

University of Groningen

Structure and domain formation in ferroelectric thin films

Vlooswijk, Ard H.G.

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version

Publisher's PDF, also known as Version of record

Publication date:

2009

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Vlooswijk, A. H. G. (2009). *Structure and domain formation in ferroelectric thin films*. s.n.

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

References

- [1] D.D. Fong et al., *Science* **304** (5677), 1650-1653 (2004).
- [2] J.W. Matthews and A.E. Blakeslee, *J. Cryst. Growth* **27**, 118-125 (1974).
- [3] R. People and J.C. Bean, *Appl. Phys. Lett.* **47**(3), 322-324 (1985).
- [4] J.S. Speck et al., *J. Appl. Phys.* **78** (3), 1696-1706 (1995).
- [5] N.A. Pertsev and A.G. Zembilgotov, *J. Appl. Phys.* **78**(10), 6170-6180 (1995).
- [6] M. Ohring, *Materials Science of Thin Films*, Second Edition (Academic Press, San Diego (USA), 2002).
- [7] D. Wolf and S. Yip, *Materials Interfaces: Atomic-level Structure and Properties*, Chapman & Hall (1992).
- [8] S. W. Bailey et al., *Acta Cryst. A* **33** (4), 681-684 (1977).
- [9] R.E. Cohen, *Nature* **358**(6382), 136-138 (1992).
- [10] G. Shirane et al., *Phys. Rev.* **80**(6), 1105-1106 (1950).
- [11] G.A. Rossetti and N. Maffei, *J. Phys.-Cond. Matt.* **17**(25), 3953-3963 (2005).
- [12] J.P. Remeika and A.M. Glass, *Mat. Res. Bull.* **5**, 37-46 (1970).
- [13] M.J. Haun et al., *J. Appl. Phys.* **62**(8), 3331-3338 (1987).
- [14] W. Cao and L.E. Cross, *Phys. Rev. B* **47**(9), 4825-4830 (1993).
- [15] D. Damjanovic, *J. Am. Ceram. Soc.* **88**(10), 2663-2676 (2005).
- [16] B. Noheda and D.E. Cox, *Phase Transitions* **79**(1-2), 5-20 (2006).
- [17] H.X. Fu and R.E. Cohen, *Nature* **403**(6767), 281-283 (2000).
- [18] S.-E. Park and T.R. Shrout, *J. Appl. Phys.* **82**(4), 1804-1811 (1997).

- [19] J.F. Scott, *Ferroelectric Memories*, Springer series in advanced microelectronics, Springer Berlin (2000).
- [20] B.B. van Aken et al., *Nature Materials* **3**(3), 164-170 (2004).
- [21] B. Noheda et al., *Appl. Phys. Lett.* **74**(14), 2059-2061 (1999).
- [22] X.F. Wu and D. Vanderbilt, *Phys. Rev. B* **73**(2), 020103 (2006).
- [23] L. Bellaiche, A. Garcia and D. Vanderbilt, *Phys. Rev. Lett.* **84**(23), 5427-5430 (2000).
- [24] D. Vanderbilt and M.H. Cohen, *Phys. Rev. B* **63**(9), 094108 (2001).
- [25] A.K. Singh and D. Pandey *J. Phys.: Condens. Matter* **13**(48), L931-L936 (2001)
- [26] Y.M. Jin et al., *J. Appl. Phys.* **94**(5), 3629-3640 (2003).
- [27] Y.U. Wang, *Phys. Rev. B* **73**(1), 014113 (2006).
- [28] R. Theissmann R et al., *J. Appl. Phys.* **102**(2), 024111 (2007).
- [29] M. Dawber, K.M. Rabe and J.F. Scott, *Rev. Mod. Phys.* **77**(4), 1083-1130 (2005).
- [30] U.V. Waghmare and K.M. Rabe, *Phys. Rev. B* **55**(10), 6161-6173 (1997).
- [31] B. Meyer and D. Vanderbilt, *Phys. Rev. B* **65**(10), 104111 (2002).
- [32] L. Landau, *Nature* **138**(3498), 840-841 (1936).
- [33] N.A. Pertsev, A.G. Zembilgotov and A.K. Tagantsev, *Phys. Rev. Lett.* **80**(9), 1988-1991 (1998).
- [34] D. Vanderbilt, *Phys. Rev. B* **41**(11), 7892-7895 (1990).
- [35] C. Lichtensteiger, *Ferroelectricity at the nanoscale: study of size effects in lead titanate thin films*, PhD thesis (2006).
- [36] D. Vanderbilt and M.H. Cohen, *Phys. Rev. B* **63**(9), 094108 (2001).
- [37] B. Meyer and D. Vanderbilt, *Phys. Rev. B* **63**(20), 205426 (2001).
- [38] J. Junquera and P. Ghosez, *Nature* **422**(6931), 506-509 (2003).
- [39] C. Lichtensteiger et al., *Appl. Phys. Lett.* **90**(5), 052907 (2007).
- [40] M.D. Biegalski et al., *J. Mater. Res.* **20**(4), 952-958 (2005).
- [41] A.M. Glazer and S.A. Mabud, *Acta Cryst. B* **34**, 1065-1070 (1978).
- [42] Q.Y. Qiu, V. Nagarajan and S.P. Alpay, *Phys. Rev. B* **78**(6), 064117 (2008).
- [43] A.G. Zembilgotov et al., *Appl. Phys. Lett.* **86**(5), 052903 (2005).

