Malaysian Journal of Science **24**: 85 (2005)

Dielectric Physics of Phospholipid Monolayers by Maxwell Displacement Current Measurement and Langmuir Technique

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The research studies cover four major work. The initial step is to set-up and fine-tunes the Maxwell-Displacement-Current (MDC) experimental apparatus. Then the MDC across two types of phospholipids i.e. phosphatidyl ethanolamine (PE) and phosphatidic acid (PA) monolayers at the air-water interface upon monolayer compression is measured. The most important work which is analyzing the results obtained from the MDC measurements is done at the third stage of this research work. The fourth part is depositing and characterizing the spectroscopic behaviours of the phospholipid Langmuir-Blodgett (LB) films on the solid substrates. The fabrication and the capacitance characterization of the metal-insulator-metal (MIM) devices of phosphatidic acid LB films have also been carried out in the final stage of this research work.

The properties of dielectric physics such as phase transition, charge flow, dipole moment, molecular orientational order and dielectric relaxation phenomena can be obtained by coupling the Langmuir technique and the MDC measuring method. The generation of the displacement current across PE and PA monolayers at the air-water interface upon molecular compression is discovered mainly due to the changes of molecular dipole moment. The vertical component of molecular dipole moment is found to be greatly dependent on the hydrophobic alkyl chains, whilst the contribution of the polar head group is insignificant. The phase transition of PE and PA monolayers on the water surface from the planar alignment to polar isotropic phase, which corresponds to the transition from 'gaseous' phase to 'gaseous/liquid' phase has been detected via the MDC measurements. The appearance of the critical area, A_c (where the phospholipid molecules start to stand-up from the water surface upon compression) is found to be greatly dependent on the phospholipids alkyl chains length.

The theoretical treatment on the MDC results has also been performed in order to explore the dielectric relaxation phenomena of the phospholipid monolayers on the water surface. The molecular distribution of these polar molecules has been analyzed on the basis of the Debye-Brownian motion equations, which then leads to the evaluation of the dielectric relaxation phenomena. The analysis reveals that the dielectric relaxation time, τ tends to decrease as the molecular area becomes smaller upon compression.

The Y-type Langmuir-Blodgett (LB) films of phosphatidic acid monolayer and multilayers have been successfully deposited onto the silicon wafer substrates. However the PE LB films can only be deposited up to two monolayers. The Fourier-Transform Infra-red (FTIR) spectra show that the phospholipid LB films are oriented perpendicularly to the solid substrates with alkyl chains in all-*trans* configuration. The MIM devices with configuration of aluminium/phosphatidic acid LB films/aluminium behave as a good insulator layer with relatively high dielectric constant ($\varepsilon \approx 3$). Besides, the MIM devices also show that a native oxide layer has been formed between the bottom aluminium electrode and LB films, possibly during deposition process.