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Design and development of functionalized electrospun bandages for wound therapy

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Ministry of Foreign Affairs
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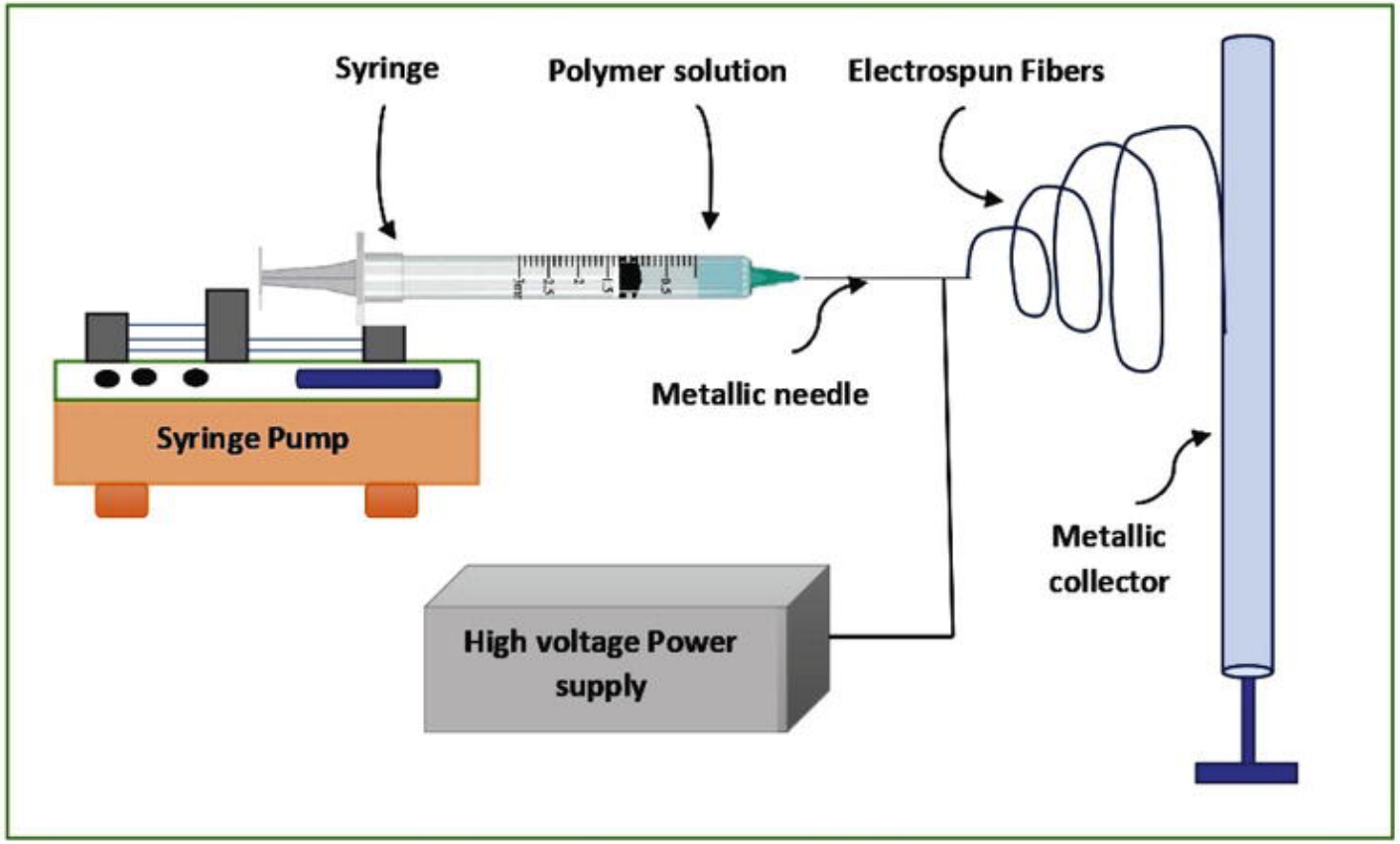
Visegrad Fund

Outline

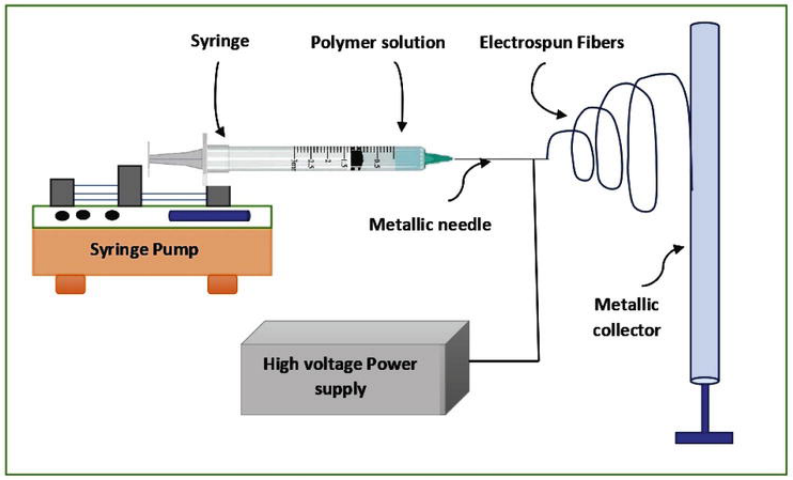
- Principle of fabrication technology
- Drug delivery - Active components for loading nanofibers
- Application possibilities
- Characterization of the products
  - Physical
  - Chemical
  - Biological
  - Pharmacological
  - Safety
  - Drug release and penetration
- Future directions

Process of electrospinning

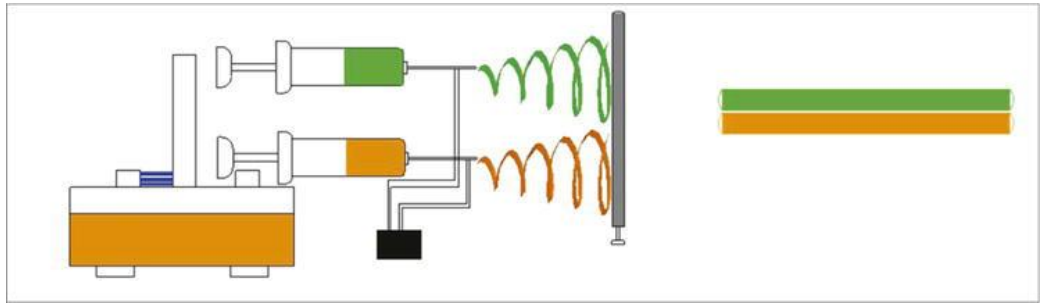


- Syringe
- Syringe pump
- Polymer solution
- Metallic needle
- High voltage power supply
- Metallic collector

electrospinning – setups



basic



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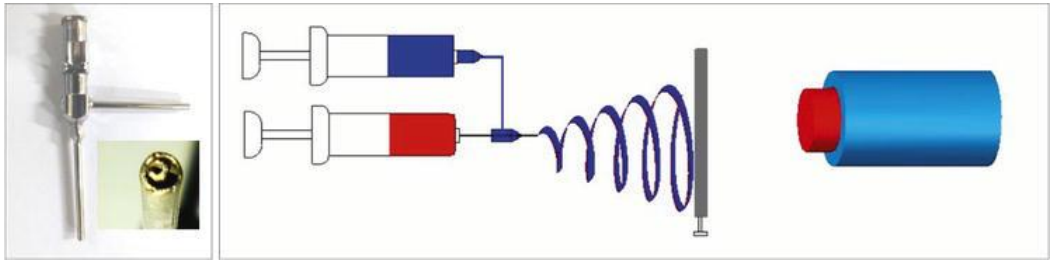
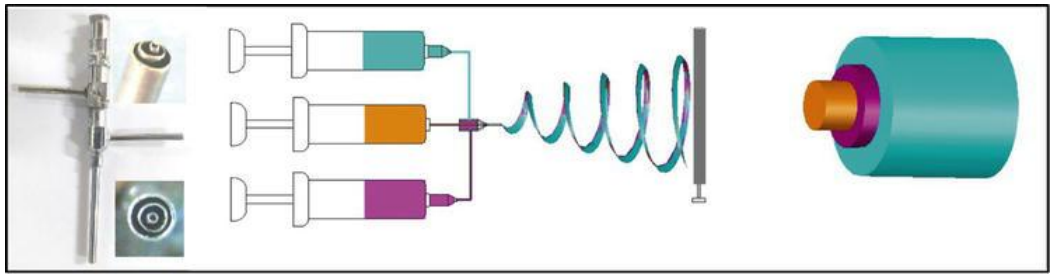


