Squeezed crystals deliver more volts per jolt

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A discovery by scientists at the Carnegie Institution has opened the door to a new generation of piezoelectric materials that can convert mechanical strain into electricity and vice versa, potentially cutting costs and boosting performance in myriad applications ranging from medical diagnostics to green energy technologies.

High-performance piezoelectric materials used today, such as those in probes for medical ultrasound, are specially grown crystals of mixed composition known as "solid solutions," making them difficult to study and expensive to manufacture. But in the January 31 *Nature* a research team led by Ronald Cohen and Russell Hemley of the Carnegie Institution's Geophysical Laboratory report that at high pressure pure crystals of lead titanate show the same transitions seen in more complex materials.

Moreover, theory predicts that lead titanate under pressure has the largest piezoelectric response of any material known. This suggests the exciting possibility of low-cost but extremely high-performance piezoelectrics.

"The most useful piezoelectric materials have a critical range of compositions called the morphotopic phase boundary, where the crystal structure changes and the piezoelectric properties are maximal," says Muhtar Ahart, a co-author of the study. "These are usually complex, engineered, solid solutions. But we showed that a pure compound can display a morphotopic phase boundary under pressure."

For the study, the researchers placed powdered crystals of lead titanate in a device called a diamond anvil cell, which can generate pressures exceeding those at the center of the Earth. They monitored the changes in crystal structure with pressure using high-energy X-ray beams of the Advanced Photon Source at Argonne National Laboratory in Illinois. Using this data and calculations based on first-principle theoretical computations, the researchers were able to determine the piezoelectric properties of the pure crystals at different pressures.

“It turns out that complex microstructures or compositions are not necessary to obtain strong piezoelectricity,” says Ahart.

The use of piezoelectrics has boomed in recent years and is rapidly expanding. Their ability to convert mechanical energy to electric energy and vice versa has made them invaluable for acoustic transducers for sonar and medical ultrasound, and for tiny, high-precision pumps and motors for medical and other applications. High-performance piezoelectrics have also opened up new possibilities for “energy harvesting,” using ambient motion and vibration to generate electricity where batteries or other power sources are impractical or unavailable.

“This is a field in which theory, experiment, and material development work side-by-side,” says Ronald Cohen, a staff scientist at the Carnegie Institution and a co-author of the study. “Delineating the underlying physics of piezoelectric materials will make it easier to develop new materials and improve existing ones. We’re now poised on the edge of hugely expanded applications of these technologies.”

Source: Carnegie Institution

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