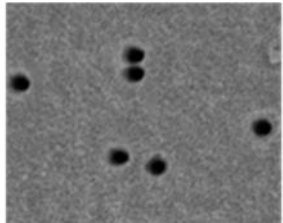
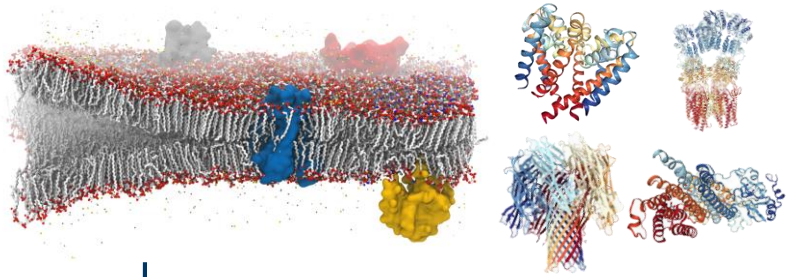


Track-etched nanopore membrane Design and application

Sébastien Balme

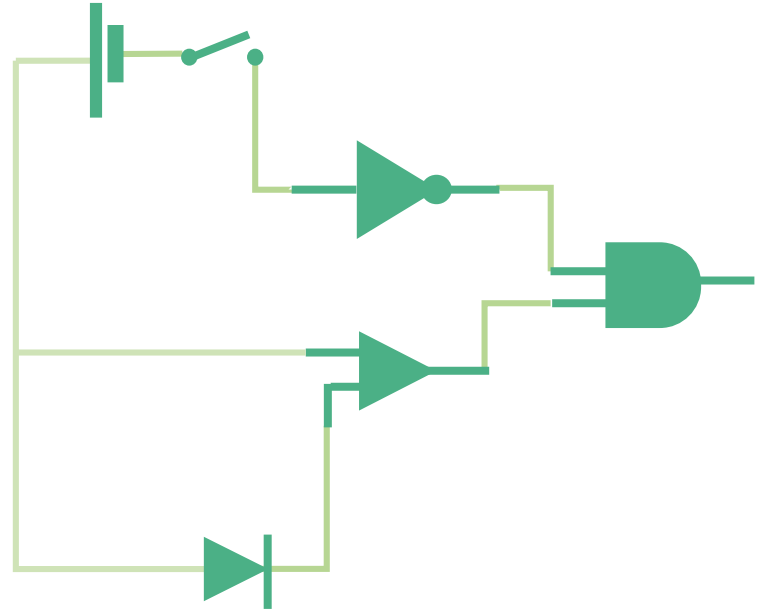
Institut Européen des Membranes - Université de Montpellier
sebastien.balme@umontpellier.fr

Our Inspiration



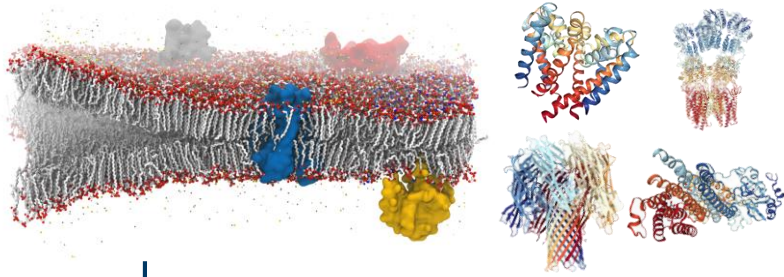
Selectivity
Responsiveness
Folding
Precision Structure
Weak interactions

A biological channel is actually....

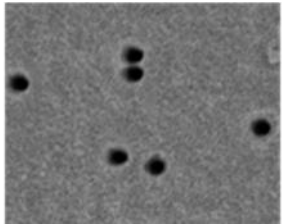


...a nanochannel
with electronic component properties

Our Inspiration



Selectivity
Responsiveness
Folding
Precision Structure
Weak interactions



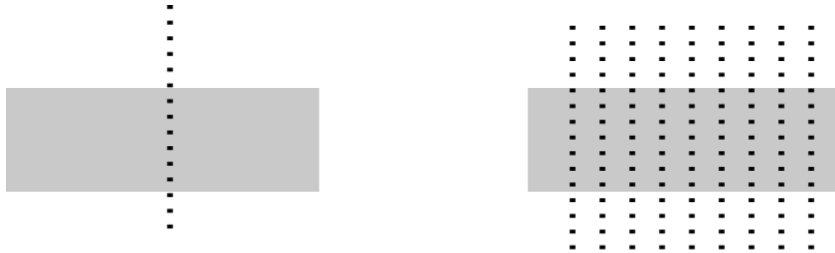
Design and study fundamental transport through single pore to solve biophysical, physical chemistry questions and design "smart" membranes

Our work

How can we design biomimetic track-etched nanopore?

