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Review Article

Review Artical On Nanofibare to Using Electrospining Technique

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ABSTRACT

Rheumatoid arthritis (RA) is an autoimmune disease manifested by chronic joint inflammations leading to serve disability premature mortality nanofibers are ultrafine fibers with diameter in the manometer range produced through various method like electrospinning have significant applications in field such as biomedical action drug delivery and filtrations nanofibers can be produced various different method the most common method is electrospinning which utilize high voltage electric field nanofibers are fibers with diameter in the nanometers range typically less than 100 nm they are known for their high surface area to volume ratio. Nanofibers can be generated from different polymer and hence have different physical properties and applications. The nanofibers are fabrications techniques such as electrospinning, phase separations, physical fabrications and chemical fabrications depending on their intended use nanofibers are manufactured using a variety of polymer it comprises, natural polymer, semi synthetic, synthetic polymer, metal oxide, ceremony carbon, nonporous materials, mesoporous material, hollow structures. Nanofibers composite are good alternative for targeted gene delivery protein and peptide delivery.

INTRODUCTION

The world of nanomaterials comprises a wide range of intriguing materials with outstanding physical and chemical properties and characteristics. These materials include zero-dimensional nanoparticles or quantum dotes one-dimensional nanowires, nanorods, nanofibers, and nanotubes, and two-dimensional nanosheets [1]. Nanofibers are extremely thin fibers, between 1 and 1000 nanometers in diameter, generated from polymers. Through use of polymeric fibers and implementation of controlled-release administration routes, drugs can be applied once or twice daily, thus improving patient adherence and avoiding toxic plasma peak concentrations that can arise from frequent administration of immediate-release formulations Small nanofibers offer

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advantages including excellent stability, targeted delivery, high drug-loading capacity, high surface area, diminished toxicity, improved mechanical properties, and suitability for delivery of thermo-sensitive drugs Various techniques can be used for the preparation of nanofibers, such as emulsion spinning, force spinning, melt spinning, and electrospinning The purpose of this review is to summarize various techniques used for fabrication, and factors influencing the electrospinning process, and to highlight the wide range of applications of nanofibers. Small nanofibers offer advantages including excellent stability, targeted delivery, high drug-loading capacity, high surface area, diminished toxicity, improved mechanical properties, and suitability for delivery of thermo-sensitive drugs Various techniques can be used for the preparation of nanofibers, such as emulsion spinning, force spinning, melt spinning, and electrospinning The purpose of this review is to summarize various techniques used for fabrication, and factors influencing the electrospinning process, and to highlight the wide range of applications of nanofibers. [2]. The ability to make large differences with micro/nano scale materials has been realized through nanotechnology The materials in the nanoscale range are a rapidly developing domain that has made a huge contribution towards revolutionizing these technologies Even though there are various nanostructured materials like nanoparticles, nanodots, nanosheets, nanorods, nanoflowers, and etc., nanofibers with their unique fabrication methods and tunable properties, have become a much-explored area for various applications in the fields of sensors tissue engineering drug delivery wound healing , energy devices , filtration distillation the environment, etc. Owing to their novel physical and chemical properties in providing high specific surface area, large surface-to-volume ratio, tunable porosity, and the ability of desired chemical functionalization, they are competent enough to overcome many limitations faced in their corresponding macroscales There are several fabrication techniques such as thermal-induced phase separation self-assembly template synthesis and electrospinning for synthesizing nanofibers. However, among these, the electrospinning technique is the most favorable choice due to the formulation into 2D and 3D structures as well as its simple, continuous, straightforward, rapid, and cost-effective process of manufacturing nanofibers [3]. Branched-out applications of the nanofibrous material are presented in Major contributions in the advancement of technologies have been observed in health care applications mainly in the aspects of biosensing tissue engineering wound dressing and drug delivery In the biomedical field, it has been recognized that the human anatomy of organs and tissues like skin, bones, collagen, cartilage, etc. can be imitated or resembled by tuning nanofiber material The large surface area is extensively exploited in these studies in enhancing adhesion to cells [4]. Nanofibers were first produced via electrospinning more than four centuries ago. Beginning with the development of the electrospinning method, English physicist William Gilbert (1544-1603) first documented the electrostatic attraction between liquids by preparing an experiment in which he observed a spherical water drop on a dry surface warp into a cone shape when it was held below an electrically charged amber. This deformation later came to be known as the Taylor cone. In 1882, English physicist Lord Rayleigh (1842-1919) analysed the unstable states of liquid droplets that were electrically charged, and noted that the liquid was ejected in tiny jets when equilibrium was established bet and electrostatic force [4].

