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APPENDIX I

Peak Height ratio data for calculating the degree of imidization

I.1 Effect of curing temperature

PI2610

Final Curing temperature (°C)		100	150	200	250	300	350	400
Peak height # at 1778 cm^{-1} (cm)	1	0.25	0.30	2.55	4.45	6.70	5.25	6.70
	2	0.25	0.35	2.95	5.40	4.60	4.60	5.60
	3	0.20	0.30	2.70	5.10	5.70	6.50	4.90
	4	0.15	0.35	2.60	5.50	6.15	5.15	5.70
Peak height # at 1015 cm^{-1} (cm)	1	0.23	0.20	0.25	0.25	0.40	0.35	0.35
	2	0.20	0.25	0.30	0.30	0.25	0.25	0.30
	3	0.20	0.25	0.25	0.30	0.40	0.35	0.29
	4	0.15	0.20	0.25	0.35	0.38	0.25	0.30
Peak Height ratio at 1778/1015	1	1.09	1.50	10.20	17.80	16.75	15.00	19.14
	2	1.25	1.40	9.83	18.00	18.40	18.40	18.67
	3	1.00	1.20	10.80	17.00	14.25	18.57	16.90
	4	1.00	1.75	10.40	15.71	16.18	20.60	19.00
Imidization (%)	1	5.68	7.84	53.28	92.99	87.50	78.36	100.00
	2	6.70	7.50	52.68	96.43	98.57	98.57	100.00
	3	5.92	7.10	63.92	100.61	84.34	109.91	100.00
	4	5.26	9.21	54.74	82.71	85.18	108.42	100.00
	average	5.89	7.91	56.15	93.18	88.89	98.81	100.00

PI-2540

Final Curing temperature (°C)		100	150	200	250	300	350	400
Peak height # at 1778 cm^{-1} (cm)	1	0.25	0.60	1.45	1.80	2.45	1.95	1.80
	2	0.35	0.60	1.45	1.40	1.23	1.65	1.80
	3	0.25	0.70	1.45	1.25	1.55	1.55	1.80
	4	0.30	0.70	1.50	1.55	1.95	1.35	1.95
Peak height # at 1015 cm^{-1} (cm)	1	0.55	1.00	0.55	0.55	0.70	0.55	0.55
	2	0.90	1.00	0.60	0.40	0.35	0.45	0.50
	3	0.65	1.10	0.55	0.35	0.45	0.45	0.55
	4	0.80	1.10	0.60	0.45	0.60	0.40	0.60
Peak Height ratio at 1778/1015	1	0.45	0.60	2.64	3.27	3.50	3.55	3.27
	2	0.39	0.60	2.42	3.50	3.51	3.67	3.60
	3	0.38	0.64	2.64	3.57	3.44	3.44	3.27
	4	0.38	0.64	2.50	3.44	3.25	3.38	3.25
Imidization (%)	1	12.82	16.92	74.36	92.31	98.72	100.00	92.31
	2	10.61	16.36	65.91	95.45	95.84	100.00	98.18
	3	11.17	18.48	76.54	103.69	100.00	100.00	95.01
	4	11.11	18.86	74.07	102.06	96.30	100.00	96.30
	average	11.43	17.65	72.72	98.37	97.72	100.00	95.45

PI-2579

Final Curing temperature (°C)		100	150	200	250	300	350	400
Peak height # at 1778 cm^{-1} (cm)	1	0.15	0.90	1.75	2.60	1.70	1.55	1.95
	2	0.15	0.95	1.65	2.30	2.20	1.65	1.70
	3	0.15	0.90	1.85	2.60	1.80	1.55	1.70
	4	0.2	0.85	1.50	2.25	1.85	1.70	1.70
Peak height # at 1015 cm^{-1} (cm)	1	0.1	0.50	0.25	0.34	0.21	0.20	0.25
	2	0.1	0.45	0.25	0.30	0.30	0.20	0.21
	3	0.1	0.45	0.25	0.34	0.25	0.20	0.23
	4	0.1	0.40	0.20	0.27	0.22	0.20	0.2
Peak Height ratio at 1778/1015	1	1.50	1.80	7.00	7.65	8.10	7.75	7.80
	2	1.50	2.11	6.60	7.67	7.33	8.25	8.10
	3	1.50	2.00	7.40	7.65	7.20	7.75	7.39
	4	2.00	2.13	7.50	8.33	8.41	8.50	8.50
Imidization (%)	1	19.35	23.23	90.32	98.67	104.45	100.00	100.65
	2	18.18	25.59	80.00	92.93	88.89	100.00	98.12
	3	19.35	25.81	95.48	98.67	92.90	100.00	95.37
	4	23.53	25.00	88.24	98.04	98.93	100.00	100.00
	average	20.10	24.90	88.51	97.07	96.29	100.00	98.53

I.2 Effect of curing rate

Polyimide films cured at 400°C minutes.

