

Tomoaki YAMADA, Assist. Prof.

Department of Innovative and Engineered Materials

1. Main achievements in 2009

- 1) Study on structural phase transition in strained SrTiO₃ films.
The antiferrodistortive (AFD) structural phase transition temperature of the in-plane compressed SrTiO₃ films has been investigated using synchrotron XRD. We found that the 30nm-thick SrTiO₃ film on LaAlO₃ substrate shows the AFD transition temperature >300K higher than that theoretically predicted.
- 2) Structural and piezoelectric analyses of a single PbTiO₃ nanowire.
The structural analysis of a single PbTiO₃ nanowire was performed by x-ray diffraction using the synchrotron micro x-ray beam. The detection of the inverse piezoelectric effect has been also tried by monitoring the lattice distortion of the nanowire under the electric field.
- 3) Orientation dependence of dielectric properties in strained epitaxial (Ba,Sr)TiO₃ films.
Orientation dependence of dielectric properties of strained (Ba,Sr)TiO₃ films was investigated by theoretical and experimental approaches. The compressively-strained (100)-epitaxial (Ba_{0.3}Sr_{0.7})TiO₃ film showed a 130K higher ferroelectric transition temperature than that for unstrained bulks, whereas the (111)-film did not show such a significant change. The obtained orientation dependence is in a good agreement with the prediction based on Landau theory.

2. Peer-reviewed articles

Papers:

- 1) T.Yamada, C.S.Sandu, M.Gureev, V.O.Sherman, A.Noeth, P.Muralt, A.K.Tagantsev, and N.Setter: "Self-Assembled Perovskite-Fluorite Oblique Nanostructures for Adaptive (Tunable) Electronics", *Advanced Materials* **21**, 1363 (2009).
- 2) D.Nuzhnyy, J.Petzelt, S.Kamba, T.Yamada, M.Tyunina, A.K.Tagantsev, J.Levoska, and N.Setter: "Polar Phonons in Some Compressively Stressed Epitaxial and Polycrystalline SrTiO₃ Thin Films", *Journal of Electroceramics* **22**, 297 (2009).
- 3) S.Ito, T.Yamada, K.Takahashi, S.Okamoto, T.Kamo, H.Funakubo, I.Koutsaroff, M.Zelner, and A.Cervin-Lawry: "Effect of Bottom Electrode on Dielectric Property of Sputtered-(Ba, Sr)TiO₃ Films", *Journal of Applied Physics* **105**, 061606 (2009).
- 4) T.Fujisawa, H.Nakaki, R.Ikariyama, T.Yamada, M.Ishikawa, H.Funakubo, and H.Morioka: "Crystal Structure and Electrical Property Comparisons of Epitaxial Pb(Zr,Ti)O₃ Thick Films Grown on (100)CaF₂ and (100)SrTiO₃ Substrates", *Journal of Applied Physics* **105**, 061614 (2009).
- 5) S.Yasui, M.Nakajima, H.Naganuma, S.Okamura, K.Nishida, T.Yamamoto, T.Iijima, M.Azuma, H.Morioka, K.Saito, M.Ishikawa, T.Yamada, and H.Funakubo: "Composition Control and Thickness Dependence of {100}-oriented Epitaxial BiCoO₃-BiFeO₃ Films Grown by Metalorganic Chemical Vapor Deposition", *Journal of Applied Physics* **105**, 061620 (2009).

