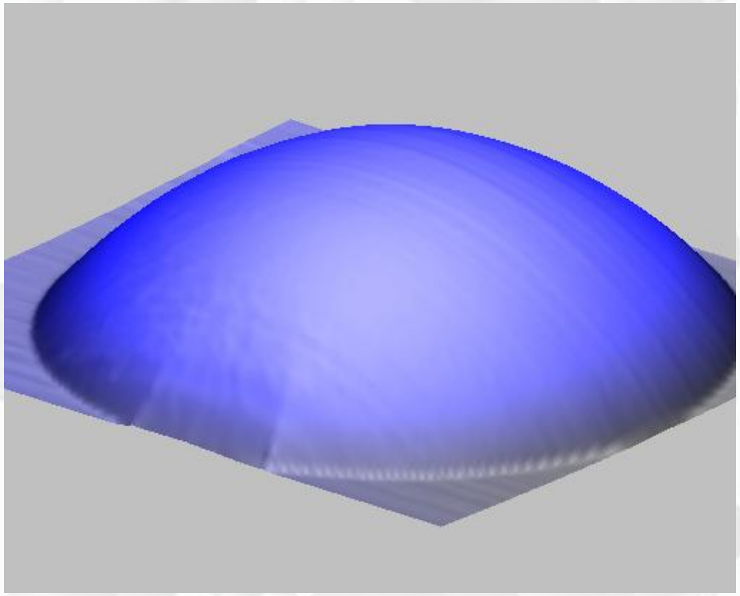
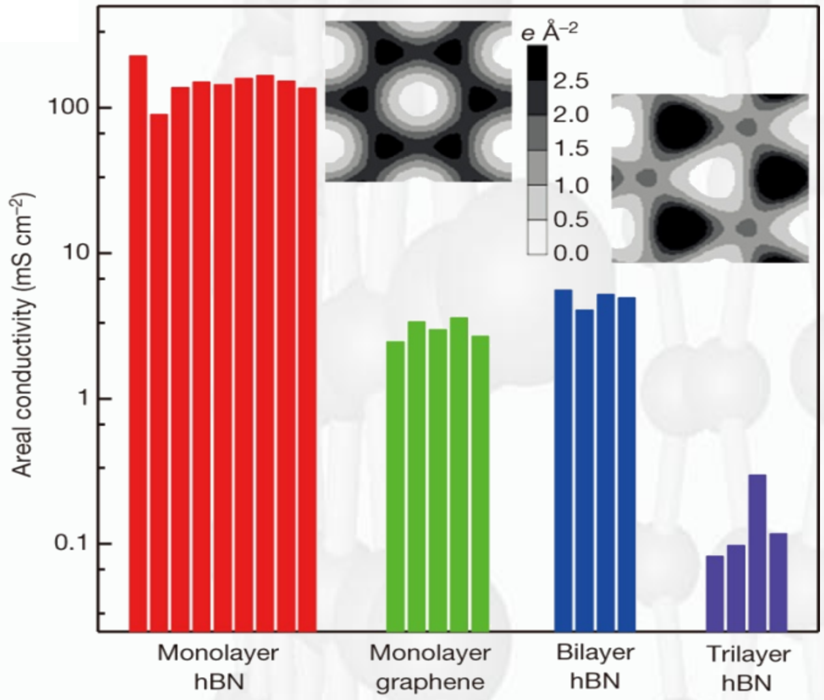
Mass Transport Through 2D Materials Based Membranes

