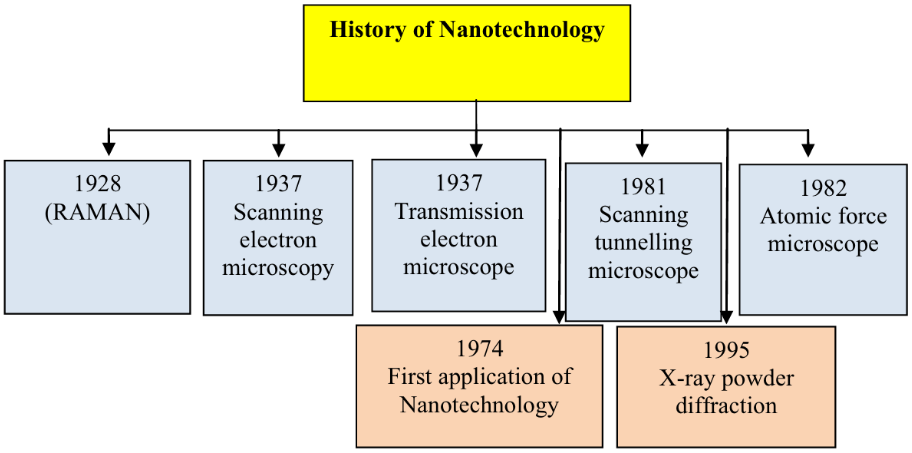
Major subfields of nanotechnology



Methodology in nanotechnology

There are two distinct approaches to doing nanoscience. And the difference in them is noticeable in business, as we will see later. But let's now outline the two approaches – bottom-up and top-down in this table:

	Bottom-up	Top-down
How:	Trough sol-gel, molecular condensation, vapour deposition, atomic layer deposition	Chemical etching, mechanical/optical/thermal process, sputtering
Who:	Start-up, labs	Industry, labs
Benefits:	Very flexible and low-cost	Controllable, precise
Drawbacks:	Hardly scalable (especially for CVD)	Costly

With nanoscience you can develop tools (nanotools), devices (nanodevices) and materials. The tools may include computer simulations, another subfield-surface science, nanolithography, spincoating, nanofluid dynamics . In devices you can develop miniatures – nanoelectronics ,spintronics, sensors (Discussion: my idea about the road sensor). And for the materials – graphene, fullerene, thin films, tubes, wires, meshes, filters, fluid canals.

You may be more interested in the material section.

Commented [ПЕ1]: The sol-gel method is a chemical process used to synthesize materials, particularly ceramics and glass, by transitioning a solution (sol) into a solid (gel) phase. It involves the hydrolysis and condensation of precursors like metal alkoxides, forming a network structure that eventually solidifies through drying and heating. This method offers precise control over material composition and structure, making it ideal for producing nanoscale and porous materials. Typical precursors are metal alkoxides.

Commented [ПЕ2]: Vapour deposition is a process used to create thin films or coatings by converting material into vapor form and then condensing it onto a substrate. There are two main types: Physical Vapour Deposition (PVD), where vapor is produced through physical means like traditional evaporation and follow-up condensation, and Chemical Vapour Deposition (CVD), where vapor is formed through chemical reactions

Commented [ПЕ3]: Sputter deposition uses the kinetic energy of fast-moving ions in a plasma to vaporise a coating material, which will then be deposited on a substrate as a thin film.

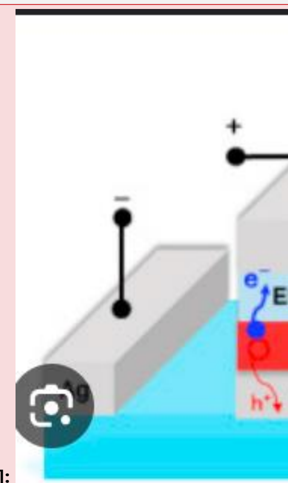
Type 1 is **carbon-dependent** nanomaterials. As the name suggests they are made of carbon atoms and take many forms, mainly hollow shape. This category holds popular examples like diamond, fullerene, nanotubes, graphite and graphene.

Type 2 represents **metal-based** nanomaterials. In our SPV experiments we use electron transport layers (ETL) and hole transport layers (HTL). They are perfect examples of this type. A good ETL is TiO_2.

