Colloquium

Dr. Marcelo Lozada-Hidalgo
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Monday, 17 October 2022
2:30 – 3:30 pm CEST

Exp.-HS (room 029, Johannisallee 29)

Ion transport through atomically thin crystals

Graphene is completely impermeable in the perpendicular direction to its basal plane to all gases – even for helium, the smallest – at ambient conditions.\(^1\,^2\) The exceptional impermeability arises because atoms at ambient conditions cannot pierce graphene’s dense electron clouds.\(^3\,^4\) Only accelerated ions have the necessary kinetic energy to do this.\(^5\) In this context, it was expected that graphene would be impermeable even to protons, nuclei of hydrogen atoms. Nevertheless, we demonstrated that the transport of thermal protons through defect-free graphene is fast and can be measured experimentally.\(^5\) Surprisingly, isotope effects, which would normally introduce only a few-percentage change in the permeability of bulk materials, yield an order-of-magnitude effect in the permeability of graphene. Deuterons, nuclei of hydrogen’s heavier isotope deuterium, permeate ~10 times slower than protons through graphene at ambient conditions.\(^7\) This is attributed to the difference in zero-point energy of the incoming isotopes.

In the in-plane direction, the space between the layer of atomically thin crystals can also be permeable to ions. In recent work, we found that ion diffusion in the interlayer space of atomically thin micas is 4 orders of magnitude faster than in bulk crystals.\(^6\) Surprisingly, isotope effects are also observed in proton transport in this direction. The effect is smaller and is inverse to that observed in the transport across the basal plane. Proton transport is slower than deuteron transport.\(^9\) This is attributed to the difference in de Broglie wavelengths of the isotopes, which become confined in the van der Waals gap between layers of hexagonal boron nitride and MoS\(_2\).

The \(^{1,2,3}\)H Colloquium will be streamed via Zoom:

https://uni-leipzig.zoom.us/j/67221664393?pwd=eFRVRm5URE9rc256WDh3ZTB3NnNlZz09

Meeting ID: 672 2166 4393 / Passcode: 245588
References


Short Bio

Marcelo Lozada-Hidalgo is a Senior Lecturer (Associate Professor) and Royal Society University Research Fellow at The University of Manchester. He is an expert on the permeability of two-dimensional crystals to protons, ions and gases at ambient conditions. His publications include 12 in Science/Nature group journal including 8 as first and corresponding author, which have established the possibility of using the 2D crystal lattice itself as a sieve. In a recent review commissioned by Nature Nanotechnology one of his papers was highlighted as one of the most influential graphene papers in the last 15 years (Pulizzi et al. *Nat. Nanotechnol.* 14, 914–918, 2019).

He was awarded a PhD in Physics from The University of Manchester (2015) and an MSc in Physics from The National Autonomous University of Mexico (2012). He now leads an independent research group in Manchester investigating ion and gas transport through 2D crystals. He was awarded an ERC Starting Grant (2021); a University Research Fellowship by the Royal Society (2020); a Dame Kathleen Ollerenshaw Fellowship by the University of Manchester (UoM) (2019); an Early Career Fellowship by the Leverhulme Trust (2016); and the ‘Andre Geim scholarship for PhD studies’ by the National Science Council of Mexico (Conacyt) and the UoM after winning a national competition in Mexico (2012).