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ARTICLES

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Water desalination using nanoporous single-layer graphene

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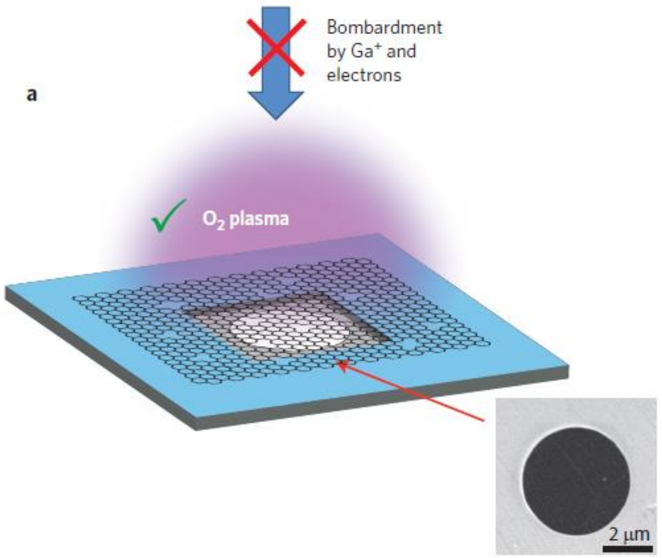

By
Biswajit
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Water desalination: Graphene cleans up water

Evelyn N wang and Rohit Karnik

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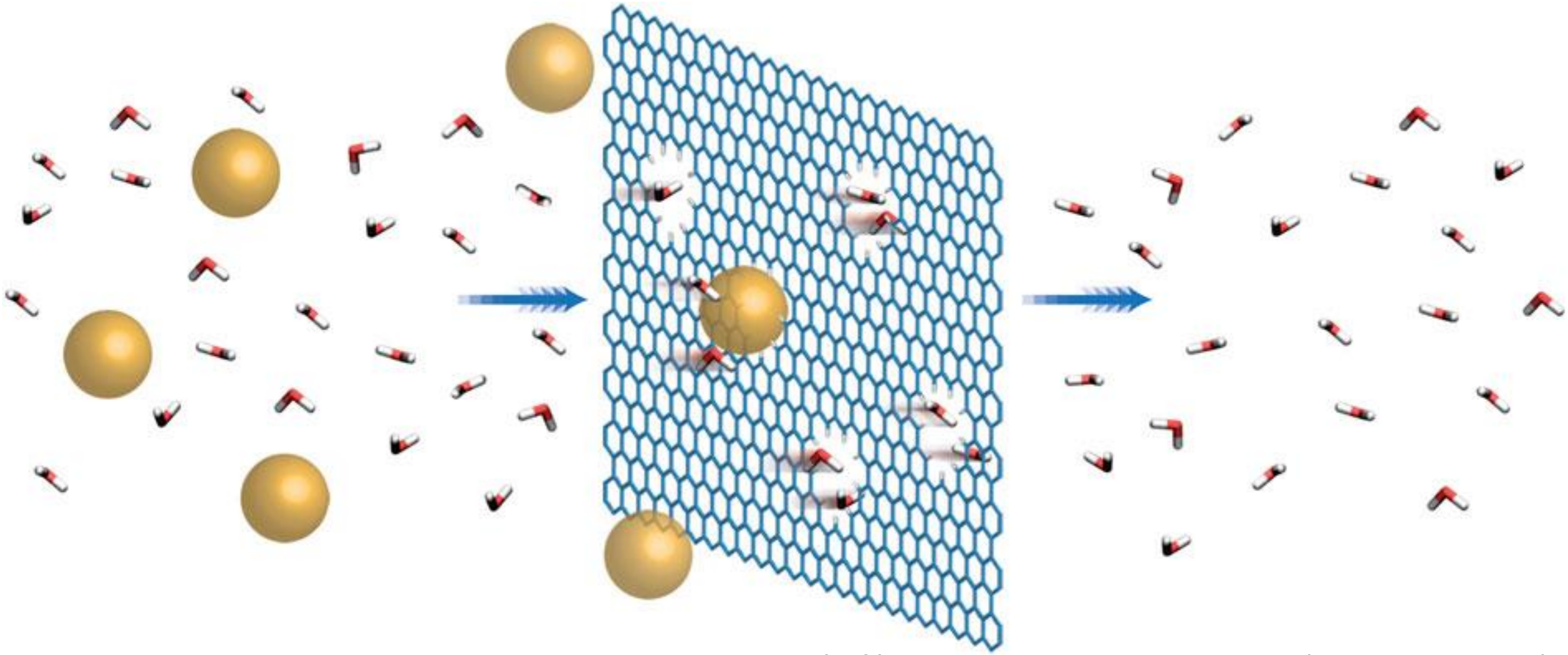

