Microemulsions: The perfect electrochemical solvent and why you should study them

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Oil + Water | Emulsion | Microemulsion

Thermodynamically stable mixture of oil and water

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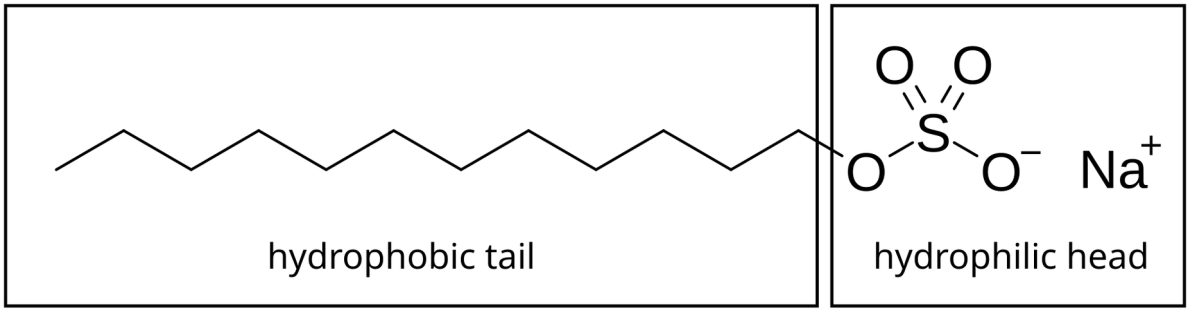
Example compositions

- Aqueous phase - Salt + water
- “Oil” - non-polar solvent
- Surfactant - Amphiphile
- Co-surfactant - optional



Components	**wt %**
H_2O	82.1
Cyclohexane	3.2
SDS	4.9
Butanol	9.8

Components	**wt %**
H_2O	50
Cyclohexane	22
SDS	9.33
Butanol	18.67

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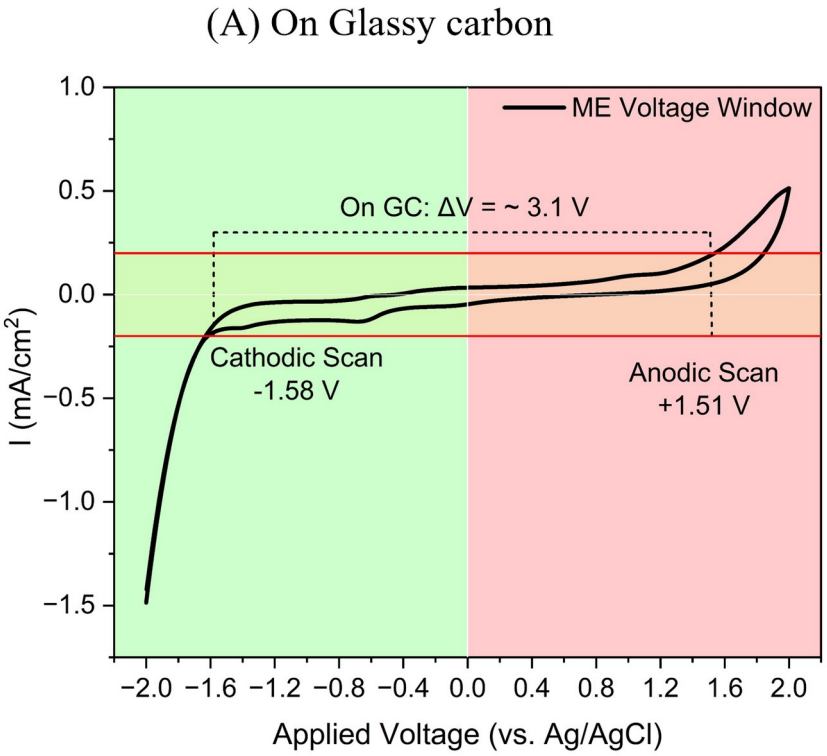
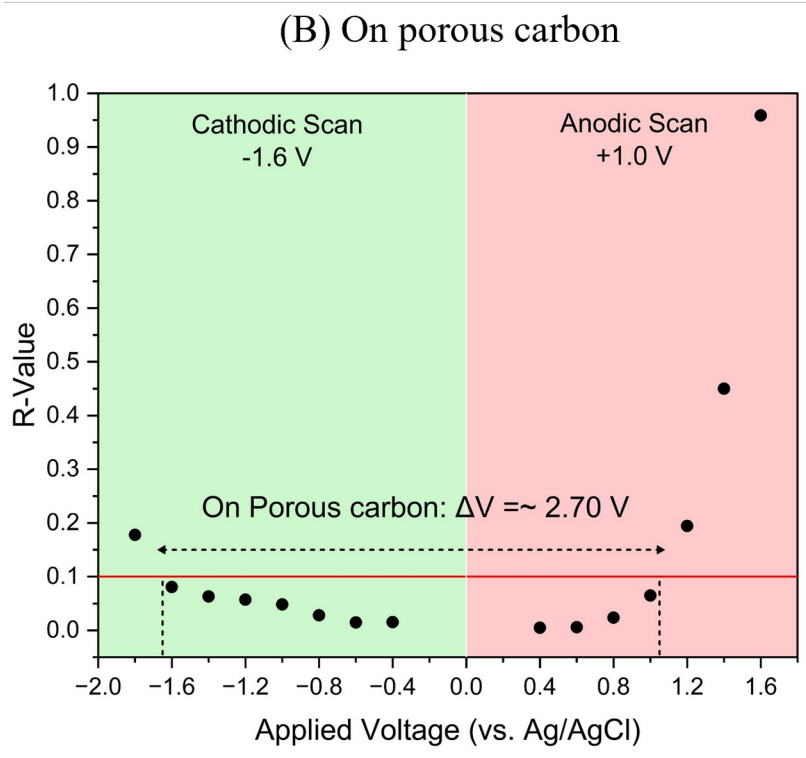
What are the biggest problems in flow battery chemistry?

