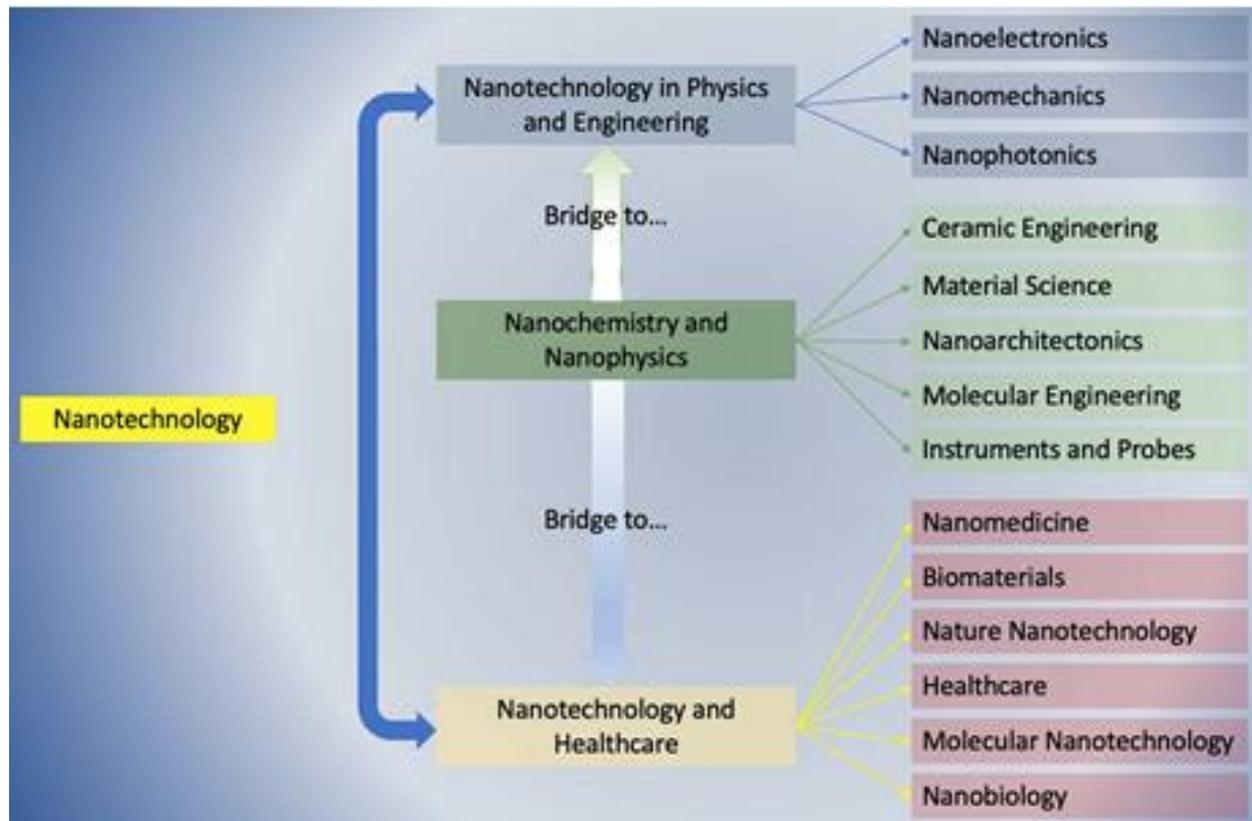


Subdivision of Nanotechnology



Nanomechanics

Nanomechanics focuses on the mechanical properties of engineered nanostructures and nanosystems and nanosystems such as the ones containing nanoscale components of importance. Such devices may be nanomachines, nanoparticles, nanopowders, nanowires, nanorods, nanoribbons, nanotubes and carbon nanotubes as well and boron nitride nanotubes, nanoshells and nanomembranes, nanocoatings and nanocomposite or nanostructured materials, nanomotors... Nanomechanics is based on general principles and specific ones. General principles regard mechanics principles including energy and momentum conservation principles, variational Hamilton's principle and symmetry principles. As nanoparticles are quite small, nanomechanics must take in account a series of other effects. First the discreteness of the object whose size is comparable to the atomic distances, then the degrees of freedom in the object, then the thermal fluctuations. Also entropic effects and quantum effects are to be considered. Novel properties of nanoscaled objects appear because of their dimensions and are not present in the macroscale objects or bulk materials. The smallness of particles gives rise to several surface effects due to the high surface–area–to–volume ratio so affecting properties like the melting point, heat capacitance and so on. Discreteness serves for the dispersion of mechanical waves in solids and some special behaviour of basic elastomechanics solutions at small scales. Degrees of freedom are the reasons for thermal tunnelling of nanoparticles through potential barriers and for the cross diffusion

of liquids and solids. The Brownian motion of nanoparticles is due to the smallness and the thermal fluctuations. Thermal fluctuations and entropy at the nanoscale give rise to phenomena like super elasticity, entropic elasticity or other exotic kinds of elasticity. Quantum effects determine novel electrical, optical and chemical properties of nanostructures and they are of great importance for areas of Nanotechnology such as nano electronics and advanced energy systems.

Nanoelectronics

Nanoelectronics is the use of Nanotechnology in electronics, covering different devices and materials. All of these possess the common feature that they are so small that interatomic interactions and quantum mechanical properties cannot be neglected and must be taken into serious account. When working at the nanoscale, physical phenomena are involved that are completely different from those we experience in the macro world, such as the quantum tunnel effect. Miniaturisation has played a key role in the research and development process in nanoelectronics, as after World War II the first transistors were over a centimetre in size, while today the smallest transistor is 7nm. This leads to billions of transistors integrated on a single chip.

Nanotribology

