Electric Field-Driven Transformations of a Floating Bilayer - a Model of Biological Membrane

Jacek Lipkowski[1] and Mansoor Vezvaie[2]

[1] Chemistry and Biochemistry, University of Guelph, Guelph, ON, Canada
[2] Canadian Neutron Beam Centre, Chalk River Laboratories, Chalk River, ON, Canada

The research was performed during the period July 2-July 10, 2013. Its objective was to investigate the structure of a floating bilayer as a model membrane for spectro-electrochemical studies of transmembrane proteins. In the floating bilayers architecture, the bilayer floats about ~2.4 nm over the supporting layer, and the lateral mobility of the lipids is significantly improved. The fBLM was selected as the most promising model for our future studies with the colicin channel since colicin E1 can be reconstituted into a supported bilayer using the Langmuir-Blodgett technique. A schematic of the model is shown in Figure 1. The lipid bilayer membrane is separated from the gold electrode surface by incorporating the monosialoganglioside GM1 in the inner leaflet of the bilayer composed of the zwitterionic phospholipid 1,2-dimyristoyl-sn-glycerol-3-phosphocholine (DMPC) and cholesterol. The inner leaflet containing GM1, DMPC, and cholesterol is physically adsorbed at the gold electrode modified with a hydrophilic thiol, 1-thio-β-D-glucose. The self-assembled monolayer (SAM) of the sugar thiol on the gold substrate is used to improve the transfer and stability of the inner leaflet. The inner leaflet is organized at the air/water interface of the Langmuir trough and then deposited onto the modified gold support using the Langmuir_Blodgett (LB) technique. The outer leaflet of the bilayer (7:3 DMPC/cholesterol) was deposited using the Langmuir_Schaefer (LS) method. The completed bilayer (including the thioglucose SAM) has a theoretical thickness of ~7 nm, assuming that the lipid acyl chains are in a fully extended state with the molecules perpendicular to the gold substrate surface (see Figure 1). GM1 acts as a "pillar", supporting the lipid bilayer membrane from the modified gold surface. The headgroup of GM1 is composed of four neutral sugar groups and a sialic acid residue. The presence of the large hydrophilic headgroup of GM1 sandwiched between the thioglucose-modified gold substrate and the lipid bilayer should encourage water entrapment under the lipid bilayer, thereby creating a water reservoir, which is essential for accommodating proteins.

The fBLM containing 30 mol% GM1 yields the most uniform, smoothest, and thickest lipid bilayer. This fBLM should be a good model for further studies with transmembrane proteins. The results of this study can be considered as a proof of concept, with the method described in this work being employed to build similar fBLMs with different mixtures of lipids and polysaccharides containing larger sugar headgroups. The originality of this fBLM design is the use of biocompatible and hydrophilic sugar groups to create a water rich space between the solid support and the membrane in which the lipid composition can vary.

Despite the fact that we have successfully assembled this membrane on a small area gold electrode and studied its properties using atomic force microscopy and infrared reflection absorption spectroscopy the results of our experiments at Chalk River were negative. The bilayer assembled at a large silicon support was not stable and floated away. Because of the instability of this sample we are not planning more experiments with this system.

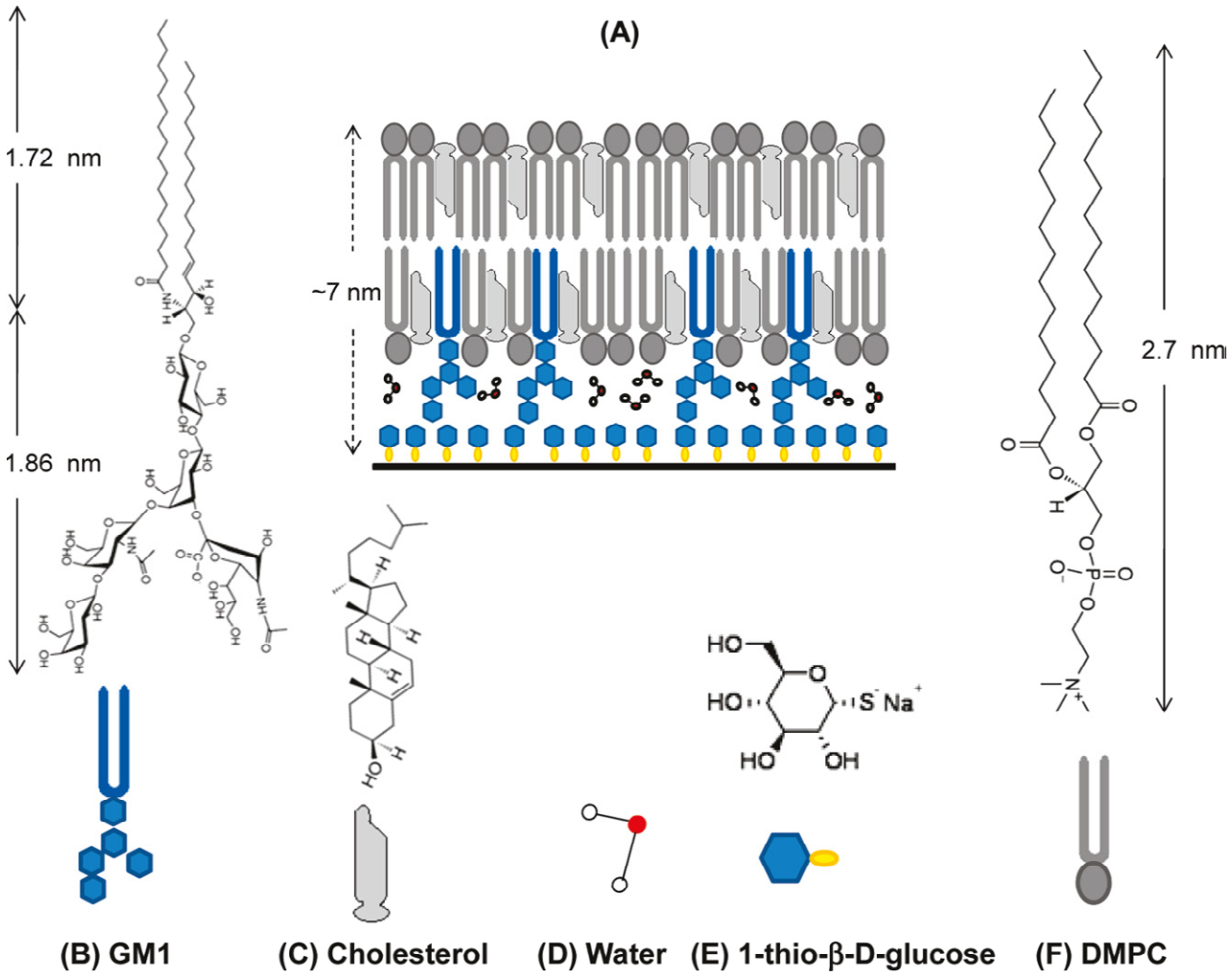

Figure 1 (A) Schematic of the floating bilayer on a thioglucose monolayer on Au(111) constructed using LB/LS deposition techniques. The expected thickness of the entire film is approximately 7 nm. (B-F) Chemical structures of the components used to build the floating lipid bilayer along with dimensions: (B) GM1, (C) cholesterol, (D) water, (E) 1-thio-β-D-glucose (~0.66 nm) and (F) DMPC.