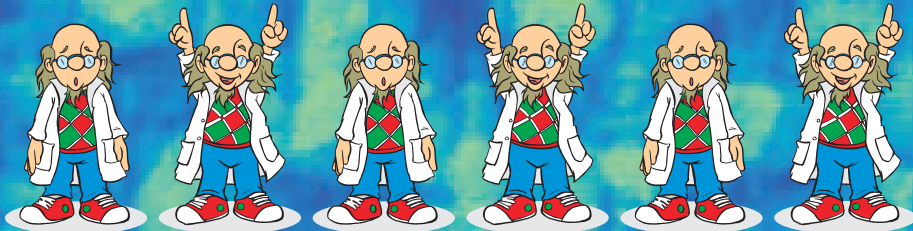
- [44] C.-L. Jia et al., *Nature Materials* **6**(1), 64-69 (2007).
- [45] H.N. Lee et al., *Phys. Rev. Lett.* **98**(21), 217602 (2007).
- [46] J.S. Speck and W. Pompe, *J. Appl. Phys.* **76**(1), 466-476 (1994).
- [47] I. Kornev, H.X. Fu and L. Bellaiche, *Phys. Rev. Lett.* **93**(19), 196104 (2004).
- [48] T. Mitsui and J. Furuichi, *Phys. Rev.* **90**(2), 193-202 (1953).
- [49] A.L. Roitburd, *Phys. Stat. Sol. A* **37**(1), 329-339 (1976).
- [50] M.L. Mulvihill et al., *J. Am. Ceram. Soc.* **80**(6), 1462-1468 (1997).
- [51] C. Kittel, *Phys. Rev.* **70** (11-12), 965-971 (1946).
- [52] A. Schilling et al., *Phys. Rev. B* **74**(2), 024115 (2006).
- [53] S.K. Streiffer et al., *Phys. Rev. Lett.* **89**(6), 067601 (2002).
- [54] A. Kopal, T. Bahnik and J. Fousek, *Ferroelectrics* **202**(1-4), 267-274 (1997).
- [55] S. Venkatesan et al., *Phys. Rev. B* **78**(10), 104112 (2008).
- [56] P.M.J. Marée et al., *J. Appl. Phys.* **62**(11), 4413-4420 (1987).
- [57] M.D. Biegalski et al., *Employing Uniform Reversible Film Strain from a Piezoelectric Substrate to Examine Effects of Strain in Epitaxial Oxide Thin Films*, oral presentation during WOE15 (2008).
- [58] G.J.H.M. Rijnders et al., *Appl. Phys. Lett.* **70**(14), 1888-1890 (1997).
- [59] G. Koster et al., *Appl. Phys. Lett.* **73**(20), 2920 (1998).
- [60] G. Binnig, C.F. Quate and Ch. Gerber, *Phys. Rev. Lett.* **56**(9), 930-933 (1985).
- [61] F. Saurenbach and B.D. Terris, *Appl. Phys. Lett.* **56**(17), 1703-1705 (1990).
- [62] S.V. Kalinin and A. Gruverman (editors), *Scanning Probe Microscopy: Electrical And Electromechanical Phenomena at the Nanoscale*, First Edition (Springer, New York (USA), 2006).
- [63] S. Gariglio et al., *Appl. Phys. Lett.* **90**(20), 202905 (2007).
- [64] H. Zhou and J. Narayan, *J. Nanopart. Res.* **8**(5), 595-600 (2006).
- [65] J. Shin et al., *Appl. Phys. Lett.* **91**(20), 202901 (2007).
- [66] F. Sánchez et al., *Surf. Sci.* **600**(6), 1231-1239 (2006).
- [67] J.H. Neave et al., *Appl. Phys. A* **31**(1), 1-8 (1983).
- [68] P.J. Dobson et al., *J. Cryst. Gr.* **81**(1-4), 1-8 (1987).

