EFFECT OF COLLECTOR ON ELECTROSPINNING TO FABRICATE ALIGNED NANOFIBER

A thesis submitted in partial fulfillment of the requirement for the degree of

Bachelor of technology

In

Bio-medical engineering

By

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under the guidance of

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National Institute of Technology, Rourkela

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CERTIFICATE

This is to certify that the project report titled "**Effect of colletor on electrospinning to fabricate aligned nano fiber"** submitted by **Mr. Pankaj Kumar, (108BM019)** in the partial fulfillment of the requirements for the award of **Bachelor of Technology** in **Bio-medical Engineering** during session **2008-2012** at **National Institute of Technology, Rourkela** (Deemed University) and is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge the matter embodied in the thesis has not been submitted to any other University/Institute for award of any Degree or Diploma.

Date: **Dr.Amit Biswas**

Place: Rourkela **Dept. of Biotechnology & Medical Engineering**

NIT Rourkela

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ABSTRACT

Nano-fiber is defined, as fiber having at least one dimension in nanometer range or less. Nano-fiber are widely used in tissue engineering for scaffold making, wound healing, implant materials, drug delivery or medicinal materials. There are various methods available to generate nano-fiber but electrospinning is one of the most widely used technique to produce nanofiber. The morphology and property of nanofiber electrospun by the Electrospinning process is affected by many factors like: solution concentration, feed rate, applied voltage, surface tension molecular weight, collector, temperature diameter of the orifice. Aligned nanofiber used in skeletal tissue regeneration, neural cell seeding in scaffold, fuel cell electrolytes, electrochemical sensing, bone and blood vessel engineering, composite metal reinforcement and many other applications. In the present study different types of collector have been used to see their effect on the alignment of the fiber. The obtained electrospun fibers are characterized under scanning electron microscope to see the morphology of the deposited fiber and the edge type provide with a better alignment compared with the other collector used in the present study.

Keywords: Electrospinning, Aligned, Nanofiber, Scaffold, Collectors, SEM

List of Figures:

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List of Abbreviations:

Abbreviated form:	Expanded form:
PVA	Polyvinyl alcohol
SEM	Scanning Electron Microscopy
EDS	Energy Dispersive Spectroscopy

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Chapter 1

Introduction

1.1. Introduction

Nano fiber is defined as the fiber having at least one dimension in nanometer range [1]. Nanofiber is used for a wide range of medical applications for drug delivery systems, scaffold formation, wound healing and widely used in tissue engineering, skeletal tissue , bone tissue, cartilage tissue, ligament tissue, blood vessel tissue, neural tissue etc [2]. It is also used in dental and orthopedic implants. Nano fiber can be formed using different techniques [3] :

- 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 nanofibers. because in elctrospinning electrostatic force is used instead of conventionally used mechanical force for the formation of fibers [6]. There are many processing parameters of electrospinning like: solution conductivity, surface tension, molecular weight, voltage, feed rate, temperature, effect of collector, diameter of orifice, humidity [8]. The aim of the project is to form aligned nanofiber using different collector in electrospinning technique. There are different collectors used to fabricate aligned nanofiber in this experiment like: plane plate collector, drum rotatory collector, grid type collector and edge type collector [12]. After collecting nanofiber on the different collectors SEM analysis is done to study the morphological characterization of obtained nanofiber and quantitative and qualitative test done on fabricated fiber by energy dispersive spectroscopy(EDS) technique [15]. It is observed that plane plate collector produced randomly oriented fiber, some mini jets also present in it. Fiber on drum rotator collectors also randomly oriented but thicker than the previous, a solid part of solution also found in the fiber. Grid type collector gave aligned fibers with higher morphological structure. From all the used collectors, it is found that grid type collector gave best result.

Chapter 2

Literature review

2.1. Nanofiber

Nano fiber consist of two terms “Nano” and “fiber”, As the latter term is looking more familiar. It is a thick–walled cells that give strength and support to plant as identified by Botanists. Anatomists observed fibers as any of the filament constituting the extracellular matrix of connective tissue, or any elongated cells or thread like structures, muscle fiber or nerve fiber. According to textile industry fiber is a natural or synthetic filament, such as cotton or nylon, capable of being spun into simply as materials made of such filaments. Physiologists and biochemists use the term fiber for indigestible plant matter consisting of polysaccharides such as cellulose, that when eaten stimulates intestinal peristalsis[1]. Historically, the term fiber or “Fibre” in British English, comes from latin “fibra”. Fiber is a slender, elongated thread like structure. nano is originated from greek word “nanos‘ or “nannos” refer to “little old man” or “dwarf”. The prefixes “nannos” or “nano” as nannoplanktons or nanoplanktons used for very small planktons measuring 2 to 20 micrometers. In modern “nano” is used for describing various physical quantity within the scale of billionth as nanometer (length), nanosecond (time), nanogram (weight) and nanofarad (charge). At the point Nanotechnology refers to the science and engineering concerning materials, structures and devices which has at least one dimension is 100nm or less.[4] This term also refers for a fabrication technology, where molecules, specification and individual atoms which have at least one dimension in nanometers or less is used to designed or built objects. Nano fiber, as the name suggest the fiber having diameter range in nanometer. Fibrous structure having at least one dimension in nanometer or less is defined as Nano fiber according to National Science Foundation (NSC). The term Nano describes diameter of the fibrous shape at anything below one micron or 1000 nm.[5]

Nanofibers can be prepared from various kinds of inorganic substances by electrospinning technique. The most frequently mentioned ceramic materials with nanofiber morphology are titanium dioxide (TiO_2), silicon dioxide (SiO_2), zirconium dioxide (ZrO_2), aluminum oxide (Al_2O_3), lithium titanate ($Li_4Ti_5O_{12}$), titanium nitride (TiN) or platinum (Pt). The synthesis of nanofibers consists of two main steps. [10]

- The polymer nanofibers are produced by electrospinning technique.
- Formed nanofiber are transformed to ceramics by heat treatment.

