Structural analysis of foam formed by mixed system of anionic surfactants and zwitterionic surfactant mixture using neutron scattering

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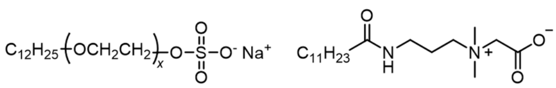
Foams are used in a variety of applications in our daily lives and in industrial processes. In the beverage industry, they are used in beer and champagne, in the cleaning and cosmetics industries they are used in shampoos and body soaps, and in the industrial sector they are used in bubble separation to remove radioactive metals, dyes and sewage, playing an important role in enriching our lives. Foams are composed of a combination of nanometer-order foam film, micrometer-order plateau borders, and millimeter-order bubbles. The macroscopic structure of foams has been investigated by evaluating foaming power and foam stability, and the microscopic structure has been investigated by evaluating the reflectance of single plane film and disjoining pressure, but there are almost no reports of research directly investigating the microscopic structure of foams. Small-angle neutron scattering (SANS) is a typical method for evaluating average structures of 1-100 nm, and is effective for analyzing the microstructure of foams, but there are very few studies on this topic.

In this study, we focused on the mixed systems of anionic surfactants ($C_{12}EO_xSO_4Na$, x = 0, 2, 4, 6, 8) and betaine-type zwitterionic surfactants ($C_{12}APB$) (Figure 1), and used SANS measurements to clarify the nanostructure of the foams formed by these surfactant mixtures.



$C_{12}EO_xSO_4Na$
(x = 0, 2, 4, 6, 8)

$C_{12}APB$

Fig. 1. Structure of $C_{12}EO_xSO_4Na$ and $C_{12}APB$.

SANS measurements of the foams were carried out at room temperature using the SANS-U at JRR-3. The beam diameter was fixed at 10 mmΦ, and the camera length was fixed at 2 m. We used a cell that we had made ourselves for the SANS measurement of the foam. Surfactant solution was poured into the cell, and air was blown in through a glass filter at a constant flow rate to create the foam. When the cell was filled with foam to a height of 45 cm from the bottom, the air supply was stopped and the foam was irradiated with neutrons for 30 minutes at a height of 25 cm.

Figure 2 shows the SANS scattering profiles of the $C_{12}EO_6SO_4Na$ / $C_{12}APB$ mixture (molar ratio 8:2) from immediately after foaming to 30 minutes later. Two inflections were observed in the scattering vector q = 0.1 to 0.5 nm^{-1} immediately after foaming. The SANS profile of a foam is the sum of the reflection from the surface of the foam film and the scattering of the solution inside the foam film, and these inflections are derived from the reflection from the surface of the foam film. The difference in scattering vector q between these bends, Δq, reflects the thickness of the foam film, and as Δq increases over time, it is thought that the thickness of the foam film decreases. The scattering intensity $I(q)$ decreases in all q regions over time, and after 20 minutes of foaming, it shows the same result as the background. From this, it is thought that the foam film becomes thinner and the number of film decreases, and that the foam breaks after 20 minutes. This result is consistent with the results of visual observation. We are currently calculating the average thickness of the foam film based on these data. Detailed structural information on the inside of the foam is expected to be useful in a wide range of industrial fields, including cleaning, cosmetics, and food.

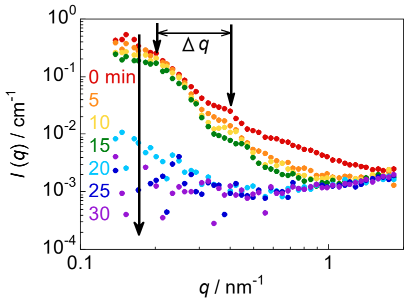


Fig. 2. SANS profile of foams stabilized by $C_{12}EO_6SO_4Na$ / $C_{12}APB$ (8:2) mixture at 10 mmol dm^{-3} in D_2O.