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ปีการศึกษา 2555

DEVELOPMENT OF POLYCARBONATE / ACRYLONITRILE STYRENE ACRYLATE BLENDS FOR OUTDOOR APPLICATIONS

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Chemical Engineering
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Thesis Title	DEVELOPMENT OF POLYCARBONATE / ACRYLONITRILE STYRENE ACRYLATE BLENDS FOR OUTDOOR
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Field of Study	Chemical Engineering
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ศิริศักดิ์ เหล่าเพ็ชรรัตน์ :การพัฒนาสารผสมของพอลิคาร์บอเนต/อะคริโลไนไตรล์สไตรีนอะคริเลตสำหรับการประยุกต์ใช้งานภายนอก.(DEVELOPMENT OF POLYCARBONATE / ACRYLONITRILE STYRENE ACRYLATE BLENDS FOR OUTDOOR APPLICATIONS)อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ดร. ศราวุธ ริมดุสิต, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม:ดร.รักษพงศ์ คุณานุรักษพงศ์, 129 หน้า

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ในงานวิจัยนี้เป็นการพัฒนาพอลิเมอร์ผสมชนิดพอลิคาร์บอเนต (PC)/อะคริโลไนไตรล์ สไตรีนอะคริเลต (ASA) ที่มีการทนแรงกระแทกสูงสำหรับการประยุกต์ใช้ในงานภายนอกโดยได้มีการเปลี่ยนแปลงชนิดของ ASA (ทั้งหมด 3 ชนิดโดยพิจารณาจากความสามารถในการไหลตัวและความสามารถในการรับแรงกระแทกที่แตกต่างกันซึ่งประกอบด้วย ASA-997, ASA-978 และ ASA-777) และเปลี่ยนแปลง อัตราส่วนระหว่าง PC และ ASA(PC 50-90% โดยน้ำหนัก) เพื่อศึกษาหาผลกระทบของชนิดและสัดส่วนของพอลิเมอร์ผสม ที่มีต่อคุณสมบัติทาง กายภาพ ทางกล และทาง ความร้อน โดยค่าสตอเรจมอดูลัส ที่อุณหภูมิห้องของพอลิเมอร์ผสม PC/ASA ทั้งหมดที่ตรวจวัดได้จากเครื่องวิเคราะห์คุณสมบัติเชิงกลทางความร้อนมีค่าเพิ่มขึ้นตามปริมาณ PC ที่เพิ่มมากขึ้น นอกจากนี้พอลิเมอร์ผสม PC/ASA-997 นั้นยังแสดงค่ามอดูลัสที่สูงที่สุดเมื่อเทียบกับระบบพอลิเมอร์ผสม PC/ASAที่เหลือคือ PC/ASA-978 และ PC/ASA-777 ส่วนอุณหภูมิการเปลี่ยนสถานะคล้ายแก้ว (T_g) ของพอลิเมอร์ผสม PC/ASA ทั้งหมดนั้น พบว่า T_g ทั้งเฟสของ PC และเฟสของ ASA นั้นมีแนวโน้มลู่เข้าหากันเล็กน้อยเมื่อ ปริมาณ PC ที่เพิ่มขึ้น นั่นแสดงถึงว่าระบบพอลิเมอร์ผสม PC/ASA นั้นจัดอยู่ในพอลิเมอร์ผสมที่สามารถผสมเข้ากันได้บางส่วน ซึ่งได้สอดคล้องจากผลการทดลองที่วิเคราะห์ได้จากเทคนิค Differential Scanning Calorimetry (DSC) ยิ่งไปกว่านั้นค่าความสามารถในการรับแรงกระแทกเมื่อวัสดุมีรอยบากของพอลิเมอร์ผสม PC/ASA ทั้งหมดที่ทดสอบได้จากเครื่องทดสอบแรงกระแทกนั้นพบว่ามีค่าสูงขึ้นอย่างชัดเจนโดยจะสูงขึ้นเมื่อปริมาณ PC ในระบบที่เพิ่มมากขึ้น โดยที่พอลิเมอร์ผสม PC/ASA-997 นั้นสามารถแสดงค่าความสามารถในการรับแรงกระแทกได้สูงที่สุดอีกด้วย แต่ทว่า พอลิเมอร์ผสม PC/ASA-777 นั้นได้แสดงค่าความสามารถในการไหลตัวได้มากที่สุด โดยที่ค่าความสามารถในการไหลตัวของพอลิเมอร์ผสม PC/ASA ทั้งหมดนั้นจะมีค่ามากขึ้นตามปริมาณ ASA ที่มากขึ้น ในจุดสำคัญนั้น ASA พบว่ายังสามารถช่วยถนวม สีและความสามารถในการรับแรงกระแทกของพอลิเมอร์นั้นให้อยู่คงเดิมได้มาก ซึ่งจากผลการทดลองโดยนำเอาพอลิเมอร์ไปเร่งสภาวะด้วยเครื่องเร่งสภาวะ (QUV) เป็นเวลาสูงสุดถึง 3 สัปดาห์ในเครื่อง โดยค่าความสามารถในการรับแรงกระแทกที่สามารถรักษาไว้ได้จะเพิ่มจาก 77% ถึง 91% เมื่อมีปริมาณการเติม ASA ในระบบเพิ่มจาก 10% ถึง 90% โดยน้ำหนักซึ่งเป็นข้อยืนยันได้ว่า ASA นั้นสามารถช่วยเสริม ความสามารถในการใช้งานภายนอกของพอลิเมอร์ผสมนี้ได้

ภาควิชา วิศวกรรมเคมี	ลายมือชื่อนิสิต
สาขาวิชา วิศวกรรมเคมี	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก
ปีการศึกษา 2555	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์ร่วม

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SIRISAK LAOPETCHARAT: DEVELOPMENT OF POLYCARBONATE / ACRYLONITRILE STYRENE ACRYLATE BLENDS FOR OUTDOOR APPLICATIONS. ADVISOR : ASSOC. PROF. SARAWUT RIMDUSIT, Ph.D., CO-ADVISOR : RUKSAPONG KUNANURSAPONG, Ph.D., 129 pp.

In this research,It aims to develop polycarbonate (PC) and acrylonitrile-styrene-acrylate (ASA) blends for high impact resistant products for outdoor applications. PC/ASA were blended at various grades of ASA (3 grades at impact strength and melt flow index different, i.e. ASA-997, ASA-978 and ASA-777)and compositions (i.e. containing 50- 90 wt% of PC) to investigate the effect of ASA grades and blend compositions on phycical, mechanical and thermal properties. The storage modulus at room temperature of all PC/ASA blends from dynamic mechanical analysis steadily increased with an increasing of PC contents. Moreover, PC/ASA-997 showed the highest modulus from the other PC/ASA blends system, i.e. PC/ASA-978 and PC/ASA-777. Glass transition temperatures (Tg) of all PC/ASA blends revealed that Tg of both PC-rich phase and ASA-rich phase slightly shifted towards each other with increasing amount of the PC. It showed that, PC/ASA blend can be classified as a partially miscible. Furthermore, notched Izod impact strength from impact tester of all PC/ASA blends clearly increased with an increasing PC contents in these polymer blends that PC/ASA-997 blend was also shown the highest impact strength. Whereas, PC/ASA-777 showed the highest melt flow index. The melt flow index of all PC/ASA blends distinctly incresed with an increasing amout of ASA in the blend. In particular, ASA was found to significantly improve the color and the impact strength retention of pure PC. From result of QUV exposure, a time period up to 3 week in QUV, the impact strength retention after weathering test increased with an increasing ASA content from 77% to 91% for 10 wt% to 50 wt% of ASA content, respectively. These evidences indicated that ASA can improve weatherability of these blends.

Department : Chemical Engineering Student's Signature ....
Field of Study : Chemical Engineering Advisor's Signature ....
Academic Year : 2012 Co-advisor's Signature ....

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CHAPTER I

INTRODUCTION

1.1 Introduction

Polycarbonate (PC) is a widely used engineering thermoplastic because it possesses several distinct properties such as transparency, high heat distortion temperature (HDT), toughness and excellent electrical resistance [1]. PC also possesses other properties such as excellent color-ability, high gloss, sterilizability, flame retardancy, biocompatibility, stain resistance and high glass transition temperature of approximately 150ºC. However,some deficiency of properties of PCdeters its specific use such as thickness dependence of the notched impact strength and the poor radiation, solvent, or hydrolysis resistance, and poor ultraviolet stability. To solvethese shortcomings, efforts have been made through development of polymer blends and alloys of PC.

When transparancy is not required, acrylonitrile-butadiene-styrene copolymer (ABS) can be blended with PC and isclaimed anaturallycompatible blend with reported synergy on impact strength, improved notch-sensititvity and enhanced flow properties. The PC/ABS blends is widely used commercially because these material provide products having outstanding balance of properties described above at reduced cost. However, PC/ABS blends have a main drawback stem from the physical (or chemical) aging of butadiene rubber in ABS. Butadiene rubber, containing a double bond in its repeat unit, undergoes physical (or chemical) aging caused by ultraviolet radiation in outdoor application [2]. The aging of butadiene rubber results in a deterioration in the mechanical strength and color changes.

Aging problems of butadiene rubber in acrylonitrile butadiene styrene copolymer for making polymer alloys with PC could be solved by using acrylonitrile-styrene-acrylate copolymer (ASA) instead ofABS [3]. ASA is also a styrenic copolymer that has been used for PC modification due to its excellent balance of properties, including high weathering resistance. ASA was prepared by grafting copolymerization of styrene and acrylonitrile monomers onto acrylic rubber particles has a similar structure as that of ABS copolymer i.e. the unsaturated butadiene rubber was replaced by a more UV stable acrylic. It provides mechanical properties similar to those of ABS with an additional aspect of excellent resistance to ultraviolet light. ASA resins are widely used in industrial applications, for example, coating, adhesives, and paints. Furthermore, ASA can also be blended with many polymers to make alloys and compounds in order to utilize ASA's weather and impact resistance [4]. Due to special acrylic ester rubber in the matrix, ASA resin provides resistance to UV radiation and atmospheric oxygen. Furthermore, under long period of exposure to UV, moisture, heat and impact, ASA shows very low level of yellowing and slightly decreases in toughness [5].

In this research, effects of various grades of ASA copolymers and their contents on mechanical, thermal and physical properties of the resulting PC/ASA blends for potential use in high impact resistant products for outdoor application will be examined. The obtained blends will also be compared with 1-2 commercial PC/ASA blends.

1.2 Objectives

1. To study the mixing condition for the preparation of wonderlite®PC/ASA blends using wonderlite®PC110 and ASA copolymers (3 grades) for high impact and outdoor applications.
2. To evaluate effects of the blend compositions on important mechanical, thermal, physical properties and miscibility of PC/ASA blends.
3. To compare essential mechanical property of the PC/ASA between before and after QUV test.

1.3 Scopes of the Study

1. Patent search for PC/ASA from WIPO, JPO, USPTO, EPO, and TPO are performed in order to obtain the wide picture of PC/ASA formulas which are already available commercially.
2. Materials to be used to prepare polymer blends and to characterize their physical, mechanical and thermal properties follow section 1.1 – 1.3.
    - 2.1 PC is wonderlite®110from Chi Mei.
    - 2.2 ASA copolymers are KIBILAC®PW-978B, PW-997S from Chi Mei and Luran®S 777K from BASF.
3. Prepare PC/ASA blends by melt mixing.
    - Parameters to be investigated are mixing temperature, speed and at PC/ASA blending ratios of: 100/0, 90/10, 80/20, 70/30, 60/40, 50/50 wt% of each grade.
4. Characterize physical, mechanical and thermal properties of the PC, ASA, and the prepared PC/ASA blends.
    - Physical Properties
        - Specific gravity
        - Viscosity (Rheometry plate&plate)
        - Melt flow index (260^{o}C/5kg)
        - Morphology (SEM)
        - Water absorption
        - Color change
        - Hardness (Rockwell)
    - Mechanical Properties
        - Tensile properties (Instron)
        - Flexuralproperties (Instron)
        - Storage and loss modulus (Dynamic Mechanical Analysis)
        - Notched Izod impact strength

    - Mechanical properties after UV exposure

- Thermal Properties
    - Glass transition temperature (Differential Scanning Calorimetry)
    - Vicat softening point
    - Heat distortion temperature
    - Thermal degradation (Thermogravimetric Analysis)

5. Provide information and guidance in the analyze parameters that affect the miscible and properties in various fields of PC/ASA blend.

1.4 Procedure of the Study

1. Prepare chemicals, apparatus, and equipment for this research such as PC, ASA, PC/ASA pellets, etc.
2. Determine mixing or processing conditions of the PC, ASA, their blends and commercial PC/ASA blends.
3. Examine PC/ASA blends by varying compositions of ASA at 100/0, 90/10, 80/20, 70/30, 60/40 and50/50 wt%
4. Evaluate physical, mechanical and thermal properties of PC/ASA blends in (3) comparing with the commercial grade PC/ASA blends.

5. Summarize the optimum ratios of PC/ASA blends in terms of physical, mechanical and thermal properties which are recommended for commercial products.

CHAPTER II

THEORY

2.1 Polycarbonate (PC)

Polycarbonate or PC are linear thermoplastic polyesters of carbonic acid with aliphatic or aromatic dihydroxy compounds. The commercial product is based on the reaction of bisphenol A and diphenyl carbonate or phosgense. Among the members of this large family only bisphenol A polycarbonate is the most widely used. The chemical structure of the polymer is shown in Figure 2.1 [6].

Figure 2.1: Structure of bisphenol A polycarbonate.

In a solid state, PC exhibits a good thermal stability up to its glass transition temperature (about 150ºC). In the dry, molten state, PC may be kept at 310ºC for hours, since its thermal degradation starts above 400ºC[7-8]. Its injection molding grades have an average molecular weight (MW) generally between 22,000 and 32,000. Tensile, unnotched impact and flexural strength steadily increase with increased MW up to about 22,000 and level off beyond this value whereas the melt viscosity continues to increase in this range. A compromise is, therefore, necessary for providing a MW sufficiently high for obtaining satisfactory mechanical properties but low enough for obtaining melt viscosities capable of imparting flow charecteristics suitable for filling complex molds [6].

The structure of PC with its carbonate and bisphenolic structures has many characteristics that promote its distinguished properties. The phenyl and methyl groups on the quartenary carbon promote a stiff structure. The ester-ether carbonate groups --OCOO- are polar, but their degree of intermolecular polar bond formation is minimized due to the steric hindrance posed by the benzene rings. The high level of aromaticity on the backbone, and the large size of the repeating unit, thus yields a molecule of very limited mobility. The ether linkage on the backbone permits some bond rotation and chain flexibility, producing high impact strength. Its amorphous nature, with long, entangled chains, contributes to the unusually high toughness. The rigidity of the molecule accounts for strong mechanical properties, elevated heat deflection temperatures, and high dimensional stability at elevated temperatures. A relatively high free volume results in a low-density polymer, with unfilled PC having a 1.22 g/cm ^{3} density. However, PC has some disadvantage including the need for drying and elevated temperature processing. PC also shows limited chemical resistance to numerous aromatic solvents, including benzene, toluene, and xylene, and exhibits a high sensitivity to notch or crack. Selected key mechanical and thermal properties are given in Table 2.1 [7-8].

Table2.1: Properties of bisphenol A polycarbonate [7-8].

Polycarbonate	
Physical Properties	
Specific gravity	1.20-1.22
Refractive index (n)	1.584
Flammability	V-0 to V-2
Water absorption - over 24 hours	0.1%
Mechanical Properties	
Young's modulus (E)	2.0-2.4 GPa
Tensile strength (σ_t)	55-75 MPa
Compressive strength (σ_c)	>80 MPa
Elongation (ε) @ break	80-150%
Izod impact strength	600-850 J/m
Thermal Properties	
Softening temperature	267 °C
Glass transition temperature (T_g)	150 °C
Upper working temperature	115-130 °C
Lower working temperature	-135 °C
Thermal conductivity (k) @ 23 °C	0.19-0.22 W/(m·K)
Chemical Resistance	
Acids – concentrated	Poor
Alkalis	Good-Poor
Aromatic hydrocarbons	Poor
Greases & Oils	Good-Fair
Economic Price	
Price	150 baht/kg*

(*Ref. http://www.tpia.org/stat/graphday.asp?chk=1, the price of polycarbonate on January 2012, Thailand.)

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Figure 2.2: Appearance of polycarbonate pellets grade WONDERLITE® PC-110. **(**Chi Mei Corporation)

Usual appearance of PC pellets of WONDERLITE®PC-110 is shown in Figure 2.2. It is transparent and colouress. In terms of flammability, polycarbonate burns with a sooty, dark yellow spitting flame, foams up and chars. It extinguishes away from the ignition source. The decomposition products smell initially slightly of and later strongly of phenol. Besides charred residues, pyrolysis results in gaseous products such as aldehydes, ketones and carbon oxides[9].

Applications of Polycarbonate.

Polycarbonate is becoming more common in housewares as well as laboratories and in industry, especially in applications where any of its main features; high impact resistance, electrical resistance, temperature resistance, optical properties are required. Therefore this polymer is widely use in relatively broad range of applications such as compact discs, safety windows, wheels, wall on deck, canopy, skylight dome, transparent roofing sheetand etc, as shown in Figure 2.3.

www.krunker.com

www.hydro-gardens.com

www.automotto.org

www.ministryoftech.com

Figure 2.3: Some applications of polycarbonate.

However, the application of PC is limited by the viscosity during processing and the notch sensitivity. In practice we can improve the above properties of this polymer by blending with styrenic copolymers such as acrylonitrile-styrene-acrylate (ASA).

2.2 Acrylonitrile Styrene Acrylate (ASA)

Acrylonitrile styrene acrylate (ASA) resin is one of the styrenic copolymers used for housings, covers and other applications which require excellent surface feature and outstanding weatherability combined with high impact resistance and stiffness. ASA is composed of a poly(styrene-acrylonitrile) matrix modified with small rubber particles. Its structure is typically core-shell structure modifier with a cross-linking polyacylate (usually poly(butyl acrylate)) core and a grafted styrene-acrylonitrile shell acting as compatilizers between the rubber particles and the SAN matrix in the ASA resin. Architecture and morphology of acrylonitrile styrene acrylate are exhibited in Figure 2.4 and Figure 2.5 respectively.

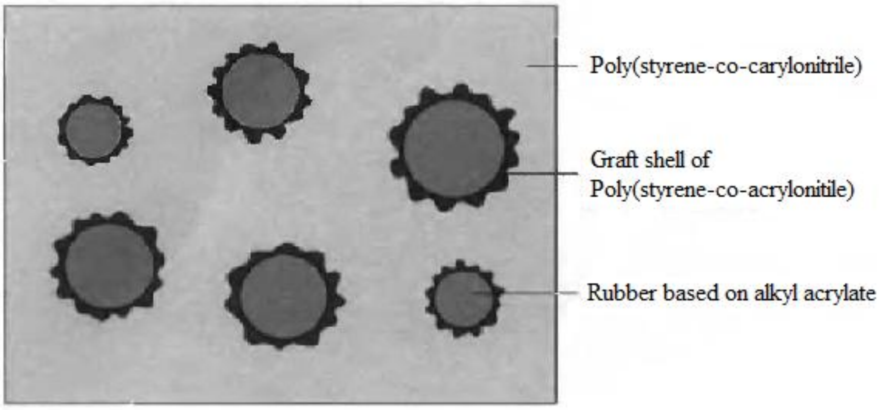


Figure 2.4: Architecture of acrylonitrile styrene acrylate [10].

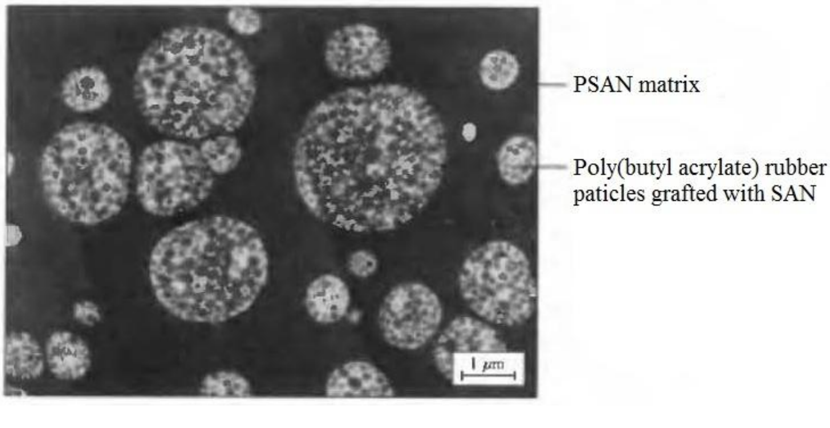
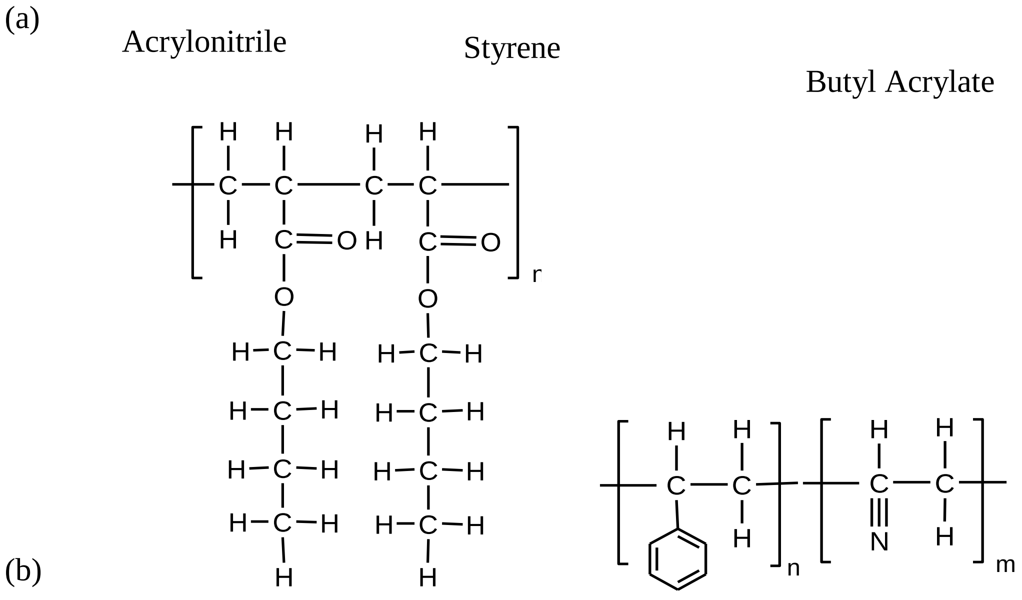


Figure 2.5: Transmission electron micrograph of ASA[10].

Polyacrylate or acrylic elastomer is also characterized by its good heat resistance and oil resistance. It can retain its properties at a temperature of 170-180℃ under dry air or in oil. Due to its saturated chain, acrylic rubber also has excellent weatherability and ozone resistance [10]. Styrene acrylonitrile copolymer is inherently transparent polymer, with high heat resistance and excellent gloss and chemical resistance. Moreover, it has a good hardness, rigidity, dimensional stability, and relatively high tensile and flexural strengths. When SAN is grafted on the poly(butyl acrylate) backbone, ASA has the useful SAN properties of rigidity and resistance to chemical and solvents, while the elastomeric component contributes to impact resistance and capability of withstanding environmental exposure [11].



Poly(butyl acrylate) Polystyreneacrylonitrile

Figure 2.6: (a) Monomer of ASA, (b) Poly(butyl acrylate) and Poly(styrene-acrylonitrile).

In comparison with ABS, the double of polybutadiene incline to oxidation and crosslinking due to oxygen, UV radiation or heat. This results in deterioration of the rubber, leading to loss of impact strength and discoloration. In contrast, the butyl acrylate rubber of ASA is free of double bond which gives ASA clear advantages in terms of weatherability and resistance against physical and chemical aging compared to ABS as illustrated in Figure 2.7. Further advantages of ASA over ABS are its better chemical resistance and higher resistance against environmentalstress cracking, especially against alcohols and many cleaning agents [10].

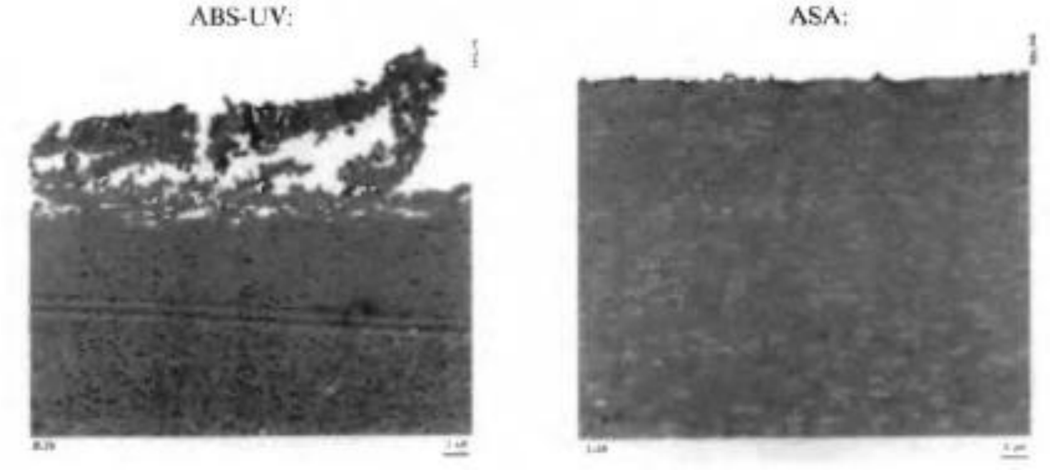


Figure 2.7: Scanning electron micrographs of a cross-section perpendicular to the exposed side of ABS and ASA after 500 hrs of UV exposure (Xenotest, ISO 4892-2A) [10].

ASA also exhibits advantages over other thermoplastic housing materials such as polycarbonate, poly(butylene terephathalate) and polypropylene. The low molding shrinkage of ASA and of PC is advantageous for housings and covers because warpage problems are almost nonexistent with these products. However, PC has only a limited resistance against environmental stress cracking, for example by alcohols and cleaning agents, and it yellows much more than ASA during outdoor exposure. Compared with polypropylene, a material widely used because of its low price, ASA has advantages in terms of stiffness, impact strength, heat distortion temperature and weatherability. In addition, owing to its high molding shrinkage, polypropylene has a high tendency to warp during or after processing, and it is much more sensitive to scratches than ASA. Since it possesses superior physical properties, and can be easily processed by injection molding or extrusion, ASA has found an increasing use in a variety of applications [10]. The typical values for some properties of the ASA are given in Table 2.2.

Table 2.2: Typical properties of acrylonitrile styrene acrylate (ASA) [12].

Properties of ASA	
Glass transition temperature	100^{o}C
Specific gravity	1.07
Tensile modulus	2.3-2.5 GPa
Tensile strength	44-49 MPa
Impact strength	110-250 J/m
Flexural modulus	2.2-2.5 GPa
Flexural strength	60-75 MPa
Water absorption	1.65% of volume
Chemical Stability (Acid, Base, Oil and Fat)	excellent
Price*	100 Bath/kg

(* Ref. http://qdzxhm.en.alibaba.com/product/459329252-212520618 /Chimei_ASA_Plastic_Material_PW997s_for_Extrusion.html, the price of ASA on January 2012, Thailand.)

Figure 2.8: Appearance of acrylonitrile styrene acrylategrade KIBILAC PW-997S. (Chi Mei Corporation)

Applications of Acrylonitrile Styrene Acrylate

Owingto its favorable combination of properties, ASA has become an important engineering plastic material. Now it is being used for many interior and exterior applications. The largest area of application for ASA is in the automotive sector. Several automotive manufacturers use ASA for unpainted exterior parts such as mirror housings, radiator grille, cowl vent grille and pillar covers. Other important applications for ASA is in the household sector. Typical applications include housings and covers for sewing machines and kitchen appliances, garden equipment such as lawnmower housings, and parts for lawn and garden. In the building sector, ASA has found various applications such as window frames and sanitary equipment [10].

http://www.made-in-china.com/

http://www.cartype.com/

http://www.made-in-china.com/

http://www.cheaplawnmowersguide.com/

Figure 2.9: Applications of acrylonitrile styrene acrylate(ASA).

2.3 Polymer Blend of PC/ASA

Part of PC produced commercially nowadays is used for blending particularly with a lower cost styrenic copolymers including SAN, ABS and ASA. The blend is commonly used in profile extrusions and co-extrusions. Application of PC/ASA blend is as automotive part, external mirror housing, side protection moldings, rear aprons, spoilers wind shields, etc. This blend results in plastic products with significantly better impact strength, higher heat distortion temperature and greater color retention than PC. In addition, the blend has cost advantages over the neat PC. Typical properties of PC/ASA blend (ASTALOY™) are shown in Table 2.3.

Table 2.3:Properties of ASTALOY™ PC/ASA blend [13].

Properties of PC/ASA		
Glass transition temperature	100^{o}C	-
Specific gravity	1.10-1.17	ASTM D792
Tensile modulus	2.3 GPa	ASTM D638
Tensile strength	45-60 MPa	ASTM D638
Impact strength	200-700 J/m	ASTM D256
Flexural modulus	2.0-2.4 GPa	ASTM D790
Flexural strength	70-90 MPa	ASTM D790
Water absorption	0.1-0.25% of volume	ASTM D570
Chemical Stability (Acid, Base, Oil and Fat)	excellent	-
Melt Flow Rate	5-13 g/10 min	ASTM D1238

http://www.made-in-china.com/ http://mytexpolymers.com

http://usionline.net http://www.widepr.com

Figure 2.10: Some applications of PC/ASA polymer blends**.**

2.4 Miscibility of Polymer Blend

Nearly every polymer exhibits a glass transition temperature. When two polymers are blended together, broad definition, one of several different events may happen; see Figure 2.11. First of all, the polymers may be miscible and one-phased. In this case, the Fox equation can be used to estimate the glass transition of the blend. The opposite extreme is that the two polymers are totally immiscible. Then the two polymers retain their original glass transition temperatures. Polymer–polymer interactions in the bulk state have been studied by a number of experimental tools. For phase-separated compositions, dynamic mechanical spectroscopy measures shifts in the glass transition temperature, which provides a measure of the extent of molecular mixing in partially mixed systems[14].

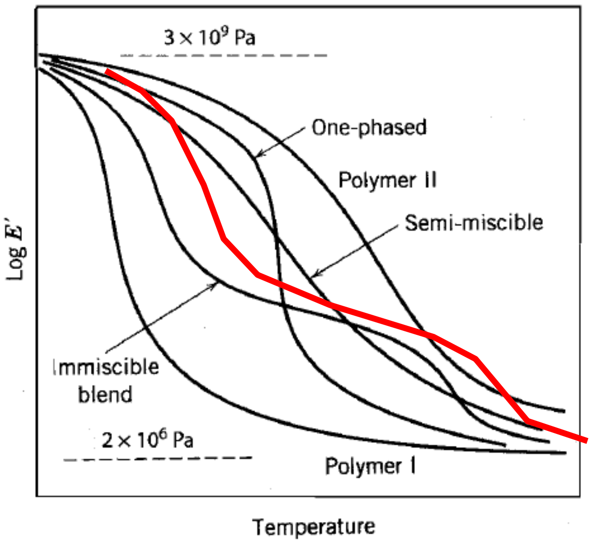


Figure 2.11: Possible glass transition behavior of polymer blends. The two polymers may be immiscible, showing two distinct glass transitions; miscible, with one glass transition defined by the Fox equation; or semimiscible, usually with one very broad glass transition [14].

2.5 Toughening Mechanisms

In a polymer science context, toughness is defined as the ability to resist fracture by absorbing energy. It is usually expressed in terms of the work done in a unit area of fracture surface. Several thermoplastics, both of the commodities kind [polystyrene (PS), polyacrylonitrile (PAN), poly(methylmethacrylate) (PMMA), polypropylene(PP), polyvinylchloride (PVC) and etc.] and engineering polymers [polyamides(PA), polyesters (PE), polycarbonates (PC), polyimides (PI), and etc.] exhibit glass transition temperatures (T_g) higher than or close to room temperature. As a result, at room temperature, they exhibit the shortcoming of brittle impact behavior, which limits their commercial end-uses. To overcome this problem, suitable rubber modifiers are added into the homopolymer matrices. These will induce locally diffused microscopic mechanisms of deformation, and make the matrix capable of dissipating large impact energies without catastrophic failure. In general impact modifiers have some required characteristics such as a sufficiently low Tg, of elastomeric behavior at room temperature, optimum particle size with a suitable particle size distribution, a homogeneous dispersion and a good adhesion to the thermoplastic matrix. Well dispersed rubber particles are able to induce in the thermoplastic matrix different mechanisms of toughening include crazing, shear yielding, and combination of crazing and shearing yielding.

Crazing

Rubber particles, with an optimum size, homogeneously dispersed in a very rigid matrix (brittle amorphous polymers, such as PS and SAN) can enhance capableof dissipating impact energies to the matrix, this results in a multicraze initiation and termination mechanism. Within the matrix, crazes initiate occurs atthe rubber particle equators where a very high stress concentration is built up. Through the application with an external load, they undergo propagation and the termination occurs when they impinge upon neighboring rubber particles. The microcrazes, diffused throughout the deformation zones of the body, are perpendicular to the direction of the applied stress and are accompanied by a marked stress whitening effect. A craze is similar to a microcrack but differs in being bridged across by several microfibrils, made by oriented polymer chains, which can maintain a certain load. The molecular weight of the matrix is an important parameter for crazing. Below a critical molecular weight, no chain entanglements, no stable crazes can be formed. The fracture under a sufficiently high load is determined by the rupture of the craze fibrils, once a crack of critical size has been developed[15].

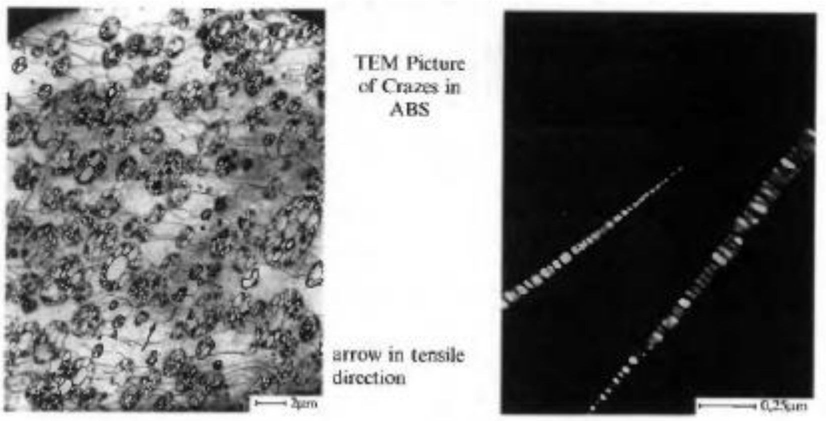


Figure 2.12: Transmission electron micrographs picture of crazes in core-shell polymers [10].

Shear Yielding

In homogeneous polymers shear deformation consists of a distortion of the body shape without significant volume change. In semi-crystalline materials shear yielding is localized and occurs by slip on particular planes of maximum shear stress. In non-crystalline materials the shear yielding is much more scatter than in the previous case, requiring large co-operative chain movements. In toughened materials a diffused shear yielding is the main energy dissipation phenomenon, preceded or followed by rubber particle cavitation (the particle must be very small, of sub-micron sizes). Particle cavitation induces a stress whitening effect, visible along the largest deformation patterns of the body. Semi-ductile polymer matrices, such as PVC, ABS, ASA, PC, and PA undergo diffuse shear yielding [15].

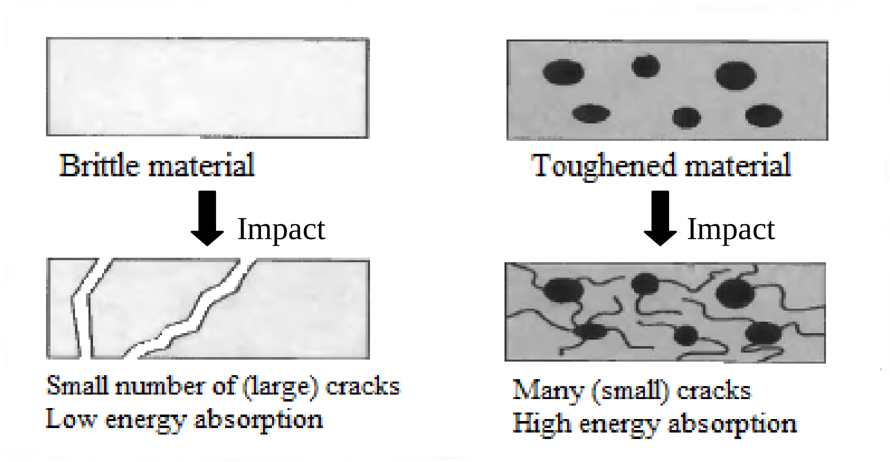


Figure 2.13: Formation of crazes after impact [10].

Stress Whitening

It is the appearance of white regions in a thermoplastic when it is stressed. A stress-whitening zone may be a sign of the formation of many microcracks and fine crazes in the specimen [16]. Stress whitening occurs fairly late in the rupture stage, just prior to yielding. The whitish surface appearance is a result of the mismatch in refractive index in the area of stress concentration.

Energy Absorption by Rubber Particles

Collyer [17] suggested that on stressing or during crack formation, the rubber particles will dissipate the bulk strain energy by the cavitation, which leads to reduction in the yield stress of the materials. With this reason, shear yielding is easily formed and enhanced by the void in the matrix caused by the cavitated rubber particles [17]. The fibrils of rubber particle will bridge across the fracture surface and inhibit crack growth. The total fracture energy is the sum of energy to break the glassy matrix and to break the rubber particle [18].

The most common mechanism of toughening by a discrete rubbery phase is based on the ability of stress concentrations at the interface to induce a combination of crazing and shear yielding in the matrix. In this way, strain energy that could otherwise drive a macroscopic crack is dissipated throughout a large volume of material

2.6 Core-Shell Impact Modifiers

Core-shell impact modifiers have commercially been used as impact modifiers since 1958. A major distinction of core-shell impact modifiers from other types of impact modifiers is that their size is set during the production process and exists the same size after they are dispersed in a host matrix.

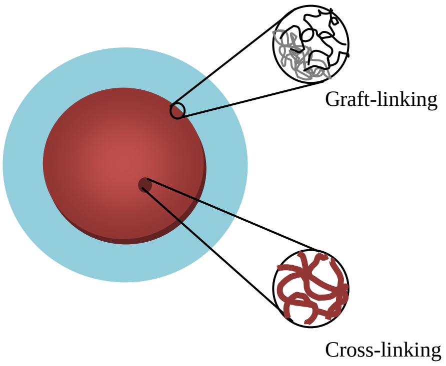


Figure 2.14: Diagram of typical core-shell modifier particle [19].

The architecture of core-shell polymers is described schematically in Figure 2.12. The core of these polymers made up of rubbery polymer whereas surrounding shell is rigid polymer that is grafted to the core. The materials commercially used as the rubbery core are poly(butyl acrylate) (PBA) or poly(butadiene). This center of the particles provides the soft second phase that induces toughening. The shell of the particles consists a glassy polymer which has a much higher glass transition temperature (T_g) than that of the core. The primary benefits of shell polymer are hard coating that keeps the rubbery core from adhering together and acting as an intermediate that merges the rubber core to the matrix. A key factor in the performance of core-shell impact modifiers is their adhesion to the matrices in which they are dispersed. A low value of the interaction parameter, indicative of miscibility, and also translates into effective toughening.

Major factors in core-shell toughening

Particle size: As a general rule, brittle glassy matrices that tend to craze benefit more from large rubber particle size. On the other hand, matrices that can absorb fracture energy via shear yielding are effectively toughened with relatively small-particle-size modifiers. Emulsion polymerization lends itself to the preparation of small particles, and therefore, core-shell polymers are more often used in shear yielding matrices, such as PC and engineering thermoplastics.

Glass transition temperature: Maintaining a consistent T_g in the polymer core as well as in the shell is one of the key factors that determine the quality of an impact modifier. As a general rule for core-shell particles, rubber cores with lower glass transition temperatures inducebetter toughening at lower temperatures. A hard shell is grafted onto the latex particles to help isolation and provide compatibility with the host matrix[19].

In rubber toughened plastics, the rubber particles constitute the dispersed phase in the polymer matrix. Theiressential role is to act as a stress concentrator. When the toughened material issubjected to stress, the localized stress experienced by the matrix inthe immediate vicinity of a rubber particle is magnified by the local stress concentration effect. The matrix will yield locally in response to this localizedstress field, thus avoiding a global brittle catastrophic failure of the material.The concentration of stress that initiates the local yielding in the matrix is justthe first step in a complex process; if the overall applied stress is increased furtherthe matrix then continues to deform by shear yielding or crazing. Shear yielding involves the creation of bands of highly oriented, stretched material at 45° to the direction of the applied stress. Crazes are cracks, spanned by elongated fibrils of the material which can carry load and thus maintain the structural integrity of the material [20].

