International Journal of Analytical, Experimental and Finite Element Analysis (IJAEFEA), Issue. 2, Vol. 6, May 2019
e-ISSN: 2394-5141, p-ISSN: 2394-5133, pp 63 - 66
DOI: 10.26706/IJAEFEA.2.6.20190405

Manufacturing of ZnO Nanofibers using Electrospinning

Nand Jee Kanu[1]
nandssm@gmail.com

Sachin Chavan[2]

Amit Pawar[3]
amitpawar356@gmail.com

Sanket Patil[4]
mrsanketpatil19@gmail.com

Bhushan Rane[5]
bhushanrane58@gmail.com

Shubham Patil[6]
shubhampatil141483@gmail.com

JSPM Narhe Technical Campus, Department of Mechanical Engineering, Pune, India

Abstract - Nanostructured zinc oxide (ZnO) materials have been of interest for researchers because of their nontoxicity, and wide range of applications. Various methods have been used to fabricate nanofibers, but electrospinning only method which is the simplest cost effective with the highly versatile technique that has been extensively used for the fabrication continuous nanofibers. This is a versatile technique, which can be used to generate nanofibers from a rich variety of materials. The variation of a zinc oxide (ZnO)-polyvinylpyrrolidone (PVP) composite structure has been investigated in morphology by electrospinning from a series of mixture solutions of ZnO sol–gel and polyvinylpyrrolidone (PVP). The main advantage of nanotechnology is its surface area to volume ratio. Adding materials in form of the nanoparticle, fibers, tubes, flakes, etc. changes the material properties significantly. The solvent used for the electrospinning solutions was Dimethylformamide (DMF) under the electric field of 24kv with flow rate of 0.5ml/hr. distance between syringe and drum 24cm. By Electrospinning technique, we can achieve the desired diameter of nanofibers. The nanofibers were characterized by scanning electron microscopy (SEM).

Index Terms— Characterization, electrospinning, ZnO

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 a fiber production method which uses electric force to draw charged threads of polymer solutions or polymer melts up to fiber diameters in the order of some hundred nanometers.

Principle of Electrospinning is that when a sufficiently high voltage is applied to a liquid droplet, the body of the liquid becomes charged, and electrostatic repulsion counteracts the surface tension and the droplet is stretched; at a critical point a stream of liquid erupts from the surface. This point of eruption is known as the Taylor cone. If the molecular cohesion of the liquid is sufficiently high, stream breakup does not occur (if it does, droplets are electrosprayed) and a charged liquid jet is formed.

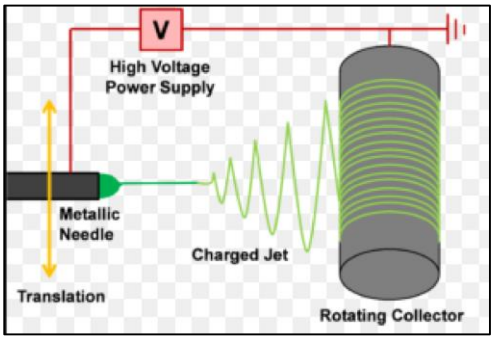

Figure1: Basic setup of the electrospinning process

As the jet dries in flight, the mode of current flow changes from ohmic to convective as the charge migrates to the surface of the fiber. The jet is then elongated by a whipping process caused by electrostatic repulsion initiated at small bends in the fiber, until it is finally deposited on the grounded collector. The elongation and thinning of the fiber due to bending instability leads to the formation of uniform fibers with nanometer scale diameters as shown in figure 1.

II. Electrospinning Setup And Electrospinning 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 discharge rod is used to diffuse current stored inside the system then the aluminium foil is carefully removed on which the fibers are collected and preserved for further test.

III. Experimental Details

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%), Polyvinylpyrrolidone and Zinc Acetate were used.

B. *Solution preparation*

Dimethylformamide solution was prepared at room temperature. Then 0.9 gm of Zinc Acetate and 5.4 gm of polyvinylpyrrolidone was mixed in 9 ml of Dimethylformamide. 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 3: Mixture of solution

Figure 4: Solvent N,N-Dimethylformamide

C. Electrospinning and characterization

The electrospinning machine was composed with the equipment's 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 24cm.

Electric supply given to the Electrospinning machine was 24KV and flow rate of syringe was 0.5ml/hr. Fibers were collected on aluminium foil.

The Electrospinning process was carried out at room temperature.

