CHAPTER 4

Experiments

In this chapter, the materials, equipment, sample preparations and procedures of the experiments will be explained.

4.1 Materials

4.1.1 Poly (bisphenol A carbonate), PC

Poly (bisphenol A carbonate), PC is a polyester of carbonic acid. Virtually all general purpose polycarbonates are based on bisphenol A as the repeating unit shown in Figure 4-1
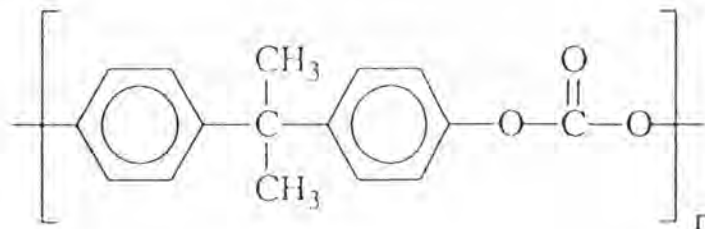

Figure 4-1 The structure of Poly(bisphenol-A-carbonate)

PC is a high performance amorphous engineering thermoplastic with exceptionally high impact strength, clarity, heat resistance and dimensional stability. The electrical properties of PC are outstanding. High corona resistance and insulation properties are achieved, as well as a dielectric constant that is almost independent of temperature. Other properties include heat resistance, flame retardant and biocompatibility [Frank, et. al. 1988].

Major applications of PC are in electronic and telecommunication equipment, food appliances and services, safety equipment and medical device, etc.

In this research, commercial grade PC was provided in the trade name of "MAKROLON" by Bayer Polymers Co., Ltd. The appearance of this PC is a transparent pellet. The glass transition temperature (Tg) of the PC is around $150^{\circ}C$.

4.1.2 Nylon 6

Nylon 6 is one of polyamide resins, which are synthesized polymers that contain an amide group (--CONH--). Nylon 6 is made from the polymerization of caprolactam with water catalyst (the structure of nylon 6 is shown in Figure 4-2).

$$\left[(CH_2)_5 - \underset{\underset{H}{|}}{N} - \overset{\overset{O}{\|}}{C} \right]_n$$
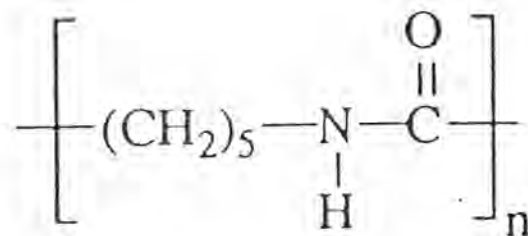
Figure 4-2 The structure of Polycaprolactam or Nylon 6

Nylon 6 is one of the most important polyamides. The key characteristic of nylon 6 is its resistance to oil and grease, solvents, bases and other chemicals. Nylon6 has excellent mechanical properties, such as fatigue, repeated impact and abrasion. The other properties are flame retardant, high service temperature and electrical properties [Melvin, et. al. 1988].

There are many applications from nylon 6, such as parts of automobile vehicles (the largest market), electrical and electronic applications, parts of industrial machines and filaments.

A commercial grade nylon 6, which is a cloudy pellet was supported by UBE Nylon Co., Ltd. The melting temperature (T_m) is around 220°C.

4.1.3 Polyoxymethylene or Acetal Copolymer (POM)

Polyoxymethylene or Acetal Copolymer is an engineering random co-polymer, which contains formaldehyde (oxymethylene) and acetaldehyde (oxyethylene) group (shown in Figure 4-3).

$$--- CH_2O --- \qquad\qquad --- C_2H_4O ---$$

Oxymethylene   Oxyethylene

Figure 4-3 The structure of repeating unit of acetal copolymer

POM is one of the highest crystallinity polymers, which is responsible for exceptional solvent resistance, fatigue resistance, surface lubricity and finish, and predictable strength and toughness over a wide range of temperatures.

Industrial and material handling applications that used this advantage of low coefficient of friction, solvent resistance and creep resistance, are the parts of electronic equipment and automotive application, which are the highest market of POM [Stephen, et. al. 1988].

POM used in this work was provided by Thai Polyacetal Co., Ltd. The melting temperature of POM is around 165°C. This POM used is the commercial grade with cloudy bead appearance.

4.1.4 Polypropylene (PP)

Polypropylene is one of the commodity thermoplastics, which is widely used in many industries. The structure of PP is shown in Figure 4-4
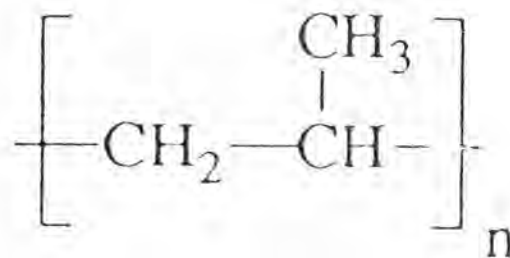
$$\left[-CH_2 - \underset{\underset{CH_3}{\mid}}{CH} - \right]_n$$

Figure 4-4 The structure of Polypropylene

Their structures, which contain the methyl group (CH_3), represent the different properties of each tacticity : isotactic, syndiotactic and atactic. The isotactic form is the most regular since the methyl group is all disposed on one side of molecules and these allow the forming of the crystal. PP in the commercial markets are usually about 90-95 % isotactic.

