NANOWARE Curriculum

MODULE 6: APPLICATIONS OF NANOTECHNOLOGY

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Contents

1. Introduction to the Module

This module shows the vast potential of nanotechnology in different scientific and technological fields. By presenting various applications, the module highlights the importance of manipulating matter at the nanoscale and uses four industries as examples (IT, Environmental Science, Medicine, Consumer Products).

Description

This module will cover basic nanotechnology applications. More specifically, it will explain how this kind of technology is applied in electronic engineering, environmental science, medicine, and food safety. Finally, it will present a few success stories and real-life examples.

Module Goals

With this module, learners will learn about various nanotechnology applications. They will also understand the vast potential of this kind of technology in numerous different fields.

Learning Objectives

This learning activity aims at familiarizing learners with the remarkable wide scope of nanotechnology and its applications. Ideally, learners will learn to recognize potential benefits from manipulating matter in the nanoscale and promote its importance in various fields.

Learning Outcomes

On successful completion of this module, learners should be able to:

- Understand how nanotechnology is applied in [Electronic Engineering]
- Understand how nanotechnology is applied in [Environmental Science]
- Understand how nanotechnology is applied in [Medicine]
- Understand how nanotechnology is applied in [Consumer Products]

Estimated seat time

The completion of the module along with the implementation of the knowledge provided will last 3 hours.

2. Applications of Nanotechnology

Nanoparticles and nanomaterials have unique physical, chemical, and electronic properties, depending on the number and kind of atoms that compose their structure. These properties allow them to have vast potential for applications in various fields; manipulating matter at the nanoscale can produce *a new class of atomically engineered materials*, thus revolutionizing research and applications (Poole & Owens, 2003).

For the purposes of this module, we will cover applications in the industries of **Electronic Engineering, Environmental Science, Medicine**, and **Consumer Products**.

2.1 Industry 1: Electronic Engineering

In electronic engineering, nanotechnology is used to create improved systems and devices with more functions, higher performance results, etc. **Precision engineering** and the wider **micro-electronics** industry can now benefit from nanostructures' unique properties and develop faster and portable systems and devices that manage, process and store larger amounts of data, while consuming lower quantities of power (Bayda et al., 2019). This is feasible thanks to nanomanufacturing.

In **nanomanufacturing**, nanomaterials are synthesized in two ways:

- **top-down** approach
- **bottom-up** approach

Top-down nanomanufacturing is about manipulating *bulk materials* to create *fine particles in nano dimensions* (Parmasimav et al., 2021). An example of this approach is the creation of **graphene-based microchips** (as opposed to silicon-based ones) – a revolutionary product with great potential.

Bottom-up nanomanufacturing is about *assembling fine particles to create nanomaterials through self-assembly or co-precipitation methods* (ibid.). An example of this approach is the creation of **nano-sized electronic devices,** like microchips, using single atoms and molecules (Marr, 2022).