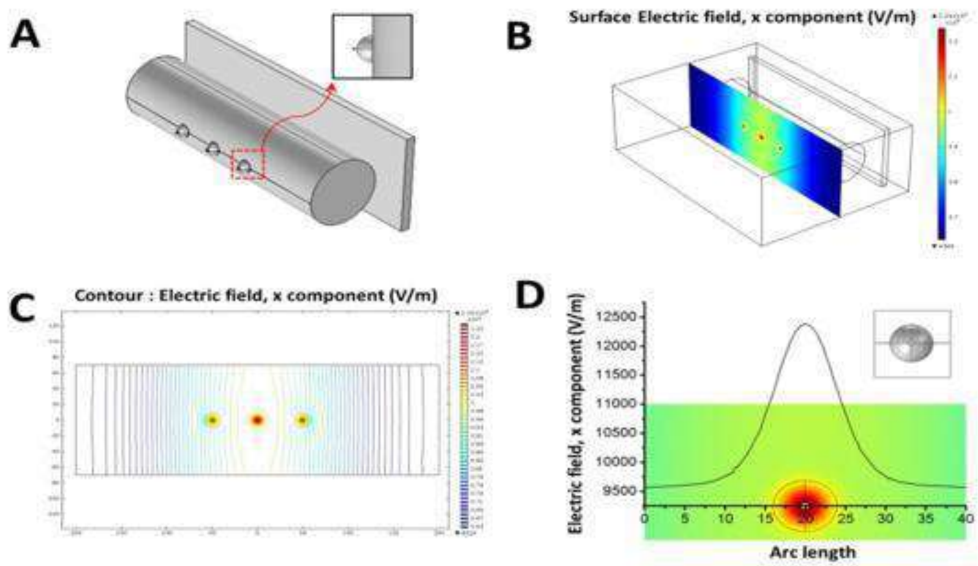


Fig -1[4] .

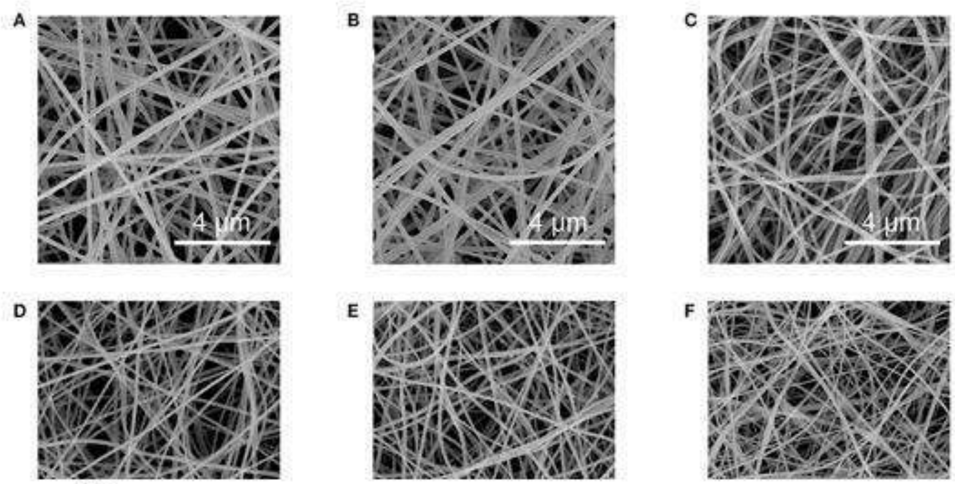


Fig -2 [5] .

