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Analysis of Factors Affecting Product Quality in the Process of Electro spun

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Abstract:

The purpose . In this article, the factors and parameters affecting the quality of the product are studied in the process of "Electrospinning" that is used in the production of nanofibers with the help of electricity .

Methods. Organization of the process of electrospinning requires the adjustment of several parameters. These are the parameters of the polymer solution used in the process, the parameters of the direct production process and the environmental parameters. Also using these methods We have also analyzed the availability of fiber that we need.

Results. According to the results of the analysis, the issues that we need to pay attention to in the process of Electrospin: Viscosity, polymer concentration, molecular weight of the polymer, conductivity, surface tension, applied voltage, distance between the needle and the collecting drum, factors such as flow rate, humidity and temperature were found to be the main parameters affecting product quality.

Summary. Taking into account that the Electrospinning method is not available in the textile industry of Uzbekistan today, adding this process to the ranks of the textile industry of Uzbekistan and fully using the possibilities of this process will serve to satisfy the need for nanofibers in our country.

Keywords: Electric field, polymer solution, flow rate, viscosity, conductivity, molecular weight, environment, room temperature and humidity.

Introduction

Organization of the process of electrospinning requires the adjustment of several parameters. These are the parameters of the polymer solution used in the process, the parameters of the direct production process and the environmental parameters. Solution parameters include viscosity, conductivity, molecular weight, and surface tension. Process parameters include the applied electric field, the spacing of the "collector" i.e. the collecting drum, and the solution consumption or flow rate[1]. (Chong et al., 2007). Each of these parameters significantly affects the morphology of the fibers obtained by electrospinning, and by properly tuning these parameters, we can obtain nanofibers with the desired morphology and diameter. In addition to the above parameters, environmental parameters also include humidity and temperature, which play an important role in determining the morphology and diameter of electrospun nanofibers[2]. (Li and Xia, 2004). Table 1 below lists the various parameters and their effect on fiber morphology. In addition, for each parameter, factors affecting the quality of the planned fiber were analyzed.

Table 1
Factors affecting fiber morphology during electrspinning

Parameters	**Effect on fiber morphology**
Solution parameters:	
Stickiness.	Low formation of knots, increase in fiber diameter, loss of knots.
Polymer concentration.	As the concentration increases, the fiber diameter increases.

Molecular weight of the polymer.	A decrease in the number of nodules and droplets with increasing molecular weight.
Conductivity.	Increase in conductivity with decreasing fiber diameter.
Surface tension.	There is no clear correlation with fiber morphology, but high surface tension requires modification of the needle through which the polymer solution flows.
Production parameters:	
Applied voltage.	As the tension increases, the fiber diameter decreases.
The distance between the needle and the pick-up drum.	Knots are formed as a result of too small or too large a distance, the minimum distance must be selected to obtain a fiber of the specified thickness.
Flow rate.	The reduction of the fiber diameter depends on the decrease of the flow rate, high flow rate leads to the formation of nodules on the fiber surface.
Environment parameters:	
Moisture.	As a result of high humidity, round holes, or pores, appear in the fibers.
Temperature.	An increase in temperature leads to a decrease in the diameter of the fibers.

Methods

1. Polymer solution parameters

Concentration

A minimum solution concentration is required for the formation of fiber by electricity. It was found that at a low concentration of the solution, a mixture of nodules and fibers is obtained, and as the concentration of the solution increases, the shape of the nodules changes from spherical to spindle, and uniform fibers with an increased diameter are formed due to high adhesion resistance [3] (Deitzel et al., 2001; Liu and Hsieh, 2002; Ryu et al., 2003; McKee et al., 2004; Ki et al., 2005; Haghi and Akbari, 2007). There must be an optimum solution concentration for the electrospinning process, because at low concentrations, spherical nodules are formed instead of fibers, and at high concentrations, continuous fiber formation is resisted, either because of the inability to maintain the solution flow at the tip of the needle or A lot of fibers are formed[4] (Sukigara et al., 2003). Researchers tried to find a relationship between solution concentration and fiber diameter, and they found a power law relationship with increasing the concentration of the gelatin solution to electrically induce fiber formation[5] (Ki et al., 2005 ; Jun et al., 2003). The surface tension and viscosity of the solution also play an important role in determining the concentration range over which continuous fibers can be obtained in electrospinning[6] (Deitzel et al., 2001).