Nano fiber are an new class of material used in various field such as medical, filtration, barrier, wipes, personal care, composite, garments, insulation and energy storage. Nano fiber is used for a wide range of applications from medical to consumer products and industrial to high-tech applications for aerospace, capacitors, transistors, drug delivery systems, battery separators, energy storage, fuel cells, and information technology.[11]

2.2. Natural polymeric materials for nanofibers :

- Hyaluronic acid,
- Gelatin
- Chitosan
- Elastin
- Silk
- Wheat protein

2.3. Synthetic polymeric materials for nanofibers :

- PLA (Poly Lactic Acid)
- PET (Poly ethylene terephthalate)
- PCL (Poly-caprolactone)
- PLGA (Poly lactic-co-glyolic acid)
- PEVA (Polyethylene vinyl acetate)
- PVA (Polyvinyl alcohol)

2.4. Properties of Nanofiber

- High surface area
- High tensile strength
- Reduced crack propagation
- Good thermal properties
- High electric properties

2.5. Applications of nanofibers in tissue engineering

- Nano fibers for musculoskeletal tissue engineering
- Nano fibers for bone tissue engineering
- Nano fibers for cartilage tissue engineering
- Nano fibers for ligament tissue engineering
- Nano fibers for skeletal muscle tissue engineering
- Nano fibers for skin tissue engineering
- Nano fibers for blood vessel tissue engineering
- Nano fibers for neural tissue engineering
- Nano fibers for controlled drug delivery
- Nano fibers for DNA, protein, and enzyme delivery
- Alumina, titanium, HA and their composites for dental and orthopedic application[13]

2.6. Methods of preparation of nanofiber

2.6.1. Drawing

Nanofibers are fabricated with citrate molecules through the process of drawing [Ondarcuhu and Joachim (1998)]. In this process a micropipette with a diameter of a few micrometers was dipped into the droplet near the contact line using a micromanipulator. The micropipette was then withdrawn from the liquid and moved at a speed of approximately $1x10^{-4}$ m/s, resulting in a nanofiber being pulled, that deposited on the surface by touching it with the end of the micropipette. This process was repeated several times on every droplet to form nano fiber. The viscosity of the material at the edge of droplet increased with evaporation. The solution was concentrated at the edge of the droplet and broke in a cohesive manner. Thus, drawing process requires a viscoelastic material that can under go strong deformations while being cohesive enough to support the stresses developed during pulling.

2.6.2. Template synthesis

The template refers to a metal-oxide membrane. In this technique, the nanofiber created by passing of polymer solution through the pores of nano-scale diameter under the application of water pressure on one side, causes extrusion of the polymer, which gave nano fiber upon coming into contact with a solidifying solution. The diameters were determined by the pores size of the membrane.

2.6.3. Phase separation Method

This method consists of five basic steps:

- Polymer dissolution
- Gelation
- Solvent extraction
- Freezing
- Freeze-drying

In this process, It is observed that gelation is the most difficult step to control porous morphology of nano fiber. Duration of gelation varied with polymer concentration and gelation temperature. At low gelation temperature, nano-scale fiber network is formed, whereas, high gelation temperature led to the formation of platelet-like structure. Uniform nano fiber can be produced as the cooling rate is increased, polymer concentration affect the properties of nano fiber, as polymer concentration is increased porosity of fiber decreased and mechanical properties of fiber is increased.4]

2.6.4. Self-Assembly

Self–assembly refers to the build-up of nano scale fibers using smaller molecules. In this technique , a small molecule is arranged in a concentric manner so that they can form bond among the concentrically arranged small molecules which, upon extension in the plane’s normal gives the longitudinal axis of a nano fiber. The main mechanism for a generic self-assembly is the inter molecular forces that bring the smaller unit together. A hydrophobic core of alkyl residues and a hydrophilic exterior lined by peptide residues was found in obtained fiber. It is observed that the nano fibers produced in this technique has diameter range 5-8 nm. approximately and several microns in length.

