in one or more dimensions (for example, length, width, depth). ENPs are so small they cannot be seen with a regular light microscope and other techniques, such as electron microscopy, are required to image them.

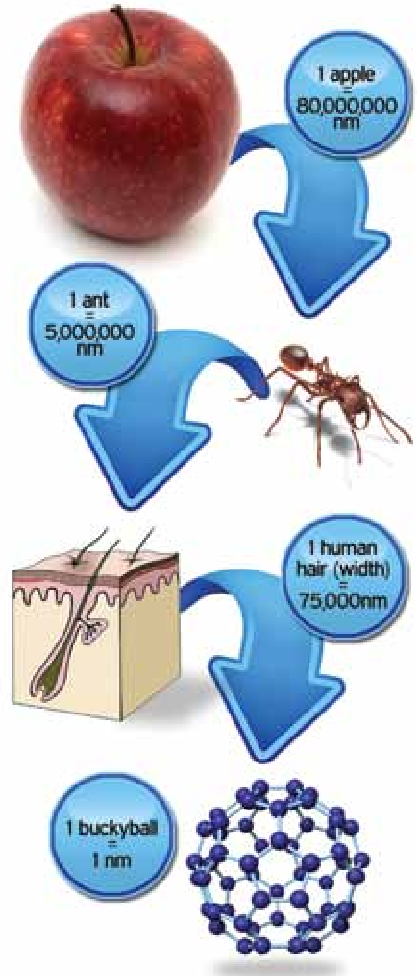
EXPOSURE PATHWAYS: Potential ways human populations are exposed to a given chemical.

NANOMATERIALS: Nanosized materials that are purposefully made. Nanomaterials are substances that contain a nanoparticle or materials with nano-scale structure that leads to a unique functionality.

NANOMETER (nm): One billionth of a meter.

NANOSCALE: Having dimensions measured in nanometers.

NANOTECHNOLOGY: Research and technology development at the atomic, molecular, or macromolecular levels, in the length scale of approximately 1 - 100 nanometer range; creating and using structures, devices and systems that have novel properties and functions because of their small and/or intermediate size; and the ability to control or manipulate on the atomic scale.



HOW SMALL IS SMALL?

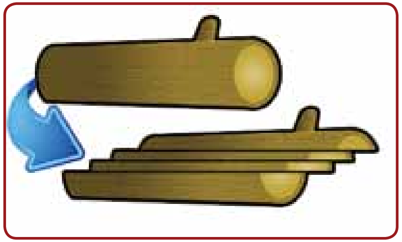
A nanometer is actually a measurement. It's one billionth of a meter. A nanometer is so small it only takes about 3-10 atoms to span the length of a nanometer.

The nanotechnology industry revolves around ENPs targeted for specific uses. In fact, nanotech is far more than one new industrial sector. Nanomaterials are being widely used in thousands of consumer products.

WHY IS SURFACE AREA SO IMPORTANT FOR NANOPARTICLES?

One of ENPs' distinguishing characteristics is their great surface-to-mass ratios. That means that an object cut into smaller pieces has more opportunities for reactions to occur on its surface than the original larger object.

A simple way to think about the greater reactivity of increased surface area is to imagine starting a wood fire. You would find it difficult to light a fire using big logs of wood. However, if you were to cut the log into smaller pieces, the wood would light much faster due to the increased amount of exposed surface area.



CUTTING OBJECTS INTO SMALL PIECES INCREASES THE AMOUNT OF EXPOSED SURFACE AREA

WHY IS NANOTECHNOLOGY USED IN ELECTRONICS?

Nanomaterials are better at conducting electricity than most conventional materials. In addition to increased surface area, the small size of nanomaterials allows for the construction of much smaller circuitry than conventional materials, which can improve overall speed and computational power.

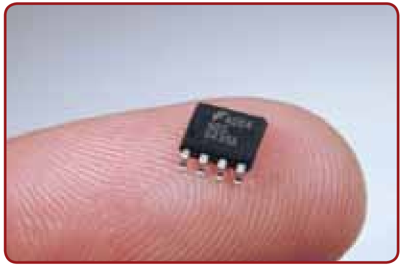
Other benefits of using nanomaterials in electronics include more efficient and effective use of materials. Batteries incorporating ENPs are lighter and have longer and larger storage capabilities. For example, nano lithium iron oxide batteries are able to hold their charges better, can be recharged up to 300,000 times, and won't overheat compared to the conventional batteries. These nano-based batteries are currently used in power tools and some automobiles. Soon they are expected to replace the conventional battery in laptops and cell phones.

