REFERENCE

Abdelkefi, H., Khemakhem, H., V´elu, G., Carru, J.C., and Von der M¨uhll, R. (2005) Dielectric properties and ferroelectric phase transitions in $Ba_xSr_{1-x}TiO_3$ solid solution, Journal of Alloys and Compounds, 399, 1–6.

Adikarya, S.U., Chana, H.L.W., Choya, C.L., Sundaravelb, B.,and Wilsonb, I.H. (2002) Characterisation of proton irradiated $Ba_{0.65}Sr_{0.35}TiO_3$/P(VDF-TrFE) ceramic–polymer composites, Journal of Composites Science and Technology, 62, 2161–2167.

Barbosa, R., Mendes, J A., Sencadas, V., Mano, J. F. and Lanceros-mendez, S. (2003) Chain Reorientation in β-PVDF Films Upon Transverse Mechanical Deformation Studied by SEM and Dielectric Relaxation. Journal of Ferroelectrics, 294: 73–83,

Bar-Cohen, Y., Xue, T. and Lih, S.S. (1996) Polymer piezoelectric transducers for ultrasonic, The e-Journal of Nondestructive Testing Vol.1 No.09

Bauer, D.R. and Multhaupt, R.G. (1999) Separate contributions to the pyroelectricity in polyvinylidene fluoride from the amorphous and crystalline phases, as well as from their interface, Journal of Applied Physics, 85(6), 3282-3288.

Birlikseven, C., Altintas, and E., Dursoy, H.Z. (2001) A low temperature pyroelectric study of PVDF thick films, Journal of Materials in Electronics, 12, 601-603.

Lu, Q., Chen, D., Jiao, X. (2004) Preparation and characterization of $Ba_{1-x}Sr_x$ TiO (x=0.1, 0.2) fibers by sol–gel process using catechol-complexed titanium isopropoxide, Journal of Alloys and Compounds, 358, pp 76–81.

Campos, J.S.C., Ribeiro, A.A., Cardoso, C.X. (2007) Preparation of characterization of PVDF/$CaCO_3$ composites. Journal of Materials Science& Engineering B, 136, pp 123-128

Cho, S.D., Lee, J.Y., Hyun, J.G., and Paik, K.W. (2004). Study on epoxy/$BaTiO_3$ composite embedded capacitor films (ECFs) for organic substrate applications. Materials science & engineering B, 110, 233-239.

Das-Gupta, D.K. (1994) Ferrooelectric Polymers and Ceramic Polymer Composites, Trans Tech .Publ, Zurich.

Dang, Z.M., Fan, L.Z., Shen, Y., and Nan, C.W. (2003) Study on dielectric behavior of a three-phaseCF/(PVDF + $BaTiO_3$) Composite, Journal of Chemical Physics Letters, 369, 95–100.

Dang, Z.M., Fan, L.Z., Shen, Y., and Nan, C.W. (2002) Dielectric behavior of novel three-phase MWNTs/$BaTiO_3$/PVDF composites, Materials Science and Engineering B, 103, 140-144.

Garcia, D., Guo, R., and Bhalla, A.S. (2000) Growth and properties of (Ba,Sr)TiO_3 single crystal fibers. Journal of Materials Letters, 42, 136–141.

Giridharan, N.V., Varatharajan, R. Jayavel, and R. Ramasamy, P. (2000) Fabrication and characterisation of (Ba,Sr)TiO3 thin films by sol–gel technique through organic precursor route. Journal of Materials Chemistry and Physics, 65, 261–265.

Gimenes, R., Zaghete, M.A., Bertolini, M., Varela, J.A., Coelho, L.O., and Silva Jr., N.F. (2004) Composites PVDF-TrFE/BT used as bioactive membranes for enhancing bone regeneration, Journal of Der Spiegel, 5385, 539-547.

Harrison, J.S., Ounaies, Z. (2001) Piezoelectric Polymers. Virginia: National Aeronautics and Space Administration

Hilczer, B., Lek, J.K., Lomska, M.P., Glinchuk, M. D., Ragulya, A. V. and Pietraszxo, A. (2005) Dielectric and pyroelectric response of $BaTiO_3$-PVDF nanocomposites, Journal of Ferroelectrics, 316, 31–41.

