Fabrication of Nanofiber using Electrospinning Technique for Biomedical Application

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Abstract— **Nanofiber is defined as the fiber having at least one dimension in nanometer range or even less than human hair. Nanofiber are widely used in tissue engineering, sensor applications, wound healing, implant materials, drug delivery or medicinal materials. There are various methods available to generate nanofiber but electrospinning is one of the most widely used versatile technique for continuous fiber forming process having less diameter (50-1000nm) with low cost, high surface area, high porosity, multi twisted fiber, current flow, interaction & binding by which either polymer solutions or melts are charged by high voltage(5-20 kv) to form fine jets of nano fiber structure with high efficiency for biomedical applications of wound healing without any side effects and short term healing. Using this method we can improve the thermal, mechanical and electrical properties of the fiber. Also it can be used in Lab. Silver Nitrate & Polyvinylbutyral(PVB) is a polymer which is used to be for this method, because it is a non-toxic, odorless, low cost, flexibility, optical clarity, environmental friendly, adhesion to many surface, strong binding ability, antimicrobial property and prepared by laboratory at 25 degree Celsius. Electrospinning generates scaffold with more homogeneity & treating the webs by heat or UV radiation. So that crystallinity is improved and it is insoluble in moisture environment. This webs has the characteristics of oxygen permeation, protection of wound from infection and dehydration. Webs was heated by heat or uv radiation to improve the crystallinity property. Also it was insoluble in moisture environment. The webs has a antimicrobial agent for treating wounds. It shows an excellent antimicrobial activity above 99.1%. But it has a one drawback of slightly colour changes in the skin after curing the wound.**

Index Terms— Electrospinning, Nano structures, PVB, Silver nitrate, Wound Dressing material

I. INTRODUCTION

A. Nano Technology

Nanotechnology (NT) is the production and use of materials at the smallest possible scale 100 nanometers or less. One hundred nanometers is approximately 1/800th the width of a human hair and 1/70th the diameter of a red blood cell. Materials at the nano scale often exhibit very different physical, chemical, and biological properties than their normal size counterparts. Nanotechnology may be able to create many new materials and devices with a vast range of applications, such as in medicines, electronics, biomaterials and energy production.

II. NANO FIBERS

Nano fibers are submicron sized fibers whose diameter is 50 - 500 nm. Nano fibers are not visible under normal microscopes, as their diameter is smaller than the wave length of light. Such exceptionally small fibers can only be seen and photographed by electron microscopes. In future will be utilized in filtration, the environment, cosmetics, medicine, hygiene, energy, IT, nano composite, composites and protective wear. nanotechnology refers to the science and engineering concerning materials, structures and devices which at least one of the dimensions is 100nm or less. This term also refers to a fabrication technology in which objects are designed and built by the specification and placement of individual atoms or molecules or where at least one dimension is on a scale of nanometers.

A. Properties And Features Of Nanofibers

Nano fibers has less diameter, high surface to weight ratio, low density, large surface area to mass, high pore volume, high porous and small pore size, basic weight: 0,05 - 5 g/m2,transparent,excellent mechanical properties in relation to their weight. It is fast and easy method to mass produce nano fibers compared to other methods of producing nano fibers and Ability to mix different fibers composed of different polymer. It can be ability to fabricate porous sub-micron fibers. Forming non-woven fabrics and yarn at an industrial level. At smaller level, can form fibers of various alignments and Fabrication of ceramic nanofiber through secondary processes

B. Synthesis Of Nanofibers

Nano fiber can be formed using different techniques: Drawing, Template synthesis, Phase separation, Self assembly, Electrospinning. Although there are a number of techniques used for the synthesis of nanofiber but Electrospinning technique is used by many industries to fabricate nano fibers. Because in elctrospinning electrostatic force is used instead of conventionally used mechanical force for the formation of fibers.

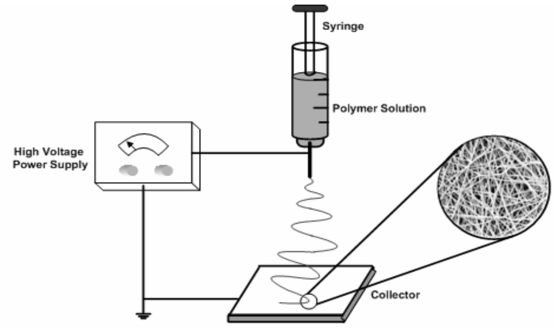

Figure 1: Basic Electrospinning setup

III. ELECTROSPINNING

Electrospinning is a relatively low cost, fast and versatile method to produce continuous nano fibers mainly from polymer solutions. This technique has not been well studied until last decade even though it was invented in 1934. A basic electrospinning setup, as shown in Fig. 1, consists of a container for polymer solution, a high-voltage power supply, spinneret (needle) and an electrode collector. During electrospinning, a high electric voltage is applied to the polymer solution and the electrode collector leading to the formation of a cone-shaped solution droplet at the tip of the spinneret, so called "Taylor cone". A solution jet is created when the voltage reaches a critical value, typically 5-20 kV, at which the electrical forces overcome the surface tension of the polymer solution. Under the action of the high electric field, the polymer jet starts bending or whipping around stretching it thinner as shown in Fig. 2. Solvent evaporation from the jet results in dry/semidry fibers which randomly deposit onto the collector forming a nonwoven nano fiber web in the most cases, as shown in Figure. 3. Extensive research has been carried out on various aspects of electrospinning including operating parameters (e.g. applied voltage, feeding rate, distance between the nozzle and collector), material properties (e.g. viscosity, surface tension, conductivity), spinningability of many different polymer.