Figure 1.High pressure applied to the salt water (left) drives water molecules (red and white) across the graphene membrane (right), while salt ions (spheres) are blocked. Chemical functionalization of the pores with hydrogen (white) increases water selectivity, whereas functionalization with hydroxyl groups (not shown) increases the speed of water transport.

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Water Desalination across Nanoporous Graphene

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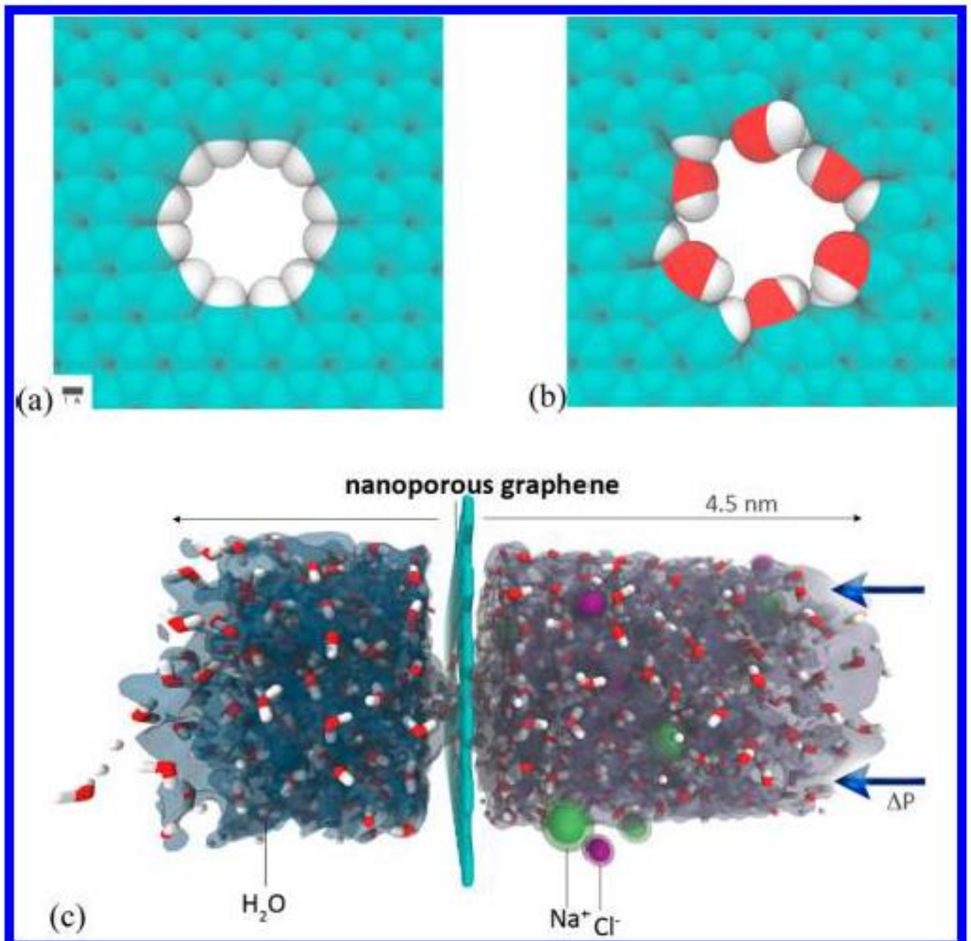


Figure 1. Hydrogenated (a) and hydroxylated (b) graphene pores, and (c) side view of the computational system investigated in this work.

