The Advanced Photon Source

A Boring Material "Stretched" Could Lead to an Electronics Revolution

The oxide compound europium titanate is pretty boring on its own. But sliced nanometers thin and chemically stretched on a specially designed template, it takes on properties that could revolutionize the electronics industry, according to research carried out at the U.S. Department of Energy's Advanced Photon Source (APS) at Argonne National Laboratory.

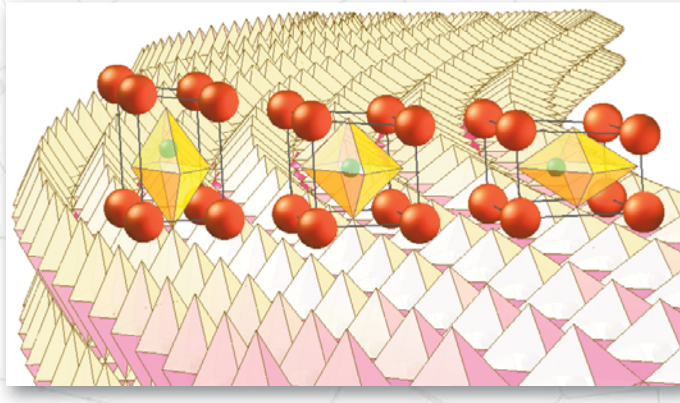
A research team from Cornell University, publishing in the journal Nature, reported that thin films of europium titanate ($EuTiO_3$) become both ferroelectric (electrically polarized) and ferromagnetic (exhibiting a permanent magnetic field) when stretched across a substrate of dysprosium scandate, another type of oxide. The best simultaneously ferroelectric and ferromagnetic material now known pales in comparison by a factor of 1,000.

"Materials by design" is an exciting new area at the confluence of advanced theory of materials and novel synthesis approaches. In the area of new magnetic materials, one of the exciting topics is materials that simultaneously show spontaneous electric and magnetic order, known as multiferroics. However, in most cases a material has either strong electric or magnetic order while the other order is quite weak. Simultaneous ferroelectricity and ferromagnetism is rare in nature and coveted by electronics visionaries. A material with this magical combination could form the basis for low-power, highly sensitive magnetic memory, magnetic sensors or highly tunable microwave devices.

The search for ferromagnetic ferroelectrics dates back to 1966, when the first such compound— a nickel boracite—was discovered. Since then, scientists have found a few additional ferromagnetic ferroelectrics, but none stronger than the nickel compound, until now. Previous researchers were searching directly for a ferromagnetic ferroelectric – an extremely rare form of matter. The strategy here was to use first-principles theory to look among materials that are neither ferromagnetic nor ferroelectric, of which there are many, and to identify candidates that, when squeezed or stretched, will take on these properties. This fresh strategy, demonstrated using the europium titanate, opens the door to other ferromagnetic ferroelectrics that may work at even higher temperatures using this same materials-by-design strategy, the researchers said.

In order to understand the details of the structural and magnetic properties, the team used polarized x-ray spectroscopy at X-ray Science Division (XSD) beamline 4-ID-C, and high-resolution diffraction at XSD beamline 6-ID-B,C, both at the APS, to explore the details of the structural and magnetic ground-state of the europium titanate. The researchers took an ultra-thin layer of the oxide and "stretched" it by placing it on top of the dyisprosium compound. The crystal structure of the europium titanate became strained because of its tendency to align itself with the underlying arrangement of atoms in the substrate.

Previous theoretical work had indicated that a different kind of material strain—more akin to "squishing" by compression—would also produce ferromagnetism and ferroelectricity. But the team discovered that the stretched europium compound displayed electrical properties 1,000 times better than the best-known ferroelectric/ferromagnetic material thus far, translating to thicker, higher-quality films.



*Strain control of perovskite structures offers new opportunities to rationally control material properties (see Lee et al., Nature **466**, 954, 19 August 2010)*

This new approach to ferromagnetic ferroelectrics could prove a key step toward the development of next-generation memory storage, superb magnetic field sensors, and many other applications long dreamed about. But commercial devices are a long way off; no devices have yet been made using this material. The Cornell experiment was conducted at an extremely cold temperature – about 4° Kelvin (-452 ° Fahrenheit). The team is already working on materials that are predicted to show such properties at much higher temperatures.

See: June Hyuk Lee[1,2], Lei Fang[3], Eftihia Vlahos[2], Xianglin Ke[4], Young Woo Jung[3], Lena Fitting Kourkoutis[1], Jong-Woo Kim[4], Philip J. Ryan[4], Tassilo Heeg[1], Martin Roeckerath[5], Veronica Goian[6], Margitta Bernhagen[7], Reinhard Uecker[7], P. Chris Hammel[3], Karin M. Rabe[8], Stanislav Kamba[6], Jürgen Schubert[5], John W. Freeland[4**], David A. Muller[1,9], Craig J. Fennie[1], Peter Schiffer[2], Venkatraman Gopalan[2], Ezekiel Johnston-Halperin[3], and Darrell G. Schlom[1*], "A strong ferroelectric ferromagnet created by means of spin–lattice coupling," Nature **466**, 954 (19 August 2010). DOI:10.1038/nature09331

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Call for APS General-User Proposals

The Advanced Photon Source is open to experimenters who can benefit from the facility's high-brightness hard x-ray beams.
General-user proposals for beam time during Run 2011-2 are due by Friday, March 4, 2011.
Information on access to beam time at the APS is at http://www.aps.anl.gov/Users/apply_for_beamtime.html or contact Dr. Dennis Mills, DMM@aps.anl.gov, 630/252-5680.

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