Journal of Polymers and the Environment (2023) 31:3106–3119
https://doi.org/10.1007/s10924-023-02803-3

ORIGINAL PAPER

SbB-g-GMA Copolymer as a Dual Functional Reactive Compatibilizer and Impact Modifier for Potential Recycling of PET and PS via Melt Blending Approach

Fatemeh Tahmasebi[1] · **Seyed Hassan Jafari**[2] · **S. Morteza F. Farnia**[1]

Accepted: 13 February 2023 / Published online: 24 February 2023

Abstract

In this research work, polyethylene terephthalate (PET) and polystyrene (PS) were melt blended using glycidyl methacrylate-grafted styrene-block-butadiene (SbB-g-GMA) as a dual functional reactive compatibilizer and impact modifier to achieve a blend with stable morphology having no distinct phase separation. Accordingly, for the fabrication of the dual functional reactive compatibilizer, copolymerization was conducted through grafting glycidyl methacrylate (GMA) onto styrene-block-butadiene copolymer (SbB). Then, different compositions of the blends were prepared with various loadings of the compatibilizer. It was demonstrated that blending of PET with PS compatibilized with dual purpose compatibilizer resulted in a blend with improved toughness, thermal and mechanical properties as compared to the uncompatibilized blend. Moreover, it was demonstrated by the field- emission scanning electron microscopy (FE-SEM) results that although the unmodified PET/ PS blend was composed of large PS droplets, the PS droplets size was significantly minimized in the compatibilized blends, indicating better miscibility, and therefore, superior mechanical properties. The results demonstrate the effectiveness of the developed dual-functional compatibilizer for potential recycling of PET and PS, as two widely consumed polymers via a simple melt blending approach. The compatibilized blends with improved properties have great potential for use in a variety of applications.

Keywords PET · PS · Polymer blends · Dual functional compatibilizer and impact modifier · SbB-g-GMA copolymer

Introduction

In the recent century, disposal of polymer wastes has been considered a severe environmental issue, arising from both the accelerated industrialization and population growth. The accumulation of waste in the nature can lead to a variety of environmental issues, health problems and safety hazards, and minimizes sustainable production in terms of not only resource recovery but also waste recycling [1, 2]. By the generation of plastics, on which modern life and the global economy depends, and its highly rapid development, critical solutions are necessary to overcome the current polymer waste drawback. This issue can also result in the formation of innovative polymers with inherent recyclability [3].

Based on one report, the worldwide output for plastics has been 370 million tons in 2019 [4, 5]. It has been reported that the average plastic content of municipal solid waste is assessed to be 9.1 wt%, attributed to more than 13 million tons of plastic waste that is annually generated. Nevertheless, it is worth mentioning that the recycling rate for the plastic waste is below 10% [6, 7]. Five main commodity polymers constitute municipal solid waste in Europe, including polyethylene (PE), polypropylene (PP), polystyrene (PS) polyethylene terephthalate (PET) and polyvinyl chloride (PVC), comprising above more than 80% of plastics in Europe [4].

Polyethylene terephthalate (PET), a semi-crystalline thermoplastic engineering polymer, is the most commonly utilized polyester and one of the polymers that are extensively used in packaging foods, beverages, juices and water,

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✉ Seyed Hassan Jafari
shjafari@ut.ac.ir

[1] School of Chemistry, College of Science, University of Tehran, Tehran, Iran

[2] School of Chemical Engineering, College of Engineering, University of Tehran, Tehran, Iran

arising from its excellent gas barrier properties, rigidity, chemical resistance, mechanical strength, versatility, light weight, high chemical resistance to organic materials and water, and the broad application temperature range [8–10]. PET is a non-biodegradable polymer possessing significant resistance to biological agents under ordinary circumstances [11]. Polystyrene (PS) is also the fourth largest produced commodity thermoplastic polymer. PS possesses numerous merits, and therefore, it is used in many applications. It is fabricated with ease, conveniently processed and recycled. Furthermore, it is not easily degraded by temperature and provides considerable stiffness and toughness values. Its optical transparency is considered a great advantage, making it interesting for numerous applications, e.g., packaging, insulation, automotive, etc. [12, 13].PS and PET are both widely used in many applications, and therefore, it is an urgent need to prevent their introduction to the environment by recycling or other strategies. Through blending two or more polymers, a variety of thermoplastic materials can be recycled [10, 14, 15]. Generally, coarse unstable phase morphologies are observed in simple blends of various polymers because most polymer blends are thermodynamically immiscible, leading to deterioration of interphase adhesion, interfacial thickness and mechanical properties. All these issues can be addressed through the introduction of several additives, often known as compatibilizer, which are usually block and graft copolymers, by which compatibility and properties of the blend is greatly enhanced [14, 16, 17]. Such compatibilization generally leads to stabilized morphology possessing a fine dispersion of the minor phase, by which the macroscopic properties of the blend are significantly affected, arising from the fact that they have tendency to concentrate at the interface as emulsifiers [15, 18].

