October 2021. Technology snapshot

Nanoscience and Nanotechnology in Catalonia

ACCIÓ Catalonia Trade & Investment

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Nanoscience and Nanotechnology in Catalonia

ACCIÓ
Regional Government of Catalonia (Generalitat de Catalunya)

Execution
ACCIÓ Strategic and Competitive Intelligence Unit

Collaboration
MAV Cluster; University of Barcelona (CCiTUB/IN2UB/Materials UB)

Barcelona, October 2021

1. Definitions of Nanoscience and Nanotechnology

Definitions of Nanoscience and Nanotechnology

The UK's Royal Society and Royal Academy of Engineering defines **nanoscience** as "the study of phenomena and manipulation of materials at **atomic, molecular and macromolecular scales.**" Nanometric structures are generally considered to be structures where at least one of the **3 dimensions** is less than **100 nm**.

The same source defines nanotechnology as "the **design, characterisation, production and application of structures, devices and systems by controlling shape and size at nanometre scale**."

Nanotechnology is the term given to those areas of science and engineering that use phenomena that occur at dimensions at a nanometric scale in the design, characterisation, production and application of structures, devices and systems.

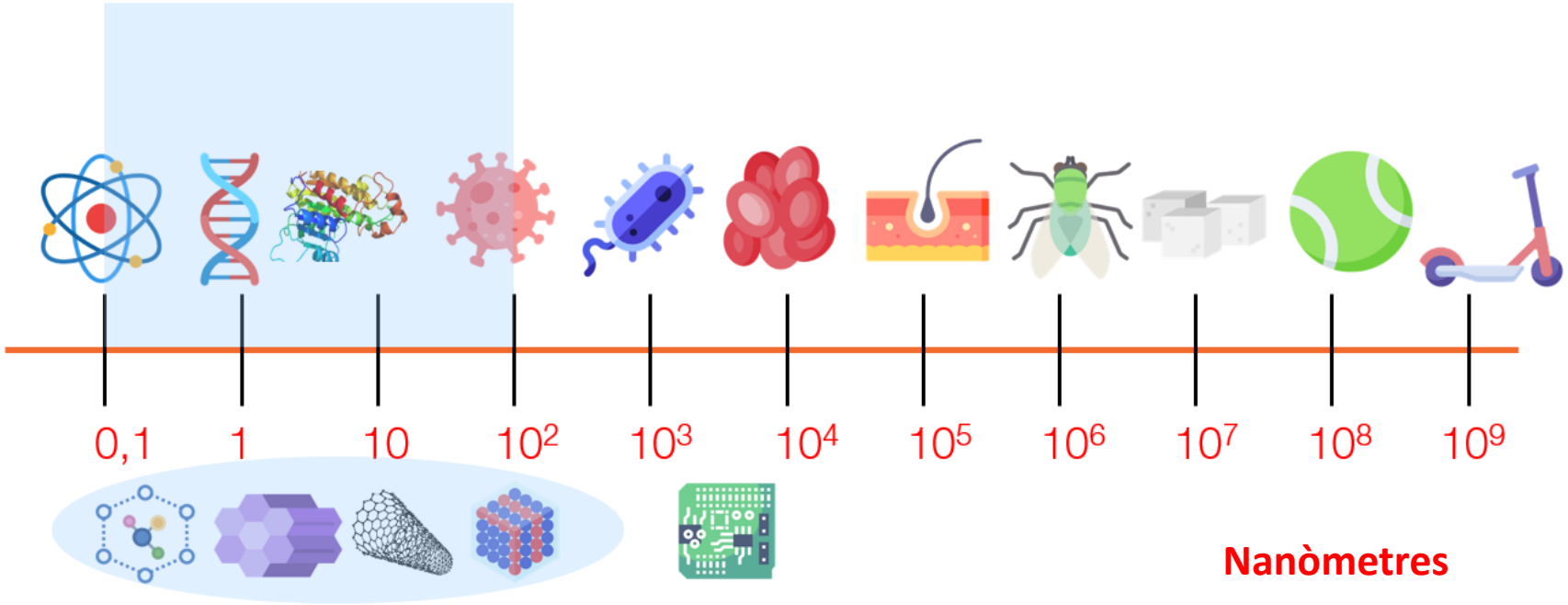
Nanoscience and nanotechnology are one of the drivers of the new industry and knowledge society from the economic and social points of view. Research into these areas has produced important advances across different sectors that very significantly impact the technological development of society and people's wellbeing.

Source: Royal Society and Royal Academy of Engineering.

Nanoscale

The **nanometre (nm)** is a unit of length equal to one-billionth of a metre **(10^{-9} m)**. The nanometre represents the scale of the molecules and is especially relevant because it is the scale at which many of the fundamental biological reactions of living beings take place and where the quantitative properties of materials begin to acquire importance.