CHAPTER III

LITERATURE REVIEWS

J. H. Kim and coworkers in 2001[21] studied the effects of AN content of SAN copolymers on morphology and interfacial tension of PC/SAN blends**.** The average diameters of the dispersed particles estimated from the micrographs as a function of AN content of SAN copolymers at three different compositions were shown in Figure 3.1. Among the various PC/ SAN blends, PC/SAN 24 blend showed minimum value in the average diameter at each composition. These results suggest that high molecular weight blends of PC and SAN copolymer are immiscible and the optimum level of AN content of the copolymer for the enhanced miscibility with PC is about 24 wt%.SAN fraction is normally presence in commercial ASA thus the above value needs to be considered for improve compatibility of ASA and PC

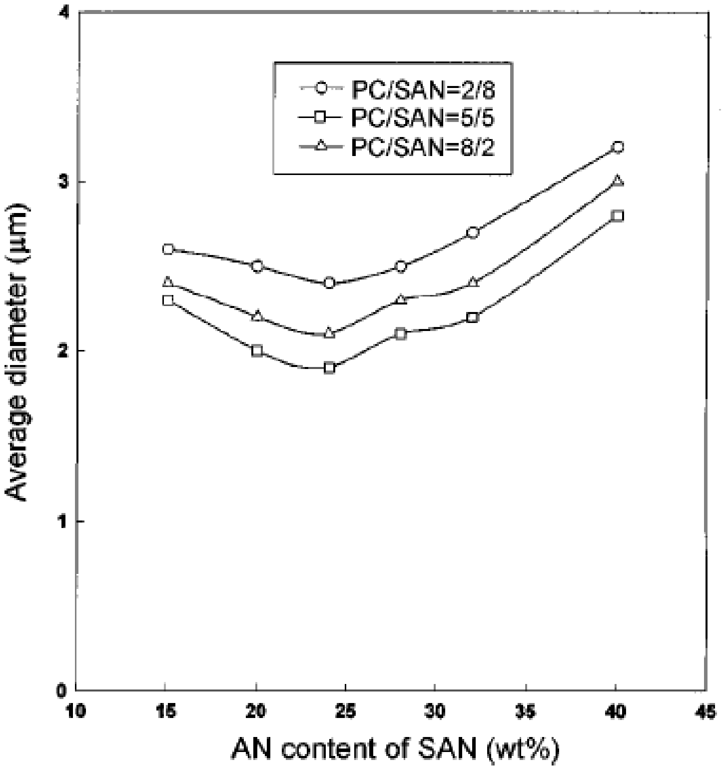


Figure 3.1: Dependence of particle size on the AN content for PC/SAN blends[21].

Figure 3.2 reveals the Interfacial tension between PC and various SAN copolymers as a function of AN content. A minimum value in the interfacial tension was also observed at around 24 wt% of AN fraction. This result confirms the morphological study that PC blended with SAN containing about 24 wt% of AN provides optimum interfacial adhesion between the two phases.

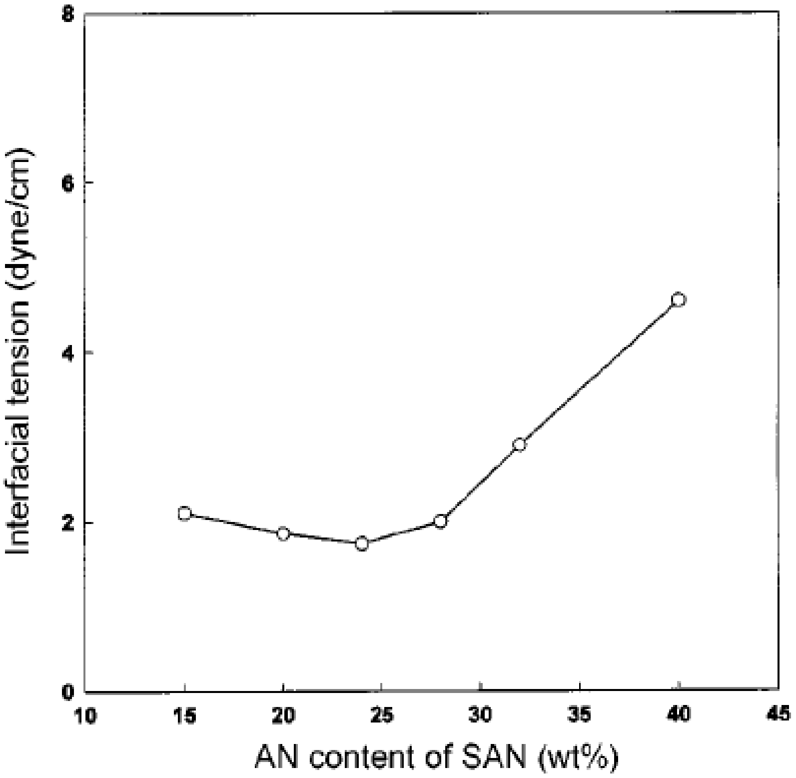


Figure 3.2: Interfacial tension between PC and SAN copolymer as a function AN content of SAN copolymers[21].

S.A. Edwards and coworkers in 2003[22] studied miscibility of PC/ASA blend by used temperature-modulated differential scanning calorimetry (TMDSC). In this experimental used conventional DSC heat flow and TMDSC determined heat capacity plots against temperature of the PC/ASA pellet are displayed in Figure 3.3.

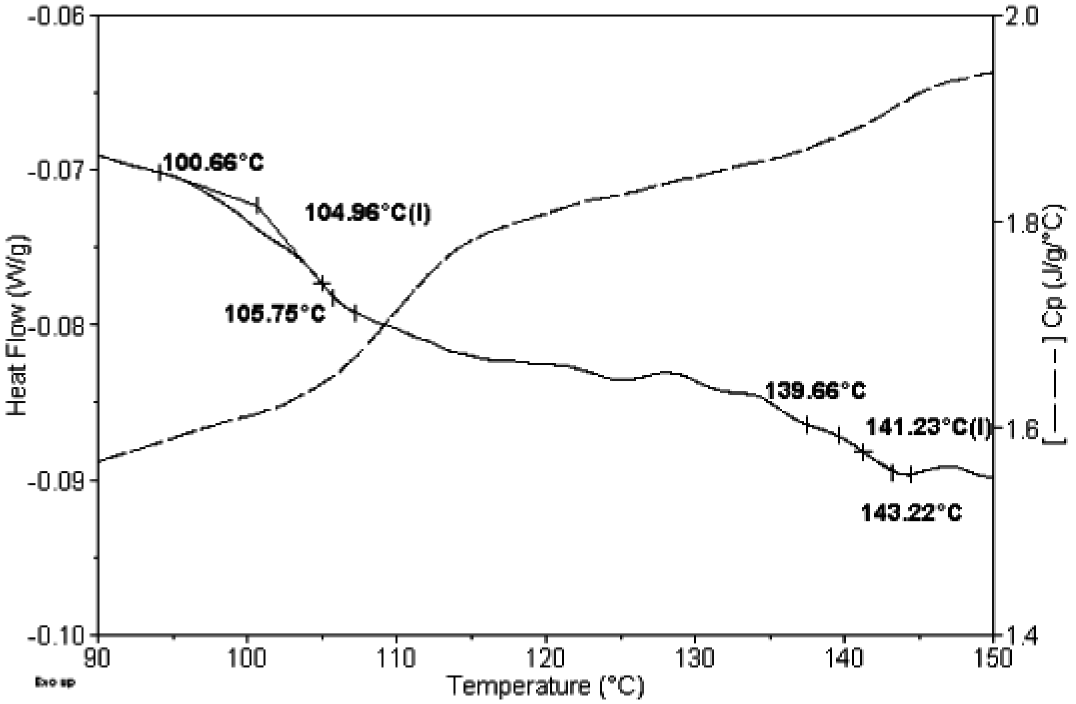


Figure 3.3: A comparison of conventional DSC heat flow and TMDSC heat capacity (C_p) signals against temperature for PC/ASA[22].

Form Figure 3.3, the heat flow trace clearly identifies the glass transition of SAN and PC at 105 and 141 ^{o}C respectively. However, this result was difficult to draw conclusions about phases and boundaries with this data alone. Taking the plot of heat capacity (Figure 3.3) and differentiating with respect to temperature dramatically increases quality of the information that can be interpreted from the plot Figure 3.4.

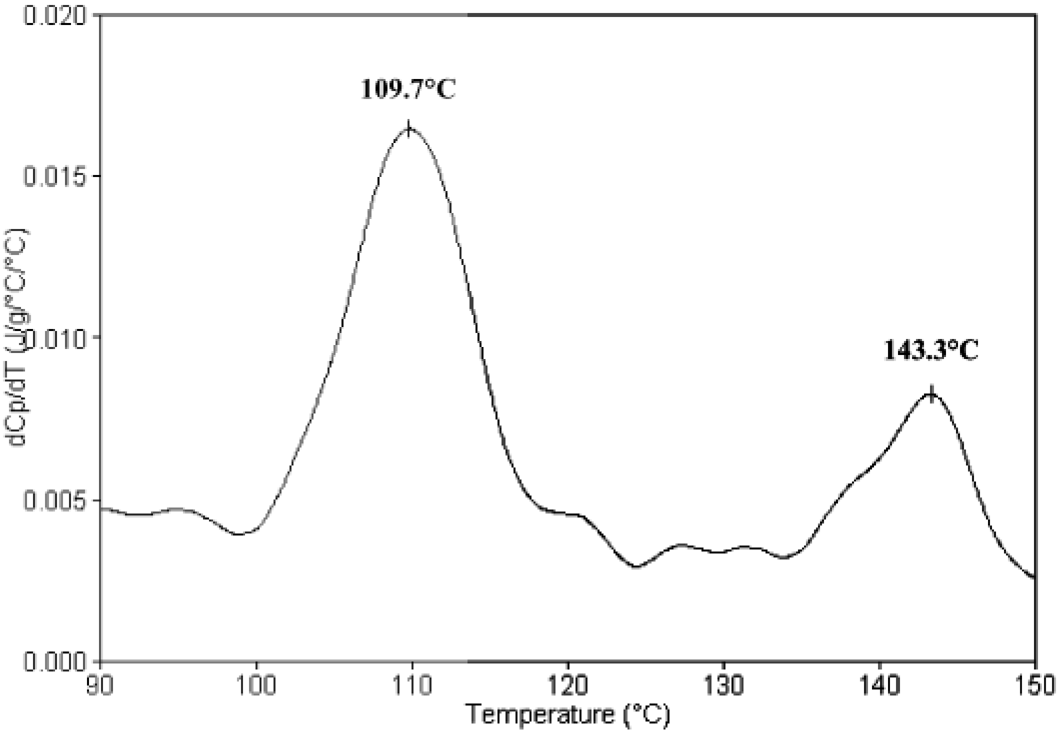


Figure 3.4: Plot of dC_p/dT against temperature for PC/ASA[22].

Figure 3.4 displayed the variation in dCp/dT with temperature signal for the PC/ASA blend. It was well known phase morphology related to a transition temperature, which combines to form a transition thermogram [23]. Clearly, the morphology between SAN and PC was not a simple two-phase structure with sharp boundaries. The glass transition temperatures of SAN and PC were clearly visible at 109.7 and 143.3 ^{o}C, respectively. It was clear from the response of the dC_p/dT signal that SAN and PC were immiscible, as two distinct transition peaks were visible and separated by over 33 ^{o}C. This was due to the large differences in polarity between the polymers.

M. S. Kang and coworkers in 2005[24] studied of enhanced interfacial and mechanical properties of PC/ASA blends. In their research, TMPC-b-SAN and PMMA were examined as compatibilizer in order that it would enhance interfacial adhesion and weld-line strength between PC and SAN matrix of ASA. The effects of compatibilizer on the weld-line strength of PC/ASA blend as shown in Figure 3.5.

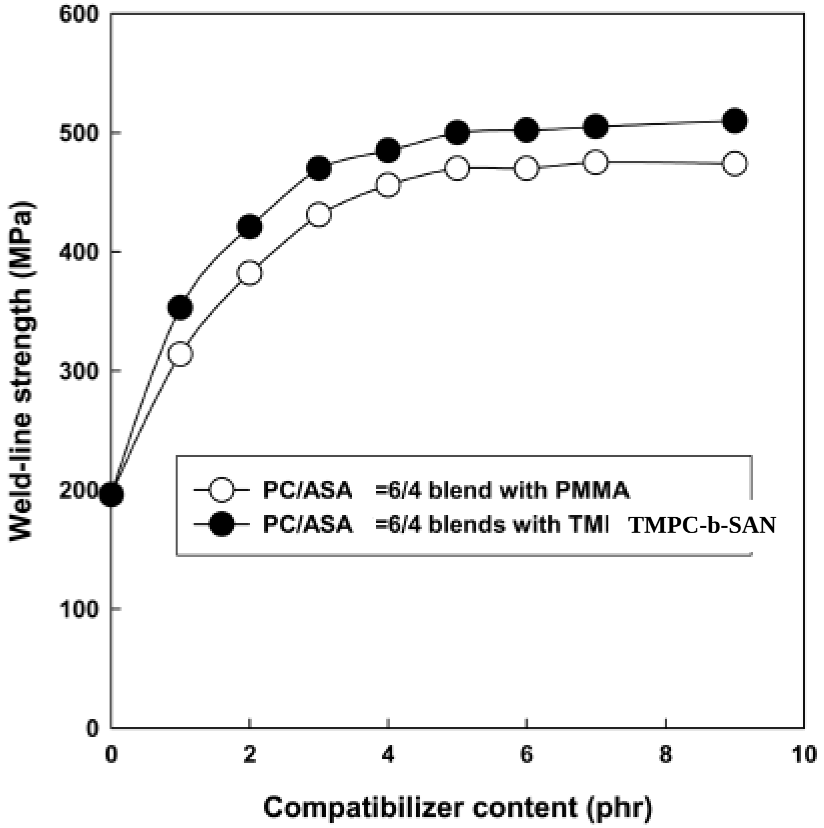


Figure 3.5: Weld-line strength of PC/ASA = 6/4 blends as a function of compatibilizer content[24].

In this figure exhibited weld-line strength of PC/ASA = 6/4 blends containing various amounts of compatibilizer. It was observed that weld-line strength of blend continuously increased with increase of compatibilizer content up to 5 phr(parts per hundred resin) and then leveled off at a fixed value. Cross sectional morphology of weld-line was observed with SEM. In this experimental, PC rich-phase was etched out with 30 wt% NaOH aqueous solution. As shown in Figure 3.6. These results showed that compatibility and weld-line strength of PC/ASA blend could be enhanced by adding proper compatibilizer.

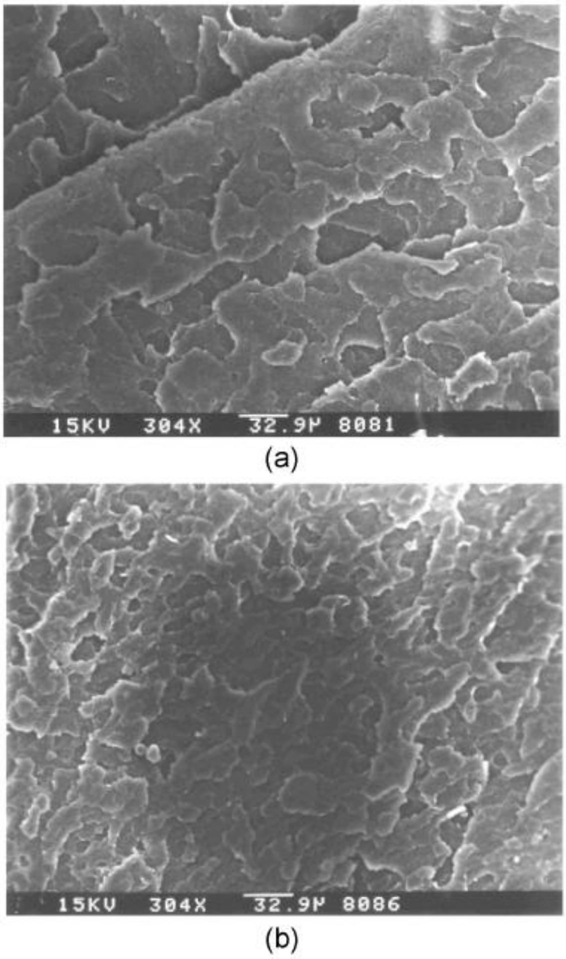
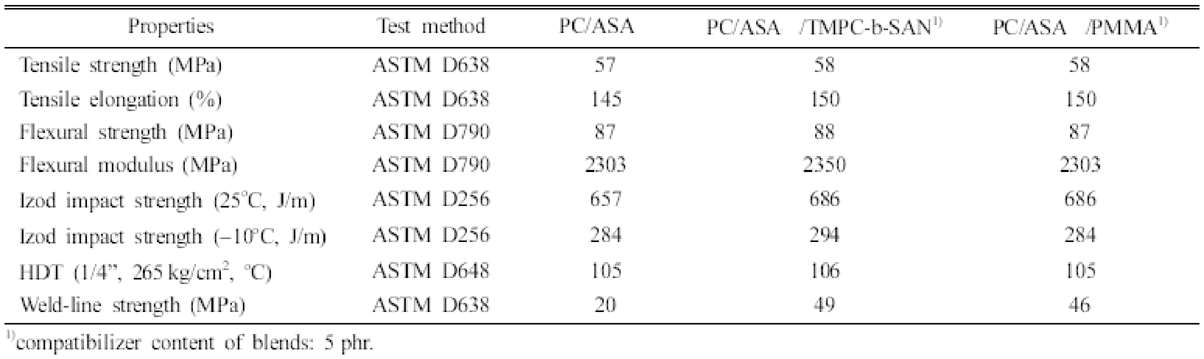


Figure 3.6.: Cross sectional morphologies at weld-line; (a) blend does not contain compatibilizer; (b) blend contains 5 phr TMPC-b-SAN copolymer as compatibilizer[24].

Table 3.1: Mechanical and thermal properties of PC/ASA =6/4 blends with or without compatibilizer[24].



Properties	Test method	PC/ASA	PC/ASA /TMPC-b-SAN[1)]	PC/ASA /PMMA[1)]
Tensile strength (MPa)	ASTM D638	57	58	58
Tensile elongation (%)	ASTM D638	145	150	150
Flexural strength (MPa)	ASTM D790	87	88	87
Flexural modulus (MPa)	ASTM D790	2303	2350	2303
Izod impact strength (25°C, J/m)	ASTM D256	657	686	686
Izod impact strength (−10°C, J/m)	ASTM D256	284	294	284
HDT (1/4", 265 kg/cm^2, °C)	ASTM D648	105	106	105
Weld-line strength (MPa)	ASTM D638	20	49	46

[1)] compatibilizer content of blends: 5 phr.

The effect of compatibilizer on mechanical and thermal properties of PC/ASA =6/4 blends shown follow in Table 1. It was observed that blends of PC/ASA exhibited similar mechanical and thermal properties whether blends contained compatibilizer or not. However, blends exhibited huge difference in weld-line strength. Weld-line strength of blend corresponded to about 35% of its tensile strength when blend did not contain compatibilzer. However, weld-line strength of blend recovered up to 85% of its tensile strength when blend contains 5 phr TMPC-b-SAN as compatibilizer. The result related to weld-line strength and cross sectional morphology of weld-line indicated that both of TMPC-b-SAN and PMMA could be used as excellent compatibilizer for PC/ASA blends. On the other hand, these compatibilizer are not affect on the mechanical properties.

C. M. Benson and R. P. Burfoford in 1995[25] examined the morphology of ASA/PBT blends. This research focused on ASA/PBT system at ratios of 40/60, 50/50, and 60/40. ASA used in this study contained 42wt% rubber. Figure 3.7 shows the tensile strength of ASA and PBT blends at different processing temperatures. It is found that processing temperature and composition of the blends are major factors that significantly effect on mechanical properties of the blends. When increasing the content of ASA in ASA/PBT blend, impact strength of blends exhibits more impact energy resistance. The two ASA-rich blends have better impact strength than PBT-rich blend. At the high processing temperature, the PBT matrix degrades rapidly at the temperature above 270ºC. A slight increase in tensile strength occurs as the temperature is increased.

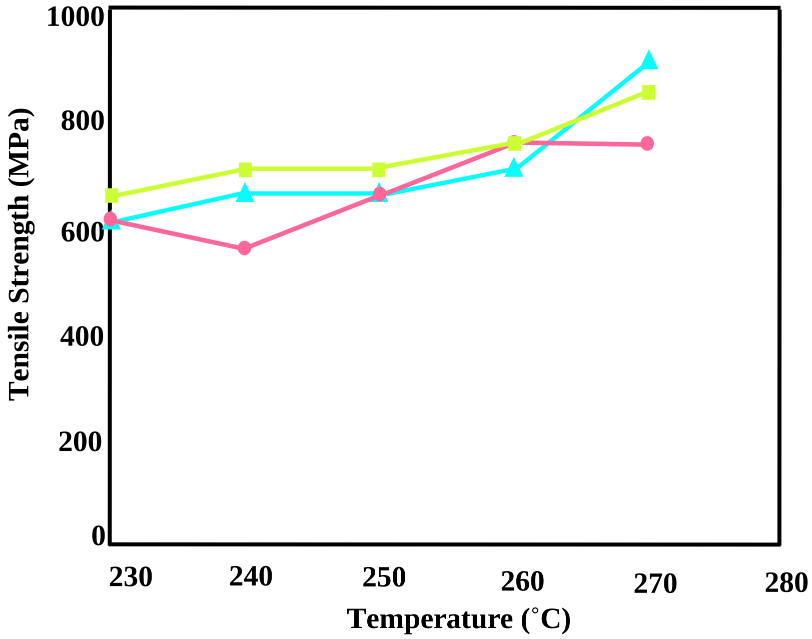
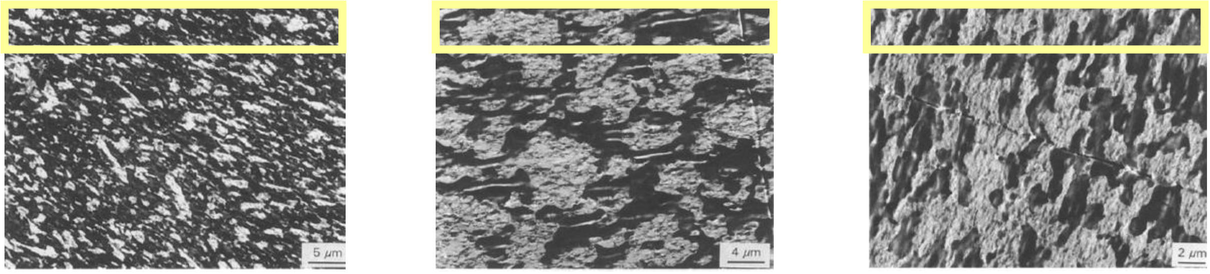


Figure 3.7: Tensile strength at break against processing temperature of the ASA/PBT blends: (■) 40:60, (●) 50:50, (▲) 60:40[25].

Figure 3.8 shows the morphology of ASA/PBT blends depicted by transmission electron microscope. In the 40:60 ASA:PBT blend, PBT is continuous in dark whereas ASA is formed as pockets within the continuous phase of PBT matrix. In addition, it is found that the rubber particles do not migrate into the PBT phase, but rather stay in SAN matrix. Similarly, in the 60:40 blends, ASA is continuous matrix containing dispersed PBT phase. For the 50:50 blends, the morphology of ASA/PBT blend indicates a co-continuous matrix. This blend refers maximum compatibility between ASA and PBT resulting in the best combination of tensile strength and impact resistance.



(a) (b) (c)

Figure 3.8: Transmission electron micrograph of ASA/PBT blends (a) 40:60, (b) 50:50, (c) 60:40 [25].

Ye Han and coworkers in 2009[26] studied effects of blend composition on mechanical properties and morphology of PC/ASA/SAN ternary blends. The effects of ASA content on the impact strength of PC/ASA/SAN blends were investigated by keeping the fixed PC content at 70 wt% and changing the ASA/SAN mass ratios in the blends as shown in Figure 3.9.

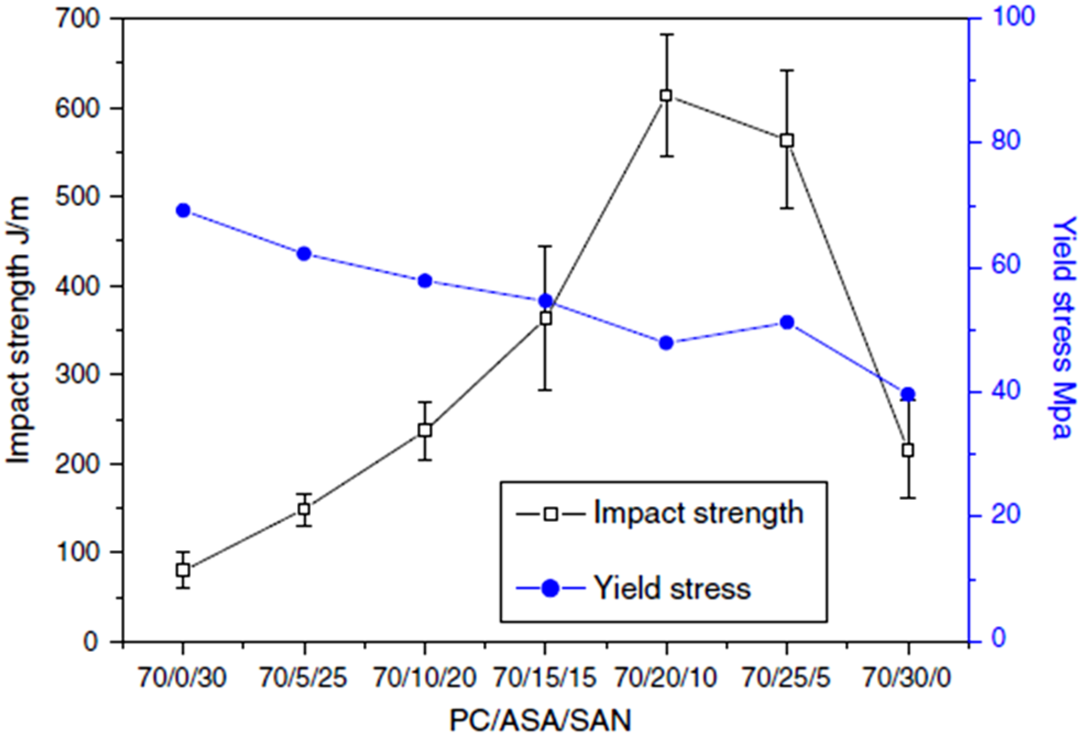


Figure 3.9: Effect of ASA content on the impact strength and yield stress of PC/ASA/SAN blends[26].

In this experiment, the ASA content was varied from 0 to 30wt% and the SAN content decreased from 30 to 0wt% accordingly in the blends. It was observed that impact strength of the obtained polymer blends increased with the ASA content from 0 to 20wt%. The impact strength showed a maximum value of 600 J/m as the ASA content reached 20wt%. However, when the ASA content was greater than 20wt%, the impact strength of the blends tended to decrease to 200 J/m as ASA content reached 30wt%. Actually PC/ASA/SAN blends contained three phases: ASA rubber phase, SAN phase, and PC phase. The rubber phase was surrounded by the SAN phase. The SAN phase and the PC phase formed the overall phase structure. When more rubber phase was introduced into the PC/SAN matrix, an increase of energy absorption and subsequently an increase of impact strength were observed. However, when more ASA was introduced into the blends, the rubber phase may become agglomerated or interpenetrated, which destroyed the strength of matrix or made some rubber particles lose the ability to toughen the matrix and led to the decrease of impact strength. On the other hand, when the ASA content reached 30wt%, and no SAN phase existed in the system, the poor interfacial adhesion would also lead to the decrease of impact strength.

Figure 3.9 also shows the effect of ASA content on the yield stress of PC/ASA/SAN blends. It was found that the yield stress of the blends decreased with the increase of ASA content, which rubber phase had the lowest yield strength compared with other two phases and led to decrease of yield stress when increase of ASA.

It is well known that the rubber phase must be crosslinked to keep appropriate elastic characteristic during the synthesis of ASA. Therefore, as the more ASA copolymer was added to the blends, the viscosity of blends would increase and the blends tended to exhibit less processing ability. Figure 3.10 depicts effects of ASA content on melt flow rate (MFR) of PC/ASA/SAN blends. MFR of the blends was observed to decrease with an increase of ASA content. Since SAN is a resin with good fluidity, the increase of ASA content must lead to an accordingly decrease of SAN, which may be another reason to cause the decrease of MFR of the blends.

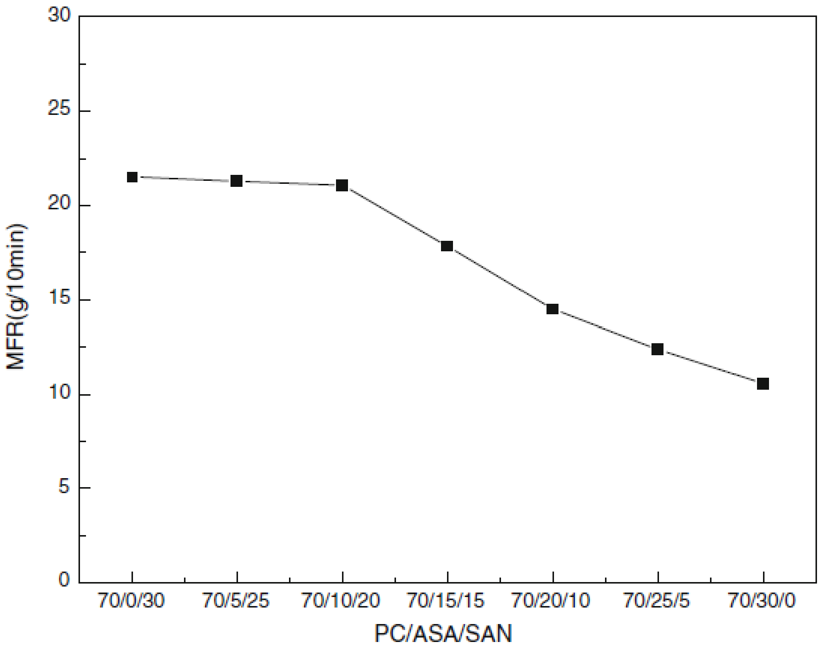
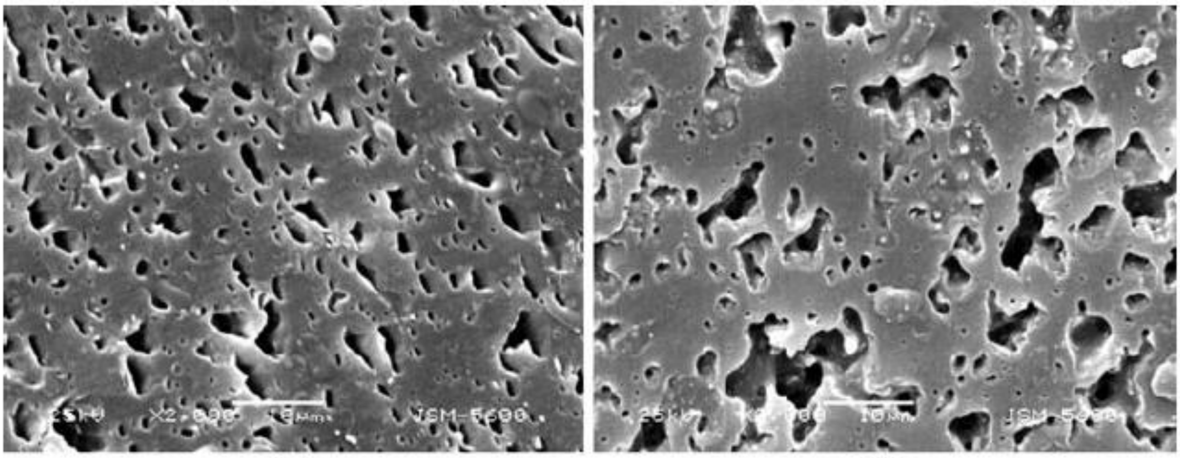


Figure 3.10: Effects of ASA content on MFR of PC/ASA/SAN blends[26].

Figure 3.11 exhibits morphology of PC/ASA blends at the ASA contents of 20 and 30wt%, respectively. In this case, no SAN was introduced to the blends. It must be noted here that the ASA portion in the micrographs was removed by etching processing, which appeared as a dark region in the micrographs. Since PC/ASA blend was a phase separated system and, in the two blend compositions above, the dispersed phase revealed a relatively heterogeneous distribution. It was also found that the dispersed phase morphology was strongly affected by the ASA rubber content in the blends. Indeed, by increasing the concentration of the ASA rubber, the number of ASA rubber particles in the system increased, which led to an increased number of particle-particle collisions. As a consequence, an increase of ASA content resulting in an increased size of coalescing particleswas evidently observed in Figure 3.10b, that led to the poor mechanical properties.



(a) (b)

Figure 3.11:SEM micrographs of PC/ASA blends with the composition of (a) PC/ASA 80/20 (b) PC/ASA 70/30[26].

U.S. Pat 3,891,719. Appl. No. 421,645[27] claimed polymer blend compositions from PC and ASA which possess substantial weatherability and impact resistance. A very useful ASA terpolymer material for blending with PC. This patent claimed that composition comprising from 95 to 5 % by weight of a polycarbonate (MW 25,000-200,000) and form 5 to 95 % by weight of a ASA (MW 60,000-300,000).

The critical thickness determined accordance with Izod ASTM D256, was found to be 5.76 mm for the pure polycarbonate. All mixture of polycarbonate and ASA (from 90:10 to 10:90 parts by weight) tested had no critical thickness up to 9 mm (no measurements were made above 9 mm). The critical thickness of the ASA-graft amounts to 6.6 mm. Mixed breaks, i.e. partly brittle to partly tough breaks, were observed from 6.6 to 7.1 mm; brittle breakes only were observed above 7.1 mm. The results were shown in Figure.3.12. Whilst the abscissa indicates the specimen thickness in mm. For the upper 8 curves, the styrene/acrylonitrile/acrylic acid ester graft copolymer content (ASA) of the moulding composition was given in percent by weight on the right hand side. The remainder was polycarbonate. The two lowermost curves relate to pure ASA and pure PC.

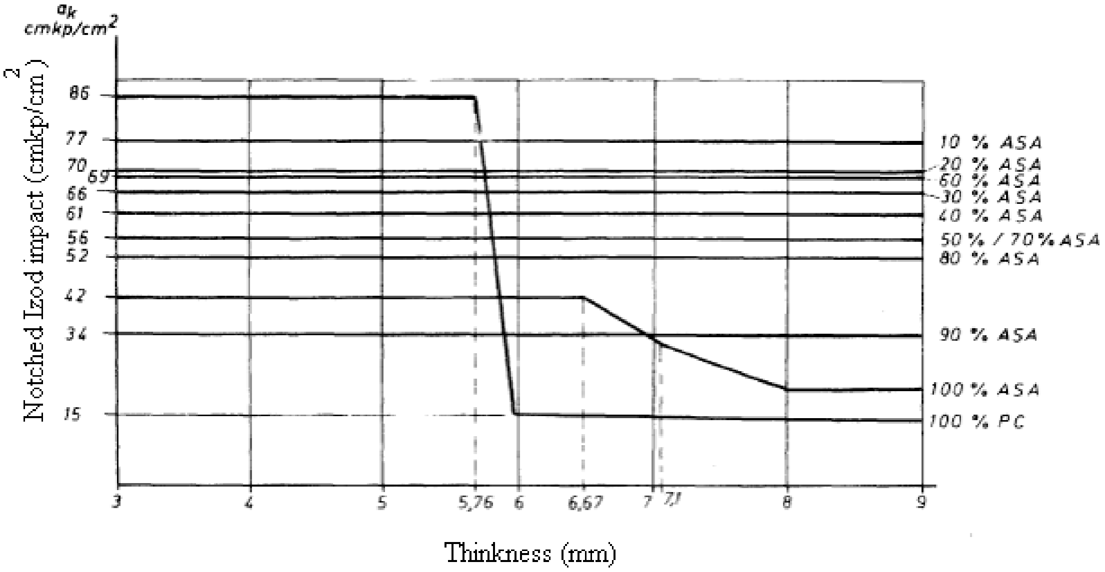


Figure 3.12: Notched Izod impact strength of PC/ASA blends at various thickness[27].

In the material specification of commercialized ASA (Luran®S) and PC/ASA blends (Luran®SC), the degree of yellowing of white plastic specimens on outdoor weathering test results is illustrated in Figure 3.13[28]. All products change color only slightly in the early stages. While ABS and PC/ABS blends show more rapid yellowing afterwards, Luran®Syellows only at a much later stage and to a much lesser extent. Furthermore Luran®Swith an additional UV stabilizer exhibits particularly excellent performance. Even after 4000 hours of sunshine, corresponding to more than two years of outdoor weathering, this product still shows virtually no yellowing. Additionally, the PC/ASA blends (Luran®SC) also shows a relatively high color stability comparable to the neat ASA and significantly better than that of the ABS-based products after 4000 hours sunshine exposure.

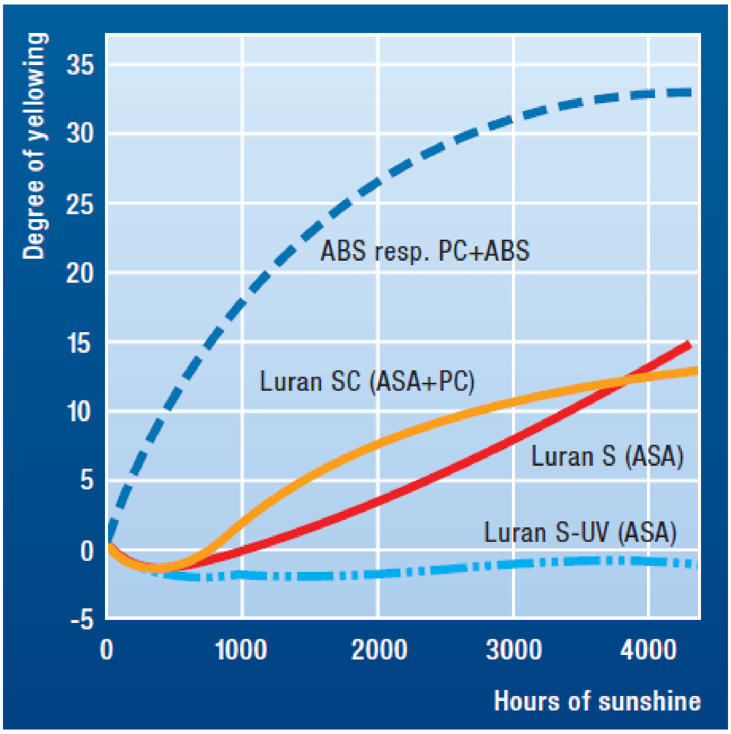


Figure 3.13: Degree of yellowing of ASA (Luran®S) and PC/ASA blends (Luran®SC) on outdoor weathering comparing with ABS systems [28].

The stability of Luran®S grades to long-term heat exposure could be proven by storage at, for example, 90 °C. While the toughness of the comparable ABS products decreases substantially in the test shown in Figure 3.14, Luran®S and the blends Luran®SC exhibits only a small change in toughness over the same test period. Likewise, the resistance to yellowing of Luran®S on exposure to heat is significantly higher than that of ABS and PC/ABS blend specimens shown in Figure 3.15.

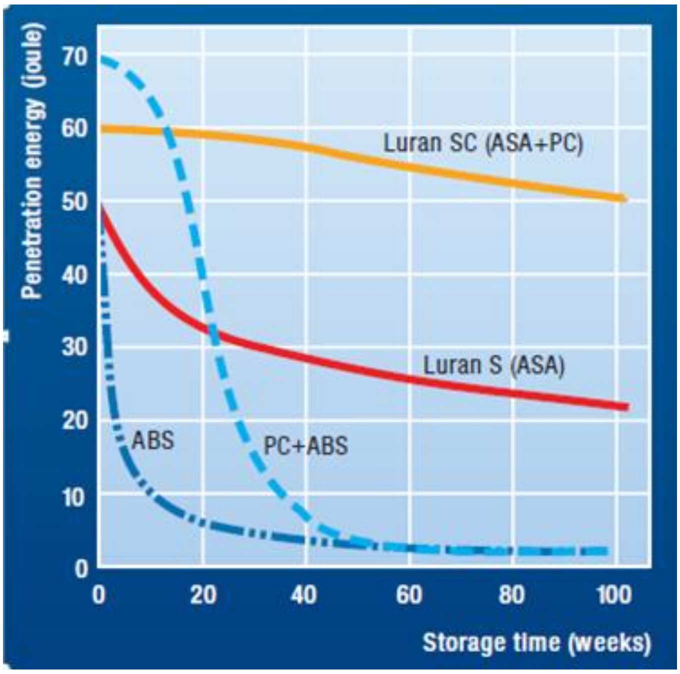


Figure 3.14: Toughness of ASA (Luran®S) and PC/ASA blends (Luran®SC) after heat aging at 90°C comparing with ABS counterparts [28].

