'Nanoresonators' might improve cell phone performance

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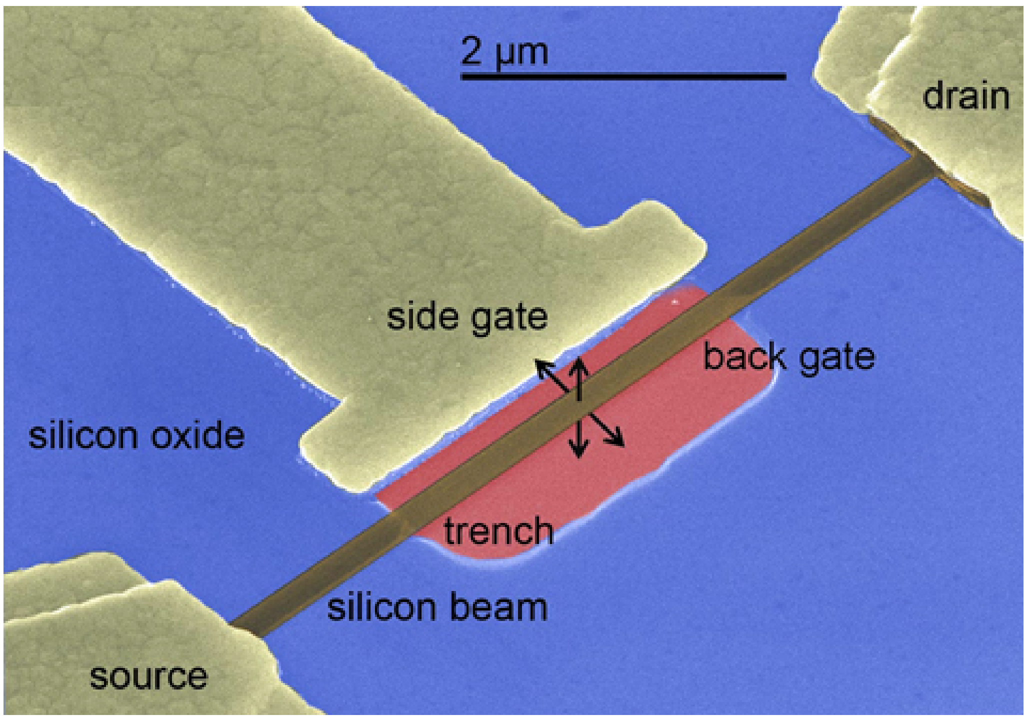

This image from a scanning electron microscope shows a tiny mechanical device, an electrostatically actuated nanoresonator, that might ease congestion over the airwaves to improve the performance of cell phones and other portable devices. (Purdue University image)

(Phys.org)—Researchers have learned how to mass produce tiny mechanical devices that could help cell phone users avoid the nuisance of dropped calls and slow downloads. The devices are designed to ease congestion over the airwaves to improve the performance of cell phones and other portable devices.

"There is not enough radio spectrum to account for everybody's handheld portable device," said Jeffrey Rhoads, an associate professor of mechanical engineering at Purdue University.

The overcrowding results in dropped calls, busy signals, degraded call quality and slower downloads. To counter the problem, industry is trying to build systems that operate with more sharply defined channels so that more of them can fit within the available bandwidth.

"To do that you need more precise filters for cell phones and other radio devices, systems that reject noise and allow signals only near a given frequency to pass," said Saeed Mohammadi, an associate professor of electrical and computer engineering who is working with Rhoads, doctoral student Hossein Pajouhi and other researchers.

The Purdue team has created devices called nanoelectromechanical resonators, which contain a tiny beam of silicon that vibrates when voltage is applied. Researchers have shown that the new devices are produced with a nearly 100 percent yield, meaning nearly all of the devices created on silicon wafers were found to function properly.

"We are not inventing a new technology, we are making them using a process that's amenable to large-scale fabrication, which overcomes one of the biggest obstacles to the widespread commercial use of these devices," Rhoads said.

