Internet Electronic Journal of Molecular Design

March 2005, Volume 4, Number 3, Pages 221–225

Editor: Ovidiu Ivanciuc

Proceedings of the Internet Electronic Conference of Molecular Design, IECMD 2003
November 23 – December 6, 2003
Part 9

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Received: November 21, 2003; Revised: August 6, 2004; Accepted: September 3, 2004; Published: March 31, 2005

Citation of the article:
D. Ghosh, S. Manna, S. De, R. Basu, S. Das, and P. Nandy, Electrical Properties of Lipid Membrane – Role of Bathing Solution Under Forward and Reverse Biased Conditions, *Internet Electron. J. Mol. Des.* **2005**, *4*, 221–225, http://www.biochempress.com.

Internet Electronic Journal of Molecular Design

BioChem Press
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Electrical Properties of Lipid Membrane – Role of Bathing Solution Under Forward and Reverse Biased Conditions [#]

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Internet Electron. J. Mol. Des. **2005**, *4* (3), 221–225

Abstract

Motivation. The nonlinearity in the I–V characteristics of lipid bilayer membrane in symmetric bathing solution has been explained earlier as due to the semiconducting nature of lipid molecules and mechanism of charge conduction in inhomogeneous system. It is of interest to know the exact conduction mechanism of lipid membranes under forward and reverse biased conditions when the bathing solution is symmetric or asymmetric.

Method. The membrane system was constructed by filling the smooth circular pores (porosity G–4) of an otherwise very tightly packed polycarbonate film with a solution of oxidized cholesterol in *n*–decane. Planar lipid membrane (PLM) was formed when bathing solution was added on both sides. For symmetric bathing solution, acridine orange (an electron donor) was added on both sides and for asymmetric condition acridine orange was replaced by iodine (an electron acceptor) on one side.

Results. The I–V characteristics curves of lipid membranes were studied under forward and reverse biased conditions. We have observed a diode like behavior when the bathing solution is asymmetric, whereas we report here symmetry in I–V characteristics when the bathing solution is symmetric.

Keywords. Bathing solution; planar lipid membrane; I–V characteristics.

Abbreviations and notations	
BLM, Bilayer lipid membrane	PLM, planar lipid membrane
I, current	V, voltage
S_v, noise power	f, frequency

1 INTRODUCTION

As in all inhomogeneous systems, the I–V characteristics of a lipid membrane is nonlinear, irrespective of the nature of the bathing solution it is embedded in. The temperature dependence of conductivity reveals the intrinsic semiconducting nature of the membrane [1–6].

However, depending on the nature of the bathing solution, the detailed feature of this

[#] Presented in part at the Internet Electronic Conference of Molecular Design, IECMD 2003.
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characteristic curves change. Presence of electron acceptors or electron donors in the bathing solution change the intrinsic semiconducting nature of the lipid membrane to an extrinsic one which is reflected in their non ohmic behavior at higher field value [7]. Flicker noise measurements were carried out to understand the conduction mechanism in details. It was inferred that an increase in the number and diameter of the thermally created hydrophilic pores due to increment of electric field were responsible for such non ohmic nature of the lipid membranes [8,9].

We have recently communicated our result which shows that use of an asymmetric bathing solution confers a diode like behavior in these lipid membranes [10]. We report here the effect of symmetric bathing solution under the effect of increasing and decreasing voltage.

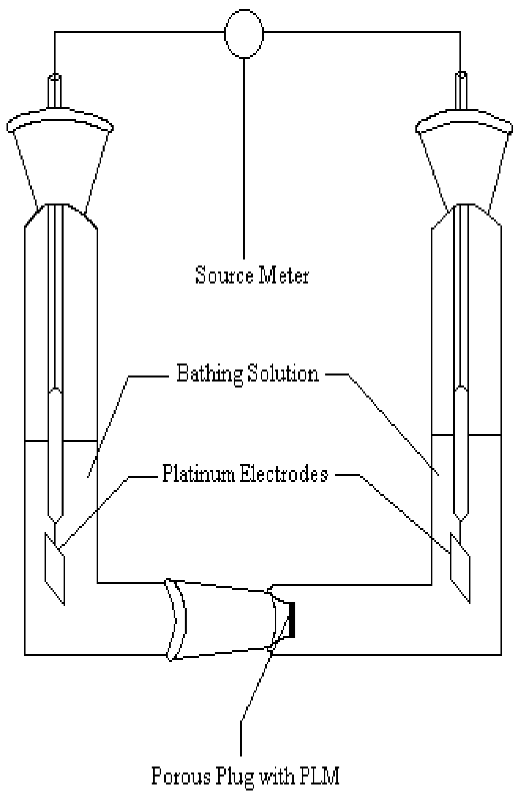

Figure 1. Schematic diagram of the experiment.

2 MATERIALS AND METHODS

Cholesterol, purchased from Sigma Chemical Company (St. Louis, MO) was oxidized and then recrystallized from *n*–octane. Analytical grade chemicals from E. Merck Ltd. (Worli, Mumbai, India) were used without further purification. Iodine was purified by resublimation.

