



CHAPTER II

LITERATURE REVIEW

Theoretical Background

1. Polypropylene Fibers

Polypropylene, the first stereoregular polymer, has been known for its industrial importance due to its versatile applications in various forms. The fibers from polypropylene were introduced to the textile arena in 1970s and have become an important member of the rapidly growing family of synthetic fibers. Today polypropylene enjoys fourth spot behind the 'big three' fiber classes, i.e. polyester nylon and acrylic. However as opposed to other commodity fibers, its use as apparel and household textiles has been rather limited; the bulk of the fiber produced is used for industrial applications. Nevertheless, the textile and household uses are growing.

Polypropylene Fiber Properties

Some advantages and shortcomings of polypropylene fibers based on their properties are summarized below.

1. Polypropylene is a light fiber; its density (0.91 gcm^{-3}) is the lowest of all synthetic fibers.
2. It does not absorb moisture. This means that the wet and dry properties of the fiber are identical. Low moisture regain is not considered a disadvantage because it helps in quick transport of moisture as is required in special applications like babies' every dry-nappies.
3. Its color do not fade/or bleed because the dyeing is done by blending color pigments/master batch with the resin itself prior to fiber extrusion.
4. It has excellent chemical resistance. Polypropylene fibers are very resistant to the most acids and alkalis.
5. Polypropylene fibers neither support the growth of mildew/fungi nor are attacked by insects and pets.
6. It is easy to process and ensures high processing yields and profitability. Its cost is lower than that of polyester and nylon fibers.
7. The thermal conductivity of polypropylene fiber is lower than that of other fibers and may be used in applications as thermal wear.

The fiber, however, has certain limitations; these are listed below.

1. It has low melting temperature, and so requires extra care during ironing.
2. It cannot be dyed after manufacture. Polypropylene is normally mass-colored before fiber extrusion; a major limitation is the lack of wide range of shades.
3. Polypropylene has low UV and thermal stability; it requires the addition of expensive UV stabilizer and antioxidants to overcome the problem.
4. Polypropylene has poor resilience compared to polyester or nylon; higher denier fiber is, therefore, desirable to overcome this problem.
5. Polypropylene undergo creep due to its low T_g (-15 to -20 °C).
6. It melts and burns like wax and is flammable; flame retardant may be added together with stabilizers.

2. Colorant

Color substances, e.g. dyes or pigments can be added to a polypropylene fiber. However, there are major differences between these coloring substances and the way they are added to fabrics.

1) Pigments

Pigments are insoluble color particles that are held on the surface of a fabric by a binding agent. Their application is quick, simple and economical. Any color can be used on any fiber because the pigments are held on mechanically. Fabric problems such as stiffening, crocking, and fading may be encountered.

Pigments need to be bonded to fiber surface. The binder works like a glue and binds the pigment to the fiber. The type of the binder is determined by the fiber content of the fabric and performance expectation for the product. Binders can be used to produce soft and flexible fabrics. Ideally, binders should not interfere with the color of the pigment, nor with the hand and function of the fabric.

Pigment is rather popular because of simple application procedure for almost all fibers and fabric, extensive color range, excellent light fastness, potential to combine some finishing with pigment coloration, and low cost.

Pigments produce the color to the paste, although some other ingredients may alter the color. Pigment colors are easier to match than dye colors because the

color is held on the surface. Dyes are more difficult to match because the chemical reactions of dyeing may cause the dye to have color shifted. The hue shift is more difficult to control in dyeing compared to pigment painting. Some of the biggest problem areas with pigments are the change in hand with some inks, wash problem, and poor dye cleaning fastness of some binders.

2) Dyes

A dye is an organic compound composed of a chromophore, the color portion of dye molecule, and an auxochrome, which slightly alters the color. The auxochrome makes the dye soluble and is a site for bonding to the fiber. Dye must be molecules that can be thoroughly dissolved in water or some other

carrier in order to penetrate the fiber. Undissolved particles of dye stay on the outside of the fiber and have poor fastness to the surface abrasion and bleeding. Dyes have great color strength; a small amount of dye is able to color large quantities of fabric. Pigments have much lower color strength; much more pigment is needed to color an equal amount of fabric. Most dyes bond chemically with the fiber and are found in the interior of the fiber, rather than on the surface where pigments are found. Most colors on textiles are achieved by dye or pigment mixtures rather than a single dye or pigment.

Dyeing process describes the environment created for the introduction of dye by hot water, steam, or dry heat. Chemical additives like salt or acid are used to regulate penetration of the dye. Knowledge of fiber-dye interactions, methods of dyeing and equipment result in a better understanding of color behavior.

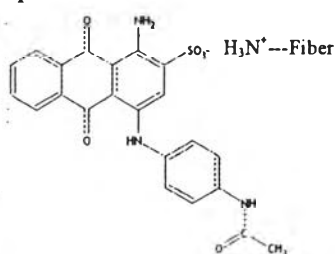
In order for fabric to be colored, the dye must penetrate the fiber and either be combined chemically with it or be locked inside it. Fibers that are dyed easily are those that are absorbent and have sites within their molecules that react with dye molecules. The dyes react with surface molecules first. Moisture swells the fiber, causing the polymer chain to move farther apart so that sites in the internal regions of the fiber are exposed to react with the dye. During cooling and drying, the chains move back together, trapping the dye in the fiber.

