Giant polarization in super-tetragonal ferroelectric thin films through a new concept of interphase strain

Lattice coupling with spin-charge-orbital is the core issue in solid matters. Recently, the research team on solid state chemistry led by Prof. Xing XianRan (邢献然) at the University of Science and Technology Beijing (USTB), developed a general and practical method for strain engineering, interphase strain, to obtain super tetragonality and giant polarization, which was published in *Science* (2018, 361: 494—497).

Generally, the chemical or physical properties strongly depend on the change of lattice. The control of lattice strain, therefore, much affects the chemical or physical properties of functional materials, which has been widely used in superconductivity, giant magnetoresistance, multiferroics, catalysis and etc. Ferroelectrics are an important functional material, which have been widely used in the field of ferroelectric memories, tunable microwave devices, large-capacity capacitors, piezoelectric sensor devices, etc. The intriguing properties of ferroelectric materials utilize the basic functional primitive parameter of polarization. This team has realized this method, interphase strain, by creating a single-lattice-parameter epitaxial composite film on $SrTiO_3$ substrate from two tetragonal materials but with different lattice parameters, $PbTiO_3$ ferroelectrics and PbO non-ferroelectrics. The results show that the method improves the lattice distortion of $PbTiO_3$ to $c/a=1.238$, compared to 1.065 in bulk. The remanent polarization is as high as 236.3 $\mu C/cm^2$, which is nearly twice the highest value of the known ferroelectrics (see Figure A and B). This composite ferroelectric thin film is very stable, and the super-tetragonal ferroelectric phase is stable up to 725℃, compared to the bulk transition temperature of 490℃.

The proposed "interphase strain" is a new concept for strain engineering to regulate lattice strain of ferroelectrics, and successfully achieved giant polarization in the super tetragonal $PbTiO_3$/PbO based ferroelectric thin films. The idea of "interphase strain" is as follows: if two kinds of materials with similar crystal structures, but different lattice parameters, are grown into a single-lattice-parameter epitaxial film, the material of the small lattice is inevitably subjected to the tensile stress from the large lattice material, thereby introducing a large lattice strain (see Figure C). The regulation of lattice strain can cause significant changes in the physical and chemical properties of the material. This new approach of interphase strain for strain engineering can be utilized to enhance the physical and chemical properties of other functional materials, such as superconductivity, giant magnetoresistance, multiferroic, and catalysis.

This work has been supported by the National Natural Science Foundation of China and the University of Science and Technology Beijing.

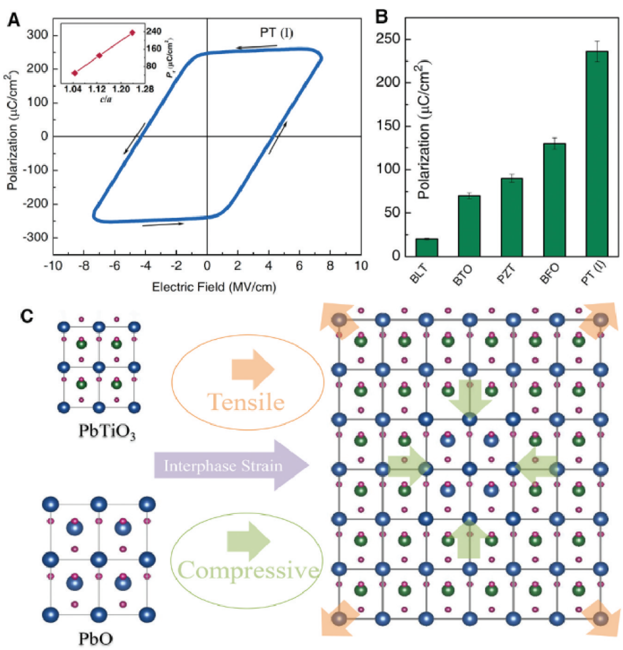

Figure Giant ferroelectric polarization in the $PbTiO_3$ epitaxial composite films and the schematic diagram of interphase strain approach.