At present, the main application of PP is the injection moulding materials. The other applications, such as sheets, pipes and wires coating are still limited. The monofilaments application is the large market for PP because of its excellent properties, such as a low density with a high tenacity and a good abrasion resistance. It's usually used in ropes and netting applications.

Many forms of PP can be applied. The copolymer of PP with other linear polyolefins like polyethylene (PE), present the good application in thin film.

In this research, the injection moulding grade PP was donated by HMC Polymers Co., Ltd. Their melting temperature is approximately $165^{\circ}C$.

4.1.5 High Density Polyethylene (HDPE)

Polyethylene (PE) is the largest volume usage of plastics, which are produced from ethylene (see in Figure 4-5). HDPE belongs to PE group, which is a thermoplastic material that is in the form of solid in its room temperature state. Under the extrusion conditions of heat, pressure, and mechanical shear, it softens into a highly viscous, molten mass under the solidified conditions in the shape of the desired end product, such as film, pipe or drum. The HDPE is characterized by its opacity, chemical

inertness, toughness at both low and high temperature, chemical resistance, moisture barrier and electrical insulating properties.
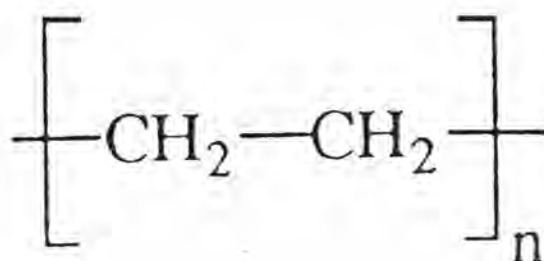
$$\left[CH_2 - CH_2 \right]_n$$

Figure 4-5 The structure of Polyethylene

The physical properties of HDPE are affected by their weight average molecular weight (M_w). As the M_w increase, the mechanical properties increase significantly. However, the polymer becomes more difficult to process.

HDPE resins, with its molecular weight unit less than 200,000 are considered as general-purpose commodity grade. These grades typically favor easier flow properties, balanced with moderate end use physical properties [Bourgeois, et. al. 1988].

In this research, a commodity grade HDPE was supported by Thai Polyethylene Co., Ltd. Their crystalline melting temperature is approximately $130^{\circ}C$.

4.1.6 Poly(methyl methacrylate) (PMMA)

Poly(methyl methacrylate) is a clear, colorless and transparent thermoplastic. The chemical structure of PMMA is shown in Figure 4-6

The commercial PMMA is available in both atactic and syndiotactic structures. The glass transition temperature of each structure is approximately 104°C (atactic) and 115°C (syndiotactic). The PMMA resist to many inorganic solvent including dilute acids and alkalis [Charrier, 1991]. The outstanding property of PMMA is its excellent transparency [Charrier, 1991]. Coupled with its unusually good outdoor weathering behavior, its transparent properties make it highly useful in all applications where light transmission is indispensable.

Many applications of PMMA are found as hard contact lenses, automobile taillight lenses, reflective devices, skylights, aircraft cabin windows, instrument and appliance covers, and home furnishing. It's also used as optical fibers [Charrier, 1991].

PMMA in this research is an atactic commercial grade, which was provided by TPI Polyacrylate Co., Ltd. Their glass transition temperature is around 95°C.
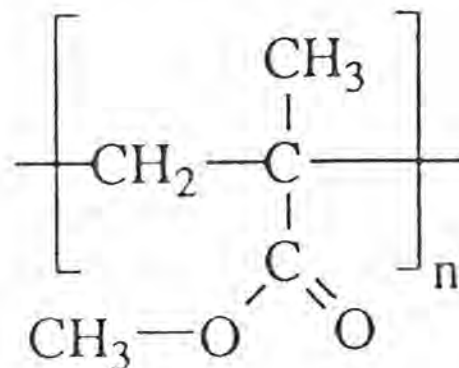

Figure 4-6 The structure of Poly(methyl methacrylate)

4.1.7 Styrene Acrylonitrile Copolymer (SAN)

Styrene Acrylonitrile Copolymer (approximately 20-30 weight percent of acrylonitrile content) have been available for a number of years and are usually produced by suspension or emulsion polymerization technique. The repeating units of styrene and acrylonitrile in SAN are shown in Figure 4-7
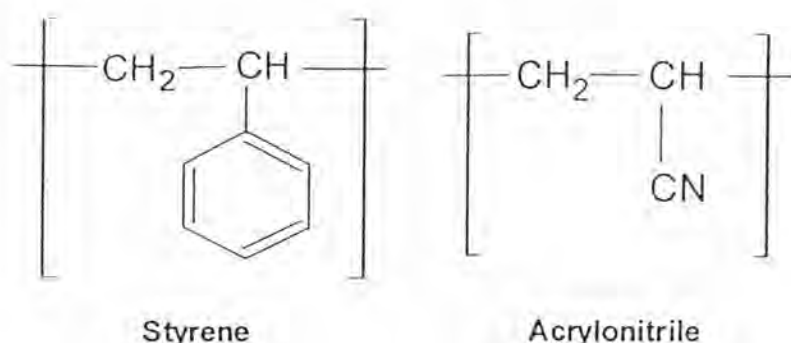

Styrene   Acrylonitrile

Figure 4-7 The structure of repeating unit of styrene acrylonotrile copolymer

Because of the polar nature of the acrylonitrile molecule, this copolymer has better resistance to hydrocarbon, oil and grease than polystyrene. They also have better resistance to stress cracking and crazing and an enhanced impact strength and yet retain the transparency of the homopolymer [Brydson, 1995]. The higher content of acrylonitrile builds greater toughness and chemical resistance but more difficult to molding and low thermodynamic compatibly.

