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CROSS MEMBRANE EMULSIFICATION

Introduction

Emulsions are widely used across many sectors, including food, pharmaceuticals and cosmetics. Traditionally, they are prepared by high pressure, ultrasonic or rotor/stator homogenisation (e.g. stirred vessels, colloid mills, and toothed disc dispersing machines).[1] Typically, none of these techniques provide good droplet size control and high energy inputs are required, which may lead to a wide droplet size distribution and poor stability of the emulsion.

Membrane emulsification has received broad attention over the last 20 years for manufacturing monodisperse emulsions. The process of cross-membrane emulsification (XME) has been reviewed and shown in Figure 1. Emulsions are produced by applying pressure to force a dispersed phase to permeate through the pores of a microporous membrane, while the continuous phase flows along the membrane surface. Droplets are formed at pore openings and detach at a certain size. The apparent shear stress is lower than the traditional emulsification systems mentioned above, because small droplets are directly formed by the permeation of the dispersed phase through the pores, instead of the disruption of large droplets in zones of high energy density.[2]

Membranes

There are many different types of membranes, including ceramic aluminium oxide (α – Al_2O_3), Shirasu Porous Glass (SPG) membrane, stainless steel membranes and polymer membranes, which have been investigated to produce monodispersed micro/nano emulsions and particulate products.

The emulsions produced are affected by the pore properties of the membranes e.g. pore size and size distribution, pore spacing, shape and orientation. Pore size and uniformity are the most important parameters in producing uniform droplets with expected sizes, once the pore spacing is sufficiently large enough to avoid any aggregation/ coalescence and interference of adjacent droplets. The droplets produced are often reported to be of diameters a few times (in the range of x2 or sometimes up to more than x10) greater than that of the pore size.

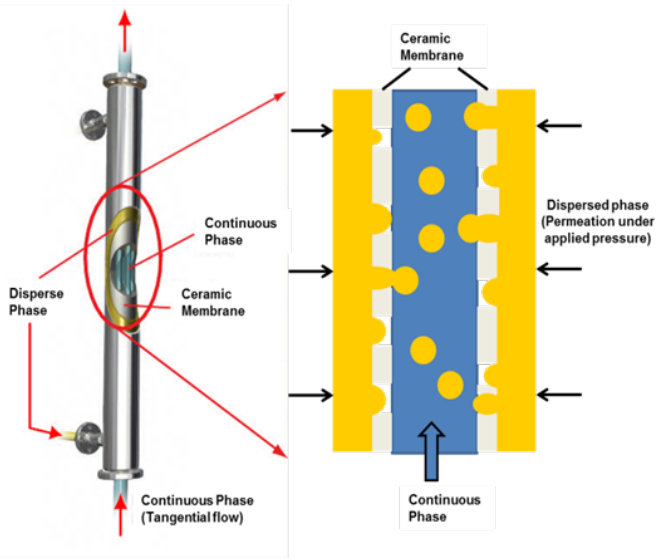

Figure 1: Schematic diagram of membrane emulsification

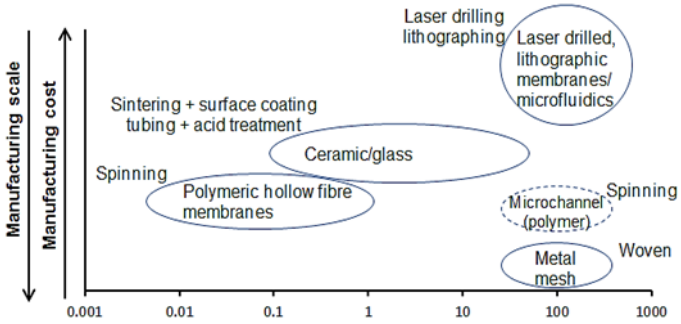

Figure 2: Pore size range of different type of membranes and manufacture scale and cost[3]

The spread of sizes is critically determined by the consistency of the pore sizes themselves and the precise hydrodynamic environment set by the user.

A simple emulsion system is composed of a hydrophobic oil phase and a hydrophilic aqueous phase. In the membrane emulsification approach, these two phases meet at the membrane surface. The precondition for

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continuous droplet creation is that the disperse phase does not spread on the outer surface of the membrane. The detachment surface, therefore, normally needs to have an opposite hydrophilicity to the disperse phase. A hydrophilic membrane surface is generally required for oil-in-water emulsions and a hydrophobic surface for water-in-oil emulsions.

Potential Applications for XME

The XME process can be developed and used for the production of mono dispersed particles with specific size ranges in various products:

- Oil in water emulsions
- Microcapsules
  - Flavours
  - Fragrances
  - Drugs
  - Pesticides
- Water in oil emulsions
  - Emulsified fuel
  - Gelatine particles
- Complex emulsions
  - Drug use
  - Low fat spreads
- Specialist particulates
  - Gelatine and alginate particles
  - Core shell particles
  - Polymer beads
  - Crystallisation

Examples

Figures 3 and 4 compare the size and size distribution of two emulsion systems prepared by cross-flow membrane technology and rotor-stator homogenization. (For the XME a ceramic tube with an average pore size of 0.2µm was used, whilst for the homogenisation a speed of 26,000 rpm was used.)

Figure 3 shows the result using castor oil and water. The XME has produced a narrower size distribution and smaller average size than the using the high speed mixer.