Nanoscience provides **insights into the properties and manipulation of materials** at atomic, molecular and macromolecular levels. Nanotechnology makes it possible to apply these insights, with an emphasis on innovation, across a broad spectrum of areas, such as medicine, biotechnology, the chemical industry, information and communication technologies, energy, nanomaterial manufacturing, etc.



The lower limit of the nanoscale is given by the measurement of atoms and the upper limit is found at around 100 nanometres, approximately the size of a virus.

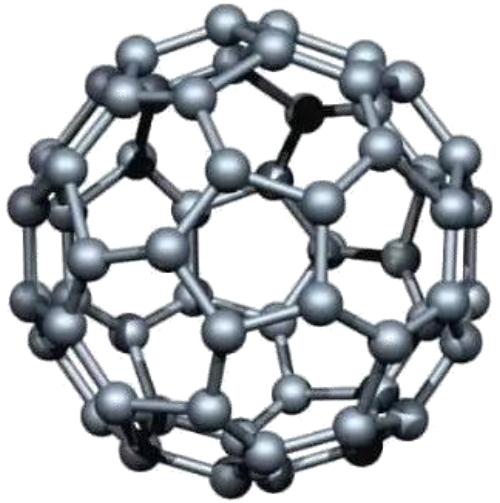
Some electronic components are on the frontier between micro and nano.

Unique properties of nanostructures

The effect of measurement (Nano effects):
in particular, the effects of quantum measurements result in mechanical, electronic, photonic and magnetic properties unique to materials at a nanometric scale.

The effect induced by the surface or interface (effects of scale):
the chemical reactivity of nanoscale materials is very different from the more macroscopic form.
Very enlarged surface by unit of mass.

New chemical forms of common chemical elements, for example new carbon allotropes such as fullerenes, carbon or graphene nanotubes, new semiconductors like quantum dots, titanium oxide, zinc oxide and other layered compounds.



Sources: Nanoscience and nanotechnology master, UB, ICN2

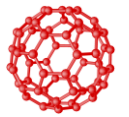
Classification of nanomaterials

Classification by type of material

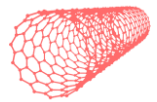
- Carbon-based nanomaterials
- Inorganic nanomaterials (ceramic, metallic)
- Organic nanomaterials (polymers, proteins, enzymes)
- Compound materials

Classification by size

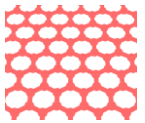
- **0D:** nanoparticles; quantum dots; fullerenes



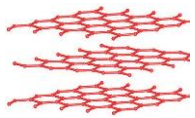
- **1D:** nanotubes, nanocables



- **2D:** graphene; nanolayers



- **3D:** dispersions; multilayer



Example of a nanomaterial: **Graphene**

Graphene is a two-dimensional nanometric material made of a single layer of carbon atoms that have a high level of cohesion through hybridisation bonds sp2 and arranged in a uniform surface with a hexagonal structure.

Graphene is one of the allotropic forms of carbon, along with graphite and diamond.

Dr Konstantin Novoselov and Dr Andre Geim discovered it in 2004 and won the Nobel Prize in Physics in 2010.

Sources: Graphenano; Graphenea; Graphene Flagship; Grafe (IEC)

Properties of graphene

Graphene is a substance with a number of very interesting properties. These properties, together with the abundance of carbon in nature, have made it a very studied material with great possibilities.

The most noteworthy properties of graphene are:

- High thermal conductivity
- High electrical conductivity
- Transparent material
- High elasticity and flexibility
- High hardness
- High resistance
- High density
- Antibacterial effect
- Low Joule effect

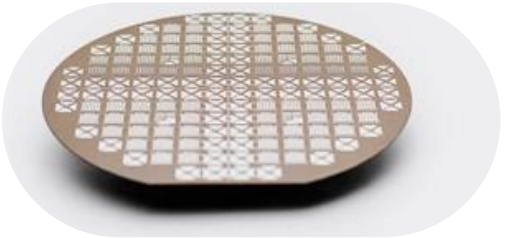


Image: Graphenea biosensor

Nanomaterials. Impact on health and environment (I)

Nanomaterials are already present in many consumer goods,

meaning that the negative or positive impact on human health and the environment depends mainly on:

- Stability, unstable compounds decompose easily.
- Size, this will determine the depth of penetration in human tissues.
- Concentration, low concentrations are easily handled by the immune system, but in large quantities may be a serious problem.
- The charge and reactivity of certain molecular groups present on the surface of nanoparticles.

The main pathways are respiratory, dermal and digestive.

Nanomaterials, including unintended products of a natural or man-made origin, such as desert dust, volcanic eruptions, combustion processes in vehicles and/or other industrial processes and activities can affect the environment and run into rivers and other water masses, the soil and the atmosphere.

It is important to know and understand the physical characteristics and chemical composition of nanomaterials and assess their potential biological interactions. Characterising them and research in this field is therefore essential.

One of the core work areas to minimise their impact is to onboard safety criteria in the design of nanomaterials and throughout their life cycle. Safety by design.