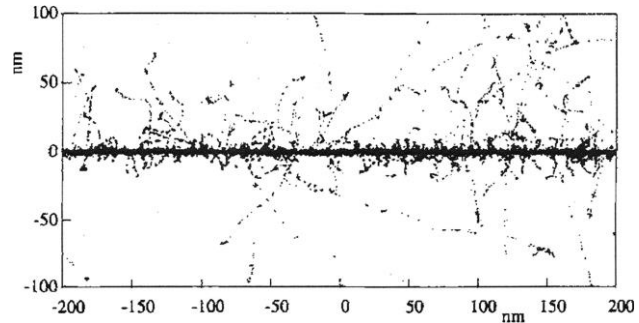
Track-etch membrane

Xeⁿ⁺, Krⁿ⁺ ~9 MeV

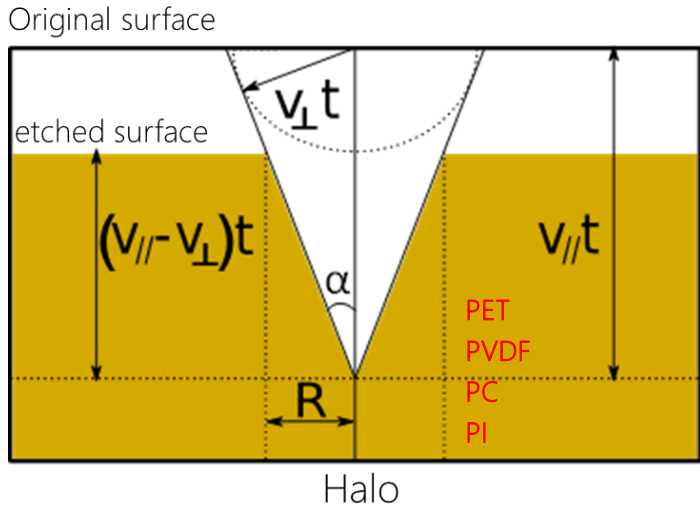


1 ion = 1 nanopore

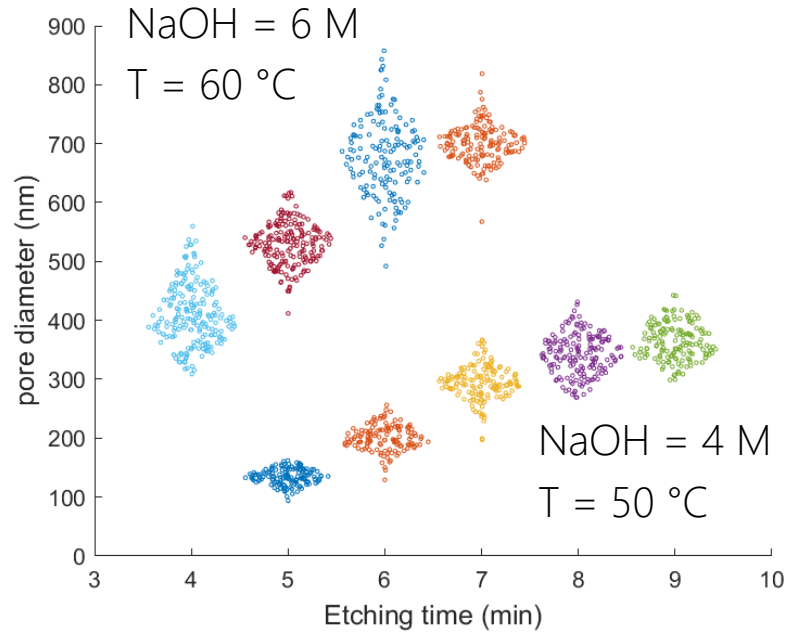
n ions = Membrane



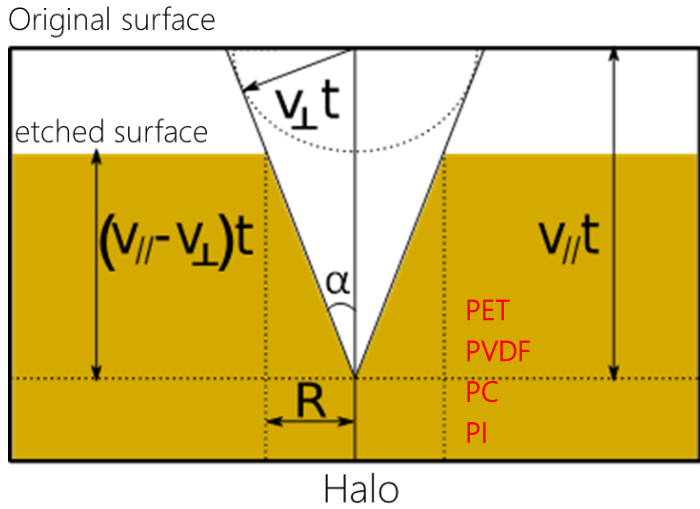
The chemical etching symmetrical condition



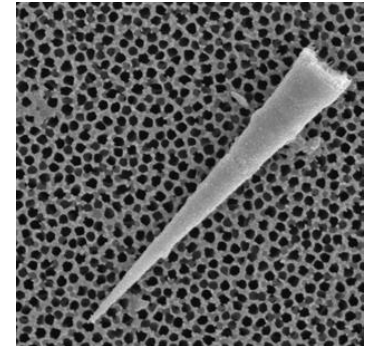
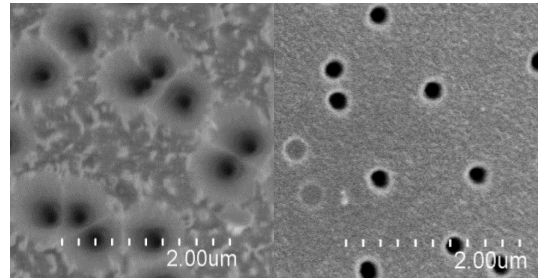
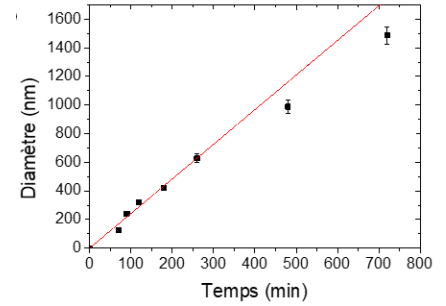
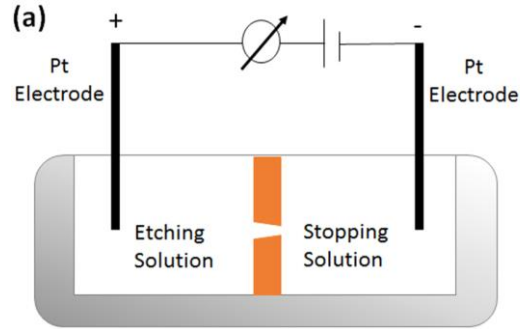
$$V_{\text{track}} / V_{\text{bulk}} = 1 / \sin \alpha$$



