

CHAPTER II

THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 Natural Rubber Latex

The only rubber plant that has been of commercial interest for the past 60 years, since the period of World War II, is the *Hevea brasiliensis*. It may be tapped from the Brazilian rubber tree for latex by gouging the bark with a tapping knife. *H. brasiliensis* belongs to the family of *Euphorbiaceae* (Mooibroek H. and Cornish K., 2000) with species which are well known for the milky suspension of rubber globules (latex). The rubber material obtained from the latex produced by certain plants and trees especially cis-1,4-polyisoprene was the only rubber of any commercial significance until 1930s, and still is one of the most important, primarily due to its molecular structure and high molecular weight. The molecular weight of fresh raw rubber typically has a number average value of about 5 millions. In addition, freshly tapped rubber contains crosslink microgel. This rubber has high performance properties than cannot easily be mimicked by artificially produced resistance, efficient heat dispersion (minimizing heat build-up under friction), and impact resistance. However, *H. brasiliensis* has strict climate requirements, limiting its cultivation to specific tropical regions. The composition of the *Hevea* Latex varies quite widely but the following may be considered to be a typical composition. Figure 2.1 illustrates the structure of cis-1,4-polyisoprene.

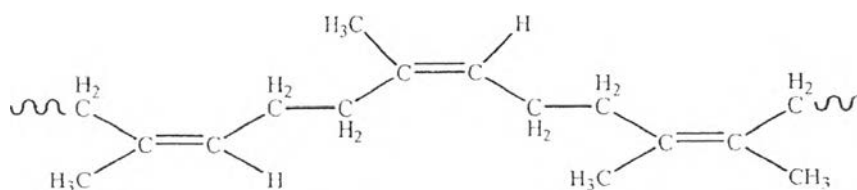


Figure 2.1 Structure formula of cis-1,4-polyisoprene in natural rubber.

Table 2.1 Typical composition of *Hevea* Latex

Total solids contents	36% (including dry rubber content, DRC, of 33%)
Proteinous substances	1-1.5%
Resinous substances	1-2.5%
Ash	Less than 1%
Sugar	1%
Water	0.6%

The latex may then either be concentrated to about 60% DRC, usually by centrifuging or evaporation, or alternately coagulated and dried.

The overall structure of rubber particles is similar in all species examined so far, they contain a homogeneous rubber core surrounded by an intact monolayer membrane (Irving and Cornish, 1997). The membrane is made up of a highly species-specific complement of lipids and proteins (Siler *et al.*, 1997) Normally, cis-1,4-polyisoprene is amorphous but crystallizes on cooling to below 0°C so that natural rubber hardens on storage at low temperatures. This may be arrested in anti-crystallizing rubber. Crystallization can also be induced by stretching and is responsible for the high tensile strength of natural rubber. At ambient temperature, linear raw rubber is a weak material becoming sticky at about 60°C and fluid at about 120°C. Natural rubber is still of major importance due to its low cost, low hysteresis, high strength, high resilience, excellent dynamic properties and fatigue resistance despite competition from the recently developed synthetic rubbers, e.g. SBR, polybutadiene, and polychloroprene, etc. The proximity of the methyl group to the double bond in natural rubber results in more reactive at both the double bond and at the α -methylene position than polybutadiene, SBR, and particularly, polychloroprene.

Hauser (1962) found that rubber particles were quite pear-shape rather than spherical, and consisted of a tough, hard, elastic shell which enclosed a viscous liquid. However, many studies have reported that the rubber particles are spherical in shape, especially the latex from young trees (Nawamawat *et al.*, 2011). It is also suggested that the shape of the latex depends on the age and type of tree.

The structure of the *Hevea brasiliensis* latex is:

Rubber hydrocarbons	86%
Water (dispersed in the rubber hydrocarbons)	10%
Proteinous substances	1%
Lipid substances	3%

Trace metals such as magnesium, potassium, and copper are included with the rubber particles at about 0.05%.

Figure 2.2 shows the structure of the NR latex particles. The NR consists of the protein structure at the outer layer of the surface. The adsorbed layer of protein determines the charge on the particle, electrophoretic mobility, and coacervation characteristics. The lipids associated with rubber particles are sterols and sterol esters, and fats and waxes such as eicosyl alcohol and phospholipids. They are found in the bulk of latex particles. They may be dissolved in rubber hydrocarbons. The phospholipids are adsorbed on the particles and are associated with the protein which is anchored to the rubber.

