FAKULTA TEXTILNÍ TUL

Textile Engineering KMI/TEN

Technical applications of nonwovens & Nanofibrous materials

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Contents of Lecture

Technical Application of Nonwovens

Nanofibrous Materials

Nanofibrous Materials

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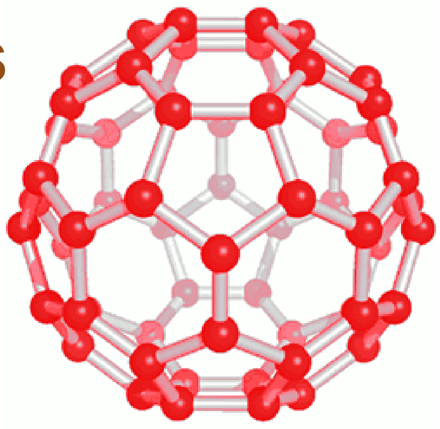
Definition of nanomaterials

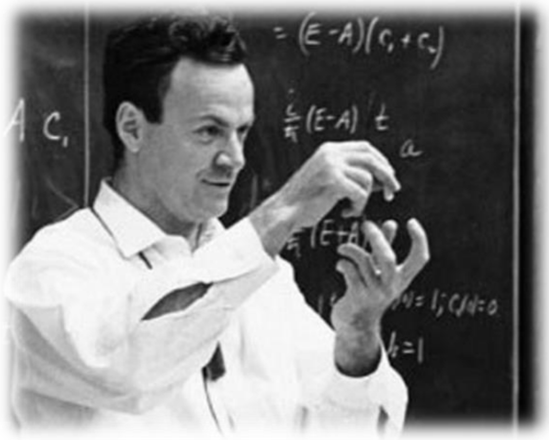


The prefix "nano-" comes from the Greek word "nanos", which means "dwarf" or "very small". The term was first used in the 1960s when the International System of Units (SI) was introduced, and it was adopted to represent one billionth of a unit of measurement. The prefix "nano-" signifies something that is extremely small or precise, and is commonly used in various fields such as physics, chemistry, biology, and engineering.

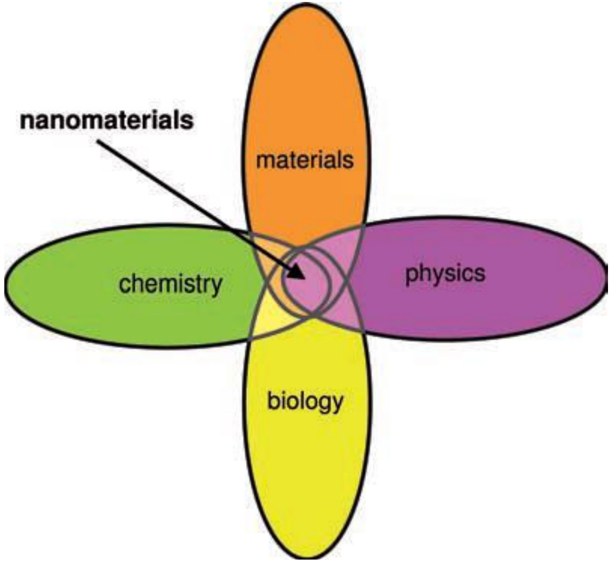
Definition of nanomaterials

Dimension: 1 to 100 nanometers (According to National Science Foundation in the United States Nanotechnology). Abbreviated as nm, is a unit for length that measures one billionth of a meter. (1 nm= 10^{-3} μm = 10^{-6} mm = 10^{-7} cm = 10^{-9} m.)

"There's Plenty of Room at the Bottom" by Prof. Richard Feyman on December 29, 1959.

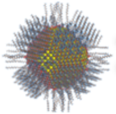


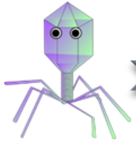
A basic understanding of physics and chemistry, and some knowledge of materials science, is necessary to understand the properties and behavior of nanomaterials.



Size of nanomaterials

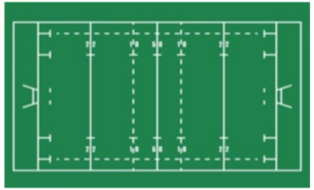
If a nanoparticle was the size of a football





A virus would be as big as a person

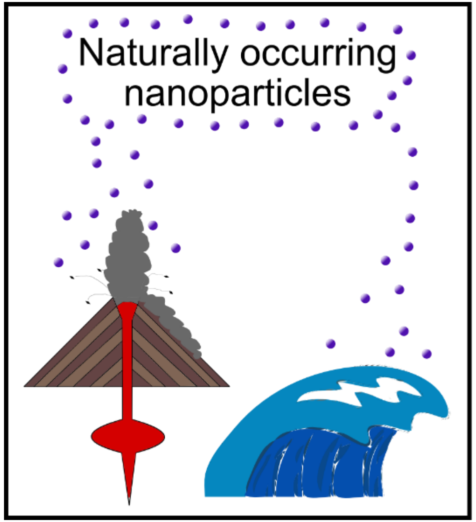
A red blood cell would be the size of a rugby field