Introduction

- Although water covers approximately 75% of the surface of the Earth, a scarcity of fresh water is a serious global challenge.
- Because seawater represents such a vast supply of water, desalination has become an important and promising approach to meet the ever increasing demand for fresh water.
- Membrane-based separation of water using techniques such as reverse osmosis offers the highest energy efficiency while maintaining the capability for use at industrial scales.
- A number of theoretical studies have predicted that graphene with sub-nanometre pores could act as a highly selective and permeable filtration membrane with greater efficiency than current state-of-the-art polymer-based filtration membranes because it is extremely thin , extremely strong, and it can be chemically modified.
- Then a few experimental studies have begun to explore the use of both graphene and graphene oxide for membrane separation and have shown promising results.

In this paper

- In this paper they have created nanopores in a layer of graphene using oxygen plasma and they have shown that it that single-layer porous graphene can be used as a desalination membrane due to its chemical and mechanical stability, its flexibility and, most importantly, its one-atom thickness.
- The resulting membranes exhibit a salt rejection rate of nearly 100% and rapid water transport.

Preparation and characterization of graphene membranes

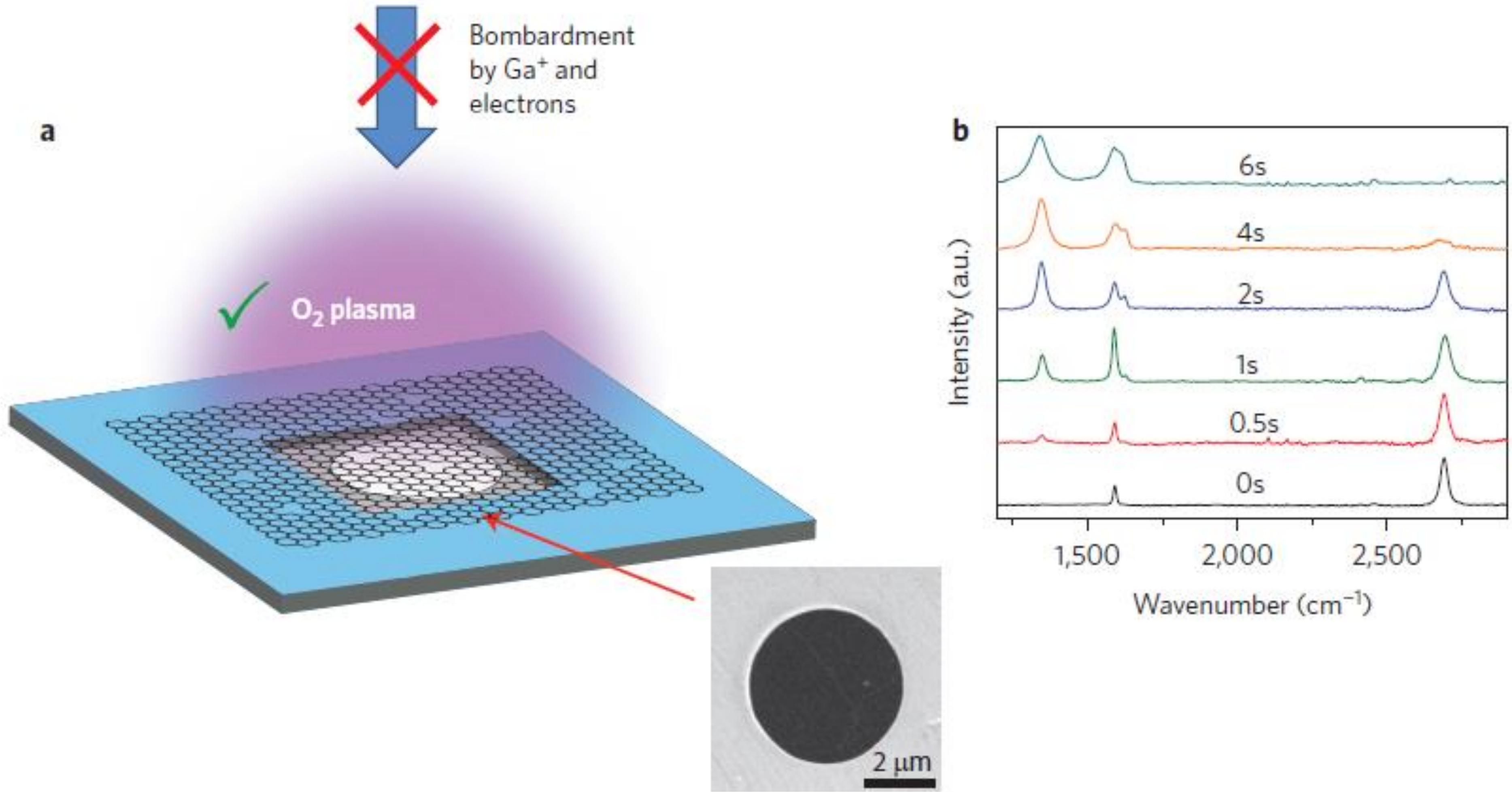
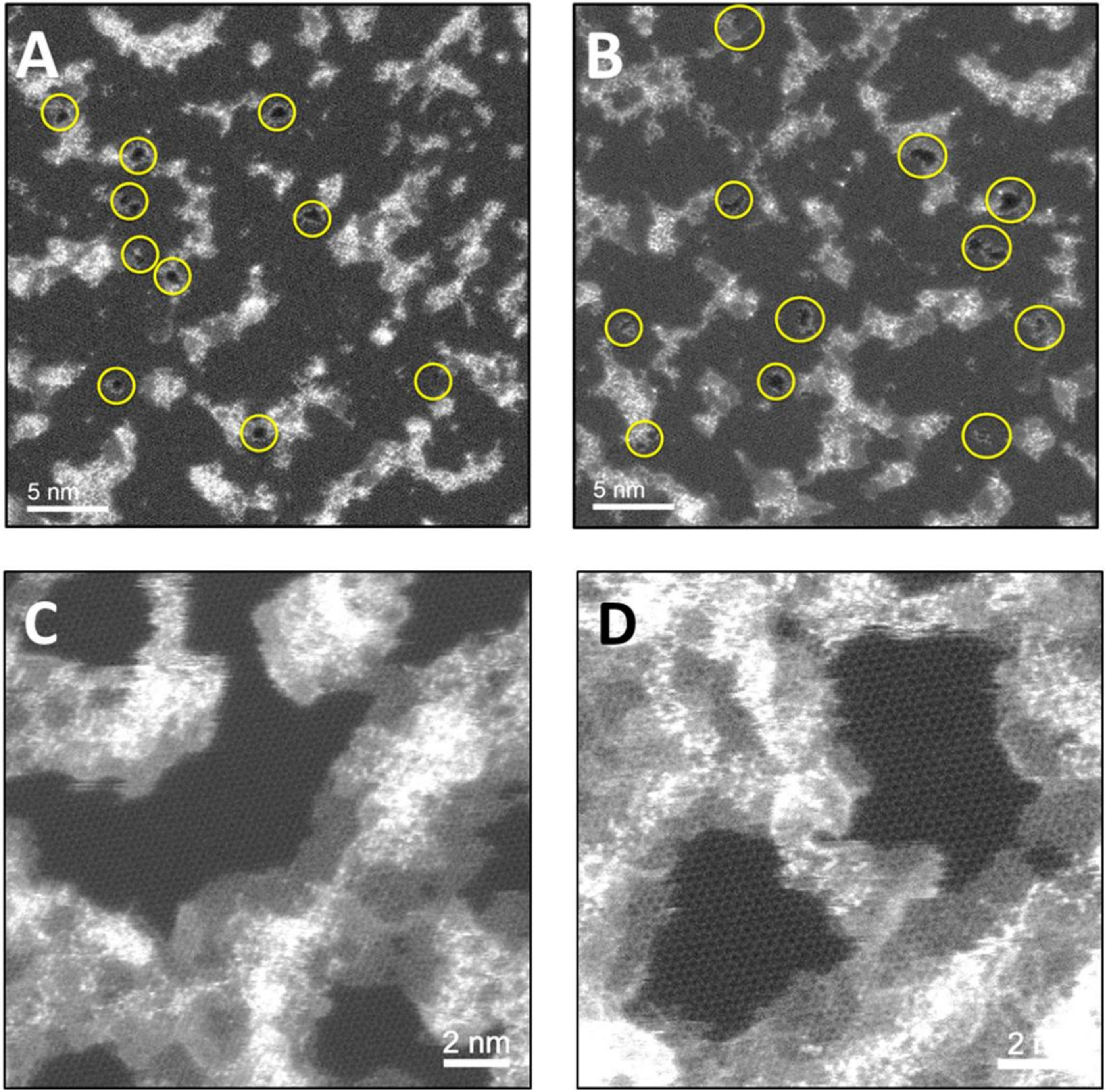


Figure 1 | Porous graphene membranes. a, Schematic and SEM image of single-layer graphene suspended on a 5-μm-diameter hole. For nanoporous graphene fabrication, several approaches have been utilized: bombardment by ions, by electrons and via O_2 plasma treatment. b, Raman spectra (514 nm excitation) of suspended graphene after different exposure times to oxygen plasma.



