SYNTHESIS AND POTENTIAL APPLICATIONS OF ELECTROSPUN POLYACRYLONITRILE NANOFIBERS

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ABSTRACT : Electrospinning is a very simple process for producing nanofibers from any polymer solution via high-electric voltage. It utilizes electric forces and hence the electrical properties of the solution are affected. It has been recognized an effective method for the manufacturing of nanofibers. In recent years nanofibers have been successfully produced by electrospinning using various polymers. Polyacrylonitrile (PAN) nanofibers have unique properties like large surface area to volume ratio, mechanical strength, and flexibility so they can be used in various applications. PAN solution has rich contents of carbon so it is mostly used for synthesis of Carbon nanofibers. This paper reports the synthesis of PAN nanofibers, their diameter and surface morphology.

Keywords: **Electrospinning, Nanofibers, and PAN nanofibers.**

1. Introduction

Nanotechnology is developing new materials for redevelop existing technologies and creates new industries. This technology conducted at the nanoscale, which is 1 to 100 nm. Physicist Richard Feynman called as father of nanotechnology. Nanomaterials are cornerstones of nanotechnology. The fields of science that are involved in nanotechnology are surface science, organic chemistry, molecular biology, semiconductor physics, micro fabrication, etc. because of their unique properties like optical, magnetic, electrical, high porosity, mechanical strength, flexibility and inherently large total surface area. Nanomaterials are classification is depend on the size of the materials [1].

Nanomaterials can be classified on the basis of their dimensions. 1) Nano scale in one dimension 2) two dimensions and 3) three dimensions. Common types of nanomaterials are nanosheets, dendrimers, quantum dots and nanofibers [2].

Nanofibers is one dimension materials means it can move free to air only in one direction. Nanofibers have their diameter in nanoscale and length in macroscale, since their diameters are in the nanometer range and the length is continuous. Nanofibers are attracting very high interest due to their extraordinary micro and nano structural characteristics [3]. Nanofibers can be produced from various polymers and hence have different physical properties and applications. Nanofibers have two types 1) Natural - chitosan, gelatin 2) Synthetic - poly (lactic acid (PLA), polycaprolactone (PCL), Polyacrylonitrile (PAN). Nanofibers can be produced from different types of polymers which have proper solubility which gives proper viscosity to the solution and hence they have different physical properties and applications. All nanofibers are unique for their large surface area-to-volume ratio, high porosity, mechanical strength, and Flexibility [4].

Nanofibers are manufacturing by various methods. Some of them are explain below

- **Drawing**

  A small drop from whose county is using a micropipette and micromanipulator forced out of nanofiber. Speed extracting fibers must be about 10-4 ms-1. This is discontinuous process and this is used only in laboratory but it is Unable to control the dimensions of the fibers [5].

- **Self-assembly**

  It has usually concentric arrangement of "giant-molecule" = nanofibers [6]. Only laboratory production Incapability to control dimensional nanostructures (only certain ranged between diameters and lengths).It can produce a very fine fibers (7-100nm in diameter).

- **Template synthesis**

  It uses templates or membranes to obtain the nanofiber materials. It is used only for laboratory production [7]. Template synthesis has ability to manage fiber diameters membranes made from special materials.

- **Electrospinning**

  Electrospinning is a method to produce thin fibers with diameters from less than 10 nm to over 1μm. Conventional technics which are used for manufacturing the fiber cannot produce fibers with diameters smaller than 2μm. It is considered the simplest and most effective technology to produce continuous polymer nanofibers from polymer solutions [8-10].

