Contribution ID: **89**

Type: **Poster**

Microflow-induced Structural Changes of Bicontinuous Microemulsions Studied by SANS

Understanding and engineering the flow-response of complex fluids made by surfactant membranes is a key challenge for their practical utilization. Nevertheless, the predicted sponge-to-lamellar transition of self-assembled surfactant membranes upon shear flow [1] has, to our knowledge, only been shown for surfactant bilayers [2,3]. The lack of experimental reports of such a transition for the monolayer analogue, namely a bicontinuous microemulsion, can be justified by the extraordinarily high shear rates required for the transition, which exceed the limitations of most rheological setups. For the first time and via the combination of small-angle neutron scattering (SANS) and microfluidics [4], we are able to show a gradual deformation of a monolayer sponge to a lamellar-like structure with applied flow. In order to achieve this deformation, we expose different bicontinuous microemulsions stabilized by a nonionic surfactant (Fig. below, right) to microflows of up to 40 mL min^{-1}, resulting in shear rates above 10^5 s^{-1}. The orientation-dependent analysis of the SANS patterns reveals the increasing formation of lamellar layers which, however, seem to be connected via passages even at these high shear rates. The exceptionally high spatial resolution of this method allows us to link structural properties like anisotropy (Fig. below, left) and domain size along with the surfactant membrane rigidity to the variation of the flow field while we probe sample volumes of down to 10 nL. As it turns out, the structure does not only vary with the flow applied but also within the flow field itself. Furthermore, one is able to amplify this response by modifying the surfactant membrane elasticity through decoration with amphiphilic diblock copolymers, known also for their efficiency boosting effects [5].

Figure 1: (Left) SANS curve of a bicontinuously structured microemulsion, fitted with the Teubner-Strey model [6] (Right) 2D-scattering patterns of the same system under flow before, inside, and after the constriction of a Microfluidic SANS chip.

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Session Classification: Poster Session and Wine&cheese