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Manufacturing and Characterization of Electrospun Carbon Nanofibers

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***Abstract*—Carbon is a chemical element having atomic number 6 and specified by using letter "C". It has high chemical bonding flexibility. Because of this property it can form number of stable organic and inorganic molecules. It is the one of the element found in all living and non-living thing. Carbon atoms can from polymers at different temperature. Atomic bonding between carbon atoms with other can form various allotropes with tremendous property. Graphite and diamond are most famous allotropes. Also it has good thermal, electrical and mechanical properties. Hence it show the ability to form fibers of different properties and characteristics. The characterization of fibers can be done using microscopes such as Scanning Electron Microscope (SEM), Scanning Tunneling Microscope (STM), etc. This paper presents the entire experimental work and manufacturing of carbon nanofiber using electrospinning process. Carbon nanofibers obtained by electrospinning process were characterized by scanning electron microscopy (SEM).**

Index Terms—Electrospinning, Carbon nanofibers, Polyacrylonitril (PAN), Dimethylformamide (DMF), Characterization.

I. Introduction

There are different methods to produce the nanofibers from there polymers. The methods are Drawing, Electrospinning, Self-assembly, Template synthesis, Thermal induced phase separation but the carbon nanofibers mainly prepared by two approaches namely, Catalytically Vapor Deposition Growth and Electrospinning method. In this paper we are discussing about the Manufacturing of carbon nanofiber using Electrospinning Method. Electrospinning is the process in which electric force is used to draw fine nanofibers of polymer. This fibers gets charged during process. Electrospinning is the method which works on the principle of electrostatic repulsion force. When adequate high voltage in the range of kilovolt is applied to liquid droplet it gets charged and electrostatic force overcomes the surface tension of the droplet due to which droplet gets stretched and form into fine fiber, the stream of liquid erupts from the surface at a critical point. The point at which eruption is occurred is known as Taylor's cone. If the molecular force of attraction between the molecules of liquid is considerably high, stream does not breaks. A jet of liquid is formed which is highly charged. This jet of liquid dries in the flight because of convective heat transfer in the flight. Whipping process on the jet causes the elongation of the jet. Also the fibers gets bend while collects on the collector drum as shown in figure 1.

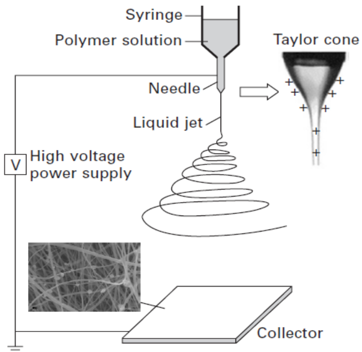

Figure1: Basic setup of the electrospinning process [21]

II. ELECTROSPINNING SETUP AND PROCEDURE

A. Electrospinning setup

The setup consist of feed rate mechanism which controls the feed rate of polymer solution filled in the syringe, Cylindrical rotating collector which collects elecrtospun ultrafine fibers, electric control panel on which we can set required flow rate of polymer solution(ml/h), rotating speed of drum collector (rpm) and voltage (kv) to be set and discharge stick. The whole assembly is placed inside the insulated cabinet. The actual setup of machine is shown in figure 2.

Figure 2: Actual setup of Electrospinning machine

B. Electrospinning procedure

In electrospinning process, before starting the setup, all the terminals inside the machine were cleaned with Acetone solution. Then the polymeric solution is taken into the syringe which is placed in the syringe holder. The drum collector is wrapped with aluminium foil, which is used for collecting fibers. The positive supply is given to the syringe whereas negative supply is given to the rotating cylinder collector, thus the syringe becomes the cathode and the collector drum become anode. All the process was carried out in atmospheric temperature. The drum collector's revolution are adjusted according to the requirement in Rpm, then the feed rate of the polymeric solution is set in ml/hr. As soon as the above procedure is completed high voltage supply is given to the machine according to the requirement in KV.

Polymeric solution inside syringe gets charged, and electrostatic force counteracts the surface tension and the liquid droplet gets stretched, at critical point a stream of liquid erupts from the surface forming Taylor's cone. The jet of solution evaporates in the way before being collected on the collector drum, thus solid nanofibers are collected in the form in non-woven mat on collector. After the fibers are collected on the collector plate the machine is shut down and the diffuser rod is used to diffuse current flowing inside the system then the aluminium foil is carefully removed on which the fibers are collected.

III. EXPERIMENTAL

A. Materials

Solvent used for the electrospinning process was N,N-Dimethylformamide, purity (≥ 99%) product code - 8.22275.0521, with molar mass of 73.09 g.mol, density (d 20°/4°C) - 0.948 - 0.949, water (KF) - (≤ 0.1%)

Polyacrylonitril $(C_3H_3N)_n$ Salt from Sigma Aldrich® of molecular mass 53.0626±0.0028 g/mog and density 1184 cm3 were used.

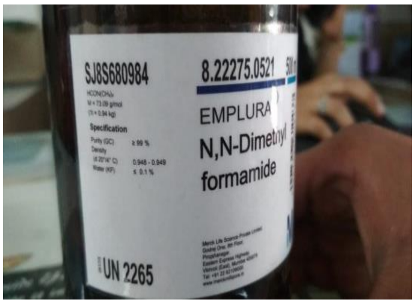

Figure 3: Solvent N,N-Dimethylformamide

B. Solution preparation

Polyacrylonitril / Dimethylformamide solution was prepared at room temperature. The Polyacrylonitril (PAN) concentration is 2.7mg in 27ml of Dimethylformamide (DMF). The stirring time of the solution in the magnetic stirrer was kept 4hrs for obtaining homogeneous mixture and kept ideal for 18hrs prior to eletrospinning.