Co-AXIAL



TRI-AXIAL

DOI: 10.5772/intechopen.105804

Main Parameters of electrospinning

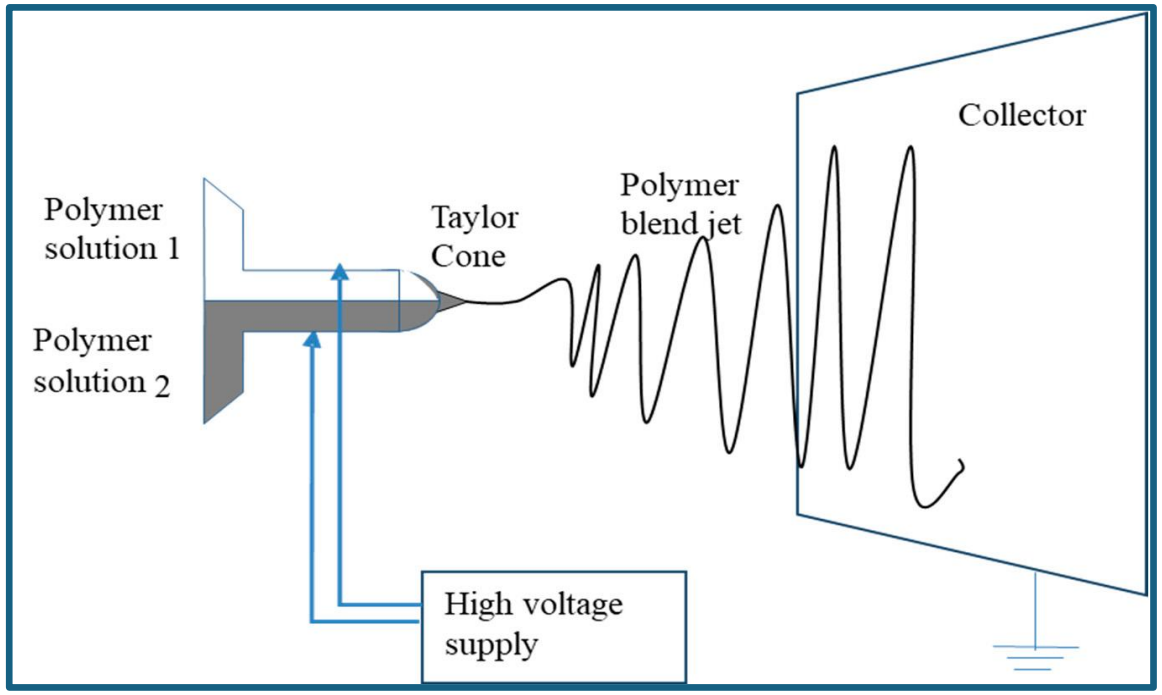
- Voltage
- Flow rate
- Collector – needle distance
- Solvent
- Temperature
- Humidity

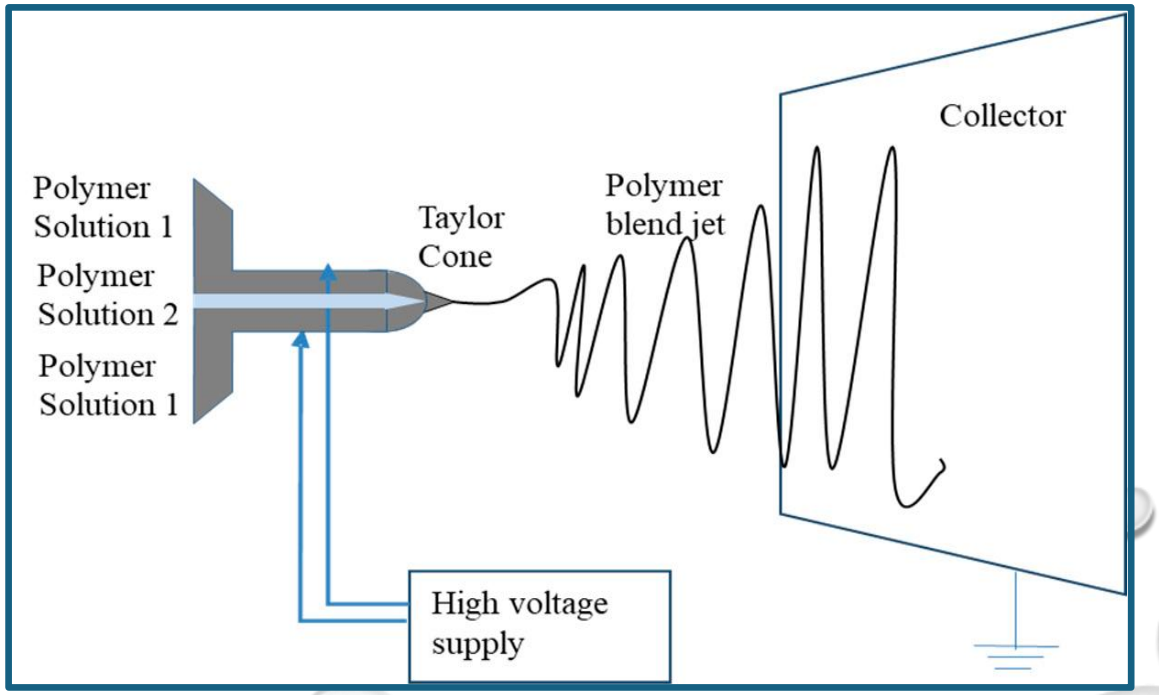
Solutions of electrospinning

- Concentration
- Molecular weight
- Viscosity
- Surface tension
- Conductivity and Surface Charge Density
- Solvent volatility

Nozzle configurations

- Side-by-side





Electrospun nanofibers in drug delivery

- Vitamins, NSAIDS and Natural Products
- Antibiotics/Antibacterial Agents and Wound Dressing
- Anticancer Agents
- DNA, RNA, Protein and Growth Factor
- Nanoparticle Impregnated Nanofibers

Vitamins, NSAIDS and Natural Products

- Used mainly in transdermal delivery systems
- For drugs that can not be taken orally
  - Rapid, extensive degradation in the GIT
  - Extensive first pass metabolism in the liver
- Fibers should be non-toxic, biocompatible (biodegradable)

Antibiotics/Antibacterial Agents and Wound Dressing

- PLA, PLGA and PCL, are primarily used in the polymeric electrospun fibers for their biodegradability
- E.g. teracyclin HCL was used in three layered polymer matrix. sustained release, killing biofilms
- Dental applications and Wound dressings, absorption of exudates, prevention of infection, accelerated healing, moisturazing, scar-free regeneration, porosity for oxygen supply

Anticancer drug delivery

- Local chemotherapy against secondary hepatic carcinoma (e.g. wrapping the whole liver with drug loaded NF mats)
- Postoperative local therapy
- Studies in tumor cell cultures (glioma cells, prostate cancer cells, lung tumor cells etc)
- **Anticancer drugs**: doxorubicin-hydrophilic-, paclitaxel –hydrphobic- , cisplatin and dichloroacetate
- incorporated into **electrospun fibers** with polymers such as PLA, PLGA and PLLA
- Lower side effects, inhibition of cell growing
- But initial burst release

DNA, RNA, Protein and Growth Factor delivery

- Sustained release ~1-3 months
- Burts release ~48hrs
- Preserved bioactivity and functionality
- Functionalized silk mats containing EGF – extremly promising in WH

Biomedical Applications of nanofibers

- Bone Cell Proliferation
- Cartilage Regeneration
- Regeneration of Ligaments and Tendons
- Nerve Regeneration
- Vascular Tissue
- Skin Tissue Engineering
- Wound Healing
- Dental Restoration Nanocomposites
- Controlled Drug Release
- Medical Implants
- Biosensors
- Cancer Therapy

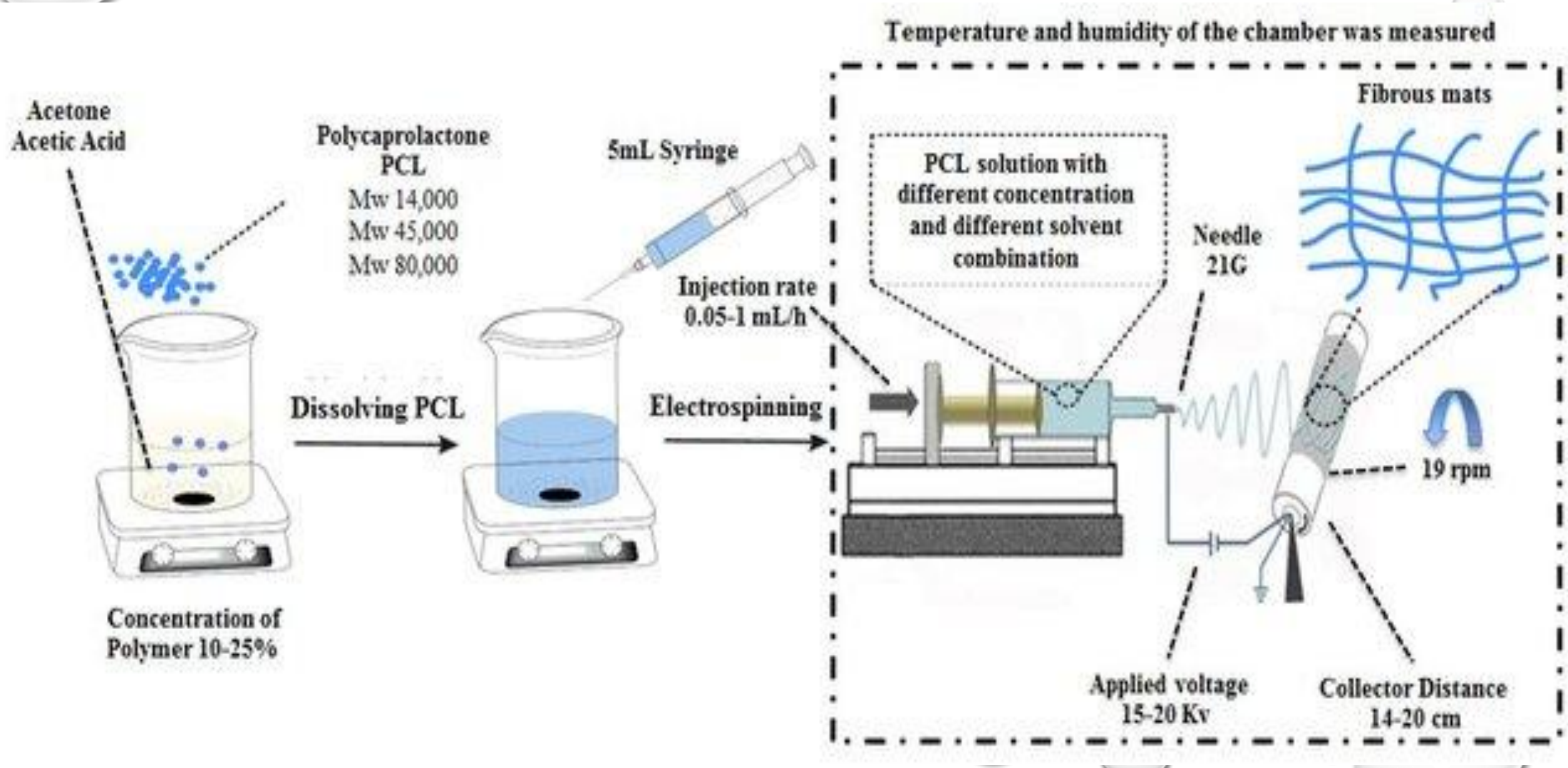
Characterization of nanofiber scaffolds

- Nanofiber Diameter(nm)
- Diameter distribution frequency
- Porosity
- Contact Angle
- Tensile Strength (MPa)
- Break Strain (%)
- Thermogravimetric analysis
- Drug loading efficiency – ATR-FTIR
- Release and penetration of the active components

