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Subject line:
High-speed switching for ultrafast electromechanical switches and sensors

(Tokyo, August 29) **Scientists at Tokyo Institute of Technology, Nagoya University, Japan Synchrotron Radiation Research Institute (JASRI), National Institute for Materials Science (NIMS) and University of New South Wales have observed high-speed switching in $Pb(Zr_{0.4}Ti_{0.6})O_3$ thin films under applied rectangular electric field pulses. Unlike the slow ferroelastic domain switching expected for ceramics, high-speed sub-microsecond ferroelastic domain switching and simultaneous lattice deformation are directly observed for the $Pb(Zr_{0.4}Ti_{0.6})O_3$ thin films. This exciting finding paves the way for high-frequency ultrafast electromechanical switches and sensors.**

Piezo micro electro mechanical systems (piezoMEMS) are miniaturized devices exhibiting piezoelectricity, i.e., the appearance of an electric charge under applied mechanical stress. These devices have many diverse applications in energy harvesters, micropumps, sensors, inkjet printer heads, switches, and so on. In permanently polarized (ferroelectric) materials, ferroelastic domain switching affects the piezoelectric properties significantly, and this behavior can be exploited for piezoMEMS applications.

$Pb(Zr_{1-x}Ti_x)O_3$ (PZT) thin films have excellent piezoelectric and ferroelectric properties; therefore, they are potential candidates for MEMS applications. Under an applied electric field, both lattice elongation and 90° ferroelastic domain switching are observed in tetragonal PZT thin films. In particular, non-180° ferroelastic domain switching has important implications for the future realization of high-performance piezoMEMS devices.

However, before the recent investigation, the speed of this 90° domain switching was unknown. In addition, the relationship between the speeds of the lattice deformation and ferroelastic domain switching had not been determined. To investigate these speeds, the research team led by Hiroshi Funakubo examined the switching behavior of $Pb(Zr_{0.4}Ti_{0.6})O_3$ thin films under applied rectangular electric field pulses.

To observe the changes in the lattice and the domain structure, time-resolved *in situ* synchrotron X-ray diffraction was carried out in synchronization with a high-speed pulse generator. These observations were performed at the BL13XU beamline at the SPring-8 synchrotron radiation facility. The electric field pulses were applied to the PZT thin films through Pt top electrodes, which were fabricated on top of the films.

Investigation of the diffraction peaks in the PZT thin films revealed elongation of the surface normal *c*-axis lattice parameter of the *c*-domain with a simultaneous decrease in the surface normal *a*-axis lattice parameter of the *a*-domain under the applied electric field. The intensities of the diffraction peaks also changed under the electric field. These observations provided direct evidence of 90° domain switching.

To determine the switching speed, the lattice elongation and domain switching behaviors were plotted as functions of time (Figure 1). These plots revealed that these processes were completed within 40 ns and occurred simultaneously in response to the applied electric field. The switching behavior was also shown to be perfectly repeatable.

The high-speed switching observed in these experiments was limited by the present electrical equipment, but is faster than that reported in previous studies. Further, this high-speed 90° switching is reversible and can be used to enhance the piezoelectric response in piezoMEMS devices by several tens of nanoseconds. Therefore, this finding is of considerable importance for the ongoing development of ultrafast electromechanical switches and sensors.

Reference

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Title of original paper: *In-situ* observation of ultrafast 90° domain switching under application of an electric field in (100)/ (001)-oriented tetragonal epitaxial $Pb(Zr_{0.4}Ti_{0.6})O_3$ thin films

