Time-resolved Electromechanical and Conductive Behavior of Nanostructured Bilayers Tethered to the Electrode with Incorporated Channel Proteins and Peptides for Sensor Development

Paweł Krysiński[1,†], Aleksandra Stefanowska[1], Michał Czapczyński[1], Adam Szewczyk[2]

[1]Faculty of Chemistry, University of Warsaw, Pasteur 1, 02-093 Warszawa, Poland
[2]Laboratory of Intracellular Ion Channels, Nencki Institute of Experimental Biology PAS, Pasteur 3, 02-093 Warsaw, Poland
† corresponding author's email: pakrys@chem.uw.edu.pl

The preparation of well-defined, biomimetic layers on solid electrodes remains crucial, due to their essential role in investigating and controlling the ion-conducting behavior of membrane integral proteins and channel peptides. Furthermore, the information gained in such studies can be utilized in the field of electrophysiology, e.g., in describing nerve conduction, the functioning of the membrane respiratory chain, enabling the selectivity of ion flux and its modulation by the transmembrane potential and other external factors such as channel inhibitors or activators that affect their behaviour [1-3]. This, in turn, underpins not only the development of derived sensors and electronic junctions but also of the screening platforms for the development of new drugs.

By employing chronoamperometry and electrochemical impedance spectroscopy (EIS), we investigated the electromechanical properties of tethered biomimetic membranes (tBLMs) on gold electrodes, as well as the conductivity behavior of the mitochondrial inner membrane potassium channel - ROMK2 and channel-forming peptides – Gramicidin A and Amphotericin B incorporated into these membranes. EIS allowed us to follow the membrane dielectric and conducting parameters related to the incorporation of ROMK2 and channel peptides. In the chronoamperometric experiments, the two time constants were resolved by applying a potential step across the membranes. We interpreted this behavior in terms of a fingerprint of electromechanical response of the membrane dielectrics – the electrostriction of tBLM under the influence of an external electric field, and the second time constant was[i] due to the passage of potassium through the channels. These conclusions were verified when potassium was replaced by sodium during the electrochemical measurements, allowing also the assessment of the number of conducting channels incorporated into the tBLMs. The effect of membrane structure on electromechanical behavior was investigated in hybrid bilayers with varying lengths of alkanethiols, revealing the impact of hydrocarbon length [4].

Although the obtained results provide only a rough estimate of the number of ROMK2-ND or Gramicidin channels, they also demonstrate the potential of utilizing tBLMs as biocompatible platforms for membrane protein biophysical studies, as well as bio-components in sensor device development. Due to their robustness and stability, these membranes exhibit substantial capabilities that can be utilized in research and screening platforms for potential pharmaceuticals and innovative drugs, as well as bio-based nanoelectronic devices. The obtained results also highlighted the crucial role of the interaction between the substrate and the membrane in the mechanical properties of the tBLM. Therefore, the potential-induced changes in the tBLMs should be considered in further studies on the structural, mechanical, and electrical properties of biomimetic films deposited on the electrodes.

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References

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