Mechanical Properties of Polypropylene/Polycarbonate Blends

by

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CERTIFICATION OF APPROVAL

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Ahmad Syamil bin Johan

A project dissertation submitted to the
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Approved by,

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MAY 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

AHMAD SYAMIL BIN JOHAN

ABSTRACT

Nowadays Polypropylene (PP) / Polycarbonate (PC) blends have received interest in polymer study and tests have been done to explore its properties and behavior. This project aim to further characterize PP/PC blends compatibilized with polypropylene-graft-maleic anhydride (PP-g-MA) with varying weight composition in the area of water absorption and tensile strength. In a practical field, organic polymer materials have been shown to express some advantages such as light weight, high strength, anti-rust, and easily processable. These advantages were based on the comparison with metal and inorganic materials. However, polymer materials degrade under various circumstances for example low and high temperature, exposure to rain and sunlight, and under the water or soil. Some plastics absorb very little water at room temperature but at higher temperature it tends to absorb high amount of water and will lose properties rapidly. Eight weight ratios are considered and they are 85/10/5, 75/20/5, 65/30/5, 55/40/5, 85/15/0, 75/25/0, 65/35/0, and 55/45/0 in PP/PC/PP-g-MA respectively. The glass transitional and melting temperatures of PP, PC, and PP-g-MA were obtained by differential scanning calorimetry (DSC) and the values were consistent with literature. Meanwhile, degradation temperatures of samples were obtained by thermogravimetric analysis (TGA). Then, the polymers were compounded in twin screw extruder and fabricated by compression and injection moulding. Water absorption test were follow the ASTM Standards: D 570-98 (Reapproaved 2005) Standard Test Method for Water Absorption of Plastics and Tensile Test were follow ASTM D638 Standard Test Method for Tensile properties of rigid plastic.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Polymer blending is considered as the most flexible and economic way to engineer a material with complex desired properties. It is cheaper to produce a polymer blend for specific properties rather than synthesizing a new polymer in laboratories. Besides, it can improve specific properties such as impact strength and solvent resistant when different types of polymer blends together. Blends of Polypropylene (PP) / Polycarbonate (PC) are in early stage of development. Many studies have been done to discover its properties and behavior. From earlier researches, first objective of blending PP was to improve PP's disadvantage which is poor impact strength [1]. But now, efforts have moved towards discovering more about the properties and behavior of PP/PC blends. The blend of PP with PC is expected to have combination of properties of PP and PC. Compared to normal pure PP, PP blend with PC is supposed to have higher impact and compression strength. At the same time, it will retain PP special properties such as high chemical and temperature resistance and low thermal conductivity.

This project aim to further characterize PP/PC blends compatibilized with polypropylene-graft-maleic anhydride (PP-g-MA) in the area of mechanical properties such as water absorption and tensile strength. Water absorption can be defined as the property of a material which relates its ability to absorb water and it is regarded as one of the most important properties of polymer [2]. It is well known that moisture induces property changes in polymers. Water is considered to act as a softening agent and spacer between chains at room temperature and above. Water is absorbed by most polymers but change of properties is induced only in specific types of polymers. Meanwhile, tensile strength can be defined as maximum load that a material can support without fracture when being stretched, divided by the original cross-sectional area of the material.

1.2 Problem Statement

In a practical field, organic polymer materials have been shown to express some advantages such as light weight, high strength, anti-rust, and easily processable. These advantages were based on the comparison with metal and inorganic materials. However, polymer materials degrade under various circumstances for example low and high temperature, exposure to rain and sunlight, and under the water or soil.

Polymer materials are applicable for various purposes for example reduction of weight, coating and covering, and heat insulation. Some products are applicable to interior and exterior parts of automobile, railway vehicle, air plane and ship. Through respective service life, various properties of polymer materials were changed by the degradation. For instance, oxidation, hydrolysis, ultra violet irradiation and chemicals influence.

Degradation process of polymer materials indicated various changes in the mechanical strength depending on the condition, type of polymer material, production process of polymer material and additive package. Therefore, differential scanning calorimetry (DSC) and Thermogravimetric analysis (TGA) were be used to obtain glass transition, melting and degradation temperature of the samples.

1.3 Objectives

The objective of this project is to study the effects of varying composition of PP/PC on mechanical properties in term of water absorption and tensile strength behavior of PP/PC/PP-g-MA blends.

1.4 Scope of Studies

The study will concentrate on the effects of varying formulation blend on mechanical properties such as water absorption, tensile strength, glass transition, melting and degradation temperature and morphology of the blends. Materials that will be used are Polypropylene (PP), Polycarbonate (PC) and Polypropylene-graft- Maleic Anhydride (PP-g-MA) with 8 weight composition ratio in PP/PC/PP-g-MA respectively. This study will follow the ASTM Standards: D 570-98 (Reapproved 2005) Standard Test Method for water absorption of plastics and ASTM D638 Standard Test Method for Tensile properties of rigid plastic [3].

Standard test method for water absorption covers the determination of the relative rate of absorption of water by plastics when immersed. Temperature range for this study is using room temperature 23 °C and 100 °C. For tensile strength, test method covers the determination of the tensile properties of unreinforced and reinforced plastics in the form of standard dumbbell shaped test specimens when tested under defined conditions of testing machine speed.

CHAPTER 2

LITERATURE REVIEW

2.1 PP and PC Blend

Polymer blending has been given attention in scientific research and industrial production. It is considered as the most versatile and economic way to produce a material with complex desired properties. In the field of polymer research, over the years there are some works which discuss about blending PP with PC. In synopsis, PP is one of the most widely produced in plastic industries because of its attractive properties and low cost but with limited impact strength and absorbs water during its life. PC on the other hand is an engineering plastic that has many advantages over conventional material. Properties of typical PP and PC are summarized by Table 1 and the molecular structure of PP and PC are shown in Figure 1 and Figure 2, respectively [4].

Table 1: Comparison between PP and PC

Mechanical Properties	PP	PC
Compressive strength	48 MPa	>80MPa
Tensile strength	31MPa	55-75 MPa
Izod impact strength	8-160 J/m	600-850 J/m
Specific gravity	0.90- 0.91	1.20
Tensile modulus	1.14-1.55 Gpa	2.38 Gpa
Yield Strength	31.0-37.2 Mpa	62.1 Mpa
Elongation at break	100-600 %	110-150 %
Thermal Properties		
Melting/Glass transition Temperature	170/-20 °C	267/150 °C
Upper/Lower working temperature	135/0 °C	130/-135 °C
Thermal conductivity	0.117 W/m.K	0.19 W/m.K

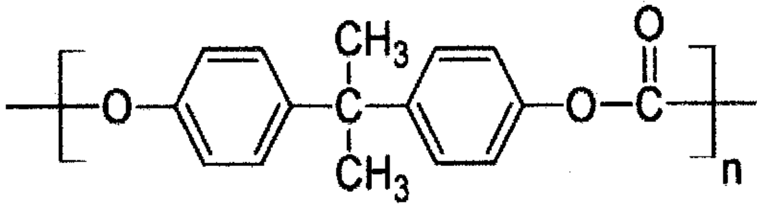


Figure 1: Molecular structure of PC

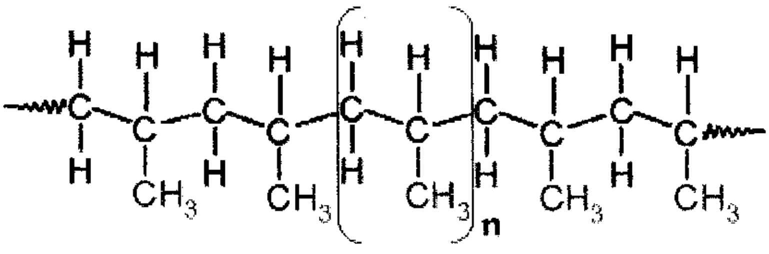


Figure 2: Molecular structure of PP

S.Dai and L.Yen have conducted a study focusing on the PP/PC blend. The blend of PP with PC is predictable to have combination of properties of PP and PC. Compared to normal pure PP, PP blend with PC is supposed to have higher impact and compression strength. At the same time, it will retain PP special properties such as high chemical and temperature resistance and low thermal conductivity [5].

Y.Zhihui, Z.Xiaomin, Z.Yajie, have done a research on compatibility of PP with PC. It is immiscible with each other because of the differences in polarity and solubility parameters [6]. In their blend morphology, PP and PC existed in separated phases. However, the blend was still desired because of the reinforcing effect of dispersed PC phase in continuous phase of PP. In other words, the miscibility of the two polymers makes their morphology like one that reinforced-composite material has which is excellent in mechanical properties.

From earlier researches, first objective of blending PP was to improve PP's disadvantage which is poor impact strength. Although PP blend with rubber shows an improvement in that area but it also results in reduce of modulus or stiffness. Thus, blend with PC was attempted to provide a mean to get PP based material that has considerably good impact strength with sufficient stiffness. Now the research of PP/PC blends has moved beyond the impact strength and stiffness, as other properties of the blends also being studied.

Chand and Hashmi [7] studied the effect of adding PC in red mud filled PP for thermal stability and rheological properties in which the thermal stability showed improvement while the melt viscosity demonstrated reduction. Fire testing was also done towards intumescent fire retardant PP/PC/ammonium polyphosphate (APP)/ PP-g-MA. The blend demonstrated lower heat release rate compared to PP/APP, which is desirable in fire retardant behavior as thermal degradation rate of the materials will be lower. L.A Dobrzanski, M.Krol, M.Bilewicz have conducted a study on fracture test for PP/PC and generally it can be concluded that as PC fraction increased, energy at break decreased while flexural modulus increased [8].

M. Bilewicz, J. C. Viana, and L.A Dobrzanski [9] have conducted a research on the reinforcement of PC as dispersed phase inside PP matrix and work enrichment of these composites by nanoclay, Montmorillonite (MMT). PP/PC blend in this research was mixed at the ratio 70/30 wt% of PP/PC while nanoparticles were blended in the ratio 67/30/3 wt% (PP/PC/MMT). The result in Figure 3 shows that pure PP/PC blend experience high fracture behavior at both melt temperatures compared to other composites (a maximum value of 0.032 J/mm2).

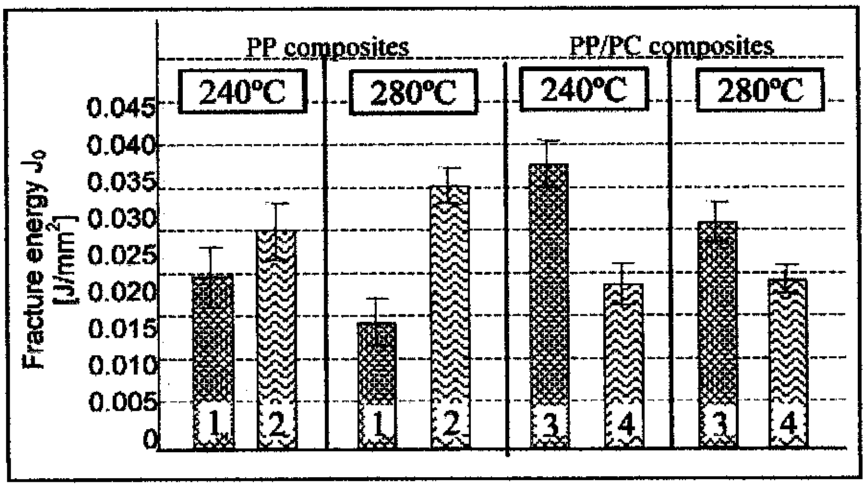


Figure 3: Fracture toughness of the material system processed by CIM, where 1- PP, 2- PP/MMT, 3- PP/PC, 4 – PP/PC/MMT

Figure 4 shows the variations of the fracture toughness of pure PP and PP/PC blend with the processing conditions for N-CIM. Results presented on graph are divided in two sections accordingly to low and high T_m. The x-axis illustrates the respective of the number and time of piston movements (strokes). The maximum fracture energy obtained in this test is by PP/PC blend with J_0 value of 0.028 J/mm2. Overall result shows that PP/PC blend presents higher values of J_0 for almost all conditions compared with the neat PP. Based on their findings, it can be concluded that the presence of PC content inside a PP matrix will cause a significant increase of mechanical properties of PP/PC blend. PC will act as a dispersed phase and provide reinforcement to PP matrix.

