REFERENCES

Barlow, F. W. (1993). Rubber Compounding: Principles, Materials, and Techniques. New York: Dekker.

Giannelis, P.E. (1996). Polymer layered silicate nanocomposites. Advanced Materials, 8(1), 29-35.

Lee, C.D., and Jang, W.L. (1997). Characterization of epoxy-clay hybrid composite prepared by emulsion polymerization. Journal of Applied Polymer Science, 68, 1997-2005.

Noh, H.M., Jang, W.L., and Lee, C.D., (1999). Intercalation of styrene-acrylonitrile copolymer in layered silicate by emulsion polymerization. Journal of Applied Polymer Science, 74, 179-188.

Pinnavaia, T. J., Lan, T., Wang. Z., Shi. H., and Kaviratna, P. F. (1995) Clay-reinforced epoxy nanocomposites: synthesis, properties, and mechanism of formation reviewed by Chow, G., and Gonsalves, K. E. Nanotechnology. Washington DC: American Chemical Society, 250-255.

Porter, L.T., Hagerman, E.M., Reynolds, P.B., Eastman, P.M., and Parnell, A.R. (1998). Inorganic/organic host-guest materials: surface and interclay reactions of styrene with copper(II)-exchanged hectorite. Journal of Polymer Science: Part B: Polymer Physics, 36, 673-679.

Thammathadanukul, V., O'Haver, H.J., Harwell, H.J., Osuwan, S., Na-Ranong, N., and Waddell, H.W. (1996). Comparison of rubber reinfocement using various surface-modified precipitated silicas. Journal of Applied Polymer Science, 59, 1741-1750.

Tyan, L.H., Lia, Y.C., and Wei, H.K. (1999). Thermally and mechanically enhanced clay/polyimide nanocomposite via reactive organoclay. Chemistry of Materials, 11, 1942-1947.

Vaia, A.R., Jandt, D.K., Kramer, J.E., and Giannelis, P.E. (1995). Kinetics of polymer melt intercalation. Macromolecules, 28, 8080-8085.

Vaia, A.R., Vasudevan, S., Krawiec, W., Scanlon, G.L., and Giannelis, P.E. (1995). New polymer electrolyte nanocomposites: melt intercalation of poly(ethyleneoxide) in mica-type silicates. Advanced Materials, 7 (2), 154-156.

Varughese, S., and Tripathy, D.K. (1992). Chemical interaction between epoxidized natural rubber and silica: studies on cure characteristics and low-temperature dynamic mechanical properties. Journal of Applied Polymer Science, 44, 1847-1852.

Vladkova, G.T., and Arnaudava, V.R. (1997). Effect of ammonium derivatives of oligoamidephosphates on the vulcanization characteristics and mechanical properties of NBR compounds. Journal of Polymer Engineering, 17(1),231.

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

Wang, S., Long, C., Wang, X., Li, Q., and Qi, Z. (1998). Synthesis and properties of silicone rubber/organomontmorillonite hybrid nanocomposites. Journal of Applied Polymer Science, 69, 1557-1561.

Wang, Z., and Pinnavaia, J.T. (1998). Nanolayer reinforcement of elastomeric polyurethane. Chemistry of Materials, 10, 3769-3771.

Wu, Q., Xue, Z., Qi, Z., and Wang, F. (2000). Synthesis and characterization of PAN/clay nanocomposite with extended chain conformation of polyaniline. Polymer, 41, 2029-2032.

Yang, Y., Zhu, K.Z., Yin, J., Wang, X., and Qi, Z. (1999). Preparation and properties of hybrids of organo-soluble polyimide and montmorillonite with various chemical surface modification methods. Polymer, 40, 4407-4414.

Yano, K., Usuki, A., Okada, A., Kurauchi, T., and Kamikaito, O. (1993). synthesis and properties of polyimide-clay hybrid. Journal of Polymer Science: Part A: Polymer Chemistry, 31, 2493-2497.

APPENDIX A

The calculation of Na^+-exchanged percentage

The 1000-ppm NaCl solution was used as the stock solution. The 100-ppm Na^+ solution was first prepared by dilution from the 1000-ppm NaCl solution. Then, the 2-, 5-, and 10-ppm Na^+ solutions were further prepared from the 100-ppm Na^+ solution. Finally, the 0.2-, 0.5-, and 1-ppm Na^+ solution were prepared by dilution from the 2-, 5-, and 10-ppm Na^+ solutions respectively, and they were subsequently used as standard Na^+ solutions to create a calibration curve as shown in Figure A1.