The chemical etching electrostopping

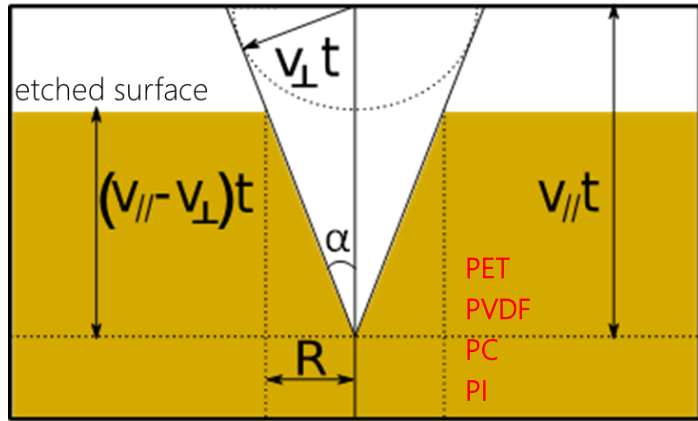


$$v_{\text{track}} / v_{\text{bulk}} = 1 / \sin \alpha$$



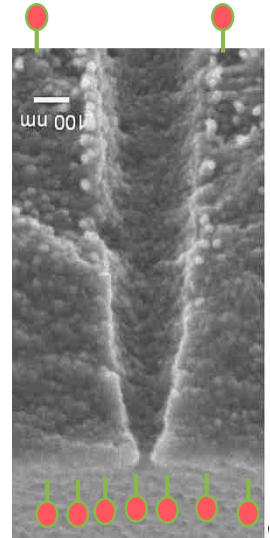
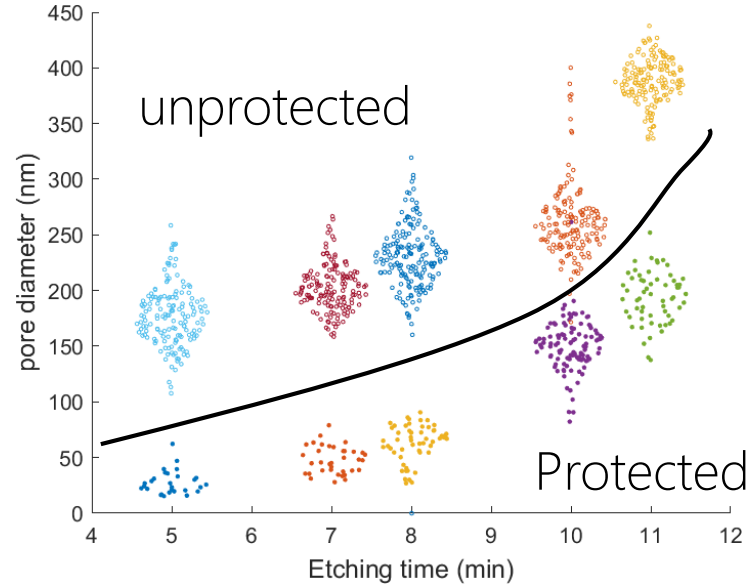
The chemical etching with surfactant

Original surface



Halo

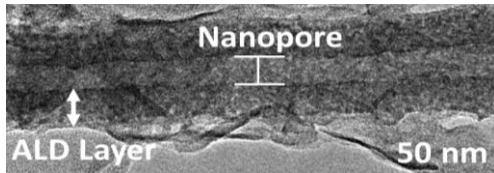
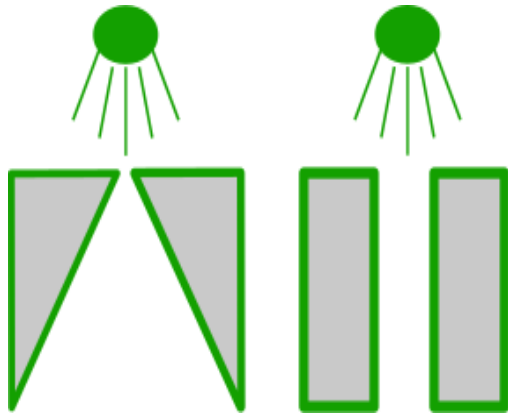
$$v_{\text{track}} / v_{\text{bulk}} = 1 / \sin \alpha$$



