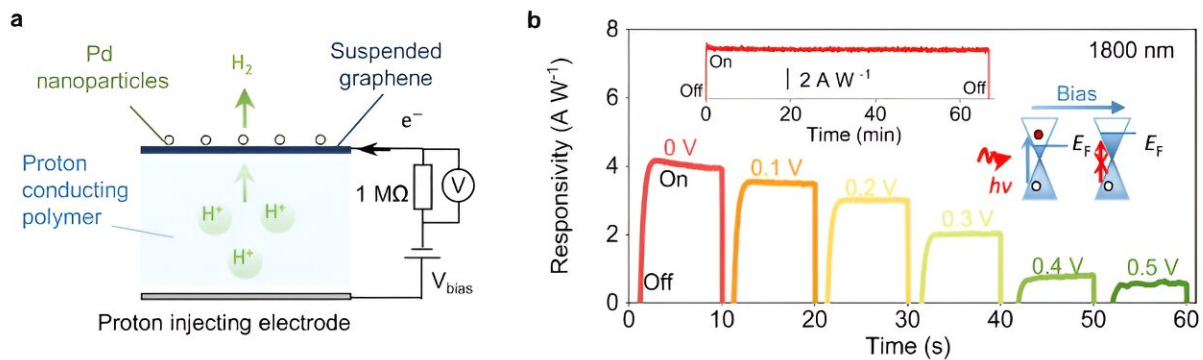


# Graphene's proton permeability: A switch for future energy technologies

November 6 2023



**a** Schematic of experimental setup.  $H_2$ , hydrogen gas;  $H^+$ , proton;  $e^-$ , electrons;  $V_{\text{bias}}$ , applied bias. **b** Examples of responsivity vs time of devices under 1800 nm light on-off pulses shown the gate-controlled suppression of the photoresponse. In the measurement, the bias is fixed as a function of time; the light is turned on and off and the process is repeated for a different bias (color coded). Left inset shows that the photoresponse is stable for over an hour of continuous illumination of 1800 nm wavelength.  $V$ -bias, 0 V. Right inset, schematic illustrating the principle behind the Pauli blocking mechanism. Initially (left),  $E_F$  (Fermi energy) is lower than half the photon energy (given by Planck's constant,  $h$ , and light frequency,  $\nu$ ), allowing absorption of the photon (marked by blue arrow). When the  $V$ -bias is applied (right),  $E_F$  rises and now blocks photon absorption (marked by crossed red arrow). Credit: *Nature Communications* (2023). DOI: 10.1038/s41467-023-42617-4

Researchers from the National Graphene Institute at the University of

Manchester have discovered a way to use light to accelerate proton transport through graphene, which could revolutionize the way we generate hydrogen.

Proton transport is a key step in many [renewable energy technologies](#), such as [hydrogen fuel cells](#) and solar water splitting, and it was also previously shown to be permeable to protons by Manchester scientists.

Their new study [published](#) in *Nature Communications* has shown that light can be used to accelerate proton transport through [graphene](#). Graphene is a single layer of carbon atoms that is an excellent conductor of both electricity and heat. However, it was previously thought that graphene was impermeable to protons.

The researchers found that when graphene is illuminated with light, the [electrons](#) in the graphene become excited. These excited electrons then interact with protons, accelerating their transport through the material.

This discovery could have a significant impact on the development of new renewable energy technologies. For example, it could lead to the development of more efficient [hydrogen](#) fuel cells and solar water-splitting devices.

"Understanding the connection between electronic and ion transport properties in electrode-electrolyte interfaces at the molecular scale could enable new strategies to accelerate processes central to many renewable energy technologies, including [hydrogen generation](#) and utilization," said lead researcher Dr. Marcelo Lozada-Hidalgo.

Graphene, a single layer of carbon atoms is an excellent electronic conductor and, unexpectedly, was also found to be permeable to protons. However, its proton and electronic properties were believed to be completely unrelated. Now, the team measured both graphene's proton

transport and electronic properties under illumination and found that exciting electrons in graphene with light accelerates proton transport.

The smoking gun evidence of this connection was the observation of a phenomenon known as "Pauli blocking" in proton transport. This is an unusual electronic property of graphene, never observed in proton transport. In essence, it is possible to raise the energy of electrons in graphene to such an extent that graphene no longer absorbs light—hence the "blocking."

The researchers demonstrate that the same blocking takes place in light-driven proton transport by raising the energy of electrons in graphene. This unexpected observation demonstrates that graphene's [electronic properties](#) are important to its proton permeation properties.

Dr. Shiqi Huang co-first author of the work said, "We were surprised that the photo response of our proton conducting devices could be explained by the Pauli blocking mechanism, which so far had only been seen in electronic measurements. This provides insight into how protons, electrons and photons interact in atomically thin interfaces."

"In our devices, graphene is being effectively bombarded with protons, which pierce its electronic cloud. We were surprised to see that photo-[excited electrons](#) could control this flow of protons," said Dr. Eoin Griffin co-first author.

**More information:** S. Huang et al, Gate-controlled suppression of light-driven proton transport through graphene electrodes, *Nature Communications* (2023). [DOI: 10.1038/s41467-023-42617-4](https://doi.org/10.1038/s41467-023-42617-4)

Provided by University of Manchester

Citation: Graphene's proton permeability: A switch for future energy technologies (2023, November 6) retrieved 28 April 2024 from <https://phys.org/news/2023-11-graphene-proton-permeability-future-energy.html>

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