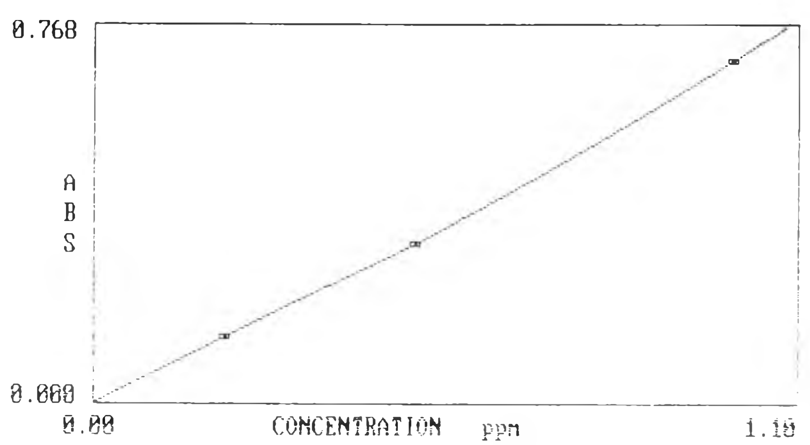

Figure A1 alibration curve obtained from standard Na^+ solutions.

The sample solution was collected from the supernatant part in the preparation of the organically modified MMT. This solution was diluted into 1000 times and used as the sample solution for AAS test. The Na^+-exchanged percentage was calculated from the following equation

$$Na^+\text{-exchanged percentage} = \frac{\text{Amount of } Na^+ \text{ in solution obtained from AAS}}{\text{Weight of montmorillonite} \times 119\ e^{-3}} \times 100$$

APPENDIX B

TGA thermograms of modifying agents and organically modified MMTs

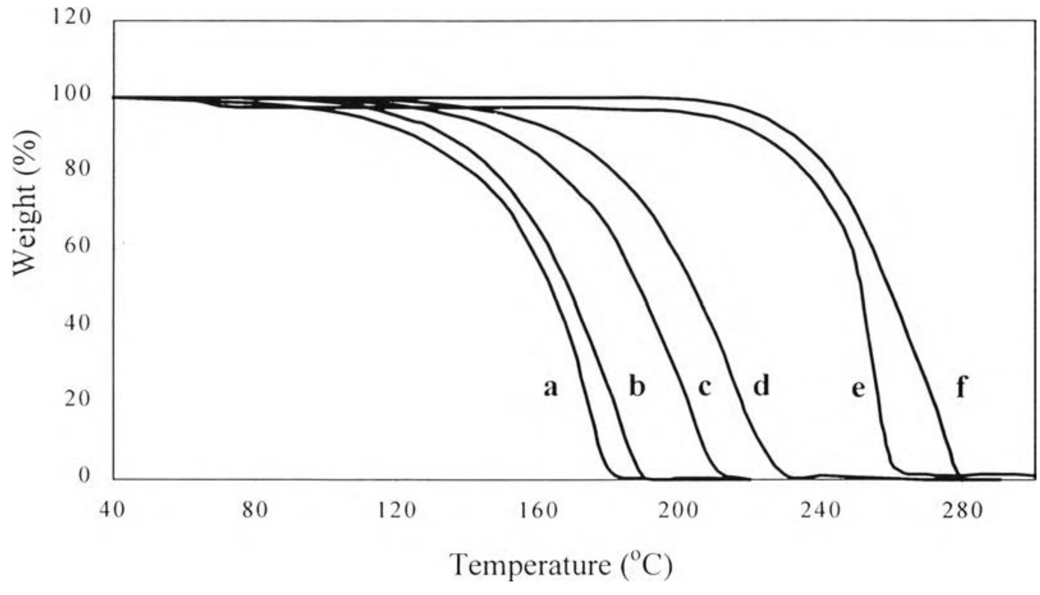

Figure B1 TGA thermograms of modifying agents: (a) DO, (b) TET, (c) HEX, (d) OC, (e) HEXT, (f) OCT.

