How Technology Is Being Transformed by Nanomechanical Resonators

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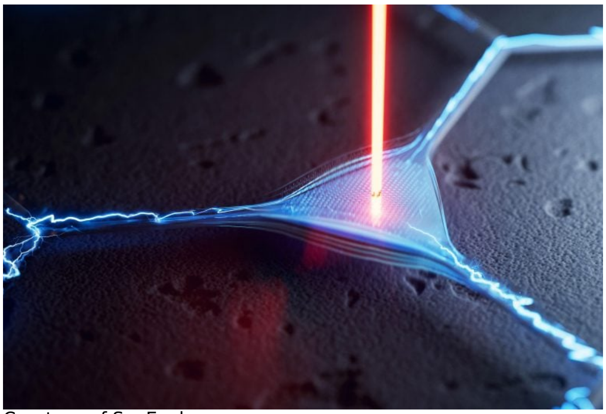

Courtesy of SynEvol
Credit: Chalmers University of Technology

Due largely to their capacity to vibrate at particular frequencies, mechanical resonators have been indispensable instruments for millennia in a variety of applications. A well-known example is the tuning fork, which emits a sound wave that is audible to humans when hit and oscillates at its resonance frequency.

Researchers have been able to reduce these resonators to micro- and nanoscale sizes because to developments in microfabrication. Compared to their larger counterparts, resonators at these tiny scales achieve noticeably increased sensitivity and vibrate at much higher frequencies.

Because of these characteristics, they can be used in precision studies to detect minute forces or changes in mass. Because of its potential applications in quantum technologies, nanomechanical resonators have recently attracted a lot of attention from quantum physicists. Witlef Wieczorek, a physics professor at Chalmers University of Technology and the study's project leader, explains that using quantum states of motion, for instance, would increase the sensitivity of nanomechanical resonators much further.

Nanomechanical resonators must be able to maintain their oscillation for extended periods of time without losing energy, which is a common need for these applications. The mechanical quality factor measures this skill. Additionally, a high mechanical quality factor suggests that quantum states of motion have a longer lifespan and that the resonator is more sensitive.

Tensile-strained silicon nitride, a material renowned for its exceptional mechanical quality, is used to create the majority of the best-performing nanomechanical resonators. In other respects, silicon nitride is somewhat "boring": it is neither magnetic nor piezoelectric, nor does it carry electricity. Applications that call for in-situ control or the interface of nanomechanical resonators to other systems have encountered difficulties because of this constraint. Then, a functional material must be added on top of silicon nitride to meet these requirements. The performance of the resonator is constrained by this modification, though, as it tends to lower the mechanical quality factor.

Using tensile-strained aluminum nitride, a piezoelectric material that retains a high mechanical quality factor, researchers at Chalmers University of Technology and the University of Magdeburg in Germany have already made significant progress in creating a nanomechanical resonator.

Electrical signals are produced from mechanical motion by piezoelectric materials, and vice versa. In sensing applications, this can be utilized for direct reading and control of the nanomechanical resonator. The lead author of the study published in Advanced Materials, Anastasiia Ciers, a research specialist in quantum technology at Chalmers, adds, "It can also be used to interface mechanical and electric degrees of freedom, which is relevant in the transduction of information, even down to the quantum regime."

The quality factor of the aluminum nitride resonator was over 10 million.

Witlef Wieczorek notes, "This implies that tensile-strained aluminum nitride could be a potent new material platform for quantum sensors or quantum transducers."

Now, the researchers' two main goals are to further increase the devices' quality factor and develop practical nanomechanical resonator designs that will allow them to exploit piezoelectricity for quantum sensing applications.