Effect of butanol on the bubble formation hysteresis in flow-focusing devices

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Abstract
The formation of a microfoam in a flow-focusing device is an important topic in microfluidics. The injection of the gas (N² in our experiment) and the liquid (water with Tween 20 at 1%/w, with or without 7%/w of butanol) can either result - depending on the parameters of the injection - in only a liquid flow, in a foam, or in a stream of gas flowing in the middle of the channel [1-2].

We observe an hysteretic behavior when increasing the liquid flow (and so the capillary number) or decreasing it, while maintaining the gas pressure constant : the stream-foam transition and the foam-stream transition occurs at different experimental conditions (see Fig.1 below). We observe that a short alcohol has a destabilizing effect on both the stream and the foam, thus reducing the hysteretic behavior.

1. Experimental setup

Pressure drop evolution when decreasing (blue) or increasing (red) the water flow-rate (indicated by the black arrows). The lines are just guides.

2. Hysteresis
The transition between I (bubbles) and II (stream) is shifted depending on whether the system is initially in state I or II. Hence, a region of bistability exists.

3. Transitions

Pressure drop evolution when decreasing or increasing the water flow-rate (indicated by the black arrows), with (red) or without (blue) butanol. The lines are just guides.

4. Effect of the butanol

The stream → bubble and bubble → stream transitions do not involve the same physical mechanisms.

5. 2D or 3D stream ?


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Butanol, which is rapidly (∆t = ~ 10ms, measured with the Maximum Bubble Pressure Method) absorbing to the interface, seems to strongly affect the transition in both ways. In the case of II → I, we observe that with butanol, the stream become unstable while still being 2-dimentional, which is contradictory to what is predicted in the litterature. We believe that this effect could be explained by taking into account the Marangoni effect, which is strongly affected by the presence of this surfactant.