❖ History of nanofibers:

Humans already exploited the reinforcement of ceramic matrixes by including natural asbestos nanofibers more than 4,500 years ago The Ancient Egyptians were also using NMs more than 4000 years ago based on a synthetic chemical process to synthesize ≈5 nm diameter PbS NPs for hair dye Similarly, "Egyptian blue" was the first synthetic pigment which was prepared and used by Egyptians using a sintered mixture nanometer-sized glass and quartz around 3rd century BC Egyptian blue represents a multifaceted mixture of $CaCuSi_4O_{10}$ and SiO_2 (both glass and quartz). In ancient geographical regions of the Roman Empire, including countries such as Egypt, Mesopotamia, and Greece, the extensive use of Egyptian blue for decorative purposes has been observed during archaeological exploration[5]. The electrospinning nanofiber process is preferred over other processes because nanofibers produced by these processes have a high surface area to volume ratio and a more significant number of inter/intra pores. The competition between laboratory-scale equipment has increased due to ongoing electrospinning research. With various spinning and collecting electrode accessories, the market activity was restarted. Many organizations have attempted to address low productivity by creating novel production techniques based on traditional electrospinning. More than four centuries ago, electrospinning was used to create the first nanofibers. William Gilbert's creation (in 1902 by American inventor John Francis Cooley as around 1600) pioneered the electrospinning technique. Gilbert's study is the first instance of a liquid being attracted electrostatically. Louis Schwabe developed some methods for spinning silk and producing synthetic fibers in 1845. Hughes and Chambers first patented for creating of carbon nanofibers in 1889. The first electrospinning machine was patented an "Apparatus for electrically distributing fluids." Rozenblum and Petryanov-Sokolov created electrospun fibers in 1938 , which they then utilized to develop "Petryanov filters," or filter materials. Radushkevich and Lukyanovich invented hollow graphitic carbon fibers 1952, and Harold L. Simons patented a machine 1966 that could create patterned fiber fabrics. By creating fibers from various polymers with sizes ranging from 50 nm to 5 m microns and a range of cross-sectional morphologies, Doshi and Reneker (1995) popularized the term "electrospinning"[6] .

❖ Advantages of nanofibers:

- High porosity [ca 90%]
- Small diameters [10nm -10mm]
- High surface area volume ratio and porosity
- Surface similar to the extracellular matrix structure of tissue
- Ease of fiber functianalizations
- Ease of material combinations
- Variety of nanofibrous structure have been constructed [7].

❖ Disadvantages of nanofibers:

- **High Production Cost:** Creating nanofibers, especially at large scales, can be expensive due to specialized equipment and energy-intensive processes like electrospinning.
- **Low Yield Scalability Issues:** Many nanofiber fabrication methods, like electrospinning, struggle with scalability. Getting a high yield of uniform nanofibers can be difficult, and maintaining quality at a large scale is a challenge.
- **Material Compatibility:** Some polymers or materials used to produce nanofibers might have poor mechanical properties or limited chemical stability, which can make them unsuitable for certain applications.
- **Limited Range of Materials:** Not all materials can be used to make nanofibers easily, limiting the flexibility of the technology
- **Inhalation Risks:** Since nanofibers are extremely small, there are concerns about their potential inhalation into the lungs, which could lead to respiratory issues or other health risks.
- **Environmental Impact:** If not properly disposed of, nanofibers can accumulate in the environment and may pose risks to ecosystems, particularly in water or soil [8].

