Supporting Information

A simple and rapid method for blood plasma separation driven by capillary force with an application on protein detection

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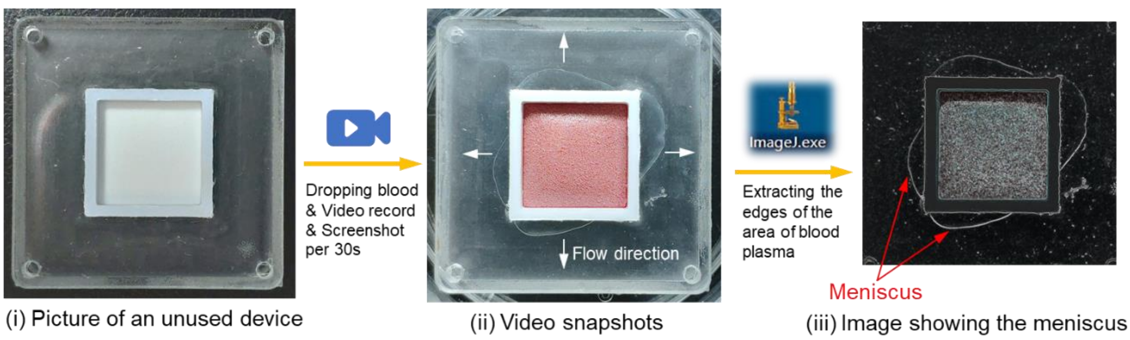

Fig. S1 Experimental images of the plasma meniscus and operating steps for plotting the location of the meniscus with various time.

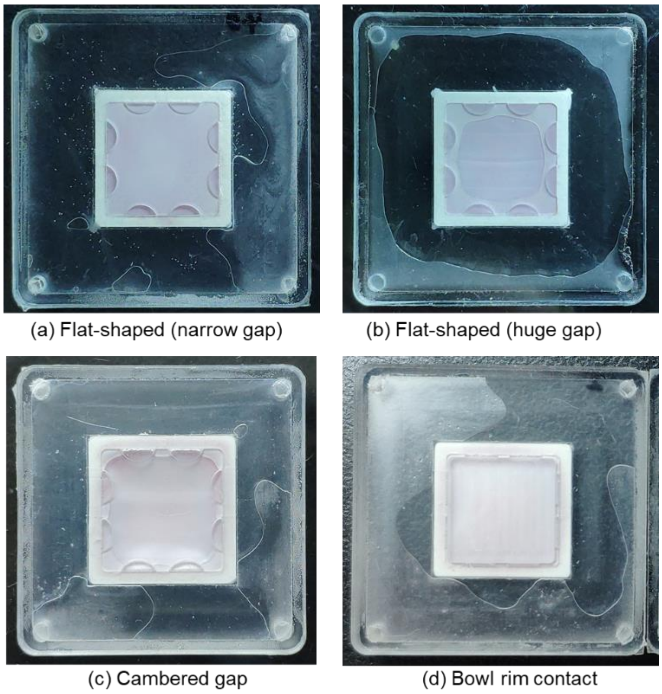

Fig. S2 Experimental images of the devices, which present their back appearances and the filling status of their capillary gaps under the membranes.

Height effect

It was reported that a liquid drop always tended to transport directionally in a parallel-nonparallel gap (p-n gap) [1], as shown in Fig. S3. This effect was called capillary liquid bridge. The cross-sectional size of the whole gap was much smaller than the width of the microchannel, thereby regarding the curvature in a width direction as infinite. Here is a two-dimension schematic. The height of the parallel microchannel and the opening angle of the nonparallel gap are denoted by h and α, respectively. In addition, θ_2 and θ_1 denote the equilibrium contact angles at the three-phase contact points on the leading and trailing edges, respectively. To illustrate the location of the trailing edge, L is used to denote the wetting length on the contact line between a wall of the nonparallel gap and the liquid (plasma). Let P_l and P_t denote the liquid pressure inside the leading and trailing edges of the capillary liquid bridge, respectively. Based on some relevant assumptions and Young-Laplace equation [1,2], P_l and P_t are given by

$$P_l = \frac{-2\gamma\, cos\theta_1}{h} + P_a\,, \tag{S1}$$

$$P_t = \frac{-2\gamma\, cos\left(\frac{\alpha}{2}\right)\cdot cos\left(\theta_2+\frac{\alpha}{2}\right)}{h+sin\alpha\cdot L} + P_a\,, \tag{S2}$$