- [69] D.H.A. Blank et al., *Appl. Phys. A* **69** [Suppl. S], S17-S22 (1999).
- [70] B.J. Kennedy and B.A. Hunter, *Physical Review B* **58**(2), 653-658 (1998).
- [71] C.J. Howard et al., *J. Phys.: Condens. Matter* **12**(4), 349-365 (2000).
- [72] Crystec GmbH, Köpenicker Strasse 325, 12555 Berlin, Germany (www.crystec.de).
- [73] R.M. Hazen, *American Mineralogist* **61**(3-4), 266-271 (1976).
- [74] MTI Corporation, 860 South 19th Street, Richmond, CA 94804, USA (www.mtixtl.com).
- [75] G. Koster, *Artificially layered oxides by pulsed laser deposition*, (PhD thesis University of Twente, 1999).
- [76] D.G. Schlom et al., *Annu. Rev. Mater. Res.* **37**, 589-626 (2007).
- [77] Gmelin-Institut für Anorganische Chemie der Max-Planck-Gesellschaft zur Förderung der Wissenschaften, *Gmelin Handbuch der anorganischen Chemie*, Springer-Verlag, Berlin (DE) (1924-1988).
- [78] CRC Press, *Handbook of Chemistry and Physics*, Editor R.C. Weast, 65th Edition (1984-1985).
- [79] S. Karimoto and M. Naito, *Physica C* **412-414**(2), 1349-1353 (2004).
- [80] T. Hasegawa, *J. Lumin.* **87-89**, 1217-1219 (2000).
- [81] K. A. Müller and H. Burkard, *Phys. Rev. B* **19**(7), 3593-3602 (1979).
- [82] S. Mochizuki et al., *Physica B: Cond. Mat*, **401-402**, 433-436 (2007).
- [83] G. Lucovsky et al., *Phys. Status Solidi B* **241**(10), 2221-2235 (2004).
- [84] J.H. Haeni et al., *Nature* **430**(7001), 758-761 (2004).
- [85] R. Thomas et al., *Sol. St. Comm.* **147**(7-8), 332-335 (2008).
- [86] H. Kroemer, *J. Cryst. Growth* **81**(1-4), 193204 (1987).
- [87] P. Boher et al., *J. Sol. St. Chem.* **57**(3), 343-350 (1985).
- [88] M.C. Desjonquères and D. Spanjaard, *Concepts in Surface Physics*, Second edition (Springer-Verlag, Berlin(DE), 1996).
- [89] J.A. Venables, *Introduction to Surface and Thin Film Processes*, Cambridge University Press, Cambridge(UK), (2000).
- [90] S. Csiszár, *X-ray diffraction and X-ray absorption of strained CoO and MnO thin films*, PhD thesis (2005).

