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Short communication

Temperature effect on nanometer-scale physical properties of mixed phospholipid monolayers

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Abstract

Mixed dipalmitoylphosphatidylcholine (DPPC) and dioleoylphosphatidylcholine (DOPC) monolayers have been deposited on mica using Langmuir–Blodgett technique, as a model system for biomembranes. Nanometer-scale surface physical properties were quantitatively characterized with the gradual temperature change using the atomic force microscope. At 25 °C, tapping mode imaging revealed the clear phase-separation in the form of microscopic DPPC domain embedded in a DOPC matrix and the obvious step height between the higher DPPC phase and the lower DOPC phase. Surface force measurement made at 25 °C in contact mode showed significant contrasts in deformation elasticity, adhesion, and jump-to-surface. These physical property differences were kept below 40 °C, while they almost disappeared over 40 °C. In addition, the reversibility of the properties for the temperature change was also found.

Keywords: Langmuir–Blodgett technique; Atomic force microscopy; Phase-separation; Deformation elasticity; Adhesion; Jump-to-surface

1. Introduction

Many efforts have been devoted to the study of physicochemical properties of lipid layer in recent years since they are crucial to understanding specific membrane function including molecular recognition, cell adhesion, cell fusion, and intercellular communication [1]. Many of these properties such as the thickness of the layer, the area per lipid value, or the order parameter are governed by temperature [2]. Indeed, lipid layers present many lamellar phases as a function of temperature, namely gel phase, liquid-crystalline phase, subgel phase, and ripple phase. It is widely accepted that many biologically relevant processes occur in the liquid-crystalline phase, and therefore many works have focused on the study of structural and mechanical properties of this phase. Amid all the studies concerning phase transitions, the thermally induced gel-fluid transition has deserved special attention due to the large number of quantities that exhibit anomalous behavior near transition temperature of lipids, such as Na^+ permeability, NMR order parameter, swelling, or hydration behavior [3–6].

Supported lipid layers on solid substrates prepared with the Langmuir trough are well-defined models for cell surfaces and for investigating molecular events in membranes [7,8]. Lipid layers with (sub)microscopic lateral organizations can be used to design surfaces patterned with given functionalities. For instance, two-phase lipid films allow one to incorporate a molecule of interest, such as a specific surface receptor, into one phase, while the other phase consists of a lipid matrix which serves as a reference surface [9].

The atomic force microscope (AFM) has become an important tool to image supported thin films with nanometric resolution. Most of the studies have focused on resolving topographic characteristics [10–17]. With the possibility of accurately controlling temperature while scanning, a novel and promising research line has been opened, mainly devoted to studying topographic surface features induced by temperature [18–23]. Besides imaging, force spectroscopy allows us to obtain valuable experimental information about the interaction forces and mechanical behavior of the studied systems with nanometric and nanonewton resolution through the force–distance curves [24].

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