Weight ratio of polymer blends is also a big factor in determining its properties. Many researches done showed that the optimum mechanical and thermal properties even morphology and crystallization behavior are best when the ratio of PP is around 70-80%, PC is about 20-30% and compatibilizer at 3-5% [3-4], [6], [8].

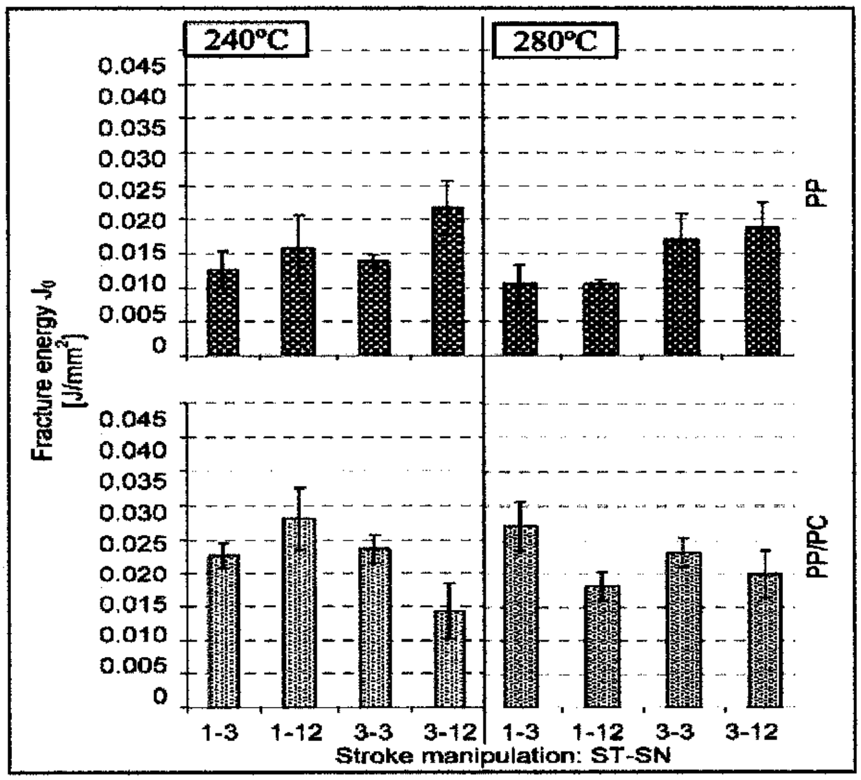


Figure 4: Fracture energy of composite for low and high temperature settings of N-CIM

2.2 Compatibilizer

A compatibilizer can develop interfacial adhesion of separated phases in polymer blend. Normally a compatibilizer is a copolymer or grafted polymer, contains the same polymer that to be blended. This compatibilizer will sit at the phase boundary of the blended polymer and tie the two phases together [5].

Besides, compatibilizer also reduces interfacial tension of phase boundaries, makes the particulates smaller in size to increase surface area in contact between the two phases. As a result of better phase adhesion and decrease particulates size, any energy or force exerted onto the blend will be transferred from one phase to another, hence improving mechanical properties of the blend [6].

Dai and Ye have conducted a try out on several compatibilizers for PC/PP blend. They were PP grafted glycidyl methacrylate (PP-g-GMA), PP-grafted GMA /styrene (PP-g-GMA-st) and (PP-g-BPA). It is found that PP-g-BPA provided the best compatibilizing effect among the group because it reduced the degradation of PP during processing [5]. L.A Dobrzanski, M.Krol, M.Bilewicz have done a comparison that PP-g-GMA was more efficient than the terpolymer ethylene/acrylic and provided better thermomechanical properties of PP/PC blend [8].

A study by Renaut et al [10] concluded that PP/PC blend with PP-g-GMA show overall good result of compatibilization as Young's modulus, tensile strength and Izod impact strength had experienced significant increase. The tensile strength of and Izod impact strength of PP/PC/PP-g-GMA are 90% and 67% higher than values for PP/PC blend (70/30). The compatibilizer reduces interfacial tension, increase interfacial adhesion and homogenizes the domain size and thus resulting in better properties [11].Ultimately all good compatibilizing effect works gave tribute to how particulate size of PC decreased with addition of compatibilizer.

A group of researchers from Chulalongkorn University consisting of S. Chongprakobkit, M. Opaprakasit and S. Chuayjulkit have done a research of using PP-g-MA as compatibilizer in Polypropylene/Polyamide 6 Blends [12]. They designed and tested 3 composition of PP/PA6 blend which are 70/30, 70/30/5, and 70/30/10 (in

PP/PA6/PP-g-MA respectively). Their research results indicated that the blend of PP/PA6 70/30 incorporated with 5 and 10 phr of PP-g-MA exhibited much higher tensile strength than uncompatibilized samples and tensile strength of the blends slightly increased as the amount of PP-g-MA increased from 5 to 10 phr. The results are as shown in Figure 5.

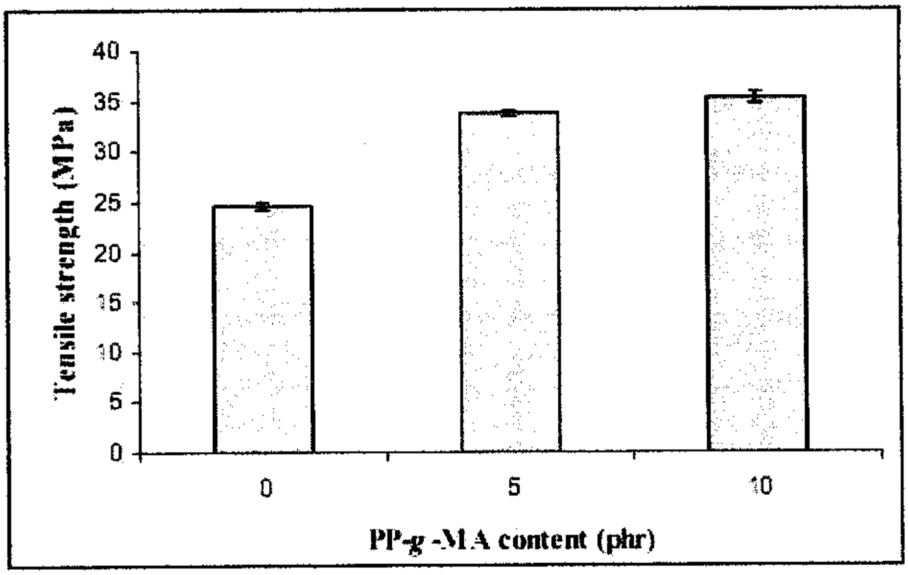


Figure 5: Tensile strength of PP/PA6 70/30 blends with various amount of PP-g-MA.

2.3 Concept of Water Absorption

Water absorption can be defined as the amount of water absorbed by a composite material when immersed in water for a stipulated period of time. It is well known that moisture induces property changes in polymers. A study by G.Bashek, G.Hartwig, F.Zahradnik concluded that water is considered to act as a softening agent (spacer between chains) at room temperature and above. At cryogenic temperatures, however the contrary is true that wet specimens are stiffer than dry ones [13].

Most polymers absorb more or less water but not all of them exhibit a change in properties. The phenomenon of moisture absorption has been studied by several authors in polymers [9] and polymer based composites mainly at room temperature and above. In that temperature range, absorbed water reduces moduli and the main glass transition temperature, enlarges fracture strain and impact strength [10]. G.Hartwig [13] concluded that only water connects to macromolecules by hydrogen bonds causes property changes. Polymer chains with strong polar groups are able to bind water by hydrogen bridges. Property of water absorption of some of the polymers is given in Table 2. Environmental influences such as moisture absorption also have a significantly effect on the behavior of polymers. For example, polyester resins can absorb up to 4-5% by weight of water if exposed to 100% relative humidity or immersed in water. Yin Zhihui, Zhang Yajie, Yin Jinghua have researched on the factors that affect water absorption of polymer [14]. Water absorption depends on temperature, time, thickness of specimen, and the amorphous content in polymer. At low temperature the Young's and shear moduli are increased and the damping spectra are drastically changed by the incorporation of water

Table 2: Water absorption of some polymers

Polymer	**Water Absorption, % in 24 h**
Polyesters	0.15 – 0.6
Polyethylene	0.3
Polycarbonate (PC)	0.08 - 0.15
Polypropylene (PP)	0.35
Polyetherether ketone (PEEK)	0.1
Polysulfone	0.2

2.4 Tensile strength in polymers

Tensile strength can be defined as maximum load that a material can support without fracture when being stretched, divided by the original cross-sectional area of the material. When stresses less than the tensile strength are removed a material returns either completely or partially to its original shape and size. As the stress reaches the value of the tensile strength, a ductile material, already begun to flow plastically rapidly forms a constricted region called a neck, where it then fractures [12].

A study by Shanshan Dai and Lin Ye concluded the mechanical properties of polymer can be roughly classified into two categories, strength and toughness. Tensile strength can be considered as material strength. Compared with neat PP, blending with PC results in enhancement of strength but suffers the toughness slightly due to the weak adhesion and high interfacial tension between two immiscible polymers [15]. The tensile strength of PP/PC blends with various compatibilizers was summarized in Table 3.

Table 3: The tensile strength of PP/PC/grafted PP binary blends

Sample	**PP**	**PP/PC (85/15)**	**PP/PC/PP-g-BPA (70/15/15)**	**PP/PC/PP-g-MA (70/15/15)**	**PP/PC/PP-g-MA (70/15/15)**
Tensile Strength (Mpa)	32.41	33.50	37.00	35.69	34.57

2.5 Degradation in polymers

Polymer materials have shown to possess some advantages. For instance, light weight, high strength, anti-rust and easily processable. These advantages are based on comparison with metal. However, the good properties of polymer can degrade over time. Based on the study by Mikiya Ito and Kazukiyo Nagai, polymer materials degrade under various circumstances such as low or high temperature, exposure to rain and sunlight, and under water or soil degradation process of polymer materials indicated various changes in the mechanical strength depending on the condition, type of polymer material, production process of polymer material, and additive package [15].

2.6 Twin Screw Extruder, Compression Molding & Injection Molding

Among various types of mixing equipment, twin-screw extruders have most widely been used to prepare polymer blends in industry. Basically, extrusion process is the molding process of a viscous thermoplastic under pressure through an open ended die. A mechanical screw or auger propels through a chamber the pelletized material which is successively compacted, melted, and formed into a continuous charge of viscous fluid [16].

