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A Fundamental Approach of Electro Spinning in Nanofiber/ Polymer Composites

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Abstract

This paper mainly focused on the current research activities on nanofiber by electro spinningmethod and the various parameters to be considered for electro spinning of nanofiber.Thenanofiber mat generated by electro spinning is generally analyzed by scanning electron microscope (SEM).The various applications of the nanofiber in the fields likesensors, cosmetic, skin mask, batteries, filters, militaryclothing,tissueengineering, industrial application and life science is discussed in this paper.

Keyword:Electrospinning,Nanofiber,scanning electron microscope (SEM).

Introduction

Nanotechnology, which is one of the new technologies, refers to the development of devices, structures, and systems whose size varies from 1 to 100 nanometers (nm). The last decade has seen advancement in every side of nanotechnology such as,nanoparticles and powders.Nano layers and coats, electrical, optic and mechanical nanodevices, and nanostructured biological materials.Presently, nanotechnology is estimated to be influential in the next 20-30 years,in all fields of science and technology.Nanotechnology is receiving a lot of attention of late across the globe. The term nanooriginates etymologically from the Greek, and it means “dwarf”.Theterm indicates physical dimensions that are in the range of one-billionth of a meter. This scale iscalled colloquially nanometer scale, or also nanoscale.Onenanometer isapproximately the length of two hydrogen atoms. Nanotechnology relates to thedesign, creation, and utilization of materials whose constituent structures exist at thenano scale, these constituent structures can, by convention, be up to 100 nm in size.Nanotechnology is a growing field that explores electrical, optical, and magnetic activity as well as structural behavior at the molecular and sub molecular level. Oneof the practical applications of nanotechnology is thescience of constructing computer chips and other devices using nano scale buildingelements.Nano scale structures permit the control of fundamental properties of materials without changing the materials chemical status as it might be inferred, nanotechnology is highly interdisciplinary as a field, and itrequires knowledge drawn from a variety of scientific and engineering arenas.Designing at the nano scale is working in a world where physics, chemistry,electrical engineering, mechanical engineering, and even biology become unified into an integrated field.The term nanotechnologywas introduced by Nori Taniguchi in 1974 at the Tokyo International Conference on Production Engineering[1]. He used the word to describe ultrafine machining.The processing of a material to nano scale precision.This work was focused on studying the mechanisms of machining hard and brittle materials such as quartz crystals, silicon, and alumina ceramics by ultrasonic machining. Years earlier, in a lecture at the annual meeting of the American Physical Society in 1959 (There's Plenty of Room at the Bottom) American Physicist and Nobel Laureate Richard Feynman argued[2](although he use the word nanotechnology) that the scanning electron microscope (SEM) could be improved in resolution and stability, so that one would be able to "see" atoms. Feynman proceeded to predict the ability to arrange atoms the way a researcher would want them, within the bounds of chemical stability, in order to build tiny structures that in turn would lead to molecular or atomic synthesis of materials [3].Nanomaterial's give impetus to new applications of the (nano) technology because they exhibit novel optical, electric, and magnetic properties.The first generation of nanotechnology (late 1990s–early 2000s) focused on performance enhancements to existing micro materials, the second generation of nanotechnology (slated for 2006–2007) will start employing nanomaterial's in much more significant and radical ways[4].Nanomaterial's with structural features at the nano scale can be found in the form of clusters, thin films, multilayers, and nano crystalline materials often expressed by the dimensionality of 0,1,2 and 3, the materials of interest include metals, amorphous and crystalline alloys, semiconductors, oxides, nitride and carbide ceramics in the form of clusters, thin films, multilayers, and bulk nano crystalline materials[5].All products are manufactured from atoms,however, interestingly the properties of those products depend on how those atoms are arranged.For example, by re-arranging the atoms in coal (carbon),one can make diamonds.It should be noted that current manufacturing techniques are very rudimentary at the atomic/molecular levelcasting,grinding, milling, and even lithography move atoms in bulk rather than in a"choreographed" or "highly controlled" fashion.Nanomaterial's often have properties dramatically different from their bulk-scale counter parts for example, nano crystalline copper is five times harder than ordinary copper with its micrometer-sized crystallinestructure.Agoal of nanotechnology is to close the size gap between the smallest lithographically fabricated structures and chemically synthesized large molecules[6].Electro spinningis the technique use for preparing nanofiber frompolymers [7].

Electro Spinning

Electro spinning is one of the methods to prepare nanofiber of polymer composite material from corresponding solutions in the process a high voltage is used to create an electrically charged jet of polymer solution.Thediameter of the fiber obtained is in the range of 10µm to10nm.A conventional electro spinning setup consists of a spinneret with a metallic needle, a syringe pump, a high-voltage power supply and a grounded collector.A polymer solution is loaded into the syringe and driven through the needle at a steady and controllable feed rate by the pump, forming a droplet at the tip of the needle. A high voltage (typically up to 30 kV) is applied between the tip and a grounded collector.When the electric field strength overcomes the surface tension of the droplet an electrified liquid jet is formed. The jet is then elongated and whipped continuously by electrostatic repulsion. Although the process may appear simple the achievement of stable operation is not an easy task[8]. Properties that are known to significantly affect the electro spinning process are the polymer molecular weight, the molecular-weight distribution, the architecture (branched, linear,etc) of the polymer, as well as the rheological and electrical properties of the solution (viscosity, conductivity, surface tension, etc[9].In addition, the operating conditions such as electric potential, flow rate, distance from the needle tip to the collection plate, ambient parameters (temperature, humidity) and geometry of the collecting target play a crucial role in controlling the electro spinningCharacteristics[10,11] because each material demands a different optimization procedure to development of each polymer nanofiber[12.13].Now a days nanomaterial's plays a most important role in defense,bio-technology,semiconductors and industrial applications and some prospective areassuch as tissue engineering[14,15],membranes[16],nano resonators [17],micro-air vehicles[18],and hydrophobic tin film[19].Electro spinning is one of the promising processes to produce continuous nano-scale fibers from both synthetic and natural polymers[20].It determines the properties of the electro spun fiber mats such as mechanical, electrical, and optical properties.It was previously shown that both the strength and the conductivity of the mat of fibers produced by electro spinning[21].

