Review – Approaches of Nanofibers Manufacturing with Bio-Medical Applications

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Abstract – *This paper is a review of the most emerging technology in the field of Nanotechnology i.e., the Nanofiber. The nanofiber has evolved gradually in the past for its effective possessions to maximize the properties of the elements by cramming them to the nanoscale with large surface areas. The ability of the nanofibers for their mass scale productions and also the simplicity by which they can be manufactured as well as its adaptability has also been a reason for the rapid growth in the usage of the nanofibers. Here we tried to momentarily present the various techniques by which the nanofibers had been manufactured for several years and its recent evolution after the drawbacks of the traditional electrospinning techniques and about the same growth of it in the applications as well. Although after so much evolution, we remain with many factors to be considered in the future for better production and much more effective usage as well as making the process of manufacturing a bit more cost-friendly.*

Key Words: *Nanofiber, Electrospinning, Nanotechnology, Applications.*

1.INTRODUCTION

Nanotechnology is a field of science that deals with those materials that lie in the range of dimension between 0.1-100nm. Nanotechnology has made a remarkable impact on material property enhancement. Nanotechnology as the novel, one-dimensional Nanomaterial that is Nanofiber is more attractive by researchers due to its aspect ratio. In this paper, we have tried to review the techniques such as Electrospinning, Drawing, Melt blown Technology, CO2 laser supersonic Drawing, Centrifugal Jet Spinning, and Solution Blow Spinning through which these nanofibers are being manufactured and their properties such as the greater surface area to volume ratio, higher porosity are achieved.[1][15] We have also shed some light upon its most widely used bio medical applications that include efficient drug delivery, diagnosis of Cancer, and wound healing purposes.

2. TECHNIQUES OF NANOFIBERS MANUFACTURING

While manufacturing a nanofiber a lot of factors are being considered so as to maximize their properties and also the parameters of the production are also a factor of concern and it may vary within different techniques. So, the techniques which we have discussed here are:

2.1 Meltblown Technology Technique

Meltblown technology includes the single stage production of fibres by polymer melt extrusion pores die and pull-down extrusion material with a hot air, usually at the same temperature as the molten polymer. Air exerts drag force to reduce melting extrude into fibres, which are later collected Form of a nonwoven mat. The Meltblown technology allows the usage of the thermoplastic polymers, here as a budget friendly spinning process option [3][6].

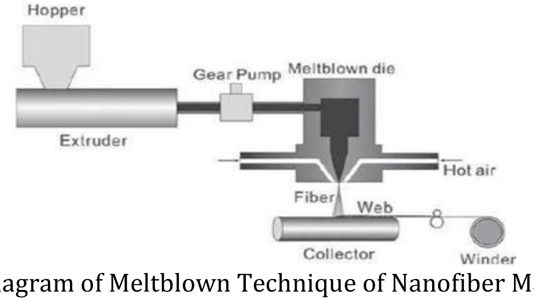


Figure (1) Diagram of Meltblown Technique of Nanofiber Manufacturing

Advantages:

- The filtration is about 99%
- Provides better cleanliness, eliminates any pollution to water bodies and reduces corrosion
- Strength offered is higher

- Higher mixability after treatment and modification

Disadvantages:

- More costly than other nanofiber production technology
- Process is complicated

2.2 Electrospinning Technique

In the electrospinning technique, a spray comprising of the polymeric solution gets released from the edge of the droplet under the influence of forces that are electrostatic in nature [15]. The produced nanofibers typically form a non-woven mat. Individual nanofiber fragments of up to several centimetres in length can be arranged and aggregated. The polymer solutions can be found in a plastic syringe tip having 0.6 mm internal diameter. A pendant drop of the polymer solution was continued at the tip of the syringe. The spray was released descending from the edge of the hanging drop of the polymer solution and involved to the loud frame of the collector disc that has been rotating around the axis which is horizontal. The frame is located 200 mm beneath the droplet. In order to generate a sturdy convergent electrostatic field, the diameter aluminium disc which is 200mm had a sharp frame with a 26.60 half angle. Due to this, an electric potential variation (15–40) kV was fashioned between the liquid drop surface and the rotating disc collector resulting in the deposition of the fibre over the disc collector and resulting in the nanofiber [2] [4-5].