Molding is the most common method for forming plastic polymers. One of the molding techniques are compression. For compression molding, the appropriate amounts of mixed polymer are placed between male and female mold members. Both mold pieces are heated. However, only one is movable. When the mold is closed, heat and pressure are applied. Before molding, raw materials will be mixed and cold pressed into a disc which is called a preform. Preheating of the preform reduces molding time and pressure, extends the die lifetime and produces a more uniform finished piece [16]. The schematic diagram of compression moulding is shown in Figure 6.

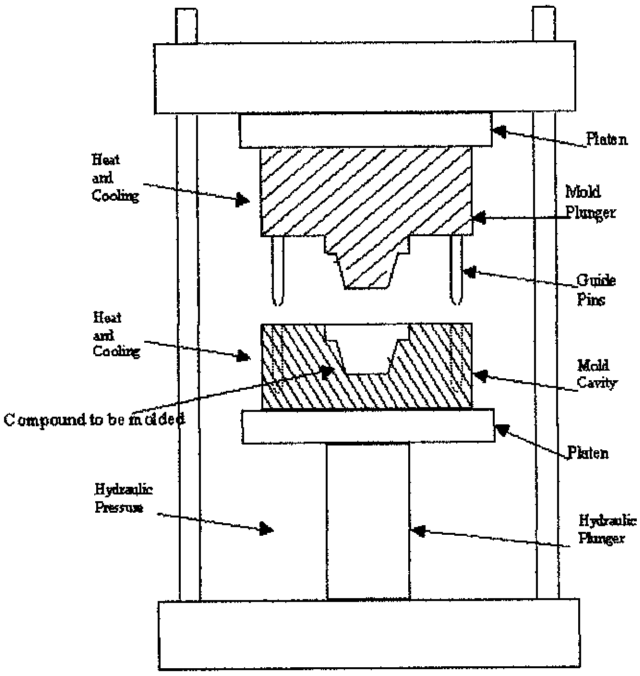


Figure 6: Schematic diagram for compression molding

Injection molding is a well-established technique used widely in the polymer processing industry. The injection molding process that occurs in a reciprocating-screw injection molding machine converts raw plastic materials usually in pellet form into products of different sizes and shapes. A typical machine, shown schematically in Figure 7, consists of four major units: the injection unit, the clamping unit, the hydraulic unit, and the control unit [17]. Prior to the molding operation, the barrel needs to be heated from room temperature to the required operating temperature, to melt the material inside. As a cyclic operation, the typical injection molding cycle can be divided into three main sequential phases: filling; packing-holding; and cooling and plastication.

A cycle begins with the mold closed. The polymer melt is injected into the mold cavity in the filling phase. Once the cavity is fully filled, the packing-holding phase starts, during which a holding pressure is maintained in the nozzle so that additional material can be pushed into the mold to compensate for material shrinkage due to solidification in the mold. In the next phase, plastication, the screw rotates. This rotation shears and melts the material in the barrel and conveys the polymer melt to the screw front for the next shot. Due to the accumulation of the melt at the nozzle front, the screw rotation is accompanied by a retraction motion during plastication. At the same time, the material in the mold cavity is cooled and, when the part becomes sufficiently rigid, the mold opens and the part is ejected.

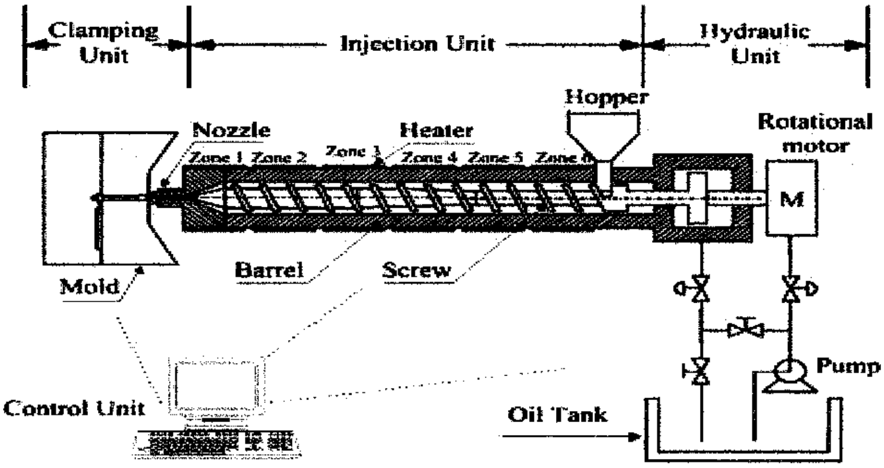


Figure 7: Schematic illustration of injection molding

CHAPTER 3

METHODOLOGY

3.1 Project overall flowchart

Figure 8 shows the overall flowchart of the project. A further research through available resources such as internet, journals, previous related FYP dissertation and discussion with fellow students and supervisor was conducted to have a clearer view of the topic. Polycarbonate (PP), polypropylene (PP), and PP-g-MA are weighed based on the formulation. Then, the melting, glass transition and degradation temperature are measured using DSC and TGA. The sample undergoes 24 hours drying process to reduce the moisture content. Next, continue with water absorption and tensile strength experiment. The result was compared and analyzed.

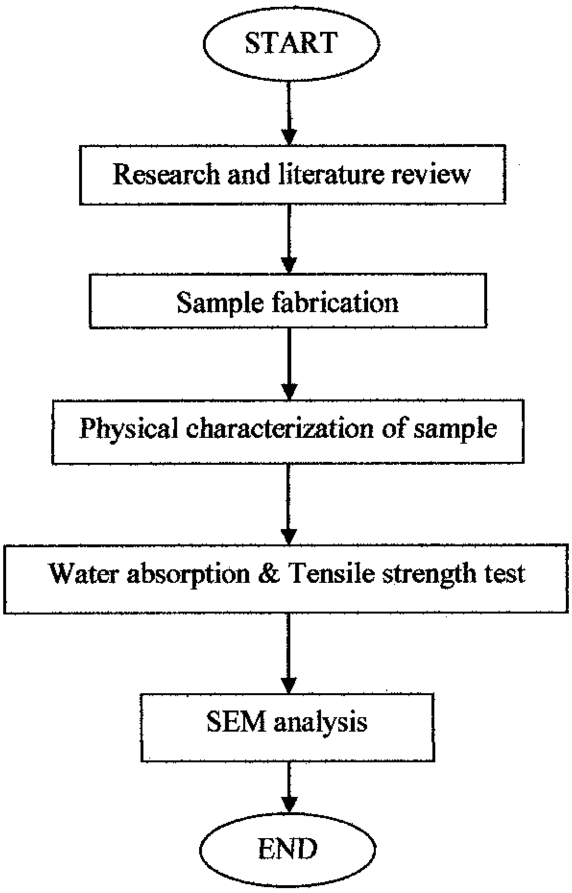


Figure 8: Project overall flowchart

3.2 Key milestone and Gantt Chart

The key milestone in this project is reached when the water absorption and tensile test experiments successfully carried out. The Gantt Charts for the project are shown in Appendix. These Gantt chart shows the work planned and summarized the elements of project for 2 semesters.

3.3 Materials

There are three polymers that are being used in this experiment. PP is from the brand Polypropylene Malaysia (PETRONAS) while PC is from the trade name Panlite grade L-1225Y manufactured by Teijin Kasei America Inc. (Teijin Chemicals). The PC has melt volume-flow rate (MVR) 11.0 cm^3 /10 min (300 °C /1.2kg). The compatibilizer selected is PP-g-MA from the brand Sigma-Aldrich, product number 427845, with molecular weight of 9100 by GPC and maleic anhydride content of 8-10%.

3.4 Sample Fabrication

The first blend formulation PP/PC has four weight composition ratios which are 85/15, 75/25, 45/55, and 35/65 in PP/PC respectively. On the other hand, the second blend formulation PP/PC/PP-g-MA which includes PP-g-MA as compatibilizer has four weight composition ratios which are 85/15/5, 75/25/5, 45/55/5, and 35/65/5. Blending of the polymers will be done by co-rotating twin screw extruder as shown in Figure 9. Temperature is to be set at 220 °C-270 °C with screw extruder rotating at 90 rpm. Upon blending, the blends will be molded according to shapes cylinder with 50.8 mm diameter and 3.2 mm thick by using compression molding [3]. Then, the sample for tensile test in dog bone shape will be molded using injection molding. Suitable parameter controls such as mold temperature, compression time, as well as pressure exerted is crucial to produce good and acceptable samples as specified by test codes.

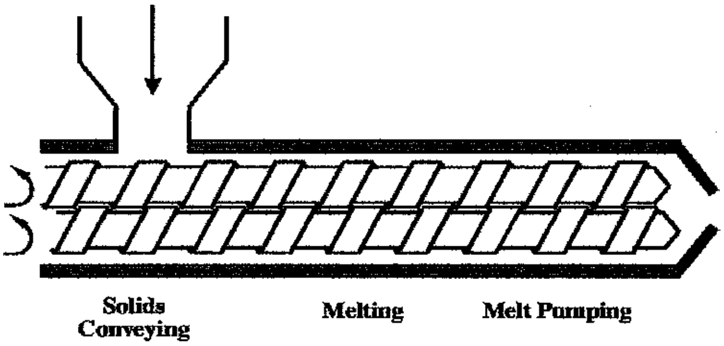


Figure 9: Schematic diagram for twin screw extruder

3.5 Characterization

The melting temperature, T_m and glass transition temperature, T_g of PP, PC, and PP-g-MA will be obtained by using differential scanning calorimetry (DSC), brand Perkin Elmer Co model Pyris 1.

First, raw materials will be weighed to around 0.5 g. Then, the sample is placed into a metal case. Next, it will be placed accordingly in DSC and heated at 10 °C /minute rate alongside a standard reference sample with sample chamber was continuously purged with dry nitrogen. Graph of heat flow versus temperature will be plotted and T_m together with T_g value will be obtained [8].

Other than that, degradation temperatures also will be determined by thermogravimetric analysis (TGA). For TGA specimens need to be prepared having weight around 8-10 mg and put into platinum pan. Next, the heating rate and temperature range are set to be 10 °C /minute and 25 °C – 800 °C respectively. Then, filled platinum pan is to be heated electrically in pure nitrogen gas atmosphere to prevent oxidation and other reaction. While the specimen in the pan is heated gradually, weight changes of the filled pan will be determined by the machine. Finally graph of weight changes against temperature can be plotted and the relationship between them and degradation temperature can be obtained.

3.6 Testing

Water absorption test will follow ASTM D570-98(2005) Standard Test Method for water absorption of plastics. Specimens for this test will be in the shape of cylinder with 50.8 mm diameter and 3.2 mm thick [3]. For each blend composition five specimens will be produced.

After fabrication, the specimens are to be dried in an oven for 24 hour at 50± 3 °C, cooled in the desiccator as shown in Figure 10. Then, immediately weighed to the nearest 0.0001 g. The specimens finally will be immersed in distilled water at room temperature which is 25 °C and after 24 hours, they will be taken out from the distilled water. Wiped with dry cloth and weighed to the nearest 0.001 g. After the weighting, the specimens shall be immersed again in the distilled water and will be weighted again after 7 days. After that, weighting will only be taken for every two week period. The steps are to be repeated for new specimens with different temperatures of distilled water at 10 °C, 35 °C and 45 °C [4].