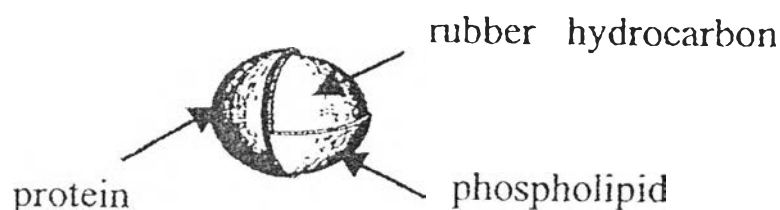


Figure 2.2 Structure of the NR latex particles.

2.1.1 Natural rubber in Thailand

The data from the Industrial Economics and planning Division, Ministry of Industry, showed that in 1992 Thailand produced 1,520,000 tons of natural rubber and exported 1,400,000 tons or 92.1% of total production. The remaining 7.9% was used in the country. Since 1994, Thailand has been the biggest in the world production of natural rubber. An area of about 12 million hectares is employed in Thailand for rubber cultivation. In 2004 Thailand produced 302.99 million tons of natural rubber. It is uneconomical to transport preserved field latex over long distances to consumer countries; the normal procedure is to change the latex form before ship-

ment. Therefore, after the natural rubber latex has been collected from the field, it is changed into many forms, which are shown in Table 2.2

Table 2.2 Different types of rubber in Thailand, 2004

Type of rubber	wt%
Smoked sheet	66.00
Block rubber	18.30
Crepe rubber	0.73
Concentrated latex	9.48
Other rubber	5.46

Source: Southern Industrial Economics Center in Thailand

Natural rubber latex is 60% dry rubber by the concentration method. In 2004, Thailand exported 131,888 tons to the USA, Taiwan, Germany and Singapore and the remaining 32,736 tons was used in the country.

2.1.2 Properties of Raw Natural Rubber

Natural rubber latex produced by the *tree Hevea brasiliensis*, consists of particles of rubber hydrocarbon and non-rubber constituents suspended in an aqueous serum phase. The average dry rubber content of latex may range between 30% and 45%. The typical composition of fresh latex is shown in Table 2.3.

Table 2.3 Composition of fresh latex and dry rubbers

Composition	Latex (%)	Dry rubber (%)
Rubber hydrocarbons	36.0	93.7
Protein	1.4	2.2
Carbohydrates	1.6	0.4
Neatral lipid	1.0	2.4
Glycolipid and Phospholipids	0.6	1.0
Inorganic constituents	0.5	0.2
Others	0.4	0.1
Water	58.5	-

2.1.3 Production of Natural Rubber Latex Concentrate

In general, natural rubber is known as natural rubber (NR) latex. The latex appears in the bark outside the cambium layer in ducts spiraling from the left to right as the latex ascends the tree. These ducts are found in concentric rings around the cambium and are really more concentrated near the cambium.

The procedure to obtain the latex is called tapping which makes a downwards spiral cut from left to right through the bark of the tree. This cut is manipulated to promote the latex to flow into a receptacle such as a plastic, glass, or earthenware cup. Fresh latex coagulates rapidly after tapping, especially in the ambient temperature. Fresh latex has a pH of 7.0. Bacteria decompose the sugar substance of latex and therefore the stability of the latex decreases continually as the pH decreases. Bacteria come from various places such as the atmosphere, the bark and the tapping the preservation of NR latex was first introduced by Johnson and Norris (1853). They suggested ammonia for using as an anticoagulant to the latex. The ammonia acts as an alkali to increase the pH of the fresh latex; thus the electrophoretic mobility of rubber tends to be negatively charged in a base environment. Fresh NR latex exuded from the tree has dry rubber content 33 wt%. In the industry, the latex is concentrated to about 60 wt%, which is economical and uniform in quality. There are several processes to concentrate latex: (1) evaporation, (2) creaming, (3) centrifuging and (4) electrodecantation.

The freshly-tapped NR latex is a whitish fluid with a density of between 0.975 and 0.980 g.cm⁻¹, and a pH from 6.5 to 7.0. Its viscosity is variable.

2.2 Surfactant

A surfactant, or surface active agent, is a chemical substance that is the most versatile product in the chemical industry. Surfactants are used in automobiles, detergents, pharmaceuticals, and are also applied to many high technology areas.

The molecular structure of a surfactant is called an amphipathic structure (Figure 2.2) because it consists of a lyophobic and a lyophilic group (a hydrophobic and a hydrophilic group, respectively in the case of aqueous solution). The surfactants should have an amphipathic structure in the solvent under the condition used for

supporting the good surface activity in a particular system. The lyophobic group of surfactant is usually a long-chain hydrocarbon while the lyophilic group is an ionic or highly polar group.

