Is graphene hydrophobic or hydrophilic?

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The National Physical Laboratory's (NPL) Quantum Detection Group has just published research investigating the hydrophobicity of epitaxial graphene, which could be used in the future to better tailor graphene coatings to applications in medicine, electronics and more. Contrary to widely-held beliefs, the findings indicate that graphene's hydrophobicity is strongly thickness-dependent, with single-layer graphene being significantly more hydrophilic than its thicker counterparts.

Graphene is a two-dimensional crystal of carbon, with many potential applications such as flexible electronics, efficient transistors and novel sensors. To encourage the uptake of graphene for electrical applications, the challenges of large-scale production and control of its properties under a variety of environmental conditions need to be addressed.

Many graphene-based devices will have to operate in ambient conditions where humidity is non-zero and not monitored. Air humidity can affect graphene's performance through changes in its mechanical and electrical properties - it is therefore critically important to obtain knowledge of graphene's water affinity.

The new study, conducted in collaboration with the Naval Research Laboratory, addresses the much-debated question of whether graphene is hydrophobic or hydrophilic. The common assumption is that graphene, as with many other carbon-based materials, is hydrophobic. This work, published in the American Chemical Society journal *ACS Nano*, has proved the question to be much more complicated than first thought.

The adhesion and friction properties of single- and double-layer graphene were studied using chemical force microscopy with a hydrophobic probe - a variant of atomic force microscopy where a substrate is studied using the forces between a probe and a surface. A larger adhesion force was measured between the probe and double/triple-layer graphene compared to single-layer graphene, showing that double/triple-layer graphene is more hydrophobic. This suggests that the hydrophobicity depends on the thickness of graphene layers.

These results were further confirmed by the nanoscale mapping of friction forces: hydrophobic domains showed a lower friction force, a result consistent with the fact that the different levels of hydrophobicity tend to affect the arrangement of surrounding water molecules and, in turn, the sliding motion of the probe tip.

The techniques demonstrated by NPL could be used in the future to further our understanding of graphene's wetting behaviour, with a particular focus on the effects of different graphene production methods. In particular, it paves the way to differentiating graphene-based coatings and tailoring them to a specific application.

For example, thicker coatings (double-layer graphene or more) are ideal for hydrophobic applications, such as medical equipment and electronic components. On the other hand, single-layer graphene coatings could be used where a hydrophilic surface is required, as for example in anti-fog glass and coatings for buildings.

More information: "Thickness-Dependent Hydrophobicity of Epitaxial Graphene." *ACS Nano*, Article ASAP DOI: 10.1021/acsnano.5b03220

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