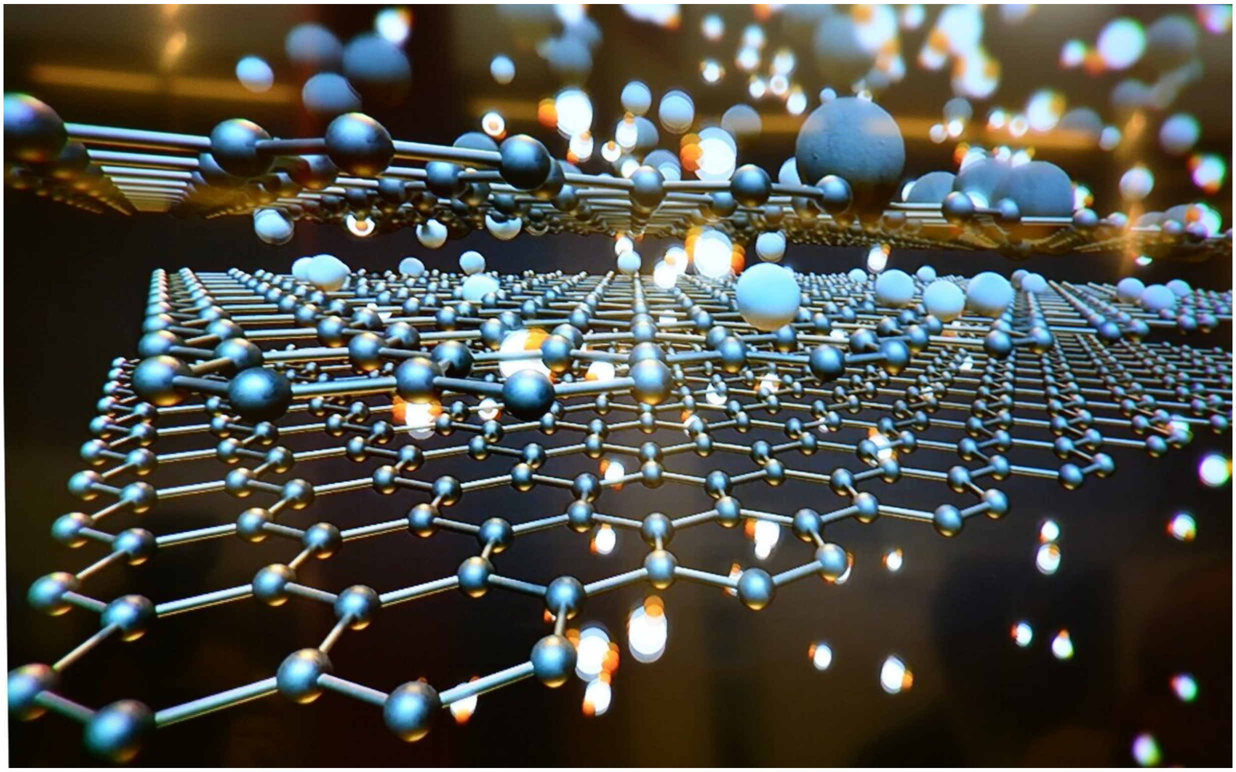
Researchers develop method to probe phase transitions in 2-D materials

June 1 2020



Credit: CC0 Public Domain

Phase transitions play an important role in materials. However, in two-dimensional materials, the most famous of which is graphene, phase transitions can be very difficult to study. Researchers from Delft University of Technology and the University of Valencia have developed a new method that helps to solve this problem. They suspended ultrathin layers of 2-D-materials over a cavity and tracked the resonance frequency of the resulting membranes using lasers. The results of their work have been published in *Nature Communications*.

Since the discovery of the exceptional electrical and mechanical properties of graphene—the first-ever two-dimensional (2-D) material—layers with thicknesses down to a single atom are attracting scientific interest. New functionalities and phenomena emerge with the recent discoveries of unique types of magnetic and electronic phases in these layers, including superconducting, charge density waves, 2-D Ising antiferromagnetic and ferromagnetic phases. Phase transitions play an important role in materials: for instance water is a liquid at room temperature and freezes below zero centigrade, forming a material with completely different properties.

Resonant motion

In large samples, there are several techniques to measure these phase transition, for instance by measuring the specific heat which can show abrupt changes at the phase transition. However, only a few methods are available to study these transitions in atomically thin samples with a mass of less than a picogram. This is particularly challenging for ultrathin insulating antiferromagnets that only weakly couple to magnetic and electronic probes.

Researchers at Delft University of Technology have now demonstrated that these phases can be studied by looking at the resonant motion of membranes made of these 2-D materials. These membranes can be formed by suspending an ultrathin crystal over a cavity in a substrate, thereby creating a nanoscale drum. "We track the mechanical resonance frequency of these membranes using a red laser while bringing them in motion at MHz frequencies by a power-modulated blue laser", researcher Makars Šiškins explains

Sudden expansion

When the researchers cooled down membranes of $FePS_3$, $NiPS_3$ and $MnPS_3$, they observed a sudden change in their resonance frequency. Šiškins: "Interestingly, this change coincides with the temperature at which these materials order their magnetic spins antiferromagnetically." The correlation between the change in resonance frequency and the magnetic order at the phase transition temperature is a consequence of the sudden expansion that occurs when the magnetic disorder increases, similar to the phase transition from liquid to gas. This expansion causes the mechanical stress in the membrane to decrease, which results in a reduction in resonance frequency, like in a guitar string.

The new measurement concept is applicable to a wide variety of thin membrane systems with different phase transitions, as the researchers demonstrate by observing charge density wave ordering in TaS_2. "For this reason, we believe that our concept has the potential to be applied to study a large range of materials: 2-D ferromagnets, thin 2-D complex oxide sheets and organic antiferromagnets", Šiškins says. "We expect this will lead to a better understanding of thermodynamics and ordering mechanisms in two-dimensional materials."

More information: Makars Šiškins et al. Magnetic and electronic phase transitions probed by nanomechanical resonators, *Nature Communications* (2020). DOI: 10.1038/s41467-020-16430-2

Provided by Delft University of Technology

Citation: Researchers develop method to probe phase transitions in 2-D materials (2020, June 1) retrieved 19 April 2024 from https://phys.org/news/2020-06-method-probe-phase-transitions-d.html