TiO2 Nanofiber and Its Potential Application: Review

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Abstract—The nanometric scale enables the materials to expand their natural properties and make them valuable in extensive variety of utilizations. The distinctive measurements of the nanomaterials structure comprehends the morphology. The additional conventional properties of nanofibers, for example, low thickness, high surface to zone proportion causes us comprehend that how in light of these applications can the nanofibers be connected to various scope of utilization. Contingent upon the usefulness and inalienable properties the goal of research was composed and made into move. various characteristics of Titanium Dioxide with good photo-stability as well as chemical and biological stable, cheap, easier to produce, non-toxic, environment, human friendly and has self-cleaning capability, transparent to visible light, low absorption coefficient, high refraction index, strong oxidizing power, good resistance to corrosion in aqueous solution is uses in various application area.

Index Terms—Environmental protection, Nanofibers, TiO2, Tissue engineering,

I. INTRODUCTION

Nanofibers are an important tone dimensional nanostructures. Because of their little distance across and high surface region alongside the properties imported from the polymers of which they are made, nanofibers have an enormous number of utilizations in different fields like that of vitality collecting and capacity, condition assurance and biomedical field. The following are a portion of the uses of nanofibers that will give an unmistakable thought of its properties and motivation behind why they are being utilized. The Nanofibers have their own properties: The properties of nanofibers have given it such extensive variety of utilizations in all areas. The accompanying enrolled are a portion of the overwhelming properties that have made nanofibers so difficult, they are as per the following: Extremely high specific area due to their tiny diameters, Nanofibers membranes square measure extremely porous with wonderful pore interconnectivity, High pore volume, and tight pore size, Physical, electrical, thermal and mechanical properties build them appropriate for varied industrial applications. Titanium dioxide or Titania is a substance which is inorganic in nature. It has following basic properties which make them helpful in many fields: Thermally steady, Non-combustible, Poorly solvent, Non-perilous. This artificially inactive component is an oxide of metal called titanium. Numerous items beginning from shopper items, for example, beauty care products, paper and paperboard, paints to mechanical merchandise, for example, water treatment specialists, machine types of gear and so on. TiO2 as a color is essentially used to streamline the dissipating of noticeable light. For this exclusive portion of molecule measure is required i.e. 400 to 700 nm is required for scrambling. TiO2 nanomaterials are intended to have measure under 100nm to make utilization of it. TiO2 nanomaterials are potential possibility for photocatalysis and are incredible UV safeguards. TiO2 is in this manner said to be an item with extensive variety of uses in the market and not hurtful to people. The properties of TiO2, it is accessible in nature in three structures in particular Rutile: One of the types of titanium dioxide and is a most common type of titanium dioxide. This gem has the most noteworthy refractive list at obvious length, Anatase: One of the three mineral types of titanium dioxide is the Anatase stage. Like rutile stage it is additionally notable as an event of polymorphs of titanium dioxide. There are
significant contrasts in the middle of the two said stages like the precious stone structure (vertical hub longer in Anatas stage), Brookite: Brookite is the orthorhombic variation of titanium dioxide TiO2, which happens in four regular polymorphic forms the precious stone structure of brookite period of TiO2 nanofibers. Rutile and Anatas phase are the two main polymorphs of this material which have excellent photolytic behaviour. Why TiO2 nanofibers? Nanofibers are an important one dimensional nanostructures.

Due to their small diameter and very high surface area along with the properties imported from the polymers of which they are made, nanofibers have a huge number of applications in various fields like that of energy harvesting & storage, environment protection and biomedical field. Below are some of the applications of nanofibers that will give a clear idea of its properties and reason why they are being used.

II. APPLICATIONS OF TiO2 NANOFIBERS

Nanofibers, a class of nanomaterials that possess extraordinary properties make researchers use nanofibers in several domains of research. According to the survey on applications of nanofibers many developers and research scientist from multifarious universities are coming up with new developments with the use of nanofibers. Many industries dealing with nanofiber products are competing in the global market. Nanofibers are being wholly used in almost each domain starting from biological, biomedical, electronics, energy storage, textiles and clothing to environmental applications such as filtration, noise reduction etc.

As shown in the figure 5.1 above usage of nanofibers are thus increasing day by day. The filtration media uses nanofibers for the filtration of gas, liquid and molecules. It yields higher filter efficiency. The sensors for physical, chemical and biological applications make use of nanofibers. Thermal sensors, piezoelectric sensor, biochemical sensor, fluorescence optical chemical sensor are the various nano sensor devices that make use of nanofibers for sensing applications in electronics as well as biomedical domains. Use of nanofibers increases the sensitivity. Each of the application is explained in detail below:

A) Energy harvest and storage

i) Dye Sensitized Solar cells (DSSCs): In the field of vitality and sun based gathering TiO2 has been a material of decision and generally broadly. This TiO2 when electrospun into vertical nanofibers is accounted for to act as a photograph terminal. The initial step to plan such vertical nanofibers of TiO2 is to electrospin, with consequent post-treatment of nanofibrous TiO2 strips and cutting of such vertically adjusted nanofibers in order to give a 3D structure.