- Gas evolution
- Cost
- Availability of active materials - Mine it or make your own?
- Instability of charged states

Greatly extended electrochemical window - NO GAS!





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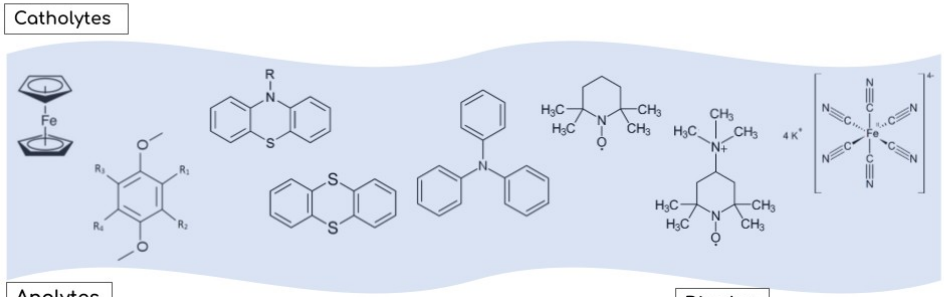
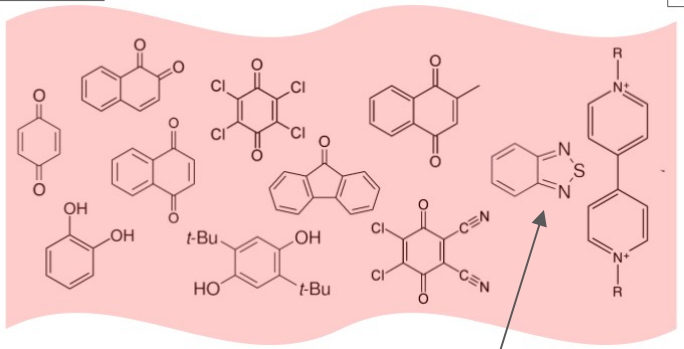
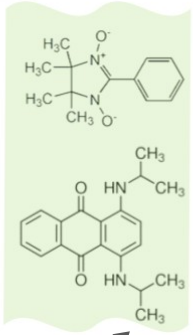
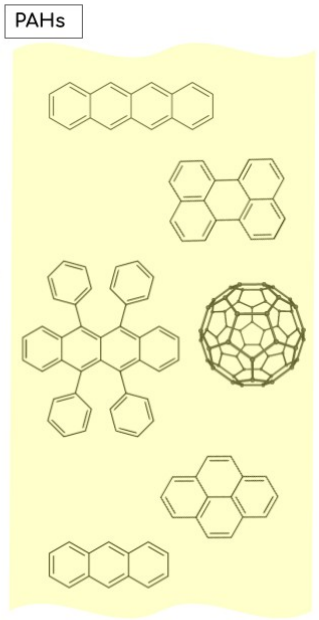
INFINITE possibility - pick or design any active material