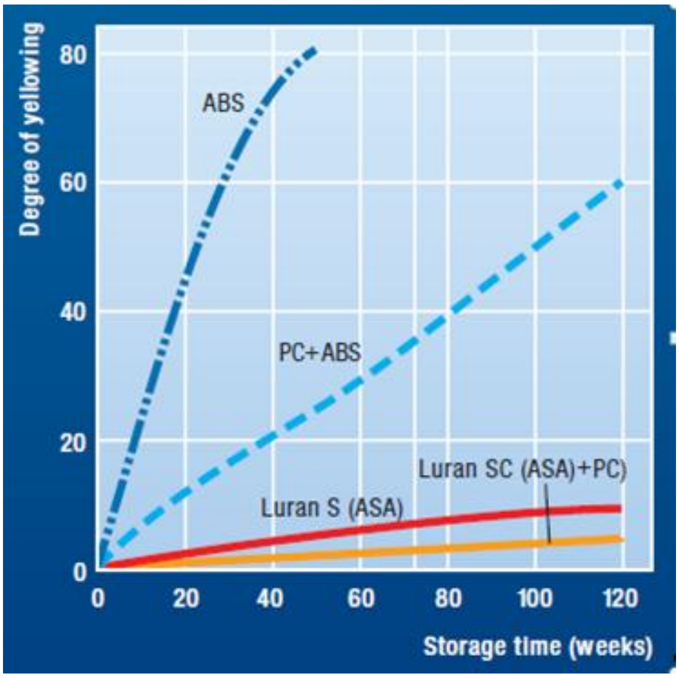


Figure 3.15: Degree of yellowing of ASA (Luran®S) and PC/ASA blends (Luran®SC) after heat aging at 90°C comparing with ABS counterparts [28].

CHAPTER IV

EXPERIMENTAL

4.1 Materials and Preparation

Polycarbonate (PC) used as one of components of the blends is Wonderlite PC 110, general grade. It was purchased from CheMei Corporation, Taiwan. Another component of the blends, acrylonitrile-styrene-acrylate graft copolymer (ASA), is KIBILAC®PW-997S, KIBILAC®PW-978B extrustion grade from Chi Mei and Luran S-777K from Baden Aniline and Soda Factory (BASF).

4.2 Preparation of Polymer Blends

Melt mixing of PC/ASA was carried out by a twin-screw extruder (Figure 4.1).Temperatures of the ten zones of the extruder were set at 210^{o}C - 240^{o}C from die side. PC and ASA were dried at 110^{o}C and 90^{o}C, respectively, for 4 hours in a vacuum oven in order to remove moisture. PC/ASA was blended at different weight ratios, which were 100/0, 90/10, 80/20, 70/30, 60/40 and 50/50 in the twin-screw extruder. The PC/ASA blend samples were cooled in water and then cut by a pelletizer. Then the pellets were dried in the vacuum oven for 4 hour at 90^{o}C. The test specimens were prepared by injection molding machine (Figure 4.2) at 240°C and compression molder (Figure 4.3) at 240°C for 3 minutes before shaping for each sample characterization.

Figure 4.1: Twinscrew extruder.

Figure 4.2: Injection molding machine.

Figure 4.3: Compression molder.

4.3 Characterization Methods

4.3.1 Physical Properties

4.3.1.1 Density Measurement

The densities of PC/ASA blends were determined by water displacement method according to ASTM D 792-00. The dimension of each rectangular shape specimen is 20 mm × 35 mm ×3 mm. All measurements were performed at room temperature.

The density of the specimen was calculated by a following equation:

$$\rho = \left[\frac{A}{(A-B)} \right] \times \rho_o$$

where ρ = Density of the sample, g/cm3.

A = Weight of the sample in air, g.

B = Weight of the sample in water, g.

ρ_o= Density of the water at the given temperature, g/cm^3.

The measurement was carried out using five specimens per sample and the average value of the sample was obtained.

4.3.1.2 Melt Flow IndexMeasurement

Melt flow index or MFI is a measure of an ease of flow of the melt of PC/ASA using a melt flow indexer (Model 10 Davenport Lloyd Instruments). It is defined as the mass of polymer, in grams, flowing in ten minutes through a capillary of an orifice with a diameter of 2.095 mm and orifice length of 8.0 mm according to ASTM D 1238 standard at 220°C/10kg load for pure ASA, at 300°C/1.2kg load for pure PC and at 260°C/5kg load for PC/ASA. All these are preheat for 6 minutes.

4.3.1.3 Rheological Property Measurement

Rheological properties of all PC/ASA blends ratio were examined by using Rheometer (Haake Rheo Stress 600, Thermo Electron Cooperation) equipped with 25 mm parallel plate geometry. The measuring gap was set at 1 mm and the experiment was performed under a dynamic frequency sweep mode using frequencies ranging from 0.1 to 100 Hz at constant temperature 210°C.

4.3.1.4 Water Absorption Measurement

Water absorption measurement was conducted following ASTM D570, using specimen in the form of a disk 50.8 mm (2 in.) in diameter and 3.2 mm (1/8 in.) in thickness. Three specimens were conditioned in an oven at 50^{o}C for 24h, cooled in a desiccator, and then weighed. The specimens were then immediately immersed in distilled water and were weighed periodically. Based on the initial mass of each specimen, the amount of water absorbed was calculated form the following equation:

$$WA(\%) = \left(\frac{M_e - M_o}{M_o} \right) \times 100$$

where WA is water absorption at time t (%).

M_e is the mass values of the specimen after immersion.

M_o is the mass values of the specimen before immersion.

4.3.1.5 Rockwell Hardness Measurement

A Rockwell hardness number is a standard method for measuring resistance to penetration of materials (hardness). This number derived from the net increase in penetration depth as the load on an indenter is increased from a minor load to a major load and then returned to a minor load according to ASTM D785. Indenters are round steel balls of specific diameters which can vary between 0.5000±0.0001 and 0.1250±0.0001inch. The Rockwell hardness number is expressed as a combination of the measured numerical hardness value and the scale letter preceded by the letters. The scale readings over 115 shall not be reported. Readings between 0 and 100 are recommended, but readings to 115 are acceptable.

In this experimental, a Rockwell hardness number was measured by Rockwell Hardness Tester (INDENTEC, model 8150LK). The specific diameter of round ball indenter is 0.2500±0.0001 inch with 60 kg major load and 10 kg minor load. The specimen had a length of 30 mm, a width of 20 mm, and a thickness of 3 mm. Each sample was measured 5 times before made an average value.

4.3.1.6 Scanning Electron Microscope (SEM)

Phase mophology has been charecterized by using JSM-5800LV scanning electron microscope (SEM). Scanning electron micrographs were used for analyze surface samples. The surfaces were gold coated using a sputterer and were etched by acidic solution made of 5 g of CrO_3, 120 ml of H_2SO_4 and 30 ml of H_2O before study the phase morphology.

4.3.2 Mechanical Properties

4.3.2.1 Notched Izod Impact Testing

Notched Izod impact is a single point test that measures a materials resistance to impact from a swinging pendulum. Izod impact is defined as the kinetic energy needed to initiate fracture and continue the fracture until the specimen is broken. notched Izod impact strength was measured by an impact tester from Yasuda Seiki Seisakusho Ltd. (Japan) according to ASTM D256. The specimens were preparedby injection molding machaine. The impact bar specimen had a length of 63 mm, a width of 12.7 mm, and a thickness of 3 mm. A notch at one side centered in the direction along the length with a depth of 2 mm was made for each specimen.

4.3.2.2 Tensile Property Measurements

Tensile properties were charecterized by a universal testing machine (Instron Instrument, Model 5567) according to ASTM D638. The test specimens were a dumbbell (dog bone) shape with a uniform thickness which were prepared by an injection machine. They were tested by using a cross-head speed of 5 mm/min with the pre-load of 10 N giving a straight tensile force. The tensile strength defined as the stress at yield or at break whereas the tensile modulus was determinedby the ratio of stress to strain that was determined from the initial slope of the stress-strain curve. Five specimens from each blend were tested and the average values were reported.

4.3.2.3 Flexural Property Measurements

Flexural modulus and flexural strength of the blend specimens were measured following ASTM D790 by a universal testing machine (Instron Instrument, Model 5567). Three-point bending test was carried out at room temperature by using the cross-head speed of 1.3 mm/min with the supporting span of 48 mm. The dimension of the specimen was 120 mm in length, 12.7 mm in width and 3mm in thickness. Five specimens from each blend were examined and the average values were reported.

4.3.2.4 Dynamic Mechanical Analysis (DMA)

The thermal mechanical characteristic of polymer blends was examined by a dynamic mechanical analyzer (DMA), model DMA 242C, NETZSCH). The test was performed in a three-point-bending mode. The dimension of the specimen was rectangular with 10 mm width, 50 mm length, and 2 mm thickness. The experiment was performed under a test temperature range from 30°C to 170°C with a heating rate of 2 °C/min. The test frequency and amplitude were 1Hz and 30µm, respectively. The glass transition temperature (Tg) was taken as the maximum point on the loss modulus and tanδ curve in the DMA thermogram.

4.3.2.5 Weatherability - Notched Izod Impact Testing after QUV Test

Notched Izod impact after weathering test was measured by an impact tester from Yasuda Seiki Seisakusho Ltd. (Japan) according to ASTM D256. The specimens were preparedby injection molding machaine after that the samples were accelerated by QUV-Weatherometer according to ASTM G154 for 1, 2 and 3 weeks. The impact bar specimen had a length of 63 mm, a width of 12.7 mm, and a thickness of 3 mm. A notch at one side centered in the direction along the length with a depth of 2 mm was made for each specimen.

4.3.3 Thermal Properties

4.3.3.1 Differential Scanning Calorimetry (DSC)

Glass transition temperature was determined by a differential scanning calorimeter (DSC) model 2910 from TA Instruments. Each specimen was sealed in an aluminum pan with cover. The temperature was equilibrated at 30°C and the specimen was heated from 30°C to 180°C using a heating rate was 10°C/min under nitrogen purging.The sample mass used was approximately 8-10 mg.

4.3.3.2 Heat Distortion Temperature (HDT) Measurements

Heat distortion temperature is defined as the temperature at which a standard test bar deflects a specified distance under a load at its center according to ASTM D648. It is used to determine short-term heat resistance. The test specimen was immersed in oil bath with a means of raising the temperature at 120°C/h or 2°C/min.

The test specimen was loaded in a three-point bending mode in the edgewise direction. A load of 1.83 MPa was placed on each specimen until it deflected 0.25 mm. The dimension of the specimens was 3×120×13 mm^3.

4.3.3.3 Vicat Softening Temperature Measurements

The vicat softening temperature is the temperature at which a flat-ended needle penetrates the specimen to the depth of 1 mm under a specific load according to ASTM D1525. The temperature reflects the point of softening to be expected when a material is used in an elevated temperature application. A test specimen was placed in the testing apparatus so that the penetrating needle rested on its surface at least 1 mm from the edge. A load of 5 kg was applied to the specimen. The test specimen was immersed in oil bath which was heated at a heating rate of 50°C/ hour from 30°C temperatures to 170°C. The dimension of the specimens was 25×25×3 mm^3.

4.3.3.4 Thermogravimetric Analysis (TGA)

Thermogravimetic analyzer (TGA/DSC 1, Mettler Toledo, Germany)was used to investigate degradation temperature (T_d) and char yield of PC/ASA specimens at various ratio. The testing temperature program was ramped at a heating rate of 20°C/min from room temperature to 800^oC under nitrogen purging with a constant flow of 80 ml/min. The sample weight was measured to be approximately 8-15 mg. Weight loss of the samples was measured as a function of temperature. Values for residues were taken at the end of the main decomposition step. The degradation temperature (T_d) was reported at 5% weight loss and the char yield were reported at 800°C.

CHAPTER V

RESULTS AND DISCUSSION

5.1Patent Review

Our patent review summarizes an overview of the development of PC/ASA blends in major industries. Thereview discloses that on the earliest stage, patents about PC/ASA blends were registered by BASF - The Chemical Company, General Electric Company (GE) and Bayer. These companies have been developed PC/ASA blends in various applications such as to reduce gloss, to improve impact strength at low temperature, to improve melting flow and to enhance flame resistant ability etc. Some examples are briefly mentioned as follows.

U.S. Pat. No. 5,162,423(1992)[29] was registered by BASF, with the objective to improve impact strength at low temperature by claiming the formulation of thermoplastic molding material containing polycabonate from about 40 – 80 wt%, SAN from about 10 – 50 wt%, ABS from about 5 – 20 wt% and ASA from about 5 – 20 wt%. The thermoplastic samples have notched impact strength at -20^{o}C about 34 – 36 kJ/m^2, which was measured according DIN 53,453.

WPO. No. 02/36688 A2(2002) [30] was registered by GE. Its objectives were to improve notched izod imapact and to reduce gate blush by claiming about thermoplastic composition consisting essentially of polycarbonate amount ranging from about 5 – 95 wt%, ASA resin amount ranging from about 5 – 70 wt% and high molecular weight acrylic copolymer or SAN, amount ranging from 0 – 5 wt%. Based on the composition of this claim, the notched izod impact strenth was claimed to at least 50 kJ/m^2 where the weight average molecular weight of the SAN used was above 4x10^5 daltons.

U.S. Pat. No. 6,476,126(2002) [31] was registered by Bayer for with a purpose to improve surface appearance, low haze and high gloss by claiming about thermoplastic molding composition comprising of ASA from about 20 – 40 wt%, SAN about 10 – 30 wt% and polycarbonate about 30 – 70 wt%. Properties of thermoplastic blend samples were summarizedin Table 5.1. From Table 5.1, the thermoplastic blend samples have maximum notched impact strength of 849 J/m with low haze and high gloss.

In addition, there are several companies that have been developing PC/ASA blendswith other additional modifiers such as Sabic Innovative Plastics, Dow Chemical Company, LG Chemical, Tei Jin Chemicaland so on.

5.2 Physical Properties

5.2.1 Density Measurementof PC, ASA and PC/ASA Blends

The density measurement of PC/ASA blend specimens was performed to examine the presence of void in the specimens. The densities of three grades PC/ASA blends at five different PC contents comparing with their theoretical densities are shown in Figure 5.1-5.3. The densities of the polymer blends are determined experimentally by water displacement method (ASTM D792) and Equation (1) by averaging the value from five specimens whereas the theoretical densities of the polymer blends were calculated from Equation (2).

$$\rho = (\frac{A}{A - B}) \times \rho_o \qquad (1)$$

Where

ρ = Measured density of the specimen, g/cm^3

A = Weight of the specimen in air, g

B = Weight of the specimen in liquid, g

ρ_o = Density of the liquid at the given temperature, g/cm^3

The theoretical density of PC/ASA blends can be calculated as follow

$$\text{Theoretical density} \quad = (\rho_{PC}X_{PC}) + (\rho_{ASA}X_{ASA}) \qquad (2)$$

Where

ρ_{PC} = density of polycarbonate, g/cm^3

X_{PC} = density of acrylonitrile-styrene-acrylate, g/cm^3

ρ_{ASA} = polycarbonate weight fraction

X_{ASA} = acrylonitrile-styrene-acrylate weight fraction

The densities of the PC and all ASA were determined to be 1.20 and 1.07 g/cm^3, respectively. The densities of all PC/ASA blends were observed to systematically increase with increasing PC contents following a rule of mixture and the values are compared in Table 5.2. From the table, the measured densities are in good agreement with the theoretical values in all three PC/ASA blends with an error of less than 1%. From the result, it can conclude that these polymer blends contained negligible void in the obtained specimens.

5.2.2 Melt Flow Index (MFI) of PC, ASA and PC/ASA Blends

The melt flow indexer was calibrated with pure PC and with three grades of commercial ASA. In the measurements, the PC was tested at 300°C by applied load of 1.2kg load and all ASA were tested at 220°C by applied load of 10kg load in order to compare the MFI values with those reported in the specification sheets of each polymer. The MFI results were determined to be 10.5, 4.2, 13.7 and 14.6 g/10min for the PC, ASA-997, ASA-978 and ASA-777, respectively. The values are in good agreement with the literature values of 10, 4, 13 and 13.9 g/10min for PC, ASA-997, ASA-978 and ASA-777, respectively, were reported in the specification sheets by Chi Mei and BASF Corporation[32, 33].

The melt flow index values of all PC/ASA blends measured at 260°C by applied load of 5kg are shown in Figure 5.4. It was found that the MFI value of the PC/ASA-777 is higher than PC/ASA-978 and the melt flow index of PC/ASA-978 is slightly higher than PC/ASA-997 as MFI values of ASA-997, ASA-978 and ASA-777 are 4, 13 and 13.9 g/10min at 220^{o}C by applied load of 10kg, respectively. This is suggested the presence of rubber phase of ASA-997 is higher than ASA-978 and rubber phase of ASA-978 is slightly higher than ASA-777, results in the greater flowability of the blends thus the higher melt flow index. In addition, it was found that the melt flow indices of the blends increased systematically with increasing the mass fraction of ASA due to the fact that ASA possesses higher MFI value or higher flowability than the PC. Those MFI values of all PC/ASA blend specimens are also summarized in Table 5.3.

5.2.3 Rheological Properties of PC, ASA and PC/ASA Blends

Complex viscosities of the PC/ASA blends as a function of frequency at various blend ratios of PC were shown in Figure 5.5. From the figure, it was observed that all of complex viscosities of the blends decreased with increased frequency, suggesting non-Newtonian behavior of a shear thinning type of these polymer blends system for all different PC contents. The complex viscosity of PC/ASA blends at various PC contents increased with the increase in PC contents compared at the fixed frequency of 1 Hz since the inherent shear viscosity of the pure PC (2012 Pa.s) was much higher than that of the pure ASA (923 Pa.s). The viscosities of the PC/ASA blends increased from 1413 Pa.s to 1846 Pa.s for the blends with 50 wt% to 90 wt% of PC fraction. The presence of ASA is able to reduce the melt viscosity of PC significantly. That means that the viscosity of ASA in the typical PC/ASA blends on processing temperatures is much more temperature-sensitive than is that for PC. A similar phenomenon was also reported in the PC/ABS blend system [46].

5.2.4 Water Absorption of PC, ASA and PC/ASA Blends

It is well known to many researchers that water absorption, the tendency of plastics to absorb moisture, can significantly alter some key mechanical, electrical, or optical property. Water absorption of PC, ASA-997, ASA-978 and ASA-777 is shown in Figure 5.6. It was found that PC has water absorption about 0.2% at 24 hour immersion whereas water absorption of ASA-997, ASA-978 and ASA-777 exhibit higher values at 24 hour immersion with the values about 0.52%, 0.50% and 0.59%, respectively. The water absorption measurement of PC, ASA-997, and their blends at varied contents of 10 wt% to 50 wt% of ASA was performed up to the saturation state as shown in Figure 5.7. The water absorption at 24 hours of PC/ASA was found to increase from 0.21 wt% to 0.34 wt% with the increasing of ASA content from 10wt%.to 50wt%. In addition, the water absorption at satuation of the blends were ranging from 0.41% to 0.71% with increasing amount of the ASA from 10wt% to 50wt% (0.35% and 1.08% for the neat PC and the neat ASA-997, respectively). This is because the presence of a highly polar moiety of an acrylonitrile component in ASA results in the greater hydrophilicity of the blends thus the higher water absorption values.

5.2.5 Rockwell Hardness of PC, ASA and PC/ASA Blends

A Rockwell hardness of PC, ASA and all PC/ASA blends were determined by a method according to ASTM D 785. The Rockwell hardness was reported in L-scale because the measured values are in the range 0-100 as discussed in the experimental procedure. The Rockwell hardness of PC, ASA and all PC/ASA blends were shown in Figure 5.8. From this result, The PC exhibited a Rockwell hardness value of about 96 whereas the Rockwell hardness of ASA-997, ASA-978 and ASA-777 were around 58, 67 and 52 respectively. Besides, the Rockwell hardness values of all PC/ASA were significantly increased with increasing PC content and can be proximated by the rule of mixture. The obtained hardness values are summarized in Table 5.4.

5.2.6 Scanning Electron Microscope (SEM) of PC/ASA Blends

To investigate the phase morphology of the PC/ASA blends, the sample surfaces were coated with gold and etched by acid solution before taking the micrographs by scanning electron microscope (SEM). The photomicrographs of scrubbed and non scrubbed surfaces of PC/ASA-997 blends at various PC contents were shown in Figure 5.9 a) – f). Figures 5.9 a)–e) show two distinct and separate phases likely of the PC and the ASA phases. The ASA dispersed phase is the darker of the two phases whereas that of PC is the lighter phase. We observed the presence of the ASA domains more clearly when its content was greater than 20 wt%. Furthermore, the ASA-rich region was expectedly found to increase with increasing its content up to 50 wt% in this work. According to our results, the PC/ASA blends with higher ASA-rich phase led to greater color retention and impact retention performance than PC/ASA blends with lower ASA contents. Figures 5.9 e)-f) show SEM micrographs of 50/50 PC/ASA with scrubbed and non scrubbed surfaces. From these figures, we found that the non scrubbed surface of 50/50 PC/ASA didn’t show the ASA domains or exhibited only the PC phase on its surface whereas the ASA-rich phase on the scrubbed surface of 50/50 PC/ASA was clearly observed. This observation suggested that PC phase tended to migrate to the outer layer of the PC/ASA blend to form skin layer on the sample surface. Therefore, surface scrubbing might be helpful in improving color retention of the blend samples.

5.3 Mechanical Properties

5.3.1 Notched Izod Impact Strength of ASA and PC/ASA Blends

In this work,impact strengths of the notched specimensprocessed from injection molding were determined and the values of notched impact strength of all three grades of ASA injected at the same temperature are shown in Figure 5.10. From the results, the notched izod impact values were detemined to be 384 J/m, 254 J/m and 202 J/m for ASA-997, ASA-978 and ASA-777, respectively. The values are in good agreement with the values of 396 J/m, 246 J/m, and 180 J/m for ASA-997, ASA-978 and ASA-777, respectively, that are reported in the specification sheets by Chi Mei and BASF Corporation [32, 33].

The impact behavior as a function of processing temperature of all PC/ASA blends was studied by Yasuda Impact Tester following ASTM D256 and is illustrated in Figure 5.11-5.13. The notched Izod impact property was observed to show a maximum value with an increasing processing temperature. This may be due to phase separation in a lower critical solution temperature type of the PC/ASA blends at high temperature[34]. It was suggested that the processing temperature had a significant effect on the impact strength. For example, in ASA/poly(butylene terephthalate)(PBT) blend system [25], the similar optimal processing temperature to yield maximum mechanical properties of the blends was found to be in a range of 230^{o}C. The same range of processing temperature of ASA/PBT system was also found to be appropriate for ASA/PET blend i.e. 210-220^{o}C[35]. The rather low impact strength at low processing temperature in our study was likely due to poor flow ability of the blend whereas the decrease in impact strength when the temperature was too high was attributed to the greater level of phase separation at this high temperature.

The effect of PC content on the toughness of the two blending systems was investigated based on the impact energy measured from the notched Izod impact tests. Figure 5.14 shows the notched Izod impact strength as a function of the blend ratios of PC/ASA-997, PC/ASA-978 and PC/ASA-777. From this result, the impact strength values were significantly increased with increasing PC content. It was also foundthat PC/ASA-997 has most highest impact strength whereof the values are summarized in Table 5.5. At room temperature PC exhibited notched Izod impact strength approximately 824-846 J/m whereas the impact strengths of ASA-997 and ASA-978 were around 354-414 J/m and 235-273 J/m, respectively. It was found that the notched Izod impact strength of PC/ASA increased steadily with an increasing PC content which obeys the rule of mixture due to the fact that of impact value of PC is higher than that of the ASA [27]. Moreover, the impact strength values of PC/ASA-997 are show the highest from all PC/ASA and the impact strength values of PC/ASA-978 are show similar values with PC/ASA-777. This is suggested that can be caused by the energy absorption by rubber particles. That is suggested the presence of rubber phase of ASA-997 is the highest from all ASA and the presence of rubber phase of ASA-978 is similar value with ASA-777, results in the greater energy absorption of the blends thus the higher impact strength values. In addtion, the impact strength values of our PC/ASA blends were observed to show similar values of those claimed in the commercial products of LuranS, Sabic and Polykemiwhen the PC/ASA fraction was about 70/30-90/10 mass ratios as clearly seen in Table 5.6.

5.3.2 Tensile Property of PC, ASA and PC/ASA Blends

The tensile properties of PC/ASA blends are shown in Figures 5.15-5.16. Figure 5.15 shows tensile modulus of all PC/ASA blends at various blend compositions. From this graph, we can see that the tensile modulus of PC was found to be 2.15GPa whereas that of ASA-997, ASA-978 and ASA-777 was 1.83 GPa, 1.85 GPa and 1.80 GPa, respectively. It can be seen that the tensile modulus exhibited slightly positive deviation for all of the blend systems compared to the neat PC and ASA. For example, in PC/ASA-997 blends systems, the tensile modulus of these blends showed the values of 2.19, 2.25, 2.22, 2.18 and 2.17 GPa from PC contents ranging from 50 wt% to 90 wt%, respectively. Whereas, the tensile moduli of the neat ASA-997 and neat PC were 1.83 and 2.15 GPa. The positive-deviation phenomenon in the tensile modulus of these blends was also reported in some previous works such as in the work of Lombardo et al. (1994) or Greco et al (1994). The existence of the inter-zones between the PC and ABS phases as discussed by Greco and coworkers was probably attributed to the very good adhesion at the interface between the two components. The authors hypothesized the invoked diffusion of low Mw species of SAN towards the PC domains resulting in certain compatibility between the SAN contained in the ABS and the PC itself [36]. The better mixing due to viscosity reduction in the blends may also increase the uniformity in the obtained blend samples thus the slightly better mechanical properties observed.

Tensile strength of PC/ASA at various blend compositions is shown in Figure 5.16. Our PC exhibits tensile strength of 61.3MPa which is substantially higher than that of all ASA (43.5 MPa for ASA-997, 44.2 MPa for ASA-978 and 43.2 MPa for ASA-777). Moreover, the tensile strength of the PC/ASA blends rendered the values between that of neat PC and neat ASA as being predicted well by the rule of mixture, indicating substantial interfacial interaction between the two polymers. Similar behavior was also observed in the PC/ASA/SAN blends [26] and the PC/ABS blends [36, 37]. However, a negative deviation in tensile strength was sometimes observed in some blend systems such as PET/ASA blends which was reported to be rather incompatible (poor interfacial interaction) in nature [25].

5.3.3 Flexural Property of PC, ASA and PC/ASA Blends

Figure 5.17 shows the flexural modulus of all PC/ASA blends with various PC contents. The flexural modulus of PC, ASA-997, ASA-978 and ASA-777 was determined to be 2.42 GPa, 2.27 GPa, 2.20 GPa and 2.22 GPa, respectively. From the results, flexural modulus of PC/ASA blends slightly increased with increasing PC contents. For example, the flexural modulus of PC/ASA-997 blends increased from 2.45 GPa to 2.55 GPa for PC contents of 50 wt% to 90 wt%. The flexural modulus also exhibited slightly positive deviation from those of the neat ASA-997 and neat PC i.e. 2.27 and 2.42 GPa. The result was also consistent with that observed in tensile modulus of these blends.

Flexural strengths of all PC/ASA at various blend compositions are shown in Figure 5.18. The strength values of PC, ASA-997, ASA-978 and ASA-777 were determined to be about 98.8 MPa, 66.5 MPa, 69.4 MPa and 65.3 MPa, respectively. The flexural strengthsof the blends showed an increasing trend with an increasing PC content which is similar to that of tensile strengths. For example, from the experiment, PC/ASA-997 exhibited the flexural strength of 81.7 MPa for the blend containing 50 wt% PC. With increasing PC content, the flexural strength increased to 93.9 MPa for the blend containing 90 wt% of the PC. This behavior is similar to that observed in ABS/SAN blends [38]. From the result, the effect of the ASA content on flexural strength of PC/ASA blends tended to follow the additivity rule confirming good interfacial interaction between the two phases as described in the tensile.

5.3.4 Dynamic Mechanical Analysis (DMA) of PC, ASA and PC/ASA Blends

Storage modulus (E′), and loss tangent (Tan δ) obtained from DMA tests were utilized to characterize the neat PC and ASA and all of their blends to get information about dynamic mechanical properties. The storage moduli of all PC/ASA blends are shown in Figure 5.19-5.21 and storage modulus of all PC/ASA blend at room temperature was also presented in Figure 5.22. According to the results, storage modulus at room temperature of PC was determined to be 2.9 GPa while that of ASA-997, ASA-978 and ASA-777 were about 1.89 GPa, 1.85 GPa and 1.82 GPa, respectively. Furthermore,storage modulus at room temperature of all PC/ASA blends was observed to increase with increasing the amount of PC in the blends due to the fact that PC was more rigid than ASA.Moreover they exhibit two-step changes corresponded to the positions of glass transition temperature (T_gs) of the PC and ASA phases. From the figure, the positions of T_gs of both PC and ASA phases in the blends were slightly shifted towards each other with increasing the fraction of PC as T_g of PC is higher than that of ASA.This is the nature of partially miscible polymer blends. Furthermore, the greater change in slope of the modulus curve vs. temperature of ASA compared to PC is one parameter indicating better thermal stability of the latter. This rapid change in slope of the modulus curve indicated thermal sensibility of the material. The enhancement in thermal stability of the blends was thus obtained due to the superior thermal stability of the PC to the ASA.

Glass transition temperatures of PC/ASA blends were also determined from the DMA thermograms based on the α-relaxation peaks of tan δ. It is widely known that the tan δ curves show the presence of single peak between the transition temperatures of the component polymers presents in a highly miscible blend [39], while two damping peaks corresponding to the Tg's of individual polymers in an immiscible system [40]. In case of partially miscible blend, Tg's are usually found to shift toward each other as a function of composition. Figure 5.23-5.25 illustrates the tan δ curves of all PC/ASA blends at various compositions. From these results, the T_g's from peak of tanδ of the neat ASA-997, ASA-978, ASA-777 and PC were found to be 118°C, 125°C, 120°C and 157°C respectively. For all PC/ASA blends, one dominant peak was observed when ASA content in the blends is less 20 wt%. However, when the ASA content was greater than 20 wt%, two clearly separated peaks of the ASA-rich phase and of the PC-rich phase were observed.This may be due to the miscibility of SAN phase with PC at low concentration of SAN. From these Figure, the position of T_g of the ASA phase increased with increasing the fraction of PC in the blends. On the other hand, T_g of PC slightly shifted to lower temperature with increasing the fraction of ASA in the blends as T_g of PC is higher than that of ASA.

5.3.5 Weatherability – Color Difference and Notched Izod Impact after QUV Test of ASA and PC/ASA Blends

PC without an aid of suitable UV stabilizers is rather sensitive to the weathering action. Its mechanical properties and color can be significantly changed as a result of photo-oxidation reaction [45]. In this experiment, all PC/ASA blend samples at various PC contents from 50 wt% to 90 wt% were exposed by QUV in a weathering test to compare its effect on the neat ASA and PC/ABS modified with UV-stabilizer samples. The test was performed in a QUV weatherometer for a time period of 1, 2 and 3 weeks, and the variation in color difference of the specimens of PC/ASA-997 as a function of time was recorded as shown in Figure 5.26. From the figure, we could see that the incorporation of ASA into PC imparted substantial color retention of PC. The reduction in color changing was reported quantitatively by measuring color difference (△E*) as calculated by measuring changes in L*, a*, and b* color values relative to unexposed controls samples of itself. Furthermore, △E* value of the PC/ASA significantly increased with increasing accelerating times whereas △E* of PC/ASA blends were found decrease with an increasing ASA content. Moreover, the color different of all PC/ASA for a time period of 1 week as a function of composition are shown in Figure 5.27. PC/ASA-777 was shown the highest color retention performance while PC/ASA-978 showed higher color retention than PC/ASA-997 for all composition.

Additionally, the impact strengths of pure ASA, PC/ASA blends at various PC content of 50 wt% to 90 wt% and PC/ABS/UV as shown in Figure 5.28. The neat ASA showed negligible change in its impact strength after 3 weeks in QUV. For the PC/ASA blends, impact retention after weathering test increased with an increasing ASA content from 77% to 91% for 10 wt% to 50 wt% of ASA content, respectively at 3 weeks in the QUV exposure test. Furthermore, impact retention of PC/ASA was found higher than PC/ABS/UV which it shows only 75% at 3 weesk in the QUV exposure test.

Consequently, the ASA was found to significantly help improve the impact retention of the blends, after aging PC/ASA blends for 3 weeks. These evidences indicated that ASA can help improve weatherability of the obtained PC/ASA blends.

5.4 Thermal Properties

5.4.1 Differential Scanning Calorimetry (DSC)of PC, ASA and PC/ASA Blends

As previously mentioned, miscible polymer blend usually exhibits single glass transition temperature (T_g) while in a partially miscible blend, two T_gs of each starting polymer component will be observed and the T_g of each component usually shifts towards each other as a function of blend composition. In the case of immiscible blend, two T_g values can be detected which are the T_g values of the two starting polymers [41, 42]. The DSC thermograms of PC, either ASA and their blends with ASA contents in a range of 0-50 wt% are shown in Figure 5.29-5.31 and also summarized in Table 5.7.The thermograms of the neat PC clearly showed a single Tg at 146°C whereas that of ASA-997, ASA-978 and ASA-777 showed a single Tg at 109, 113 and 106°C, respectively that represents to Tg of SAN phase in ASA matrix [24]. In addition, of the rubber phase, polybutylacrylate is reported to be about-40°C [43] but it wasn’tdetermined in this experiment.

From these figure, T_g of the PC/ASA blend appears as two step changes according to the T_gs of ASA and PC phases. Both T_g is slightly shifted towards each other with increasing amount of the PC. For example, T_g of the ASA-997 in the blend was found to shift to higher value from 109^{o}C of the neat ASA-997 to 112^{o}C in 70/30 wt%. In PC phase, T_g value shifted from 146^{o}C of the neat PC to 142^{o}C in 70/30 wt% while the T_g’s of ASA in the blends were more difficult toobserve when ASA content less than 20% likewise the other two PC/ASA blends. As a consequence,our all PC/ASA blends can be classified as a partially miscible blend.This is an important character of the partially miscible blend that corresponded to the results from dynamic mechanical analysis. The higher T_g with increasing amount of PC suggests the improvement in the thermal stabilityof the blend which allows greater service temperature of the resulting materials.

5.4.2 Heat Deflection Temperature (HDT) & Vicat Softening Point of PC, ASA and PC/ASA blends

The effects of PC contents on the heat distortion temperature (HDT) of all PC/ASA blends were measured by a method according to ASTM D648 and shown in Figure 5.32. From the results, the HDT of ASA-997, ASA-978, ASA-777 and PC were determined about 85°C, 88°C, 84°C and 129°C, respectively. Furthermore, the HDT of all PC/ASA blends was observed to increase with an increasing mass fraction of PC whichhasalinearrelationship. This is because of the HDT of PC significantly higher than that of ASA.

In terms of vicat softening temperature, which was determined by a method according to ASTM D 785, the obtained values of the same PC content were higher than those obtained from HDT measurement about 15^{o}C as follow in Figure 5.33. This figure shows the vicat softening temperature versus the blend ratio of all PC/ASA blends. The vicat softening temperature of ASA-997, ASA-978, ASA-777 and PC were found to be about 92°C, 99°C, 91°C and 142°C, respectively. Both HDT and vicat softening temperature values of pure PC and pure ASA are in good compliance with the values that are reported in the specification sheets by Chi Mei and BASF Corporation [32, 33]. The same trend was observed for the vicat softening of the PC/ASA blends. The results suggested improved thermal stability and service temperature of the blend with the presence of the PC in the ASA which there are consistent with the results of DSC. Those HDT and vicat softening temperature values of all PC/ASA blend specimens are also summarized in Table 5.8.

5.4.3 Thermogravimetric Analysis (TGA) of PC, ASA and PC/ASA Blends

Thermal degradation behavior of PC, three grades of ASA and all PC/ASA blends at various compositions is presented in Figure 5.34-5.36. The degradation temperature at 5% weight loss is one parameter to determine thermal stability of polymers. From the figure, we found that the degradation temperatures of pure PC, ASA-997, ASA-978 and ASA-777 at 5 % weight loss were 503, 383, 374 and 382^{o}C, respectively. The all PC/ASA blends were indicated decomposition in a two-step process. The first decomposition step corresponds mainly to the decomposition of ASA phase and the second mass loss step corresponds to the decomposition of PC phase.

The degradation temperature of all PC/ASAblends increased with increasing mass fraction of PC in the blend which was also illustrated in Figure 5.37. Benefit of blending PC into the ASA is thus to improve the thermal stability of the blend as a result of adding a highly thermally stable like PC into the blends. The same trend was shown in PC/ABS blends system [44]. Moreover, the residual weight at 800^{o}C of all PC/ASA blends was also found to increase with increasing PC mass fraction in the blend. The residual weights of pure PC, ASA-997, ASA-978 and ASA-777 were determined to be 23.1, 0.9, 1.4 and 3.4%, respectively.The residual weights of all blends at various PC content from 50 wt% to 90 wt% were also summarized in Table 5.9.

Table 5.1: Properties of thermoplastic blends based on PC/ASA at different blend ratios [41].

	I	II	III	IV	V	VI	VII	VIII	IX
ASA-1	25	17.5	-	-	-	-	-	-	-
ASA-2	-	-	-	-	-	-	37	-	-
ASA-3	-	-	25	25	17.5	17.5	-	12.5	-
ASA-4	-	-	-	-	-	-	-	12.5	25
PC	50	50	50	50	50	50	50	50	50
SAN	25	32.5	25	20	32.5	27.5	13	25	25
PMMA	-	-	-	5	-	5	-	-	-
Haze	190	182	62	54	61	55	130	56	58
Gloss	74	74	91	91	92	92	74	92	89
Izod,(J/m)	502	480	480	459	395	379	486	849	834

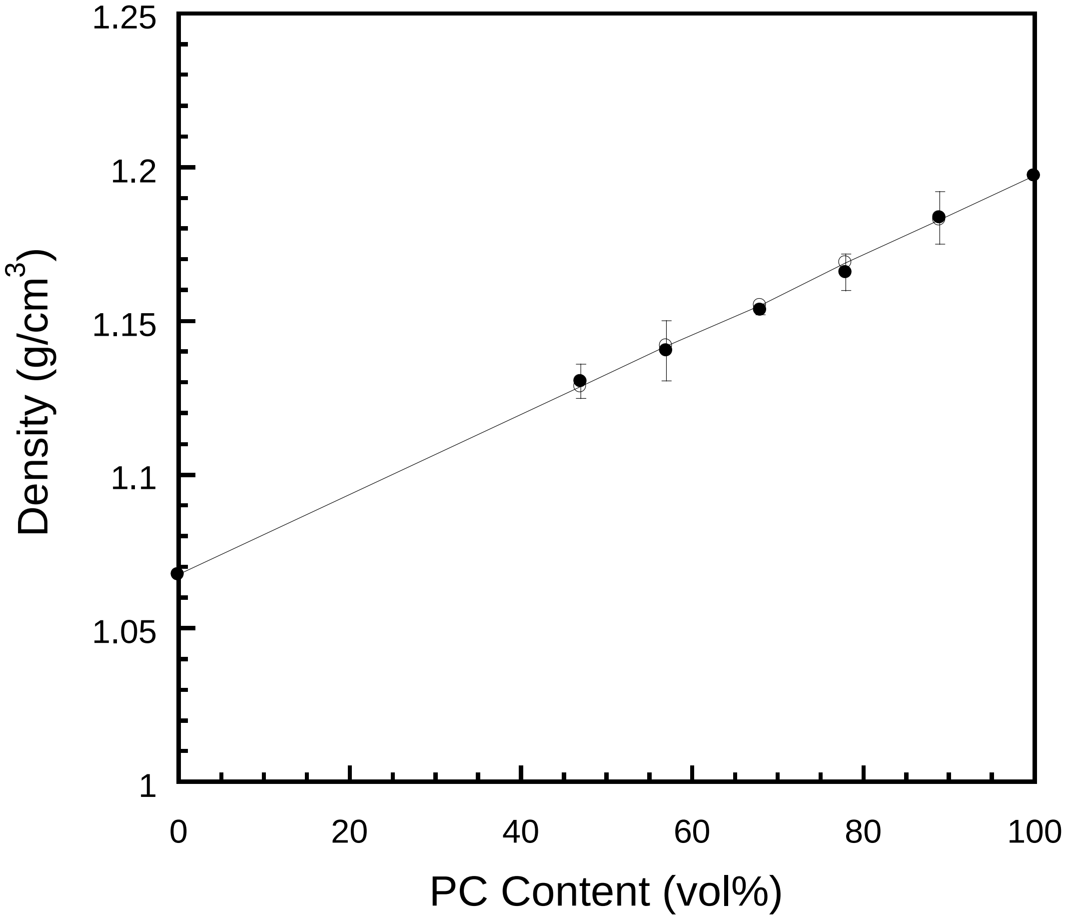


Figure 5.1: Density versus blend ratios of PC/ASA-997:

(•) actual density, (—●—) theoretical density.

