Design of a Single Lamina for a Microchannel Dialyzer with a Focus on Bubble Removal

By Mahshid Mohammadi
Candidate for Doctor of Philosophy in Mechanical Engineering

Abstract

A microchannel-based hemodialyzer offers a novel approach to hemodialysis practice and holds many promises for improving dialysis treatment efficiency and life quality for kidney patients. The hollow fiber hemodialyzer, a conventional dialysis device, has certain limitations including non-uniformity of the dialysate flow path which necessitates the use of a high dialysate flow rate. In the microchannel-based design, successive stacked layers alternate between blood flow and dialysate flow. A flat porous membrane between these layers allows for the transport of toxins from the blood side to the dialysis fluid side. This design improves mass transfer characteristics and enables the use of lower dialysate to blood flow rate ratios suitable for a home hemodialysis system. One of the current issues in dialyzers is the emergence of bubbles through blood-outgassing and air ingress. This dissertation provides an in depth study of the bubble pinning phenomenon and the impact of the geometrical design of a single lamina of the microchannel dialyzer on bubble removal.

The effects of contact angle hysteresis and contact line (pinning) forces as well as the dewetting velocity on bubble stagnation have been studied. A theoretical model that estimates the required pressure drop along the length of a stagnant bubble to overcome pinning forces to stimulate motion has been developed. The model has been validated by experimental results.

A single lamina of a microchannel dialyzer is comprised of an inlet manifold, an outlet manifold and parallel microchannels; the manifolds feature a micropost arrangement that supports the membrane. The overall manifold geometry was designed for uniform flow distribution while the suggested arrangement of microposts inside the manifolds was aimed at exhibiting low bubble retention.

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