Next test is tensile and the standard that will be implemented to measure the tensile strength of the samples is ASTM D638 Standard Test Method for Tensile properties of rigid plastic. The specimens will be in type 1 tensile bar. Prior to the test, specimens will be conditioned at 23 °C and 50% relative humidity for not less than 40 hour. The specimen will be placed under universal testing machine (UTM) and a known load will be applied and recorded at a standard speed of 10.0 mm/min until specimen stretches or elongates to that breaking point. Tensile tests produce a stress-strain diagram, which is used to determine tensile modulus. An extensometer is used to determine elongation and tensile modulus.

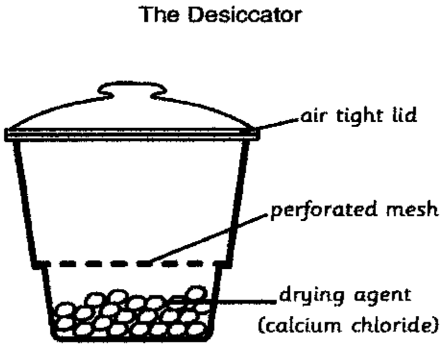


Figure 10: Schematic diagram of desiccator

3.7 Microstructure Observation

Scanning Electron Microscope (SEM) will be used to check the morphology of each blend formulation with different weight composition ratios. Specimens are to be fractured by liquid nitrogen and plated with gold as preparation before their morphology can be displayed by SEM [6].

CHAPTER 4

RESULT & DISCUSSION

4.1 Sample Preparation

Four weight composition which are 85/15, 75/25, 65/35, and 55/45 for PP/PC respectively were measured by using mass balance machine as shown in Figure 11. Besides, the process to prepare the specimens is already started by using twin screw extruder and compression molding.

Figure 11: PP and PC blend formulations.

4.2 Data Gathering & Analysis

Based on the Figure 12, there are comparison between specimens with difference parameter and technique of compression molding. It is crucial to produce good and acceptable specimen as specified by test codes. After do the analysis there are three factors that affect specimen condition. The factors are mould temperature, compression time, as well as pressure exerted. Besides, mass of material to put inside the mould also need to consider. About 6.0 g of material blend need to place inside the mould for each specimen. It is because at the end of the process, the specimen will become 3.0 g only. The other 3.0 g will become waste.

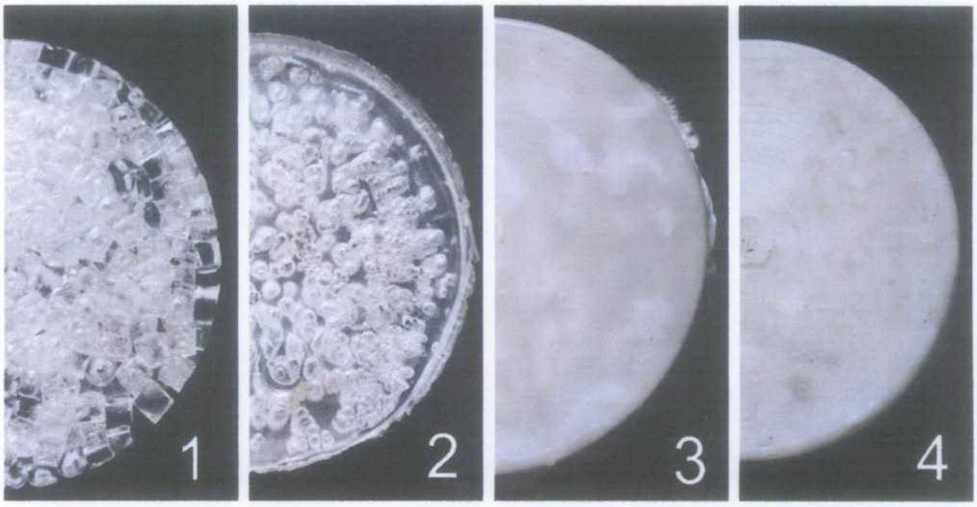


Figure 12: Comparison between specimens compounded at varying processing parameters.

4.3 DSC Analysis

PP/PC and PP/PC/PP-g-MA have been characterized by DSC to determine their glass transition temperature T_g and melting temperature T_m. For PP/PC, T_g is 87.28 ^{0}C and T_m is 164.11 ^{0}C. For PP/PC/PP-g-MA T_g is found to be 159.09 ^{0}C while for T_m it is not possible to know since a peak indicating its melting temperature does not appear. The graphs of heat flow versus temperature for PP/PC and PP/PC/PP-g-MA plotted by DSC are shown in Figure 13, 14, 15 and 16. This could be due to improper sample preparation or wrong DSC configuration. These T_g and T_m values are important because when fabrication of specimen takes place, the melt processing temperature must be high enough for the polymer to melt and flow.

