Gel structure with excess water in a surfactant solution

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In a binary system consisting of surfactant and water, a hydrated solid phase is formed below the Kraft temperature, where the hydrophobic tails extend to the length with all trans. Figure 1 shows the T-ϕ phase diagram of a non-ionic surfactant $C_{16}E_7$ ($C_{16}H_{33}$ ($OC_2H_4)_7OH$) and water system. As shown in Fig. 1, the hydrated solid phase is a two-phase coexistence of excess water and lamellar structure L_β of bilayers whose hydrophilic tails are " solid-like " gel and interdigitated. The hydrated solid phase is strongly turbid and has a viscoelastic property, which is applied in cosmetic industry and so on. So far, we have investigated the structural formation of the hydrated solid phase in the $C_{16}E_6$/water and $C_{16}E_7$/water system by means of small angle X-ray scattering (SAXS) and optical microscope. Even though those surfactants are slightly different from each other in the head length, we found clearly different structures in nm $\sim$ μm scale. In μm scale observation using optical microscope, vesicle structures and worm-like lamellar domains are observed in the $C_{16}E_7$ system and $C_{16}E_6$ system, respectively. The SAXS experiments showed that the formation processes of membranes are different between the both system. The hydrophobic parts of surfactants hinder extends of the hydrophilic tails of the $C_{16}E_7$ system, while those of the the $C_{16}E_6$ system tend to extend to the full length. In this report, we compare the dynamic and static structures of the $C_{16}E_7$ system with those of the $C_{16}E_6$ system by using the results obtained from the SANS and NSE experiments.

The SANS experiments were carried out using the SANS-U spectrometer. The momentum transfer q ranged over $0.003 \le q \le 0.2$ Å^{-1}. The NSE experiments were performed using the iNSE spectrometer.

The observed range of momentum transfer q and Fourier time t, were $0.09 \le q \le 0.15$ Å^{-1} and $0.15 \le t \le 15$ ns, respectively. Temperature was set to 8 °C for the $C_{16}E_7$ system, and to 20 °C for the $C_{16}E_6$ system. The concentration of $C_{16}E_7$ and $C_{16}E_6$ is 10 wt.%, respectively. For the NSE experiments, we started the experiments after waiting 1 hour from setting each sample to the sample cell holder because the sample structures should be stable.

In order to investigate the head and tail length of surfactants, we analyzed those profiles using the form factor of bilayers taking the hydration of hydrophilic parts into account. Figure 2 indicates the time evolutions of the length of hydrophilic tails in each system after the temperature jump, which are obtained from the SAXS experiments. The results obtained from SANS experiments are consistent with those obtained from SAXS experiments. We confirmed that the hydrophilic tails of the $C_{16}E_7$ system are hindered from extending to the full length around $\sim 2000sec$. Figure 3 shows the universal plot of the intermediate correlation functions obtained from the NSE experiments. If the NSE results obey the theory proposed by Zilman and Granek [1], these plots should be straight lines. The solid lines in Fig. 3 are the fitting results by using Zilman and Granek model. From this analysis, we found that the bending modulus κ of bilayers in the $C_{16}E_7$ system is $\sim k_BT$, while that in the $C_{16}E_6$ system is $\sim 10k_BT$. This indicates that the bilayers of the $C_{16}E_7$ system are flexible because the tail length becomes short, while those of the $C_{16}E_6$ system are rigid because the tails tend to extend to the full length.

References

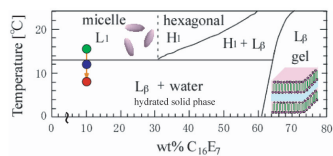[1] A. G. Zilman and R. Granek, Phys. Rev. Lett., **77**, 4788 (1996).

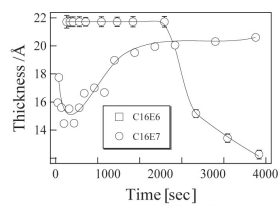Figure 1 : Phase diagram of C16E7-water system.

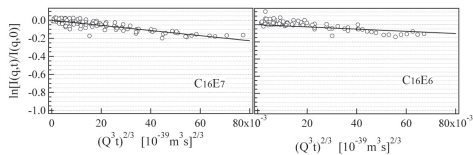Figure 2 : The time evolution of hydrophilic tail length.

Figure 3 : Universal plot of the intermediate correlation function.

Fig. 1. Figure 1 : Phase diagram of C16E7-water system. Figure 2 : The time evolution of hydrophilic tail length. Figure 3 : Universal plot of the intermediate correlation function.