Supplementary Fig. 1. Large area, single layer graphene STEM image. Pore density is estimated to be 1 pore per 100 nm^2, which roughly translates to *La*~10nm for average distance between the point defects. Pristine graphene (C,D) prior to plasma treatment does not have any visible pores confirming very large *La* measured from their Raman spectra.

Water transport and salt rejection measurements

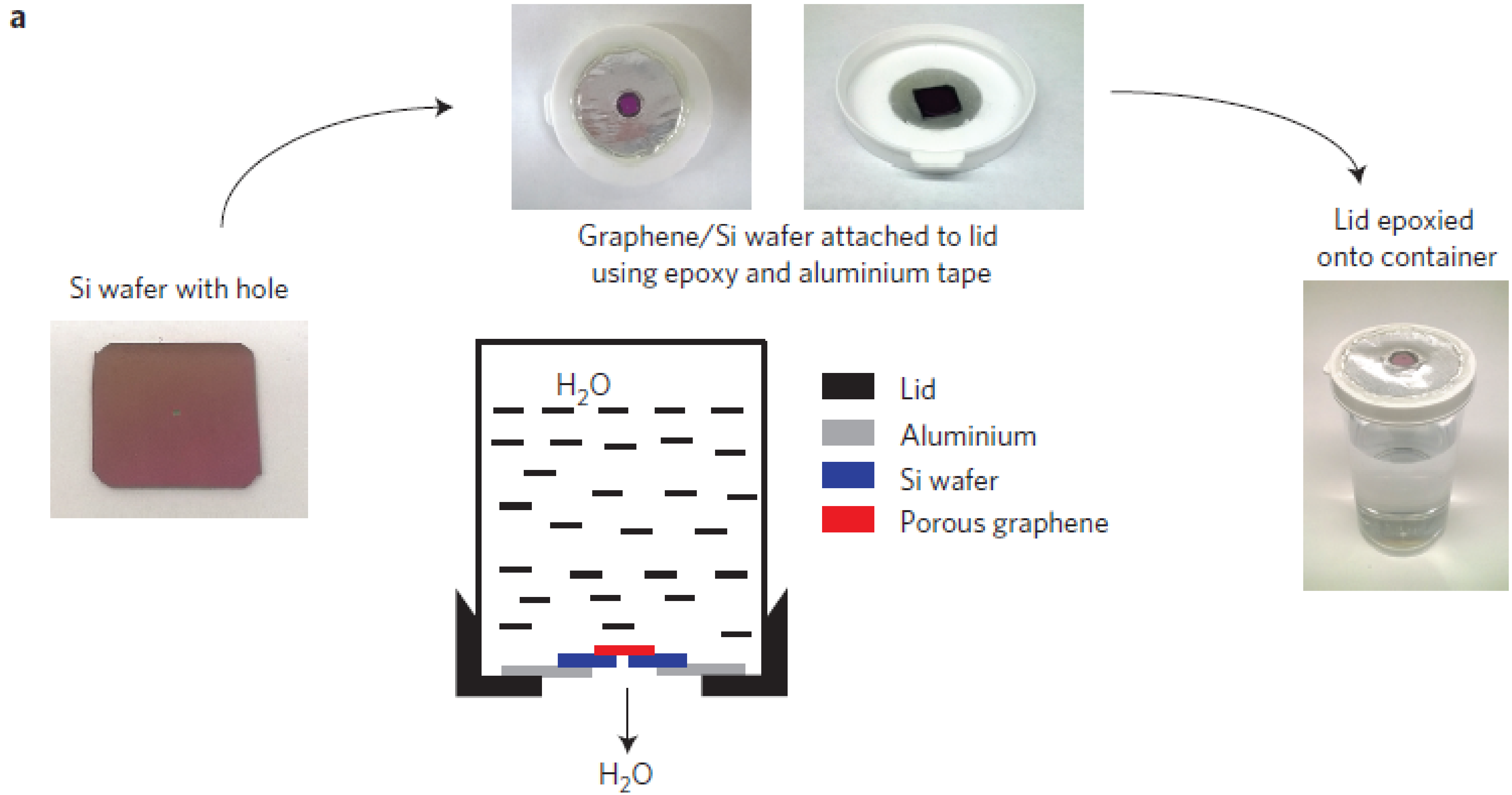


Figure 2 | Water transport measurements and desalination experiments. a, Porous graphene membrane assembly for water flux measurements. A graphene membrane on a silicon chip