TECHNICAL UNIVERSITY OF LIBEREC

New Opportunities for the Development of Education at the Technical University of Liberec

Specific objective A2: Development in the field of distance learning, online learning and blended learning

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KNT_TNA_Modification of nanofibers

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NextGenerationEU

CZECH RECOVERY PLAN

MINISTRY OF EDUCATION, YOUTH AND SPORTS

Repetition

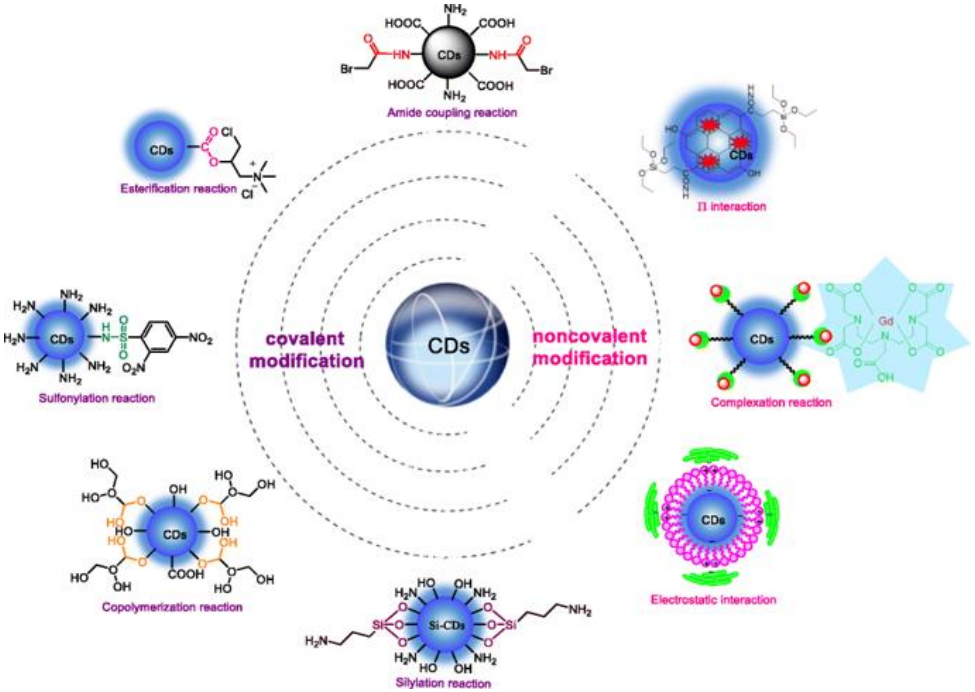
- Production of nanofibers:
  - Electrostatic spinning
  - Centrifugal spinning
  - Melt-blown
  - Drawing
  - …
- Use:
  - Filtration
  - Tissue engineering
  - Isolation
  - …

Modification

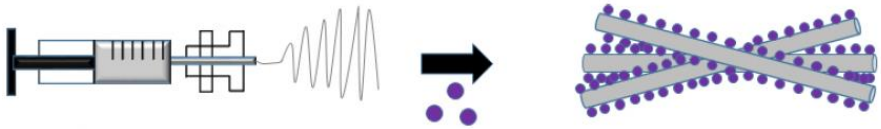
- For various applications, it is necessary to produce nanofibers with defined properties
- Properties of nanofibers affect wettability, electrical conductivity, optical properties, biocompatibility,…
- By modifying nanofibers, we will expand their possible use

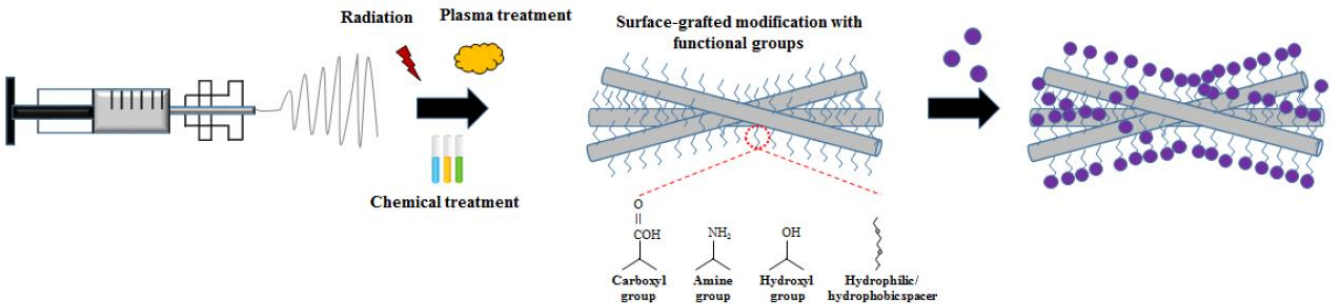
Surface modification

- We bind specific molecules on the surface of the material
- These are: small molecules, surfactants, dendrimers, polymers and biomolecules