- [91] V. Holy, U. Pietsch, T. Baumbach, *High-Resolution X-Ray Scattering from Thin Films and Multilayers*, Springer Tracts in Modern Physics, Springer-Verlag, Berlin Heidelberg New York, (1999).
- [92] P. van der Sluis, *J. Phys. D: Appl. Phys.* **26**(4A), A188-A191 (1993).
- [93] C. Thompson et al., *Appl. Phys. Lett.* **71**(24), 3516-3518 (1997).
- [94] K. Lee and S. Baik, *Annu. Rev. Mater. Res.* **36**, 81116 (2006).
- [95] M. Renninger, *Z. Phys.* **106**, 141176 (1937).
- [96] S.L. Morelhão and J.Z. Domagala, *J. Appl. Cryst.* **40**(3), 546-551 (2007).
- [97] L. Pintilie, M. Lisca and M. Alexe, *Integr. Ferr.* **73**(1), 37-48 (2005).
- [98] J. Robertson and C. W. Chen, *Appl. Phys. Lett.* **74**(8), 1168-1170 (1999).
- [99] Alessio Morelli, University of Groningen, PhD thesis to be published in 2009.
- [100] C.B. Sawyer and C.H. Tower, *Phys. Rev.* **35**(3), 269-273 (1930).
- [101] K.S. Cole and R.H. Cole, *J. Chem. Phys.* **9**, 341-351 (1941).
- [102] J.F. Scott, *J. Phys.-Cond. Mat.* **20**(2), 021001 (2008).
- [103] Radiant Technologies Inc., *PUND - Discussion*, Ferroelectric Test System Help File, updated 27/12/2005.
- [104] A. Erbil et al., *J. Cryst. Growth* **124**(1-4), 684-689 (1992).
- [105] O. Dahl, J.K. Grepstad and T. Tybell, *J. Appl. Phys.* **103**(11), 114112 (2008).
- [106] R. Takahashi et al., *J. Appl. Phys.* **104**(6), 064109 (2008).
- [107] T. Yamanaka, N. Hirai and Y. Komatsu, *Amer. Mineral.* **87**, 1183-1189 (2002).
- [108] C. Thompson et al., *Appl. Phys. Lett.* **93**(18), 182901 (2008).
- [109] Q. Gan, K. Wasa and C.B. Eom, *Mat. Sc. and Eng. B* **56**(2-3), 204-208 (1998).
- [110] T. Maeda et al., *Mat. Sc. & Eng. B - Sol. St. Mat. Adv. Tech.* **41**(1), 134-137 (1996).
- [111] G. Rijnders et al., *Appl. Phys. Lett.* **84**(4), 505-507 (2004).
- [112] S. Stemmer et al., *J. Appl. Phys.* **87**(7), 3526-3531 (2000).
- [113] S.B. Mi et al., *J. Cryst. Growth* **283**(3-4), 425-430 (2005).
- [114] C.J. Palmstrøm, *Annu. Rev. Mater. Sci.* **25**, 389-415 (1995).
- [115] U. Gebhardt et al., *Phys. Rev. Lett* **98**(9), 096101 (2007).
- [116] H. Cole, F. H. Chambers and H. M. Dunn, *Acta Cryst.* **15**, 138-144 (1962).

- [117] L.C. Feldman and J.M. Poate, *Annu. Rev. Mater. Sci.* **12**, 149-176 (1982).
- [118] S. Habouti et al., *J. Appl. Phys.* **104**(10), 104101 (2008).
- [119] B.S. Kwak et al., *Phys. Rev. B* **49**(21), 14865-14879 (1994).
- [120] Y.-F. Chen et al., *Appl. Phys. A* **65**(1), 63-67 (1997).
- [121] L. Pintilie et al., *Phys. Rev. B* **75**(10), 104103 (2007).
- [122] G.A. Rossetti Jr., L.E. Cross and K. Kushida, *Appl. Phys. Lett.* **59**(20), 2524-2526 (1991).
- [123] R.P. Tandon et al., *Journal of Materials Science Letters* **11**(12), 883-885 (1992).
- [124] I. Vrejoiu et al., *Adv. Mat.* **18**, 1657-1661 (2006).
- [125] R.P. Liferovich and R.H. Mitchell, *J. Sol. Stat. Chem.* **177**(6), 2188-2197 (2004).
- [126] N. Nakagawa, H.Y. Hwang and D.A. Muller, *Nature Materials* **5**(3), 204-209 (2006).
- [127] D. Rubi, A.H.G. Vlooswijk and B. Noheda, *Thin Solid Films* **517**(6), 1904-1907 (2009).
- [128] J. Choi et al., *Appl. Phys. Lett.* **79**(10), 1447-1449 (2001).
- [129] W.A. Harrison et al., *Phys. Rev. B* **18**(8), 4402-4410 (1978).
- [130] A.H.G. Vlooswijk et al., *Appl. Phys. Lett.* **91** (11), 112901 (2007).
- [131] W. Pompe et al., *J. Appl. Phys.* **74**(10), 6012-6019 (1993).
- [132] K. Dayal and K. Bhattacharya, *Acta Materialia* **55**(6), 1907-1917 (2007).
- [133] P. Aguado-Puente and J. Junquera, *Phys. Rev. Lett.* **100**(17), 177601 (2008).
- [134] G. Catalan et al., *J. Phys.: Condens. Matter* **19**(2), 022201 (2007).
- [135] M. Foeth, P. Stadelmann and M. Robert, *Phys. A* **373**, 439-444 (2007)
- [136] V.M. Kaganer et al., *Phys. Rev. B* **55**(3), 1793-1810 (1997).
- [137] S. Venkatesan et al., *J. Appl. Phys.* **102**(10), 104105 (2007).
- [138] S.V. Kalinin et al., *Adv. Mat* **16**(9-10), 795-799 (2004).
- [139] D. Byrne et al., *Nanotechnology* **19**(16), 165608 (2008).
- [140] I.I. Naumov, L. Bellaiche and H.X. Fu, *Nature* **432**(7018), 737-740 (2004)
- [141] M. Dawber et al., *Adv. Mat.* **19**(23), 4153-4159 (2007).
- [142] I. Ponomareva, I.I. Naumov and L. Bellaiche, *Phys. Rev. B* **72**(21), 214118 (2005).