Findings are detailed in a research paper appearing online in the journal *IEEE Transactions on Nanotechnology*. The paper was written by doctoral students Lin Yu and Pajouhi, Rhoads, Mohammadi and graduate student Molly Nelis.

In addition to their use as future cell phone filters, such nanoresonators also could be used for advanced chemical and biological sensors in medical and homeland-defense applications and possibly as components in computers and electronics.

The devices are created using silicon-on-insulator, or SOI, fabrication—the same method used by industry to manufacture other electronic devices. Because SOI is compatible with complementary metal–oxide–semiconductor technology, or CMOS, another mainstay of electronics manufacturing used to manufacture computer chips, the resonators can be readily integrated into electronic circuits and systems.

The resonators are in a class of devices called nanoelectromechanical systems, or NEMS.

The new device is said to be "highly tunable," which means it could enable researchers to overcome manufacturing inconsistencies that are common in nanoscale devices.

"Because of manufacturing differences, no two nanoscale devices perform the same rolling off of the assembly line," Rhoads said. "You must be able to tune them after processing, which we can do with these devices."

The heart of the device is a silicon beam attached at two ends. The beam is about two microns long and 130 nanometers wide, or about 1,000 times thinner than a human hair. The beam vibrates in the center like a jump rope. Applying alternating current to the beam causes it to selectively vibrate side-to-side or up and down and also allows the beam to be finely adjusted, or tuned.

The nanoresonators were shown to control their vibration frequencies better than other resonators. The devices might replace electronic parts to achieve higher performance and lower power consumption.

"A vivid example is a tunable filter," Mohammadi said. "It is very difficult to make a good tunable filter with transistors, inductors, and other electronic components, but a simple nanomechanical resonator can do the job with much better performance and at a fraction of the power."

Not only are they more efficient than their electronic counterparts, he said, but they also are more compact.

"Because the devices are tiny and the fabrication has almost a 100 percent yield, we can pack millions of these devices in a small chip if we need to," Mohammadi said. "It's too early to know exactly how these will find application in computing, but since we can make these tiny mechanical devices as easily as transistors, we should be able to mix and match them with each other and also with transistors in order to achieve specific functions. Not only can you put them side-by-side with standard computer and electronic chips, but they tend to work with near 100 percent reliability."

The new resonators could provide higher performance than previous MEMS, or microelectromechanical systems.

In sensing application, the design enables researchers to precisely measure the frequency of the vibrating beam, which changes when a particle lands on it. Analyzing this frequency change, allows researchers to measure minute masses. Similar sensors are now used to research fundamental scientific questions. However, recent advances may allow for reliable sensing with portable devices, opening up a range of potential applications, Rhoads said.

Such sensors have promise in detecting and measuring constituents such as certain proteins or DNA for biological testing in liquids, gases and the air, and the NEMS might find applications in breath analyzers, industrial and food processing, national security and defense, and food and water quality monitoring.

"The smaller your system the smaller the mass you can measure," Rhoads said. "Most of the field-deployable sensors we've seen in the past have been based on microscale technologies, so this would be hundreds or thousands of times smaller, meaning we should eventually be able to measure things that much smaller."

More information: Tunable, Dual-Gate, Silicon-on-Insulator (SOI) Nanoelectromechanical Resonators, *IEEE Transactions on Nanotechnology*, 2012.

ABSTRACT
Resonant nanoelectromechanical systems (NEMS) have the potential to have significant impact in mass sensing, signal processing and field detection applications if the challenges associated with processing, material and geometric variability can be mitigated. The research presented here details a breakthrough in the design and development of resonant NEMS aimed at addressing these challenges. Specifically, the work details the fabrication, characterization and tuning of dual-gate silicon nanoelectromechanical resonators, which are transduced electrostatically and realized with close to 100% yield. These devices are fabricated on a silicon-on-insulator (SOI) substrate using only top-down microfabrication techniques and can be easily integrated with SOI-CMOS transistors, enabling the development of fully integrated CMOS-NEMS with highly-tunable nonlinear frequency response characteristics.

Provided by Purdue University

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