The surfactant can be divided into 4 types. It depends on the nature of the hydrophilic group.

1. Anionic surfactant: The hydrophilic group consists of negative charge, for example, $\text{RC}_6\text{H}_4\text{SO}_3\text{Na}^+$ (alkylbenzene sulfonate).
2. Cationic surfactant: The hydrophilic group consists of positive charge, for example, $\text{RNH}_3^+\text{Cl}^-$ (salt of long chain alkyl amine).
3. Zwitterionic surfactant: The hydrophilic group may give both negative and positive charge, for example, $\text{RNH}_2^+\text{CH}_2\text{COO}^-$ (long-chain amino acid).
4. Nonionic surfactant: The hydrophilic group does not contain any ionic charge, for example, $\text{RCOOCH}_2\text{CHOHCH}_2\text{OH}$ (monoglyceride of long-chain fatty acid).

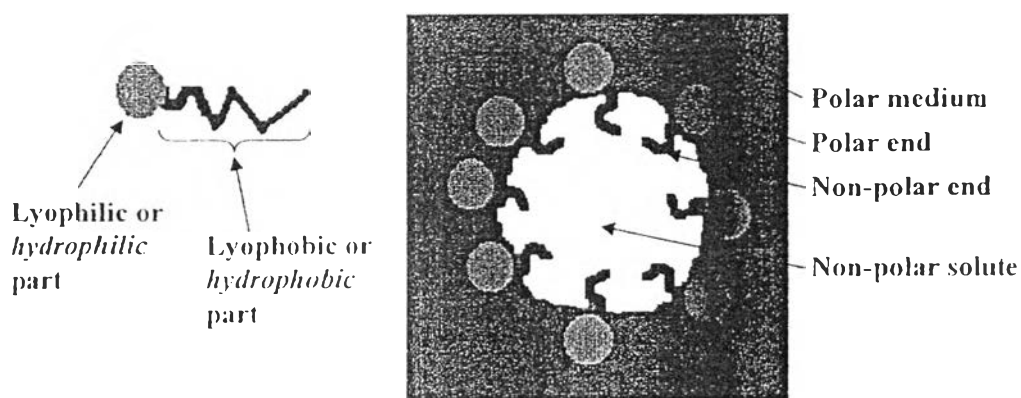


Figure 2.3 Structure of surfactant.

2.3 Surfactant Adsorption

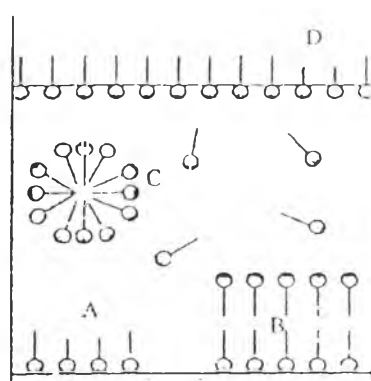
The surfactant adsorption is a process of transfer of surfactant molecules from bulk solution phase to the surface/interface. The adsorption of surfactant at the solid-liquid interface plays an important role in many technological and industrial applica-

tions, such as detergency, mineral flotation, corrosion inhibition, dispersion of solids and oil recovery. In a system with low surfactant concentration, the surfactant tends to adsorb at a surface or interface.

The adsorption of surfactant have influenced from this factors:

1. The nature of the structural groups on solid surface (e.g. polar group, or nonpolar group).
2. The molecular structure of the surfactant (e.g. anionic, cationic, or nonionic surfactant).
3. The environment of the aqueous phase (e.g. pH, electrolyte content and temperature).

In aqueous solution, surfactant molecules nucleate to form micelles at concentrations higher than the critical micelle concentration (CMC). The CMC is a specific characteristic of each surfactant. Surfactants can form at least three different types of aggregates: Monolayer, called a hemimicelle, or bilayer, called an admicelle at the liquid-solid interface, a micelle in solution, and a monolayer aggregate at the air-liquid interfaces, as shown in Figure 2.4



A : Hemimicelle

B : Admicelle

C : Micelle

D : Monolayer aggregate at air-liquid interface.

Figure 2.4 Surfactant aggregates.

