Electronic Supplementary Information

Carbon dioxide bubble-propelled microengines in carbonated water and beverages

Yan Zhang,[a] Hong Zhu,[a] Wenxuan Qiu,[a] Yilu Zhou,[a] Gaoshan Huang,*[a] Yongfeng Mei,[a] and Alexander A. Solovev*[a]

Department of Materials Science, Fudan University, 220 Handan Rd., Shanghai, P. R. China.
E-mail: gshuang@fudan.edu.cn; solovevlab@gmail.com

Several samples were tested (S1: Ti/Cr tubes on photoresist; S2: Ti/Cr, Ti/Fe/Cr on table salt; S3: SiO/SiO_2 on photoresist). Cr layer was chosen for better mechanical stability of rolled-up nanomembranes.

S1: Ti/Cr = 20/20 nm layers were evaporated on spin-coated sacrificial photoresist layer ARP 3510 using angle 60^0 followed by under-etching of patterned photoresist layer in acetone.

S2: Ti/Cr = 20/20 nm, Ti/Fe/Cr = 20/5/20 nm nanomembranes evaporated on sacrificial water-soluble NaCl layer, evaporation was done without tilted angle. Ti/Cr and Ti/Fe/Cr microtubes were mechanically scratched using paper to dissolve NaCl layer in water. Supercritical point dryer was adopted to dry samples and create gas pockets inside the rolled-up geometries.

S2: SiO/SiO_2 = 5/20 nm layers thickness was evaporate at angle 30^o. However, due to transparent walls of silicon oxide/dioxide microtubes it is possible to observe gas pockets trapped inside of microtubes when a dry sample is immersed in water. Initially, samples were located in 1 % v/v Walch brand soap aqueous solution to avoid tubes collapsing by high surface tension. Later, it was found that tubes can be stable also in DI water.

It is known that for preparation of sparkling water and brewed beverages carbon dioxide can be dissolved through the dissolution under high pressure or during natural fermentation process. In our experiments aqueous carbonated water was made prior to experiments using soda maker (*Nordica Sodamaster Gazelle*). Air/CO_2 gas pockets can be contracted/dissolved in DI water if left during minutes, if water does not contain dissolved carbon dioxide gas.

Ti/Cr microtubes were more active and typically on average 95 % of on-chip microtubes generated bubbles when CO_2 was added. While only around 10 % of 100 micrometers long SiO/SiO_2 showed gas pockets. However, we observed that longer SiO/SiO_2 tubes (several millimeters) can be much more active, indicating that longer tubes can more efficiently store bubbles in rolled-up multilayers during sample mixture with carbonated water.