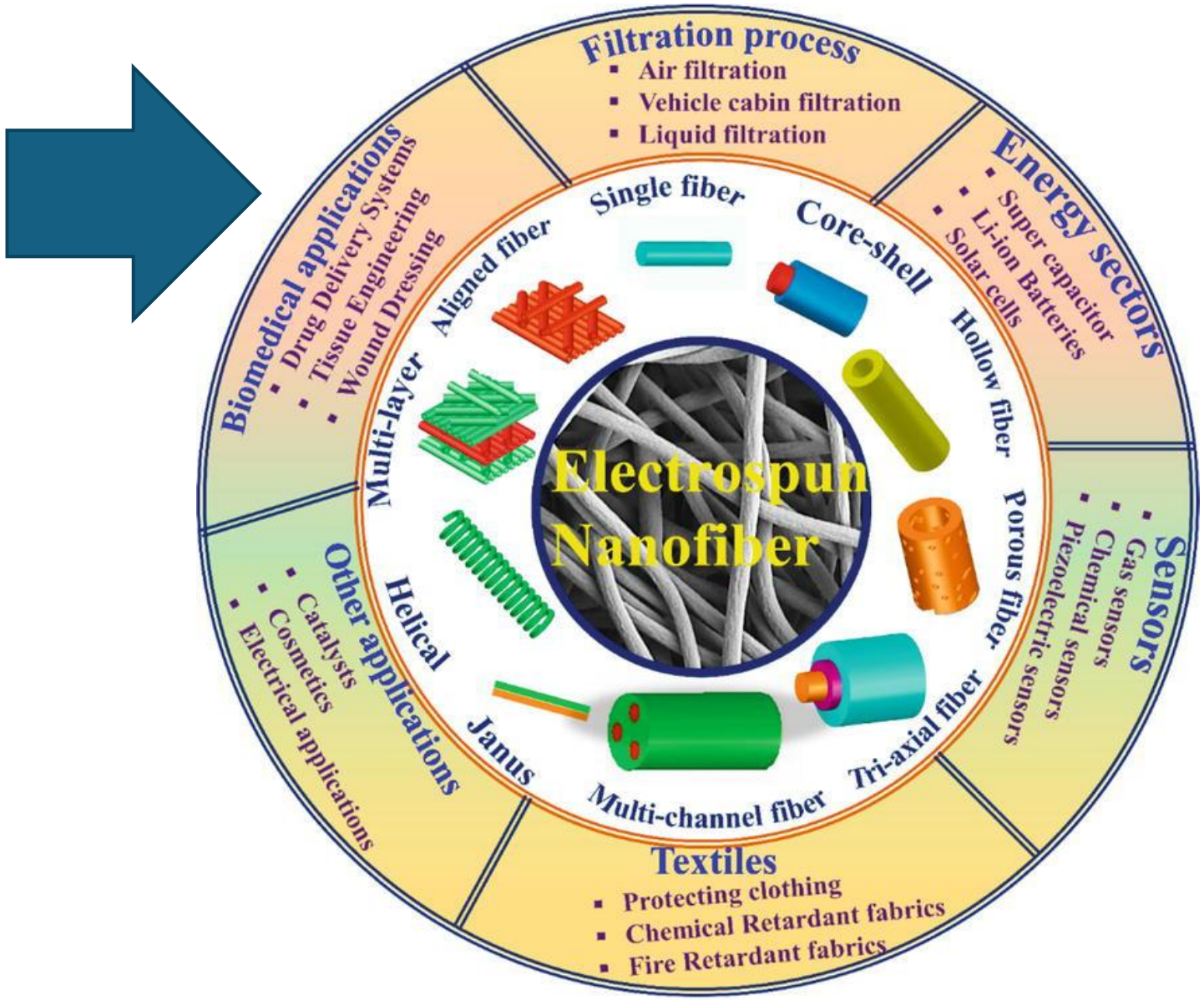
Advantages and Disadvantages of Polymer Nanofibers

Advantages	Disadvantages
high surface area to volume ratio	Use of organic solvents in electrospinning poses financial and ecological challenges
Excellent mechanical properties: high strength and flexibility	Residual solvents may be toxic, limiting biomedical applications
Small pore size allows selective permeability	Solution electrospinning is costly
Easily modifiable/functionalizable with additives, nanoparticles, or chemical groups	Low productivity rate of nanofiber production
Can be made from a wide range of materials (polymers, ceramics, metals, carbon-based materials)	Significant challenges remain for industrial-scale applications
Some types (e.g., carbon nanotubes, graphene-based nanofibers) have excellent electrical and thermal conductivity	
Can be engineered for controlled substance release (e.g., drugs, fertilizers)	