The thermoplastic fibers are sometimes difficult to dye because their absorbency is low. However, most of these fibers are modified to accept different

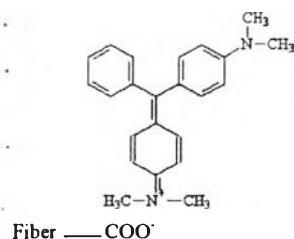
classes of dyes. This makes it possible to achieve different color effect or a good color in blends of unlike fibers by piece dyeing.

Classification of Dyes

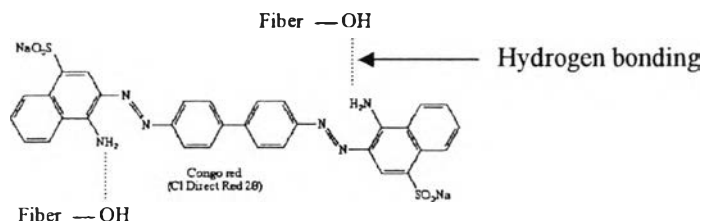
1) Acid dye is an anionic dye and often applied from an acid dye bath. It is applied to fibers such as silk, wool, nylon and modified acrylic fibers using neutral to acid dyebaths. Attachment to the fiber is attributed, at least partly, to salt formation between anionic groups in the dyes and cationic groups in the fiber. Acid dye can attach with fiber by ionic force and dispersion force.



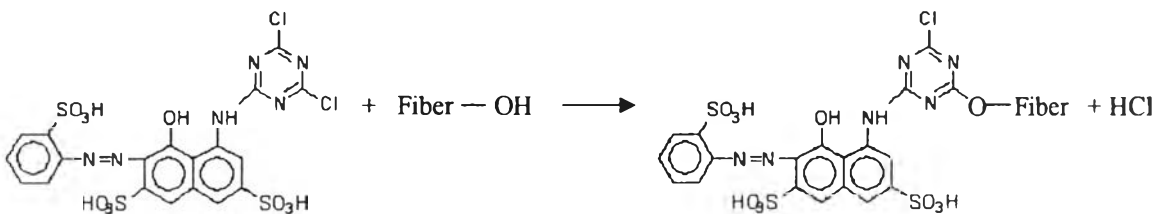
2) Basic dye is a cationic dye. It is mainly applied to acrylic fibers, but finds some use for wool and silk. Usually acetic acid is added to the dyebath to help the uptake of the dye onto the fiber. The mechanism of dye retention is ionic forces.



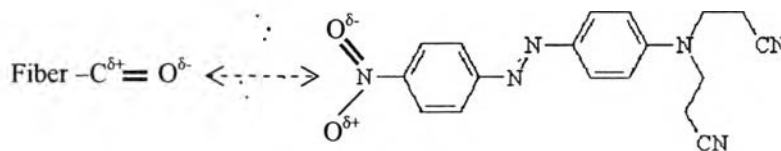
3) Direct dye is an anionic dye which is normally applied from aqueous dyebath containing an electrolyte. Direct dye is used on cotton, paper, leather, wool, silk and nylon. This dye can interact with fiber by hydrogen bonding.



4) Reactive dye is a type of dye which is capable of forming a covalent bonding with the substrate. Reactive dye is by far the best choice for dyeing cotton and other cellulose fibers.



5) Disperse dye is a low water soluble dye which is usually applied as a dispersion in an aqueous bath. It can be used to dye nylon, cellulose triacetate, polyester and acrylic fibres. This dye can attach with fiber by forming of dipole-dipole attraction and mechanical trapping.



3. Clay

Common clays are naturally occurring minerals and are thus subject to natural variability in their constitution. The purity of the clay can affect final nanocomposite properties. Many clays are aluminosilicates, which have a sheet-like (layered) structure, and consist of silicate SiO_4 tetrahedral bonded to alumina AlO_6 octahedral in a variety of ways, Figure 2.1. A 2:1 ratio of the tetrahedral to the octahedral results in smectite clays, the most common of which is montmorillonite. Other metals such as magnesium may replace the aluminium in the crystal structure. Depending on the precise chemical composition of the clay, the sheets bear a charge on the surface and edges, this charge being balanced by counter-ions, which reside in part in the inter-layer spacing of the clay. The thickness of the layers (platelets) is of the order of 1 nm and aspect ratios are high, typically 100-1500. The clay platelets are truly nanoparticulate. In the context of nanocomposites, it is important to note that the molecular weight of the platelets (ca. 1.3×10^8) is considerably greater than that of typical commercial polymers, a feature which is often misrepresented in schematic diagrams of clay-based nanocomposites.