Functionalization : the toolbox

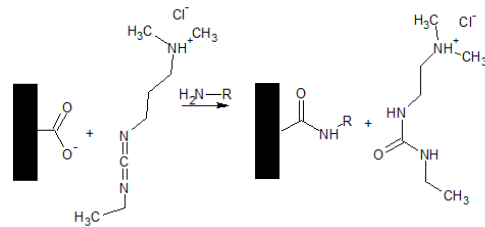
Physical deposition

ALD



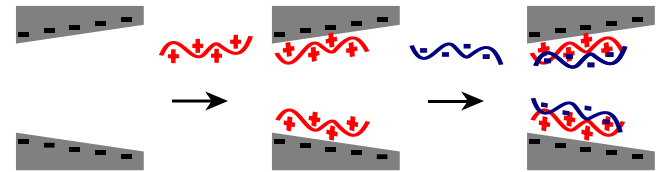
Chemical grafting

Amide moieties

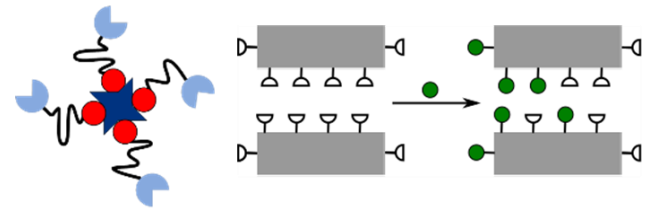


Supramolecular self-assembly

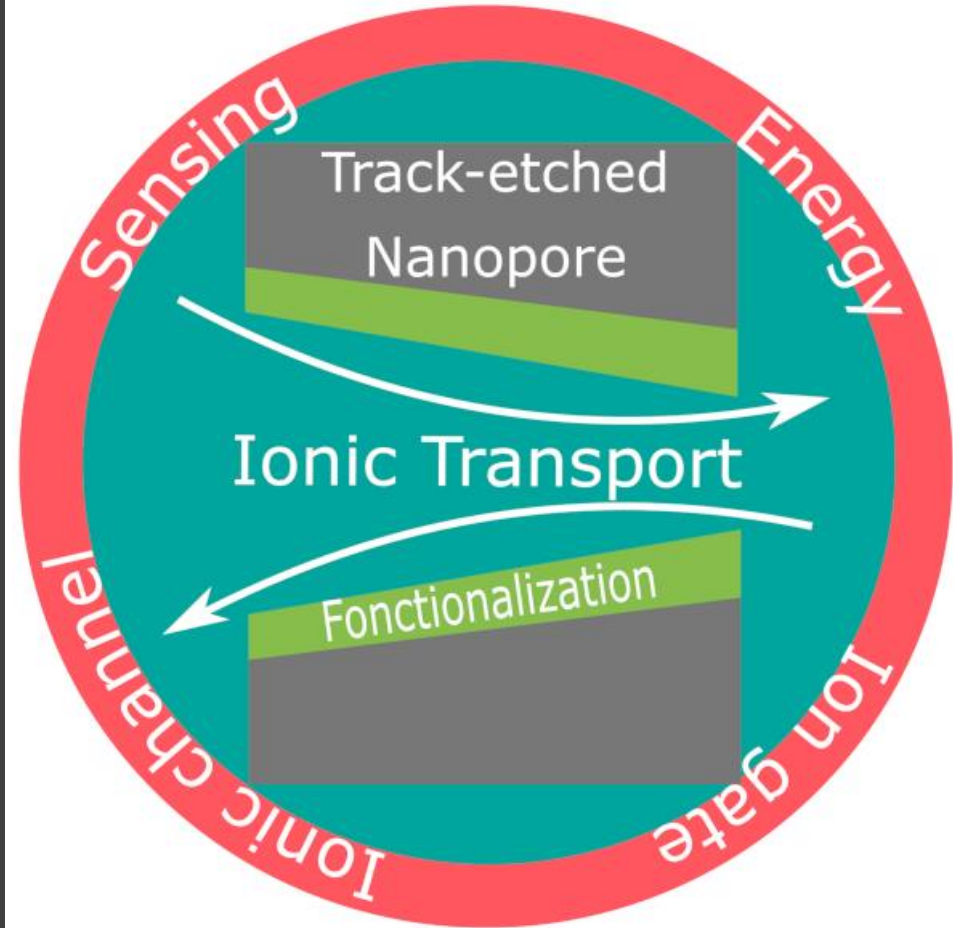
Polyelectrolyte layer by layer deposition



