Numerical and Experimental Studies of a Capillary Channel

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Introduction: Capillary effects are common in microfluidics due to large surface-to-volume ratio. In this work we design a capillary channel for transporting methanol in fuel cell, and investigate its performance numerically and experimentally.

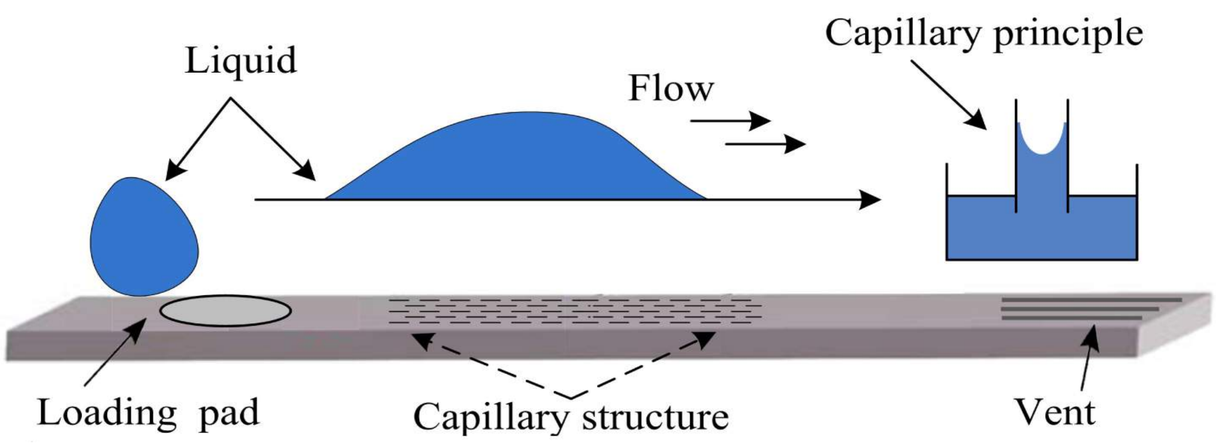

Figure 1. Principle of the channel

Computational Methods: Our design consists of a capillary channel between a loading pad and a vent as shown in Figure 1. Once loaded on the pad, methanol will automatically move towards the vent driven by capillary force.

$$\frac{\partial \phi}{\partial t} + \mathbf{u} \cdot \nabla \phi = \gamma \nabla \cdot \left(\varepsilon \nabla \phi - \phi(1-\phi) \frac{\nabla \phi}{|\nabla \phi|} \right)$$

$$\rho \frac{\partial \mathbf{u}}{\partial t} + \rho(\mathbf{u} \cdot \nabla)\mathbf{u} = \nabla \cdot [-p\mathbf{I} + \eta(\nabla \mathbf{u} + (\nabla \mathbf{u})^T)] + \mathbf{F}_{st} + \rho \mathbf{g}$$

We use the Two-Phase Flow, Laminar, Level Set application mode for simulation. Main equations are as shown above. Figure 2 presents the model defined in COMSOL and a SEM photo of a part of a real device.

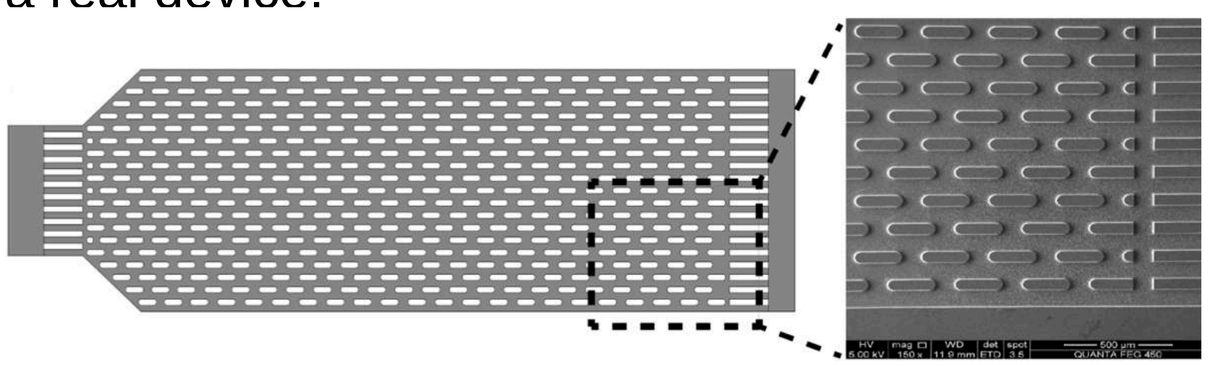

Figure 2. Model and SEM photo of the channel

Results: Figure 3 shows the movement of the methanol-gas interface, with meniscus interface changing from a convex to concave shape, which matches with experiment results. It also takes a longer time to fill the channel with water than methanol due to contact angles of these two liquids.