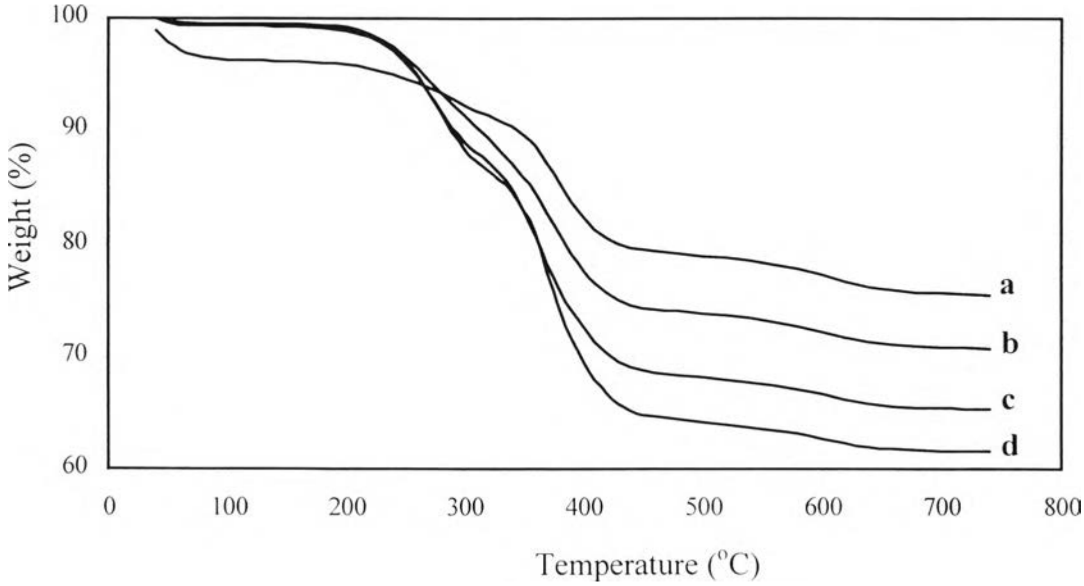

Figure B2 TGA thermograms of primary-alkylamine modified MMTs: (a) DO-MMT, (b) TET-MMT, (c) HEX-MMT, (d) OC-MMT.

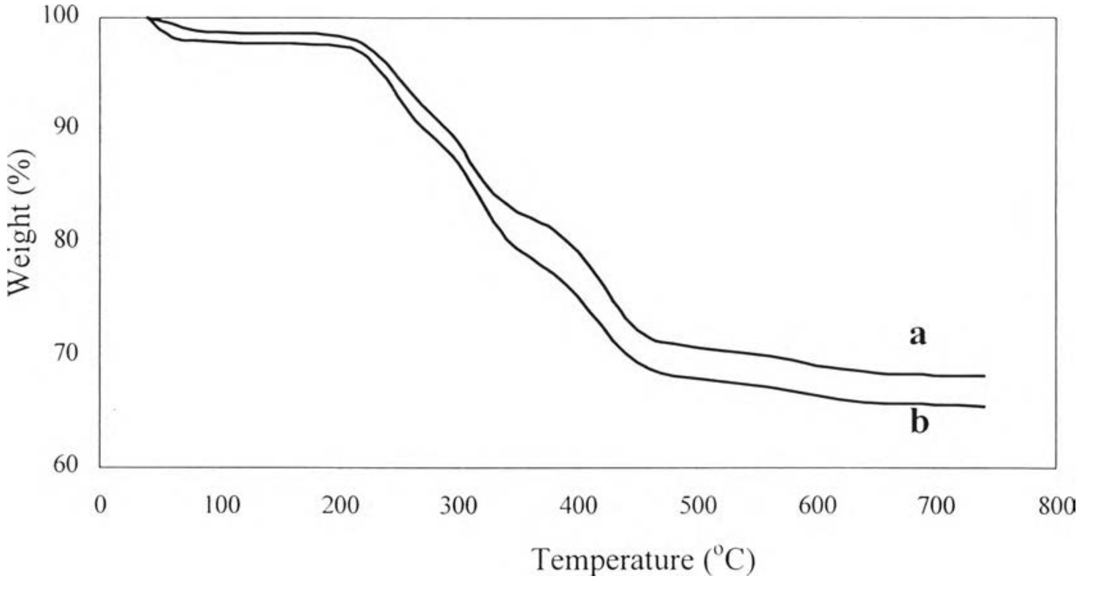

Figure B3 TGA thermograms of quaternary-ammonium-salt modified MMTs: (a) HEXT-MMT, (b) OCT-MMT

APPENDIX C

Tensile testing data of organically modified MMT/NR composites

Table C1 Tensile strength testing data of organically modified MMT/NR composites prepared by solution technique

Type of modified clay	Tensile strength (MPa)					
	1	2	3	4	Average	SD
NR	18.5	19.6	18.0	19.8	19.0	0.9
Na-MMT	22.9	22.2	22.5	23.7	22.8	0.6
DO-MMT	30.1	28.1	30.2	29.1	29.4	1.0
TET-MMT	31.0	30.0	28.9	29.1	29.7	1.0
HEX-MMT	30.7	32.0	32.7	30.6	31.5	1.0
OC-MMT	32.1	32.1	33.6	31.5	32.3	0.9
HEXT-MMT	28.9	29.9	29.8	28.9	29.4	0.6
OCT-MMT	30.8	28.8	31.1	29.3	30.0	1.1