Regulatory frameworks and recommendations for the use and handling of nanomaterials have therefore been established at the global level.

Sources: Master's in nanoscience and nanotechnology. University of Barcelona, Catalan Institute for Occupational Health and Safety (ICSSL)

Nanomaterials. Impact on health and environment (II)

European regulation on nanoforms

Although nanotechnology can have numerous applications and benefits across many areas, it also raises questions, particularly around its effects on health and the environment. That is why nanotechnologies present regulatory challenges.
The European Union has specific regulations covering cosmetics, biocides, food and so on.

REACH has been applying new legal requirements to companies that make or import nanomaterials or nanoforms, especially with regards the information on them, since January 2020. This regulation affects the areas of describing nanoforms or groups of nanoforms included on the register; assessment of their chemical safety; information requirements around registration and use guides throughout the value chain.

Impact on health

There are important concerns around the effects of nanomaterials on health. The Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) found there were proven health hazards associated with a number of manufactured nanomaterials.

The European Agency for Safety and Health at Work (EU-OSHA) has prepared different materials and recommendations for their handling in companies.

The effects of nanoparticles (NPs) on health depend on a series of specific characteristics that differentiate them from larger-sized particles. The toxicity of NPs comes from their physical/chemical characteristics and the property of translocation, making the entrance, distribution, metabolization and excretion of NPs in the body deserving of dedicated study. The action mechanisms that can harm health are linked to their size and capacity for reaction.
Yet not all nanomaterials have a toxic effect and a case-by-case approach is necessarily while research continues.

Sources: https://echa.europa.eu/regulations/nanomaterials;
https://osha.europa.eu/en/emerging-risks/nanomaterials
https://treball.gencat.cat/ca/ambits/seguretat_i_salut_laboral/riscos_i_condicions_treball/mesures_per_risc/nanomaterials/#bloc2

Nanomaterials. Impact on health and environment (III)

In Catalonia

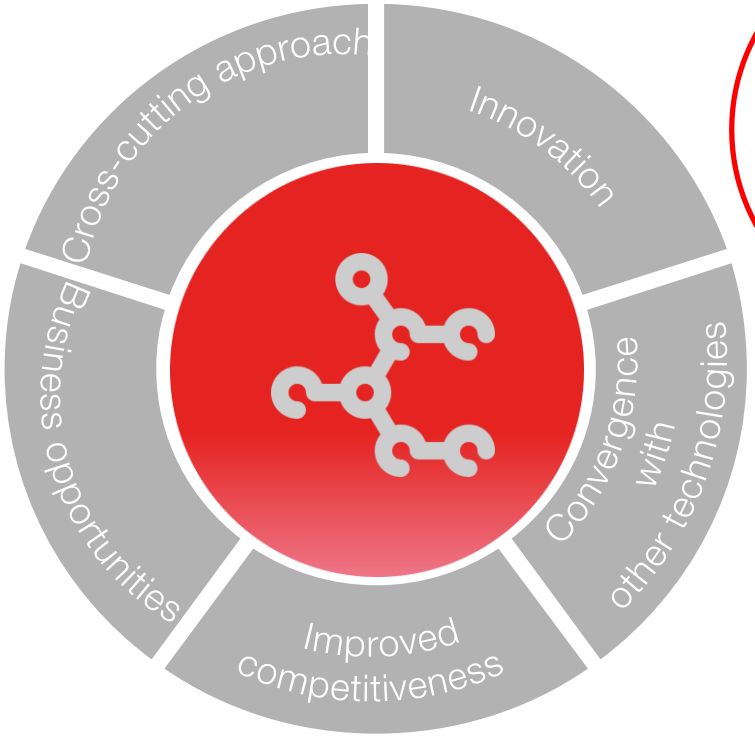
In Catalonia, **the Catalan Institute for Occupational Health and Safety (ICSSL)** has also developed materials and information on on-the-job exposure and risk management due to exposure to nanomaterials in the workplace, with recommendations for their handling, risk assessment and possible preventive measures.

Sources: https://echa.europa.eu/regulations/nanomaterials;
https://osha.europa.eu/en/emerging-risks/nanomaterials
https://treball.gencat.cat/ca/ambits/seguretat_i_salut_laboral/riscos_i_condicions_treball/mesures_per_risc/nanomaterials/#bloc2

Importance for industry

Nanotechnology can transform and impact many sectors, including aerospace, energy, ICT, health and transport. It enables the rollout of more lightweight, stronger and more durable materials. Nanotechnology also has promising uses in other sectors, including energy, solar batteries and panels, soil and water remediation, etc.

The application of nanoscience entails the development of new production sectors and the transformation of some traditional industries. Nanomaterials, nanoelectronics, nanobiology, nanoinstruments, etc. as well as the programs to model and control them.



New nanomaterials are being discovered and created that can provide answers to the challenges and technical limitations of certain materials and be used across a wide range of applications, while new properties are being discovered at the same time. This favours research and innovation in this field.