Although there are a number of techniques used for the synthesis of nanofiber but Electrospinning represents an attractive technique to fabricate polymeric biomaterial into nanofibers. Electrospinning is one of the most commonly utilized method for the production of nanofiber. It has wide advantage over the previously available fibre formation techniques because here electrostatic force is used instead of conventionally used mechanical force for the formation of fibers.[4]

2.7. Electrospinning

In the electrospinning process, an electrostatic force is applied to a polymeric solution to produce nanofiber (Hohman et. al 2001a, 2001b) with diameter ranging from 50 nm to 1000 nm or greater (Reneker and Chun 1996; Shin et. al. 2001a; Fridrikh et. al. 2003). Due to surface tension the solution is held at the tip of syringe . Polymer solution is charged due to applied electric force. In the polymer solution, a force is induced due to mutual charge repulsion that is directly opposite to the surface tension of the polymer solution. Further increase in the electrical potential leads to the elongation of the hemispherical surface of the solution at the tip of the syringe to form a conical shape known as “Taylor cone” (Doshi and Reneker 1995; Yarian et. al. 2001). The electric potential is increased to overcomes the surface tension forces to cause the formation of a jet, ejects from the tip of the Taylor cone. Due to elongation and solvent evaporation, charged jet instable and gradually thins in air primarily (Zeleny 1914; Reneker et. al. 2000; shin et. al. 2001a, 2001b; frenot et. al. 2003). The charged jet forms randomly oriented nanofibers that can be collected on a stationary or rotating grounded metallic collector (Doshi and Reneker 1995; Kameoka and Craighead 2003). Electrospinning provides a good method and a practical way to produce polymer fibers with diameters ranging from 40-2000 nm(Reneker et. al., Nano technology 7 (1996) 216-223).[1,2.3,11]

2.7.1. Structural design of an electrospinning machine

Apparatus used in electro spinning technique :

- Syringe
- High voltage power supply
- Metallic needle with an orifice at the tip
- Polymer or composite solution
- Collector electrode

The whole electro spinning setup is placed in a Plexiglass box that helps in limited exposure of the whole system to the exterior. This box helps in isolating the electro spinning process from unpredictable parameters that can alter the fibre production process. Plexiglas box also contains acetone used to saturate the electro spinning environment with acetone. A computer controlled device used to input desired data.The syringe is driven by a syringe pump which is used to control the flow rate and volume of the polymer being ejected. The syringe being leads to a thin needle that ejects the polymer solution.The electrode plate was placed on a stand made of acrylic acid. The electrode is generally grounded and is used for the collection of both random and aligned fibres. [8,10]

2.7.2. Working principle of an electrospinning machine

Electro spinning process can be explained in 5 steps, such as :

a) Charging of the polymer fluid
b) Formation of the cone jet (Taylor cone)
c) Thinning of the jet in the presence of an electric field
d) Instability of the jet
e) Collection of the jet

a) Charging of the polymer fluid

The syringe is filled with an polymer solution, the polymer solution is charged with a very high potential around i.e. 10-30kV. The nature of the fluid and polarity of the applied potential free electrons, ions or ion-pairs are generated as the charge carriers form an electrical double layer. This charging induction is suitable for conducting fluid, but for non-conducting fluid charge directly injected into the fluid by the application of electrostatic field.

b) Formation of the cone jet (Taylor cone)

The polarity of the fluid depends upon the voltage generator. The repulsion between the similar charges at the free electrical double layer works against the surface tension and fluid elasticity in the polymer solution to deform the droplet into a conical shaped structure i.e known as Taylor-cone. Beyond a critical charge density Taylor-cone becomes unstable and a jet of fluid is ejected from the tip of the cone.[9]

c) Thinning of the jet in the presence of an electric field

The jet travels a path to the ground, this fluid jet forms a slender continuous liquid filament. The charged fluid is accelerated in the presence of electrical field. This region of fluid is generally linear and thin.

d) Instability of the jet

Fluid elements accelerated under electric field and thus stretched and succumbed to one or more fluid instabilities which distort as they grow following many spiral and distort path before collected on the collector electrode. This region of instability is also known as whipping region.

e) Collection of the jet

Charged electro spun fibers travel downfield until it impact with a lower potential collector plate. Orientation of the collector affects the alignment of the fibers. Different type of collector also affects the morphology and the properties of produced nanofiber. Different type of collectors are used : Rotating drum collector, moving belt collector, rotating wheel with bevelled edge, multifilament thread, parallel bars, simple mesh collector etc.

2.7.3. Electrospinning technique is affected by different parameters.

a) Polymer solution parameters

1) Molecular weight and solution viscosity
2) Surface tension
3) Solution conductivity
4) Dielectric effect of solvent

b) Processing parameters

1) Voltage
2) Feed rate
3) Temperature
4) Effect of collector
5) Diameter of the orifice of needle

a) Polymer solution parameters

1) Molecular weight and solution viscosity

Higher the molecular weight of the polymer, increases molecular entanglement in the solution, hence there is increase in viscosity. The electro spun jet eject with high viscosity during it is stretched to collector electrode leading to formation of continuous fiber with higher diameter (Koshki et. al., materials letters 60 (2006), but very high viscosity makes difficult to pump the solution and also lead to the drying of the solution at the needle tip. As very low viscosity lead to bead formation in the resultant electro spun fiber, so the molecular weight and viscosity should be acceptable to form nanofiber.