Surfactant adsorbs onto the solid surface at the interface to form hemimicelle and admicelle aggregates that can be quantified by adsorption isotherm. Surfactant adsorption is one of its singularly important features in an oriented fashion. This property has been studied and applied in many areas, such as detergent to remove soil or dust from clothes. The adsorption polymerization process has been increasingly utilized in nano-coated film of polymer substrates for various purposes.

The adsorption of surfactant on the substrate surface is controlled by several parameters including the electrochemical nature of the substrate, the type of surfactant molecule, the pH of solution, and added counter-ion. Charge on the substrate surface can be manipulated to be either positive or negative by adjusting the pH of the contacting aqueous solution because both hydronium and hydroxide ions are potential determining ions for substrates. The solution pH at which the surface exhibits a net surface charge of zero is called the point of zero charge or PZC. At pH values below the PZC, the surface becomes protonated and more positively charged; above the PZC, the surface is negatively charged. Consequently, anionic surfactants adsorb well below the PZC and cationic surfactants above the PZC.

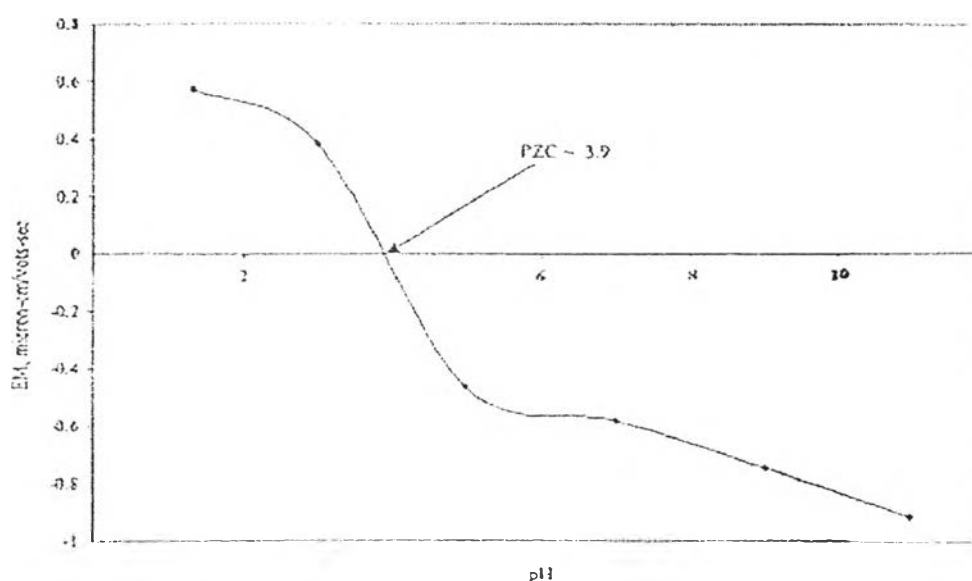


Figure 2.5 The point of zero charge on natural rubber surface. (Bunsomsit *et al.*, 2002)

Figure 2.6 presents the adsorption of surfactants on substrates is a well-known phenomenon. For the adsorption of ionic surfactants on a solid surface, the adsorption isotherm curve is typically an S-shaped graph when one plots the log of adsorbed surfactant versus the log of equilibrium concentration of surfactant. The S-shaped isotherm can be separated into four regions. In region I, surfactant adsorption is mainly by ion exchange and the amount of surfactant adsorption increases linearly with an increase in surfactant concentration. In region II, there is a marked increase in the slope of the graph resulting from interaction of the hydrophobic chains of oncoming surfactant with those previously adsorbed to form admicelles, bilayer aggregates, on the solid surface. In region III, the slope of the isotherm is reduced because adsorption now must overcome electrostatic repulsion between the oncoming ions and the like-charged head groups of surfactants on the surface. Surfactant surface coverage can be limited either by the attainment of the CMC below bilayer coverage at low surface charge densities or by the attainment of bilayer coverage below the CMC at high surface charge densities. In either case, the adsorbed surfactants reach equilibrium in region IV where the amount of surfactant adsorption remains constant with a further increase in surfactant concentration. In admicellar polymerization, the surfactant concentration is chosen to be in region III to obtain maximum admicelle formation with no micelles in the solution to avoid emulsion polymerization.