In this research, commercial grade SAN was provided by Bayer Polymers Co., Ltd. under trade name "LUSTRAN" with acrylonitrile content of 25 weight percent. It appears in slightly yellowish transparent pellet. The glass transition temperature (Tg) of SAN is around 105°C.

4.1.8 Low Molar Mass Liquid Crystal

Low molar mass thermotropic liquid crystals were used in this work. There were manufactured by MERCK CO., LTD. under the trade name of LICRISTAL® . There were four liquid crystals which were selected to study effect of anisotropic temperature on application in this work.

4.1.8.1 CBC33

CBC33 is in the form of a white powder as received. Its structure which contains Cyclohexyl - Biphenyl - Cyclohexane backbone is shown in Figure 4-8 and its properties are presented in Table 4-1.
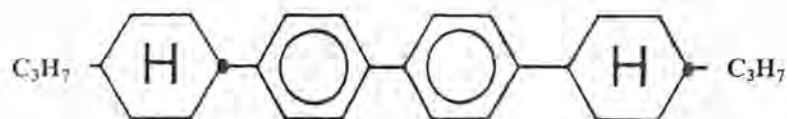

Figure 4-8 The structure of CBC33

4.1.8.2 CBC53

CBC53 is in the form of a white powder as received. Its structure also contains Cyclohexyl - Biphenyl - Cyclohexane backbone is shown in Figure 4-9 and its properties are presented in Table 4-1.
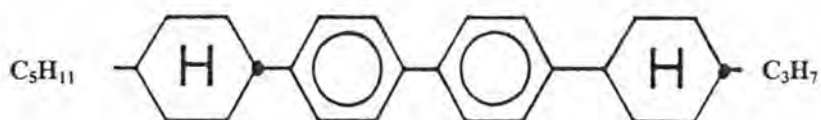

Figure 4-9 The structure of CBC53

4.1.8.3 HP5N

HP5N is in the form of a white powder as received. Its structure which contains Phenyl - Cyclohexyl - Benzoates backbone is shown in Figure 4-10 and its properties are presented in Table 4-1.
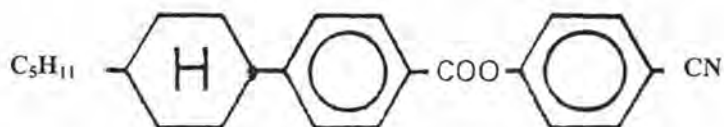
Figure 4-10 The structure of HP5N

4.1.8.4 BCH5

BCH5 is in the form of a white powder as received. Its structure which contains Biphenyl - Cyclohexane backbone is shown in Figure 4-11 and its properties are presented in Table 4-1.
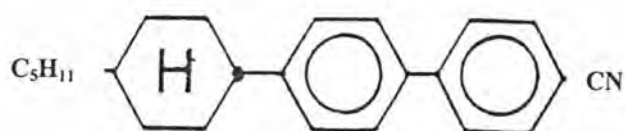
Figure 4-11 The structure of BCH5

Table 4-1 Properties of low molar mass thermotropic liquid crystal

Properties	Type	CBC33	CBC53	HP5N	BCH5	HD35
Melting point $^{\circ}C$	158	64	111	96	127
S$\rightarrow$N temperature $^{\circ}C$	223	260	-	-	126
Clearing Temperature $^{\circ}C$	327	317	226	219.3	191.1
Molecular weight	420.67	430.72	375.52	331.51	398.64

4.2 Equipment

4.2.1 Digital Hot Plate Stirrer

A Cole-Parmer digital hot plate stirrer was used in this study for preparing or mixing the polymers with liquid crystal. This hot plate stirrer is programmable. All functions can be set from digital panel and display their status on LCD. The plate temperature, stir speed and time are controllable.

4.2.2 Twin Screw Extruder

The blends of SAN/PMMA in this experiment were prepared by a Brabender twin screw extruder model PL-2000. This extruder is a counter rotating type with three heating zone and the L/D is 42/7. This extruder was also used to blend polymers and liquid crystals.

4.2.3 Grinder

The Thomas-Wiley Laboratory Mill grinder was used to scratch the pellet of polymer into small powder before mixing with liquid crystals.

4.2.4 High Speed Mixer

The local made high-speed mixer was applied to pre-blend of polymer and liquid crystal before pouring into the extruder.

4.2.5 Hydraulic Hot Press

A local made hydraulic hot press was used in these experiments. The maximum working temperature of this machine is $600^{\circ}C$ and the maximum pressure is 5000 psi. This equipment is used to prepare the samples in this research.