The widespread use of nanomaterials presents challenges and opportunities for the development of technologies that enable their application in different sectors and throughout the value chain.

New materials can bring down costs, reducing the quantity of certain production components or modifying product properties to improve their quality.

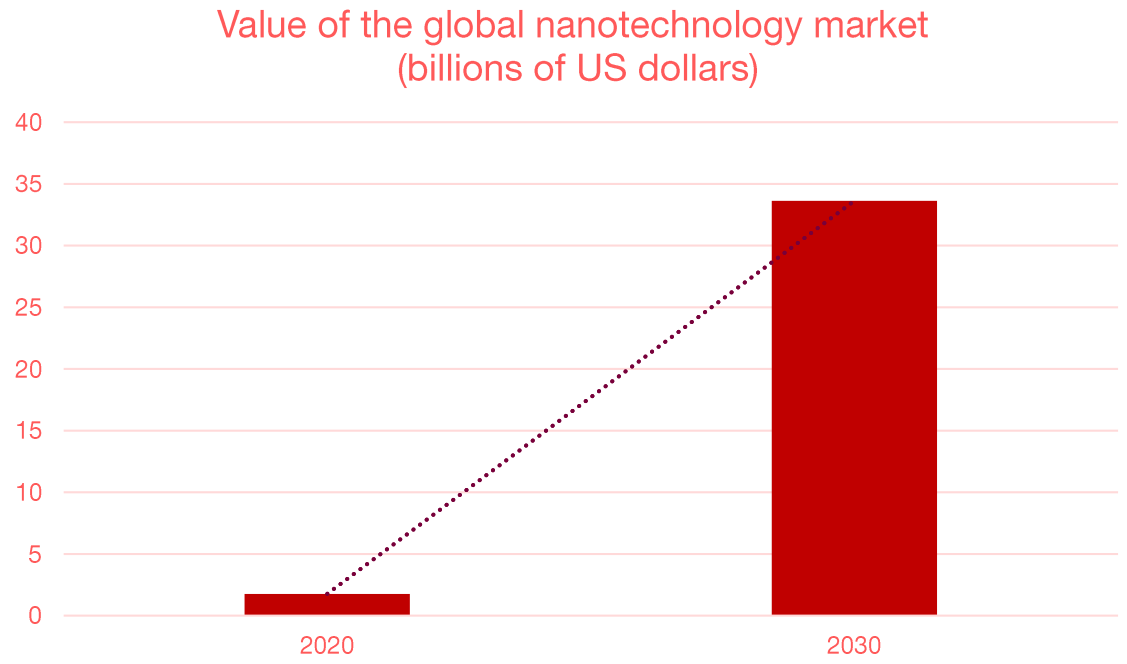
2. The global nanoscience and nanotechnology market

Global market. Current and prospective data

The global nanotechnology market was valued at $US1.76Bn in 2020 and is expected to reach $US33.63Bn by 2030, with a compound annual growth rate of 36.4% from 2021 to 2030.

Nanotechnology has an important impact and is a disruptive technology available for application in different industrial areas such as communications, medicine, transport, agriculture, energy, materials and manufacturing and consumer goods. Emerging uses and applications are expected to continue being one of the key factors that will contribute to the growth of the nanotechnology market.

Factors such as the increased onboarding of nanotechnology in medical diagnostics and imaging and technological progress in nanotechnology devices and their application in water and material treatments for renewable energy are driving the growth of the global nanotechnology market. However, the hardest part of the nanotechnology market is scaling production, and questions concerning the rollout of nanodevices in extreme conditions and the high cost of the technology act as the main barriers hampering market growth.



Sources: Allied Market Research; Global Nanotechnology Market Analysis 2020

World's main companies investing in nanotechnology

By sectors, of note are chemical and electronic companies and by nationality, the USA.

Sources: Author's own work taken from emergenresearch; alliedmarketresearch; researchandmarkets

Presence in Catalonia

Investments in nano startups

The **10 most important funding rounds*** in nanotechnology in 2020 were:

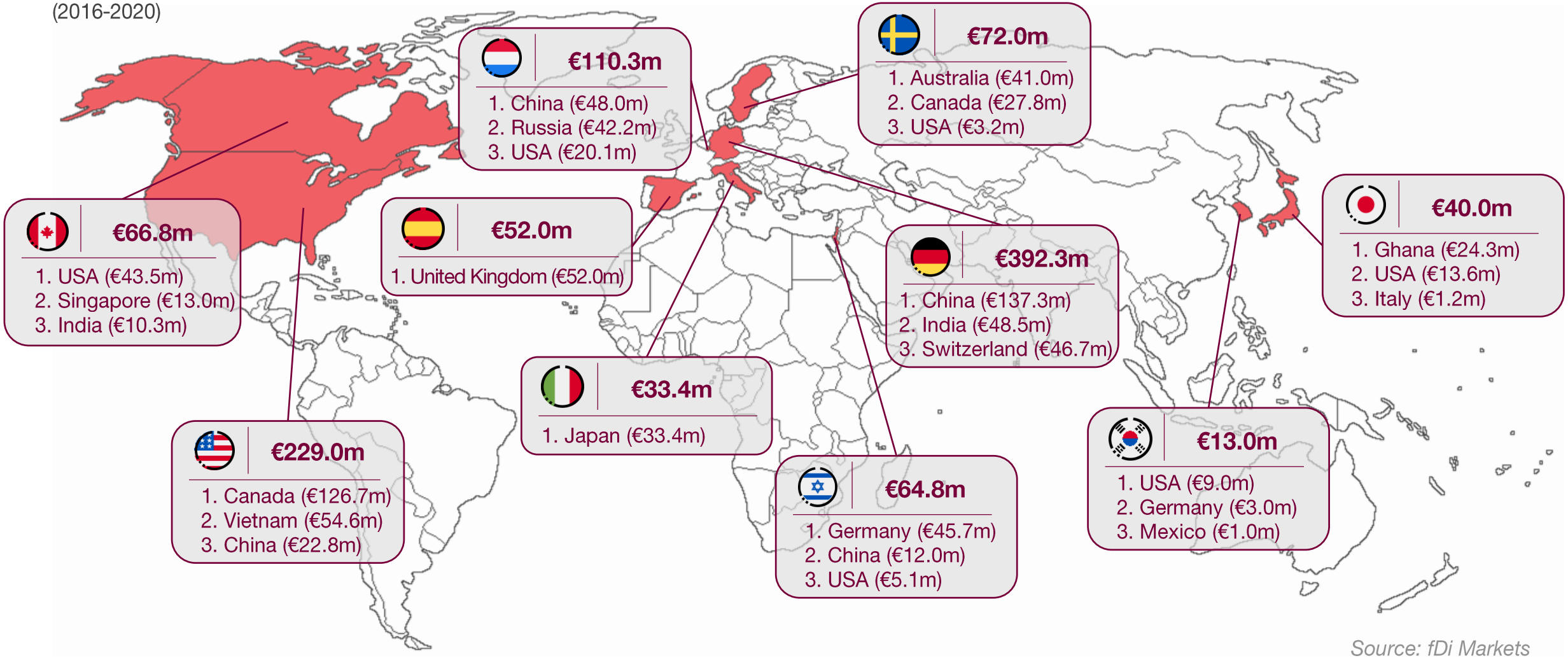
1. Nanox Imaging, July 2020
   Round value: **$US59m**
2. Glympse Bio, July 2020
   Round value: **$US46.7m**
3. Nanox Imaging, January 2020
   Round value: **$US26m**
4. PredaSAR, March 2020
   Round value: **$US25m**
5. Nanox Imaging, June 2020
   Round value: **$US25m**
6. Peak Nano Optics, April 2020
   Round value: **$US25m**
7. Advano, January 2020
   Round value: **$US18.5m**
8. Group14, December 2020
   Round value: **$US17m**
9. Huake Tek, January 2020
   Round value: **$US14.5m**
10. NAWA, February 2020
    Round value: **$US14.1m**

The sectors showing the most interest are medical imaging and biotechnology, along with the application of nanotechnology in batteries and energy storage systems.

Source: Crunchbase.
**Criteria: Pre-seed, Seed and Series A, B and C funding rounds.*

Foreign investment in nano around the world

Top 10 source countries for foreign investment in nanotechnology and nanoscience, with their total value and main destinations by investment volume
(2016-2020)