Methods of modification

- Physical adsorption 
- By grafting
  - Plasma
  - Radiation
  - Chemical



- Spinning of mixtures 
- Coaxial spinning 

Physical adsorption

- The binding of specific molecules to the surface of the material is achieved through non-binding interactions
  - Hydrogen bond
  - Hydrophobic interactions
  - Electrostatic forces

- The disadvantage of physical adsorption is the rapid release of bound molecules

- The coating method is used to physically modify the surface

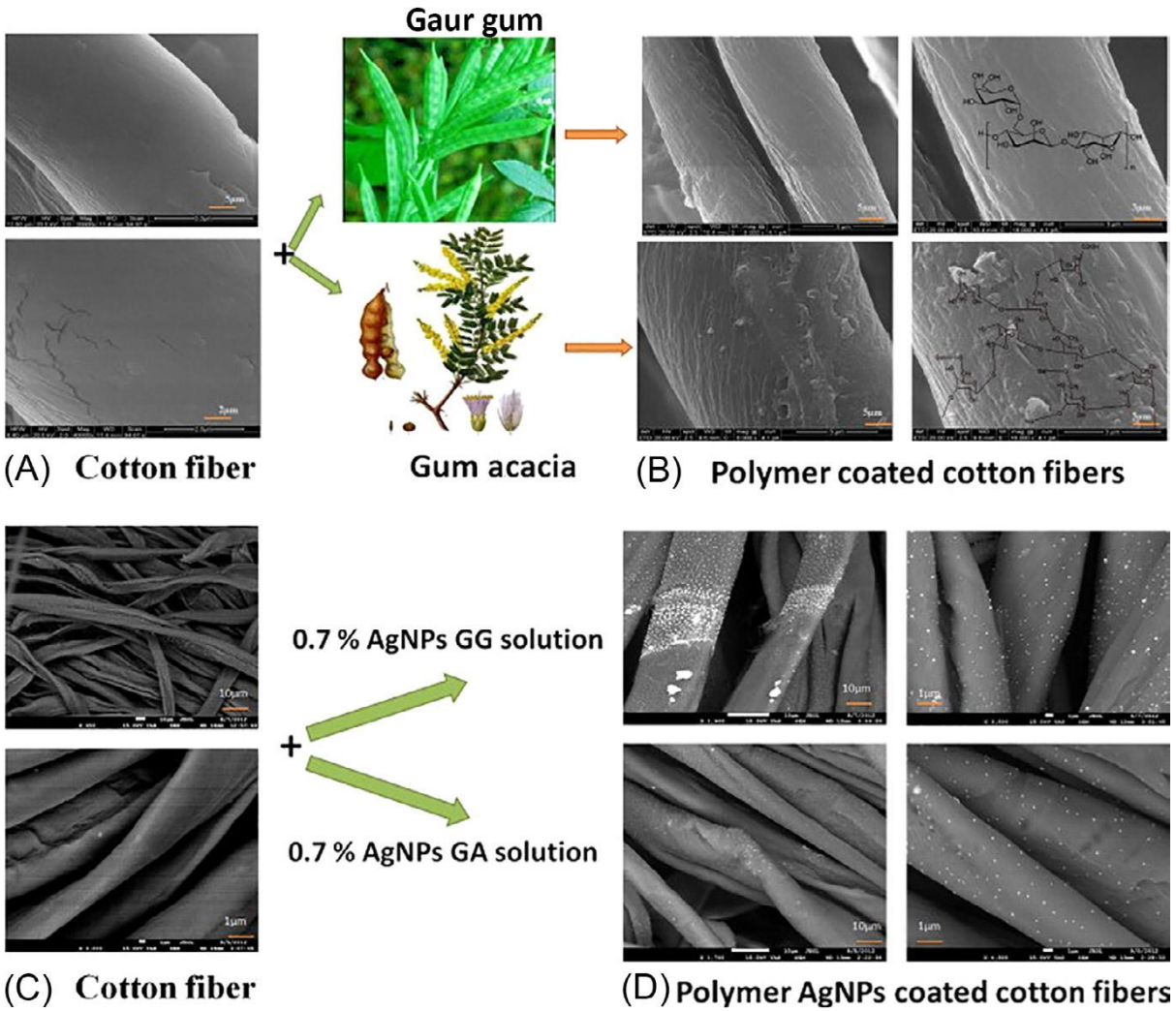
Coating

- Creating one or more layers on the surface of the material
- The coating formed may be ordered or disordered
- Coating methods:
  - Dry way - physical deposition, chemical deposition, plasma, pyrolysis