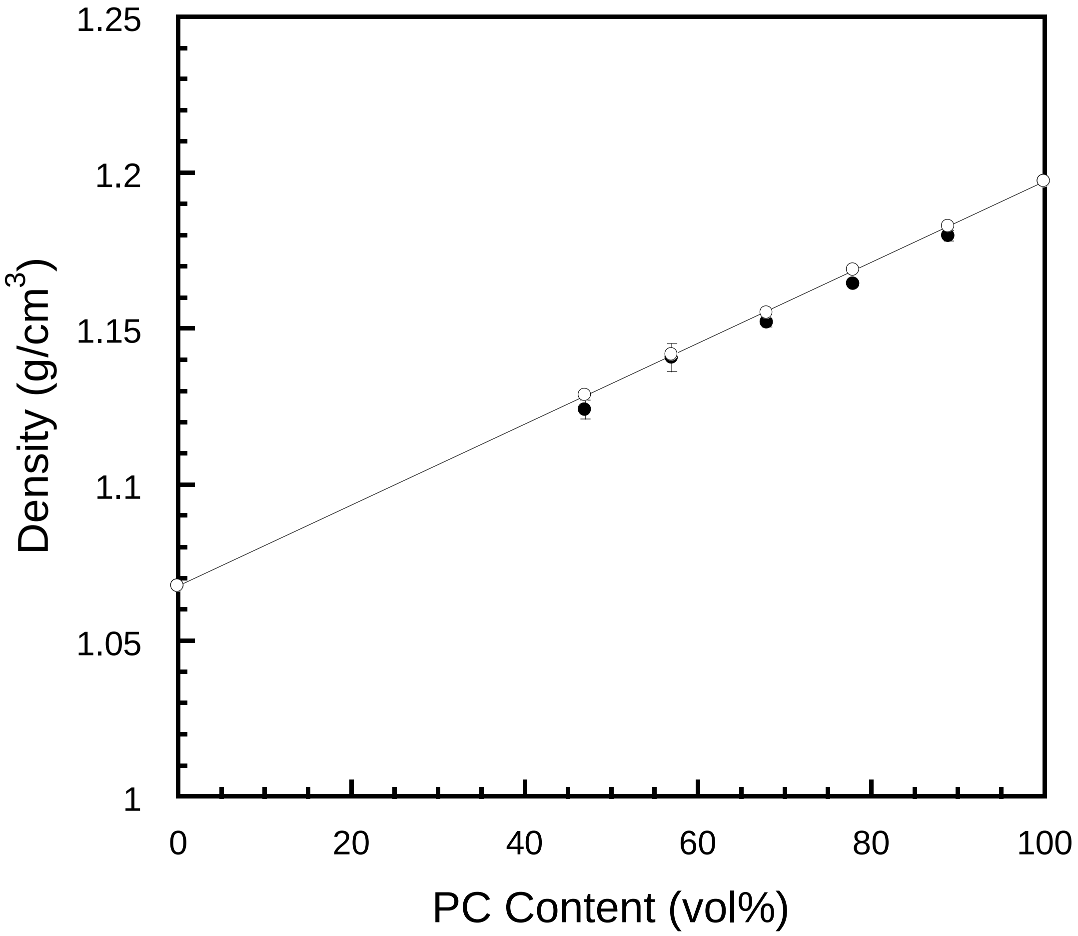


Figure 5.2: Density versus blend ratios of PC/ASA-978:

(•) actual density, (—●—) theoretical density.

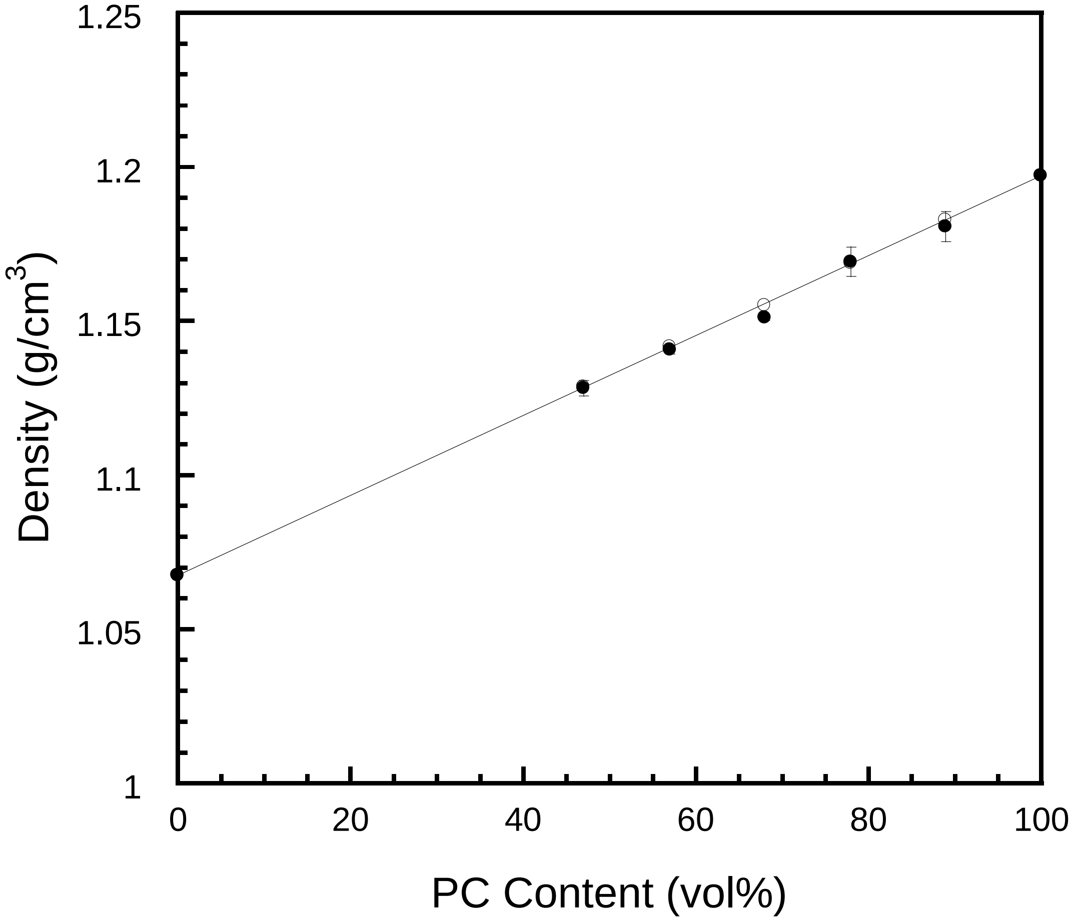


Figure 5.3: Density versus blend ratios of PC/ASA-777:
(•) actual density, (—●—) theoretical density.

Table 5.2: Actual and theoretical densities of all PC/ASA blends at various blend compositions.

Sample	Actual Density of PC/ASA-997 (g/cm^3)	Actual Density of PC/ASA-978 (g/cm^3)	Actual Density of PC/ASA-777 (g/cm^3)	Theoretical Density (g/cm^3)
PC/ASA 90:10	1.1835±0.008542	1.1797±0.001657	1.1806±0.004854	1.1827
PC/ASA 80:20	1.1657±0.005922	1.1642±0.000582	1.1691±0.004772	1.1687
PC/ASA 70:30	1.1535±0.001582	1.1519±0.001385	1.1510±0.000861	1.1550
PC/ASA 60:40	1.1402±0.009822	1.1405±0.004425	1.1405±0.001231	1.1416
PC/ASA 50:50	1.1302±0.005698	1.1239±0.003020	1.1282±0.002457	1.1285

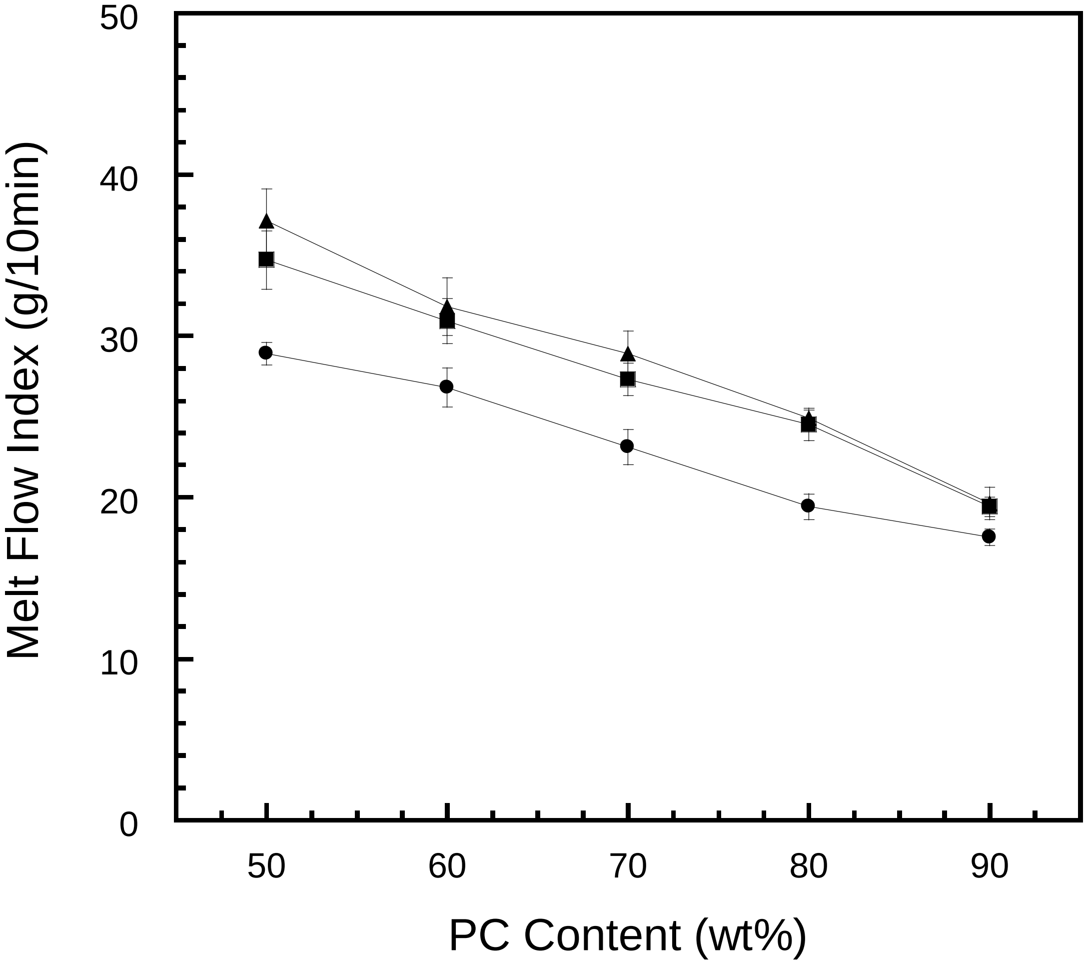


Figure 5.4: Melt flow index versus blend ratios of PC/ASA at various ASA grades: (●) PC/ASA-997, (■) PC/ASA-978 and (▲) PC/ASA-777.

(test condition: temperature = 260°C, applied load = 5 kg, preheating time = 6 min)

Table 5.3: Melt flow index of all PC/ASA blends at various blend compositions. (test condition: temperature = 260°C, applied load = 5 kg, preheating time = 6 min)

Sample	Melt flow index (g/10min) (PC/ASA-997)	Melt flow index (g/10min) (PC/ASA-978)	Melt flow index (g/10min) (PC/ASA-777)
PC/ASA 90:10	29±0.7	35±1.8	37±2.0
PC/ASA 80:20	27±1.2	31±1.4	32±1.8
PC/ASA 70:30	23±1.1	27±1.0	29±1.4
PC/ASA 60:40	19±0.8	25±1.0	25±0.5
PC/ASA 50:50	18±0.5	19±0.6	20±1.0

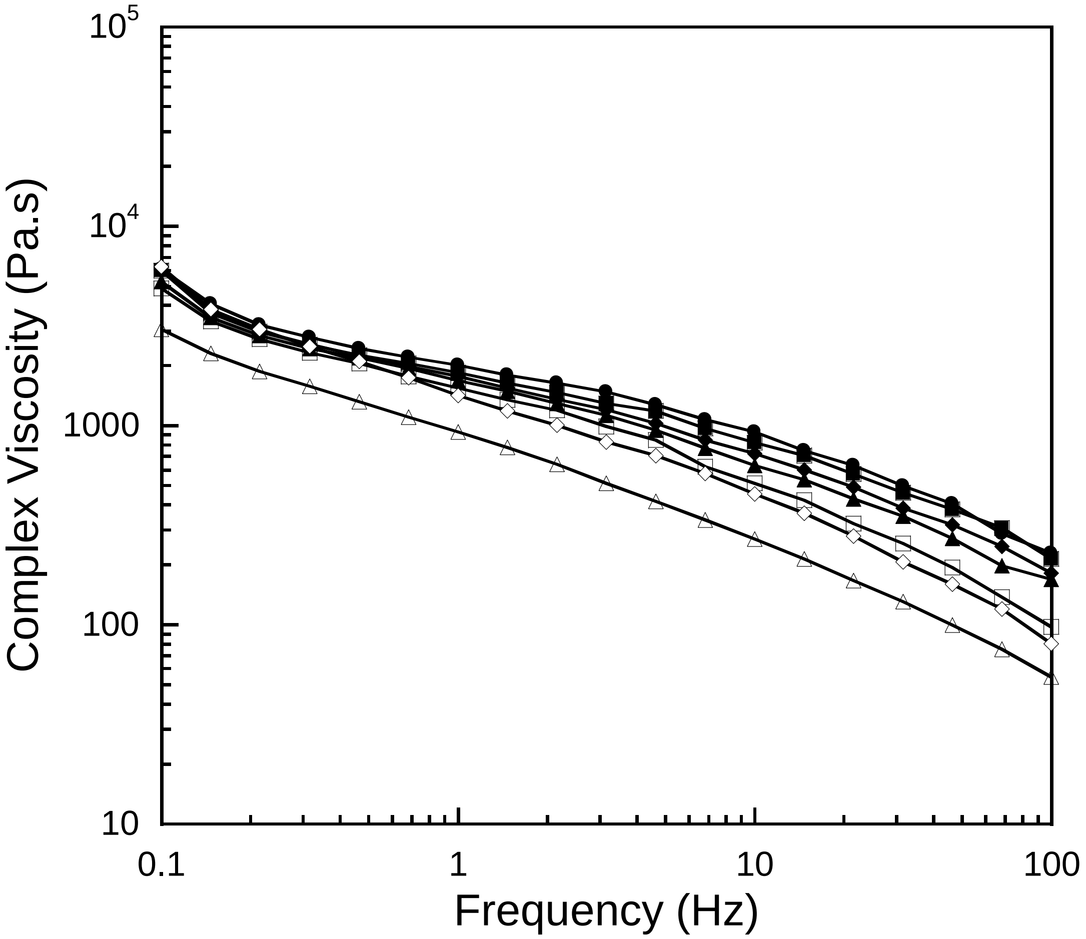


Figure 5.5: Complex viscosity versus frequency of PC/ASA-997 blends at various blend ratios tested at 210°C: (●) PC, (■) PC/ASA 90:10wt%, (◆) PC/ASA 80:20wt%, (▲) PC/ASA 70:30wt%,(□) PC/ASA 60:40wt%, (◇) PC/ASA 50:50wt% and (△) ASA-997.

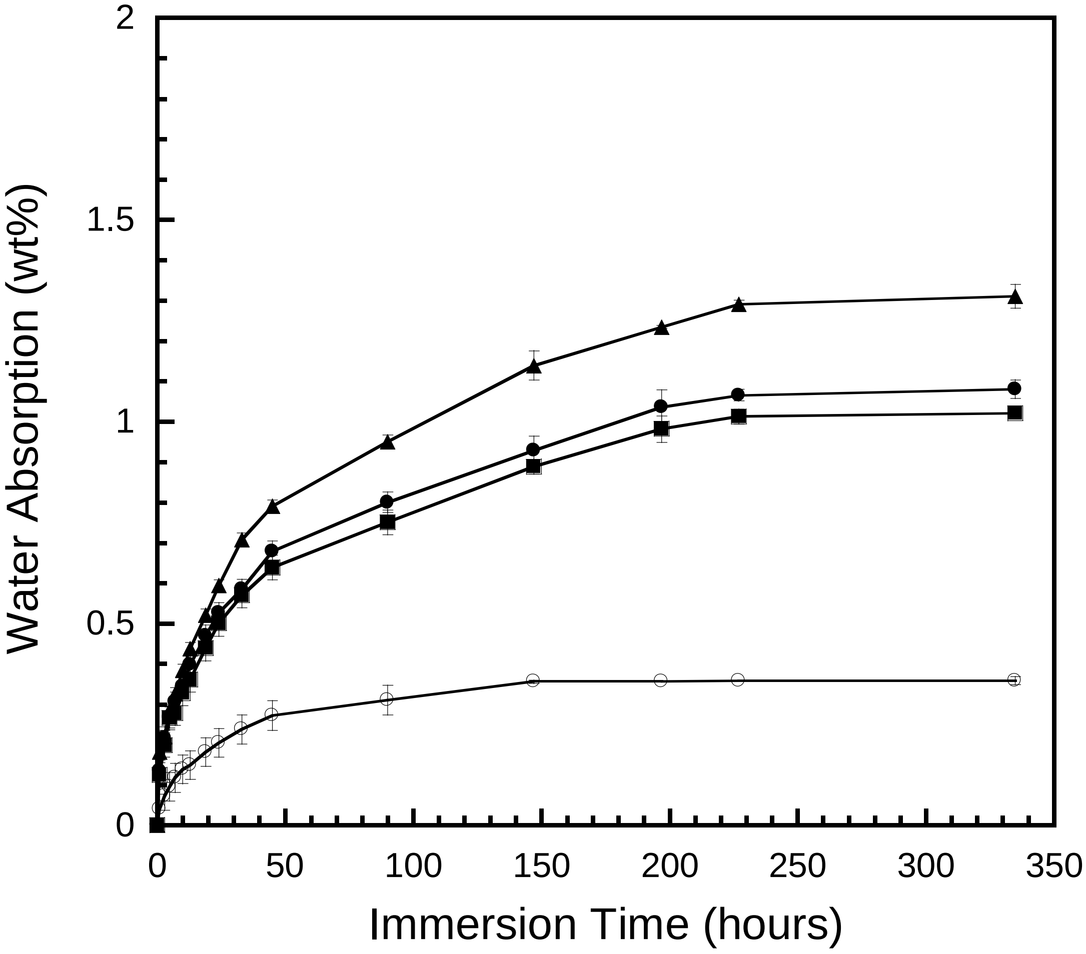


Figure 5.6: Water absorption versus immersion tiome of pure PC and pure ASA: (○) PC, (●) ASA-997, (■) ASA-978 and (▲) ASA-777.

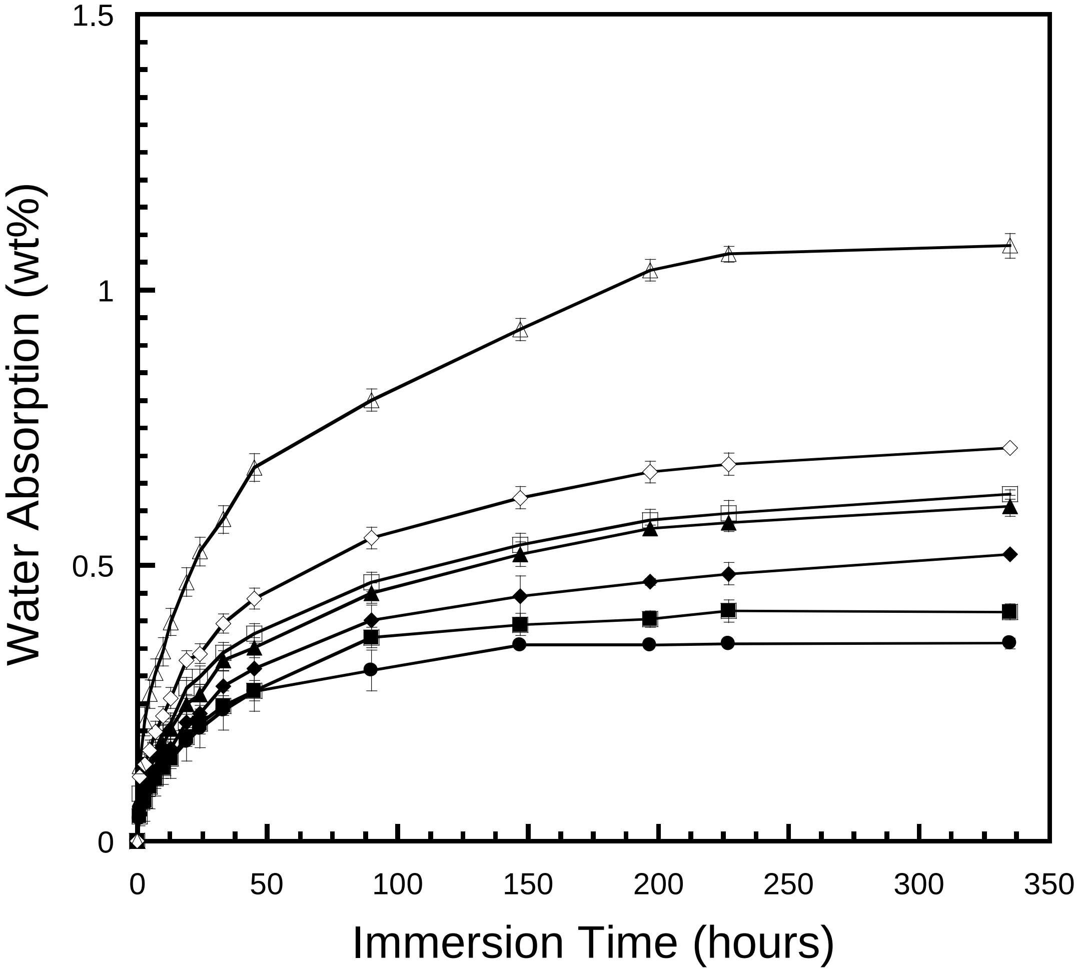


Figure 5.7: Water absorption versus immersion tiome of PC/ASA-997 blends at various blend ratios. (●) PC, (■) PC/ASA 90:10wt%, (◆) PC/ASA 80:20wt%, (▲) PC/ASA 70:30wt%,(☐) PC/ASA 60:40wt%, (◇) PC/ASA 50:50wt% and (△) ASA-997.

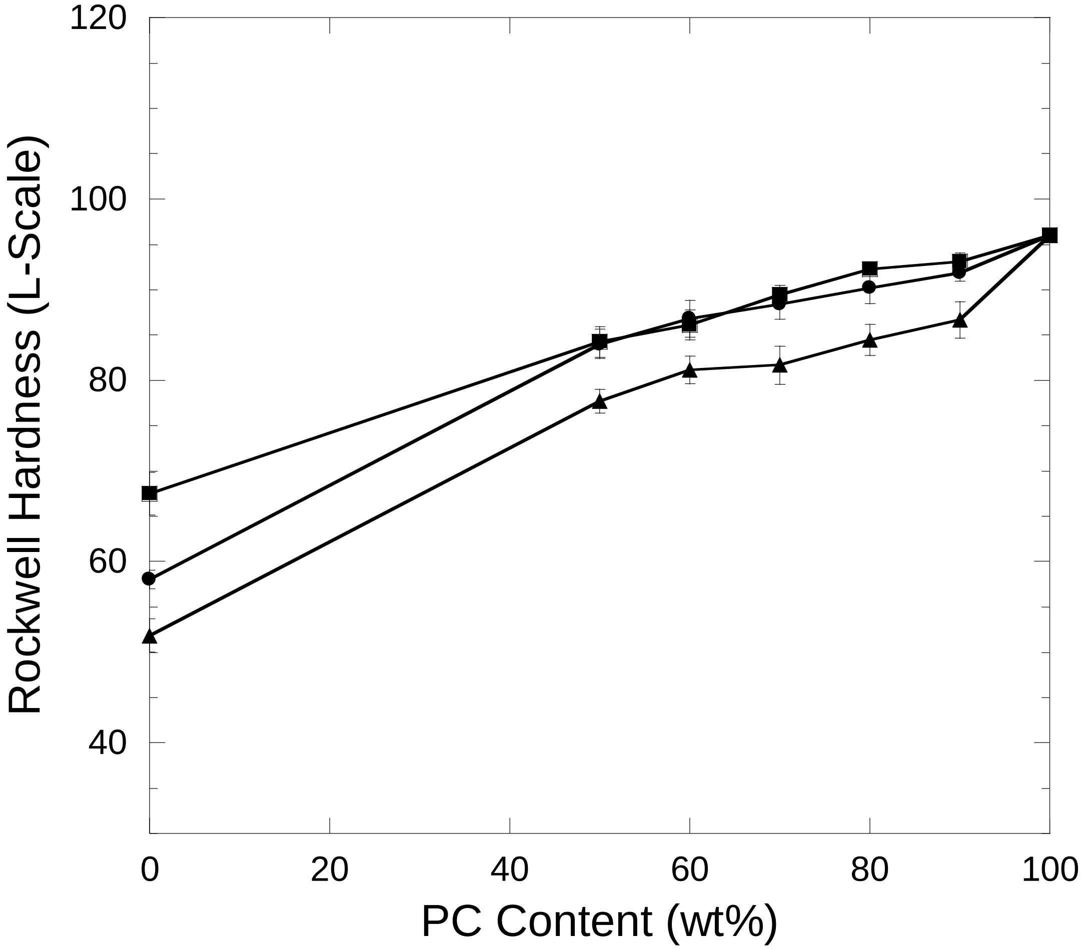
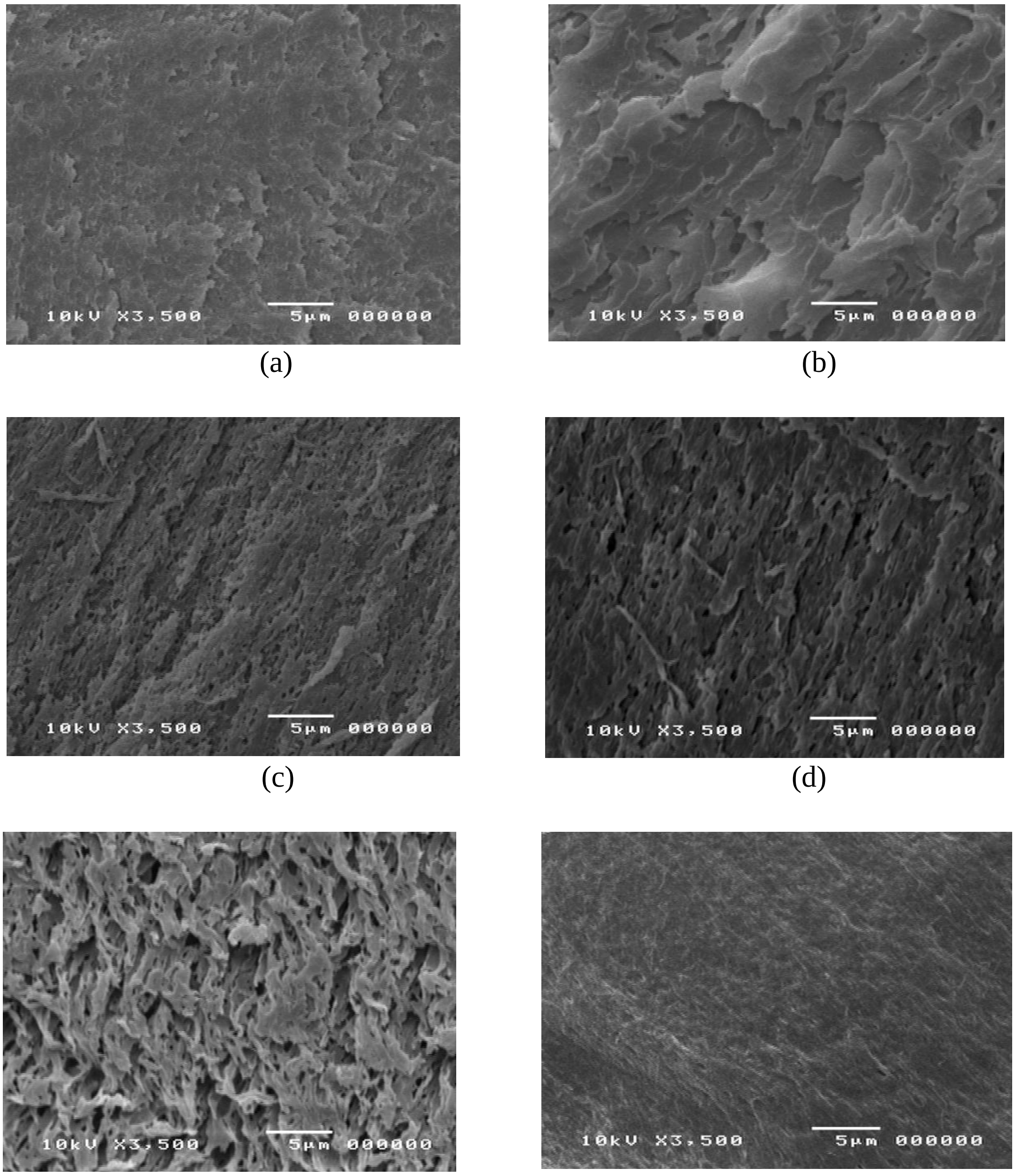


Figure 5.8: Rockwell hardness (L-scale) versus blend ratios of PC/ASA at various ASA grades: (●) PC/ASA-997, (■) PC/ASA-978 and (▲) PC/ASA-777.

Table 5.4: Rockwell hardness of PC, ASA and all PC/ASA blends at various blend compositions.

Sample	Rockwell Hardness (L-scale)		
	PC/ASA-997	PC/ASA-978	PC/ASA-777
Neat PC	96±0.6	96±0.6	96±0.6
PC/ASA 90:10	92±0.9	93±1.0	87±2.0
PC/ASA 80:20	90±1.7	92±0.5	85±1.7
PC/ASA 70:30	88±1.6	89±1.0	82±2.1
PC/ASA 60:40	87±2.0	86±1.7	81±1.5
PC/ASA 50:50	84±1.6	84±1.7	78±1.3
Neat ASA	58±1.0	67±2.3	52±1.8



(a) (b)

(c) (d)

(e) (f)

Figure 5.9: SEM micrographs of surfaces of PC/ASA-997 blends at various blend ratios etched by an aqueous acid solution: (a) 90/10 PC/ASA, (b) 80/20 PC/ASA, (c) 70/30 PC/ASA, (d) 60/40 PC/ASA, (e) 50/50 PC/ASA and (f) 50/50 PC/ASA (non scrubbed surface).

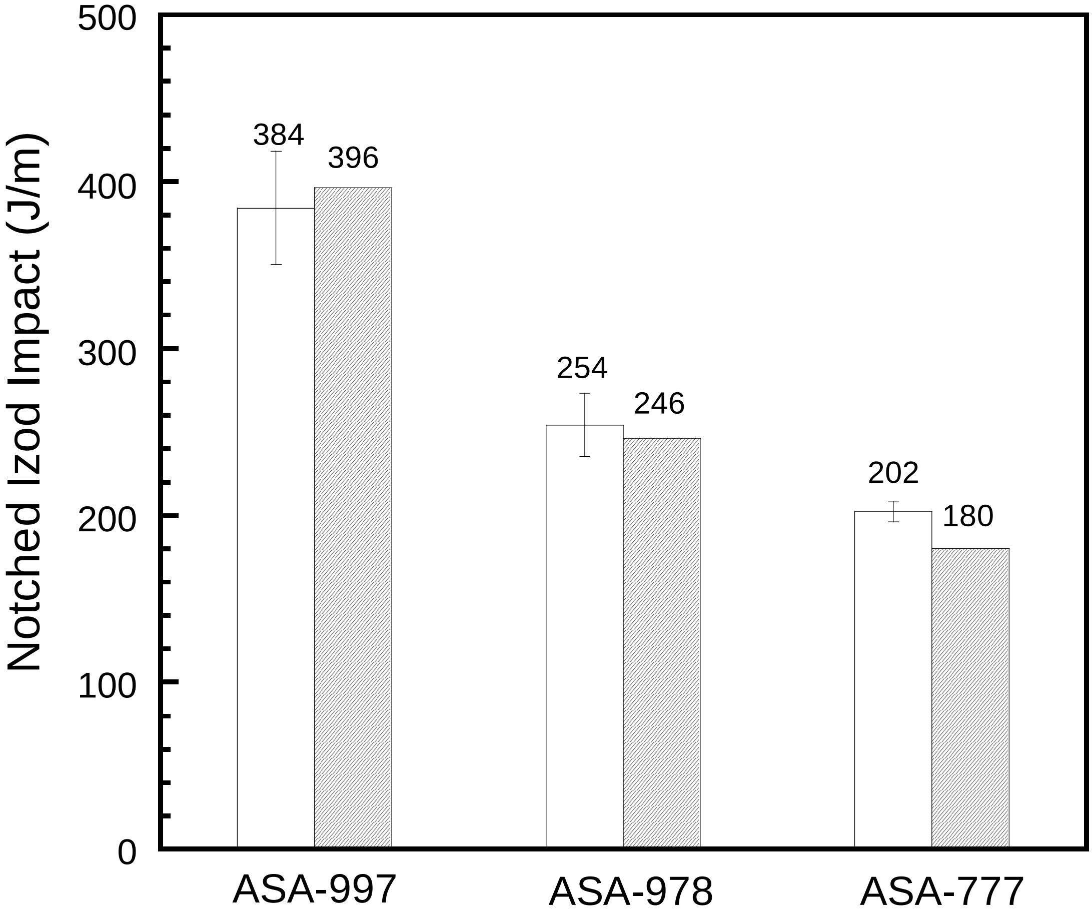


Figure 5.10: Notched Izod impact strength of ASA processed by injection molding: (☐) values from experimental and (▨) values from specification sheet.

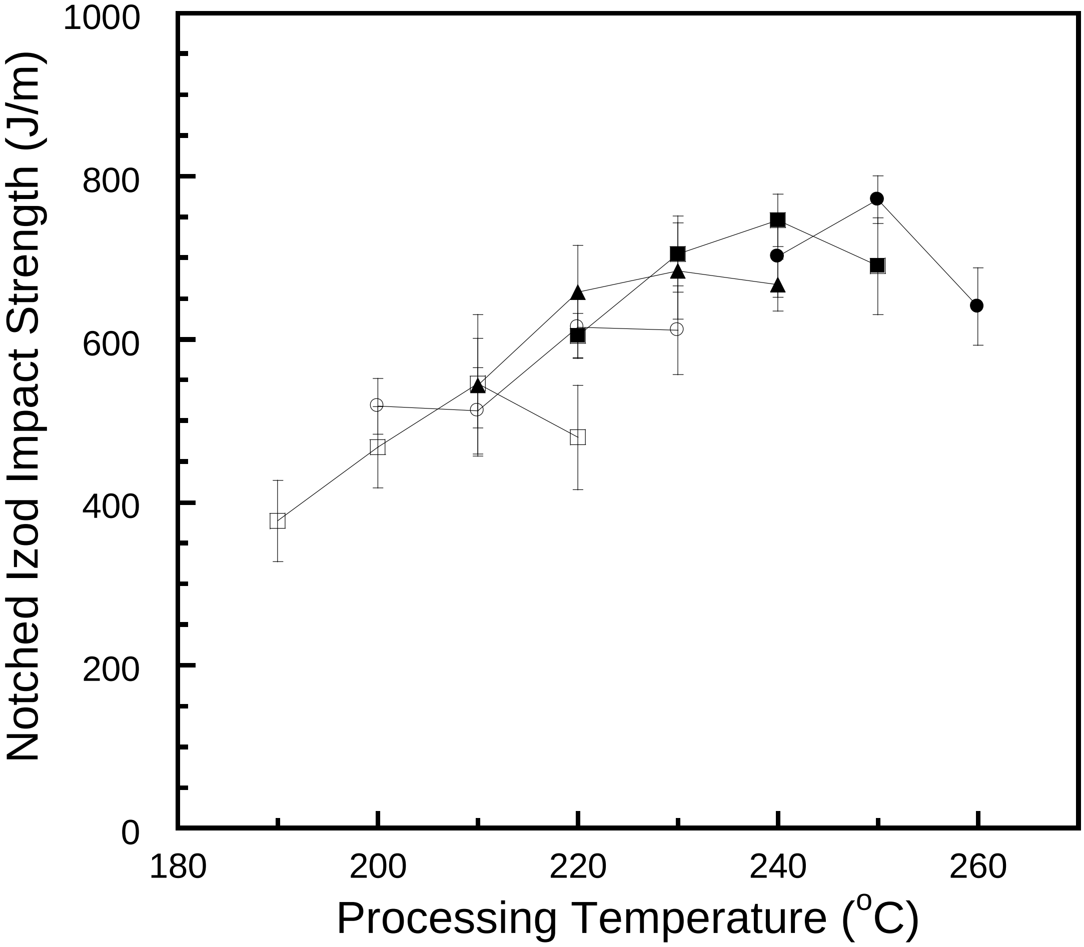


Figure 5.11: Notched Izod impact strength versus processing temperature of PC/ASA-997 blends at various blend ratios: (●)PC/ASA 90:10wt%, (■)PC/ASA 80:20wt%, (▲)PC/ASA 70:30wt%, (○)PC/ASA 60:40wt%, (□)PC/ASA 50:50wt%.

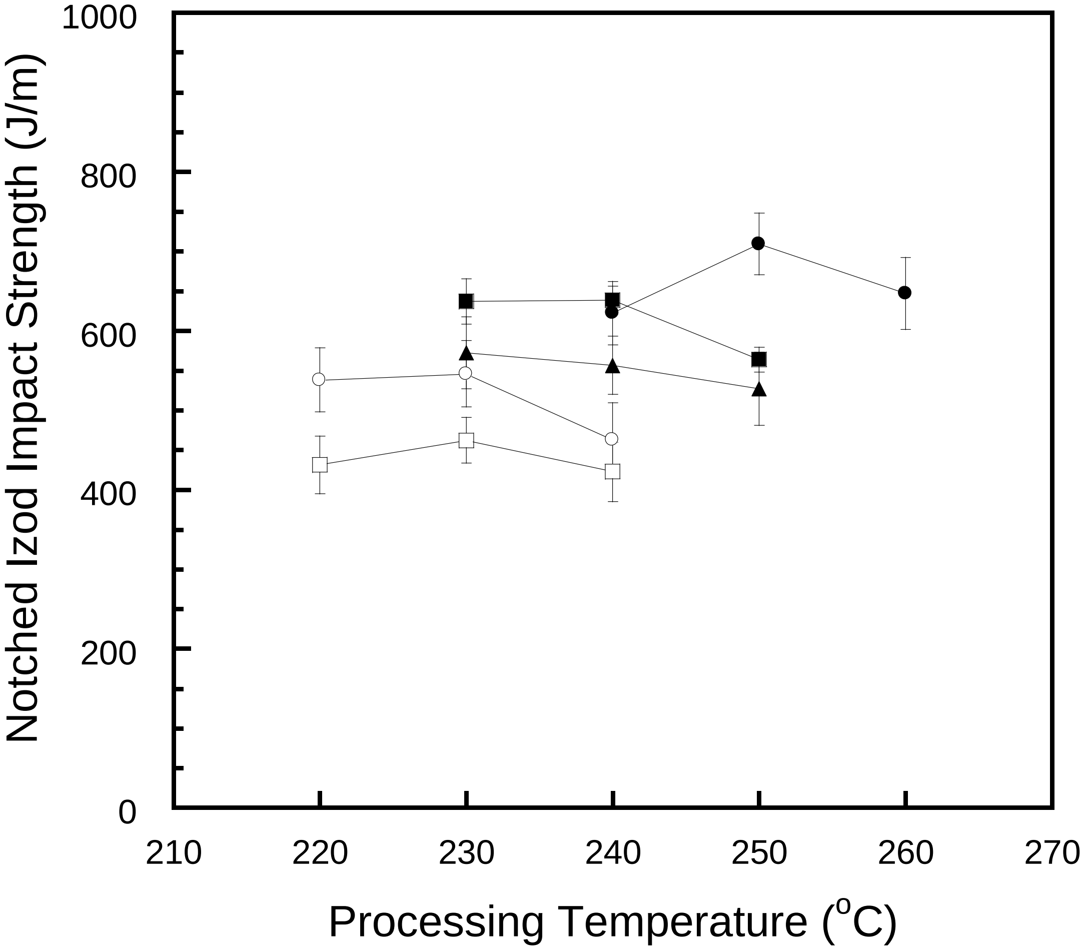


Figure 5.12: Notched Izod impact strength versus processing temperature of PC/ASA-978 blends at various blend ratios: (●)PC/ASA 90:10wt%, (■)PC/ASA 80:20wt%, (▲)PC/ASA 70:30wt%, (○)PC/ASA 60:40wt%, (□)PC/ASA 50:50wt%.

