A Microfluidic Based Bubble Formation Enables Analysis of Physical Property Change in Phospholipid Surfactant Layers by Interfacial Ozone Reaction

Supplementary Information

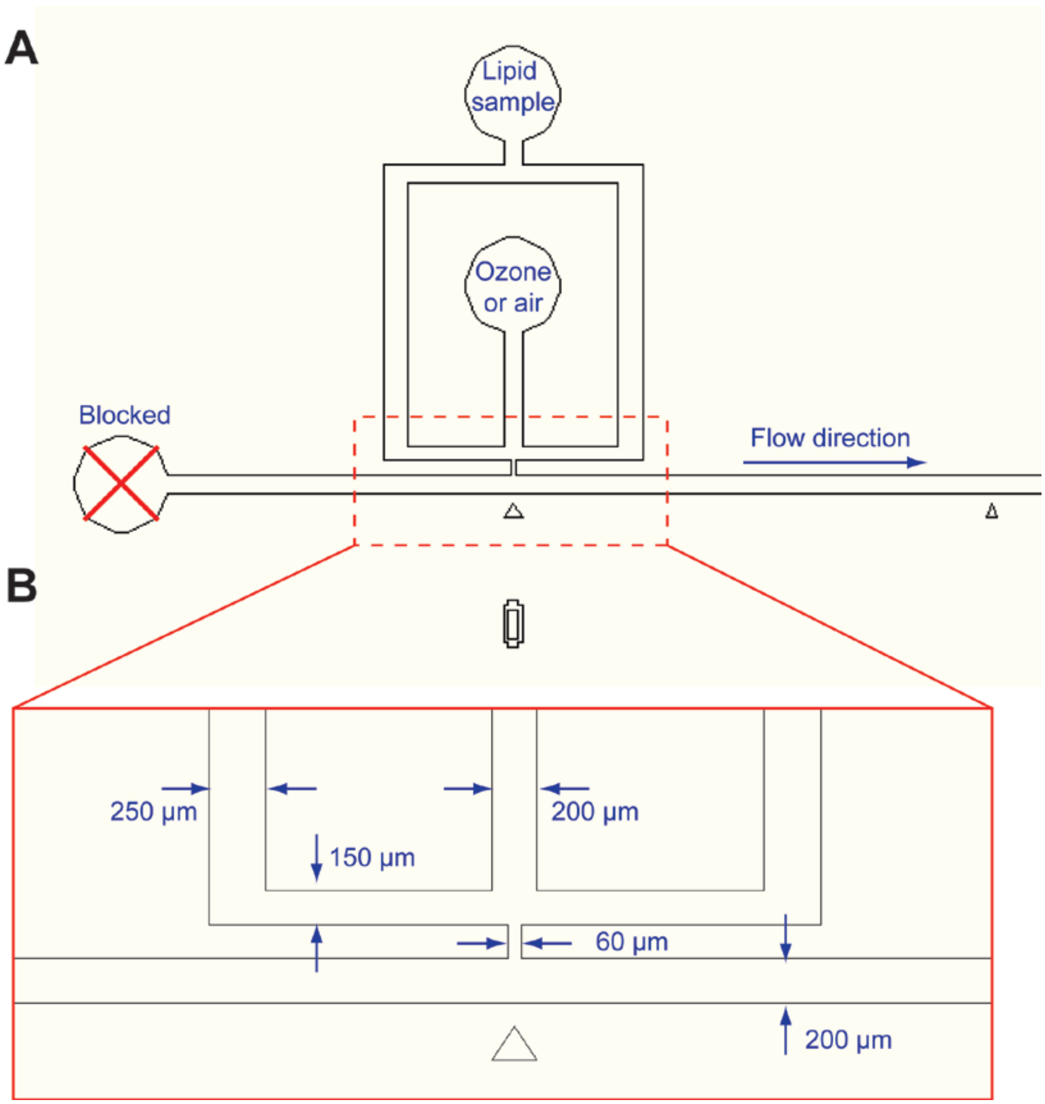

Fig. S1. Design of the microfluidic device for the bubble generation. (A) AutoCAD drawing for the bubble generation component. Either air or ozone is introduced from the center channel and the lipid sample flows in from the outer two channels. Lipid sample flow pinches off the gas to form bubbles. The hole in the left is used to introduce water right after plasma-based bonding for the hydrophilicity of the channel and remains blocked with a pin-plug for the rest of the process. (B) Zoomed in image of the main components of the bubble formation with dimensions.

