REFERENCES

Akinlabi, A.K., Okieimen, F.E., Egharevba, F., and Malomo, D. (2006) Investigation of the effect of mixing schemes on rheological and physico-mechanical properties of modified natural rubber blends. Materials and Design, 27, 783-788.

Arayawongkul, S., Nithitanakul, M., Kitiyanan, B., and O'Haver, J.H. (2002) Characterization of polystyrene produced by admicellar polymerization. M.S. Thesis, The Petroleum and Petrochemical College, Chulalongkorn University, Bangkok, Thailand.

Asaletha, R., Groeninckx, G., Kumaran, G., and Thomas, S. (1998) Melt rheology and morphology of physically compatibilized natural rubber-polystyrene blends by the addition of natural rubber-g-polystyrene. Journal of Polymer Science, 69, 2673-2690.

Bhowmick, A.K., and Shanmugharaj, A.M. (2004) Rheological properties of styrene-butadiene rubber filled with electron beam modified surface treated dual phase fillers. Radiation Physics and Chemistry, 69, 91-98.

Boochathum, P., and Chiewnawin, S. (2001) Vulcanization of cis-and trans-polyisoprene and their blends: crystallization characteristics and properties. European Polymer Journal, 37, 429-434.

Bunsomsit, K., Magaraphan, R., O'Rear, E.A., and Grady, B.P. (2002) Polypyrrole-coated natural rubber latex by admicellar polymerization. Colloid Polymer Sci, 280, 509-516.

Chenal, J.M., Chazeau, L., Guy, L., Bomal, Y., and Gauthier, C. (2007) Molecular weight between physical entanglements in natural rubber: A critical parameter during strain-induced crystallization. Polymer, 48, 1042-1046.

Dick, J.S. (2001) Rubber technology: compounding and testing for performance. 329-331. Munich: Hanser.

Funkhouser G.P., Arevale, M.P., Glatzhofer, D.T., and O'Rear E.A. (1995) Solubilization and adsolubilization of pyrrole by sodium dedecyl sulfate: polypyrrole formation on alumina surfaces. Langmuir, 7(8), 1175-1178.

Gahleitner, M. (2001) Melt rheology of polyolefins. Progress in Polymer Science, 26, 895-944.

Leblanc, J.L. (2002) Rubber-filler interactions and rheological properties in filled compounds. Progress in Polymer Science, 27, 627-687.

Menon, A.R.R. (2003) Melt rheology of ethylene propylene diene rubber modified with phosphorylated cashew nut shell liquid prepolymer. Iranian Polymer Journal, 12(4), 305-313.

Nakason, C., Kaesaman, A., Samoh, Z., Homsin, S., and Kiatkamjornwong, S. (2002) Rheological properties of maleated natural rubber and natural rubber blends. Polymer Testing. 21, 449-455.

Nakason, C., Saiwari, S., and Kaesaman, A. (2006) Rheological properties of maleated natural rubber/polypropylene blends with phenolic modified polypropylene and polypropylene-*g*-maleic anhydride compatibilizers. Polymer Testing. 25(3), 413-423.

Nontasorn, P., Chavadej, S., Rangsunvigit, P., O'Haver, J.H., Chasirimahamorakot, S., and Na-Ranong, N. (2005) Admicellar polymerization modified silica via a continuous strirred-tank reactor system: Comparative properties of rubber compounding. Chemical Engineering Journal, 108, 213-218.

Paria, S., and Khilar, K.C. (2004) A review on experimental studies of surfactant adsorption at the hydrophilic solid-water interface. Advances in Colloid and Interface Science, 110, 75-95.

Poh, B.T., Ismail, H., and Quah, E.H. (2001) Fatique, resilience and hardness properties of unfilled SMR L/ENR 25 and SMR L/SBR blends. Polymer Testing, 20, 389-394.

Pongprayoon, T., Yanumet, N., and O'Rear, E.A. (2002) Admicellar polymerization of styrene on cotton. Journal of Collid and Interface Science, 249, 227-234.

Preechasup, N. (2006) A novel processible-white natural rubber modified by admicellar polymerization of styrene as nano-core shell structure. M.S. Thesis, The Petroleum and Petrochemical College, Chulalongkorn University, Bangkok, Thailand.

Rungruang, P., Grady, B.P., and Supaphol, P. (2006) Surface-modified calcium carbonate particles by admicellar polymerization to be used as filler for isotactic polypropylene. Colloids and Surfaces A: Physicocehm. Eng. Aspects, 275, 114-125.

Srinarang, V. (2004) Admicellar polymerization of polystyrene on natural rubber particles. M.S. Thesis, The Petroleum and Petrochemical College, Chulalongkorn University, Bangkok, Thailand.

Thomas, S., Oommen, Z., Premalatha, C.K., and Kuriakose, B. (1997) Melt rheological behavior of natural rubber/poly(methyl methacrylate)/natural rubber-g-poly(methyl methacrylate) blends. Polymer, 38, 5611-5621.

Thomas, S., Mathew, A.P., and Packirisamy, S. (2001) Studies on the thermal stability of natural rubber/polystyrene interpenetrating polymer networks: thermogravimetric analysis. Polymer Degradation and Stability, 72, 423-439.

Varghese, S., Vinod, V.S., and Kuriakose, B. (2002) Degradation behavior of natural rubber-aluminium powder composites: effect of heat, ozone and high energy radiation. Polymer Degradation and Stability, 75, 405-412.

Weddell, W.H., O'Haver, J.H., Harwell, J.H., Osuwan, S., Na-Ranong, N., and Thammathadanukul, V. (1996) Journal of Applied Polymer Science, 59, 1741-1751.

Wood, A.K., Sombatsompop, N., and Tan, M.C. (1997) Flow analysis of natural rubber in capillary rheometer. 1: Rheological behavior flow visualization in the barrel. Polymer Engineering and Science, 37(2), 270-280.

Wu, J., Harwell, J.H., and O'Rear, E.A. (1987) Langmuir, 3(4), 531-537.

Xin, W., Andrew, D.W., Walter, A., and Grady, B.P. (2003) Journal of Colloid and Interface Science, 264, 296-300.