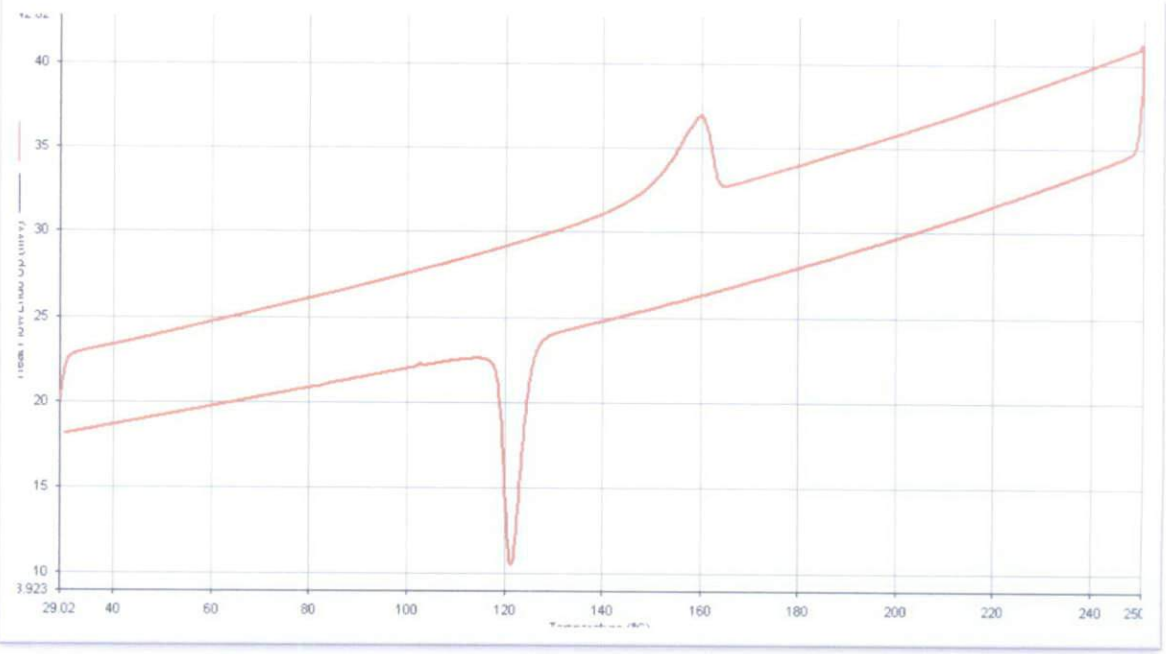


Figure 13: Heat Flow versus Temperature of PP/PC

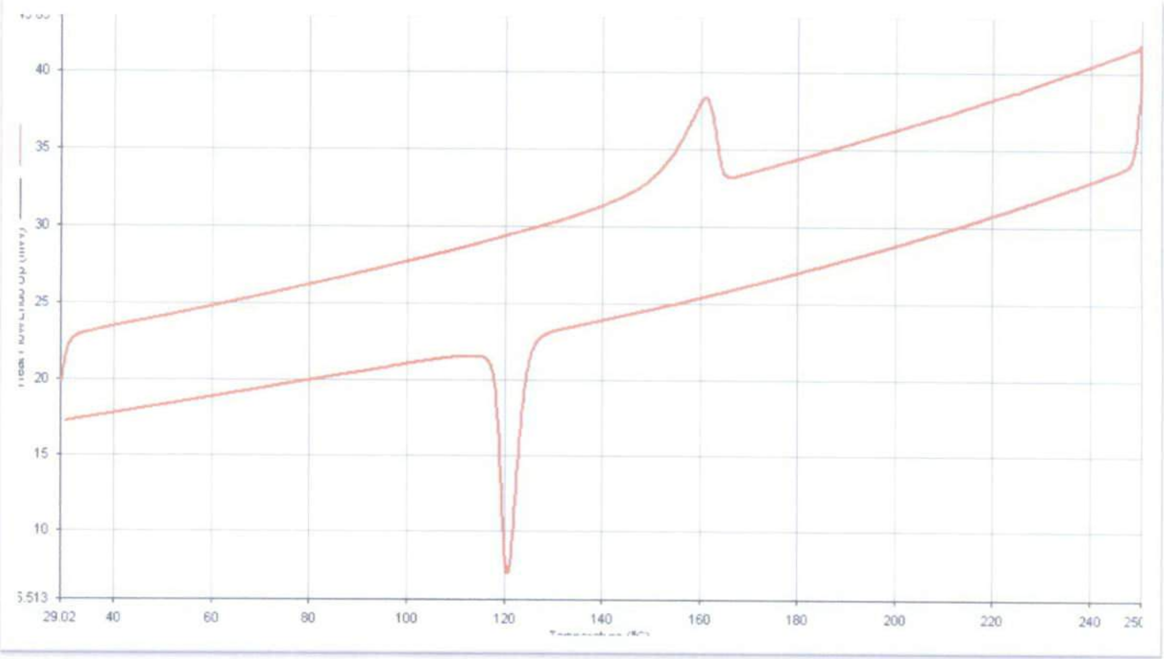


Figure 14: Heat Flow versus Temperature of PP/PC/PP-g-MA

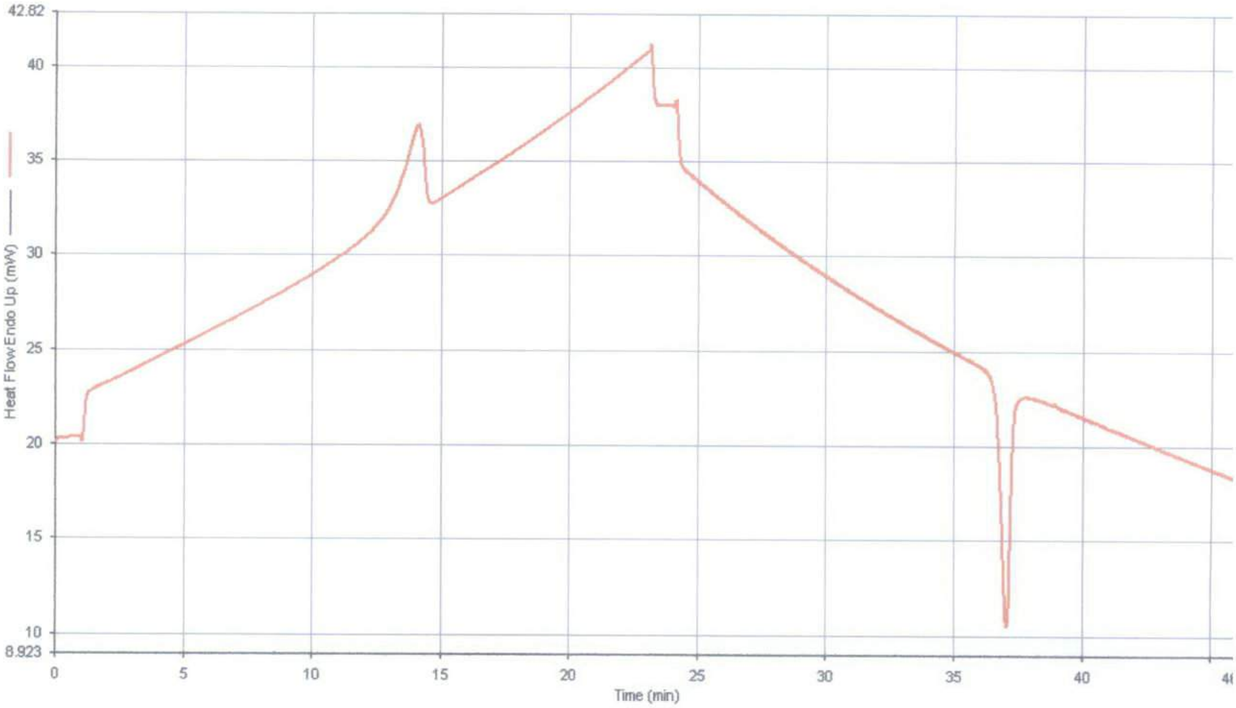


Figure 15: Heat Flow versus Time of PP/PC

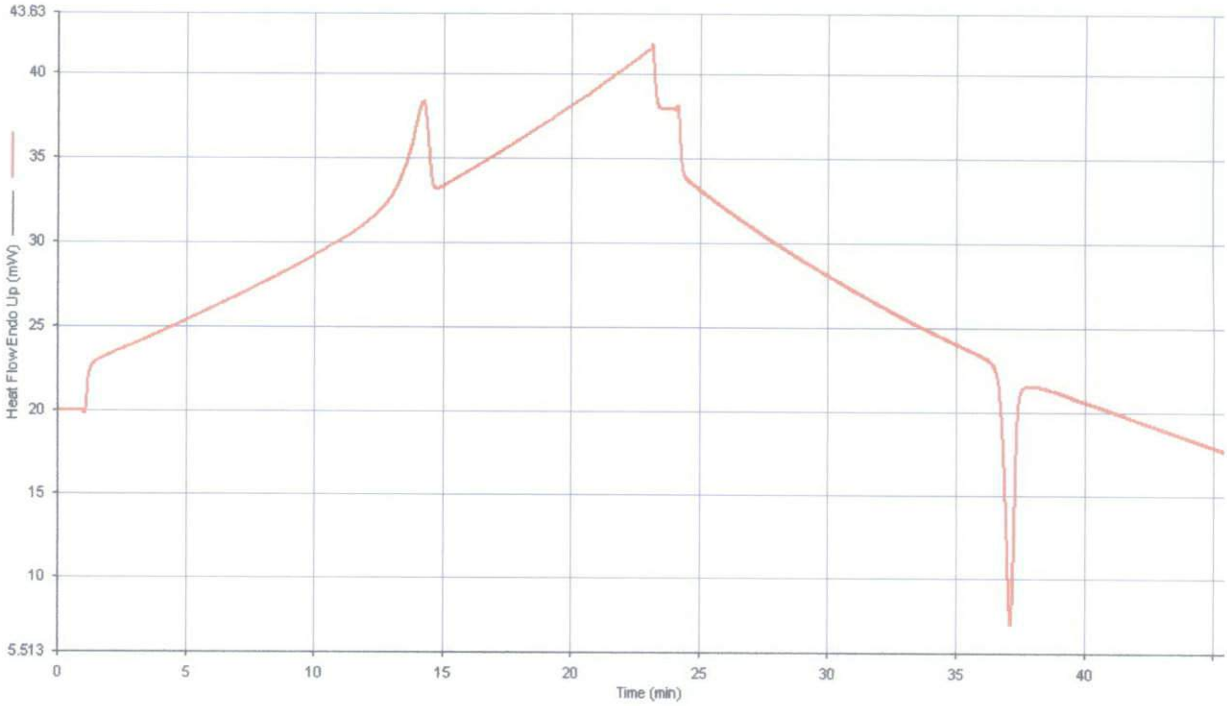


Figure 16: Heat Flow versus Time of PP/PC/PP-g-MA

4.4 TGA analysis

PP/PC and PP/PC/PP-g-MA have been characterized by TGA to determine their degradation temperature. The value of degradation temperature is important because when fabrication of specimen takes place, the melt processing temperature must be high enough for the polymers to melt and flow but it must not exceed the degradation temperature to avoid deterioration in its properties. For PP/PC degradation temperature is 280 °C and PP/PC/PP-g-MA is 350 °C. Temperature for PP/PC/PP-g-MA is higher than PP/PC because the effect of compatibilizer. The graphs plotted by TGA are shown in Figure 17, 18, 19 and 20.

