Emulsification: a comparison between membranes and microfluidic devices

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Currently, emulsification research is very lively with many different new emulsification technologies being published; all with their own pros and cons. Membranes are mostly applied either in cross-flow mode or in pre-mix mode. During cross-flow emulsification (see Figure 1 a), the to be dispersed phase is pressurized through the membrane where it forms small droplets on top of the membrane, that are consecutively sheared off by the cross-flowing continuous phase once they have grown to a certain size. During pre-mix emulsification, the big droplets of a pre-emulsion are broken up into smaller ones, as is the case in the classic emulsification techniques (see also Figure 1 b).

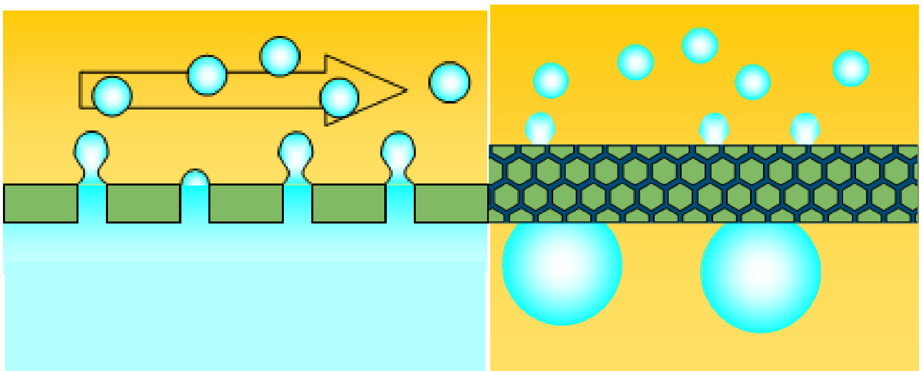

Figure 1. Schematic representations of a. Cross-flow membrane emulsification, in which the cross-flowing continuous phase shears-off the droplets. b. Pre-mix emulsification, in which a coarse emulsion is broken up into smaller ones through passage through a membrane.

When comparing membrane emulsification with the more classic techniques (Figure 2), it is clear that cross-flow emulsification is a much milder less energy consuming technique than e.g. high pressure homogenizers are. In some cases, the energy density is orders of magnitude less. Pre-mix emulsification, seems to be more in line with the traditional techniques, but may be useful in the production of relatively large droplets. Also, this technology is not that developed as cross-flow emulsification. In order to develop membrane emulsification further, it is necessary to understand the underlying mechanisms and for this microfluidic devices are important tools.

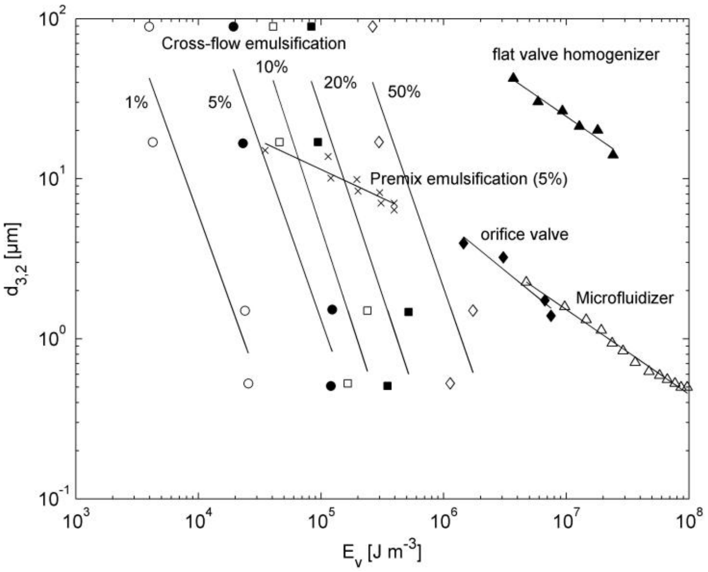

Figure 2. Energy efficiencies of various emulsification methods (Nazir et al, 2011).

During cross-flow emulsification, it is hard to observe droplet formation, if not even completely impossible. Therefore, various efforts were made to idealize a membrane or even a pore and learn from that. Pioneering work was done with so-called microsieves invented by Van Rijn, which are extremely flat porous plates, which have uniform pore size, and allow observation of droplet formation from the top. Besides, so-called T- and Y-junctions were used to investigate droplet snap-off from the side and compared to computational results. In a T-junction, the to-be-dispersed phase is pressurized into a channel with the cross-flowing continuous phase, where it slowly protrudes into the continuous phase channel. Due to the shear of the continuous phase, the to-be-dispersed phase the droplet(s) will snap off, and this process can be summarized in scaling relations. Besides shear based methods, also spontaneous droplet formation (due to Laplace pressure differences) is used for emulsification; these processes have been investigated in detail, and scaling relations are available.

In the presentation, the various methods will be discussed and compared based on the energy density, and monodispersity of the emulsion. Further, options for up-scaling and improved designs will be presented based on the scaling relations obtained from our microfluidic investigations, and an outlook will be given for membrane and microfluidic emulsification.

Key Words: (Maximum 4 key words). Membrane emulsification, microfluidic devices, emulsions.

References: Nazir, A. , Schroën, K., Boom, R. Premix emulsification: A review (Review), Volume 362, Issue 1-2, October 2010, Pages 1-11.