4.2.6 Parallel Plate Rheometer

A Haake rheometer model RS 75 was taken to investigate the shear viscosity of samples. The parallel plate sensor with both plate diameter of 20 mm. was used. The set of equipment compounded with rheometer, temperature controller, air compressor which are connected with a computer, as shown in Figure 4-12. The shear stress, shear rate, temperature and other condition could be directly controlled by computerized system.

The shear viscosity of samples was defined by response of friction force that resisted the movement of mechanical torsion as shear force (shear stress). The shear stress could be applied step by step (ramp of shear stress or shear rate) or at constant shear stress to investigated effect of time, temperature, etc.

4.2.7 Tensile Testing Machine

The tensile tests were performed by a LLOYD tensile testing machine model 2000R. These tests could obtain the stress-strain behavior of polymers and their blends. The test procedure is modified by a ASTM D-882 which covered the determination of tensile properties of thin sheet or thin film plastics.

Each test specimen was mounted on the machine as shown in Figure 4-13. The force necessary to elongate and break that specimen was measured by load cell in the machine. The stress occurred at the yield point was designated as the tensile stress at yield. The stress occurred at the break was designated as the tensile stress at break. The mean value of five measurements was used. In this study, the cross head speed was set at constant proportional rate for each polymer at the maximum load cell of 1 kN.
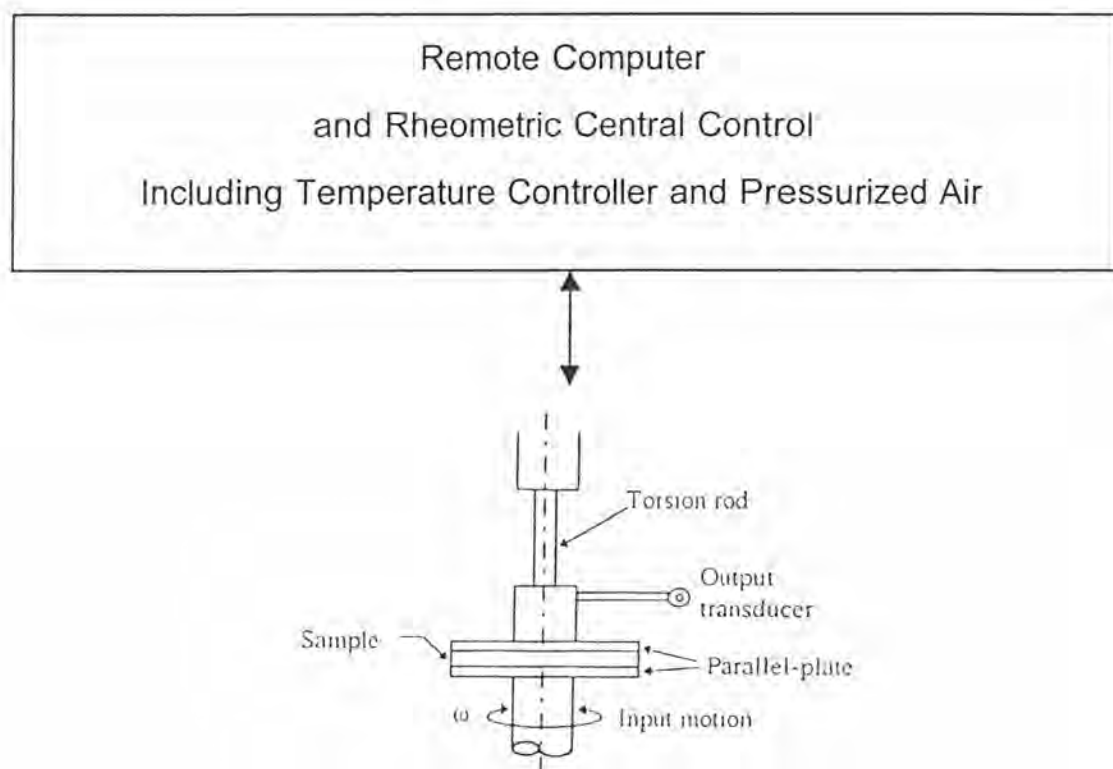
Figure 4-12 Rheometric measurements with parallel plate sensor
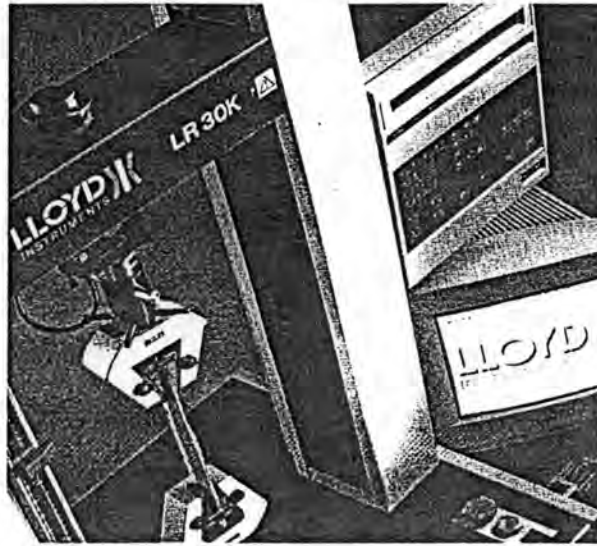
Figure 4-13 The tensile testing machine

4.2.8. Differential Scanning Calorimeter (DSC)

The glass transition temperatures of samples were determined by using a differential scanning calorimeter (DSC). DSC is a thermal analysis technique which measures heat flow into or out of a sample and a reference as a function of time or temperature. Figure 4-14 presents the schematic work of DSC.