Table C2 Tensile strength testing data of organically modified MMT/NR composites prepared by melt technique

Type of modified clay	Tensile strength (MPa)					
	1	2	3	4	Average	SD
NR	19.9	19.5	19.1	18.8	19.3	0.5
Na-MMT	21.5	22.1	22.6	21.2	21.9	0.6
DO-MMT	22.0	22.9	23.0	23.0	22.7	0.5
TET-MMT	24.3	24.7	25.2	25.1	24.8	0.4
HEX-MMT	26.2	25.8	26.5	27.0	26.4	0.5
OC-MMT	26.7	26.6	27.6	27.0	26.9	0.5
HEXT-MMT	21.2	22.1	20.1	21.9	21.3	0.9
OCT-MMT	21.9	21.8	21.0	22.2	21.7	0.5

Table C3 Tensile strength testing data of organically modified MMT/NR composites prepared by solution technique as a funtion of clay loading

Clay loading (phr)	Tensile strength (MPa)					
	1	2	3	4	Average	SD
1	26.9	26.2	26.6	27.6	26.8	0.6
3	29.8	29.9	29.4	30.1	29.8	0.3
7	32.5	32.1	32.6	31.6	32.2	0.5
10	29.1	29.7	30.5	29.8	29.8	0.6
12	28.9	28.8	29.7	29.3	29.2	0.4

Table C4 Tensile strength testing data of organically modified MMT/NR composites prepared by melt technique as a funtion of clay loading

Clay loading (phr)	Tensile strength (MPa)					
	1	2	3	4	Average	SD
1	25.0	24.9	25.3	25.9	25.3	0.5
3	26.1	26.2	26.8	25.8	26.2	0.4
7	26.7	25.6	26.8	26.7	26.4	0.6
10	25.1	25.6	24.7	25.2	25.2	0.4
12	24.8	24.7	24.3	23.4	24.3	0.7

Table C5 Elongation-at-break testing data of organically modified MMT/NR composites prepared by solution technique

Type of modified clay	Elongation (%)					
	1	2	3	4	Average	SD
NR	745	749	759	729	745	13
Na-MMT	723	702	718	706	712	10
DO-MMT	724	712	745	730	728	14
TET-MMT	711	748	734	725	729	16
HEX-MMT	734	713	729	710	722	12
OC-MMT	742	742	735	716	734	12
HEXT-MMT	619	622	643	638	630	12
OCT-MMT	605	629	625	639	624	14

Table C6 Elongation-at-break testing data of organically modified MMT/NR composites prepared by melt technique

Type of modified clay	Elongation (%)					
	1	2	3	4	Average	SD
NR	752	749	759	762	756	6
Na-MMT	724	732	712	726	723	8
DO-MMT	709	708	711	724	713	8
TET-MMT	711	705	719	722	714	7
HEX-MMT	709	721	713	702	713	6
OC-MMT	743	729	729	723	731	9
HEXT-MMT	654	675	637	662	657	16
OCT-MMT	638	661	661	658	655	11

Table C7 300 % Modulus testing data of organically modified MMT/NR composites prepared by solution technique

Type of modified clay	300 % Modulus (MPa)					
	1	2	3	4	Average	SD
NR	2.2	2.2	2.0	2.1	2.1	0.1
Na-MMT	2.1	2.2	2.1	2.2	2.2	0.1
DO-MMT	3.9	3.8	3.9	3.9	3.9	0.1
TET-MMT	4.4	4.1	4.1	4.3	4.2	0.1
HEX-MMT	4.2	4.2	4.2	4.0	4.2	0.1
OC-MMT	4.4	4.1	4.5	4.4	4.3	0.1
HEXT-MMT	5.8	5.7	5.5	5.5	5.6	0.1
OCT-MMT	6.1	6.1	6.2	6.0	6.1	0.1

Table C8 300 % Modulus testing data of organically modified MMT/NR composites prepared by melt technique

Type of modified clay	300 % Modulus (MPa)					
	1	2	3	4	Average	SD
NR	2.5	2.5	2.3	2.5	2.4	0.1
Na-MMT	2.4	2.4	2.2	2.4	2.3	0.1
DO-MMT	2.7	2.8	2.9	2.8	2.8	0.1
TET-MMT	3.3	3.3	3.1	3.2	3.2	0.1
HEX-MMT	3.2	3.3	3.3	3.3	3.3	0.0
OC-MMT	3.2	3.4	3.4	3.4	3.3	0.1
HEXT-MMT	2.9	3.0	3.0	2.9	2.9	0.0
OCT-MMT	2.9	2.7	2.8	2.8	2.8	0.1