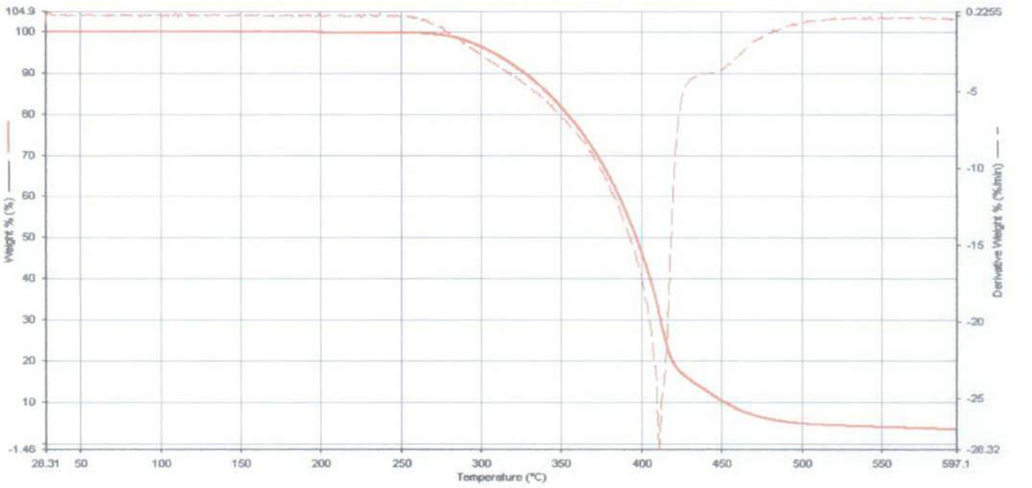


Figure 17: Weight vs Temperature PP/PC

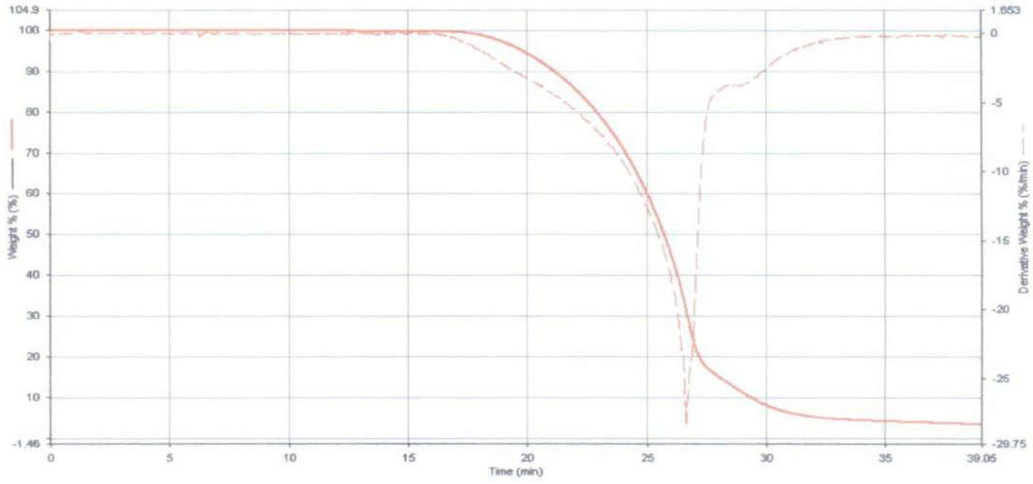


Figure 18: Weight vs Time PP/PC

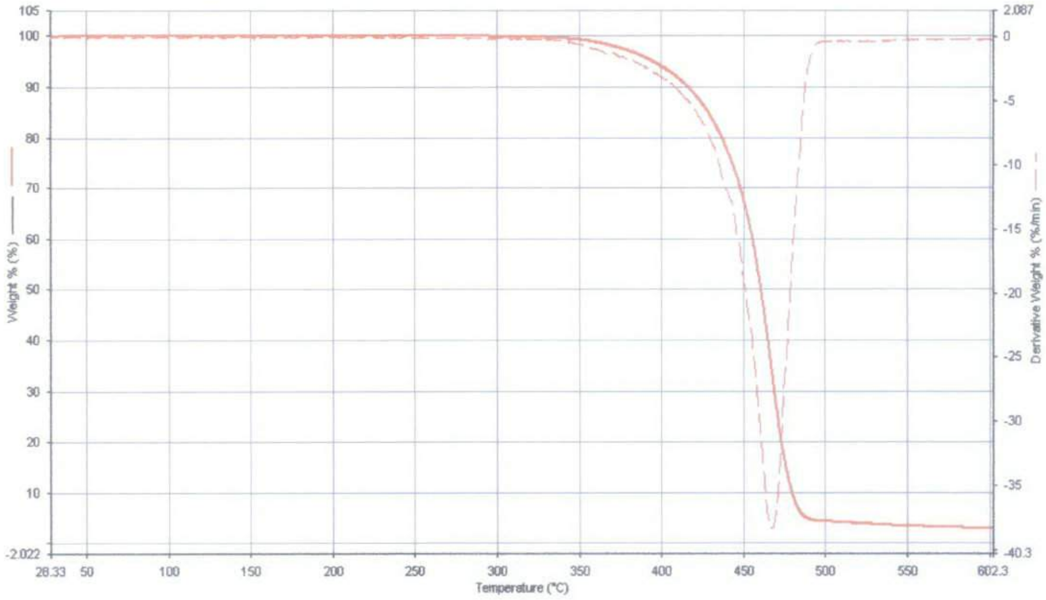


Figure 19: Weight vs Temperature PP/PC/PP-g-MA

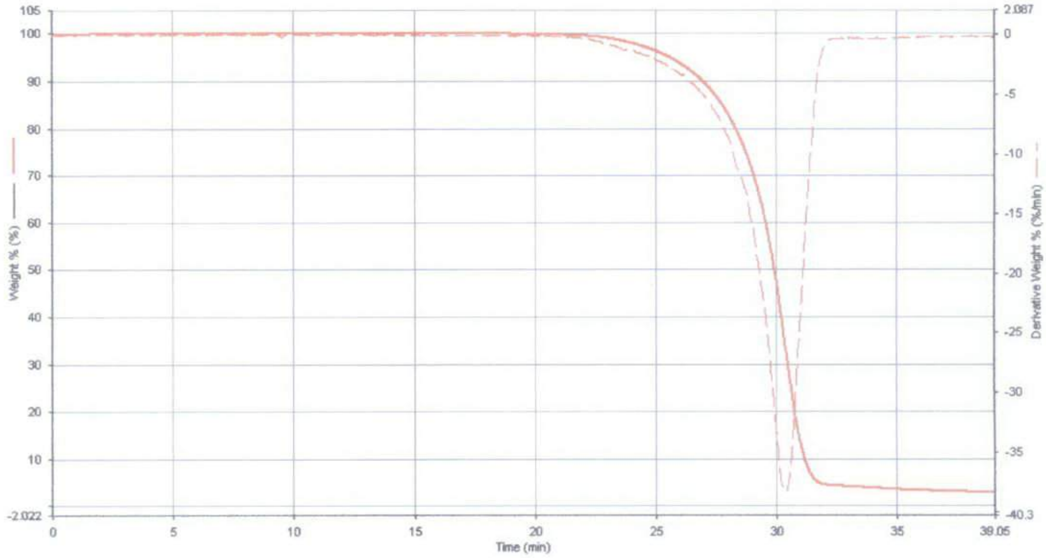


Figure 20: Weight vs Time PP/PC/PP-g-MA

4.5 Morphologies of PP/PC/PP-g-MA blends

The effects of composition on the morphology of PP/PC/PP-g-MA blends are shown in Figure 21. PP/PC blends are immiscible and phase separation between PP/PC is observed for all the blends. For PP/PC (45/55) blends, PP is the minor phase as small droplets dispersed in the PC matrix. Co-continuous phase morphology formed in PP/PC (65/35) blends as shown in Figure 21(b). When PP fraction is more than 50%, PC became dispersed phase with different shapes. For PP/PC (75/25) blends, the minor phase is not regular, appearing as fibers or having elliptical and spherical shape. When the PC fraction is less than 20%, PC dispersed as small droplets as shown in Figure 21(d).

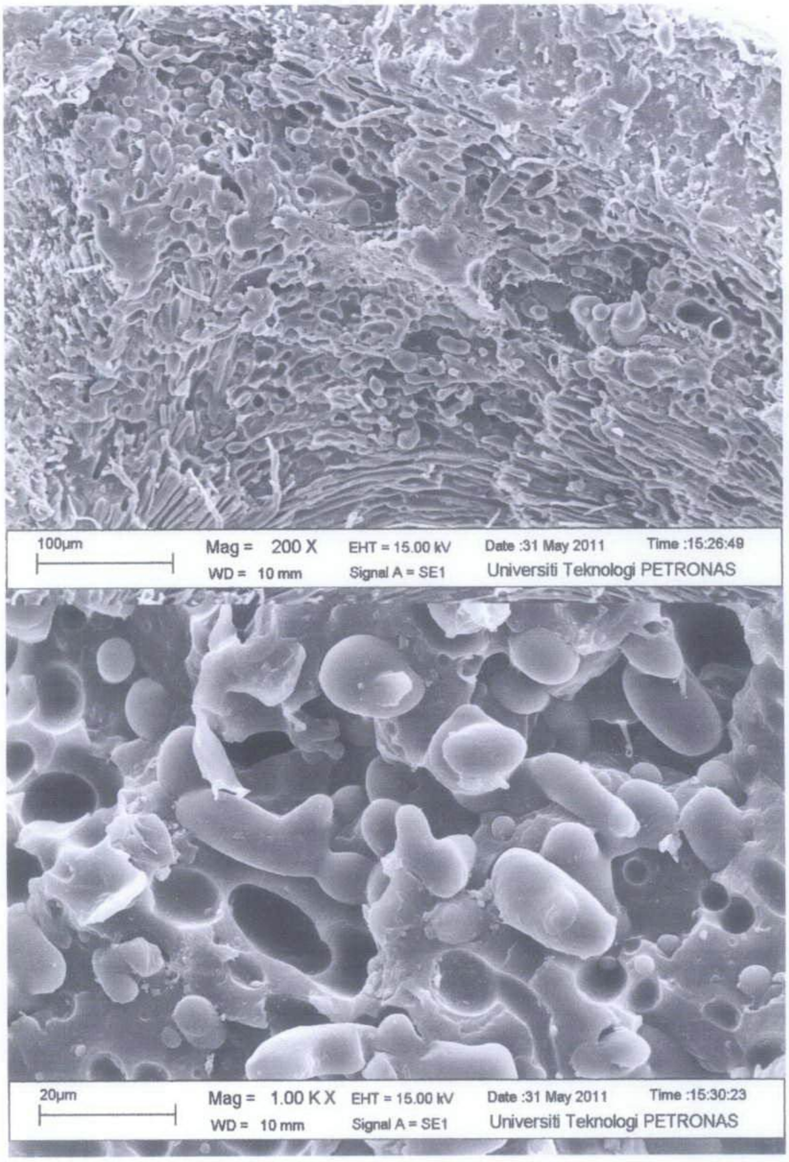


Figure 21(a): SEM PP/PC (45/55)

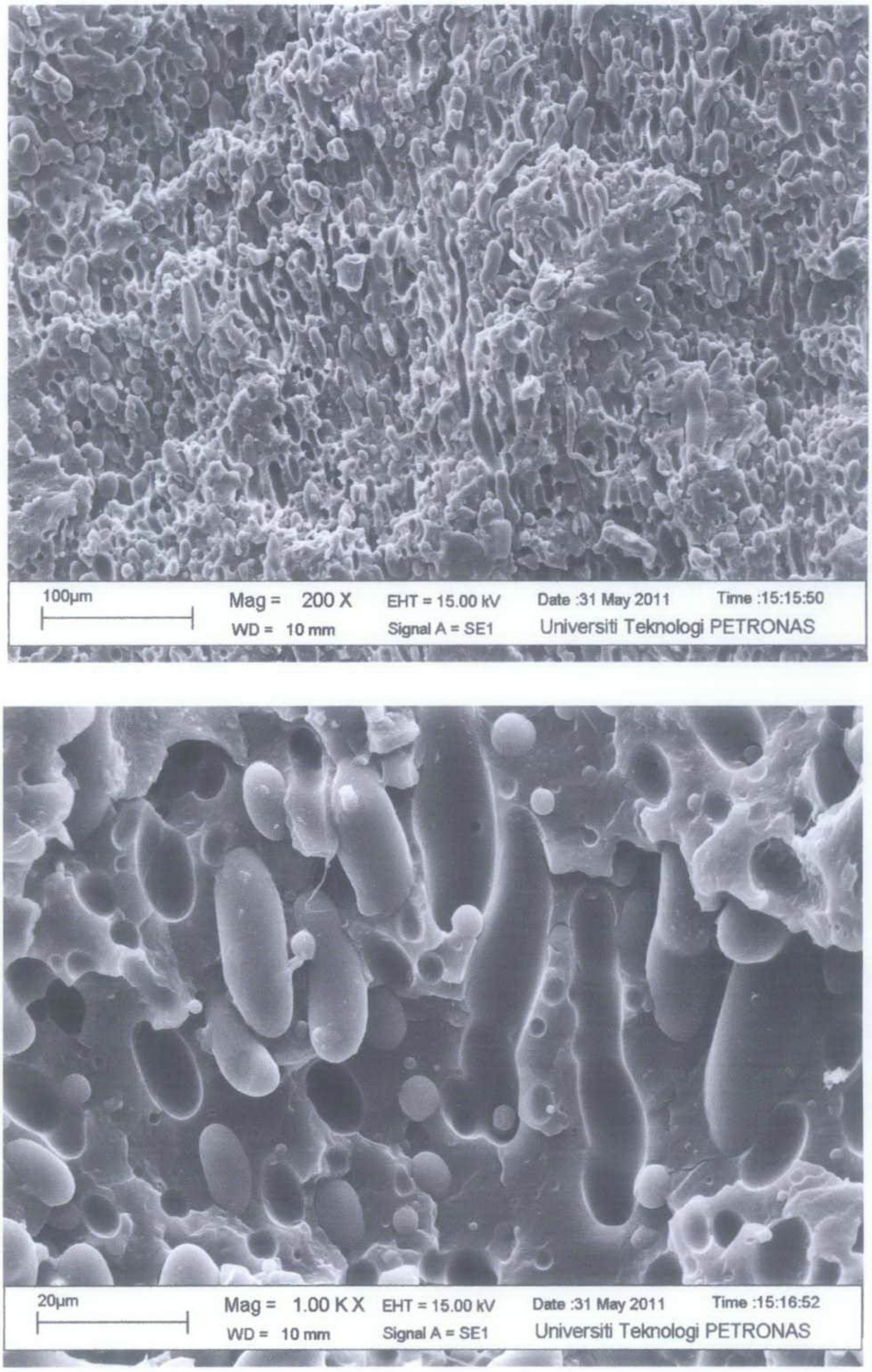


Figure 21(b): SEM PP/PC (65/35)

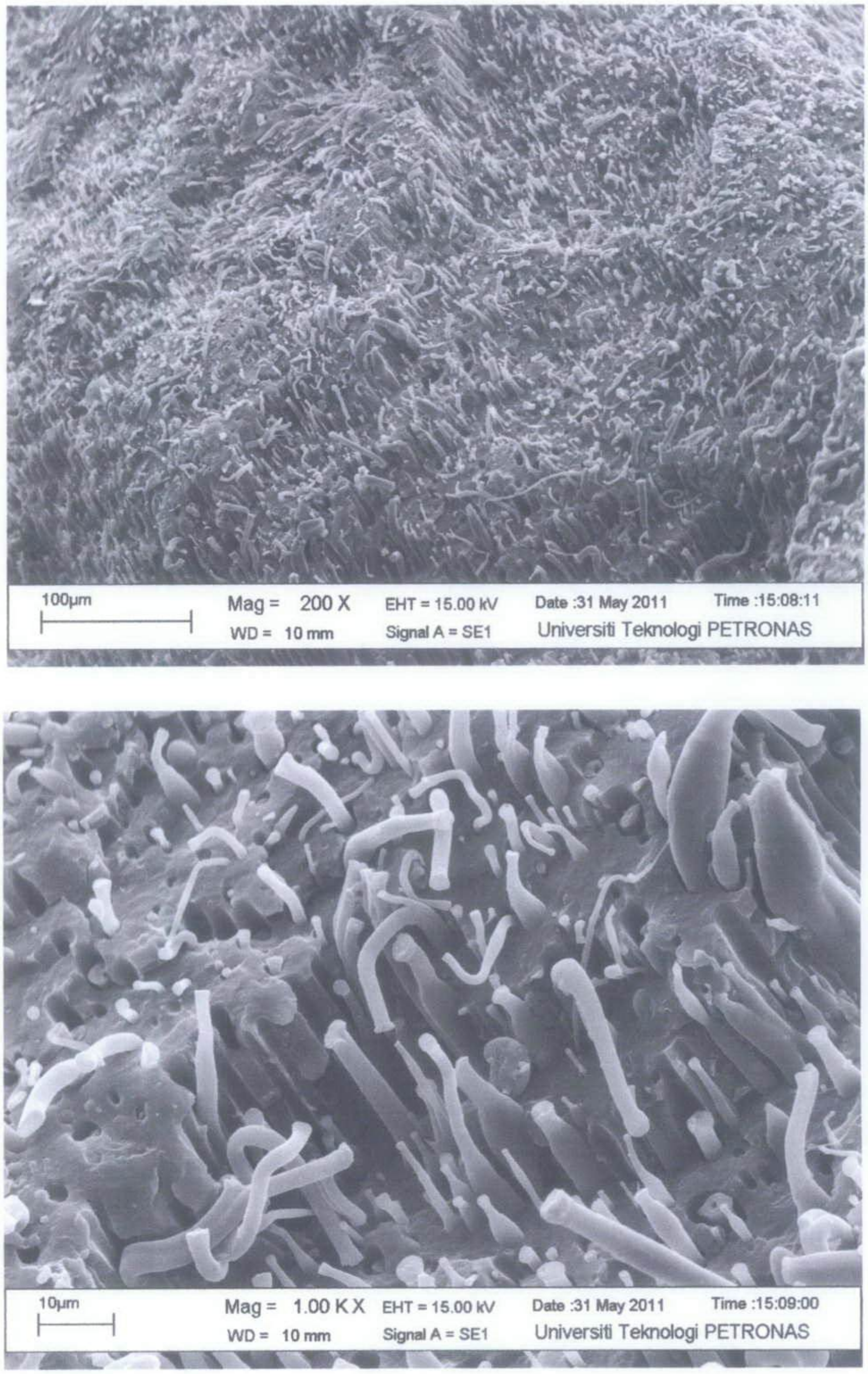


Figure 21(c): SEM PP/PC (75/25)

