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Extended Abstract

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Thermodynamic stability of supported lipid bilayers on atomically smooth surfaces

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Supported lipid bilayers (with or without membrane proteins) on solid surfaces have promising potential for bio-sensing applications, unique separation processes, and can be used as simplified models to study biological membranes. The simplest technique to prepare supported lipid bilayer is illustrated in Figure 1, and is often called 'vesicle fusion'. In 'vesicle fusion, lipids are first hydrated in aqueous solution to allow the self-assembly of vesicles. These vesicles then adhere to the surface, rupture, and fuse into supported lipid bilayer. It is often assumed that the vesicles fuse into a continuous lipid bilayer; however, AFM studies show that upon vesicle fusion, lipids can adapt different structures, such as (1) patchy lipid bilayer, (2) lipid bilayer with holes (defects), (3) continues lipid bilayer, (4) multilayer lipid membrane or (5) layer of intact vesicles on the surface.

Importantly, some applications require specific lipid structure. For instance, for separation processes the lipid bilayer must be continuous (defect-free); yet, there is no clear understanding what is the thermodynamically favorable lipid configuration on the surface for a given system (lipid composition, ionic composition, pH, temperature and surface chemistry). During the talk the author will present a simple, yet quantitative mechanism for vesicle fusion on atomically smooth hydrophilic surfaces, such as silica or mica. The model takes into account the adhesion energy between the lipids and the surface, the line tension and the bending modulus of the lipid bilayer. The model can be used to determine whether patchy lipid bilayer, lipid bilayer with holes, or continuous lipid bilayer is the thermodynamically favorable configuration. Then, AFM and impedance spectroscopy measurements will be presented in order to support the proposed mechanism. The proposed mechanism is expected to be useful for engineering the dynamics (rate of vesicles fusion) and thermodynamic stability (long lasting) of supported lipid bilayers for diverse applications. The lipid bilayer is one of the most eloquent and important self-assembled structures in nature. It not only provides a protective container for cells and sub-cellular compartments, but also hosts much of the machinery for cellular communication and transport across the cell membrane. Solid supported lipid bilayers provide an excellent model system for studying the surface chemistry of the cell. Moreover, they are accessible to a wide variety of surface-specific analytical techniques. This makes it possible to investigate processes such as cell signaling, ligand–receptor interactions, enzymatic reactions occurring at the cell surface, as well as pathogen attack. In this review, the following membrane systems are discussed: black lipid membranes, solid supported lipid bilayers, hybrid lipid bilayers, and polymer cushioned lipid bilayers. Examples of how supported lipid membrane technology is interfaced with array based systems by photolithographic patterning, spatial addressing, microcontact printing, and microfluidic patterning are explored. Also, the use of supported lipid bilayers in microfluidic devices for the development of lab-on-a-chip based platforms is examined. Finally, the utility of lipid bilayers in nanotechnology and future directions in this area are discussed. Phospholipid bilayers closely resemble cell membranes in some key respects. For example, they retain two-dimensional fluidity and can be an excellent environment for presenting membrane proteins. Model bilayer systems allow for the investigation of biological processes that occur at the cellular level, providing information about ligand–receptor interactions viral attack and cellular signaling events. In the 1960s Mueller et al. developed the first system for the investigation of the electrical properties of a planar phospholipid bilayer. This system, usually referred to as a black lipid membrane, consisted of phospholipid molecules painted across a 1 mm hole between two solution chambers. Twenty years later Tamm and McConnell deposited lipid membranes directly onto solid supports. In 1997 Boxer et al. pioneered the partitioning of supported phospholipid bilayers into lithographically patterned corrals. This led to the development of individually addressed arrays of solid supported phospholipid bilayers by Cremer and Yang and sensor arrays for the study of cell adhesion by Groves et al. In this review, the effects of substrate structures and properties on the atomic and nanometer scales on the solid-supported lipid bilayers, including our recent reports. Even the surfaces of mica and a SiO2 layer on a Si wafer, which are flat, biologically inert and the most widely used substrates in SLB studies, show differences in the physical structure and properties of the supported membranes. First, we briefly describe the preparation of SLBs by the vesicle fusion method and how the SLB formation process is affected by solid substrates. Second, I describe the effects of substrates on the lateral diffusion of lipids and proteins in SLBs. Finally, the dependence of the two-dimensional domain formation in SLBs on substrate materials and their structures is presented. It also relates to the chemical reactivity of SLB to peptides.

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