NANO LITHIUM BATTERIES ARE EXPECTED TO BE USED IN LAPTOPS AND CELL PHONES

HOW IS NANOTECHNOLOGY USED IN ELECTRONICS?

Nanoscale components are now found in consumer electronics ranging from cell phones, computer chips, computers, MP3 players, digital cameras, and video game consoles.[2]

Nanotech is expected to usher in a new era of “molecular” electronics, in which transistors and memory devices used in computer chips are made with nanowires. Their miniscule size means that manufacturers could potentially fit millions of transistors on a single microchip the size of a blood cell.[3]



NANOTECHNOLOGY WILL ALLOW ELECTRONICS TO BECOME SMALLER AND SMALLER

COATINGS

ENPs are also used as exterior coatings on electronics. For example, they can be found on some computer keyboards and mouse devices as well as cell phones. The nanocoating is designed to prevent bacteria from surviving on the surface of the product.

VISUAL DISPLAYS

Using nanotechnology makes the visual displays in your TV, computer, and cell phone brighter and smaller than conventional materials.[2]

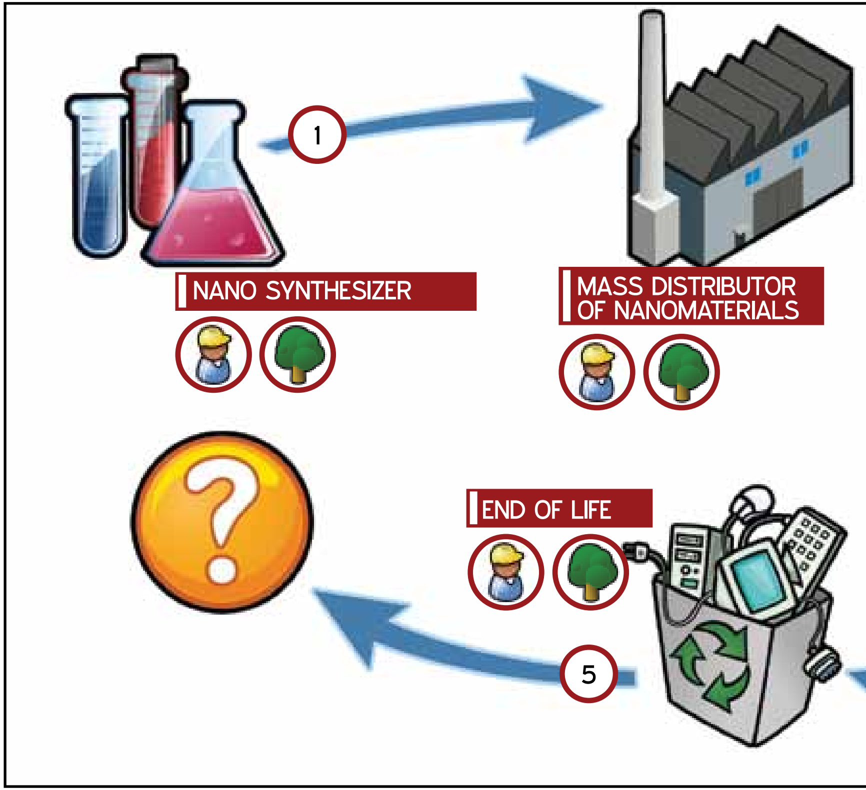
2: Woodrow Wilson International Center for Scholars. Project on Emerging Nanotechnologies. *http://www.nanotechproject.org* [Accessed March 01, 2010].
3: Strickland, Jonathan. “How Nanowires Work” 29 October 2007. HowStuffWorks.com. *http://science.howstuffworks.com/nanowire.htm*, [Accessed August 31, 2010].

