REFERENCES

1. Rubin, I. I. Handbook of plastic Materials and Technology. United States of America: John Wiley & Sons, Inc., 1990.
2. Brydson, J. A. Plastic Materials 6th edition. UK: Butterworth Heinemann Limited, 1995.
3. Moore, D.M.; Robert, C. and Reynolds, Jr. "Identification of Mixed-layered Clay Mineral" X-ray Diffraction and the Identification and Analysis of Clay Minerals. 2nd edition. New York: Oxford University Press, 1997.
4. Bergaya, F. and Lagaly, G. "Surface Modification of Clay Minerals" Applied Clay Science. 2001, 19, 1-3.
5. Deer, W.A.; Howie, R.A. and Zussman, J. An Introduction to the Rock-Forming Minerals. China: Addison Wesldy Longmann Limited, 1996.
6. Giannelis, E.P.; Krishnamoorti, R.; Manias, E. "Polymer-Silica Nanocomposites: Model Systems for Confined Polymers and Polymer Brushes" Adv. Polym. Sci. 1999, 118, 108-147.
7. Theng, B.K.G. The Chemistry of Clay-Organic Reactions. New York: Wiley, 1974.
8. Khayankarn, O. Adhesion and Permeability of Polyimide-Clay Nanocomposite as Protective Coating for Microelectronic Gas Sensor. Master's thesis. Petroleum and Petrochemical College. Chulalongkorn University.
9. Hang, P.T.; and Brindley, G.W. "Methylene Blue Absorption by Clay Minerals: Determination of Surface Areas and Cation Exchange Capacities (Clay-Organic Studies XVIII)" Clays and Clay Minerals, 1970, 18, 203–212.
10. Clarke, G. "Industrial Clays (A special review) " Industrial Minerals Division of Metal Bulletin, 1989, 78-79.
11. Cases, J. M. and Villieras, F. "Thermodynamic Model of Ionic and Nonionic Surfactants Adsorption-Abstraction on Heterogeneous Surfaces" Langmuir, 1992, 8, 1251-1264.

12. Xu, S. and Boyd, S. A. "Cationic Surfactant Adsorption by Swelling and Nonswelling Layer Silicates" Langmuir, 1995, 11, 2508-2514.

13. Lagaly, G. Smectic clays as ionic macromolecules, in: A.D. Wilson, H.J. Prosser (Eds.), Development in Ionic Polymers. Elsevier, London, 1986.

14. Lee, S.Y. and Kim, S.J. "Delamination Behavior of Silicate Layers by Adsorption of Cationic Surfactants" Journal Colloid and Interface Science, 2002, 248, 231–238.

15. Ishida, H.; Campbell, S. and Blackwell, J. "General Approach to Nanocoposite Preparation" Chem. Mater, 2000, 12, 1260-1267.

16. Giannelis, E.P. "Polymer layered silicate nanocomposites" Adv. Mater. 1996, 8, 29.

17. Alexandre, M. and Dubois, P. "Polymer-Layered Silicate Nanocomposites: Preparation, Properties and Use of a New Class of Materials" Materials Science and Engineering, 2000, 25, 1-63.

18. Wu, J. and Lerner, M. "Structural, thermal, and electrical characterization of layered nanocomposites derived from sodium-montmorillonite and polyethers" Chem. Mater., 1993, 5, 835.

19. Lan, T. and Pinnavaia, T. "Clay-reinforced epoxy nanocomposites, Chem. Mater., 1994, 6, 2216-2219.

20. Usuki, A.; Kato, M.; Okada, A. and Kurauchi, T. "Synthesis of polypropylene-clay hybrid" J. App. Polym. Sci, 1997, 63, 137-139.

21. Dong, C.L. and Lee, W. J. "Preparation and characterization of PMMA-clay hybrid composite by emulsion polymerization" J. Appl Polym. Sci, 1996, 61, 1117-1122.

22. Hirata, T.; Kashiwagi, T. and Brown, J. E. "Thermal and oxidative degradation of poly(methyl methacrylate): weight loss" Macromolecules, 1995, 18, 1410-1418.

