Structure and stability of oil-in-water-in-oil complex nanoemulsions

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Double emulsions have enabled the preparation of colloids with sophisticated internal structure and function due to their ability to encapsulate and compartmentalize active molecules that have different polarity or are incompatible. Typical methods for preparing double emulsions include (1) a two-step process of first forming an oil-in-water emulsion, followed by emulsification of this mixture in oil, which leads to rather large polydisperse double emulsions, and (2) microfluidic methods that produce micrometer size monodisperse double emulsions. Therefore, the synthesis of nanometer-scale double emulsions remains a significant challenge, the solution to which would open up new possibilities for creating structured nanoparticles.

The preparation of oil-in-water-in-oil (OWO) double nanoemulsions, with both inner and outer droplets under 100 nm with ultrasonication using a mixture of conventional ethoxylated co-surfactants is here demonstrated. Specifically, we examine the non-equilibrium behavior of water/cyclohexane with the co-surfactants in a wide range of water and surfactant concentrations. Detailed structural analysis by small angle neutron scattering shows that the nanoemulsion structure can be varied between simple water-in-oil nanoemulsions, or OWO double nanoemulsions containing either one or multiple inner-droplets, depending on the surfactant composition, i.e. the total surfactant concentration and average surfactant HLB, and the water volume fraction. We also study the kinetic evolution of droplet structure to examine the stability of the double nanoemulsions. These results demonstrate that it is possible to control both the internal structure and stability of double nanoemulsions by systematically tuning the average interfacial curvature.