Supplementary information

Honey, I shrunk the bubbles: microfluidic vacuum shrinkage of lipid-stabilized microbubbles

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Flow Diagram of the Experimental Setup

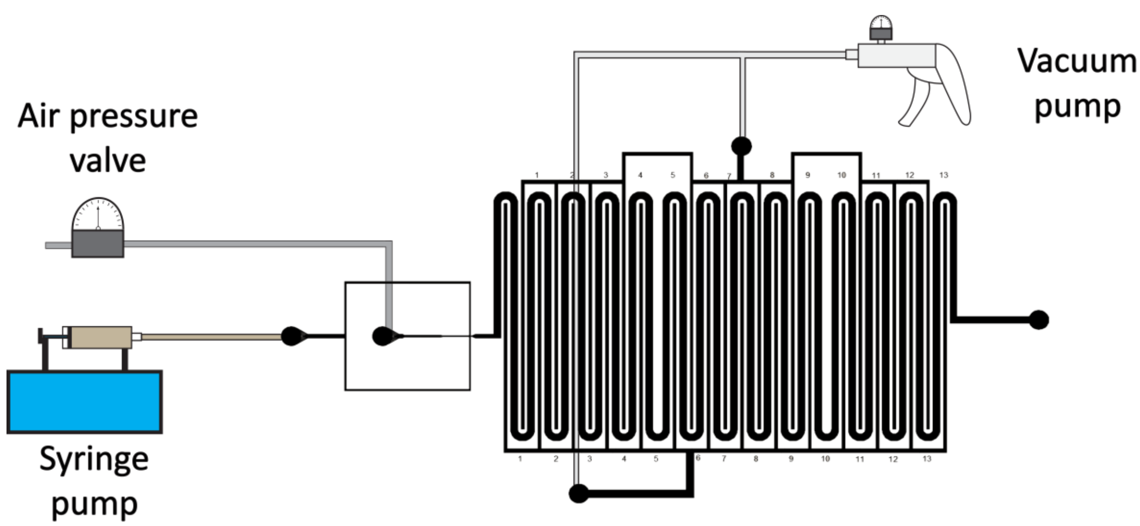

Figure S1: The schematic diagram of the microbubble shrinkage system. We supply air through a pressure valve where we fix the inlet air pressure to P_a = 4 psi for all the experiments. Simultaneously, we infuse the lipid-mixture using a syringe pump. The infuse flow rate is also fixed at Q = 4μL/min for all the experiments. Our only tuned variable, vacuum pressure, P_v, is supplied through two inlets using a Mityvac vacuum pump, which consists of an integrated control valve. The bubble is generated at the flow focusing orifice between air and lipid mixture channels, and flows downstream through the serpentine channel where the microbubbles shrink due to the effect of vacuum in the adjacent interdigitated vacuum channels. The schematic diagram is not in scale.

Calculation of the Volume of Discoid and Spherical Microbubbles

We use the following equations to calculate the volume of the discoid microbubbles at the orifice and the spherical microbubbles at the downstream of the microchannel.

In the simple experimental condition where the microbubble diameter *d*, is smaller than the channel height *h*, the microbubbles take on a spherical shape whose volume *V* is given by (Fig. S1a),

$$V = \frac{1}{6}\pi d^3.$$

The volume V of an equivalent spherical cap (Fig. S1b) is given by,

$$V = \frac{1}{3}\pi h_c^3(3R - h_c),$$

where, the height of the cap is given by h_c.

In experimental conditions where the projected microbubble diameter *D*, measured as the microbubble diameter from the top or bottom view using a microscope objective, is greater than the channel height *h*, the microbubble is confined by the microchannel and takes on a discoid shape (Fig. S1c). In this case, the volume V_d of the discoid microbubble is given by reference [1],

$$V_d = \frac{\pi}{12}\{2D^3 - (D - h)^2(2D + h)\},$$

where, the height h of the channel is also the height of the discoid microbubble sectioned from the top and the bottom, and is defined as,

$$h = 2(0.5d - h_c).$$

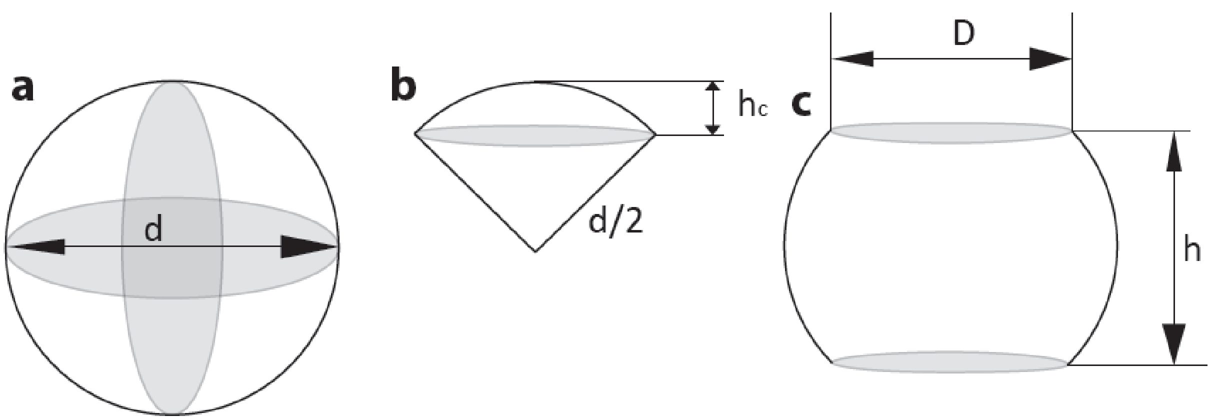

Figure S2: Schematic representation of different shapes of microbubbles. (a) Spherical microbubble, (b) spherical cap of a microbubble, and (c) a discoid microbubble.

Supplementary Information Movie Legend:

Supplementary Information Movie 1:

Video shows microbubbles generated at the orifice and the shrinkage of the microbubbles in the serpentine region of the microchannel. Due to the effect of vacuum in the vacuum microchannels, the microbubbles shrink as they move downstream. In the video, most of the microbubbles disappear when they arrive near the outlet. In this specific experiment, we use the inlet air pressure, P_a = 4 psi, continuous phase mixture inlet flow rate, Q = 4 μL/min and vacuum pressure, P_v = -90 kPa. Here, the video is recorded at a frame rate of 100 fps and played at 24 fps. Scale bar represent 50 μm.

References

[1] Nie, Z., Seo, M., Xu, S., Lewis, P. C., Mok, M., Kumacheva, E., … Stone, H. A. (2008). Emulsification in a microfluidic flow-focusing device: Effect of the viscosities of the liquids. *Microfluidics and Nanofluidics*, *5*(5), 585–594. http://doi.org/10.1007/s10404-008-0271-y