❖ Types of polymers:

Over the past 20 years, nanoscience and nanotechnology have produced numerous distinct forms of nanoparticles nanofibers, nanorods, nanowires, and nanosheet nanomaterials. The dimensions of the nanostructure and its constituent parts are used to evaluate and categorize various nanostructured materials. This classification identifies nanofibers as 1D nanomaterials with less than 100 nm diameter. The nanofibers and nanofibrils are categorized according to their size, form, and content (for example, metals, metal oxides, ceramics, polymers, carbon, nonporous, mesoporous, hollow, core-shell, bicomponent and multi-component.

❖ **Inorganic nanofibers**

CuO, ZnO, SnO_2, $BaTiO_3$, and ZnS nanofibers are oxide and sulfide nanofibers, whereas TiO_2/Bi_2WO_6 and $LiCl/TiO_2$ nano-multicomponent nanofibers are examples of composite nanofibers. The metal nanofibers like Cu, Ni, and Ag are examples of inorganic nanofibers. Several inorganic nanofibers have been produced using electrospinning, followed by the calcination step The photocatalysis has prepared inorganic nanofibers from a few metal oxides, including TiO_2, ZnO, Fe_2O_3, SnO_2, CeO_2, and WO_3. According to the current study, using nanofibers is the most effective manner to lessen the toxicity and dangers associated with using nanoparticles in healthcare products, particularly sunscreen coated with layers of graphene. Carbon nanofibers that have been electrospun or vapor-grown are cylindrical nanostructures with stacked graphene layers.

❖ **Carbon nanofibers :** One-dimensional (1D) nanomaterials, carbon nanofibers (CNFs), are primarily carbon-based. Carbon nanotubes (CNTs) are structurally more complex systems than CNFs. Due to their characteristics, CNFs have lately undergone innovation in various sectors. The orientation of the carbon layers influences the mechanical characteristics of CNFs. CNFs are linear, sp2-based dis-continuous filaments with one double bond and two single bonds with an aspect ratio of more than 100. Recent studies showed that most carbon nanofibers' layers of graphitic planes are typically not aligned along the fiber's axis Ideally, carbon nanotubes are cylinder-shaped nanofibers have the forms of cones, cups, or plates Carbon nanofibers (CNFs) have been an exciting area of research due to important characteristics like high electrical conductivity, excellent mechanical strength and promising morphological properties The significant surface area can adsorb different sensing and therapeutic agents in diagnosis and therapy

❖ **Polymer-based based nanofibers**

Polymer-based fibers are used in different areas, such as garments, fishing nets, cigarette filters, air conditioner filters, surgical masks, heart valves, and vascular grafts. Typically, micro-sized fibers manufactured of various polymers are used in these applications. Electrospinning has produced ultrafine fibers from more than 50 polymers ranging from 3 nm to 1 m in diameter. Nanofibers with various forms and structural traits were produced by enhancing the spinneret design and collecting system. Many polymer nanofiber morphologies, like flat, branching, split, and ribbon nanofibers, It is necessary to conduct polymer melt electrospinning in a vacuum. The metal-collecting screen and the capillary tube must be enclosed in a vacuum. Due to the requirement for highly complicated and advanced device technology, melt spun a few industries are only exploring split nanofibers. The most popular organic fibers are nanofibers made of polyacrylonitrile (PAN). The catalytic fiber's degradation function is good when polyacrylonitrile nanofibers are used as carriers. PAN nanofibers are also used to make electrodes, antifungal medications, and adsorbent materials.

