Investigation of Streaming Potential in Electrical Double Layers

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Introduction

- **Electrical double layers (EDLs):** a structure that forms when a solid is immersed in liquid
- **Streaming potential:** fluid flow generates electrical potential; driving force: electroosmosis
- **Motivation:**
  - **Physicists:** flow affects the accuracy of electrodynamic calculations
  - **General public:** EDLs have applications in biology, geophysics, and everyday colloidal systems. EDLs on fat globules prevent coagulation of milk.
- **Goals** include investigating**:**
  1. the dependence of streaming potential on salinity and type of ions (NaCl, KCl, Na_2SO_4)
  2. the effect of flow on impedance and dielectric constant of sand

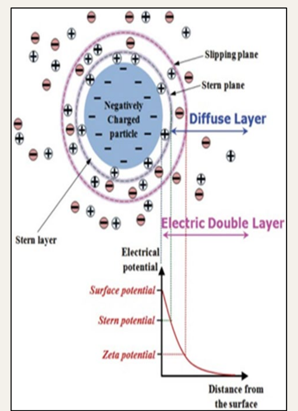


Fig 1. EDL.

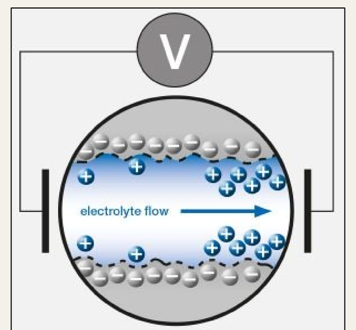


Fig 2. Streaming potential.

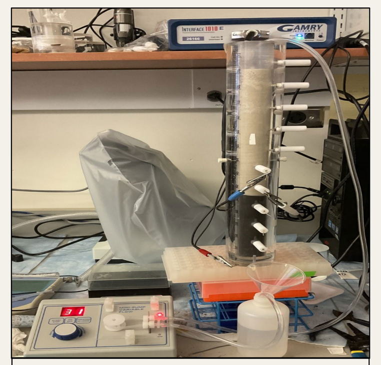


Fig 3. Picture of setup in lab.

Experimental Setup

- **Instrumentation:**
  - **Impedance spectroscopy:** an AC voltage is applied to a sample at different frequencies and the electrical current is measured

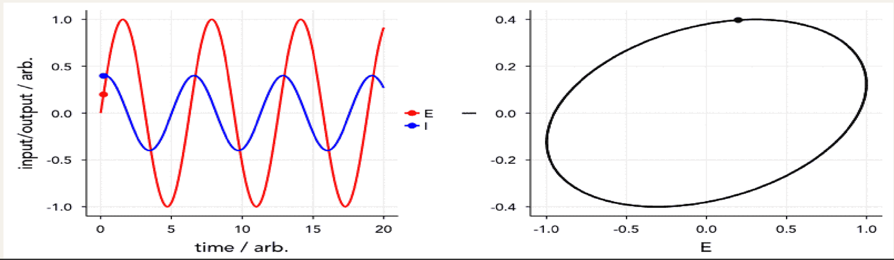


Fig 4a. Representation of impedance spectroscopy; **Fig 4b**. Lissajous curve

  - We used the Gamry 1010 potentiostat to take three sets of measurements:
    1. Voltage measurements
    2. Impedance spectroscopy measurements & single frequency impedance measurements
- **Basic setup:**
  - Flow: outflow and pump are synchronized
  - No flow: outflow and pump are stopped simultenosuly

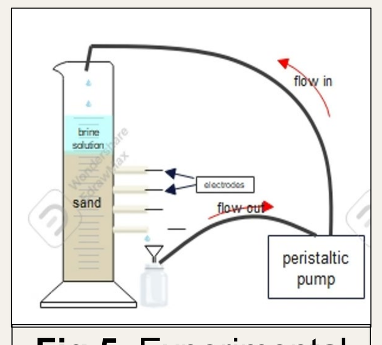


Fig 5. Experimental setup.