2) Surface tension

Lower viscosity leads to decrease in surface tension resulting bead formation along the fiber length because the surface area is decreased, but at higher viscosity effect of surface tension is nullified because of the uniform distribution of the polymer solution over the entangled polymer molecules. So, lower surface tension is required to obtain smooth fiber and lower surface tension can be achieved by adding of surfactants in polymer solution

3) Solution conductivity

Higher conductivity of the solution followed higher charge distribution on the electrospinning jet which leads to increase in stretching of the solution during fiber formation. Increased conductivity of the polymer solution lowers the critical voltage for the electro spinning. Increased charge leads to the higher bending instability leading to the higher deposition area of the fiber being formed, as a result jet path is increased and finer fiber is formed. Solution conductivity can be increased by the addition of salt or polyelectrolyte or increased by the addition of drugs and proteins which dissociate into ions when dissolved in the solvent.formation of smaller diameter fiber.[10]

4) Dielectric effect of solvent

Higher the dielectric property of the solution lesser is the chance of bead formation and smaller is the diameter of electro spun fiber. As the dielectric property is increased, there is increase in the bending instability of the jet and the deposition area of the fiber is increased. As jet path length is increased fine fiber deposit on the collector.[16]

b) Processing condition parameters

1) Voltage:

Taylor cone stability is depends on applied voltage, at higher voltage greater amount of charge causes the jet to accelerate faster leading to smaller and unstable Taylor cone. Higher voltage lead to greater stretching of the solution due to fiber with small diameter formed. At lower voltage the flight time of the fiber to collector plate increases that leads to the formation of fine fibers. There is greater tendency to bead formation at high voltage because of increased instability of the Taylor cone, and theses beads join to form thick diameter fiber. It is observed that better crystallinity in the fiber obtained at higher voltage, because with very high voltage acceleration of fiber increased that reduced flight time and polymer molecules donot have much time to align themselves and fiber with less crystallinity formed. Instead of DC if AC voltage is provided for electro spinning it forms thicker fibers .

2) Feed rate

As the feed rate is increased, there is increase in the fiber diameter because greater volume of solution being drawn from the needle tip.

3) Temperature

At high temperature, viscosity of the solution is decreases and there is increase in higher evaporation rate which allows greater stretching of the solution and a uniform fiber is formed.

4) Effect of collector

In electro spinning, collector material should be conductive. Collector is grounded to create stable potential difference between needle and collector. a non-conducting material collector reducing the amount of fiber being deposited with lower packing density. But in case of conducting collector there is accumulation of closely packed fibers with higher packing density. Porus collector yields fibers with lower packing density as compared to non-porus collector plate. In porus collector plate the surface area is increased so residual solvent molecules gets evaporated fast as compared to non-porus. Rotating collector is useful in getting dry fibers as it provides more time to the solvents to evaporate. It also increase fibremorphology(Vladimir et. al. Czech Republication, EU, 2011). The specific hat target with proper parameters has uniform surface electric field distribution, the target can collect the fiber mats of uniform thickness and thinner diameters with even size distribution.(Yang et. al. vol. 16, No. 3; June 2009).

5) Diameter of pipette orifice

Orifice with small diameter reduces the clogging effect due to less exposure of solution to the atmosphere and leads to the formation of fibers with smaller diameter. However, very small orifice has the disadvantage that it creates problem in extruding droplet of solution from the tip of the orifice.

Other application of Nanofiber

- Cosmetic
- Drug delivery
- Tissue Engineering scaffold
- Sensor devices
- Wound dressing
- Filter media
- Protective clothing
- Electrical conductors
- Optical Application
- Material reinforcement
- Haemostatic devices
- Medical prosthesis
- Photocatalytic air/water purification

After so much study about production of nanofiber with electrospinning technique, It is found that not so much work has done on to see the effect of collector on fibrous structure produced in electrospinning to fabricate aligned fiber.

2.8. Objectives :

1) **Preparation of polymer solution for electrospinning process.**

2) **Collection of fiber on the different collector during electro spinning.**

3) **Characterizaion of the fiber using Scanning Electron Microscopy**

Chapter3

Materials and Methodology

3.1. Experimental procedure

PREPARATION OF SOLUTION

↓

FABRICATION OF NANOFIBER ON DIFFERENT COLLEECTORS

↓

CHARACTERIZATION OF NANOFIBER

3.2. Preparation of solution

A solution is prepared for the formation of nano fiber by electrospinning method.PVA is mixed with distilled as per the composition given below.

- Concentration of PVA ----- 8 % w/v in 1000 mL ; 8gm in 1000 mL
- Volume of solution ----- 5 mL
- PVA granules required ----- 0.4 gm in 5 mL distilled water

STEPS :

1).Weighing of PVA

- A weight 0.4 gm of PVA is measured from electronic weighing machine.

2). Measurement of solvent

- 5mL distilled water is measured with measuring cylinder.

3). Mixing (Magnetic stirrer)

- A beaker containing magnetic beat, PVA and distilled water put on magnetic stirrer at 80◦ C for 7-8 hours for proper mixing of solution.

4). Desired solution

- After 7-8 hrs solution is taking off from the magnetic stirrer and our solution is ready to generate nanofiber.