Summary of test conditions

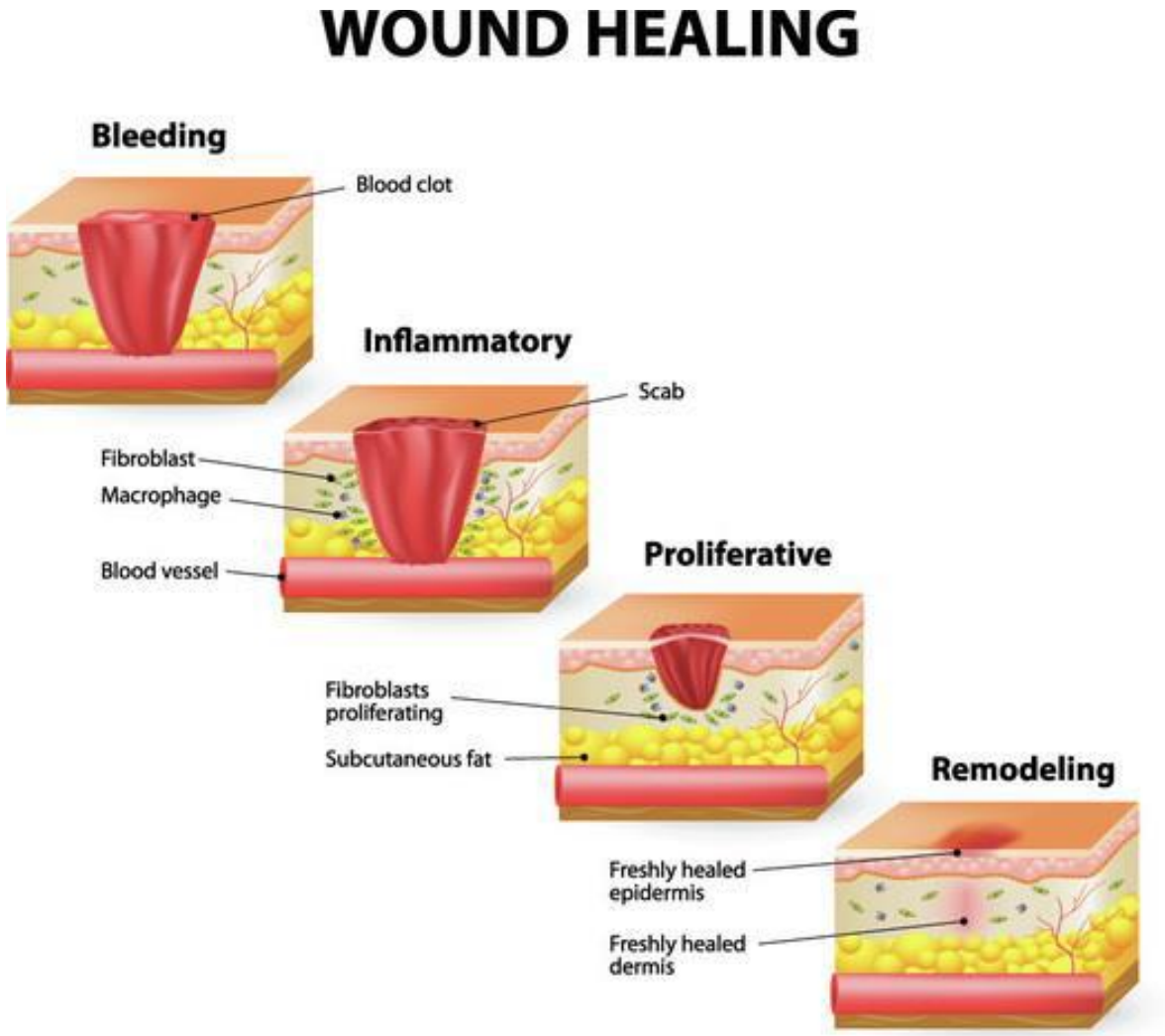


Fields of application of electrospinning

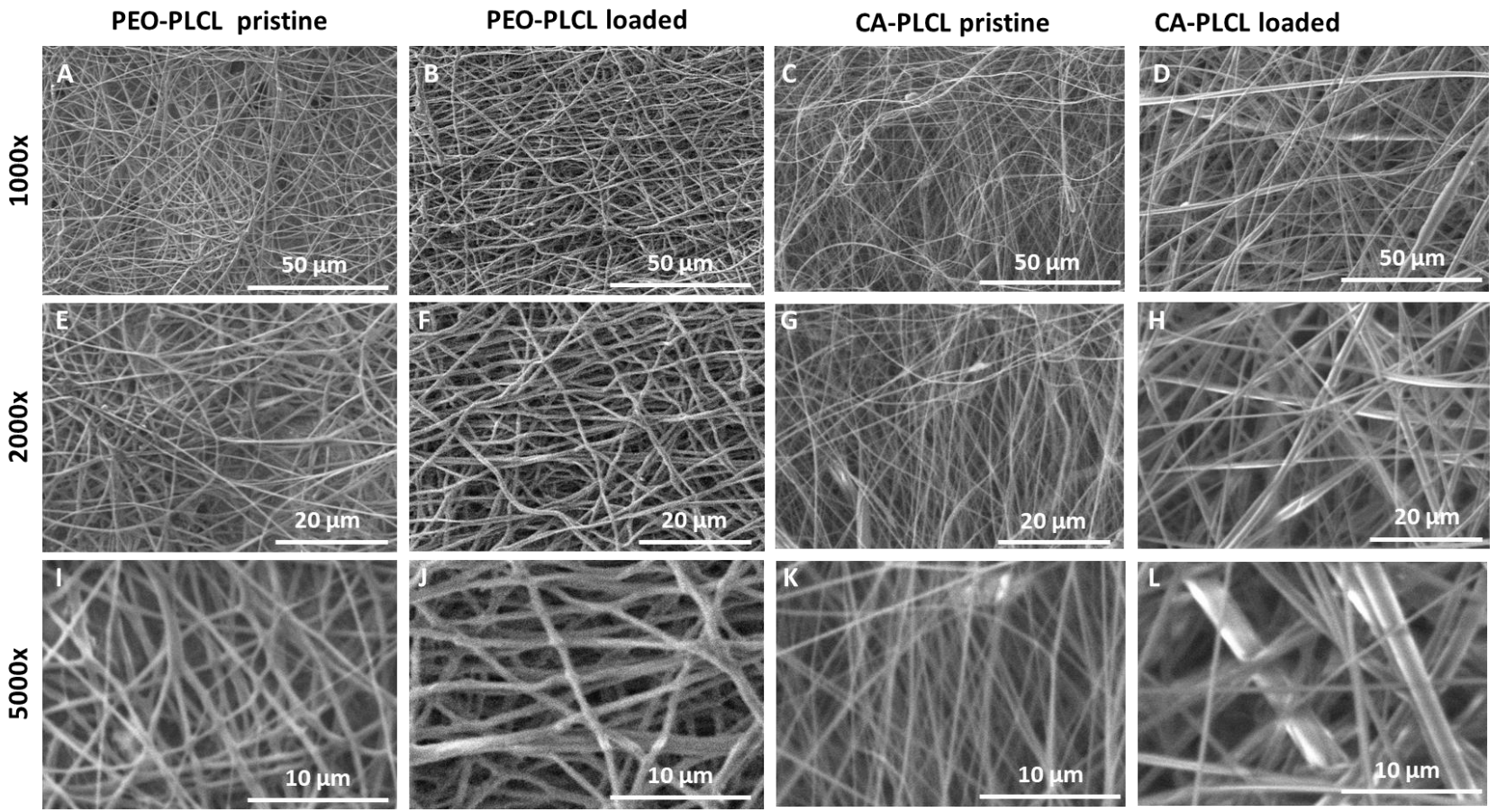


Wound healing - bandages

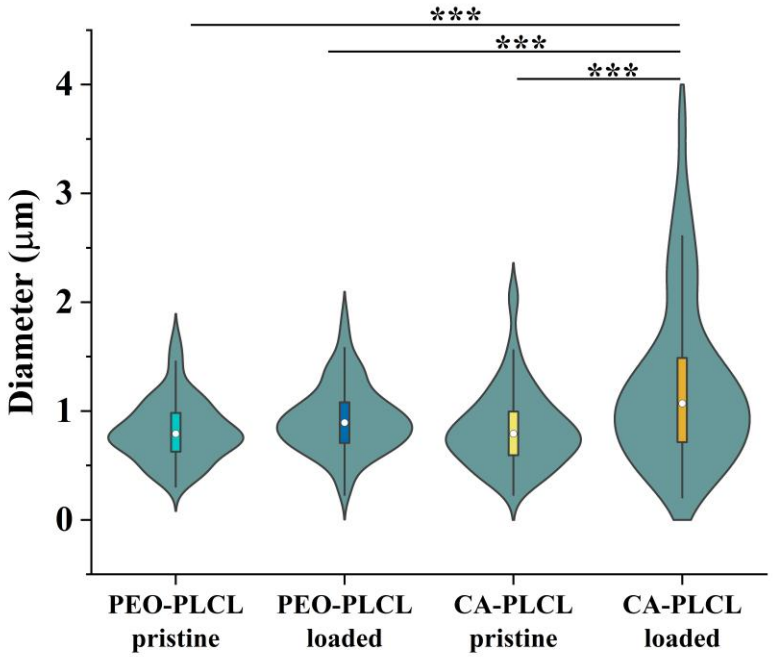
- Therapeutic indications (eg.)
  - Pressure ulcers
  - Diabetic foot ulcers
  - Military injuries
- Benefits:
  - Antibacterial
  - Adsorptiv, hemostatic
  - Antiinflammatory
  - Stimulate Proliferation
  - Stimulate Remodelling
  - Long-term effect, sustained release

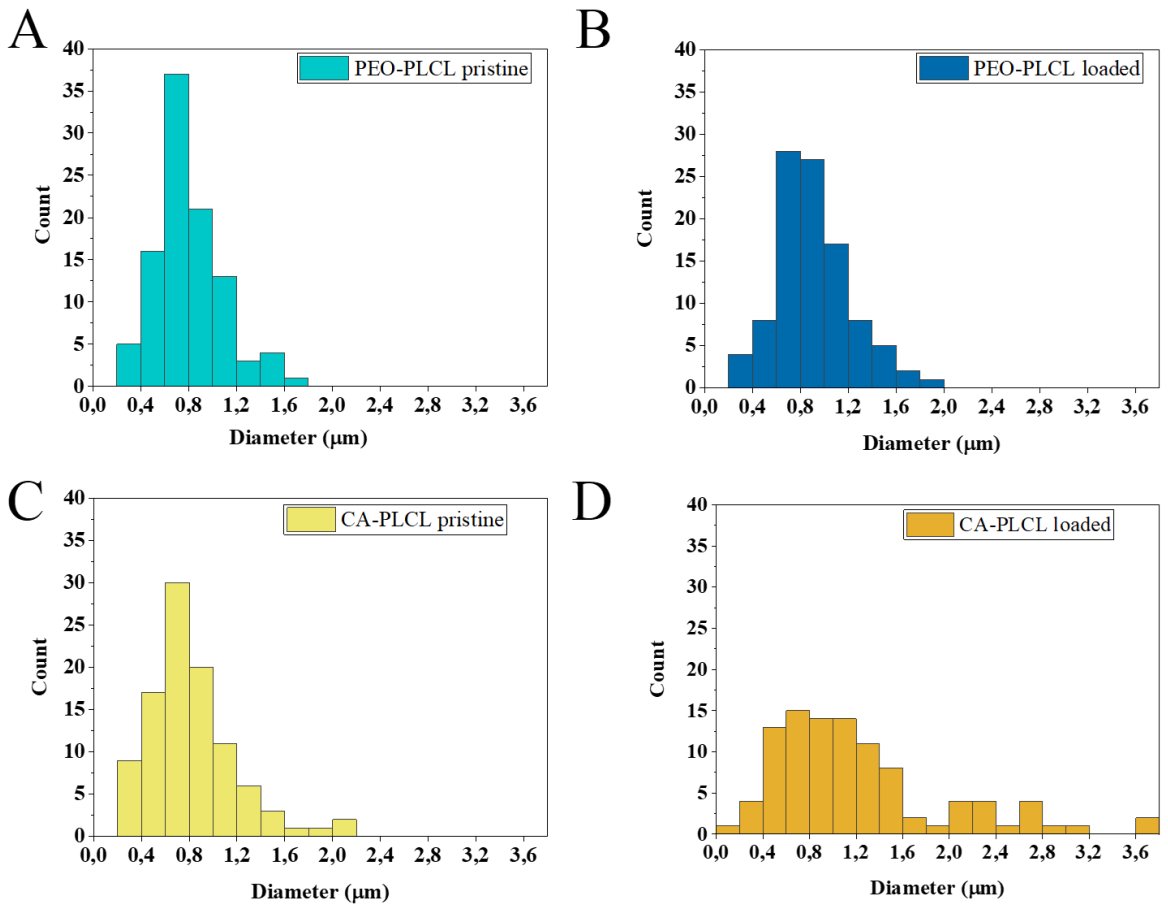


Morphology of pristine and loaded NFs - SEM



Diameter distribution frequency





Contact angle image of water droplet on nanofiber patches at 0 s (A), change in contact angle of water droplet from 0 s to 120 s (B).