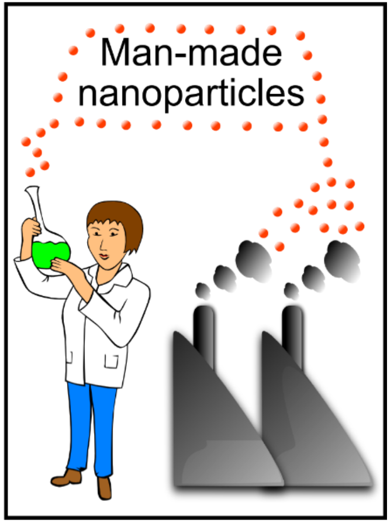


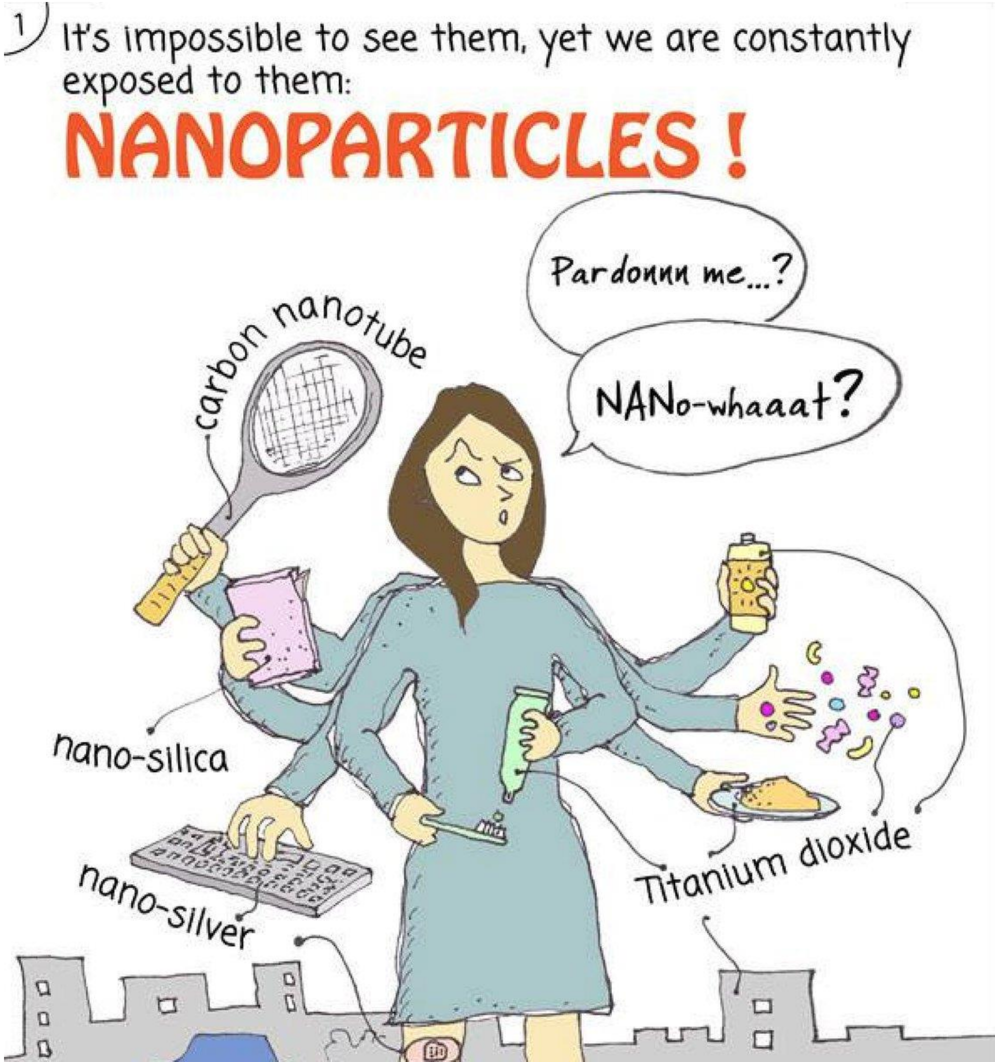
A doughnut would be as big as New Zealand

A kiwi would be as big as the world

Where are the nanomaterials?







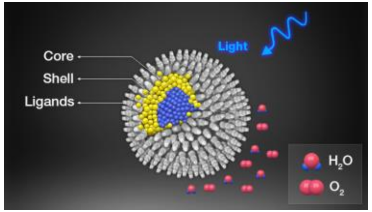
Classification of nanomaterials

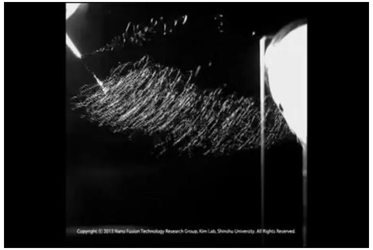
- Zero dimensional structures (0D): In these nanomaterials, all three dimensions are in the range of 1 to 100 nm; One example is quantum dots.

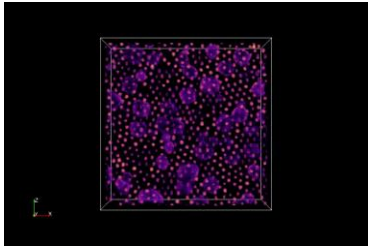
- One dimensional nanostructures (1D): In these nanomaterials, one of dimensions is limited to nanometer scale. One interesting example is nanofibers.