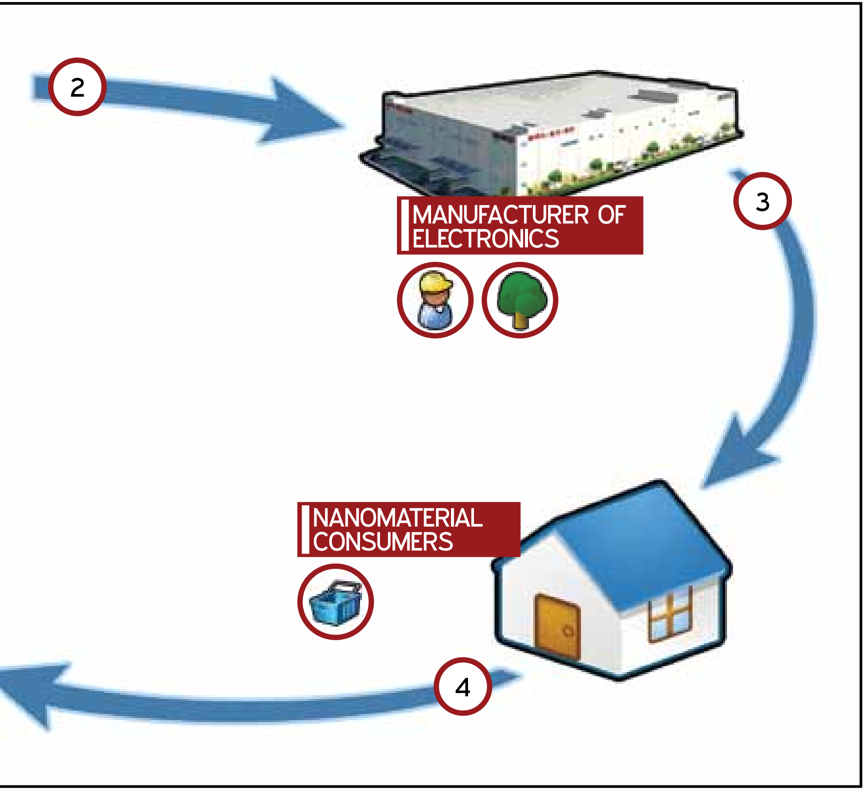
LIFE CYCLE OF NANOTECHNOLOGY IN ELECTRONICS : POTENTIAL IMPACTS ON HUMAN AND ENVIRONMENT HEALTH

The nanotech industry is heavily investing in the production of nanomaterials. Unfortunately, the same "investment" to understand the risk of human and environmental exposure (to workers, consumers, and the environment) is not being made. It is crucial that we begin to investigate the impact nanotechnology may have on life systems.

The life cycle impact model (refer to graphic on the right) serves as an aid in the exploration of potential impacts of particular chemicals; here we apply a basic demonstration of the model to nanomaterials.

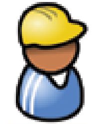
Nanomaterials may be released into the environment (i.e., air, water, soil) in the form of industrial emissions from nanomaterial synthesis, nanomaterial distribution, or electronic product manufacturing. Those who work with nanomaterials may be exposed to nanomaterials during synthesis,





distribution, manufacture, and disposal of electronics that contain nanomaterials. In addition, consumers of products that contain nanomaterials may potentially be exposed to nano-related hazards. During disposal (end of product's life), materials contaminated with nanoparticles, or their hazardous constituents, may leach out of landfills or recycling facilities into the surrounding environment (i.e., air, water, soil) where human and ecological populations may be exposed.

KEY



- WORKERS

- ENVIRONMENT

- CONSUMERS

WHY SHOULD YOU BE CONCERNED ABOUT NANOTECH IN ELECTRONICS?

The properties that make nanomaterials potentially beneficial, such as their size, shape, and high reactivity, may also make the materials more toxic.

A systematic approach for understanding these potential risks does not exist. Unfortunately, resources from the federal government and companies conducting nanotech research are disproportionately allocated to the research and development of new nanomaterials and products, rather than to evaluating the safety of the materials. The lack of data on ENPs does not allow for adequate hazard assessment.

Large knowledge gaps exist with regard to the potential human health and environmental risks associated with exposure to ENPs. There are countless ways in which ENPs can be released from the manufacture of nanomaterials — or from consumer products — into the environment, resulting in potential exposure to the workers and general public. Other chemicals used in the electronics industry have been released from manufacturing and recycling facilities, and these chemicals invariably find their way into the environment and our bodies. For example, brominated flame retardants (BFRs), which are used in computer plastics and circuit boards, have been measured in human breast milk and even in polar bears. In many developing countries the recycling of visual display glass (from televisions and computer monitors) has significantly contaminated the soil with lead. Those working with electronics in the U.S., Europe, and Asia have reported contracting cancer and from being exposed to the many chemicals in electronic manufacturing facilities.

