REFERENCES

Chaisirimahamorakot, S. (2001) Modification of silica surface for rubber reinforcement using a continuous admicellar polymerization system. M.S. Thesis in Petrochemical Technology, The Petroleum and Petrochemical College, Chulalongkorn University.

Chinpan, N. (1996) Comparison of rubber reinforcement using various surface modified silicas. M.S.Thesis in Petrochemical Technology, The Petroleum and Petrochemical College, Chulalongkorn University.

Esumi, K., Maedomari, N., and Torigoe , K. (1996) Adsolubilization of 2-naphthol by binary mixtures of cationic and nonionic surfactant on silica. Langmuir, 17 7350-7354.

Fan, A., Somasundaran, P., and Turro, N.J. (1997) Adsorption of alkyltrimethyammonium bromides on negatively charged alumina. Langmuir, 13(3), 506-510.

Harwell, J.H., Hoskins, J.C., Schechter, R.S. and Wade, W.H. (1985) Pseudophase Separation Model of Surfactant Adsorption: Isomerically Pure Surfactant, Langmuir, 1, 251-262.

Hough, D.B. and Rendall, H.M. (1983) Adsorption from Solution at Solid/Liquid Interface. London: Academic Press.

Iler, R.K. (1979) The Chemistry of Silica. New York: John Wiley & Son.

Ismail, H., Ishiaku, U.S., Ishak, Z.A.M., and Freakley, P.K. (1997) The effects of a cationic surfactant (fatty diamine) and a commercial silane coupling agent on the properties of a silica filled natural rubber compound. European Polymer Journal, 33(1), 1-6.

Kittiyanan, B., O'Haver, J.H., Harwell, J.H., and Osuwan, S. (1996) Adsolubilization of styrene and isoprene in cetyltrimethylammonium bromide admicelle on precipitated silica. Langmuir, 12(9), 2162-2168.

Kudisri, R. (1997) Comparison of surface modified fillers to clay for natural rubber composites. M.S. Thesis in Polymer Scicence, The Petroleum and Petrochemical College, Chulalongkorn University.

Lim-Ochakun, R. (2000) Cure and mechanical properties of filled natural rubber vulcanisates. M.S. Thesis in Polymer Scicence, The Petroleum and Petrochemical College, Chulalongkorn University.

Nontasorn, P. (2002) Improvement of Natural Rubber Properties by Modification of Silica Surface Using a Continuous Admicellar Polymerization System. M.S. Thesis in Petrochemical Technology, The Petroleum and Petrochemical College, Chulalongkorn University.

O'Haver, J.H., Harwell, J.H., Evans, L.R., and Weddell, W.H. (1996) Polar copolymer-modified precipitated silica. Journal of Applied Polymer Science, 59, 1427-1435.

O'Haver, J.H., Harwell, J.H., O'Rear, E.A., Waddell, W.H., Snodgrass, L.J., and Parker, J.R. (1993) Formation of ultrathin polystyrene films in adsorbed surfactant bilayers on silica. Materials Research Society, 304, 161-166.

Porter, M.R. (1994) Handbook of Surfactant. Blackie New York: Academic & Professional.

Rosen, M.J. (1989) Surfactants and Interfacial Phenomena, 2nd Edition. New York: John Willey and Sons.

Laughlin, R.G. (1991) Fundamentals of the zwitterionic hydrophilic group. Langmuir, 7, 842-847.

Sakhalkar, S.S. and Hirt, D.E. (1995) Admicellar polymerization of polystyrene on glass fibers, Langmuir 11, 3369-3373

Sharma, B.G., Basu, S., and Sharma, M.M. (1996) Characterization of adsorbed ionic surfactants on a mica substrate, Langmuir, 12, 6506-6512.

Somasundarun, P. and Fuerstenau, D.W. (1966) Mechanism of Alkyl Sulfonate at the Alumina-Water Interface, Journal of Physical Chemistry, 79, 90-96.

Thammathadanukul, V., O'Haver, J.H., Harwell, J.H., Osuwan, S., Na-Ranong, N., and Weddell, W.H. (1995) Comparison of rubber reinforcement using various surface-modified precipitated silicas. Journal of Applied Polymer Science, 59, 1741-1750.

Waddell, W.H., O'Haver, J.H., Evans, L.R., and Harwell, J.H. (1995) Organic polymer-surface modified precipitated silica. Journal of Applied Polymer Science, 55, 1627-1641.

Wu, J., Harwell, J.H., and O'Rear, E.A. (1987) Two-dimentional reaction solvents: surfactant bilayers in the formation of ultrathin films. Langmuir, 3(4), 531-537.

