Project C2: Mapping the electric field in protein-membrane interfaces

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Outline. The interfacial potential distribution across membranes is associated with strong local electric fields that may affect structure and reaction dynamics of proteins attached to the lipid bilayer. Whereas numerous examples of the electric-field control of biological processes at interfaces have been reported, the quantification of the electric field is yet a challenge. On the basis of the achievements of the previous PhD works in this project that were dedicated to map the electrostatics on protein surfaces and self-assembled monolayers (SAMs) on electrodes (Fig. 1), we will now aim at determining the electric field strength at different positions of bilayer model membranes adducts as a prerequisite for a comprehensive understanding of interfacial processes of proteins.

Research within the German group. The studies will focus on the heme protein cytochrome c (Cyt-c) and model peptides immobilised on and in model membranes, respectively. These models are designed to mimic biological membranes, i.e. phospholipid vesicles and electrodes coated with hybrid bilayers. To determine the local electric field, we will exploit the vibrational Stark effect (VSE) of reporter groups, the frequencies of which respond sensitively to the local electric field. Such reporter groups are, for instance, nitrile, thiocyanate, or azide functions that may be site-specifically introduced at engineered protein variants, attached to (synthetic) peptides, or incorporated into the membrane via labelled cholesterol derivatives. To probe the VSE in such protein/membrane devices, IR, surface enhanced IR absorption (SEIRA), Raman and surface enhanced Raman (SER) spectroscopy will be employed. For each VSE reporter group, a detailed experimental and theoretical analysis must be carried out to determine the Stark tuning rate and the vibrational frequency at zero-field. This task includes sorting out interfering effects on the vibrational mode, mainly originating from hydrogen bonding interactions. Furthermore, we will then evaluate the modulation of the electric field in supported lipid bilayers by varying the electrode potential. On the basis of these studies, the well-characterised functional and structural properties of the electron-transferring protein Cyt-c and ion-conducting peptides will be related to the distribution of the electric field inside and on the surface of lipid bilayers.

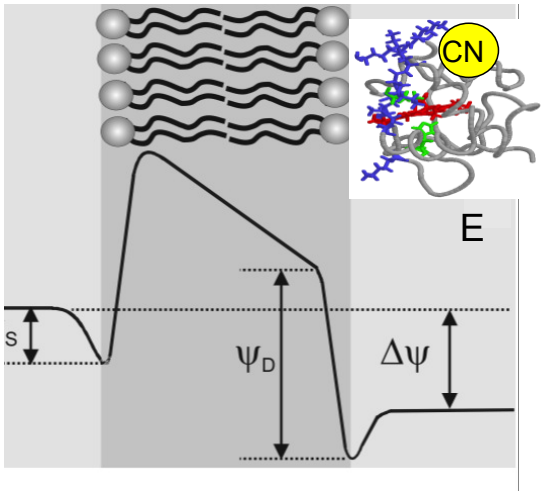

Fig. 1. Incorporation of VSE reporter groups at different positions of the SAM/protein interface allows determining the local electric field.

Longer-term perspective. Later in the continuation period, the studies will be expanded to multicomponent liposomes that represent more realistic models for biological membranes (collaboration with Dimova, MPIKGF). Here methodological developments are required to adapt Raman and IR microscopic approaches in order to probe electric-field heterogeneities in domain-containing liposomes.

Complementary work in the US partner group. The Franzen group will contribute to theoretical analyses on the VSE and IR spectroscopic studies on dehaloperoxidase which will further analysed by SERR and SEIRA spectroscopy in our group.

Status of the project. This project is tightly linked to the projects of Dimova and Lipowsky that are dedicated to studies of multicomponent lipid membranes. In addition, we will make available vibrational spectroscopic techniques to all projects in the IRTG.