APPENDICES

Appendix A Calculation of Percent Weight Polystyrene in Admicelled PS-NR

Weight of PS = [conc. Of styrene monomer x 104.5 x total volume]/ 1000 ml

Example The calculation of wt % PS in admicelled PS-NR with 50 mM-styrene

Weight of PS = [50 (mM) x 104.5 (g/mol) x 1000 ml]/1000 ml

= 5.225 g

Total weight of admicelled PS-NR = 50 + 5.225 = 55.225 g

wt.% of PS = (5.225 x 100)/55.225 = 9.46 %

Table A1 wt.% of PS in admicelled PS-NR with different concentrations of styrene monomer

Samples	NR used (g)	Calculated PS (g)	Admicelled PS-NR (g)	Wt % of PS (%)
50 mM-styrene	50	5.225	55.225	9.46
100 mM-styrene	50	10.450	60.450	17.29
200 mM-styrene	50	20.900	70.900	29.48
300 mM-styrene	50	31.350	81.350	38.54

Appendix B Data of Protein Contents Measurement

Table B1 Protein contents of admicelled PS-NR by using modified lowry method

Samples	Water soluble protein (μg/g)
0 mM-styrene (NR)	15
50 mM-styrene	14
100 mM-styrene	12
200 mM-styrene	13
300 mM-styrene	15

Appendix C Data of Molecular Weight Measurement

Table C1 Molecular weight of admicelled PS-NR measured by GPC method

Samples	Mn	Mw
50 mM-styrene	1,501	42,419
100 mM-styrene	7,953	120,482
200 mM-styrene	57,660	451,630
300 mM-styrene	115,627	453,652

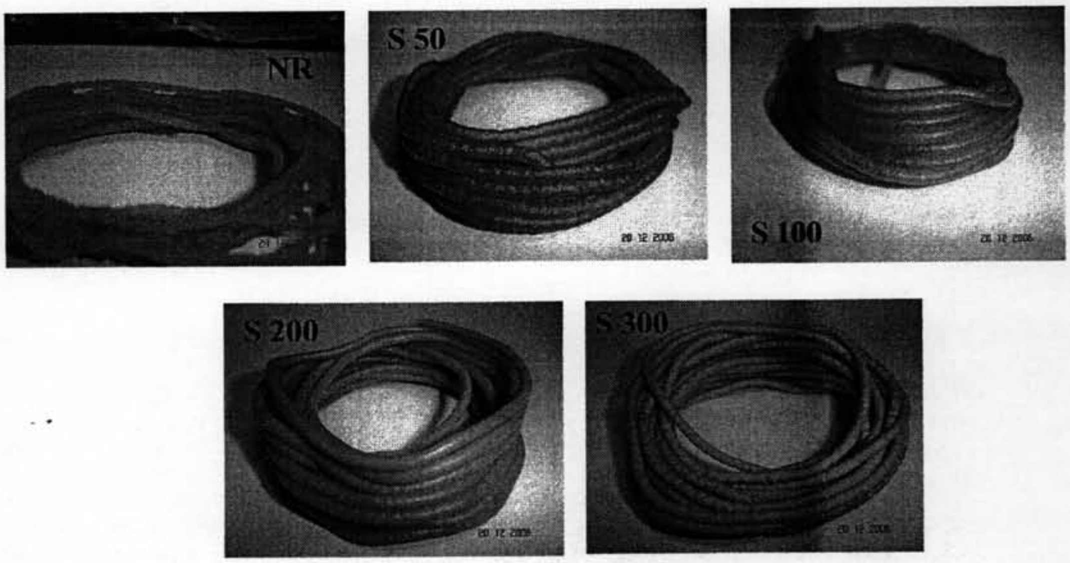

Figure C1 Extrudate photos of 30 phr-silica filled admicelled PS-NR with different concentrations of styrene monomer using circular die.

Appendix D Chemicals Amount used for Synthesis of Admicelled PS-NR

- Total volume of 1 batch synthesis = 1,000 ml
- Molar ratio of styrene to initiator = 1:0.04 (S:I)
- CTAB concentration used = 2,8000 μm

Table D1 Chemical ingredients for admicelled PS-NR

Ingredients	Admicelled PS-NR			
	50 mM-styrene	100 mM-styrene	200 mM-styrene	300 mM-styrene
NR Latex	50 g	50 g	50 g	50 g
CTAB (20,000 μM)	140 ml	140 ml	140 ml	140 ml
Styrene (8.62 M)	5.80 ml	11.6 ml	23.20 ml	34.80 ml
V50 (250 mM)	8 ml	16 ml	32 ml	48 ml
Water with pH 8	Fill to make solution volume til1,000 ml			

Appendix E Data of Rheology

Table E1 Die swell data of pure NR

L/D ratio	shear rate (s^{-1})	Temperature (°C)				
		130	140	150	160	170
0.5	10	135	104	109	102	105
	50	136	110	170	96	79
	100	151	131	118	105	95
	300	188	171	154	114	111
	600	183	170	158	136	119
	1000	240	206	165	133	128
5	10	173	70	72	99	65
	50	96	82	58	62	54
	100	110	87	81	69	53
	300	136	163	82	77	68
	600	173	140	110	86	73
	1000	176	147	122	100	82
20	10	76	60	60	61	122
	50	68	89	54	56	46
	100	77	70	62	61	52
	300	92	88	71	62	49
	600	114	102	80	72	58
	1000	125	112	85	76	65

Table E2 Die swell data of pure admicelled PS-NR with 50 and 100 mM-styrene

Styrene concentration	L/D ratio	shear rate (s^{-1})	Temperature (°C)				
			130	140	150	160	170
50 mM	0.5	10	170	153	133	120	122
		50	181	148	147	148	138
		100	170	158	154	151	146
		300	189	185	180	171	163
		600	193	179	178	178	163
		1000	195	194	182	179	174
	5	10	90	106	96	100	95
		50	106	109	97	99	99
		100	120	115	112	99	93
		300	133	118	110	108	102
		600	136	122	114	112	104
		1000	135	128	119	121	119
	20	10	84	72	72	64	63
		50	81	72	76	71	54
		100	88	73	73	73	63
		300	104	93	92	77	77
		600	109	95	93	91	83
		1000	116	103	102	92	88
100 mM	0.5	10	136	132	132	141	121
		50	139	134	111	126	118
		100	149	136	127	131	118
		300	154	144	135	142	123
		600	166	158	152	150	141
		1000	168	177	147	167	147
	5	10	91	91	98	91	81
		50	88	92	86	86	78
		100	88	95	90	86	83
		300	104	104	92	99	84
		600	114	110	109	103	100
		1000	121	111	113	107	99
	20	10	70	72	70	71	70
		50	76	73	78	70	69
		100	78	74	72	68	73
		300	84	80	80	74	74
		600	93	89	84	83	81
		1000	99	93	92	86	82

