Application of electrospun composite textile fabrics in the field of biomedicine and medical textiles

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Abstract: With the continuous improvement of people's understanding of the special properties and high adaptability of such nanomaterials, more and more researches began to focus on nanomaterials and nanocomposite structures. Among them, electrospinning technology is a preparation method with simple operation, wide adaptability of raw materials and easy realization of large-scale production of nanomaterials. Electrospun nanofibers have a high specific surface area and porosity, which not only has a wide range of applications in the field of biomedicine, but also shows great application potential in the fields of filter materials and personal protection. Electrospinning technology can directly process drugs into film, tube, layer and coating shapes coated with other materials. By adjusting the processing parameters and adjusting the diameter and length of the fiber, the resulting spun material can be very convenient to obtain the products we need. Therefore, the composite structure produced by combining electrospinning with other materials will also provide ideas for solving the problem of unstable size and release time of nano drug carriers in the actual process in the future.

1. Introduction to Electrostatic Spinning
Electrospinning, a spinning technique, is a unique approach using electrostatic forces to produce fine fibers from polymer solutions or melts and the fibers thus produced have a thinner diameter (from nanometer to micrometer) and a larger surface area than those obtained from conventional spinning processes. Furthermore, a DC voltage in the range of several tens of kVs is necessary to generate the electrospinning. Various techniques such as electrostatic precipitators and pesticide sprayers work similarly to the electrospinning process and this process, mainly based on the principle that strong mutual electrical repulsive forces overcome weaker forces of surface tension in the charged polymer liquid [1][2]. Currently, there are two standard electrospinning setups, vertical and horizontal. With the expansion of this technology, several research groups have developed more sophisticated systems that can fabricate more complex nanofibrous structures in a more controlled and efficient manner [3] [4]. Electrospinning is conducted at room temperature with atmosphere conditions. The typical set up of electrospinning apparatus is shown in Fig. 1 (a and b).

Electrospinning technology has played a very important role in the construction of one-dimensional nanostructured materials. The application of electrospinning technology has successfully prepared nanofiber materials with various structures. Through different preparation methods, such as changing the nozzle structure, controlling the experimental conditions, etc., it is possible to obtain solid, hollow, core-shell structured superfine fibers or spider web-like structure of two-dimensional fiber membranes; by designing different collection devices, Obtain single fibers, fiber bundles, highly oriented fibers or randomly oriented fiber membranes. However, electrospinning technology still faces some challenges in terms of fiber structure control: First, in order to realize the industrial application of electrospinning
fibers, it is necessary to obtain staple fibers or continuous nanofiber bundles. The preparation of oriented fibers solves this problem. It provides an effective way, but there is still a lot of distance from the target. Future work must try to make the fibers as straight and oriented as possible by improving the nozzle, receiving device and adding auxiliary electrodes, so as to obtain oriented fibers with excellent comprehensive performance. Array. Secondly, as a new research field of electrospun nanofibers, the research on nano cobwebs is still in its infancy. The theoretical analysis and model establishment of the formation process of nano cobwebs still need in-depth research. In addition, in order to improve the application performance of electrospun fiber membrane in the field of ultra-fine filtration, it is necessary to reduce the diameter of the fiber. How to reduce the average fiber diameter below 20nm is a challenge faced by electrospinning technology; to improve the fiber in the sensor It is an effective method to increase the specific surface area of fibers by preparing nanofibers with porous or hollow structures for application performance in the fields of catalysis, etc., but further research is still needed.

Figure 1. Schematic diagram of set up of electrospinning apparatus (a) typical vertical set up and (b) horizontal set up of electrospinning apparatus.[1]

2. Electrospinning polymer
In recent years, electrospinning technology has been used in dozens of different polymers, including a large variety of synthetic fibers produced by traditional technologies, such as: polyester, nylon, polyvinyl alcohol and other flexible polymers for electrospinning. It also includes electrospinning of elastomers such as polyurethane and butadiene-styrene block copolymer (SBS) and electrospinning of liquid-state rigid polymer poly-phenylene terephthalamide. In addition, proteins and nucleic acids, including silk and spider silk, have also been electrospun. After spinning through a high-voltage electrostatic field, polymer fibers can be obtained that are intertwined with each other and have a wide diameter distribution range (usually a few microns to tens of nanometers).

