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## 1. Main Research Result

- 1) Orientation dependence of dielectric properties in strained epitaxial (Ba,Sr)TiO<sub>3</sub> films

Comprehensive study on the orientation dependence of dielectric properties of strained (Ba,Sr)TiO<sub>3</sub> films was performed by fabricating the films on various substrates having different thermal expansion coefficient. It was found that, in the case of in-plane compressive strain, the (100)-films show the ferroelectric phase transition temperature higher than that of unstrained bulks; on the contrary, the (111)-films show the slightly lower ferroelectric phase transition temperature.

- 2) Structural control of self-assembled composite films

The self-assembled composite films consisting of ferroelectric BaTiO<sub>3</sub> and low-permittivity dielectric CeO<sub>2</sub> have the oriented composite structure, which results in large nonlinear dielectric property. The CeO<sub>2</sub> facets in the initial growth stage may be of importance for the formation of such composite structures. It was found that the structure of CeO<sub>2</sub> facets varies by the kinds of substrate, substrate orientation, CeO<sub>2</sub> thickness and post-annealing.

## 2. List of publication

*Papers:*

- 1) S.Utsugi, T.Fujisawa, Y.Ehara, T.Yamada, S.Yasui, M.-T.Chentir, H.Morioka, T.Iijima, and H.Funakubo: "Orientation Control of (001) and (101) in Epitaxial Tetragonal Pb(Zr,Ti)O<sub>3</sub> Films with (100)/(001) and (110)/(101) Mixture Orientations", *Journal of the Ceramic Society of Japan* **118**, 627 (2010).
- 2) K.Yazawa, S.Yasui, H.Morioka, T.Yamada, H.Uchida, A.Gruverman and H.Funakubo: "Composition Dependence of Crystal Structure and Electrical Properties for Epitaxial Films of Bi(Zn<sub>1/2</sub>Ti<sub>1/2</sub>)O<sub>3</sub>-BiFeO<sub>3</sub> Solid Solution System", *Journal of the Ceramic Society of Japan* **118**, 659 (2010).
- 3) T.Yamada, J.Wang, O.Sakata, C.S.Sandu, Z.He, T.Kamo, S.Yasui, N.Setter, and H.Funakubo: "Synchrotron X-ray Diffraction Study on a Single Nanowire of PX-Phase Lead Titanate", *Journal of the European Ceramic Society* **30**, 3259 (2010).
- 4) M.Nakajima, T.Fujisawa, Y.Ehara, T.Yamada, H.Funakubo, H.Naganuma, S.Okamura, K.Nishida, T.Yamamoto, and M.Osada: "Single-crystal-like Selection Rules for Unipolar-axis Oriented Tetragonal Pb(Zr,Ti)O<sub>3</sub> Thick Epitaxial Films", *Applied Physics Letters* **97**, 111901 (2010).
- 5) S.Utsugi, Y.Ehara, H.Tanaka, T.Yamada, H.Funakubo, H.Uchida: "Growth of Polar Axis Oriented Tetragonal Pb(Zr,Ti)O<sub>3</sub> Films on CaF<sub>2</sub> Substrates with Transparent (La<sub>0.07</sub>Sr<sub>0.93</sub>)SnO<sub>3</sub>", *Journal of Crystal Growth* **312**, 3127 (2010).
- 6) T.Yamada, J.Wang, O.Sakata, H.Tanaka, Y.Ehara, S.Yasui, N.Setter, and H.Funakubo: "Structural Property and Electric Field Response of a Single Perovskite PbTiO<sub>3</sub>