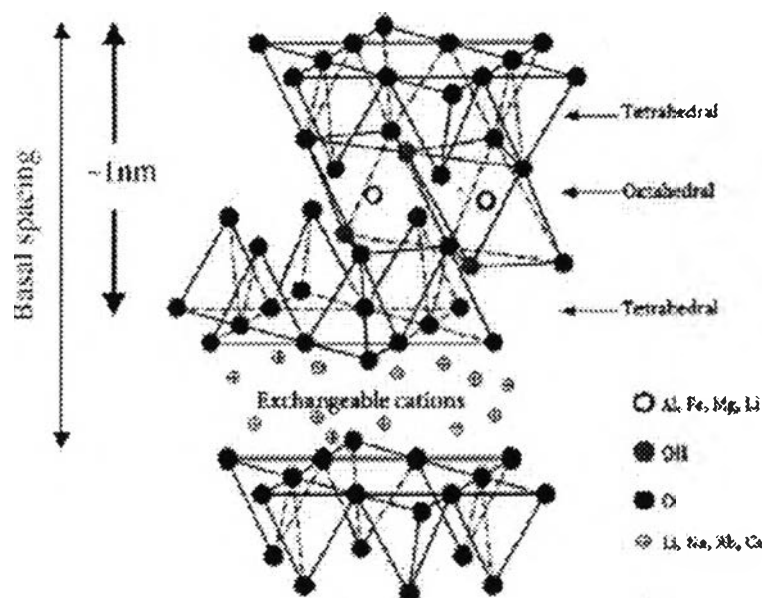
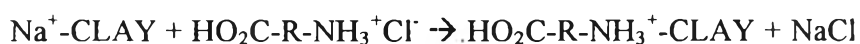


Figure 2.1 Structure of 2:1 phyllosilicates.

In addition, platelets are not totally rigid, but have a degree of flexibility. The clays often have very high surface areas, up to hundreds of m^2 per gram. The clays are also characterized by their ion (e.g. cation) exchange capacities, which can vary widely. One important consequence of the charged nature of the clays is that they are generally highly hydrophilic species and therefore naturally incompatible with a wide range of polymer types. A necessary prerequisite for successful formation of polymer-clay nanocomposites is therefore alteration of the clay polarity to make the clay 'organophilic'. Organophilic clay can be produced from normally hydrophilic clay by ion exchange with an organic cation such as an alkylammonium ion. For example, in montmorillonite, the sodium ions in the clay can be exchanged for an amino acid such as 12-aminododecanoic acid (ADA):



The way in which this is done has a major effect on the formation of particular nanocomposite product forms and this is discussed further below. Although the organic pre-treatment adds to the cost of the clay, the clays are nonetheless relatively cheap feedstocks with minimal limitation on supply. Montmorillonite is the most common type of clay used for nanocomposite formation;

however, other types of clay can also be used depending on the precise properties required from the product. These clays include hectorites (magnesium silicates), which contain very small platelets, and synthetic clays (e.g. hydrotalcite), which can be produced in a very pure form and can carry a positive charge on the platelets, in contrast to the negative charge found in montmorillonites.

In polypropylene (PP) nanocomposites, maleic anhydride grafted PP is used as a compatibilizer. Polymerization initiators can be anchored to the clay platelet surface and this approach has been extended to living free radical polymerization of styrene, where an initiating species bonded to the TEMPO free radical is attached to the surface of the clay platelets via ion exchange.

Clay can be modified by surfactant; therefore, the modification results in an increasing of inter-layer spacing of clay and trapping dye molecules in clay by the interaction between surfactants and dye molecules. (see Figure 2.2)

