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Enhancing the Mechanical Strength of Electrospun Nanofiber Membrane by in-situ Polymerization

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ABSTRACT

Nanofiber-based membrane has been considered as a superior material for many applications, including air filtration, rechargeable batteries, solar cells, sensors, and drug delivery. Typical electrospun nanofiber membranes are featured with submicron fiber diameter, interconnected porous structure, and large porosity. However, a main drawback of electrospun nanofiber membrane is its poor mechanical strength. The electrospun nanofibers are piled together and lack inter-fiber binding. As a result, electrospun membranes typical have poor mechanical strength with inadequate durability in many applications. Therefore, there is a need to enhance the mechanical strength of electrospun nanofiber membranes.

In this study, we enhance the mechanical properties of electrospun nanofiber membranes by in-situ polymerization. Polyacrylonitrile (PAN) solution of 7 wt.% was prepared and fed into a lab-made electrospinning device to produce PAN nanofiber membrane with the following operational parameters: solution feed speed of 0.65 mL/h, applied voltage of 11.25 kV, and tip-to-collector distance of 12 cm. PAN nanofibers were collected using a rotating drum collector. Then, the as-prepared PAN nanofiber membrane was soaked into a pyrrole solution, followed by adding sodium ferrocyanide and Ammonium persulphate as dopant and oxidant, respectively. After that, the treated nanofiber membrane samples were thoroughly washed using deionized water. Finally, the membrane samples were dried in an oven for characterization.

Scanning electron microscope (SEM) and universal testing machine systems were used to characterize the morphology and mechanical property of the electrospun membrane samples before and after post-treatment. The SEM results reveal that a core-shell fiber structure was formed after sample post-treatment. The sheath layer has resulted from the in-situ polymerization of pyrrole onto the electrospun PAN fiber surface. More importantly, the in-situ polymerization also resulted in the binding of adjacent fibers. These binding points reinforce the mechanical strength of the fibrous membrane. Based on the data obtained from the universal testing machine systems, the plotted stress–strain curve clearly showed that the maximum tensile strength of the membrane increased after in-situ polymerization treatment. The results from this study suggest that the in-situ polymerization treatment can enhance the mechanical strength of electrospun nanofiber-based membranes.

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