Fabrication of Polyvinyl alchol (PVA) and CNT filled PVA Nanofibers by Electro hydro jets spinning

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Abstract

Electrospinning is a versatile tool for the formation of nanofibers from the materials of diverse origin like organic polymers, ceramics, and polymers/ceramics composites. Here we demonstrate the formation of Polyvinyl Alcohol (PVA) nanofibers with an average diameter in the range of 60 nm to 150 nm. The FTIR data gives the presence of PolyvinylAlcohol (PVA) and their chemical bonding. The structure and the alignment of the nanofibers were observed using Scanning Electron Microscope (SEM).

Introduction

Medical and healthcare textile are a rapidly growing part of the textile industry. These textiles have been engineered to have particular properties like good strength, flexibility and sometimes moisture and air permeability for medical and surgical applications. Recently electrospun nanofibers have attracted a great deal of attention for the use in medical and healthcare textile.

Electrospinning is a simple, low-cost and effective technology to produce nanofibers with the diameter being in sub-micron down to nanometer range from materials of diverse origin like biopolymers, engineering plastics, conductive polymers, polymer blends, ceramics and composite materials. The electrospun nanofibers are collected on the collector are often randomly oriented and have a wide range of applications like composite reinforcement, membrane- based separation and tissue engineering. Other application being microelectronics, photonics and blood vessel scaffolds.

Experimental Details

For the fabrication of polymer nanofibers we use electrospinning setup which has a dual syringe pump (KDS 200 series, KDS scientific, Inc.) and a high voltage electric power supply (Model ES30P, Gamma High Voltage Research, Inc.).

The PVA polymer solution is prepared and is placed in the syringe pump. We used a 10 ml volume, 12.6 mm diameter syringe to pump the PVA solution. The grounded zinc plate is used as a collector to collect the nanofibers.

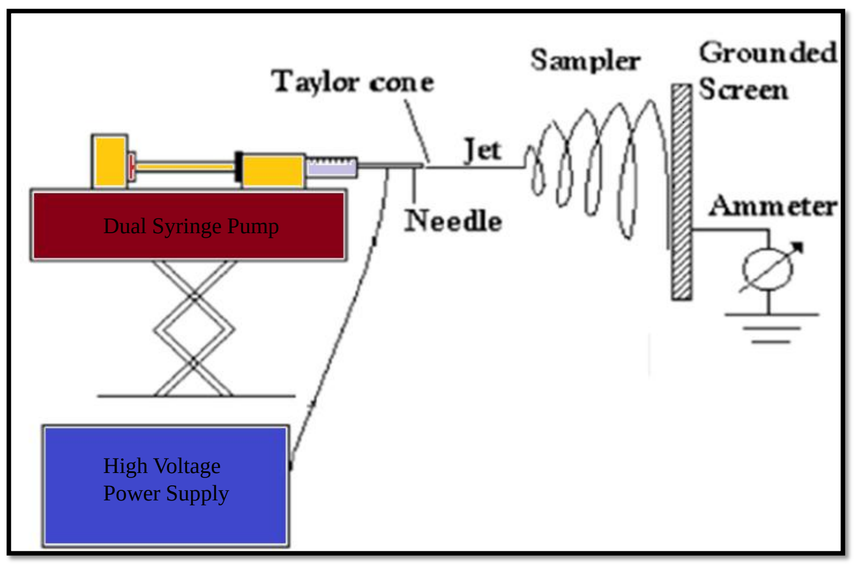


Fig 1. Electrospining setup with dual syringe pump and high voltage electric power supply *Patra and co-workers / Polymer 46 (2005) 7191–7200*