PI-2610

Curing rate (°C/minute)		1	2	4	6	8
Peak height # at 1778 cm^{-1} (cm)	1	5.90	6.70	4.20	6.65	6.15
	2	5.35	5.60	4.55	6.35	5.55
	3	5.30	6.15	4.60	4.65	5.85
	4	5.80	5.70	4.40	5.20	5.25
Peak height # at 1015 cm^{-1} (cm)	1	0.33	0.35	0.25	0.35	0.40
	2	0.30	0.30	0.25	0.35	0.30
	3	0.35	0.30	0.30	0.25	0.35
	4	0.35	0.30	0.30	0.35	0.30
Peak Height ratio at 1778/1015	1	17.88	19.14	16.80	19.00	15.38
	2	17.83	18.67	18.20	18.14	18.50
	3	15.14	20.50	15.33	18.60	16.71
	4	16.57	19.00	14.67	14.86	17.50
	average	16.85	19.33	16.25	17.65	17.02

PI-2540

Curing rate (°C/minute)		1	2	4	6	8
Peak height # at 1778 cm^{-1} (cm)	1	1.55	1.80	2.05	2.40	2.00
	2	1.55	1.80	2.60	2.45	2.10
	3	1.55	1.80	1.25	2.35	1.90
	4	1.70	1.95	2.00	2.30	1.80
Peak height # at 1015 cm^{-1} (cm)	1	0.55	0.55	0.70	0.80	0.55
	2	0.55	0.50	0.80	0.85	0.55
	3	0.55	0.55	0.60	0.75	0.60
	4	0.60	0.60	0.70	0.75	0.55
Peak Height ratio at 1778/1015	1	2.82	3.27	2.93	3.00	3.64
	2	2.82	3.60	3.25	2.88	3.82
	3	2.82	3.27	2.08	3.13	3.17
	4	2.83	3.25	2.86	3.07	3.27
	average	2.82	3.35	2.78	3.02	3.47

PI2579

Curing rate (°C/minute)		1	2	4	6	8
Peak height # at 1778 cm^{-1} (cm)	1	1.70	1.95	1.75	1.65	2.05
	2	1.70	1.70	1.80	1.87	2.10
	3	1.70	1.70	1.80	1.80	2.10
	4	1.80	1.70	1.75	1.70	2.05
Peak height # at 1015 cm^{-1} (cm)	1	0.25	0.25	0.20	0.25	0.30
	2	0.25	0.21	0.25	0.25	0.30
	3	0.25	0.23	0.20	0.25	0.30
	4	0.25	0.20	0.20	0.25	0.30
Peak Height ratio at 1778/1015	1	6.80	7.80	8.75	6.60	6.83
	2	6.80	8.10	7.20	7.50	7.00
	3	6.80	7.39	9.00	7.20	7.00
	4	7.20	8.50	8.75	6.80	6.83
	average	6.90	7.90	8.40	7.00	6.90

APPENDIX II
THERMOGRAVIMETRIC DATA

II.1 Degradation temperature and weight loss of the bare polyimide films with the scanning rate at 10°K/min.

BPDA/PDA (PI-2610, semirigid) scanning rate 10°K/min.

Curing temperature (°C)	2 nd regime			3 rd regime			4 th regime		
	t_D (min)	T_D (°C)	Wt loss (%)	t_D (min)	T_D (°C)	Wt loss (%)	t_D (min)	T_D (°C)	Wt loss (%)
100 (1)	14.00	52.70	6.90	52.70	577	33.70	120	950	68.00
100(2)	14.10	53.00	7.00	55.30	600.3	35.90	120	950	67.80
average	[illegible]	52.85	[illegible]	[illegible]	588.65	[illegible]	120	950	[illegible]
150(1)	16.10	192.80	8.50	53.50	567.00	31.20	120	950	74.60
150(2)	15.90	190.70	8.70	53.80	565.50	30.80	120	950	62.90
average	[illegible]	191.75	8.60	[illegible]	566.25	31.00	[illegible]	[illegible]	68.75
200(1)	16.20	197.10	5.60	52.90	557.30	27.10	120	950	63.10
200(2)	14.30	175.00	4.80	56.10	607.70	31.70	120	950	63.20
average	[illegible]	[illegible]	[illegible]	[illegible]	582.50	[illegible]	120	[illegible]	[illegible]
250(1)	-	-	-	56.32	600.30	10.10	120	950	48.40
250(2)	-	-	-	54.45	621.40	10.10	120	950	48.40
average	-	-	-	55.40	603.35	[illegible]	[illegible]	950	[illegible]
300(1)	-	-	-	54.90	580.90	7.30	120	950	44.20
300(2)	-	-	-	55.40	583.70	8.90	120	950	48.50
average	-	-	-	55.15	582.30	8.10	120	950	[illegible]
350(1)	-	-	-	54.60	574.20	7.20	120	950	47.30
350(2)	-	-	-	54.30	575.20	7.40	120	950	47.00
average	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	950	[illegible]
400(1)	-	-	-	54.30	572.60	5.50	120	950	42.20
400(2)	-	-	-	54.40	572.20	5.40	120	950	42.30
average	[illegible]	-	[illegible]	54.35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