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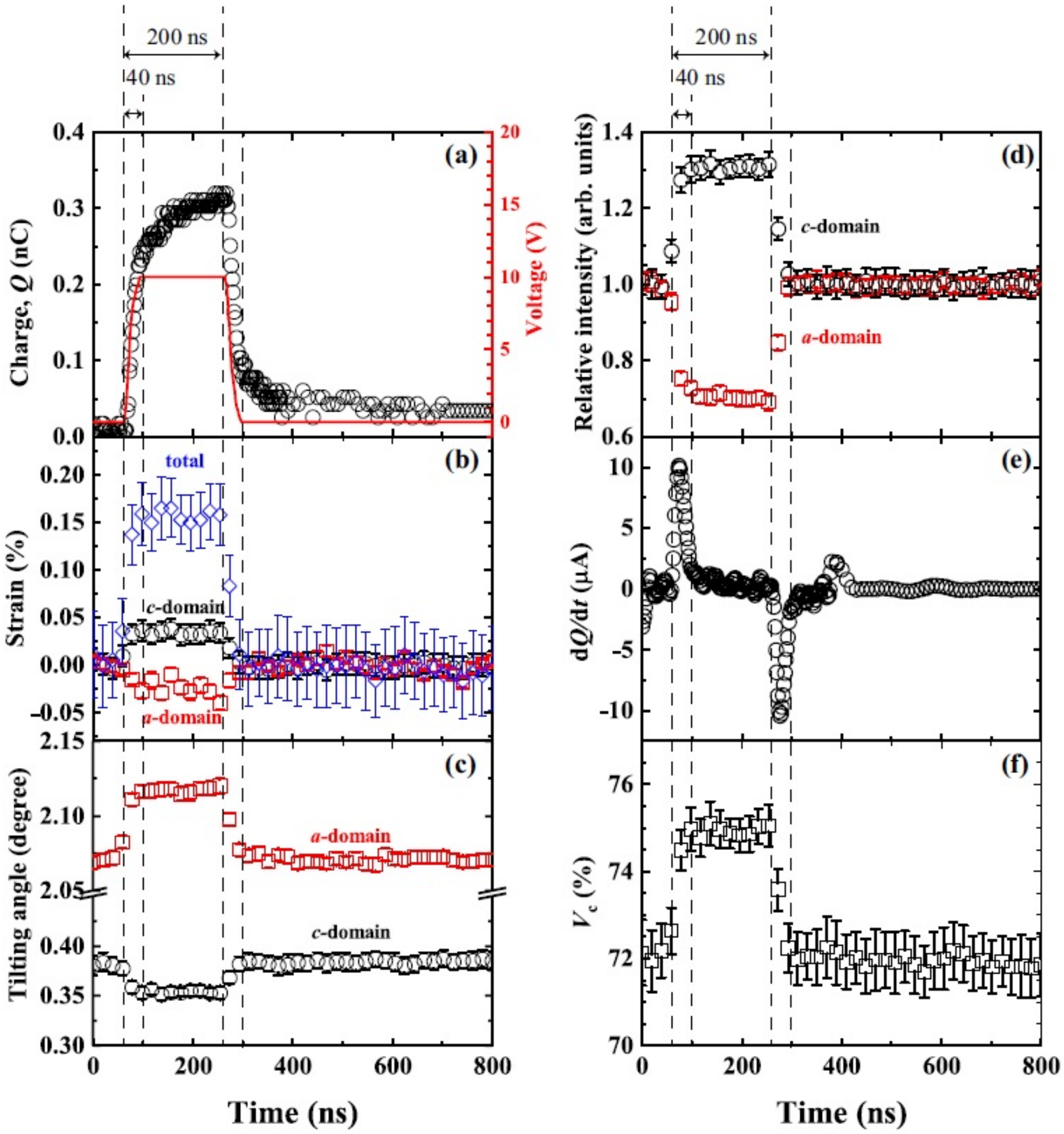

Figure 1. Responses of PZT thin film properties to applied electric field.

The (a–f) capacitance, strain, tilting angle, intensity, difference capacitance, and volume fraction of the *c* domain were measured as functions of time, respectively. The elastic deformation and ferroelastic domain switching were completed within 40 ns.

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About Tokyo Institute of Technology

Tokyo Institute of Technology stands at the forefront of research and higher education as the leading university for science and technology in Japan. Tokyo Tech researchers excel in a variety of fields, such as material science, biology, computer science and physics. Founded in 1881, Tokyo Tech has grown to host 10,000 undergraduate and graduate students who become principled leaders of their fields and some of the most sought-after scientists and engineers at top companies. Embodying the Japanese philosophy of "monotsukuri," meaning technical ingenuity and innovation, the Tokyo Tech community strives to make significant contributions to society through high-impact research.
Website: http://www.titech.ac.jp/english/

About Nagoya University

Nagoya University has a history of 146 years, with its roots in a temporary medical school/hospital established in 1871. Once the last university to become a Japanese Imperial University in 1939, our University has since then continued to achieve significant growth. We've maintained a tradition of having a free and vibrant academic culture, and after setting a high basic objective in the 2000 Nagoya University Academic Charter, we have worked hard to achieve that objective. The fact that 6 out of the 16 Japanese Nobel laureates who were awarded in the 21st century clearly shows that our research abilities are top class on a global scale. Nagoya University, throughout its long history, has produced many leaders in various areas of society and introduced them to the world, and thus contributed to the development and growth of not only Japan but also the world.
Website: http://en.nagoya-u.ac.jp/

About the National Institute for Materials Science (NIMS)

NIMS is Japan's only national research institute specializing in R&D related to materials science. It was founded in April 2001 by merging the National Research Institute for Metals and the National Institute for Research in Inorganic Materials, under the jurisdiction of the Ministry of Education, Culture, Sports, Science and Technology (MEXT). Within its fourth mid- to long-term project, which was started in April 2016, NIMS is further strengthening its research capabilities and international competitiveness. Its core goal is to "speedily leverage research results for the good of society".
Website: http://www.nims.go.jp/eng/index.html

About University of New South Wales, Sydney Australia
UNSW Sydney (The University of New South Wales) is one of Australia's leading research and teaching universities ranked among the top 50 universities in the world. Among many achievements, UNSW has led transformative social policy and public law, and contributed hugely to the cultural, artistic and intellectual life of our community, while also pioneering the global development of solar energy technologies, helping to control devastating epidemics such as HIV, developing new therapies for depression and anxiety, and making previously unimaginable breakthroughs in quantum computing. With more than 50,000 students from over 120 countries, it is one of Australia's most diverse and cosmopolitan universities.