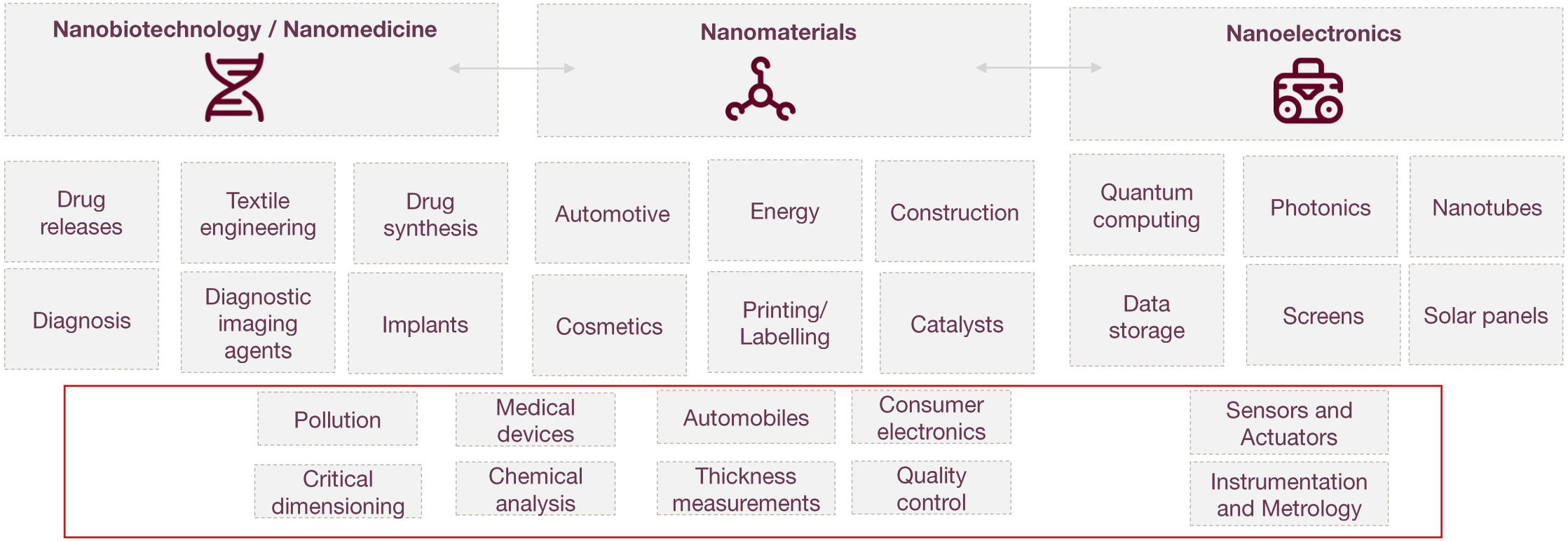


Source: fDi Markets

3. Main recent and prospective applications by demand sector and SDGs

Segmentation of nanotechnology applications

The strong convergence of nanotechnology with the areas of electronics, biotechnology and materials results in the areas of **nanoelectronics**, **nanobiotechnology** and **nanomaterials**.



Source: Nanociencia y Nanotecnología en España de Phamtons Foundation

Applications in demand sectors

Energy

Improve production system, storage (manufacturing of more efficient and less polluting batteries) and energy distribution. Solar cells. Battery catalysts.

Food industry

Packaging to extend food conservation time.
Nanosensors to control food status.
Functional nanofoods.

Agriculture

Nanoencapsulated conventional fertilisers, pesticides and herbicides aid the slow and sustained release of nutrients and agrochemicals, resulting in precise plant dosing. Soil remediation.

Health. Nanomedicine

Early disease detection, early and customised treatment and precise monitoring of evolution. Biosensors.

Covid-19 nanotechnology

Use of nanofibres and nanoparticles in making protective material, formulating antiviral coatings, nanobiosensor-based detection systems, nanoencapsulation of vaccine proteins.

Cosmetics and hygiene

Maintain formulation properties and stability. Extend cosmetic effect duration. Sunscreens.

Architecture and construction

Lighter and more resistant new materials. Improve paint and varnish properties; steel part coatings to prevent corrosion, etc.

Electronics

Carbon nanotubes for microchip manufacture. Lighter, more conductive and resistant quantum nanocables.
Graphene for flexible touchscreen development.

Textile industry

Extend textile lifespan and provide antiwrinkle, antibacterial, stain-repellent and UV protection properties.

Prospective. Opportunities and Challenges

Disruptive technology

Advances in research will drive emerging applications and the uptake of nanotechnology in medical diagnostics and imaging, while technological progress in nanodevices could be a key factor in growing the nanotechnology market.

New materials

Creation of lighter new materials with good mechanical properties that can also leverage other properties such as thermal or electromagnetic insulation. These new materials can be applied to the design of transport vehicles and to store energy, batteries, hydrogen and nanocatalytic processes.

Nanosensors

Nanosensors will be key to enabling real-time control of water, rivers and air quality, as well as diagnosis equipment.

Graphene and quantum dots

Graphene and quantum dots are two areas of research with strong potential for application across different sectors.

Challenges

The rollout of nanodevices in extreme conditions, the high cost of the technology and the scalability of the means of production are the main barriers hampering the growth of the nanotechnology market. Additionally, the scarcity of chips due to the Covid-19 pandemic has threatened many industries and nanotechnology could be a good partner for digitalisation.

Multidisciplinary approach

Next-generation nanotechnology will be deployed in remote, inaccessible or biological environments and present many challenges to the design of sensors, materials, device functionality and packaging. All these aspects require a multidisciplinary approach to push past these challenges.

Nanotechnology and the SUSTAINABLE DEVELOPMENT GOALS (I)

1. No poverty:

Nanotechnology can be harnessed to reduce water and fertiliser use, making it possible to step up farming productivity, especially in drought-affected countries.

2. Zero hunger:

Nanocomposite smart packaging could enable longer and safer food storage.

3. Good health and well-being:

Nanotechnology is expected to bring health and quality-of-life benefits to society in the long term.

6. Clean water and sanitation:

New nanotechnology-based components in the water treatment and purification process could improve access to water for many people.

7. Affordable and clean energy:

Photovoltaic devices based on nanostructures could step up device efficiency.