PMDA/ODA (PI-2540, semiflexible), scanning rate 10°K/min

Curing temperature (°C)	2 nd regime			3rd regime			4th regime		
	tD (min)	TD (°C)	Wt loss (%)	tD (min)	TD (°C)	Wt loss (%)	tD (min)	TD (°C)	Wt loss (%)
100 (1)	12.70	159.40	6.40	53.40	563.90	37.30	120	950	66.00
100(2)	12.30	155.30	8.30	53.40	563.90	39.20	120	950	68.00
average	12.50	157.35	7.35	53.40	563.90	38.25	120	950	67.00
150(1)	12.60	158.50	6.60	52.70	558.80	29.60	120	950	63.90
150(2)	12.60	157.00	6.20	53.00	559.20	34.00	120	950	62.90
average	12.60	157.75	6.40	52.85	559.00	31.80	120	950	63.40
200(1)	16.30	197.70	3.80	53.30	560.80	34.90	120	950	55.70
200(2)	16.00	191.10	3.60	52.80	559.20	19.90	120	950	55.80
average	16.15	194.40	3.70	53.05	560.00	27.40	120	950	55.75
250(1)	19.00	223.10	2.70	52.50	558.70	12.20	120	950	51.90
250(2)	18.90	219.30	3.10	52.90	558.50	13.30	120	950	51.90
average	18.95	221.20	2.90	52.70	558.60	12.75	120	950	51.90
300(1)	-	-	-	53.00	559.40	9.50	120	950	48.80
300(2)	-	-	-	52.80	558.00	9.20	120	950	55.70
average	-	-	-	52.90	558.70	9.35	120	950	52.25
350(1)	-	-	-	51.20	543.40	8.20	120	950	55.30
350(2)	-	-	-	51.70	547.00	9.80	120	950	49.30
average	-	-	-	51.45	545.20	9.00	120	950	52.30
400(1)	-	-	-	52.70	556.1	7.5	120	950	52.00
400(2)	-	-	-	52.60	557.6	6.9	120	950	46.00
average	-	-	-	52.65	556.85	7.2	120	950	49.00

BTDA/ODA-MDA (PI-2579, flexible), scanning rate 10°K/min.

Curing temperature (°C)	2 nd regime			3rd regime			4th regime		
	t_D (min)	T_D (°C)	wt loss (%)	t_D (min)	T_D (°C)	wt loss (%)	t_D (min)	T_D (°C)	wt loss (%)
100 (1)	13.3	166	8.548	51.5	544	37.702	120	950	66
100(2)	12.5	157.9	8.5	50.7	537.7	37.519	120	950	68.8
average	12.9	161.95	8.524	51.1	540.85	37.610	120	950	67.4
150(1)	13.4	166.5	7.059	51.2	540.3	34.912	120	950	63
150(2)	14.50	177.10	7.70	51.10	539.80	32.85	120	950	63.70
average	13.95	171.80	7.88	51.15	540.05	33.88	120	950	63.35
200(1)	15.80	189.50	6.25	46.00	491.80	23.13	120	950	69.70
200(2)	15.00	181.50	5.35	50.30	532.30	25.96	120	950	57.80
average	15.40	185.50	5.80	48.15	512.05	24.54	120	950	63.75
250(1)	25.30	251.50	3.72	50.50	535.00	11.67	120	950	47.30
250(2)	18.00	251.50	2.43	50.10	531.80	11.19	120	950	47.41
average	21.65	251.50	3.08	50.30	533.40	11.43	120	950	47.35
300(1)	-	-	-	50.40	533.00	9.18	120	950	49.20
300(2)	-	-	-	50.40	533.30	7.52	120	950	48.72
average	-	-	-	50.40	533.15	8.35	120	950	48.96
350(1)	-	-	-	50.40	534.10	9.04	120	950	49.09
350(2)	-	-	-	50.30	534.80	8.18	120	950	48.80
average	-	-	-	50.35	534.45	8.61	120	950	48.95
400(1)	-	-	-	51.60	546.50	8.15	120	950	50.78
400(2)	-	-	-	49.90	528.20	8.81	120	950	50.55
average	-	-	-	50.75	537.35	8.4	120	950	50.6

II.2 Degradation temperature and weight loss of the bare polyimide films with the scanning rate at 60°K/min.