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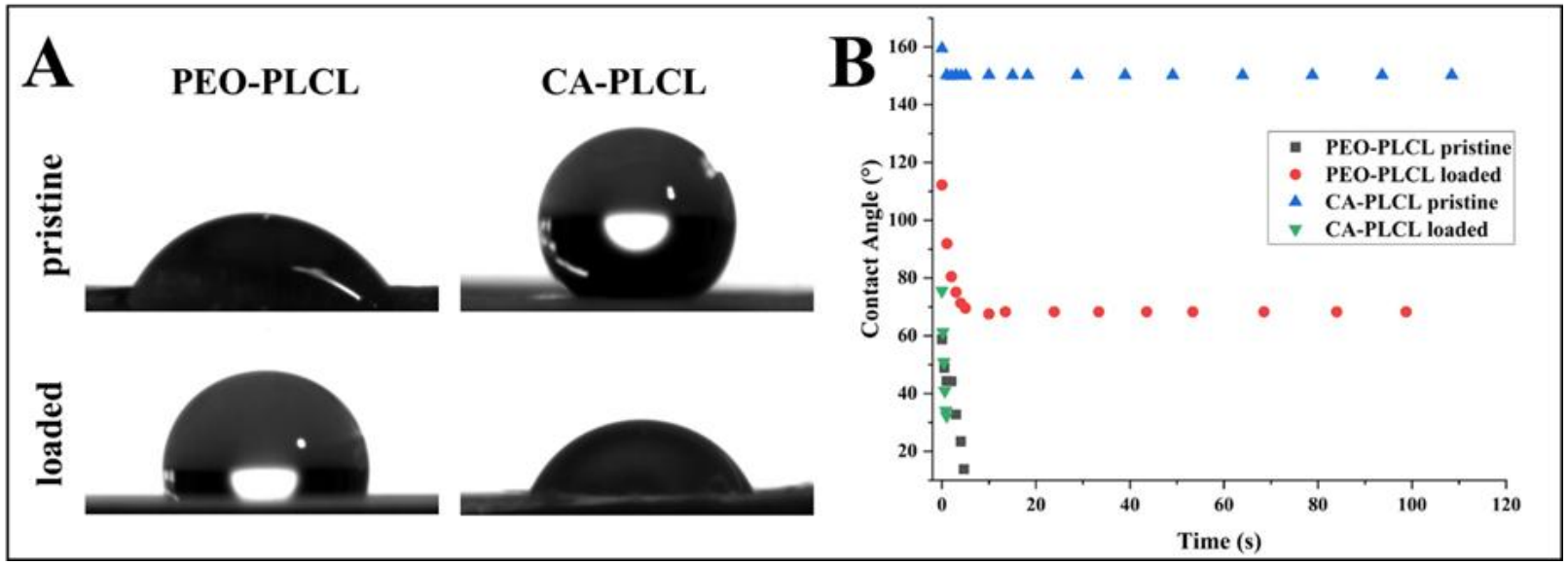

TGA (A) and DTG (B) data from nanofibers show the weight loss behavior of the nanofibers after subjecting them to a temperature program from 30-700 °C at 10 °C min-1.

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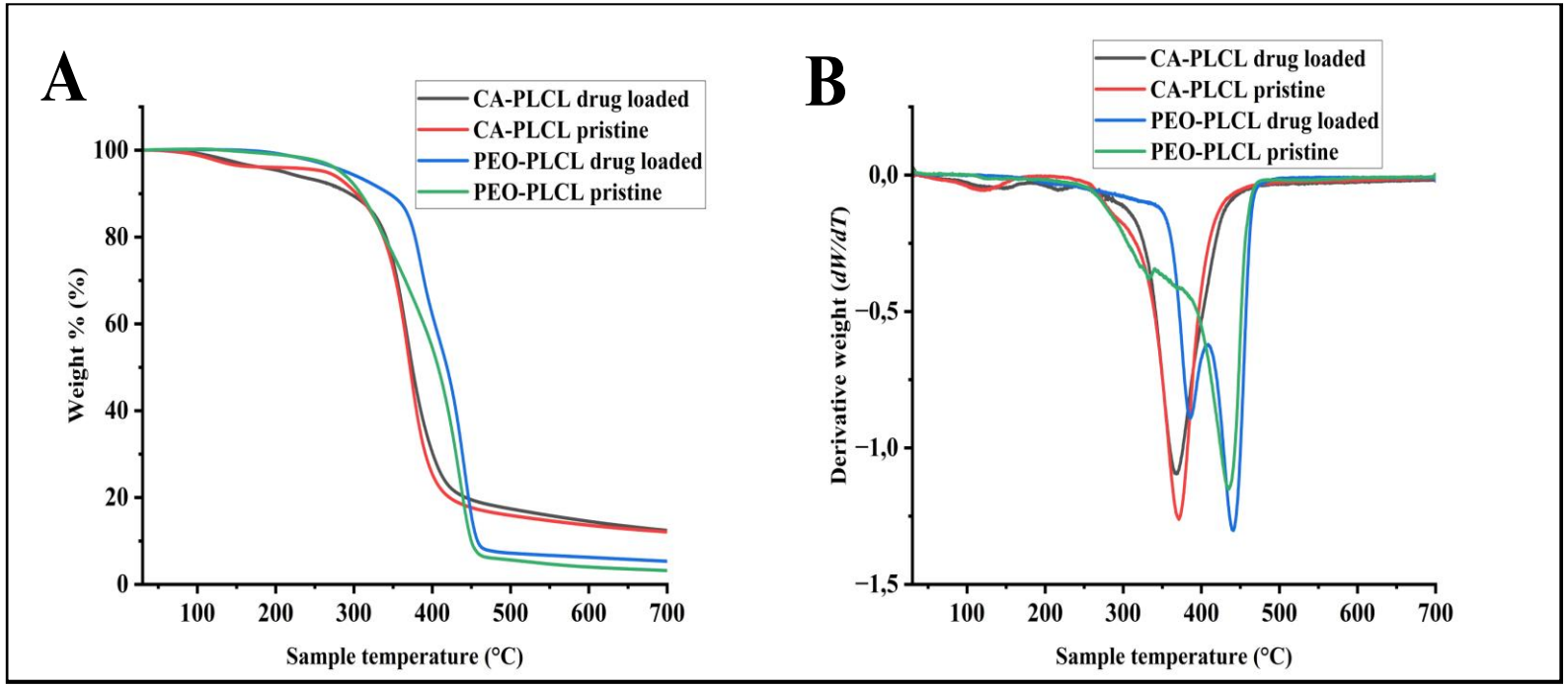
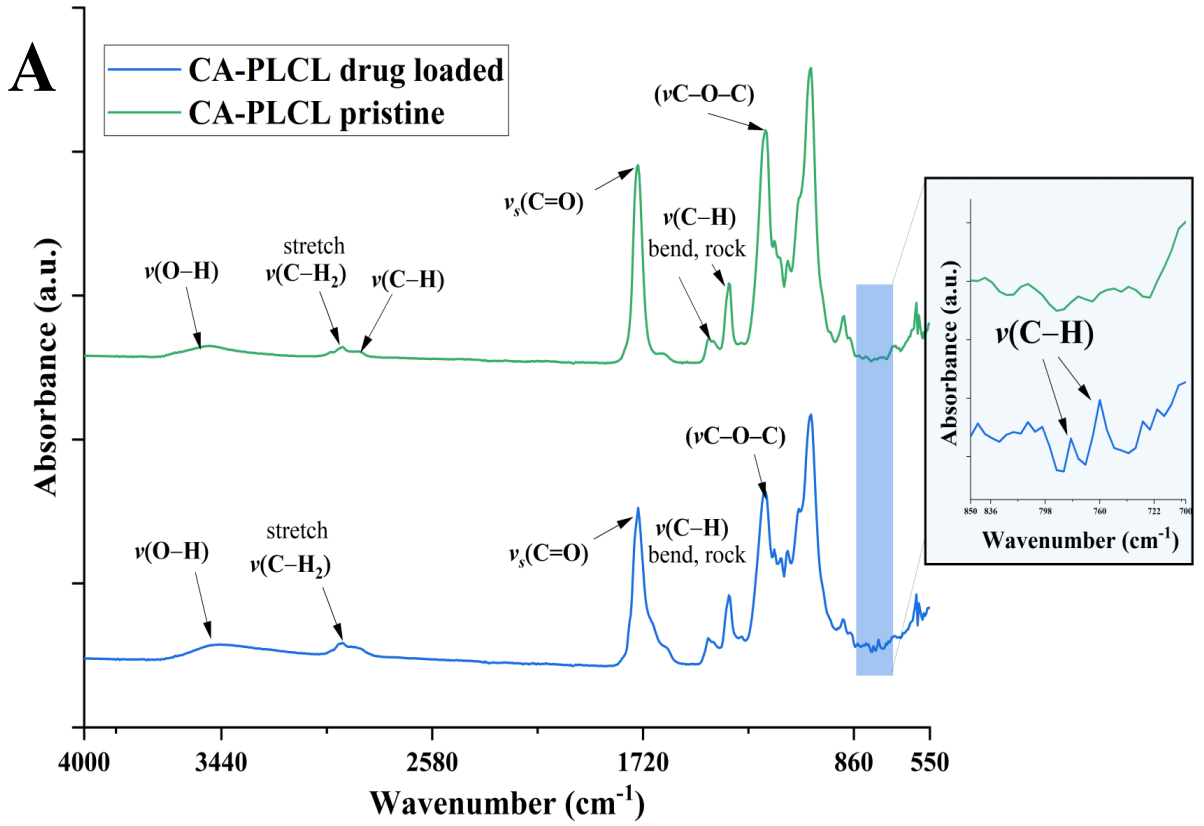
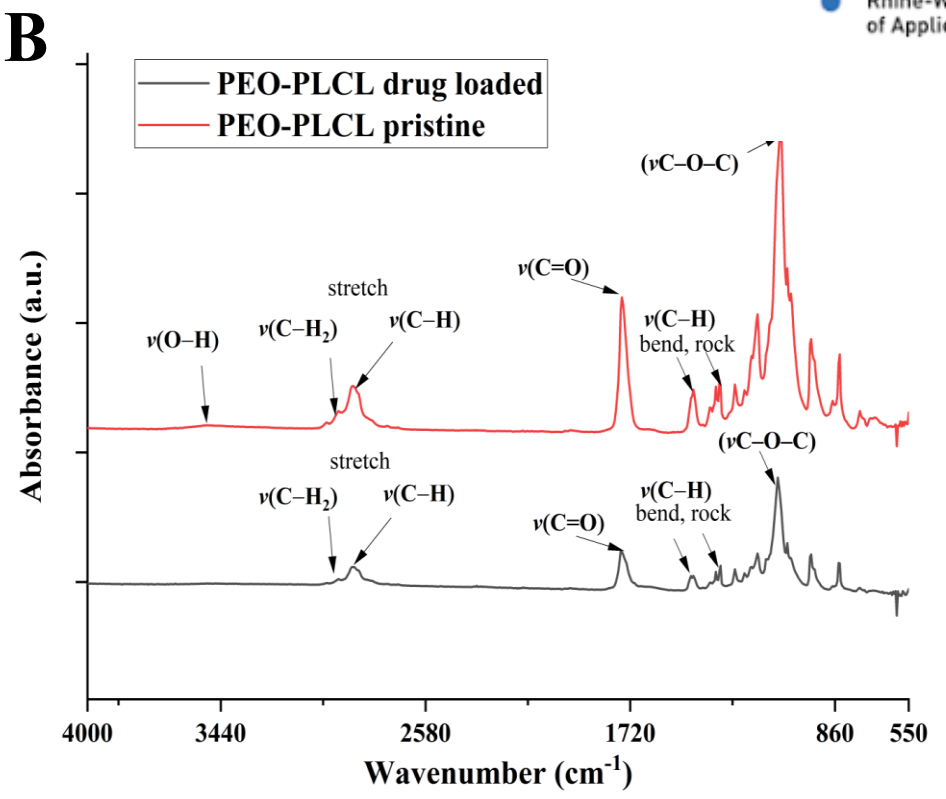
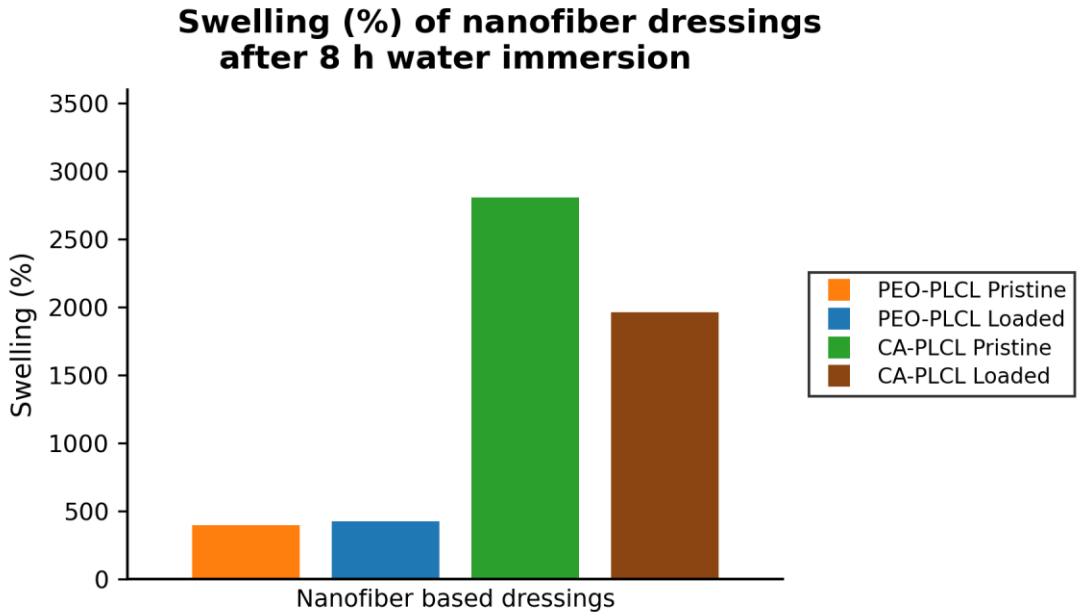