Figure 2: shows Potential Applications of Nanofibers

The tallness of vertical nanofibers arranged is of around 27 μm however is variable from 10 to 100 μm with a normal zone of 0.2 cm² and 90±30 nm width. Vitality is one of the essential necessities for advancement of present day world. The Rapid annihilation in the petroleum products made a need being developed of option effective wellsprings of vitality preservation. This prompt a logical viewpoint towards nanotechnology and its different applications. The traditional sun powered cells confront two noteworthy impediments of less productivity and high
assembling cost, nanotechnology prepared sun oriented cells may beat these confinements. [1-3, 4-6].

ii) Li-ion batteries: According to the report the cathode material of Li-ion batteries using the 3-D structures of LiFePO4 coated nanofiber nonwovens were successfully prepared. It showcased good performance with discharge delivering capacity of 156 &152 mAh/g at discharge rates of c/25 & c/10 at room temperature, respectively of uniformly distributed LiFePO4 crystallites over the surface area of carbon nonwoven fibers. This finding correlates to the 92% of the theoretical value of the former and 89.5% of the later discharge rates. Thus, such electro spun cathode materials can undoubtedly correspond to the material of a high electronic conductivity and a high “free” surface area of the carbon nanofibers. These electro spun fiber mats used for electronic components have the ability of improving battery power, increasing energy density of capacitors, fuel cell and solar cell efficiency. The Li-ion batteries use Poly (olefin) microporous membranes as commercial separators. As battery membranes require materials with high specific area electro spun fiber mats are a good candidate as a result of high porosity [60].

iii) Hydrogen storage: The use of hydrogen is being thought of as a candidate for solving energy related crisis. Currently the major issue is faced for the storage of hydrogen. This can be easily solved by the help of nanotechnology. Carbon based nanofibers are potential platform for the storage of hydrogen. Other carbon based materials can also be used such as CNT’s, graphite. Various polymers such as PAN, PANi and PCS have been used [8-11].

iv) Fuel Cell: Function: Fuel cells are electrochemical devices which use metal catalyst for converting hydrogen fuels and hydrogen rich fuels into electric current charge. The different types of fuel cells are as follows: Proton exchange material fuel cells, Direct methanol fuel cells, Alkaline fuel cells, Solid Oxide fuel cells. The need for Fuel cells is because electro spun materials are being used in fuel cells instead of Platinum nanoparticles due to its high cost. The platinum Nano particles also pose limited commercialization. Thus there was a need of an economic replacement of Electro spun materials which are made for an alternative catalyst which has properties like high catalytic efficiency, highly durable [12-21].

v) Mechanical energy harvesters: Nanogenerators have been accounted for to have the capacity to change over the mechanical vitality straightforwardly to electrical power. The making of such nanogenerators require magnificent controlled conditions. By the procedure of electrospinning, piezoelectric materials can be consolidated into the nanofibers and process. Reports have indicated expanded vitality stockpiling and searching. Polymer, for example, PVdF has been of awesome utilize [22-28].

B) Biomedical Applications:

i) Wound healing: Wound healing is a method of regenerating damaged tissues. Wound healing takes long time for generation when nature of wound is deeper and regeneration is solely dependent on edges of damaged tissues. The process of healing after tissue damage includes: a) Inflammatory phase. Proliferative phase, Remodelling phase, Epithelialisation. a) Inclusion of silk electro spun nanofiber mats to the process of wound healing has shown faster rate of healing by 90%as compared to traditional wound healing techniques. b) Experiment and comparison analysis, between electro spun collagen nanofiber mat and normal cotton gauze has shown the results in the favour of electro spun collagen nanofiber and thus help healing with much faster rate. c) Electro spun collagen nanofiber mats contains special type of antibiotic agents which help to reduce adhesion which are caused after abdominal surgery. d) The process of electrospinning can be made effective by adding Ag ions. This includes adding. e) AgNO3 directly to solution thus proving advantages of antimicrobial ability as end result [29-41].

ii) Drug Delivery: Drug delivery is the process by which medication is administrated to the patient at a controlled rate for optimum delivery, prevention against drug toxicity and to minimize any side effects. In this system, a carrier material is used to load the drug and this is then detached from the carrier whenever delivery of the drug is required. Electrospun fibers due to their hydrophilic and highly porous
character have proved to be excellent drug carriers. They have very high specific surface area which guarantees higher controlled release rate than bulk films. All three different drugs i.e. water soluble, water insoluble and water sparingly soluble along with macromolecules like bioactive proteins and DNA have been tested on biodegradable polymers and have demonstrated excellent drug delivery potential depending on nanofiber morphology i.e. hydrophobic or hydrophilic character.[42-46].