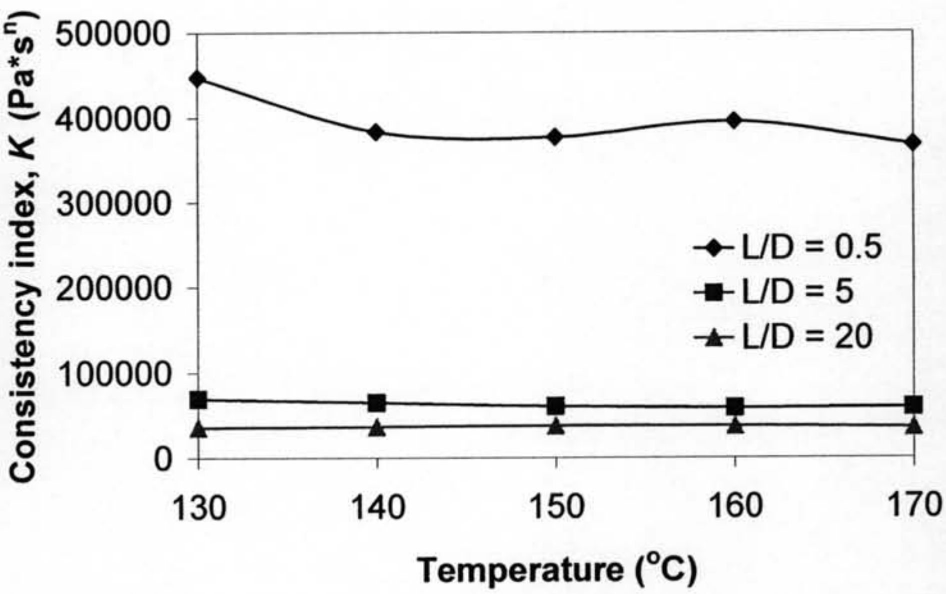

Figure E1 Consistency index of pure NR versus temperature using circular die at different L/D ratios.

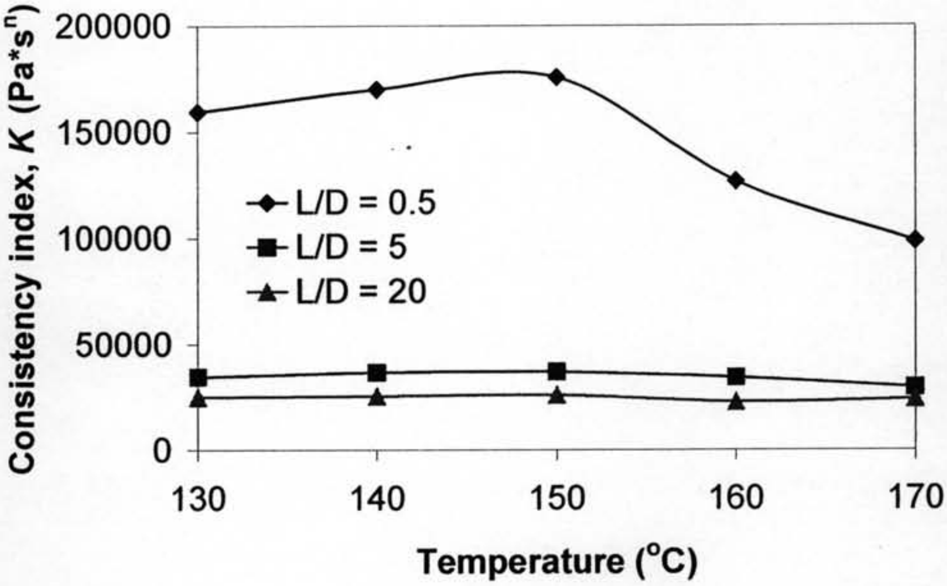

Figure E2 Consistency index of pure admicelled PS-NR with 50 mM-styrene versus temperature using circular die at different L/D ratios.

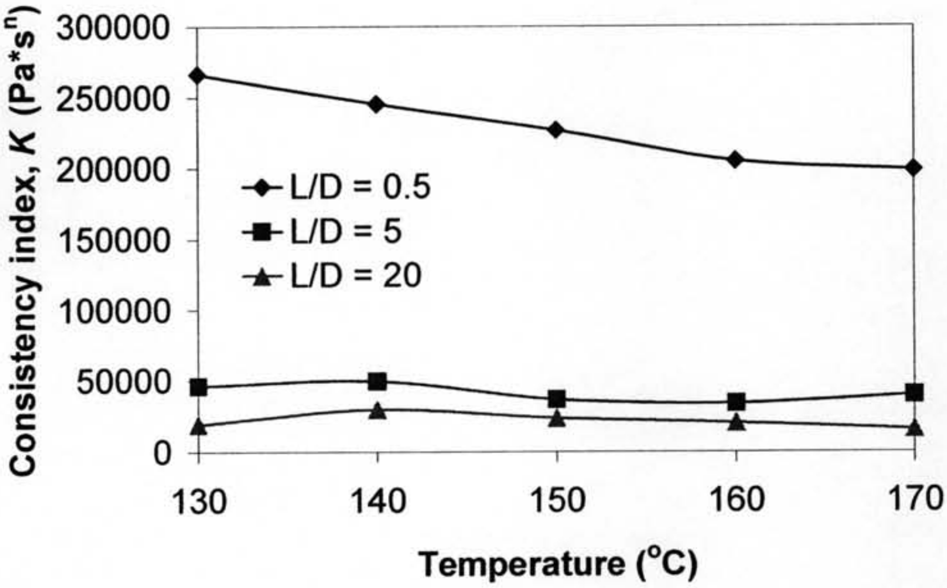

Figure E3 Consistency index of pure admicelled PS-NR with 100 mM-styrene versus temperature using circular die at different L/D ratios.

