NANOWARE Curriculum

MODULE 1: WHAT IS NANOTECHNOLOGY?

DELIVERABLE: R1/T1.1

NANOWARE

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ATERMON

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Contents

1. Introduction to the Module

This module offers basic knowledge about the difference between micro, macro and nano scales, as well as the difference between microscopy and nanoscience. It also briefly explains the history and evolution of nanotechnology with the scope to introduce the learner to the idea of matter's manipulation. Finally, the module presents three success stories of nanotechnology used to improve different fields.

Description

This module is about providing basic knowledge about nanotechnology. To achieve this, first, we will explain the differences in macro, micro, and nanotechnology. Then, learners will discover the history of nanotechnology and its evolution to present relevant case studies and success stories.

Goals

Through this module, learners will understand the basic concepts regarding nanotechnology. They will also know the differences in macro, micro, and nanotechnology. Finally, they will learn and appreciate nanotechnology features and applications through case studies and success stories.

Learning Objectives

With this module, we hope to give schoolteachers the appropriate tools to understand and, subsequently, efficiently teach the basics of nanotechnology. Ideally, learners will understand differences in scale, and, through the history of nanotechnology, will appreciate its evolution and its applications in life.

Learning Outcomes

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

- Know about the History and evolution of Nanotechnology
- Understand the basic principles and differences in Macro, Micro, and Nano technology

Estimated seat time

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

2. Macro, Micro and Nanotechnology

Macro, micro and nano refer to **different scales** that help us conceive the **size** of objects, their **applications**, and their **properties**.

2.1 Macrotechnology

The **macroscale** concerns anything that can be seen with the **naked eye**, or else the “*geometry on the order of millimeters and above”* (ScienceDirect, 2022). In other words, macro is something **large in scale**.

The **macroscale** is also used to observe natural phenomena like the weather. In meteorology, macroscale refers to “*synoptic events occurring on a scale of thousands of kilometers, such as warm and cold fronts*” (AMS, 2012).

Example: The scale of a lightbulb is macro.

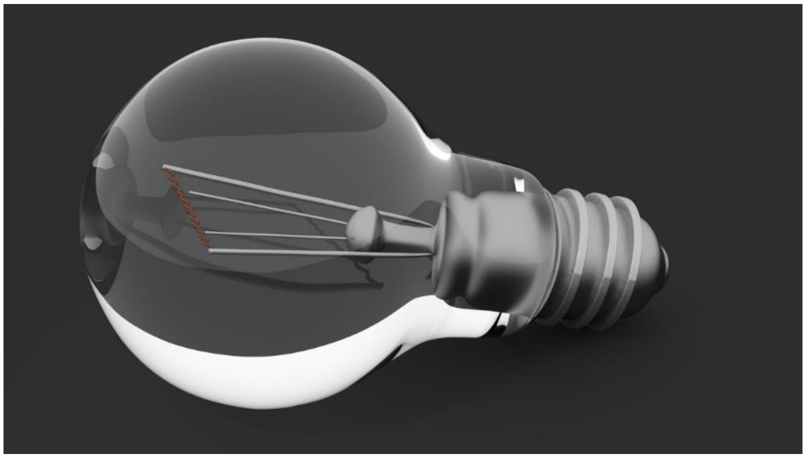

Image title: Lightbulb
Source: Pixabay.com

2.2 Microtechnology

The **microscale** refers to "*submillimeter length scales down to the micrometer range"* (ibid.). The Microscopic matter is **not visible** to the naked eye without the use of a **microscope**.

Microscopy is the scientific field that uses microscopes to ***view and study structures and properties*** of materials (U.Ed., 2022).

Image title: Microscope
Source: Pixabay.com

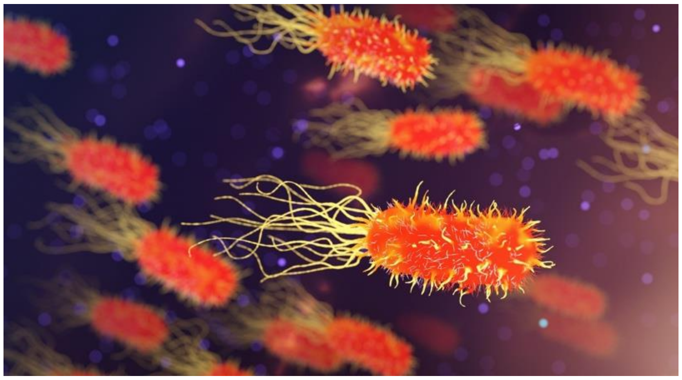

Image title: Bacteria, Microbiology
Source: Pixabay.com

Microtechnology is the technology that creates or uses miniature components, equipment, and systems for multidisciplinary purposes, usually in electronics, computer systems, mechanics, chemical processes etc. (SCME, 2017).