Yeskie, M.A. and Harwell, J.H. (1988) On the structure of aggregates of adsorbed surfactants: the surface charge density at the humimicelles / admicelle transition. Journal of Physical Chemistry, 92(8), 2346-2352.

APPENDICES

Appendix A Adsorption isotherm.

Adsorption Isotherm

Table A1 Adsorption isotherm of CTAB alone

	Initial micro Mol	Final*	Final** micro Mol	Adsorb* micro Mol	Adsorb** micro mol/g silica
1	1000	5.77	11.74	988.26	39.53
2	2000	9.13	18.58	1981.42	79.26
3	3000	15.48	31.50	2968.50	118.74
4	4000	19.8	40.29	3959.71	158.39
5	5000	24.35	49.54	4950.46	198.02
6	6000	27.18	55.30	5944.70	237.79
7	7000	31.09	63.26	6936.74	277.47
8	8000	35.47	72.17	7927.83	317.11
9	9000	38.07	77.46	8922.54	356.90
10	10000	49.22	100.14	9899.86	395.99
11	11000	47.75	97.15	10902.85	436.11
12	12000	74.65	151.88	11848.12	473.92
13	13000	123.1	250.46	12749.54	509.98
14	14000	243.2	494.81	13505.19	540.21
15	15000	435.6	886.27	14113.73	564.55
16	16000	659.8	1342.43	14657.57	586.30
17	17000	844.2	1717.61	15282.39	611.30
18	18000	1044	2124.12	15875.88	635.04
19	19000	1519	3090.56	15909.44	636.38
20	20000	1779	3619.55	16380.45	655.22

Final** = Final* x 2.0346

11.74 = 5.77 x 2.0346

Adsorb* = initial - Final**

988.26 = 1000 - 11.74

Adsorb**= 0.5 x 20 x Adsorb*/1000

39.53 = 0.5 x 20 x 988.26/1000

Table A2 Adsorption isotherm of 1:3 CTAB:Triton X-100 molar ratio

	Initial	Final*	Final**	Adsorb*	Adsorb**
	micro Mol	ppm	micro Mol	micro Mol	micro mol/g silica
1	400	22.28	51.91	348.09	13.92
2	600	26.6	61.98	538.02	21.52
3	800	28.35	66.05	733.95	29.36
4	1000	30.93	72.06	927.94	37.12
5	1300	39.37	91.73	1208.27	48.33
6	1500	35.02	81.59	1418.41	56.74
7	2000	35.93	83.71	1916.29	76.65
8	3000	41.98	97.81	2902.19	116.09
9	4000	49.65	115.68	3884.32	155.37
10	5000	60.21	140.28	4859.72	194.39
11	6000	71.98	167.71	5832.29	233.29
12	6500	113	263.28	6236.72	249.47
13	7000	119.1	277.49	6722.51	268.90
14	7500	129.8	302.42	7197.58	287.90
15	8000	231.7	539.84	7460.16	298.41
16	8500	140.8	328.05	8171.95	326.88
17	9000	236.8	551.72	8448.28	337.93
18	9500	354.6	826.19	8673.81	346.95
19	10000	697.2	1624.42	8375.58	335.02
20	20000	4425	10309.88	9690.12	387.60

Final** = Final* x 2.33

51.91 = 22.28 x 2.33

Adsorb* = initial - Final**

348.09 = 1000 - 51.91

Adsorb**= 0.5 x 20 x Adsorb*/1000

13.92 = 0.5 x 20 x 348.09/1000

Table A3 Adsorption isotherm of 1:1 CTAB:Triton X-100 molar ratio

	Initial	Final*	Final**	Adsorb*	Adsorb**
	micro Mol	ppm	micro Mol	micro Mol	micro mol/g silica
1	500	5.80	2.78	497.22	19.89
2	1000	9.93	4.76	995.24	39.81
3	2000	11.57	5.54	1994.46	79.78
4	3000	13.22	6.33	2993.67	119.75
5	4000	16.17	7.75	3992.25	159.69
6	5000	20.22	9.69	4990.31	199.61
7	5500	22.83	10.94	5489.06	219.56
8	6000	27.34	13.10	5986.90	239.48
9	6500	34.83	16.69	6483.31	259.33
10	7000	41.19	19.73	6980.27	279.21
11	7500	46.56	22.31	7477.69	299.11
12	8000	51.75	24.79	7975.21	319.01
13	8500	56.79	27.21	8472.79	338.91
14	9000	62.47	29.93	8970.07	358.80
15	9500	96.18	46.08	9453.92	378.16
16	10000	248.3	118.96	9881.04	395.24
17	11000	484	231.88	10768.12	430.72
18	12000	768.5	368.19	11631.81	465.27
19	13000	1014	485.81	12514.19	500.57
20	14000	1277	611.81	13388.19	535.53
21	15000	1818	870.81	14129.19	565.17
22	16000	1944	931.18	15068.82	602.75
23	17000	2204	1055.74	15944.26	637.77
24	18000	2526	1210.01	16789.99	671.60