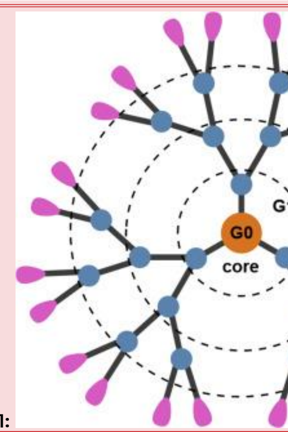
Dendrimers (type 3) are nano-sized branched polymeric materials that are composed of three diverse architecture constituents: core, branches, and terminal functional groups. A dendrimer's surface is covered in multiple chains ends that can be configured to carry out particular chemical tasks.

Composites are combinations of nanoparticles with other nanoparticles or with larger, bulkier materials. To develop them, clays and polymers can be employed.

Another classification is by dimensions: g one dimension (e.g. thin films, layers, and surfaces), two dimensions (e.g. nanowires and graphene sheets which can be rolled into nanotubes), and three dimensions (e.g. nanoparticles, fullerenes, graphite sheets, dendrimers and quantum dots). Based on composition, nanomaterials can be categorized as single phase solids (e.g. crystalline, amorphous particles and layers), multiphase solids (e.g. matrix composites, coated particles), and multiphase systems (e.g. colloids, aerogels, Ferrofluids). All types of nano-sized substances are categorized as metals, ceramics, polymers, or composite materials



Commented [ПЕ4]: All-inorganic perovskite cell. FTO serves as a transparent to prevent contacts from leaking to charge carrier layers,



Commented [ПЕ5]:

Commented [ПЕ6]: Керамиката е общото наименование на изделия от неорганични, неметални материали и техните смеси с минерални добавки.

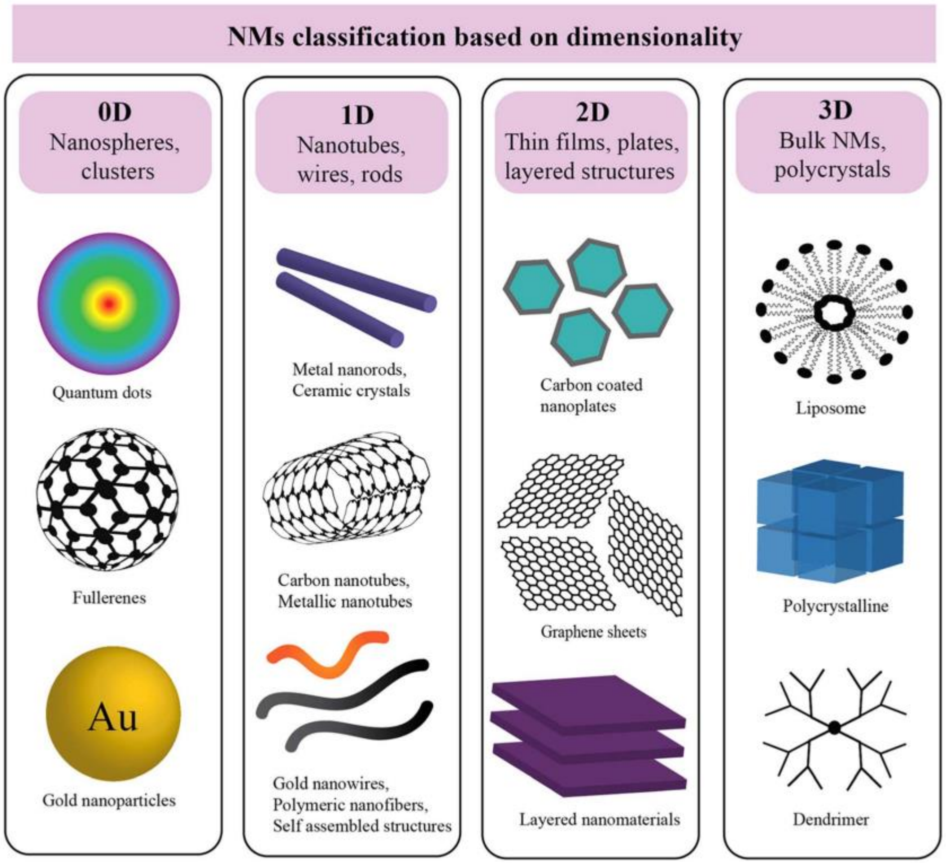


Fig.2. Classification of nanomaterials by dimensions. [5]

But the important thing to remember about all these materials is that their surface area per unit volume is higher results in higher surface activity which means efficiency of many processes can be significantly improved.