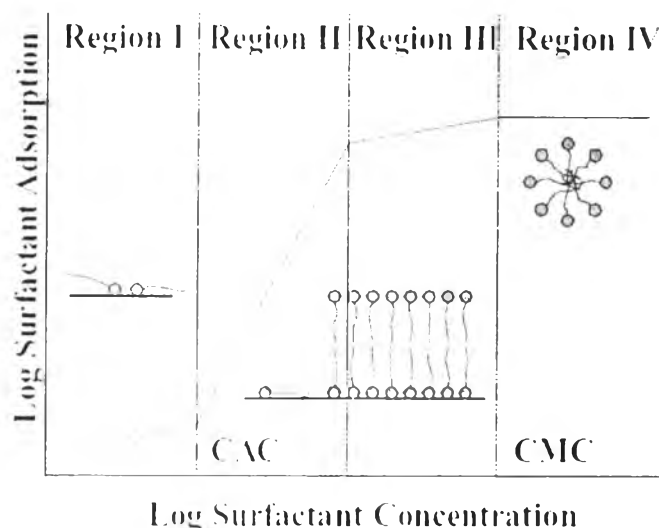


Figure 2.6 Typical adsorption isotherm of surfactants on a solid surface.
(Pongprayoon *et al.*, 2002)

2.4 Admicellar Polymerization Technique

The phenomena of surfactant micelles, solubilization of molecules in surfactant micelles, and subsequent reactions in these surfactant micelles have been known and studied for more than 50 years. The fact that surfactants adsorb on solid surfaces has also been known for a long time. These separate concepts came together in the mid-1980s when the nature of adsorbed surfactant aggregates (admicelles) became better understood, particularly the similarities between admicelles and micelles. Several studies clearly indicated that admicelles had the ability to solubilize other compounds (adsolubilization), just as solubilization occurs in micelles. This background led to examining the possibility of polymerizations occurring in these adsorbed aggregates, just as polymerizations take place in micelles. Admicellar polymerization was the term assigned to describe this new process. (Rungruang *et al.*, 2006)

As shown in Figure 2.7, admicellar polymerization is typically a four-step process, with some of the steps being performed concurrently for certain applications.

The solvent used for this process is water, although other solvents could possibly be used.

Step 1 consists of surfactant adsorption to form a bilayer on a solid surface. Several factors must be considered in this step, including the nature of the substrate, the polymerization scheme to be utilized, the monomers used, and the type of surfactant. Most substrates can acquire a surface charge in aqueous solution, a charge that is typically pH dependent. The pH value at which the surface charge is completely neutralized is called the point of zero charge, or PZC. At a pH above the PZC, the surface of the substrate is negatively charged; below the PZC, the surface is positively charged.

Step 2 in the process is adsolubilization or the solubilization of the monomer(s) into the adsorbed surfactant aggregates. This step may be done after the first step or simultaneously with it. Small molecules, such as monomer molecules, can shift the adsorption isotherm, but the effect is typically small and is usually neglected. Compatibility between the monomer(s) and the surfactant is necessary in order to maximize the amount of adsolubilization.

Step 3 is the polymerization of the monomer. The monomer concentrated at the surfactant bilayer is reacted with a water-soluble initiator. The polymerization is occurred and the monomers are converted to polymer.

Step 4 involves surfactant removal, usually by repeated or continuous contact of the modified solids with an excess of water. As Figure 2.5 implies, removing all of the surfactant is usually difficult, especially on porous substrates. Mass balances on porous systems suggest that even after vigorous washing, fully half of the surfactant remains on the modified particle.