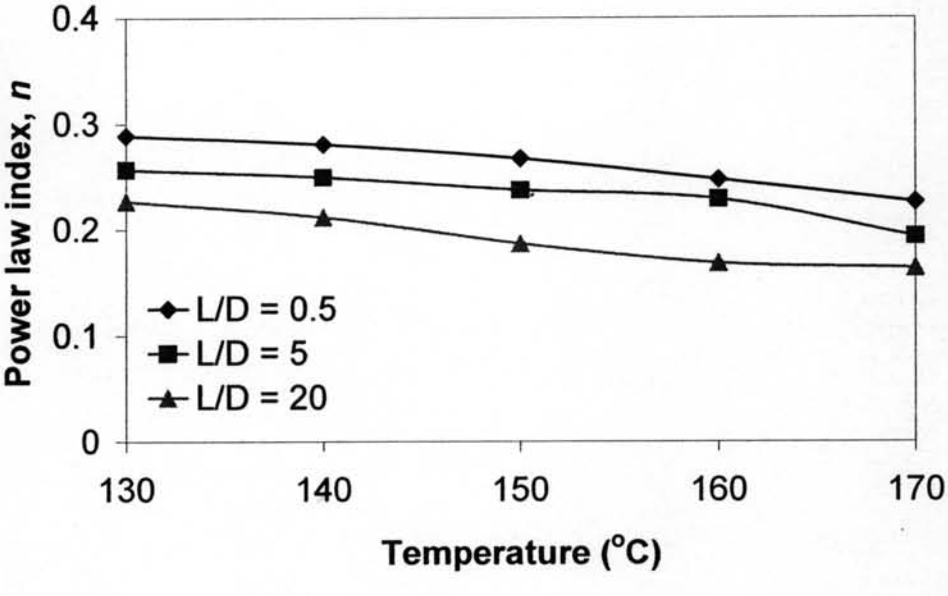

Figure E4 Power law index of pure NR versus temperature using circular die at different L/D ratios.

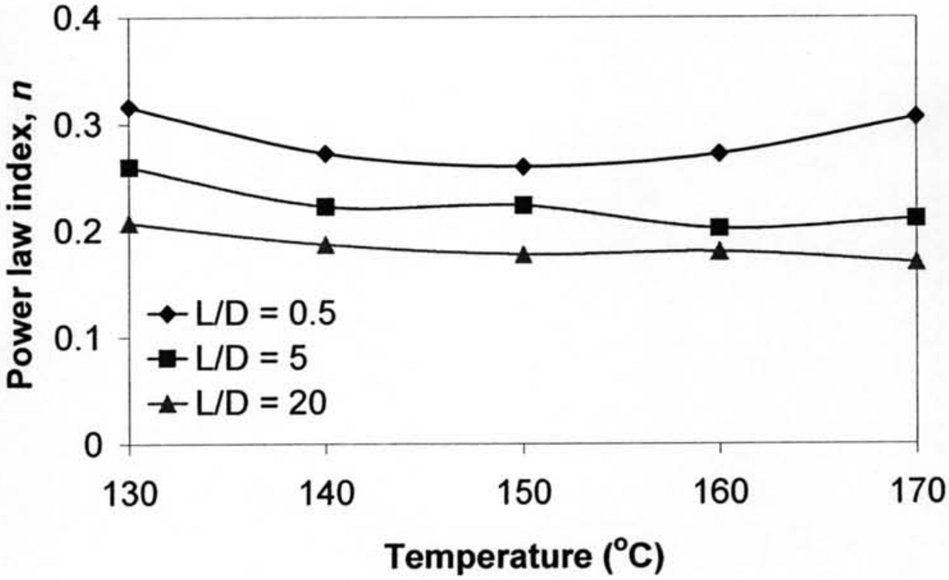

Figure E5 Power law index of pure admicelled PS-NR with 50 mM-styrene versus temperature using circular die at different L/D ratios.

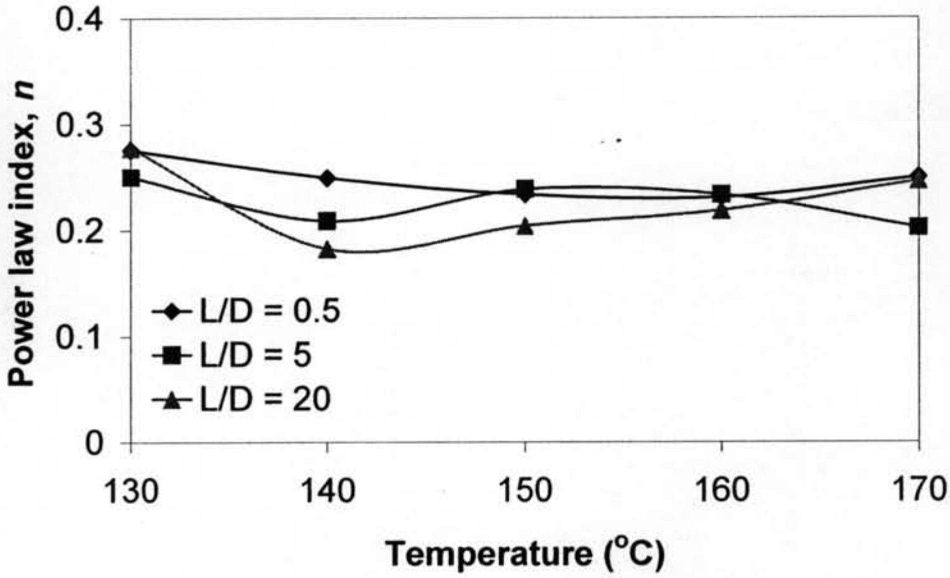

Figure E6 Power law index of pure admicelled PS-NR with 100 mM-styrene versus temperature using circular die at different L/D ratios.