Table C9 Shore hardness testing data of organically modified MMT/NR composites prepared by solution technique

Type of modified clay	Hardness (Shore A)					
	1	2	3	4	Average	SD
NR	40.3	40.2	39.7	39.8	40.0	0.3
Na-MMT	43.3	42.9	43.1	43.0	43.1	0.2
DO-MMT	54.0	54.1	53.8	53.5	53.9	0.3
TET-MMT	56.8	57.1	56.9	57.3	57.0	0.2
HEX-MMT	59.2	60.0	58.9	59.3	59.4	0.5
OC-MMT	60.4	60.9	60.9	61.6	61.0	0.5
HEXT-MMT	58.8	58.7	59.9	60.2	59.4	0.8
OCT-MMT	59.7	60.6	60.7	61.5	60.6	0.7

Table C10 Shore hardness testing data of organically modified MMT/NR composites prepared by melt technique

Type of modified clay	Hardness (Shore A)					
	1	2	3	4	Average	SD
NR	39.2	39.0	39.0	40.1	39.3	0.5
Na-MMT	42.6	42.7	42.8	42.9	42.8	0.1
DO-MMT	44.6	45.1	45.3	45.9	45.2	0.5
TET-MMT	51.0	50.8	50.4	50.7	50.7	0.3
HEX-MMT	52.9	52.1	52.3	51.4	52.2	0.6
OC-MMT	53.3	53.8	54.0	53.6	53.7	0.3
HEXT-MMT	45.7	45.3	45.7	45.5	45.6	0.2
OCT-MMT	45.3	45.1	46.1	45.9	45.6	0.5

APPENDIX D

Torque-time-temperature relationship of NR/clay (7 phr) composites prepared by melt technique using Brabender Plasticorder

Abbreviations

A	:	Loading peak	B	:	Minimum
G	:	Inflection point	X	:	Maximum
E	:	End			

A-B	:	Loading peak to Minimum
B-X	:	Minimum to Maximum
X-E	:	Maximum to End = Fusion time (t)
A-X	:	Loading peak to End

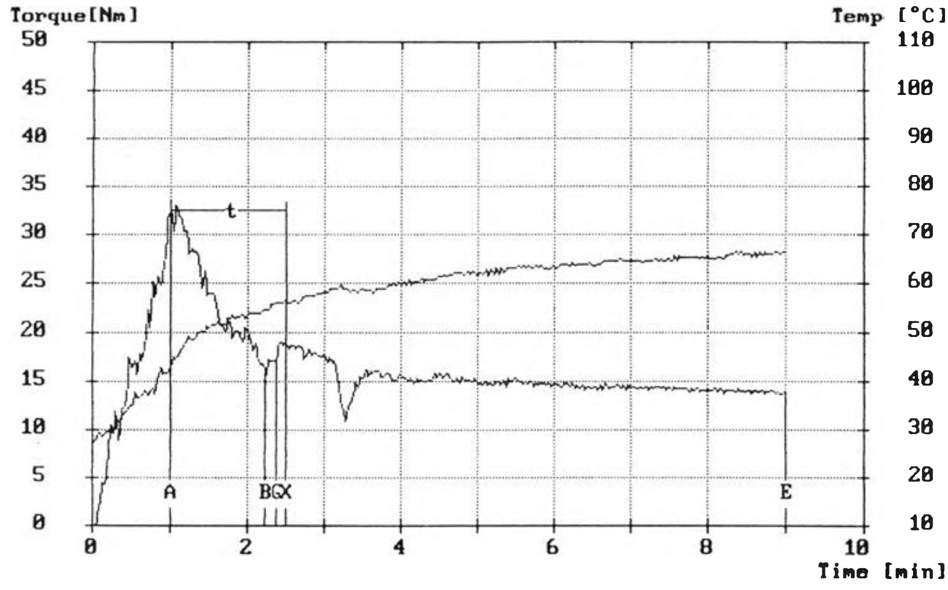

Figure D1 Torque-time-temperature relationship of NR.