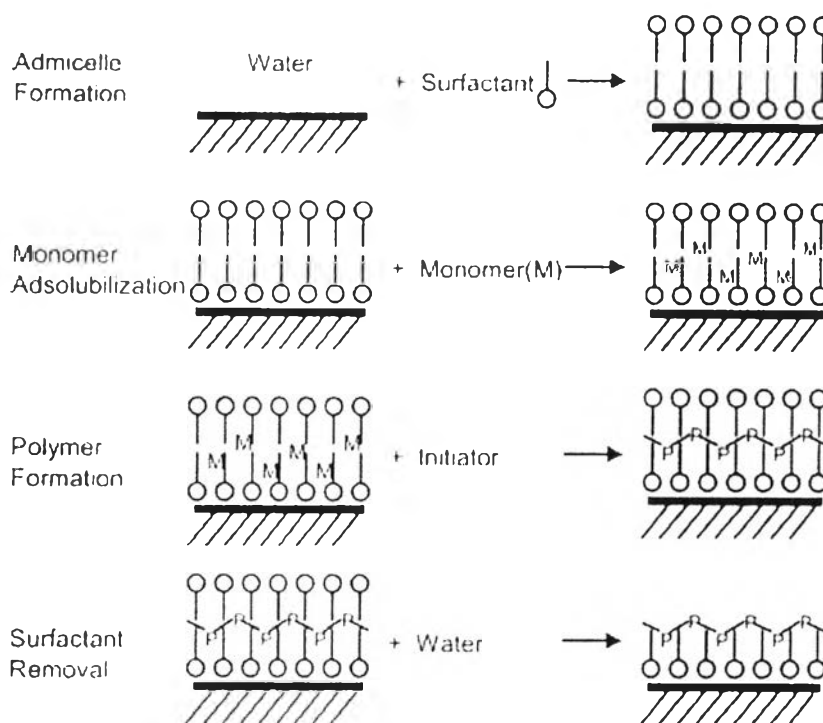


Figure 2.7 Admicellar polymerization technique. (Wei *et al.*, 2003)

Admicellar polymerization was developed about two decades ago. There are many researches involved this technique. Each of research studied in many different systems of monomer, surfactant and substrate. There are some studied researches and reviews involved the behavior of surfactant adsorption of the solid substrate and the admicellar polymerization technique from various different substrate, surfactant, monomer and condition, which are briefly showed as follows:

Wu *et al.*, (1987) tried to use admicellar polymerization to form ultrathin polymer film on a solid surface. They used styrene monomer, sodium dodecyl sulfate (SDS) for surfactant and alumina for solid substrate. Their experiments illustrated that admicellar polymerization consists of three steps including admicelle formation, monomer adsorption and polymer formation. From adsorption isotherm of SDS, the presence of styrene was found to increase SDS adsorption. Ultrathin film of polystyrene of several nanometers thick was found on alumina surface.

Esumi *et al.*, (1991) investigated about the polymerization of styrene adsorbed in surfactant bilayer on alumina. They used styrene monomer, sodium 10-undecenoate surfactant and alumina for solid substrate. They found that the adsorbed amount of styrene increases with equilibrium concentration of styrene and reach a plateau. The polymerization of such a system with UV irradiation in the presence of an initiator enhances dispersion stability of the alumina compared with the polymerization of bilayer of sodium 10-undecenoate alone on the alumina.

In 1995, Waddell *et al.* improved silica reinforcing filler by admicellar polymerization. In composite material, silica is an important component used as reinforcing filler especially in rubber compound. Problem of silica reinforcing filler is non-bond interaction between silica and polymer functionalities. Modified surface silica was developed to improve compatibility between hydrocarbon elastomer and precipitate silica. They used many types of polymers and copolymers for coating. After admicellar polymerization, modified silica can improve mechanical properties of rubber compounds and improve cure time. The different of chemical substance and reaction condition give a result in different properties of modified silica.

Funkhouser *et al.*, (1995) was successfully coating polypyrrole on alumina surface using SDS surfactant. They studied the effects of electrolyte and pyrrole concentration on adsorption isotherm of SDS surfactant. They found that, pyrrole caused a decrease in SDS adsorption while salt caused an increase in SDS adsorption.

In 1995, Sakhalkar *et al.* found coating glass fiber with polystyrene via admicellar polymerization technique. They studied about adsorption isotherms of two different surfactants in the experiments to form admicelles, namely dodecyltrimethylammonium bromide (DTAB) and cetylpyridium chloride (CPC). Glass fiber can form unhomogenous surface. The result showed that styrene in supernatant reduced with time after equilibrium of bilayer surfactant was formed on the substrate because styrene moved to the interior of micelle and polymerized. In addition, polymerization also occurred in aqueous phase but it was lower than that in micelle. The reason of nonuniformity of glass fiber surface was unhomogeneous of fiber surface.

O'Haver *et al.*, (1996) modified precipitated silica surface using polarcomonomer and a cationic surfactant, cetyltrimethylammonium bromide (CTAB). They found that they could produce new classes of reinforcing fillers where improved the physical properties of rubber compound.

In 1996, Kitiyanan *et al.* tried to study adsolubilization mechanism of styrene and isoprene in CTAB surfactant admicelle on precipitated silica. The adsolubilization equilibrium constant is important because it indicated amount of styrene adsolubilized into the palisade layer. In comonomer systems, slope of adsolubilization isotherm dramatically increased. It can be concluded that comonomer adsolubilization is better than monomer system.

In 2002, Polypyrrole coated on natural rubber latex and used sodium dodecyl sulfate (SDS) surfactant was investigated by Bunsomsit *et al.* They studied admicellar polymerization process under each of step and found the influence of chemical substance to reaction. In this work, they found the PZC of natural rubber latex and absorption isotherm. They studied the effect of salt concentration to SDS adsorption isotherm and adsolubilization of pyrrole. They found that, salt concentration caused an increase in SDS adsorption and pyrrole adsolubilize. Moreover, they studied the effect of pyrrole concentration on SDS adsorption isotherm.