3.3. Fabrication of nanofiber

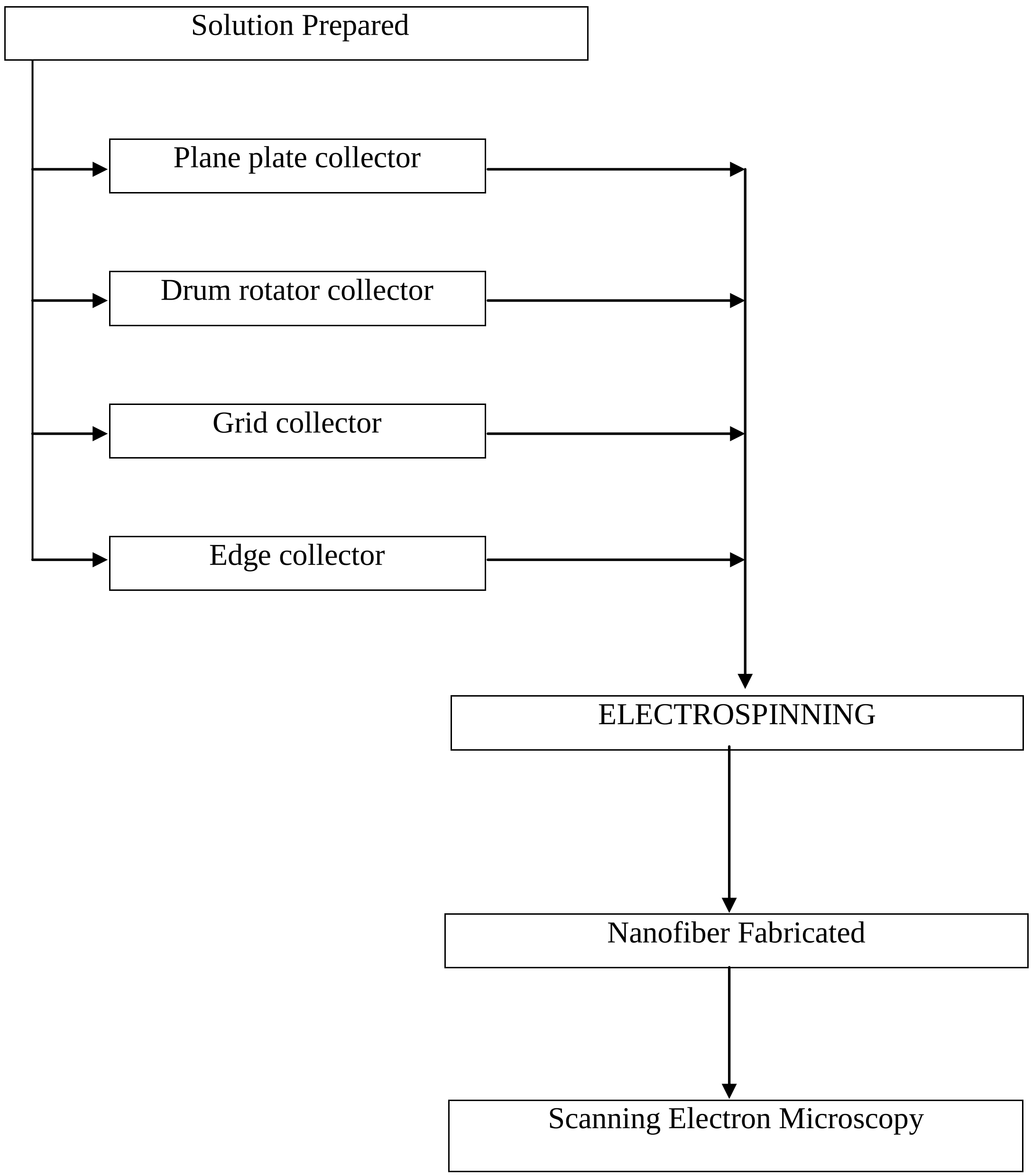
STEPS :

- Electrospining setup is turned ON.
- Solution is poured into syringe and put in the electrospinning setup.
- Desired collector and tip to collector distance is adjusted in the setup.
- A software pico-Espin is opened and parameters inserted in it like : feed rate, type of syringe.and the software is run.
- A high voltage is applied and adjusted in the setup, depending upon the various parameter of solution.
- Syringe pump is turned ON
- Finally, pico-Espin software is run after giving all input to the machine
- Set up is left for some hours to fabricate nano fiber on collector.
- When enough fiber is deposited on collector, machine is turned OFF and our fiber is ready for characterization

Table 3.1 : The process parameter that are described above are :

Process parameters	Parameters used
Solution	PVA + Distilled water
Polymer solution concentration	PVA 8 wt%
Flow rate	0.2 mL/hr
Applied voltage	16 kV
Tip to collector distance	10 cm
Syringe dimension	70mm x 25 mm(5 ml)
Collectors	Plane plate, Rotatory drum Edge , Grid

3.4. WORK DONE :



3.5. Types of collectors used in experiment

a) Plane plate collector

A simple plane plate collector rectangular shaped aluminium plate with dimension 20 cm x 15 cm is used as a the collector plate for collection of fibres. The fibres are collected on the surface of the plate collector.