These toxics find their way into our bodies through what scientists call “exposure pathways.” The main routes through which humans can be exposed to nanoparticles include inhalation, ingestion, and skin absorption. Consumer products are not the only potential sources of exposure to nanomaterials; contaminated air, water, and soil are also potential sources of environmental exposure. What makes nanotechnology particularly concerning when compared with conventional chemicals, is that the small size and greater surface area of nanoparticles allows them to penetrate deeper into our bodies with greater reactivity.

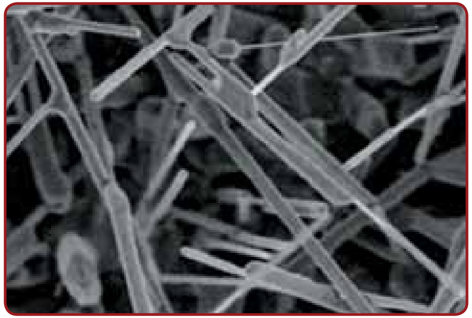
INHALATION

Sneezing, blowing our noses, and coughing are typical methods our bodies use to clear particles that we unintentionally breathe in, such as pollen and dust. However, studies have shown that nanoparticles are so small, or of a particular shape, that they are not always expelled successfully by these typical methods. Therefore, inhaled nanoparticles can enter the lungs and become deposited deep in the lung tissue. If these particles cannot be cleared, they may lead to health problems such as pulmonary fibrosis (lung tissue scarring) and cancer. Studies have shown that some types of nanoparticles have similar toxic properties to those observed with other fibrous particles, such as asbestos.[4]

Inhaled nanoparticles can also reach the blood and lymph circulation systems, which then carry them to potentially sensitive sites, including the bone marrow, lymph nodes, spleen, heart, and central nervous system.[5] It has been shown that nanoparticles are able to migrate from the respiratory tract along nerves leading to the olfactory bulb (part of the brain).[5] Concerns have been raised that the deposition of metal particles may have a link to neurodegenerative disorders such as Parkinson's and Alzheimer's disease.

▲ MICROSCOPY IMAGE OF ASBESTOS FIBERS

▼ MICROSCOPY IMAGE OF ZINC OXIDE NANOPARTICLES



4: Pacurari M, Castranova V, Vallyathan V. Single- and multi-wall carbon nanotubes versus asbestos: are the carbon nanotubes a new health risk to humans? J Toxicol Environ Health A. 2010 Jan;73 (5):378-95.
5: NIOSH. (2009). Approaches to safe nanotechnology: Managing the health and safety concerns associated with engineered nanomaterials. Department of Health and Human Services,Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. DHHS (NIOSH) publication No. 2009-125.

INGESTION

If nanoparticles are cleared from the respiratory tract they can subsequently be ingested into the gastrointestinal tract (GI tract). Alternatively, nanoparticles can be ingested directly, for example, through contaminated food, water, or dirty hands. Once in the GI tract, nanoparticles may either be eliminated from the body or may remain to interact with target organs and cellular systems.

DERMAL

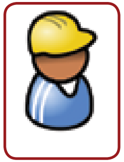
Our skin keeps many types of materials from entering our bodies. However, nanoparticles are so small that some can pass through the skin. Once embedded in the skin layers, nanoparticles may locate to other areas of the body such as target organs or cellular systems. Other potential pathways for nanoparticles may include the dense networks of blood circulation and sensory nerves in the dermis layer of the skin.

HOW CAN NANOMATERIALS GET FROM YOUR ELECTRONIC PRODUCTS INTO THE ENVIRONMENT AND INTO OUR BODIES?

It is difficult for consumers to conceptualize the dangers posed by their electronics because most people just do not think about how the chemicals in these products can impact their health and safety.

Yet the footprint of consumer electronics is very real, and this becomes most apparent when we understand the life cycle of these products and realize that the electronics that surround us contain extremely hazardous substances such as lead, mercury, cadmium, and other toxic chemicals.

From production to disposal of electronics, there are multiple ways that toxic chemicals are released and pose a risk to humans and the environment. This threat applies to nanotechnology because humans can be exposed to these materials in much the same way we are exposed to conventional toxics.



WORKERS

There is a long history of workers being exposed to chemicals in electronics factories. Over 200 lawsuits were filed against IBM on behalf of former IBM workers, alleging that chemical poisoning had resulted in cancer or other diseases. Furthermore, more than 50 suits were filed against IBM by former workers whose children were born with birth defects attributable to the parents' exposure to chemicals within IBM plants.[6]

U.S. electronics manufacturers have since relocated their manufacturing facilities from the Silicon Valley to Asian countries such as China and Korea, where workers' complaints about conditions, illness, and cancer rates due to chemical exposures have continued.[7, 8, 9]

It is estimated that two million workers will be employed in the nanotechnology industry by 2020.[10] Workers in a manufacturing facility are on the front line of exposure for any ENP used in the manufacturing process due to their close proximity to the ENPs and the length of time that they are exposed.