Hornebecq, V., Huber, C., Maglione, M., Antonietti, M., and Elissalde, C. (2004). Dielectric properties of pure (Ba,Sr)TiO_3 and composites with different grain sizes ranging from the nanometer to the micrometer. Journal of advanced functional materials, 14(9), 899-904.

Ioachim, A., Ramer, R., Toacsan, M.I., Banciu, M.G., Nedelcu, L., Dutu, C.A., Vasiliu, F., Alexandru, H.V., Berbecaru, C., Stoica,G., Nita, P. (2006) Ferroelectric ceramics based on the Bao-SrO-TiO_2 ternary system for the microwave applications, Journal of the European Ceramic Society, 27, pp 1177-1180

Jiang, Y.Y., Wu, Y., Zeng, Z., Yang, H., and Li, Y.W. (2005) Characterization and ferroelectric properties of electric poled PVDF films, 12th International Symposium on Electrets.,132- 135.

Judovits, L. (2006). Thermal analysis of poly(vinylidene fluoride) film, Journal of Thermochimica Acta, 442, 92–94.

Kim, B. S., Lee, J.Y. and Porter, R.S.(1998) The Crystalline phase Transformation of Poly(Vinylidene Fluoride)/Poly(vinyl Fluoride) Blend Films, Polymer Engineering And Science, 38(9), pp 1359-1365.

Lang, S.B. and Das-Gupta, D. K. (2000) Pyroelectricity, Funcdamentals and Application, Ferroelectrics Review, 2, 217-354.

Lu, Q., Chen, D., and Jiao, X. (2003) Preparation and characterization of Ba Sr TiO (x=0.1, 0.2) fibers by sol–gel process using catechol-complexed titanium isopropoxide, Journal of Alloys and Compounds, 358, 76–81.

Mohammadi, B., Yousefi, A.A., Bellah, S. M. (2007) Effect of tensile strain rate and elongation on crystalline structure and piezoelectric properties of PVDF thin films, Polymer Testing, 26, pp 42-50.

Mao, C., Dong, X., Zeng,T. Chen, H. Cao, F. (2006) Nonhydrolytic sol-gel synthesis and dielectric properties of ultrafine-grained and homogenized $Ba_{0.7}Sr_{0.3}TiO_3$, Ceramic International, xxx, pp xxx

Naarayan, S.S. Rao, L., and Sivakumak, S.M. (2005) Electromechanical behavior of form I uniaxially and biaxial stretched PVDF, Journal of Ferroelectrics, 325, 155–164.

Nayak, M., Lee, S.Y., and Tseng, T.Y. (2002) Electrical and dielectric properties of $(Ba_{0.5}Sr_{0.5})TiO_3$ thin films prepared by a hydroxide–alkoxide precursor-based sol–gel method, Materials Chemistry and Physics, 77, 34–42.

Olszowy, M. (1997) Piezoelectricity and Dielectric Properties of PVDF/$BaTiO_3$ Composites, Journal of Der Spiegel, 3181, 69-72.

Rollik, D., Bauer, S. and Gerhard-Multhaupt, R. (1999) Separate contributions to the pyroelectricity in poly(vinylidene fluoride) from the amorphous and crystalline phases, as well as from their interface, Journal of Applied Physics, 85(6), pp 3282-3288

Salimi, A. and Yousefi, A. A. (2004) Conformational changes and phase transformation mechanisms in PVDF solution-cast films, Journal of Polymer Science: Part B: Polymer Physics, 42, 3487–3495.

Safari, A. (1994) Development of piezoelectric composites for transducers. Journal of Physics III France, 4, 1129-1149.

Tahan, D., Safari, A., and Klein, L. C. (1994) Sol-preparation of barium strontium titanate thin films, Journal of IEEE Applications of Ferroelectrics, 427-430.

Wua, D., Li, A., Ling, H., Yin, X., Ge, C., Wang, M., Ming, N. (2000) Preparation $(Ba_{0.5}Sr_{0.5})TiO_3$ thin films by sol–gel method with rapid thermal annealing. Journal of Applied Surface Science, 165, 309–314.

Zhou, L., Vilarinho, P. M., and Baptista, J. L. (1999) Dependence of the Structural and Dielectric Properties of $Ba_{1-x}Sr_xTiO_3$ Ceramic Solid Solutions Raw Material Processing. Journal of the European Ceramic Society, 19, 2015-2020.

