Disorder Enables Extreme Sensitivity in Piezoelectric Materials

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A research team working at the National Institute of Standards and Technology has found an explanation for the extreme sensitivity to mechanical pressure or voltage of a special class of solid materials called relaxors. The ability to control and tailor this sensitivity would allow industry to enhance a range of devices used in medical ultrasound imaging, loudspeakers, sonar and computer hard drives.

Relaxors are piezoelectrics—they change shape when a battery is connected across opposite ends of the material, or they produce a voltage when squeezed. “Relaxors are roughly 10 times more sensitive than any other known piezoelectric,” explains NIST researcher Peter Gehring. They are extremely useful for device applications because they can convert between electrical and mechanical forms of energy with little energy loss.

A team of scientists from Brookhaven National Laboratory, Stony Brook University, Johns Hopkins University and NIST used the neutron scattering facilities at the NIST Center for Neutron Research (NCNR) to study how the atomic “acoustic vibrations,” which are essentially sound waves, inside relaxors respond to an applied voltage. They found that an intrinsic disorder in the chemical structure of the relaxor crystal apparently is responsible for its special properties.

Atoms in solids are usually arranged in a perfect crystal lattice, and they vibrate about these positions and propagate energy in the form of sound waves. In typical piezoelectric materials, these acoustic vibrations persist for a long time much like the ripples in a pond of water long after a pebble has been thrown in.

Not so with relaxors: these vibrations quickly die out. The research team led by Brookhaven's Guangyong Xu, compared how the sound waves propagated in different directions, and observed a large asymmetry in the response of the relaxor lattice when subjected to an applied voltage.

"We learned that the lattice's intrinsic chemical disorder affects the basic behavior and organization of the materials," says Gehring. The disorder that breaks up the acoustic vibrations makes the material structurally unstable and very sensitive to applied pressure or an applied voltage.

That disorder occurs because the well-defined lattice of atoms alternates randomly between one of three of its elements—zinc, niobium and titanium—each of which carries a different electrical charge.

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