Both inhalation and exposure to skin are thought to be the major routes of exposure in occupational settings. However, the nature of exposure is not well understood, and while engineering controls, work practice standards, and personal protective equipment (PPE) are being prescribed, their effectiveness in protecting the worker from exposure to nanomaterials has not been determined.[5]

6: Ted Smith, DavidSonnefeld and David Naguib Pellow, eds., Challenging the Chip: Labor Rights and Environmental Justice in the Global Electronics Industry (Temple University Press, 2006), 32.
7: Elizabeth Grossman, Were they Canaries? The Short Lives of Park Ji Yeon and Yu-Mi Hwang, Huffington Post, http://www.huffingtonpost.com/elizabeth-grossman/were-they-canaries-the-to_b_536726.html [Accessed: April 10, 2010].
8: Ted Smith, DavidSonnefeld and David Naguib Pellow, eds., Challenging the Chip: Labor Rights and Environmental Justice in the Global Electronics Industry (Temple University Press, 2006), 66-67
9: Students and Scholars against Corporate Misbehaviour, "An Investigative Report on Labor Conditions of the ICT Industry: Making Computers in South China," www.sacom.hk, 2006. P6
10: Schulte, P., Geraci, C., Zumwalde, R., Hoover, E., Kuempel, E. (2008). Occupational risk management of engineered nanoparticles. J Occup Environ Hyg. 5:239-249.

ENVIRONMENT

People seldom understand where their electronic products come from and what happens to those products once they are discarded. Manufacturers of nanotechnology may release nanomaterials into the environment during production and, as a result, contaminate the water, soil, and air.

Disposal and recycling also present potential hazards. Often, discarded electronics are transferred overseas to developing nations, where they are typically burned in open pits, smelted, dumped in landfills, or smashed and dismantled mainly by women and children in resource-deprived communities.

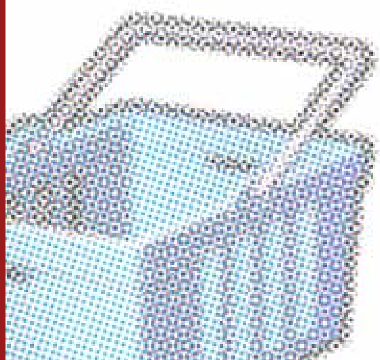
The dismantling and processing of these products often exposes workers and communities to hazardous chemicals and inevitably results in the contamination of their water, soil, and air. These practices beg the question of whether or not the same fate will confront nano-containing products and, if so, what can we do to mitigate the risks posed by ENPs?

Even if products containing ENPs are sent to responsible recycling facilities with the proper equipment, it is unknown what kind of impact ENPs will have on the workers, environment, and consumers. However, the gap in knowledge regarding ENPs' health impacts, and the fact that it is difficult to cost-effectively separate and recycle these products, may prove to be a significant barrier to the development of recyclable ENPs.

EXPOSURE TO THE CONSUMER WHILE THE PRODUCT IS IN USE

Although workers may experience the highest possible risk of exposure to ENPs, users of products containing ENPs face similar risks. Currently there is no legal requirement for companies to identify or label whether their products contain ENPs. This hinders the consumer's ability to make informed decisions about the products that they purchase, how they interact with the product, as well as how they dispose of the product at the end of its life.

As an electronics consumer, there does not appear to be a great risk of exposure to nanomaterials since ENPs are generally embedded in a matrix housed inside the product. Alternatively, the risk for exposure is different for nanomaterials coated on the outside of products. For example, nanosilver is an anti-microbial agent that is often used as a coating on the outside surface of computer keyboards and mouse devices, as well as cell phones. Such coatings could potentially be absorbed through the skin by the user, and consequently induce toxic effects.



TAKE ACTION!

- Be an informed consumer by finding out if your cell phone, laptop, television, and MP3 players contain nanomaterials
- If they do, encourage the company to label products which contain nanomaterials
- Ask the manufacturer how to properly dispose of products which contain nanomaterials
- Support a mandatory labeling requirement for all products containing nanomaterials
- Stay informed about these issues by signing up for SVTC's E-Alerts at www.svtc.org

svtc.org/nano

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