Successful applications

An application that deserves the most attention because, after all, we’re all humans is cancer therapy. Imagine a group of cancer cells that reside somewhere in your body. If you inject a nanoparticle there and excite it with infrared waves then you are able to safely kill those cancer cells. I call it semi-invasive technique.

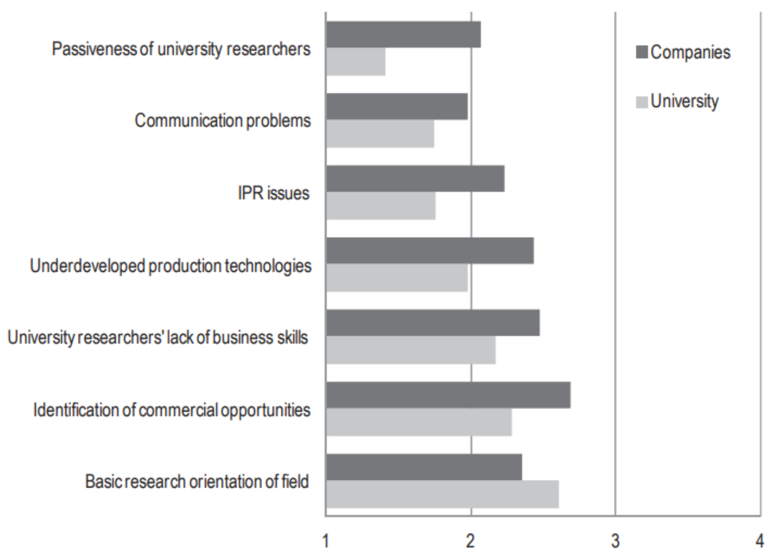
Other impactful uses of nanotech can be discovered in:

Area	Instrument
Water treatment	Nanofilters,nanoscale metal oxides, nanophotocatalysts
Agri-food production	Bioactive compounds
Оптоелектроника	Transparent conducting electrodes

Problems from industry's point of view

A study by Palmberg (2008) looks at challenges for transferring nanotechnology from universities to industry (Figure 2.1) in Finland. University researchers view their basic research orientation as the most significant challenge. Researchers in industry highlight the identification of commercial opportunities in university research, university researchers' lack of business skills, and underdeveloped manufacturing technologies as the core challenges. Further, university researchers' basic research orientation appears to be an inhibiting factor for patenting and licensing of nanotechnology research.

Figure 2.1 Challenges for technology transfer: university researchers versus companies



Note: All differences statistically significant at 5% level. The results are based on 476 survey responses. The x-axis measures the degree of importance of challenges on a scale from 1-4.

Source: Palmberg (2008).

It may of interest to comment the barriers to commercialization thought by executives.

Barriers to commercialization (thoughts of executives 2003,2005,2009)

US	Germany (majority are startups)	Australia	Finland
Few efficient manufacturing methods, lack of infrastructure equipment, fragmented markets, few early adopters	Costs and funding	lack of customer demand for nanotechnology products	identifying commercial applications
High initial investment costs for building AND maintaining facilities	Lack of skilled personel	Lack of skills for maintaining the development processs	lack of standards or customer/consumer acceptance
Competent academic entrepeneurs	Partners		difficulties in achieving reliable mass production
Lengthy time-to-market	Market potential + Legislative issues (least common)		shortage of funding
Poor process scalability			
EHS concerns			

Maine and Garnsey (2006) have undertaken empirical work on nanotechnology value chains based on company interviews. They focus on commercialisation challenges of new ventures (company start-ups) in the upstream segments of the nanotechnology value chain, highlighting the challenges these ventures face for managing scientific and technological developments, on the one hand, and market needs, on the other. According to the study, the science-based nature of nanotechnology, and its broad applicability, implies that **replication of laboratory attributes in prototypes and production processes is very complex, demanding and expensive**. As nanomaterials are often used in larger product systems (for example nanocoatings for car engines) interoperability between materials, components and the whole system is also important. These issues introduce high levels of technological and market uncertainties for commercialisation.