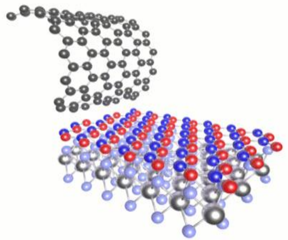
- Two dimensional structures (2D): These nanomaterials benefit from two dimensions larger than 100 nm. Nano-coatings are the most significant example.

- Three dimensional nanostructures (3D): These materials have three dimensions larger than 100 nm, but components of their microstructures are at nanoscale. Nanocrystalline or nanoporous materials are useful examples.



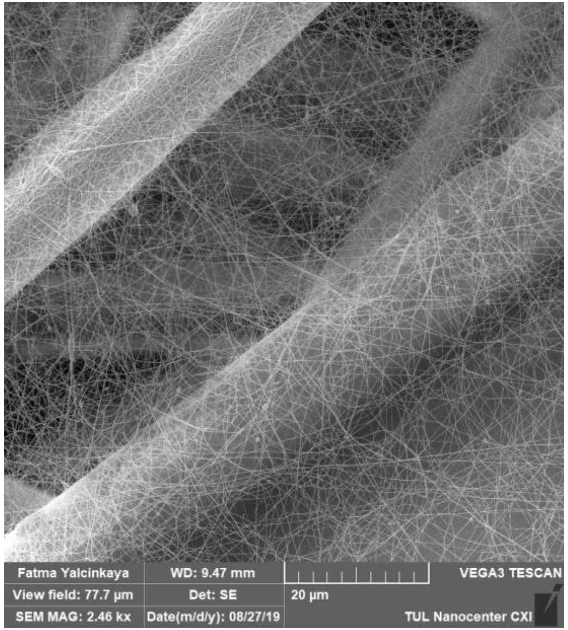


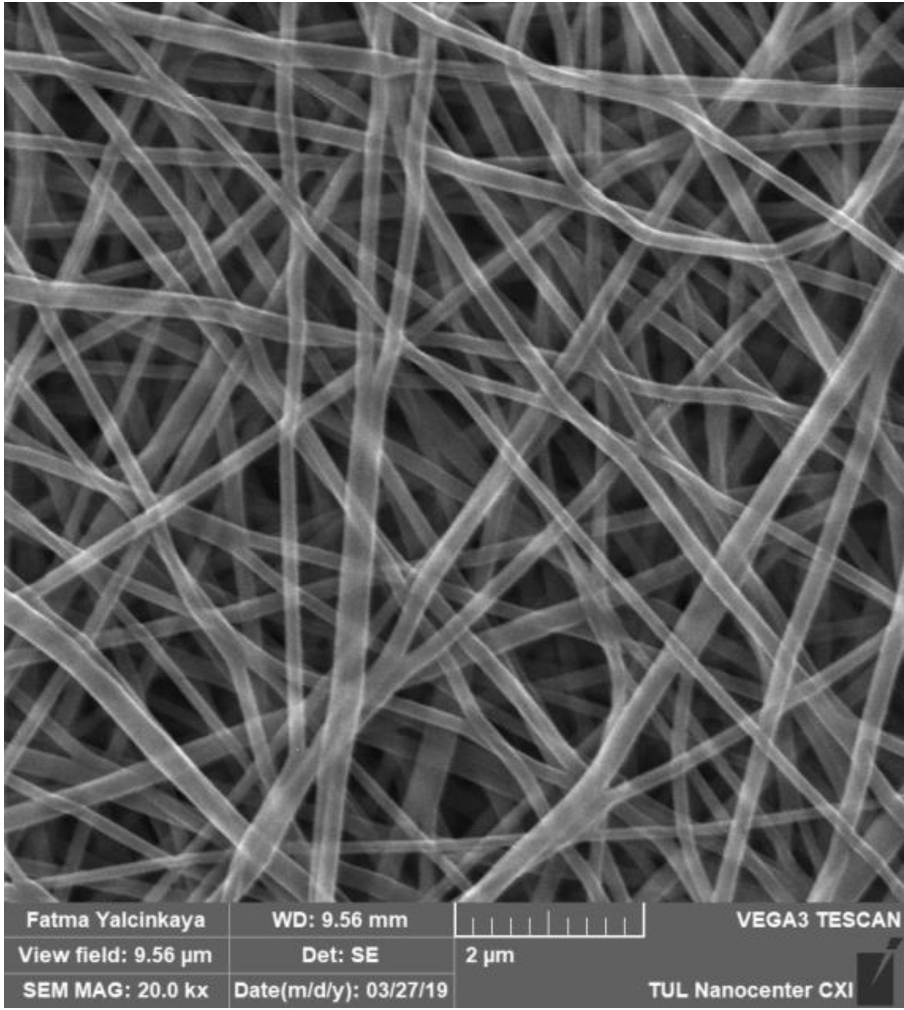




What is nanofiber?

Fibers that has less than 1000 nanometer size called as "Nanofibers".