Dr. Yang SU

Perfect graphene flakes



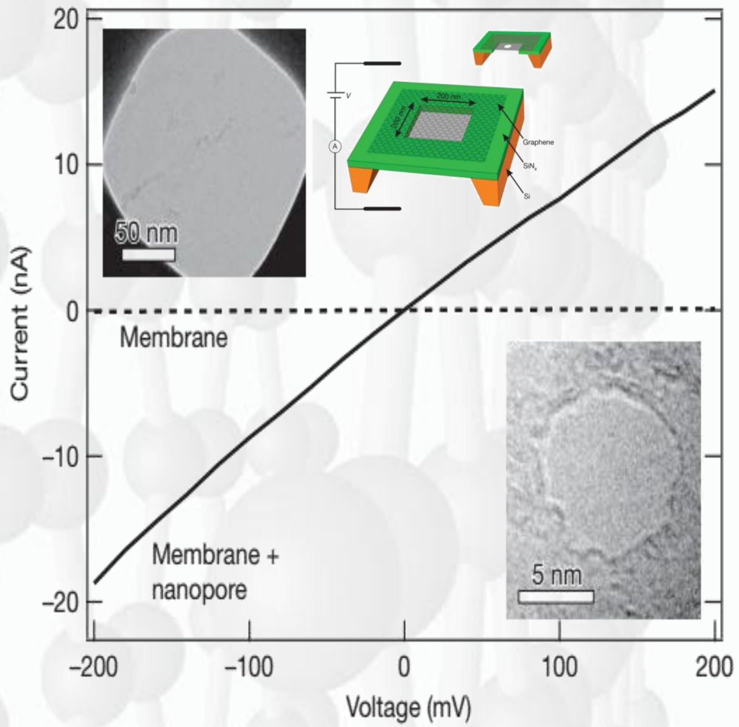


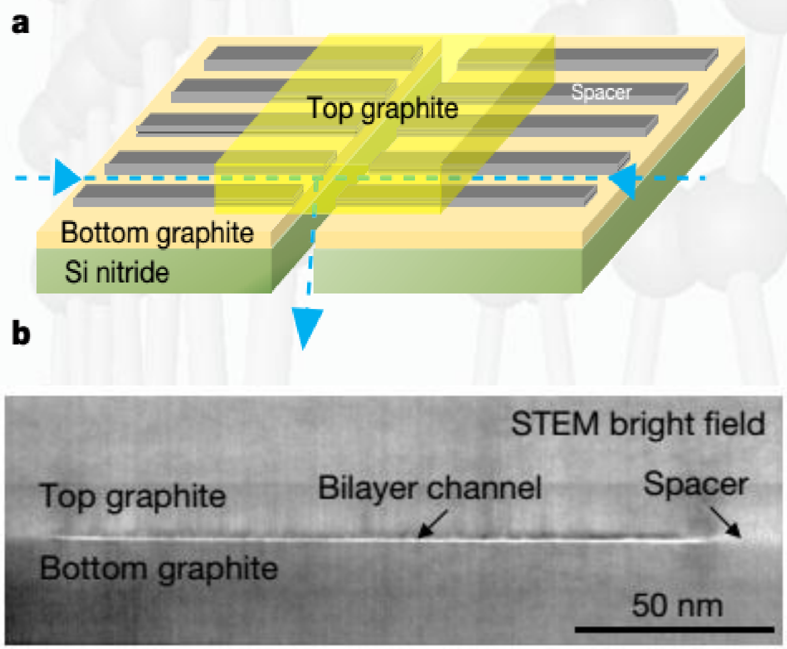
Impermeable to standard gases

Permeable to proton

Nano Lett. 8, 2458-2462 (2008)
Nature 516, 227–230 *(2014)*

Perfect graphene flakes + Artificial pores

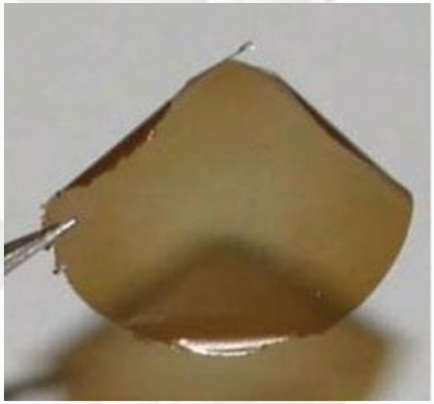


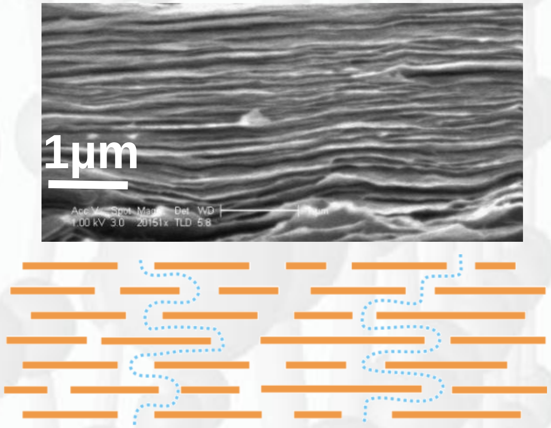


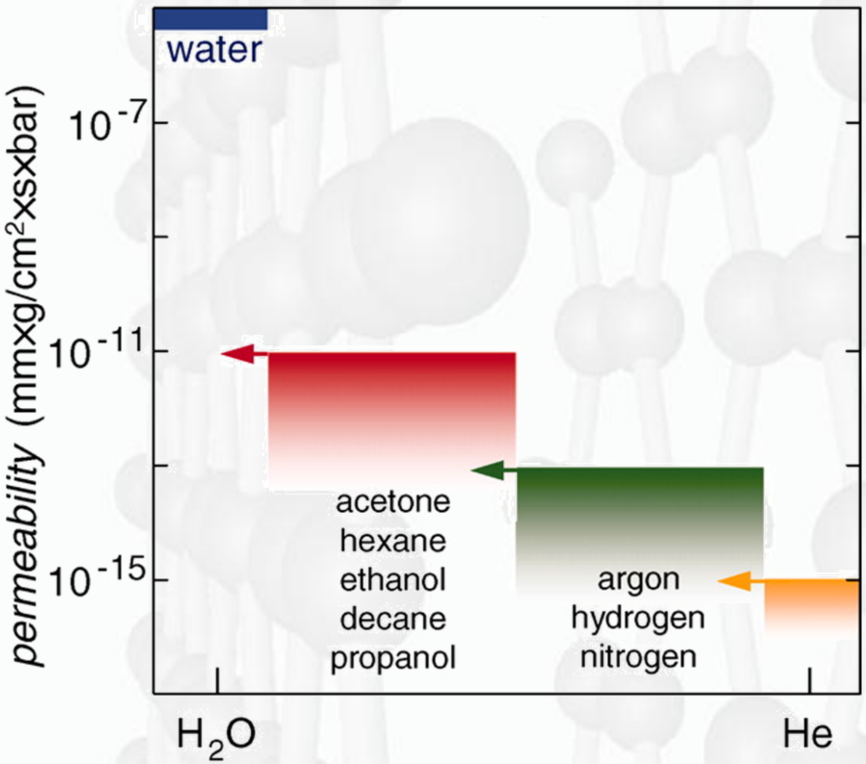
Graphene-based sieve

Nature 467, 190 (2010).
Nano Lett. **10**, 3163 (2010).
Nano Lett. **10**, 2915 (2010).
Nature 538, 222-225 (2016).