  - Wet way - sol-gel process, emulsification, solvent evaporation

Use of coating

- The coating formed on the surface of the material can be used for:
  - Protection against rapid degradation
  - Control of the rate of release of substances
  - Extension of the functional time of bioactive substances
  - Creation of antimicrobial film
  - Creation of conductive fibers
  - …

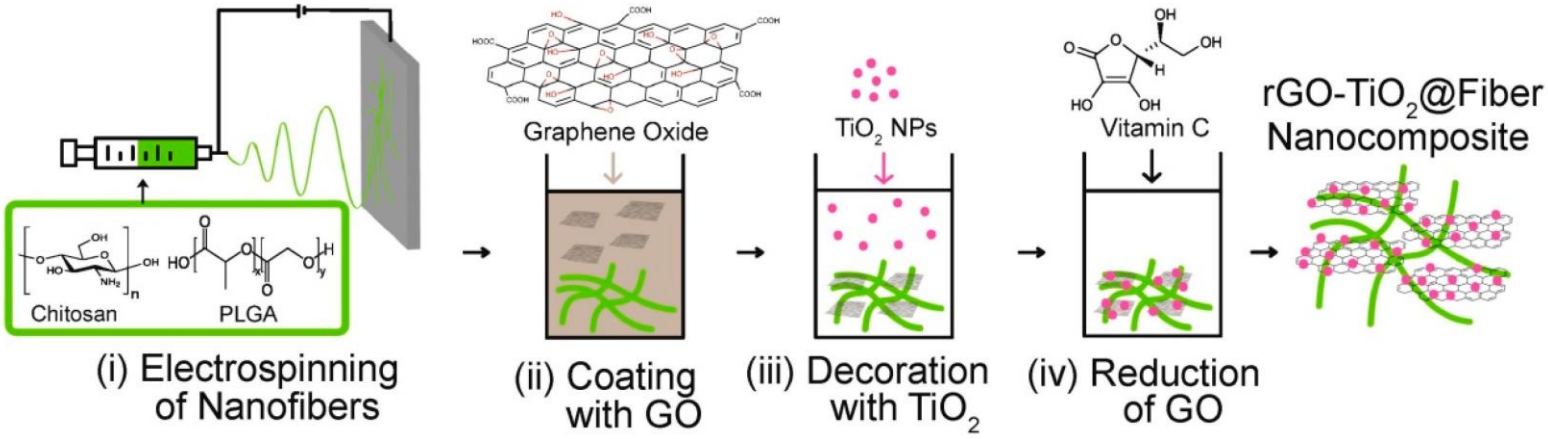
Antimicrobial film



Cellulose-silver nanocomposite fibers. (A) Cotton fiber, (B) Polymer coated cotton fibers, and (C) Polymer AgNPs coated cotton fibers.

Conductive fibers

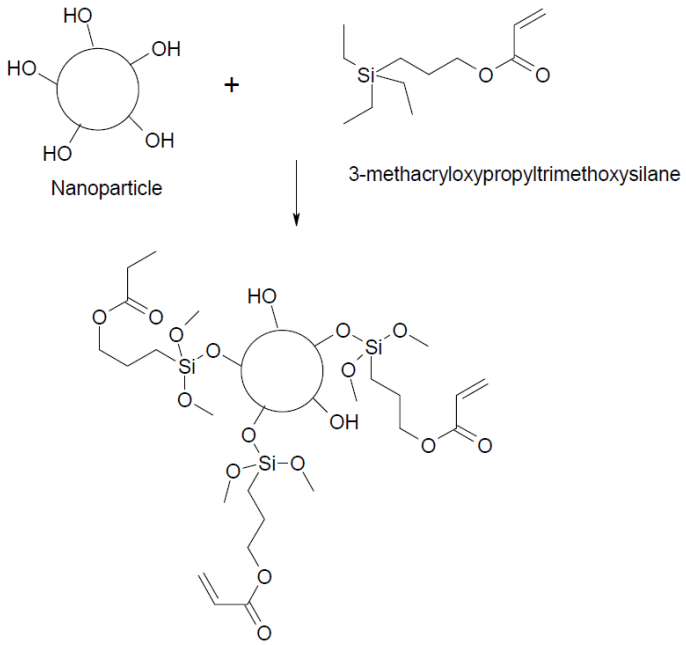
- By means of the coating, it is possible to form conductive fibers from otherwise non-conductive or low-conductivity fibers