BPDA/PDA (PI-2610, semirigid) , scanning rate 60°K/min.

Curing temperature (°C)	2nd regime			3rd regime			4 th regime		
	tD (min)	TD (°C)	Wt loss (%)1	tD (min)	TD (°C)	Wt loss (%)	tD (min)	TD (°C)	Wt loss (%)
100 (1)	3.00	204.40	11.70	9.50	600.30	36.89	45	950	67.00
100(2)	3.00	203.60	12.01	9.70	614.80	40.92	45	950	66.39
average	3.00	204.00	11.86	9.60	607.55	38.90	45	950	66.69
150(1)	3.40	230.50	10.18	9.60	604.00	31.87	45	950	63.03
150(2)	3.00	207.10	8.85	9.70	612.40	37.99	45	950	63.10
average	3.20	218.80	9.52	9.65	608.20	34.93	45	950	63.06
200(1)	3.30	226.50	6.84	9.70	610.80	24.31	45	950	61.29
200(2)	3.20	220.90	5.94	9.60	607.70	27.68	45	950	58.30
average	3.25	223.70	6.39	9.65	609.25	25.99	45	950	59.79
250(1)	-	-	-	9.90	624.90	10.31	45	950	47.81
250(2)	-	-	-	9.90	621.70	9.42	45	950	47.19
average	-	-	-	9.90	623.30	9.87	45	950	47.50
300(1)	-	-	-	9.80	619.90	7.60	45	950	43.10
300(2)	-	-	-	9.90	628.00	8.77	45	950	51.01
average				9.85	623.95	8.75	45	950	47.20
350(1)	-	-	-	9.80	616.20	7.45	45	950	49.83
350(2)	-	-	-	10.10	638.90	14.70	45	950	48.84
average				9.95	627.55	10.30	45	950	48.62
400(1)	-	-	-	9.80	618.40	6.403	45	950	45.968
400(2)	-	-	-	9.70	606.70	8.397	45	950	43.962
average	-	-	-	9.75	612.55	7.4	45	950	44.965

PMDA/ODA (PI-2540, semiflexible), scanning rate 60°K/min.

Curing	2nd regime			3rd regime			4th regime		
temperature (°C)	t_D (min)	T_D (°C)	Wt loss (%)	t_D (min)	T_D (°C)	Wt loss (%)	t_D (min)	T_D (°C)	Wt loss (%)
100 (1)	3	208.7	9.99	9.2	578.80	40.48	45	950	73.15
100(2)	2.9	202	11.28	9.5	599.70	42.01	45	950	69.74
average	2.95	205.35	10.63	9.35	[illegible]	41.248	45	[illegible]	71.44
150(1)	2.9	198.7	6.31	9.4	594.90	31.25	45	950	61.83
150(2)	2.9	199.9	5.89	9.4	594.60	31.34	45	950	61.36
average	2.9	199.3	6.10	9.4	[illegible]	31.30	45	[illegible]	61.59
200(1)	3.6	243.1	5.68	9	572.4	22.40	45	950	59.98
200(2)	3.4	227.9	5.01	9.5	596.1	30.13	45	950	55.29
average	3.5	235.5	5.34	9.25	584.25	26.27	45	950	57.63
250(1)	4.2	281.2	4.73	9.3	585.6	15.38	45	950	59.56
250(2)	4.8	318.7	3.60	9.9	620	10.71	45	950	50.75
average	4.5	299.95	4.16	9.6	602.8	13.04	45	950	55.16
300(1)	-	-	-	9.5	603.1	4.78	45	950	48.26
300(2)				9.3	587	11.20	45	950	56.19
average	-	-	-	9.4	595.05	7.99	45	950	52.23
350(1)	-	-	-	9.3	583.8	10.20	45	950	52.94
350(2)	-	-	-	9.3	589	8.33	45	950	51.21
average	-	-	-	9.3	586.4	9.26	45	950	52.08
400(1)	-	-	-	9.5	599.7	10.16	45	950	47.92
400(2)	-	-	-	9.8	618.6	17.72	45	950	50.79
average	-	-	-	9.65	609.15	13.94	45	950	49.35

BTDA/ODA-MDA (PI-2579, flexible), scanning rate 60°K/min.