Graphene oxide(GO) laminate







- Controllable thickness, Industrially Scalable ,Easy to functionalise
- Water permeates at least 10^{10} times faster than helium

Science 335, 442 (2012)

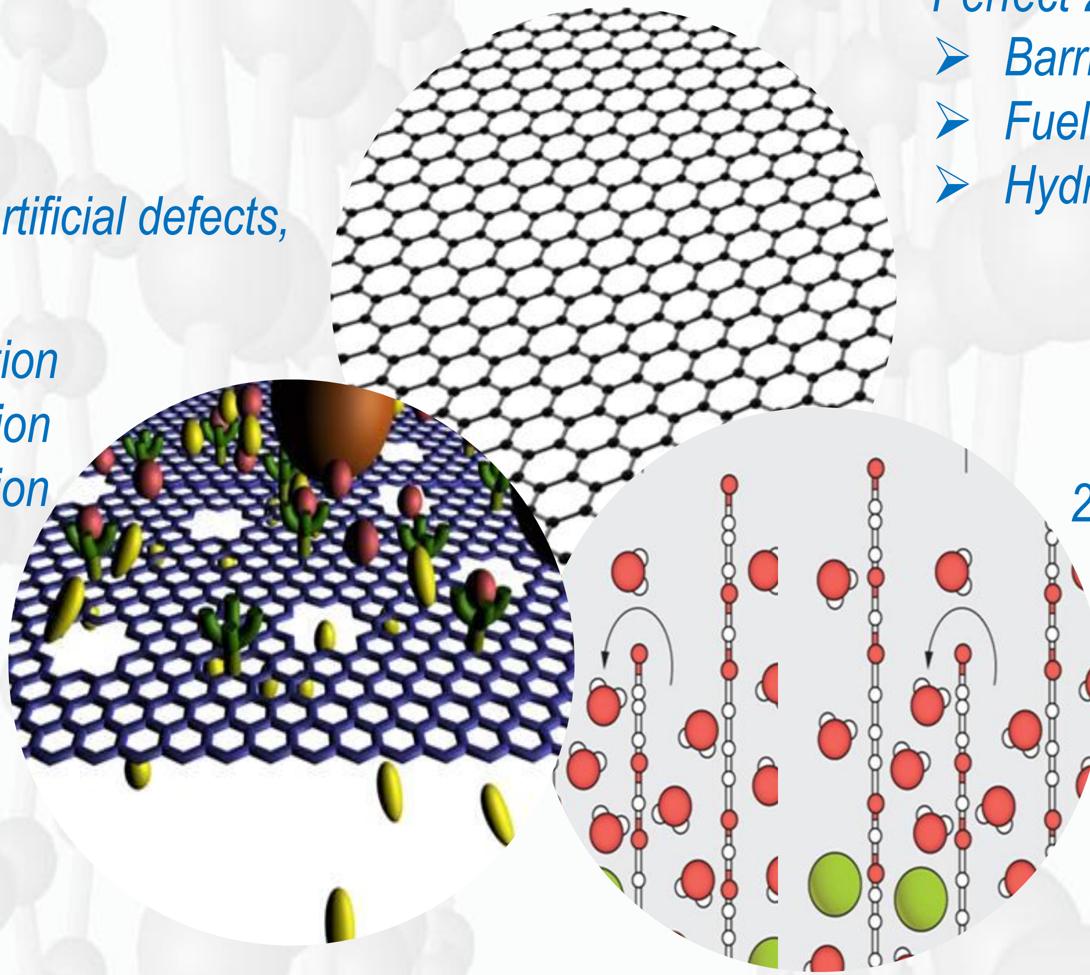
2D Material based platforms for mass transport