Figure 4-14 Schematic representation DSC

4.3 Mixing and Samples Preparation

The mixing and samples preparation condition in this work was selected differently, depending on type of polymers in this experiment. The samples were classified into nine systems.

4.3.1 System 1 : Polycarbonate and CBC 33

4.3.1.1 Blending of polymer and liquid crystal

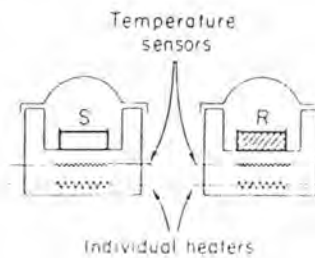The blends of PC and CBC33 were prepared by using a digital hot plate stirrer at the compositions of 0.25, 0.5 and 1 percent by weight of CBC33. PC was weighted in a beaker about 30 g. and CBC33 was weighted corresponding to the desired compositions. Each blend was placed on a teflon-coated plate and placed on the digital hot plate stirrer. The hot plate was set at $290^{o}C$ and the blends were mixed together for 10 minutes by mechanical stirring polymer melt in order to have a uniform mixture. After that, the blends were compressed to form a thin plate and cut into small pellets. The pure PC was treated like the blends to have the same thermal history. The blend was separated into 2 parts. One part was measured for shear viscosity by rheometric measurement and another part was measured for tensile properties.

4.3.1.2 Sample preparation for rheometric measurements

The pellets of each blend were placed into a perforated plate stainless mould with the diameter of 20 mm and 1 mm thickness. The mould was coated with releasing plates and heated for about 5 minutes until the polymer was almost all melted, then compressed by a hydraulic hot press at $290^{o}C$ and 4,000 psi for

5 minutes. After cooled by air for 5 minutes, the pieces of sample were removed from the mould and taken to measure shear viscosity by the parallel plate rheometer.

4.3.1.3 Tensile Specimen preparation

The tensile specimen in this work was prepared in sheets with the thickness of 0.1 – 1.0 mm. The pellets of each blend were placed in a square aluminum mould with the width of 100 mm and 0.3 mm. thickness. The mould was coated with releasing plates and heated for about 5 minutes until the polymer was almost all melted, then compressed by a hydraulic hot press at 290°C and 4,000 psi for 5 minutes. The plate of samples was removed from mould after cooled by air for 5 minutes.

Each plate of blends was cut into rectangular shapes of 10 x 100 mm^2. The test specimens were performed on the tensile testing machine to obtain the tensile properties.

4.3.2 System 2 : Polycarbonate and CBC 53

4.3.2.1 Blending of polymer and liquid crystal

The blends of PC and CBC53 were prepared by using a digital hot plate stirrer at the compositions of 0.25, 0.5 and 1 percent by weight. PC was weighted in a beaker about 30 g. and CBC53 was weighted corresponding to the desired compositions. Each Blend was placed on a teflon-coated plate and place on the digital hot plate stirrer. The hot plate was set at 290°C and the blends were mixed together for 10 minutes by mechanical stirring polymer melt in order to have a uniform mixture.

After that, the blends were compressed to form a thin plate and cut into small pellets. The pure PC was treated like the blends to have the same thermal history. The blend was separated to 2 parts. One part was measured for shear viscosity by rheometric measurement and another part was measured for tensile properties.

4.3.2.2 Sample preparation for rheometric measurements

The pellets of each blend were placed into a perforated plate stainless mould with the diameter of 20 mm and 1 mm thickness. The mould was coated with releasing plates and heated for about 5 minutes until the polymer was almost all melted, then compressed by a hydraulic hot press at 290°C and 4,000 psi for 5 minutes. After cooled by air for 5 minutes, the pieces of sample were removed from the mould and taken to measure shear viscosity by the parallel plate rheometer.

4.3.2.3 Tensile Specimen preparation

The tensile specimen in this work was prepared in sheets with the thickness of 0.1 – 1.0 mm. The pellets of each blend were place in a square aluminum mould with the width of 100 mm and 0.3 mm. thickness. The mould was coated with releasing plates and heated for about 5 minutes until the polymer was almost all melted, then compressed by a hydraulic hot press at 290°C and 4,000 psi for 5 minutes. The plate of samples was removed from mould after cooled by air for 5 minutes.

Each plate of blends was cut into rectangular shapes of 10 x 100 mm^2. The test specimens were performed on the tensile testing machine to obtain the tensile properties.

4.3.3 System 3 : Nylon 6 and CBC 53

4.3.3.1 Blending of polymer and liquid crystal

The blends of Nylon 6 and CBC53 were prepared by using a twin screw extruder at the compositions of 0.1, 0.2 and 0.4 percent by weight of CBC53. Nylon 6 after dried into oven at 70°C for 3 hr. was weighted in a beaker about 300 g. and CBC53 was weighted corresponding to the desired compositions. The Nylon 6 was ground into powder with a grinder. Pre-blend of Nylon 6 and CBC53 was performed in a high-speed mixer, and extruded in a twin screw extruder. The screw speed was set at 40 rpm and temperature set at 210°C, 220°C and 230°C for each zone. The pure Nylon 6 was treated like the blends to have the same thermal history. The blend was separated to 2 parts. One part was measured for shear viscosity by rheometric measurement and another part was measured for tensile properties. All samples were stored in a dessicator to prevent them from humidity.