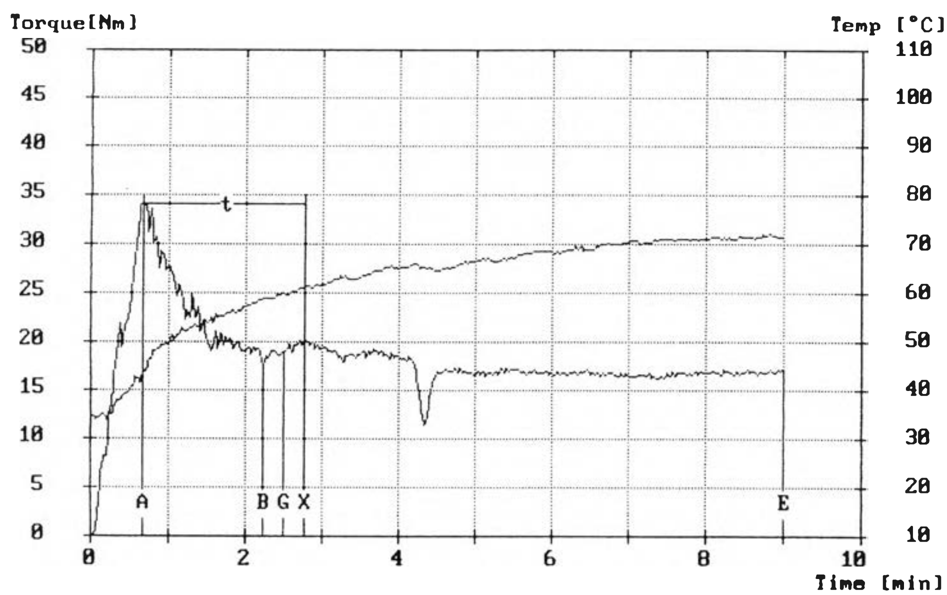

Figure D2 Torque-time-temperature relationship of Na-MMT/NR.

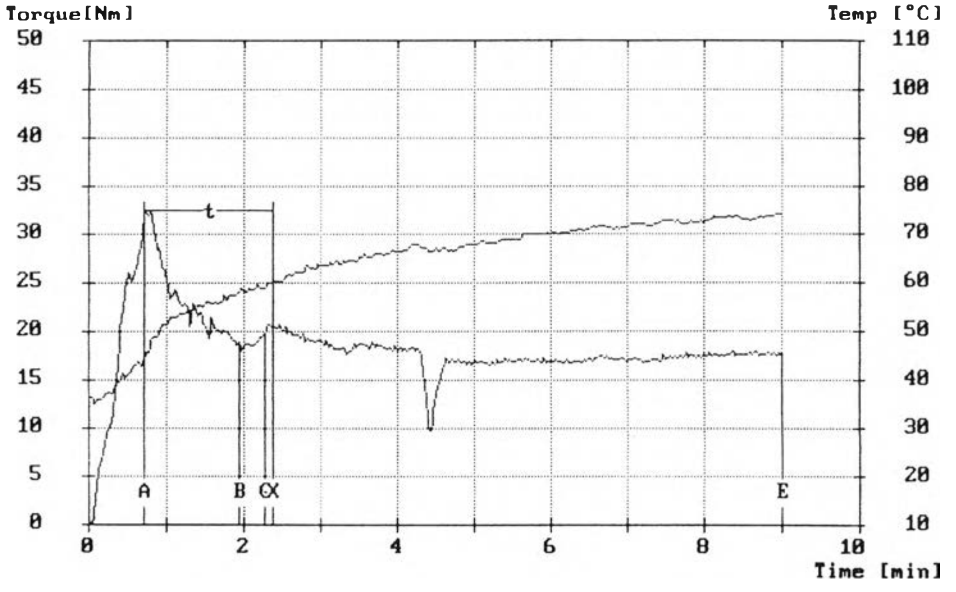

Figure D3 Torque-time-temperature relationship of DO-MMT/NR.

