

Electrospinning and Electrospun Fibers: Advanced Nanostructures for Biomedical and Industrial Applications

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Editorial

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ABSTRACT

Electrospinning is a versatile and widely used technique for the fabrication of ultrafine fibers with diameters ranging from nanometers to micrometers. Electrospun fibers exhibit unique properties such as high surface area-to-volume ratio, tunable porosity, and structural similarity to the extracellular matrix (ECM), making them highly suitable for biomedical applications. This article provides an overview of the electrospinning process, factors influencing fiber formation, and the properties of electrospun fibers. It also highlights their applications in tissue engineering, drug delivery, filtration, and energy storage. Challenges and future directions in the field are also discussed, emphasizing the potential of electrospinning technology in advancing material science and healthcare.

Keywords

Electrospinning, Nanofibers, Electrospun Fibers, Tissue Engineering, Drug Delivery, Biomaterials

INTRODUCTION

Electrospinning is a simple and cost-effective technique used to produce continuous fibers with nanoscale diameters using an electrostatic force. The process involves applying a high-voltage electric field to a polymer solution or melt, resulting in the formation of fine fibers collected on a grounded surface.

Electrospun fibers have attracted significant attention due to their structural resemblance to natural extracellular matrices, which makes them ideal for supporting cell growth and tissue regeneration. Their versatility allows the use of a wide range of natural and synthetic polymers, expanding their applications across multiple fields ^[1].

ELECTROSPINNING PROCESS AND FIBER FORMATION

The electrospinning process consists of three main components: a high-voltage power supply, a syringe pump containing the polymer solution, and a collector. When voltage is applied, electrostatic forces overcome surface tension, forming a jet that elongates and solidifies into fibers as the solvent evaporates.

Several parameters influence fiber formation, including solution viscosity, polymer concentration, applied voltage, flow rate, and environmental conditions such as temperature and humidity. By controlling these factors, researchers can tailor fiber diameter, morphology, and alignment. The ability to produce fibers with controlled properties makes electrospinning a highly adaptable technique for various applications ^[2].

PROPERTIES OF ELECTROSPUN FIBERS

Electrospun fibers possess distinct characteristics that differentiate them from conventional materials. Their high surface area enhances interactions with cells, drugs, or contaminants, depending on the application.

The porosity of electrospun mats allows efficient transport of gases and nutrients, which is particularly beneficial in tissue engi-

neering. Mechanical properties can be tuned by selecting appropriate polymers and adjusting processing parameters. Additionally, electrospun fibers can be functionalized with bioactive molecules, nanoparticles, or drugs to impart specific functionalities such as antimicrobial activity or controlled drug release ^[3].

APPLICATIONS OF ELECTROSPUN FIBERS

Electrospun fibers are widely used in biomedical applications, especially in tissue engineering, where they serve as scaffolds that mimic the extracellular matrix. These scaffolds support cell adhesion, proliferation, and differentiation, enabling the regeneration of tissues such as skin, bone, and cartilage. In drug delivery, electrospun fibers provide a platform for controlled and sustained release of therapeutic agents. Drugs can be incorporated within the fibers or coated onto their surface.

Electrospun nanofibers are also extensively used in filtration systems due to their ability to capture fine particles and microorganisms. They are applied in air and water purification systems. In addition, electrospinning has applications in energy storage devices such as batteries and supercapacitors, where nanofibrous materials improve performance due to their high surface area and conductivity ^[4].

CHALLENGES AND FUTURE PERSPECTIVES

Despite its advantages, electrospinning faces several challenges. One major limitation is the scalability of the process for industrial production. Maintaining uniform fiber quality at large scales remains difficult. Another challenge is the use of toxic solvents, which can pose environmental and health risks. Researchers are exploring greener alternatives and solvent-free methods to address this issue.

Mechanical strength and durability of electrospun fibers can also be limiting factors in certain applications. Efforts are being made to enhance these properties through composite materials and post-processing techniques. Future developments in electrospinning are expected to focus on advanced techniques such as coaxial electrospinning, multi-jet systems, and 3D electrospinning, enabling the fabrication of more complex and functional structures ^[5].

CONCLUSION

Electrospinning is a powerful and versatile technique for producing nanofibrous materials with unique properties and wide-ranging applications. Electrospun fibers have demonstrated significant potential in biomedical engineering, filtration, and energy storage due to their high surface area, porosity, and tunable properties. Although challenges such as scalability and solvent toxicity remain, ongoing research is driving innovations that will enhance the efficiency and sustainability of this technology. As advancements continue, electrospinning is expected to play a crucial role in the development of next-generation materials for healthcare and industrial applications.

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CONFLICT OF INTEREST

None.

REFERENCES

1. Li D, Xia Y. Electrospinning of nanofibers: Reinventing the wheel? *Advanced Materials*,2004;16:14, 1151–1170.
2. Greiner A, Wendorff H. Electrospinning: A fascinating method for the preparation of ultrathin fibers. *Angewandte Chemie International Edition*,2007;46:30, 5670–5703.
3. Bhardwaj N, Kundu C. Electrospinning: A fascinating fiber fabrication technique. *Biotechnology Advances*,2010;28:3, 325–347.
4. Huang Z. A review on polymer nanofibers by electrospinning and their applications. *Composites Science and Technology*,2003;63:15, 2223–2253.
5. Ramakrishna S. *An introduction to electrospinning and nanofibers*. World Scientific Publishing,2005.