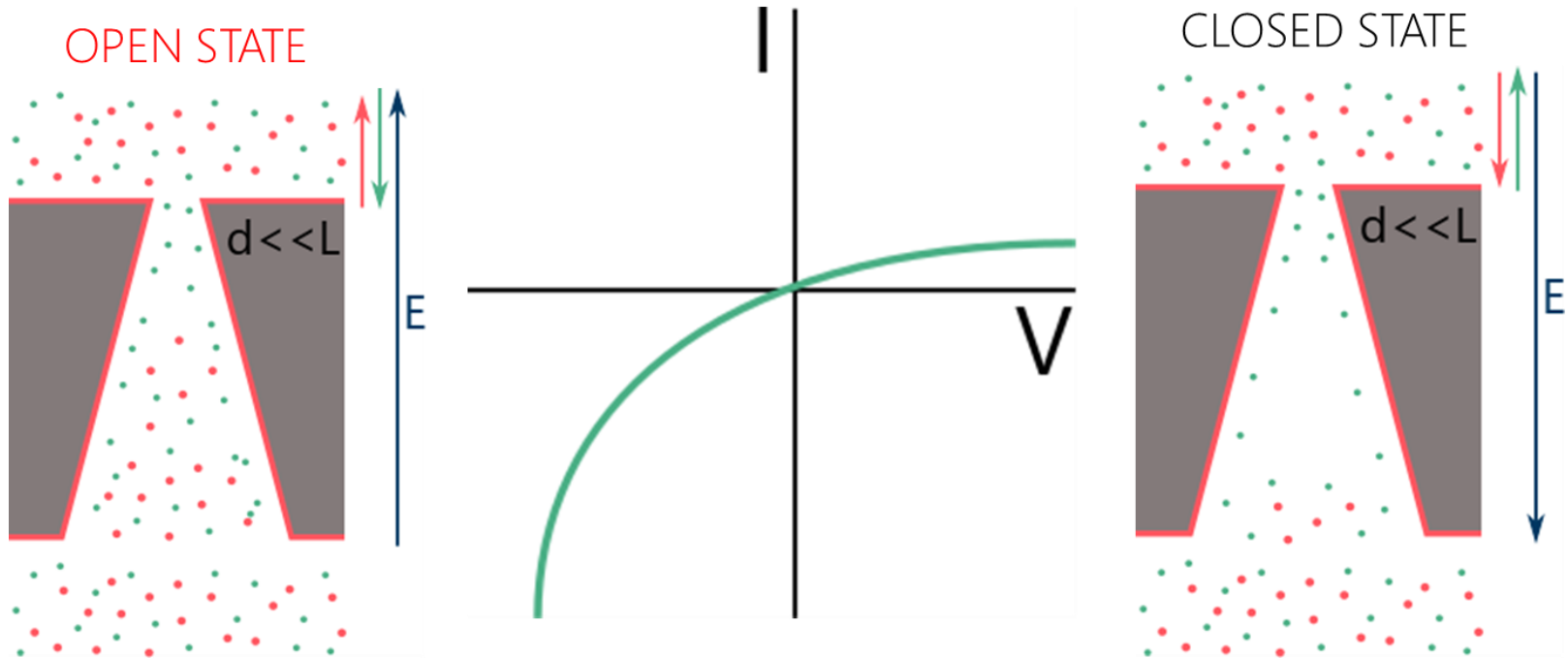
Protein-ligand interactions



Application of nanopore membranes



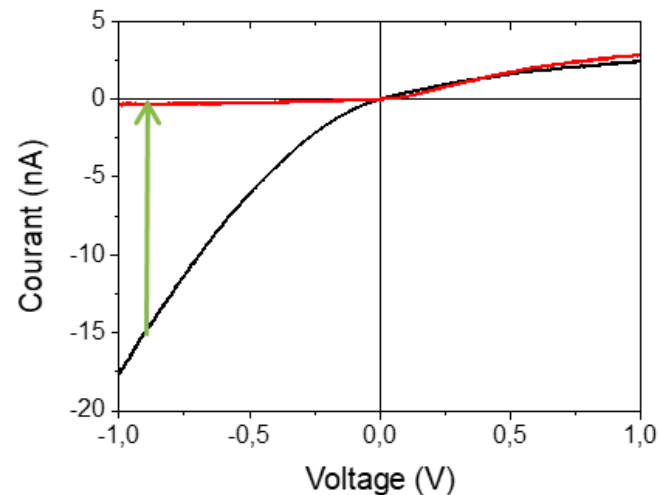
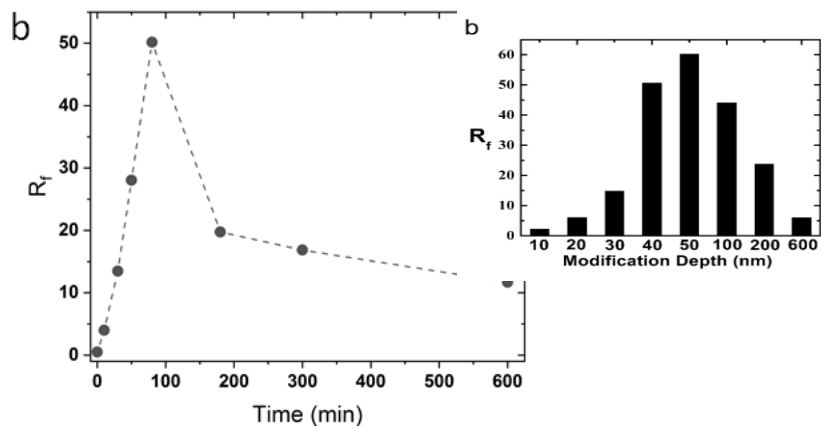
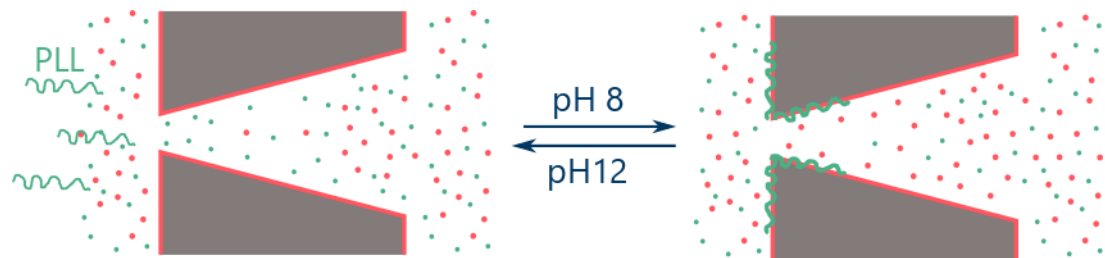
Application of track-etched membranes.



Application : iontronic


Tunable Current Rectification and Selectivity Demonstrated in Nanofluidic Diodes through Kinetic Functionalization

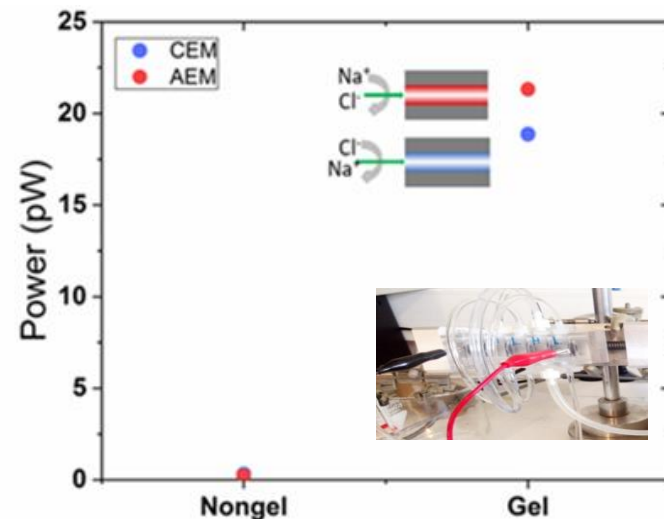
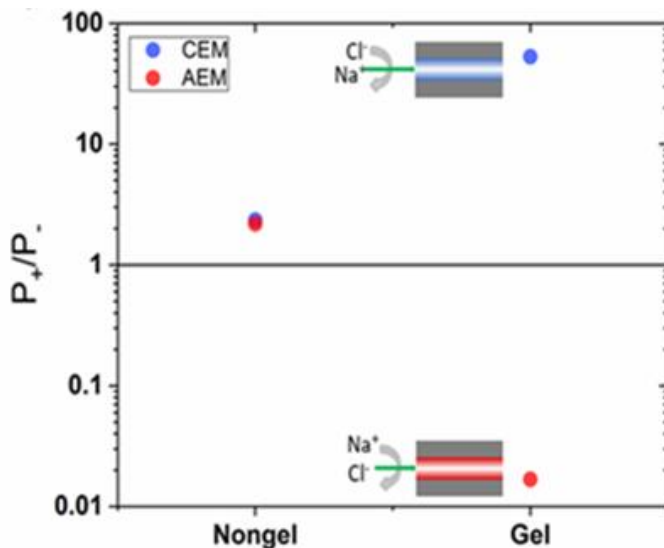
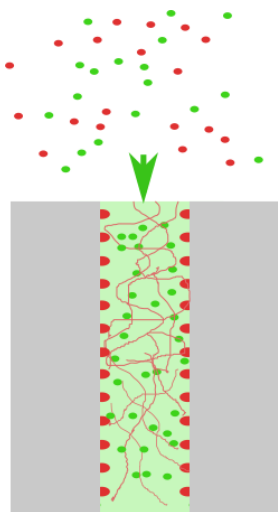
Chih-Yuan Lin,^{*,†,‡,+} Tianji Ma,^{§,+} Zuzanna S. Siwy,^{†,||,⊥} Sébastien Balme,^{*,§} and Jyh-Ping Hsu^{*,‡}