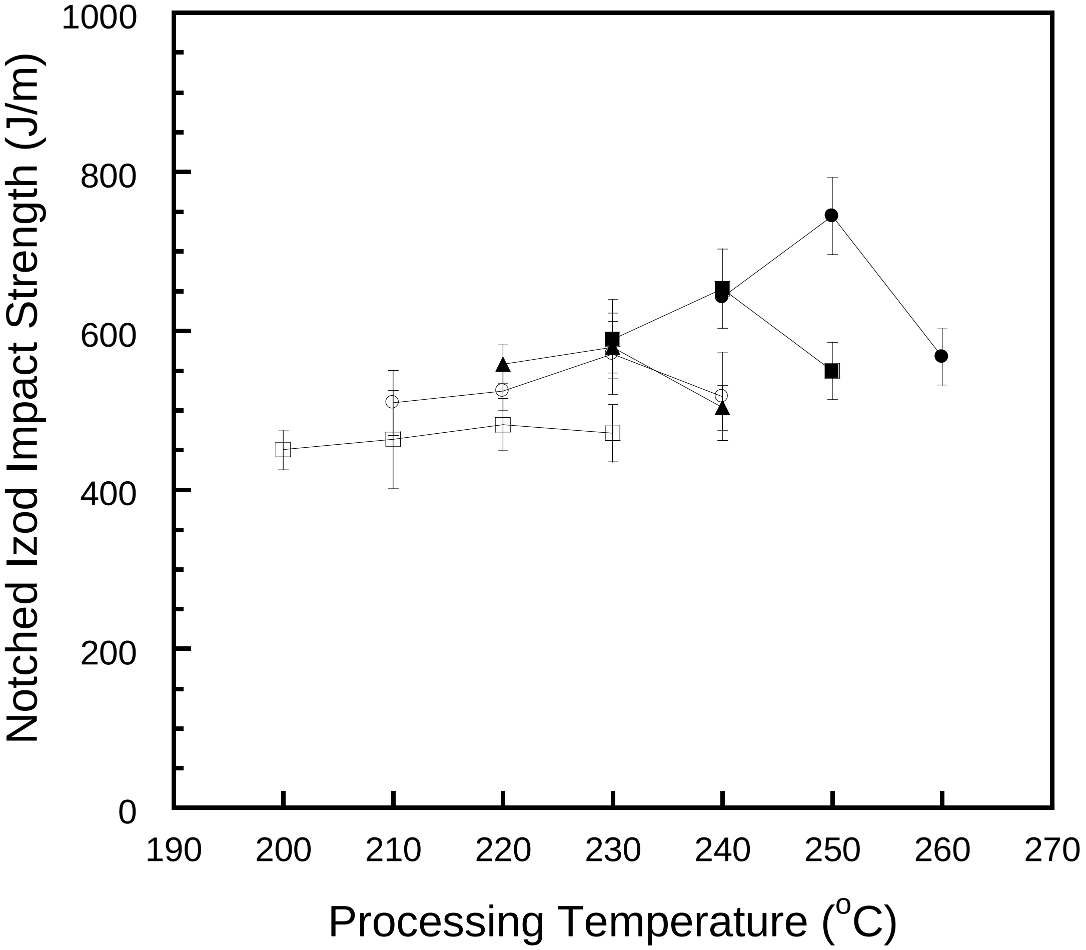


Figure 5.13: Notched Izod impact strength versus processing temperature of PC/ASA-777 blends at various blend ratios: (●)PC/ASA 90:10wt%, (■)PC/ASA 80:20wt%, (▲)PC/ASA 70:30wt%, (○)PC/ASA 60:40wt%, (□)PC/ASA 50:50wt%.

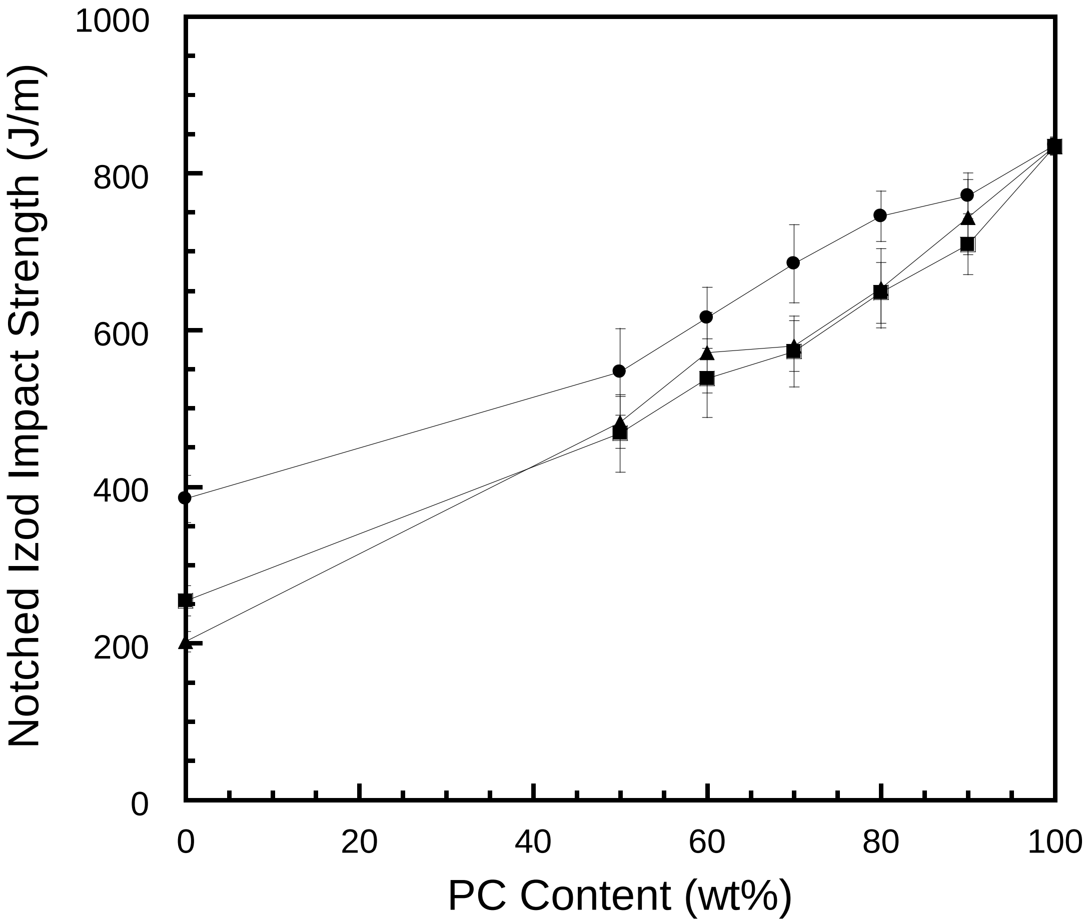


Figure 5.14: Notched Izod impact strength versus blend ratios of PC/ASA blends at various ASA grades: (●) PC/ASA-997, (■) PC/ASA-978 and (▲)PC/ASA-777.

Table 5.5: Notched Izod impact strength of PC/ASA-997 and PC/ASA-978 blends at various blend compositions.

Sample	Notched Izod Impact Strength of PC/ASA-997 (J/m)	Notched Izod Impact Strength of PC/ASA-978 (J/m)	Notched Izod Impact Strength of PC/ASA-777 (J/m)
Pure PC	835±11	834±11	834±11
PC/ASA 90 : 10	771±29	708±38	743±48
PC/ASA 80 : 20	745±32	647±38	652±50
PC/ASA 70 : 30	684±50	572±45	579±32
PC/ASA 60 : 40	615±39	538±50	570±51
PC/ASA 50 : 50	546±55	467±49	481±33
Pure ASA	384±30	254±19	202±13

Table 5.6: Comparition properties of ours PC/ASA blends with commercial PC/ASA products.

Company	Grade	Density (g/cm^3)	Ours blend (density)	Izod impact (J/m)	Ours blend (izod impact)	MVR (cm^3/10min)	MFR (g/10min)	Ours blend (MVR)	Ours blend (MFR)
LuranS	KR 2863 C	1.16	70/30 (1.16)	700	684	18	-	20	23.1
	KR 2861/1 C	1.15		600		14	-		
Sabic	Geloy XTPM307	1.15	70/30 (1.16)	640	684	16	-	20	23.1
	Geloy XTPM309	1.16		685		13	-		
	Geloy XTPM309E	1.16		675		17	-		
	Geloy FXW751SK	1.16		300		-	8.3		
	Geloy HRA170D	1.16		750		29	30		
	Geloy HRA222F	1.17		385		-	-		
	Geloy XTPMFR15	1.19	90/10 (1.18)	700	771	-	30	17	19.4
Polykemi	Scanblend FS7	1.13	50/50 (1.13)	450	546	-	20	15	17.5
	Scanblend FS7 uv4	1.13		460		-	20	26	28.9

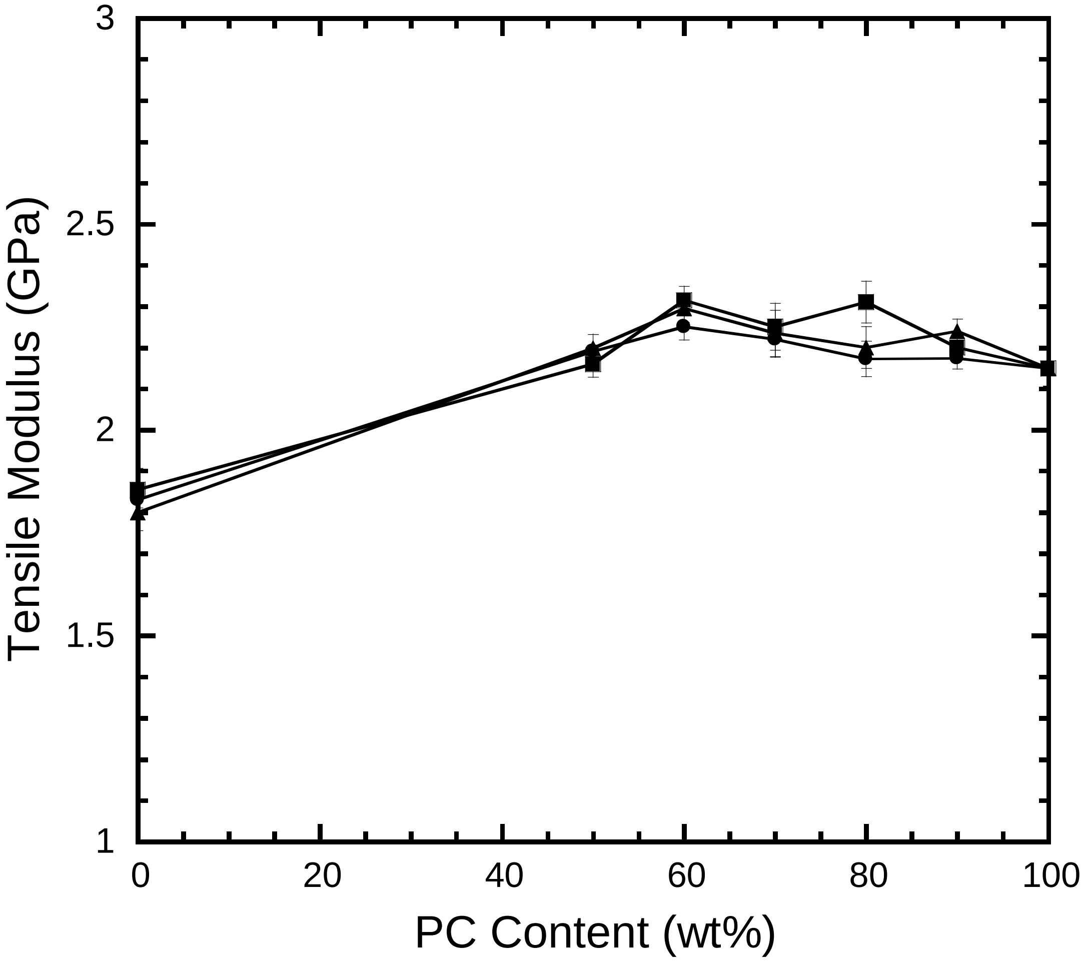


Figure 5.15: Tensile modulus versus blend ratios of PC/ASA at various ASA grades: (●) PC/ASA-997, (■) PC/ASA-978 and (▲) PC/ASA-777.

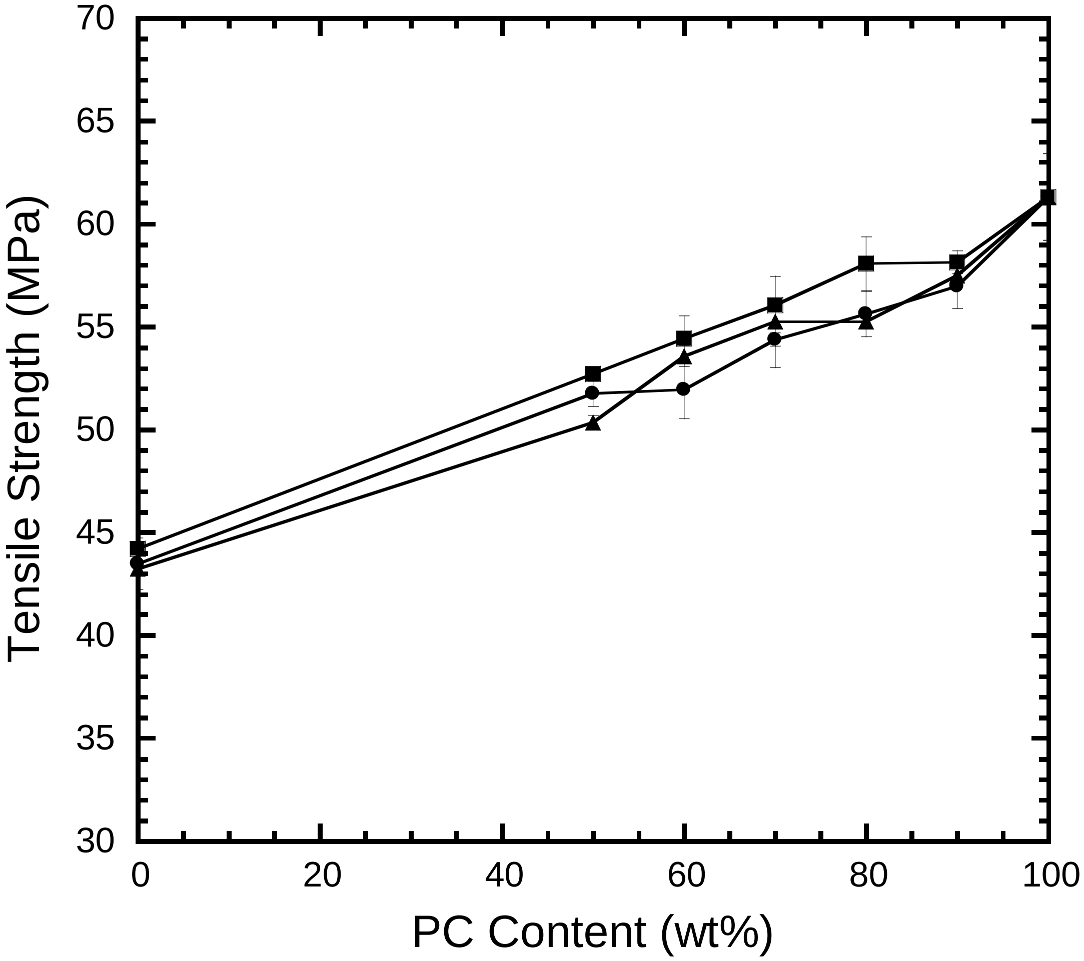


Figure 5.16: Tensile strength versus blend ratios of PC/ASA at various ASA grades: (●) PC/ASA-997, (■) PC/ASA-978 and (▲) PC/ASA-777.

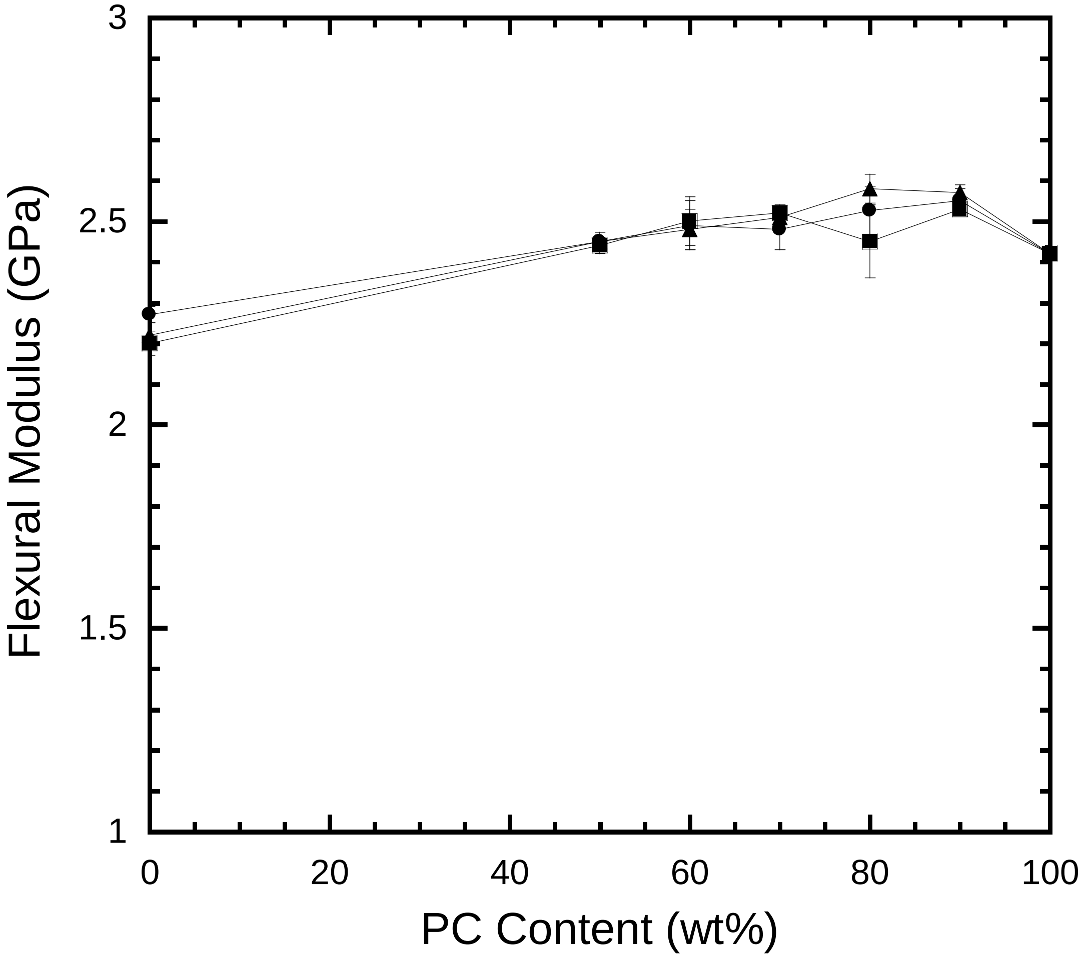


Figure 5.17: Flexural modulus versus blend ratios of PC/ASA at various ASA grades: (●) PC/ASA-997, (■) PC/ASA-978 and (▲) PC/ASA-777.

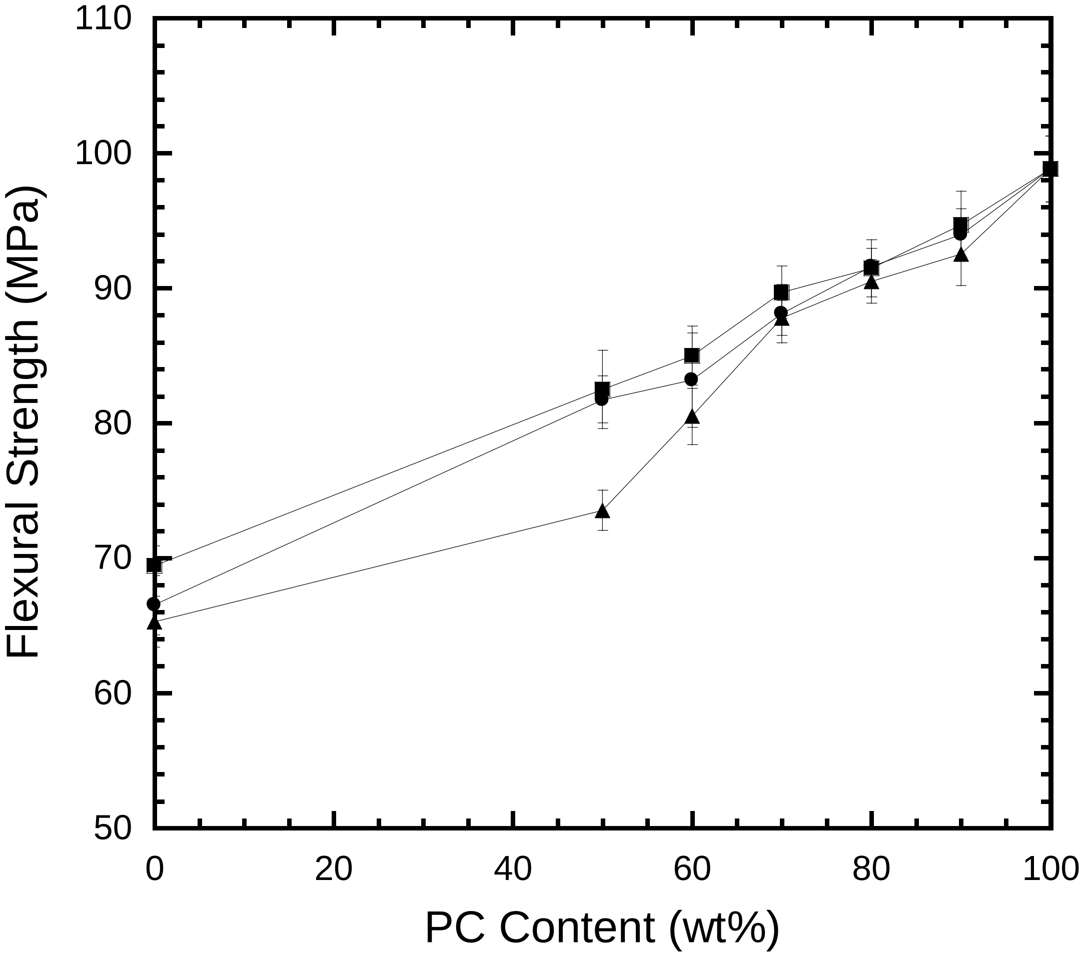


Figure 5.18: Flexural strength versus blend ratios of PC/ASA at various ASA grades: (●) PC/ASA-997, (■) PC/ASA-978 and (▲) PC/ASA-777.

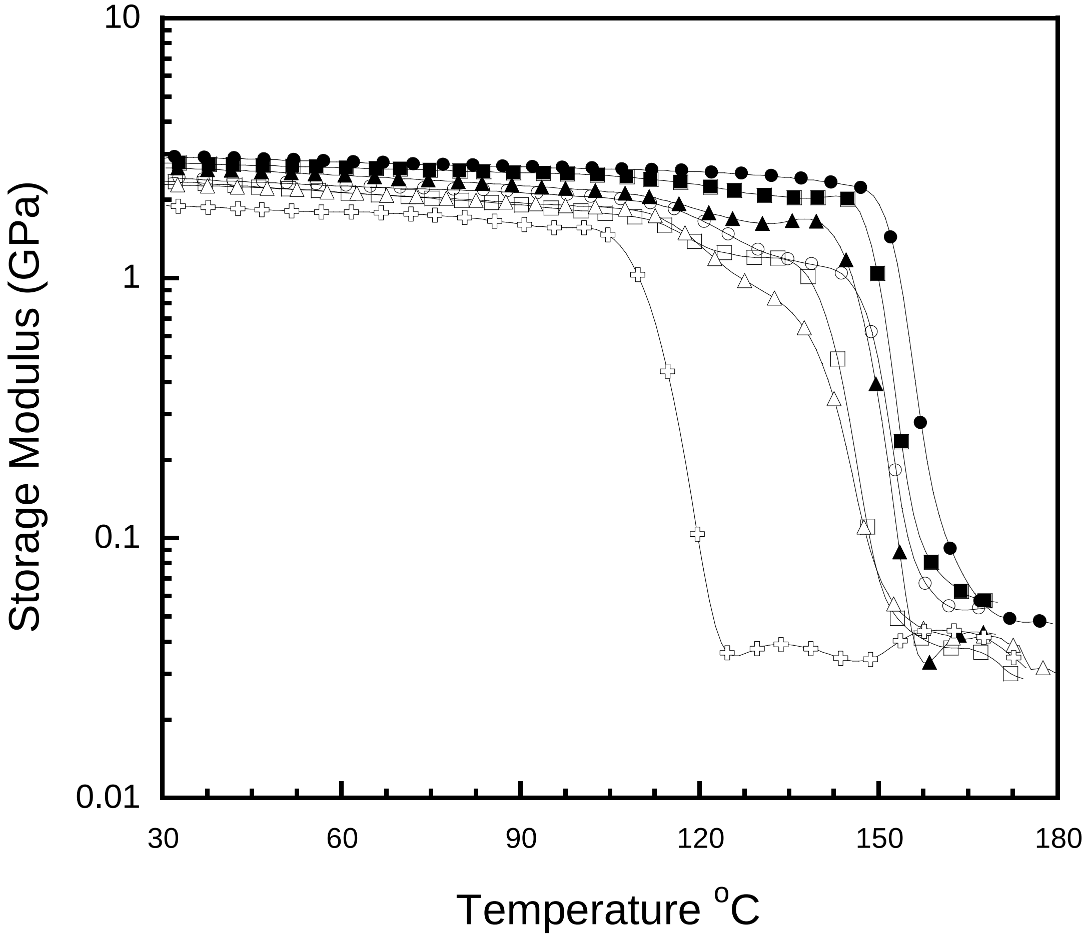


Figure 5.19: Storage modulus versus temperature (°C) of PC/ASA-997 blends at various blend ratios: (●)PC, (■)PC/ASA 90:10wt%, (◆)PC/ASA 80:20wt%, (▲)PC/ASA 70:30wt%**,** (□)PC/ASA 60:40wt%, (◇)PC/ASA 50:50wt%, (△)ASA-997.

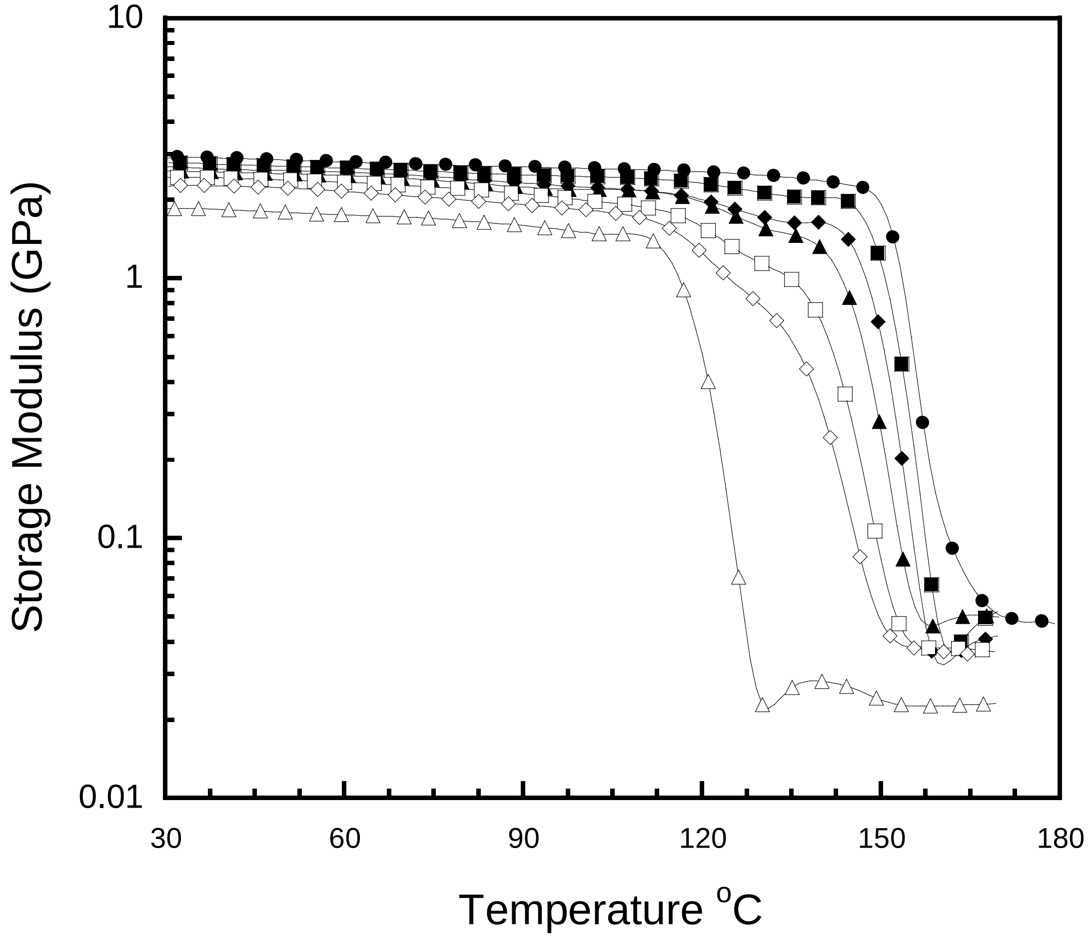


Figure 5.20: Storage modulus versus temperature (°C) of PC/ASA-978 blends at various blend ratios: (●)PC, (■)PC/ASA 90:10wt%, (◆)PC/ASA 80:20wt%, (▲)PC/ASA 70:30wt%**,** (□)PC/ASA 60:40wt%, (◇)PC/ASA 50:50wt%, (△)ASA-978.

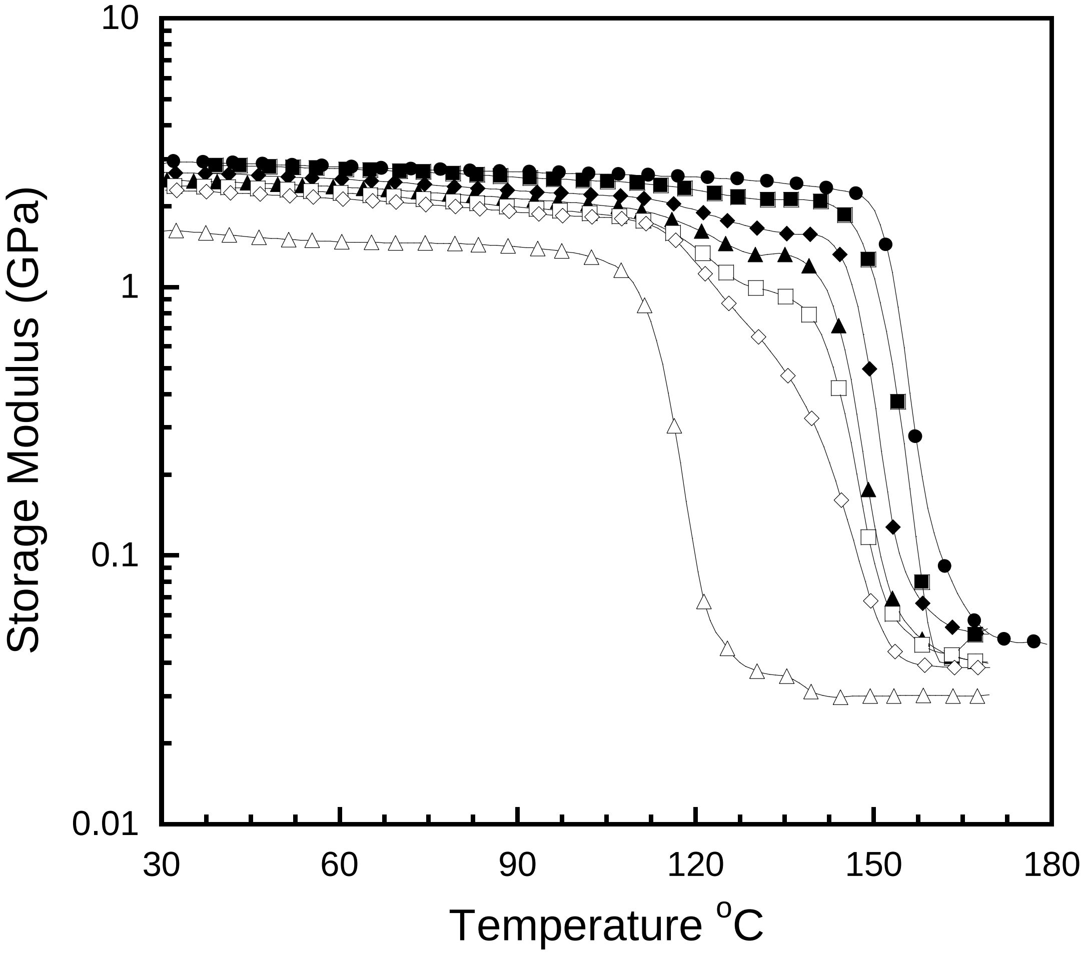


Figure 5.21: Storage modulus versus temperature (^{o}C) of PC/ASA-777 blends at various blend ratios: (●)PC, (■)PC/ASA 90:10wt%, (◆)PC/ASA 80:20wt%, (▲)PC/ASA 70:30wt%, (□)PC/ASA 60:40wt%, (◇)PC/ASA 50:50wt%, (△)ASA-777.

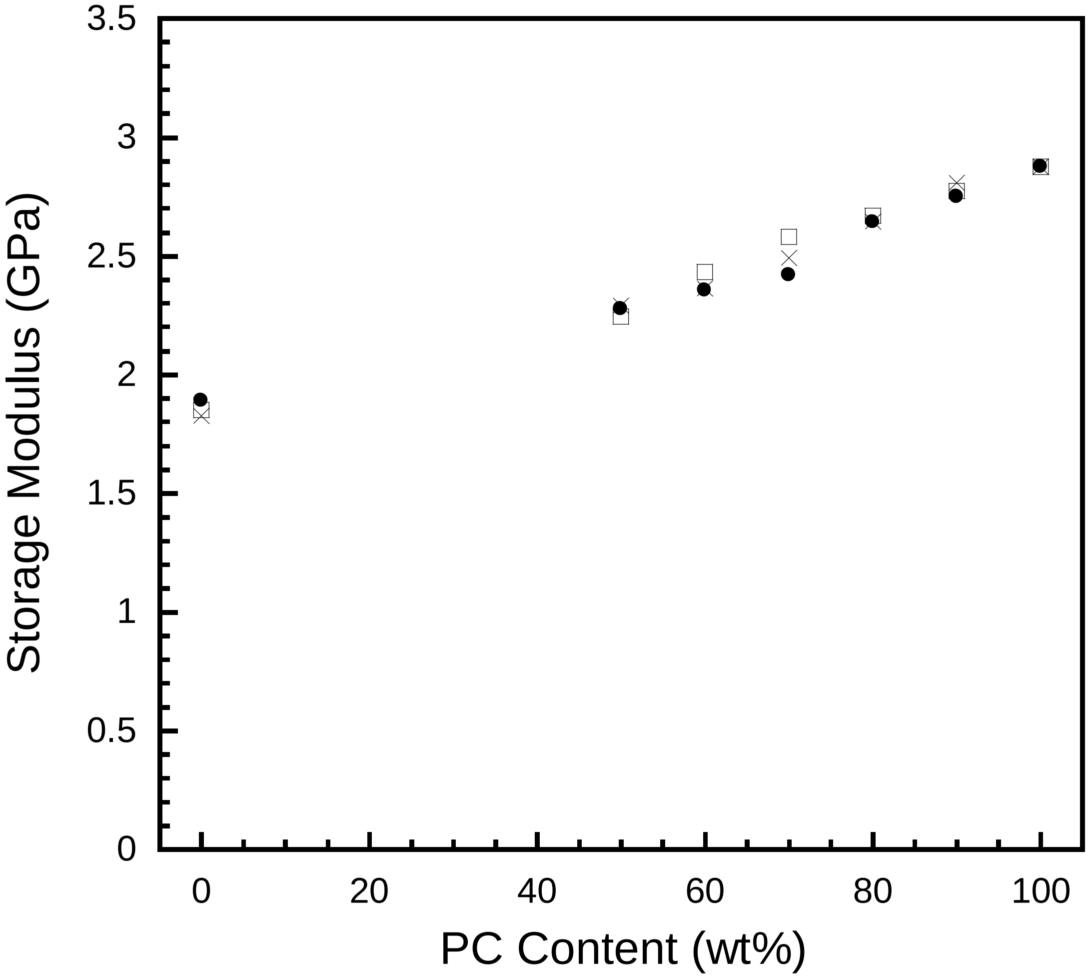


Figure 5.22: Storage modulus of all PC/ASA blends at 40°C: (○) PC/ASA-997, (□) PC/ASA-978**,** (×) PC/ASA-777.

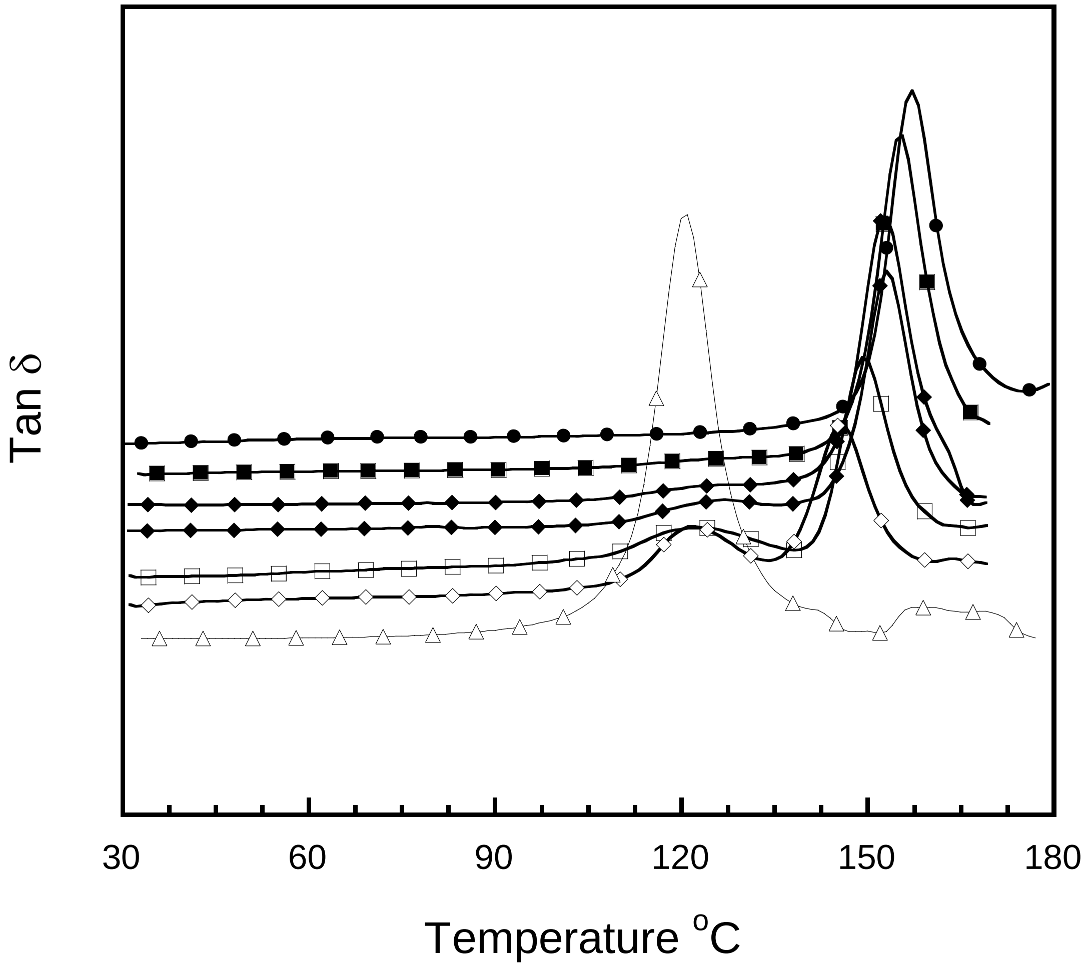


Figure 5.23: Loss tangent versus temperature (^{o}C) of PC/ASA-997 blends at various blend ratios: (●)PC, (■)PC/ASA 90:10wt%, (◆)PC/ASA 80:20wt%, (▲)PC/ASA 70:30wt%**,** (□)PC/ASA 60:40wt%, (◇)PC/ASA 50:50wt%, (△)ASA-997.