Nanotribology regards interactions of objects at the nanoscale. Because structures are shrinking in size and information is compressed in space, these interactions become very important. Reducing friction between the interacting surfaces is fundamental in the area of micro and nano devices; in other words, nanotribology deals with macroscopic phenomena like friction but at a molecular level. Interfacial processes during adhesion, friction, wear, nano indentation and thin-film lubrication are investigated. As for other properties of nanoparticles compared to ones of the bulk dimension, the behaviours studied through nanotribology are quite different from the ones observed at macroscopic levels. Understanding tribological behaviours can help manipulating matter at the nanoscale (Hsu, Ying 2002, Sherrington, Rowe and Wood 2002, Bhushan 2001).

Nanophotonics

With the term Nanophotonics the study of the behaviour of light at 10–9m scale is intended. Also, the interaction of nanometric objects with light will be considered. This is a new interdisciplinary branch of optics that includes optics itself, Nanotechnology, electrical and optical engineering. This discipline deals with metallic components that can transport and focus light through surface plasmon polaritons. Nanophotonics can also be called nanooptics; nanooptics usually has to do with wavelengths from ultraviolet to near-infrared. It is known that optical microscopy and optical instruments cannot normally focus light to nanometric scales, due to the diffraction limit – Rayleigh criterion –. In certain cases, however, it is possible to bring light down to the nanometric scale using different techniques like surface plasmons, localized surface plasmons around nanoscale metal objects, and the nanoscale doors and sharp tips used in Near-field Scanning Optical Microscopy (Pohl, Denk and Lanz 1984), NSOM (Dürig, Pohl and Rohner 1986, Betzig, Harootunian, Isaacson and Kratschmer 1986) or sometimes referred as SNOM.

Nanomaterials

Materials in which a single unit of size is between 1nm and 100nm are called nanomaterials. ISO/TS 80004–1:2015 describes the standard and the core terms for Nanotechnology and was confirmed in 2019. A nanomaterial is defined as the “material with any external dimension in the nanoscale or having internal structure or surface structure in the nanoscale”, with nanoscale defined as the “length range approximately from 1nm to 100nm”. This includes both nanoobjects, which can be defined as pieces of material at discrete dimensions, and nanostructured materials, whose internal or surface structure on the nanoscale (ISO/TS 80004 2019). On October 18th, 2011, the European Commission adopted this definition for a nanomaterial: “A natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range 1nm 100nm. In specific cases and where warranted by concerns for the environment, health, safety or competitiveness the number size distribution threshold of 50% may be replaced by a threshold between 1% to 50%” (European Commission 2011).