Final** = Final* x 0.4291

2.78 = 5.77 x 2.0346

Adsorb* = initial - Final**

497.22 = 1000 - 2.78

Adsorb**= 0.5 x 20 x Adsorb*/1000

19.89 = 0.5 x 20 x 497.22/1000

Table A4 Adsorption isotherm of 3:1 CTAB:Triton X-100 molar ratio

	Initial	Final*	Final**	Adsorb*	Adsorb**
	micro Mol	ppm	micro Mol	micro Mol	micro mol/g silica
1	500	7.62	14.26	485.74	19.43
2	1000	12.22	22.87	977.13	39.09
3	1500	13.8	25.82	1474.18	58.97
4	2000	16.89	31.61	1968.39	78.74
5	3000	19.08	35.70	2964.30	118.57
6	4000	22.15	41.45	3958.55	158.34
7	5000	27.49	51.44	4948.56	197.94
8	6000	33.89	63.42	5936.58	237.46
9	6500	38.11	71.32	6428.68	257.15
10	7000	39.91	74.68	6925.32	277.01
11	7500	42.45	79.44	7420.56	296.82
12	8000	46.25	86.55	7913.45	316.54
13	8500	49.14	91.96	8408.04	336.32
14	10000	66.53	124.50	9875.50	395.02
15	15000	1421	2659.12	12340.88	493.64
16	20000	2934	5490.39	14509.61	580.38

Final** = Final* x 1.87

14.26 = 7.62 x 1.87

Adsorb* = initial - Final**

485.74 = 1000 - 14.26

Adsorb**= 0.5 x 20 x Adsorb*/1000

19.43 = 0.5 x 20 x 485.74/1000

Table A5 Adsorption isotherm of Triton X-100 alone

	Initial	Final*	Final**	Adsorb*	Adsorb**
	micro Mol		micro Mol	micro Mol	micro mol/g silica
1	100	0.04	29.81	70.19	2.81
2	200	0.08	62.40	137.60	5.50
3	400	0.13	99.12	300.88	12.04
4	600	0.15	117.36	482.64	19.31
5	800	0.17	130.71	669.29	26.77
6	2000	0.19	147.40	1852.60	74.10
7	3000	0.23	178.91	2821.09	112.84
8	4000	0.25	197.85	3802.15	152.09
9	5000	0.29	227.27	4772.73	190.91
10	5500	0.33	252.88	5247.12	209.88
11	6500	0.36	282.37	6217.63	248.71
12	7000	0.40	307.21	6692.79	267.71
13	7500	0.42	322.58	7177.42	287.10
14	8000	0.44	337.95	7662.05	306.48
15	9000	0.63	485.81	8514.19	340.57
16	9500	1.03	799.47	8700.53	348.02
17	10000	1.70	1320.28	8679.72	347.19

Final** = Final* x 776.18

29.81 = 0.04 x 776.18

Adsorb* = initial - Final**

70.19 = 100 - 29.81

Adsorb**= 0.5 x 20 x Adsorb*/1000

2.81 = 0.5 x 20 x 70.19/1000

Appendix B Continuous stirred tank reactor.

Co-monomer loading calculation

Table B1 Calculation of the amount of co-monomer loading for the surface modification

Monomer	Styrene	Isoprene
Mole ratio	1	3
Molecular weight	104.15	68.12
Density	0.906	0.681

Mole factor	Weight (g)		Total weight	Volume (ml)	
	Styrene	Isoprene		Styrene	Isoprene
0.01621	1.688	3.3120	5	0.0147	0.0331

Pump flow rate determination

Table B2 Calculation of pump flow rate for 30 min retention times of the surface modification

Reactor size	1	liter (V)
Total run volume	12.5	liters

(τ)	($v = V / \tau$)		($t = \tau / v$)		
Mean resident time (min)	Flow rate		Total run time		
	ml / sec	ml / min	min	h	h : min
30	0.556	33.33	375	6.25	6:15

Calculation is based on a ratio of 80 grams silica per liter of CTAB solution, and for one-kilogram silica modification per a run.

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