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A Review on the Effect of Electrospinning Parameters and Nanofibers and their Applications

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Abstract **Review Article**

Nanofibers are of great importance and are characterized by properties including high surface area as well as good porosity. They are biodegradable in the human body and transport drugs to the farthest parts of the body. These materials are considered new and produced with high-precision technology. Nanofibers are produced from industrial and natural polymers and can be introduced into many fields. Industrial polymers include nylon, acrylic, polycarbonate, polysulfonate, fluoropolymers, and natural chitosan and others that are produced from plant extracts. There are three important techniques in the formation of nanofibers: electrospinning, assembly, and separation. Electrospinning is the most widely used method at this time.

Keywords: Nanotechnology, Nanofiber, Electrospinning, Drug delivery, Polymers.

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1. INTRODUCTION

The importance of electrospinning increased at the end of the twentieth century among scientists and in industries as well, and this is considered a scientific, vital and commercial achievement and project [1,2]. Various nanotechnologies have been mentioned in the literature, including self-assembly, phase separation, and electrospinning [3, 4]. The use of electrospinning has become much preferred over the casting method and the phase separation process because nanofibers have a large surface area to volume ratio as well as porosity, so this technique is preferred for use [5]. This technology has an advantage over other technologies in all fields. An example of this is that nanofibers have an effective role in biological tissues and their materials [6, 7]. It is known that fibers work to enhance interactions between the cell and the scaffold. Nanofibers are also used to transport drugs to the sites they are intended to target [8]. Nanofibers are used in environmental protection [9,10]. Some researchers reported that they are used as sensors, for example the compound nitro(2,4-dinitrotoluene -DNT) [11]. Nanofibers can be used to form nanotubes [12]. Tubes are prepared by coating electrospun nanofibers with nanotube raw materials and then evaporating the solvent [13,14]. This review includes a general theoretical statement on electrospinning topics.

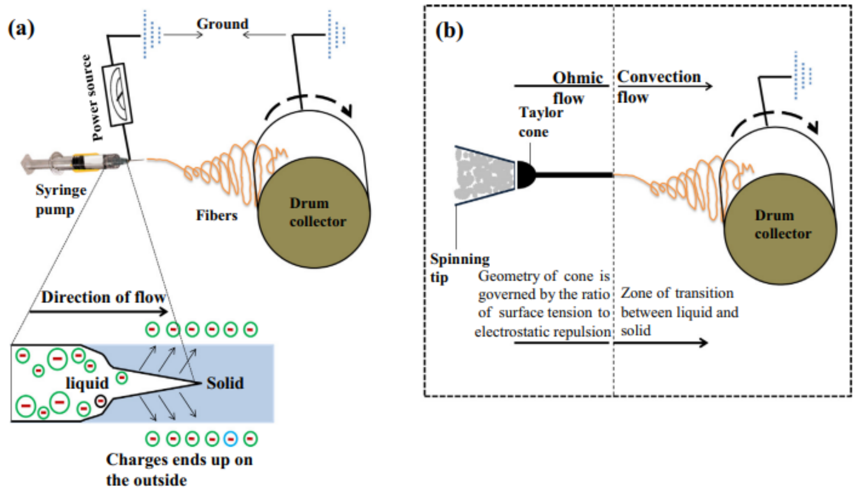

Fig.1. Diagram showing the electrospinning apparatus [5].

2. ELECTROSPINNING PARAMETERS AND THEIR EFFECT

Through previous and expanded studies on electrospinning [15]. from Fig.1a, we can count four basic technologies: the high-voltage source, the syringe in which the polymer solvent, the needle, and the collector are present. The electrospinning mechanism occurs as a result of the transfer of an electric charge. Or charges to the solvent through the needle. This causes instability of the solvent inside the syringe, resulting in the charges being pushed onto the solvent drop. This surface tension force produces mutual repulsion between the charges, and finally the dissolved polymer flows in the direction of the electric field, as in Fig.1b. As the electric field increases, it turns the drop into a conical shape. After that, we obtain extremely small nanofibers from the polymer drop, which is called a Taylor cone [16].

2.1. Voltage of the Effect

The voltage applied to the metal needle causes the droplet to deform and turns it into a conical shape. After that, nanofibers are formed at the critical voltage (Figure 2a-c) [17]. The applied voltage varies from one polymer to another, and the formation of nanofibers increases the diameter of the nanofiber with increasing high voltages [18]. Also, the beads in the nanofiber increase with increasing voltages, and also with increasing voltages, the Taylor cone decreases [19].

