

MULTI-NANOEMULSIONS: NANODROPLETS IN NANODROPLETS FOR FORMULATION DESIGN

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In recent years, multiple emulsions – i.e., droplets with internal structure – have generated great research interest due to their potential applications in materials, foods, cosmetics, pharmaceuticals, and chemical separations. Microfluidic methods have already demonstrated the ability to create micron- and larger scale complex emulsions with breathtaking sophistication and control, as well as compartmentalize encapsulation of molecules within them. However, scaling the size of such droplets to the nanoscale has been extremely challenging due to limitations on the devices and energies required to produce nanoscale droplets, i.e. nanoemulsions.^[1] Here, we will review new methodologies we have developed to fabricate scalable quantities of multiple nanoemulsions of various morphologies (Figure 1).^[2-4] These methods combine high-energy emulsification with co-surfactants possessing highly asymmetric molecular geometry. The former aids the generation of nanoscale droplets, whereas the latter influences their morphology through ultra-low surface tension and control over frustrated spontaneous curvature, resulting in the reproducible generation of droplets with a range of controlled complex morphologies. The size, stability, internal morphology and chemical compartmentalization of these complex nanoemulsions have been quantified using a combination of scattering, optical microscopy and cryogenic-transmission electron microscopy techniques. Importantly, we show that the preferred droplet morphology is selected by the composition of the fluid alone,^[2,4] providing a wide new design space for tailoring the structure and properties of multi-nanoemulsions. These complex droplet morphologies are retained upon the addition of various material pre-cursors, and the droplets are stable over the time scales required for material chemistry, thereby enabling their use as templates for complex nanoparticles.^[4] As a detailed demonstration, we show how oil-in-water-in-oil double nanoemulsions can be used to template the synthesis of oil-filled nanogels for encapsulation and controlled delivery of hydrophobic active ingredients.^[5]

References

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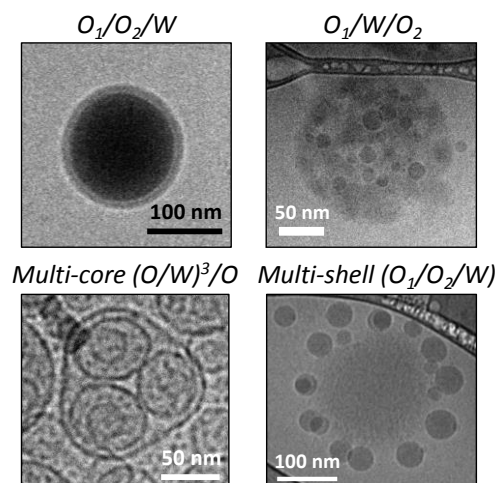


Figure 1 – Cryo-TEM micrographs of various multi-nanoemulsion morphologies.