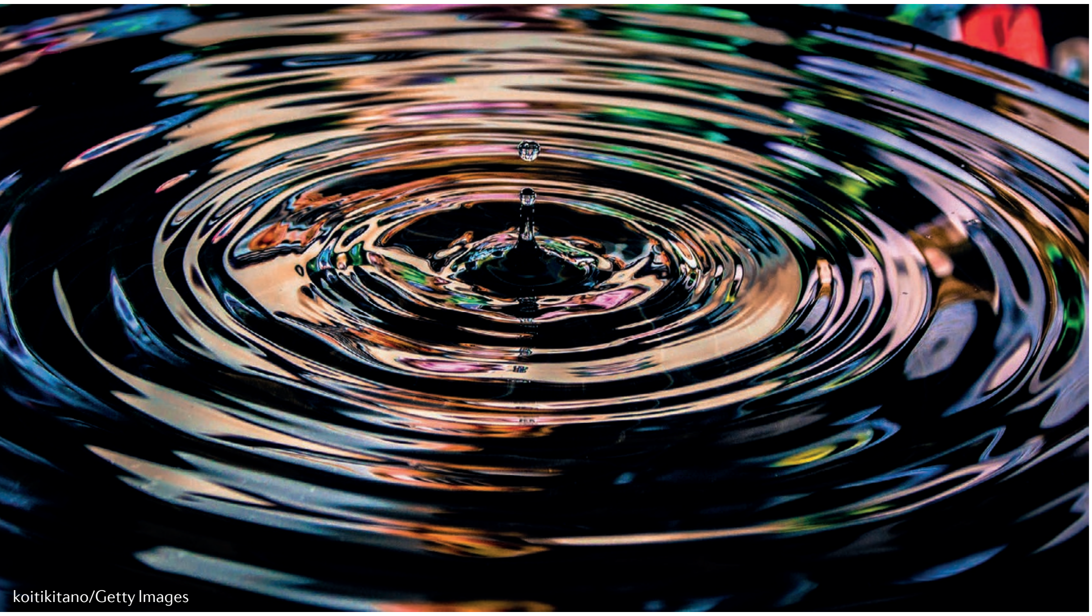

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GRAPHENE

Taming the ripples

2D materials are often described as flat. However, the presence of ripples at the microscopic scale is an intrinsic feature of isolated 2D layers and determines their structural stability, as well as their electronic and transport properties. In a study recently published in the *Proceedings of the National Academy of Sciences*, Jianbo Hu and colleagues report the observation of ultrafast rippling dynamics in suspended graphene.

Ripples have a strong influence on the transport properties of graphene, because they scatter charge carriers, which effectively contributes to electrical resistivity. Indeed, the carrier mobility measured in graphene is almost one order of magnitude lower than the value predicted for a perfectly flat sheet. Moreover, ripples can affect the electronic structure of graphene and induce a small bandgap, which is potentially interesting for optoelectronic applications. Thus, the ability to control ripples in 2D materials would provide a handle for controlling their properties. The use of strain engineering to introduce ripples in graphene has been demonstrated but leads to ripples with lateral sizes that are much larger than in intrinsic rippling.

The researchers use ultrafast electron diffraction (UED), in which femtosecond laser pulses are used to initiate the rippling dynamics in the suspended graphene; its temporal evolution is then monitored using an electron probe beam. Simply put, the photons in the laser beam excite electrons in the graphene, which in turn decay exciting phonons — that is, quantized vibrational modes. “UED is the only technique that can give access to the dynamic behaviour of graphene with atomic spatial resolution and femtosecond temporal resolution, thanks to the high scattering cross section of electrons and matter,” notes Hu. Using UED, ripples can be modulated through the excitation and interaction of different phonon modes. Immediately after the optical excitation, the graphene sheet undergoes an ultrafast expansion (~5 ps), which is mediated by the excitation of in-plane phonons that attenuate the ripples by stretching the graphene layer. A contraction follows on a longer timescale (50 ps), mediated by out-of-plane phonons, which recover and even enhance the rippling, driving the system to thermal equilibrium.

“UED is the only technique that can give access to the dynamic behaviour of graphene with atomic spatial resolution and femtosecond temporal resolution”

Because ripples are observed in most 2D materials, these results should be of general applicability. In addition to furthering the current understanding of the intrinsic properties of 2D materials, these findings provide a way to control their properties, in particular their electric resistivity, on ultrafast timescales. “The most obvious application would be an ultrafast optoelectronic switch, but other uses can be imagined. For instance, by tuning the height of the ripples it would be possible to control the storage and release of encapsulated hydrogen, which are crucial in hydrogen-based fuel cells,” explains Giovanni M. Vanacore, co-author of the paper.

The next steps in this study include the application of UED to the investigation of other 2D materials and heterostructures. On the technical side, “we are currently developing alternative pumping sources, in which intense ultrafast terahertz radiation is used instead of the near-infrared lasers, so that specific degrees of freedom can be resonantly excited,” concludes Hu. “The physical phenomena to explore will be numerous and exciting, such as photoinduced structural transformations and quantum transitions.”

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