2. Experimental

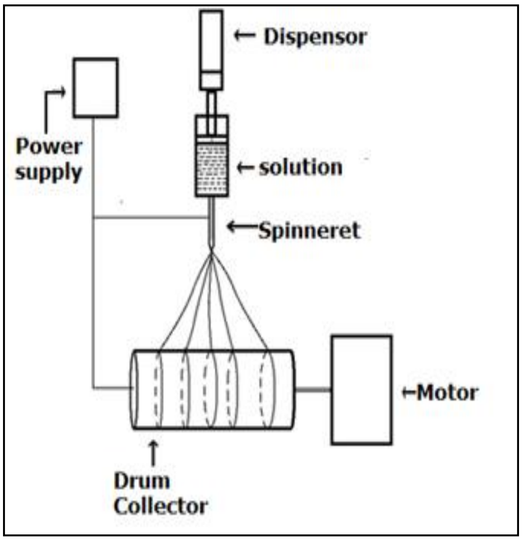
2.1 PAN Solution Preparation

PAN is one of the most widely used polymers in many areas. PAN solution was prepared by mixing PAN powder with dimethylformamide (DMF). Average molecular weight of PAN was 150,000. Solutions were prepared by using concentrations from 6% to 10% in 10ml DMF. PAN was dissolved in DMF by using stirrer hot plate with temp 500 to 800C and mixing duration was 4 hours. Before dissolved PAN in DMF colour of solution was transparent and after mixing solution color becomes light yellow [11-14].

2.2 Electrospinning Process

Electrospinning is a simple process which can produce polymer fibers ranging from micrometre to nanometre from polymer solution. When an electric potential is applied to polymer solution it converts the polymer solution and forms a cone shaped droplet at the tip of the nozzle [15-21].

When an electrostatic force is sufficient enough to overcome the surface tension of the solution droplet, the tip of droplet stretches towards a collector drum which is in the form of a grounded metal target resulting in a formation of a jet. This charged jet undergoes stretching mode, called instability region where it splits into multiple fine fibers and travels to the target [22]. The solvent fades while the dry and fine fibers are deposited on the collector drum. The process parameters on which the properties of the nanofibers depend upon are characterized into four main groups, Process parameters, System parameters, solution parameters and physical parameters.



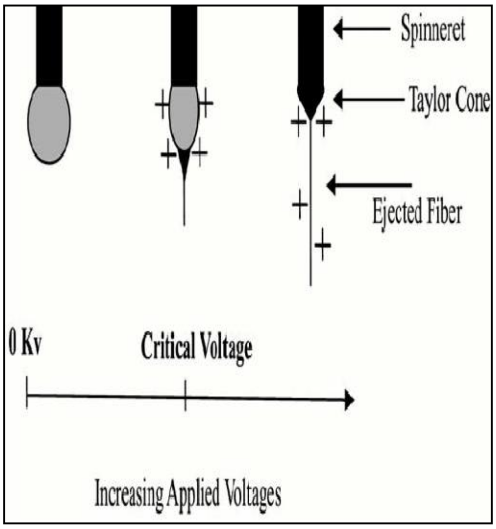


Figure 1: Schematic diagrams of manufacturing of electrospun nanofibers

The electrospinning technique was realized and patented in 1934 by Formhals. This relates to a process and apparatus for the production of artificial fibers by the use electrical field on liquids, which contain solid materials dissolved in them [24-29]. In this invention the solutions are passed into an electrical field formed between electrodes in drops in order to separate them into variety of threads. This result tells us about threads which repel each other when spaced apart in the electrical field, pile up in parallel to be collected as bundle [30].

2.3 Parameters of electrospinning

- Solution properties (viscosity, conductivity and surface tension)
- Ambient parameters (temperature, humidity and air velocity in the chamber)
- Electric potential, flow rate and concentration
- Distance between the capillary and collection screen
- Motion and size of target screen (collector)

2.4 Parameters of electrospinning affecting on the size of nanofibers

2.4.1 Polymer concentration

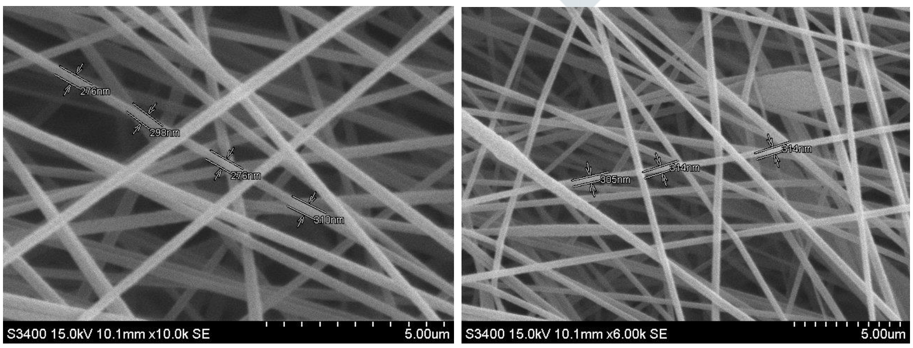
A polymer solution evolving jet does not break up into droplets. As the concentration is increased, beads are seen, and with further increase there is decrease in bead formation until only smooth fibers are formed [31, 32]. When the concentration was increased more fibers became rather thick and not uniform. But the concentration was too high, for example 12 wt. % high viscosity and rapid fading of solvent made the extension of jet more difficult. Thicker and ununiformed fibers were formed.