One **micrometer** is 10^{-6} (a millionth) of a meter.

2.3 Nanotechnology

As a unit prefix, nano means **one billionth** (10^{-9} or 0.000000001).

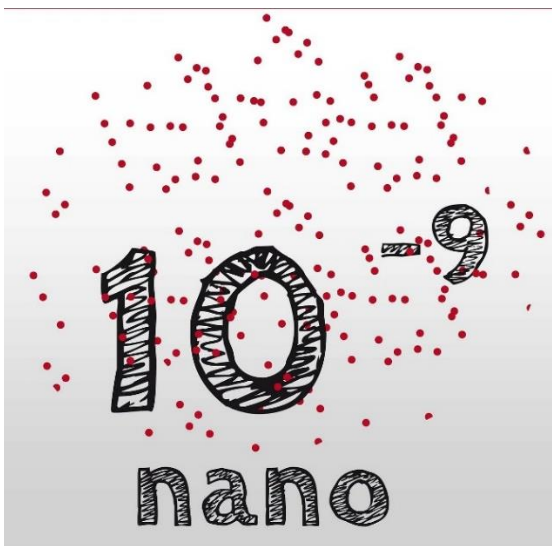

Image title: Nano

Source: Pixabay.com

The **nanoscale (1-100 nm)** refers to matter measured in extremely small units of length called **nanometers**.

A nanometer (nm) is equal to a billionth of a meter (NGS, 2022).

! **A strand of human hair is about 80,000 to 100,000 nm wide.**

Nanotechnology is the ***understanding and control of matter at the nanoscale*** (NGS, 2022). At this scale, materials present ***unique physical, chemical, mechanical, and optical properties***; the manipulation of materials in the nanoscale can produce ***new structures, materials, and devices*** thanks to their special properties (CDC, 2020). As a result, nanotechnology can be used across various fields, like ***chemistry, biology, physics, material science, and engineering*** (NNI, 2022).

"*Intro to Nano*": https://www.nisenet.org/whatisnano (https://vimeo.com/11362918)

"Nanoscience and nanotechnology involve the ability to ***see and to control individual atoms and molecules***" (NNI, 2022). By manipulating matter at the nanoscale (e.g., by changing the size of particles), scientists can alter the surface areas of a material, thus allowing more atoms to interact with other materials. Increased surface areas make nanometer-scale materials "***stronger, more durable, and more conductive than their larger-scale (called bulk) counterparts"*** (NGS, 2022).

Nanoscience can also be defined as "***the study of novel phenomena and properties of materials that occur at extremely small length scales***" (nanoHUB, 2009).

2.4 Microscopy versus nanotechnology

Microscopy is about working at smaller dimensions by using microscopes to ***understand the behavior*** of material components that are not visible to the naked eye.

Nanotechnology is *about **utilizing the unique properties** (physical, chemical, mechanical, optical) of materials that occur naturally at the nanoscale* (ibid.).

Through this process, scientists can intervene and alter or improve consumer products, revolutionize medicine, or even tackle environmental issues (ibibd.).

Image title: Nanotechnology
Source: Pixabay.com

Please, watch the following videos!

Introduction: What is Nanotechnology? https://www.youtube.com/watch?v=j_wQgy97Pi4

Nanotechnology is not simply about making things smaller | Noushin Nasiri | TEDxMacquarieUniversity

https://www.youtube.com/watch?v=M8d3pxVb4c4

3. History of Nanotechnology

Physicist **Richard Feynman** is considered the father of nanotechnology, as he introduced ideas and concepts behind nanoscience and nanotechnology in the 1960s. In his infamous talk entitled "*There's Plenty of Room at the Bottom*" at an American Physical Society meeting at the California Institute of Technology (CalTech), Feynman described "a process in which scientists would be able to ***manipulate and control individual atoms and molecules***" (NNI, 2022).

In 1974, Professor **Nori Taniguchi** used the term nanotechnology to describe "the processing of separation, consolidation, and deformation of materials by one atom or one molecule" (ScienceDirect, 2022).

In 1981, Gerd Binnig and Heinrich Rohrer developed the ***Scanning Tunneling Microscope (STM)*** which images material surfaces at the **atomic level** (Poole, 2017). Modern nanotechnology began thanks to:

- **STM** and its ability to see and control **individual atoms**
- **Atomic Force Microscopy (AFM):** a **high-resolution non-optical imaging technique** first demonstrated by Binnig, Quate, and Gerber in 1985 (Binnig et al., 1986).

