Field effects in proton transport and chemisorption in graphene

Marcelo Lozada-Hidalgo
The University of Manchester, *Department of Physics and Astronomy, Manchester, UK*
marcelo.lozadahidalgo@manchester.ac.uk

Graphene is impermeable to all atoms and ions under ambient conditions in the direction perpendicular to its basal plane but is permeable to thermal protons[1, 2]. Protons can also chemically adsorb on graphene and recent work demonstrated that this process can be driven electrochemically, triggering a robust conductor-insulator transition in graphene[3], though its mechanism remains unknown. In this talk I'll discuss our recent investigating the mechanism of the electrochemical hydrogenation of graphene[4]. We will then discuss our recent work on the selective acceleration of proton transport and hydrogenation in double-gated monolayer[5] and twisted bilayer graphene[6]. Our main finding is that independent control of the charge density and the electric field in graphene enables the selective acceleration of these otherwise coupled processes. This represents a new way of diving electrochemical processes with applications in logic-and-memory devices and energy.

References

[1] Hu, S. *et al.* Proton transport through one-atom-thick crystals. *Nature* **516**, 227-230 (2014).
[2] Wahab, O. J. *et al.* Proton transport through nanoscale corrugations in two-dimensional crystals. *Nature* **620**, 782-786 (2023).
[3] Li, S. *et al.* Large transport gap modulation in graphene via electric-field-controlled reversible hydrogenation. *Nature Electronics* **4**, 254-260 (2021).
[4] Soong, Y. C. *et al.* Mechanism of the electrochemical hydrogenation of graphene. *Nature Communications* **16**, 10741 (2025).
[5] Tong, J. *et al.* Control of proton transport and hydrogenation in double-gated graphene. *Nature* **630**, 619-624 (2024).
[6] Tong, J. et al. Layer selective hydrogenation and proton transport in twisted bilayer graphene (2026). *Nature Communications* (in press).