2.4.2 Applied voltage

The diameter of fibers reduced as the applied voltage increased. It is due to increasing of the pulling and stretching force [33-36]. If the increasing of electrostatic force pulls much more solution out of the syringe, the fiber diameter would increase with increasing applied voltage.

3. CHARACTERIZATION

FESEM images of PAN fibers. Figure show that the nanofibers have size from 200nm -500nm. The low magnification image shows the network like structure.



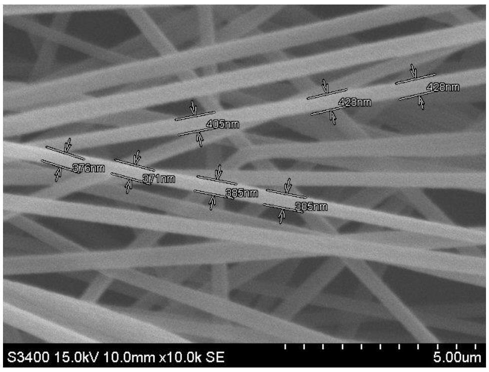


Figure 2: FESEM of PAN nanofibers

4. APPLICATIONS

4.1 Carbon Nanofibers

Carbon nanofibers have large storage capacity. Carbon nanofibers can be made by heating the PAN nanofibers. PAN precursors are rich in carbon. PAN nanofibers can be easily manufactured by electrospinning method. Electrochemical properties of carbon prepared from PAN executed to estimate the performance of the manufactured materials in the perception of supercapacitor device.

4.2 Medicine

In medicinal industry nanofibers has wide used. Due to ability of storage and high resistivness to outer environment these fiber may use as storing sensitive medicines [37]. There are various methods in which nanofibers are used such as Drug delivery, Wound healing, Tissue engineering, Barrier textiles [38-40].

1. **Drug delivery:** nanofibers membranes can be used as bioactive material. It improves bioavailability for poor soluble drugs.
2. **Wound Healing:** nanofibers which are biocompatible can be used as a dressing in wound healing process.
3. **Tissue engineering:** nanofibers which are made from biopolymers can be used for growing cells with appropriate mechanical and structural properties**.**
4. **Barrier textiles:** nanofibers which are hydrophobic can be used as effective barriers for penetration of micro-organism.

4.3 Battery separators

Separators are most importance parts in batteries. The working of separators is to separate the electrodes with positive and negative charge. For flowing of current there must be a flow of ions between cathode and anode. But if the cathode and anode are connected then there is possibility of short circuit. To avoid this condition one separator should be used which will resist the connectivity of electrode but easily conduct the ions [41, 42]. Nanofibers can be used efficiently as battery separators as they can resist the connection of electrodes with thin layer in between them. They can easily conduct the electrons due to their porousness [43].

Performance requirements for battery separators:

1. Chemical stability
2. Tensile strength
3. Thermal stability
4. porosity

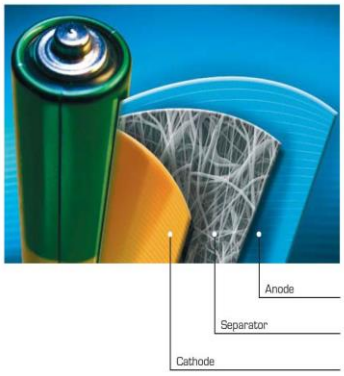


Figure 3: Nanofibers are battery separators [32].

5. CONCLUSIONS

For manufacturing nanofibers, electrospinning is a very simplest and effective technology to produce continues and thin nanofibers which having diameters less than 10 nm to over 1.5µm. Diameter of the fibers is depending upon the four basic parameters respectively as distance, flow rate, voltage, and concentration, in that voltage and concentration of the solution are the most affects to the diameter of the fiber. Nanofibers did not produce below critical voltage of electrospinning system.

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