Mechanical exfoliated
Perfect 2D crystals

- Barrier Coating
- Fuel Cell
- Hydrogen Extraction

2D materials
With Intrinsic/artificial defects, holes, etc

- Gas separation
- Liquid filtration
- Size exclusion



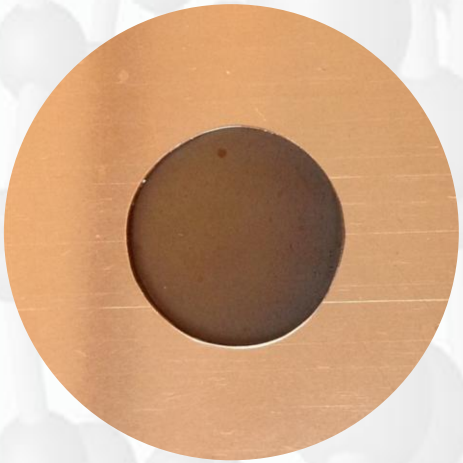
2D materials laminates

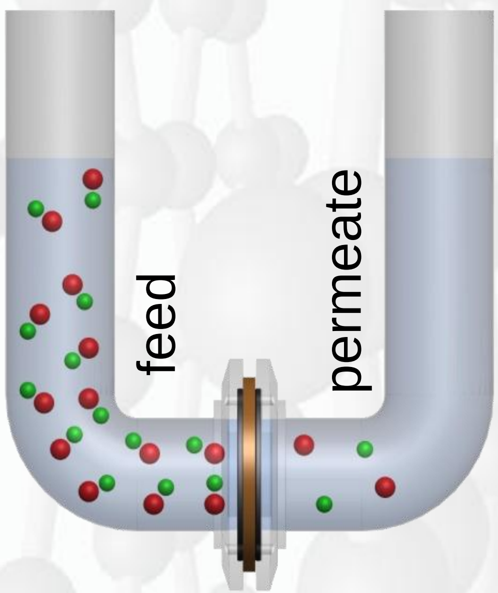
- Size exclusion
- Gas separation
- Desalination