Schematic diagram of fabrication of nanocomposite-enabled nanofibers (rGO-TiO_2@Fiber). (i) Generation of amine-functionalized fibrous mats by electrospinning a mixture of poly(lactic-*co*-glycolic) acid (PLGA) and chitosan (10:1 mass ratio, respectively). (ii) Dip-coating of fibers in graphene oxide (GO). (iii) Dip-coating in titanium dioxide nanoparticle (TiO_2 NP) suspension at pH 4. (iv) Reduction of GO with vitamin C for two hours.

Grafting

- It consists in the formation of functional groups on the surface of the material
- Formation of covalent bonds between the functional group of the material and the added molecule



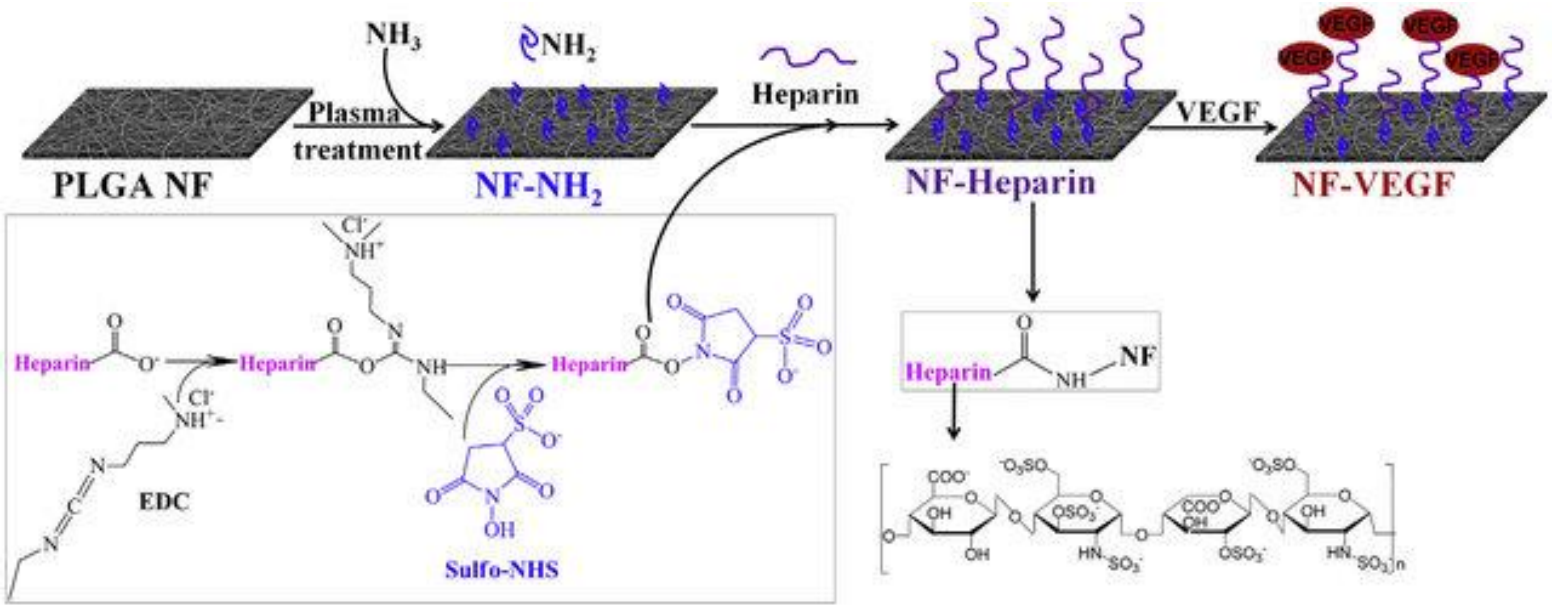
- Grafting can occur:
  - Plasma
  - Radiation
  - Chemical