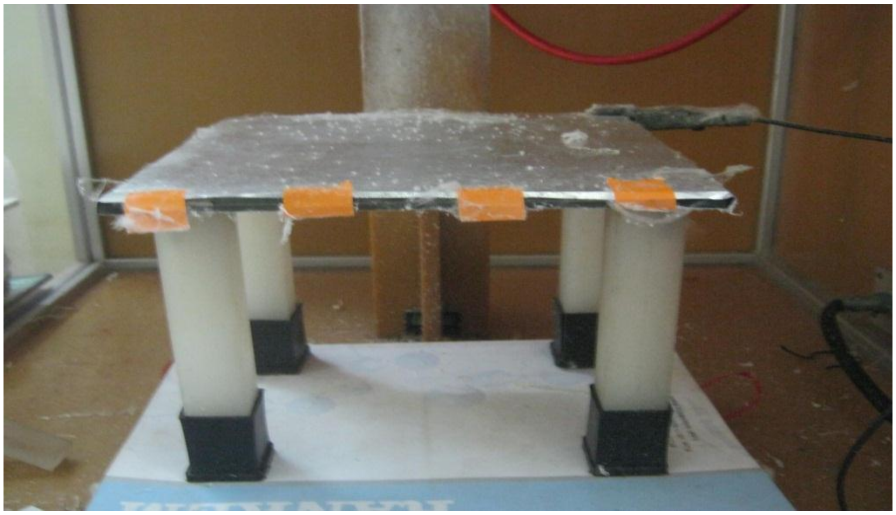


Figure 3.1 : Plane plate collector

c) Drum Rotatory collector

A rotating drum is as a collector plate for the collection of fibres. Here, the length of the drum is 20cm**,** and that of shaft is 15 cm. The Drum is rotating at a speed of 1800 rpm and the fibers collected over its surface during electrospinning.

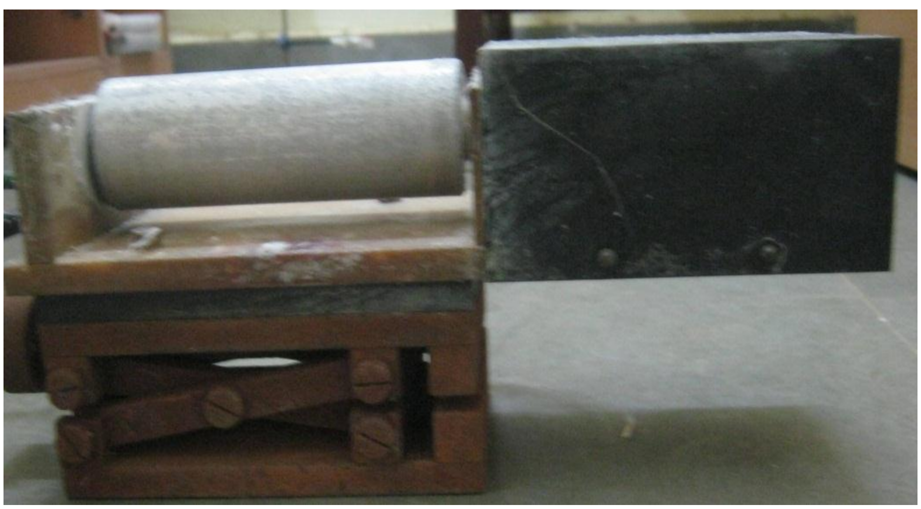


Figure 3.2: Drum rotatory collector

d) Grid type collector

Normal steel net is used as the grid collector having open pores dimension 3mm x 3mm.Collector is 20×15 to form fiber. Collector is put in the electrospinning setup and fiber is obtained over the mesh.

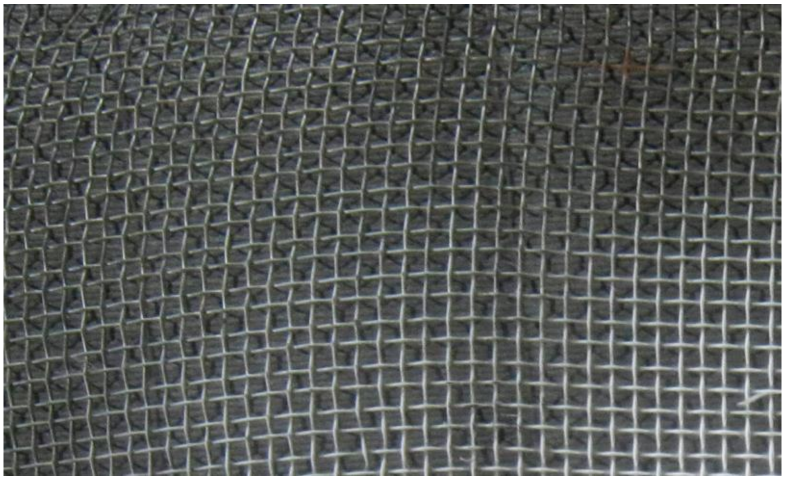


Figure 3.3 : Grid type collector

e) Edge type collector

Parallel plates of conducting material having space between them 3mm fixed longitudinal on one of the conducting material is used as an edge type collector in the present study.Fibers are allowed to deposited on the edges of the conducting material.

Figure3.4 : Edge type collector

3.6. Characterization of nano fiber

The fiber produced on different collectors technique is taken under SEM for morphological characterization.

a) Scanning Electron Microscopy (SEM)

A scanning electron microscopy (SEM) is used to check the surface morphology of the fiber. SEM characterization of electro spun nano fiber was performed using JeolJSM-6480lV (acceleration voltage15 kV) scanning electron microscopy in Metallurgical and Material Engineering Department. The fiber samples collected on the aluminium foil was peeled out and then mounted in the SEMs sample holder using graphite impregnated adhesive conductive black 'carbon tape'. This sample holder loaded with fibers of different collectors then resulting sample coated with platinum to ensure enough conductivity of the sample while performing SEM. Now, these platinum coated samples were visualized under SEM at various magnifications e.g. 1500X, 4000X, 10000X, 15000X, 20000X and EDS of individual samples were taken at the same time.

b) Energy Dispersive Spectroscopy (EDS)

This is energy dispersive spectroscopy in which X-ray is used for the analysis of the sample. EDS characterize elements on the basis of their atomic structure and each element has a unique atomic structure allowing unique set of peaks on its X-ray spectrum. In EDS, high energy particles are incident on the surface of the sample to form the spectrum. It provides the chemical composition present in the solution.

