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EDITORIAL

STM reveals first view of graphene ripples in motion

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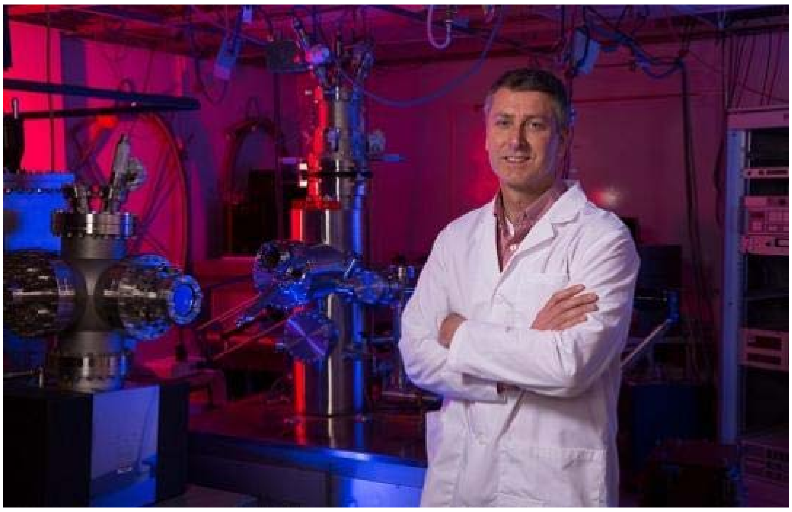

Rebecca Pool

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Top image: Paul Thibado, University of Arkansas, Professor of physics.

Using scanning tunnelling microscopy, an international team of physicists has, for the first time, tracked the dynamic movement of ripples in freestanding graphene at the atomic level.

Graphene is set to emerge as a replacement for silicon in microprocessors but its mechanical and thermal properties remain elusive to researchers worldwide.

Observing how ripples - out-of-plane carbon atom motions - form is critical to understanding electronic transport in the material, with the new STM method providing a much-needed atomic-scale probe to analyse this behaviour.

As Professor Paul Thibado (https://cavern.uark.edu/depts/physics/apps/profiles/view/paul-thibado), University of Arkansas (https://www.uark.edu/), explains, the ripples have been very difficult to study as the vertical atom movement has led to blurry images.

"Physicists have known that these ripples exist, but have only measured them as static, in time," he says. "Theory requires that they fluctuate but until our experiment no-one had successfully measured this dynamic property."

To track the ripples, Thibado and colleagues from Belgium-based University of Antwerp (https://www.uantwerpen.be/en/), Shahid Rajaee Teacher Training University (http://www.srttu.edu/), Iran, and Switzerland-based University of Basel (http://www.unibas.ch/), first transferred a sheet of

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graphene to one side of a copper grid, mounted on a tantalum plate.

This was then placed face-down in the chamber of an Omicron ultrahigh-vacuum, low temperature STM, operated a room temperature.

As Thibado explains, in this system, the tungsten STM tip points upwards at the downward-facing graphene, monitoring its surface through the holes of the copper grid.

By changing the tunnelling parameters, the researchers could control the shape and temperature of the graphene.

In this way they imaged individual carbon atoms on the surface, measuring the very low frequency fluctuations of the atoms in a one-square-angstrom region, over long periods of time.

"While imaging an area corresponding to a single carbon atom, the vertical movement of the graphene was easily monitored with unparalleled precision," says Thibado.

"The observed fluctuations were found to exhibit random, periodic or mirror-buckling behaviour," he explains. "The periodic oscillations had current dependent characteristics, consistent with predictions of elasticity theory, under the influence of thermal stress."

The researchers expect their STM method will lead to new studies in graphene from fundamental experiments to quantum charge control and thermal load applications.

"No other technique has demonstrated the ability to probe such low frequency flexural modes at the atomic scale," concludes Thibado. "This permits direct investigation of the dynamic ripples that affect almost every property of graphene."

Research is published in *Nature Communications* (http://www.nature.com/ncomms/2014/140428/ncomms4720/full/ncomms4720.html#affil-auth).

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