Molecular weight

The molecular weight of a polymer has a significant effect on rheological and electrical properties such as viscosity, surface tension, conductivity and dielectric strength[7]. This is an important decisive parameter affecting the morphology of the electrospun fiber , and high molecular weight polymer solutions are usually used in electrospinning because they provide the necessary viscosity for fiber production. It was found that the very low molecular weight solute formed knots rather than fibers, and the high molecular weight solute formed fibers with a larger average diameter. The molecular weight of a polymer indicates the entanglement of the polymer chains in the solution, thus directly affecting the viscosity of the solution. In the process of electrospinning, the entanglement of chains plays an important role. Thus, even at low polymer concentration, HM-PLLA (high molecular weight poly-L-lactic acid) can maintain a sufficient amount of entanglement of the polymer chains. It is considered necessary to provide a sufficient level of viscosity of

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the solution in order to stop the effect of surface tension and flat jet production during electrospinning, which plays an important role in the formation of knots in electrospinning nanofibers[8]. The researchers synthesized PMMA with molecular weights ranging from 12.47 to 365.7 kDa to study the effect of polymer molecular weight, and found that the number of nodules and droplets decreased with increasing molecular weight. It has been observed that high molecular weights are not always necessary for the electrospinning process if sufficient intermolecular interactions can replace the interchain cross-linking resulting from chain entanglement, and researchers have been able to grow oligomers from lecithin solutions by electrospinning. prepared non-woven membrane fabrics from phospholipids of size[9].

Stickiness

Melt viscosity plays an important role in determining fiber size and morphology during spinning of polymeric fibers. It was found that with very low viscosity, continuous fiber formation will not occur, and with very high viscosity, it will be difficult to eject the polymer solution from the needle, so the electrospinning process requires the best viscosity. The viscosity range of different polymer solutions used for assembly is different. Researchers have reported that the maximum viscosity varies from 1 to 215[10] (Baumgarten, 1971; Doshi and Reneker, 1995; Deitzel et al., 2002; Buchko et al., 1999). Fong et al studied polyethylene oxide (PEO) nanofiber formation at different viscosity levels and found that a viscosity range between 1 and 20 was suitable for producing uniform nanofibers in electrical assembly. The viscosity of the polymer is related to the concentration and molecular weight of the polymer. The viscosity of the solution is closely related to the concentration of the solution, and the relationship between the polymer viscosity or concentration and the fibers obtained from the electrospinning process is poly(lactic-glycolic acid) (PLGA) (Kim et al., 2005a), poly(ethylene oxide) (PEO) (Huang et al., 2001a; Son et al., 2004c) poly (vinyl alcohol) (PVA) (Ding et al., 2002; Koski et al., 2004; Li et al.,) Zhang et al., 2005b), poly (methyl methacrylate) (PMMA) (Gupta et al., 2005), polystyrene (Jarusuwannapoom et al., 2005), poly(L-lactic acid) (PLLA) (Jun et al., 2003), gelatin (Ki et al., 2005) and dextran (Jiang et al., 2004a) have conducted scientific research in several systems[11].

Very high viscosity polymer solutions typically exhibit longer flow times, which prevent solution breakage from the needles during electrospinning. An increase in solution viscosity or concentration results in larger and more uniform fiber diameter[12] (Deitzel et al., 2001). In the electrospinning process, the viscosity of the solution plays an important role in determining the range of concentrations from which continuous fibers can be obtained. For low-viscosity solutions, surface tension is the main factor, and above a critical concentration, globular nodular fibers form. This means that it has a continuous fibrous structure and its morphology is affected by the concentration of the solution[13]. Conducted studies show that during the electrospinning process, it is necessary to take into account the optimum viscosity level of polymers, and this property has a direct effect on the morphology of fibers.

Surface tension

The surface tension, which may be a function of the solution components, requires reducing the surface tension of the solution to obtain nanofibers with uniform cross-section during electrospinning, thereby playing an important role in obtaining knot-free fibers. Different solutions can produce different surface tensions. In general, the high surface tension of the solution hinders the electrospinning process due to stagnation of flows and the formation of spray droplets[14] (Hohman et al., 2001). The formation of droplets, knots and fibers depends on the surface tension of the solution, and the low surface tension of the spinning solution allows the electrospinning process to occur at a lower electric field[15] (Haghi and Akbari, 2007). However, the lower surface tension of the solvent is more suitable for the operation of the electrospinning process. Basically, the surface change determines the upper and lower limits of the electrospinning process if all other parameters are held constant[16] (Fong et al., 1999; Zhang et al., 2005b; Pham et al., 2006). .

