Electrical Characterisation of Model Membrane Interfaces using Electrochemical Impedance Spectroscopy

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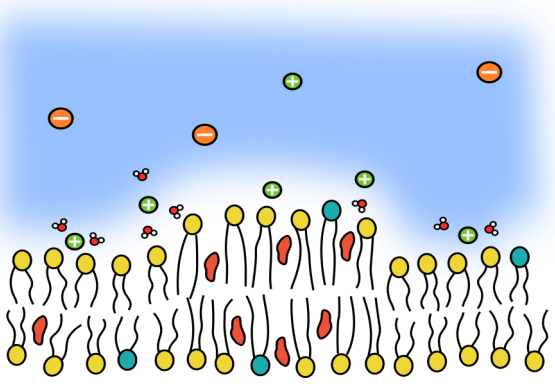
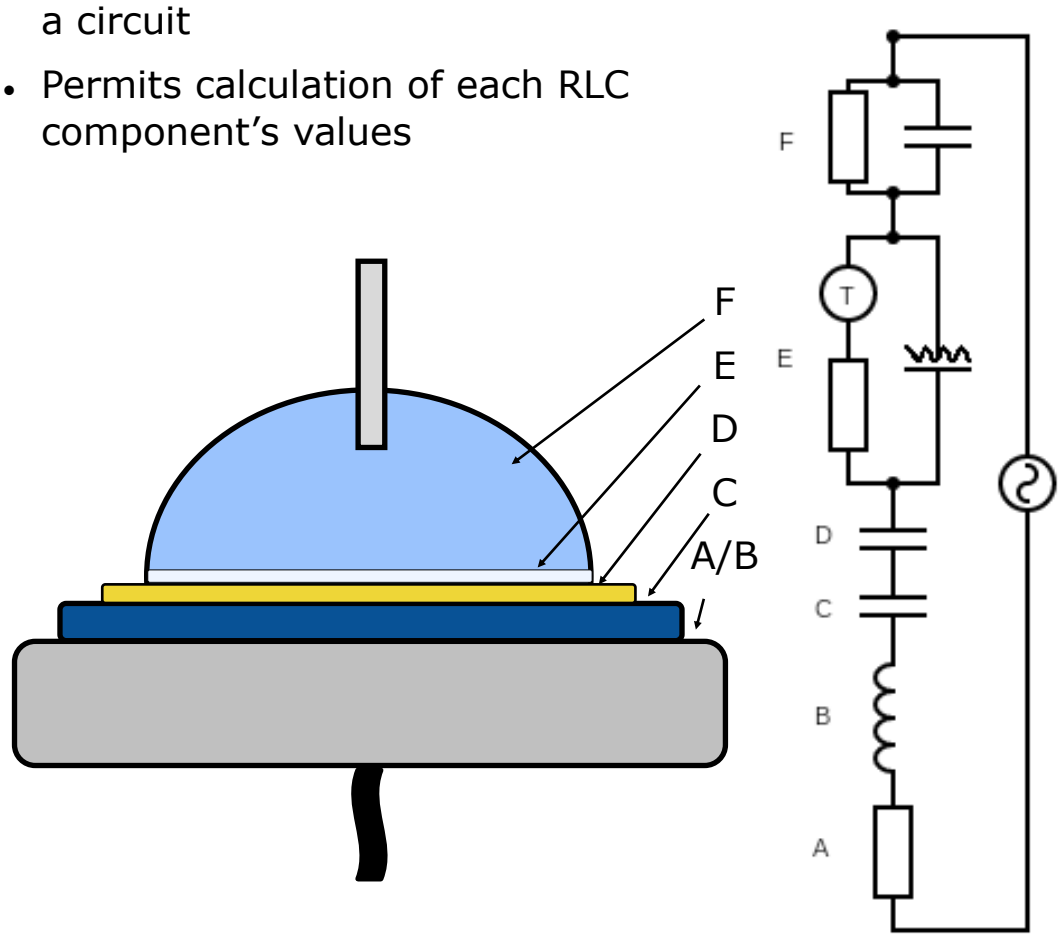
Background and Motivation

- Ionic interactions with cellular membranes are intrinsic to many biological processes and cell functionality
- Our understanding is limited by ion-specific hydration effects [1], difficulty modelling MD variables (e.g. pH) and mesoscale dynamics [2]
- Charge-transfer behaviour and transmembrane potentials in bio-mimetic environments especially hard to replicate
- Electrical characterisation of the interfaces desirable for direct SPM and interpretation