Modelling

- Modelling EDLs as circuits helps us find useful information such as dielectric constant
- **Dielectric constant** gives information about the interfacial polarization
- System is roughly modeled by a capacitor and resistor connected in a parallel configuration to get the dielectric constant
  - **Capacitor:** the separation of charges
  - **Resistor:** the leak of charges between the capacitor

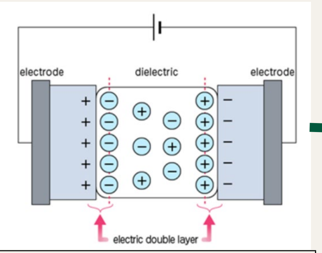


Fig 6. EDL

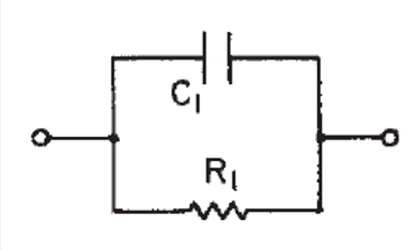


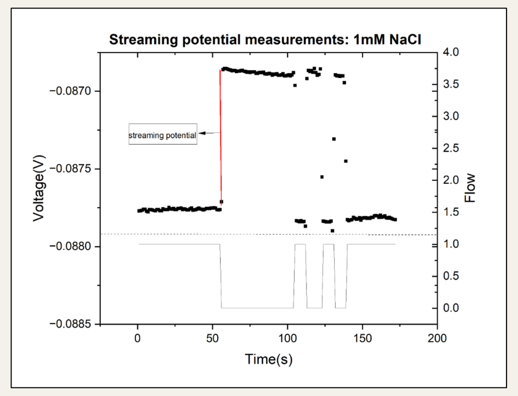
Fig 7. RC circuit

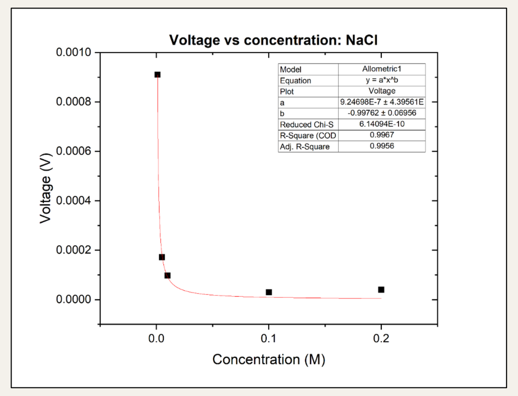
$$\epsilon = -\frac{X}{R^2 + X^2}\frac{1}{\omega}\frac{d}{A}\frac{1}{\epsilon_0}$$

Dielectric constant formula

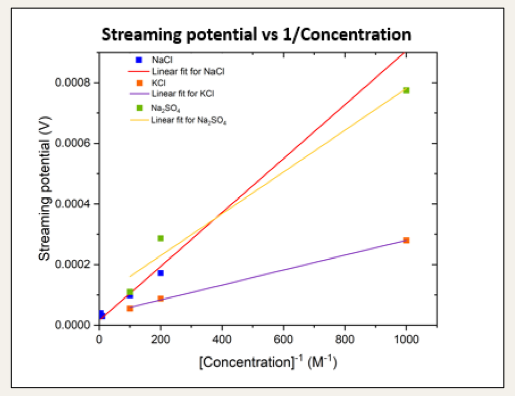
Results and Discussion

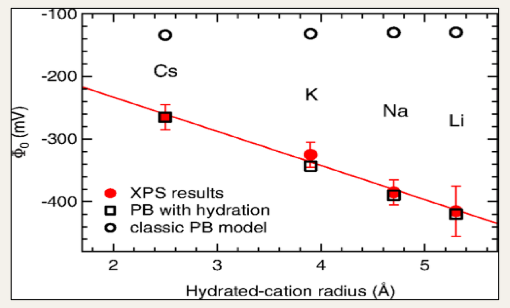
- **Dependence of streaming potential on salinity:**
  - We demonstrated that streaming potential decreases with increasing salinity





  - This is because the **Debye length** decreases with increasing salinity and thus, affects streaming potential
- **Dependence of streaming potential on types of ion:**
  - We demonstrated that cation-specificity of streaming potential is more significant that its anion-specificity
  - The streaming potentials of NaCl were greater than KCl

