Improve your ferroelectric memory with calcium

Barium titanate ($BaTiO_3$) is fascinating for science and extremely useful in industry. This is due to the Ti shifting within the oxygen octahedral cage, which leads to spontaneous polarization, namely a ferroelectric state, in the crystal. In addition to its wide usage in MLCC capacitors, $BaTiO_3$ also allows scientists to make non-volatile memory with its switchable polarization. But memories formed by $BaTiO_3$, and stored in the summer, may lose this information during the winter because the polarization state can change around ice point due to a phase transition. Although $BaTiO_3$ was first investigated some sixty years ago, scientists are still trying to enhance its performance.

The Fu team, Shizuoka University

Now, Desheng Fu at the Shizuoka University and his Japanese colleagues in the Tokyo Institute of Technology are exploring a novel approach to control the polarization state in $BaTiO_3$. A method of incorporating off-centred small-Ca into the bulky Ba-site provides an easy way to finely shift the structural transition from around room temperature in $BaTiO_3$ down to a temperature as low as 0 K, but maintain its room-temperature polarization state. Such a property, together with the ability to maintain the high dielectric constant and spontaneous polarization of pure $BaTiO_3$, suggests the application of (Ba, Ca)TiO_3 system as a temperature-robust material is possible.

How can small-Ca substitution maintain the polarization state of $BaTiO_3$? In a recent study published in Journal of Physics: Condensed Matter, with the precise determination of its lattice constants, Fu and his team revealed that the lattice shrinks with small-Ca substitution as expected, and that it scales with a nearly constant rate of c/a. As the ferroelectric lattice distortion is associated with the ionic displacement, such a scaling behavior then suggests a constant value of spontaneous polarization in the system.

Is this prediction true? With a series of polarization measurements, Fu and his colleagues determined that the Ca-substituted system has the same polarization value as $BaTiO_3$. Furthermore, when the spontaneous polarization is switched by an electric field, it is much more stable in comparison with that of pure $BaTiO_3$. The switchable and stable polarization, together with its large value, is extremely useful in applications such as ferroelectric memory. Fu and his team are now trying to integrate such a system into a silicon-based technique. They are also exploring the potential applications in electro-optical or electro-mechanical devices by using its large polarizability and its robustness to temperature change.

About the author

Desheng Fu, Associated Professor, is leading a new group in the Division of Global Research Leaders, Shizuoka University, Japan. Mitsuru Itoh is a Professor in the Materials and Structures Laboratory, Tokyo Institute of Technology, Japan. Shin-ya Koshihara is a Professor in the Department of Materials Science, Tokyo Institute of Technology. In the past five years, he headed the Koshihara Non-equilibrium dynamics project of JST-ERATO (Exploratory Research for Advanced Technology of JST). He is now heading another five-year project of JST-CREST.