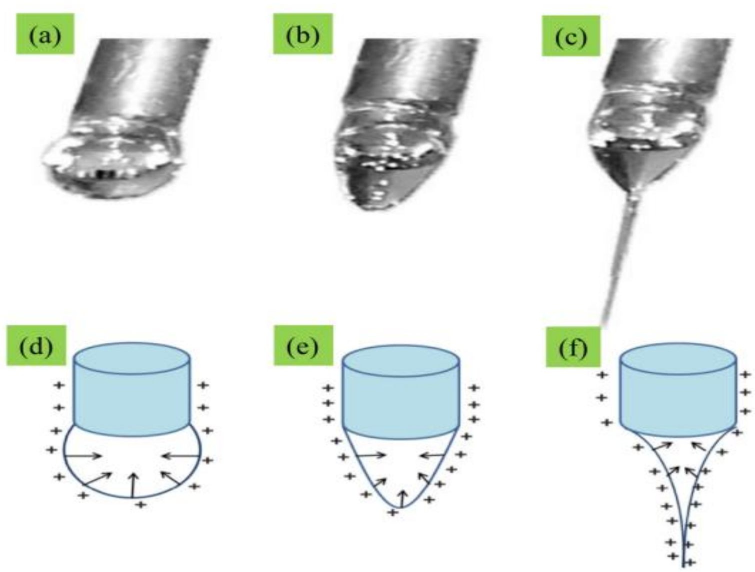

Fig.2. (a–c) shows the formation of polyvinyl droplets under increasing voltages. Figure (d-f) shows the effect of electrical charge on a drop of polymer solution[20].

2.2. Effect Flow Rate

We conclude that some previous studies have clarified the relationship between fiber size and flow rate. It was found that the smaller the flow, the smaller the diameter of the fiber [21]. On the contrary, the greater the flow, the greater the swelling of the nanofiber [22,23].

2.3. Effect of the Distance between the Collector and the Needle

Nanofibers formed by electrospinning, the distance between the collector and the needle plays a major role in this formation. In addition to the flow rate and high voltages, the distance is not constant and varies from one polymer solution to another. The formation of the nanofiber is definitely affected by the distance [24]. Any change in distance affects the morphology of the nanofiber [25]. Scientific research has concluded that the greater the distance between the needle and the collector, the larger diameters we obtain, in contrast to that at large distances [26]. There are cases that the nanofibers do not change in the distance between the collector and the needle [27].

2.4. Effect of Viscosity and Concentration of the Polymeric Solution

Electrospinning depends on this basic feature, which is viscosity, and it increases with increasing concentration of the polymer solution. When the concentration is low, we get surface tension, but not at the desired level, and we get interwoven mats of polymer, but they contain beads [28]. An increase in the concentration of the polymeric solution leads to an increase in viscosity and overcoming surface tension, and we obtain nanofibers without beads [29].

3. Characteristics of Nanofibers

Nanofibers are characterized by properties such as surface-to-weight ratio, high surface area, high porosity, and low density. These properties favor nanofibers [30].Fig. 3 shows a comparison between the size of a human hair and a nanofiber, which is 50-150 micrometers, and Fig.4 shows a comparison between a nanofiber and the size of a pollen grain. Flexibility is achieved.The modulus of a polymeric nanofiber less than 350 nm is 1.0 ± 0.2 Gpa.

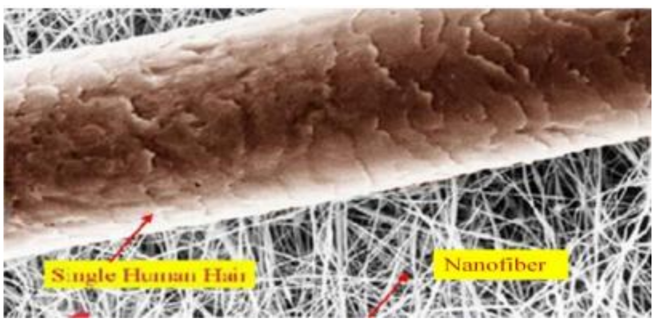

Fig. 3.Comparison between nanofiber and human hair [31]