Unmodified Molecules already at scale









Difficult to analyse

12M soluble in toluene

Dye molecules

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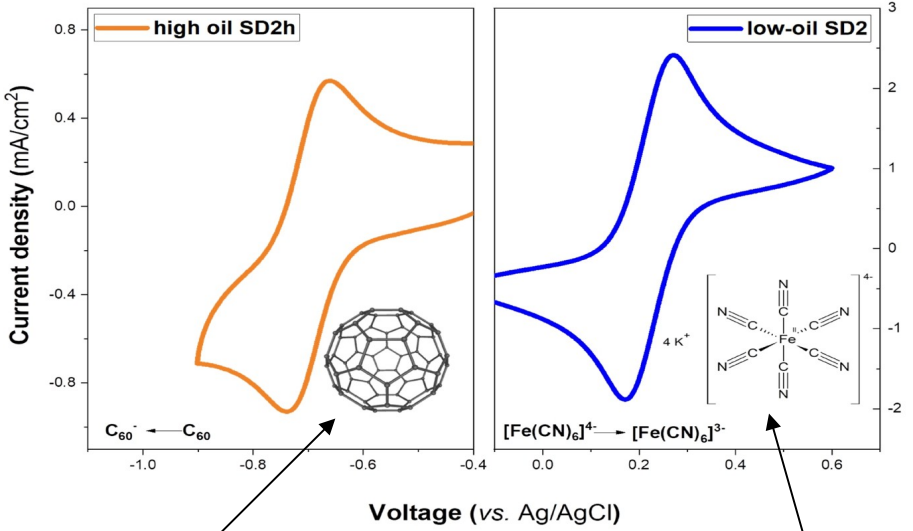
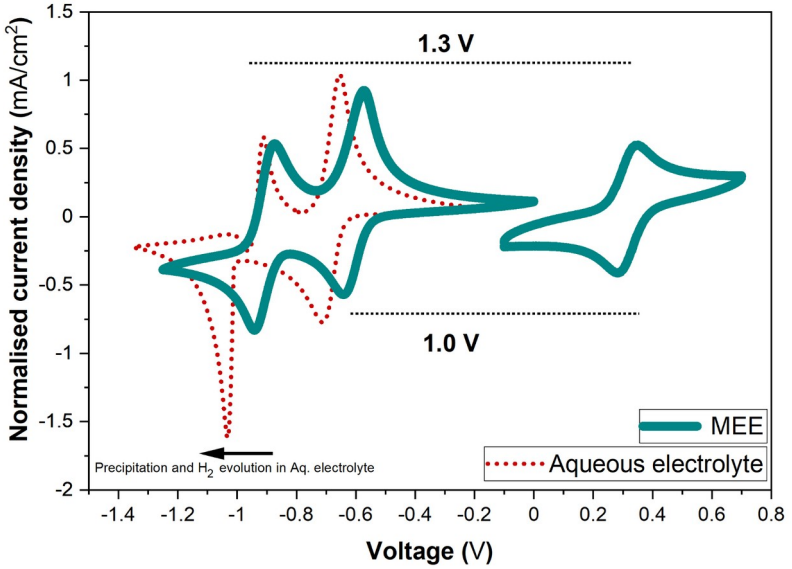
INFINITE possibility - pick or design any active material





Observe even the most complex molecules

Doesn't interfere with standard aqueous chemistry

2 electron process with no need to worry about solubility

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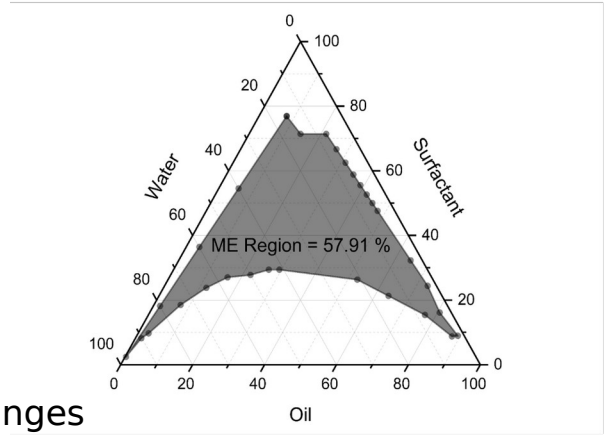
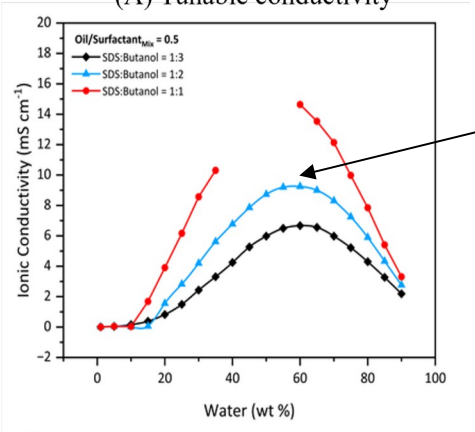
Customise the electrolyte you want!



