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APPENDICES

Appendix A Barium Strontium Titanate Analysis

Lattice parameter of the calcined $Ba_{0.7}Sr_{0.3}TiO_3$ at 1000°C

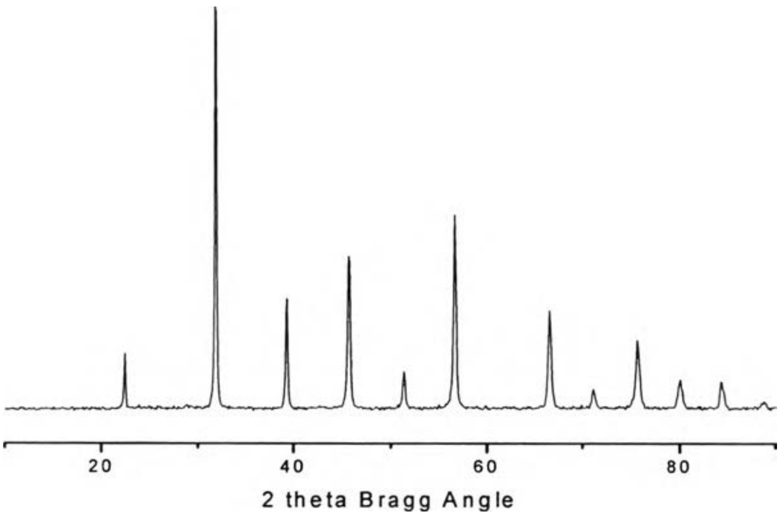

Table A1 Lattice parameter of calcined $Ba_{0.7}Sr_{0.3}TiO_3$ at 1000°C

peak No.	λ (nm)	(1~3)	h	k	l	2θ(degree)
1	0.15418	3	1	0	0	22.33
2	0.15418	3	1	1	0	31.8
3	0.15418	3	1	1	1	39.28
4	0.15418	3	2	0	0	45.66
5	0.15418	3	2	1	1	56.76
6	0.15418	3	2	2	0	66.68

a=	0.3971
c=	0.39697
c/a	0.99967

Lattice parameter of the sintered $Ba_{0.7}Sr_{0.3}TiO_3$ at 1330°C

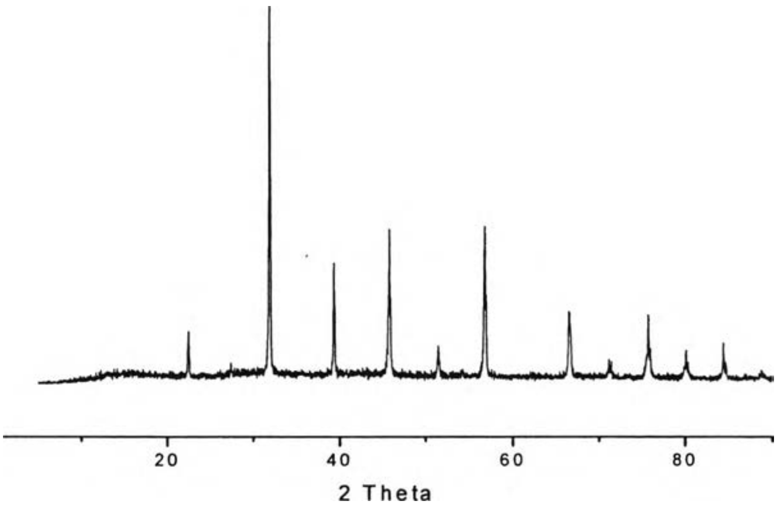

Table A2 Lattice parameter of sintered $Ba_{0.7}Sr_{0.3}TiO_3$ at 1330°C for 2 h.

peak No.		λ (nm)	(1 ~ 3)	h	k	l	2θ(degree)
1		0.15418	3	1	0	0	22.44
2		0.15418	3	1	1	0	31.9
3		0.15418	1	1	1	1	39.3
4		0.15418	1	2	0	0	45.72
5		0.15418	1	2	1	1	56.76
6		0.15418	1	2	2	0	66.52
a=	0.3969						
c=	0.39749						
c/a	1.001325						

Appendix B Polyvinylidene Fluoride Analysis

The degree of crystallinity was measured as the ratio between ΔH_m and ΔH_0, as following equation

$$\% \text{ Crystallinity } = \frac{\Delta H_m}{\Delta H_0} x100$$

where ΔH_m is the melting enthalpy of the material under study and ΔH_0 is the melting enthalpy of totally crystalline material (ΔH_0 = 104.50 J/g for PVDF).