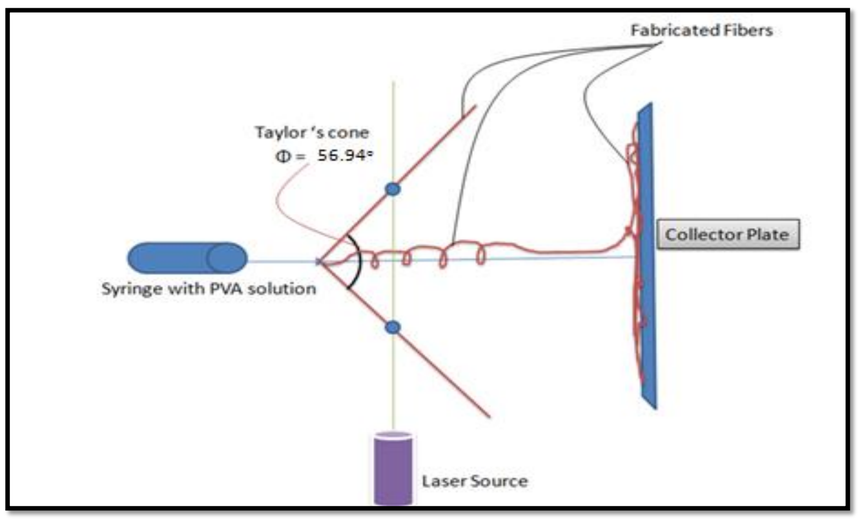


Fig 2. Estimation of Taylor's Cone angle using Laser source

As shown in Figure 1 electrospinning setup has a dual syringe pump, 0-30Kv DC high voltage electric power supply and a collector. The needle attached to the syringe is connected to a positive electrode and the collector is grounded. We apply a high voltage as high as 15 KV in order to produce the nanofibers. The PVA solution was prepared in water at a concentration of 10 % w/v. A weighted amount of PVA powder (Sigma Aldrich, Inc.) was dissolved in the water at 90° C, under slight steering for 2 hours until the we get crystal clear solution of PVA water. A fixed electrical potential of 15 KV was applied over a fixed distance of 10 cm (approximately 1Kv over 1cm) at a rate of 1.5ml/ hr.

***Acknowledgement**: We would like to thank Professsor P.M. Ajayan and Paris Cox for their support in characterization of nanofibers with SEM and FTIR.*

Results and Discussion

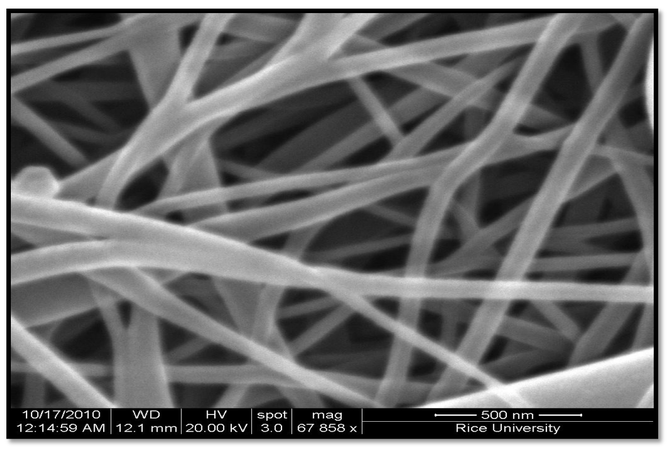


Fig. 3 (a)

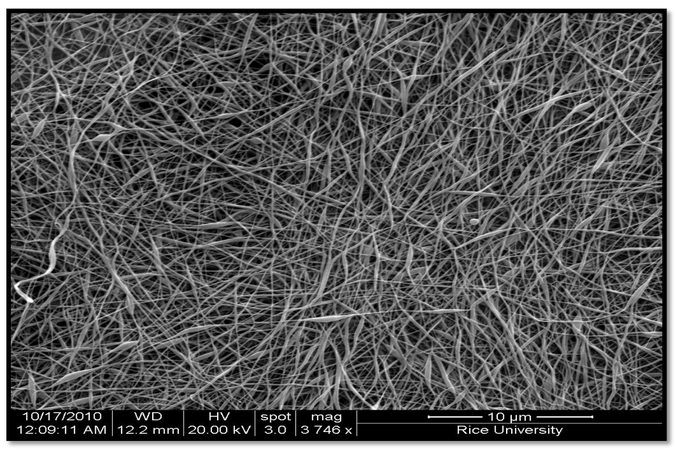


Fig. 3 (b)

Fig 3. Scanning Electron Microscope (SEM) image of 10 % PVA at 20Kv and at a distance of 15 cm. Fig (a) 500 nm , Fig (b) 10 um