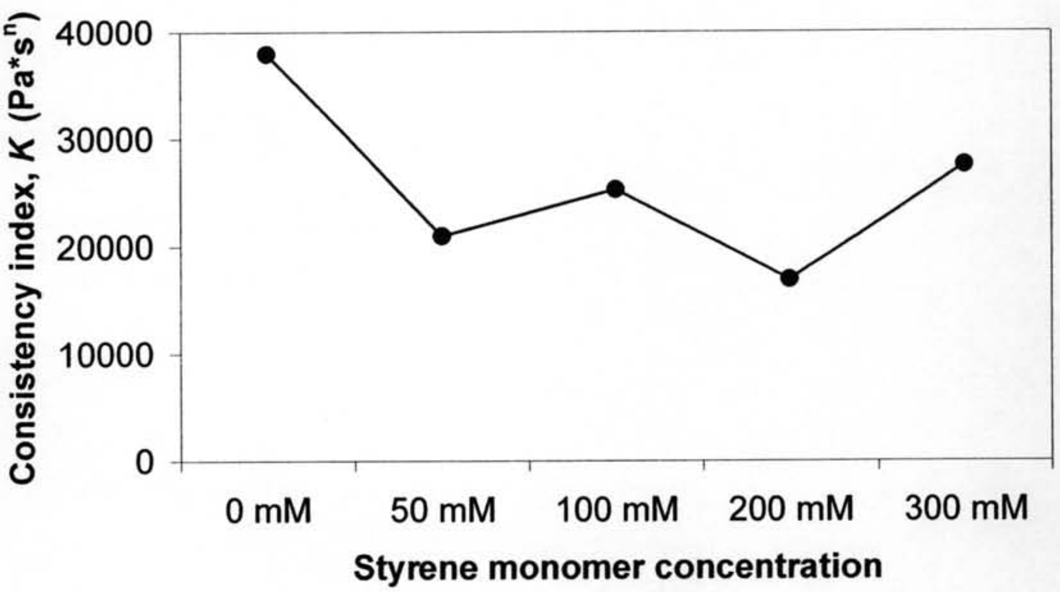

Figure E7 Consistency index of 50/50 NR/admicelled PS-NR blends at 150°C using circular die with L/D ratio of 7.5 (die length =15 and die diameter =2 mm).

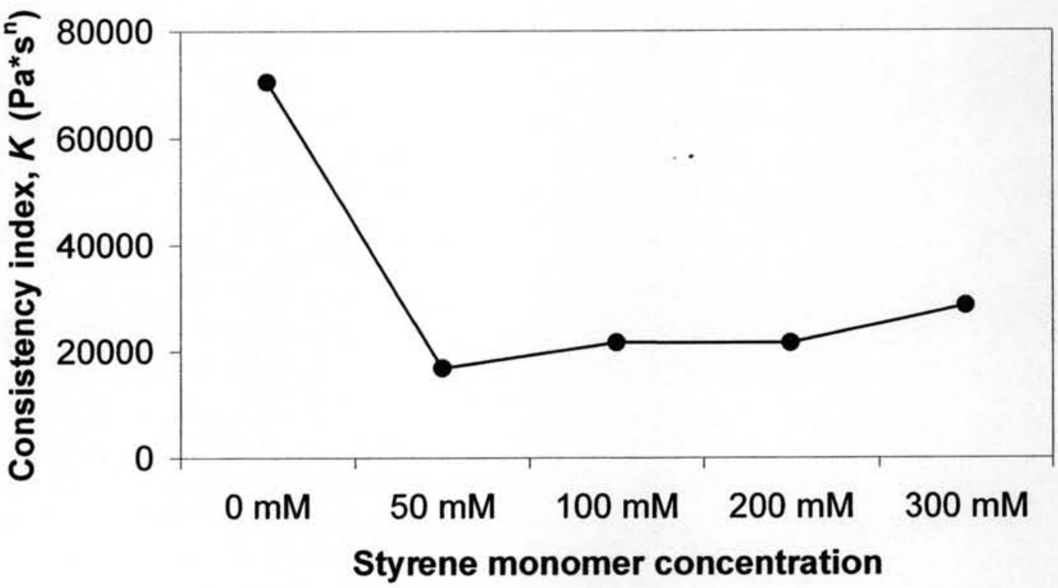

Figure E8 Consistency index of 30 phr-silica filled admicelled PS-NR at 150°C using circular die with L/D ratio of 7.5 (die length =15 and die diameter =2 mm).

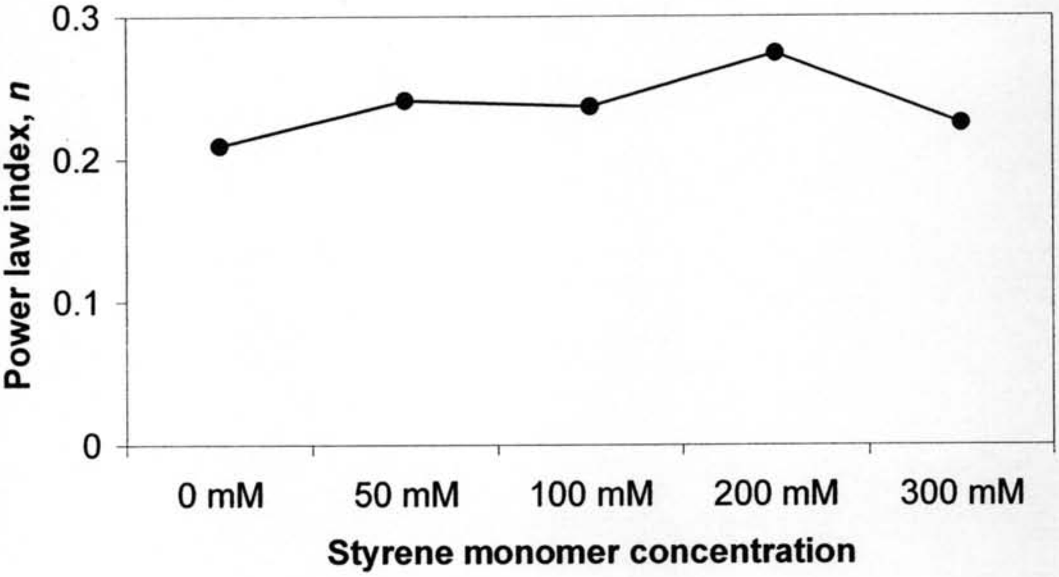

Figure E9 Power law index of 50/50 NR/admicelled PS-NR blends at 150°C using circular die with L/D ratio of 7.5 (die length =15 and die diameter =2 mm).