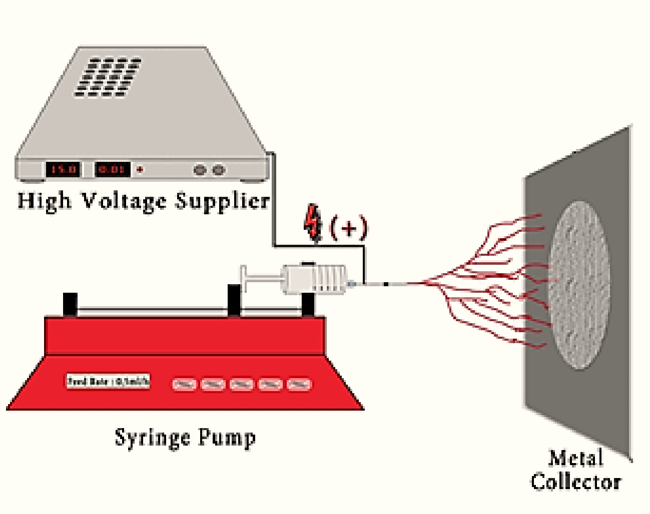
History of nanofibers

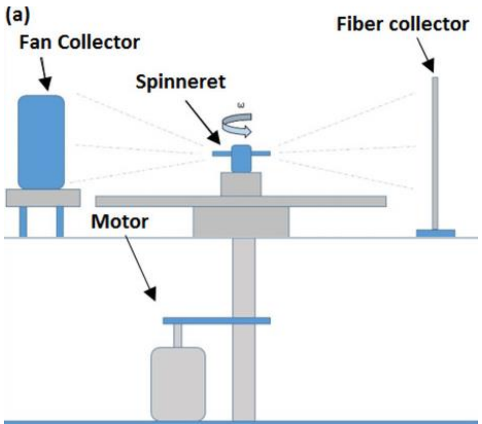
- In1902: The first patent for electrospinning was filed by J.F. Cooley
- Mid-20th century: Researchers first begin studying electrospinning process to produce ultra-fine fibers.
- 1960s: Electrospinning used to produce ultra-fine fibers for air filtration and other applications.
- 1990s: Electrospinning becomes widely used for production of nanofibers.
- Early 2000s: Nanofibers explored for use in tissue engineering to create scaffolds to support growth of cells and tissues.
- Since early 2000s: Nanofibers used in a wide range of applications, including drug delivery, wound healing, energy storage, water filtration, and many others.
- Recent years: Significant progress made in production of nanofibers using sustainable and biodegradable materials, leading to development of new applications in areas such as environmental remediation and sustainable packaging.

Production methods of Nanofibers

Electrospinning: This is the most widely used method for producing nanofibers. It involves the use of an electric field to create a charged jet of polymer solution or melt, which is then drawn towards a collector to form nanofibers. Electrospinning is versatile, and can be used with a variety of materials.

Forcespinning™: This is a proprietary technology developed by a company called Nanofiber Solutions. It involves the use of centrifugal force to spin polymer solutions into nanofibers. Forcespinning™ can be used to produce highly uniform nanofibers with high throughput.

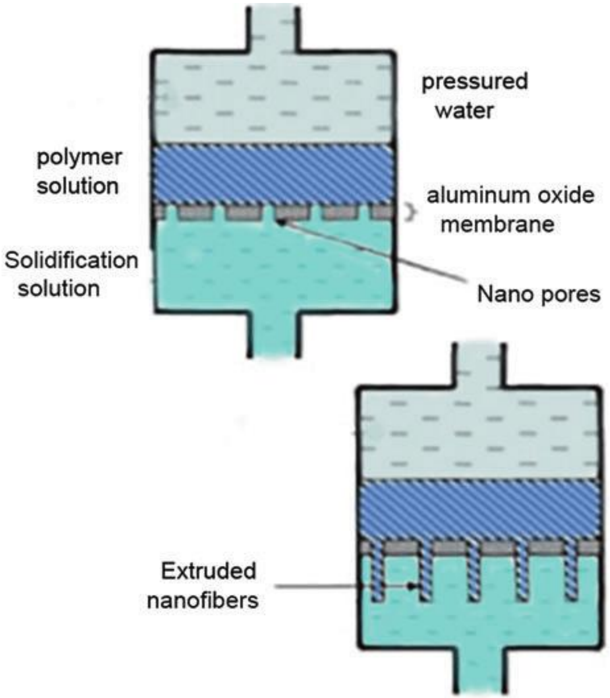




Production methods of Nanofibers

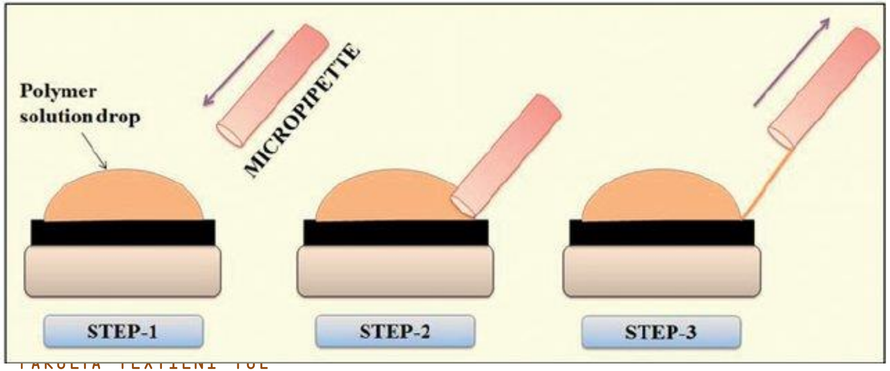
Template Synthesis: This method involves the use of a porous template to create nanofibers. The template is coated with a precursor material, which is then solidified to form nanofibers. This method is limited by the availability of suitable templates and can be time-consuming.

