How Small is Too Small? Researchers Find that Polarization Changes at the Nanoscale

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(PhysOrg.com) -- How small is too small to be useful? Researchers at North Carolina State University have done nanoscale analysis on ferroelectric thin films – materials that are used in electronic devices from computer memories to iPhones and polarize when exposed to an electric charge – and found that when it comes to polarization, both size and location matter.

The finding suggests that, in creating tiny electrical devices, the use of extremely small components comes with the possibility of decreased effectiveness.

Ferroelectric thin films are like sandwiches – layers of material held between two metals. When a charge is applied to the material in the sandwich, it polarizes, taking on a uniformly positive or negative charge. Researchers have theorized that when ferroelectric thin films are miniaturized, at a certain size the material loses its ability to polarize.

NC State's Dr. Marco Buongiorno-Nardelli, associate professor of physics, and Dr. Matías Nuñez, post-doctoral researcher in physics, found that this is not exactly the case: The atoms in the ferroelectric thin film still polarize, even on the nanoscale, but they don't do so in a uniform way, as they do at a larger scale. Instead, the polarization is disorganized with some atoms taking on a positive and others a negative charge, changing the overall properties of the material and allowing for residual polarization to exist.

Their results were published online in the journal *Physical Review Letters*.

Buongiorno-Nardelli and Nuñez used computer modeling to examine how individual atoms within the thin film interacted with one another, and focused specifically on the distribution of the electrons within the atoms, since electron distribution determines whether the ferroelectric will polarize with a positive or negative charge. They discovered that at a thickness of around 20 to 30 nanometers (a nanometer is one billionth of a meter – for scale, a human hair is 100,000 nanometers wide), disorganization appears in the material.

"When you get to the nanoscale, you have individual atoms interacting with one another instead of groups of atoms," Buongiorno-Nardelli says. "At that point, it is no longer the property of the material itself – the ferroelectric – that counts, because the property of the interface, where the atoms bond, becomes dominant."

Provided by NC State University

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