RESEARCH ARTICLE

Preparation and Application of Electrostatic spinning Nanofibers

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Abstract: Electrostatic spinning is a simple, effective, cheap and pollution-free new method for preparing nanofibers, which has been widely used in the field of preparing nanofibers in recent years. Because of its high porosity and large specific surface area, it has a good application prospect in the fields of filtration materials, biomedicine, transducers, electronic devices, etc. In this paper, the basic principle and recent development of the preparation of nanofibers by electrospinning are reviewed. In this paper, the research status of electrostatic spinning fibers in filtration materials, biomedicine, sensors, electronic devices and other special fields at home and abroad is reviewed. The development trend and research direction of electrostatic spinning nanofibers are prospected.

Keywords: Electrostatic spinning; nanofibers; filter materials; biomedical; sensors; electronic devices

Introduction

Nanomaterials refer to solid materials consisting of extremely fine particles with characteristic sizes ranging from 1 nm to 100 nm. Broadly speaking, nanomaterials refer to materials with at least one dimension of nanometer size in three-dimensional space. Among them, zero-dimensional nano-materials mean that the three-dimensional dimensions of the material are nano-scale, i.e. nano-particles, atomic clusters, etc. One-dimensional nano-materials mean that the material is nano-scale in two dimensions of space, i.e. nanowires, nanorods. Nanotubes, etc., or nanofibers in general; two-dimensional nanomaterials refer to nanoscale sizes of the material on one dimension of space, that is, ultrathin films, multilayers, superlattices, and so on. Ultra-thin fiber products can be regarded as two-dimensional nanomaterials.

At present, there are many methods to fabricate nanofibers, such as stretching, template polymerization, microphase separation, self-organizing and electrostatic spinning, etc. Electrostatic spinning is a simple and effective method to synthesize nano-fiber dimension, which can be directly synthesized. The continuous preparation of polymer nano-fiber dimension has the advantages of mild experimental conditions, low cost, easy operation and many kinds of materials that can be combined. The spinning process is controllable and various forms can be spun according to the need. The fibers with various orientations can meet the requirements of a variety of properties. The nanofibers prepared by electrospinning have the properties of Small size, large specific surface area, high porosity, high aspect ratio, mechanical properties[2,3].It can be good and soon.

1. Preparation of nanofibers by electrostatic spinning

1.1 Basic principle

The preparation of ultrafine fibers by electrostatic force rather than by mechanical force. The principle is to strain charged polymer solutions (or melts) under electrostatic field forces. Then solidified by solvent evaporation (or melt cooling), an overrun, or electrospinning, of fibrous substances is obtained. Unlike traditional spinning methods, electrostatic spinning is the process of polymer jet electrostatic drawing spinning. The traditional method is difficult to produce

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fibers with diameter less than 500 nm, while the electrostatic spinning method can produce ultrafine fibers with a minimum diameter of up to 1 nm[4].

1.2 Installation

A typical electrospinning device consists of three main components: an electrostatic high voltage power supply, a liquid supply (microinjection pump and syringe), and a fiber collection device. Flow control systems (e.g. microinjection pumps) are used to accurately control the flow rate. A metal wire is used to connect the needle to the positive pole of the high voltage generator. The collector is a metal collector plate at the opposite end of the capillary. It can be a metal plane (e.g. aluminum foil or wire mesh), or a rotating roller, etc. Various types of collectors to meet the requirements of different experiments. The collector board is grounded with a conductor as a negative electrode and is connected to a high-voltage power supply.

Electrospinning uses electrostatic force as traction to prepare ultrafine fibers. In electrospinning, the solution forms droplets at the spinneret under the combined action of its own viscous force, surface tension, internal charge repulsion force and external electric field force. The droplets are applied to the spinning solution or melt by thousands to thousands of times. Tens of thousands of volts of high-voltage static electricity will create a strong electric field between the spinneret and the grounded fiber collector. When applied to the surface of the droplet, ions with the same polarity as the electrode will accumulate on the surface of the polymer solution fixed at the end of the spinneret by surface tension, producing charges. The charges repel each other and are reversed. Compression of surface charges by charged electrodes produces a force directly opposite to the surface tension[5] If the electric force equals the surface tension of the spinning solution or melt, the charged droplet will hang at the end of the spinneret and lie flat.

With the increase of the electric field force, the hemispherical droplets at the end of the spinneret will be stretched into a cone under the action of the electric field force, which is called Taylor cone[6] to further increase the electric field strength and overcome the electrostatic repulsive force of the surface tension of the droplets to reach a critical value. The charged polymer jet accelerates as it moves from the end of the spinneret to the receiving device. After an unstable stretching process, the jet is stretched very thin and very long in the electric field. The solvent evaporates or solidifies during the jet process, and the filamentous polymer or melt eventually lands on the receiving device. To the microfiber net in the form of non-woven fabrics[7].