Pongprayoon *et al.*, (2002) investigated thin film polystyrene coated on cotton fiber using linear alkylbenzene (LAS) surfactant. They studied the rate of LAS adsorption, effects of pH and electrolyte on adsorption of LAS on cotton. At high pH, LAS adsorption will be low. At high concentration of salt, LAS adsorption will be high. After the cotton was coated with polystyrene, it showed the increasing in water resistance.

Arayawongkul *et al.*, (2002) characterized polystyrene that produced by admicellar polymerization which they focused on the effects of surfactant loading, monomer loading and reaction time on the characteristics of polymer. They used cetyltrimethylammonium bromide (CTAB) surfactant and extracted polystyrene from the surface of modified silica with tetrahydrofuran (THF). They reported that the re-

action time for conducting admicellar polymerization should not shorter than two hours to obtain relatively high molecular weight polystyrene. The extent of polystyrene film and amount of polystyrene forming on silica particles increased with increasing CTAB adsorption and adsolubilized styrene.

Bourgeat-Lami *et al.*, (2002) synthesized 3-(trimethoxysilyl)propyl methacrylate (MPS) as a functional (co)monomer on the surface of polystyrene in emulsion polymerization, according to the MPS monomer is reactive in free radical polymerization so they used potassium persulfate (KPS) as an initiator. The ratio of monomer: initiator was 1:0.01.

In 2002, Luna-Xavier *et al.* had been synthesized and characterized of silica/poly(methyl methacrylate) nanocomposite latex particles through emulsion polymerization using a cationic azo initiator and they also studied about the adsorption isotherm of NP 30 (nonionic surfactant) on the surface of silica for the formation of the film on the surface of silica.

See *et al.*, (2003) used atomic force microscopy to investigated ultrathin polystyrene films formed by admicellar polymerization on silica disks. Their goal was to examine changes in the properties and morphology of the formed polymer films due to changes in the surfactant and monomer feed levels. They found a smooth thin film that occurred at high concentrations of styrene but a lower styrene loadings, the polystyrene film became unstable and formed drop-like aggregates. When samples were examined again after 1 year, the polystyrene films had agglomerated forming larger aggregates arranged in straight-line or ring-like structures at higher feed concentrations.

Xin *et al.*, (2003) used X-ray photoelectron spectroscopic to study hydrophilic surfaces of a rough solid and porous solid modified via admicellar polymerization. They studied the removal of polymer after admicellar polymerization with water and followed by Soxhlet extraction with toluene. They found organic material can be removed only 30% after water washing and 50% if followed by Soxhlet extraction with toluene. Moreover, on the outside surface, the ratio of surfactant to polymer af-

ter admicellar polymerization and the solvent washes is approximately 1:1 whereas the ratio on the interior surface is approximately 3:1

Preparation and characterization of natural rubber dispersed in nano-matrix was studied by Kawahara *et al.*, (2003). They investigated in terms of graft-copolymerization of deprotenized natural rubber latex with styrene, using tert-butyl hydroperoxide/tetraathylene-pentamine as an initiator. They used H-NMR spectroscopy, size-exclusion-chromatography and transmission electron microscopy after staining the films with OsO₄ for characterization. They found that natural rubber particle of about 0.5 μm in diameter was dispersed in polystyrene-matrix of about 15 nm in thickness and the stress at break was found to be the highest due to not only nano-matrix of polystyrene but also the highest grafting efficiency.

Srinarang (2004) investigated the admicellar polymerization of polystyrene on natural rubber particles using hexadecyltrimethylammonium bromide (CTAB) as the surfactant and 2,2'-azobis(2-methylpropionamide) (V50) as the soluble initiator. The suitable pH, time of surfactant adsorption, CTAB concentration and styrene concentration were studied. They found that the suitable pH was chosen at higher than 3.3 to achieve the adsorption of the cationic surfactant CTAB. The presence of salt resulted in increasing CTAB adsorption and styrene adsolubilization. Moreover, it improved the amount, orientation and packing of CTAB. Time of 15 hrs was sufficient for surfactant adsorption. They also found that the higher initial styrene concentration resulted in the higher equilibrium styrene concentration and the higher styrene adsolubilization.