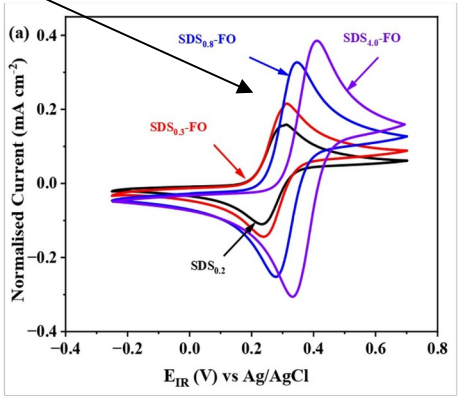
(A) Tunable conductivity

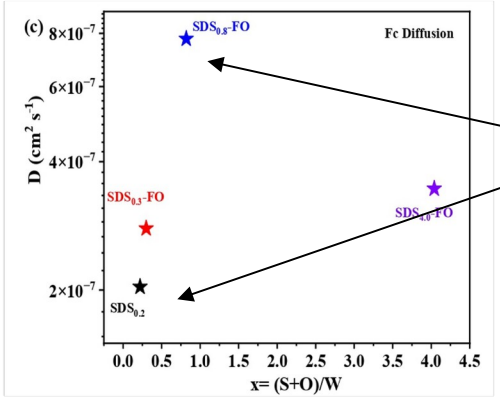


Peak at ~60% water content

Voltage changes with composition

(B) Enhanced mass diffusion and kinetics





Diffusion changes with composition

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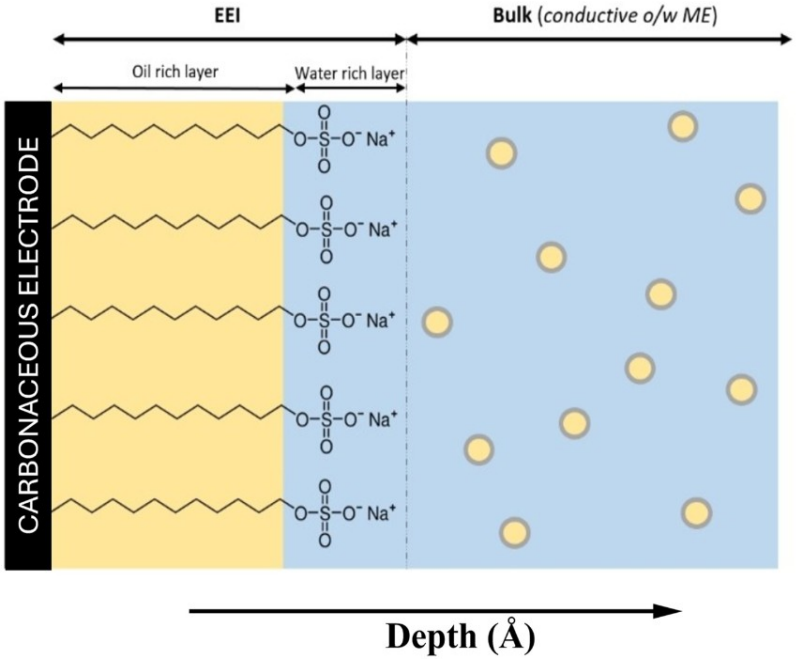
Research case study: What does the electrode interface look like?



Oil rich layer prevents water from reaching the electrode - preventing water splitting!

Outer sphere processes in water soluble compounds can still occur

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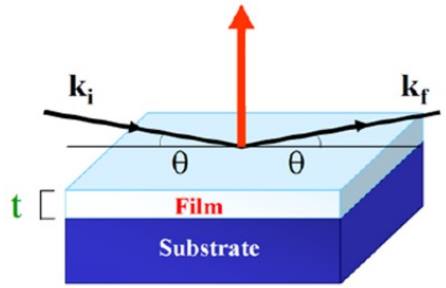
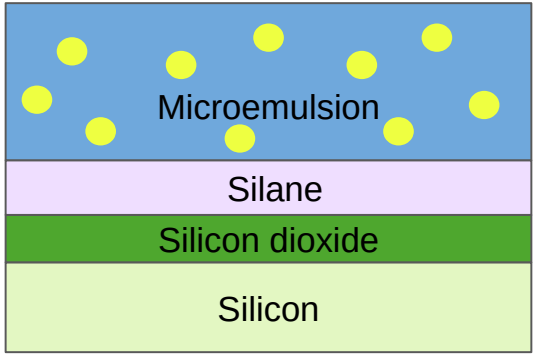
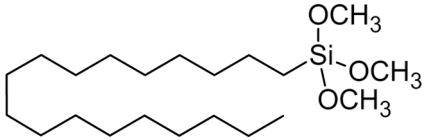
Neutron reflectometry - Resolve Depth



- “Reflectivity” changes as a function of depth comparing k_i to k_f
- See changes in composition with depth



- Silicon for flatness
- Silicon dioxide for customisation
- Silane for hydrophobicity



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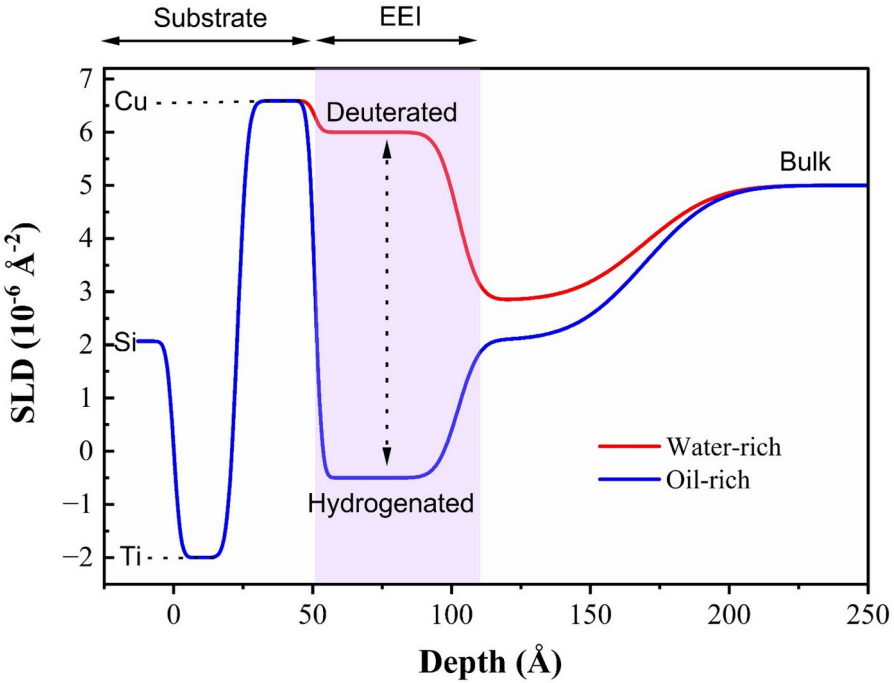
Nanoscale information