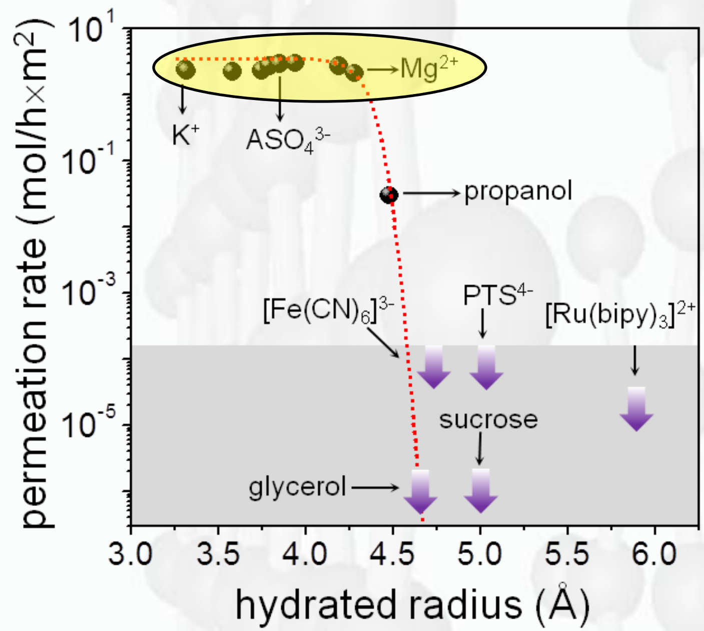
Controllable pore size

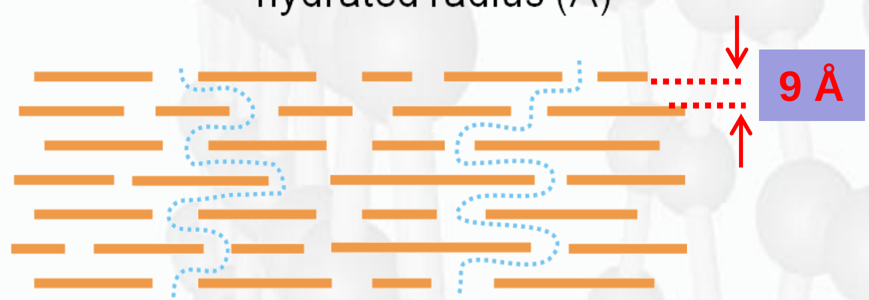
Ionic transport through GO laminate

Ion transport through GO membranes







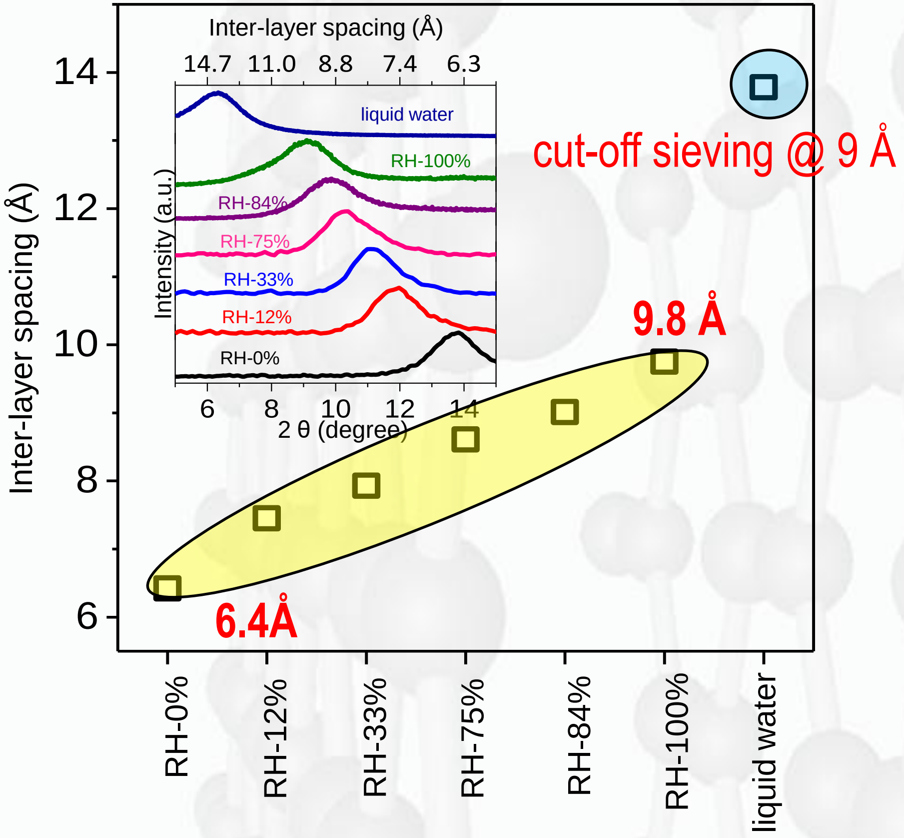


Sharp molecular sieving@ 9 Å

Science 343, 752 (2014)

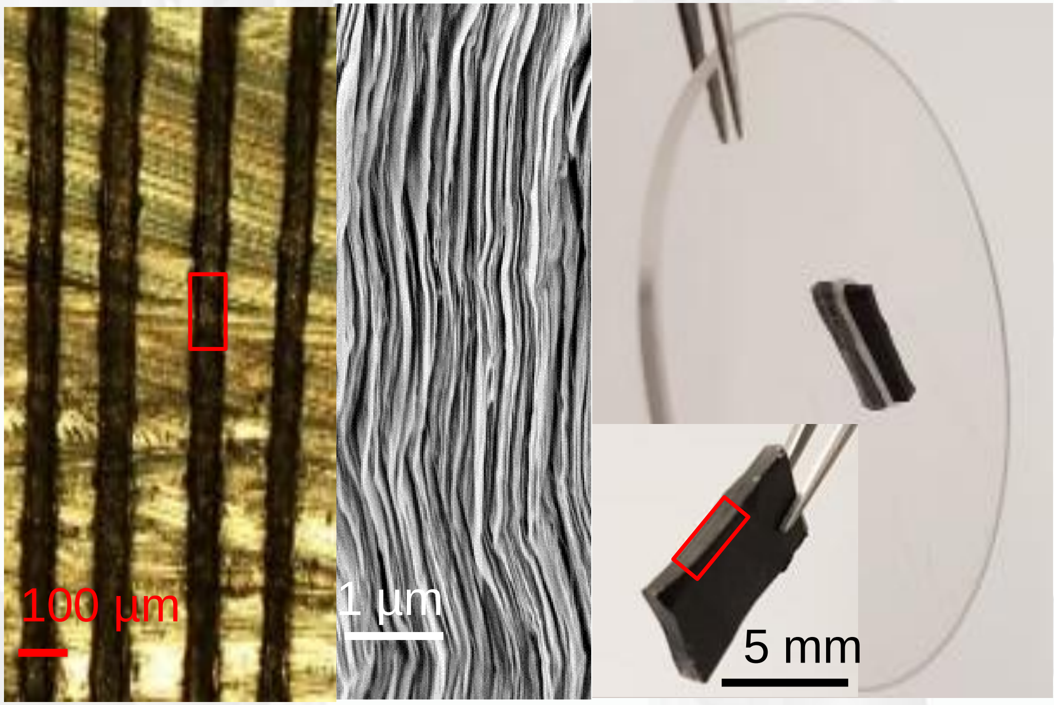
Could we differentiate ions <0.9 nm?

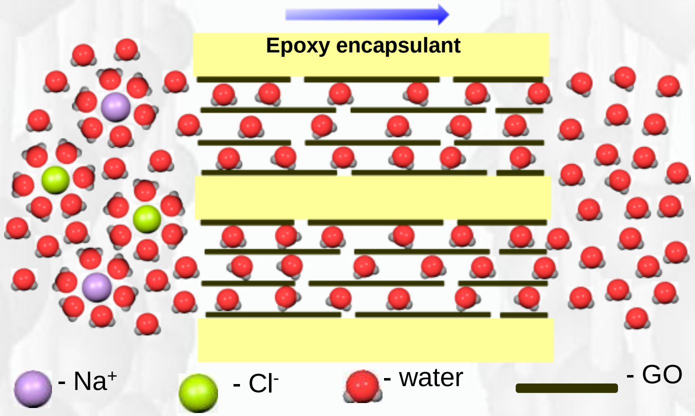
Ions	Hydrated Diameter(Å)
K^+	6.6
Na^+	7.1
Li^+	7.6
Ca^{2+}	8.2
Mg^{2+}	8.5