2. Application of electrospun nanofibers

2.1 Filter material

Compared with traditional fiber filter materials, electrospun nanofibers have great specific surface area, surface area-volume ratio, porosity and permeability, and are easier to adsorb and separate micro-particles. As a filter material, electrospun nanofibers have high efficiency and low resistance, and are used in the filtration of submicron particles. The filtration efficiency of electrospun nanofibers is higher than that of conventional filters. In addition, the polymer nanofibers can be used in molecular filtration, chemical and biochemical drug isolation and so on, besides conventional filtration. As an adsorption medium, it is easier to adsorb and separate small particles, and can easily capture small particles with a size of 0.5 micron. It can be used in various filtration fields with high requirements, and has a good filtering accuracy. It has a wide range of applications in the fields of metal ion adsorption, air filtration, liquid filtration, electronics, biology, medicine and protection, etc. The filtering performance has been greatly improved in various application fields.

Abbasizadeh *et al.*[10] prepared polyvinyl alcohol/thio-titanium dioxide nanofiber membranes by electrospinning, and studied their adsorption properties for U (VI) and Th (IV) ions. The adsorption properties of thio-PVA/TiO2 nanofibers for these two ions were significantly better than that of unmodified nanofibers at 4. The maximum adsorption capacities of U(VI) and Th(IV) ions at pH 4.5 and 5.0 were 196.1 and 238.1 mg/g, respectively. The adsorption capacity of the two ions was endothermic and spontaneous, and there was no significant change after five adsorption-desorption. The selective order of adsorption for the two ions was Th(IV). The adsorption inhibition of Th (IV) on U (VI) was stronger than that of U (VI) on Th (IV). The adsorption kinetics showed that the adsorption belonged to physical adsorption and was divided into two stages. The adsorption rate of the first stage was faster than that of the second stage.

Polyoxyethylene (PEO) nanofiber membranes were prepared by electrospinning with an average diameter of 208 nm. The effects of air velocity, packing density and thickness of nanofiber layer on air filtration efficiency and membrane resistance were investigated. When the degree of filtration increases from 3.9 *10-3 to 36 *10-3, the filtration accuracy increases from 140 nm to 90 nm. When the air velocity increases from 5 cm/s to 10 cm/s, the filtration efficiency decreases slightly. When the particle size is smaller, especially when the packing density of nanofibers is less than 100 nm, the filtration efficiency decreases more. When the thickness of nanofiber membrane is 3 times of that of single layer, the filtration accuracy increases from 140 nm to 120 nm. By increasing the density of single layer of nanofiber membrane, the resistance increases obviously, but the filtration efficiency does not increase significantly, and the filtration performance decreases. The nanofiber membrane can be made into multi-layer structure. It effectively reduces filtration resistance and greatly improves filtration efficiency.

2.2 Biomedicine

Electrospun fibers have been widely used in drug controlled release, tissue engineering scaffolds, graft coatings, wound repair, artificial blood vessels, wound dressing products, etc.[12,13]

Zhang[14] *et al*. Gel and beta -TCP nanoparticles were directly mixed with gelatin and ultrasonic dispersion to prepare gel / beta -TCP composite nanofibers. The results showed that the attachment, dispersion, proliferation and early osteogenic differentiation of simulated osteoblast MG-63 on the composite nanofibers and beta -TCP nanoparticles The gel / beta -TCP composite nanofibers were significantly improved in mechanical properties, degradation behavior and cell affinity compared with the polymer or ceramic component scaffolds alone.

2.2.1 Controlled release of drugs

In the aspect of controlled drug release, drug release and degradation can be effectively controlled by changing the membrane morphology, chemical composition and fiber diameter, reducing side effects on the body and improving bioavailability. Drug-loaded nanofibers can precisely regulate drug delivery systems. Drug release rates are controlled by the size of the surface area of the corresponding carrier. The high specific surface area of nanofibers makes it possible for them to be used as drug carriers without drugs in the embedding process. Loss. In recent years, research has shifted from oral, high-dose rapid drug delivery systems to the use of drug-loaded biocompatible electrospun nanofibers for low-dose, slow-loading drug delivery therapy[17]. Coaxial electrospinning is a new electrospinning technology developed in recent years, which can be used. Drug-coated nanofibers with a shell-core structure were prepared. He Chuanglong[18] successfully prepared composite fibers with a wall thickness of about 100 nm, which can be directly embedded in human tissues and completely degraded in a relatively short time, with good biocompatibility and no obvious side effects. He Chuanglong can play an important role in medical and other fields.

