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A new approach to modeling liquid intrusion in hydrophobic fibrous membranes with heterogeneous wettabilities

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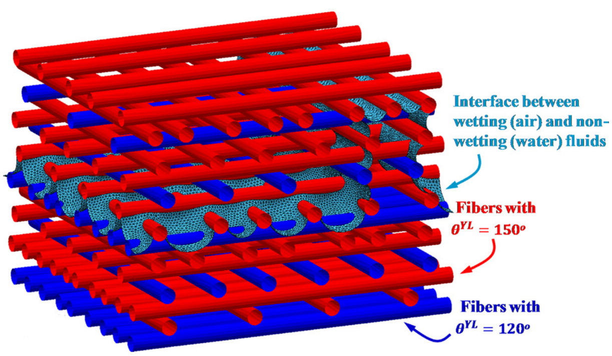
GRAPHICAL ABSTRACT



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ABSTRACT

The current paper presents an energy minimization method, implemented in the Surface Evolver code, for tracking the air–water interface intrusion in a hydrophobic fibrous membrane and thereby studying the effects of the membrane's microstructure on its resistance to water intrusion (i.e., membrane's liquid entry pressure). The simulation method developed in this work is computationally affordable and it is accurate in its predictions of the air–water interface shape and position inside the membrane as a function of pressure (and the size or contact angles of the fibers). Due to challenges in applying the present interface tracking method to membranes having highly complex internal microstructures (e.g., media comprised of dissimilar fibers with random three-dimensional orientations), this study is limited to membranes comprised of orthogonally oriented fibers. Application of the proposed simulation method in studying effects of fiber diameter or contact angle heterogeneity on water intrusion pressure is demonstrated for such orthogonal fibrous structures.

1. Introduction

Capillarity is the major factor in characterizing the nature of fluid interaction with a porous material. Fibrous materials with positive capillary pressure are hydrophobic and they can be used as a membrane or as a water-resisting barrier for a variety of applications [1–12]. Precise capillary pressure prediction is also important for proper design of gas diffusion layers (GDLs) for fuel cells [13–17] or for applications

Abbreviations: L, liquid; G, gas; SVF, solid volume fraction; AWI, air–water interface; YLCA, Young-Laplace contact angle

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