Novel Nanostructure Response Opens Possibilities for Electrical Devices

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A University of Arkansas physicist and her colleagues have examined dielectric susceptibilities of nanostructures (that is the response of their polarization to electric fields) and found novel, seemingly contradictory properties that may change how such materials can be used by scientists and engineers to build electronic devices.

Inna Ponomareva, Laurent Bellaiche and Raffaele Resta of the Università de Trieste reported their findings in the journal *Physical Review Letters*.

Ponomareva and her colleagues examined a property called the dielectric susceptibility of a material, or its polarization response to an electric field. High dielectric responses mean engineers and scientists can build highly sensitive devices, so knowing how to maximize this property in nanostructures will help scientists and engineers make small, efficient electronic devices. The researchers used physical and mathematical models to examine the effect of an electric field on a nanostructure of lead zirconate, a ferroelectric material -- a material that can exhibit a electrical polarization even after the electric field has disappeared.

At the nanoscale, scientists have discovered that the dielectric response has three different aspects, unlike in the bulk level. These include the change of polarization with respect to the external field, called external susceptibility, and the change in polarization with respect to the internal field, called internal susceptibility. Both of these are characteristic of the shape of the material - that is, the susceptibility is dependent upon whether the object is a nanorod, a nanodot, or a nanofilm. The third aspect - called intrinsic susceptibility - is a characteristic of the material.

Ponomareva and her colleagues determined that the internal susceptibility can be negative - in other words, a positive electric field created a negative polarization within the material. This finding contradicted what was previously thought.

"It was believed that negative susceptibility meant that the system was unstable," Ponomareva said. Such negative sign can open the door to the realization of novel technological devices.

The researchers also wanted to see what would happen with the material when the electric field was supplied by perfect electrodes, that were 100 percent efficient, and also with less efficient electrodes.

"In many practical applications, it is really hard to find perfect electrodes," Ponomareva said. Based on their calculations, they found that the highest external dielectric response occurred for electrodes that are around 90 percent efficient. This indicates a point at which the material can be most easily manipulated by an external electric field.

"It's important to know what happens from many angles," she said. "These characteristics may have useful applications, but right now we have more of a fundamental interest in them."

Ponomareva is a research assistant professor in the J. William Fulbright College of Arts and Sciences.

Source: University of Arkansas