❖ **Composite nanofibers**

Multiple phases of various chemical structures or components are commonly used to formulate composite nanofibers. The characteristics of composite nanofibers are a large surface ures, exceptional conductivity, and high cycle stability. This type of nanofibers has been used in numerous fields because of their improved physical and chemical characteristics. The desired material is produced by thermally or chemically processing composite nanofiber mats. By electrospinning nanoparticle-containing polymer solutions, composite nanofibers can be made. Composite nanofibers are produced using polymer template processes. Composite nanofibers are produced using polymer template processes. Composite nanofibers have been created using polymer template techniques. The dis-advantages of this technology include the prolonged processing time and the inability to control the amount of substance absorbed into the fibers. The polymers used in nanofiber technology are proteins, cellulose, and silk, which are present in nature, many others, like nylon, polystyrene, and polyethylene, can only be made synthetically. Polymers with high extension characteristics under ambient conditions frequently produce elastomers. Natural fibers like cotton, wool, and silk can be effectively replaced with synthetic fibers, namely nylon and polyester. Commercially available plastic resins can have two or more polymers and a range of fillers and additives. These enhance processability, thermal or environmental stability, and mechanical properties.

❖ Types of polymers

1. Natural

Nanofibers made using natural and synthetic polymers can be explored for transdermal drug delivery. Due to the excellent properties of natural polymers, like biodegradability, biocompatibility, and low toxicity, natural polymers are preferred compared to synthetic polymers-based nanofibers. Polysaccharides and proteins are the most frequently used natural polymers to prepare nanofibers using electrospinning. Electrospun polysaccharides containing cellulose, alginate, and chitosan derivatives can be made into nanofibers and employed as a delivery mechanism. d-glucose amine and N-acetyl-d-glucose amine are linear co-polymers that combine to form chitosan. Cellulose is a polymer in plant cell walls, despite having a porous structure and being extremely strong and stiff mechanically. By combining polyvinyl alcohol (PVA), and cellulose acetate, hybrid electrospun nanofibers were produced to encapsulate the fungus that offered the removal of water tainted with aflatoxin B2. In the medical device sector, hyaluronic acid (HA) and its derivatives are frequently employed in implant materials, drug delivery systems, and tissue engineering scaffolds due to their outstanding biocompatibility and biodegradability. A thiolated-HA derivative (for instance, 3,3′-dithiobis (propanoic dihydrazide)-modified hyaluronic acid; HADTPH) were created and electrospun to create nanofibrous matrices, which were then used to replicate the structure of the natural extracellular matrices. There may be applications for HA-DTPH nanofibrous matrices in cell encapsulation and tissue regeneration, given that NIH 3 T3 fibroblasts adhered to the matrix and distributed throughout it with an enlarged dendritic architecture. Noorani et al. formulated a chitosan and gelatin-containing nanofibrous scaffold having a mean diameter of 180 nm. They showed that adding gelatin improved chitosan's hydrophilicity and breakdown with lessened mechanical properties. The lower tensile strength and Young's modulus were observed for samples with higher gelatin amounts. The scaffold comprising gelatin/chitosan (50/50) showed the highest tensile strength 6.93 + 0.63 MPa, and the 30% chitosan-containing scaffold showed 3.51 ± 0.45 ($p < 0.05$) tensile strength. The nanofibers prepared using gelatin/chitosan in 70/30 and 50/50 ratios indicated Young's modulus of 1.05 and 2.24 mPa, respectively. Thus, scaffolds with excellent biological and mechanical characteristics were developed by adding gelatin to chitosan.

2. Semi-synthetic

Natural polymers retrieved in their valuable forms through chemical procedures are known as semi-synthetic polymers. Cellulose, a natural polymer, is the starting point for semi-synthetic polymers. Thermoplastic polymers are another name for semi-synthetic polymers. The method of making cellulose is known as acetylation; acetic anhydride and sulfuric acid are used to prepare cellulose diacetate. Typically, this material is used to develop thread-like film spectacles. Examples of semi-synthetic polymers include gun cotton and cellulose nitrate etc. Fawalet al. prepared a PVA/Hydroxyethylcellulose (HEC) scaffold comprising fluorescein isothiocyanate (FITC) encapsulated ethosomes for transdermal use. The transdermal permeability and release study of FITC encapsulated ethosomes was studied by the Franz diffusion method and FITC-eluting technique. The study results showed a burst release in the first 12 h and 33.2%, 39.5%, and 43.5% release for 5, 10 and 15 µg/ml of FITC encapsulated ethosomes, which was more (26.5%) than the control group. The results also indicated increased mobility and deformability of the ethosomes via rat skin due to ethanol. The FITC passage via the skin cells is direct diffusion through the cytomembrane because of lipids in ethosomes structure. It results in membrane fusion during endocytosis, aiding the cellular uptake of the drug-encapsulated ethosomes