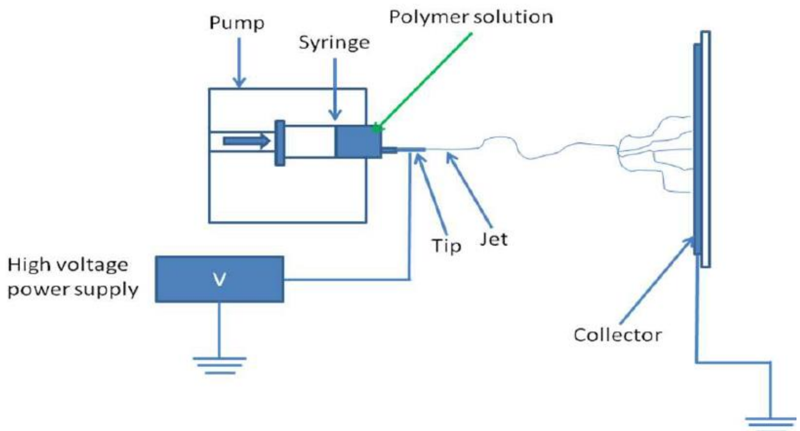


Figure (2) Block Diagram of the Electrospinning Technique of Nanofiber Manufacturing Setup

ADVANTAGES:

- High surface area to volume ratio
- Excessive variability of polymers and materials can be used by this technique to form nanofibers
- Ease of fiber functionalization and also ease in material combination
- Relatively low set up cost and low learning curve of basic electrospinning

DISADVANTAGES:

- Large volume scaffold is difficult to manufacture using this technique
- The jet used in this technique might be unstable
- Technique is a bit complex

2.3 CO_2 Laser Supersonic Drawing Technique

The laser Supersonic Drawing technique is mostly preferred in those cases where there is the nonattendance of chemical solvents. With the help and use of a CO2 laser, original fibres within the diameter range of 100-200µm, are melted first and then passed on, a later stage, through a Supersonic airflow to get the supersonic drawing of the nanofiber, by using the force of the air. Long-chain nanofibers can be produced by this technique as it is a single continuous process. Generally, the CO2 laser supersonic drawing technique is applied in various fields of thermoplastic polymers like Polyglycolic acid (PGA), Polyethylene terephthalate (PET) and Polylactic acid (PLLA) [7].

The synthesis of nylon-66 nanofibers tends to have a high melting point near the equilibrium melting point while using this technique [7]. This technique also allows us to produce polymeric nanofibers which can have extended chains and an improvement in the mechanical properties can be achieved as well.

ADVANTAGES:

- It creates very high power with comparative efficiency, making it an instant choice for those sectors where materials processing is required [12]
- CO2 laser bids low cost per watt in addition to decent beam quality and gives high power output which varies from few watts to 15KWatts
- Its efficacy is healthier than He-Ne and argon laser types

DISADVANTAGES:

- Deviation of CO2 laser is superior to He-Ne and argon laser. Deviation varies from 1 to 10 milliradians [12]
- The width of the beam ranges from 3 mm to 100 mm
- The optical cavity is a bit thick and short

2.4 Solution Blow Spinning Technique

Solution Blow Spinning technique was developed to overcome the limitations of the conventional electrospinning technique that includes low electrical potential and in-situ synthesis of the nanofibers. But in solution blow spinning, we don't face this issue. This new technique is used to produce micro and nanofibers. The setup for this process is costly and it also has advantages and gives good nanofibers within the required range.[8]

This technique majorly asks for three things and those are a polymer solution which should be concentrated, a modest marketable airbrush and a compressed gas source. With the help of these three things, the technique can be employed for in-situ admission of nanofiber mats and scaffolds for the accordant coverage of the non-conducting targets. The applications of this technique can also be for numerous tissue engineering and surgical fields.

