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DPPC–DOPC Langmuir monolayers modified by hydrophilic silica nanoparticles: Phase behaviour, structure and rheology

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ABSTRACT

Langmuir monolayers of 1,2-dioleoyl-sn-glycero-3-phosphocholine (DOPC) and mixtures of DOPC with 1,2-dipalmitoyl-sn-glycerol-3-phosphocholine (DPPC), at a ratio of 37:63 in weight, spread on pure water and on silica nanoparticle dispersions, have been investigated using a combination of thermodynamic, surface rheology, BAM and AFM diagnostics. The compression surface pressure isotherms were determined in a Langmuir trough as well as the surface pressure response to harmonic area variation of the monolayer. Composite layers were obtained at selected thermodynamic states by transfer from the fluid interface to solid substrates and then analysed by AFM diagnostics. Aim of this study was to evaluate the effect of the incorporation of silica nanoparticles on the phase behaviour and structural properties of these monolayers. In fact, as shown in previous works on similar lipid systems, the hydrophilic silica nanoparticles dispersed in the sub-phase are transferred into the monolayer due to the interaction with lipid molecules which makes them partially hydrophobic. The results here obtained indicate that the appreciable influence of silica nanoparticles, previously observed for DPPC alone, is also important for DOPC and DOPC–DPPC mixture. Moreover, as confirmed by the AFM results on the deposited layers, these effects are mainly due to the disruption of the molecular packing and to the modification of the miscibility between the two lipid components.

1. Introduction

The effect of additional components, such as solid nanoparticles, on the properties of Langmuir monolayers of fatty amphiphiles is a topic of increasing interest because of its application as model in several fields involving biological systems, biomembranes response [1] or respiratory physiology [2,3]. Lipid monolayers have been widely investigated by the analysis of the surface pressure–area (Π–A) isotherms [1,4–6] which allows structural features to be identified through essentially thermodynamic information. The phase behaviour of these systems is in fact related to the structural changes induced by the molecular lateral packing in the monolayer [7,8], which is modified by the increasing of the lipid surface concentration. The structure of these monolayers has been investigated in many works using in situ diagnostic techniques, such as X-ray diffraction [9], infrared reflection absorption spectroscopy (IRRAS) [10], fluorescence microscopy [11], laser light scattering [12], and Brewster Angle Microscopy (BAM) [13,14].

The interaction and/or incorporation of external components modifies the phase behaviour and the structure of these monolayers essentially because of the effects on the lateral packing. This is of particular importance for biologically relevant structures which are mostly composed by complex mixtures of surface active components [15], among them, the lung surfactant (LS) [2].

The study of the impact of nanoparticles on the respiratory functionality is a topic of extreme interest in relation to environmental particulate and to the increasing utilisation of nanomaterials [16–19]. Considering that, as show in previous works [20–24], the segregation of nanoparticles at the liquid surface influences the interfacial tension and the dilational rheology of surfactant systems, it is clear the importance to investigate the effects on the surface properties and dilational rheology of lipid Langmuir monolayers, to understand the potential negative effect on the respiratory functionality. LS is in fact a complex mixture of lipids and proteins whose surface tension changes during the respiratory cycle [2,25] ensuring suitable mechanical properties to the lungs.

In a previous work [26] the effect of nanoparticles on the properties of lipid monolayers has been investigated spreading 1,2-dipalmitoyl-sn-glycerol-3-phosphocholine (DPPC) and palmitic acid on silica nanoparticle dispersions. These systems were studied from the thermodynamic and structural point of view, using a Langmuir trough technique coupled with Brewster Angle Microscopy diagnostics. The above lipids are relevant in the field of LS.

In the present work, the effect of silica nanoparticles has been similarly analysed for Langmuir monolayers of 1,2-dioleoyl-sn-glycero-3-phosphocholine (DOPC) and a mixture, 63:37 in weight,

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