2.1. Wound dressing
The ideal wound dressing should be able to isolate excess exudate, and can transfer water vapor at a suitable rate, which is conducive to the flow of air and fits the contour of the wound surface (that is, it has a good fit with healthy tissue and does not stick to the injured tissue). Recently, there have been
many reports of fibrous wound dressings with both biodegradability and compatibility. Among them, nanofibers have a high specific surface area, high drug release efficiency, fiber hygroscopicity, flexibility and permeability are conducive to cell adsorption, as well as cell transfer and proliferation that can promote wound healing, so they can temporarily replace natural cells. The outer matrix can also be used as a carrier for antibacterial drugs and other growth factors. In Asghar Eskandarinia’s study[18], polycaprolactone/gelatin (PCL/Gel) scaffold was electrospun on a dense membrane composed of polyurethane and ethanolic extract of propolis (PU/EEP). The PU/EEP membrane was used as the top layer to protect the wound area from external contamination and dehydration, while the PCL/Gel scaffold was used as the sublayer to facilitate cells’ adhesion and proliferation. The bilayer wound dressing was investigated regarding its microstructure, mechanical properties, surface wettability, anti-bacterial activity, biodegradability, biocompatibility, and its efficacy in the animal wound model and histopathological analyzes. In addition, animal studies revealed that the PU/EEP-PCL/Gel bilayer wound dressing can significantly accelerate the wound healing progression and shorten wound closure time. Taking together, the PU/EEP-PCL/Gel bilayer wound dressing can be a potential candidate for biomedical application due to the high biocompatibility and significant anti-bacterial and wound healing activities.

Figure 2. Wound closure process and stained section pictures[18]

2.2. Deodorant and antibacterial materials
Microcapsule technology is mainly used in fabrics for aromatic finishing, antibacterial finishing, flame retardant finishing, UV protection finishing, etc. The principle is to use the characteristics of the core material to change the fabric properties. At present, there is little research on the effect of microcapsule finishing on the comprehensive wearability of fabrics. Finish the cotton fabric with the best technology. Wang Hui test the antibacterial durability and antibacterial washing resistance of cotton fabric after microcapsule finishing of wormwood essential oil[19]. They used water-based polyurethane ADM-F209 to microcapsule the fabric. Before finishing, use sodium dodecylbenzene sulfonate as a dispersant to uniformly disperse the finished microcapsules in the finishing solution, and then bond with water-based
polyurethane to make the wormwood essential oil micro capsule is bonded to the fabric. Hamid Asadia’s composite drug-loaded film [20] appeared in the experiment also has a significant antibacterial effect.

![Image of inhibition zone experiment](image)

**Figure 3.** Schematic diagram of inhibition zone experiment[19]

2.3. **Drug-loaded composite fabric**

In terms of sustained drug release, microcapsules can be used alone as drug monomers, or they can be combined with textile materials to produce some textile composite materials with antibacterial and health care functions. In this work, zein/Graphene oxide (GO) composite nanofibers were fabricated[20]. Furthermore, tetracycline hydrochloride (TCH) was incorporated in dressings by loading on GO nanosheets. The morphology, mechanical properties, and biological activity of the composites were characterized. Scanning electron microscopy (SEM) images revealed that the nanofiber diameter decreased with increased GO loading. Tensile testing indicated that incorporation of GO up to 1 wt% significantly increased the mechanical properties of the zein nanofibers. Drug loaded nanofibers showed a significantly prolonged release profile compared to zein nanofibers. Additionally, cellular studies demonstrated that GO content up to 1 wt% enhanced adhesion and proliferation of cells.
3. Development trend

The application of electrospun nanofibers in biomedical materials mainly includes tissue engineering, drug release, biomimetic materials, artificial organs, etc. Because the nanofibrous scaffold prepared by electrospinning is similar to the extracellular matrix in morphology and structure, it can be used in tissue engineering. The nanofiber scaffold has high surface area and porosity, which is conducive to cell adhesion and entry into the scaffold. The scaffold polymer materials that can be used for tissue engineering include collagen, polylactic acid, polycaprolactone, gelatin, polyethylene glycol, etc. They are all biocompatible and degradable. This hemostatic natural bandage made of nanofibers can promote wound healing and can be naturally degraded and absorbed by the human body. With the enhancement of people's awareness of environmental protection and the improvement of quality of life, the negative impact caused by the environment has attracted more and more attention. Green and pollution-free products with antibacterial properties, environmental protection and high comfort are more and more popular. The composite structure produced by combining electrospun micro-nano composite materials and fabrics has great development prospects and research value in wound dressings, drug-loaded composite carriers, and antibacterial deodorant materials used in people's underwear and socks.

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