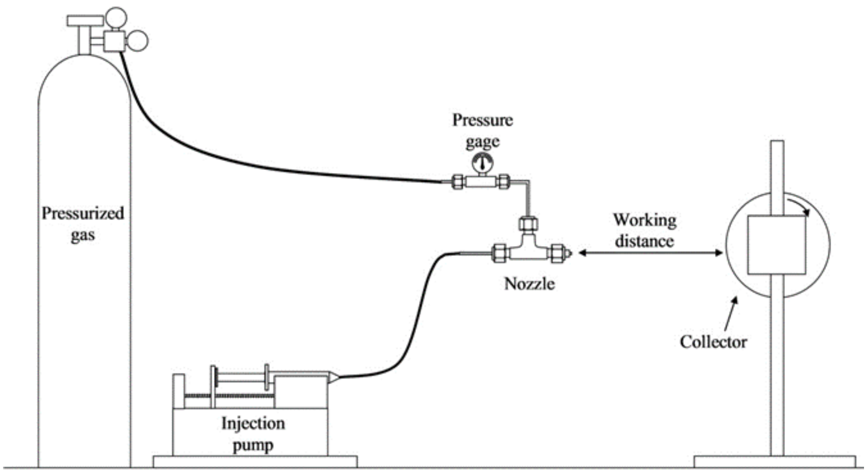


Figure (3) Block Diagram of Solution Blow Spinning Technique Setup

2.5 Centrifugal Jet Spinning

The major agenda of this technique is for the synthesis of micro or nanofibers which are relatively lower in cost, gives advanced effective fibres and high output [9-11]. The principle on which this technique works is, thinning of a solution filament which is then formed into the nanofibers by the use of the centrifugal jet spinning technique, which is achieved by the controlled manipulation of centrifugal force, viscoelasticity and mass transfer characteristics of the spinning solutions. Also, the evaporation rate of solution and elasticity of the solvent respectively will change the corresponding diameter of the prepared nanofiber [11].

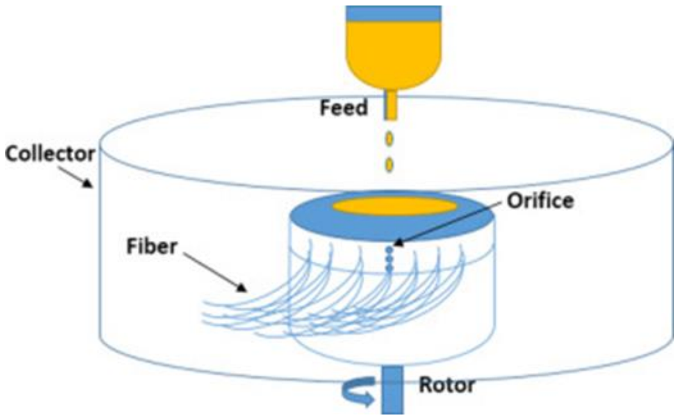
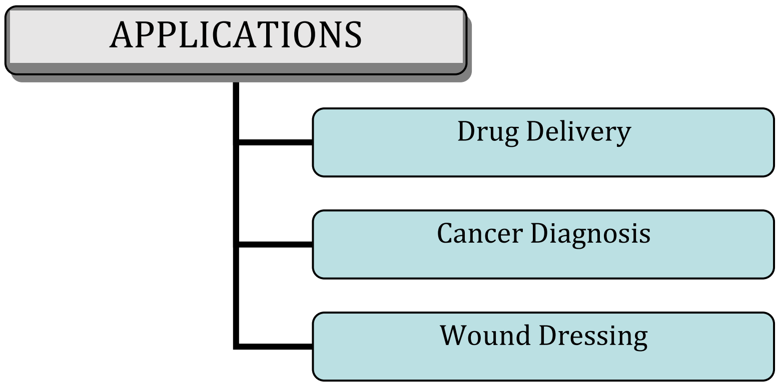


Figure (4) Block Diagram of Centrifugal Spinning Setup

3. APPLICATIONS

The Nanofibers have tremendous applications in all the major engineering fields but if it has caused a revolution then it has been in the bio-medical field where it has resulted a much more effective treatment of the patients keeping in consideration the healing time as well as understanding the importance of reducing the side effects caused by the regular medicines.