SLD = Scattering length density, changes with composition, deuteration can resolve layers

Lower SLD = More Oil
Higher SLD = More water

$$SLD = \frac{\Sigma_{i=1}^{n} b_i}{V_m}$$

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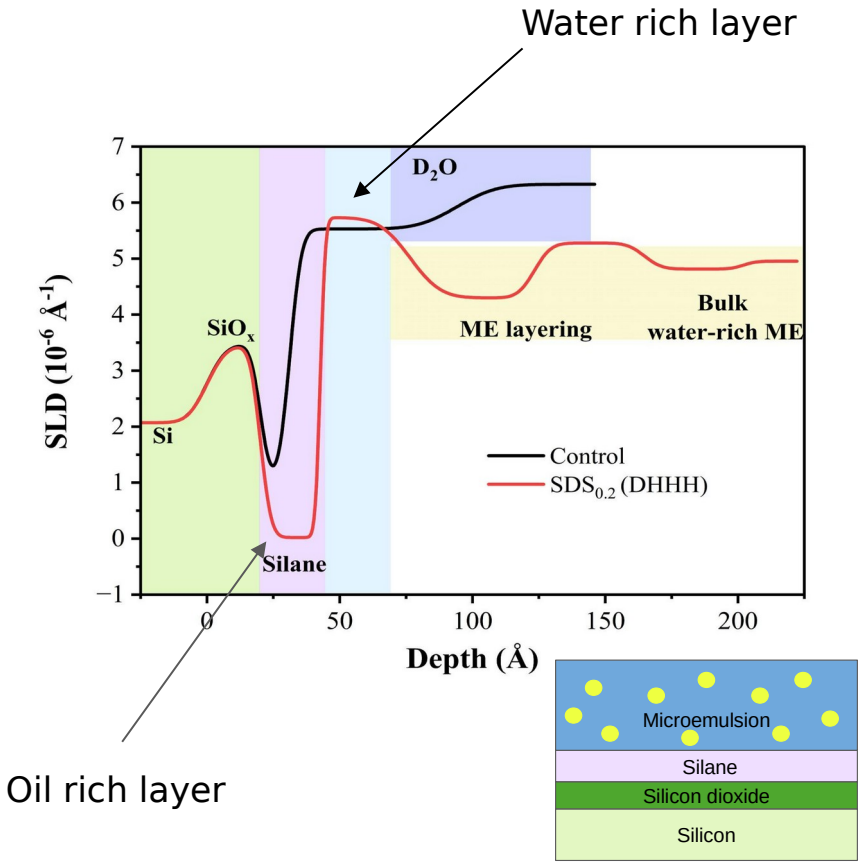
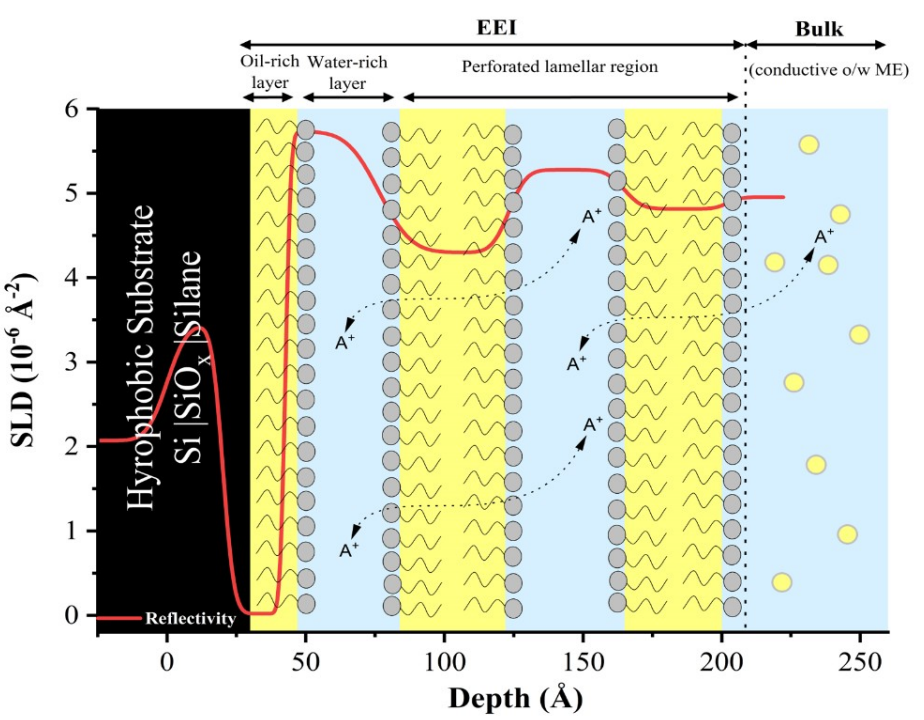
Results