3.Synthetic:-

Synthetic polymers comprise most materials used to create nanofibers with biological components. The most common synthetic polymers used to create nanofibers are PEO, PVA, PCL copolymers, polyvinylpyrrolidone, and polylactic acid. These have received US Food and Drug Administration (USFDA) approval for use as tissue engineering scaffolds or drug delivery systems. These polymers can be mixed with other synthetic and natural polymers or utilized independently. Hydrophilic, biocompatible, and non-toxic polymer polyethylene oxide is commonly used in tissue engineering and drug delivery. Polyvinylpyrrolidone, polycaprolactone, and polylactic acid comprise most nanofiber compositions. Additionally, using methylmethacrylate and methacrylic acid polymers, nanofibers have been electrospun. [9].

❖ METHODS AND MATERIAL:

- **Electrospinning:**

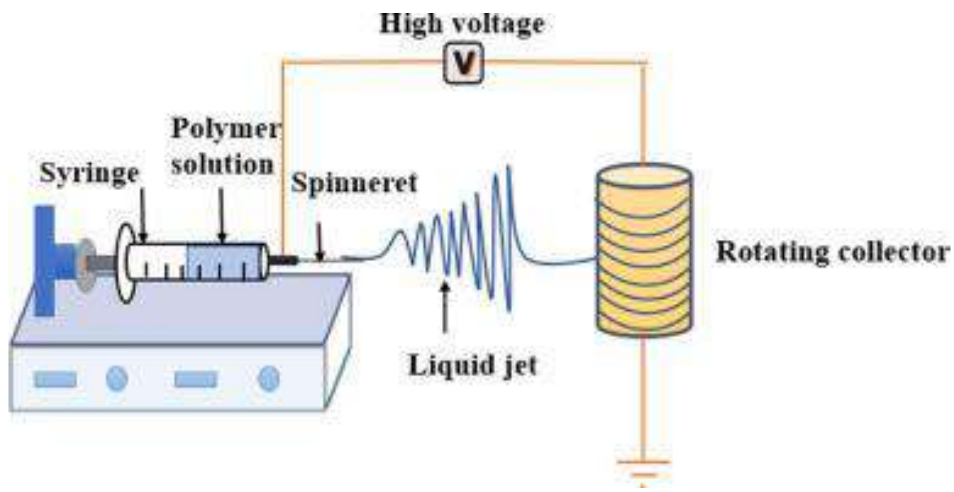
Electrospinning is a widely used electrostatically driven traditional technique for producing nanofibers because of its efficiency, easy adaptability, low production cost, and simplicity The nanofibers made by this method are considered more advantageous due to their higher surface area, less fiber diameter, which ranges from nano to microscale, and good porosity. An electrospinning setup comprises four major components such as high voltage power supplier, a syringe pump, a spinneret or a needle with a blunt tip, and a collector). According to the principle of electrospinning. The fabrication of nanomaterials with the polymer of choice and suitable solvent to prepare polymer solution along with drug, peptides, nanoparticles, etc., using high voltage, i.e., the spinneret ejects the endless jet strands towards the grounded collector with the aid of high voltage applied to the liquid polymer. The interfacial tension of the polymer droplet is controlled by an applied electric field. Then the droplet is elongated to form a cone called "Taylor cone" and dislodged from the cone to form a fiber jet. The important parameters to be considered in this process are the type of polymer, based on the concentration, conductivity, viscosity, flow rate, nozzle to collector distance Despite the wider usage of the electrospinning method, it has certain drawbacks like high voltage usage, which makes it less safe, low yield, and scaling up of electrospinning is expensive. An electrically charged polymer jet has three instabilities that affect electrospinning. The axisymmetric Rayleigh instability fragments the polymer jet. Another instability emerges in a greater electric field than the Rayleigh instability. Non-symmetrical axis blending and whipping instability occurs from electrostatic repulsion between polymer jet surface charges in a strong electrostatic field. Whipping instability, which causes the jet to bend and stretch as it flows, must be enhanced to make thinner nanofibers. A wide range of electrospinning techniques was developed over the last two decades, like solution electrospinning, melt electrospinning, multiple jet electrospinning, coaxial electrospinning magnetic field-assisted electrospinning Coaxial electrospinning is used to produce core-shell nanofibers in which the bioactive molecules are kept secured inside the core and can be released on the degradation of the outer polymer coating Immobilizing in-situ polymerized PPy-NPs by solution electrospinning led to the induction of conductive properties in PCL nanofiber scaffolds, which in turn led to enhanced simulated body fluid A potential novel strategy for bone regeneration in dental and maxillofacial surgery relies on melt electrospun 3D scaffolds made of medical-grade PCL that are suited for cell adhesion and proliferation Improved bone regeneration by fabrication of PCL/gelatin multilayer scaffold based on melt electrospinning writings and solution electrospinning [10].