Plasma grafting

- Plasma is a high-energy state of matter in which gas is partially ionized into charged particles, electrons and neutral molecules
- Plasma is used to immobilize polar groups (carboxyl or amine) on the surface of the material
- Oxygen, ammonia, argon, or air are most commonly used for plasma grafting

Plasma grafting

- Biomolecules can then bind to the functional groups formed, leading to increased cell adhesion and proliferation

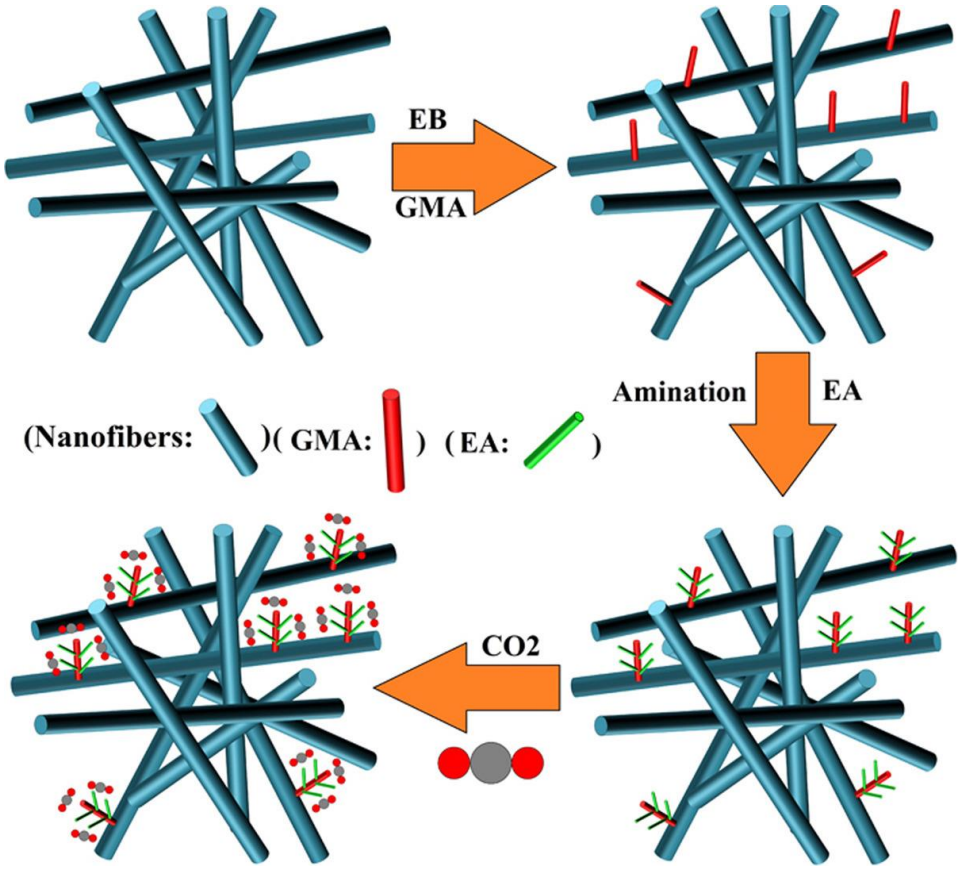


Schematic diagram of PLGA nanofibers modification process. Ammonia plasma treatment was done to introduce amine group to PLGA NF, and then heparin was grafted through crosslinker of EDC/NHS, finally, VEGF was covalently banded to NF-Heparin surface.