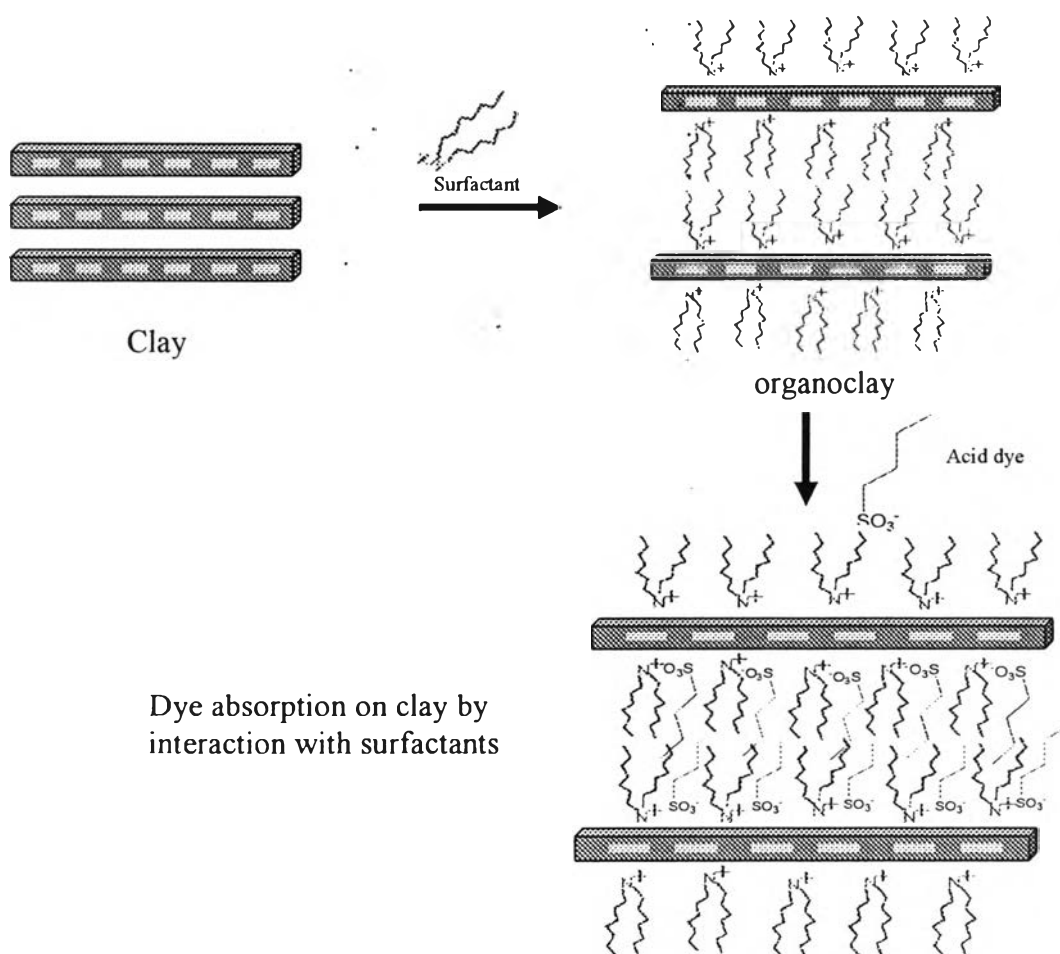


Figure 2.2 Organo-modification and dye absorption of clay.

4. Melt Spinning

Melt spinning (Figure 2.3) is the simplest method of fiber manufacture the polymer is melted and pumped through a spinneret (die) with numerous holes (one to thousands). The molten fibers are cooled, solidified, and collected on a take-up wheel. Stretching of the fibers in both the molten and solid states provides for orientation of the polymer chains along the fiber axis. It is the most economical method because there is no solvent to be recovered as in solution spinning and because the spinning rates are so high.

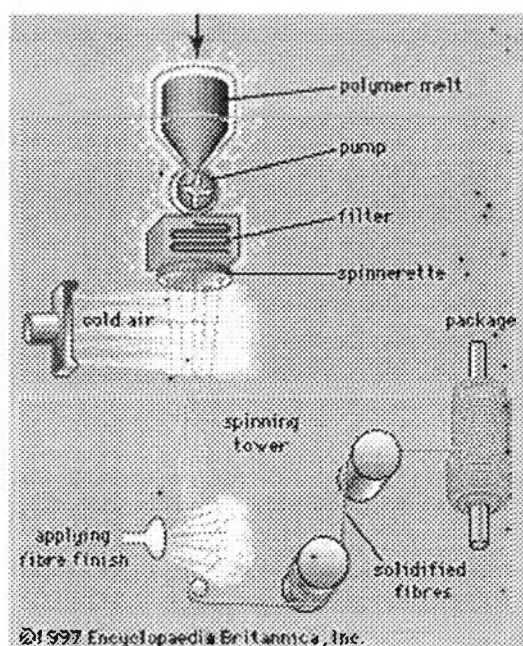


Figure 2.3 Melt spinning.

Literature Review

Polypropylene is the most widely used material for fibers because of its properties such as good chemical resistant, excellent physical properties and inexpensive. However, due to its structure without reactive group to attach functional group of dyes, polypropylene lacks of dyeing properties. Research to improve the dyeability of polypropylene is interesting. There are many methods to improve dyeability of polypropylene fiber.

In 1997, *Yukio M. et al.* studied the dyeable polypropylene fiber by copolymerization. The polypropylene composite was prepared by copolymerizing

glycidyl methacrylate (GMA)- divinyl benzene (DVB) in molten polypropylene. The results showed that tensile strength, Young's modulus and elongation of modified fiber were not much changed from those values of unmodified fiber. The crystallinity of modified fiber was similar to the modified one. They reported that the modified polypropylene fiber could be well dyed with all the dispersion dyestuff by carrier dyeing, although the epoxy value of the fiber was pretty small against expectation.

Graft copolymerization was also been used for improving dyeability of polypropylene. *Muskatell M. et al. (1997)* have prepared dyeable polypropylene fiber by grafting with pentabromobenzyl acrylate. They measured dyeability by Kubelka Munk coefficient and the result showed an increased in dyeability as amount of bromine increased. And after laundering, slight color change was observed but there was more color stability than the pure polypropylene. But this grafting method resulted in the reduction in mechanical properties such as tenacity at break, strength, and elongation at break. In 1999, *Bhutanese G. et al.* modified polypropylene fiber by graft with polyacrylonitrile (PAN) by preirradiation method to enhance moisture absorption and disperse dyeability. The polar nature of nitrile group in graft fiber caused an enhancement of moisture regain of polypropylene. The equilibrium dye uptake increased with the increased in the degree of grafting but tended to be level off beyond the 7% graft level. The grafting with PAN resulted in a change in crystalline-amorphous ratio because it led to a decrease in the crystallinity of fiber. In addition, the birefringence value of polypropylene fiber decreased with the increased in the graft level. This suggested that the disordering of the chains took place due to the incorporation of PAN grafts in fiber matrix. It was expected that the disordering chains would enhance the dye penetration within the fiber matrix. It was also reported that the dye uptake increased with the decreased in the fiber crystallinity because the fiber structure became more accessible to the dye diffusion. In addition, the dipolar interaction between the polar groups in the dye and fiber might also contribute to the enhancement in the dye uptake. However, in this research an effect to study the mechanical properties of the modified polypropylene fiber was not carried out.