❖ Self-Assembly:

self-assembly is a bottom-up approach in which the small materials will be gathered to form defined molecular materials like nanofibers. Convergent synthesis is a chemical process that synthesizes molecules required for self-assembly). The morphology and other characteristics of the nanofiber produced by this method depend on the interaction between molecules. The self-assembly mechanism is mediated by ionic and hydrogen bonds, which are weak covalent bonds, hydrogen bonds, or van der Waals interaction. These interactions are weaker when isolated but stronger when combinedAlthough this method can fabricate thinner and multifunctional nanofibers, the main drawbacks of this method are low production rates and complex manufacturing processes .[10]

❖ Phase separation:

Phase separation is another method to fabricate nanofibers. In this technique, a homogeneous polymer solution is made by dissolving a polymer into a solvent like THF (Tetrahydrofuran). Then they will be allowed to separate into two phases based on physical inconsistency, with the upper polymer phase and bottom solvent phase either by adding a nonsolvent or by thermal treatment, thereby causing gelation. Gelation of polymers is considered the most significant step in phase separation since it plays a major role in maintaining the porosity and size of the polymer). After gelation, the gel will be frozen by a freeze-drying method, making it easy to remove the solvent. The structure formation can be modified by using different varieties of solvents by changing the temperature and concentration of the polymer [11].



❖ **Evolution test of nanofibers:**

Preformulation studies: -

❖ **Organoleptic Properties:**

The Organoleptic Properties of drug samples were studied for appearance, color and odor. UV spectroscopy (Determination of λmax) The standard solution of piroxicam was scanned between 200-400 nm using a UV spectrophotometer in a solution of 0.1M methanolic HCl. Drug excipients interaction studies by ATR-FTIR ATR-FTIR spectrum was used to identify and validate the drug.

❖ **Evaluation Studies for Prepared Nanofiber Patches: -**

Morphology Analysis (Scanning Electron Microscope Study)

The morphology for plain and prepared nanofiber patches was analyses by using a Hitachi S-4700 SEM (scanning electron microscope in Hitachi Company, Japan). Before being considered, samples were placed on metal ends using double-sided adhesive tape and vacuum-coated with a gold sputter layer.

❖ **Entrapment Efficiency: -**

Due to their large surface area, electrospum nanofibers are projected to have a high drug entrapment efficiency (EE). The efficiency of the preparation process for incorporating the medication into the carrier system is described by EE. Weighing and dissolving the drug loaded nano-fibre patch in phosphate buffer pH 7.4 A UV spectrophotometer set to 330 nm was used to test the solution for entrapped drug concentration in triplicate.