23. Messersmith, P.B. and Giannelis, E.P. "Synthesis and Characterization of Layered Silicate-Epoxy Nanocomposites" Chem. Mater., 1994, 6, 1719-1725.

24. Shi, H.; Lan, T. and Pinnavaia, T. "Interfacial effects on the reinforcement properties of polymer-organoclay nanocomposites" Chem. Mater., 1996, 8, 1584.

25. Vaia, R.A.; Ishida, H. and Giannelis, E.P. "Synthesis and Propertied of two-dimensional Nanostructures by Direct Intercalation of Polymer Melts in Layered Silicates" Chem Mater, 1993, 5, 1694-1696.

26. Vaia, R.A.; Jaudt, K.D.; Kramer, E.J. and Giannelis, E.P. "Microstructural Evolution of Melt Intercalated Polymer-Organically Modified Layered Silicates Nanocomposites" Chem Mater, 1996, 8, 2628-2635.

27. Vaia, R.A. and Giannelis, E.P. "Lattice Model of Polymer Melt Iintercalation in Organically-Modified Layered Silicates" Macromolecules, 1997, 30, 7990-7999.

28. Huang, X.; Lewis, S.; Brittain, W.J. and Vaia, R.A. "Synthesis of Polycarbonate-Layered Silicate Nanocomposites via Cyclic Oligomers" Macromolecules, 2000, 33, 2000-2004.

29. Wilson, O.C.; Olorunyolemi, T.; Jaworski, A.; Borum, L.; Young, D.; Siriwat, A.; Dickens, E.; Oriakhi, C. and Lerner, M. "Surface and Interfacial Properties of Polymer-intercalated Layered Double Hydroxide Nanocomposites" Appl. Clay Sci, 1999, 15, 265-279.

30. Oriakhi, C.O.; Farr, I.V. and Lerner, M.M. "Thermal Characterization of Poly(styrene sulfonate)/layered Double Hydroxide Nanocomposites" Clays and Clay Minerals, 1997, 45, 194-202.

31. Okada, A.; Kawasumi, A.; Usuki, A.; Kojuma, Y.; Kurauchi, T. and Kamgaito, O. "Nylon 6-Clay Hybrid" Mater. Res. Soc. Proc., 1990, 171, 45-50.

32. Lee, D.C. and Jang, L. W. "Preparation and Characterization of PMMA-clay Hybrid Composite by Emulsion Polymerization" J. Appl. Polym. Sci., 1996, 61, 1117-1122.

33. Kojima,Y.; Usuki, A.; Kawasumi, M.; Okada, A.; Fukushima,Y.; Karauchi, T. and Kamigaito,O. "Mechanical Properties of Nylon-6-clay Hybrid" J. Mater. Res., 1993, 6, 1185-1189.

34. Liu, L.M.; Qi, Z.N. and Zhu, X.G. "Studies on Nylon-6 Clay Nanocomposites by Melt-intercalation Process" J. Appl. Polym. Sci., 1999, 71, 1133-1138.

35. Messersmith, P.B. and Giannelis, E.P. "Synthesis and Barrier Properties of Poly(ε-Caprolactone)-Layered Silicate Nanocomposites" J. Appl. Polym. Sci. Part A, 1995, 33, 1047-1057.

36. Kojima,Y.; Fukumori, A.; Usuki, A.; Okada, A. and Karauchi, T. "Gas Permeabiities in Rubber-Clay Hybrid" J. Mat. Sci. Letters, 1993, 12, 889-890.

37. Blumstein, A. "Polymerization of Adsorbed Monolayers: II. Thermal Degradation of the Inserted Polymers" J. Polym. Sci. 1965, A3, 2665-2673.

38. Gilman, J.W. "Flammability and Thermal Stability Studies of Polymer Layered-silicate (clay) Nanocomposites" Appl. Clay Sci., 1999, 15, 31-49.

39. Dietsche, F. and MuÈlhaupt, R. "Thermal Properties and Flammability of Acrylic Nanocomposites based upon Organophilic Layered Silicates" Polym. Bull., 1999, 43, 395-402.

