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Design and Development of Novel antibacterial nanofiber tea bags for clean drinking Water

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Abstract: Polymeric nanofibers can be effectively used in water purification process. These can be used for filtration process because of the highly porous mesh size. For such applications membranes with a hydrophilic surface are preferred, as a hydrophilic surface is less susceptible to membrane fouling. The nanofiber with antimicrobial property will have an additional benefit in water purification. The development of a nanofiber water purification system using electrospinning of hydrophobic polystyrene and hydrophilic 1, 6-hexanediol diacrylate followed by trapping of an antibacterial material for water purification is described. This report is a review of design and development of an anti-microbial tea bag using nanofibers embedded with scallop shell powder.

Index terms: nanofiber, hydrophilic membrane, scallop shell powder, antimicrobial activity.

1. INTRODUCTION

The increase in the world population and contamination of existing water sources by chemicals, bacteria and viruses has contributed higher demand for fresh water and energy resources. A widely used method to inactivate pathogenic microorganisms in water and wastewater and for preventing waterborne diseases throughout the world is the application of membrane technologies, ozonization, chlorination, and UV light. Nanofibre membrane can be used as a cost-effective alternative since it has a small pore size and large surface area to volume ratio compared to nonwovens[1]. This, together with their low density and interconnected open pore structure, make the nanofibre nonwoven appropriate for a wide variety of filtration applications

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The development of electrospun nanofibrous membranes (ENMs) have shown that ENMs can be potentially applied as microfiltration (MF), ultrafiltration (UF) and nanofiltration (NF) membranes in water filtration due to enhanced flux, lower operational pressure and energy savings[2]. When mid-layer made up of ENMs produced by electrospinning has been applied in the thin film composite (TFC) configuration in NF application; higher permeate fluxes than conventional membranes were achieved due to the high porosity, low trans membrane pressure and interconnected pore structure of ENMs.

Most of the known polymeric membrane materials used for electrospinning are hydrophobic in nature. This hydrophobic nature is highly undesirable for the pressure driven membrane processes in the water treatment applications. For such applications membranes with a hydrophilic surface are preferred, as a hydrophilic surface is less susceptible to membrane fouling. It is a major obstacle to the widespread use of this technology. Membrane fouling can cause severe flux decline and affect the quality of the water produced[3]. Severe fouling may require intense chemical cleaning or membrane replacement. This increases the operating costs of a treatment plant. For such applications membranes with hydrophilic surfaces are preferred, as a hydrophilic surface is less susceptible to membrane fouling. Also they tend to increase the flux and rejection. In the present proposal, a novel method for the synthesis of electrospun hydrophilic polymeric nanofibers is described. Here two types of nanofiber membranes will be discussed: (i) electrospinning of hydrophobic polystyrene and hydrophilic 1, 6-hexanediol diacrylate materials followed by deposition of nanoparticles on this nanofiber support for water purification studies. It is proposed to develop an anti-microbial tea bag using nanofibers embedded with scallop shell powder. The flexible nature of the hexanediol diacrylate material will enhance both the hydrophilicity and life span of the membrane [4] (Figure 2). (ii) Electrospinning of hydrophobic polymers with hydrophilicity and coating of nanofibers by novel polymer support resin through post treatment conditions. Comparison of above concepts and testing for desalination and waste water treatment applications will be carried out.

2. NANOTECHNOLOGY FOR WATER PURIFICATION

Nanofibers are an exciting new class of material used for several value added applications such as medical, filtration, barrier, wipes, personal care, composite, garments, insulation, and energy storage. They are able to form a highly porous mesh. Nanofibrous filtration has the advantage of high surface to volume ratio, low basis weight, high permeability and small pore size. This can remove unwanted particles smaller than 0.3 µm. These can use to separate solid impurities from liquid phase by filtration, adsorption or neutralization.

3. ELECTROSPINNING NANOFIBERS FOR WATER TREATMENT

Polymeric nanofibers are produced by an electrospinning process[5]. Electrospinning is a highly versatile technique that can be used to

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create ultrafine fibres of various polymers and other materials, with diameters ranging from a few micrometers down to tens of nanometres.

Electrospinning is a process that spins fibers of diameters ranging from 10nm to several hundred nanometers. The nonwoven webs of fibers formed through this process typically have high specific surface areas, nano-scale pore sizes, high and controllable porosity and extreme flexibility with regard to the materials used and modification of the surface chemistry of the fibres. A combination of these features is utilized in the application of electrospun nanofibres to a variety of water treatment applications, including filtration, solid phase extraction and reactive membrane[6].