Curing temperature (°C)	2nd regime			3rd regime			4th regime		
	t_D (min)	T_D (°C)	Wt loss (%)	t_D (min)	T_D (°C)	Wt loss (%)	t_D (min)	T_D (°C)	Wt loss (%)
100 (1)	9.00	.203.9	7.356	9.00	568.30	35.98	45	950	61.65
100(2)	9.00	206.90	10.202	9.00	567.30	35.52	45	950	64.03
average	9.00	205.40	8.779	9.00	567.80	35.75	45	950	62.84
150(1)	9.00	212.70	6.007	9.00	571.40	33.64	45	950	61.80
150(2)	9.00	169.90	5.711	9.00	569.10	37.53	45	950	61.80
average	9.00	191.30	5.859	9.00	570.25	35.59	45	950	61.80
200(1)	8.90	221.00	4.052	8.90	566.80	24.15	45	950	58.00
200(2)	8.90	211.70	7.01	8.90	558.10	27.01	45	950	58.25
average	8.90	216.35	5.531	8.90	562.45	25.58	45	950	58.13
250(1)	9.00	261.60	3.45	9.00	567.00	15.85	45	950	49.20
250(2)	8.80	276.20	4.68	8.80	560.60	12.89	45	950	48.82
average	8.90	268.90	4.065	8.90	563.80	14.37	45	950	49.01
300(1)	8.90	280.90	5.64	8.90	556.50	16.27	45	950	54.16
300(2)	8.70	270.90	4.38	8.70	565.80	13.97	45	950	56.89
average	8.80	275.90	5.01	8.80	561.15	15.12	45	950	55.52
350(1)	-	-	-	9.00	565.60	12.76	45	950	50.15
350(2)	-	-	-	8.90	565.80	9.64	45	950	48.37
average	-	-	-	8.95	565.70	11.20	45	950	49.26
400(1)	-	-	-	9.10	564.60	10.17	45	950	46.75
400(2)	-	-	-	9.10	573.20	10.17	45	950	45.90
average	-	-	-	9.10	568.90	10.17	45	950	46.32

II.3 Degradation time and temperature of the polyimide films on silicon wafer at various curing rate which was cured at 400°C for 30 minutes, ramping rate was 2°C/min. The scanning rate for thermogram was 60°K/min.

Curing rate	PI-2610		PI-2540		PI-2579	
(°C/min)	t_D (min)	T_D (°C)	t_D (min)	T_D (°C)	t_D (min)	T_D (°C)
1 (1)	9.7	612.00	9.70	612.00	9.60	595.50
1 (2)	9.7	601.60	9.70	601.60	9.40	593.80
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2 (1)	9.6	607.40	9.60	607.40	9.10	574.90
2 (2)	9.6	605.40	9.60	605.40	9.10	580.10
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4 (1)	9.5	600.20	9.50	600.20	9.30	582.80
4 (2)	9.9	643.30	9.90	643.30	9.20	584.30
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6 (1)	10	606.70	10.00	606.70	9.20	586.90
6 (2)	10	628.80	10.00	628.80	9.20	587.20
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8 (1)	9.6	600.00	9.60	600.00	9.40	592.00
8 (2)	9.7	609.00	9.70	609.00	9.40	590.50
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

II.4 Degradation time and temperature of BPDA/PDA (PI-2610) films on silicon wafer which were cured at 400°C at various curing time. The ramping rate was 2°C/min. The scanning rate of thermogram was 60°K/min.

Curing time	Degradation	
(min.)	t_D (min)	T_D (°C)
30 (1)	9.7	612
30 (2)	9.7	601.6
[illegible]	[illegible]	[illegible]
60 (1)	10.2	641.7
60 (2)	10.2	642.9
[illegible]	[illegible]	[illegible]
120 (1)	10.3	644.3
120 (2)	10.1	634.8
[illegible]	[illegible]	[illegible]
180 (1)	10.3	645.9
180 (2)	10.3	648.1
[illegible]	[illegible]	[illegible]
240 (1)	10.5	641.5
240 (2)	10.5	659.7
[illegible]	[illegible]	[illegible]

APPENDIX III
THERMOMECHANICAL DATA

III.1 Definition of coefficient of linear thermal expansion, expansion temperature and yielding temperature.

(a) Expansion temperature

Definition: The temperature at the inflection point of the curve of the coefficient of linear thermal expansion (CTE) versus temperature which the CTE change drastically as shown in the Figure below.