Su B., Holmes, J.E., Cheng, B.L. and Button, T.W. (2002) Processing Effects on the Microstructure and Dielectric Properties of barium Strontium Titanate (BST) Ceramics. Journal of Electroceramics, 9, 111–116

APPENDICES

Appendix A Barium Strontium Titanate Analysis

Table A1 Lattice parameter of calcine $Ba_{0.7}Sr_{0.3}TiO_3$ at 800°C before sintering

sol-gel calcine						
peak No.	X (nm)	(1~3)	**h**	**k**	**l**	**2θ(degree)**
1	0.154184	3	1	0	0	22.380
2	0.154184	3	1	1	0	31.800
3	0.154056	1	1	1	1	39.280
4	0.154056	1	2	0	0	45.660
5	0.154056	1	2	1	1	56.760
6	0.154056	1	2	2	0	66.680
a=	3.959					

Table A2 Lattice parameter of calcine $Ba_{0.7}Sr_{0.3}TiO_3$ at 800°C after sintering

sinter tetragonal						
peak No.	λ (nm)	(1~3)	**h**	**k**	**l**	**2θ(degree)**
1	0.154184	3	1	0	0	22.680
2	0.154184	3	1	1	0	32.100
3	0.154184	3	1	1	1	39.540
4	0.154184	3	2	0	0	45.960
5	0.154184	3	2	1	1	56.960
6	0.154184	3	2	2	0	66.740
a=	3.9794					
c=	3.98214					

Table A3 Lattice parameter of calcine $Ba_{0.7}Sr_{0.3}TiO_3$ at 100°C before sintering

BST sol-gel at 1000 is cubic						
peak No.	X (nm)	(1~3)	**h**	**k**	**l**	**2θ(degree)**
1	0.154184	3	1	0	0	22.200
2	0.154184	3	1	1	0	31.800
3	0.154056	1	1	1	1	39.200
4	0.154056	1	2	0	0	45.600
5	0.154056	1	2	1	1	56.800
6	0.154056	1	2	2	0	66.600
a	3.95954					

Table A4 Lattice parameter of calcine $Ba_{0.7}Sr_{0.3}TiO_3$ at 1000°C after sintering

BST sinter at 1000 is tetragonal

peak No.	X (nm)	(1~3)	h	k	l	2θ(degree)
1	0.154184	3	1	0	0	22.640
2	0.154184	3	1	1	0	32.080
3	0.154184	3	1	1	1	39.900
4	0.154184	3	2	0	0	45.840
5	0.154184	3	2	1	1	56.860
6	0.154184	3	2	2	0	66.680

a	3.9903
c	3.95356

Appendix B Polyvinylidene Fluoride Analysis

% Crystallinity of PVDF is calculated by following Eq. 1:

$$\%crystallinity = (\Delta H_f / \Delta H^0_f) \times 100 \qquad (1)$$

where ΔH^f_o is heat of fusion of 100 % crystallized PVDF ΔH_f is the measure heat fusion of each them

Table B1 Melting temperature and crystallinity temperature of PVDF at different ratio

Sample	T_m (°C)		T_c (°C)	
	Onset	Peak	Onset	Peak
Pure PVDF	167.915	172.666	156.861	151.3
ratio2 PVDF	165	168.866	141.26	136.8
ratio4	165.803	170.533	142.087	134.966

Table B2 % Crystallinity of PVDF

Sample	ΔH_f (J/g)	% Crystallinity	True % Crystallinity	% PVDF	ΔH^f_o(J/g)
Pure PVDF	31.648	35.00885	35.00885	100	90.4
ratio2 PVDF	39.817	44.04535	44.04535	100	90.4
ratio4	40.478	44.77655	44.77655	100	90.4

F(β) of PVDFis calculated by following Eq. 2:

$$F(\beta) = \frac{X_\beta}{X_\alpha + X_\beta} = \frac{A_\beta}{(K_\beta + K_\alpha)A_\alpha + A_\beta} = \frac{A_\beta}{1.26\ A_\alpha + A_\beta} \qquad (2)$$