40. Wang, Z.; Lan, T. and Pinnavaia, T. "Hybrid Organic-Inorganic Nanocomposites Formed from and Epoxy Polymer and a Layered Silicic Acid (Magadiite)" Chem Mater, 1996, 8, 2200-2204.

41. Wang, Z. and Pinnavaia, T. "Nanolayer Reinforcement of Elastomeric Polyurethane" Chem Mater, 1998, 10, 3769-3771.

42. Park, J.H. and Jana, S.C. " The Relationship between Nano- and Micro-structures and Mechanical Properties in PMMA-epoxy-nanoclay Composites" Polymer, 2003, 44, 2091-2100.

APPENDICES

Appendix A: Particle Size Sedimentation

The sedimentation is the method to settle out the particles. The ability of the settling particles depends on several factors.

The factors to control the settling are

1) Particle size
2) Particle specific gravity
3) Viscosity of liquid
4) Specific gravity of liquid

The particle size is a particle diameter and the viscosity of liquid, is, in Poise. The specific gravity of particle is the density of particle divided by density of the liquid. The basis theory is based on Stoke's law. For particles in the same liquid, the large size will settle faster than the small size one.

The large particle will settle faster than small particle in the same liquid as follow by

$$t = \frac{18\eta h}{(\rho_2 - \rho_1)gD^2} \qquad \text{(A-1)}$$

Where :

t = minutes of time particle settling,
η = viscosity of medium
ρ_1 = density of liquid
ρ_2 = density of clay
g = 980 cm/s^2
D = diameter of particle

For centrifugal sedimentation, the centrifugal time can be calculated by

$$t = \frac{63x10^8 \eta \log_{10}(R/S)}{N_m^2 - D_\mu^2 \Delta S} \qquad \text{(A-2)}$$

Where :

N_m = speed of centrifuge in rpm,

ΔS = difference specific gravity,

D_μ = diameter of particle in micron,

R = distance from the rotation axis to sediment,

S = distance from the rotation axis to suspension.

Appendix B: The Amount of Surfactant in Organoclay Calculation from TGA Method

The amount of surfactant in organoclaly is measured in term of millimole (mmol) to 1 gram of dry clay (mmol/g clay). The amount of surfactant measurerment from the TGA method is calculated from the mass lost of surfactant after initiate up to 800°C.

Mass of dried clay (mg) = Total mass of organoclay (mg) – mass lost from inigtiate (mg)

Mass of surfactant (mg) = Mass lost from inigtiate (mg)

$$\text{Mole of surfactant (mmol/g)} = \frac{\text{Mass of surfactant (mg)}}{\text{Mass of dried clay (mg)} \times \text{MW of surfactant}}$$

Appendix C: Determination of Cation Exchange Capacity (CEC) by Methylene Blue

2.0 grams of purified clay were dispersed in 300 mL. The suspension was stirred until a uniform dispersion is obtained. The pH was adjusted to 2.5 to 3.8 by sulfuric acid. The suspension was continued stirring for 15 minutes. Methylene blue solution (0.01 normal) was added slowly by buret into the clay slurry while maintains a constant stirring. A drop of the suspended solution was place on a filter pater for end point detection. The end point was indicated by a formation of a light blue halo around the drop. The methylene blue was continued to add at 1.0 mL increasing until the end point was reached. After the end point was reached, the soluton was stirred of 2 min and retest for the end point.

The calculation the methylene blue index can calculated from equation (B-1).

$$MBI = \frac{E \times V \times 100}{W} \qquad \text{(C-1)}$$

Where:

MBI = methylene blue index for the clay in meq/100g clay,

E = concentration of the methylene blue (in miliequivalents of methylene blue per milliter),

V = amount of methylene blue (in milliter) required for the titration,

W = weight of dry clay in gram.