Fibers obtained from electrospinning vary from uniform fibers to fibers with an irregular beads molecular weight distribution, electrical conductivity, surface tension, viscosity and solvent and the operating parameters such as electrical field, the distance from the nozzle tip and the collector and the flow rate of the polymer, as well as ambient conditions . The small fiber diameter and large aspect ratio lead to extremely high surface to-volume (weight) ratio, which makes the electrospun nanofiber desirable for many applications.

A. Factors Affecting Electrospinning

Molecular Weight, Molecular-Weight Distribution and Architecture of the polymer are the system parameters. Viscosity, conductivity & and surface tension are the solution parameters. And Electric potential, Flow rate & Concentration, Distance between the capillary and collection screen, Ambient parameters (temperature, humidity and air velocity in the chamber), Motion of target screen are the process parameters. With increasing electric

Figure 2: Fibers prepared in lab

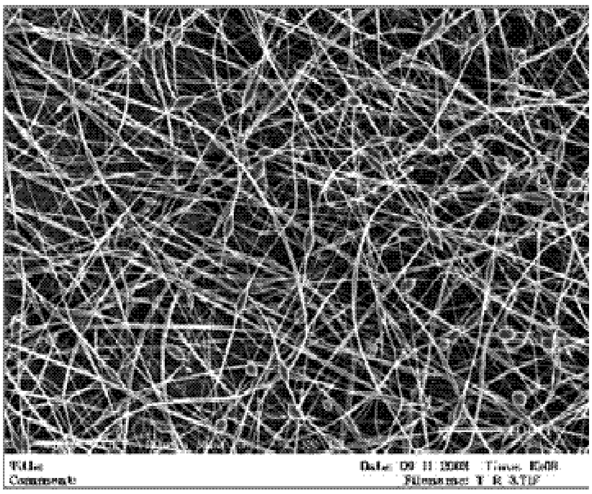

Figure 3: Thin polymer filaments deposited on the collector

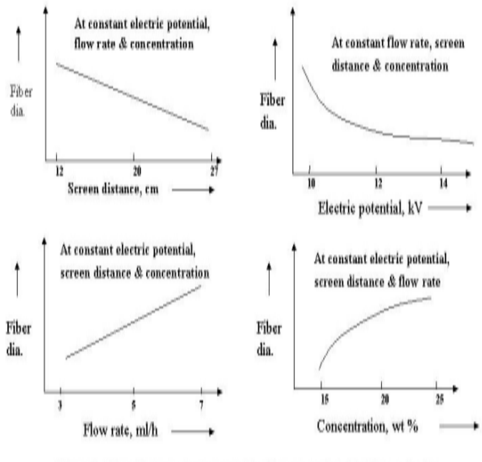

Figure 6. Effect of process parameters on fiber diameter, produced by Electrospinning

Figure 4: Factors affecting Electrospinning

potential, the polymer jet is discharged with a greater electrostatic repulsion that causes it to undergo higher levels of drawing stress. This results in the decrease of the fiber diameter as shown in Fig. 4. However, at higher electric potential (~ 15 kV) the fiber diameter distribution becomes increasing broader. Hence the control of the process at high electric potential, flow rate & concentration becomes increasingly difficult summarizes the effects of the different process parameters.

B. *Merits Of Electrospinning*

The fabrication of nanofiber using electrospinning are simple, Cost effective, fast, flexibility, versatile method, long continuous fibers can be produced. control of the fiber diameter from micro to nanometer dimensions, Spatial alignment of multiple fibers, formation of membranes with very high surface-to-volume rate. Used in lab.

IV. MATERIAL USED

A. *Polyvinylbutyral(PVB)*

The polyvinylbutyral (PVB) was chosen for this project because it is low cost, non-toxic, odourless and environment friendly, adhesion to many surface. PVB(Mw=60,000 g/mol; Mowital Kuraray Specialities Europe (KSE) was consecutively dissolved in methanol, ethanol, isopropanol and butanol as 6, 10 and 14 wt % solution. The PVB solutions were prepared by a laboratory shaker at 25°C overnight.

B. *Hansen Solubility Parameter*

For the prediction of PVB solubility in various solvents there were used Hansen solubility parameters (HSP) δD (representing energy from dispersion bonds between molecules), δP (representing energy from polar bonds between molecules), and δH (representing energy from hydrogen bonds between molecules) representing each molecule as shown in Table 1.