where P_a is the atmospheric pressure, γ is the surface tension of the liquid (plasma) and the range of α is $0 < \alpha < 90°$. When the two edges halt, the equilibrium state should satisfy a condition of

$$P_l = P_t\,. \tag{S3}$$

So, the formula of the wetting length L on the nonparallel gap can be derived as

$$L = \frac{cos\theta_2 - cos\theta_1 + cos(\theta_2+\alpha)}{cos\theta_1\cdot sin\alpha}\cdot h = C\cdot h\,, \tag{S4}$$

where α, θ_1 and θ_2 are commonly constant. When the equivalent value $C > 0$, the wetting length L

will be proportional to the height h of the parallel microchannel. Therefore, the residual volume of the liquid in the nonparallel gap determines by [h, α, θ_1, θ_2] and the width of the gaps.

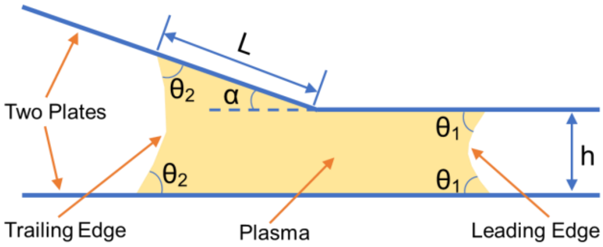

Fig. S3 Cross-sectional view schematic of a liquid halting in a parallel-nonparallel gap. There is an equilibrium system called capillary liquid bridge.

For our designed device, when blood plasma stopped flow in a microchannel, the microfluidic system could be regard as a liquid bridge. The filter membrane integrated into the device was an Asymmetric Polysulfone membrane with a porous gradient in the direction of blood flow, on which the mean pore diameters at the upstream side and the downstream side were 5.0 μm and 1.8 μm respectively. So, the membrane pores could be regard as the nonparallel gaps mentioned above. A membrane was the assemble of these nonparallel gaps. And, microchannels in the devices (with a height range of 40-160 μm) could be considered as the parallel gaps mentioned above. They together formed a liquid bridge with blood plasma.

In fact, the pores' hydrophilicity of the used membrane was stronger than the walls of microchannels, i. e., $\theta_1 < \theta_2$. Further, for the equation (S4), $C > 0$. Thus, the wetting length L was proportional to the height h in the parallel microchannel. For an equilibrium status, L increased with h increasing, resulting in increasing volume of residual plasma in nonparallel gaps and decreasing volume in parallel microchannels, as shown in Fig. S4. As a result, because the total volume of plasma in a system was a constant, the volume of extracted plasma in the microchannel decreased with the increase of height when blood plasma separation finished, as shown in Fig. 6e.

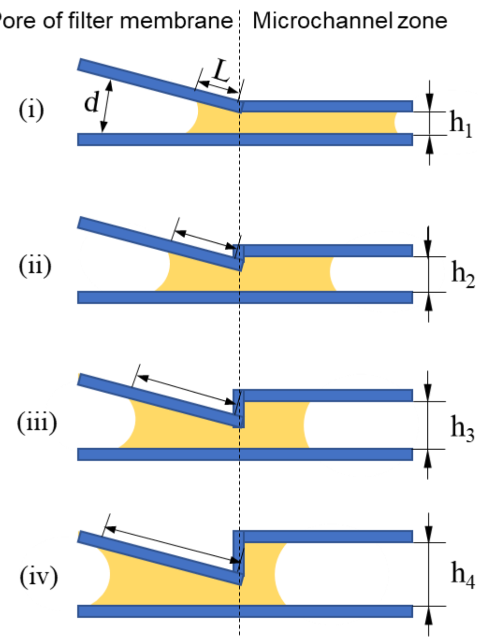

Fig. S4 Schematic of equilibrium status for plasma transporting between pores of membrane and microchannels. It is a geometric model, where residual volumes of the plasma in the pores increase with the height of microchannels.

Reference:

1. Y. Huang, L. Hu, W. Y. Chen, X. Fu, X. D. Ruan and H. B. Xie, *Langmuir*, 2018, **34**, 4484.

2. P. G. de Gennes, F. Brochard-Wyart and D. Quéré, *Capillarity and Wetting Phenomena: Drops, Bubbles, Pearls, Waves*, Springer, New York, 2004.