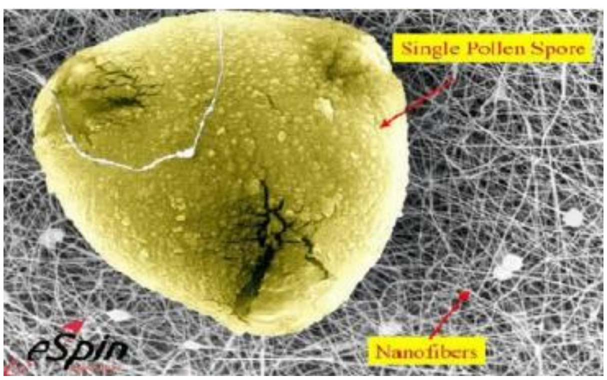

Fig.4. The nanofiber and the pollen spore trapped in it [31]

4. MECHANICAL CHARACTERISTICS

A high porosity surface shape, high tensile strength, modulus of elasticity, and Young's modulus are characteristics of the nanofiber produced by electrospinning. Research has shown that thermoplastics produced by electrospinning maintain their Young's coefficients unchanged. At the highest applied stress, the elongation reduces by 60% and the tensile strength decreases by 40% when compared to materials manufactured by electrospinning and those utilising the casting process. When compared to polymeric materials including glass or carbon, composites incorporating nanofibers were shown to have good mechanical characteristics[32].

5. NANOFIBERS FABRICATION

5.1. First Principle

Through nanofibers, the method of drug delivery depends on increasing the surface areas to dissolve the drugs. The polymeric nanofiber has other properties, unlike what it is, only the packaging of medicines, including to improve treatment and the safety of the medicine when it reaches the desired place. In addition, we choose polymers that are in the form of compounds, delivery and delivery in the specified place [33]. The nanofiber has the ability to deliver and release active materials. Biology. It has been proven that the process of forming nanofibers depends on three basic techniques: electrospinning, phase separation and self-assembly [34,35].

5.2. Self-Assembling

It produces non-small particles that are graduated to the nanoscale and may even be nanofibers, whether manmade or natural [36]. Self-assembly is defined by non-covalent bonding with a stable structure and regular shapes, which means that the structures and forms that arise naturally and without human assistance are derived from both technology and nature [37].

5.3. Separation of Phases

Phase difference technology is widely used in nanoscale scaffolds. It is possible that phase separation works to separate polymeric solutions into the formation of solvent-rich domains and polymer-rich domains. The morphology can be corrected through cooling. In this case, the solvent volatilizes, and during drying we obtain fibers with good porosity. Separation occurs as a result of a change in temperature or the addition of soluble substances to the polymers. It is called heat-induced and non-solvent-induced [38]. The fibers or scaffolds that we obtain by phase separation are in a spongy shape or have high porosity, unlike what is the case in self-starvation. The phase separation technique is simple and does not require specialized technical equipment. It is easy to form and maintain consistency. We also point out that this technique is limited to specific types of Polymers [39].

6. ELECTROSPUN NANOFIBER APPLICATION

Nanomaterials vary among themselves, either in the form of a tube, a rod, or a wire, which are included in wide areas of technology [40]. Nanofibers manufactured by electrospinning are used in a wide range of fields, the most important of which is in the field of medicine (Table 1). They are also used in the field of optics, electronics, and sensing. They are also used in the treatment of damaged and ulcerated skin, cartilage, and bones. Therefore, nanofibers are an essential element in wound dressing and power delivery. To the farthest point in the body [41]. Nanofibers are characterized by many features, the most important of which is high porosity, which indicates cell adhesion and biological response [42]. Nanofibers have been widely studied and can be used as filters for pollutants. An example of this is the coffee filter that we use in our daily lives.

Table.1. Electrospun nanofibers made of natural biopolymers [7]

Materials	Solvent	
Cellulose acetate	Acetone/DMAc	[43]
Chitin	HFIP/PBS	[44]
Silk fibroin	Formic acid	[45]
Gelatin	TFE/HFIP	[46]
Collagen	HFIP	[47]
Wheat protein	HFIP	[48]
Chitosan	TFA	[45]
Hyaluronic acid	DMF/water	[49]
Fibrinogen	DMF/water	[7]
Elastin	Water	[50]
Soy protein	HFIP	[51]
Whey protein	Acidic aqueous solution	[52]

6.1. Engineering of tissues

Nanofibers are characterized by their ability to decompose in the human body, unlike traditional fibres. Nanofibers have the ability to provide the necessary environment for cell cultivation, so the interest in electrospinning in tissue engineering has increased [53]. Studies are increasing in the field of tissue engineering in the use of electrospinning technology. Nanofibers did not show the interaction occurring between one cell and another, but rather a cell was used with another matrix [54]. Electrospun nanofibers have good cell growth [55]. Studies and researchers have focused on natural materials, including (chitosan, alginate, collagen, silk protein, hyaluronic acid, alginate), and there are other materials in which these materials or polymers are distinguished by their biocompatibility [56]. Synthetic polymers have been used and mixed with nature to obtain tissues with high durability, including cartilage tissue [57]. Bone tissue [58]. One of the industrial polymers that has special properties and will be used for tissue regeneration, high biodegradability, and biocompatibility is (glycolic acid and lactic acid) (PLGA).