with a 5 µm hole in a 300-nm-thick SiN membrane is sealed on a glass vial filled with deionized water. The vial is turned upside down and placed in an oven at 40 °C. Water loss is measured by monitoring the mass of the vial.

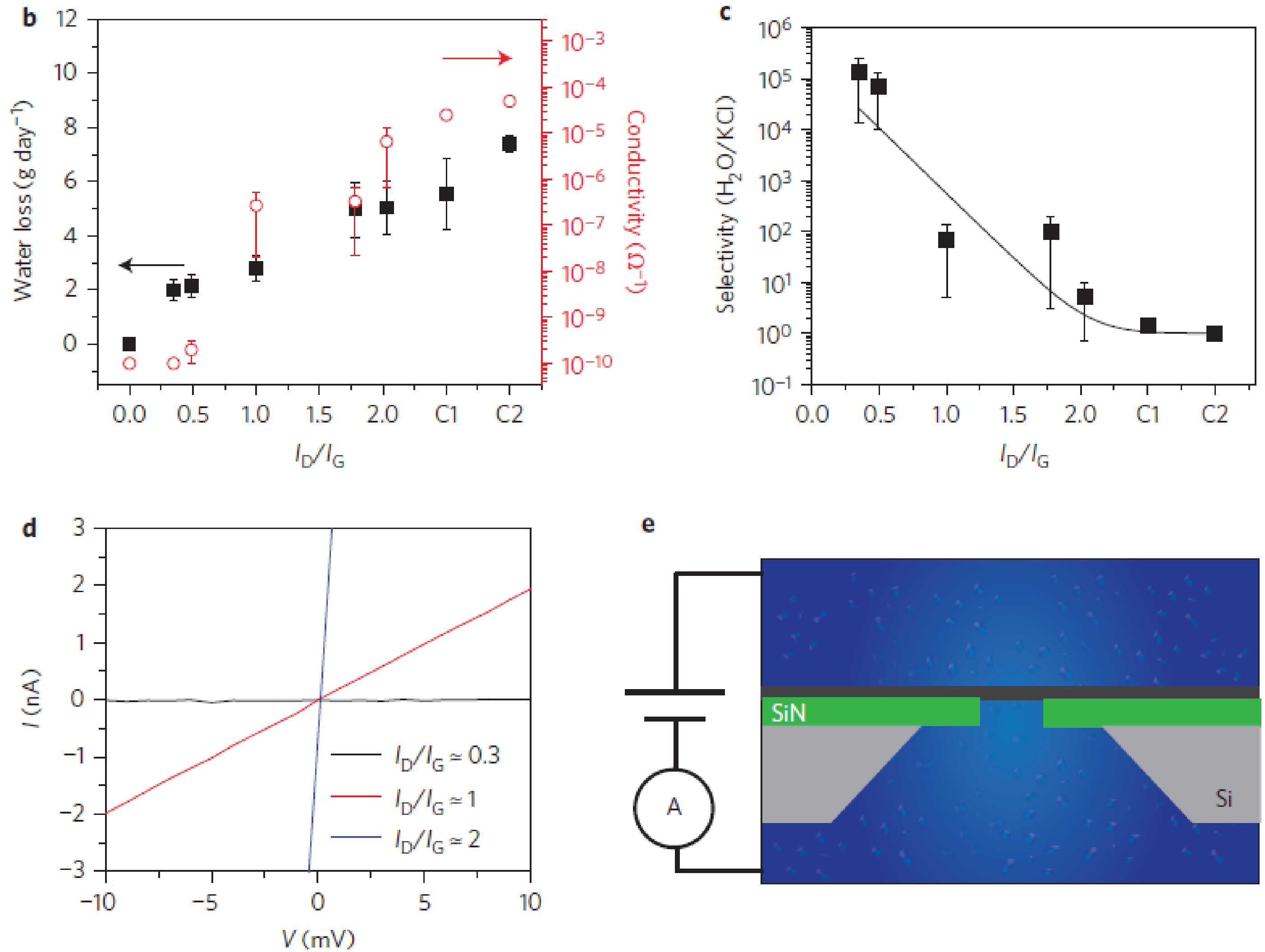
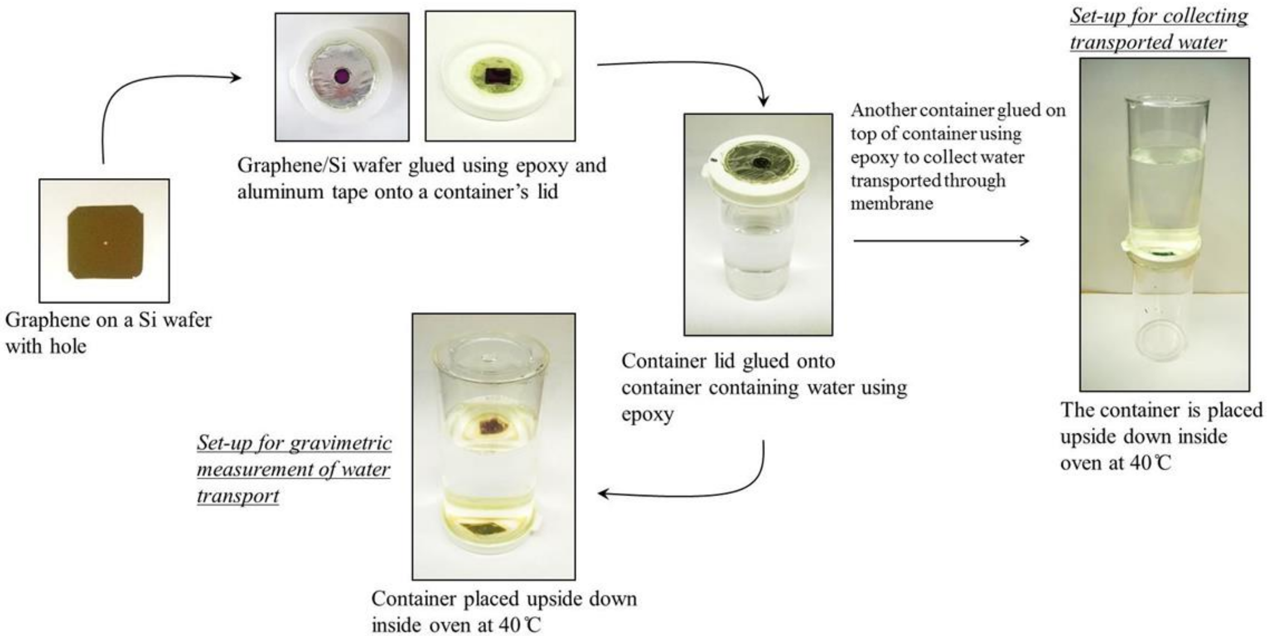