Self-Assembly: This method involves the spontaneous assembly of nanofibers from molecular precursors. It is a promising method for producing functional nanofibers, but is limited by the availability of suitable precursors.



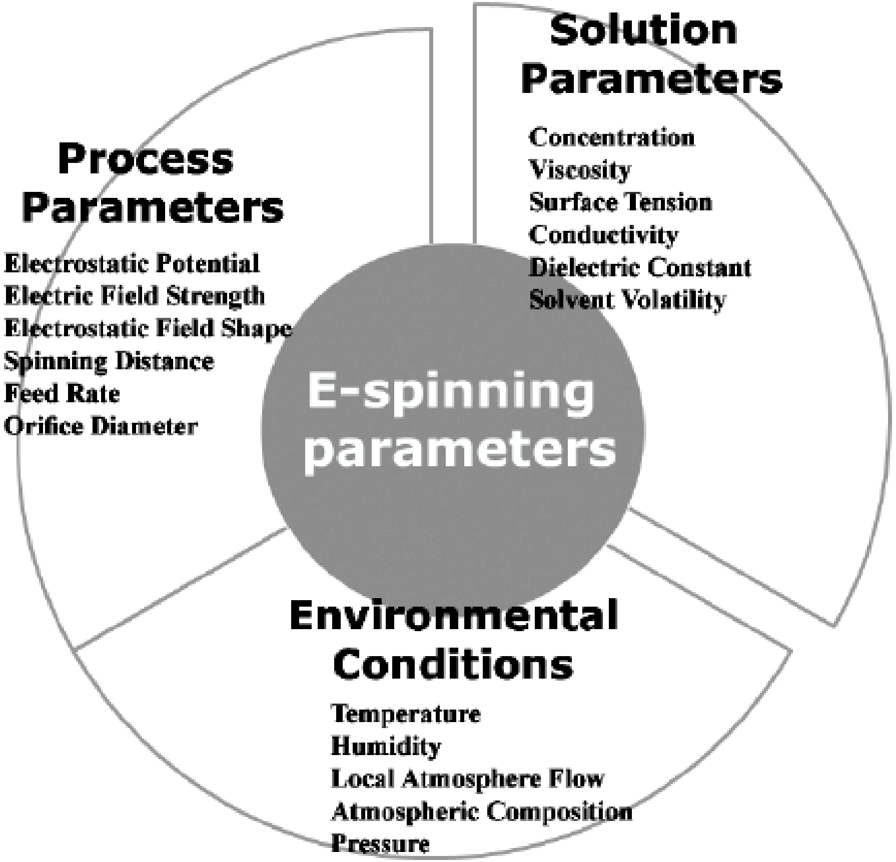
Production methods of Nanofibers

Phase Separation: This method involves the separation of a polymer solution into two phases, followed by the selective removal of one of the phases to leave behind nanofibers. This method is versatile and can be used with a variety of materials, but can be time-consuming.



Drawing: This method involves the stretching of a polymer or biopolymer into a fiber. In some cases, the fiber can be further stretched to the nanoscale using other methods such as electrospinning.

Parameters of electrospinning



Hasanzadeh, M., et al. "Issues in production of carbon nanotubes and related nanocomposites: a comprehensive review." Cellulose Chemistry and Technology 49.3-4 (2015): 237-257.