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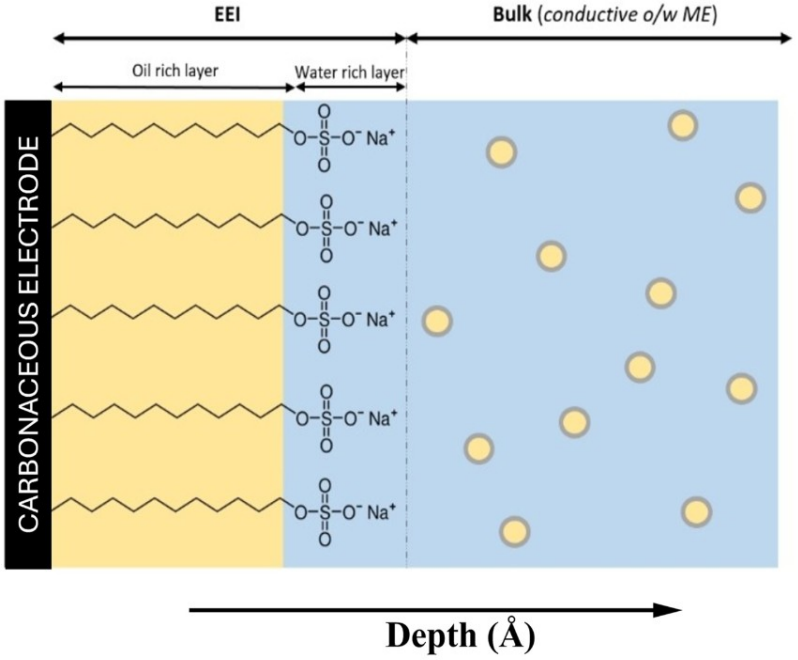
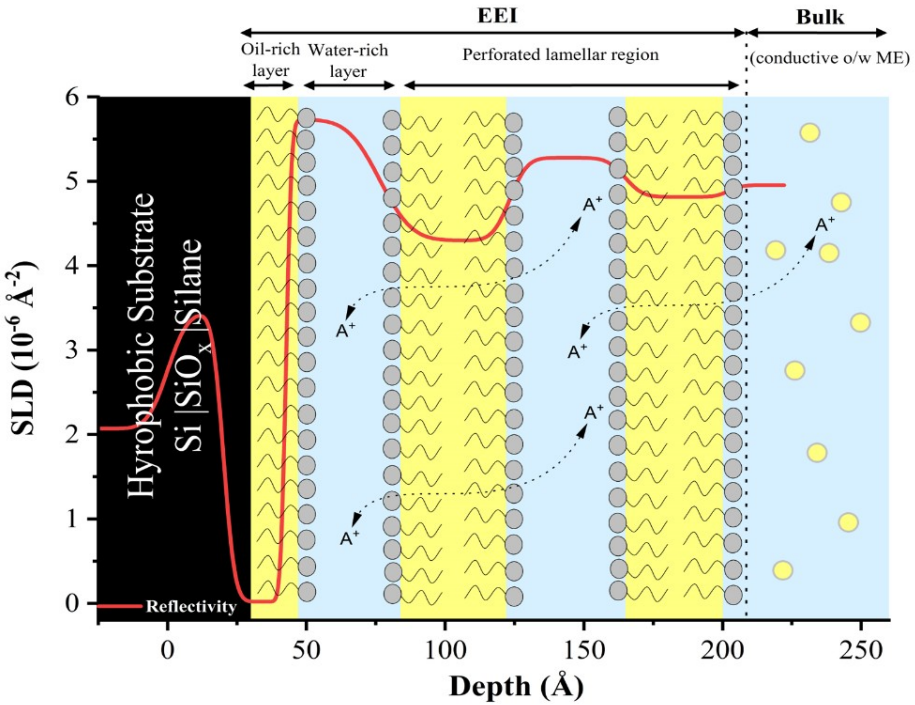

EEI
Bulk (conductive o/w ME)
Oil rich layer
Water rich layer
CARBONACEOUS ELECTRODE
Depth (Å)


EEI
Bulk
Oil-rich layer
Water-rich layer
Perforated lamellar region
(conductive o/w ME)
Hyrophobic Substrate
Si |SiOx |Silane
Reflectivity
SLD (10-6 Å-2)
Depth (Å)