Table B3 F(β) of PVDF

pure PVDF	Aβ(763)	1.66		
solution PVDF	Aβ (763)	2.5		
ratio2	Aβ (763)	2.45		
ratio4	Aβ (763)	2.4		
pure PVDF	Aα(840)	1.68	Aα (840)*1.26	2.1168
solution PVDF	Aα (840)	1.3	Aα (840)*1.26	1.638
ratio2	Aα (840)	1.58	Aα (840)*1.26	1.9908
ratio4	Aα (840)	1.3	Aα (840)*1.26	1.638
pure PVDF	Aα(840)*1.26+Aβ(763)	3.7768		
solution PVDF	Aα(840)*1.26+Aβ(763)	4.138		
ratio2	Aα(840)*1.26+Aβ(763)	4.4408		
ratio4	Aα(840)*1.26+Aβ(763)	4.038		
pure PVDF	F(β)	0.439526	%	43.95255
solution PVDF	F(β)	0.604157	%	60.41566
ratio2	F(β)	0.551702	%	55.17024
ratio4	F(β)	0.594354	%	59.43536

Table B4 Physical properties of PVDF (SOLEF 1008).

SOLEF® 1008

PVDF Homopolymer

Low viscosity - Injection

Physical properties	Standards	Units	
Density	ISO 1183	g/cm^3	1.78
Water absorption (24 h at 23°C)	ISO 62 (method 1)	%	< 0.04
Melt Flow Index	ASTM D 1238		
	230°C, 10 kg	g/10 min	-
	230°C, 5 kg	g/10 min	24
	230°C, 2.16 kg	g/10 min	8
Mechanical properties			
Tensile	ASTM D 638		
Tensile stress at yield	23 °C, 50 mm/min	MPa/psi	53 - 57/7685 - 826
Tensile stress at break	23 °C, 50 mm/min	MPa/psi	35 - 50/5075 - 725
Elongation at yield	23 °C, 50 mm/min	%	5 - 10
Elongation at break	23 °C, 50 mm/min	%	5 - 10
Modulus	23 °C, 1 mm/min	MPa/psi	2600/377000
Flexion	ASTM D 790		
Maximum load	23 °C	MPa/psi	78/11310
Modulus	2 mm/min	MPa/psi	2200/319000
IZOD impact (notched V 10 mm - at 23 °C - 4 mm thick)	ASTM D 256	J/m	55
Shore D Hardness (2 mm thick)	ASTM D 2240	-	78
Abrasion resistance	TABER CS 10/1 kg	mg/1000 rev	5 - 10
Friction coefficient: static	ASTM D 1894	-	0.2 - 0.4
Friction coefficient: dynamic		-	0.2 - 0.3
Thermal properties			
Crystallinity by DSC	ASTM D 3418		
Melting point		°C/°F	174/345
Heat of fusion (80 °C to end of melting)		J/g	67
Crystallizing point		°C/°F	140/284
Crystallizing heat		J/g	59
VICAT point (4 mm thick)	ISO 306		
load 1 kg		°C/°F	171/340
Deflection temperature (4 mm thick)	ASTM D 648		
load 0.46 MPa	after annealing	°C/°F	148/298
load 1.82 MPa		°C/°F	115/239
Glass transition (Tg)	DMTA	°C/°F	- 30/ -22
Brittleness temperature (on 2 mm pressed sheet)	ASTM D 746 A	°C/°F	0 - 10/32 - 50

Thermal properties (continuation)	Standards	Units	
Molding shrinkage		%	2 - 3
Thermal stability	TGA beginning- and at 1% weight loss in air	°C/°F	375 - 400/707 - 752
Linear thermal expansion coefficient	ASTM D 696	10^{-6} K^{-1}	120 - 140
Thermal conductance at 23°C	ASTM C 177	W/m.K	0.2
Specific heat	23 °C & 100 °C	J/g.K	1.2 - 1.6
Electrical properties			
Surface resistivity, Voltage < 1V, after 2 min - 500 V at 23 °C	ASTM D 257, DIN 53483	ohm/square	≥ 1.10^{14}
Volume resistivity, Intensity = 10 mA, after 2 min at 23 °C	ASTM D 257, DIN 53483	ohm.cm	≥ 1.10^{14}
Fire resistance			
UL-94 Flammability test	UL-94	Class	V-O
Limiting Oxygen Index (sheet 3 mm thick)	ASTM D 2863	%	44

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1. Kittikun Kohpaiboon, Hathaikarn Manuspiya, Pitak Laoratanakul (2006, December 10-14) 0-3 Connectivity of PVDF/BST Piezoelectric Composites. Poster presented at 5th Asian Meeting on Electroceramics, Bangkok, Thailand.