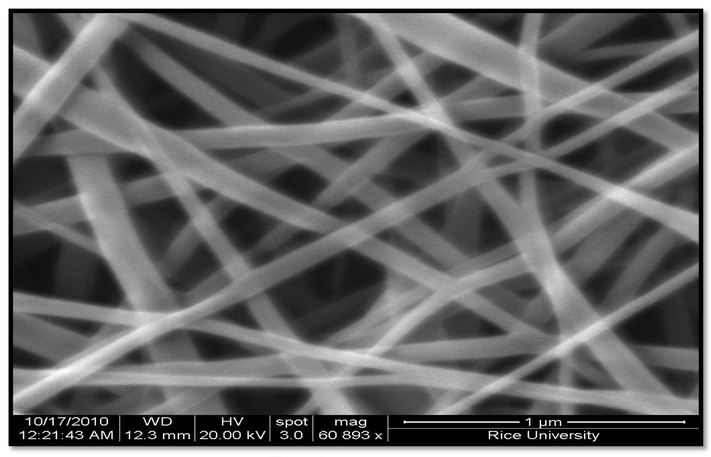


Fig. 4(a)

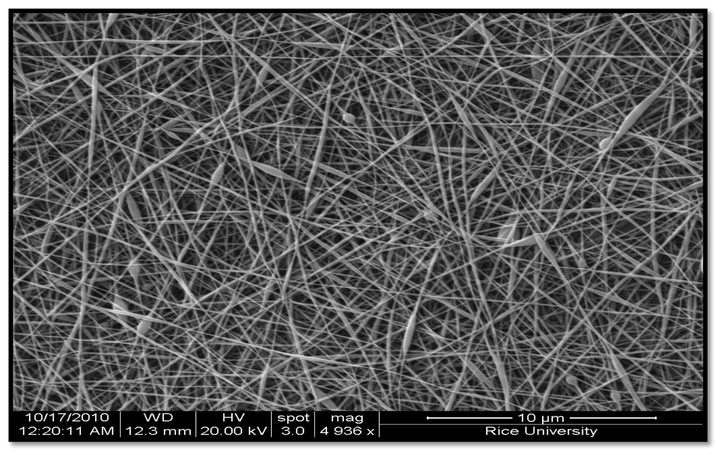


Fig. 4 (b)

Fig 4. Scanning Electron Microscope (SEM)image of 10 % PVA at 15Kv and at a distance of 10 cm. Fig (a) 1 um, Fig (b) 10 um

Above are the images taken 2 hrs after the electrospinning of nanofibers . These nanofibers were collected on the Zinc plate which is a square of 30cm X 30 cm in size. Fig 3 (a, b) shows the PVA fibers made from 10 % PVA, 15 cm distance and 20 Kv. Fig 3 (a) shows the image area with 500 nm magnification. Here we observe that the fibers are little less uniform in the diameter throughout the length. But the 10 um (Fig 3 (b)) magnification image shows us that there are very few beads formation in nanofibers. In this the average diameter of the fibers is around 45 nm to 133 nm in diameter. Fig 4 (a,b) shows the nanofibers made from 10 % PVA solution, 10 cm of distance and 15 Kv. Fig 4 (a) shows the SEM image of 1 um of magnification. Here we observe that the fibers are more uniform in the diameter and the average diameter is in the range of 60 nm to 150 nm. Fig 4 (b) show that 10 um magnification of the nanofibers . Here we observe that many beads formation but that overall the fibers are of uniform diameter.

FTIR spectroscopy characterization

We performed the Fourier Transform Infrared spectroscopy to characterize the presence of PVA and to find their chemical bonding. From the literature previously published we confirm the presence of C-H bond at 2800 to 3000 cm $^{-1}$ spectral range, Hydrogen bond at 3200 to 3550 cm $^{-1}$ range and O-H bond band is 3600 to 3800 cm $^{-1}$.

