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NANOSPIDER TECHNOLOGY AND ITS APPLICATIONS

D. Kala *, M. S. Athira and Malini Mohan

College of Pharmaceutical Sciences, Government T. D. Medical College, Alappuzha - 688005, Kerala, India.

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Correspondence to Author:
Dr. D. Kala

Professor,
Pharmaceutics College of Pharmaceutical Sciences,
Government T. D. Medical College
Alappuzha - 688005, Kerala, India.

E-mail: kaladmohan@gmail.com

ABSTRACT: Electrospinning is a process wherein polymer fibers are developed on applying high voltage. Its principle is based on charge accumulation on the surface of the polymer solution as a result of high voltage which causes the solution to get ejected out as a thin jet by forming a taylor cone. Nanospider is a modified version of electrospinning developed by Technical University in the year 2003. The idea of generating a technology named nano spider was to produce electrospun fibers around 50-400 nm in diameter from the free liquid surface. This technique is employed in many fields such as tissue engineering, drug delivery, wound healing, enzyme immobilization etc due to its easy maintenance, a requirement of less quantity of raw material and its ease of fabrication. Advancements in technology have increased the need for nanofibers and their products which could not be delivered by the conventional fiber spinning method. This urges the need to develop methods such as nanospider which can generate polymer fibers in high yield.

INTRODUCTION: Nanospider is a modified electrospinning method that requires the use of high-voltage electrostatic field to create an electrically charged stream of polymer solution or melt [1-2]. This is a simple and versatile method for the production of ultrathin fibers from a variety of materials including polymers. The technology revolves around the possible creation of Taylor Cones and the subsequent flow of material not only from the tip of a capillary but also form a thin film of a polymer solution. Nano spider technology is flexible in optimizing the results of nanofiber production through precise adjustment of many process parameters.

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Solution parameters include conductivity, temperature, surface tension, while environmental parameters comprise mainly of temperature and humidity. Cross and surface electrical resistance along with voltage and electrode distance falls under the category of material and equipment parameters, respectively.

The technology provides

- Production of very thin fibers in the order of few nanometers with large surface areas.
- Ease of functionalization for various purposes.
- Superior mechanical properties and ease of the process.
- High productivity and scalability.

The set up contains a syringe which is filled with a polymeric solution that is mounted on top of an insulting stand.

The syringe is then connected to metal electrodes which will induce a charge on the surface of the polymeric solution in the needle tip. By further increasing the voltage, the polymer solution gets accelerated towards the earthed collector, placed at a distance from the needle tip by the formation of a taylor cone. The solution gets evaporated during the process and the polymeric fibers get deposited on the collector.

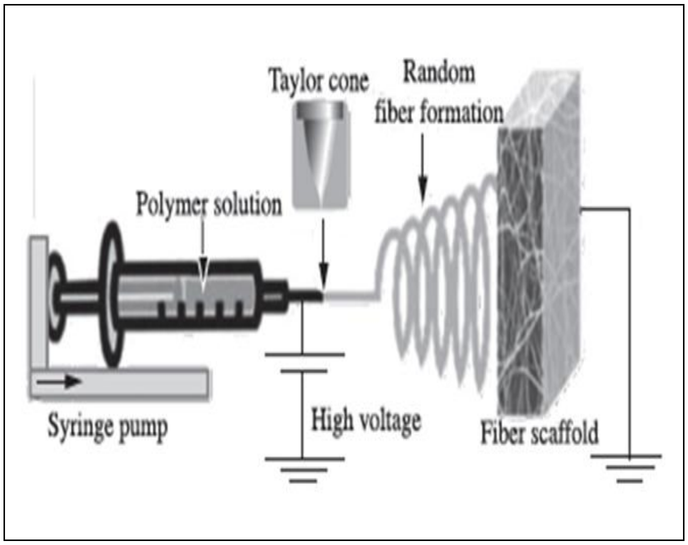

FIG. 1: EXPERIMENTAL SET UP OF ELECTROSPINNING PROCESS [3]