Application : osmotic energy

Nanopore Functionalized by Highly Charged Hydrogels for Osmotic Energy Harvesting

Tianji Ma,[†] Emmanuel Balanzat,[‡] Jean-Marc Janot,[†] and Sébastien Balme^{*,†} 



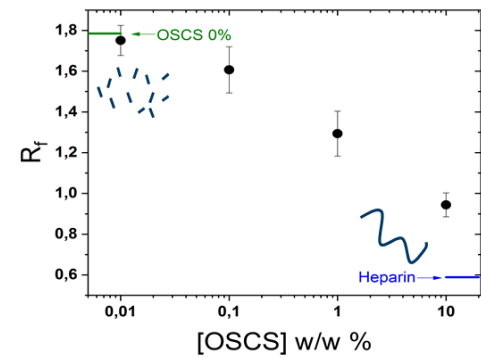
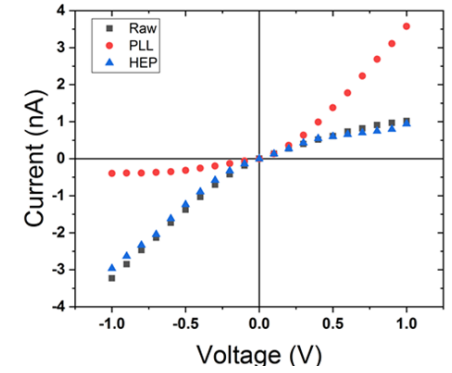
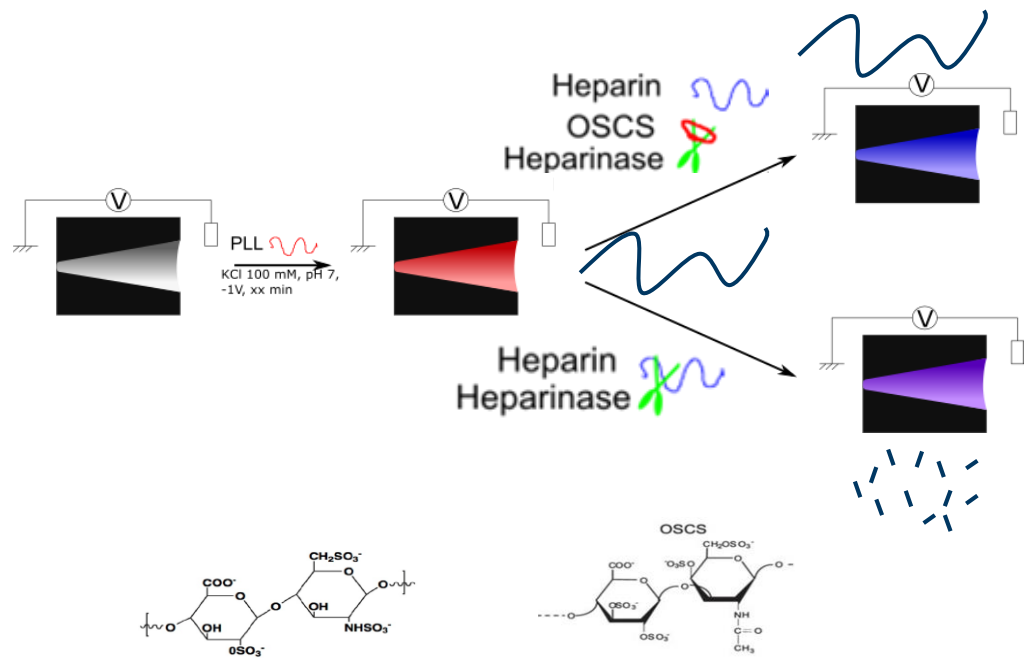
$3 \cdot 10^9$ pore/cm²
 0.37 W m⁻²

Application of sensing

Single conical track-etched nanopore for a free-label detection of OSCS contaminants in heparin



Tianji Ma^a, Emmanuel Balazat^b, Jean-Marc Janot^a, Sébastien Balme^{a,*}

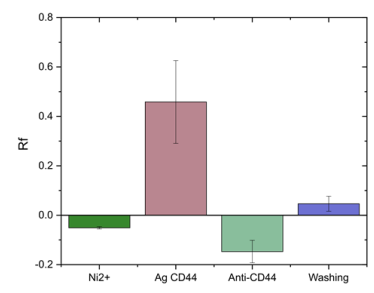
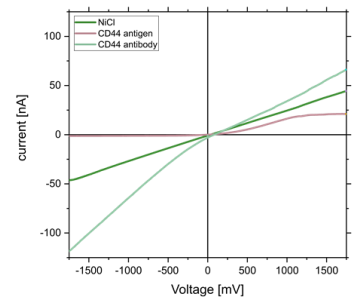
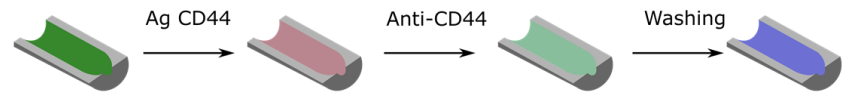
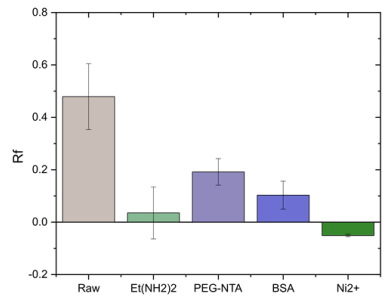
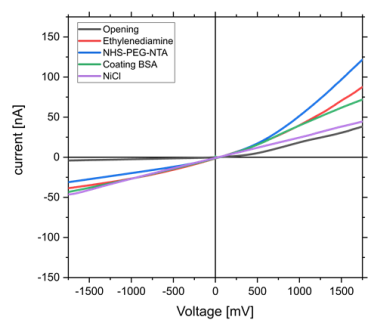
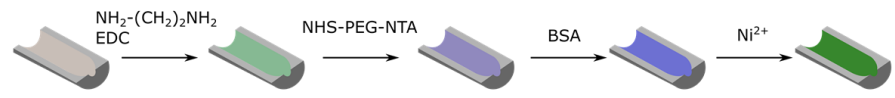