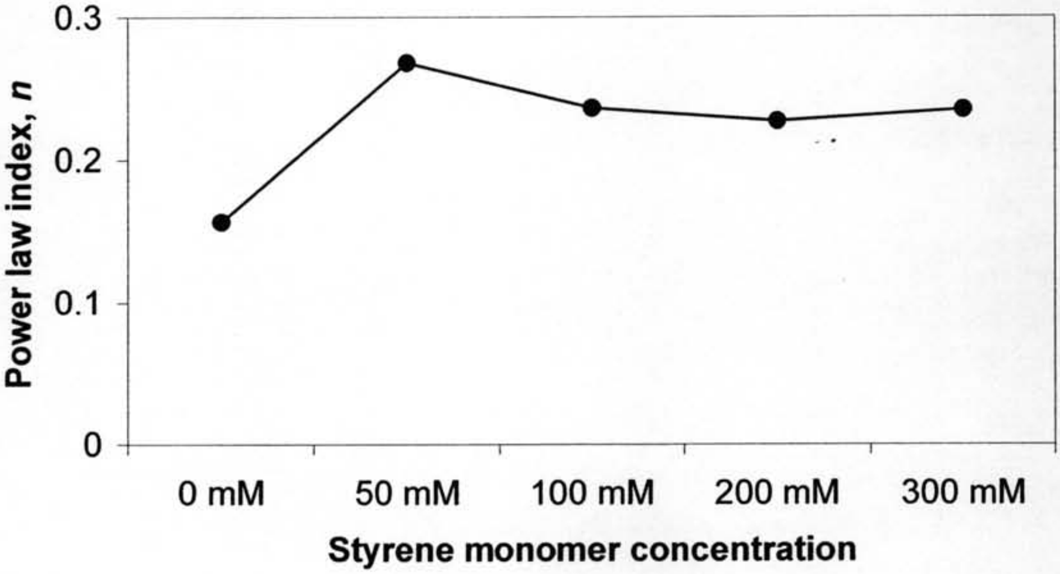

Figure E10 Power law index of 30 phr-silica filled admicelled PS-NR at 150°C using circular die with L/D ratio of 7.5 (die length =15 and die diameter =2 mm).

Appendix F Data of Crosslink Density

The calculation of crosslink density was measured by using Flory-Rehner equation as following:

$$\nu_e = \rho_d / M_c = -[\ln(1-V_r) + V_r + \chi_1 V_r^2]/[V_1(V_r^{1/3} - V_r/2)]$$

$$\text{and} \quad V_r = [W_d/\rho_d]/[(W_d/\rho_d) + (W_s/\rho_s)]$$

where:

ν_e = network chain density (mol/cm^3)

V_r = volume fraction of polymer in a swollen network in equilibrium with pure solvent

W_d = weight of dry rubber (g)

W_s = weight of solvent adsorbed by sample (g)

ρ_d = density of dry rubber (g/cm^3)

ρ_s = density of toluene = 0.867 g/cc

χ_1 = rubber-toluene interaction parameter = 0.391

V_1 = molecular volume of toluene = 106.3 cm^3/mol

M_c = average molecular weight between the network crosslinks (g/mol)

Table F1 Crosslink density of cured admicelled PS-NR with different concentrations of styrene monomer using Flory-Rehner equation

Samples	ρ_d	W_d	W_s	V_r	ν_e	M_c
0 mM-styrene (NR)	0.9786	0.2982	0.9138	0.2243	1.90x10^{-4}	5146
50 mM-styrene	0.9704	0.2831	0.8412	0.2312	2.05x10^{-4}	4740
100 mM-styrene	0.9597	0.2887	0.8951	0.2256	1.93x10^{-4}	4967
200 mM-styrene	0.9483	0.2683	0.8469	0.2246	1.91x10^{-4}	4962
300 mM-styrene	0.9670	0.2867	0.8821	0.2256	1.93x10^{-4}	5003

Appendix G Data of Tensile Testing

Table G1 Tensile strength of admicelled PS-NR samples with different concentrations of styrene monomer

Sample types	Styrene concentration	Tensile strength (MPa)						
		Number of dumbbell specimens					Median	S.D.
		1	2	3	4	5		
Cured samples	0 mM (NR)	31.89	25.42	22.62	26.20	21.46	25.42	4.06
	50 mM	27.59	28.79	22.37	19.94	17.92	22.37	4.73
	100 mM	23.01	20.22	19.86	23.26	25.29	23.01	2.27
	200 mM	8.99	24.74	22.07	22.98	27.30	22.98	7.12
	300 mM	25.16	24.32	25.90	29.05	26.35	25.90	1.79
Cured samples with aging	0 mM (NR)	12.32	11.16	1.67	7.93	14.85	11.16	5.08
	50 mM	13.84	12.09	12.80	12.77	9.16	12.77	1.78
	100 mM	11.49	6.84	3.79	10.78	10.97	10.78	3.35
	200 mM	6.42	6.91	7.11	11.27	10.09	7.11	2.17
	300 mM	8.64	8.24	10.71	8.97	14.36	8.97	2.52
Silica filled samples	0 mM (NR)	3.24	3.82	3.63	4.05	2.95	3.63	0.44
	50 mM	0.95	1.05	1.04	0.95	1.00	1.00	0.05
	100 mM	1.43	1.20	1.11	1.46	1.40	1.40	0.16
	200 mM	1.56	1.32	1.73	1.70	1.29	1.56	0.21
	300 mM	3.43	2.97	3.10	3.37	3.04	3.10	0.20
NR blended samples	0 mM (NR)	0.41	0.45	0.50	0.41	0.46	0.45	0.03
	50 mM	0.33	0.35	0.32	0.37	0.37	0.35	0.03
	100 mM	0.36	0.28	0.37	0.36	0.32	0.36	0.04
	200 mM	0.26	0.32	0.35	0.31	0.39	0.32	0.05
	300 mM	0.57	0.46	0.38	0.52	0.48	0.48	0.07

Table G2 Elongation at break of admicelled PS-NR samples with different concentrations of styrene monomer

Sample types	Styrene concentration	Elongation at break (%)						
		Number of dumbbell specimens					Median	S.D.
		1	2	3	4	5		
Cured samples	0 mM (NR)	2594	2224	2269	2645	2242	2269	206
	50 mM	2492	2348	2624	1707	1741	2348	430
	100 mM	1821	1827	1714	1854	1907	1827	70
	200 mM	752	1657	1411	1681	1957	1657	456
	300 mM	1373	1143	1397	1424	1228	1373	122
Cured samples with aging	0 mM (NR)	1562	1583	237	1253	1731	1562	605
	50 mM	1508	1511	1480	1406	1239	1480	114
	100 mM	1334	896	552	1185	1311	1185	331
	200 mM	582	639	669	959	869	669	162
	300 mM	485	525	612	525	790	525	122
Silica filled samples	0 mM (NR)	1331	1504	1624	1521	1548	1521	108
	50 mM	1444	1718	1545	1605	1684	1605	110
	100 mM	1381	1325	1409	1438	1359	1381	44
	200 mM	1346	1033	1295	1315	1086	1295	144
	300 mM	1286	1135	1156	1257	1201	1201	64
NR blended samples	0 mM (NR)	623	649	751	499	632	632	90
	50 mM	823	941	1058	917	1080	941	106
	100 mM	829	658	605	821	586	658	117
	200 mM	552	698	753	440	723	698	133
	300 mM	819	677	527	740	617	677	112