In 2001, *Chengbing Y. et al.* blended polypropylene with polystyrene to improve polypropylene properties. The results showed the reduction of tensile

strength, an increase in the elongation but these values did not show large change from those values of pure polypropylene fiber. The degree of crystallinity and orientation of blend fibers decreased heavily, especially the degree of crystallinity. The loosening of the internal structure of polypropylene fiber by incorporating small amounts of polystyrene resulted in a higher dye uptake. As the polystyrene component increased from 0-8%, the dye uptake increased as a consequence. However, the dye absorption did not increase proportionally with the amount of polystyrene present in the blend. When the additive was altered from 4 to 6%, dye uptake increased obviously. Fiber with 0 to 4% additive absorbed less dye stuff because only small amounts of the additive component were present. Four year later, *Xin H. et al.* (2005) modified polystyrene (PS) by copolymerization with acrylic acid (AA), sodium acrylate (SA), and butyl acrylate (BA). Then, modified polystyrene were blended with polypropylene and formed into fibers. The fabric made of PP/PS-SA resulted in improve color intensity over fabrics made of PP or PP/PS. The presence of modified PS in PP reduced the fiber crystallinity and introduced the interfaces between the phases. These interfaces and amorphous parts formed the tunnels into the fibers, and the interfaces increased the surface for dye adsorption. The presence of the polar groups from the acrylic acid and acrylate part significantly increased the dyeability of fibers. For the mechanical properties, the modified PS/PP fibers showed tensile strength similar to that of pure PP fiber and the elongation at break were slightly higher than that of pure PP fiber.

The chemical oxidation is also another method used to improve dyeability of polypropylene. *Ali B. et al.* (2004) studied the effect of chemical oxidation treatment on dyeability of polypropylene. In this work, the drawn filament of polypropylene was oxidized in potassium chlorate (KClO_3) and sulfuric acid (H_2SO_4) mixture. From IR spectrum showed the peak of polar groups such as hydroxyl and carbonyl that came from the oxidation reaction. And the oxidized polypropylene showed some physical changed on the surface when compared to the untreated polypropylene. They found that the oxidation caused the reduction of tensile strength, breaking strain, and work of rupture of the sample. Light fastness properties of used dyes on treated polypropylene were poor to moderate, but washing and rubbing fastness properties were moderate to good.

The use of nanoparticles is one of the interesting methods for improving the dyeability of polypropylene fibers. Nanoclay is employed because of its commercial availability with consistent quality and reasonable prices. Nanoclay has been recognized to remove textile dyes in the treatment of water from the widespread contamination of soil and ground water by synthetic organic chemical (e.g., dyes). The removal of textile dyes by using of clay nanoparticles was widely reported in the literatures. *Ozlem C. et. al. (2001)* studied the absorption of some textile dyes by hexadecyltrimethylammonium bentonite. In this work, bentonite was modified by hexadecyltrimethylammonium (HDTMA) to render its organophilic. Then, the absorption of textile dyes such as Everdirect supra Yellow PG, Everdirect supra Orange26 CG, Everdirect supra Rubine BL, Everdirect supra Blue 4BL and Everdirect supra Red BWS on Na-bentonite and HDTMA-bentonite were investigated. They showed that the textile dyes were strongly adsorbed on HDTMA-bentonite. On the other hand, no sorption of textile dyes occurred on Na-bentonite. This could be explained by adsorption interaction between the adsorbed dye molecules and hydrophobic alkyl group on HDTMA-bentonite, which should enhance the adsorptive capacity of the bentonite.

In 2005, the effect of chain length and size of surfactant on dye uptake by montmorillonite was studied by *Piyamaporn J. et. al.* The Quaternary Ammonium Cation (QACs) used as cationic surfactant for organoclay were tetramethylammonium chloride (TMA), tetradecyltrimethylammonium bromide (TDTMA), hexadecyltrimethylammonium bromide (HDTMA) and benzyldimethyl hexadecylammonium bromide (BDHDMA). In this work, fixed-beds of raw and organo-montmorillonite were evaluated for the elimination of methylene blue represented a cationic dye and methyl orange as an azo dye, see Tables 2.1-2.2. They found that methylene blue was removed more effectively by montmorillonite than by the organoclays and it was not absorbed at all by BDHDMA-clay. Methylene blue is not only soluble in water indicating hydrophilic nature but also carries positive charge which can enter into the precursor via cation exchange reaction. For the organoclays, the higher the QACs loaded on the sorbent clay, the lower the methylene blue uptake. This is because the QACS already occupied the cation exchange sites of the precursor clays, making its more difficult for methylene blue to

be adsorbed. In the case of methyl orange, it is an anionic dye; its repulsion with the negatively charged layer of the clays would be likely. However it was seen that the presence of the QACs in organoclays caused significant adsorption of methyl orange as a result of hydrophobic interaction between hydrocarbon tail of QACs and methyl orange. The methyl orange adsorption capacity increased with the order of the organic carbon contents of these clays.