Nanospider


ELMARCO
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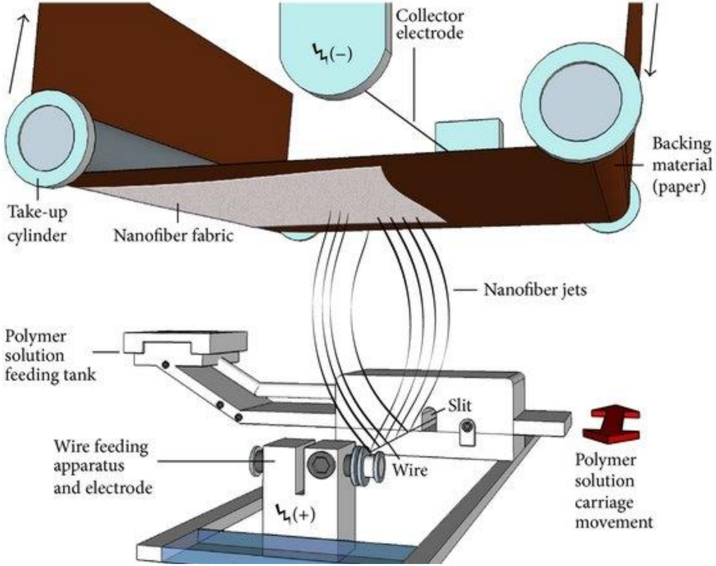
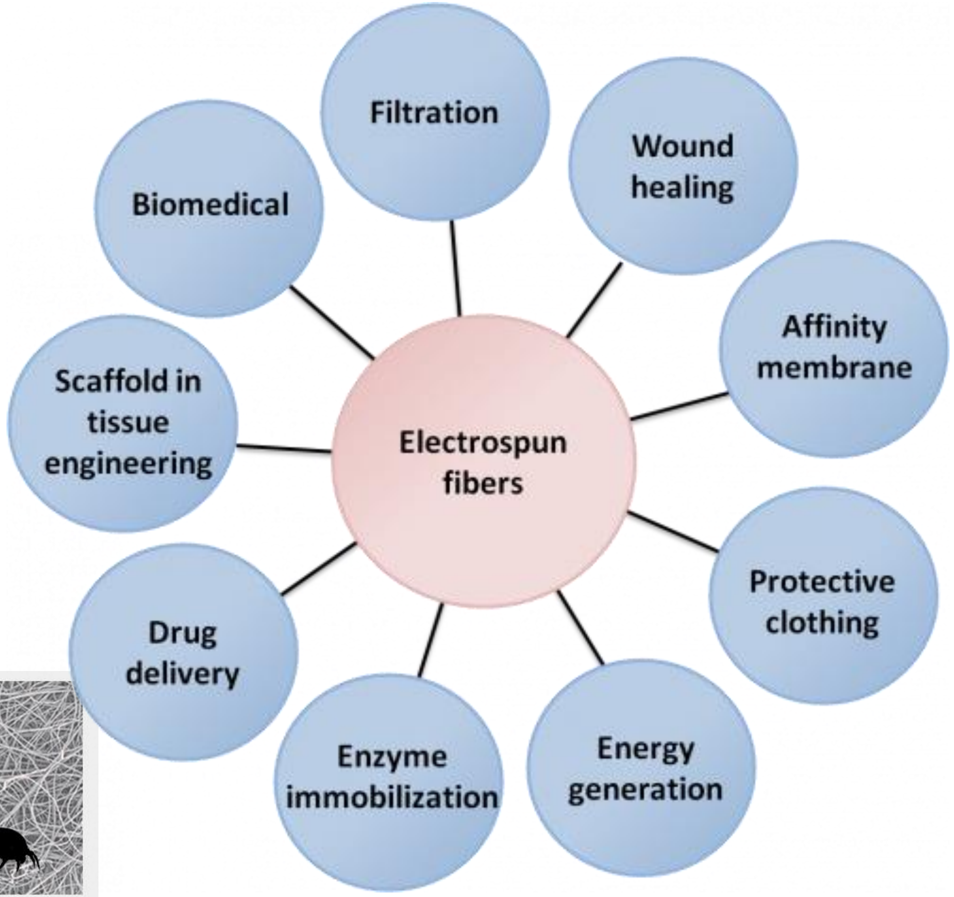
nanospider
NS LAB


makeagif.com


Collector
electrode
(−)
Backing
material
(paper)
Take-up
cylinder
Nanofiber fabric
Nanofiber jets
Polymer
solution
feeding tank
Slit
Wire feeding
apparatus
and electrode
Wire
(+)
Polymer
solution
carriage
movement

Importance of nanofibers in various industries

Under 10,000X magnification, you can see the dense web of fibres creating a physical barrier to dustmites.



Nanofiber Fire Retardant Cartridge Filter
SUPERIOR AIR PRODUCTS

Application of Nanofibers

1. <u>Biomedical applications</u>
- Tissue engineering
- Drug delivery
- Wound healing
- Antibacterial applications

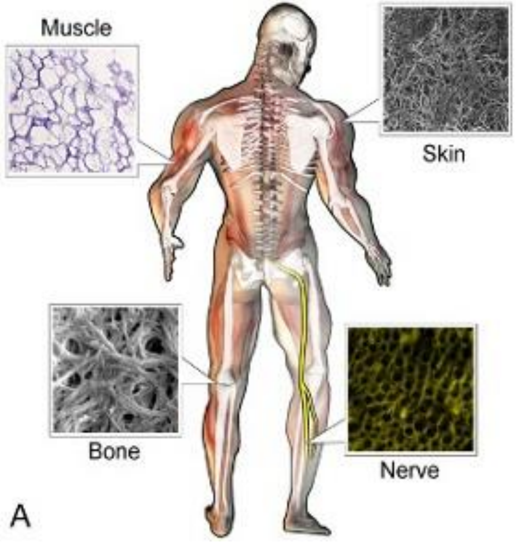
2. <u>Environmental applications</u>
- Water filtration
- Air filtration
- Oil spill cleanup

3. <u>Energy applications</u>
- Lithium-ion batteries
- Solar cells
- Fuel cells

4. <u>Other applications</u>
- Textiles
- Sensors
- Catalysis

Biomedical applications

- Tissue Engineering
- Drug Delivery
- Wound Healing
- Biosensors
- Neural Tissue Engineering
- Implants
- Antibacterial applications