Radiation grafting

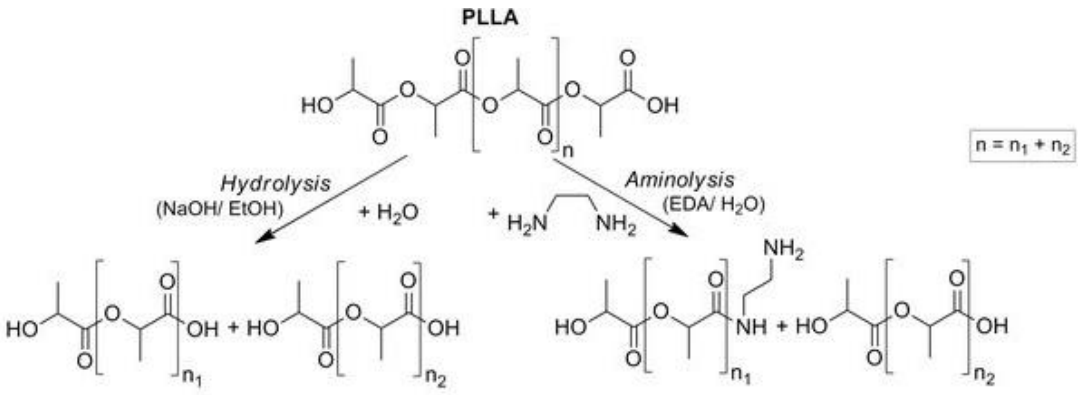
- UV or gamma radiation is used to treat the surface
- Reactive sites are formed through the radiation, which after exposure to the gas can become functional groups or can be used to cleave the polymer chain.
- By changing the radiation dose, the beam penetration can be adjusted
- In comparison with the plasma treatment, the modification also takes place directly in the material

Radiation grafting



Chemical grafting

- Acidic or basic reagents are used for grafting
- Carboxyl or hydroxyl groups are formed on the surface of the material by excision of ester bonds
- The process results in the formation of carboxyl and hydroxyl groups on the surface of conventional hydroxyesters without chemical functional groups

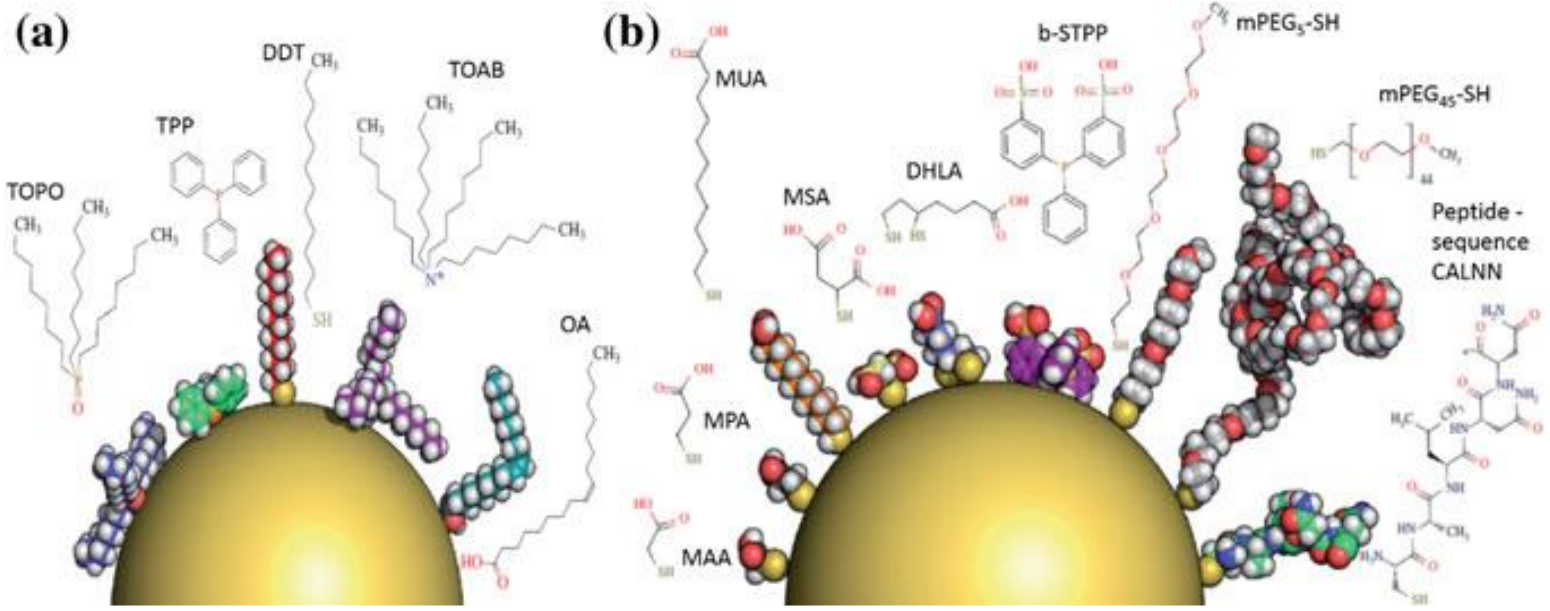


Use of grafting

- By grafting, we change the chemical composition of the material
- The modification is stable compared to physical adsorption
- Specific molecules bound to the material can be used to:
  - Wetting adjustment
  - Promoting cell adhesion
  - Fluorescent staining
  - …