Figure 2 | b, Water loss after 24 h and ionic conductivity through the same porous graphene membranes etched at various exposure times. C1 and C2 are controls with large tears or completely broken graphene membranes, respectively. c, Water/salt selectivity as a function of I_D/I_G ratio showing exceptionally high selectivity for a short etching time. d, Examples of I–V curves measured in 1 M KCl solution across a porous graphene membrane for different plasma exposure times. e, Sketch of experimental set-up for I–V measurements where dark grey represents graphene. Two Ag/AgCl wires are used as electrodes.

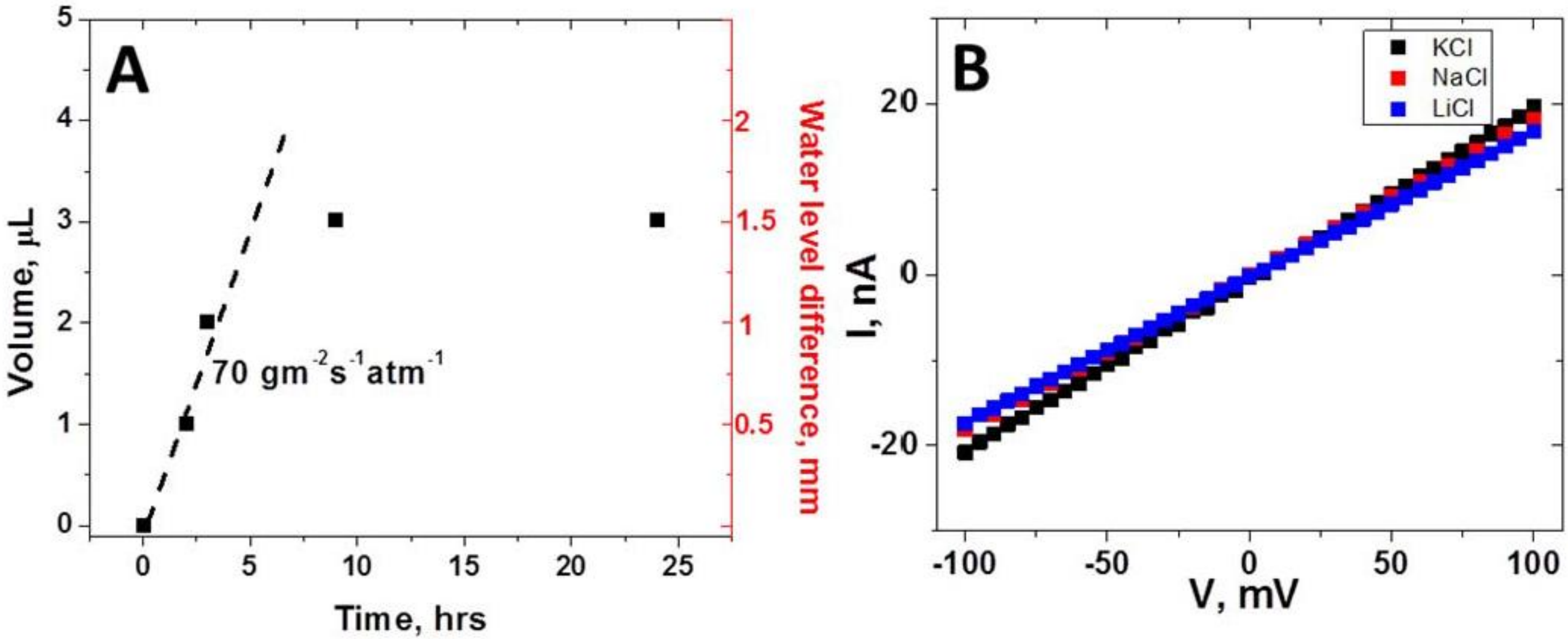


Supplementary Fig. 7. *Schematics and images showing the experimental set-up.* Bottom container always had a small hole (~1mm in diameter) to equilibrate the pressure with the atmosphere.

Table 1 | Filtration of KCl solution (6 mM) through graphene membranes.

Sample	Feed solution conductivity ($\mu S\ cm^{-1}$)	Water collected after 24 h (ml)	Permeate conductivity ($\mu S\ cm^{-1}$)
SiN pore	950	7.2	675
Graphene/SiN pore	950	0	-
Porous graphene/SiN pore ($I_D/I_G = 0.6$)	950	2.6	<11

Measurements of the ionic current and of the water flow through nanopores induced by osmotic pressure gradient



Supplementary Fig. 6. Measurement of the water flux induced by osmotic pressure and ionic current across a nanoporous graphene membrane using different electrolytes. (**A**). Water flux induced by osmotic pressure **(B)** Normalized to the bulk conductivities ionic currents across a membrane in different electrolytes. All I-V curves measurements were performed within 30 min after assembly.

Conclusion

- In this paper they have shown the potential utility of nanoporous graphene as a selective membrane that can be used for water desalination.
- They have shown that oxygen plasma can be used as a very convenient method for the fabrication of tailored nanopores of desired dimension in suspended single-layer graphene, with high precision.
- The resulting nanopores showed tremendous water molecule selectivity over dissolved ions (K^+, Na^+, Li^+, Cl^-).

Thank You

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