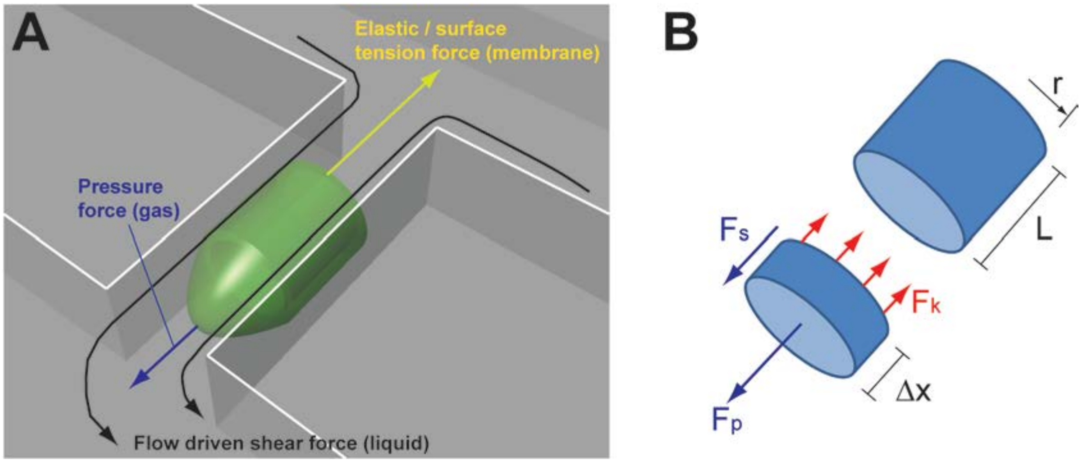

Fig. S2. (A) Major force components for the bubble generation on the lipid monolayer in the narrow channel region. Elastic force of the phospholipid monolayer at the air-liquid interface counter act to the pressure force from the gas and the shear force from the bulk lipid flow. Since the pressure for the gas and the flow rate for the bulk lipid flow are fixed, the physical characteristics of the lipid monolayer plays a major role in the bubble formation process. (B) Free body diagram for the force balance. The interface in the thread (the narrow channel region) is assumed as a cylinder.

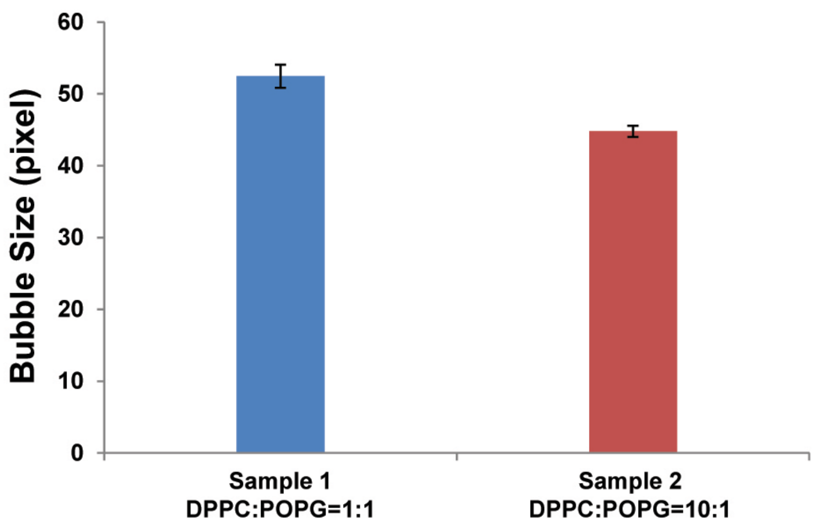

Fig. S3. Bubble size in terms of length for different phospholipid compositions. Sample 1 was prepared in 1:1 ratio of 20 µM DPPC and 20 µM POPG and Sample 2 was prepared in 10:1:9 ratio of 20 µM DPPC, 20 µM POPG, and 1×PBS. 6µl/min and 0.33 psi are used for the lipid sample flow rate and the pressure for the air, respectively. It can be noticed that bubble size decreases as the amount of POPG decreases, which further supports the ozone effect on the bubble size in the main text.

Supplementary Table 1. Bubble size (in pixel) and the polydispersity index

	Air	Ozone
Average	64.482	61.724
Standard deviation	0.665	1.150
Polydispersity Index	1.032	1.863

$$polydispersity\ index = \frac{standard\ deviation}{average} \times 100$$

Supplementary Table 2. Parameters for the effective elastic modulus calculation

	Air	Ozone
p	0.42 psi	
L	75 µm	
r	30 µm	
Δx	4.575 µm	3.575 µm
f *	3.48 Hz	3.52 Hz
m	1.68×10^{-14} kg	1.31×10^{-14} kg
E_{eff}	37973.5 Pa	48595.5 Pa

* Frequency was obtained from the stable region in oscillation: for the air condition, 1.25~3.55 sec and for the ozone condition, 13.75 ~ 17.30 sec regions were chosen to obtain the frequency.