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# VOLTAMMETRIC METHOD AS A TOOL IN DETECTING SURFACTANT-INDUCED DISRUPTION OF A LANGMUIR-BLODGETT FILM

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The interaction of surfactants with a stearic acid LB membrane on a glassy-carbon electrode is shown to be conveniently evaluated by cyclic voltammetry. The membrane disrupting effect of surfactants depended on their structure: the length of hydrophobic carbon chain and the charge of hydrophilic group.

**KEYWORDS** voltammetry; LB membrane; stearic acid; membrane disruption; surfactant

The interaction of surfactants with lipid membranes has received considerable attention from the standpoint of enhancement in percutaneous drug absorption$^{1)}$ and solubilization of membrane components.$^{2)}$ In order to investigate such interaction, it will be worthwhile to develop a simple procedure for evaluating the membrane-disrupting ability of surfactants,$^{3)}$ where artificial lipid membranes, often employed as models for biomembranes, can be used conveniently. In this paper, we approach the subject by an electrochemical method based on the concept similar to that reported for ion-channel sensors.$^{4)}$ Stearic acid Langmuir-Blodgett(LB) membrane transferred onto a glassy-carbon (GC) plate electrode as Y-type trilayer$^{5)}$ was used as the model membrane, and the voltammetric behavior of $Fe(CN)_6{}^{3-}$ at the electrode was examined.

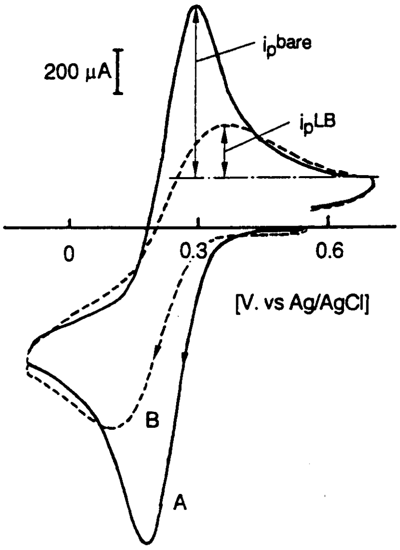

Fig. 1. Cyclic Voltammograms of 1mM $Fe(CN)_6{}^{3-}$ at the Bare GC Electrode(A) and the Membrane-Coated Electrode(B) in 10mM Acetate Buffer (pH 6) Containing 50mM $K_2SO_4$ at 15 °C (Voltage scan rate, $0.5Vs^{-1}$)

Figure 1 shows the cyclic voltammograms of $Fe(CN)_6{}^{3-}$ at the GC electrode with and without the stearic acid LB membrane. The distorted voltammetric wave at the coated electrode indicates that the LB membrane inhibits the access of $Fe(CN)_6{}^{3-}$ to the electrode surface. As reported for the voltammetry of $Fe(CN)_6{}^{3-}$ at membrane-coated electrodes,$^{6)}$ the ratio $R(= i_p{}^{LB}/i_p{}^{bare})$ of anodic currents (see Fig.1) for the coated electrode will represent the degree of this inhibition. If the structure of the lipid membrane is disrupted by a surfactant, the flux of $Fe(CN)_6{}^{3-}$ to the electrode surface will be enhanced and the shape of the voltammogram will be restored to that observed at the bare electrode, i.e., the R value will approach 1.0. Thus, the membrane-coated electrode was immersed in a solution containing one of the following surfactants for 5 min and then rinsed with distilled water for 10 s : $CH_3(CH_2)_7N(CH_3)_3Br$ (**1a**), $CH_3(CH_2)_{11}N(CH_3)_3Br$ (**1b**), $CH_3(CH_2)_{15}N(CH_3)_3Br$ (**1c**), $CH_3(CH_2)_{17}N(CH_3)_3Cl$ (**1d**), $CH_3(CH_2)_{11}SO_4Na$ (**2**), $CH_3(CH_2)_{11}(OCH_2CH_2)_{23}OH$ (**3**). All procedures were performed at 15 °C.

The R values obtained by the coated electrode after the treatment with surfactants(**1**~**3**) are shown in Fig. 2. Among the surfactants with hydrophobic C12-alkyl chain in common [a cationic(**1b**), an anionic(**2**), and a nonionic(**3**) surfactant], the cationic one (**1b**) induced a significant increase in the R value, indicating that disruption of the stearic acid LB membrane is brought about by the surfactant(**1b**) at the concentration near $10^{-2}$M. However, greatly pronounced disrupting effects were exhibited by cationic surfactants(**1c** and **1d**) with hydrophobic alkyl chaines (C16 and C18) similar to that of stearic acid (C17). It can be seen that the disrupting effects are not directly correlated to the critical micelle concentration7) of the surfactants (vertical arrows in Fig. 2). The structure dependence, observed by the present method, of the ability of surfactants to disrupt a lipid membrane is comparable to that of the effectiveness of saturated straight fatty acids8) and alkane sulfonates9) to enhance percutaneous drug absorption.