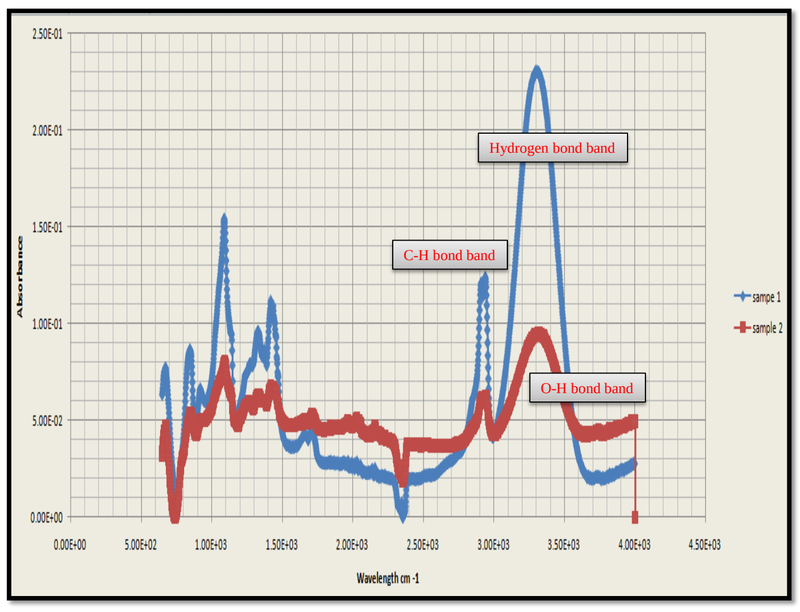


Fig 5. FTIR spectra of PVA

Conclusion

We are demonstrating a technique for the formation of nanofibers with the diameter in the range of 60 nm to 150 nm. In our approach we found less bead formation and overall more uniform diameter across the length of the fiber. We have clearly shown the SEM characterization to see the fibers at nm level and the FTIR spectroscopy characterization. Our future scope of this project would be to test these fibers for mechanical strength under tension and shear. And also to test the electrical properties when spun with CNT.

Parallel research projects snippets

Semi quantitative estimation of stress on a single cellular level.

In this project we are working on the area of single cell biomechanics, where we plan to investigate the effect of application of force on single fibroblast cell and try to find the structure-property-function relationship to possibly predict the disease in advance. In order to apply the force we use Atomic Force Microscope that has the force resolution down to pn and distance resolution down to nm. Fig 6. depicts one of the ways to apply the mechanical force to the single cell using fibrinogen and cell interaction.

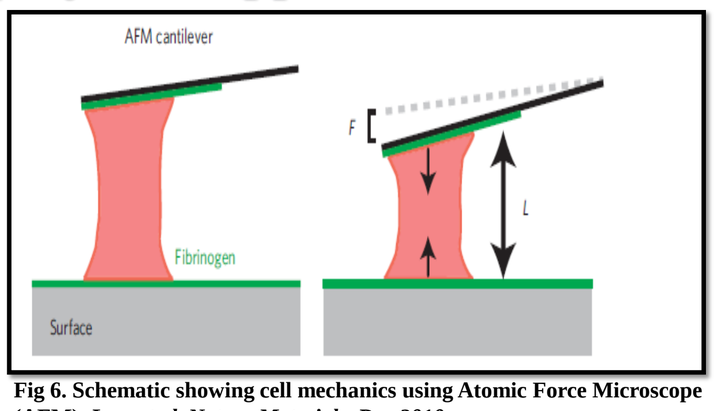
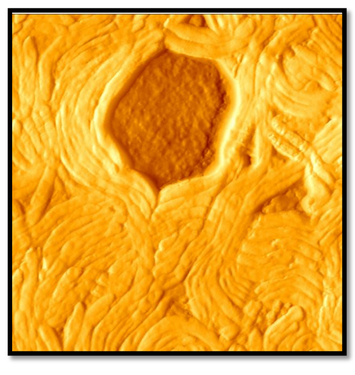


Fig 6. Schematic showing cell mechanics using Atomic Force Microscope (AFM). *Lam et al. Nature Materials, Dec 2010*

In-Situ Nanoscale study of early Bio-Film Formation

In collaboration with Professor Saion Sinha, University of New Haven

Formation of bacterial biofilms is one of the primary causes for implants and other internal medical devices (e.g. catheters, pacemakers, tooth crowns etc.) getting severely infected from time to time. Though biofilms have been widely investigated the detailed mechanism pertaining to initial phase of biofilm formation and its growth from engineering perspective remained largely un-explored. In this project we are working to provide evidence for supporting the critical reason for biofilm formation and the nanoscale length scale of the surface i.e. features around 100 nm or less. We are also working on a computational model that can predict the growth of biofilm formation under specific conditions.



Graphene Nanoribbons and DNA self assembly

Dr. William Sherman and Dr. Dmytro Nykypanchuk at Brookhaven National Laboratories (BNL), Prof. Sinha at University of New Haven, Prof. Cristian Bach, Prof. Hassan Bajwa, Ashish Aphale, Isaac Macwan and Prof. Prabir Patra at University of Bridgeport

We plan to understand the attachment of graphene with single-stranded DNA by a self-assembly process under strong ultrasonication and in the resulting water-dispersible graphene-DNA hybrids. We intend to achieve monolayers of *ss*-DNA molecules adsorbed on both sides of the graphene sheets by a non-covalent – stacking and other secondary forces that will eventually lead to development of graphene-DNA based devices in the long run.