The Applications which we have discussed here has been depicted in the flow chart and then explained accordingly:



3.1 Drug Delivery

Efficient drug delivery has been one of the major and biggest applications of nanofiber. The proper delivery of the therapeutics to the required area mainly depends upon the choice of the drug carrier. The main purpose of the drug carrier is to make sure that the drug makes supreme effect while it reaches the prescribed area, it needs to retain all the properties from the initial stage to the point where it reaches the organs and then a proper proclamation of the drug for better recovery. The Nanofibers very much fulfils all these criteria of effective drug delivery. The usage of the polymers in the nanofibers such as gelatin proves to be a choice that provides better fabrication for the manufacturing because it provides efficient compatibility with the human body and also biodegradable, thus causes no impairment to the organs and neither allows any setting of the toxins inside the human body [13]. The delivery of the medicines on the exact region in the treatment of the wounds faces the issue of the side effects caused by those medicines but with the help of these nanofibers which systematically absorbs the drug helps in the reduction or complete removal of those side effects. The nanofibers also act as a shield that protects the external enzymes and molecules that may depreciate the ongoing process of healing [14]. All these factors when considered and understood makes us feel that nanofibers are an efficient drug delivery carrier.

3.2 Cancer Diagnosis and Treatment

Cancer has been a kind of problem for the natural entity that has made everyone weak due to its limitations in curing. But nanofibers have shown an impressive performance in the case of a cancer diagnosis as well. Currently, pathologic examination is the technique to detect the tumors present in the body but this sole sample testing fails to deliver the genomic character of the tumor [17]. To counter that Liquid Biopsy is being preferred heavily which is a blood draw that comprises of the Circulating Tumor Cells (CTC) being injected directly into the bloodstream by the solid tumors. The nanofibers are very useful in regulating or in delivering these CTCs with much more ease [18]. The Cancer cells can also be cured and treated efficiently with the use of magnetic nanofibers which performs in such a way that the magnetic nanoparticles which are present in the nanofibers, heats the tumor present inside and then it gets destroyed. This heat is generated with the help of an exterior alternating magnetic current field (AMF). Although the regulation of heat here is still a major concern [16]. Thus, this proves the Nanofiber to be an effective technique for Cancer Diagnosis and treatment.

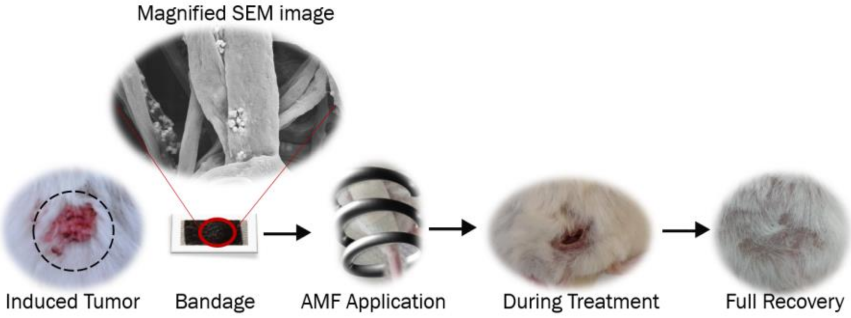


Figure (5) Treatment of Induced Tumor in a Mice by the heat generated from Alternating Magnetic Field

3.3 Wound Dressing

The nanofiber mats that can be used in wound dressing acts as protective covers that endorses curing as well as protects it from any other hazardous wound. The nanofiber mat that will be used for the wound dressing should particularly be designed in such a way that its structure compliments porosity since it will allow to maintain the humidity level and should have the ability to sustain at the region of a wound and can fight against the external pathogens that may react unnecessarily to the wound. The major factor for effective wound healing is the effect of humidity, as a dry nature will lead to dehydration which eventually leads to the death of the cells and deteriorates the healing. The structure with porosity can be obtained with the electrospinning process which has a versatile nature and thus it will manipulate the pore size and will vary its distribution accordingly [14].

4. CONCLUSION

In conclusion, we would say that Nanofibers has proved to be a kind of research that has helped mankind in a much more efficient way. The techniques that have been mentioned have allowed catalyzing the properties of the nanofiber keeping in consideration the time and ease by which these nanofibers can be manufactured and reduce the side effects while using them for bio-medical purposes such as wound healing, efficient delivery of drugs and in the detection of cancer cells as well as curing it. In future, the researchers can converge their focus upon making the techniques much more budget-friendly and also make the fundamental functioning much simpler to save time in understanding the functioning and also maximize its usage not only in the bio-medical field but everywhere possible.

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