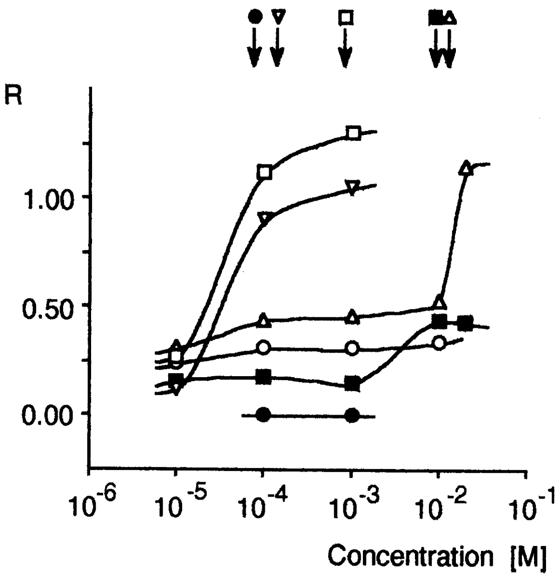

Fig. 2. Effects of Surfactants on the Cyclic Voltammograms of $Fe(CN)_6^{3-}$ at the GC Electrode Coated with Stearic Acid LB Membrane [in 10mM Acetate Buffer (pH 6) Containing 50mM $K_2SO_4$] Vertical arrows represent the c.m.c. values of the corresponding surfactants. The c.m.c. value of **1a** is not shown. (○)(1a), (▲)(1b), (□)(1c), (▼)(1d), (■)(2), (●)(3).

The R values for the cationic surfactants with C12-, C16-, and C18-alkyl chain(**1b**~**d**) at their highest concentration employed were unexpectedly beyond unity. To identify the origin of this phenomenon, the bare GC electrode was treated with surfactants by the same method as described for the membrane-coated electrode, and the voltammograms of $Fe(CN)_6^{3-}$ were obtained by the treated electrode. As seen in Fig. 3, the $R^0(=i_p^s/i_p^{bare})$ values for the cationic surfactants(**1a**~**d**), where $i_p^s$ represents the corresponding anodic current of $Fe(CN)_6^{3-}$

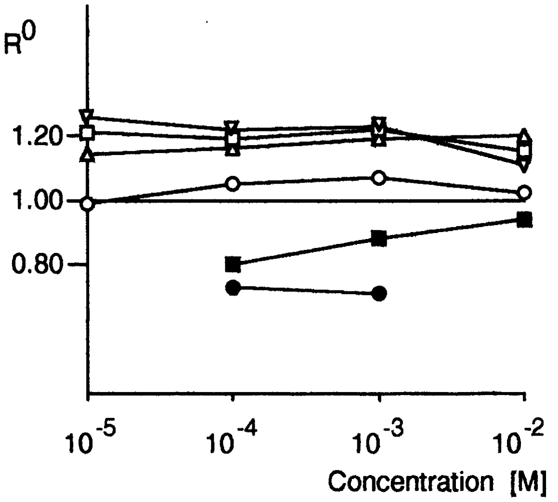

Fig. 3. Effects of Surfactants on the Cyclic Voltammograms of $Fe(CN)_6^{3-}$ at the Bare Electrode [in 10 mM Acetate Buffer (pH 6) Containing 50mM $K_2SO_4$] (○)(1a), (▲)(1b), (□)(1c), (▼)(1d), (■)(2), (●)(3).

(cf. Fig. 1), were all larger than unity and essentially independent of the surfactant concentration. In this case, the shape of the voltammogram became sharper than that at the untreated bare electrode: the cathodic and the anodic peaks were shifted to positive and negative directions, respectively. On the other hand, the $R^0$ values were less than unity for the anionic and nonionic surfactants. These results suggest that the surfactants are adsorbed on the electrode surface, and that those with cationic hydrophilic group enhance the access of $Fe(CN)_6^{3-}$ to the electrode by electrostatic attraction while those with nonionic or anionic group inhibit the access by steric and/or electrostatic repulsion. When the LB membrane on the coated electrode is disrupted by a cationic surfactant, similar adsorption of the surfactant can be expected and the R value will then exceed unity.

Although the observed effects of surfactants on the stearic acid LB membrane (Fig. 2) should be explained by considering the adsorption of the surfactants (Fig. 3), we believe that the present electrochemical method will serve as a useful tool to investigate the interaction between surfactants and lipid membranes. Application of the present electrochemical method to other lipid membranes and markers other than $Fe(CN)_6^{3-}$ is in progress.

## REFERENCES AND NOTES

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