- Nanowire using Micro X-ray Beam”, *Japanese Journal of Applied Physics* **49**, 09MC09 (2010).
- 7) S.Yasui, K.Yazawa, T.Yamada, K.Nishida, H.Uchida, M.Azuma, and H.Funakubo: “Effect of Film Thickness and Crystal Orientation on the Constituent Phase in Epitaxial BiFeO<sub>3</sub>-BiCoO<sub>3</sub> Films Grown on SrTiO<sub>3</sub> Substrates”, *Japanese Journal of Applied Physics* **49**, 09MB04 (2010).
  - 8) M.Noda, T.Yamada, K.Seki, T.Kamo, K.Yamashita, H.Funakubo, and M.Okuyama: “Comparison of BST Film Microwave Tunable Devices based on (100) and (111) MgO Substrates”, *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control* **57**, 2221 (2010).
  - 9) M.Nakajima, H.Nakaki, Y.Ehara, T.Yamada, K.Nishida, T.Yamamoto, M.Osada, and H.Funakubo: “In-situ Raman Spectroscopy for Characterization of the Domain Contributions to Electrical and Piezoelectric Responses in Pb(Zr,Ti)O<sub>3</sub> Films”, *Applied Physics Letters* **97**, 181907 (2010).
  - 10) T.Yamada, T.Kamo, D.Su, T.Iijima, and H.Funakubo: “Influence of Epitaxial Growth Orientation on Residual Strain and Dielectric Properties of (Ba<sub>0.3</sub>Sr<sub>0.7</sub>)TiO<sub>3</sub> Films Grown on In-plane Compressive Substrates”, *Ferroelectrics* **405**, 262 (2010).
  - 11) 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 SrTiO<sub>3</sub> Film Grown on (La, Sr)(Al, Ta)O<sub>3</sub> Substrate”, *Integrated Ferroelectrics* **115**, 57 (2010).
  - 12) A.Noeth, T.Yamada, A.K.Tagantsev, and N.Setter: “Integration of Coplanar Barium-Strontium Titanate Tunable Capacitors on Micro-Machined Silicon”, *Integrated Ferroelectrics* **115**, 110 (2010).
  - 13) 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 Conf. Series: Materials Science and Engineering* **8**, 012010 (2010).
  - 14) 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*, **1234**, 151 (2010).
  - 15) 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)O<sub>3</sub> Films”, *Mater. Res. Soc. Symp. Proc.*, **1199**, 1199-F08-08 (2010).
  - 16) T.Kiguchi, K.Aoyagi, T.Konno, S.Utsugi, T.Yamada, and H.Funakubo: “Geometric Phase Analysis of Nano-Scale Strain Fields Around 90° Domains in PbTiO<sub>3</sub>/SrTiO<sub>3</sub> Epitaxial Thin Film” *Mater. Res. Soc. Symp. Proc.*, **1199**, 1199-F09-08 (2010).
  - 17) M.Nakajima, S.Okamoto, H.Nakaki, T.Yamada, and H.Funakubo: “Enhancement of 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* (2011) in press.
  - 18) T.Yamada, T.Kamo, H.Funakubo, D.Su, and T.Iijima: “Strong Growth Orientation Dependence of Strain Relaxation in Epitaxial (Ba,Sr)TiO<sub>3</sub> Films and The Resulting Dielectric Properties” , *Journal of Applied Physics* (2011) in press.

#### Books

- 19) H.Funakubo, S.Yasui, M.Ishikawa, and T.Yamada: “Chemical Vapor Deposition of Ferroelectric Thin Films: A Critical Review”, *Ferroelectric Films at Microwave*

*Frequencies* (edited by T.J. Jackson, P.M. Suherman, and P.Bao), *Research Signpost*, 171-182 (2010).

### 3. International and domestic conferences (Presenter underlined)

#### *International conferences:*

- 1) (Invited talk) T.Yamada, I.Takuwa, T.Kamo, T.Iijima, D.Su, and H.Funakubo: “Dissimilar Influence of Biaxial Strain on Phase Transition in Differently Oriented Epitaxial (Ba,Sr)TiO<sub>3</sub> Films”, International Symposium on Integrated Functionalities (ISIF) (Puerto Rico, USA) Jun. 2010.
- 2) (Oral)T.Yamada, O.Sakata, A.K. Tagantsev, T.Kiguchi, N.Setter, and H.Funakubo: “Antiferrodistortive Phase Transitions in Compressively-strained Epitaxial SrTiO<sub>3</sub> Films”, Russia/CIS/Baltic/Japan Symposium on Ferroelectricity (RCBJSF-10) (Yokohama, Japan) Jun. 2010.
- 3) (Invited talk) T.Yamada, I.Takuwa, T.Kamo, O.Sakata, A.K.Tagantsev, T.Kiguchi, T.Iijima, D.Su, N.Setter, and H.Funakubo: “Strain Manipulation for Differently Oriented SrTiO<sub>3</sub> and (Ba,Sr)TiO<sub>3</sub> Films, and the Impact on Phase Transition Behavior”, XIX International Materials Research Congress 2010 (IMRC2010) (Cancún, Mexico) Aug. 2010.
- 4) (Oral/Poster)T.Yamada, C.S.Sandu, M.Gureev, A.K.Tagantsev, N.Setter, and H.Funakubo: “Self-Assembled Nano-oblique Structure for RF Tunable Applications”, 2nd Japanese-Russian Young Scientists Conference on Nano-Materials And Nano-Technology (Tokyo, Japan) Sep. 2010.

#### *Domestic conferences:*

- 1) (Oral)O.Sakata, T.Yamada, J.Wang, H.Tanaka, Y.Ehara, S.Yasui, H.Funakubo and N.Setter: “Structural Analysis and Piezoelectric Property of a Single Pb-Ti-O Nanowire using Micro X-ray Beam”, The 27th Meeting on Ferroelectric Materials and Their Applications (FMA-27) (Kyoto) May 2010.

### 4. Awards

- The 64th Ceramic Society of Japan (CerSJ) Awards for Advancements in Ceramic Science and Technology