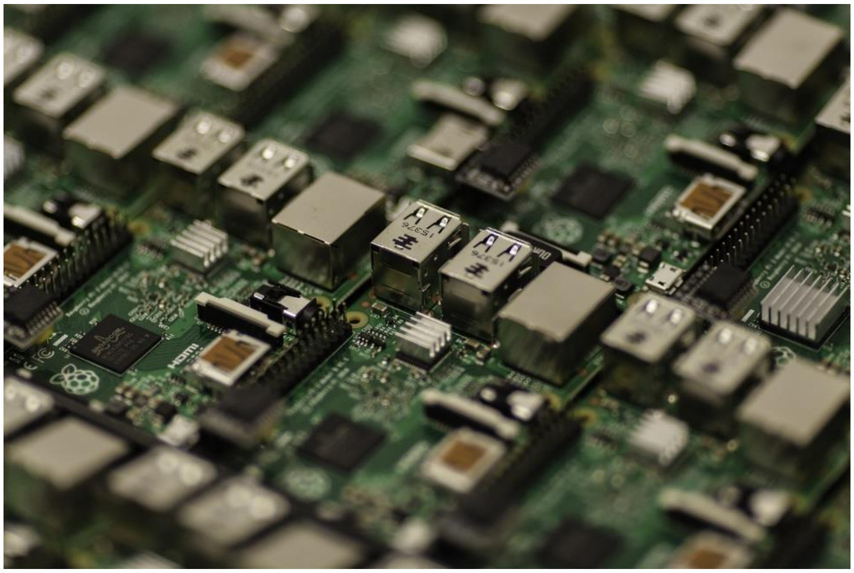

Image title: USB_Technology

Source: Pixabay.com

2.2 Industry 2: Environmental Science

Researchers and scientists are experimenting with various nanotechnology applications for environmental purposes and for energy saving solutions. With efficiency and affordability in mind, high technology at the nanoscale is used to create new structures and devices that consume less energy, are lighter, produce less or zero emissions, are easy to install, and so on.

Nanotechnology is especially popular in the research and experimentation for ***alternative energy sources applications.*** For example, scientists are testing the potential of printable solar panels as a more efficient alternative that will also be easier to install and cheaper (NGS, 2022).

Image title: Solar energy

Source: Pixabay.com

In **water quality** research, nanomaterials are used to reduce toxicity by eliminating toxic metals and organic molecules like dangerous chemicals, virus cells, etc. An example of this approach is the use of bacteriophages as “nano engineering tools” to monitor the quality of water and wastewater and detect pathogens (Bayat et al., 2020).

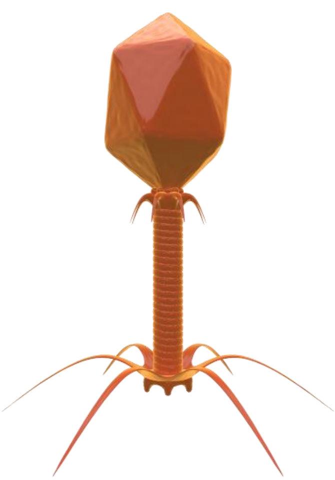

Image title: Bacteriophage

Source: Pixabay.com

Similarly, magnetic nanomaterials are used to remove **oil spill pollution** particles (Singh et al., 2020).

2.3 Industry 3: Medicine

Researching and manipulating matter at the nanometer scale has given scientists and researchers a better understanding of molecular behavior and function, as well as the origin of disruptions like diseases. Subsequently:

Biology and medicine can now improve ***drug design and targeting*** (EC, 2006).

Nanomaterials are also used in ***analytical and instrumental applications***, including tissue engineering and imaging (ibid.).

Nanotechnology is also used to ***improve procedures, disease treatments and drug delivery, medical devices, medical tools***, etc.

As research has shown, nanotechnologies can significantly advance biomedicine in the **diagnosis** (including molecular imaging) and **therapy/drug delivery** of various diseases (Bayda et al., 2019). This is mainly because nanoparticles can be used to detect and trap specific proteins or diseased cells.

Nano pharmaceuticals are already popular in **drug delivery** and **regenerative medicine** (ibid).

'Nano pharmaceuticals' are revolutionary pharmaceuticals developed by nanobiotechnology to utilize nanoparticles' unique properties and functions (Jain, 2017).

The application of **nanobiotechnology** ensures optimal drug delivery, targeted cancer treatment, antimicrobial activity, tissue regeneration, nerve protection, etc.

Nano-oncology improves the efficacy of traditional chemotherapy drugs, by directly targeting tumour sites without damaging healthy tissue; in this way, nano-oncology has *higher response rates* and *reduced systemic toxicity* compared with traditional chemotherapy (Bayda et al., 2019).

DNA nanotechnology is about controlling molecular self-assembly; various DNA nanostructures assembly approach exist, and they are applied in such areas as *biophysics, diagnostics, nanoparticle and protein assembly, biomolecule structure determination, drug delivery and synthetic biology* (Seeman & Sleiman, 2017).