Chapter 4

Results and Discussion

4.1. Morphological Characterization

The morphology of the electro spun nano fiber is characterized by Scanning electron microscope. From figure 4.1 (A) it is observed that globular structures are present in the fibers, which is collected on plane plate collector. Globular structure may be formed due to less flight time. As a result the fiber get solidify before reaching the collector plate and solid structure deposit on the collector. The fibers produced on plane plate collector are found to be randomly oriented and globular structures present in the fiber are attached with fine fibers.

It is observed that spherical beads are found in the fiber collected on drum rotatory collector as shown in figure 4.1 (B). Spherical beads may be formed due to complete evaporation of solvent before reaching the collector. A web of fibers with spherical beads is found on the surface of drum rotatory collector. Beads present in the fibrous structure are found to be interconnected with fine fibers.

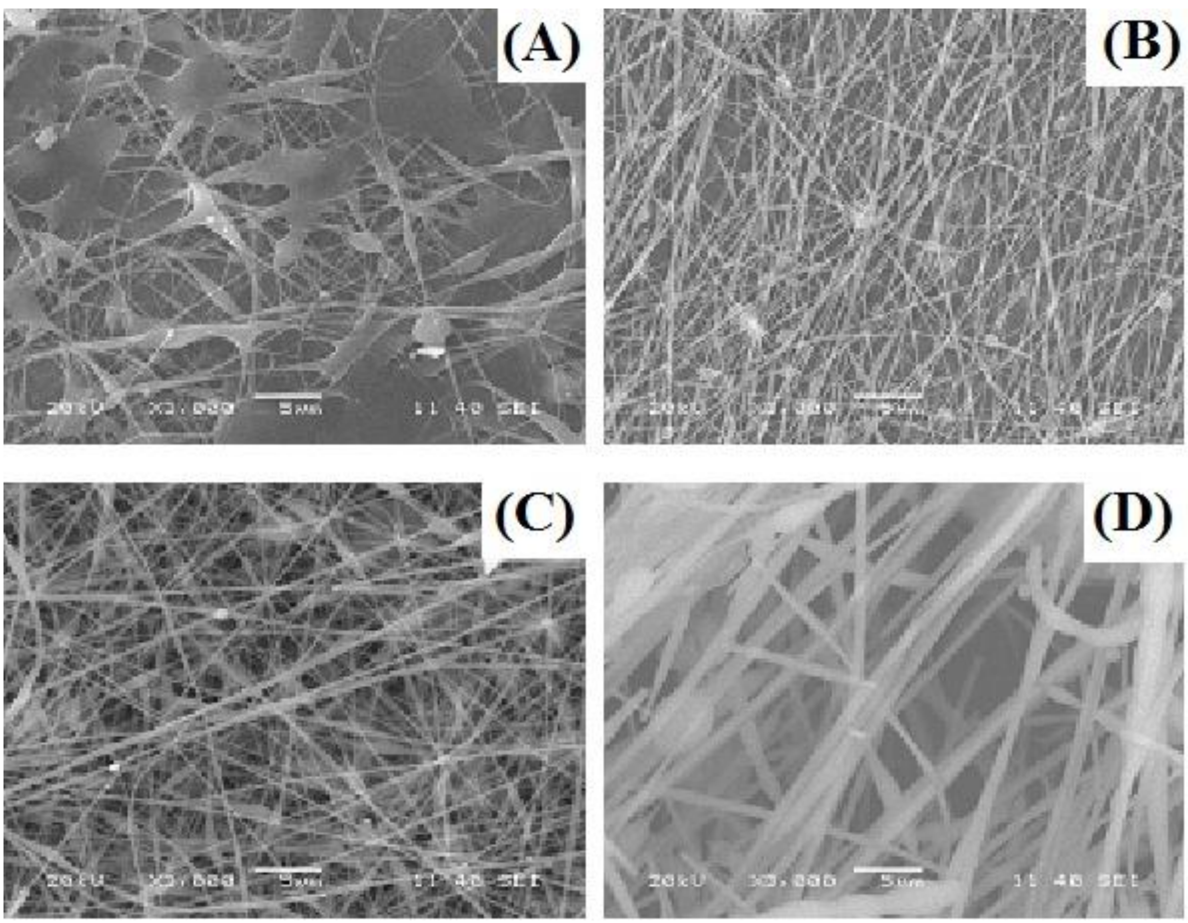


Figure :4.1: Scanning elctron micrograph of fiber deposited on (A) Plane plate collector (B)Drum rotatory collector, (C)Grid collector and (D)Edge collector

It is observed from figure 4.1 (C) that fiber with spindle beads are collected on the surface of grid type collector. The jet is more stretched due to the increase in charge density which alter the bead structure from spherical to spindle shape. A complete randomly oriented fiber with poor morphology is obtained on grid type collector.

Fiber collected on edge type collector has good morphology as shown in figure 4.1(D). It is observed that fibers do not have any bead or such kind of structure in this case.

It is observed from figure 4.2 (A), (B) and (C) that the diameter range for the fiber deposited on plane plate, drum rotatory collector and grid type collector are found to be 190-206 nm, 192-286 nm and 262-398 nm respectively.