Nie *et al*. developed a drug delivery system that can be used to load a variety of drugs. Polyethylene oxide (PEO) and chitosan were electrospun as substrates for amphiphilic block copolymer methyl ether-terminated polyethylene glycol-polylactic acid (MPEG-b-PLA) micelles. MPEG-b-PLA micelles and shells were prepared by electrospinning. Electrospun nanofibers with core-shell structure were prepared from polysaccharides and polyethylene oxide. The hydrophilic model drug cephalosporin and hydrophobic model drug 5-FU were encapsulated in the core-shell structure of the electrospun nanofibers. It was found that MPEG-b-PLA micelles were successfully loaded on chitosan and polyethylene oxide. In the spinning nanofibers, it was found that the sudden release rate of the drug carrier prepared by this method was significantly decreased, the release time of the drug was effectively prolonged, and the release effect was very good. The cells are effectively killed within 3 days.

2.2.2 Tissue engineering

In the field of tissue engineering, cell scaffolds act as extracellular matrix, consisting of three-dimensional fiber networks formed by layers of nano-fibers, which mimic the structure and function of extracellular matrix. Compared with traditional dressings, nanofiber scaffolds are more conducive to cell adhesion and entry. The high surface area and porosity of electrospun nanofiber materials can quickly initiate signaling pathways to attract fibroblasts to the dermis and secrete wounds. Extracellular matrix components important for healing, such as collagen and a variety of cytokines (growth factors and angiogenic factors)[20]. Membranes have fairly small pore sizes that prevent bacterial penetration, high specific surface areas that facilitate fluid absorption and skin administration. At the same time, nanofiber membranes exist in a nonwoven form and are beneficial. Cell attachment and increased[21]. during wound healing

Polycaprolactone (PCL) and natural polymer gelatin were selected to graft gelatin sponge layer onto polycaprolactone electrospun nanofiber membrane. The elastic modulus of PCL scaffolds before hydrolysis and after hydrolysis were 66-77.3 MPa, 62.3-75.4 MPa, respectively. The scaffolds with double-layer porous structure prepared by grafting gelatin sponge layer by soft hydrolysis showed good hydrophilicity and ideal mechanical strength. Compared with PCL electrospun membrane, adipose-derived mesenchymal stem cells had better adhesion and growth performance on the scaffolds with double-layer porous structure. These results suggest that bilayer porous scaffolds have potential applications in wound dressing and tissue engineering.

2.3 Sensor material

Sensing performance of nanofiber sensor is much better than that of corresponding thin film sensor. Sensitivity is an important index of sensor. It is proportional to the surface area of unit mass film. The surface adsorption ability can be controlled by controlling the surface area. Nano-sized functional polymers have high specific surface area. (about 103 m2 / g) and excellent electrochemical properties, electrospun nanofibers have made great progress in the sensing detection of inorganic gases[24], organic compounds and their volatile vapors, and biological molecules. Nanofibers can be used as biosensors to detect toxic cells in organisms and thus should be used more widely. It is used in medical field.

Electrospun polyaniline nanofiber sensors doped with camphor sulfonic acid were prepared by Pinto Nicholas *et al*.[28] and their sensing properties in the presence of different fatty alcohol gases were tested. Compared with the single polyaniline electrospinning nanofiber sensor, the single nanofiber sensor has stronger response to macromolecular alcohols and small molecular alcohols vapor, and has the advantage of micro-detection. The size of the molecules and the addition of ions determine whether ethanol molecules can penetrate the sensor. Electrospun nanofibers can achieve faster response and selective deposition in the preparation of this low cost, low energy consumption and fast response sensor.

2.4 Electronic devices

Nanofibers have special arrangement of polymer molecules, often called "crystal defects". They have the function of nano-devices and can move and rotate polymer molecules. Nanofibers prepared by electrospinning can not only improve specific surface area, but also obtain ideal chemical properties. A variety of nano-devices, such as nanowires, light-emitting diodes, photovoltaic cells and sensors, can also be used to connect a large number of nano-devices into a larger scale system[29,30]. Nanofibers have potential applications in low-light-emitting electronics and optoelectronics.

3. Conclusions and Prospects

Electrospinning technology has the advantages of simple equipment, strong operability and high efficiency; nanofibers have been widely used in traditional industries and high-tech fields due to their unique characteristics and have potential development prospects. It is expected that electrospinning nanofibers will be more widely used in the future as electrospinning technology moves from laboratory to workshop production line.

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