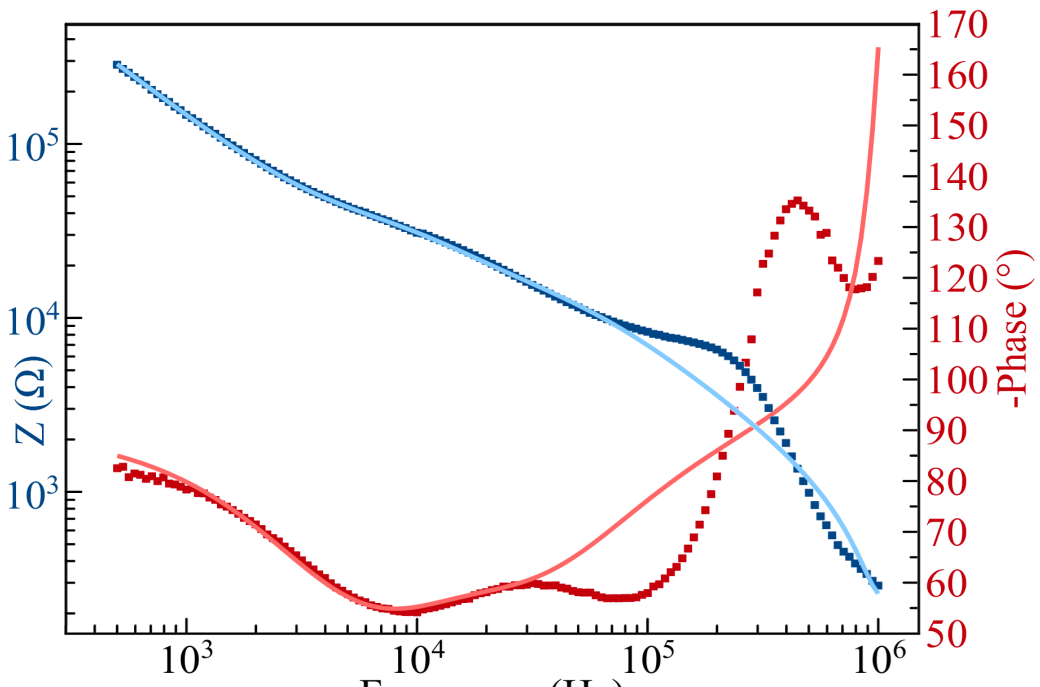


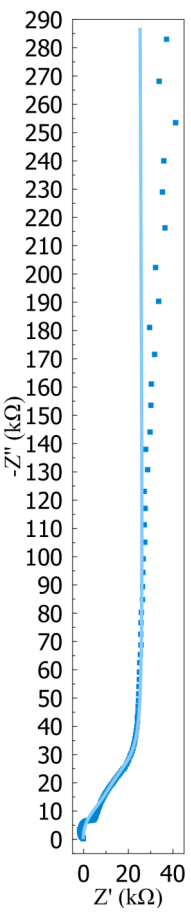
Experimental Method

- Supported lipid bilayers (SLBs) on blocking electrodes in alkali-halide electrolytic concentrations ranging from 0.1-150 mM
- Electrochemical impedance spectroscopy allows for determining the electrical characteristics of various membrane-liquid interfaces
- Individual aspects of interface can be modelled as equivalent RLC components
- Varying-frequency AC field implemented across the system
- Impedance Z(ω) determined for each component as a circuit
- Permits calculation of each RLC component's values



Experimental Results





Example Fitting Results: 0.1 mg/mL DOPC on 50 nm Silica Wafer in 1 mM NaCl

Aspect	'Equivalent'	Component	Value
A	Wiring/ components	R	257 Ω
B	Wiring/ components	L	108 μH
C/D	Silica/SLB	C	3.81 nF
E	EDL(s)	R	25.0 kΩ
		T	10.2 μS√s 2.73×10^{-4} √s
		Q	244 $pSs^{0.9}$
F	Electrolytic solution	R	10.4 kΩ
		C	308 pF

Conclusions and Future Work

- EIS is a versatile method for determining the specific RLC values of certain characteristic systems following basic physics (phew!)
- When SLB RLC characteristics are confidently determined, next steps are to incorporate the impedance spectroscopy rig into our AFM to allow for imaging of membrane-liquid interfaces under realistic transmembrane potentials with single-ion resolution [2]
- Hopefully leads to improved understanding of molecular transport, disease signalling, oncogenesis [3] and thermomechanical behaviour of membranes for insight into new theoretical models and beyond nanometre and nanosecond MD
- Ask me about my LEGO AFM...

References

[1]: N. Schwierz, D. Horinek, R. R. Netz, *Langmuir*, **2015** 31, 215

[2]: M. Ricci, W. Trewby, C. Cafolla, K. Voïtchovsky, *Sci. Rep*, **2017** 7, 43234

[3]: J. A. Olzmann P. Carvalho, *Nat. Rev. Mol. Cell. Biol.*, **2019** 20, 137-155

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