The Reversible Electrical Breakdown of Lipid Bilayer Membranes and its Resealing Process

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Charge-pulse experiments were performed with lipid bilayer membranes from oxidized cholesterol/n-decane at relatively high voltages (several hundred mV). The membranes show an irreversible mechanical rupture if the membrane is charged to voltages on the order of 300 mV. In the case of the mechanical rupture, the voltage across the membrane needs about 50-200 μsec to decay completely to zero. At much higher voltages, applied to the membrane by charge pulses of about 500 nsec duration, a decrease of the specific resistance of the membranes by nine orders of magnitude is observed (from 10^8 to 0.1 cm^2), which is correlated with the reversible electrical breakdown of the lipid bilayer membrane. Due to the high conductance increase (breakdown) of the bilayer it is not possible to charge the membrane to a larger value than the critical difference V_c. For alkali ion chlorides V_c was about 1 V [1].

Between charging times of 300 ns and 5 μs at 25°C and between 100 ns and 2 μs at 40°C, V_c showed a strong dependence on the charging time of the membrane and decreases from 1.2 V to 0.5 V (25°C) and from 1 V to 0.4 V (40°C). For other charging times below and above these ranges the breakdown voltages seemed to be constant. The results obtained with extremely short pulses indicate that the breakdown phenomenon occurs in less than 10 ns [2].

The resealing process of lipid bilayer membranes after reversible electrical breakdown was investigated with current pulses. The decrease in membrane conductance during the resealing process could be fitted to a single exponential curve with a time constant of 10 to 2 μs in the temperature range between 2°C and 20°C. The activation energy for this exponential decay process was found to be about 50 kJ/mol, which might indicate a diffusion process. Above 30°C the resealing process is controlled by two exponential processes.

The data obtained for the time course of the resealing process can be explained in terms of pore formation in the membranes in response to the high electrical field strength. A radius of about 4 nm is calculated for the initial pore size. From the assumed exponential change of the pore area with proceeding resealing time a diffusion constant of 10^{-8} cm^2/sec for lateral at lipid diffusion can be estimated.

1. Benz, R., Beckers, F. and Zimmermann, U. (1979) J. Membrane Biol. 48, 181 - 204
2. Benz, R. and Zimmermann, U. (1980) Biochim. Biophys. Acta 597, 637 -642