Analysis of nanoemulsion formation, produced by low energy phase inversion concentration (PIC) method

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Nanoemulsions, which are structurally located between thermodynamically stable microemulsions (< 10nm) and kinetically stable macroemulsions (> 200nm), became quite popular in the last years. Such metastable nanoemulsions, that possess radii in the range of 10-200nm, can be formed by different high- or low-energy methods and lend themself to versatile purposes in industry. Especially nanoemulsions formed by low-energy methods are particularly attractive, due to the mild conditions of preparation, but also not well understood yet with respect to the surfactant composition required and the structural pathway of formation. In particular, we are interested in the Phase-Inversion-Concentration (PIC) method [1] that forms nanoemulsions at a certain oil/water-ratio due to the change of interfacial composition during dilution. Our work is based on an industrial formulation (®Tego Wipe DE) [2], that we modified in a systematic fashion with respect to the composition of the surfactant and oil components. For such modified surfactant/oil mixtures we observed either unstable or very long-term stable nanoemulsions, showing a bimodal size distribution, depending on the detailed composition and the formation process. The physico-chemical characterisation of the nanoemulsions was done by means of conductivity, viscosity, density, UV/Vis-transmittance, and zeta-potential measurements. A more refined structural picture was obtained by means of small-angle neutron and x-ray scattering (SANS/SAXS) and some complementary cryo-TEM micrographs. Time resolved SANS/SAXS and turbidity measurements (stopped-flow technique) allowed us to follow the dynamics of the formation process in detail. These experiments show that this process evolves very rapidly while the microemulsions formed at lower water dilution are formed in a much slower process. Additional neutron spin-echo (NSE) measurements in combination with SANS allow us to determine the bending modulus for the surfactant monolayer and correlate it with the stability of the formed nanoemulsions, thereby relating it to the molecular architecture of the nanoemulsion systems.