Interlayer distance can be tuned from 13.5 Å to 6.4 Å

Physical confined GO membranes

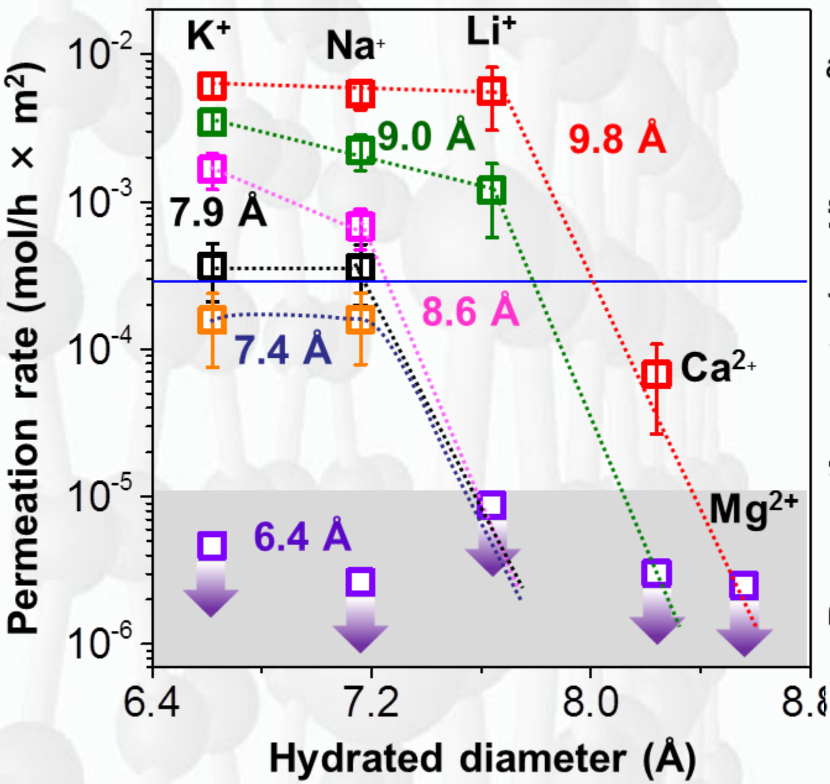


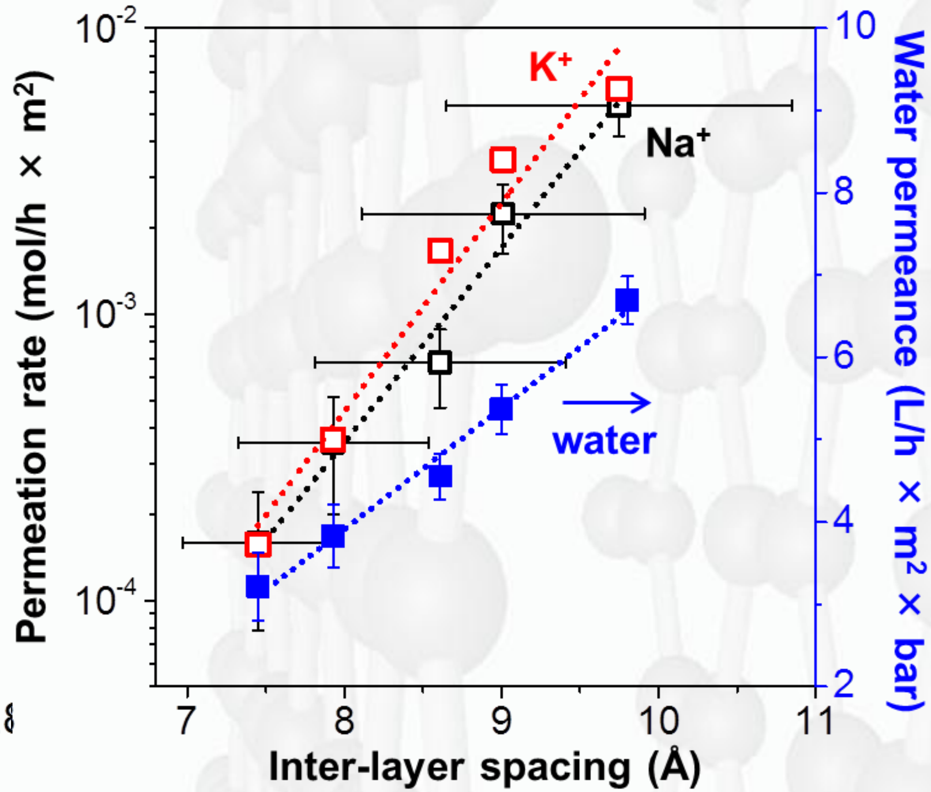


In-plane ion transport