Figure 4: Mixture of solution

C. Electrospinning and characterization

The electrospinning machine was composed with the equipment of syringe (2 mL), a cylindrical collector and a high voltage supply, as shown in Figure 1. The air gap maintained between the syringe and the cylindrical collector was 15cm.Electric supply given to the Electrospinning machine was 18KV and flow rate of syringe was 1.5ml/hr. Fibers were collected on aluminium foil. Whole experimental process was carried out at room temperature (25°C).

The characterization of CNFs was done in "Icon Analytical" lab with Scanning Electron Microscope at facility near Mumbai to determine the diameter of fiber obtained through electrospinning.

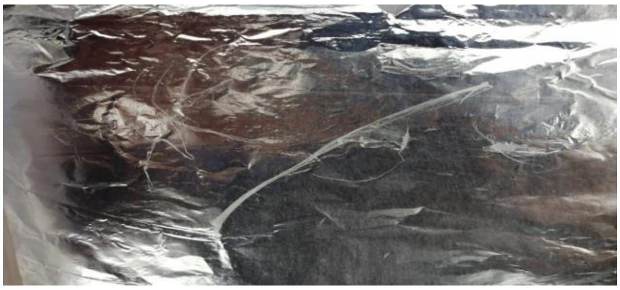

Figure 5: Image of obtained elecrtospun fiber on aluminum foil

D. SEM images of characterization

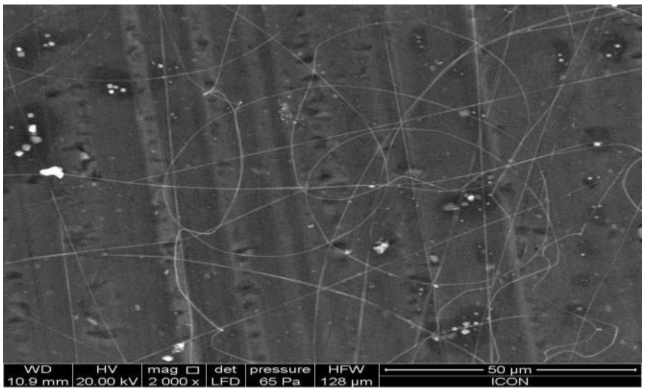

Figure 6: SEM image of CNFs at magnification of 2000x

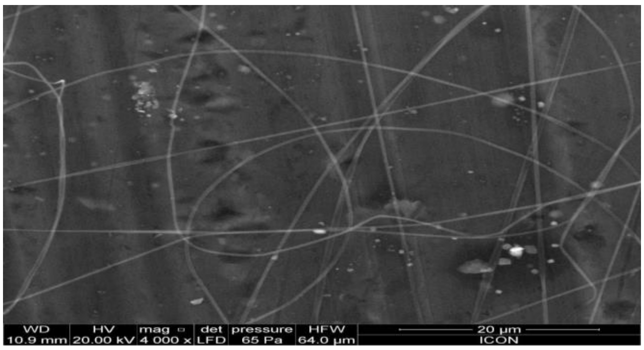

Figure 7: SEM image at 4000x

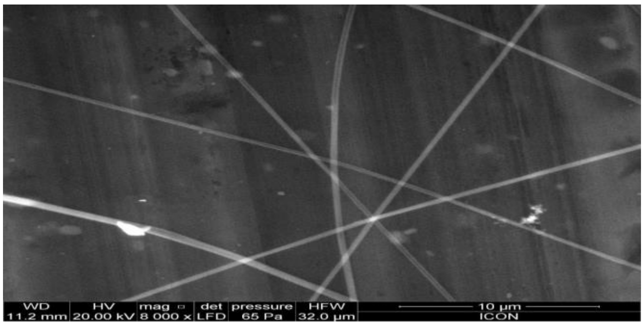

Figure 8: SEM image at 8000x

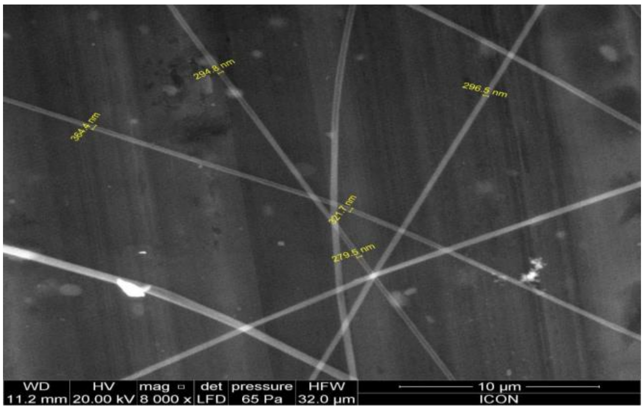

Figure 9: SEM image of CNFs with various diameters

IV. Conclusion

Electrospinning is the cost efficient method for obtaining nanofibers from variety of different solutions. Minimum diameter of 279.5nm of Polyacrylonitril (PAN) fibers were obtained from parameters, Distance - 15cm, Voltage - 18KV, Flow rate - 1.5ml/hr. No Beeds formation took place in the fibers. Pure fibers were obtained with zero foreign particles. Distance plays very importance role in diameter optimization, as the distance increases the diameter reduces.

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