- [143] J. Hong and D. Fang, *Appl. Phys. Lett.* **92**(1), 012906 (2008).
- [144] A.N. Morozovska, M.D. Glinchuk and E.A. Eliseev, *Phys. Rev. B* **76**(1), 014102 (2007).
- [145] M.D. Glinchuk and A.N. Morozovskaya, *Ferroelectrics* **288**, 199-210 (2003).
- [146] M.D. Glinchuk and P.I. Bykov, *J. Phys.: Condens. Matter* **16**(37), 6779-6788 (2004).
- [147] S.P. Li et al., *Phys. Lett. A* **212**(6), 341-346 (1996).
- [148] W.L. Zhong, Y.G. Wang and P.L. Zhang, *Phys. Lett. A* **189**(1-2), 121-126 (1994).
- [149] T. Tanase et al., *Thin Solid Films* **485**(1-2), 22-26 (2005).
- [150] H. Nonomura et al., *Appl. Phys. Lett.* **86**(16), 163106 (2005).
- [151] W. Ma, D. Hesse and U. Gösele, *Small* **1**(8-9), 837-841 (2005).
- [152] W. van Zoelen, *PS-b-P4VP(PDP) comb-shaped supramolecules*, PhD thesis, University of Groningen (2009).
- [153] M. Suzuki and T. Ami, *Mat. Sc. & Eng. B* **41**(1), 166-173 (1996).
- [154] H.N. Lee et al., *Nature* **433**(7024), 395-399 (2005).
- [155] E. Bousquet et al., *Nature* **452**(7188), 732-736 (2008).
- [156] M. Dawber, et al., *Phys. Rev. Lett.* **95**(17), 177601 (2005).
- [157] J.C. Jiang et al., *Appl. Phys. Lett.* **74**(19), 2851-2853 (1999).
- [158] V.R. Cooper, K. Johnston and K.M. Rabe, *Phys. Rev. B* **76**(2), 020103(R) (2007).
- [159] N. Stucki, *Artificial Ferroelectric Materials*, PhD thesis (2008).
- [160] T. Yu et al., *Appl. Surf. Sc.* **138-139**, 609-612 (1999).
- [161] V.G. Koukhar, N.A. Pertsev and R. Waser, *Phys. Rev. B* **64**(21), 214103 (2001).
- [162] N. Choudhury et al., *Phys. Rev. B* **77**(13), 134111 (2008).
- [163] J. Robertson and C.W. Chen, *Appl Phys. Lett.* **74**(8), 1168-1170 (1999).



university of
 groningen

Zernike Institute for Advanced Materials
 Ph.D. thesis series 2009-09
 ISBN 978-90-367-3836-1
 ISSN 1570-1530

