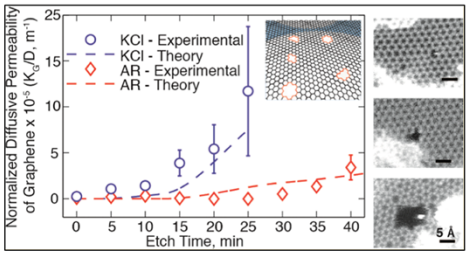
Selective Ionic Transport through Tunable Subnanometer Pores in Single-Layer Graphene Membranes



(Left) Comparison between experiment and theory of diffuse permeability for different molecules. Inset shows the schematic of graphene holes generated by irradiation. (Right) Z-contrast STEM images of graphene membranes with different hole sizes.

Electron microscopy was performed as part of a User Project at the Center for Nanophase Materials Sciences.

Scientific Achievement

Selective ionic transport through controlled, high-density, subnanometer diameter pores in macroscopic monolayer graphene membranes.

Significance and Impact

This study addresses a significant challenge in the development of advanced nanoporous graphene membranes for nanofiltration, desalination, gas separation, etc.

Research Details

- CVD-grown graphene was bombarded with gallium ions accelerated at 8 kV to form the nano-pores
- Defects (pores) in the graphene sheets were characterized by low-voltage (60 kV) aberration-corrected scanning transmission electron microscopy (CNMS Nion UltraSTEM).
- Transport measurements were performed in a diffusion cell via monitoring changes of conductivity.

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جامعة الملك فهد للبترول والمعادن King Fahd University of Petroleum & Minerals

OAK RIDGE National Laboratory

Narrative Highlight Text: We report selective ionic transport through controlled, high-density, subnanometer diameter pores in macroscopic single-layer graphene membranes. Isolated, reactive defects were first introduced into the graphene lattice through ion bombardment and subsequently enlarged by oxidative etching into permeable pores with diameters of 0.40 ± 0.24 nm and densities exceeding 1012 cm−2, while retaining the structural integrity of the graphene. Transport measurements across ion-irradiated graphene membranes subjected to in situ etching revealed that the created pores were cation-selective at short oxidation times, consistent with electrostatic repulsion from negatively charged functional groups terminating the pore edges. At longer oxidation times, the pores allowed transport of salt but prevented the transport of a larger organic molecule, indicative of steric size exclusion. The ability to tune the selectivity of graphene through controlled generation of subnanometer pores addresses a significant challenge in the development of advanced nanoporous graphene membranes for nanofiltration, desalination, gas separation, and other applications.

Reference

"Selective Ionic Transport through Tunable Subnanometer Pores in Single-Layer Graphene Membranes"

Sean C. O'Hern,[1] Michael S. H. Boutilier,[1] Juan-Carlos Idrobo,[2] Yi Song,[3] Jing Kong,[3] Tahar Laoui,[4] Muataz Atieh,[4] and Rohit Karnik[1]

[1] Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, United States
[2] Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, United States
[3] Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, United States
[4] Departments of Mechanical and Chemical Engineering, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia

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