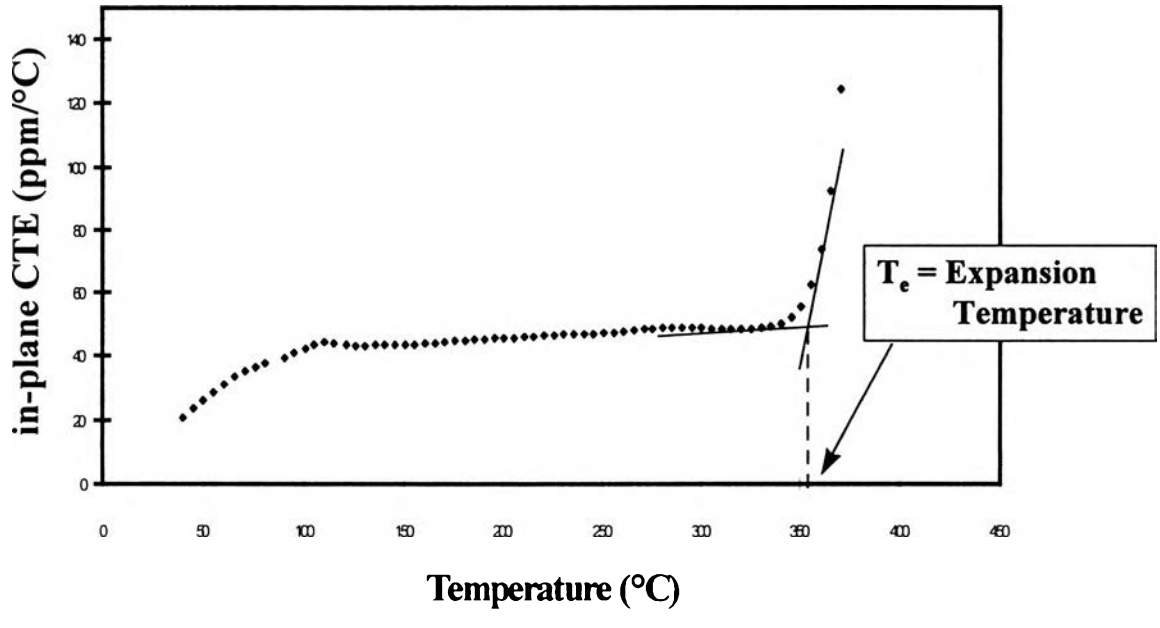

Figure a. The definition of expansion temperature.

(b) Yielding temperature

Definition: The temperature at which the polyimide films start expand. As seen in Figure b, the yielding temperature is the 0.2% off-set of the elongation axis.

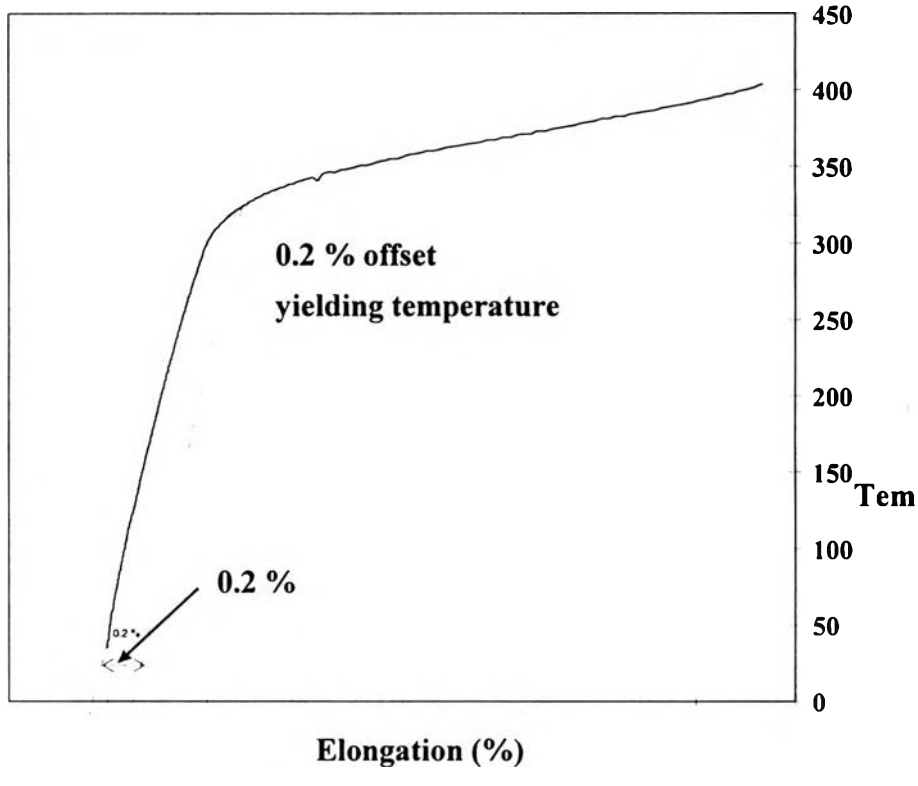

Figure b. The definition of 0.2 % off-set yielding temperature.