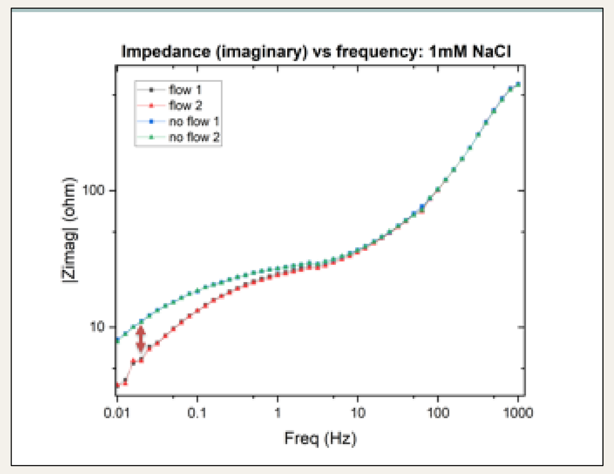


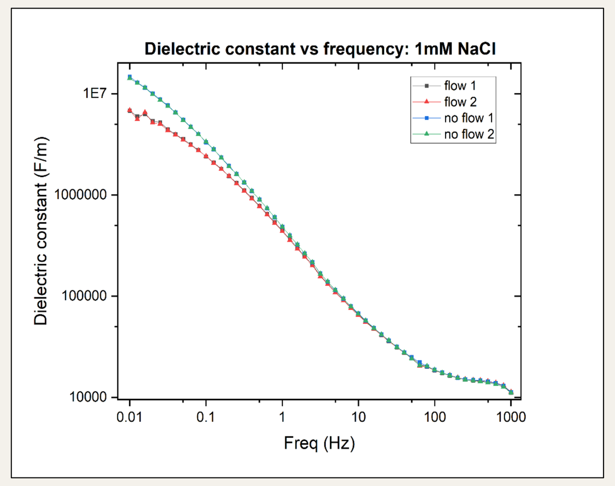


  - This is because the sand has an affinity for cations at pH 7
  - Since the hydration radius of Na is bigger than that of K, the Debye length of NaCl is greater, thus, streaming potential is greater

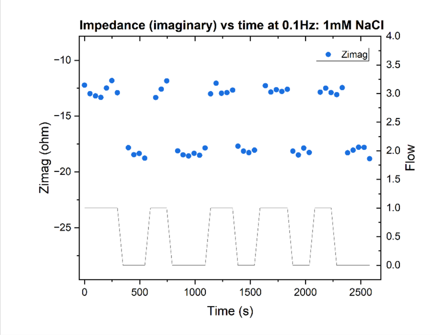
Results and Discussion (cont.)

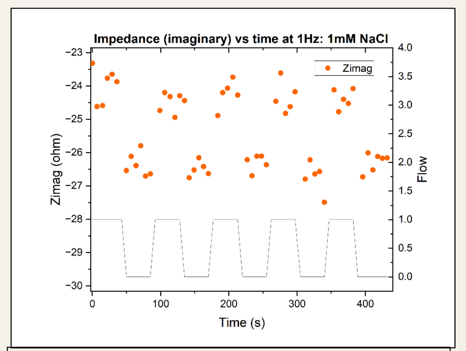
- **Effect of flow on impedance and dielectric constant:**
  - We observed that change in impedance (imaginary) and dielectric constant due to flow only for low frequencies

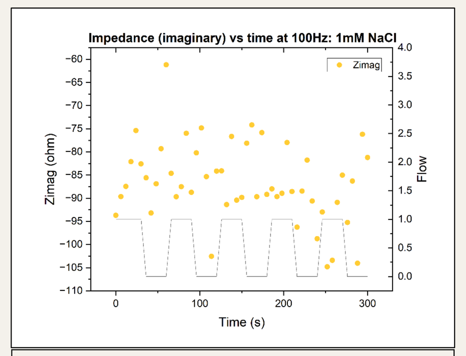




  - This change is repeatable over time as shown by single frequency measurements


0.1Hz


1Hz


100Hz

  - Flow affects the capacitance which in turn, affects the imaginary component of impedance
  - We are still speculating why this occurs only over low frequencies
- **Future work:**
  - Explore other ions particularly anion specificity
  - Explore other parameters such as flow rate and pH

Applications

- Streaming potential electrokinetic sensors generate electrical signals without the need of any additional energy source.
- These self-powered sensors can detect the adsorption of chemicals, drugs, or biological markers

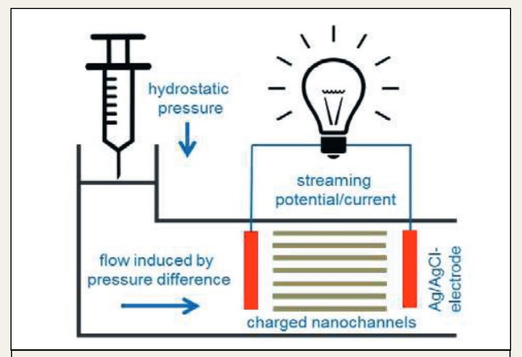


Fig 8. Self-powered sensors

Acknowledgements

This project was supported by the Alexandre Honors Carolina Expendable Fund administered by Honors Carolina. I would like to thank Dr. Yue, Dr. Patrick Doyle, Dr. Alfred Kleinhammes for guiding and mentoring me

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