Thin polystyrene film coated on cotton with and without a cross-linking agent was characterized by Pongprayoon *et al.*, (2005). They used divinylbenzene (DVB) as a crosslinking agent to form network polystyrene. It can be improved film coverage. The result showed that fiber improved in a wettability property. The optimum amount of cross-linking agent was around 1%. Above this value, both the coverage and wettability began to decrease.

Nontasorn *et al.*, (2005) modified the silica surface by using admicellar polymerization in a continuous stirred-tank reactor system (CSTR) to improve the compatibility between the silica and rubber. The ingredient was comprised of precipitated silica, cetyltrimethylammonium bromide (CTAB) cationic surfactant, styrene and isoprene comonomers, and 2,2'-azobisisobutyronitrile initiator. The result showed that the modified silica reduced T_{90} cure times and improved modulus, abrasion resistance, and compression set. The optimum conditions for surface modification of silica by the admicellar polymerization process were 5 g comonomer loading per kg silica and a 30 min reaction time. In comparison with the modified silica using a batch process, the modified silica obtained from the CSTR process was found to be superior in the performance of rubber compound.

The modified surface calcium carbonate (CaCO_3) particles by admicellar polymerization were used as filler for isotactic polypropylene system that was investigated by Rungruang *et al.*, (2006). Sodium dodecyl sulfate (SDS) and sodium persulfate ($\text{Na}_2\text{S}_2\text{O}_8$) were used as surfactant template and the thermal initiator, respectively. Non-isothermal crystallization was studied and indicated that surface treatment of CaCO_3 particles reduced the ability of CaCO_3 particles to nucleate the isotactic PP matrix. The behavior of these coated particles in an isotactic PP matrix was compared from that of uncoated and stearic acid-coated ones. The composites made with stearic acid-coated and admicellar-treated CaCO_3 particles had lower tensile strength, Young's modulus and flexural strength, but higher impact strength.

In 2006, Preechasup *et al.* studied the admicellar polymerization of styrene coated on natural rubber using two different types of surfactant (SDS and CTAB) and optimum conditions with ratio of styrene to initiator at 1:0.04. Under aging condition, the modulus, tensile strength and thermal mechanical property can be improved caused by increasing of the compatibility between two components.

Isahoh *et al.*, (2007) investigated the admicellar polymerization of styrene coated on natural rubber by varying styrene concentrations from 50 to 300 mM. The cure rate and minimum torque of admicellar PS-NR with any styrene concentration were lower than that of NR but the maximum torque was vice versa. In the physical

properties study, the cured admicellar PS-NR with 300 mM-styrene has the highest tensile strength, modulus and hardness but lowest elongation at break. The rheological behavior of admicelled PS-NR, using a Capillary rheometer, indicated better processability after blending and mixing with 50 wt% NR and 30 phr silica, respectively.

In 2007, Maserti *et al.* studied about the extraction of citrus leaf proteins and separation by 2D electrophoresis. In this work they used a strong detergent (C7BzO) in the solubilization/rehydration buffer.

Srirachya (2009) studied about thin layers of polystyrene (PS) and poly(methyl methacrylate) (PMMA) were coated on natural rubber (NR) particles via admicellar polymerization using bilayers of cetyltrimethylammonium bromide (CTAB) as a reaction template. The work aims to study polystyrene coated on natural rubber by admicellar polymerization technique by varying conditions of reaction such as the effects of natural rubber (5, 10 and 20 wt%), styrene monomer and CTAB concentration.

Tragoonwichian *et al.*, (2009) produced bifunctional cotton fabric by double coating via repeat admicellar polymerization using dodecylbenzenesulfoni acid sodium salt (DBSA), as the surfactant. 2-Hydroxy-4-acryloyloxybenzophenone (HAB) was first coated on a cotton fabric in order to improve its ultraviolet protection and then methacryloxymethyltrimethylsilane (MSi) was coated to create a water-repellent surface. Adsorption of DBSA on the HAB-coated substrate was found to be less than on the untreated surface. The polymeric coating on the surface was characterized by SEM and FTIR. It was found that the double coating process was successfully carried out. The treated fabric was found to have very good ultraviolet protection factor (UPF) together with high water repellency as determined by the contact angle measurement. The optimum amount of monomers was found to be 1.5 mM HAB and 5 mM MSi.

Zhao *et al.*, (2011) tried to improve tensile and thermal properties of poly(lactic acid) composites with admicellar- treated rice straw fiber. They used me-

thyl methacrylate as the monomer and cetypyridinium chloride (CPC) as the surfactant for admicellar polymerization.