III.2 Expansivity in in-plane direction of polyimide films cured at 400°C with a ramping rate of 2°C/min.

BPDA/PDA

Curing time (min.)	CTE avr (50-300°C) (10^{-6}/°C)	Te expansion temp (°C)	Off-set yield temperature, T_y (°C)
30 (1)	17.15	338	322
30 (2)	16.59	350	372
average	16.87	344.00	347.00
60 (1)	17.18	304	337
60 (2)	17.92	294	326
average	17.55	299.00	331.50
120 (1)	17.03	340	334
120 (2)	16.64	333	366
average	16.84	336.50	350.00
180 (1)	17.25	353	384
180 (2)	19.06	351	384
average	18.15	352.00	384.00
240 (1)	17.12	314	366.5
240 (2)	18.12	329	375
average	17.62	321.50	370.75

PMDA/ODA

Curing time (min.)	avr in-plane CTE (50-300°C) (10^{-6}/°C)	Te expansion temp (°C)	Off-set yield temperature, T_y (°C)
30 (1)	44.14	359	390
30 (2)	42.72	350	369
average	43.43	354.50	379.50
60 (1)	40.99	364	386
60 (2)	34.34	364	378
average	37.67	364.00	382.00
120 (1)	35.59	365	380
120 (2)	35.14	358	380
average	35.36	361.50	380.00
180 (1)	39.39	355	405
180 (2)	36.62	366	396
average	38.01	360.50	400.50
240 (1)	40.91	357	386
240 (2)	41.43	362	392
average	41.17	359.50	389.00

BTDA-ODA/MDA

Curing time (min.)	In-plane CTE (50-300°C) (10^{-6}/°C)	Te expansion temp (°C)	T_y, Off-set yield temperature, (°C)
30 (1)	54.25	292	310
30 (2)	45.59	305	313
average	49.92	298.50	311.50
60 (1)	47.81	303	324
60 (2)	48.91	300	316
average	48.36	301.50	320.00
120 (1)	45.32	304	354
120 (2)	44.78	301	318
average	45.05	302.50	336.00
180 (1)	46.66	337	332
180 (2)	45.42	337	346
average	46.04	337.00	339.00
240 (1)	41.03	293	318
240 (2)	45.04	296	316
average	43.04	294.50	317.00

III.3 Expansivity in out-of-plane direction

Polyimide films	Out-of-plane CTE, a_Z (ppm/°C)		
	PI-2610	PI-2540	PI-2579
#1	1940	769	140
#2	1821	629	290
average	1881	699	215
standard deviation	84.15	98.99	106.07

III.4 Thermal cycling experiment for polyimide film in in-plane direction.

Instrument: Thermomechanical Analyzer TMA 7 with the quartz extension probe.

Samples: Polyimide films which was cured at 400°C for 1 hours with the ramping rate 2°C/min.

Procedure: The dimension of the thin films were 2 mm width and 15 mm long. The specimen was clamped between the chucks and annealed from 35°C to 300°C with the heating rate of 10°C/min and then cool down to 35°C with the cooling rate 5°C/min. The instrument was run to monitor the length of the thin film between the chucks when heating from 35°C to 300°C with the ramping rate at 5° C/min

Cycle #	In-plane CTE (α_{xy}) (°C/ppm)		
	PI2610 Semirigid	**PI2540** Semiflexible	**PI2579** Flexible
1	14.7	40.8	49.3
2	14.6	40.8	48.4
3	15.9	38.4	45.6
4	14.8	39.4	50.7
5	16.5	40.7	51.8
6	15.5	39.5	52.9
7	14.8	41.7	52.9
8	14.1	41.5	57.5
9	14.5	39.3	56.5
10	14.8	40	57.5

APPENDIX IV
DIELECTRIC STRENGTH MEASUREMENT

Follow Testing Method for Electric Strength of Solid insulating Material (JIS C2110)

1. Kind of ambient medium : Air
2. Pretreatment condition : conditioning the samples for 96 hours at 23°C, 24% relative humidity.
3. Testing condition: Testing in the air at 23°C, 70% relative humidity.
4. Electrode type

electrode material	iron
shape	sphere
dimension	diameter 12.5 mm of sphere
compression force	500 g.