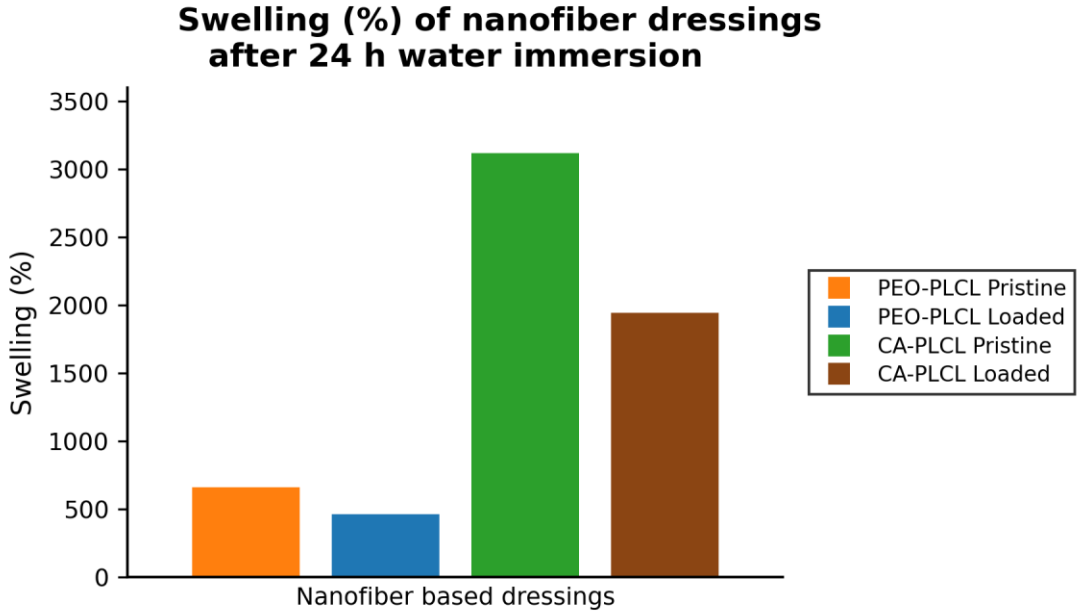
Characteristic ATR-FTIR absorbance peaks were observed from A) CA-PLCL nanofibers and B) PEO-PLCL nanofibers.