Nanochemistry

The combination of inorganic and organic chemistry with Nanotechnology is called Nanochemistry. This discipline deals with synthesis of building blocks where size is strongly under control, together with shape, surface and defect properties. Nanochemistry is at the base of chemical science, of course, materials and physical sciences, as well as of engineering, biological and medical applications. The synthesis of nanocompounds depends on how surface, size and shape lead to self assembly of building blocks into the desired structures. Among the materials that show the properties of nanochemistry we can name silica, gold, carbon, cadmium selenide, iron oxide, polydimethylsiloxane. For example, iron oxide, common rust, can be the most effective contrast agent in Magnetic Resonance Imaging (MRI). This oxide has the ability to detect certain cancer cells and eventually kill them if the disease is at an initial stage. Silica – in glass – can be used to bend or stop light paths. The scope of Nanochemistry is to find a way to arrange atoms, to solve problems, controlling additional degrees of freedom of atoms and particles, beyond the capabilities of traditional Chemistry. This way, it is possible to control the properties and behaviour of the new materials obtained (Cademartiri and Ozin 2009).

Nanophysics

There is a world of dwarves sized a billionth of a metre. It is called the nanoworld and its laws are different from the macroscopic ones we are used to, as the laws of Quantum Mechanics applied to very small structures give rise to new properties, the ones scientists are interested in. The same substance in its bulk form and at the nanoscale may show totally different features. The electronic properties of these materials, together with its optical properties and surface ones are detected and investigated. This fundamental research needs the continuous 230 Andrea Durlo – Ph.D. Thesis, 2023, University of Lille, France development of imaging and detection, refining the instruments and the tools available, or the realization of new ones. The resolution goes to the nanoscale and the atomic scale. Observation is fundamental, the key for new exciting discoveries and this appears to be particularly true when nanoscale is the object. The observation of materials at the nanoscale can be performed using electrons, photons, scanning probes, ions, atoms and so on. A wide range of techniques is available in each of these areas and systematic applications of several tools lead to the understanding of the system (Pradeep 2008). The most common analytical tools to characterize materials are listed here (Table 1.3).

Table. 1.3 Analytical tools for characterization of materials (Pradeep 2008).

AES	Auger Electron Spectroscopy
AFM	Atomic Force Microscope
APECS	Auger Photoelectron Coincidence Spectroscopy
APFIM	Atom Probe Field Ion Microscopy
APS	Appearance Potential Spectroscopy
ARPES	Angle Resolved Photoelectron Spectroscopy
ARUPS	Angle Resolved Ultraviolet Photoelectron Spectroscopy
ATR	Attenuated Total Reflection
BEEM	Ballistic Electron Emission Microscopy
BIS	Bremsstrahlung Isochromat Spectroscopy
CFM	Chemical Force Microscopy
CM	Confocal Microscopy
DRIFTS	Diffuse Reflectance Infra-Red Fourier Transform Spectroscopy
EDX	Energy Dispersive X-ray Analysis
EELS	Electron Energy Loss Spectroscopy
EMS	Electron Momentum Spectroscopy
EPMA	Electron Probe Micro-Analysis
ESCA	Electron Spectroscopy of Chemical Analysis
ESD	Electron Stimulated Desorption
ESDIAD	Electron Stimulated Desorption Ion Angle Distribution
EXAFS	Extended X-ray Absorption Fine Structure
FEM	Field Emission Microscopy
FIM	Field Ion Microscopy
FRET	Fluorescence Resonance Energy Transfer
FTIR	Fourier Transform Infra-red Spectroscopy
FT RA-IR	Fourier Transform Reflectance-Absorption Infra-red
HAS	Helium Atom Scattering
HEIS	High Energy Ion Scattering
HOPG	Highly Oriented Pyrolytic Graphite
HREELS	High Resolution Electron Energy Loss Spectroscopy
IETS	Inelastic Electron Tunneling Spectroscopy
KRIPES	k-Resolved Inverse Photoemission Spectroscopy
ILS	Ionization Loss Spectroscopy
INS	Ion Neutralization Spectroscopy
IPES	Inverse Photoemission Spectroscopy
IRAS	Infra-red Absorption Spectroscopy
ISS	Ion Scattering Spectroscopy
LEED	Low Energy Electron Diffraction
LEEM	Low Energy Electron Microscopy
LEIS	Low Energy Ion Scattering
LFM	Lateral Force Microscopy
MBS	Molecular Beam Scattering
MCXD	Magnetic Circular X-ray Dichroism

