SANS-Guided Design of Responsive Microemulsions

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Microemulsions are mixtures of water, oil, surfactant, and co-surfactant that spontaneously self-assemble into diverse nanostructures governed by composition and environmental conditions. Although their phase behavior has been studied for decades, designing food-grade, pH-responsive microemulsions remains a challenge. Their rational design depends on a molecular-level understanding of structural response mechanisms. Beyond molecular composition, surface interactions, spatial confinement, and hierarchical structuring play a decisive role in directing the functional behavior of these materials.

This presentation demonstrates pH- and composition-responsive microemulsions engineered for applications such as nutrient extraction and drug delivery. It provides a fundamental analysis of the pH-triggered co-assembly of lecithin and oleic acid with selected bioactives. Using in situ SAXS and (GI)SANS combined with selective deuteration and solvent contrast variation, we analyse structure formation in both, the bulk phases and at the liquid-liquid interface across diverse length and time scales. We track the evolution of spatial confinement and hierarchical structuring as pH and ionic strength are varied. Supported by numerical data modelling, we map the distribution of molecules within these systems. These studies are complemented by tensiometry and release experiments for a direct connection between material properties and function.

The structural transformations are interpreted within theoretical frameworks such as the critical packing parameter model. They are correlated macroscopic changes of material parameters, such as drug uptake and release, and rheological properties. Building on these findings, we propose advanced design principles for creating adaptive, functional microemulsions that bridge formulation science and state-of-the-art nanostructural characterization.

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