4.3.3.2 Sample preparation for rheometric measurements

The pellets of each blend were placed into a perforated plate stainless mould with diameter of 20 mm and 1 mm thickness. The mould was coated with releasing plates and heated for about 3 minutes until the polymer was almost all melted, then compressed using the hydraulic hot press at 225°C and 4,000 psi for 3 minutes. After cooled by air for 5 minutes, the pieces of sample were removed from the mould and taken to measure for shear viscosity by the parallel plate rheometer.

4.3.4 System 4 : Polyoxymethylene and HP5N

4.3.4.1 Blending of polymer and liquid crystal

The blends of POM and HP5N were prepared by using a digital hot plate stirrer at the compositions of 0.1, 0.2 and 0.4 percent by weight of HP5N. POM was weighted in a beaker about 30 g. and HP5N was weighted corresponding to the desired compositions. Each blend was placed on a teflon-coated plate on the digital hot plate stirrer. The hot plate was set at $200^{\circ}C$ and the blends were mixed together for 10 minutes by mechanical stirring polymer melt in order to have a uniform mixture. After that, the blends were compressed on thin plate and cut into small pellets. The pure POM was treated like the blends to have the same thermal history. The blend was separated into 2 parts. One part was measured for shear viscosity by rheometric measurement and another part was measured for tensile properties.

4.3.4.2 Sample preparation for rheometric measurements

The pellets of each blend were placed into a perforated plate stainless mould with the diameter of 20 mm and 1 mm thickness. The mould was coated with releasing plates and heated for about 5 minutes until the polymer was almost all melted, then compressed by a hydraulic hot press at $200^{\circ}C$ and 4,000 psi for 5 minutes. After cooled by air for 5 minutes, the pieces of sample were removed from the mould and taken to measure for shear viscosity by the parallel plate rheometer.

4.3.4.3 Tensile Specimen preparation

The tensile specimen in this work was prepared in sheets with the thickness of 0.1 – 1.0 mm. The pellets of each blend were placed in a square aluminum mould with the width of 100 mm. and 0.3 mm. thickness. The mould was coated with releasing plates and heated for about 5 minutes until the polymer was almost all melted, then compressed by a hydraulic hot press at $200^{\circ}C$ and 4,000 psi for 5 minutes. The plate of samples was removed from the mould after cooled by air for 5 minutes.

Each plate of blends was cut into rectangular shapes of $10 \times 100 \ mm^2$. The test specimens were performed on the tensile testing machine to obtain the tensile properties.

4.3.5 System 5 : Polypropylene and HP5N

4.3.5.1 Blending of polymer and liquid crystal

The blends of PP and HP5N were prepared by using a twin screw extruder at the compositions of 0.1, 0.2 and 0.4 percent by weight of HP5N. PP was weighted in a beaker about 300 g. and HP5N was weighted corresponding to the desired compositions. The PP was ground into powder with a grinder. Pre-blend of PP and HP5N were performed in a high-speed mixer, and extruded in a twin screw extruder. The screw speed was set at 30 rpm and temperature set at $170^{\circ}C$, $185^{\circ}C$ and $200^{\circ}C$ for each zone. The pure PP was treated like the blends to have the same thermal history. The blend was separated into 2 parts. One part was measured for shear

viscosity by rheometric measurement and another part was measured for tensile properties.

4.3.5.2 Sample preparation for rheometric measurements

The pellets of each blend were placed into a perforated plate stainless mould with the diameter of 20 mm and 1 mm thickness. The mould was coated with releasing plates and heated for about 5 minutes until the polymer was almost all melted, then compressed by a hydraulic hot press at $200^\circ C$ and 4,000 psi for 5 minutes. After cooled by air for 5 minutes, the pieces of sample were removed from the mould and taken to measure shear viscosity by the parallel plate rheometer.

4.3.5.3 Tensile Specimen preparation

The tensile specimen in this work was prepared in sheets with the thickness of 0.1 – 1.0 mm. The pellets of each blend were placed in a square aluminum mould with the width of 100 mm and 0.3 mm. thickness. The mould was coated with releasing plates and heated for about 5 minutes until the polymer was almost all melted, then compressed by a hydraulic hot press at $200^\circ C$ and 4,000 psi for 5 minutes. The plate of samples was removed from the mould after cooled by air for 5 minutes.

Each plate of blends was cut into rectangular shape of 10 x 100 mm^2. The test specimens were performed on the tensile testing machine to obtain the tensile properties.