8. Decent work and economic growth:

The rise in these manufacturing processes will have a positive economic impact.

Nanotechnology and the SUSTAINABLE DEVELOPMENT GOALS (II)

15. Life on land:
Nanotechnology could power the recovery of places with contaminated soil.

13. Climate action:
Onboarding nanotechnology could ramp up energy efficiency by leveraging more efficient lighting devices or new materials able to reduce energy loss in transmission lines.

12. Responsible consumption and production:
Production and consumption processes could tap nanotechnology for more sustainable materials and uses.

11. Sustainable cities and communities:
Nanotechnology could become a technological driver of production processes, reducing pollution and material and energy consumption.

9. Industry, innovation and infrastructure:
Nanotechnology could lead to improvements across different manufacturing processes and foster product and process innovation.

4. Nanoscience and Nanotechnology in Catalonia

Value chain segmentation in Catalonia (I)

Nanobiotechnology / Nanomedicine

Businesses devoted to drug design and drug releases, diagnostics and medical imaging, implants and tissues.

Nanomaterials

Companies that work on the design and improvement of materials for different applications in the metal industry, surface modification and catalysts in different sectors.

Nanotextiles

Applications specific to the textile industry to enhance performance and features.

Nanoelectronics

Use of nanotechnology in electronic parts such as transistors, chips, semiconductors, etc.

Instrumentation and Metrology

Instrumentation equipment for the study, research, production and quality control of nanomaterials such as microscopes, particle size analysers, spectrophotometers, etc.

Value chain segmentation in Catalonia (II)

The strong convergence of nanotechnology with the areas of electronics, biotechnology and materials results in the areas of **nanoelectronics**, **nanobiotechnology** and **nanomaterials**.

Nanobiotechnology / Nanomedicine

Nanomaterials

Nanotextiles

Nanoelectronics

Instrumentation and Metrology

Nanotechnology map in Catalonia

107 companies

€430m

779 jobs

62.6% of the total are SMEs

31.7% of the companies have turnover in excess of **€1m** and **15.8%** in excess of **€10m.**

18.6% of the companies are less than 10 years old

25.25% are startups

Gender diversity in management

29.5% of the companies employ women in management

Degree of internationalisation

53.2% of the companies are exporters

By area, 42.9% of the companies engage in **nanomaterials**; 42.0% in **nanobiology/nanomedicine**; and 23.4% in **nanoelectronics***.

**Companies can be classified into more than one segment within the nanotechnology value chain.*

Source: ACCIÓ (latest available figures)

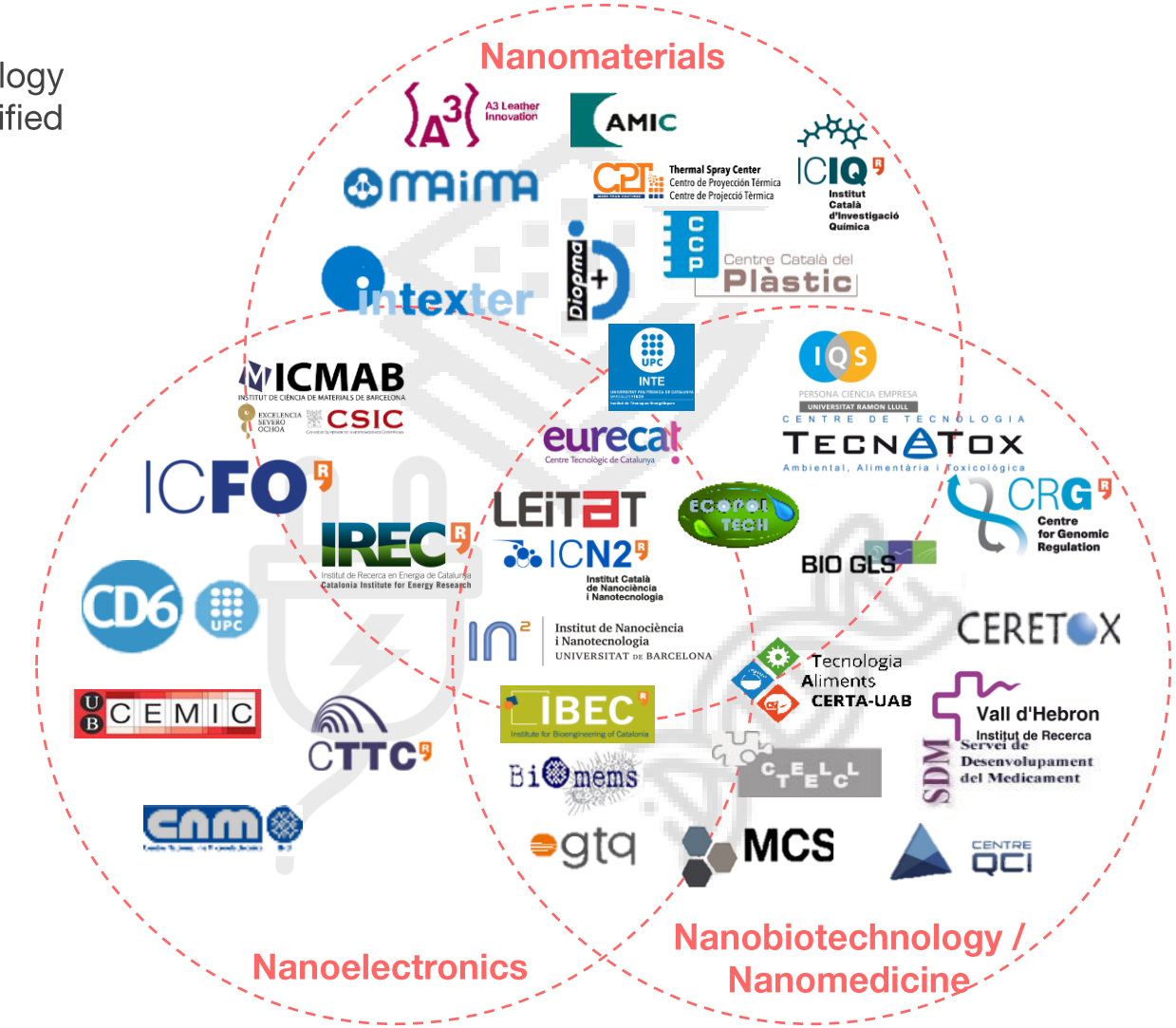
Nanotechnology ecosystem agents in Catalonia