6.2. Dressing for wounds

To control and heal wounds, nanofibers have a major role in wound healing, to protect wounds and remove damage and secretions. In this case, excellent dressings must be provided for the purpose of controlling the wound, and to promote healing, a suitable moist environment must be created, inhibiting microbes and dealing with them. An example of this is resistant bacteria [59]. Through electrospinning, a wound dressing is prepared that has properties comparable to that of a traditional dressing [60]. Nanofibers are characterized by high porosity and surface area, and the electrospinning process can be used in the manufacture of cosmetic masks . It is possible to integrate and treat skin by adding treatment to nanofibers [61]. Nanofiber has the ability to inhibit and treat, so it has been used as a skin mask. Fig.5 shows the preparation of materials used as a dressing for wounds and antimicrobial agents.

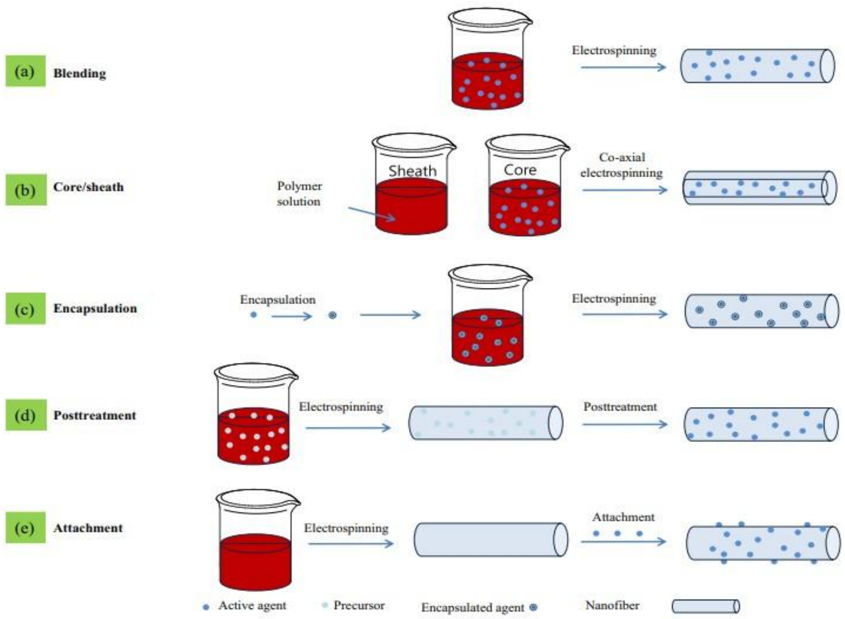

Fig.5. Several techniques for making an appropriate wound dressing [60]

6.3. Delivery of drugs

One of the important applications that nanofibers work on is drug delivery, as the fibers have large surface areas, so the drug dissolves more as the surface area increases[62]. There are many drugs that have been loaded onto nanofibers, antibiotics, proteins, ant-carcinogens, and many others. Because nanofibers are a good conductive medium and reach the farthest places in the body [63]. The nanofibers manufactured by electrospinning are in the form of a carrier or nanocarrier that carries the drug [64]. One of the advantages of electrospinning is that it reduces the toxicity of the substance and enhances the effectiveness of the treatment. There are many researchers who are interested in this technique for nanofibers, loading the drug onto it and delivering it [65].

7. CONCLUSION

The characteristics applied to nanofibers, such as molecular weight, voltage, viscosity, and the separation between the solvent, needle, and collector, all have an impact on them. The process of electrospinning is straightforward, affordable, and manageable. The most significant use of nanofibers is in drug administration, but they can also be used in tissue engineering, wound healing, sensing, filtration, and wound healing. From the various ways that nanofibers are used in medicine, as well as in cell adhesion and transplantation, we can draw conclusions.

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