- 6) S.Utsugi, T.Fujisawa, R.Ikariyama, S.Yasui, H.Nakaki, T.Yamada, M.Ishikawa, M.Matsushima, H.Morioka, and H.Funakubo: “Domain Structure of (100)/(001)-oriented Epitaxial PbTiO₃ Thick Films with Various Volume Fraction of (001) Orientation Grown by Metal Organic Chemical Vapor Deposition”, *Applied Physics Letters* **94**, 052906 (2009).
- 7) S.Yokoyama, H.Funakubo, H.Morioka, K.Saito, T.Yamada, and M.Ishikawa: “Composition Dependency of Epitaxial Pb(Zr,Ti)O₃ Films with Different Film Thickness”, *Ferroelectrics* **389**, 10 (2009).
- 8) S.Yasui, O.Sakata, M.Nakajima, S.Utsugi, K.Yazawa, T.Yamada, and H.Funakubo: “Piezoelectric Properties of {100}-Oriented Epitaxial BiCoO₃-BiFeO₃ Films Measured Using Synchrotron X-ray Diffraction”, *Japanese Journal of Applied Physics* **48**, 09KD06 (2009).
- 9) M.Ishikawa, K.Yazawa, T.Fujisawa, S.Yasui, T.Yamada, T.Hasegawa, T.Morita, M.Kurosawa, and H.Funakubo: “Growth of Epitaxial KNbO₃ Thick Films by Hydrothermal Method and Their Characterization”, *Japanese Journal of Applied Physics* **48**, 09KA14 (2009).
- 10) A.Noeth, T.Yamada, P.Muralt, A.K.Tagantsev, and N.Setter: “Tunable Thin Film Bulk Acoustic Wave Resonator based on Ba_xSr_{1-x}TiO₃ Thin Film”, *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control* **57**, 379 (2010).
- 11) M.Ishikawa, S.Yasui, S.Utsugi, T.Fujisawa, T.Yamada, T.Morita, M.Kurosawa, and H.Funakubo: “Growth of Epitaxial Potassium Niobate Film on (100)SrRuO₃/(100)SrTiO₃ by Hydrothermal Method and their Electromechanical Properties”, *Mater. Res. Soc. Symp. Proc.*, **1139**, 1139-GG03-52 (2009).
- 12) T.Fujisawa, H.Nakaki, R.Ikariyama, M.Nakajima, T.Yamada, M.Ishikawa, H.Morioka, T.Iijima, and H.Funakubo: “Growth of Epitaxial Pb(Zr,Ti)O₃ Thick Films on CaF₂ Substrates with Perfectly Polar-axis-orientation and Their Electrical and Mechanical Property Characterization”, *Mater. Res. Soc. Symp. Proc.*, **1129**, 1129-V11-02 (2009).
- 13) T.Yamada, T.Kamo, D.Su, T.Iijima, and H.Funakubo: “Influence of Epitaxial Growth Orientation on Residual Strain and Dielectric Properties of (Ba_{0.3}Sr_{0.7})TiO₃ Films Grown on In-plane Compressive Substrates”, *Ferroelectrics* (2009) in press.
- 14) A.Noeth, T.Yamada, A.K.Tagantsev, and N.Setter: “Effect of Mechanical Loading on the Tuning of Acoustic Resonances in Ba_xSr_{1-x}TiO₃ Thin Films”, *Journal of Electroceramics* (2009) in press [online: DOI 10.1007/s10832-009-9564-0].
- 15) S.Utsugi, T.Fujisawa, Y.Ehara, T.Yamada, M.Matsushima, and H.Funakubo: “Experimental Evidence for Orientation Property of Pb(Zr_{0.35}Ti_{0.65})O₃ by Manipulating Polar Axis Angle using CaF₂ Substrate”, *Applied Physics Letters* (2010) in press.
- 16) T.Yamada, C.S.Sandu, M.Gureev, A.K.Tagantsev, P.Muralt, H.Funakubo, and N.Setter: “Self-Assembled Ferroelectric-Dielectric Nanocomposite Films for Tunable Applications”, *IOP Conference Series: Materials Science and Engineering* (2009) in press.
- 17) M.Noda, T.Yamada, T. Torii, T. Kamo, K. Yamashita, H. Funakubo and M. Okuyama: “Rf-Sputtered BST Film Microwave Tunable Device on Comparison between MgO(111) and (100) substrate”, *Proc. IEEE 18th International Symposium on the Applications of Ferroelectrics*, (2009) in press.
- 18) O.Sakata, S.Yasui, T.Yamada, M.Yabashi, S.Kimura, and H.Funakubo: “In-situ Lattice-Strain Analysis of a Ferroelectric Thin Film under an Applied Pulse Electric Field”, *AIP Conference Proceedings* (2010) accepted.
- 19) M.Noda, T.Yamada, K.Seki, T.Kamo, K.Yamashita, H.Funakubo, and M.Okuyama: “RF-Sputtered BST Film Microwave Tunable Device on Comparison between