Application of antibody sensing and separation



Combining ionic diode, resistive pulse and membrane for detection and separation of anti-CD44 antibody

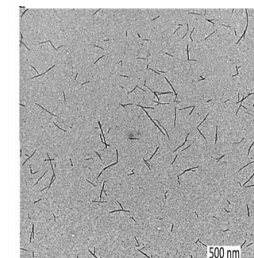
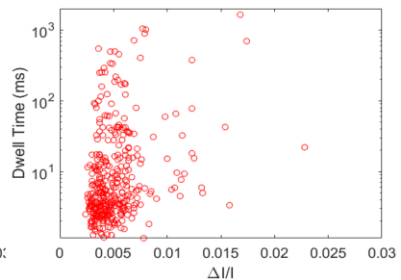
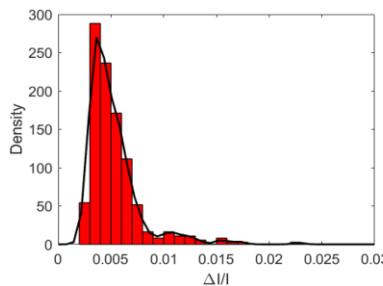
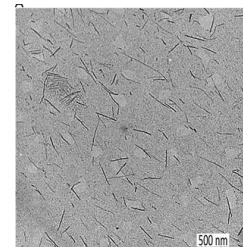
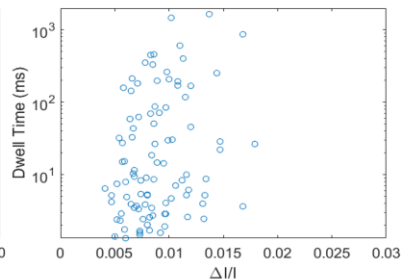
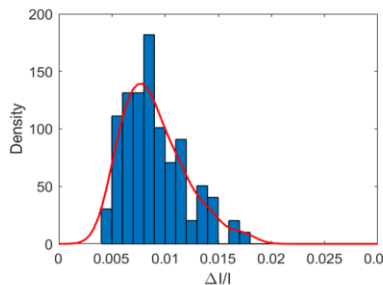
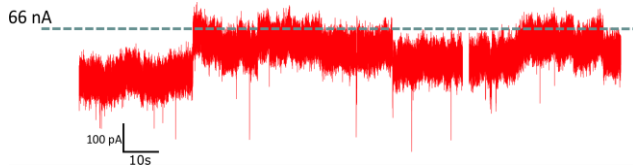
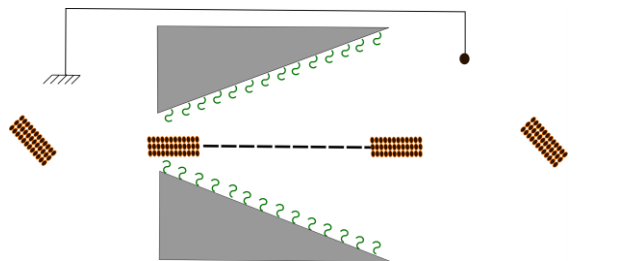
Imad Abrao-Nemeir^a, Oumaima Zaki^a, Nathan Meyer^{a,b}, Mathilde Lepoitevin^c, Joan Torrent^b, Jean-Marc Janot^a, Sebastien Balme^a



Application of single amyloid sensing

Detection of Amyloid- β Fibrils Using Track-Etched Nanopores: Effect of Geometry and Crowding

Nathan Meyer, Nicolas Arroyo, Jean-Marc Janot, Mathilde Lepoitevin, Anna Stevenson, Imad Abrao Nemeir, Veronique Perrier, Daisy Bougard, Maxime Belondrade, Didier Cot, Jérémy Bentin, Fabien Picaud, Joan Torrent, and Sebastien Balme*

