Electrooptical and Conductometrical Relaxation Techniques and the Crossmembrane Transport of Genetic Polyelectrolytes

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In biophysical chemistry, external electric fields have traditionally been applied to probe ionic and dielectric properties of molecules and membranes and to manipulate biological cells and tissue. In particular, the membrane electroporation techniques have gained increased importance for clinical medicine. The method includes the direct electrophoretic transfer of DNA genes, oligonucleotides (in gene therapy) as well as drugs and drug-coding DNA (in electrochemotherapy).

New concepts have been developed for the analysis of electrooptical and conductometrical relaxation data reflecting rapid structural changes and dynamical transport processes in high electric fields. The methods are applicable for cells, organelles and lipid bilayer vesicles in suspensions as well as for planar lipid bilayer membranes in voltage patch clamp configurations. One of the main results is that the primary field effect is interfacial membrane polarization causing an amplified transmembrane field and global entrance of water leading to membrane swelling besides local electropore formation. Closed vesicle and cell membranes are elliptically deformed.

Adsorbed polyionic proteins like the human annexin V and adsorbed polyelectrolytes like DNA facilitate electroporation of the interfacial contact regions. The mean open times of the electropores are enormously increased, from about 1 us in pure bilayers up to several ms in the Ca^{2+}-mediated ternary complexes.

The patch clamp data are consistent with the electroporation concept suggesting nonlinear pore flickering and actual crossmembrane electrodiffusion of polyelectrolytes.

The relaxation spectrometric results are the basis for the goal-directed optimization of the electroporation technique for the electroporative transfer of drugs and genes in tissue.