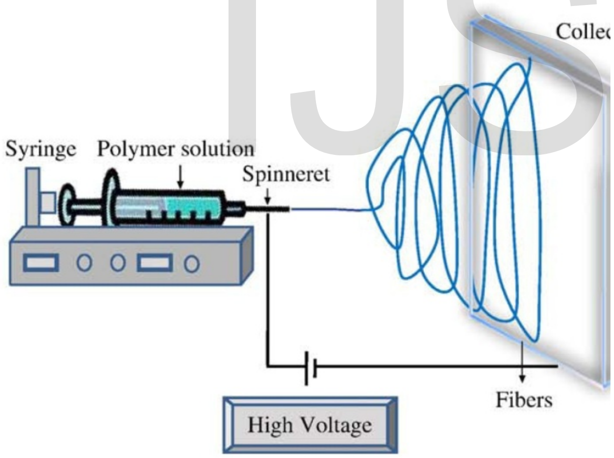


Figure 1: Schematic representation of electrospinning

4. PREPARATION OF POLYMERIC NANOFIBER

Electrospinning is a fiber production method which uses electric force to draw charged threads of polymer solutions or polymer melts up to fiber diameters in the order of some ten nanometers. Nanofibers have significant applications in the area of filtration since their surface area is substantially greater and have smaller micropores than melt blown (MB) webs[7]. High porous structure with high surface area makes them ideally suited for many filtration applications. Nanofibers are ideally suited for filtering submicron particles from air or water. Electrospun fibers have diameters three or more times smaller than that of MB fibers. This leads to a corresponding increase in surface area and decrease in basis weight.

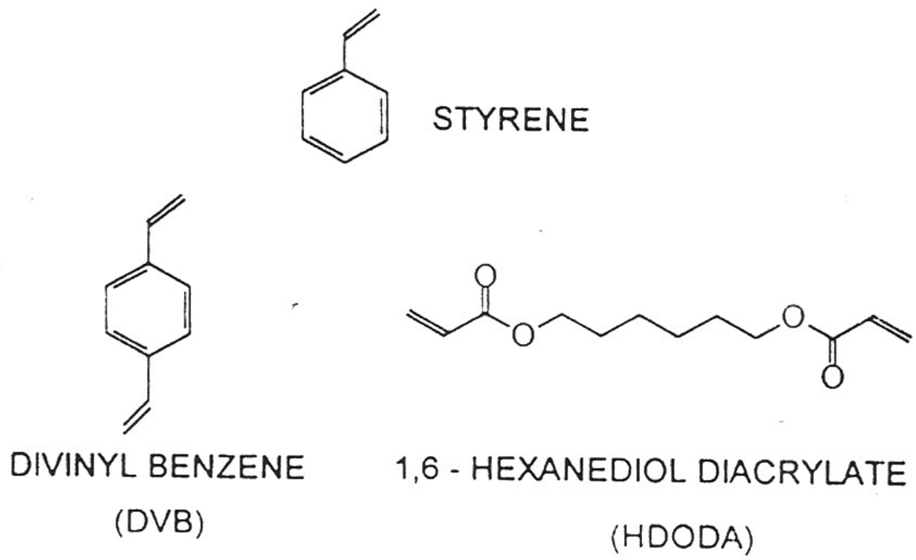
Relatively a small number of polymers have been tried to be electrospun into nanofibers, and the understanding in electrospinning process, property characterization of nanofibers obtained by this process, and in the exploration of these nanofiber applications specifically for nanocomposites is very limited. Extensive researches and developments in all these three areas are required in the future. Most of the known polymeric membrane materials used for electrospinning are hydrophobic in nature. This hydrophobic nature is highly undesirable for the pressure driven membrane processes in the water treatment applications. For such applications membranes with a hydrophilic surface are preferred, as a hydrophilic surface is less susceptible to membrane fouling. It is a major obstacle to the widespread use of this technology. Membrane fouling can cause severe flux decline and affect the quality of the water produced. Severe fouling may require intense chemical cleaning or membrane replacement. This increases the operating costs of a treatment plant. For such applications membranes with hydrophilic surfaces are preferred, as a hydrophilic surface is less susceptible to membrane fouling. Also they tend to increase the flux and rejection. In the present proposal, a novel method for the synthesis of electrospun hydrophilic polymeric nanofibers is described. Here two types of nanofiber membranes will be prepared: (i) electrospinning of hydrophobic polystyrene and hydrophilic 1, 6-hexanediol diacrylate materials followed by deposition of nanoparticles on this nanofiber support for water purification studies. The flexible nature of the hexanediol diacrylate material will enhance both the hydrophilicity and life span of the membrane. (ii) Electrospinning of hydrophobic polymers with hydrophilicity and coating of nanofibers by novel polymer support resin through post treatment conditions. Comparison of above concepts and testing for desalination and waste water treatment applications will be carried out