Figure 4 shows the result using coconut oil and water. This is similar to Figure 3 but with the XME producing an even narrower size distribution and smaller average size than with using the high speed mixer, which has a broader size distribution.

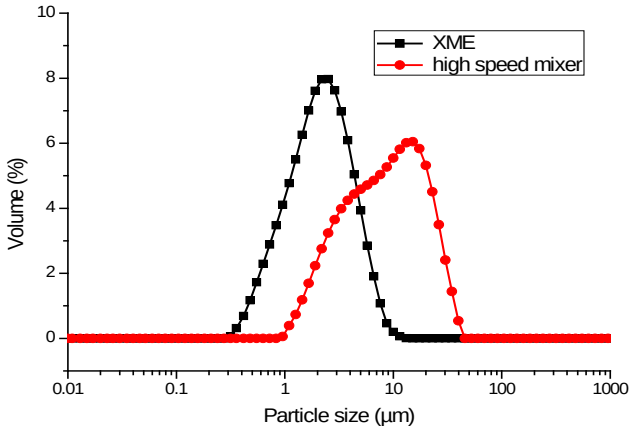

Figure 3: Volume size distributions of emulsions of castor oil and water made using either XME or a high speed mixer

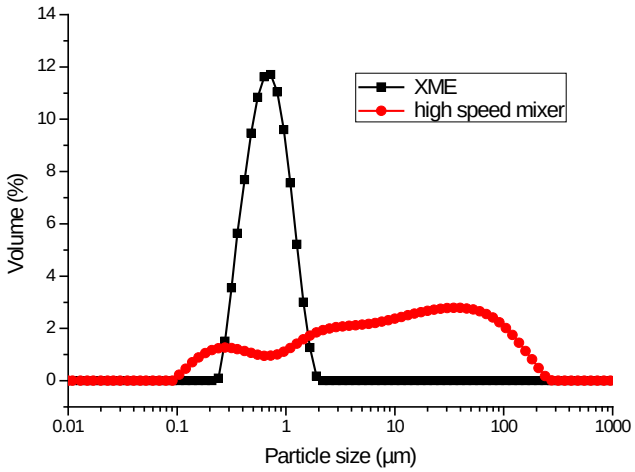

Figure 4: Volume size distributions of emulsions of coconut oil and water made using either XME or a high speed mixer.

Figure 5 shows an application of using the XME process to manufacture controlled emulsions by selecting different membrane pore sizes.[4]

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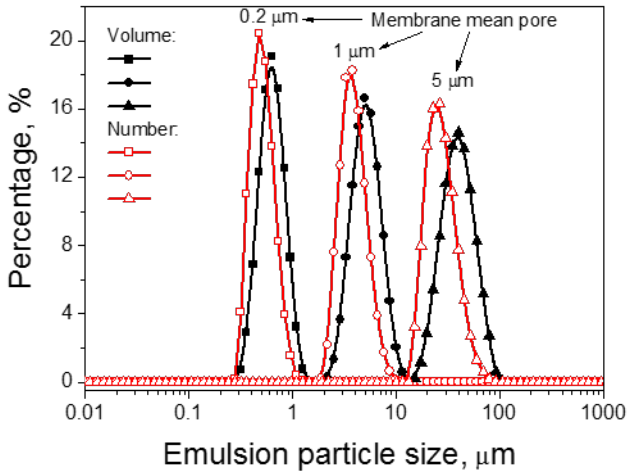

Figure 5 (a) Particle size distributions of emulsions prepared by using XME4

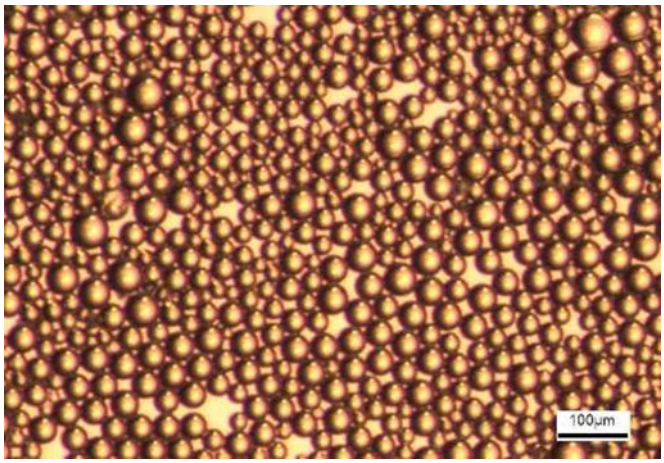

Figure 5(b): Particle size distributions of emulsions prepared by using XME4

References

[1] Vladisavljevi´c GT and Schubert H, Preparation and analysis of oil-in-water emulsions with a narrow droplet size distribution using Shirasu-porous-glass (SPG) membranes. Desalination 144:167–172 (2002).

[2] Charcosset, C., Limayem, I. and Fessi, H., The membrane emulsification process—a review. Journal of chemical technology and biotechnology, 79(3), pp.209-218 (2004).

[3] Yuan, Q & Williams, RA, 'Precision emulsification for droplet and capsule production' Advanced Powder Technology, vol 25, no. 1, pp. 122-135, (2014).

[4] Yuan Q., Hou R., Aryanti N., Williams R A., Biggs S., Lawson S., Silgram H., Sarker M. & Birch R., Manufacture of controlled emulsions and particulates using membrane emulsification, Desalination, 224 215-220, (2008).

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