Lab on a Chip RSCPublishing

A microfluidic bubble trap or transistor?

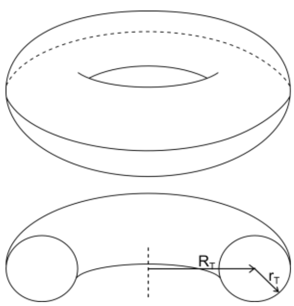
# Supplementary information

**Supplementary Movie S1**: Trapping of air inside water at a flow rate of 110μL/min.

**Supplementary Movie S2**: Trapping of air inside 100% ethanol at a flow rate of 110μL/min.

**Supplementary Movie S3**: Trapping of air inside cell culture medium (RPMI) at a flow rate of 110μL/min.

**Derivation of the Young-Laplace equation for a toroidal interface**




The work which is needed to expand a specific interface is balanced by the surface energy created by the surface tension. This means that for a change in shape of an interface, work is needed which has to be equate by surface energy:

$$dW = dE_s$$

$$dW = \Delta p * dV \; \& \; dE_s = \gamma * dA$$

Keeping the large radius $R_T$ of the torus constant, the toroidal interface is only a function of the small radius $r_T$. Therefore the infinite small changes in surface (dA) and volume (dV) can be calculated as follows:

$$A = 4\pi^2 R_T r_T \;\rightarrow \frac{dA}{dr_T} = 4\pi^2 R_T \;\rightarrow dA = 4\pi^2 R_T * dr_T$$

$$V = 2\pi^2 R_T {r_T}^2 \;\rightarrow \frac{dV}{dr_T} = 4\pi^2 R_T r_T \;\rightarrow dV = 4\pi^2 R_T r_T * dr_T$$

With the above equations the Young-Laplace equation for a toroidal interface becomes:

$$\Delta p * 4\pi^2 R_T r_T * dr_T = \gamma * 4\pi^2 R_T * dr_T \rightarrow \; \Delta \boldsymbol{p} = \frac{\boldsymbol{\gamma}}{\boldsymbol{r_T}}$$

In the above case $r_{curvature}$ is equal to $r_T$. In the general case the Young-Laplace equation depends on the curvature of the toroidal interface:

$$\Delta \boldsymbol{p} = \frac{\boldsymbol{\gamma}}{\boldsymbol{r_{curvature}}}$$

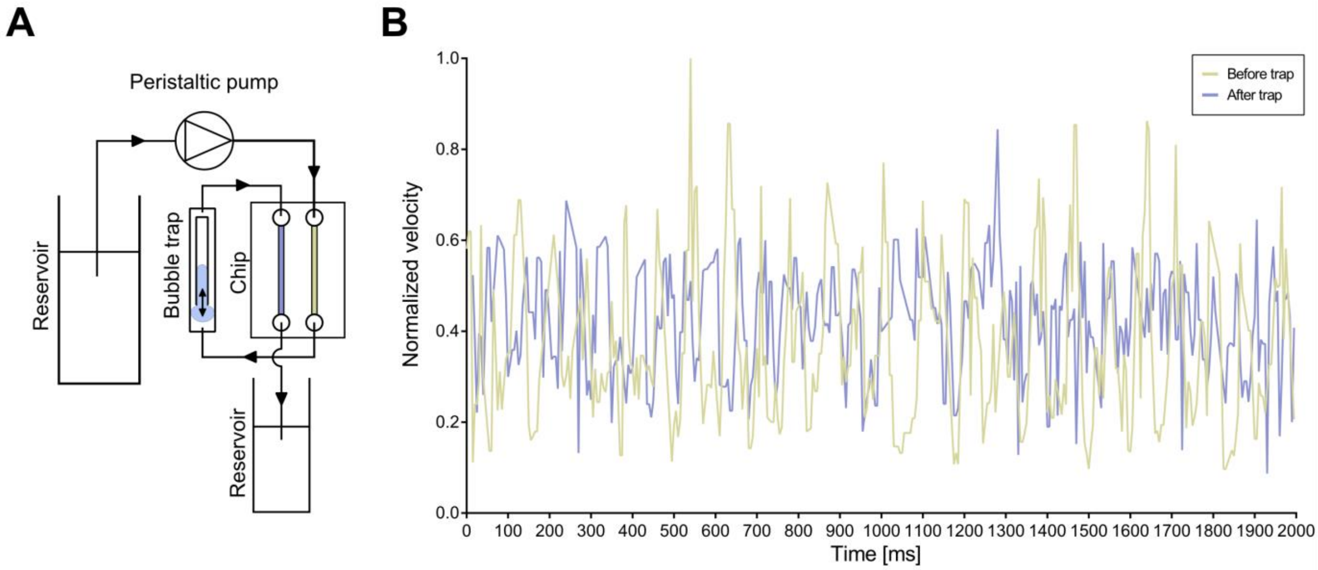
Lab on a Chip

RSCPublishing

A microfluidic bubble trap or transistor?

**Assessment of the oscillation effect on the stability of the flow**

**Description of the experiment:** A solution of 10 um fluorescent beads in 100% ethanol was introduced in the flow path to assess the effect of the bubble oscillation on the flow characteristics. The movements of the beads inside the microchannels were recorded at 200 fps for both locations (before and after the trap). Then the movies were processed in Fiji (NIH, USA) and Matlab (MathWorks, USA) to calculate the flow velocities of the beads in one frame ($dx/dt_{exposure}$) and then the mean was taken over each frame. These mean velocity values were afterwards normalized to the maximum value and plotted as function of time for both locations. The average time differences between the peak velocities in the case 'before the trap', is about 77.8ms. This corresponds well with the time interval of the metal rolls of the peristaltic pump (110uL/min =100rpm having 8 metal rolls ➔ $dt_{roll}$=75ms), showing the "normal" fluctuation of the flow created by a peristaltic pump. The comparison of the two flow profiles shows that the bubble oscillation ($f_{bubble} \approx 1$ Hz) as no additional effect on the pulsatile flow behavior inside the microfluidic channel. Therefore one can say that the bubble oscillation has no significant effect on the flow characteristics inside microfluidic channels.




**Supplementary Figure 1.** Effect of the bubble oscillation on the fluid velocity inside a microfluidic chip. A) Schematic of the experimental setup, the oscillations are observed in two 750µm wide, 100µm high and 10mm long microchannels. B) Normalized velocity profiles of 10um fluorescent beads inside the microfluidic channels, before and after the trap.