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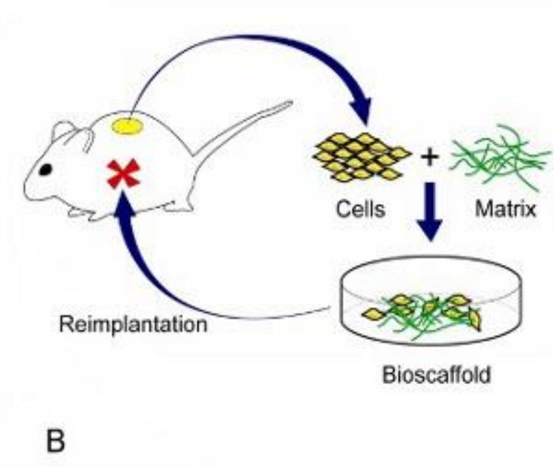
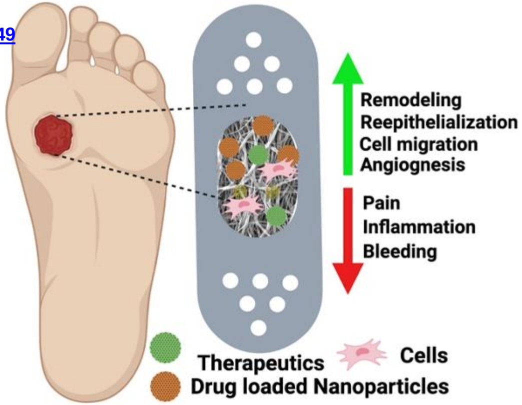


https://doi.org/10.1002/cnma.202100349



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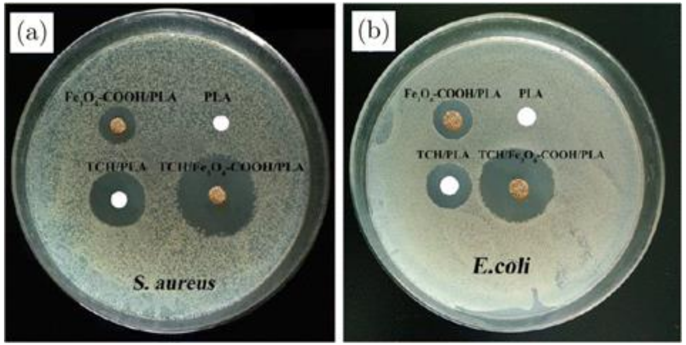
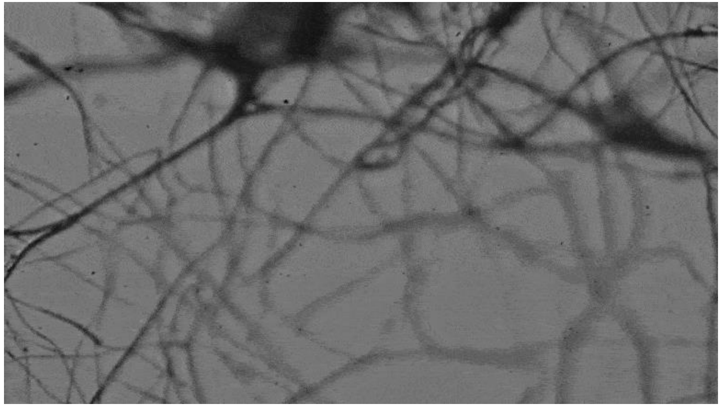
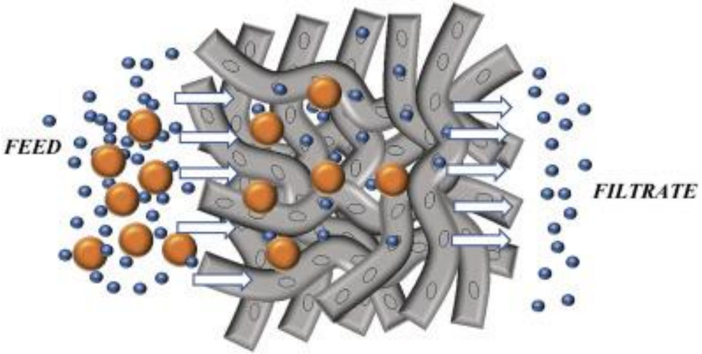
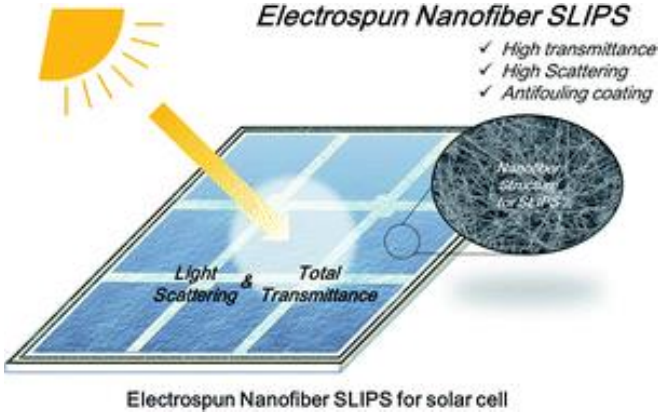


Environmental applications

- Air Filtration
- Water Filtration
- Catalysis
- Energy Storage
- Soil Stabilization
- Oil Spill Clean-up
- Solar Cells