- MgO(111) and (100) Substrate”, *Transactions on Ultrasonics, Ferroelectrics, and Frequency Control* (2009) under revision.
- 20) A.Noeth, T.Yamada, A.K.Tagantsev, and N.Setter: “Integration of Coplanar Barium-Strontium Titanate Tunable Capacitors on Micro-machined Silicon”, *Integrated Ferroelectrics* (2009) submitted.
 - 21) T.Yamada, T.Kiguchi, A.K.Tagantsev, H.Morioka, T.Iijima, H.Ohsumi, S.Kimura, M.Osada, N.Setter, and H.Funakubo “Antiferrodistortive Structural Phase Transition in Compressively-strained Epitaxial SrTiO₃ Film Grown on (La, Sr)(Al, Ta)O₃ Substrate”, *Integrated Ferroelectrics* (2009) submitted.
 - 22) H.Nakaki, S.Utsugi, T.Fujisawa, M.Nakajima, Y.Ehara, T.Yamada, H.Morioka, T.Ifuku, and H.Funakubo: “Determination Factors of Strain-relaxed Complex Domain Structure Observed in Thick Epitaxial Pb(Zr, Ti)O₃ Films”, *Mater. Res. Soc. Symp. Proc.*, (2009) submitted.
 - 23) S.Utsugi, T.Fujisawa, Y.Ehara, T.Yamada, S.Yasui, H.Morioka, T.Iijima, and H.Funakubo: “Volume Fraction Control of Epitaxial Tetragonal Pb(Zr,Ti)O₃ Films with (001)/(100), (101)/(110) and (111) Orientations Grown on CaF₂ Substrates and their Characterization”, *Mater. Res. Soc. Symp. Proc.*, (2009) submitted.
 - 24) T.Kiguchi, K.Aoyagi, T.Konno, S.Utsugi, T.Yamada, H.Funakubo: “Geometric Phase Analysis of Nano-Scale Strain Fields Around 90° Domains in PbTiO₃/SrTiO₃ Epitaxial Thin Film” *Mater. Res. Soc. Symp. Proc.*, (2009) submitted.
 - 25) M.Nakajima, S.Okamoto, H.Nakaki, T.Yamada, and H.Funakubo: “The Enhancement of The Piezoelectric Response in (100)/(001) Oriented Tetragonal PZT Films by Controlling the Tetragonality and the Volume Fraction of the (001) Orientation”, *Journal of Applied Physics* (2010) submitted.
 - 26) M.Nakajima, H.Nakaki, T.Yamada, K.Nishida, T.Yamamoto, M.Osada and H.Funakubo: “Impact of Large Piezoelectric Response Induced by the 90° Domain Rotation in (100)/(001) Oriented Tetragonal PZT Film Evidenced by In-situ Raman Spectroscopy”, *Applied Physics Letters* (2010) submitted.
 - 27) T.Yamada, T.Kamo, H.Funakubo, D.Su, and T.Iijima: “Strong Growth Orientation Dependence of Strain Relaxation in Epitaxial (Ba,Sr)TiO₃ Films and The Resulting Dielectric Properties” , *Journal of Applied Physics* (2010) submitted.
 - 28) T.Yamada, J.Wang, O.Sakata, C.S.Sandu, Z.He, T.Kamo, S.Yasui, N.Setter, and H.Funakubo: “Synchrotron Radiation X-ray Diffraction Study on a Single Nanowire of PX-Phase Lead Titanate”, *Journal of the European Ceramic Society* (2010) submitted.

Reviews:

- 1) H.Funakubo, S.Yasui, T.Yamada, and M.Ishikawa, “MOCVD growth of BiFeO₃-based ferroelectric films and their characterization”, *Material Integration TIC*, **22**, 2, 25 (2009).
- 2) H.Funakubo, T.Fujisawa, T.Yamada, and M.Ishikawa, “Growth of Polar-axis-oriented Pb(Zr,Ti)O₃ Thick Films for Large Piezoresponse”, *Jidosha Gijutsu*, **63** (4), 94 (2009).
- 3) H.Funakubo, T.Fujisawa, S.Utsugi, T.Yamada, M.Ishikawa, and T.Iijima, “Growth and Characterization of Polar-axis-oriented PZT Thick Films”, *Material Integration TIC*, **22**, 9-10, 17 (2009).

3. Books

- 1) H.Funakubo, S.Yasui, M.Ishikawa, and T.Yamada: “Chemical Vapor Deposition of

Ferroelectric Thin Films: A Critical Review”, *Ferroelectric Thin Films at Microwave Frequencies*, *Research Signpost books* (2010) in press.

4. International and domestic conferences (Presenter underlined)

International conferences:

- 1) (Invited talk) T.Yamada, C.S.Sandu, M.Gureev, A.K.Tagantsev, H.Funakubo, and N.Setter: “Self-Assembled Ferroelectric-dielectric Nanocomposite Films for Tunable Applications”, E-MRS 2009 Spring Meeting (Strasbourg, France) Jun. 2009.
- 2) (Oral) T.Yamada, T.Kamo, D.Su, T.Iijima, and H.Funakubo: “Strong Orientation Dependence of Strain Relaxation in Epitaxial (Ba,Sr)TiO₃ Films and the Resulting Dielectric Properties”, Joint meeting of 12th International Meeting on Ferroelectricity and 18th IEEE International Symposium on Applications of Ferroelectrics (IMF-ISAF-2009) (Xian, China) Aug. 2009.
- 3) (Oral) T.Yamada, A.K.Tagantsev, T.Kiguchi, T.Iijima, M.Osada, J.Trodahl, H.Morioka, N.Setter, and H.Funakubo: “Impact of Strain Modulation on Two Instabilities in (100)-Epitaxial SrTiO₃ Thin Films”, Joint meeting of 12th International Meeting on Ferroelectricity and 18th IEEE International Symposium on Applications of Ferroelectrics (IMF-ISAF-2009) (Xian, China) Aug. 2009.
- 4) (Poster) T.Yamada, T.Kamo, D.Su, T.Iijima, and H.Funakubo: “Strong Growth Orientation Dependence of Strain Relaxation Behavior of Epitaxial (Ba,Sr)TiO₃ Films and the Resulting Dielectric Properties”, International Symposium on Integrated Ferroelectrics and Functionalities (ISIF2) (Colorado Springs, USA) Sep. 2009.
- 5) (Invited talk) T.Yamada, T.Kamo, A.K.Tagantsev, I.Takuwa, T.Kiguchi, T.Iijima, M.Osada, O.Sakata, D.Su, N.Setter, and H.Funakubo: “Strain-Controlled Epitaxial Perovskite Films For The Induced Ferroelectricity”, International Conference on Electroceramics 2009 (New Delhi, India) Dec. 2009.
- 6) (Invited talk) T.Yamada, A.Noeth, V.Cherman, A.K.Tagantsev, and N.Setter: “Micro- to Nano-Composite Structures for Performance-Enhancement of Tunable Ferroelectrics in RF Applications”, International Conference on Electroceramics 2009 (New Delhi, India) Dec. 2009.

Domestic conferences:

- 1) (Oral) T.Yamada, J.Wang, C.Sandu, Z.He, N.Setter, O.Sakata, and H.Funakubo: “Structural Analysis and Piezoelectric Property of Pb-Ti-O, Pb-Zr-Ti-O Single-crystal Nanowires using Micro X-ray Beam”, The 70th Autumn Meeting of the Japan Society of Applied Physics, (Toyama, Toyama) Sep. 2009.
- 2) (Invited talk) T.Yamada, C.Sandu, M.Gureev, A.K.Tagantsev, N.Setter, and H.Funakubo: “Self-assembled Growth of BaTiO₃-CeO₂ Oriented Nanocomposite Films and their Tunable Dielectric Properties”, The 22nd Fall Meeting of the Ceramic Society of Japan (Matsuyama, Ehime) Sep. 2009.

- 3) (Oral) T.Yamada, T.Kamo, and H.Funakubo: “Orientation Dependence of the Residual Strain in Epitaxial (Ba,Sr)TiO₃ Thin Films and the Resulting Dielectric Properties”, The 22nd Fall Meeting of the Ceramic Society of Japan (Matsuyama, Ehime) Sep. 2009.
- 4) (Oral) T.Yamada, A.K.Tagantsev, T.Kiguchi, T.Iijima, M.Osada, J.Trodahl, H.Morioka, N.Setter, and H.Funakubo: “Antiferrodistortive and Ferroelectric Phase Transition in In-plane Compressive SrTiO₃ Thin Films”, The 1st Future Ferroelectrics (Atami, Shizuoka) Oct. 2009.
- 5) (Oral) T.Yamada, I.Takuwa, T.Kamo, T.Iijima, and H.Funakubo: “Orientation Dependence of Dielectric Properties in Strained Epitaxial (Ba,Sr)TiO₃ Films”, The 57th Spring Meeting of the Japan Society of Applied Physics (Hiratsuka, Kanagawa) Mar. 2010.
- 6) (Oral) T.Yamada, I.Takuwa, T.Kamo, T.Iijima, and H.Funakubo: “Orientation Dependence of Ferroelectric Transition Temperature in Strained Epitaxial (Ba,Sr)TiO₃ Films”, 2010 Annual Meeting of the Ceramic Society of Japan, (Koganei, Tokyo) Mar. 2010.
- 7) (Oral) H.Funakubo, T.Yamada, C.Sandu, M.Gureev, A.K.Tagantsev, and N.Setter: “Self-assembled Growth of BaTiO₃-CeO₂ Oriented Nanocomposite Films and their Tunable Dielectric Properties”, 2010 Spring Annual Meeting of The Japan Institute of Metals, (Tsukuba, Ibaraki) Mar. 2010.

5. Patents and Licenses

4 national patents (in preparation)

6. Awards

N/A

7. International collaborations

Collaboration with Dr. Dong Su in Center for Functional Nanomaterials (CFN) of Brookhaven National Laboratory: ‘Dislocations in epitaxial (Ba,Sr)TiO₃ films and their impact on tunable dielectric properties’ (CFN Proposal No. 358).

8. Press release

N/A

9. Other remarks

N/A