4.3.6 System 6 : Polyethylene and BCH5

4.3.6.1 Blending of polymer and liquid crystal

The blends of PE and BCH5 were prepared by using a digital hot plate stirrer at the compositions of 0.1, 0.2 and 0.4 percent by weight of BCH5. PE was weighted in a beaker about 30 g. and BCH5 was weighted corresponding to the desired compositions. Each blend was placed on a teflon-coated plate on the digital hot plate stirrer. The hot plate was set at $200^{\circ}C$ and the blends were mixed together for 10 minutes by mechanical stirring polymer melt in order to have a uniform mixture. After that, the blends were compressed on thin plate and cut into small pellets. The pure PE was treated like the blends to have the same thermal history. The blend was separated into 2 parts. One part was measured for shear viscosity by rheometric measurement and another part was measured for tensile properties.

4.3.6.2 Sample preparation for rheometric measurements

The pellets of each blend were placed into a perforated plate stainless mould with the diameter of 20 mm and 1 mm thickness. The mould was coated with releasing plates and heated for about 5 minutes until the polymer was almost all melted, then compressed by a hydraulic hot press at $200^{\circ}C$ and 4,000 psi for 5 minutes. After cooled by air for 5 minutes, the pieces of sample were removed from the mould and taken to measure shear viscosity by the parallel plate rheometer.

4.3.6.3 Tensile Specimen preparation

The tensile specimen in this work was prepared in sheets with the thickness of 0.1 – 1.0 mm. The pellets of each blend were placed in a square aluminum mould with the width of 100 mm and 0.3 mm. thickness. The mould was coated with releasing plates and heated for about 5 minutes until the polymer was almost all melted, then compressed by a hydraulic hot press at $200^{\circ}C$ and 4,000 psi for 5 minutes. The plate of samples was removed from the mould after cooled by air for 5 minutes.

Each plate of blends was cut into rectangular shapes of 10×100 mm^2. The test specimens were performed on the tensile testing machine to obtain the tensile properties.

4.3.7 System 7 : Poly(methyl methacrylate) and BCH5.

4.3.7.1 Blending of polymer and liquid crystal

The blends of PMMA and BCH5 were prepared by using a digital hot plate stirrer at the compositions of 0.1, 0.2 and 0.4 percent by weight of BCH5. PMMA was weighted in a beaker about 30 g. and BCH5 was weighted corresponding to the desired compositions. Each Blend was placed on a teflon-coated plate on the digital hot plate stirrer. The hot plate was set at $200^{\circ}C$ and the blends were mixed together for 10 minutes by mechanical stirring polymer melt in order to have a uniform mixture. After that, the blends were compressed on thin plate and cut into small pellets. The pure PMMA was treated like the blends to have the same thermal history. The blend was

separated into 2 parts. One part was measured for shear viscosity by rheometric measurement and another part was measured for tensile properties.

4.3.7.2 Sample preparation for rheometric measurements

The pellets of each blend were placed into a perforated plate stainless mould with the diameter of 20 mm and 1 mm thickness. The mould was coated with releasing plates and heated for about 5 minutes until the polymer was almost all melted, then compressed by a hydraulic hot press at $200^{\circ}C$ and 4,000 psi for 5 minutes. After cooled by air for 5 minutes, the pieces of sample were removed from the mould and taken to measure shear viscosity by the parallel plate rheometer.

4.3.7.3 Tensile Specimen preparation

The tensile specimen in this work was prepared in sheets with the thickness of 0.1 – 1.0 mm. The pellets of each blend were placed in a square aluminum mould with the width of 100 mm and 0.3 mm. thickness. The mould was coated with releasing plates and heated for about 5 minutes until the polymer was almost all melted, then compressed by a hydraulic hot press at $200^{\circ}C$ and 4,000 psi for 5 minutes. The plate of samples was removed from the mould after cooled by air for 5 minutes.

Each plate of blends was cut into rectangular shapes of 10 x 100 mm^2. The test specimens were performed on the tensile testing machine to obtain the tensile properties.

4.3.8 System 8 : Styrene Acrylonitrile copolymer and BCH5

4.3.8.1 Blending of polymer and liquid crystal

The blends of SAN and BCH5 were prepared by using a digital hot plate stirrer at the compositions of 0.1, 0.2 and 0.4 percent by weight. SAN was weighted in a beaker about 30 g. and BCH5 was weighted corresponding to the desired compositions. Each blend was placed on a teflon-coated plate on the digital hot plate stirrer. The hot plate was set at 200°C and the blends were mixed together for 10 minutes by mechanical stirring polymer melt in order to have a uniform mixture. After that, the blends were compressed on thin plate and cut into small pellets. The pure SAN was treated like the blends to have the same thermal history. The blend was separated into 2 parts. One part was measured for shear viscosity by rheometric measurement and another part was measured for tensile properties.

4.3.8.2 Sample preparation for rheometric measurements

The pellets of each blend were placed into a perforated plate stainless mould with the diameter of 20 mm and 1 mm thickness. The mould was coated with releasing plates and heated for about 5 minutes until the polymer was almost all melted, then compressed by a hydraulic hot press at 200°C and 4,000 psi for 5 minutes. After cooled by air for 5 minutes, the pieces of sample were removed from the mould and taken to measure shear viscosity by the parallel plate rheometer.

4.3.8.3 Tensile Specimen preparation

The tensile specimen in this work was prepared in sheets with the thickness of 0.1 – 1.0 mm. The pellets of each blend were placed in a square aluminum mould with the width of 100 mm and 0.3 mm. thickness. The mould was coated with releasing plates and heated for about 5 minutes until the polymer was almost all melted, then compressed by a hydraulic hot press at 200°C and 4,000 psi for 5 minutes. The plate of samples was removed from the mould after cooled by air for 5 minutes.