J. Abraham et al. arXiv:1701.05519
Nature Nanotechnology (accepted)

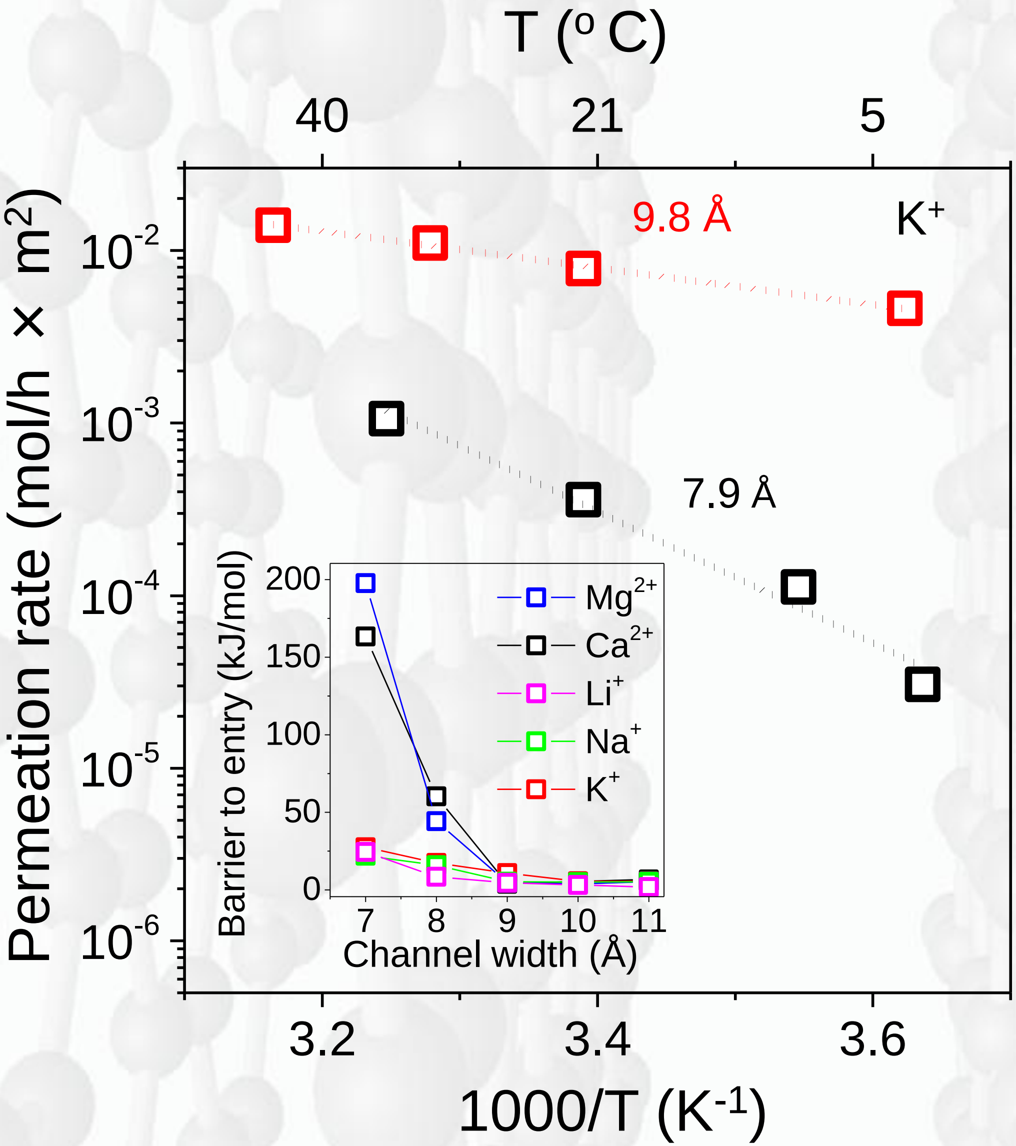
Tunable ion transport





Ion permeation decreases exponentially with spacing but water transport is weakly affected

