Materials Regain Properties Previously Thought to Disappear under Pressure

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University of Arkansas physicists working with researchers in France have shown that a group of materials used in military sonar and medical ultrasound regain their unique properties at high pressures, overturning a belief held for more than 30 years that these properties disappear at high pressures.

"There is different kind of ferroelectricity that appears under high pressures," said Igor Kornev, research professor of physics in the Fulbright College of Arts and Sciences. Kornev and Laurent Bellaiche, associate professor of physics in Fulbright, together with French researchers Pierre Bouvier of Grenoble, Pierre-Eymeric Janolin and Brahim Dkhil of Paris and Jens Kreisel of Grenoble, reported their findings in the Nov. 4 issue of **Physical Review Letters**.

Kornev and Bellaiche study ferroelectric materials, which possess spontaneous electrical dipoles, or charge separations. The electrical dipoles allow them to create the images seen in medical ultrasounds and naval sonar by converting mechanical energy into electrical energy. These materials also are used to convert signals to sound in cell phones and other audio devices.

The researchers use computational models to determine what will happen to such materials at different temperatures or pressures.

At a certain high pressure, the ferroelectric properties of these materials, called perovskites, were commonly thought to disappear. Researchers

believed that this critical pressure caused the atoms to get "stuck," which made it impossible for them to convert energy, meaning that the effect would not reappear even at higher pressures.

Kornev and Bellaiche decided to use a computer model to track the predicted behavior of a system containing lead titanium oxide at pressures higher than those at which the material typically loses its ferroelectric properties. When they performed the computer simulations, they found to their surprise that after a certain higher pressure threshold, the material began to exhibit ferroelectric properties once again.

"It was an unexpected result," Kornev said. Puzzled by these results, the researchers collaborated with physicists at laboratories in Grenoble and Paris, France, to conduct laboratory experiments using the lead titanium oxide under high pressures. They produced the same result: After a certain pressure point was reached, the ferroelectric properties of the material returned.

However, the ferroelectricity stems from different sources at the different pressures, Kornev said.

At low pressures, the lead ions move away from their ideal positions, causing a dipole, or charge separation. However, this dipole gradually disappears as pressure begins to rise. At high pressures, the electron cloud associated with the titanium and the oxygen appears to be responsible for the reappearance of the dipole and the ferroelectric properties, Kornev said.

"In principle, it means that it is possible to use these materials at higher pressures than previously thought," Kornev said.

Source: University of Arkansas