Image title: DNA

Source: Pixabay.com

2.4 Industry 4: Consumer Products

At the nanoscale, matter behaves very different than at other scales: the physical and chemical properties of nanoparticles are significantly different than the properties of materials at larger scales. Depending on shape, size, surface characteristics and inner structure, nanoparticles can change properties when met with certain chemicals and can have **attractive or repulsive interactions** between them that will either group or separate them (EC, 2006).

Many consumer products already contain nanoparticles. Nanotechnology seeks to improve their properties and resilience, thus making them indispensable to consumers.

Examples:

- **Clothing:** By embedding nanoparticles in coating methods, scientists can now make water-repellent or more stain-resistant fabrics.
- **Surface protection materials:** Nanoparticles stronger, more resilient, lighter, and ‘smarter’ solutions for surfaces and systems (e.g., scratchproof eyeglasses, crack-resistant paints, anti-graffiti coatings for walls, etc.).
- **Car safety:** Nanoparticles be used to increase car safety. For example, they can increasee tyre adhesion to the road, improve the stiffness of the car body, or prevent glare or condensation on displays and panels.

- **Cosmetics:** Nanoparticles' special properties are used to improve cosmetics and develop high quality products (e.g., transparent sunscreens with higher UV protection, products with enhanced clarity and better absorption, etc.).
- **Athletics:** Embedding nanoparticles to sports equipment can create lighter and more resilient products (e.g., tennis balls that can retain their bounce for longer).
- **Food safety and Packaging:** By embedding nanoparticles in coating methods, scientists can now enhance food conservation and ensure safe foods transportation.
- **Food enhancers:** Nanotechnology can improve food texture and flavours, or even be used to develop healthier versions of traditional foods (e.g., mayonnaise).

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"*For example, mayonnaise – made by combining oil, egg yolks, vinegar and flavourings into an emulsion – typically contains around 70% fat when made traditionally. Its texture is provided by tiny, naturally nano-sized fat droplets in the emulsion. By manipulating these droplets and filling them with water instead of fat, researchers hope to keep the thick, creamy texture of the mayonnaise, but reduce the overall fat content to less than 40%*" (Oakes, 2020).

3. Success stories & best practices

'Smart bandage'

https://www.uri.edu/news/2021/01/smart-bandage-detects-could-prevent-infections/

URI chemical engineers have developed a specially engineered type of bandage that detects and can prevent infections.

In the fibers of this bandage, they have embedded carbon nanotubes "*create a continuous, noninvasive way to detect and monitor an infection in a wound*" (NNI, 2021).

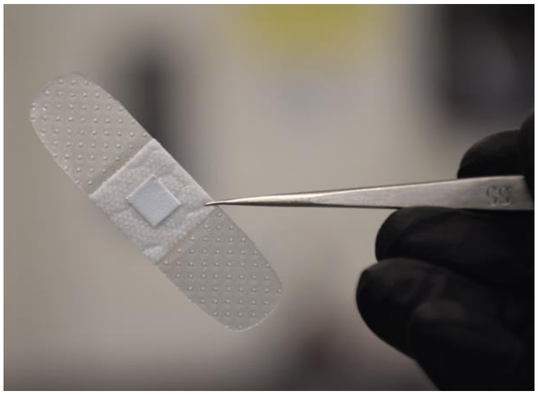

Image title: Smart bandage

Source: URI.edu

Wilson's 'double-core' tennis ball

https://www.wilson.com/en-us/tennis

Specializing in tennis, Wilson uses nanotechnology to increase its competitive advantage.

For example, it has introduced a double-core tennis ball, the inner core of which is coated with clay nanoparticles. Acting as a sealant, this makes it far more difficult for air to escape and the ball retains its pressure and bounce for twice as long as ordinary balls.

Image title: Tennis

Source: Pixabay.com

Hydrophobic coating

https://kriya-materials.com

Kriya Materials (Netherlands) has developed a hydrophobic and oleophobic coating technique for products using nanotechnology. Due to the high contact angle, the company's coating provides easy-to-clean properties, eextreme abrasion resistance and durability towards stains and markers -among others.

The company offers custom-made solutions in various applications, like plastic covers, protection films, advertising panels, in-car infotainment etc.

Image title: Surface_drops

Source: Pixabay.com

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