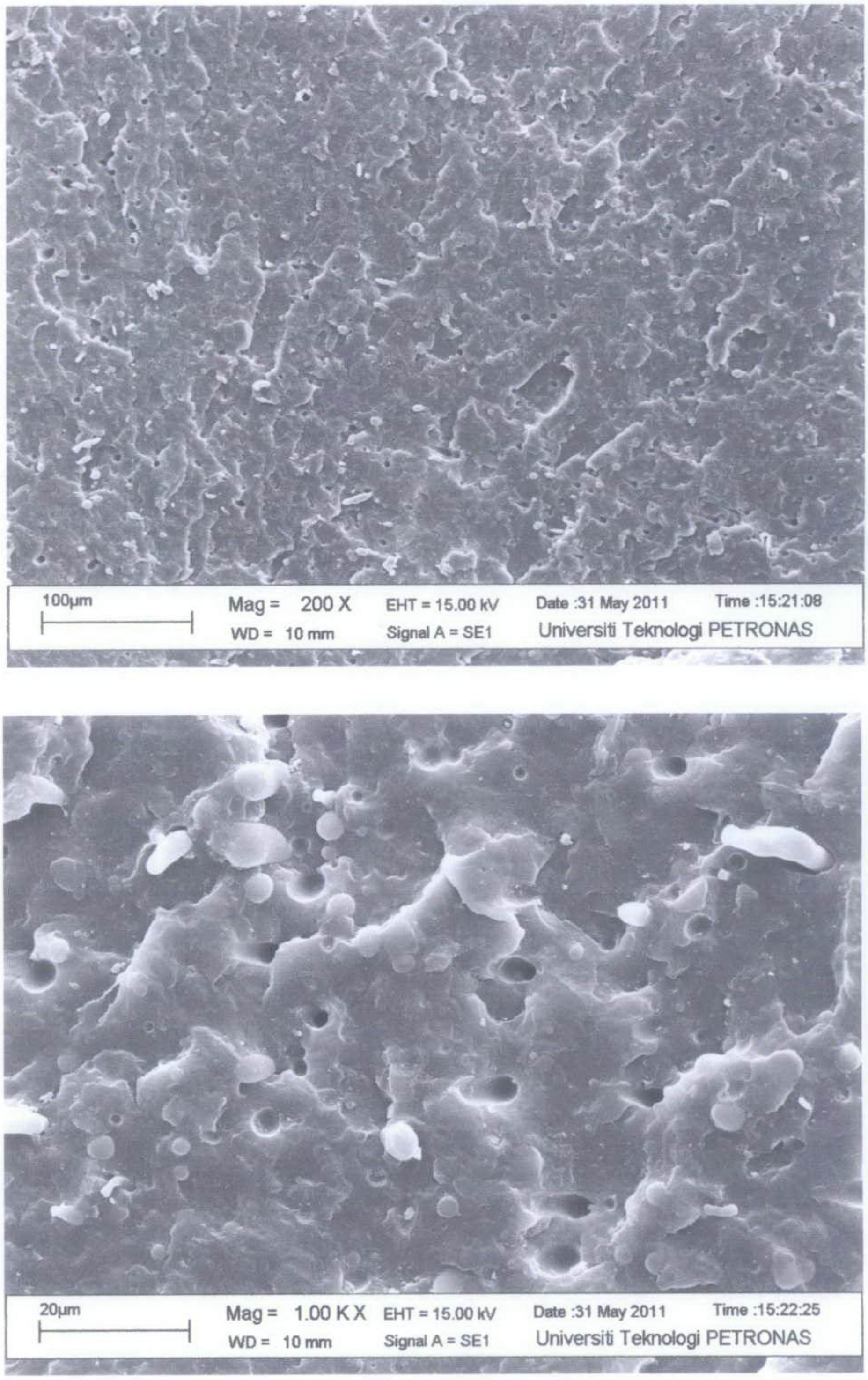
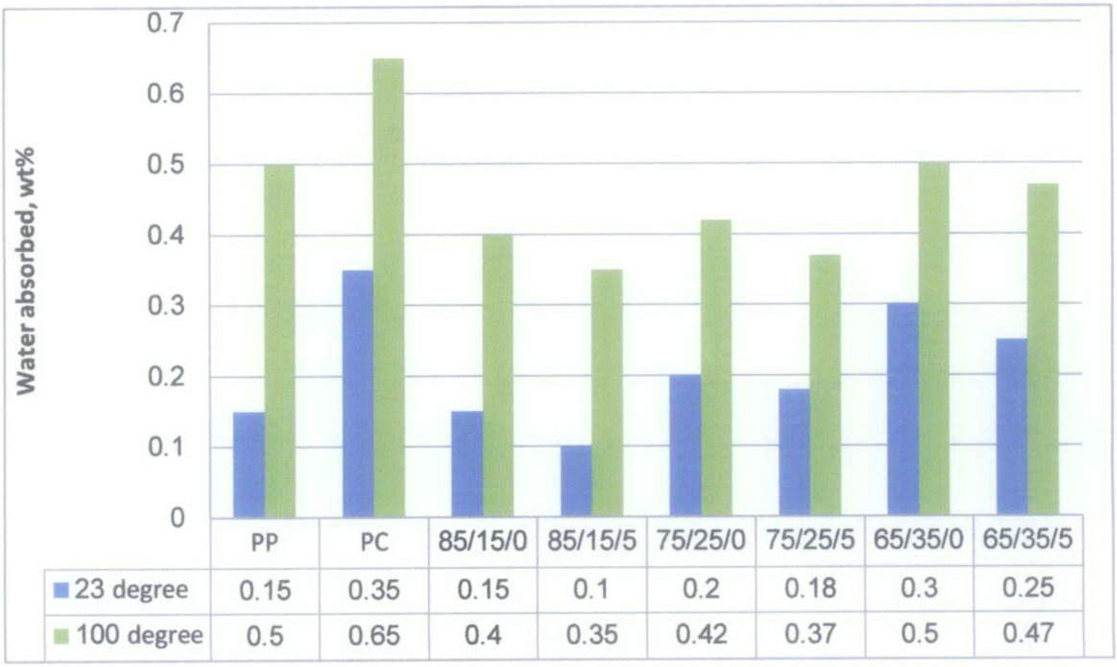


Figure 21(d): SEM PP/PC (85/15)

4.6 Water Absorption Analysis

For water absorption, the higher polycarbonate (PC) contents in PP/PC/PP-g-MA blends, the higher its water absorption. Based on the Figure 22, weight percentage of water absorption increase from 0.15% (PP) to 0.35% (PC) and the value continuously increased as percentage PC increased in formulation. Solvent solute interaction "like dissolves like" will apply and polar solvent like water affects polar polymer such as PC. PC also contains oxygen in carbonate group, CO_3 which is susceptible to water absorption [17]. However, weight percentage had significant decreased when PP/PC blends were compatibilized. The dispersion and interfacial adhesion of the blend was improved hence the properties also significantly became better.



	PP	PC	85/15/0	85/15/5	75/25/0	75/25/5	65/35/0	65/35/5
■ 23 degree	0.15	0.35	0.15	0.1	0.2	0.18	0.3	0.25
■ 100 degree	0.5	0.65	0.4	0.35	0.42	0.37	0.5	0.47

Figure 22: Weight Percentage of Water Absorption

4.7 Tensile strength analysis

Tensile strength is the stress at the maximum on the engineering stress-strain curve. The strength of a material is its ability to withstand external forces without breaking. In brittle materials, the tensile strength will at the end of the linear-elastic portion of the stress-strain curve or close to the elastic limit. In ductile materials, the tensile strength will be well outside of the elastic portion into the plastic portion of the stress-strain curve [15]. The results of the test are shown in Figure 23. Based on the figure the tensile strength is increased when the percentage of PC is increased in the formulation. This is significantly improved the tensile strength properties of PP. For pure PP the value is 31.439 Mpa and 65/35/5 is 34.824 Mpa.

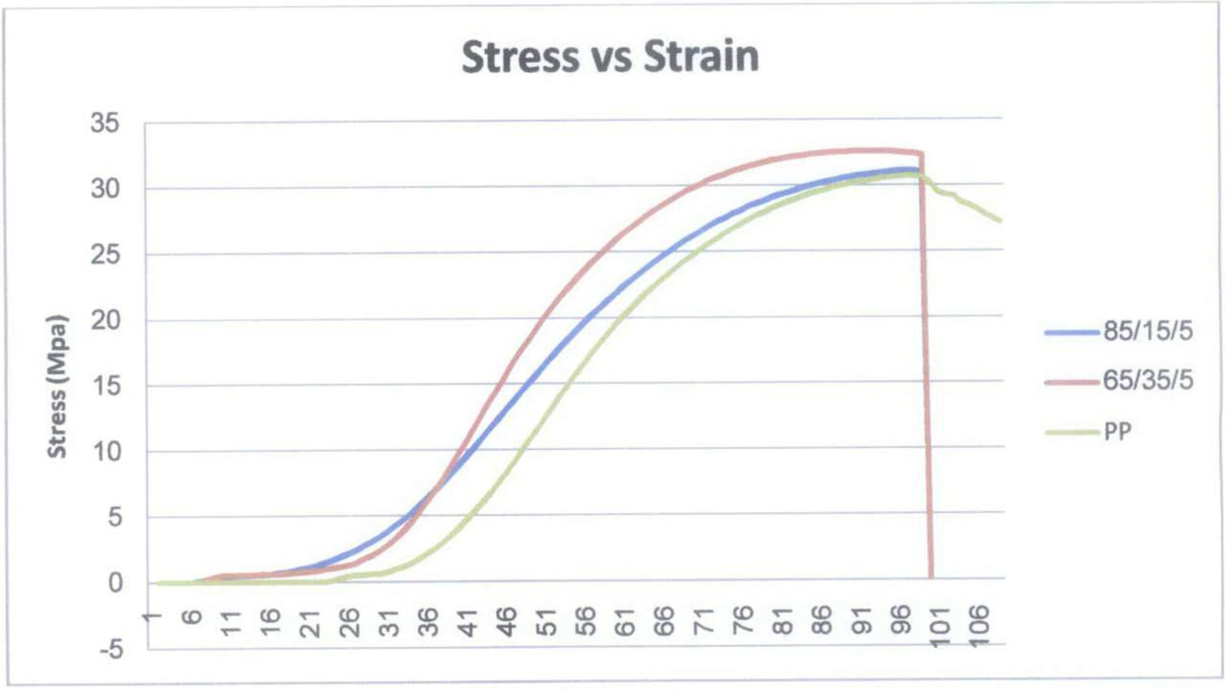


Figure 23: Stress Strain graph

CHAPTER 6

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APPENDICES A

No	*Detail/Week*	*1*	*2*	*3*	*4*	*5*	*6*		*7*	*8*	*9*	*10*	*11*	*12*	*13*
1	Primary Research Work	▨						*Mid-semester break*							
2	Submission of Preliminary Report	▨	▨	▨	▨	▨	▨		▨	▨	▨	▨	▨	▨	▨
3	Project work (prepare specimens with screw extruder. Weight composition of PP/PC 85/15, 75/25, 65/35, 55/45	▨	▨	▨	▨	▨	▨		▨	▨	▨				
4	Polymers will be mixed in extruder and fabricated by compression moulding				▨										
5	Obtained melting & glass transition temperature				▨	▨	▨								
6	Project work (water absorption test. Dry specimen in oven. Immersed in distilled water at 250-350 K								▨	▨					
7	Submission of Progress Report									▨					
8	Seminar (compulsory)									▨	▨	▨			
9	Submission of Interim Report Final Draft											▨	▨	▨	
10	Oral Presentation(study week)														

Figure A1: Gantt chart for FYP I.

