MATERIALS

Water 'walks' on 2D material

ANTHONY KING

Individual water molecules interact with 2D materials in unexpected ways, according to new research, and this could have implications for innovative coatings that could control wetting or resist icing.

The research team investigated the behaviour of water molecules on graphene and hexagonal boron nitride (hBN), both structurally similar 2D honeycomb materials (*Nature Communications*, 2025, DOI: 10.1038/s41467-025-65452-1).

On graphene, single water molecules discretely hopped when traversing the surface. On hBN, however, they showed a smooth rolling motion, described as walking. 'On boron nitride they moved more like how a planet progresses around the sun, advancing and spinning at the same time,' says Marco Sacchi, a computational chemist at the University of Surrey, UK.

Water experiences significantly lower friction on hBN, particularly when it is supported on a nickel substrate, with the activation energy for motion about 2.5 times lower than on graphene. Activation energy is the thermal energy required for water to begin moving. These dynamics are not captured by classical models and point to a fundamentally different form of water transport on polar 2D surfaces.

On graphene, the combination of higher activation energy and stronger friction allows water molecules to jump between sites but limits how far they can travel. 'The molecule can move, but it does not go far because it is trapped by friction,' explains Sacchi. On hBN, motion begins more easily and lower friction allows water to continue moving further. 'It is much easier for water to move across boron nitride,' says Anton Tamtögl, an experimental physicist at Graz University of Technology in Austria, who collaborates with Sacchi.

The supporting substructure matters. hBN on nickel shows lower friction than graphene on nickel, which is the opposite to the behaviour seen for free-standing layers. 'Whenever you put anything near these 2-dimensional materials you essentially dope them,' says Sacchi. 'Even the proximity of another surface induces electronic or structural changes, or a fraction of an Ångström change in position of the atoms, can be enough to shift the properties of the material.'

This sensitivity suggests that substrate choice, and possibly even its thickness, could tune the characteristics of a 2D material. The insights could assist in the design of new materials that manipulate water at the nanoscale, with potential applications in coatings, lubricants and desalination membranes.

'The interaction energy of water with hBN and graphene single layers, which have very similar structures, can be straightforwardly quantified experimentally by measuring the contact angle that water droplets make on such surfaces, notes Roland Netz, a physicist at the Free University of Berlin, Germany. 'One finds the interaction energy of water with those two surfaces to be rather similar.'

'The interesting finding is that despite the similar interaction with water, the water dynamics on the two surfaces are very different,' he adds. 'Controlling the friction of liquids – and in particular water – at surface is important for nanotechnological applications. This is where these findings can be really helpful.'

The research relied on helium spin-echo spectroscopy, which is the only surface-sensitive technique capable of tracking water molecules on picosecond timescales (10^{-12} seconds). 'Water is so mobile on these surfaces that conventional microscopic techniques do not have sufficient time resolution,' Sacchi explains. Graphene is electrically conductive, making it useful for future electronics and in batteries, whereas hBN is an electrically insulating ceramic used in high-performance coatings and thermal-management applications.

COMMENT

Updating EU CLP

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In 2025, recognition of widespread 'hidden hazards', from PFAS to dust, led experts to emphasise that a 'bare minimum' approach to chemical management is more than reckless, it's a fatal oversight.

The statutory tide is turning, and in 2026, the EU Classification, Labelling & Packaging (CLP) Regulation (Regulation (EU) 2024/2865) will require updates to the classification, labelling, and packaging of substances. Through the required analysis of individual components, businesses will gain the visibility needed to improve protections across the supply chain, from suppliers and manufacturers to those using them in workplace operations.

CLP compliance in Europe will have wider ranging impacts on global businesses; once in effect on 1 July, companies outside the EU must have measures in place. At present, we're seeing organisations prioritise health and safety protocols while unintentionally omitting the consideration of chemical management. Moving forward, I expect we'll see a rush of businesses proactively preparing for implementation, adding chemical safety to already existing health and safety measures.

To keep up, keep compliant, and keep workers safe, EHS leaders will have be more active in their approaches to chemical safety. Viewing it as a competitive advantage rather than a compliance exercise is a critical mindset shift I expect to see in the first half of 2026. Whether implementing new tools like Safety Data Sheets (SDS) and chemical substitution technology or implementing new processes, like phasing out hazardous substances, 2026 will see leaders taking measured steps to protect workers and streamline future compliance processes.