Appendix D: Data of Surface Hardness of PMMA/Clay Nanocomposite by Rockwell Hardness Tester in Scale-M Unit

Table D-1 Data of surface hardness of PMMA-TTMBNH with various organoclay loadings

Organo-clay loading (%wt)	Value of Surface Hardness (Scale M)										Mean
0	95.1	95.5	95.5	95.2	95.5	95.6	95.8	95.4	95.2	95.4	95.42
2	98.5	98.5	99.0	98.4	98.9	99.1	98.9	98.8	98.8	99.0	96.79
4	96.6	97.2	97.9	96.8	96.8	96.8	96.8	97.2	96.6	97.0	96.97
6	95.6	95.6	95.8	95.8	95.7	95.8	96.0	95.9	95.6	94.4	95.62

Table D-2 Data of surface hardness of PMMA-OMHBNH with various organoclay loadings

Organo-clay loading (%wt)	Value of Surface Hardness (Scale M)										Mean
0	95.1	95.5	95.5	95.2	95.5	95.6	95.8	95.4	95.2	95.4	95.42
2	97.4	97.6	97.8	97.6	97.5	97.4	97.2	98.0	97.7	97.6	97.58
4	96.5	96.5	96.3	96.5	96.4	96.6	96.5	96.4	96.4	96.6	96.47
6	91.6	91.5	92.5	91.5	91.5	91.7	91.8	91.9	91.8	91.5	91.73

Table D-3 Data of surface hardness of PMMA-ODMHBNH with various organoclay loadings

Organo-clay loading (%wt)	Value of Surface Hardness (Scale M)										Mean
0	95.1	95.5	95.5	95.2	95.5	95.6	95.8	95.4	95.2	95.4	95.42
2	99.5	98.8	99.6	99.2	99.1	99.7	99.3	99.2	99.1	99.3	99.28
4	97.1	97.1	97	96.8	96.6	97.1	96.5	96.6	96.6	96.8	96.82
6	94.9	95.0	95.7	95.2	94.8	95	94.5	94.7	95	94.8	94.96

Appendix E: Data of Impact Resistance of PMMA/Clay Nanocomposite

Table E-1 Data of impact resistance of PMMA-TTMBNH with various organoclay loadings

Organo-clay loading (%wt)	Value of Impact Resistance (kJ/m^2)										Mean
0	17.9	20.5	18.7	19.8	20.1	18.2	18.5	18.8	18.5	18.7	18.97
2	8.8	8.7	9.1	9.3	9.1	8.9	9.1	9.2	9.6	8.9	9.07
4	8.3	8.5	7.8	7.9	8.4	8.8	8	8.5	8.4	7.7	8.23
6	6.4	6.3	6.6	6.1	5.9	5.1	5.6	6.2	6.4	5.9	6.05

Table E-2 Data of impact resistance of PMMA-OMHBNH with various organoclay loadings

Organo-clay loading (%wt)	Value of Impact Resistance (kJ/m^2)										Mean
0	17.9	20.5	18.7	19.8	20.1	18.2	18.5	18.8	18.5	18.7	18.97
2	9	9.2	8.5	8.7	8.3	8.5	8.8	9.1	8.7	8.9	8.77
4	8.5	8.1	8.6	8	7.8	8.1	7.9	7.5	8.3	7.4	8.02
6	5.4	6.8	6.5	5.9	5.6	6.4	5.9	6.2	6.6	5.8	6.11

Table E-3 Data of impact resistance of PMMA-ODMHBNH with various organoclay loadings

Organo-clay loading (%wt)	Value of Impact Resistance (kJ/m^2)										Mean
0	17.9	20.5	18.7	19.8	20.1	18.2	18.5	18.8	18.5	18.7	18.97
2	10.8	11.9	10.7	11.6	10.7	10.9	11.5	10.9	11.5	11.6	11.21
4	9.5	9.6	9.6	9.2	8.8	10.3	10.1	8.9	9.8	9.4	9.52
6	5.9	6.3	5.8	6.1	6.5	6.4	6.8	6.2	5.8	6.3	6.21

VITAE

Name : Miss Patcharaporn Ngumnunjai

Born : March 25 th, 1979

Education : 2001 B. Sc. (Chemistry), Burapha University, Chonburi, Thailand

2003 M. Sc. (Petrochemistry and Polymer Science), Chulalongkorn University, Bankok, Thailand.