Table B1 % Crystallinity of PVDF

Material	T_m Onset (°C)	Tm Peak (°C)	heat of fusion ΔH_m, J/g	Crystallinity %
solution-casted PVDF	162.3	172.3	65.5	62.6
stretched PVDF X2	162.2	170.1	65.9	63.1
stretched PVDF X4	161.9	170.3	64.4	61.6
stretched PVDF X6	165.3	169.1	66.3	63.4

F(β) of PVDF system containing α and β phase the relative fraction of the β phase, $F(\beta)$, was calculated by the following equation:

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

Where X_α and X_β are the degree of crystallinity of α and β phases, A_α and A_β are the absorbances of α and β phases at 763 and 840 cm^{-1}, respectively.

Table B2 F(β) of PVDF

Material	**A_α (normalized 763 cm^{-1})**	**A_β (normalized 840 cm^{-1})**	**% β phase content $F(\beta)$,**
solution-casted PVDF	0.01695	0.42586	95.22
stretched PVDF X2	0.02108	0.33825	92.72
stretched PVDF X4	0.027384	0.43282	92.62
stretched PVDF X6	0.030339	0.446089	92.11

Table B3 Physical properties of PVDF (SOLEF 1008).

SOLEF®

SOLEF® 1008
PVDF Homopolymer

Low viscosity - Injection

Physical properties	Standards	Units	
Density	ISO 1183	g/cm³	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 - 8265
Tensile stress at break	23 °C, 50 mm/min	MPa/psi	35 - 50/5075 - 7250
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	174/346
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

page 1/2

Solvay Solexis

SOLVAY

SOLEF®

SOLEF® 1008

PVDF Homopolymer

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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Appendix C Lamination Film Analysis

The effective dielectric constant of the multilayer structure is a series connection model of PVDF and PVDF/BST composite layer dielectrics. the effective dielectric constant, ε_{eff}, can theoretically be expressed as:

$$\frac{1}{\varepsilon_{eff}} = \left[\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} + \frac{1}{\varepsilon_3} + ...\right] / (t_1 + t_2 + t_3 + ...)$$

where t is thickness of each layer

Table C1 Dielectric constant of PVDF x4 and PVDF/BST40% composite

Material	**Thickness (μm)**	**Dielectric constant (ε_r)**			
		1 kHz	**10 kHz**	**100 kHz**	**1 MHz**
PVDF x4	40	4.77	4.60	4.37	3.89
composite	280	23.03	22.53	21.62	18.41

Table C2 Dielectric constant of Laminate films

Material	**Dielectric constant**							
	1 kHz		**10 kHz**		**100 kHz**		**1 MHz**	
	ε_r	ε_{eff}	ε_r	ε_{eff}	ε_r	ε_{eff}	ε_r	ε_{eff}
P-C	19.01	15.58	18.63	15.15	17.8	14.48	15.03	12.55
P-C-P	17.22	12.445	16.84	12.07	16.18	11.52	13.64	10.06
C-P-C	18.48	18.35	18.09	17.88	17.45	17.12	14.9	14.74

Remark P-C is PVDF-Composite bilayer film

P-C-P is PVDF-Composite-PVDF trilayer film

C-P-C is PVDF-Composite-PVDF trilayer film

ε_r is experimental dielectric constant

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2. Sodsong, T.; and Manuspiya, H. (2009, March 22-27) Improvement in dielectric properties by using lamination technique of stretched polyvinylidene fluoride and polyvinylidene fluoride/barium strontium titanate composite film. Proceedings of the NanoThailand Symposium 2008, Bangkok, Thailand.
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