Table 2.1 Methyl orange adsorption capacity by mean of Langmuir isotherm

Sorbent Clay	Sorption Capacity (mg/g)	R ²
50%CEC-HDTMA-clay	21.6	0.95
100%CEC-HDTMA-clay	48.8	0.94
200%CEC-HDTMA-clay	196.08	1
200%CEC-TDMA-clay	138.89	0.99
100%CEC-BDHTMA-clay	126.58	0.99

Table 2.2 Methylene blue adsorption capacity by mean of Langmuir isotherm

Sorbent Clay	Sorption Capacity (mg/g)	Sorption Capacity (meq/100 g of clay)	R ²
Montmorillonite	322.6	100.9	0.99
100%CEC-TMA-clay	172.4	53.9	0.99
200%CEC-HDTMA-clay	217.4	68	0.99
50%CEC-HDTMA-clay	243.9	76.3	0.99
100%CEC-HDTMA-clay	227.3	71.1	0.99
200%CEC-HDTMA-clay	13.3	4.3	0.99
50%CEC-TDMA-clay	163.9	51.3	0.99
100%CEC-TDMA-clay	178.6	55.9	1
200%CEC-TDMA-clay	208.3	65.2	0.99

P. Baskaralingam et. al. (2006) studied the adsorption of acid dye (Acid Red 151) onto organobentonite. In this research (Table 2.3), two organic cations with different structures had been used these were cetyldimethylbenzylammonium chloride (CDBA) and cetylpyridinium chloride (CP).

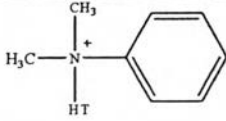
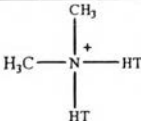
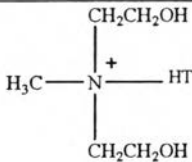
Table 2.3 Langmuir constant for adsorption of AR 151 onto CDBA-bentonite and CP-bentonite

Adsorbent	Langmuir constants			
	Q_0 (mg g ⁻¹)	b (Lmg ⁻¹)	R_L	R_L^2
CDBA-bentonite	357.14	0.5714	0.024	0.9985
CP-bentonite	416.66	12.04	0.00118	0.9998

The results showed that the langmuir model was the best fit model for the adsorption of AR 151 on to CDBA-bentonite and CP-bentonite. CP-bentonite had higher adsorption capacity than CDBA-bentonite due to steric factor. In CP modified bentonite, there was one pyridine ring and a long chain acetyl group. But in CDBA modified bentonite, there was two more methyl group in addition to one benzene ring and a long chain acetyl group. The extra methyl group may hinder the dye molecule from entering into the adsorption sites. However, the result indicated that both modified bentonite had high adsorption capacity; they could be used as adsorbent for color removal of acid dyes.

Yiqi Y. et. al. (2005) carried out a research in the title of nanoclay and modified nanoclay as sorbents for anionic, cationic and nonionic dyes. Surfactants (Table 2.4) employed in the study were aromatic quaternary ammonium (Cloisite10A), aliphatic quaternary ammonium (Cloisite 15A) and quaternary ammonium with hydroxyl groups (Cloisite 30B).

Table 2.4 Chemical constitution of the quaternary ammonium used for modification of the clay

Name of Modified Clay	Chemical Constitution of the Quaternary Ammonium*
10A	
15A	
30B	

* T is tallow with 65% C18, 30% C16 and 5% C14. HT is hydrogenated tallow. Anion for the quaternary ammoniums is chloride.

Study on the dye sorption isotherm indicated that nanoclay had very strong sorption ability due to its high surface area and strong van der Waals, hydrophobic and ionic interactions with dyes. They found that the clay treated with quaternary ammonium had a very strong sorption capability to acid, direct and disperse dyes, but relatively low sorption to reactive dye and very low sorption to basic dye. The 10A had the highest sorption of both the acid and disperse dyes. It was indicated that the addition of aromatic ring into the structure of quaternary ammonium remarkably increased dye sorption. The attraction between aromatic systems was called π - π interactions, which was mainly van der Waals interaction. The Cloisite 30B could enhance the sorption of hydrophilic sorbate, especially with hydrogen bonding sites. The acid dye sorption on 30B was very high, but the sorption of the disperse dye was not as good, due to the hydrophobic properties of disperse dye. For Cloisite 15A, the disperse and acid dyes sorptions were high at low concentration of dye. This was probably due to large voids between clay platelets created by two long tallow tails of quaternary ammonium on 15A. At high dye concentration the sorption of disperse dye was similar to 30B due to the limitation of spaces between the platelets. The Na-clay

showed very low sorption of acid dye because of the ionic repulsion between clay and dye. Low sorption of disperse dye onto Na-clay was due to the hydrophilicity of clay surface. However, Na-clay was ideal for the sorption of cationically charged basic dye.