Conductivity or surface charge density

Polymers are essentially conductive, with the exception of dielectric materials, and the charged ions in the polymer solution have a large effect on reactive formation. The conductivity of the solution mainly depends on the type of polymer, the solvent used and the presence of ionizing salts. It was found that as the

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electrical conductivity of the solution increases, the diameter of electrospun nanofibers decreases significantly, and if the conductivity of the solution is low, it is observed that fibers do not stretch and knots form as a result of insufficient electrical charge of the solution to produce a uniform fiber . Hayati and others. (1987) found that superconducting solutions become highly variable in the presence of strong electric fields, leading to sharp tilt variability and wide diameter distributions. In general, nanofibers with the smallest fiber diameter can be obtained with the highest electrical conductivity, and it has been found that the decrease in fiber size is associated with an increase in electrical conductivity. It has been found that the radius of the reactive needle changes inversely with the cube root of the electrical conductivity of the solution[17] (Baumgarten, 1971; Fong et al., 1999; Huang et al., 2001a; Zong et al., 2002a; Jiang et al. , 2004a; Mit-Uppatham et al., 2004; Zuo et al., 2005; Kim et al., 2005b; Haghi and Akbari, 2007). Natural polymers are usually polyelectrolytic, for example gelatin. The ions increase the charge-carrying capacity of the reactive needle, thereby causing it to become highly charged with the applied electric field. Thus, the ability of gelatin to form fibers is less than that of synthetics. Zong et al. (2002 a) showed the effect of ions by adding ionic salt on the morphology and diameter of boron electrospun fibers, and with the addition of ionic salts such as $KH_2 PO_4$, $NaH_2 PO_4$ and Na Cl, relatively smaller diameters were less than 200 nm. It was found that fibers without spherical knots up to 1000 nm were produced. This method of increasing the permeability of the solution by adding salt has also been used for other polymers, such as PEO (Fong et al. 1999), type I-PEO collagen (Huang et al., 2001a), PVA (Zhang et al., 2005b) polyacryl acid (PAA) (Kim et al. 2005b), polyamide-6 (MitUppatham et al., 2004) and others. When using salts, the uniformity of fibers increases and the formation of knots is reduced.

2. Production parameters

Operating voltage

In electrocycling, the decisive force is the voltage applied to the solution. Only after the voltage reaches the limit, the formation of the fiber occurs, which together with the electric field creates the necessary resistance for the solution and starts the process of fiber formation by electricity. During the process of forming a fiber from a certain polymer, it has been proven experimentally that the structure of the fiber changes depending on the tension, viscosity , and flow rate of the solution. (Baumgarten, 1971, Abdullaev A and others 2021). There is little controversy about the behavior of the applied voltage in the electroforming process. In a study conducted by Reneker and Chun (1996), it was found that the effect of the electric field on the diameter of the fiber during the electrical fiber formation of polyethylene oxide is not significant. Researchers have hypothesized that when higher voltage is applied, the yield of polymer-generated fibers is greater, which facilitates the formation of larger diameter fibers[18-19]. Other authors have suggested that increasing the applied voltage (ie, by increasing the electric field strength) increases the electrostatic impulse strength in the fluid flow and consequently promotes a reduction in fiber diameter. In most cases, the higher voltage causes the solution to stretch due to the stronger coulombic forces and electric field in the jet needle, and these effects lead to a decrease in the diameter of the fibers, as well as rapid evaporation of the solvent from the fibers. There is a high probability of spherical nodules appearing even at high voltage[20] (Buchko et al., 1999; Deitzel et al., 2001; Demir et al., 2002; Megelski et al., 2002; Lee et al., 2004; Mo et al., 2004; Katti et al., 2004; Pawlowski et al., 2004; Haghi and Akbari, 2007). The variation of fiber diameter with applied stress was also studied by Larrondo and Manley (1981a,b,c). They showed that by doubling the applied electric field, the diameter of the fiber was reduced by about half. They found that by doubling the applied electric field, the diameter of the fiber was reduced by about half. Thus, the tension affects the fiber diameter, but the degree of importance varies with the concentration of the polymer solution and the distance between the needle and the collecting drum.