5. ANTIMICROBIAL TEA BAGS

Nanofibers in bags trap contaminants and granules of carbon which are harmless to humans, kill off bacteria by shredding through their cell membranes. Heated scallop shell powder (HSSP) [8,9,10] possesses broad antimicrobial action against the vegetative cells of bacteria, spores and fungi. Heated Scallop Shell Powder is made by treating scallop shell powder with a special firing process. The main component of scallop shell is $CaCO_3$ which is converted to CaO when heated. The antimicrobial action of scallop shell originates from the CaO generated. CaO exhibited strong antibacterial and antifungal activity against a wide range of microorganisms. The nanofibers prepared can be embedded with scallop shell powder so that it can act as a water purification system.

6. FABRICATION OF ANTIMICROBIAL AGENTS INTO NANOFIBER

The development of a nanofiber water purification system using electrospinning of hydrophobic polystyrene and hydrophilic 1, 6-hexanediol diacrylate followed by trapping of an antibacterial material for water purification is described. The flexible nature of the hexanediol diacrylate material will enhance both the hydrophilicity and life span of the membrane. It is proposed to develop an anti-microbial tea bag using these nanofibers embedded with scallop shell powder in the form of a sachet. Such tea bags could be used as a filter or dipper before drinking tap water. These tea bags will be beneficial to the third world countries where getting clean water is still a huge challenge.



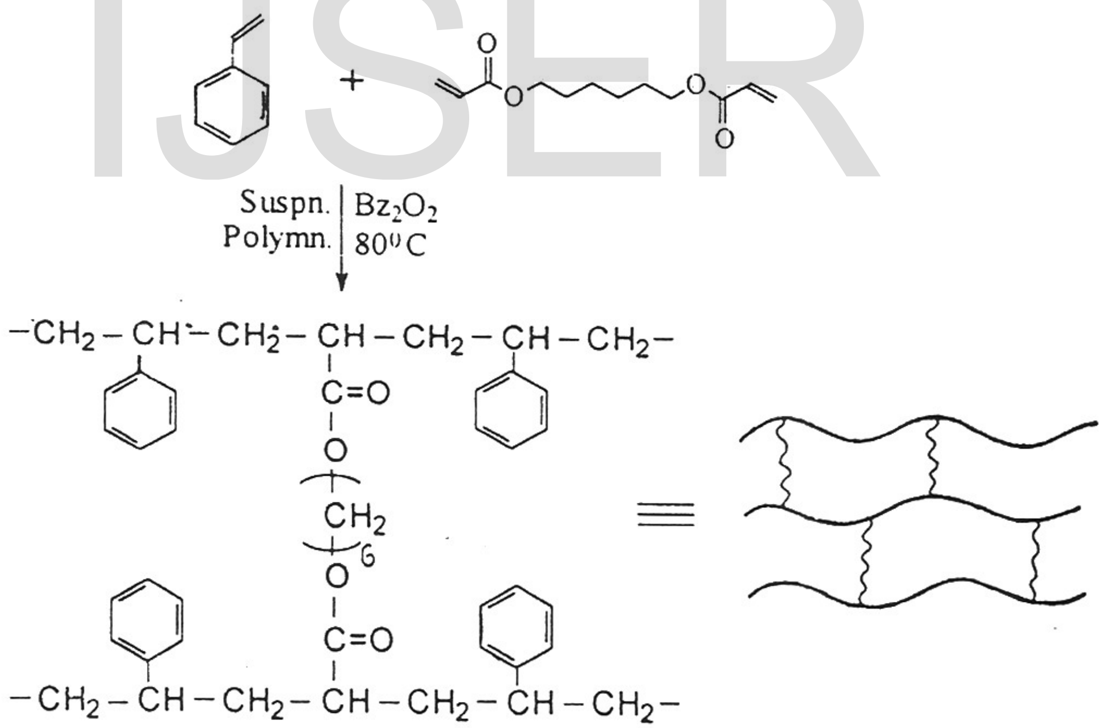


Figure 2: Preparation of HDODA-crosslinked polystyrene by suspension polymerization

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