MEIS	Medium Energy Ion Scattering
MFM	Magnetic Force Microscopy
MIES	Metastable Impact Electron Spectroscopy
MIR	Multiple Internal Reflection
NEXAFS	Near-Edge X-ray Absorption Fine Structure
NSOM	Near Field Scanning Optical Microscopy
PAES	Positron Annihilation Auger Electron Spectroscopy
PEEM	Photoemission Electron Microscopy
PED	Photoelectron Diffraction
PIXE	Proton Induced X-ray Emission
PSD	Photon Stimulated Desorption
RAIRS	Reflection Absorption Infra-red Spectroscopy
RAS	Reflectance Anisotropy Spectroscopy
RBS	Rutherford Back Scattering
RDS	Reflectance Difference Spectroscopy
REFLEXAFS	Reflection Extended X-ray Absorption Fine Structure
RHEED	Reflection High Energy Electron Diffraction
RIFS	Reflectometric Interference Spectroscopy
SAM	Scanning Auger Microscopy
SCM	Scanning Confocal Microscope
SEM	Scanning Electron Microscopy
SEMPA	Scanning Electron Microscopy with Polarization Analysis
SERS	Surface Enhanced Raman Spectroscopy
SEXAFS	Surface Extended X-ray Absorption Spectroscopy
SFS	Sum Frequency Spectroscopy
SHG	Second Harmonic Generation
SH-MOKE	Second Harmonic Magneto-optic Kerr Effect
SIM	Scanning Ion Microscope
SIMS	Secondary Ion Mass Spectrometry
SKS	Scanning Kinetic Spectroscopy
SLM	Scanning Light Microscope
SMOKE	Surface Magneto-optic Kerr Effect
SNMS	Sputtered Neutral Mass Spectrometry
SNOM	Scanning Near Field Optical Microscopy
SPIPES	Spin Polarized Inverse Photoemission Spectroscopy
SPEELS	Spin Polarized Electron Energy Loss Spectroscopy
SPLEED	Spin Polarized Low Energy Electron Diffraction
SPM	Scanning Probe Microscopy
SPR	Surface Plasmon Resonance
SPUPS	Spin Polarized Ultraviolet Photoelectron Spectroscopy
SPXPS	Spin Polarized X-ray Photoelectron Spectroscopy
STM	Scanning Tunneling Microscopy
SXAPS	Soft X-ray Appearance Potential Spectroscopy
SXRD	Surface X-ray Diffraction
TDS	Thermal Desorption Spectroscopy
TIRF	Total Internal Reflectance Fluorescence
TPD	Temperature Programmed Desorption
TPRS	Temperature Programmed Reaction Spectroscopy
TXRF	Total Reflection X-ray Fluorescence
UPS	Ultraviolet Photoemission Spectroscopy
XANES	X-ray Absorption Near-Edge Structure
XPD	X-ray Photoelectron Diffraction
XPS	X-ray Photoemission Spectroscopy
XRR	X-ray Reflectometry
XSW	X-ray Standing Wave

Nanomedicine

We call the medical application of Nanotechnology Nanomedicine. As nanomaterials exhibit completely new properties due to their extremely small scale, when these same properties are compared with the bulk material, strong chances for their interactions with biological systems appear. Biological systems possess components whose dimensions are nano scaled (such as proteins, membranes, nucleic acids and so on). So, nanomaterials can be applied to both in vitro and in vivo biomedical research and applications. Scientists can add different functionalities to nanomaterials to get diagnostic devices, contrast agents, analytical tools, applications to physical therapies or drug transport systems. This fact opens new doors to research as synergies among nanosystems and biological components may improve health and quality of life, from one side; on the other side, ethical implications arise about the legitimate use of such new discoveries and the awareness of their side effects.