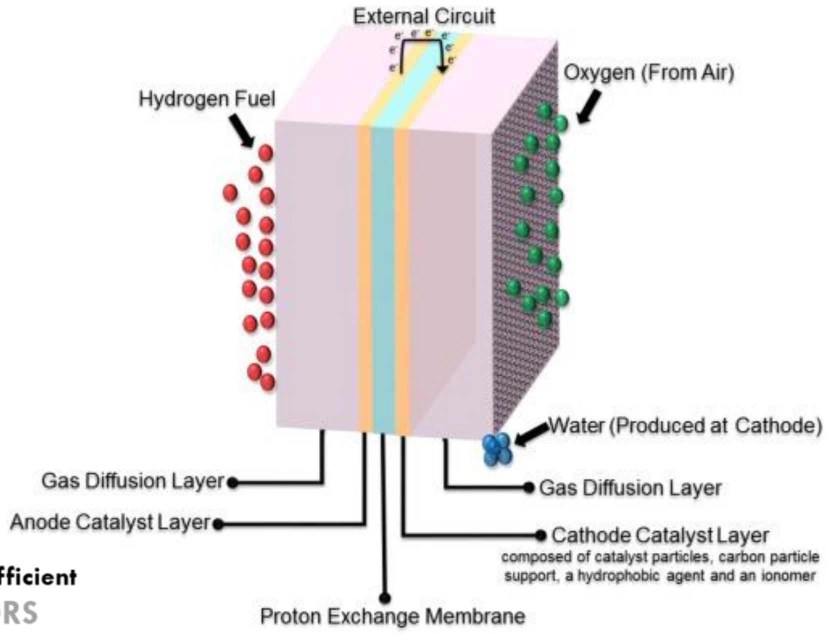




DOI https://doi.org/10.1039/C6RA00276E

Energy applications

- Solar Cells
- Energy Storage
- Fuel Cells
- Thermoelectric Materials
- Hydrogen Storage
- Energy conversion
- Energy harvesting



https://doi.org/10.1016/j.nanoen.2016.06.027

Other applications

Application of nanofibers in Textiles:

- Filtration can be used in textile filters to improve the filtration efficiency and reduce the pressure drop.
- Antibacterial properties suitable for use in medical textiles, such as wound dressings, and protective clothing.
- Thermal insulation suitable for use in winter clothing and home insulation.
- Moisture management suitable for use in sportswear and outdoor clothing.
- UV protection suitable for use in sun protective clothing.

Other applications

Application of nanofibers in Sensors:

- Gas sensing; can be used in gas sensors to detect various gases, such as carbon monoxide, nitrogen oxides, and hydrogen sulfide.
- Biosensing; can be used in biosensors to detect biomolecules, such as glucose, cholesterol, and DNA.
- Strain sensing; can be used in strain sensors to measure the deformation of materials.
- Pressure sensing; can be used in pressure sensors to measure the pressure of gases and liquids.
- Temperature sensing; can be used in temperature sensors to measure the temperature of materials.

Other applications

Application of nanofibers in Catalysis:

- Catalyst support; can be used as a support material for catalysts, such as metals or metal oxides.
- Catalyst immobilization; can be used to immobilize catalysts, such as enzymes, for various applications, including biocatalysis and chemical synthesis.
- Photocatalysis; can be used in photocatalysis to degrade organic pollutants and generate hydrogen from water.
- Gas-phase catalysis; can be used in gas-phase catalysis to convert various gases, such as carbon monoxide, nitrogen oxides, and volatile organic compounds, into less harmful substances.
- Electrocatalysis; can be used in electrocatalysis to generate and store energy, such as in fuel cells and batteries.

Challenges and Future Directions

Nanofibers have shown great potential for various applications due to their unique properties, such as high surface area, high porosity, and superior mechanical properties. However, there are still several challenges that need to be addressed in order to fully realize the potential of nanofibers. Some of these challenges include:

Scalability
Uniformity
Toxicity
Integration
Durability
Cost
Standardization
Long term stability

Future directions in nanofiber research

Multifunctionality; Future research should focus on developing nanofibers with multiple functions for specific applications.

Sustainability; Future research should focus on developing sustainable methods for producing and disposing of nanofibers, such as using renewable materials and recycling.

Biomedical applications; Future research should focus on developing nanofibers with improved biocompatibility, stability, and functionality for specific biomedical applications.

Energy applications; Future research should focus on developing nanofibers with improved energy storage capacity, efficiency, and stability.

Artificial Intelligence; machine learning algorithms that can predict the properties of nanofibers based on their composition and production methods.

3D printing; Future research should focus on developing 3D printing techniques for nanofibers that are scalable and cost-effective.

Conclusion

Nanofibers have demonstrated considerable potential for different applications in diverse disciplines, including healthcare, electronics, energy, and environmental remediation. Nanofibers' unique characteristics, such as their high surface area-to-volume ratio, tunable porosity, and high mechanical strength, make them desirable for the development of innovative materials and devices with enhanced performance and usefulness.

Applications for nanofibers are numerous and expanding rapidly.

However, there are still various problems that need to be overcome before the commercialization of nanofiber products can be reached. These obstacles consist of production costs, scalability, laws and standards, intellectual property, and market demand. Manufacturers and researchers must collaborate to overcome these obstacles and provide novel solutions that will enhance the effectiveness, cost, and safety of nanofiber products.

Děkuji za pozornost

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