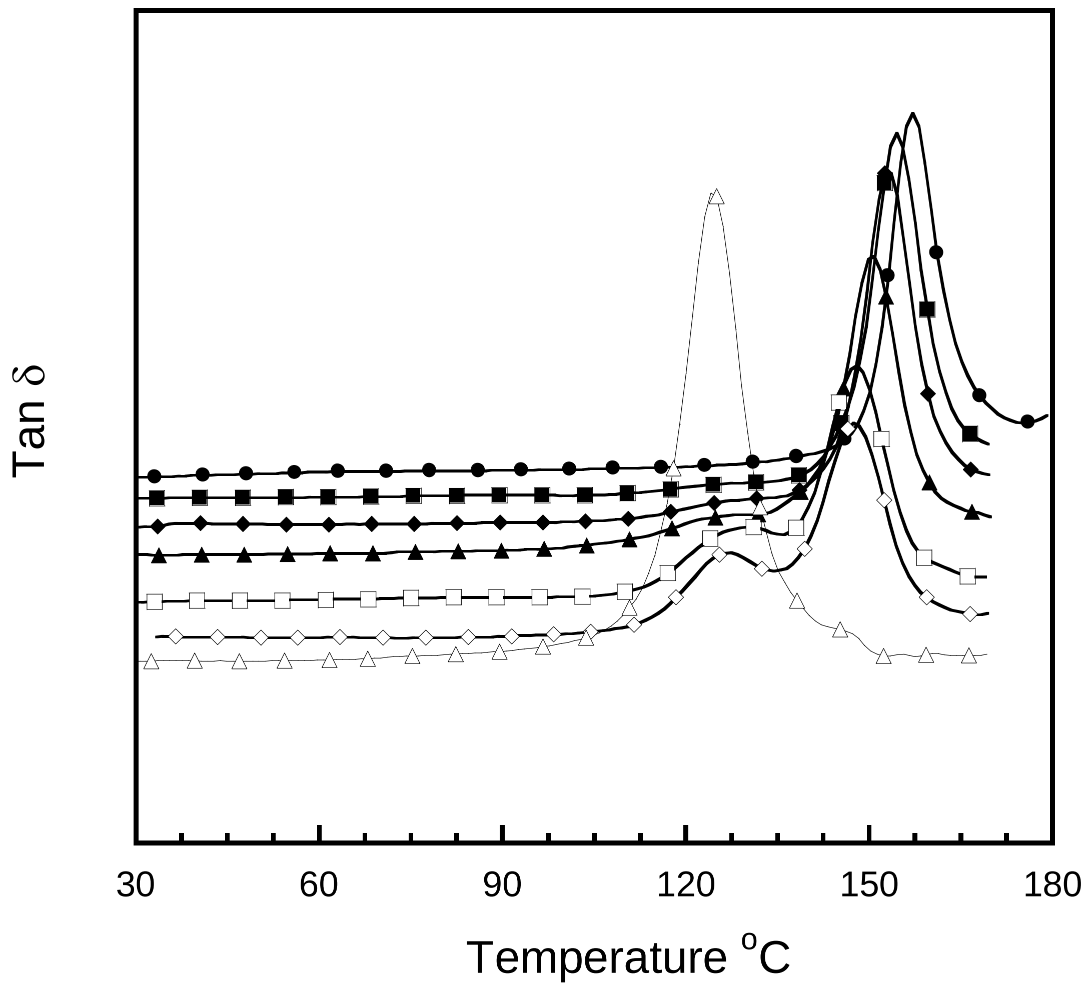


Figure 5.24: Loss tangent versus temperature (°C) of PC/ASA-978 blends at various blend ratios: (●)PC, (■)PC/ASA 90:10wt%, (◆)PC/ASA 80:20wt%, (▲)PC/ASA 70:30wt%, (□)PC/ASA 60:40wt%, (◇)PC/ASA 50:50wt%, (△)ASA-978.

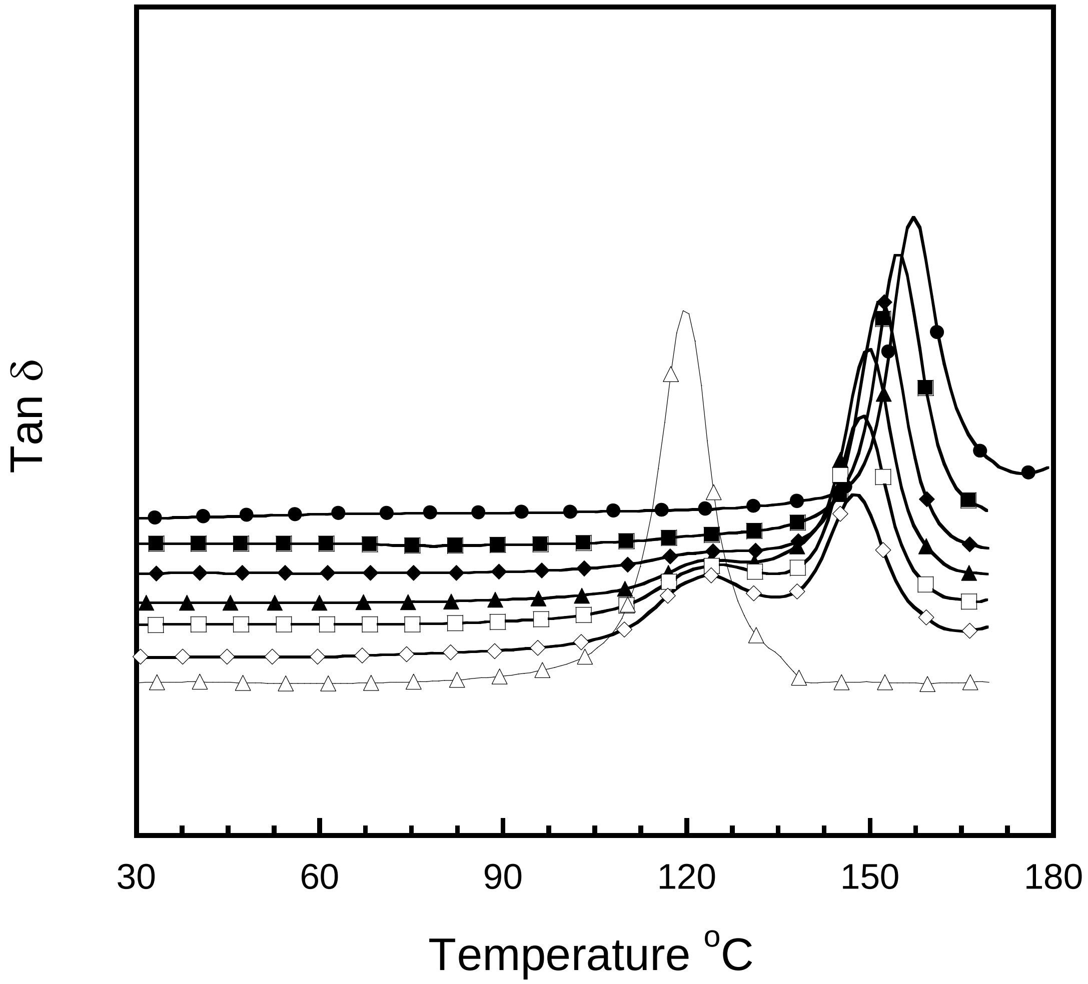


Figure 5.25: Loss tangent versus temperature (°C) of PC/ASA-777 blends at various blend ratios: (●)PC, (■)PC/ASA 90:10wt%, (◆)PC/ASA 80:20wt%, (▲)PC/ASA 70:30wt%, (□)PC/ASA 60:40wt%, (◇)PC/ASA 50:50wt%, (△)ASA-777.

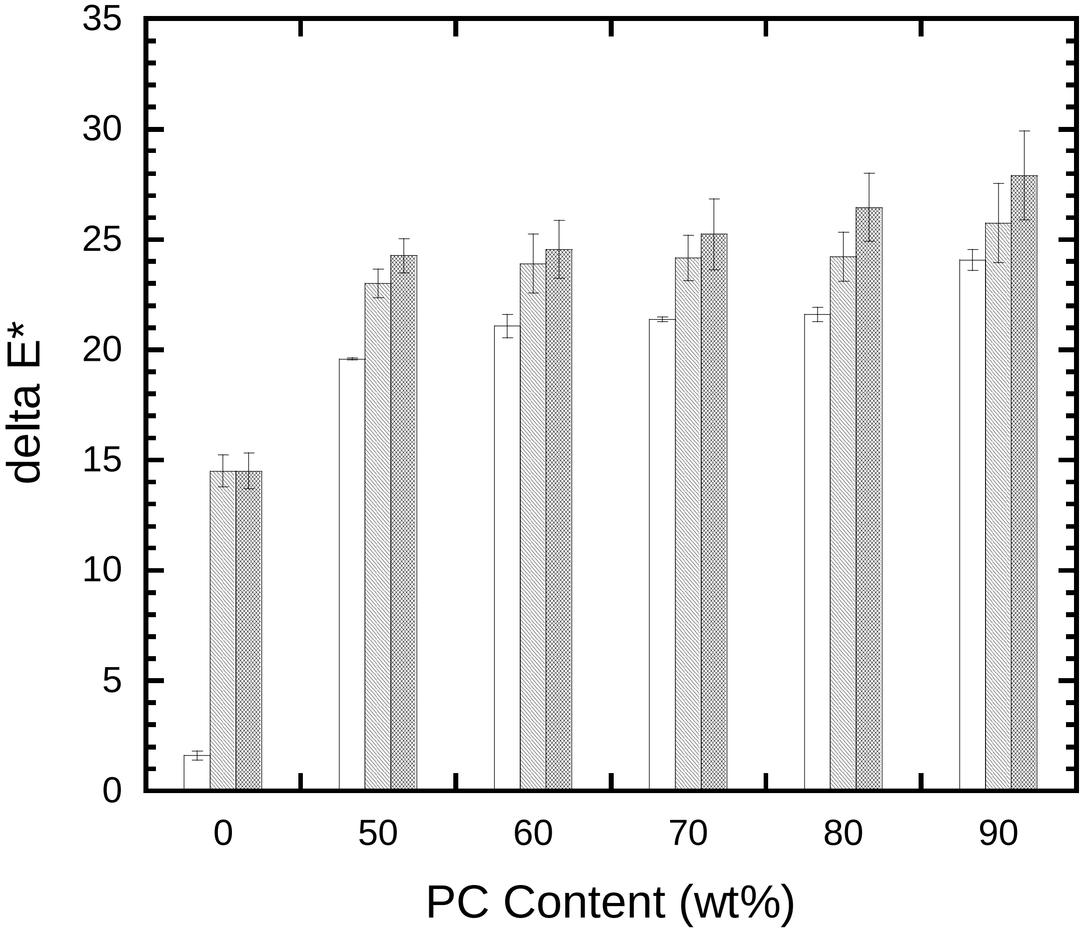


Figure 5.26: Color different after accelerated by QUV of PC/ASA-997 at various period time: (☐) 1 week, (▧) 2 weeks and (☒) 3 weeks.

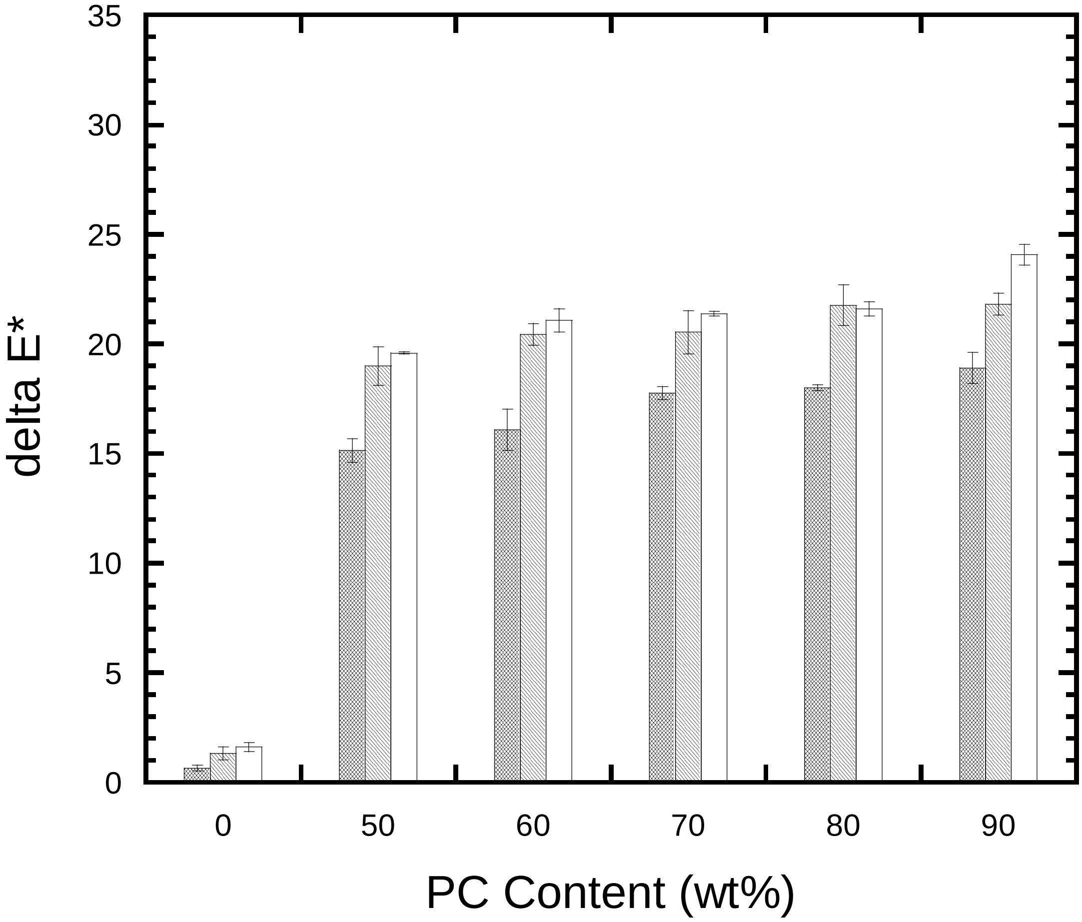


Figure 5.27: Color different after accelerated by QUV of all PC/ASA at various blend ratios for 1 week in QUV: (☐) PC/ASA-997, (▧)PC/ASA-978 and (☒) PC/ASA-777.

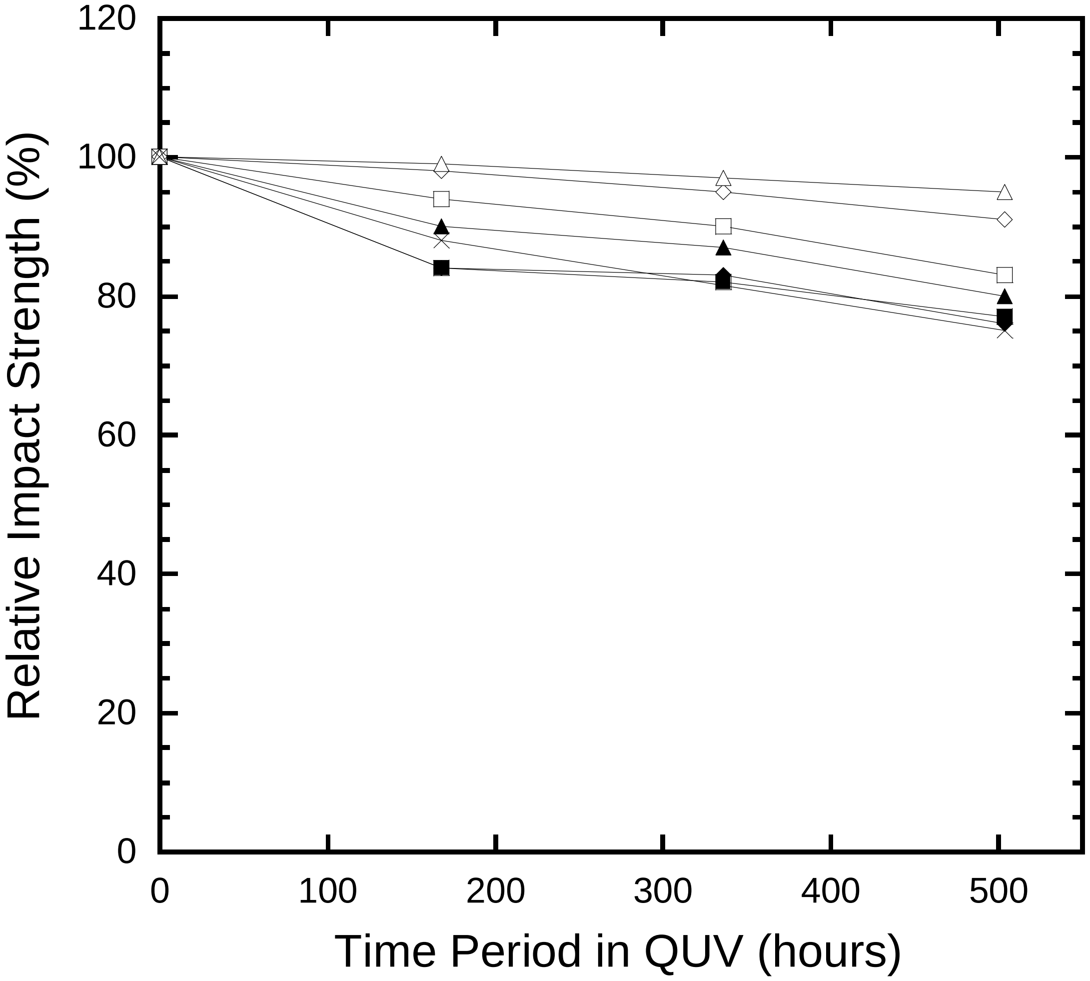


Figure 5.28: Impact retention after weathering at various outdoor exposure times: (●)PC, (■)PC/ASA 90:10wt%, (◆)PC/ASA 80:20wt%, (▲)PC/ASA 70:30wt%**,** (□)PC/ASA 60:40wt%, (◇)PC/ASA 50:50wt%, (△)ASA-997, (x)PC/ABS/UV.

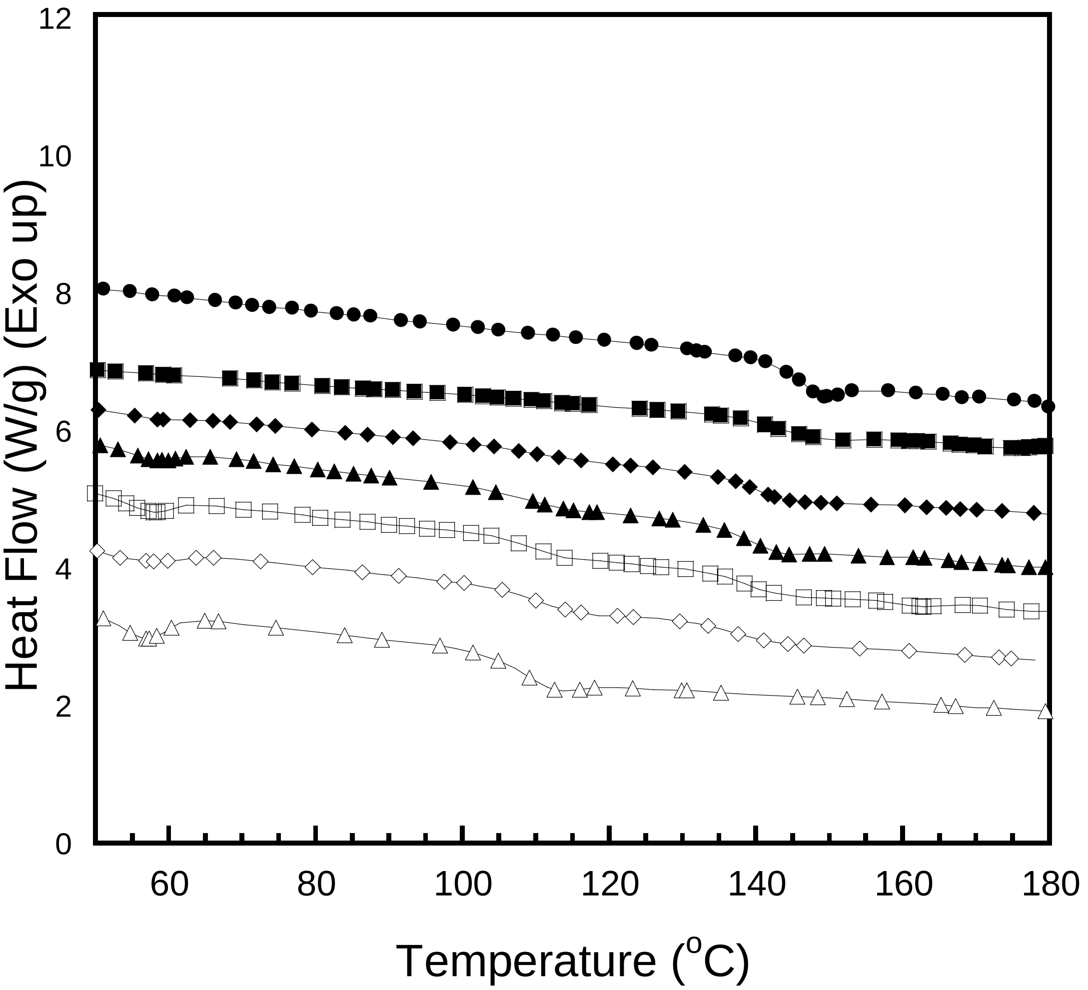


Figure 5.29: Differential scanning calorimetry (DSC) thermograms of PC/ASA-997 blends at various mass blending ratios: (●)PC, (■)PC/ASA 90:10wt%, (◆)PC/ASA 80:20wt%, (▲)PC/ASA 70:30wt%**,** (□)PC/ASA 60:40wt%, (◇)PC/ASA 50:50wt%, (△)ASA-997.

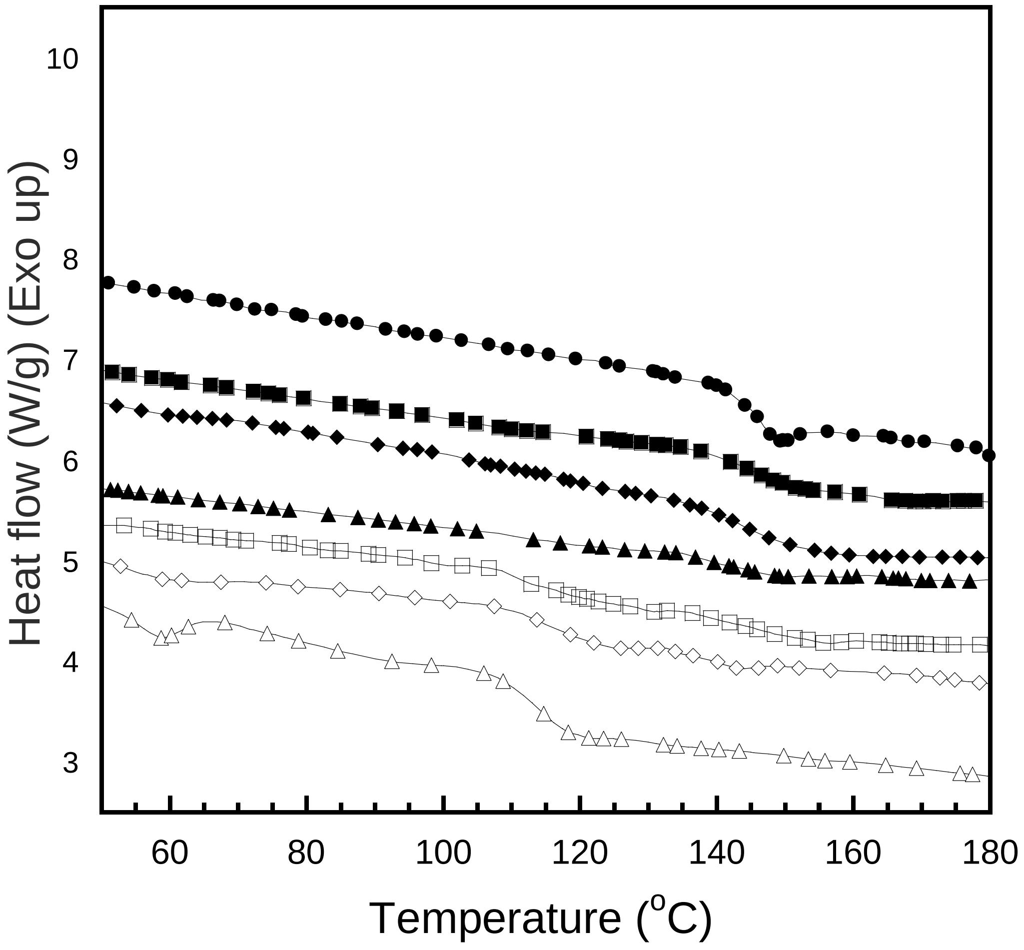


Figure 5.30: Differential scanning calorimetry (DSC) thermograms of PC/ASA-978 blends at various mass blending ratios: (●)PC, (■)PC/ASA 90:10wt%, (◆)PC/ASA 80:20wt%, (▲)PC/ASA 70:30wt%**,** (□)PC/ASA 60:40wt%, (◇)PC/ASA 50:50wt%, (△)ASA-978.

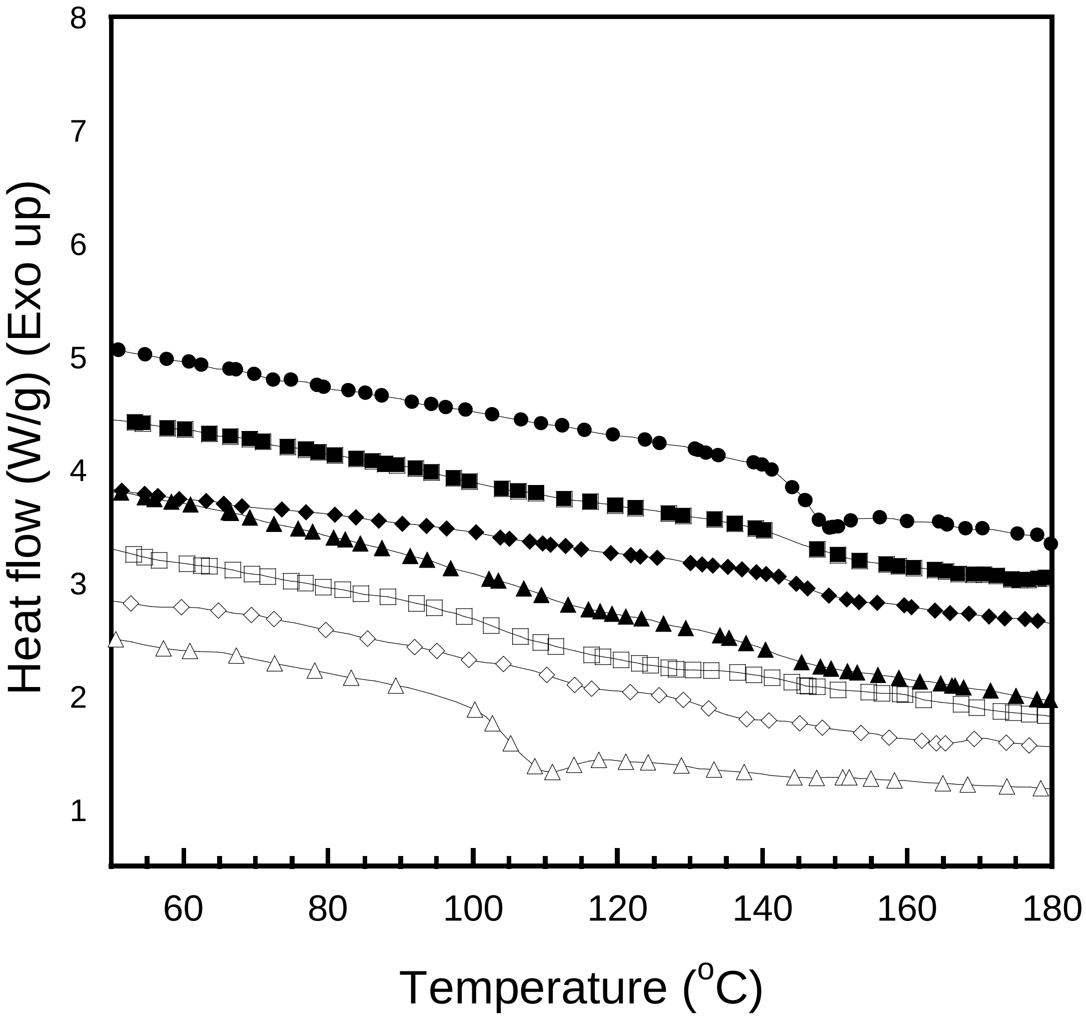


Figure 5.31: Differential scanning calorimetry (DSC) thermograms of PC/ASA-777 blends at various mass blending ratios: (●)PC, (■)PC/ASA 90:10wt%, (◆)PC/ASA 80:20wt%, (▲)PC/ASA 70:30wt%, (□)PC/ASA 60:40wt%, (◇)PC/ASA 50:50wt%, (△)ASA-777.

Table 5.7: Glass transition temperatures of all PC/ASA blends at various blend compositions from DSC curves.

Sample	**PC/ASA-997**		**PC/ASA-978**		**PC/ASA-777**	
	T_{g1} (^oC)	**T_{g2} (^oC)**	**T_{g1} (^oC)**	**T_{g2} (^oC)**	**T_{g1} (^oC)**	**T_{g2} (^oC)**
Pure PC	-	146	-	146	-	146
PC/ASA 90 : 10	**	144	**	145	**	145
PC/ASA 80 : 20	**	143	**	144	**	144
PC/ASA 70 : 30	112	142	118	142	110	143
PC/ASA 60 : 40	111	141	115	141	109	141
PC/ASA 50 : 50	110	139	115	140	107	139
Pure ASA	109	-	113	-	106	-

** undetectable

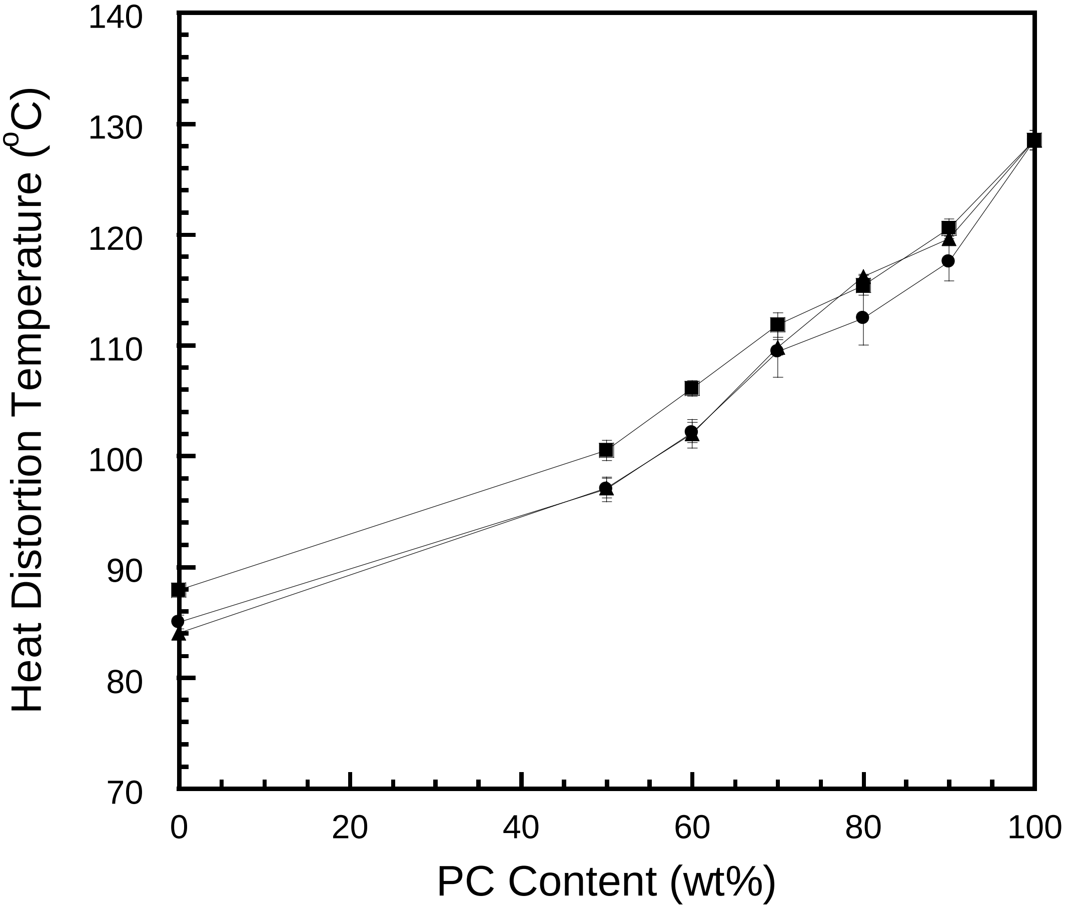


Figure 5.32: Heat distortion temperature (HDT) versus blend ratios of PC/ASA at various ASA grades: (•) PC/ASA-997, (■) PC/ASA-978 and (▲) PC/ASA-777.

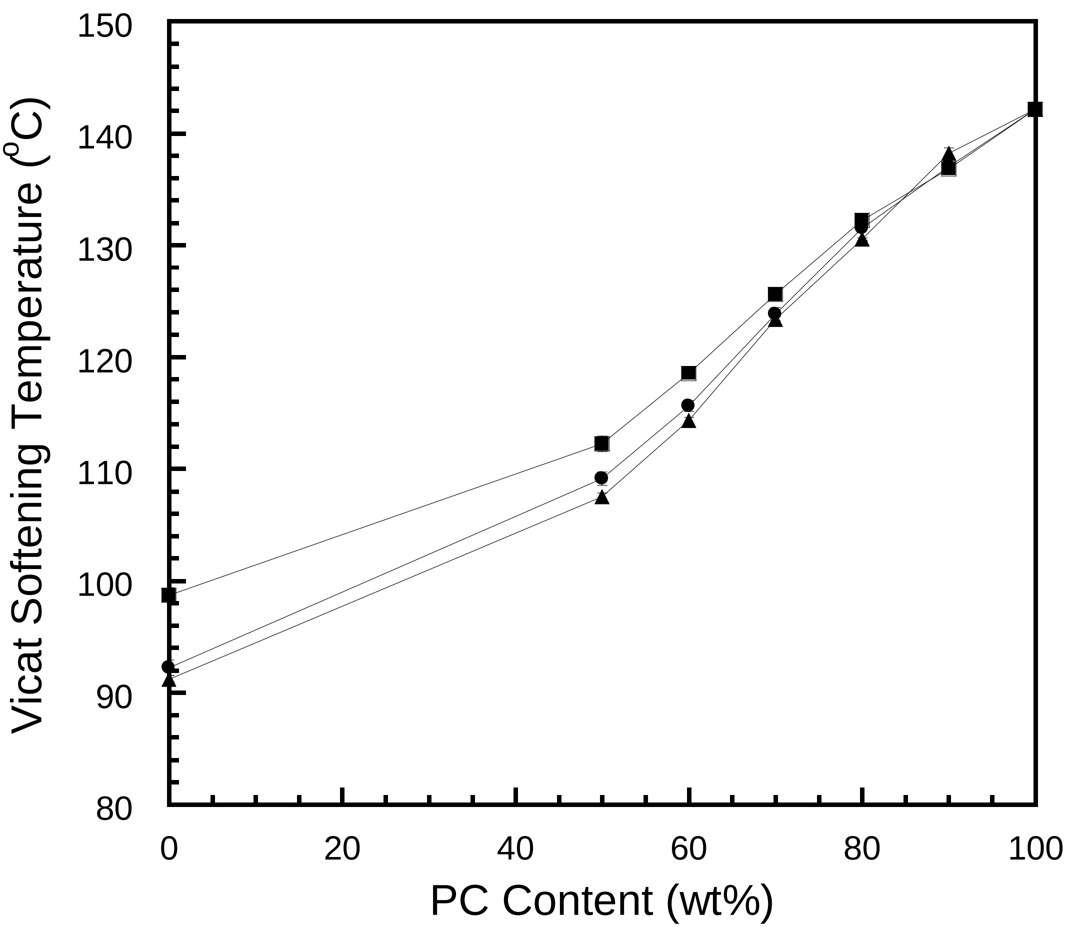


Figure 5.33: Vicat softening temperature versus blend ratios of PC/ASA at various ASA grades: (•) PC/ASA-997, (■) PC/ASA-978 and (▲) PC/ASA-777.

Table 5.8: Heat distortion temperature (HDT) and vicat softening temperature of all PC/ASA blends at various blend compositions.

Sample	PC/ASA-997		PC/ASA-978	
	HDT(^{o}C)	Vicat (^{o}C)	HDT(^{o}C)	Vicat (^{o}C)
Neat PC	129±0.9	142±0.6	129±0.9	142±0.6
PC/ASA 90:10	118±1.7	137±0.7	121±0.9	137±0.1
PC/ASA 80:20	112±2.4	132±1.2	115±0.9	132±0.4
PC/ASA 70:30	109±2.3	124±0.6	112±1.1	126±0.3
PC/ASA 60:40	102±0.9	116±0.5	106±0.7	119±0.3
PC/ASA 50:50	97±1.1	109±0.6	101±0.9	112±0.7
Neat ASA	85±0.6	92±0.7	88±0.6	99±0.1

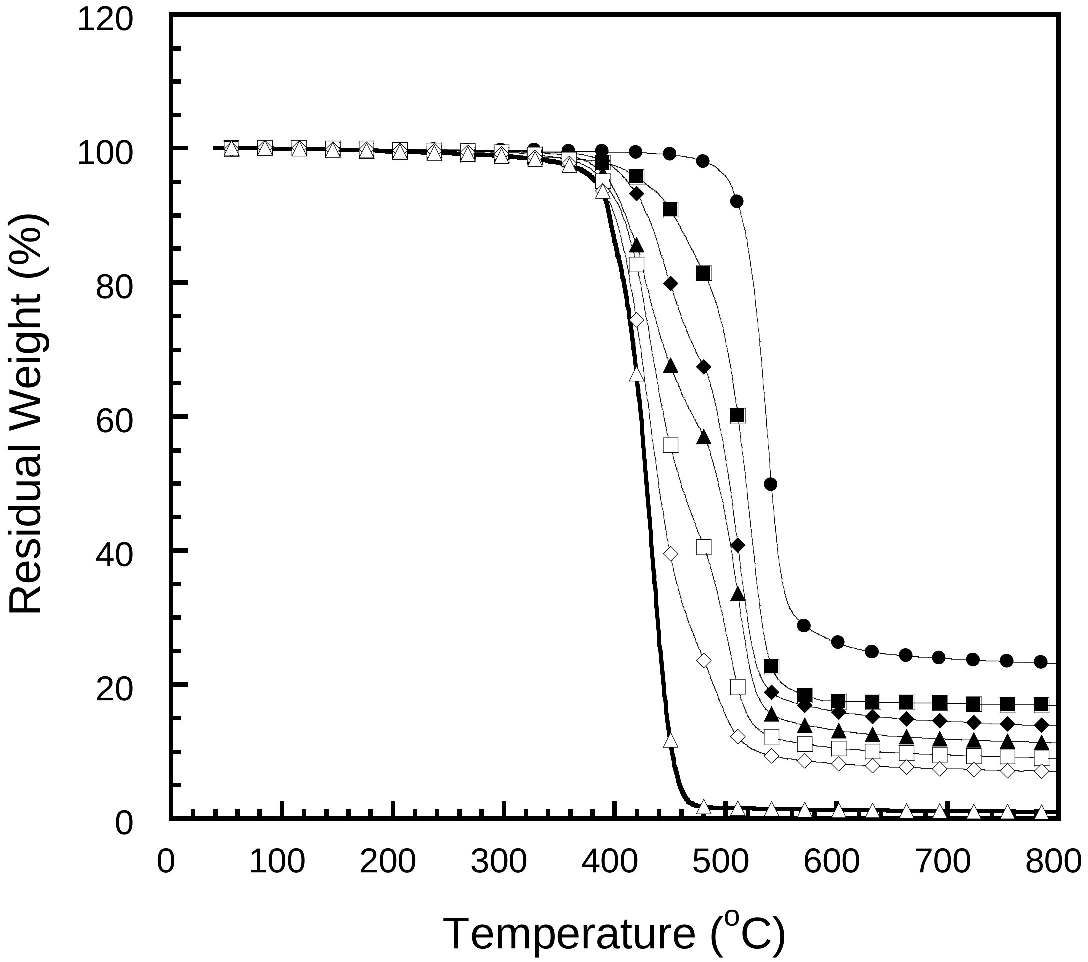


Figure 5.34 Thermogravimatric analysis (TGA) of PC/ASA-997 blends at various mass blending ratios: (●)PC, (■)PC/ASA 90:10wt%, (◆)PC/ASA 80:20wt%, (▲)PC/ASA 70:30wt%**,** (□)PC/ASA 60:40wt%, (◇)PC/ASA 50:50wt%, (△)ASA-997.

