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Multilayered membrane spacer: does it enhance solution mixing?

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Abstract

The present review systematically investigates and illustrates the effect of multilayered membrane spacers on the features of fluid dynamics that influence all performance metrics. Multilayer spacers are frequently composed of three sets of filaments (i.e., top, middle, and bottom layers), which has the benefit of increasing mass transfer and decreasing membrane surface fouling when compared to ordinary monolayer (*e.g.*, extruded spacer) and two-layer spacers. The review found that the multilayer spacer's middle layer disperses primary flow to the thin side spacers placed near the membrane's surfaces. The thin side spacers will then form narrow passageways to keep the solution *in situ* for as long as mass transfer is achievable. The employment of thin spacers close to the membranes at satisfactory operational conditions (e.g., adequate flow velocity) results in swirling flows and incorporation of transverse and longitudinal eddies near to the membranes, reducing the boundary layer's width and making the associated ion concentration domain at the membranes much more consistent. The concept and implementation of multilayer geometry in feed channels appears to be promising, since a multilayered spacer can function at a lower maximum flow velocity than normal two-layer spacers, saving operational energy while minimizing concentration gradients at the membrane surfaces. Furthermore, the multilayer structure's durability and mechanical strength may help to reduce membrane deformation and maintain long processes. Future studies might look at significantly reducing spacer thickness for industrial uses.

Keywords: membrane spacer geometry; multilayered membrane spacer; spacer–bulk attack angle; spacer filaments/strands; pressure drops; electrodialysis desalination; channel hydrodynamics; ion exchange membranes; mass transfer; membrane fouling/clogging; wastewater treatment

INTRODUCTION

Maigrot and Sabates first described the theory of electrodialysis desalination in 1890, and its industrialization began more than 50 years ago.[1] Electrodialysis has been used in the chemical, food, and pharmaceutical industries, as a result of the evolution of ion-exchange membranes (IEMs).[2] Moreover, significant advancements have enabled electrodialysis to be scaled up and utilized in the wastewater sector.

Conventional structures of electrically driven membrane processes are made up of bonded repeating subsystems, as with electrodialysis-related processes.[3] Anion-exchange membranes (AEM), cation-exchange membranes (CEM), bordering silicon gasket-linked spacers, outlet/inlet openings per compartment, and couple conductors (or electrodes) are put to use in electrically driven membrane processes.[3] A thick silicone sheet is included as a sealing gasket positioned among terminal membranes and closing layers in all stacks to cover the meshes (or spacers) and secure the sidewalls of the electrolyte, concentrate, and dilute sections to prevent liquid leaks.[4]

Cation- and anion-exchange membranes possessing active sites are at all times alternately packed among two end plates at fixed distances (i.e., inter-membrane interval), which are set by membrane spacers of particular widths (μm). Every repeating cell pair in the stack constitutes a dilute and concentrated section. Pumps force and draw fluids to stream within ducts supplied with membrane spacers. Figure 1 demonstrates a stack of reverse electrodialysis, as an example of electrically driven membrane operation consisting of four components bonded together.

Membrane spacers, which serve as motionless mixers, are interposed at standard distances among every couple of IEMs to keep the membranes apart, safeguard the intermembrane span for fluids to transport through, and strengthen the mechanical properties of the membrane layers facing elevated inlet hydraulic pressure and membrane rupture.[6,7] With regard to intermixing characteristics, meshes are utilized to form and retain the critical stream pattern within neighboring membranes, to minimize the risk of short circuits in narrow cells, and to stimulate turbulent regimes and higher ion transport at the IEMs and electrodes. If

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