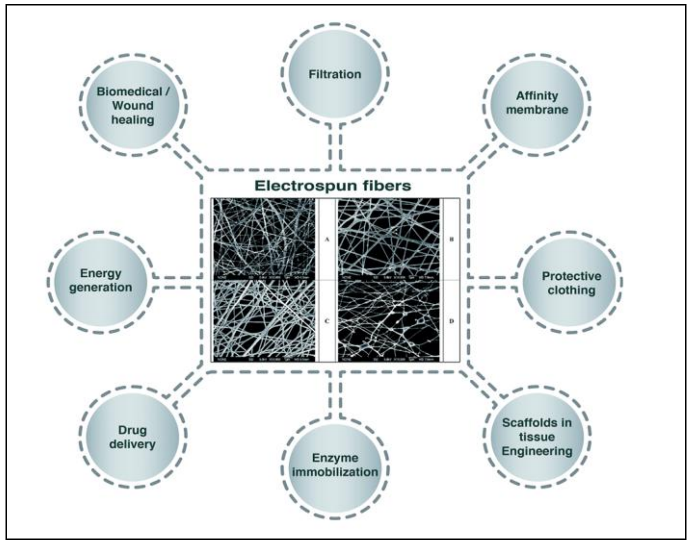

FIG. 2: GENERAL APPLICATIONS

Drug Delivery: Electrospinning is a straight forward method to produce ultrafine fibers with micro to nanometer range diameters and with controlled surface morphology. The ultrafine fibers are generated by the application of a strong electric field on polymer solution or melt. The high loading capacity, high encapsulation efficiency, simultaneous delivery of diverse therapies, ease of operation and cost-effectiveness are appealing features of electro-spinning which promote its usage in drug delivery. Several antibiotics, anticancer agents, proteins, aptamers, DNA and RNA, have been incorporated into electrospun fibers [4, 5].

Compared with other dosage forms like liposomes, micelles, hydrogels, and nanoparticles, electrospun mats could potentially reduce system toxicity and increase the local drug concentration especially in the case of solid tumors. Doxorubicin which was loaded in the fibers was released and diffused into the tumor site, underneath the fiber mat leading to a greater inhibitory effect on tumor growth thereby reducing damage to other organs.

These results provide an encouraging prospect of using drug-loaded electrospun nanofibers in local chemotherapy, especially for those patients receiving complete tumor resection or cyto-reductive surgery.

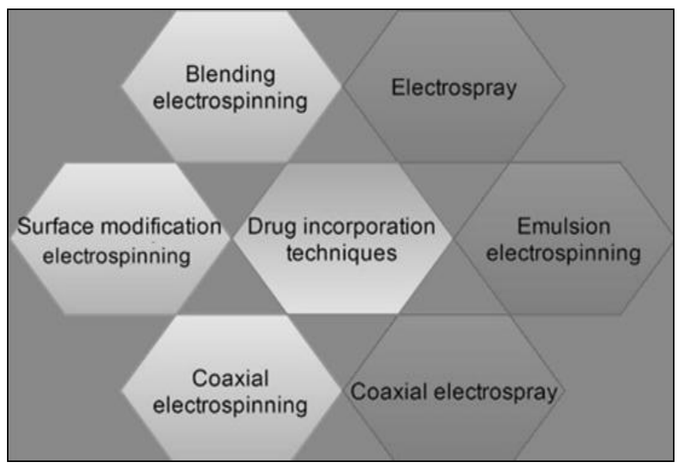

FIG. 3: DRUG INCORPORATION TECHNIQUES ELECTROSPINNING

Bone Tissue Regeneration: Nanofibrous structures so developed from electrospinning technology mimic extracellular matrix conditions and offer increased surface area thereby favoring anchorage, migration, and differentiation of tissue cells [6]. Moreover, this technology has been employed in fabricating cell culture scaffolds and for the regeneration of damaged tissues such as blood vessels, muscles, skins, tendons, ligaments, cartilage, nerves, and bones [7]. The efficiency of such nanofibers can be raised substantially by incorporating it with various bioactive molecules such as growth factors, adhesive proteins *etc*.

For Wound Healing: Electrospinning has gained recognition in wound healing for the production of biomimetic nanofibrous material that promotes cellular infiltration for dermal regeneration. This eliminates possible limitations associated with 2D nanofiber materials. Skin extracellular micro-environment can be recreated by immobilizing extracellular matrix molecules to the surface of electrospun nanofibers *via* electrostatic interactions, hydrogen bonding or covalent bonding. These electrospun fibers can be molded into sutures, dressings and epidermal substitutes. Studies revealed that electrospun poly nanofiber dressing loaded with polypropylene fumarate provides conformal coverage of the injured tissue, thereby reducing the level of pro-inflammatory cytokines and re-epithelialization [8-10].