Figure 5: Image of obtained elecrtospun fiber on aluminum foil

D. SEM images of characterization

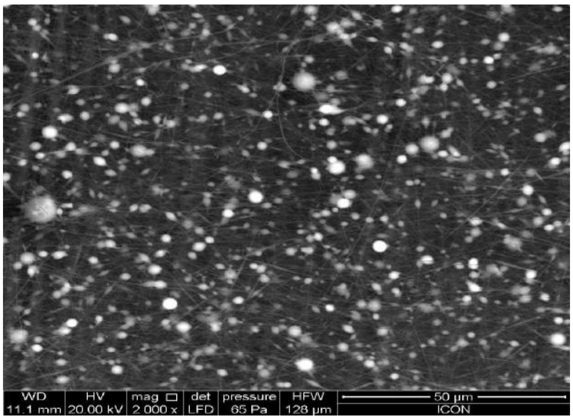

Figure 6: SEM Images of ZnO Nanofibers At 4000x

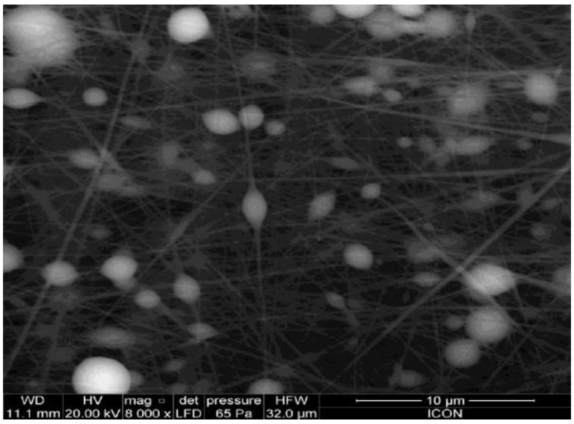

Figure 7: SEM Images of ZnO Nanofibers At 8000x

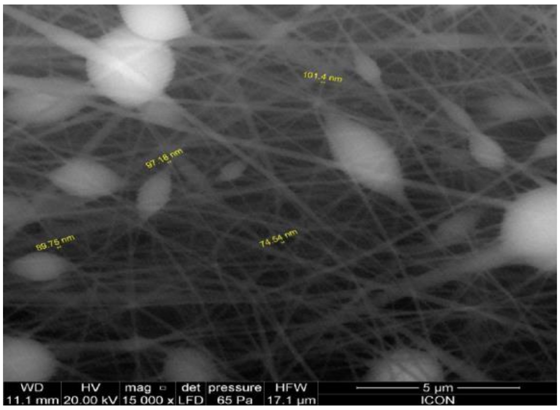

Figure 8: SEM Images of ZnO Nanofibers At 15000x

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

IV. Conclusions

- Electrospinning is the cost efficient method for obtaining nanofibers from variety of different solutions.
- Minimum diameter of 74.54nm of ZnO nanofibers were obtained from parameters: Distance - 24cm, Voltage - 24KV, Flow rate - 0.5ml/hr.
- Pure fibers were obtained with zero foreign particles
- Distance between the needle and collector plate, voltage, feed rate, solution properties plays very important role in optimization of diameters of nanofibers.

References

[1] Bayu Sutanto, Zainal Arifin, Suyitno, "Structural Characterization and Optical Properties of Aluminum-doped Zinc Oxide Nanofibers Synthesized By Electrospinning" Journal of Engineering Science and Technology, Vol. 13, No. 3, 2018, 715 – 724.

[2] Yingjie Liao, Takeshi Fukuda, Norihiko Kamata and Makoto Tokunaga, "Diameter Control of Ultrathin ZnO Nanofibers Synthesized By Electrospinning", Nanoscale Research Letters, 2014, 9:267.

[3] Dr. Raad S. Sabry, Al-mustansiriyah, Firas S. Mohammed, Roonak Abdulsalam A. Alkareem, "Fabrication Of Electro Spinning 1d Zno Nano Fibers As UV-photoconductor" ICNAMA 2015, 3-4 Nov, 2015

[4] Zhengtao Zhu, Lifeng Zhang, Jane Y. Howe, Yiliang Liao, Jordan T. Speidel, Steve Smith, and Hao Fonga, "Aligned Electrospun ZnO Nanofibers For Simple and Sensitive Ultraviolet Nanosensors", Supplementary Material (ESI) for Chemical Communications, 2009

[5] V. I. Kondratiev, I. Kink, A.E. Romanov, L. Dolgov, "Transparent Films From Aluminium-doped Zinc Oxide Fibers Prepared By Electrospinning Method", Materials Physics and Mechanics, Volume 27, 2016, 133-141.

[6] Anna Baranowska-Korczyc, Anna Reszka, Kamil Sobczak, Bo_zena Sikora, Piotr Dziawa, "Magnetic Fe doped ZnO nanofibers obtained by electrospinning", J. Sol-Gel Sci Technol, 2011, DOI10.1007/s10971-011-2650-1.

[7] Ehsan Ghafari, Yining Feng, Yao Liua, Ian Ferguson, Na Lu, "Investigating process-structure relations of ZnO nanofiber via electrospinning method", Composites Part B: Engineering, Volume 116, 2017, 40-45.

[8] Kalyani Vijaykumar Jada, Namrata Deshmukh , Dr. S. S. Chavan, Dr. Kirtan Tarwadi, Dr. Jadhav "ZnO nanofiber application area and ZnO properties review", International Journal of Innovative Research in Technology, Volume 4 Issue 1, June 2017.