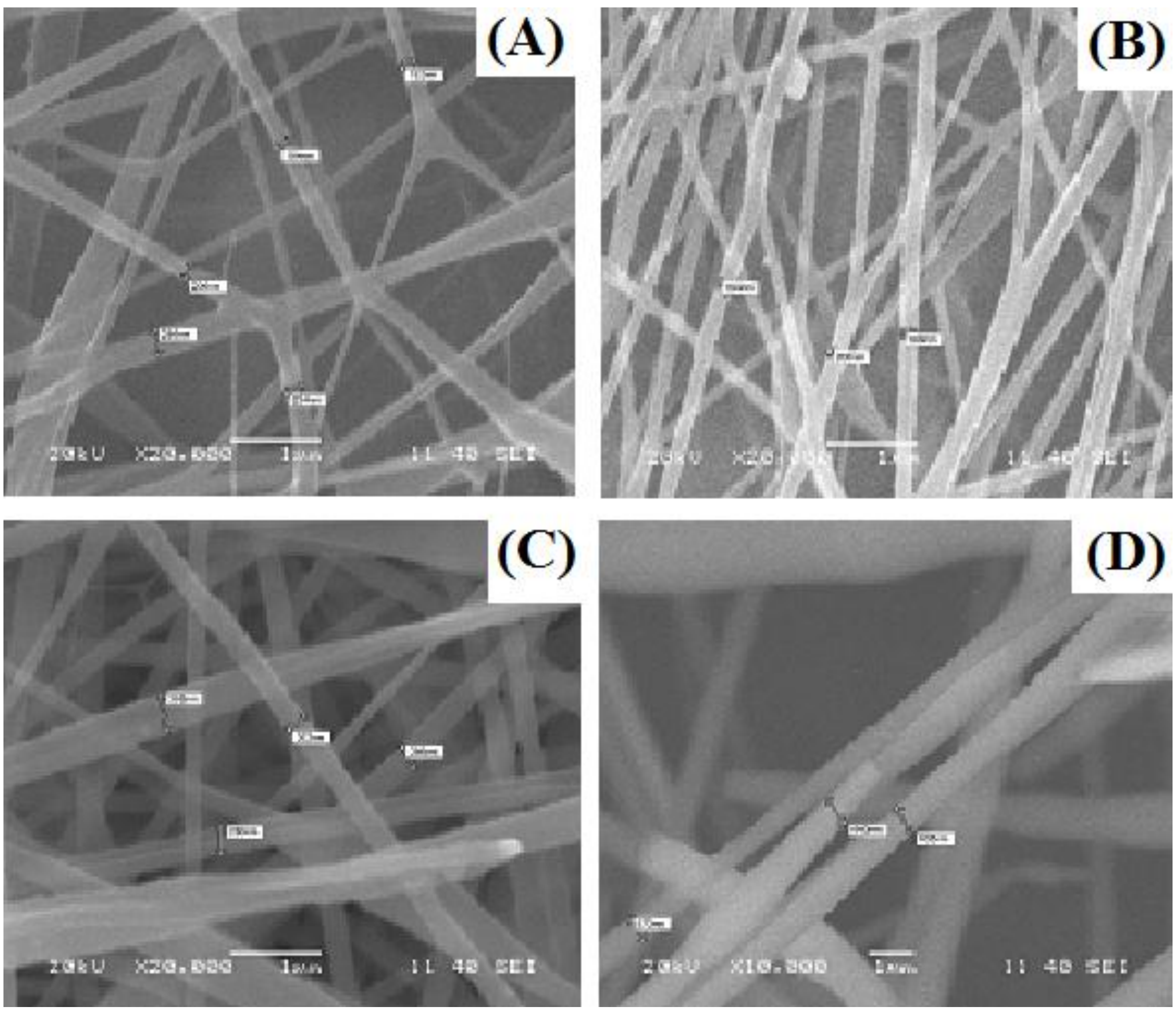


Figure :4.2: Scanning elctron micrograph of fiber deposit on (A) plane plate collector, (B)Drum rotatory collector, (C)Grid collector and (D)Edge collector

It is found that thick fibers were obtained when grid type collector was used as compared to the plane plate and drum rotatory collector. It is observed that fiber collected on plane plate collector(A) and grid type collector(C) are randomly oriented. Partially aligned fibers were obtained on drum rotatory type collector.

Fiber deposited on the edge type collector shows good morphological characteristics with alignment. The diameter is ranging from 570nm to 640 nm, as shown in figure 4.2(D).

Table 4.1 :The diameter range of fiber collected on the different collectors :

Collector	Diameter(nm)	Average Diameter
Plane plate type	190-206	196.67
Drum rotator	192-286	222.4
Grid type	262-398	301.4
Edge	570-640	605.67

Chapter 5

Conclusion

5.1. Conclusion

Among all of the above studied collector, edge type collector gives the best result. It gives aligned fibers on the collector plate with good morphological characteristics. it is also observed that there is no bead like structure found in the fiber obtained with edge type collector. The fibers has a diameter range between 570 to 640 nm. Drum rotatory collector gave partially aligned fiber with diameter ranging from 190-206nm. Grid type collector gives completely random oriented fiber with diameter between 262 to 398 nm. Globular structures are found on the plane plate collector, which are attached with fine fibers having diameter range varying from 190-206 nm.

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