Tunable ion transport



$\exp(-E/k_BT)$

E= 20±2 KJ/mol

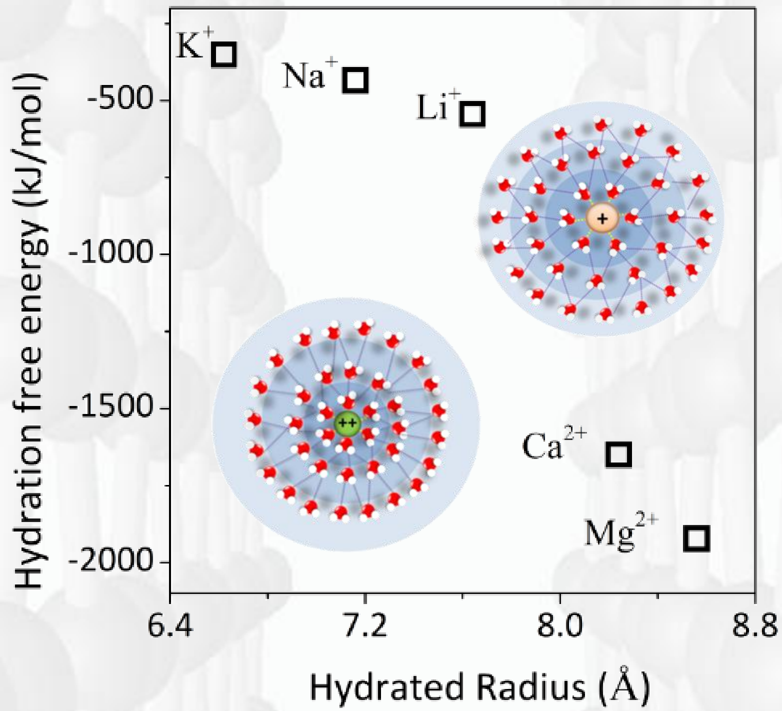
Increase in energy barrier

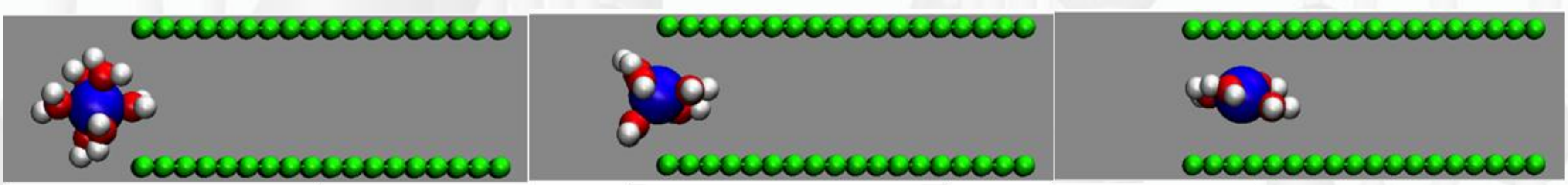
E= 72 ±7 KJ/mol

J. Abraham et al. arXiv:1701.05519
Nature Nanotechnology (accepted)

Smaller the pore size, larger will be the energy barrier

Ion dehydration defined selectivity

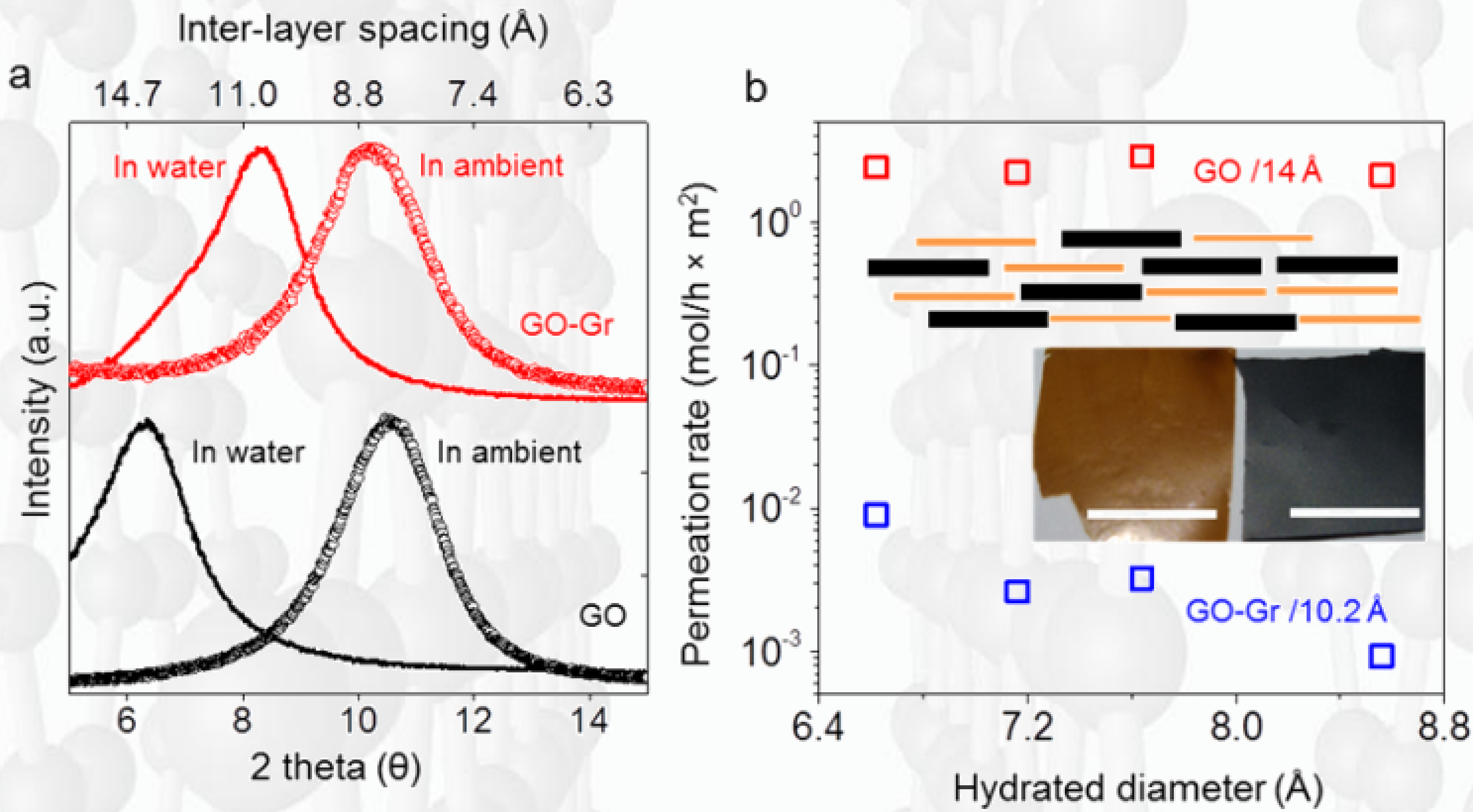




Higher dehydration free energy – Lower permeation

Ion selectivity is defined by ion dehydration

Graphene/GO composite



- **Significant low interlayer expansion** in Grpahene/GO composite membran
- Forward osmosis:**~97% rejection to NaCl, with water flux 0.5L/m^2xh**

J. Abraham et al. arXiv:1701.05519
Nature Nanotechnology (accepted)

Summary

- The interlayer spacing of GO laminate could be controlled in the range below 10 Å.

- The ion permeation is exponentially suppressed with decreasing Interlayer spacing, While, the water is much less affected.

- Ion permeation in narrow interlayer space is dominated by the additional energy barriers from dehydration of ions, so that ions could fit into narrow channel,

- A simple scalable method by control the interlayer space of GO laminate showed 97% rejection to NaCl.

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Thank you!