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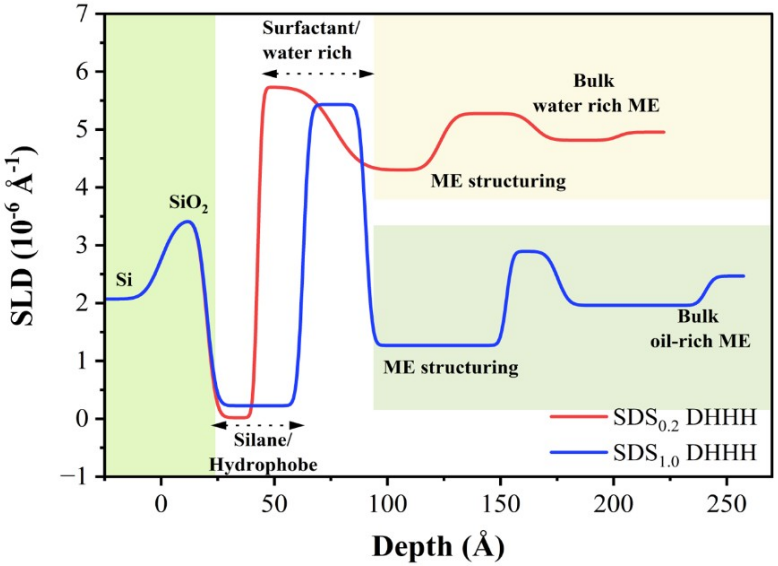
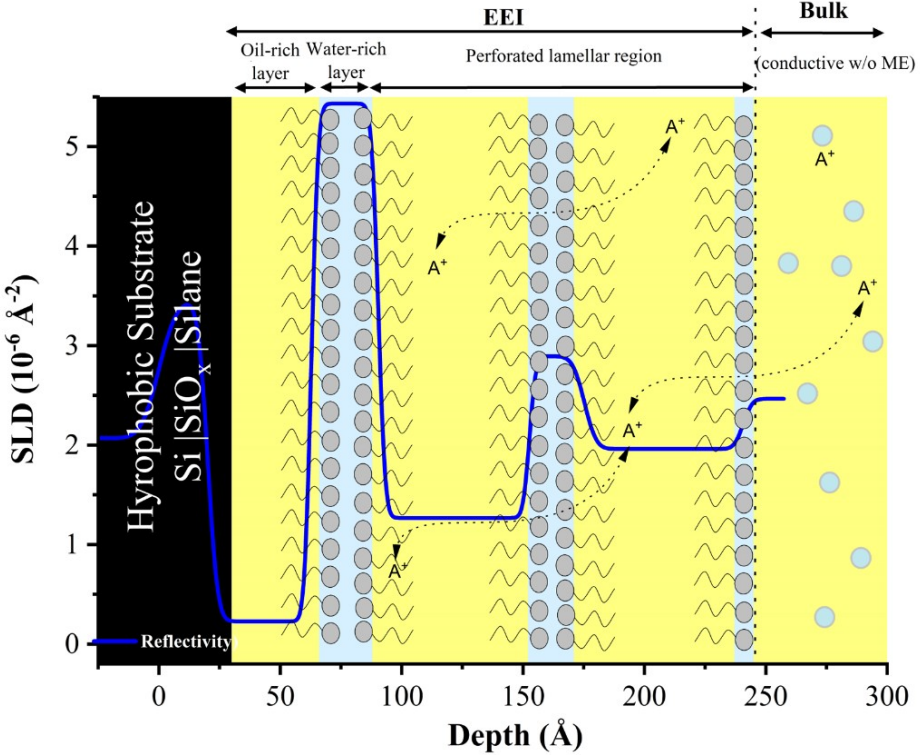
Compositional changes