No	*Detail/Week*	*1*	*2*	*3*	*4*	*5*	*6*	*7*		*8*	*9*	*10*	*11*	*12*	*13*	*14*	
1	Literature review	▨	▨	▨	▨	▨	▨	▨	*Mid-semester break*	▨	▨	▨	▨	▨	▨	▨	
2	Project work (prepare specimens) 85/10/5, 75/20/5, 65/30/5, 55/40/5.	▨	▨														
3	Polymers will be mixed in extruder and fabricated by injection molding			▨													
4	Project work (tensile test)				▨	▨											
5	SEM analysis						▨										
6	**Submission of Progress report**									▨							
7	**Pre EDX**												▨				
8	**Submission draft report**													▨			
9	**Submission of Dissertation (soft bound) and Technical paper**														▨		
10	**Oral presentation**															▨	
11	**Submission of Dissertation Final Draft (hard bound)**																▨

Figure A2: Gantt chart FYP II

APPENDICES B

Figure B1: Compression molding

Figure B2: Compression molding mould

Figure B3: Injection molding

Figure B4: Universal tensile machine

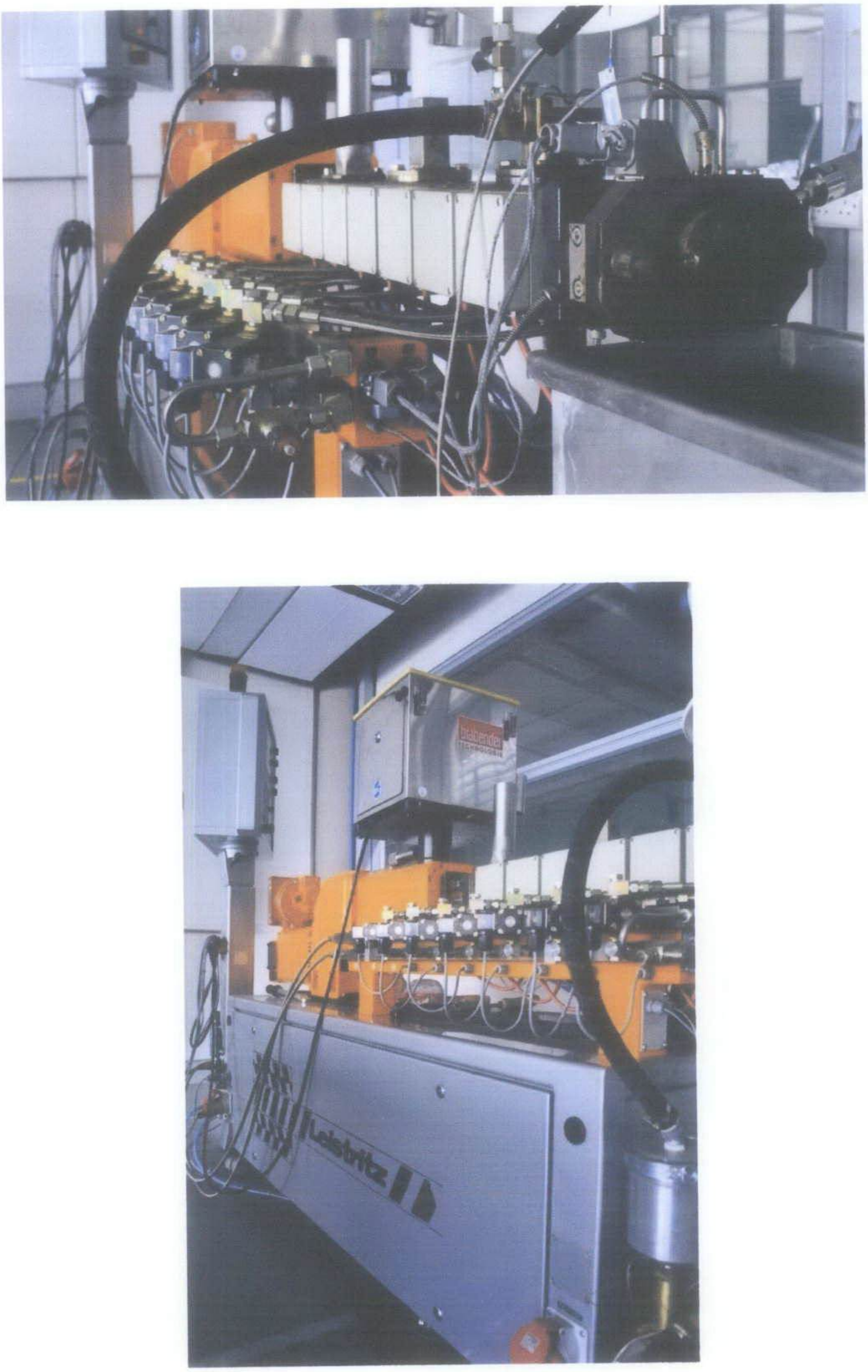

Figure B5: Twin screw extruder

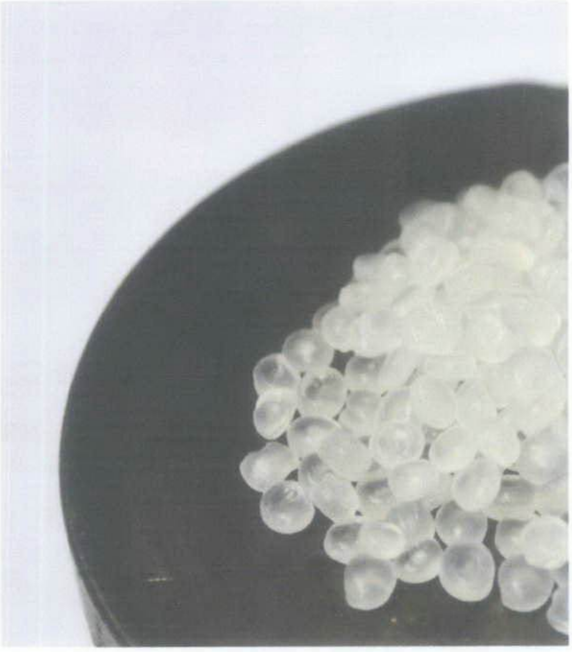

Figure B6: Polypropylene (PP)

Figure B7: Polypropylene/Polycarbonate (PP/PC)

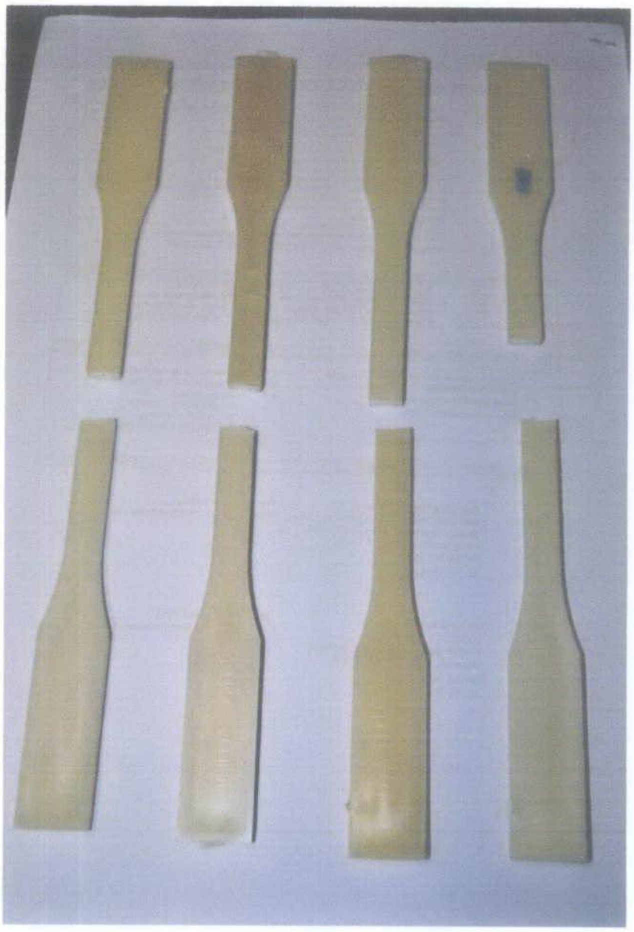

Figure B8: Samples of tensile strength analysis

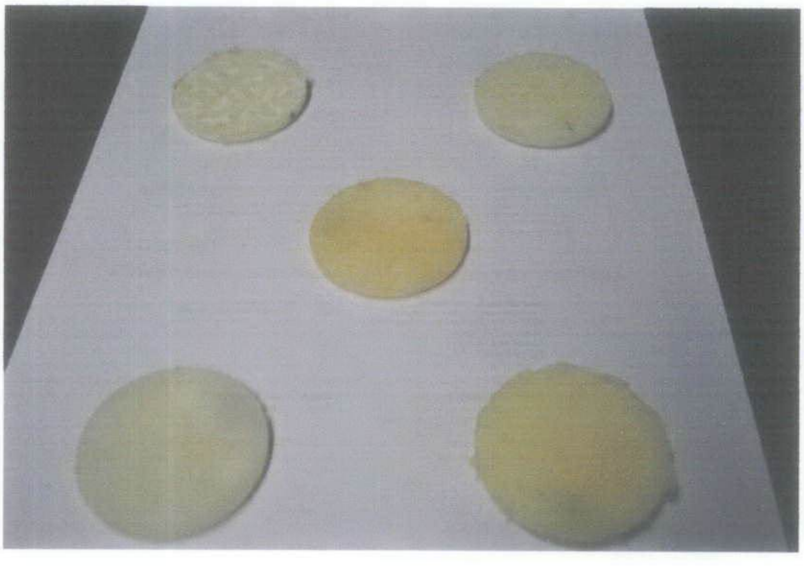

Figure B9: Samples of water absorption analysis