Nanotoxicology

The study of toxicity of nanoparticles is called nanotoxicology (Buzea, Pacheco and Robbie 2007). Features like quantum size effects or their large surface to volume ratio may affect the toxicity of the nanoparticles. Serious side effects such as inflammation, fibrosis or carcinogenicity, i.e. the tendency of an active ingredient to produce cancer (O'Toole 2003) are possible hazards of inhalation exposure of some nanoparticles. Skin contact and ingestion exposure are to be seriously considered. Nanotechnology can be considered a relatively recent development in science and its effects on health, despite the studies conducted so far, are yet to be deeply understood. We could consider Nanotechnology a rather recent scientific development so it is fundamental to know how exposures to these agents may affect the health and safety of workers and users, or what level of exposure will be acceptable. As health is to be protected above all, it is important to take precautions to minimize hazardous exposure and side effects (NIOSH, 2014). We can say that nanotoxicology is a new sub-speciality of particle toxicology. As the properties of nanoparticles differ from the bulk ones due to their nanometric dimensions, so their toxicity appears to be different due to the same reason: dimension. For example, a metal like gold which is known to be inert at bulk dimensions becomes very active at nanometric dimension. This is why a discipline such as nanotoxicology is becoming more and more important, trying to establish if and to what extent these properties may become hazardous to human health and the environment (Mahmoudi, Hofmann, Rothen Rutishauser and Petri-Fink 2012). It is not correct to believe that nanoparticles are man-engineered artificial structures only, like carbon nanotubes for instance. In fact, it is possible to find them in Nature as combustion-derived nanoparticles, like in diesel soot, or as naturally occurring nanoparticles from volcanic eruptions, atmospheric chemistry and so on. So, the hypothetical threat is coming from different sides, none of them to be neglected. Once they have entered the body, through inhalation, swallowing or skin absorption, due to their small size, the particles can migrate inside the body and affect distant sites such as brain and other organs, conveyed by the cardiovascular apparatus.

Nanorobotics....Nanomachine...

Nanobiology ...

Nanobiotechnology...

Completarea vocabularului:

Nanoage	Nanocrystalline	Nanomanufacturing	Nanorobotics
Nanoarray	Nanocube	Nanomaterial	Nanorod
Nanoassembly	Nanodevice	Nanomechanics	Nanoscale
Nanobacteria	Nanodivide	Nanomedicine	Nanoscience
Nanobiologist	Nanodomain	Nanomembrane	Nanoscope
Nanobiology	Nanodot	Nanometer	Nanosecond
Nanobiomedicine	Nanodrug	Nanomicelle	Nanoshell
Nanobiotechnology	Nanoelectromechanical	Nanomotor	Nanostructured
Nanobot	Nanoelectronics	Nanoparticle	Nanostructures
Nanocapsule	Nanoencapsulation	Nanoparticulate	Nanoswarm
Nanocar	Nanofabrication	Nanophase	Nanosystem
Nanocassette	Nanofibers	Nanophotonics	Nanotechnology
Nanocatalyst	Nanofilter	Nanophysics	Nanotool
Nanochemistry	Nanofluidics	Nanoplatelets	Nanotoxicology
Nanoclay	Nanohealth	Nanoporous	Nanotransistor
Nanocoating	Nanolayer	Nanopowder	Nanotribology
Nanocomponent	Nanoliter	Nanoproduct	Nanotube
Nanocomposite	Nanolithography	Nanoreactor	Nanotweezers
Nanoconnection	Nanomachine	Nanoreplicator	Nanowire
Nanocosm	Nanomagnetic	Nanoribbon	Nanoworks
Nanocrystal	Nanomanipulator	Nanorobot	Nanoworld