Image title: Nanotechnology

Source: Pixabay.com

3.2 Evolution of Nanotechnology

Even though the term nanotechnology was born in the mid-20th century and nanoscience evolved in the decades that followed, nanoparticles and structures have been used for centuries.

In the fourth century AD, Romans discovered that **adding gold and silver particles in glass** creates an impressive effect: the glass appears green from the outside but bright red when lit from the inside. The famous ceremonial vessel called “Lycurgus Cup” (British Museum collection) is a perfect example of this technique.

Image title: The Lycurgus Cup

Source: Researchgate.net

Copper and other nanoparticles were used to glaze pottery in Asia and Europe for many centuries (9^{th}-17^{th}).

Medieval stained-glass windows are famous among the examples of pre-modern use of nanomaterials in Europe: small particles of gold and silver were used in varying quantities to produce bright reds and yellows (NGS, 2022).

Italian Renaissance pottery (16^{th} century) was inspired by Ottoman techniques.

During the 13th-18th centuries, various techniques in the Islamic world led to the creation of the famous "Damascus" steel. Damascus blades had a characteristic wavy pattern and were exceptionally sharp and resilient; high-resolution transmission electron microscopy reveals that the Damascus steel contains carbon nanotubes as well as cementite nanowires (Reibold et al., 2006).

In 1857, Michael Faraday examined the ruby color of colloidal gold, adding to a series of *investigations into the relations of matter and electrical, magnetic, and optical phenomena* and leading to the undoubtful emergence of nanoscience and nanotechnology (Thompson, 2007).

The invention of the STM in the 1980s was the start of imaging surfaces at the atomic level; STM was also used to manipulate atoms and molecules to create new structures (Bayda et al., 2019).

After STM, scientists developed AFM and scanning probe microscopes (SPM) that nanoscience uses in this day (ibid.). All these new imaging and manipulation techniques led to **carbon** chemistry, offering new flexible and resilient carbon compounds with the potential of numerous applications (see, for example, nanotech discoveries like carbon nanotubes).

By the end of the 20th century, nanoscience and nanotechnology were already very popular, with governments and companies investing in such a promising field. Nanoscience spread in many fields, such as computer science, engineering, biology, and medicine. Since the early 2000s, nanomaterials have been used in a wide variety of consumer products, ranging from sports equipment to digital cameras (NGS, 2022).

3.3 Case studies and success stories

Nanotechnology in the 21st century is widespread in the developed world and revolutionizes various scientific and technical fields. A simple online search can reveal a multitude of results concerning successful applications of nanoscience and nanotechnology. Here are a few examples of companies making an impact through the manipulation of matter at the nanoscale:

Anavo Medical: "*Cutting-edge nanotechnology that heals wounds*"

https://www.anavo.ch

Anavo Medical is a Swiss start-up that has been awarded the Nanotechnology Start-up Prize from the Swiss MNT Network.

The company manipulates nanoparticles to heal wounds and safely regenerate tissue. Along with leading clinicians in the field, the scientific team has developed a unique formulation based on cutting-edge nanotechnology: they have developed mixed metal oxide nanoparticles that stimulate regeneration and have anti-inflammatory and antimicrobial properties.

The team's revolutionary work comes as a promising solution in an ageing world where chronic illnesses causing non-healing wounds like diabetes are widespread.

Nfinite Nanotechnology: "*Protect the Earth, one atom at a time*"

https://www.nfinitenano.com

Nfinite Nanotechnology has developed a superior nano-coating technique that enhances the performance of sustainable packaging. With this technique, compostable and recyclable packaging is enriched with nano-coating features resulting in fresh food preservation for longer.

Nano-coating is food-safe and environmentally friendly, while it is also multifunctional and features antimicrobial and UV protective properties. Furthermore, it is flexible and resilient, compatible with fully compostable and recyclable materials, and cost-effective in that it can be integrated directly into production lines.

As a result, Nfinite's nano-coating is an attractive solution for the food industry and a promising alternative for a sustainable future with no plastic waste.

Bridgestone: "Technology to Control Molecular Structures- NanoPro-Tech™"

https://www.bridgestone.com/technology_innovation/nanopro-tech/

Bridgestone's R&D team works on the design technology at the molecular level using "Nanostructure-Oriented Properties Control Technology" (NanoPro-Tech). This unique technology disperses silica and rubber, thus producing a wide range of end results that can satisfy diverse end-user needs.

Nanotechnology in tires-production increases efficiency, resilience and grip performance, thanks to new tire materials and compounds that respond to a multitude of tire performance requirements.

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