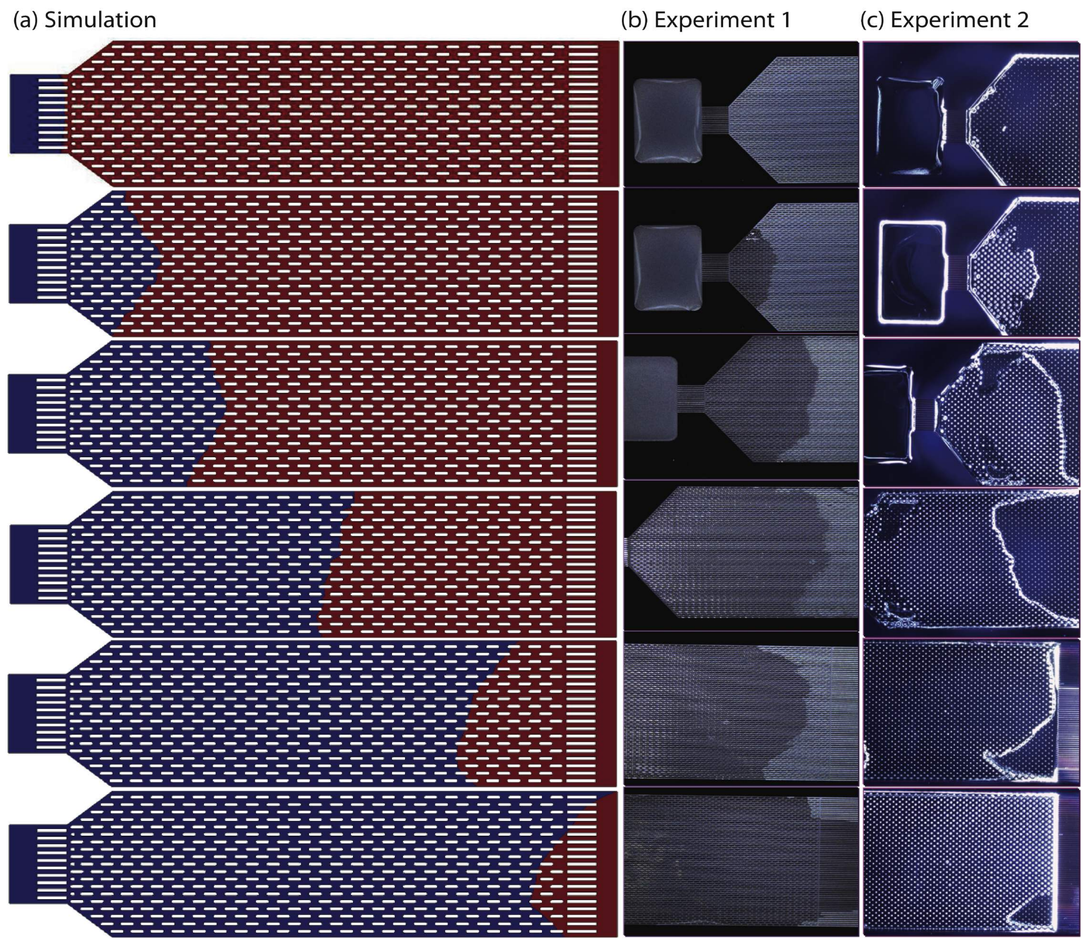

Figure 3. Numerical and experimental results

(a)

	Pure Methanol	10M Methanol	5M Methanol	2M Methanol
Contact Angle *(Degree)*	15	22	31	49
Time *(experiment)*	1.000	1.310	1.862	2.931
Time *(simulation)*	1.000	1.163	1.581	1.744

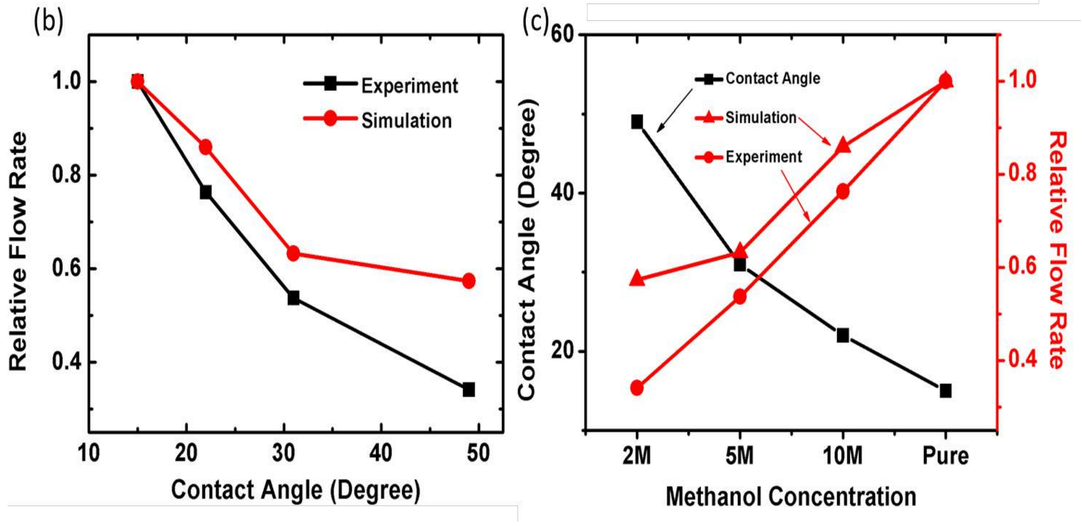

Figure 4. Flow rate vs. methanol concentration

Conclusions: This capillary channel can be adapted for other minute liquid transport besides methanol. The experimental and numerical methods presented in this work can serve as guidelines for further investigations of capillary transport.

References:

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2. Saha Ashish, et al. "Effect of dynamic contact angle in a volume of fluid (VOF) model for a microfluidic capillary flow.", Journal of colloid and interface science, 339, 461-480 (2009)
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