Adjustment of wettability

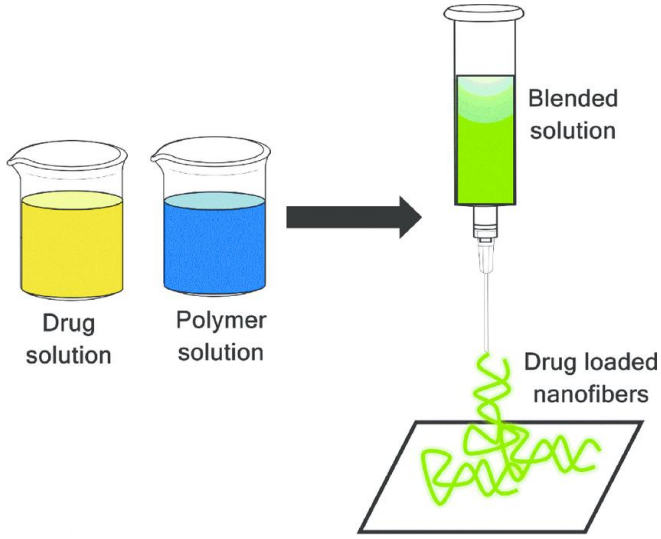
- By binding specific molecules to the surface of the material, a hydrophobic / hydrophilic surface can be created



Surface modification of NPs using hydrophobic ligand molecules (a) and hydrophilic ligand molecules (b).

Spinning of the mixtures

- Specific molecules are added to the polymer solution
- The mixture is spun, the so-called blend
- Compared to physical adsorption, the release of particles is slower



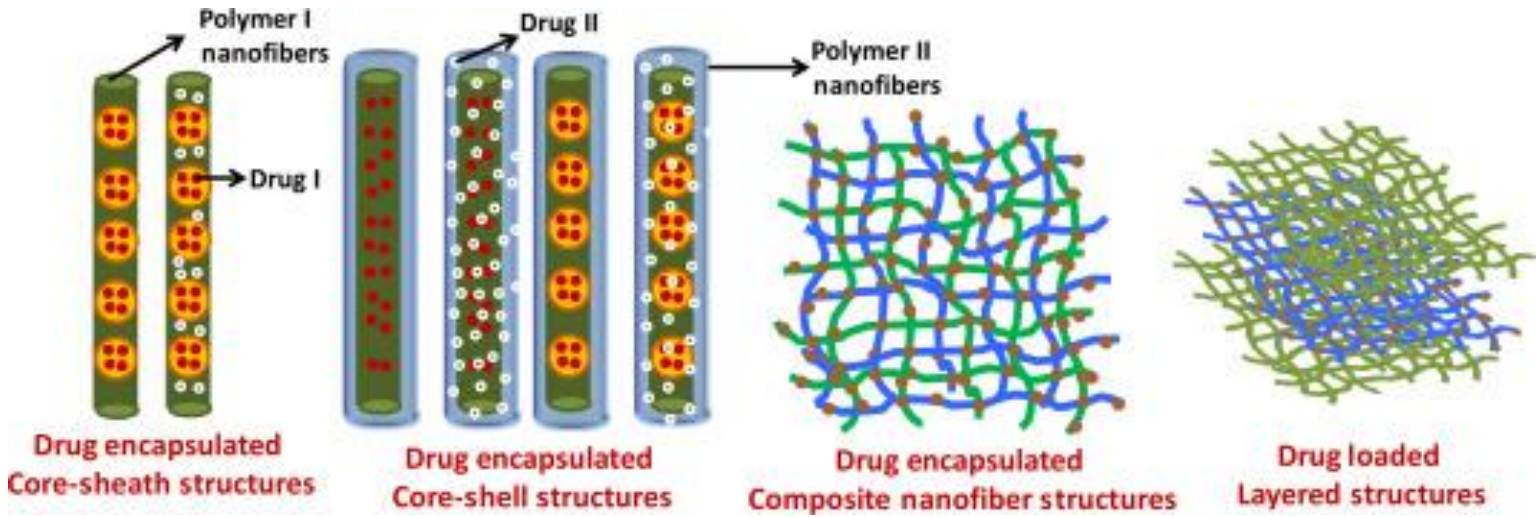
- The following can be used to create blends: antibiotics, peptides, proteins, growth factors, but also organic and inorganic particles

