New Synthetic Materials Could Help Enhance Technology

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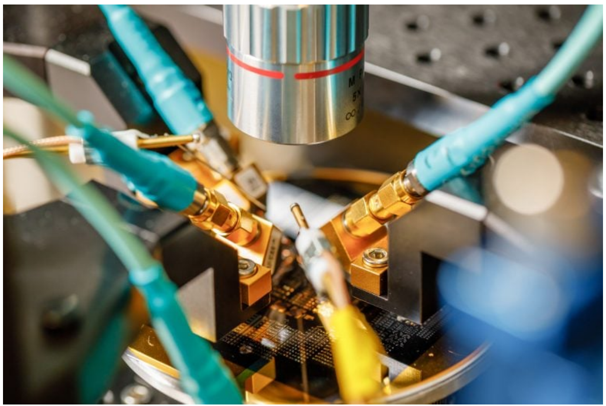


Courtesy of SynEvol
Credit: Bret Latter/ Sandia National Laboratories

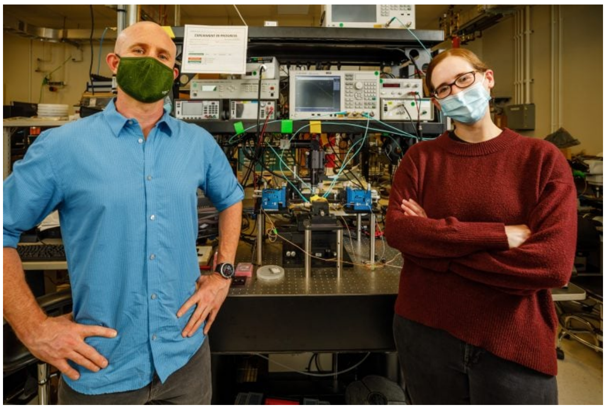
Imagine if your earbuds had the same functionality as your smartphone, just better. It could turn out that what sounds a little like science fiction is not that far off. The next wave of wireless technology may be ushered in by a new class of synthetic materials that allow gadgets to be smaller, require less signal strength, and consume less power.

Similar to photonics, the field of phononics holds the key to these advancements. Both offer fresh approaches to technological advancement while utilizing comparable physical laws. Photonics uses photons, or light, but phononics uses phonons, which are physical particles that carry mechanical vibrations through a material that are similar to sound but occur at frequencies that are too high to be heard.

Researchers from Sandia National Laboratories and the University of Arizona's Wyant College of Optical Sciences have reported achieving a significant step toward phononics-based practical applications in a work that was published in Nature Materials. The researchers were able to create enormous nonlinear interactions between phonons by combining highly specialized semiconductor materials with piezoelectric materials that aren't usually utilized together. This opens the door to the prospect of creating smaller, more powerful, and more efficient wireless devices, such as smartphones or other data transmitters, in conjunction with earlier advances that demonstrated phonon amplifiers utilizing the same materials.

"The primary purpose of the roughly thirty filters found inside cell phones is to convert radio waves into sound waves and back, which is a fact that most people would probably find surprising," stated Matt Eichenfield, the study's senior author and joint employee of Sandia National Laboratories and the UArizona College of Optical Sciences in Albuquerque, New Mexico.

These piezoelectric filters, which are built on specialized microchips and are a component of front-end processors, are required to convert sound and electromagnetic waves several times whenever a smartphone receives or sends data, the speaker stated. The physical size of your device is significantly larger than it needs to be because these can't be made of the same materials, like silicon, as the other crucial chips in the front-end processor. Additionally, there are losses from switching between radio waves and sound waves along the way, which add up and lower performance, according to Eichenfield.



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According to him, "phonons typically exhibit entirely linear behavior, which means they don't interact with one another." "They just go through each other; it's like shining one laser pointer beam through another."

According to Eichenfield, nonlinear phononics describes what occurs in some materials when phonons can and do interact with one another. The researchers presented what he refers to as "giant phononic nonlinearities" in the publication. The phonons interacted with each other far more intensely in the synthetic materials that the study team created than in any traditional substance.

"If you were to turn on the second laser pointer, it would be like switching the frequency of the photons in the first laser pointer," he explained using an analogy of laser pointers. "The beam from the first one would change color as a result."

The researchers proved that one phonon beam can, in fact, alter the frequency of another beam using the new phononics materials. Furthermore, they demonstrated that phonons could be controlled in ways that, up until recently, were only possible with transistor-based electronics.

The most recent publication demonstrates that the group's goal of creating all the parts required for radio frequency signal processors on a single chip using acoustic wave technologies rather than transistor-based electronics in a way that is compatible with standard microprocessor manufacturing can be achieved. In the past, the researchers were successful in creating switches, amplifiers, and other acoustic components. They have completed the picture with the acoustic mixers detailed in the most recent edition.

"Now, you can identify each part in a schematic of a radiofrequency front-end processor and affirm that, yes, you can produce all of these on a single chip using acoustic waves," stated Eichenfield. "We're prepared to proceed with creating the entire thing in the acoustic realm."

Devices like cell phones and other wireless communication devices might be reduced by up to a factor of 100 if all the parts required to create a radio frequency front end were included on a single chip, according to Eichenfield.

The group used extremely specialized materials to create microelectronic-sized devices that they used to transmit acoustic waves in order to achieve their proof of principle. In particular, they placed an ultra-thin layer (less than 100 atoms thick) of a semiconductor containing indium gallium arsenide on a silicon wafer that already had a tiny layer of lithium niobate, a synthetic material widely used in piezoelectronic devices and cell phones.

Lead author Lisa Hackett of Sandia Engineering stated, "We were able to experimentally access a new regime of phononic nonlinearity when we combined these materials in just the right way." "This implies that we have a future path toward developing high-performance technology for the transmission and reception of radio waves that are smaller than ever before."

In this configuration, as sound waves pass through the materials, they exhibit nonlinear behavior. Information can be encoded and frequencies can be changed using this effect. Nonlinear effects are a mainstay of photonics and have long been utilized to turn invisible laser light into visible laser pointers. However, due to material and technological restrictions, their application in phononics has been limited. For instance, lithium niobate is one of the most nonlinear phononic materials known, yet when employed alone, its nonlinearities are extremely weak, making it less usable for technological purposes.

The addition of the indium-gallium arsenide semiconductor by Eichenfield's group produced an environment in which the distribution of electrical charges in the indium-gallium arsenide semiconductor film is affected by the acoustic waves traveling through the material. This allows the acoustic waves to mix in specific, controllable ways, thereby opening up the system to various applications.

According to Eichenfield, "it's crazy how much more effective nonlinearity you can generate with these materials—hundreds or even thousands of times larger than was possible before." "You would completely transform the field of nonlinear optics if you could accomplish the same."

Physical size is one of the primary constraints of modern, state-of-the-art RF processing hardware, thus the authors speculate that the new technology may pave the way for far more capable electronic devices. There will soon come communication devices that are nearly space-saving, offer improved signal coverage, and have longer battery lives.

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