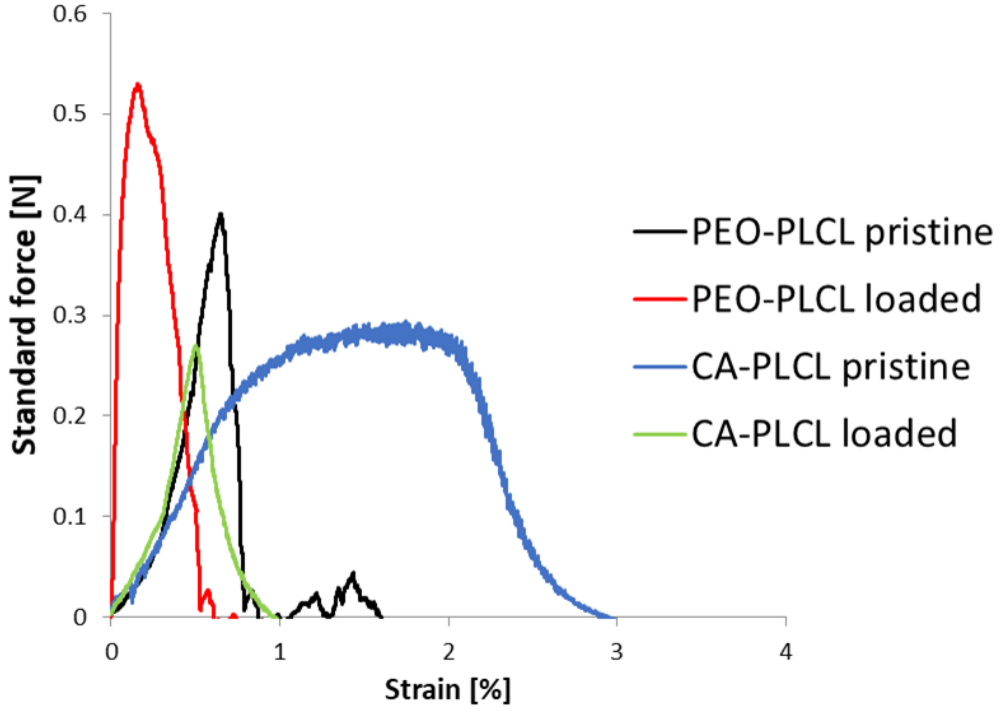
Water uptake capacity

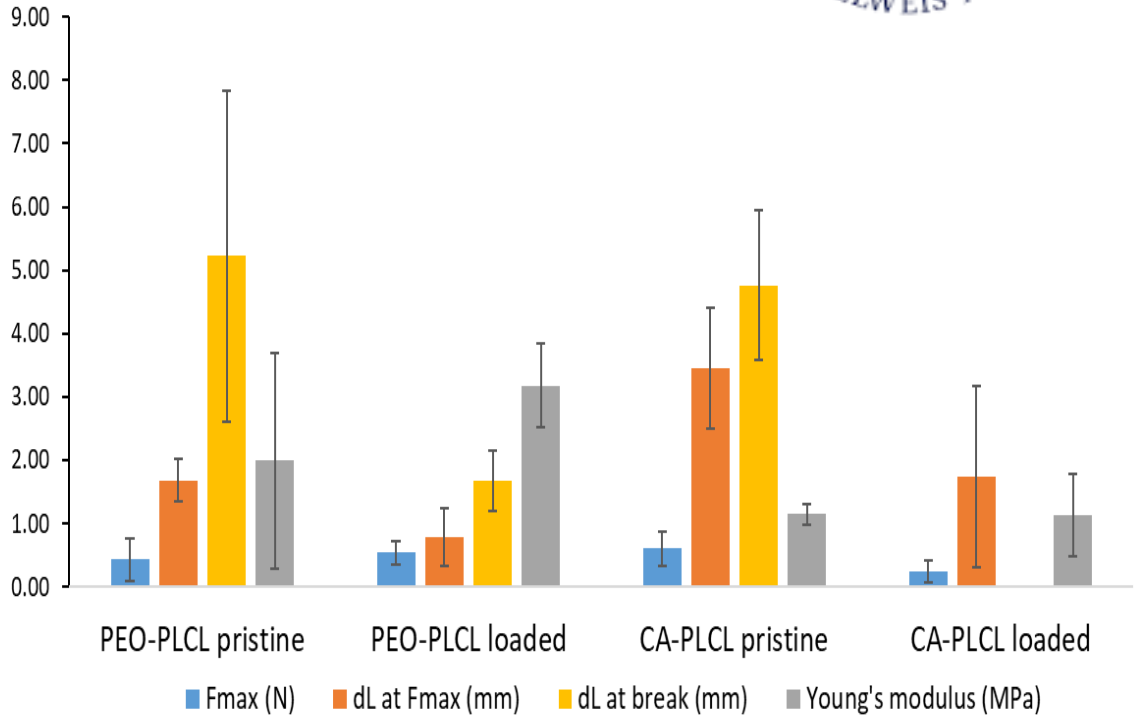




Nanofiber dressings	Layer thickness	n	Swelling (%)	
	mean +/- SD		8h	24h
	mm			
Hydrophilic Pristine	0,038+/-0,002	3	399,57	663,09
Hydrophilic Loaded	0,062+/-0,015	3	424,21	465,87
Hydrophobic Pristine	0,048+/-0,010	3	2806,16	3118,49
Hydrophobic Loaded	0,045+/-0,002	3	1964,62	1943,87

Tensile test





Viscosity testing

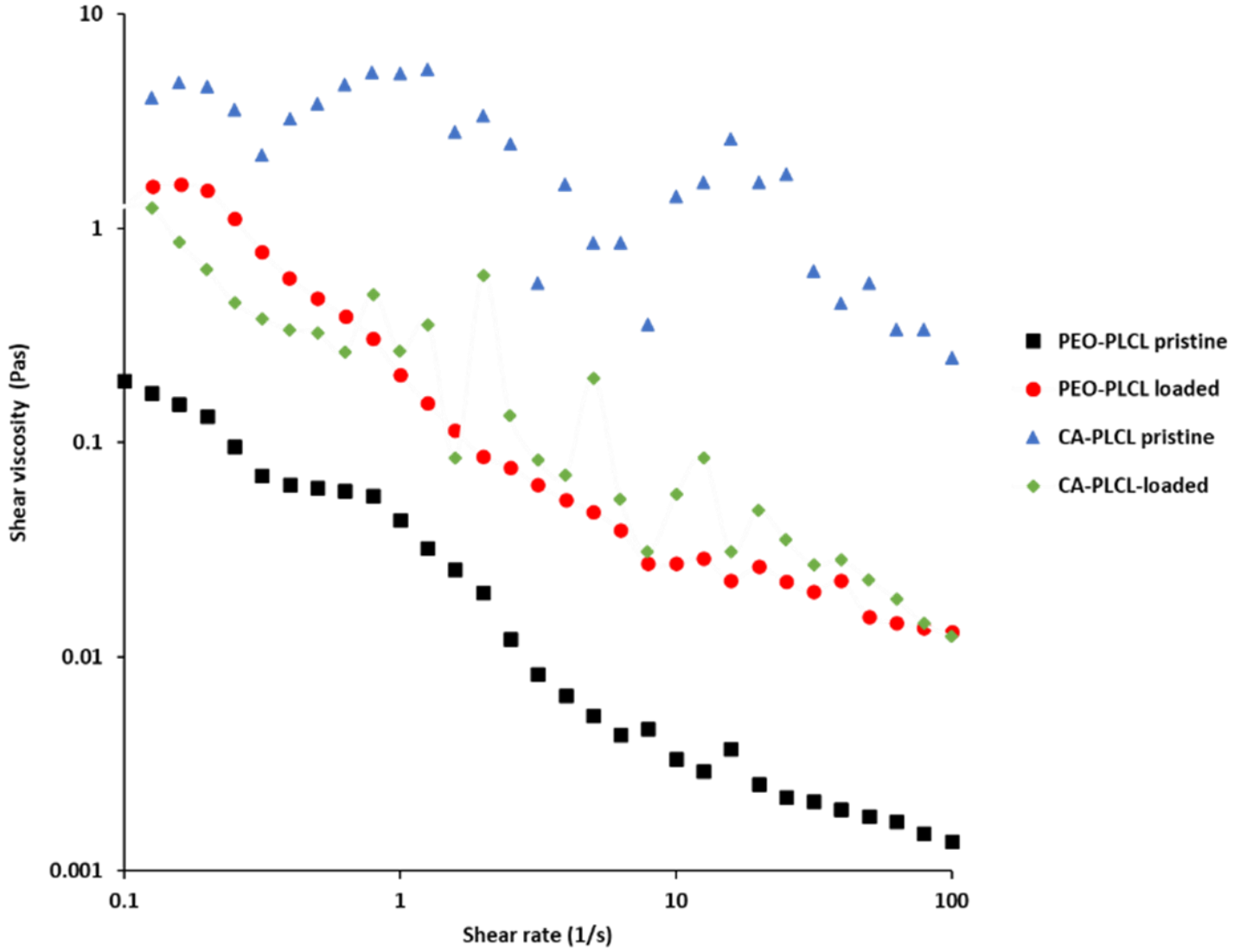


Figure S2: Cytotoxicity assessment of the nanofibers in primary dermal fibroblasts and human immortalized keratinocyte (HaCaT) cell lines.

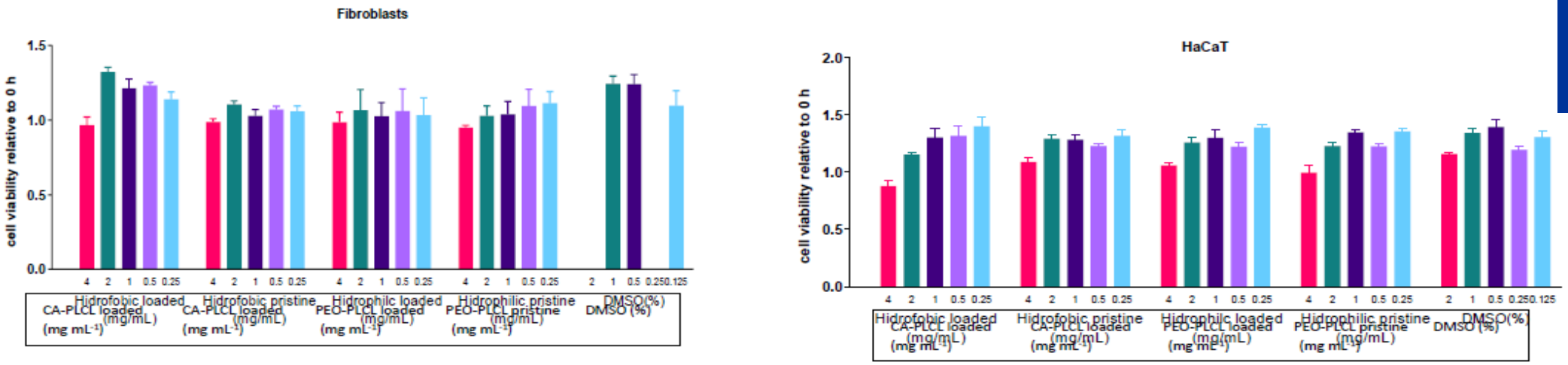
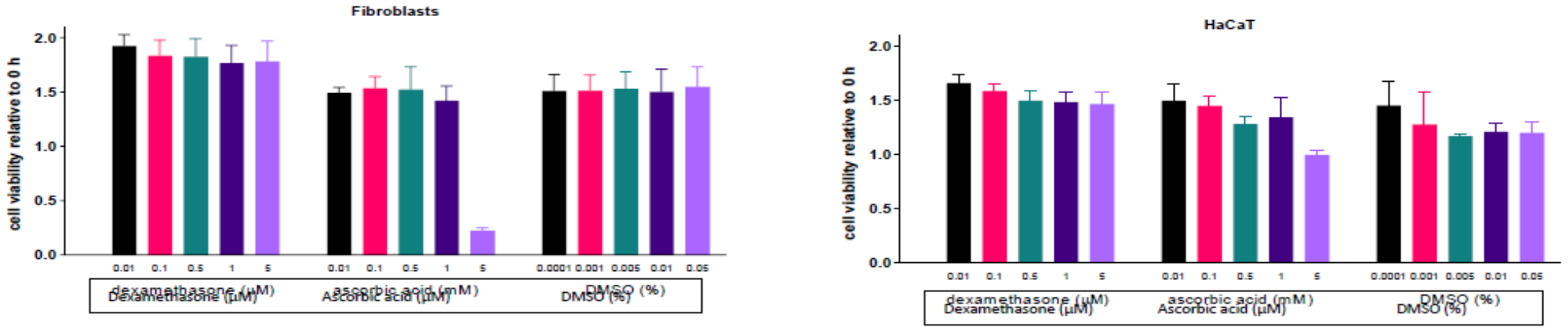
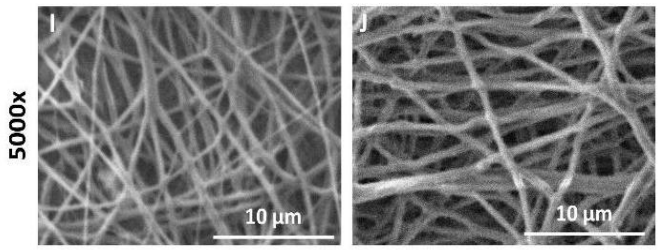
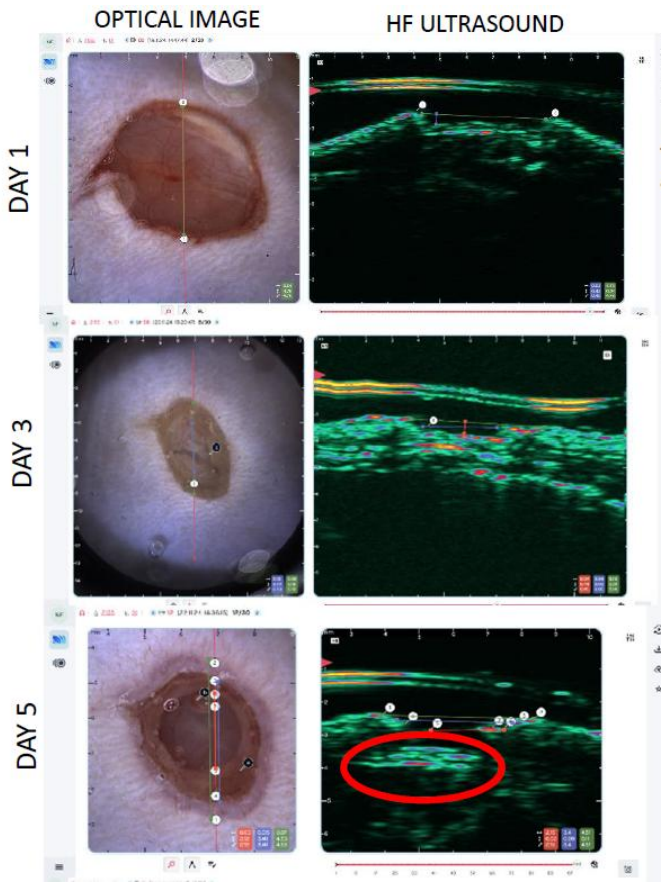


