Fabrication and characterization of ferroelectric oxides, including bulk and film forms

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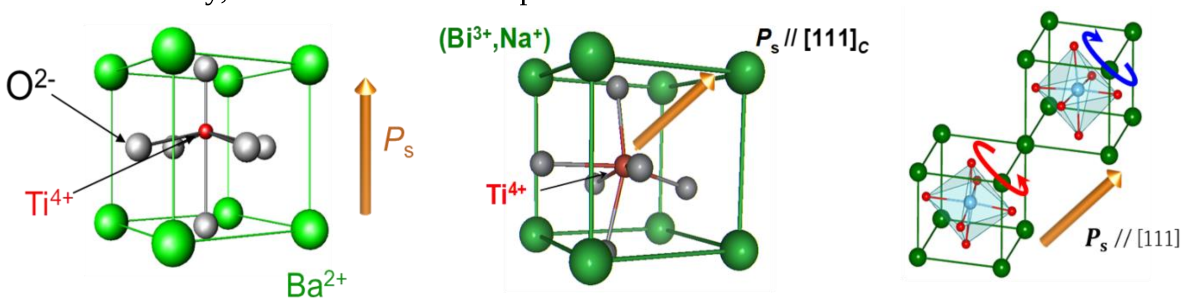
Spontaneous polarization (P_s) in ferroelectrics has provided unprecedented opportunities for practical applications such as nonvolatile memories, actuators, sensors and medical imaging transducers. In $BaTiO_3$-based ceramic capacitors, P_s-derived ferroelectric domains play an important role in dielectric properties and device reliabilities. Historically, the developments and refinements of ferroelectric and related devices suffered from defect-derived problems, and at present the migration of point defects and their related phenomena prevent ferroelectrics from being used in widespread applications.

In this tutorial, I intend to overview the fabrication of characterization of ferroelectric oxides, based on the defect chemistry, in bulk ceramics, single crystals and epitaxial thin films. The outline of my tutorial will be as follows:

1. The defect chemistry of $BaTiO_3$ and related materials,
2. Role of multivalent acceptors in $BaTiO_3$ for capacitor applications, the interaction between acceptors and oxygen vacancies, the alignment of defect dipoles with respect to P_s, and the electronic structures of transition-metal doped $BaTiO_3$,
3. Subtle but important points for fabricating and characterizing $BaTiO_3$-based ceramics, single crystals and epitaxial films.
4. Defect-related problems and high-quality materials synthesis for Bi-based ferroelectric oxides, $BiFeO_3$, $(Bi,Na)TiO_3$ and Bi-layer structured oxides ($Bi_4Ti_3O_{12}$ etc.) and their related ferroelectrics, especially in single-crystal and film forms. In addition, techniques for fabricating high-quality 'powder' samples for structural analysis will be included.
5. Recent topics on ferroelectric oxide: photovoltaic effect, electrocaloric effect, improper ferroelectricity, electric-field-induced phase transitions.



$BaTiO_3$ (Tetragonal, $P4mm$) — $(Bi_{0.5}Na_{0.5})TiO_3$ (Rhombohedral, $R3c$) — $BiFeO_3$ (Rhombohedral, $R3c$)

References: Noguchi *et al.*, ***Nature Communications***, 8, Article number: 207 (2017), ***Journal of the Ceramic Society of Japan***, 125 [6] 463-467 (2017), ***Physical Review B***, 94, 214111 (2016), ***Scientific Reports***, 6, 32216 (2016), ***Japanese Journal of Applied Physics***, 55, 10TA03 (2016). ***Journal of the Ceramic Society of Japan***, 124(6), 634–638 (2016), ***Applied Physics Letters***, 108, 032901 (2016). ***Scientific Reports***, 5, 14741 (2015), ***Journal of Applied Physics***, 118, 114101 (2015), ***Japanese Journal of Applied Physics***, 54, 10NA03 (2015), ***Japanese Journal of Applied Physics***, 54, 10NC05 (2015), ***Physical Review B***, 89, 104104/1-9 (2014), ***Journal of the Ceramic Society of Japan***, 122[6], 373-380 (2014), ***Journal of Applied Dielectrics***, 4(1), 1450003/1-6 (2014).