From dye absorption properties of clay, it can be used as a complement for polypropylene which lack of dyeing property. There were a lot of study employed clay nanoparticles for improving other properties of polypropylene, but there were few work focused on the dyeing property.

Xiuqin Z. et. al. (2004) successfully prepared polypropylene(PP)/organomontmorillonite (OMMT) nanocomposite by melt intercalation and subsequently submitted for melt spinning. There was the addition of polystyrene for destroying the dense structure of polypropylene and PP-g-maleic anhydride (MAH) as compatibilizer. The XRD results (Figure 2.4) indicated that organic treatment of MMT could expand or exfoliate the silica layers.

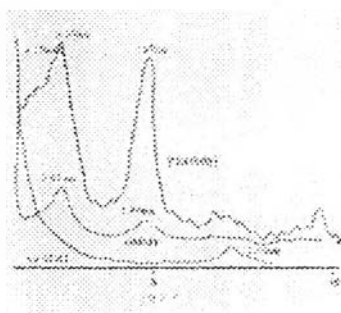


Figure 2.4 XRD curves of Na-MMT and PP/MMT

The introduction of OMMT increased the crystallization rate of PP chains. This effect could be explained by the assumption that the silicate layers act as efficient heterogeneous nucleating agents for the crystallization of PP matrix. Due to the good dispersity of OMMT in PP matrix, there were able to successfully make as-spun fibers from PP/OMMT nanocomposites and did not need to adjust the spinning condition as used for pure PP resins. The crystallinity of PP/OMMT hybrid fibers was much larger than that of pure PP fiber at all draw ratios. The orientation of PP/OMMT hybrid fibers was much lower than that of pure PP fibers at the same draw ratios, which beneficial to moisture absorption and dyeing ability of PP/OMMT hybrid fibers. The SEM micrograph in Figure 2.5 showed that the surface of pure PP

fiber was smooth, whereas that of PP/OMMT hybrid fiber had many flaws and grooves, which might result in the major change of the physical properties, such as moisture absorption.

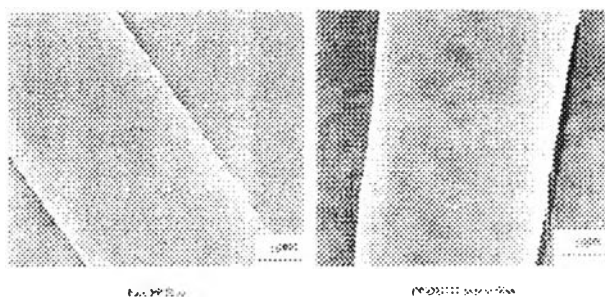


Figure 2.5 SEM images of pure PP fiber and PP/OMMT hybrid fiber.

They also reported that the introduction of OMMT and PP-g-MAH increased the amount of hydrophilic groups, and the addition of polystyrene led to the formation of the flaws and grooves on the fiber surface. In this work, the introduction of OMMT increased the crystallinity of fibers, thus decreased the hydrophilic properties of fibers. So, as seen in Table 2.5, the improvement of moisture absorption of PP/OMMT fiber was an equilibrating/competing result. And in this experiment, the influence of the increased polar group prevails over that of the crystallinity enhancement.

Table 2.5 Moisture absorption of pure PP and PP/OMMT fibers

Sample	Draw ratio	Moisture absorption (%)
Pure PP	4	0.40
PP/OMMT	4	0.55
Pure PP	3	0.45
PP/OMMT	3	0.60
Pure PP	2	0.50
PP/OMMT	2	0.63

Two years later, *M. Joshi et. al.* (2006) prepared polypropylene (PP)/nanoclay (OMMT) composite filament by melt spinning. Their result was

similar to that of Xiuqin Z. in that the crystallinity of PP/nanoclay fiber was higher than pure PP fiber. A possible reason was the addition of OMMT promoted the nucleation and growth of the crystals and perfected the α -crystalline form. The presence of OMMT in PP fiber also led to improve tensile properties and dynamic mechanical properties.

In 2001, *Qinguo F. et. al.* studied the feasibility of forming polypropylene fibers infused with nanoparticles that create dye sites to facilitate the dyeing of polypropylene materials. Quaternary ammonium salt (Cloisite 15A) was used as a surfactant. In this work, samples in the form of film were dyed in acid and disperse dyes. The result indicated that higher nanoclay add-on could result in better color yield on PP/nanoclay. They also observed that if there was insufficient homogenizing time, it would lead to the agglomeration of nanoclay in the PP matrix. The levelness of dyeing was dependent on the uniformity of the nanoparticles distribution in PP matrix. In addition, a longer homogenizing time generally produced a comparatively level dyeing. However, they found that the dyeing were uneven indicated that nanoclay was not properly dispersed in PP matrix. In 2002, *Qinguo F. et. al.* tried to solve on the dispersion of nanoclay in PP matrix problem. To achieve the uniform dispersion of nanoparticles, titanate-coupling agent was added to reduce the viscosity of polymer melt and to increase the compatibility between nanoparticles and the polymer. The coupling agent was used to bridge between polypropylene molecules and the inorganic particles. The results from the particle size analyzer indicated that the particle size could be reduced by ball milling and the ultrasonic also caused a reduction of particle size. In addition, the greater time allowed for ultrasonication, the better the result. They found that milled and ultrasonic clay particles (NC2, NC3, NC4 and NC5) gave better dyeing properties than the as received one (NC1), see Figure 2.6.