Each plate of blends was cut into rectangular shapes of 10 x 100 mm^2. The test specimens were performed on the tensile testing machine to obtain the tensile properties.

4.3.9 System 9 : Blends of SAN/PMMA at various compositions with BCH5

4.3.9.1 Blending of SAN/PMMA

The blends of SAN/PMMA were prepared by using a twin screw extruder at compositions of 80:20, 60:40 and 40:60 percent by weight of SAN and PMMA respectively. The SAN and PMMA were weighted at above percentage in a beaker, the total weight of mixture was about 500 g. The melt blending were performed in a twin screw extruder. The screw speed was set at 30 rpm and temperature set at 190°C, 200°C and 210°C for each zone.

4.3.9.2 Blending of polymer alloys and liquid crystal

The blends of SAN/PMMA at various composition and BCH5 were prepared by using a digital hot plate stirrer at the compositions of 0.1, 0.2 and 0.4 percent by weight of BCH5. The blends of SAN/PMMA were weighted in a beaker about 30 g. and BCH5 was weighted corresponding to the desired compositions. Each ternary blend was placed on a teflon-coated plate on the digital hot plate stirrer. The hot plate was set at $200^{\circ}C$ and the blends were mixed together for 10 minutes by mechanical stirring polymer melt in order to have a uniform mixture. After that, the blends were compressed on thin plate and cut into small pellets. The binary blends of SAN/PMMA was treated like the blends to have the same thermal history.

4.3.9.3 Sample preparation for rheometric measurements

The pellets of each blend were placed into a perforated plate stainless mould with diameter of 20 mm and 1 mm thickness. The mould was coated with releasing plates and heated for about 5 minutes until the polymer was almost all melted, then compressed by a hydraulic hot press at $200^{\circ}C$ and 4,000 psi for 5 minutes. After cooled by air for 5 minutes, the pieces of sample were removed from mould and taken to measure shear viscosity by parallel plate rheometer.

4.4 Method of selective properties determination

4.4.1 Shear Viscosity

Rheological measurements were carried out using the torque rheometer with parallel plate sensor. The procedures for measuring shear viscosity were studied with two experiments, step-change shear rate and frequency sweep.

4.4.1.1 Shear viscosity by shear sweep.

The procedure was carried out by using parallel plate sensor with 20 mm. plate diameter. Firstly, dry the air baring with nitrogen for 1 hr ; switch on the air compressor, temperature controller, rheometer testing instrument and computer. Then, start the control software and log in the shear sweep mode. The parameters were set as follows,

Maximum stress	:	100 kPa
Shear rate	:	0 to 500 sec^{-1}
Measuring Time	:	10 minutes
Temperature	:	depend on studying system

System 1, PC and CBC33	:	$290^{\circ}C$
System 2, PC and CBC53	:	$290^{\circ}C$
System 3, PA6 and CBC53	:	$225^{\circ}C$
System 4, POM and HP5N	:	$200^{\circ}C$
System 5, PP and HP5N	:	$200^{\circ}C$
System 6, PE and BCH5	:	$200^{\circ}C$

4.4.1.2 Shear viscosity by frequency sweep.

The procedures are carried out by using parallel plate sensor with 20 mm. plate diameter. Firstly, dry the air baring with nitrogen for 1 hr ; switch on the air compressor, temperature controller, rheometer testing instrument and computer. Then, start the control software and log in the shear sweep mode and run the preliminary experiment to determine the relation between shear stress and strain. Select the shear stress that presents the linearity range from this curve to set the shear stress applied in the frequency sweep experiments. The parameters were set as follows :

Frequency   : 10^{-2} to 10^{2} Hz.

Shear stress   : 10^{3} Pa.

Temperature   :   depend on studying system

System 7, PMMA and BCH5 : 200°C

System 8, SAN and BCH5   : 200°C

System 9 : Blends of SAN/PMMA : 200°C

4.4.2 Tensile properties

The tensile property of tensile testing specimens with gauge length 50 mm. wase determined by the tensile testing machine with roller grips (for thin film experiments), operated at various cross head speed, appropriated to types of testing polymer as shown in Table 4-2.

Table 4-2 Test speed of each polymer for tensile strength experiments

Types of polymer	Cross head speed (mm/min)
PC	100
POM	100
PP	15
PE	50
PMMA	100
SAN	100

4.4.3 Glass transition temperature

The glass transition temperature of the pure polymers, polymer alloys and their blends with liquid crystal was measured by DSC. Indium was used as a standard for calibration. The samples of 10 – 20 mg., weighted on aluminum pan were scanned from the room temperature to $200^{\circ}C$ with the heating rate of $10^{\circ}C$/min. Each sample was quenched by liquid nitrogen with cooling rate 20°/min. to room temperature to erase its thermal history and scanned to $200^{\circ}C$ again with the heating rate of $10^{\circ}C$/min to determine the glass transition temperature at this second run. The DSC thermograms of heat flow versus temperature were analyzed. The glass transition is taken to be the inflection slope of the curve.