5. Method of voltage application :
   short time breakdown
6. Instrument:
   Electric Puncture Tester, Yasuda Seiki Seisakusho LTD.
7. Dielectric Breakdown and thickness

polyimide films	**No.**	**thickness (mil)**	**dielectric breakdown voltage (V)**	**dielectric strength (V/mil)**	
PI2610 (BPDA//PDA)	1	0.688	5300	7703.5	
	2	0.664	4400	6626.5	
	3	0.848	5700	6721.7	
	4	0.488	3700	7582.0	
	5	0.48	3400	7083.3	
	6	0.544	3500	6433.8	
	7	0.648	4000	6172.8	
	8	0.664	3400	5120.5	
	9	0.544	3900	7169.1	
	10	0.784	4600	5867.3	
					stdev
Mean value of dielectric breakdown strength				**6648.1**	**793.5646**

polyimide film	No.	thickness (mil)	dielectric breakdown voltage (V)	dielectric strength (V/mil)	
PI2579 (BTDA//ODA-MDA)	1	0.592	3200	5405.4	
	2	0.464	3500	7543.1	
	3	0.656	3200	4878.0	
	4	0.84	4700	5595.2	
	5	0.752	5000	6648.9	
	6	0.648	4300	6635.8	
	7	0.76	3100	4078.9	
	8	0.696	5000	7183.9	
	9	0.96	5000	5208.3	
	10	0.752	5000	6648.9	
					stdev
Mean value of dielectric breakdown strength				**5982.7**	**1111.536**

polyimide film	No.	thickness (mil)	dielectric breakdown voltage (V)	dielectric strength (V/mil)	
PI2540 (PMDA//ODA)	1	1.304	6800	5214.7	
	2	1.264	7000	5538.0	
	3	1.232	6500	5276.0	
	4	1.248	6600	5288.5	
	5	1.504	7500	4986.7	
	6	1.44	7800	5416.7	
	7	1.352	7500	5547.3	
	8	0.928	5900	6357.8	
	9	0.92	6100	6630.4	
	10	0.944	3500	3707.6	
					stdev
Mean value of dielectric breakdown strength				**5396.4**	**786.6422**

polyimide film	No.	thickness (mil)	dielectric breakdown voltage (V)	dielectric strength (V/mil)	
Polyethylene		1.432	7300	5097.8	
(Plastic bag)		1.336	6500	4865.3	
		1.264	6600	5221.5	
		1.336	6700	5015.0	
		1.352	6900	5103.6	
		1.128	6400	5673.8	
		1.096	6800	6204.4	
		1.416	7100	5014.1	
		1.352	7000	5177.5	
		1.208	6300	5215.2	
					stdev
Mean value of dielectric breakdown strength				**5258.8**	**394.4655**

APPENDIX V
DIELECTRIC CONSTANT AND DISSIPATION FACTOR

Dielectric constant Measurement

Definitions

1. capacitance, C is the property of a system of conductors and dielectrics which permits the storage of electrically separated charges when potential differences exist between the conductors. Numerically it is the ratio of a quantity, Q, or charge to a potential difference, V. A capacitance value is always positive. The units are farads when the charge is expressed in coulombs and the potential in volts

$$C = Q/V \qquad (a)$$

2. dielectric constant, (permittivity, capactivity, or specific inductive capacity), κ' is the ratio of the capacitance, C_X, of a given configuration of electrodes with a material as the dielectric, to the capacitance, C_V of the same electrode configuration with a vacuum (or air for most practical purposes) as the dielectric:

$$k' = C_X/C_V \qquad (b)$$

3. dielectric phase angle, θ is the angular difference in the phase between the sinusoidal alternating potential difference applied to a dielectric and the component of the resulting alternating current having the same period as the potential difference

4. dielectric dissipation factor, or loss tangent, D

the tangent of the loss angle or the cotangent o the phase angle.

$$D = \tan\delta - \cot\theta = X_p/R_p \quad (c)$$

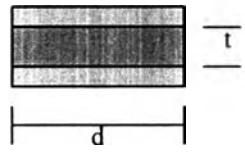

Figure a The electrode system for dielectric measurement

From Micrometer electrode Measurement

1. Dielectric Constant (k'_x)

$$k'_x = \{1/[1-(\Delta C_p/C_p)(t_o/t)\} \quad (d)$$

where

t_o = parallel plate spacing

t = average thickness of specimen

ΔC_p = capacitance change when specimen is inserted (when capacitance increases.)

C_p = capacitance with specimen in place

2. Dissipation Factor, (D_x)

$$D_x = D_c + M\, k'_x\, \Delta D \quad (e)$$

where

D_c = dissipation factor with specimen in place.

M = to/t - 1

ΔD = increase in dissipation factor when specimen is inserted

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