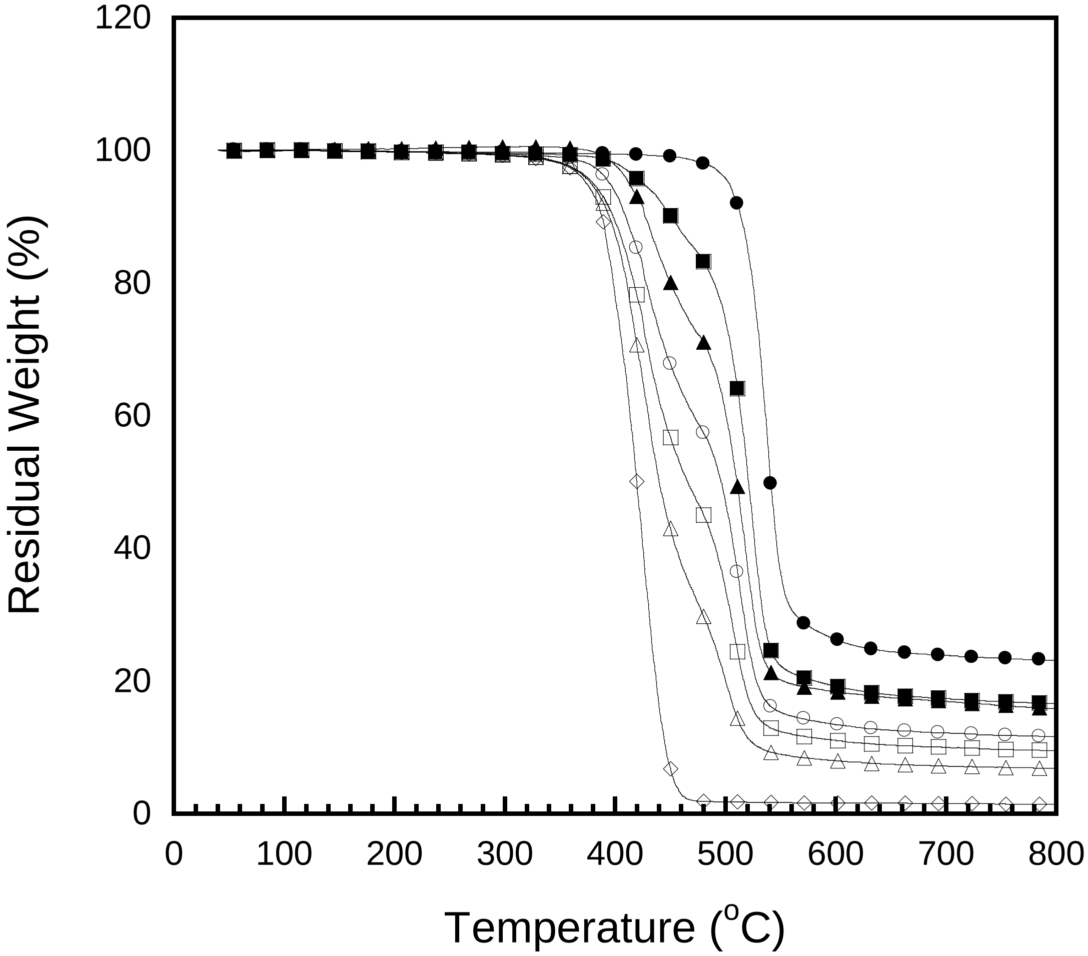


Figure 5.35: Thermogravimatric analysis (TGA) of PC/ASA-978 blends at various mass blending ratios: (●)PC, (■)PC/ASA 90:10wt%, (◆)PC/ASA 80:20wt%, (▲)PC/ASA 70:30wt%, (□)PC/ASA 60:40wt%, (◇)PC/ASA 50:50wt%, (△)ASA-978.

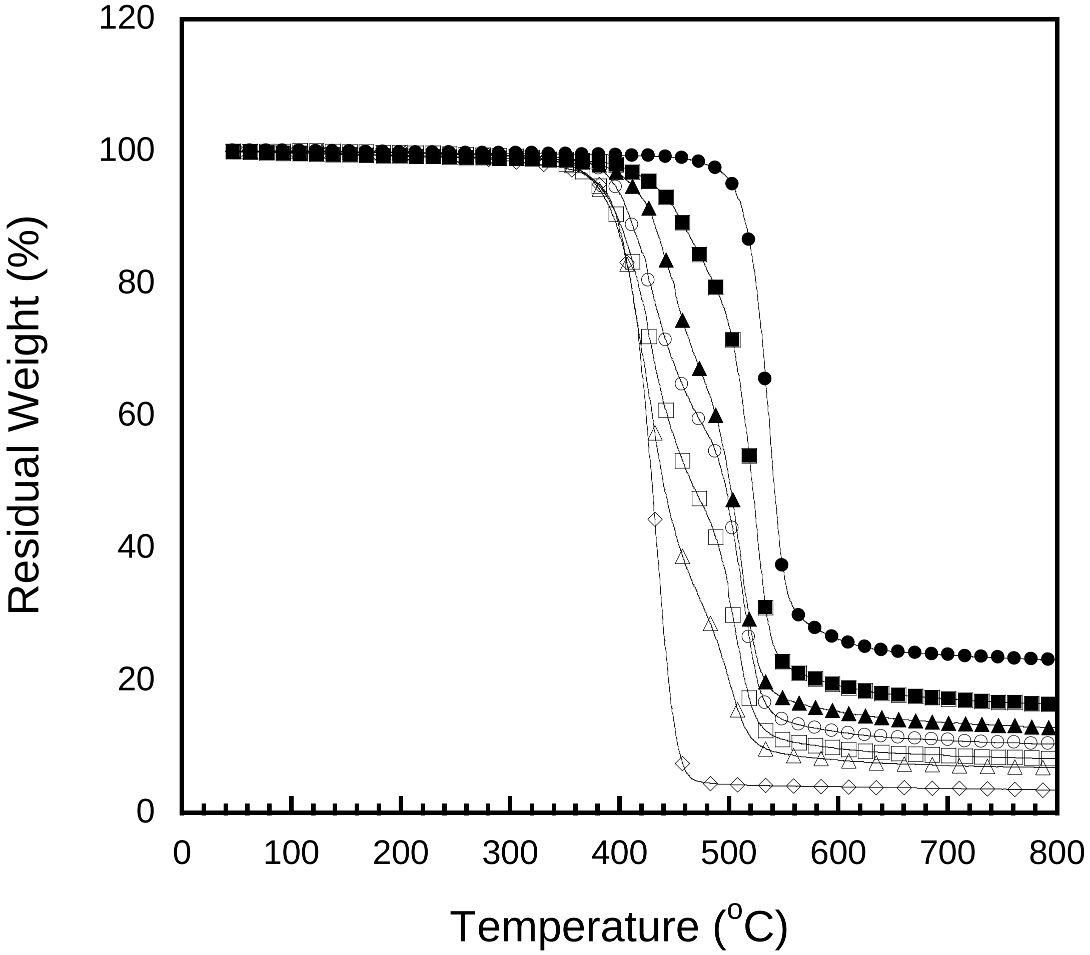


Figure 5.36: Thermogravimatric analysis (TGA) of PC/ASA-777 blends at various mass blending ratios: (●)PC, (■)PC/ASA 90:10wt%, (◆)PC/ASA 80:20wt%, (▲)PC/ASA 70:30wt%, (□)PC/ASA 60:40wt%, (◇)PC/ASA 50:50wt%, (△)ASA-777.

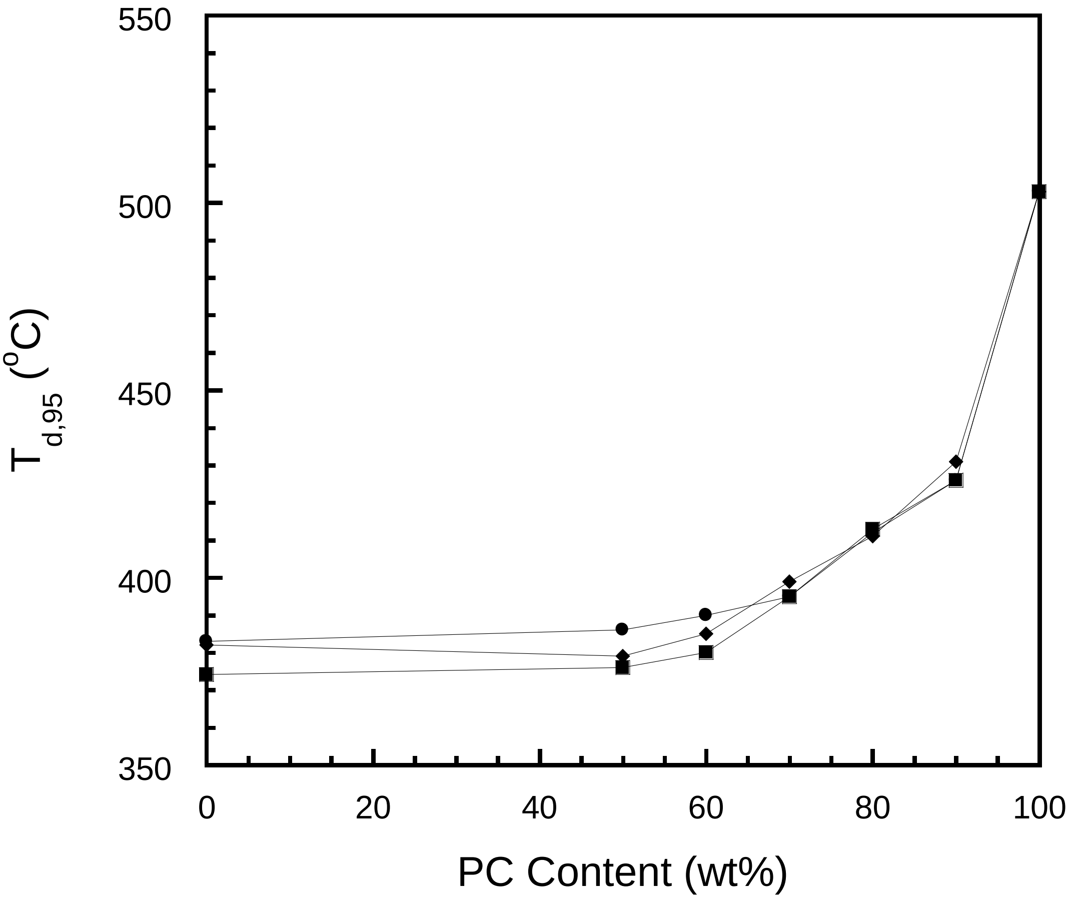


Figure 5.37: Degradation temperature (T_d) versus blend ratios of PC/ASA at various ASA grades: (●) PC/ASA-997, (■) PC/ASA-978, (◆) PC/ASA-777.

Table 5.9: Thermogravimetric analysis (TGA) of all PC/ASA blends at various blend compositions.

PC/ASA	ASA-997		ASA-978		ASA-777	
	T_d (^oC)	Char (%)	T_d (^oC)	Char (%)	T_d (^oC)	Char (%)
100:0	503	23.1	503	23.1	503	23.1
90:10	426	16.9	426	17.6	431	16.3
80:20	412	13.8	413	14.8	411	12.8
70:30	395	11.2	395	11.6	399	10.3
60:40	390	8.9	380	9.5	385	8.2
50:50	386	7.0	376	6.8	379	6.1
0:100	383	0.9	374	1.4	382	3.4

CHAPTER VI

CONCLUSIONS

1. Density of all PC/ASA blends systematically increased with an increase of PC contents following the rule of mixture.

2. Melt flow index of all PC/ASA blends increased steadily with increasing the percentages of ASAimplying flow property enhancement of the PC by the ASA fraction.

3. The complex viscosity of all PC/ASA blends increased with an increasing PC contents.

4. Water absorption at 24 hours of all PC/ASA was found to increase with the increasing of ASA content.

5. Rockwell hardness scale was reported in L-scale increasing with an increase of PC contents.

6. Processing temperature showed substantial effect on impact property of the blends. The optimal processing temperature tended to increase with the PC contents in the blend.

7. Notched Izod impact strength of all PC/ASA blends was found to increase steadily with an increasing PC content following the rule of mixture and was approached to commercial products.

8. Both tensile and flexural modulus values of all PC/ASA blends exhibited slightly positive deviation suggesting the better mixing due to viscosity reduction in the blends may also increase the uniformity in the obtained blend samples.

9. Both tensile and flexural strength values of all PC/ASA blends increased with increasing PC contents.

10. Storage modulus at room temperature of all PC/ASA blends was found to symmetrically increase increasing the amount of PC in the blends.

11. PC/ASA blends exhibited two glass transition temperature(T_gs). Both T_gs of ASA and PC phases shifted towards each other with increasing amount of PC suggesting the partially miscible nature of the PC/ASA blends.

12. Heat distortion & Vicat softening temperature of all PC/ASA blends increased steadily with an increase of PC content.

13. Degradation temperature(T_d) of all PC/ASA blends increased with an increasing PC contentslikewise char yield values of all PC/ASA blendsincreased with increasing PC contents.

14. Colore and impact retention after QUV exposure weathering test increased with increasing ASA content. These evidences indicated that ASA can significantly help improve the impact retention of the obtained PC/ASA blends.

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Appendix

CHIMEI
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CHI MEI CORPORATION

Typical Properties of WONDERLITE®(PC -110)

Typical Properties		Test Method	Unit	Condition	PC-110
Melt Flow Index		ASTM D1238	g/10min	300℃, 1.2 kg	10
Specific Gravity		ASTM D792	-	23/23℃	1.20
Water Absorption (immersion)		ASTM D570	%	24hr at 23℃	0.20
Light Transmission		ASTM D1003	%	3 mm thick	89
Haze		ASTM D1003	%	3.2 mm thick	< 0.8
Refractive Index		ASTM D542	-	-	1.585
Tensile Strength at Yield		ASTM D638	Kg/cm^2	1/8”,6 mm/min	630
Tensile Elongation	Yield	ASTM D638	%	1/8”,6 mm/min	6
	Break			1/8”,6 mm/min	110
Flexural Strength		ASTM D790	Kg/cm^2	1/4”,2.8 mm/min	920
Flexural Modulus		ASTM D790	Kg/cm^2	1/4”,2.8 mm/min	24000
Izod Impact Strength (Notched)		ASTM D256	Kg · cm/cm	1/4”	15
				1/8”	87
Rockwell Hardness		ASTM D785	M Scale	-	M-77
Compressive Strength		ASTM D695	Kg/cm^2	-	780
Heat Distortion Temperature (unannealed)		ASTM D648	℃	4.6 Kg/cm^2, 120℃/hr	136
				18.6 Kg/cm^2, 120℃/hr	125
Vicat Softening Temperature		ASTM D1525	℃	1 Kg, 50℃/hr	150
Coefficient of Linear Expansion		ASTM D696	x10^{-5} cm/cm/℃	40~100℃	6~8
Thermal Conductivity		ASTM C177	W/m℃	-	0.2
Mold Shrinkage		ASTM D955	%	parallel	0.5-0.7
				across	0.5-0.7
Flammability		UL 94	-	-	2.5mm V-2
Volume Resistivity		ASTM D257	x10^{16}Ω.cm	-	3
Dielectric Constant		ASTM D150	-	60 Hz	2.95
				10^6 Hz	2.9
Dielectric Dissipation Factor (tanδ)		ASTM D150	-	60 Hz	0.0004
				10^6 Hz	0.009
Dielectric Breakdown Strength		ASTM D149	kV/mm	1.6mm	30
Arc Resistance (Tungsten electrode)		ASTM D495	sec	-	110

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Typical Properties of KIBILAC®PW-978B

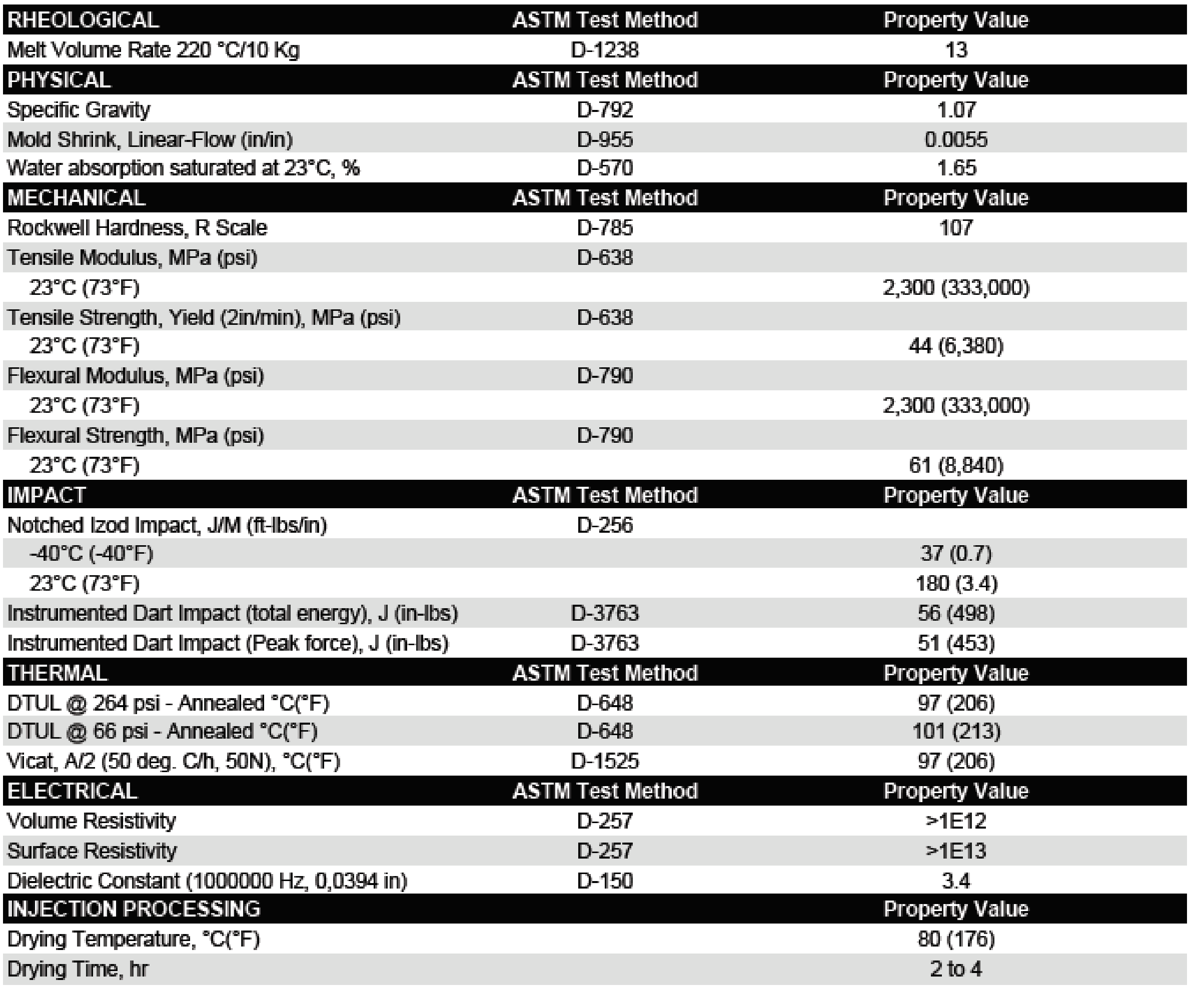
特性(Properties)	測試方法(Test Method)	測試條件(Test Condition)	單位(Unit)	PW-978B
引張強度 Tensile Strength	ASTM D638	1/8”,6 mm/min	Kg/cm^2(lb/in^2)	470(6665)
彎曲強度 Flexural Strength	ASTM D790	1/4”,2.8 mm/min	Kg/cm^2(lb/in^2)	680(9610)
IZOD 衝擊強度 Izod Impact Strength	ASTM D256(Notched)	1/4”,23℃ 1/8”,23℃	Kg-cm/cm(ft-lb/in) Kg-cm/cm(ft-lb/in)	11(2.0) 25(4.6)
流動係數 Melt Flow Index	ASTM D1238	220℃, 10Kg	g/10min	13
比重 Specific Gravity	ASTM D792	23℃	-	1.07
光澤度 Gloss	ASTM D523	-	-	97
軟化點 Vicat Softening Temp	ASTM D1525	1/8”,50℃/hr	℃(℉)	113(235)
熱變形溫度 H.D.T Annealed Unannealed	ASTM D648	1/4”,120℃/hr	℃(℉)	103(217) 93(199)

CHIMEI
奇美實業股份有限公司
CHI MEI CORPORATION

Typical Properties of KIBILAC®PW-997S

Properties	Test Method	Test Condition	Unit	PW-997S
Tensile Strength	ASTM D638	1/8”,6 mm/min	Kg/cm^2(lb/in^2)	450(6380)
Flexural Strength	ASTM D790	1/4”,2.8 mm/min	Kg/cm^2(lb/in^2)	660(9330)
IZOD Izod Impact Strength	ASTM D256(Notched)	1/4”,23℃ 1/8”,23℃	Kg-cm/cm(ft-lb/in) Kg-cm/cm(ft-lb/in)	25(4.6) 40(7.4)
Melt Flow Index	ISO1133	220℃,10Kg	g/10min	4
Gloss	ASTM D525		%	93
Specific Gravity	ASTM D792	23℃	-	1.07
Vicat Softening Temp	ASTM D1525	1/8”,50℃/hr	℃(℉)	105(221)
H.D.T Annealed Unannealed	ASTM D648	1/4”,120℃/hr	℃(℉)	95(203) 85(185)

Typical Properties of Luran®S 777K



RHEOLOGICAL	ASTM Test Method	Property Value
Melt Volume Rate 220 °C/10 Kg	D-1238	13
PHYSICAL	**ASTM Test Method**	**Property Value**
Specific Gravity	D-792	1.07
Mold Shrink, Linear-Flow (in/in)	D-955	0.0055
Water absorption saturated at 23°C, %	D-570	1.65
MECHANICAL	**ASTM Test Method**	**Property Value**
Rockwell Hardness, R Scale	D-785	107
Tensile Modulus, MPa (psi)	D-638	
23°C (73°F)		2,300 (333,000)
Tensile Strength, Yield (2in/min), MPa (psi)	D-638	
23°C (73°F)		44 (6,380)
Flexural Modulus, MPa (psi)	D-790	
23°C (73°F)		2,300 (333,000)
Flexural Strength, MPa (psi)	D-790	
23°C (73°F)		61 (8,840)
IMPACT	**ASTM Test Method**	**Property Value**
Notched Izod Impact, J/M (ft-lbs/in)	D-256	
-40°C (-40°F)		37 (0.7)
23°C (73°F)		180 (3.4)
Instrumented Dart Impact (total energy), J (in-lbs)	D-3763	56 (498)
Instrumented Dart Impact (Peak force), J (in-lbs)	D-3763	51 (453)
THERMAL	**ASTM Test Method**	**Property Value**
DTUL @ 264 psi - Annealed °C(°F)	D-648	97 (206)
DTUL @ 66 psi - Annealed °C(°F)	D-648	101 (213)
Vicat, A/2 (50 deg. C/h, 50N), °C(°F)	D-1525	97 (206)
ELECTRICAL	**ASTM Test Method**	**Property Value**
Volume Resistivity	D-257	>1E12
Surface Resistivity	D-257	>1E13
Dielectric Constant (1000000 Hz, 0,0394 in)	D-150	3.4
INJECTION PROCESSING		**Property Value**
Drying Temperature, °C(°F)		80 (176)
Drying Time, hr		2 to 4

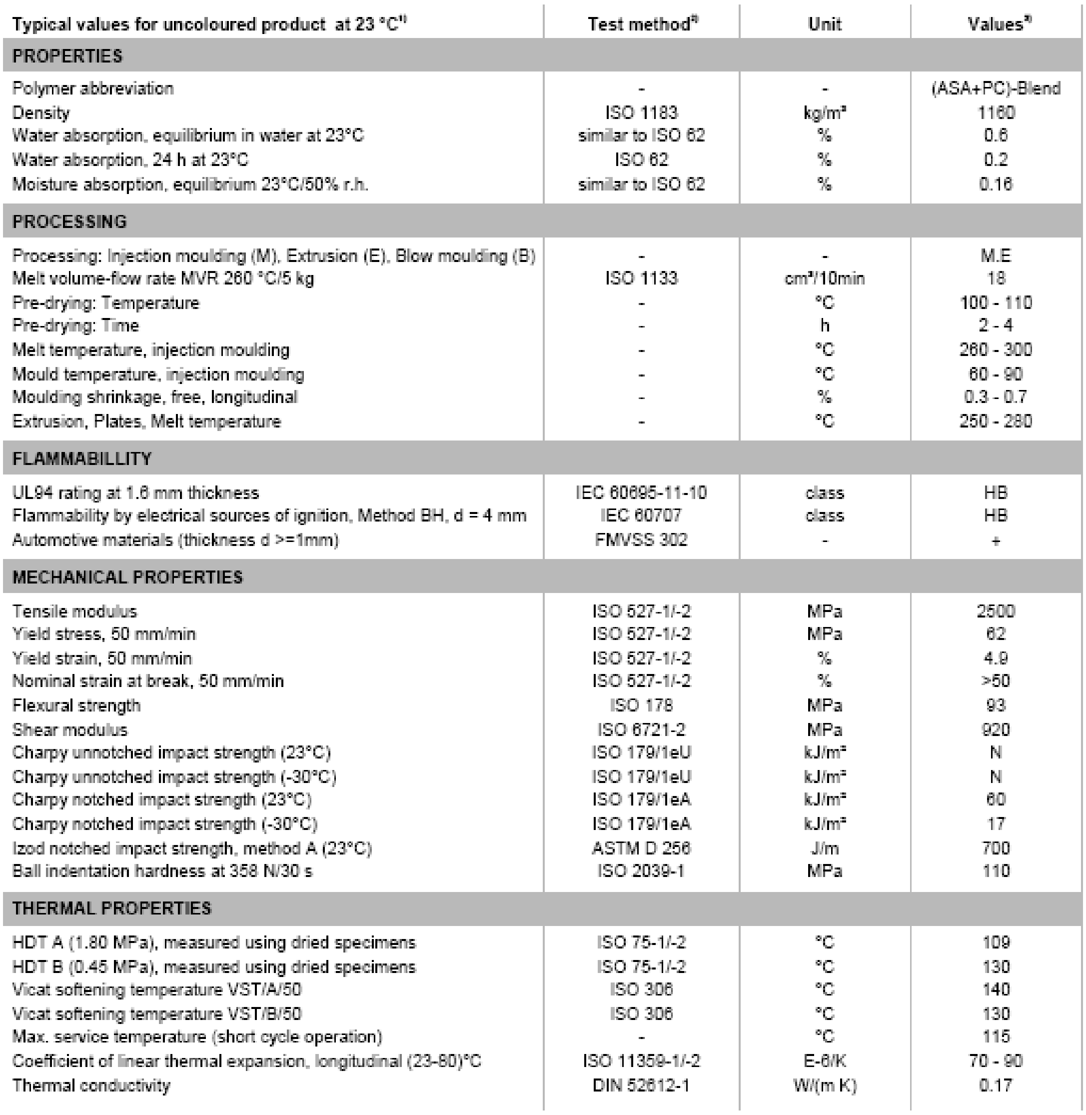
PRODUCT INFORMATION

STYROLUTION

Luran® S 09-2011

KR 2863 C (ASA+PC)-Blend

PC/ASA KR 2863 C



Typical values for uncoloured product at 23 °C$^{1)}$	Test method$^{2)}$	Unit	Values$^{3)}$
PROPERTIES			
Polymer abbreviation	-	-	(ASA+PC)-Blend
Density	ISO 1183	kg/m^3	1160
Water absorption, equilibrium in water at 23°C	similar to ISO 62	%	0.6
Water absorption, 24 h at 23°C	ISO 62	%	0.2
Moisture absorption, equilibrium 23°C/50% r.h.	similar to ISO 62	%	0.16
PROCESSING			
Processing: Injection moulding (M), Extrusion (E), Blow moulding (B)	-	-	M.E
Melt volume-flow rate MVR 260 °C/5 kg	ISO 1133	cm^3/10min	18
Pre-drying: Temperature	-	°C	100 - 110
Pre-drying: Time	-	h	2 - 4
Melt temperature, injection moulding	-	°C	260 - 300
Mould temperature, injection moulding	-	°C	60 - 90
Moulding shrinkage, free, longitudinal	-	%	0.3 - 0.7
Extrusion, Plates, Melt temperature	-	°C	250 - 280
FLAMMABILLITY			
UL94 rating at 1.6 mm thickness	IEC 60695-11-10	class	HB
Flammability by electrical sources of ignition, Method BH, d = 4 mm	IEC 60707	class	HB
Automotive materials (thickness d >=1mm)	FMVSS 302	-	+
MECHANICAL PROPERTIES			
Tensile modulus	ISO 527-1/-2	MPa	2500
Yield stress, 50 mm/min	ISO 527-1/-2	MPa	62
Yield strain, 50 mm/min	ISO 527-1/-2	%	4.9
Nominal strain at break, 50 mm/min	ISO 527-1/-2	%	>50
Flexural strength	ISO 178	MPa	93
Shear modulus	ISO 6721-2	MPa	920
Charpy unnotched impact strength (23°C)	ISO 179/1eU	kJ/m^2	N
Charpy unnotched impact strength (-30°C)	ISO 179/1eU	kJ/m^2	N
Charpy notched impact strength (23°C)	ISO 179/1eA	kJ/m^2	60
Charpy notched impact strength (-30°C)	ISO 179/1eA	kJ/m^2	17
Izod notched impact strength, method A (23°C)	ASTM D 256	J/m	700
Ball indentation hardness at 358 N/30 s	ISO 2039-1	MPa	110
THERMAL PROPERTIES			
HDT A (1.80 MPa), measured using dried specimens	ISO 75-1/-2	°C	109
HDT B (0.45 MPa), measured using dried specimens	ISO 75-1/-2	°C	130
Vicat softening temperature VST/A/50	ISO 306	°C	140
Vicat softening temperature VST/B/50	ISO 306	°C	130
Max. service temperature (short cycle operation)	-	°C	115
Coefficient of linear thermal expansion, longitudinal (23-80)°C	ISO 11359-1/-2	E-6/K	70 - 90
Thermal conductivity	DIN 52612-1	W/(m K)	0.17

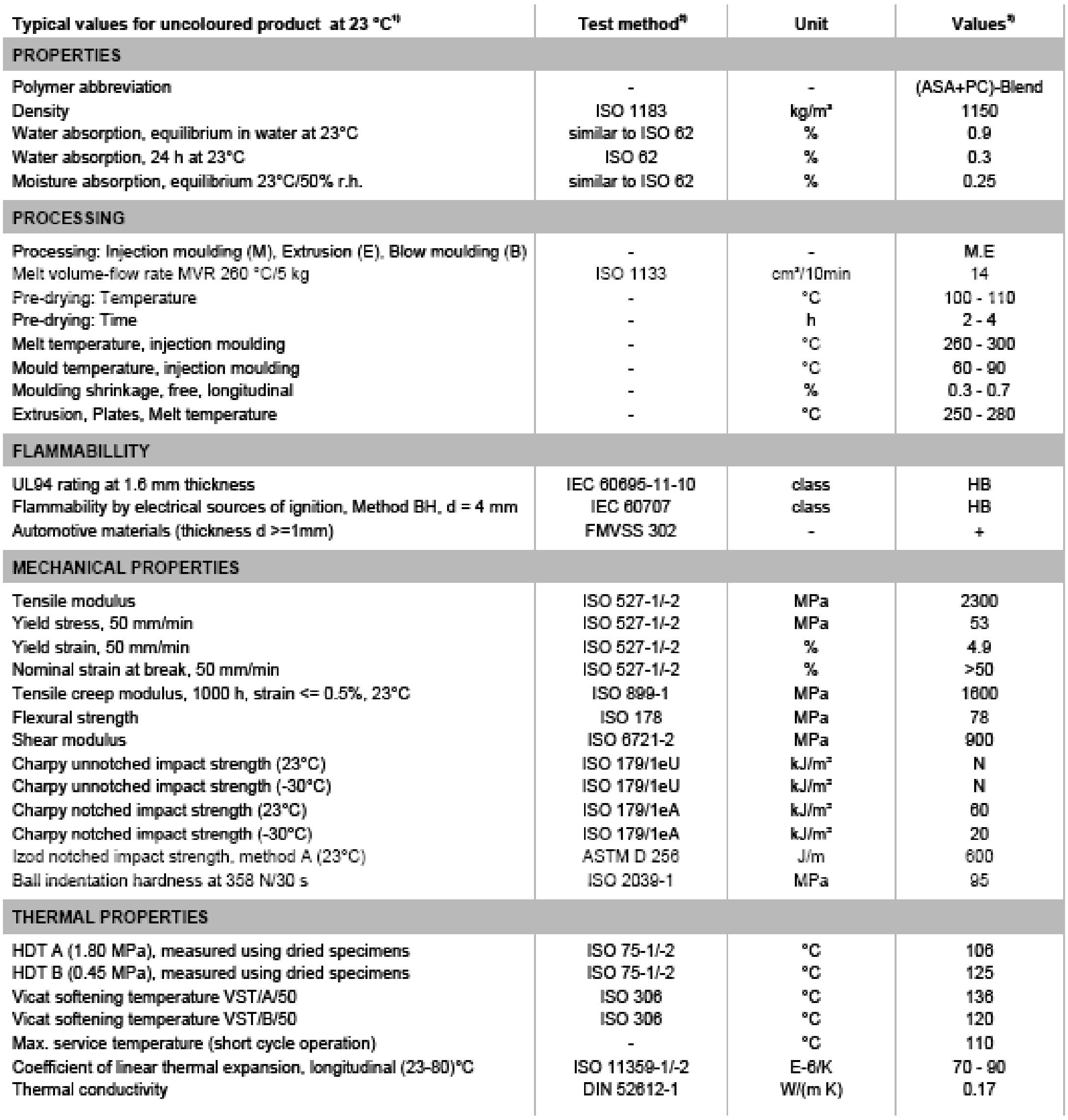
PRODUCT INFORMATION

STYROLUTION

Luran® S 09-2011

KR 2861/1 C (ASA+PC)-Blend

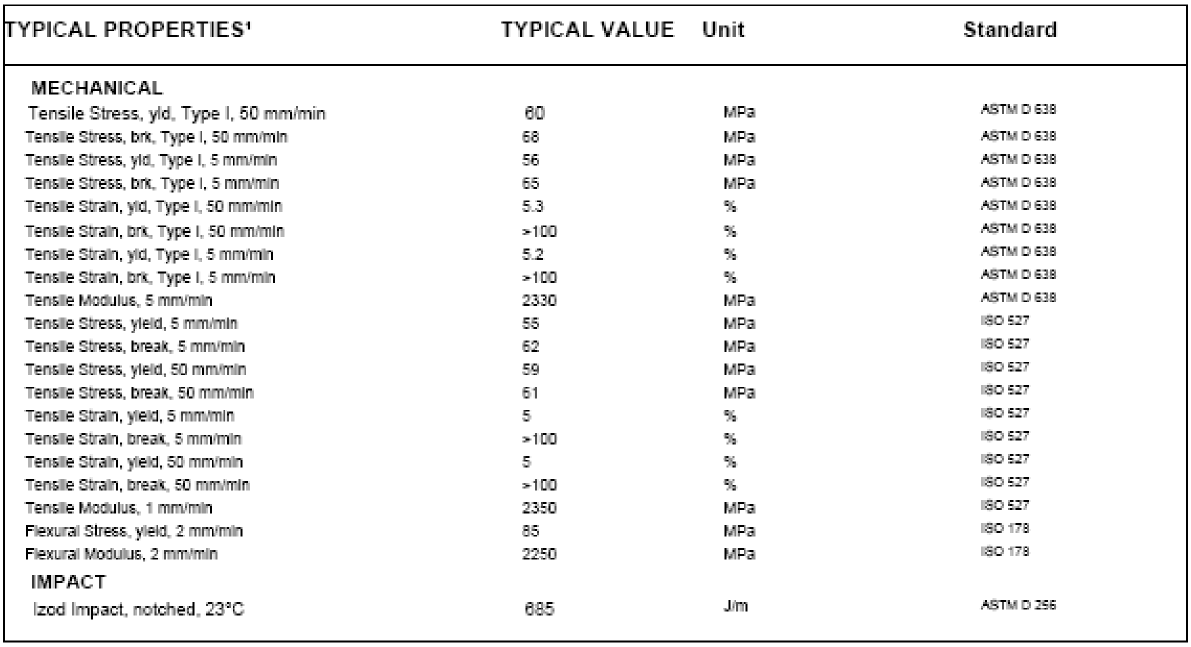
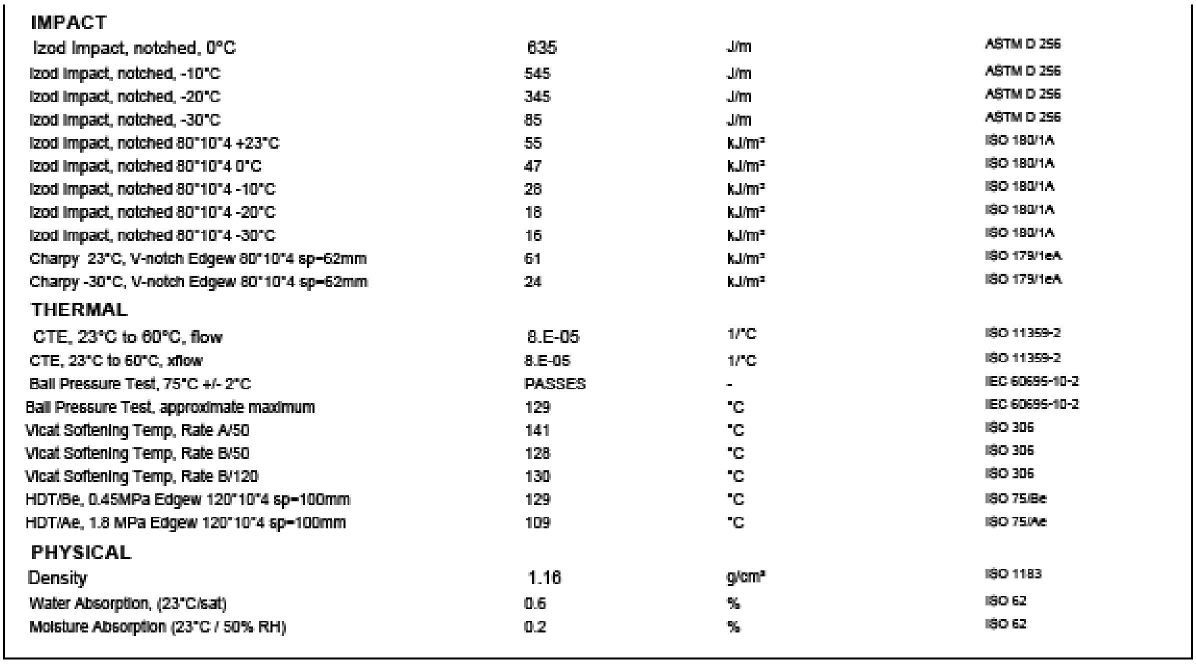
PC/ASA KR 2861/1 C



