Water nanodroplets zip across graphene faster than a cheetah

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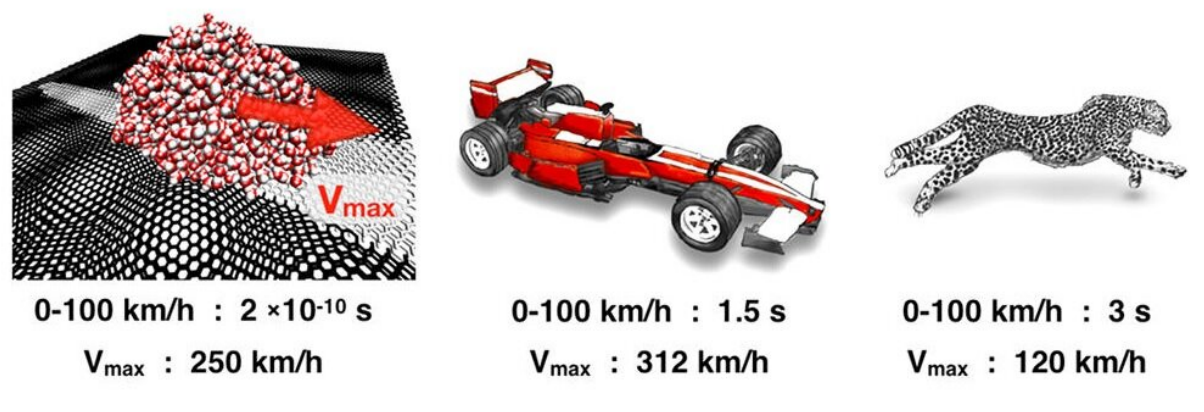

A comparison of velocities of water nanodroplets on patterned graphene, a race car, and a cheetah. Credit: Papadopoulou et al. ©2019 American Chemical Society

In a new study, researchers have propelled water nanodroplets across a graphene surface at speeds of up to 250 km (155 miles) per hour—which, for comparison, is about twice as fast as a sprinting cheetah. The water droplets' ultrafast velocities don't require any pump, but instead occur simply due to the geometric patterns on the graphene surface, which create different contact angles at the front and back of the moving droplets to propel them forward.

The researchers, Ermioni Papadopoulou and Petros Koumoutsakos at

ETH Zürich, Constantine M. Megaridis at the University of Illinois at Chicago, and Jens H. Walther at ETH Zürich and the Technical University of Denmark, have published a paper on the fast-moving water droplets in a recent issue of *ACS Nano*.

"We can get very high-speed directed transport of water droplets on the nanoscale, without expending any energy but simply through the patterning of graphene," Koumoutsakos told *Phys.org*. "This may have important applications in nano-fabrication and precise drug delivery. It also provides for the first time a simple quantitative explanation for the ultrafast transport of water at the nanoscale."

This nano-/microscale mode of transport is very different than anything observed on the macroscale. The graphene surface was structurally patterned to create wettability gradients, ranging from hydrophobic to hydrophilic. The water nanodroplets, each consisting of approximately 1500 water molecules, were then placed on the surface. The different surface patterns created large contact angles on the hydrophobic domains and smaller contact angles on the hydrophilic domains. The differences in the contact angles at the advancing and receding ends of the water droplets set the droplets in motion and accelerated them forward.

Similar mechanisms are found in nature, such as on the surface of the Namib desert beetle and the vein network of banana leaves. These surfaces have patterns that result in the improved collection and transport of water.

In experiments with the graphene, the researchers observed water droplet velocities on the order of 100 meters per second, which is two orders of magnitude faster than the highest velocities reported for water droplets propelled by certain other methods, such as surface energy gradients. As expected, smaller droplets move faster than larger ones due to the larger droplets' increased inertia and greater friction with the surface.

After analyzing the underlying mechanisms for the water transport, the researchers derived a scaling law and developed a model that can be used to predict droplet trajectories. This information can be used to design future devices for potential applications, such as high-efficiency drug delivery, electricity generation, and ultrafast heat dissipation for nano- and microscale systems. The researchers plan to further investigate high-speed water transport mechanisms in places other than graphene.

"We are examining ultrafast transport of water in other nanostructures, such as carbon nanotubes," Koumoutsakos said.

More information: Papadopoulou et al. "Ultrafast Propulsion of Water Nanodroplets on Patterned Graphene." *ACS Nano*. DOI: 10.1021/acsnano.9b00252