Red = low oil ME

Blue = high oil ME

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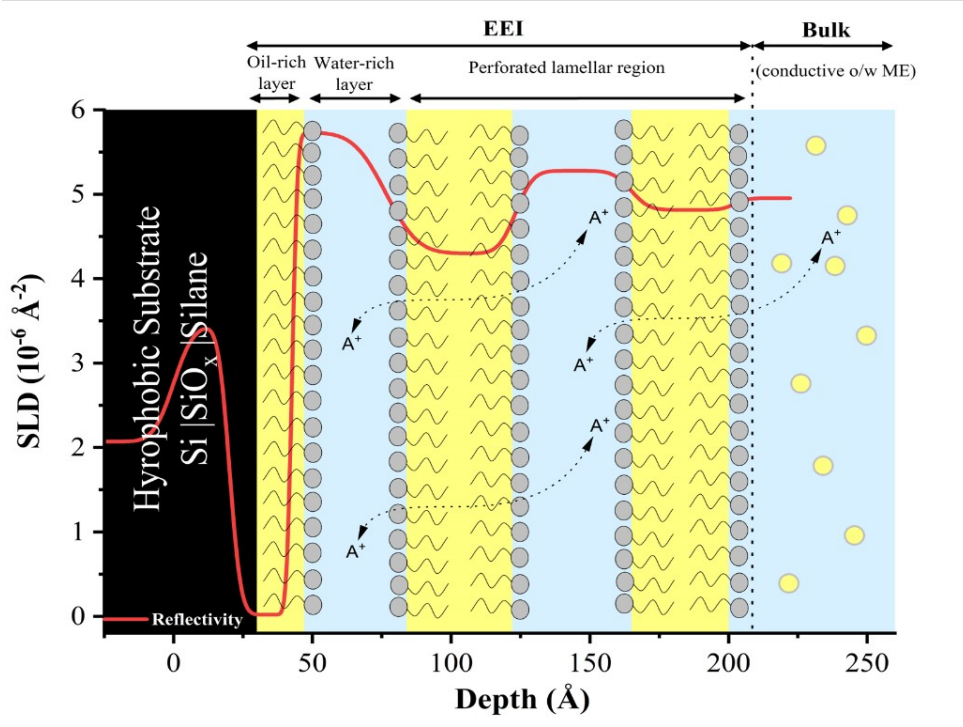
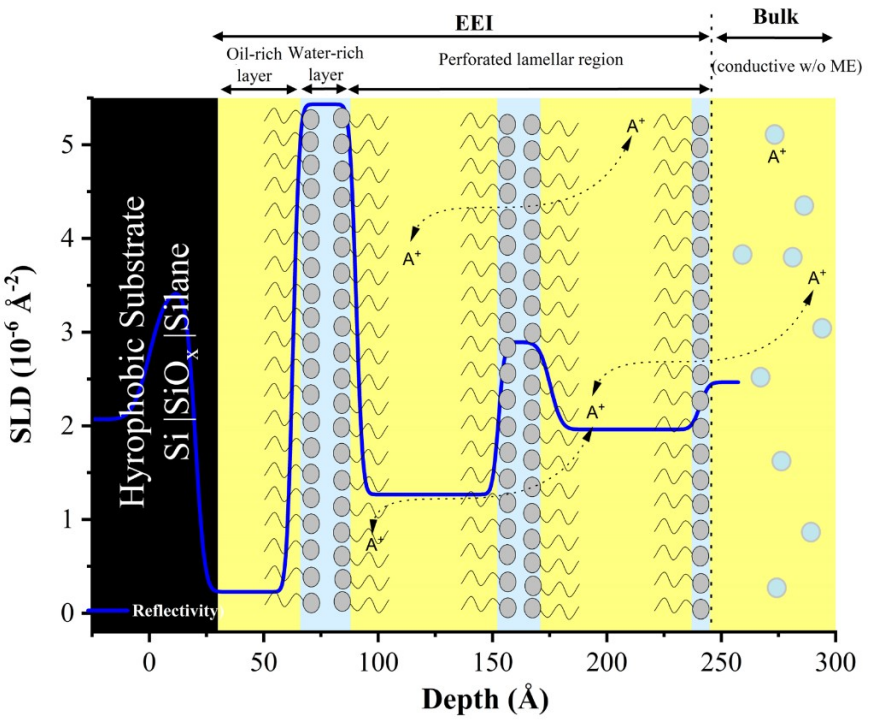
Fine control over interface structure



Low oil content



High oil content

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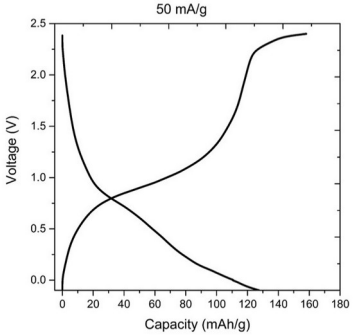
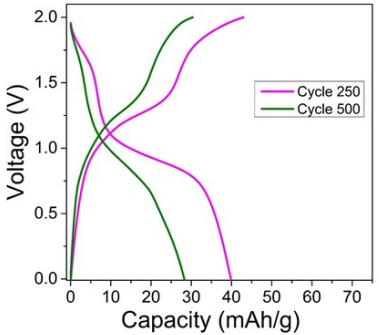
Paper ideas: Utilise academic freedom!

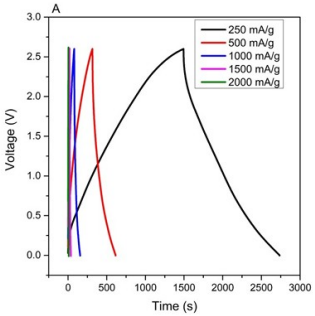
- Influence of surfactants on membranes (in-situ ion exchange?)
- Kinetic enhancements in microemulsions
- **Design the best molecule you can without the constraint of solubility or voltage**
- Electrosynthesis in microemulsions
- Extreme environments solved by microemulsions (>100C)



Lithium Ion batteries



Sodium Ion batteries



Supercapacitors

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The team at Allegro Energy - Driven to make GW and GWh a reality