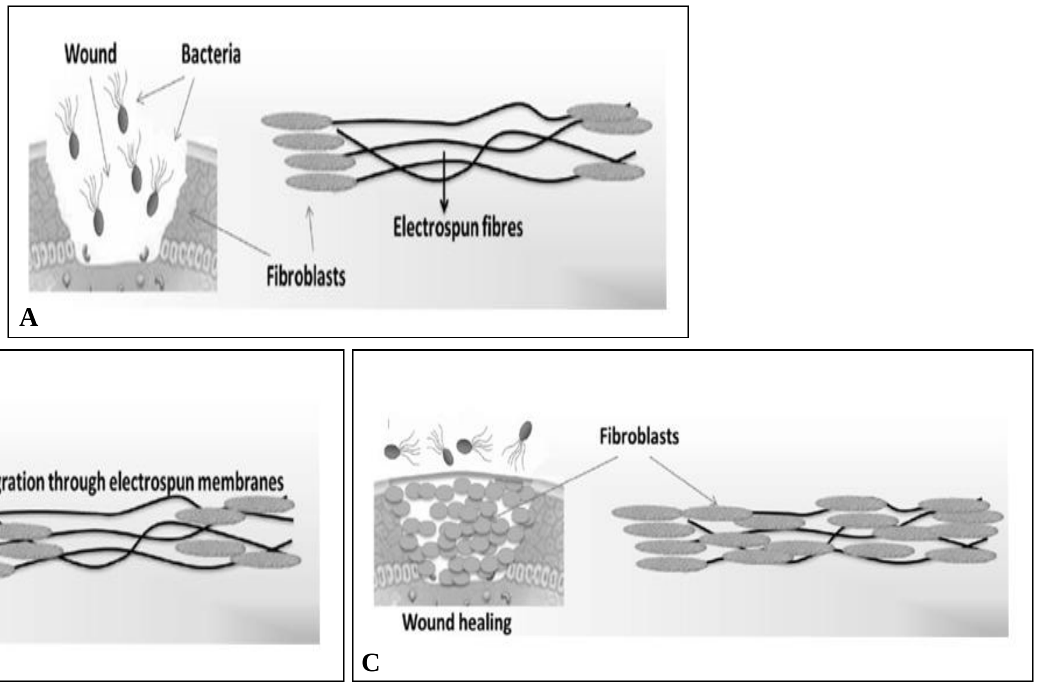

FIG. 4: SCHEMATIC REPRESENTATION OF THE ROLE OF ELECTROSPUN MEMBRANES AS SKIN SUBSTITUTES. (A) IN AN OPEN WOUND, BACTERIA WILL COLONIZE AND RETARD WOUND HEALING (B) WHILE APPLYING ELECTROSPUN MEMBRANES ON THE WOUND, BACTERIAL ENTRY IS PREVENTED AND CELLS GUIDED TOWARDS THE CENTRE OF WOUND (C) AND FINALLY, THE WOUND IS HEALED WITHOUT COMPLICATIONS AND MUCH INFLAMMATORY RESPONSE

Enzyme Immobilization: Nano-structured supports are believed to retain the catalytic activity as well as to ensure the immobilization efficiency of the enzyme to a greater extent. Enzymes that are physically confined or localized in a defined region of space with retention of catalytic activities are referred to as immobilized enzyme [11]. Electrospun nanofibers have been proven to be an excellent support for enzyme immobilization since they provide high surface-area-to-volume ratio, pore functionalized surfaces, multiple sites for interaction or attachment, and low mass-transfer limitation when compared to other nanostructured supports [12]. Enzyme immobilization using nano-fiber can be done by two different methods such as surface attachment and encapsulation [13]. Immobilization reduces the cost of enzyme and enzymatic products.

The performance of immobilized enzymes depends on the properties of supports. Mesoporous silica, nanotubes, nanoparticles and nanofibers are commonly used as supports. The microenvironment of the encapsulated enzymes can be improved either by incorporating biocompatible components into the spinning solution or by in situ polymerizations/ side chain modification [14].

