Design of a novel electrochemical solid state nanopore sensor for medical applications

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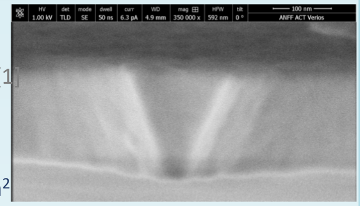
Introduction

- Development of a novel electrochemical nanopore sensor for disease detection and monitoring.
- Combination of recent advancements in ion track technology, nanopore fabrication, biochemistry, microfluidic systems, and lab-on-a-chip devices.
- Affordable, high precision sensing of biomarkers related to diabetes and MS in bodily fluids such as blood or saliva.

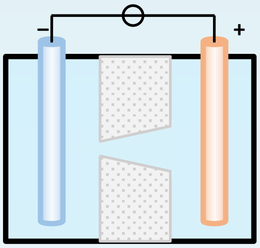
Nanopore membrane

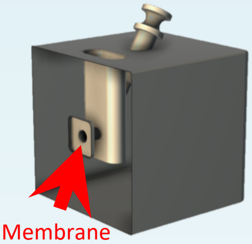
- Conical nanopores in silicon dioxide (silica, SiO_2)
  - Length: <800 nm
  - Base diameter: >335 nm
  - Tip diameter: >20 nm
  - Single pores or 1e8 pores/cm^2

[1]



Measurement setup



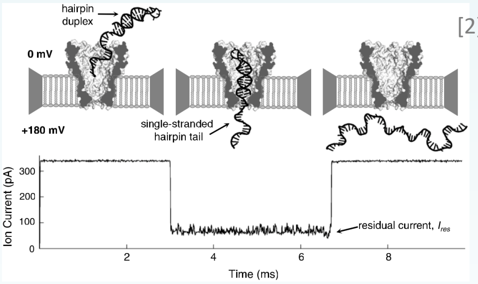


- Electrochemical cell
  - Two chambers containing an electrolyte separated by the nanopore membrane
  - An applied voltage causes anions and cations to flow through the nanopores and an ionic current can be measured

Theoretical background

Current blocking

- Particles passing through a nano-pore partially block it
  - Ionic current decreases



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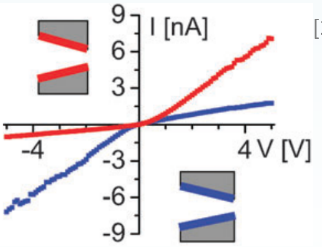
Current rectification

- Cone shape results in higher charge flow in one direction
- Negatively (blue) or positively (red) charged pore surface acts as cation or anion trap
  - Asymmetric current



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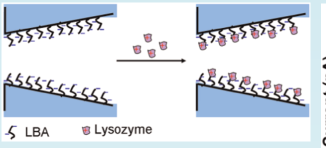
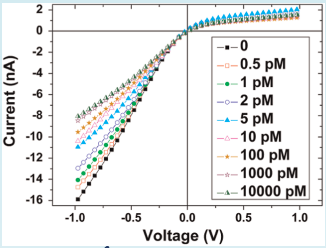
Nanopore sensing by current rectification

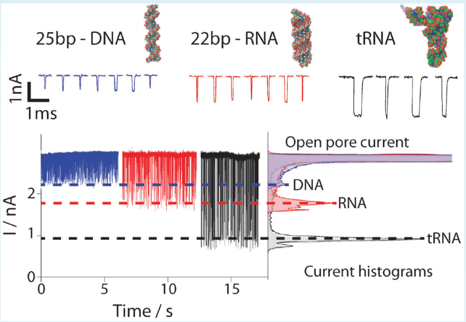




- Functionalised nanopore surface that shows selective binding to target analyte
  - Target analyte attaches to nanopore surface
  - Surface charge changes
  - Current rectification changes

[4]

Single-molecule detection by resistive pulse sensing



[5]

- Analyte passing through a nanopore causes a resistive pulse
  - Frequency and intensity of these pulses can be used to determine concentration and size of analyte

Filtration and purification of liquids

- Charge- and size-based separation of macromolecules by tuning the size and surface charge of the nanopores

Possible applications:

- Purification of water containing toxic dyes in industrial wastewater without the use of chemicals
- Separating proteins and antibodies out of bodily fluids for further analysis

Summary and outlook

- Silica nanopore membranes have not yet been utilised for sensing applications
- Combines the advantages of 2D materials and polymers
  - Very stable and robust
  - Easy to functionalise
  - Excellent signal-to-noise ratio
  - Lab-on-a-chip capable

Future work:

- Optimise sensing platform to precisely detect biomarkers related to diabetes and MS

References

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