Use of spinning mixtures

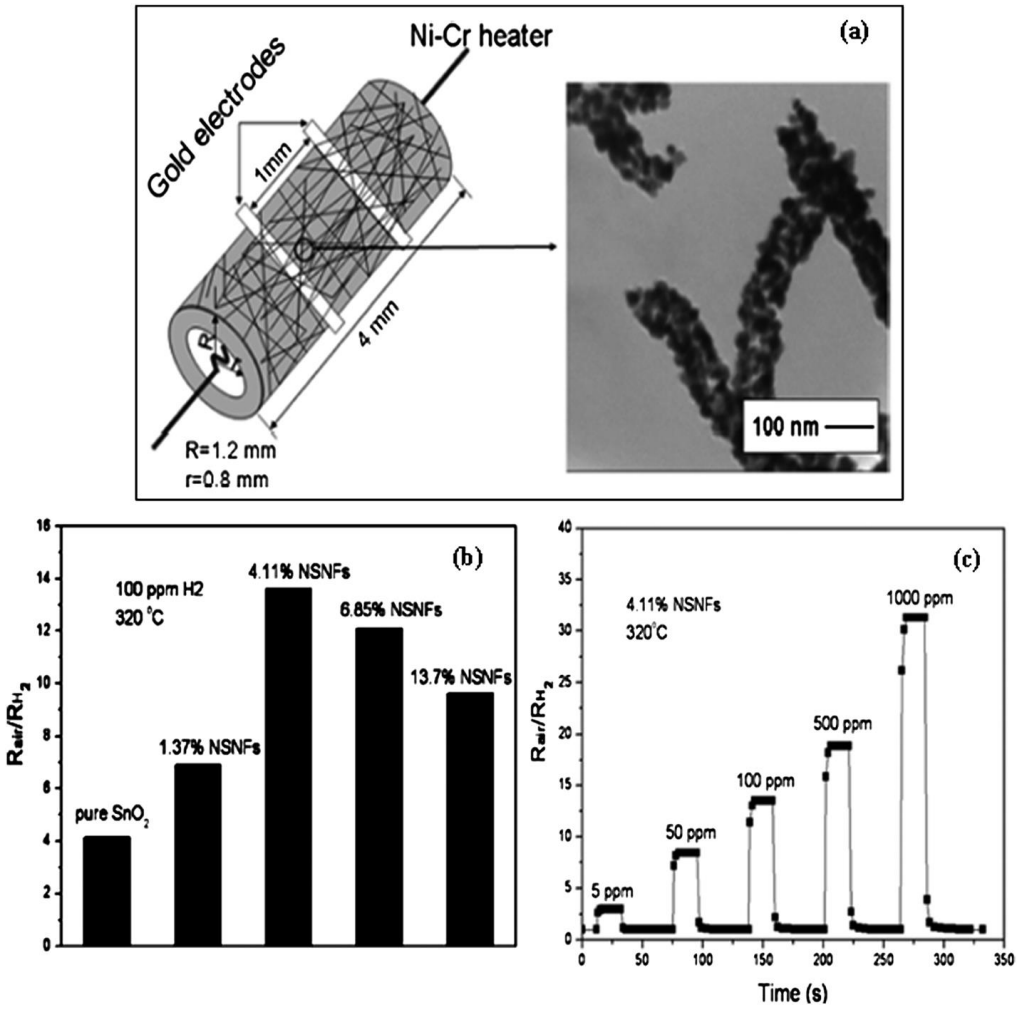
- Creation of composite nanofibers
- Due to the degradation of the fiber, the substances are gradually released into their surroundings
- Nanofibers prepared from blends are used in a number of areas, especially in:
  - Tissue engineering
  - Delivery of drugs
  - Energy systems
  - Sensors
  - Filtration
  - …

Drug delivery

- Targeted on-site drug delivery
- Due to the degradation of the fiber, the drugs are gradually released



Sensors



SEM images of (a) 4.11 mol% NiO–SnO2 composite nanofibers, (b) responses of the sensors to 100 ppm H2 at 320 C, (c) response and recovery characteristic curves of the sensor based on 4.11 mol% NSNFs to H2 in the range of 5–1000 ppm at 320 C.99

Thank you for your attention!

TEST

- What methods of nanofiber modification exist?
- How do you create a temporary modification?
- What are the possible ways of grafting?