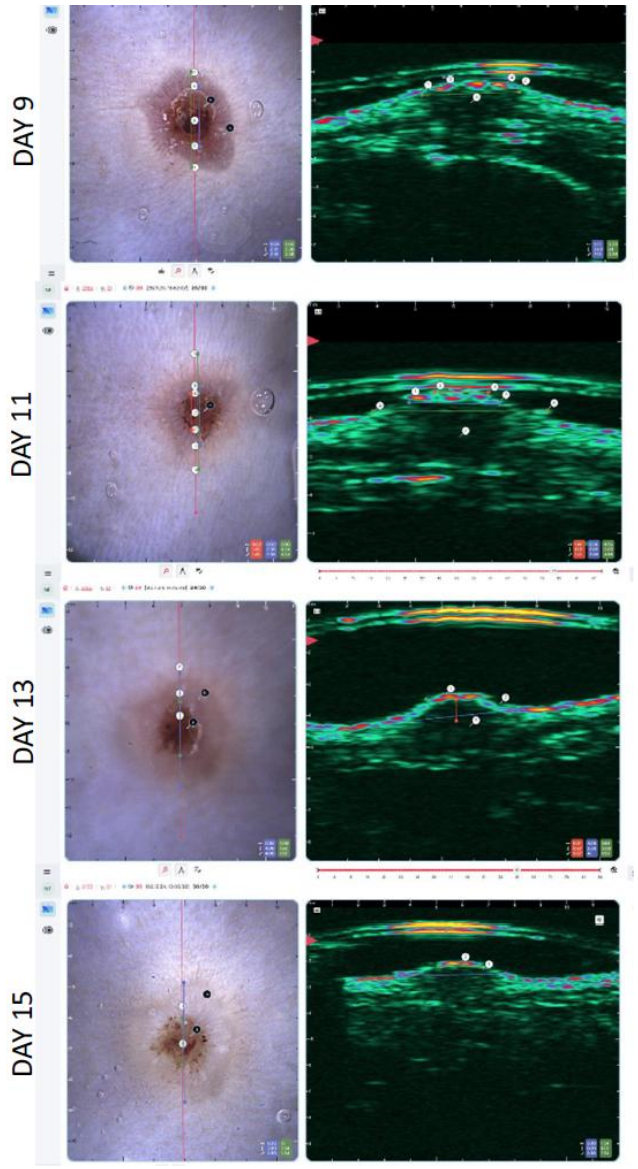
Figure S3: Cytotoxicity assessment of the active components dexamethasone and ascorbic acid in primary dermal fibroblasts and human immortalized keratinocyte (HaCaT) cell lines.

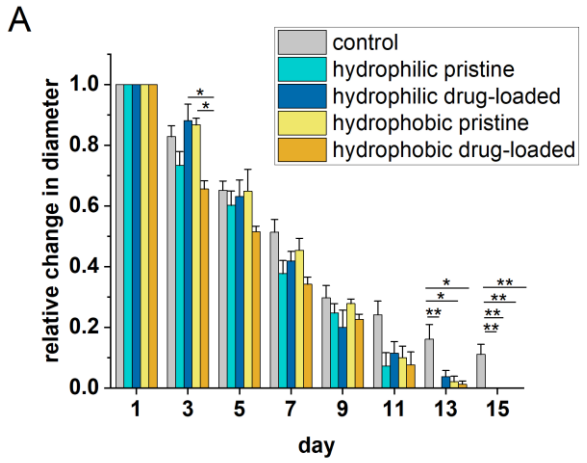


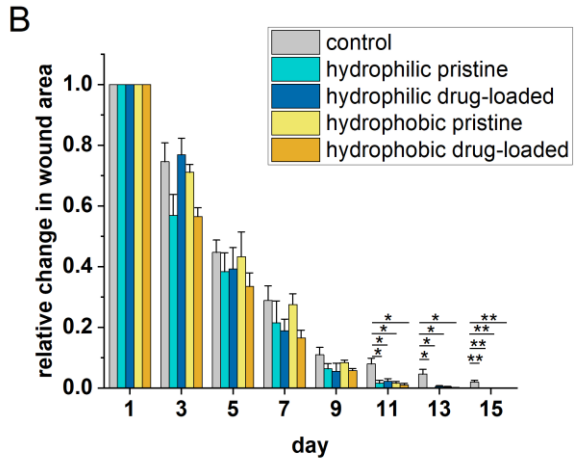
In vivo wound healing in hairless mice

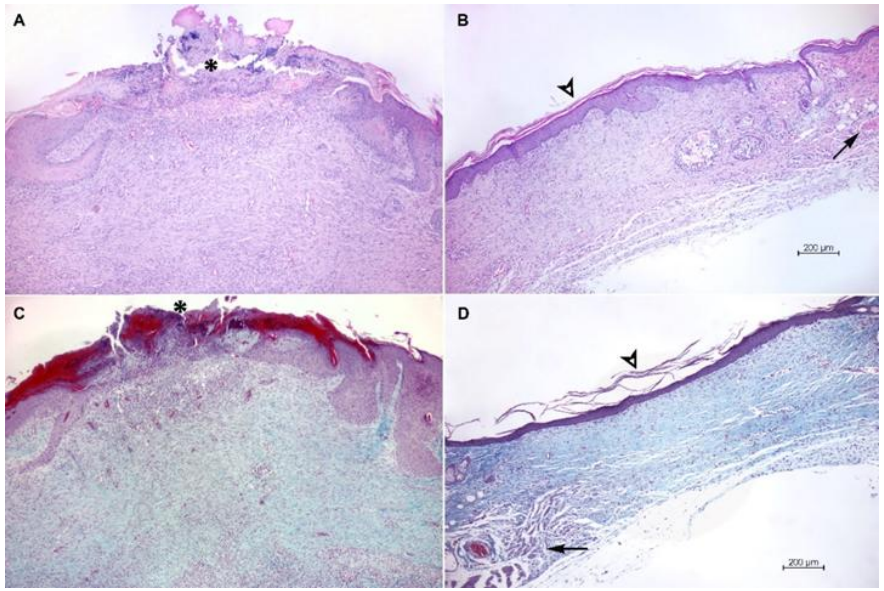












Hybrid nanofibers for multimodal accelerated wound healing

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Advanced Healthcare Materials

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Perspectives

Challenges and Future Directions:

- Scalability
- Cost-effectiveness
- Material Selection (green technology)
- Multi-functionality
- Long-term Stability

Need collaboration

- Fabrication
- Bioanalitics
- ATR-FTIR
- Viscosity
- In vitro cell culture studies
- Histology, IH
- Clinical partners

Summary

electrospun nanofibers represent a promising technology with a wide range of potential applications. Continued research and development efforts are needed to overcome current limitations and fully harness their unique properties for various industries.

Our laboratory joined to this research recently. We are open for collaborations and student exchange programs to extend our research capacity.

Pázmány Péter Katolikus Egyetem

references

- doi:10.3390/pharmaceutics11010005
- doi.org/10.3390/surfaces8010007
- doi.org/10.1038/s41598-025-94608-8
- doi.org/10.1088/1748-605X/adda81
- doi.org/10.1016/j.arabjc.2015.11.015
- doi.org/10.3390/molecules29174271
- doi.org/10.3390/nano14151305
- doi.org/10.1002/wnan.1954
- doi.org/10.3390/jcs8010032
- DOI: 10.1007/978-3-319-39715-3_4
- doi.org/10.3390/polym14081508
- doi.org/10.3390/mi14071477
- doi.org/10.1016/j.ijbiomac.2023.126642
- DOI: 10.1039/d4tb00149d
- doi.org/10.3390/polym15183837

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Thank you for your attention

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