As Filtration Membrane: Electrospun membrane is used as a filtration membrane in the separation of sub microparticles, removal of heavy metal ions, dyes, purification of proteins *etc.* [15]. High porosity, pore size, high surface area to volume ratio are attractive features offered by an electrospun nanofibrous membrane which enables them to be used in air filters [16]. Studies revealed that the absorption properties of the electrospun membrane can be increased by incorporating it with metal or its oxides. The efficiency of the electrospun membrane to absorb fine submicroparticleis demonstrated by Kusumaatmaja *et al.*[17]

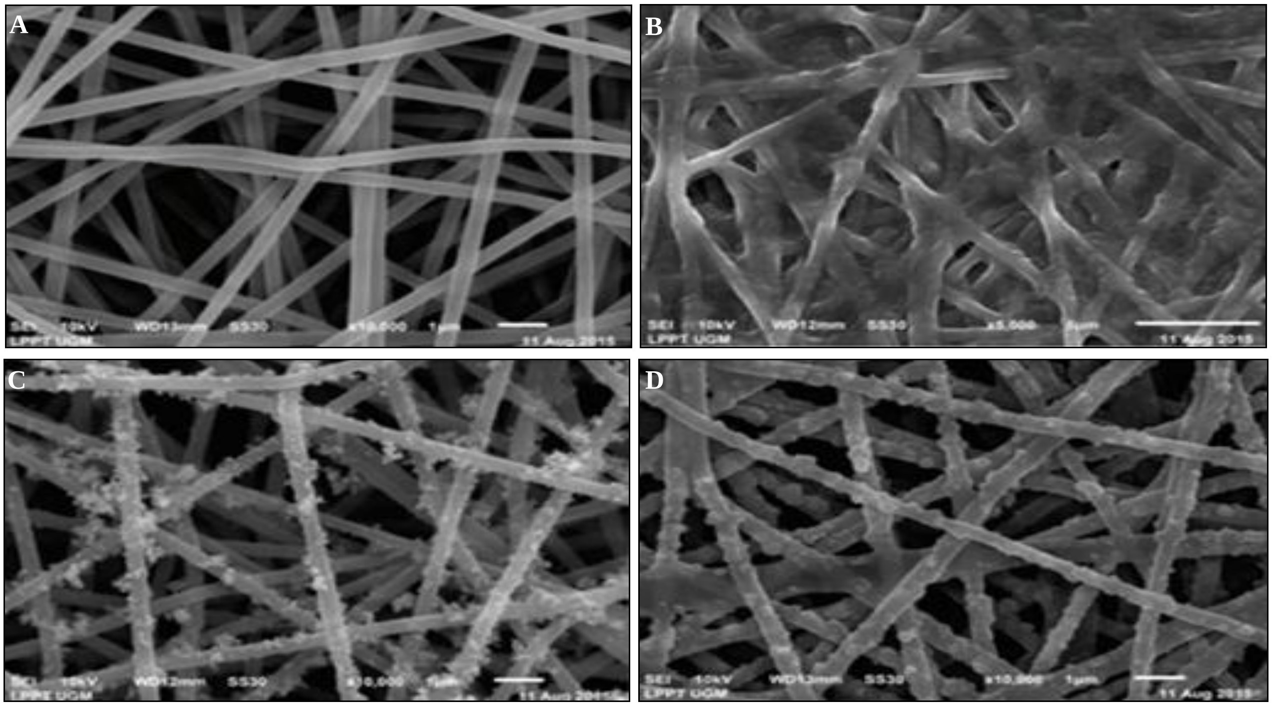

FIG. 5: SEM IMAGES OF ELECTROSPUN PVA MEMBRANE (A) BEFORE FILTRATION; AFTER FILTRATION OF (B). CIGARETTE SMOKE, (C) SMOKE FROM WASTE COMBUSTION, (D) SMOKE FROM VEHICLE COMBUSTION

CONCLUSION: Nanospider technology is a modified electrospinning process used for the production of nanoscale fibrous materials. High surface-area-to-volume ratio ease of functiona-lization and tunable porosity, making them attractive for widespread applications such as drug delivery, chemical fragmentation, ultraviolet cutting, enzyme immobilization, wound healing *etc.* Large numbers of biodegradable and biocompatible polymers have also been electrospun by conventional or modified methods. Electrospun materials are going to take a major place in the future for various biomedical applications.

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