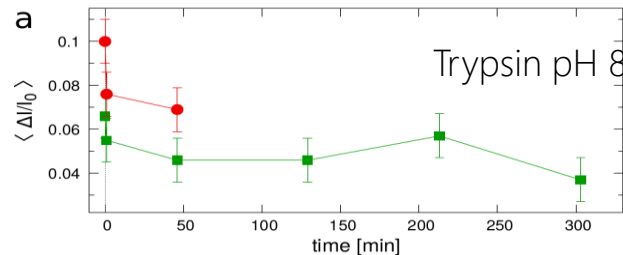
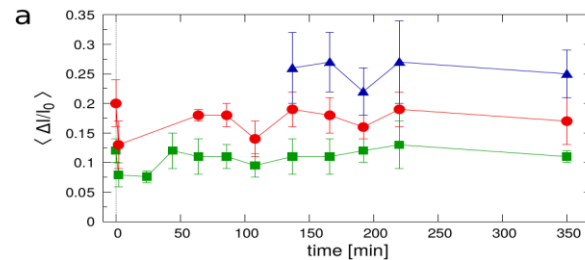
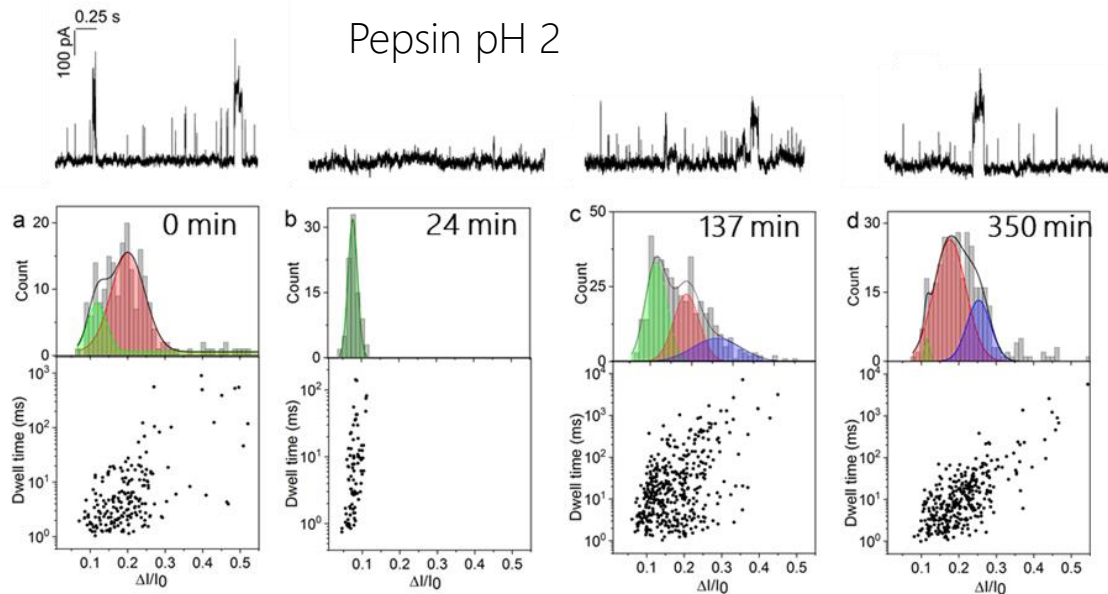


Application to follow enzymatic reaction

Characterization of Food Amyloid Protein Digestion by Conical Nanopore

Nicoletta Giambianco, Jean-Marc Janot, Alberto Gubbiotti, Mauro Chinappi, and Sebastien Balme*

Pepsin pH 2



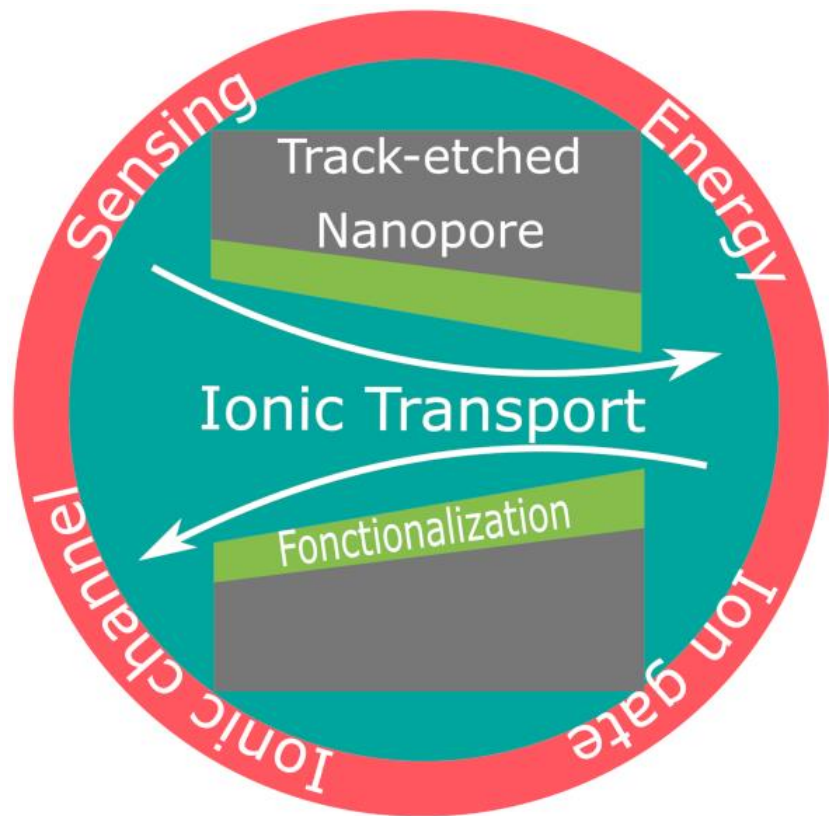
Conclusion

REVIEW *Small Methods* 2020, 2000366

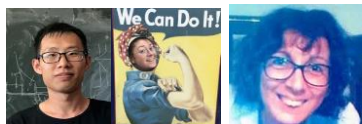
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method
www.small-methods.com
Check
update

Track-Etched Nanopore/Membrane: From Fundamental to Applications

Tianji Ma, Jean-Marc Janot, and Sébastien Balme*



Acknowledgments



Young investigator award « Nanodiag »



Collaborations

Y Ngono-Ravache E. Balanzat (Caen CIMAP),

J. Torrent, V. Perrier (INM), L.Y. Lin, Hsu (Taiwan) Chinappi (Tor Vergata, Italia)
F Picaud, (Besançon LINT), M. Lepoitevin (ENS, Paris)

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Track-Etched Nanopore/Membrane: From Fundamental to Applications

Tianji Ma, Jean-Marc Janot, and Sébastien Balme*

Advances in Colloid and Interface Science 298 (2021) 102561



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Historical Perspective

Solid-state and polymer nanopores for protein sensing: A review

Nathan Meyer^{a,b}, Imad Abrao-Nemeir^a, Jean-Marc Janot^a, Joan Torrent^b,
Mathilde Lepoitevin^c, Sébastien Balme^{a,*}



sebastien.balme@umontpellier.fr