iii) Tissue engineering: Tissue engineering which consists of artificial tissue growth for replacement or repair of the damaged organs is one field which has turned into reality thanks to the scaffolds made of nanofibers. The procedure consists of growing a tissue in lab by supporting the cell culturing on an artificial scaffold/ matrix made of nanofibers. When this tissue fully grows into the organ to be replaced it is then replaced in the body with damaged organ. Being highly porous and biodegradable, this artificial scaffold then degrades in the body to be excreted away. Thus, its basic functioning is to give proper shape and size to the artificial organ being grown. On similar grounds blood vessels are ultra-thin with great mechanical properties and come in different sizes. If these needs to be replaced, similar properties are expected of nanofibrous materials, luckily which they possess if fabricated accordingly. The design if made bilayered of the nanofibers, proved to be an excellent choice for blood vessel replacement and cell culturing. This bilayered nanofibrous artificial blood vessel consists of a still outer oriented layer and a randomly oriented inner layer.

The materials used for fabrication can be poly(lactic acid) (PLA), poly(ester-urethane)urea etc. Similarly, it has been found that the scaffolds made of poly(capro lactone) (PCL), when treated with mesenchymal stem cells in the presence of extracellular matrix and collagen (type I) were able to form bone like appearance demonstrating the possibility of these nanofibers in bone tissue engineering. These scaffolds showed significant improvement in their functioning when blended with materials like nanoparticles of calcium carbonate, gelatin or hydroxapatite.[81-91]

iv) Blood vessels: Replacement of Blood Vessels is a difficult process and becomes even more complex when the blood vessels are fine, i.e. in the range below 6 um. Fabrication of bi-layered electro spun can be carried out in order to impart then with various properties pertaining to the original blood vessel.

C) Sensor: Sensors are being used on large scale for detection of hazardous chemicals present in the air. In addition these sensors are can be applied for purification of water, checking humidity, medical detection, and safety and defence applications. Various nanofibers have been incorporated either directly or indirectly. The sensing capacity of nanofibers decides its usage for application point of view. Sensors that are of different type are used with combination of nanofibers. For example for water purification, electrospun PAA nanofibers are used for detecting the metal ions present in the water. Conductivity is an important factor for the sensor to perform and produce correct results. Oxide nanofibers, conducting nanofibers can be produced by the process of electrospinning. Semiconducting oxides, polymers (PANi, PAA, PEO etc.) can be used during this process [58-78].

D) Environmental Protection:

i) Filtration: It is infrequently imperative to expel strong particles from whatever other media like gas or fluid stage substances. This can be completed by filtration. Large scale estimated particles are sifted by sieving though fine particles are channels by different wonders like searing movement, electrostatic fascination, translation and so on. Filtration locate an enormous number of utilizations in the field of
medicinal, vehicle, family unit, resistance and other everyday tasks. Electrospun strands show attributes which are perfect for filtration. It has been accounted for that electrospun nanofibers filtration capacities outperformed even the filtration capability of HEPA channel whose filtration proficiency is 99.97%. PVA, Polystyrene are a portion of the materials utilized for the creation of nano-strands for filtration [79-80].

ii) Metal ion adsorption and recovery: Water contamination is a significant issue our reality is confronting today and should be cooked as soon and as effectively as could be allowed. Water contains particles which are decidedly charged as polluting influences and these can be inconvenient to human wellbeing and posture extraordinary hazard. These particles however have been observed to be expelled by proclivity towards certain useful gatherings by physical or substance ways. Electrospun nanofibrous materials have indicated awesome potential towards this objective. Their inalienable property of being functionalized while being electrospun, their high surface range and high porosity ensure that such particles are caught once these nanofibers are utilized as channels. Cases incorporate keratin/silk nanofibers for gathering Cu (II) metal particles and amidoxime-altered PAN nanofibers for catching in Cu (II) and additionally Pb(II) polluting influences [81-86].

iii) Catalyst and enzyme carriers: The fundamental capacity of impetus helps in nano-fiber innovation as well. The property of impetus to improve a synergist response helps in making productive nanofibers. The qualities to upgrade the catalysis movement, enhanced security and making the procedure substantially less complex makes it potential candidate in the field of nanotechnology. As the electrospun nanofibers are being utilized as tangle for impetus bearer, it gives an expansive surface region and dynamic destinations. Different techniques are additionally utilized for uniting of impetus onto the electrospun nanofibers, for example, covering and surface alteration [85-84].

III. CONCLUSION
Applications of the electrospun nanofibers were discussed including scaffolds for bone tissue engineering, skin grafting and wound healing, water purification and other filtration techniques etc are clarified for TiO2 nanofibers. In this manner other than pushing ahead to adjust these utilizations of 1D nanostructure endeavors are additionally made to make ethical implications of nanotechnology has an entire to maintain a strategic distance from or limit any undesirable impacts of nanotechnology.

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