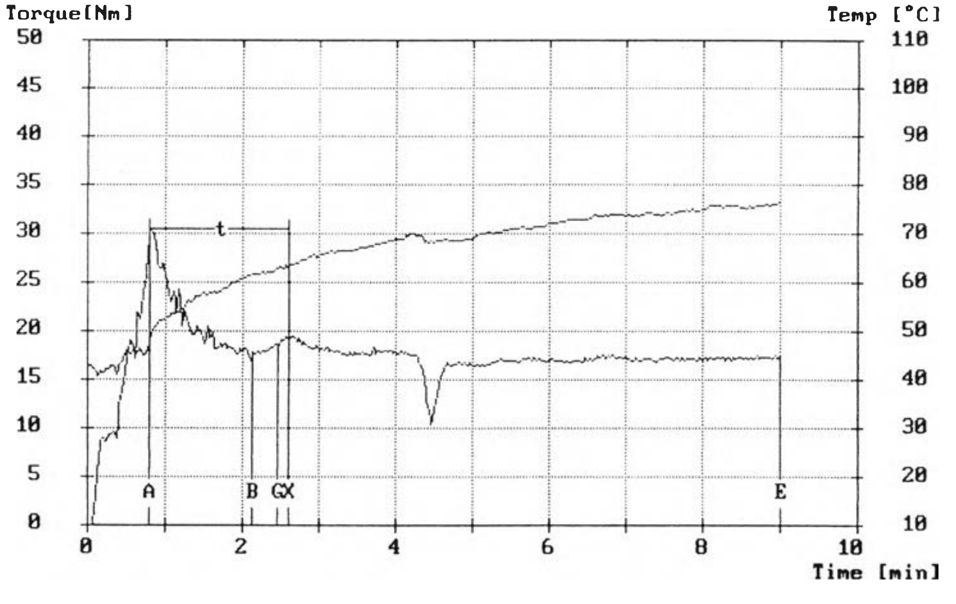

Figure D4 Torque-time-temperature relationship of TET-MMT/NR.

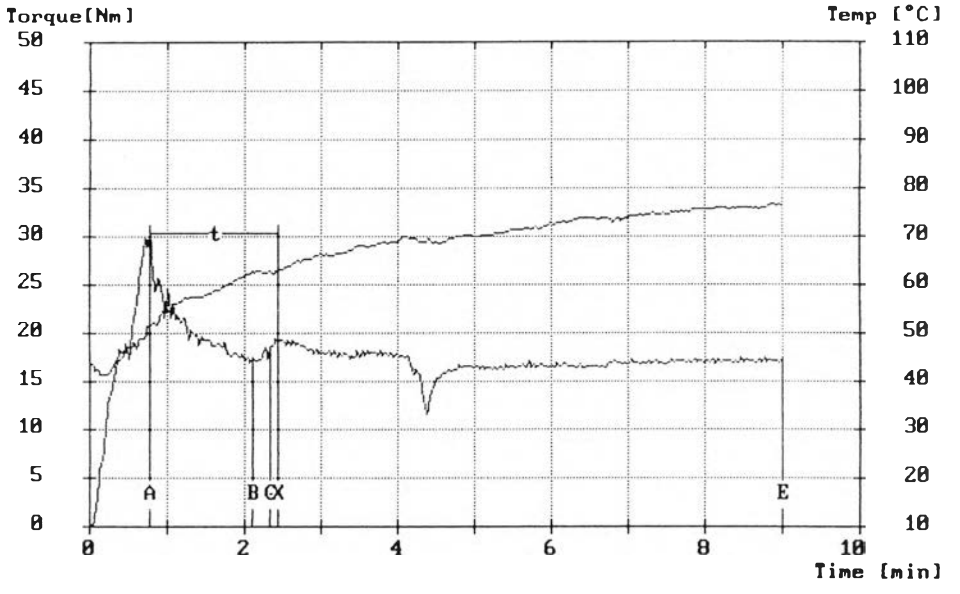

Figure D5 Torque-time-temperature relationship of HEX-MMT/NR.

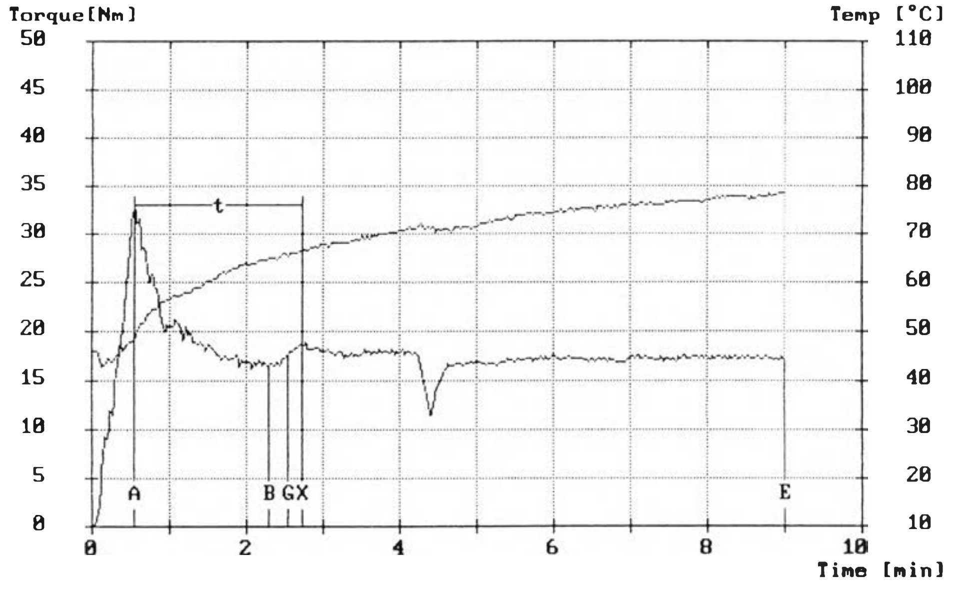

Figure D6 Torque-time-temperature relationship of OC-MMT/NR.