Percentage of Moisture Content :-

The produced transdermal films were weighed separately and maintained at room temperature for 24 hr in desiccators with fused calcium chloride. The films were re-weighed after 24 hr

❖ **Tensile Strength of Patches :-**

Tensile strength is a mechanical property that determines a formulation's capacity to withstand wear and tear during transit and handling With the use of clamps, nanofibers measuring 8 cm in length and 4 cm in width were arranged vertically along the axis of the Brookfield texture analyzer. After base localization, the instrument was permitted to operate with a minimum sensitivity force of 3 gm/cm2.

Skin irritation test and to check PH [12].

- **Nanofibers And Their Applications: -**

absorption of the drug Nanofibers amongst other uses, are an intriguing new material utilised in medical, filtration, barrier, wiping, personal care, composite, clothing, insulation and storage of energy. Nanofibers have proven their importance and convenience as medical carriers. Nanofibers are of significant interest for many applications due to their favourable features such as large surface area and porosity with tiny pore diameters 5. Lately, nanofibers have been utilised as a means of delivery for a variety of illnesses in healthcare systems. We covered some of the most important nanofibers uses below Wound healing using nanofibers Wound healing dressings cover the wound, absorb excess organic wound exudates, and accelerate the healing process. The polymer nanofibers that are generated by the generation and extension of a fluid jet are electrospun The Electrospun nanofibers are an excellent wound dressing alternative because to their unique features; the tiny pores and high-specific surface area limit the introduction of foreign microorganisms and help to regulate fluid drainages. In addition, the electrospinning method allows the integration of medicinal products in nanofibers for antibacterial and medical application It exhibited high oxygen permeability in addition to inhibiting the invasion of foreign microorganisms. Wound cures cover the wound, eliminate more bodily fluids and accelerate the cure. The wound dressing material performs such tasks, while simultaneously penetrating the moisture and oxygen as a physical barrier to the wound be Function in the medication delivery system As long as the drug content is stable, the rate of release from electrospun nanofiber may be modified by differing in the composition, porosity and form of the nanofibers. Nanofibers preserve the medication from disintegration after systemic administration as suitable via electrospun carriers. The nanofibers are employed in the delivery of drugs to a particular wound region, decreasing systemic substantially and at the same time minimising any undesirable drug effects. The idea is that as a drug's surface area and the associated carrier expands, the drug's dissolution rate also increases. Pharmaceutices products are dispersed across polymer Nanofibers. Depending on the kind of polymer carrier utilised in nanofibers production the dissolution of medicinal dose shapes may be delayed, immediate, fast, or altered. Nanofibers have been utilised successfully to carry antibody medicines, lipophilics and hydrophilics

- **The use of protective clothes:-** Due to their lightweight, high-porosity, broad surface area, resistance to chemical penetration and good filtering effectiveness, electrospun nanofibers have been identified as potential options for protective clothing.

- **In enzyme immobilisation :-**

Enzymes are employed to speed up chemical processes as a catalyst. Encourage the mobility of enzymes by introducings a variety of benefits including improved reaction control and reuseability enhance their functionality and performance in bioprocessing applications. Enzymes were immobilisated on nanofibers by physical adsorption, fibre grafting enzyme and cross-linking followed by electrospinising. Enzymes are immobilised. The polymer is supposed to include reactive groups which may chemically interact with the enzyme to penetrate the nanofibre. Electrospinning also may be utilised for incorporating enzymes into nanofibers and effectively preventing enzyme leaking after cross-linking. Due to its wide area of activity, Elektrospun nanofibers may be used as carrier for catalysts, thus enhancing catalytic performance. Nanofibre membrane has many benefits, such as its ability to be produced in a range of shapes, including well-aligned trays, and its endurance compared to carbon tubes and nanoparticles.[13,14]

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