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Research Note

Electrospun membranes: Next generation membranes for desalination and water/wastewater treatment

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Population growth, life style changes, and urbanization have always been and will remain as the main drivers of energy and water demand, along with larger amount of wastewater generation. As the world population rises dramatically, we would also be faced with a more serious environmental crisis, i.e. water resource pollution, which could lead to the serious health problem in all parts of the world. By some projections there will be almost 9 billion people inhabiting on the planet by 2050 and one of the many issues raised by this expected population surge is how to supply fresh water for all those people [1]. Consequently, the need for technological innovation to enable novel desalination and water/wastewater treatments cannot be overstated. Nano-engineered membranes hold great potential in advancing water and wastewater treatment to improve the efficiency of impurities removal as well as to augment water supply via safe use of un-conventional water resources. In this regard, electrospinning technology, for fabricating nanofibers, as emerging and versatile techniques have promising features.

Electrospinning is a technique that relies on repulsive electrostatic forces to draw a viscoelastic solution into nanofibers [2]. It is worth quoting that besides electrospinning, there are various techniques used for preparation of nanofibers. Even though each method carries along its advantages, the electrospinning has a leading edge over all of them. This is due to the fact that this technology is able to easily control the fabrication, orientation and morphology of the nanofibers [3]. Although the production rate of fibers via electrospinning is relatively low compared with conventional fiber production processes, a number of strategies have been implemented towards scaling up the electrospinning technology [4]. With an increase in the number of companies active in this field, i.e. electrospun nanofibers, over the last decades, the electrospinning technology is expected to progressively move from bench-scale in the laboratory to an industrial-scale process.

Microporous polymeric membranes, which have been used progressively for various applications [5], can be fabricated through different methods [6]. Each method has its own benefits and limitations. In the past few years, electrospinning technology has been investigated by several groups for the fabrication of microporous polymeric membranes [7]. Hence, the development of electrospun membranes, either microfibrous or nanofibrous, with a three-dimensional (3D) interconnected pore structure has opened up a new window in membrane separation processes.

In the liquid filtrations through pressure-driven membrane processes, it is necessary for the filter to separate particulate, bacteria, etc. Although this need is increasingly met by membrane technology, low throughputs of these membrane-based separations have driven the new and novel membranes. In this regard, electrospun membranes are gaining increased attention in the literature [8]. The main advantages of electrospun nanofibrous membranes (ENMs) are the presence of the fibrous network, which provides a high internal surface area and hence enormous dirt loading capacity when compared to conventional membranes with a 2D structure. Having high porosity and a 3D interconnected pore structure are other advantages of ENMs [7].

For further application of electrospun membranes as direct filtration media, electrospun polymeric webs can be used as the support layer for the new generation of thin film composite (TFC) UF/NF/RO membranes. TFC membranes comprise three fundamental layers, including the top ultrathin selective layer, middle porous support layer and bottom nonwoven fabric layer. Recently, there is a worldwide attention to application of electrospun fibers as the support layer of TFC membranes [9].

While higher hydrophilicity and lower surface roughness of electrospun nanofibrous membranes are useful when they are used for pressure-driven membrane processes, being hydrophobic, or even super-hydrophobic, is critical when such membranes are used for the membrane distillation (MD) process. MD is a thermally-driven separation in which pure water could be separated from a contaminated source such as saline water (e.g. seawater, brackish water or even a wastewater sample containing non-volatile impurities) [1]. In contrast to worldwide attention to the MD process, especially for desalination and water/wastewater treatment purposes, this method has not yet been introduced on an industrial scale. One of the most important reasons for this is the lack novel and specific membranes for the MD process. The applied membranes in the MD process should confirm some specifications before they can be used, e.g. should be hydrophobic, as highly porous as possible, high liquid entry pressure (LEP), good thermal/chemical/mechanical stability, etc. [10]. However, most of the applied membranes for MD are those commercially fabricated for MF purposes and made of hydrophobic polymers. In this regard, ENMs have shown promising features to be used in the MD process [11].

The presence of difficult to separate emulsions, mostly oily wastewaters, can be a costly problem in various industries [12]. Oily contaminants can cause final products to be off-specification, deactivate expensive catalysts, foul stripping trays and delay downstream storage tanks, and consequently increase the costs for wastewater treatment. On the other hand, breaking stable emulsions can be a difficult task depending on the physical properties of the oil, water and surfactant system. Liquid-liquid coalescing filtration can be used to accelerate the merging of many droplets to form a fewer number of droplets, but with a greater diameter. Settling/rising of the larger droplets downstream of the coalesce element then requires considerably less residence time. The coalescing medium is the heart of such treating systems. In this regard, ENMs with more contacting surface (i.e. nanofibers surface) can effectively be used for enhancing the coalescing performance [13].

Electrospun nanofibrous membranes (ENMs), as the next generation of filtration media, have promising features and can make good opportunities for advanced filtrations in the future. To enhance the morphological and topographical features of ENMs, various methodologies including molecular bonding, *in situ* polymerization and addition of molecular dopants can be combined with electrospinning technology. Moreover, strategies for surface modifications, e.g. nanoparticles coating, treatment with chemicals or heat, grafting and interfacial polymerization, are found to be suitable techniques to alter the surface characteristics and improve the filtration performance of ENMs. The ENMs were also effectively used in the oily wastewater treatment. In recent years, many groups have paid more attention to the functionalities of ENMs and improve their applications to the industrial scales.

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