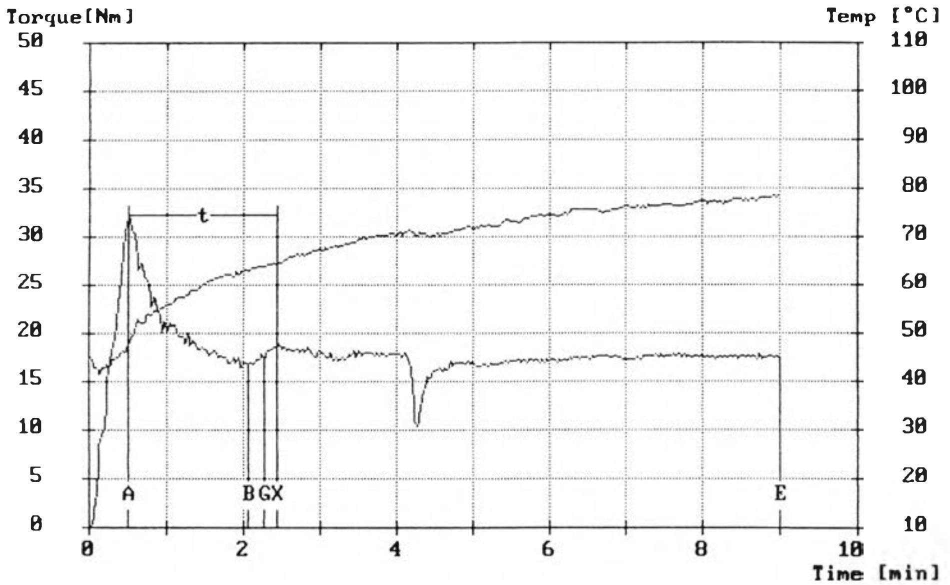

Figure D7 Torque-time-temperature relationship of HEXT-MMT/NR.

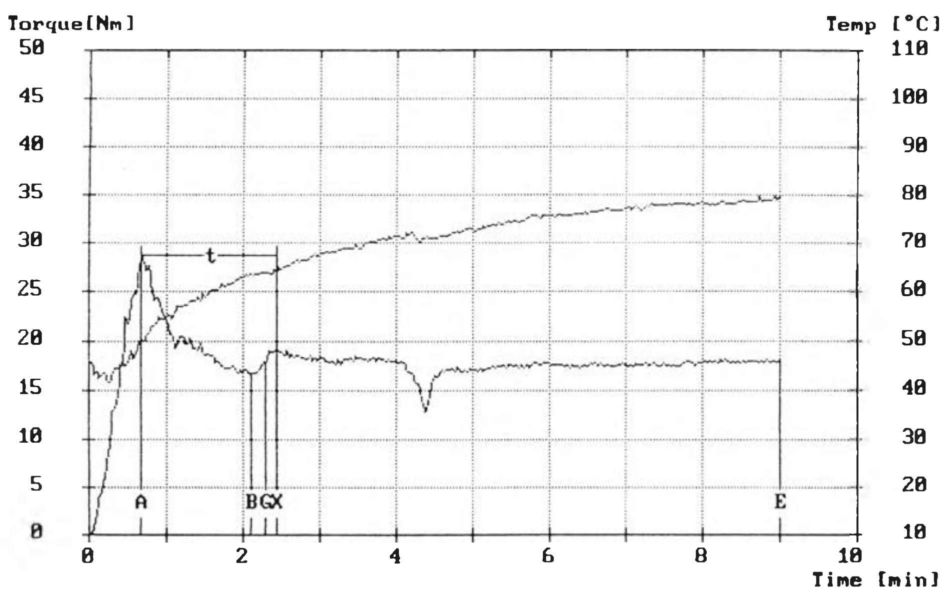

Figure D8 Torque-time-temperature relationship of OCT-MMT/NR.

CURRICULUM VITAE

Name: Woothichai Thaijaroen

Date of Birth: May 8, 1975

Nationality: Thai

University Education:

1994-1997 Bachelor Degree of Science in Chemistry,
Prince of Songkhla University, Hatyai, Sonhkla,
Thailand 90110