Table G3 Young's modulus of admicelled PS-NR samples with different concentrations of styrene monomer

Sample types	Styrene concentration	Young's modulus (MPa)						
		Number of dumbbell specimens					Median	S.D.
		1	2	3	4	5		
Cured samples	0 mM (NR)	1.23	1.14	1.00	0.99	0.96	1.00	0.12
	50 mM	1.11	1.23	0.85	1.17	1.03	1.11	0.15
	100 mM	1.26	1.11	1.16	1.25	1.33	1.25	0.09
	200 mM	1.20	1.49	1.56	1.37	1.39	1.39	0.14
	300 mM	1.83	2.13	1.85	2.04	2.15	2.04	0.15
Cured samples with aging	0 mM (NR)	0.79	0.71	0.70	0.63	0.86	0.71	0.09
	50 mM	0.92	0.80	0.86	0.91	0.74	0.86	0.08
	100 mM	0.86	0.76	0.69	0.91	0.84	0.84	0.09
	200 mM	1.10	1.08	1.06	1.17	1.16	1.10	0.05
	300 mM	1.78	1.57	1.75	1.71	1.82	1.75	0.10
Silica filled samples	0 mM (NR)	0.24	0.25	0.22	0.27	0.19	0.24	0.03
	50 mM	0.07	0.06	0.07	0.06	0.06	0.06	0.00
	100 mM	0.10	0.09	0.08	0.10	0.10	0.10	0.01
	200 mM	0.12	0.13	0.13	0.13	0.12	0.13	0.01
	300 mM	0.27	0.26	0.27	0.27	0.25	0.27	0.01
NR blended samples	0 mM (NR)	0.07	0.07	0.07	0.08	0.07	0.07	0.01
	50 mM	0.04	0.04	0.03	0.04	0.03	0.04	0.00
	100 mM	0.04	0.04	0.06	0.04	0.05	0.04	0.01
	200 mM	0.05	0.05	0.05	0.07	0.05	0.05	0.01
	300 mM	0.07	0.07	0.07	0.07	0.08	0.07	0.00

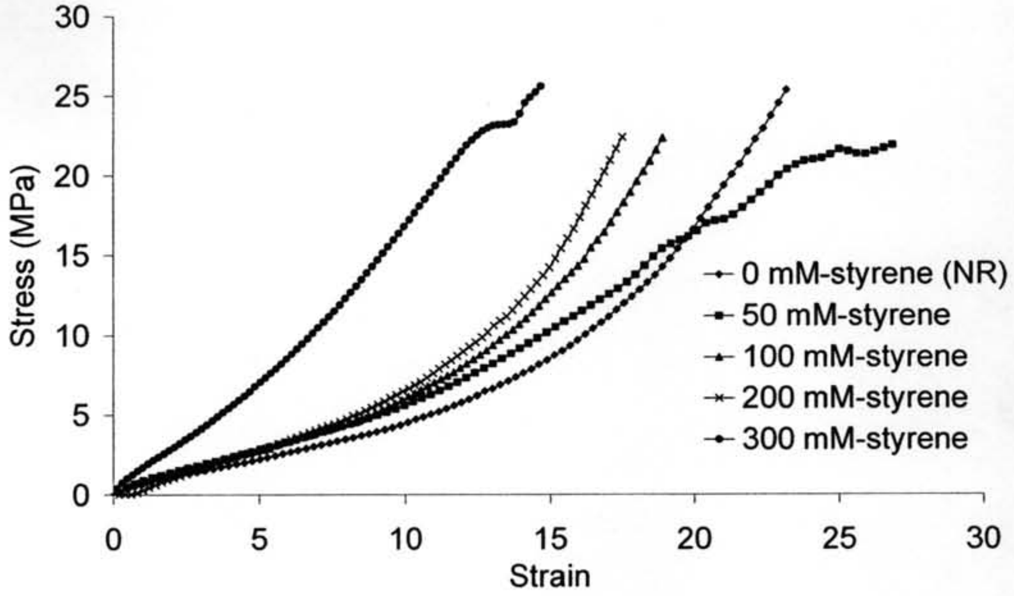

Figure G1 Stress-strain curves of cured admicelled PS-NR with different concentrations of styrene monomer.

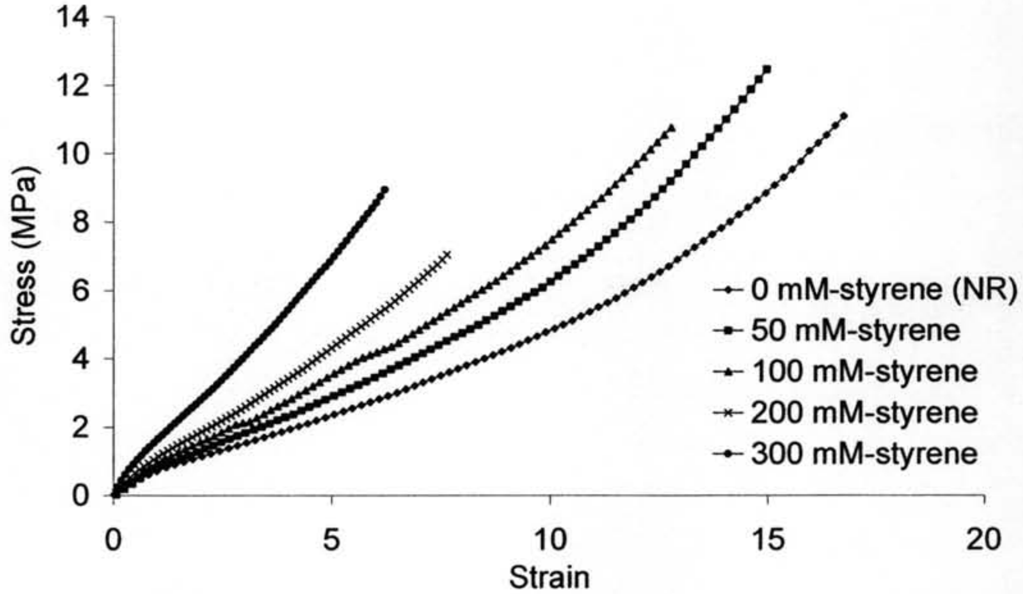

Figure G2 Stress-strain curves of cured admicelled PS-NR with different concentrations of styrene monomer under aging condition.