The ecosystem around nanotechnology has strong potential and is highly dynamic

Source: ACCIÓ

Technology centres and research institutes with a nanotechnology research area

The Venn diagram shows the Catalan technology centres with research areas in nanotechnology classified by area of dedication.



Educational offer in nanoscience and nanotechnology

Degrees

Dedicated nanoscience and nanotechnology degree

Universitat Autònoma de Barcelona

Universities offering degrees with nanoscience and nanotechnology content

Universitat Autònoma de Barcelona · Universitat de Barcelona · Universitat de Girona · Universitat Politècnica de Catalunya BarcelonaTech · Universitat Pompeu Fabra Barcelona · Universitat Rovira i Virgili · UVIC

Examples:

- Degree in Biological Systems Engineering
- Degree in Biotechnology
- Degrees in Chemistry and Physics
- Degree in Biomedical Engineering
- Degree in Bio-IT

Master's Degrees

Universitat Autònoma de Barcelona	Universitat de Barcelona	Universitat Pompeu Fabra Barcelona	Universitat Rovira i Virgili
Master of Nanoscience and Nanotechnology	Master of Nanoscience and Nanotechnology	Master of Multidisciplinary Research in Experimental Sciences	Master of Nanoscience, Materials and Processes Frontier Chemical Technology

Outreach in Catalonia

NanoEduca is a programme designed to introduce nanoscience and nanotechnology to high-school students and teachers. The companies behind the initiative are the University of Barcelona (UB), the Catalan Institute for Nanoscience and Nanotechnology (ICN2), the Autonomous University of Barcelona (UAB) and the CESIRE organisation at the Government of Catalonia's Department of Education.

NanoInventum aims to bring the world of nanotechnology to primary-school students.
It is a pedagogical proposal that works across different curriculum areas by harnessing worksheets and activities with appeal for children and leveraging their capabilities. The core methodology turns on reasoning, deduction, play and relations with others.

The "10Alamenos9" festival, the most important initiative at the Ibero-American level for nanotechnology outreach. The Festival is coordinated by the University of Barcelona as part of the NanoDivulga UB project and takes different approaches to the scientific dialogue around nanotechnologies.
It was established in 2016 with the goal of promoting events in the nano world and revealing what is being done in research and technology. The sixth edition of the Festival, held in 2021, drew around 70 organisations (universities and research centres) from 40 cities in 15 Ibero-American countries.

5. Business cases and projects in Catalonia

Business cases and projects in Catalonia (I)

GRAPHCAT– The Graphene Community in Catalonia

NanoHub.cat – Advanced Materials Cluster Platform

ASTREA MATERIALS – Nanocatalysts for the elimination of air pollution

Ecostratar - Nanocapsules that reduce cancer drug toxicity

BASF - Nanomaterial responsible innovation

ADVANCED NANOTECHNOLOGIES. Nanocoatings

Business cases and projects in Catalonia (II)

BrainCoin – The graphene implant to treat epilepsy patients

GRAPHENICA LAB. Printing of graphene flexible sensors and electronic devices on any surface

OptiNanoPro – Lightweight materials for the automotive industry

Nanomol technologies – New DELOS nanomedicine for the treatment of complex injuries

ROVALMA – BAINWEAR: Nanostructured bainitic steel for greater durability of wear-resistant components

Thank you!

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More information about the sector and related news:
http://catalonia.com/industries-in-catalonia/sectors/chemical-energy-and-resources/

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