Supply speed and flow rate

The rate at which the polymer exits the syringe is an important process parametric because it affects the flow rate and the rate at which the material is wrapped. In the direct production process, a lower solution supply rate is acceptable because the substance used to dissolve the solution must have enough time to evaporate [21] (Yuan et al., 2004). There should always be a minimum flow rate of the spinning solution. It was found that in the case of polystyrene (PS) fibers, with an increase in the polymer flow rate, the fiber diameter and the pore diameter increase, and by changing the flow rate, the morphological structure can be

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slightly changed. A review of several studies revealed that the relationship between fiber morphology and size of solution supply or flow rate requires systematic investigation [22]. High flow rates lead to formation of knotted fibers due to lack of proper drying time before reaching the collecting drum[23] (Wannatong et al., 2004; Yuan et al., 2004; Kim et al. , 2005a; Zuo et al., 2005).

Types of collecting drum

One of the most important aspects of the electrospinning process is the type of pick-up drum used. In this process, the drum acts as a conductive substrate on which the nanofibers are assembled. Generally, aluminum foil is coated on the surface of the collecting drum and used as a collector, but due to the difficulty of transferring the collected fibers and the need for fibers that are used for various other industries, other types of collectors are also used. For example, conductive paper, conductive cloth, wire mesh, lumps, rotating sieve and rotating wheel, non-liquid solvent such as methanol coagulation bath and several others There are widespread types[24] (Wang et al., 2005 b), (Sundaray et al., 2004), (Li et al., 2004), (Xu et al., 2004), (Ki et al., 2007). In their research, Wang et al. used two types of collectors, aluminum foil and wire mesh, in the electrospinning process of hyaluronic acid blowing, and the area of less conductivity of the wire conductor has a negative effect on fiber collection. revealed that he had shown a secret. Because the conductor area is less, knotted fibers appeared on the surface area. Another study compared wire mesh with aluminum foil and wire mesh without aluminum foil in the same conductor area and found that pure wire mesh was a better collector for collecting fibers because wire mesh it became easier to transfer fibers to other substrates[25] (Kumbar et al., 2008). The produced nanofibers are deposited into the collector as a random mass due to the bending instability of the polymer material emerging from the highly charged needle[26] (Reneker et al., 2000; Shin et al., 2001a). Several research groups have demonstrated the use of a rotating drum or spinning wheel-like spool or metal frame as a collector to arrange the electrospun fibers more or less parallel to each other[27] (Doshi and Reneker, 1995; Deitzel et al., 2001; Fong et al., 2002).

Results

3. Environment parameters

solution preparation and fermentation parameters, there are also environmental parameters including humidity, temperature, etc. Several studies have been reviewed to investigate the effect of environmental parameters (i.e., temperature and humidity) on the electrospinning process. Mit-Uppatam and others. (2004) studied the effect of temperature on the electrospinning process of polyamide-6 fibers at temperatures from 25 to 60 °C and found that the diameter of the fiber decreased with increasing temperature, and this decrease was explained by the decrease in viscosity of polymer solutions at high temperatures[28] . There is an inverse relationship between viscosity and temperature. Changes in humidity in polystyrene solution spinning were studied and it was noted that as a result of increasing humidity, small circular holes appeared on the surface of the fibers, and further increase in humidity led to coalescence of the holes[29] (Casper et al., 2004). It was found that when the humidity is too low, the volatile solvent dries quickly because the solvent evaporates faster. Sometimes the rate of evaporation of the solvent is faster than the rate of polymer leaving the tip of the needle , causing problems in the electrospinning process. As a result, it only takes a few minutes for the needle tip to jam during electrospinning[30] (Baumgarten, 1971). It is also suggested that high humidity favors the production of electrospun fibers[31-33] (Li and Xia, 2004; Li et al., 2005a). Therefore, in addition to solution and production parameters, environmental parameters also significantly affect the electrospinning process.

Conclusions

1. Electrospinning is a simple, versatile, and cost-effective technology that produces fibers for nonwovens with high surface area to volume ratio and hollow porous fibers. is considered a promising method for various applications, especially for tissue engineering, due to its feasibility.
2. Melt and production parameters such as viscosity, molecular weight, polymer concentration, applied voltage, distance between the pick-up drum and the melt exit needle , conductivity, etc. significantly affect fiber morphology, and manipulation of these parameters By doing this, you can select the desired features for a particular application.

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3. Fibers spun by this method are widely used in various fields, such as tissue engineering, wound healing, drug delivery, enzyme immobilization, biosensor membrane, protective clothing, cosmetics, cell membranes, filtration applications, and other fields. is being used.

Taking this into account, the introduction of this industry to the textile industry of Uzbekistan is considered one of the major tasks facing the scientists and employees of this industry today.

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