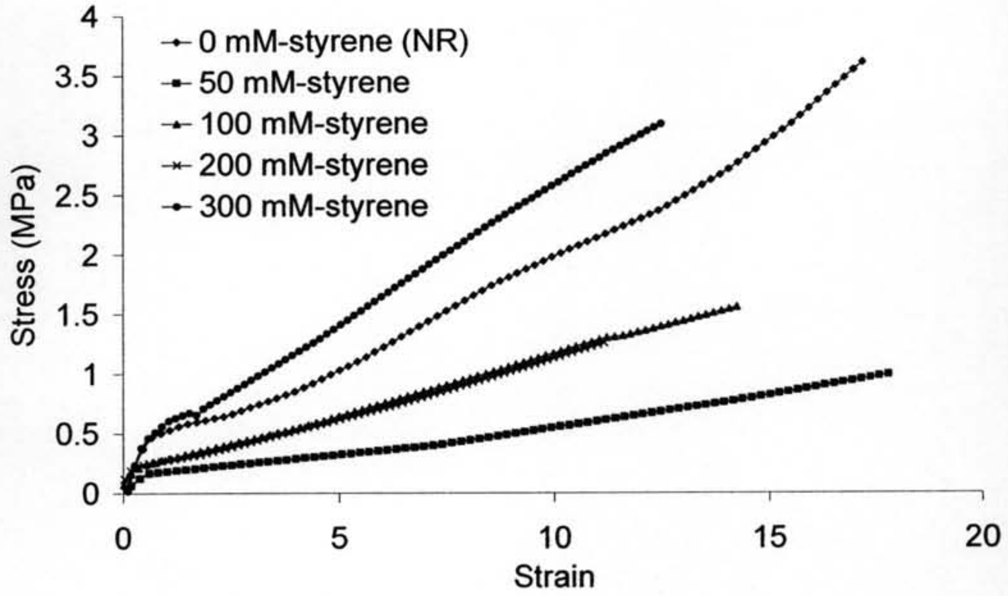

Figure G3 Stress-strain curves of 30 phr-silica filled admicelled PS-NR with different concentrations of styrene monomer.

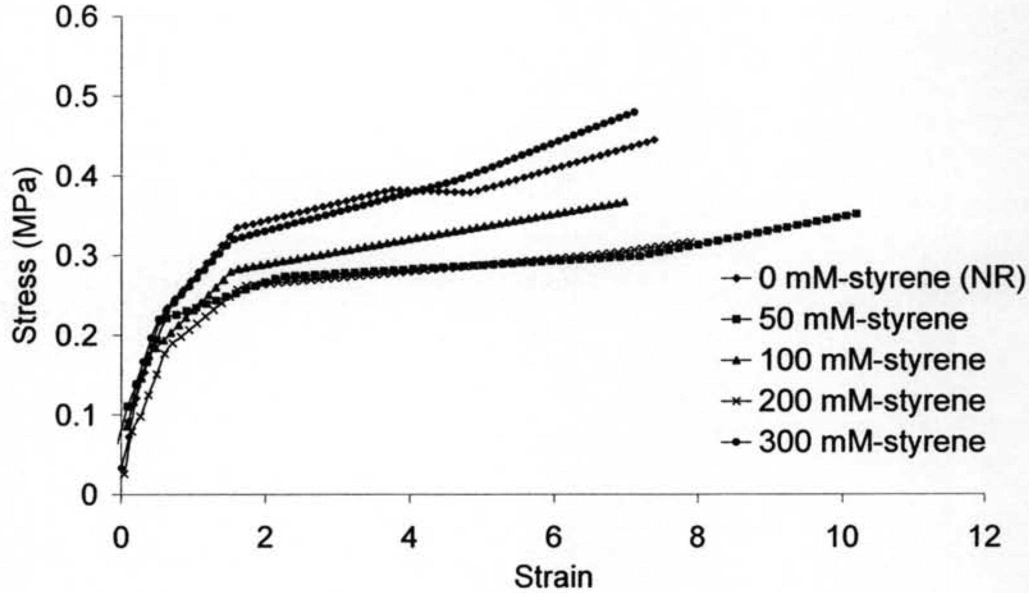

Figure G4 Stress-strain curves of 50/50 NR/admicelled PS-NR blends with different concentrations of styrene monomer.

Appendix H Data of Hardness

Table H1 Hardness of admicelled PS-NR samples with different concentrations of styrene monomer measured by shore A durometer

Sample types	Styrene concentration	Hardness (shore A)						
		Position of determination					Median	S.D.
		1	2	3	4	5		
Cured samples	0 mM (NR)	48	49	49	49	47	49	0.9
	50 mM	52	52	54	51	53	52	1.2
	100 mM	52	52	52	52	53	52	0.5
	200 mM	59	58	57	59	58	58	0.9
	300 mM	65	65	62	65	63	65	1.4
Cured samples with aging	0 mM (NR)	49	49	49	50	50	49	0.3
	50 mM	52	52	52	52	55	52	1.4
	100 mM	53	52	53	54	51	53	1.3
	200 mM	58	58	58	59	58	58	0.5
	300 mM	65	67	64	67	65	65	1.3
Silica filled samples	0 mM (NR)	48	50	48	48	49	48	0.9
	50 mM	32	33	32	32	34	32	0.9
	100 mM	39	42	40	40	41	40	1.1
	200 mM	43	44	38	40	44	43	2.7
	300 mM	60	63	65	64	60	63	2.3
NR blended samples	0 mM (NR)	25	24	24	25	25	25	0.5
	50 mM	19	18	21	20	20	20	1.1
	100 mM	20	18	20	20	20	20	0.9
	200 mM	22	23	24	24	25	24	1.1
	300 mM	23	26	27	27	27	27	1.9

CURRICULUM VITAE

Name: Mr. Saman Isahoh

Date of Birth: August 6, 1980

Nationality: Thai

University Education:

1998-2001 Bachelor Degree of Rubber Technology, Faculty of Science and Technology, Prince of Songkla University, Pattani Campus, Pattani, Thailand

Working Experience:

2000	Position:	Internship student
	Company name:	Thai Bridgestone Co., Ltd.
2002-2005	Position:	Quality engineer
	Company name:	Michelin Siam Co., Ltd.