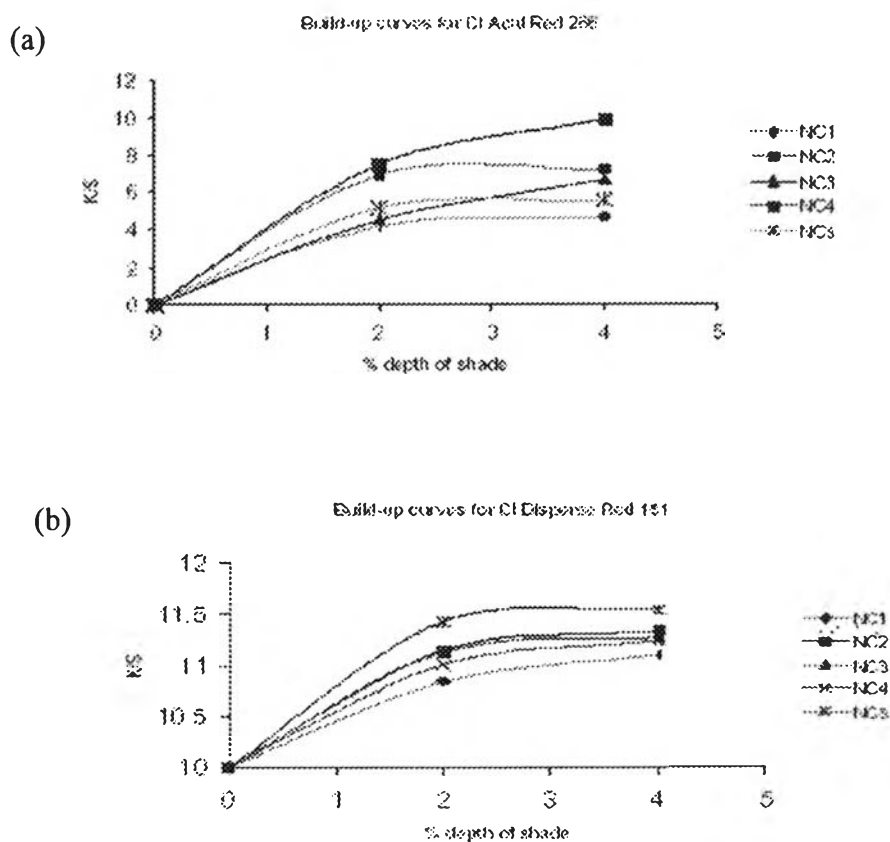


Figure 2.6 Build up curves for (a) the CI Acid Red 266 (b) the Disperse Red 151

In 2004, Qinguo observed that all the prepared PP nanocomposites were evenly dyed with both acid and disperse dyes at different percentage of dye concentration with satisfactory wash and light fastness. The saturation of K/S value was observed indicating the dyeability of PP nanocomposites cannot be increased infinitely. It was recommended that the PP nanocomposites would better be prepared with 2% clay add-on and dye at 1% of dye concentration, see Figure 2.7. This could reduce the overall cost of the dyeable PP through saving in the dyes and the nanoclay particles.

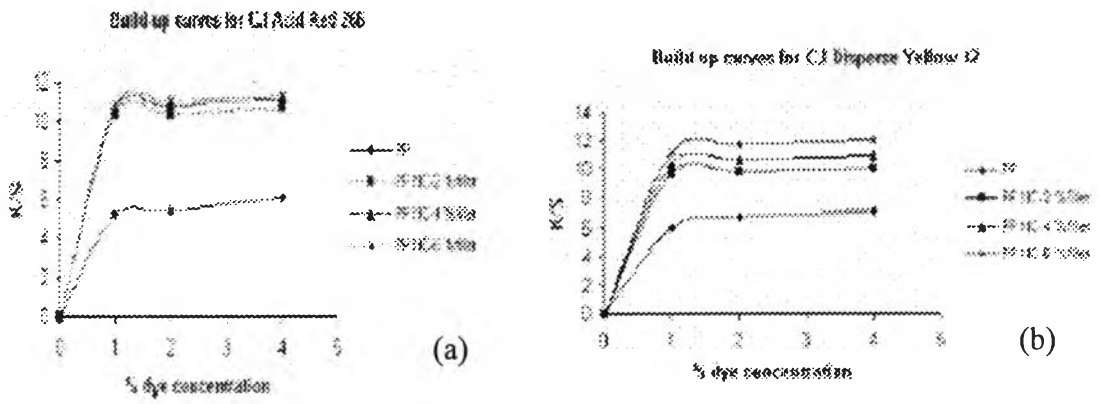


Figure 2.7 Build up curve for (a) C.I. Acid Red 266 (b) C.I. Disperse Red 65