Targeted Project / AY 2025 -2026

The study of charge transport on the surface of bio-membranes

Project Reference: TRG-CHE-SM

Supervisor: Dr Svetlana Menkin (sm2383@cam.ac.uk)

Department/Institute: Chemistry

Website: https://www.ch.cam.ac.uk/person/sm2383

Co-supervisor: Dr Jenny Zhang (Chemistry)

BBSRC DTP main strategic theme: Transformative technologies

BBSRC DTP secondary strategic theme: Bioscience for renewable resources and clean growth

Project outline:

Charge transport is one of the most critical drivers in bioenergetics. Measuring the charge transport rate on the membrane-electrolyte interface is expected to contribute to understanding living cells' physiology and their interactions with other cells. Furthermore, understanding biological energy harvesting and storage mechanisms is expected to help advance biotechnologies for renewable energy conversion, climate mitigation efforts, and agriculture.

A scanning electrochemical microscope (SECM) has been used to investigate transport across synthetic and biological membranes, molecular transport paths and mechanisms. [1] SECM has advantages in biological studies because measurements can be carried out with a scanning electrode that does not touch the specimen and that interferes with the sample much less than tips of alternative scanning probe techniques (e.g., atomic force microscopy).

SECM is used to probe the bacterial chemical environment, a cell's distribution and role within a biofilm topography, and mechanisms of anti-bacterial resistance and bacterial respiration (by mapping oxygen concentrations). Typical SECM measurements utilise a redox mediator that does not interfere with the measured system [2-3]. More advanced potentiometric and alternating current (AC) methods in SECM bear the intrinsic advantage of neither disturbing nor changing the target of investigation. Moreover, AC-SECM measurements do not require redox mediators. [4] When the AC-SECM is paired with basic electrochemical methods, simultaneous topography measurements and selective chemical and electrochemical information can be obtained. [5]

Significant expertise in using SECM and impedance spectroscopy (EIS) for studying metal-electrolyte interfaces in batteries has been developed in the Menkin group. Developing unique SECM and EIS methodologies will allow us, for example, to probe approximately 1000 times per square centimetre of a sample in a single experiment or achieve chemical specificity by adjusting the electrochemical potential of the SECM tip. [1]

This project aims to develop SECM techniques to monitor and ultimately control charge transfer processes across biofilms, individual cells and bio-membranes. In collaboration with the Zhang group in Chemistry, this project aims to understand charge transfer mechanisms of electro-active biological cells relevant to energy conversion and climate mitigation space. These include dinoflagellates (implicated in coral bleaching), cyanobacteria and algae (engineered for bioelectronics for power and chemical generation) and bacillus (a model system for understanding biofouling and anti-biotic resistance).

Objectives:

• Develop an SECM setup for the study of bio-interfaces with electrochemical specificity.

• Study charge transport mechanism across bio-interfaces and achieve a general understanding of the interplay between live cell electrochemical activity and its environment.

• Feedback insights for enhancing bioenergy harvesting processes.

References:

Scanning Electrochemical Microscopy, Imprint CRC Press. [1] Chapters 9 and 11, 2nd ed. [2] Chapter 11 3rd Ed.

[3] Diakowski et al. Phys. Chem. Chem. Phys., 2007, 9, 5966–5974

[4] Eckhard et al. Analyst, 2008, 133, 1486–1497

[5] Koch et al. Anal. Chem. 2012, 84, 9537−9543