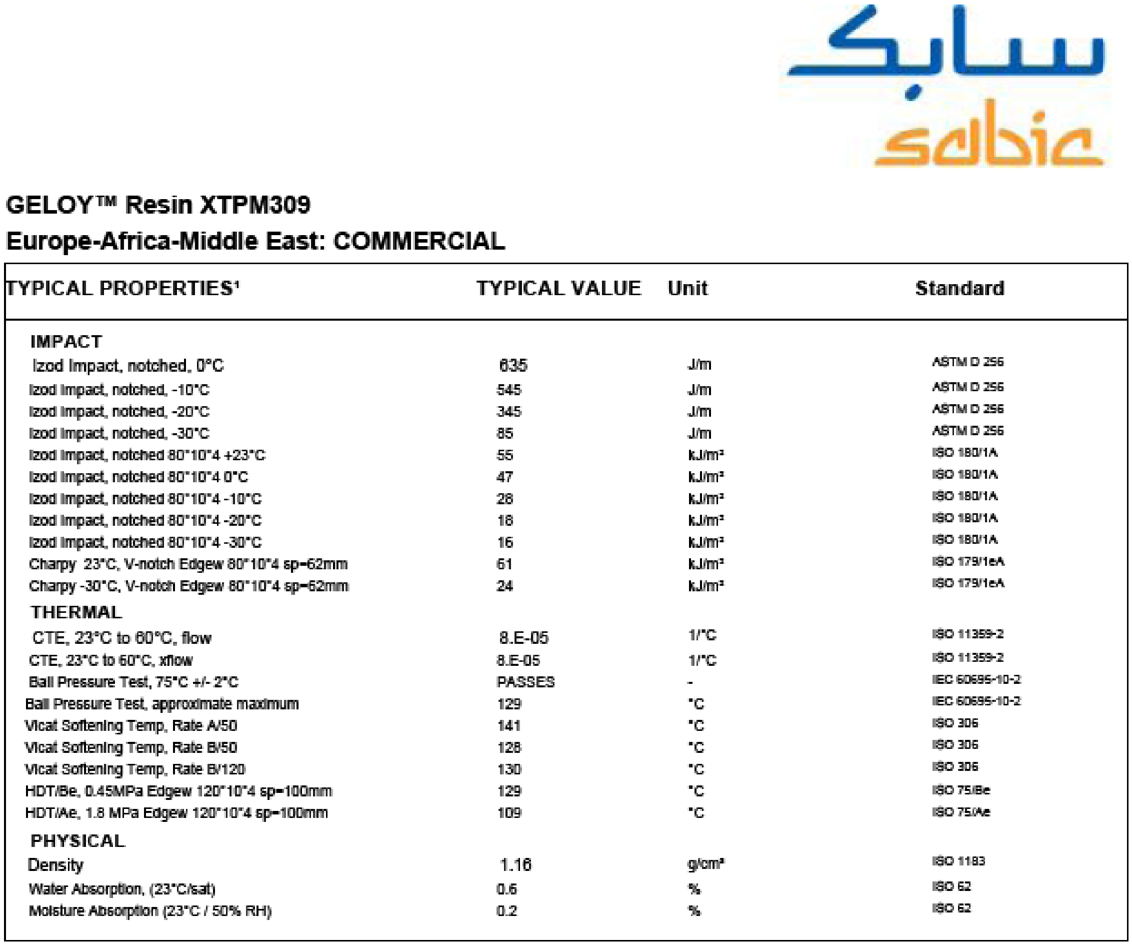
Typical values for uncoloured product at 23 °C[1]	Test method[2]	Unit	Values[3]
PROPERTIES			
Polymer abbreviation	-	-	(ASA+PC)-Blend
Density	ISO 1183	kg/m^3	1150
Water absorption, equilibrium in water at 23°C	similar to ISO 62	%	0.9
Water absorption, 24 h at 23°C	ISO 62	%	0.3
Moisture absorption, equilibrium 23°C/50% r.h.	similar to ISO 62	%	0.25
PROCESSING			
Processing: Injection moulding (M), Extrusion (E), Blow moulding (B)	-	-	M.E
Melt volume-flow rate MVR 260 °C/5 kg	ISO 1133	cm^3/10min	14
Pre-drying: Temperature	-	°C	100 - 110
Pre-drying: Time	-	h	2 - 4
Melt temperature, injection moulding	-	°C	260 - 300
Mould temperature, injection moulding	-	°C	60 - 90
Moulding shrinkage, free, longitudinal	-	%	0.3 - 0.7
Extrusion, Plates, Melt temperature	-	°C	250 - 280
FLAMMABILLITY			
UL94 rating at 1.6 mm thickness	IEC 60695-11-10	class	HB
Flammability by electrical sources of ignition, Method BH, d = 4 mm	IEC 60707	class	HB
Automotive materials (thickness d >=1mm)	FMVSS 302	-	+
MECHANICAL PROPERTIES			
Tensile modulus	ISO 527-1/-2	MPa	2300
Yield stress, 50 mm/min	ISO 527-1/-2	MPa	53
Yield strain, 50 mm/min	ISO 527-1/-2	%	4.9
Nominal strain at break, 50 mm/min	ISO 527-1/-2	%	>50
Tensile creep modulus, 1000 h, strain <= 0.5%, 23°C	ISO 899-1	MPa	1600
Flexural strength	ISO 178	MPa	78
Shear modulus	ISO 6721-2	MPa	900
Charpy unnotched impact strength (23°C)	ISO 179/1eU	kJ/m^2	N
Charpy unnotched impact strength (-30°C)	ISO 179/1eU	kJ/m^2	N
Charpy notched impact strength (23°C)	ISO 179/1eA	kJ/m^2	60
Charpy notched impact strength (-30°C)	ISO 179/1eA	kJ/m^2	20
Izod notched impact strength, method A (23°C)	ASTM D 256	J/m	600
Ball indentation hardness at 358 N/30 s	ISO 2039-1	MPa	95
THERMAL PROPERTIES			
HDT A (1.80 MPa), measured using dried specimens	ISO 75-1/-2	°C	106
HDT B (0.45 MPa), measured using dried specimens	ISO 75-1/-2	°C	125
Vicat softening temperature VST/A/50	ISO 306	°C	136
Vicat softening temperature VST/B/50	ISO 306	°C	120
Max. service temperature (short cycle operation)	-	°C	110
Coefficient of linear thermal expansion, longitudinal (23-80)°C	ISO 11359-1/-2	E-6/K	70 - 90
Thermal conductivity	DIN 52612-1	W/(m K)	0.17

GELOY™ Resin XTPM309
Europe-Africa-Middle East: COMMERCIAL

PC/ASA XTPM 309

TYPICAL PROPERTIES¹	TYPICAL VALUE	Unit	Standard
MECHANICAL			
Tensile Stress, yld, Type I, 50 mm/min	60	MPa	ASTM D 638
Tensile Stress, brk, Type I, 50 mm/min	68	MPa	ASTM D 638
Tensile Stress, yld, Type I, 5 mm/min	56	MPa	ASTM D 638
Tensile Stress, brk, Type I, 5 mm/min	65	MPa	ASTM D 638
Tensile Strain, yld, Type I, 50 mm/min	5.3	%	ASTM D 638
Tensile Strain, brk, Type I, 50 mm/min	>100	%	ASTM D 638
Tensile Strain, yld, Type I, 5 mm/min	5.2	%	ASTM D 638
Tensile Strain, brk, Type I, 5 mm/min	>100	%	ASTM D 638
Tensile Modulus, 5 mm/min	2330	MPa	ASTM D 638
Tensile Stress, yield, 5 mm/min	55	MPa	ISO 527
Tensile Stress, break, 5 mm/min	62	MPa	ISO 527
Tensile Stress, yield, 50 mm/min	59	MPa	ISO 527
Tensile Stress, break, 50 mm/min	61	MPa	ISO 527
Tensile Strain, yield, 5 mm/min	5	%	ISO 527
Tensile Strain, break, 5 mm/min	>100	%	ISO 527
Tensile Strain, yield, 50 mm/min	5	%	ISO 527
Tensile Strain, break, 50 mm/min	>100	%	ISO 527
Tensile Modulus, 1 mm/min	2350	MPa	ISO 527
Flexural Stress, yield, 2 mm/min	85	MPa	ISO 178
Flexural Modulus, 2 mm/min	2250	MPa	ISO 178
IMPACT			
Izod Impact, notched, 23°C	685	J/m	ASTM D 256
IMPACT			
Izod Impact, notched, 0°C	635	J/m	ASTM D 256
Izod Impact, notched, -10°C	545	J/m	ASTM D 256
Izod Impact, notched, -20°C	345	J/m	ASTM D 256
Izod Impact, notched, -30°C	85	J/m	ASTM D 256
Izod Impact, notched 80*10*4 +23°C	55	kJ/m^2	ISO 180/1A
Izod Impact, notched 80*10*4 0°C	47	kJ/m^2	ISO 180/1A
Izod Impact, notched 80*10*4 -10°C	28	kJ/m^2	ISO 180/1A
Izod Impact, notched 80*10*4 -20°C	18	kJ/m^2	ISO 180/1A
Izod Impact, notched 80*10*4 -30°C	16	kJ/m^2	ISO 180/1A
Charpy 23°C, V-notch Edgew 80*10*4 sp=62mm	61	kJ/m^2	ISO 179/1eA
Charpy -30°C, V-notch Edgew 80*10*4 sp=62mm	24	kJ/m^2	ISO 179/1eA
THERMAL			
CTE, 23°C to 60°C, flow	8.E-05	1/°C	ISO 11359-2
CTE, 23°C to 60°C, xflow	8.E-05	1/°C	ISO 11359-2
Ball Pressure Test, 75°C +/- 2°C	PASSES	-	IEC 60695-10-2
Ball Pressure Test, approximate maximum	129	°C	IEC 60695-10-2
Vicat Softening Temp, Rate A/50	141	°C	ISO 306
Vicat Softening Temp, Rate B/50	128	°C	ISO 306
Vicat Softening Temp, Rate B/120	130	°C	ISO 306
HDT/Be, 0.45MPa Edgew 120*10*4 sp=100mm	129	°C	ISO 75/Be
HDT/Ae, 1.8 MPa Edgew 120*10*4 sp=100mm	109	°C	ISO 75/Ae
PHYSICAL			
Density	1.16	g/cm^3	ISO 1183
Water Absorption, (23°C/sat)	0.6	%	ISO 62
Moisture Absorption (23°C / 50% RH)	0.2	%	ISO 62



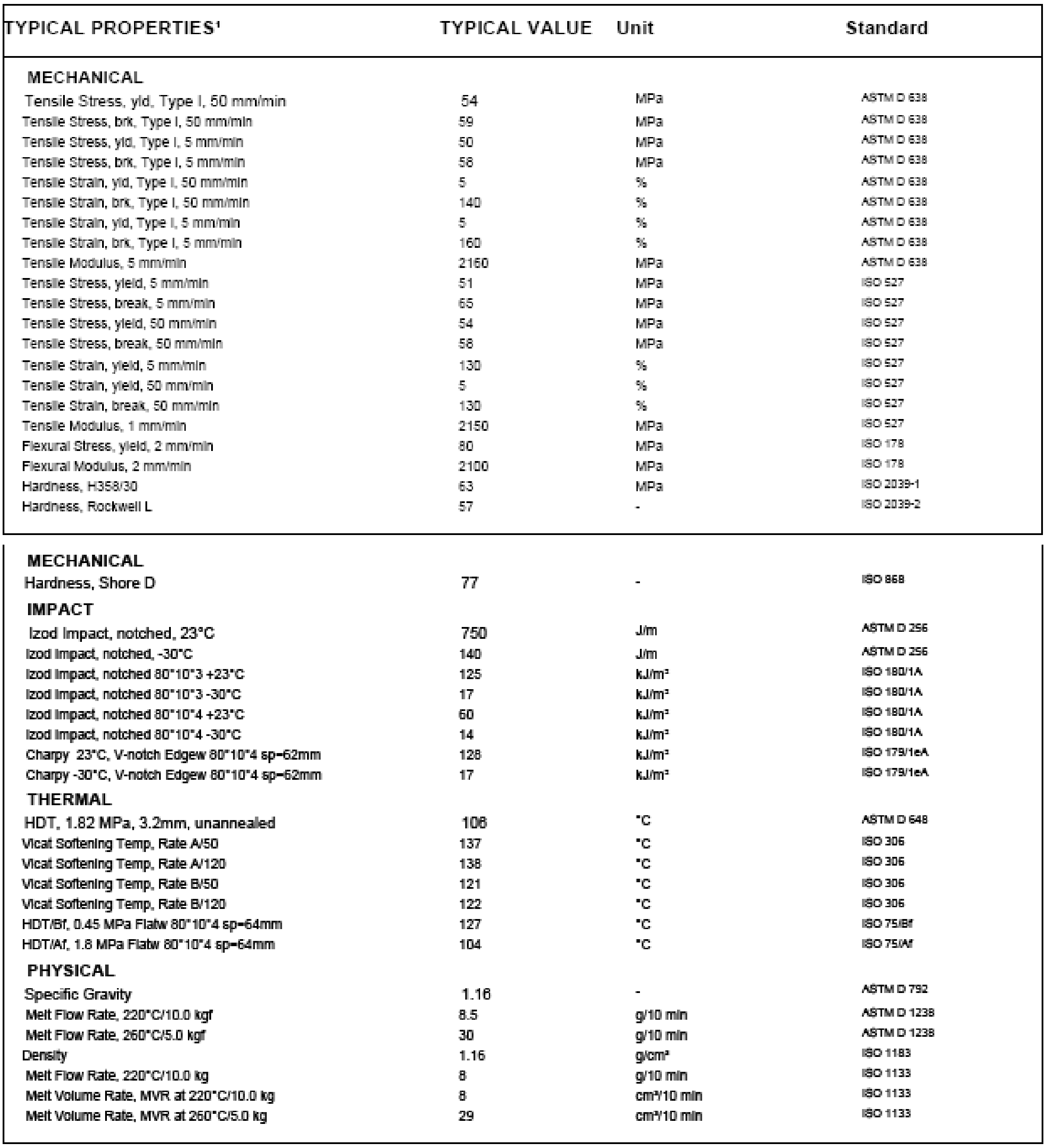
GELOY™ Resin XTPM309

Europe-Africa-Middle East: COMMERCIAL

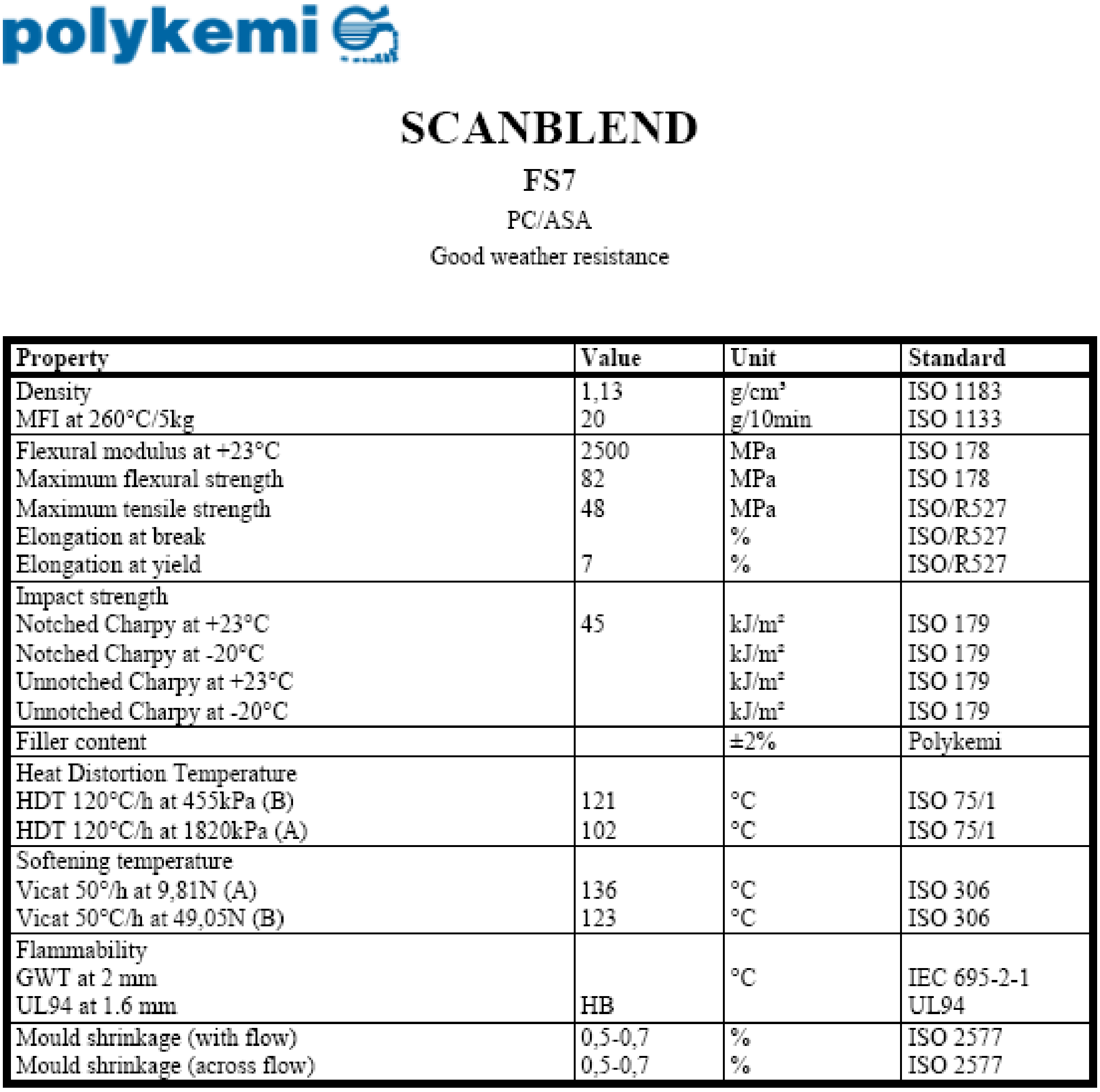
TYPICAL PROPERTIES[1]	TYPICAL VALUE	Unit	Standard
IMPACT			
Izod Impact, notched, 0°C	635	J/m	ASTM D 256
Izod Impact, notched, -10°C	545	J/m	ASTM D 256
Izod Impact, notched, -20°C	345	J/m	ASTM D 256
Izod Impact, notched, -30°C	85	J/m	ASTM D 256
Izod Impact, notched 80*10*4 +23°C	55	kJ/m^2	ISO 180/1A
Izod Impact, notched 80*10*4 0°C	47	kJ/m^2	ISO 180/1A
Izod Impact, notched 80*10*4 -10°C	28	kJ/m^2	ISO 180/1A
Izod Impact, notched 80*10*4 -20°C	18	kJ/m^2	ISO 180/1A
Izod Impact, notched 80*10*4 -30°C	16	kJ/m^2	ISO 180/1A
Charpy 23°C, V-notch Edgew 80*10*4 sp=62mm	61	kJ/m^2	ISO 179/1eA
Charpy -30°C, V-notch Edgew 80*10*4 sp=62mm	24	kJ/m^2	ISO 179/1eA
THERMAL			
CTE, 23°C to 60°C, flow	8.E-05	1/°C	ISO 11359-2
CTE, 23°C to 60°C, xflow	8.E-05	1/°C	ISO 11359-2
Ball Pressure Test, 75°C +/- 2°C	PASSES	-	IEC 60695-10-2
Ball Pressure Test, approximate maximum	129	°C	IEC 60695-10-2
Vicat Softening Temp, Rate A/50	141	°C	ISO 306
Vicat Softening Temp, Rate B/50	128	°C	ISO 306
Vicat Softening Temp, Rate B/120	130	°C	ISO 306
HDT/Be, 0.45MPa Edgew 120*10*4 sp=100mm	129	°C	ISO 75/Be
HDT/Ae, 1.8 MPa Edgew 120*10*4 sp=100mm	109	°C	ISO 75/Ae
PHYSICAL			
Density	1.18	g/cm^3	ISO 1183
Water Absorption, (23°C/sat)	0.6	%	ISO 62
Moisture Absorption (23°C / 50% RH)	0.2	%	ISO 62

GELOY™ Resin HRA170D
Europe-Africa-Middle East: COMMERCIAL

PC/ASA HRA 170D



TYPICAL PROPERTIES[1]	TYPICAL VALUE	Unit	Standard
MECHANICAL			
Tensile Stress, yld, Type I, 50 mm/min	54	MPa	ASTM D 638
Tensile Stress, brk, Type I, 50 mm/min	59	MPa	ASTM D 638
Tensile Stress, yld, Type I, 5 mm/min	50	MPa	ASTM D 638
Tensile Stress, brk, Type I, 5 mm/min	58	MPa	ASTM D 638
Tensile Strain, yld, Type I, 50 mm/min	5	%	ASTM D 638
Tensile Strain, brk, Type I, 50 mm/min	140	%	ASTM D 638
Tensile Strain, yld, Type I, 5 mm/min	5	%	ASTM D 638
Tensile Strain, brk, Type I, 5 mm/min	160	%	ASTM D 638
Tensile Modulus, 5 mm/min	2160	MPa	ASTM D 638
Tensile Stress, yield, 5 mm/min	51	MPa	ISO 527
Tensile Stress, break, 5 mm/min	65	MPa	ISO 527
Tensile Stress, yield, 50 mm/min	54	MPa	ISO 527
Tensile Stress, break, 50 mm/min	58	MPa	ISO 527
Tensile Strain, yield, 5 mm/min	130	%	ISO 527
Tensile Strain, yield, 50 mm/min	5	%	ISO 527
Tensile Strain, break, 50 mm/min	130	%	ISO 527
Tensile Modulus, 1 mm/min	2150	MPa	ISO 527
Flexural Stress, yield, 2 mm/min	80	MPa	ISO 178
Flexural Modulus, 2 mm/min	2100	MPa	ISO 178
Hardness, H358/30	63	MPa	ISO 2039-1
Hardness, Rockwell L	57	-	ISO 2039-2
MECHANICAL			
Hardness, Shore D	77	-	ISO 868
IMPACT			
Izod Impact, notched, 23°C	750	J/m	ASTM D 256
Izod Impact, notched, -30°C	140	J/m	ASTM D 256
Izod Impact, notched 80*10*3 +23°C	125	kJ/m^2	ISO 180/1A
Izod Impact, notched 80*10*3 -30°C	17	kJ/m^2	ISO 180/1A
Izod Impact, notched 80*10*4 +23°C	60	kJ/m^2	ISO 180/1A
Izod Impact, notched 80*10*4 -30°C	14	kJ/m^2	ISO 180/1A
Charpy 23°C, V-notch Edgew 80*10*4 sp=62mm	128	kJ/m^2	ISO 179/1eA
Charpy -30°C, V-notch Edgew 80*10*4 sp=62mm	17	kJ/m^2	ISO 179/1eA
THERMAL			
HDT, 1.82 MPa, 3.2mm, unannealed	106	°C	ASTM D 648
Vicat Softening Temp, Rate A/50	137	°C	ISO 306
Vicat Softening Temp, Rate A/120	138	°C	ISO 306
Vicat Softening Temp, Rate B/50	121	°C	ISO 306
Vicat Softening Temp, Rate B/120	122	°C	ISO 306
HDT/Bf, 0.45 MPa Flatw 80*10*4 sp=64mm	127	°C	ISO 75/Bf
HDT/Af, 1.8 MPa Flatw 80*10*4 sp=64mm	104	°C	ISO 75/Af
PHYSICAL			
Specific Gravity	1.16	-	ASTM D 792
Melt Flow Rate, 220°C/10.0 kgf	8.5	g/10 min	ASTM D 1238
Melt Flow Rate, 260°C/5.0 kgf	30	g/10 min	ASTM D 1238
Density	1.16	g/cm^3	ISO 1183
Melt Flow Rate, 220°C/10.0 kg	8	g/10 min	ISO 1133
Melt Volume Rate, MVR at 220°C/10.0 kg	8	cm^3/10 min	ISO 1133
Melt Volume Rate, MVR at 260°C/5.0 kg	29	cm^3/10 min	ISO 1133



polykemi

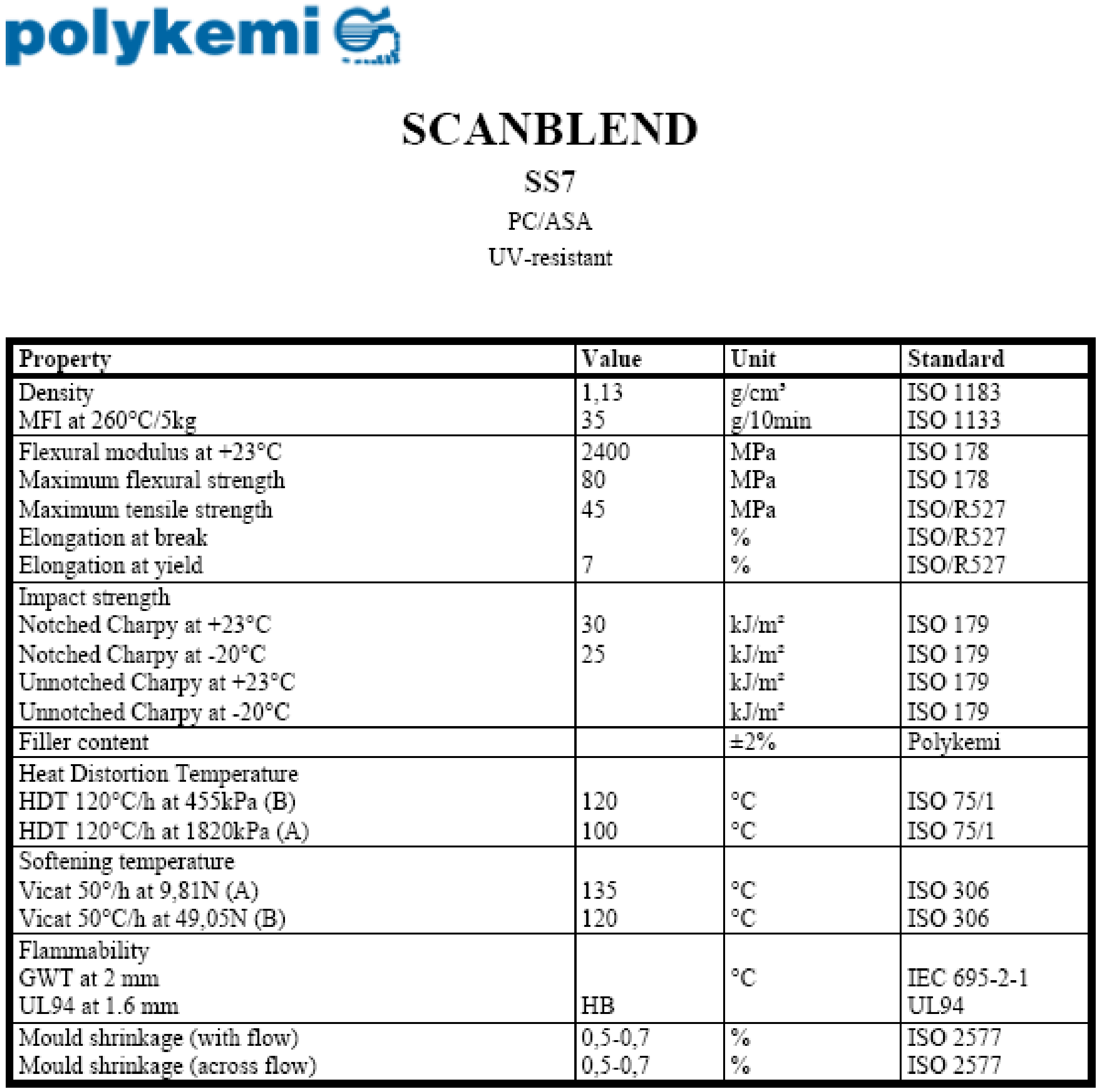
SCANBLEND

FS7

PC/ASA

Good weather resistance

Property	Value	Unit	Standard
Density	1,13	g/cm^3	ISO 1183
MFI at 260°C/5kg	20	g/10min	ISO 1133
Flexural modulus at +23°C	2500	MPa	ISO 178
Maximum flexural strength	82	MPa	ISO 178
Maximum tensile strength	48	MPa	ISO/R527
Elongation at break		%	ISO/R527
Elongation at yield	7	%	ISO/R527
Impact strength			
Notched Charpy at +23°C	45	kJ/m^2	ISO 179
Notched Charpy at -20°C		kJ/m^2	ISO 179
Unnotched Charpy at +23°C		kJ/m^2	ISO 179
Unnotched Charpy at -20°C		kJ/m^2	ISO 179
Filler content		±2%	Polykemi
Heat Distortion Temperature			
HDT 120°C/h at 455kPa (B)	121	°C	ISO 75/1
HDT 120°C/h at 1820kPa (A)	102	°C	ISO 75/1
Softening temperature			
Vicat 50°/h at 9,81N (A)	136	°C	ISO 306
Vicat 50°C/h at 49,05N (B)	123	°C	ISO 306
Flammability			
GWT at 2 mm		°C	IEC 695-2-1
UL94 at 1.6 mm	HB		UL94
Mould shrinkage (with flow)	0,5-0,7	%	ISO 2577
Mould shrinkage (across flow)	0,5-0,7	%	ISO 2577



polykemi

SCANBLEND

SS7

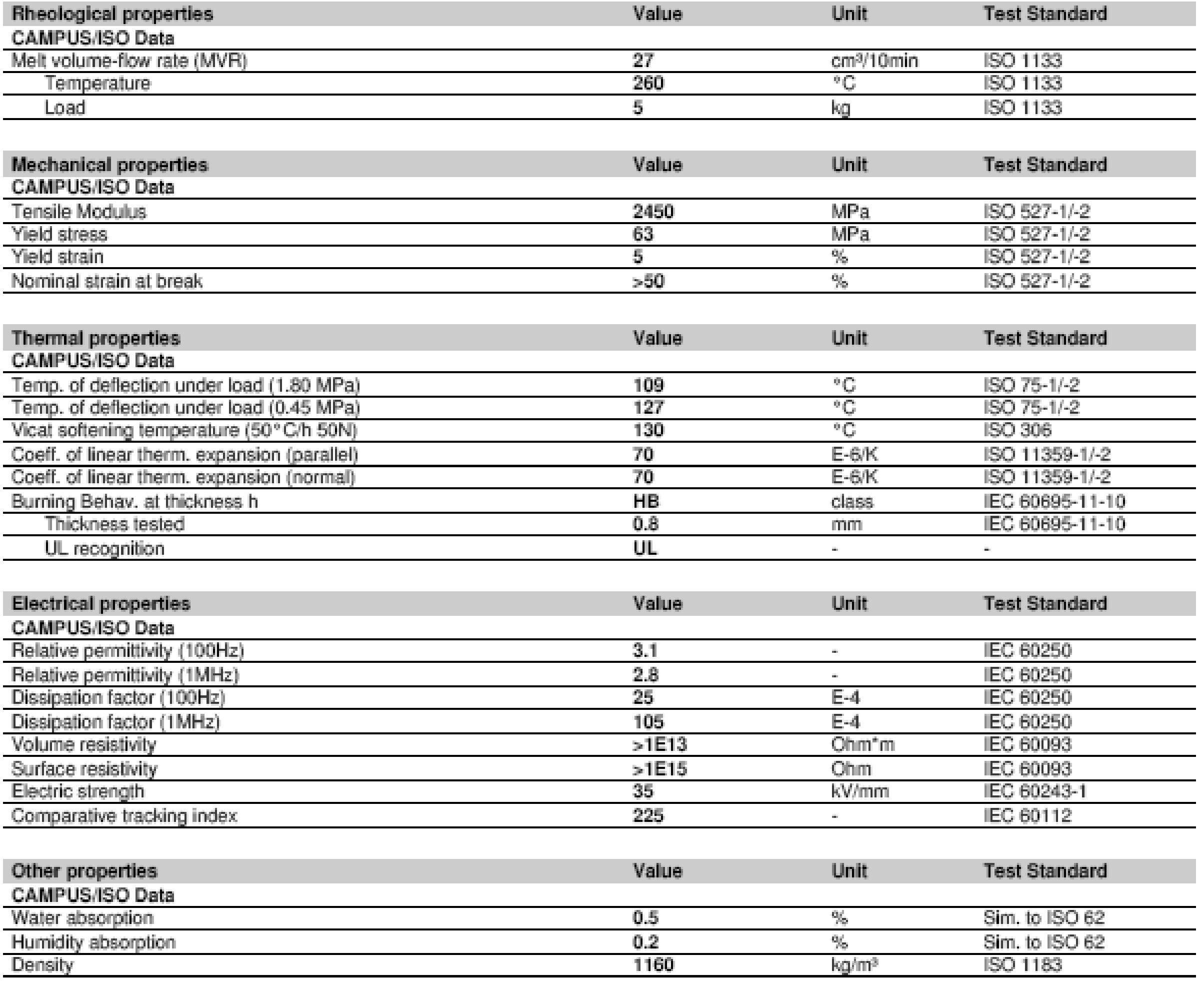
PC/ASA

UV-resistant

Property	Value	Unit	Standard
Density	1,13	g/cm³	ISO 1183
MFI at 260°C/5kg	35	g/10min	ISO 1133
Flexural modulus at +23°C	2400	MPa	ISO 178
Maximum flexural strength	80	MPa	ISO 178
Maximum tensile strength	45	MPa	ISO/R527
Elongation at break		%	ISO/R527
Elongation at yield	7	%	ISO/R527
Impact strength			
Notched Charpy at +23°C	30	kJ/m²	ISO 179
Notched Charpy at -20°C	25	kJ/m²	ISO 179
Unnotched Charpy at +23°C		kJ/m²	ISO 179
Unnotched Charpy at -20°C		kJ/m²	ISO 179
Filler content		±2%	Polykemi
Heat Distortion Temperature			
HDT 120°C/h at 455kPa (B)	120	°C	ISO 75/1
HDT 120°C/h at 1820kPa (A)	100	°C	ISO 75/1
Softening temperature			
Vicat 50°/h at 9,81N (A)	135	°C	ISO 306
Vicat 50°C/h at 49,05N (B)	120	°C	ISO 306
Flammability			
GWT at 2 mm		°C	IEC 695-2-1
UL94 at 1.6 mm	HB		UL94
Mould shrinkage (with flow)	0,5-0,7	%	ISO 2577
Mould shrinkage (across flow)	0,5-0,7	%	ISO 2577

Bayblend® W85 XF
(PC+ASA)
Bayer MaterialScience

PC/ASA W85 XF



Rheological properties	**Value**	**Unit**	**Test Standard**
CAMPUS/ISO Data			
Melt volume-flow rate (MVR)	**27**	cm³/10min	ISO 1133
Temperature	**260**	°C	ISO 1133
Load	**5**	kg	ISO 1133

Mechanical properties	**Value**	**Unit**	**Test Standard**
CAMPUS/ISO Data			
Tensile Modulus	**2450**	MPa	ISO 527-1/-2
Yield stress	**63**	MPa	ISO 527-1/-2
Yield strain	**5**	%	ISO 527-1/-2
Nominal strain at break	**>50**	%	ISO 527-1/-2

Thermal properties	**Value**	**Unit**	**Test Standard**
CAMPUS/ISO Data			
Temp. of deflection under load (1.80 MPa)	**109**	°C	ISO 75-1/-2
Temp. of deflection under load (0.45 MPa)	**127**	°C	ISO 75-1/-2
Vicat softening temperature (50°C/h 50N)	**130**	°C	ISO 306
Coeff. of linear therm. expansion (parallel)	**70**	E-6/K	ISO 11359-1/-2
Coeff. of linear therm. expansion (normal)	**70**	E-6/K	ISO 11359-1/-2
Burning Behav. at thickness h	**HB**	class	IEC 60695-11-10
Thickness tested	**0.8**	mm	IEC 60695-11-10
UL recognition	**UL**	-	-

Electrical properties	**Value**	**Unit**	**Test Standard**
CAMPUS/ISO Data			
Relative permittivity (100Hz)	**3.1**	-	IEC 60250
Relative permittivity (1MHz)	**2.8**	-	IEC 60250
Dissipation factor (100Hz)	**25**	E-4	IEC 60250
Dissipation factor (1MHz)	**105**	E-4	IEC 60250
Volume resistivity	**>1E13**	Ohm*m	IEC 60093
Surface resistivity	**>1E15**	Ohm	IEC 60093
Electric strength	**35**	kV/mm	IEC 60243-1
Comparative tracking index	**225**	-	IEC 60112

Other properties	**Value**	**Unit**	**Test Standard**
CAMPUS/ISO Data			
Water absorption	**0.5**	%	Sim. to ISO 62
Humidity absorption	**0.2**	%	Sim. to ISO 62
Density	**1160**	kg/m³	ISO 1183

ASTALOY™

PC/ASA ALLOY
ENGINEERING THERMOPLASTIC

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ASTALOY™ PC/ASA 403

	CONDITIONS	UNITS	TYPICAL VALUES	TESTING METHODS
1. Mechanical Properties				
Notched Izod Impact Strength	12.7 mm x 3.2 mm	J/m	700	ASTM D256
Falling Dart Impact Strength	3.2 mm plaque	J	60	ASTM D3029
Tensile Strength	12.7 mm x 3.2 mm @ 5.0 mm/min	MPa	50	ASTM D638
Elongation to Fail	12.7 mm x 3.2 mm @ 5.0 mm/min	%	150	ASTM D638
Flexural Strength	12.7 mm x 3.2 mm @ 1.3 mm/min	MPa	76	ASTM D790
Flexural Modulus	12.7 mm x 3.2 mm @ 1.3 mm/min	MPa	2250	ASTM D790
2. Thermal Properties				
Heat Deflection Temperature	12.7 mm x 12.7 mm @ 1.82 Mpa	°C	104	ASTM D648
Heat Deflection Temperature	12.7 mm x 6.4 mm @ 1.82 Mpa	°C	99	ASTM D648
Heat Deflection Temperature	12.7 mm x 3.2 mm @ 1.82 MPa	°C	94	ASTM D648
VICAT Softening Temperature	1 kg	°C	132	ASTM D1525
Coefficient of Linear Thermal Expansion		cm/cm/°C	7.20E-05	ASTM D696
3. Flammability Properties				
UL Flammability	1.6 mm	Rating	HB	UL 94
Glow Wire Temperature	1.6 mm	°C	550	AS/NZS 60695.2.12
4. Physical Properties				
Melt Flow Rate	250°C, 3.8 kg	g/10 min	6.5	ASTM D1238
Melt Flow Rate	220°C, 10 kg	g/10 min	-	ASTM D1238
Specific Gravity		-	1.12	ASTM D792
Rockwell Hardness	R Scale	R	108	ASTM D785
Water Absorption	24 hours	%	0.25	ASTM D570
Mould Shrinkage	3.0 mm plaque	%	0.6 ± 0.2	ASTM D955

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ASTALOY™ PC/ASA 405

	CONDITIONS	UNITS	TYPICAL VALUES	TESTING METHODS
1. Mechanical Properties				
Notched Izod Impact Strength	12.7 mm x 3.2 mm	J/m	675	ASTM D256
Falling Dart Impact Strength	3.2 mm plaque	J	75	ASTM D3029
Tensile Strength	12.7 mm x 3.2 mm @ 5.0 mm/min	MPa	53	ASTM D638
Elongation to Fail	12.7 mm x 3.2 mm @ 5.0 mm/min	%	150	ASTM D638
Flexural Strength	12.7 mm x 3.2 mm @ 1.3 mm/min	MPa	87	ASTM D790
Flexural Modulus	12.7 mm x 3.2 mm @ 1.3 mm/min	MPa	2400	ASTM D790
2. Thermal Properties				
Heat Deflection Temperature	12.7 mm x 12.7 mm @ 1.82 Mpa	°C	122	ASTM D648
Heat Deflection Temperature	12.7 mm x 6.4 mm @ 1.82 Mpa	°C	116	ASTM D648
Heat Deflection Temperature	12.7 mm x 3.2 mm @ 1.82 MPa	°C	109	ASTM D648
VICAT Softening Temperature	1 kg	°C	140	ASTM D1525
Coefficient of Linear Thermal Expansion		cm/cm/°C	6.90E-05	ASTM D696
3. Flammability Properties				
UL Flammability	1.6 mm	Rating	HB	UL 94
Glow Wire Temperature	1.6 mm	°C	750	AS/NZS 60695.2.12
4. Physical Properties				
Melt Flow Rate	250°C, 3.8 kg	g/10 min	7.0	ASTM D1238
Melt Flow Rate	260°C, 5.0 kg	g/10 min	-	ASTM D1238
Specific Gravity		-	1.16	ASTM D792
Rockwell Hardness	R Scale	R	116	ASTM D785
Water Absorption	24 hours	%	0.25	ASTM D570
Mould Shrinkage	3.0 mm plaque	%	0.6 ± 0.2	ASTM D955

VITAE

Mr. Sirisak Laopetcharat was born in Nonthaburi province, Thailand on June 27, 1989. He obtained a high school diploma in 2006 from Wat Bowonniwet school. In 2010, he received a Bachelor’s Degree in Chemical Engineering from the Department of Chemical Engineering, Faculty of Engineering, King Mongkut's University of Technology Thonburi. After that, he pursued his graduate study for a Master Degree in Chemical Engineering at the Department of Chemical Engineering, Faculty of Engineering, Chulalongkorn University.