Working Principle

Electro spinning is an easy technique for preparation of nanofiber. In the electro spinning setup consist of three main equipment's, a syringe pump, a high voltage source and a ground collector shown in fig 1 and 2.

Figure1: ElectrospinningApparatus

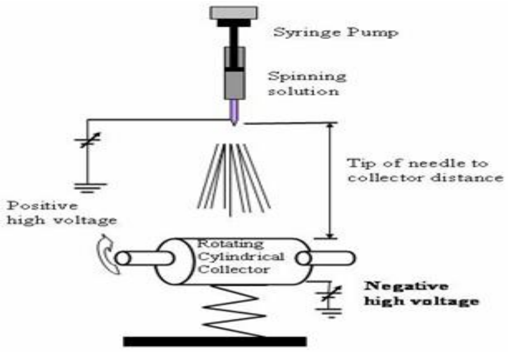

Figure2: Working Principle of Electro Spinning

Indigenous Syringe Pump:
Syringe pump can accommodate 2ml,5ml,10ml and 20ml syringes. Flow rate is controlled by computer using a USB based data acquisition /control card.

Parameters Affecting Electro Spinning:
Nanofiber, molecular weight, viscosity, concentration, surfacetension, electricpotential, flowrate,distance and temperature are the major parameters affecting the electrospinning.

Applications
Applications of electro spunnano fiber is very wider in the engineering field ,cosmetic skin mask, life science application, tissueengineering, filtration media,military applications, industrial application and nano sensors are the examples of the nano materials product.

Electro Spun Polymer Fibers:
The fiber mat is classified into three types based on the fiber orientation,random,aligned, andcriss-cross fibers respectively.

Results and Discussions

Random Nano Fiber:
Polymer fibers were deposited randomly on a flat copper collector, in the form of stacked layered meshes during electrospinning. Various patterned meshes were successfully prepared using patterned collectors and their morphology was analyzed by scanning electron microscope shown in fig [3].It is also have intermediate tensile modulus.

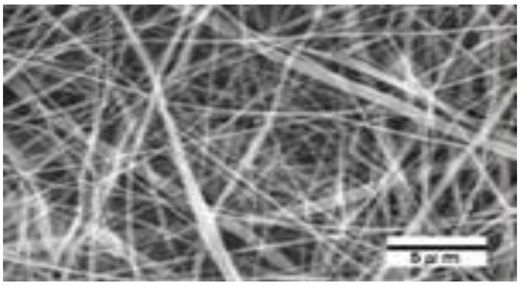

Figure3:SEM Imageof Random Fibers

Aligned Nano Fiber:
A thin, steel pin was used as a counter electrode and was placed behind a rotating, non-conductive cylindrical collector drum, aligned fibers greater than 10 cm in length were obtained shown in fig[4].It is used in as a proton exchange membrane and the composite membrane containing nano fiber may have potential application for use in fuel cells.

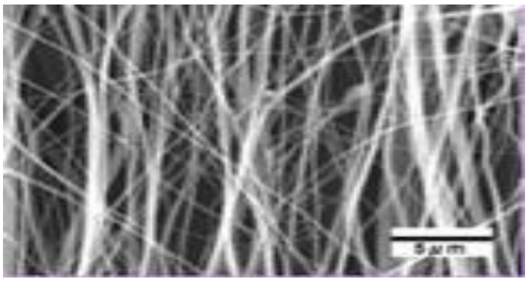

Figure4:SEM Image of AlignedFibers

Cisss-Cross Nano Fibers
Parallel electro spunnanofiber were collected continuously across a rectangular rack for 3 or 6 minutes. This fiber array was then transferred to a two-piece polycarbonate frame that was held together with screws. Composite films were fabricated with criss-crossednanofibers.It hasgoodmechanical properties.

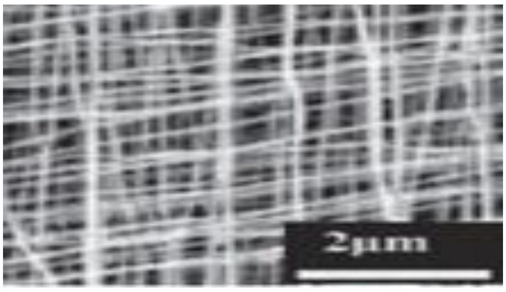

Figure5:SEM image of Criss-Cross fibers

Conclution
Different types ofnanofiberare prepared by the electro spinning process. By this method the nanofibers are wellaligned,criss-cross and random fiber mats can be generated. Thefigure3, 4 and 5 shows theSEM images of random fiber, alignedfiber andcriss-cross fiber respectively. The random nanofibers are used as replacement of tissus, filtrationmedia, industrial applications and nano sensor. The aligned nanofibers areused as the replacement of brain damage caused due to traumatic brain injury, replacement of damaged neurons and spinal cord injury. Thecriss-cross fibers are used as military protective clothing, electronic devices and electronic circuit board.

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