These three parameters can be visualized using a spherical representation. The radius of the sphere, R (radius of interaction), indicates the maximum difference in affinity for which a good interaction takes place. The HSPs of the good solvents are located closer to a centre of the sphere, the poorer ones approach the radius, and non-solvents are located outside of the sphere.

C. *Characteristics Of The PVB*

The PVB dissolved in a poor solvent exhibited viscosity enhancement in the presence of an electric field and its electrospinning formed nonporous circular shaped fibers without defects. It can be deduced that these solvents are suitable for electrospinning. The influence of concentration was found, but it is negligible for the poor solvents whereas quality of electrospinning of the polymer solutions with the good solvents is dependent on concentration.

V. CHARACTERIZATION TECHNIQUE

ERT nano fibers were produced by using electrospinning technique. There are various methods to characterize the nano fibers. Here the Nanofiber was characterized using scanning electron microscope(SEM) as shown in Fig. 5.

TABLE I. HANSEN SOLUBILITY PARAMETERS

	Hansen solubility parameters		
	δD	***δP***	***δh***
Methanol	14.9	12.4	22
Ethanol	15.8	8.8	19.2
Isopropanol	16.3	7.0	16.8
Butanol	16.0	5.6	15.8
PVB	18.6	4.4	13.0

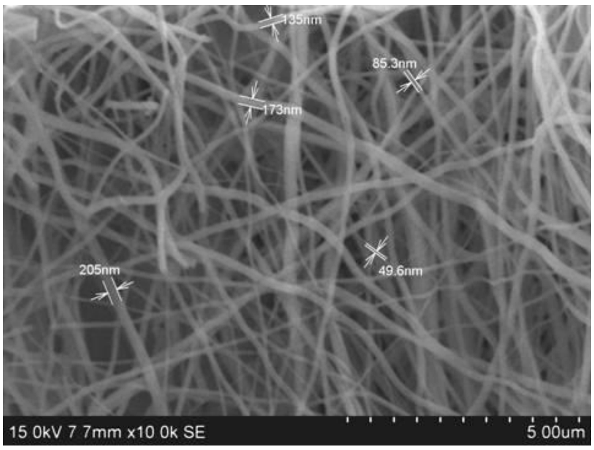

Figure 5: SEM images

VI. WOUND DRESSING MATERIAL

Electrospinning could generate scaffold with more homogeneity besides meeting other requirements like oxygen permeation and protection of wound from infection and dehydration for use as wound-dressing materials. The conventional skin substitutes are made up of fibroblasts and/or keratinocytes on collagen scaffolds, mainly generated by freeze drying (FD) which generates structural

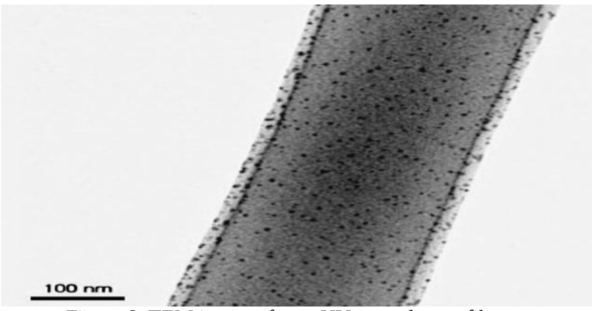

Figure 6: TEM image of post UV treated nano fiber

heterogeneity. ES could provide wound-dressing materials in a simple way. Comparison of FD and ES skin substitutes based on natural polymer, collagen. They are compared for cell distribution, proliferation, organization, and maturation engraftment and healing of full thickness wounds. Although no significant difference in cell proliferation, surface hydration or cellular organization between FD and ES scaffold were seen, wound contraction was potentially reduced with ES scaffold. This provides the advantage of reduced morbidity in patients treated with skin substitutes from ES collagen. Further, wound-dressing material was prepared by electrospinning of silver nitrate & PVB Polymer aqueous solution into non-woven webs and then treating the webs by heat or UV radiation. Through SEM, TEM analyses, it was observed that the nano particles were generated and existed in the near surface of the electrospun nano fibers. Heat treatment as well as UV radiation reduced the ions in the electrospun fiber web into the Ag nano particles. Also the heat treatment improved the crystallinity of the electrospun fiber web and so it made the web insoluble in moisture environment. As we know, has long been recognized as a broad-spectrum and highly effective antimicrobial agent for treating wounds and burns as shown in Fig. 6. Antimicrobial test was identified by using trypan blue assay test which indicates blue ring in the sample which contains the plate chamber. The indication of blue ring shows the anti microbial property for treating wounds and burns which contains in the sample. It was tested Bio technology lab.

CONCLUSION

Thus the nano fibers developed by electrospinning technique using polyvinylbutyral and silver nitrate as a polymer are fabricated. Using Scanning electron microscope, the diameter of the fiber are measured which were 50-300nm. The webs has a antimicrobial agent for treating wounds. It shows an excellent antimicrobial activity above 99.1% by trypan blue assay test.But it has a one drawback of slightly colour changes in the skin after curing the wound.

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