The membrane system was constructed by filling the smooth circular pores (porosity G–4) of an otherwise very tightly packed polycarbonate film with a solution of oxidized cholesterol in *n*–decane. Planar lipid membrane (PLM) was formed when bathing solution was added on both sides.

This system is similar in some respect to the more frequently used bilayer lipid membrane (BLM) but overcomes many of its deficiencies. The major advantage of PLM is that it is much more stable compared to the BLM and an asymmetry in bathing solution can be maintained across the membrane. Because of its stability, PLM has been used as a model for thylakoid membrane and a device for solar energy conversion [11].

Platinum electrodes of 1 cm square were used (inter electrode distance ~ 6 cm) for the application of electric field across the membrane (Figure 1). For asymmetric bathing solution, double distilled water, one saturated with iodine (electron acceptor) and the other saturated with acridine orange (electron donor), both of concentration 1 mM, were used on two sides of the membrane. For symmetric bathing solution, double distilled water, saturated with acridine orange of concentration 1 mM was used on two sides of the membrane.

A Keithley source meter 2400 was used to supply a constant dc voltage across the membrane and to measure the corresponding current values.

3 RESULTS AND DISCUSSION

Above a threshold voltage, the I–V characteristic curves of oxidized cholesterol in symmetric bathing solution of acridine orange show a nonlinear dependence of current on voltage. This has been explained in terms of field induced pore formation and the intrinsic semiconducting property of lipid molecules [7]. This conclusion was further supported by noise spectrum measurement in this system [8], where we have shown that the noise power S_v has a 1/f dependence. The decrease in slope of the S_v – V plot at the onset of non–linearity is the signature of pore formation in the lipid aggregates in hydrated state. The field induced pores help to facilitate the ion transport across the membrane and the size, frequency and conductivity of these pores are also nonlinear functions of the applied bias [2,4].

In the presence of acridine orange, which is an electron donor, the intrinsic semiconducting nature of the lipid molecules changes to an *n*–type semiconductivity [12]. This change in the semiconducting property of the lipid molecules due to presence of an external agent is manifested in the finer details of the I–V characteristics.

Under the asymmetric and forward biased conditions, there is a stepwise increase in the value of the current with voltage, whereas under reverse bias condition the current increases continuously with voltage [10]. This behavior resembles that of a diode and has been explained in terms of double electrode behavior of the membrane [13,14].

We report here that in presence of symmetric bathing solution, another very interesting phenomenon takes place when the voltage is slowly increased and then slowly decreased. Here the I–V Characteristic curves do not trace back the same path, but the pattern is highly symmetrical as displayed in Figure 2.

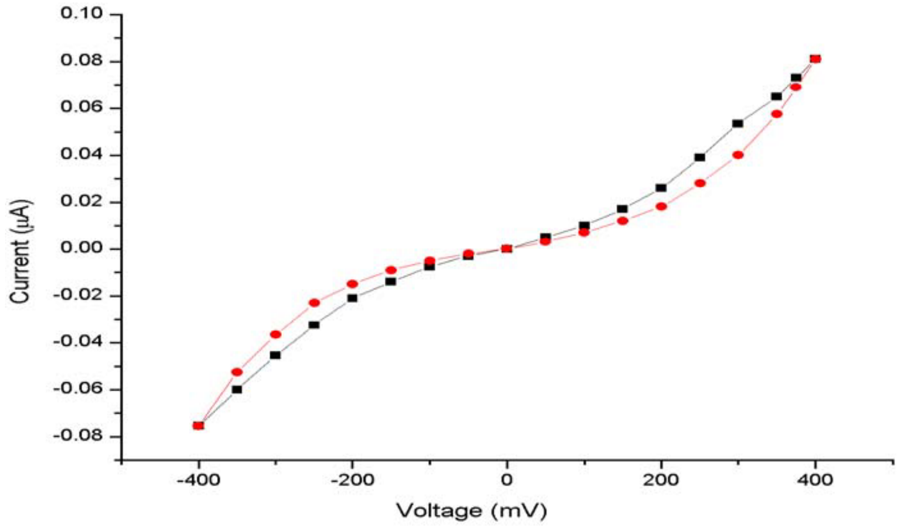

Figure 2. I–V characteristic curve in symmetric bathing solution. Black plot – increasing voltage; red plot – decreasing voltage.

This perhaps indicates a change in the conductance states under the ascending and descending voltage conditions, causing the conduction to be different in the two cases at a particular voltage. This is possible if the conducting channels those were formed while the voltage was increasing closes due to decrease in voltage and also due to thermal agitation.

4 CONCLUSIONS

Charge–conduction across lipid membrane is an important key feature in all life–sustaining processes. Our use of planar lipid membranes as a model for investigation of this mechanism has shown that the electrical behavior of these membranes are different depending upon the nature of the bathing solution they are embedded in, which in turn influences the charge–conduction mechanism across them.

Acknowledgment
Financial assistance from UGC and CSIR, Government of India, is thankfully acknowledged.

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