For instance, Ju et al. utilized dual compatibilizers composed of styrene maleic anhydride random copolymer and poly[methylene (phenylene isocyanate)] for the modification of PET/ PS blends, by which finer phase domain along with superior mechanical properties was obtained, arising from the ability of the compatibilizer to anchor along the interface [18]. In another study, Xing et al. reported the fabrication of polystyrene-block-poly(styrene-alt-maleic anhydride) functionalized block copolymers through RAFT polymerization technique for blending with PET, by which not only were small copolymer phase droplets formed, but also blends with significant thermal and mechanical properties were formed [19].

Due to inherent rigidity of both PET and PS, their compatibilized blends are usually not having desirable toughness in spite of having improved interfacial adhesion, and therefore, the studies focused on recycling of PET and PS via blending approach are very limited. It seems there is a need to use a compatibilizer which could improve the toughness of the blend of these two polymers simultaneously. Here, PET/PS blends were prepared by melt mixing, in which glycidyl methacrylate-grafted styrene-block-butadiene (SbB-g-GMA), as a synthesized dual functional reactive compatibilizer, was added to the blends for achieving a stable morphology and improved toughness. In this approach, reactive terminal functional groups of PET (–COOH and –OH) are able to react with many reactive groups, such as anhydrides [20, 21], carboxylic acids [22, 23], oxazoline [24–26], epoxides [27, 28], etc. The SbB-g-GMA copolymer can chemically react with hydroxyl and carboxyl groups of PET through its side chains containing epoxy rings and, on the other hand, polystyrene chains of SbB-g-GMA can be physically miscible with the dispersed PS phase. Besides that, the rubbery component of the compatibilizer can act as an efficient impact modifier. The innovative aspect of this work is on possibility of recycling of PET and PS by a melt blending approach to obtain a tough and compatibilized blend with improved mechanical, thermal and morphological properties via utilization of a synthesized SbB-g-GMA copolymer as a dual functional reactive compatibilizer and impact modifier for PET/PS blend.

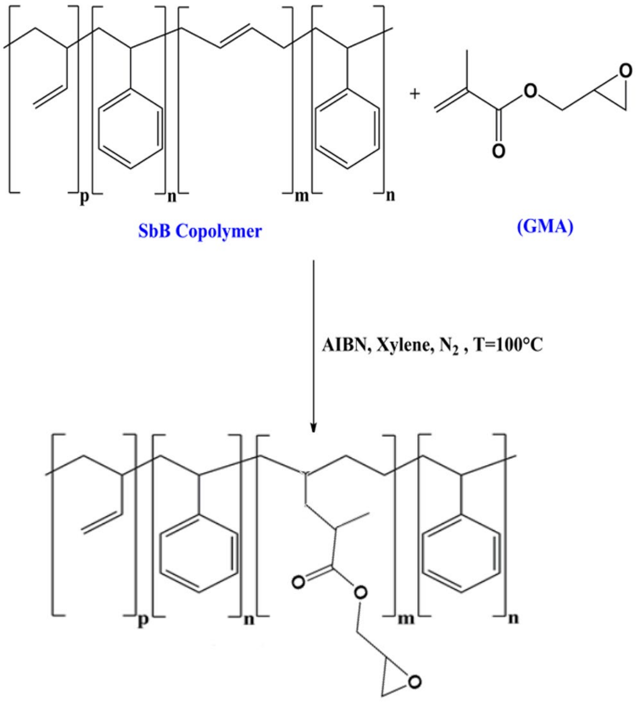
Materials and Methods

Materials

The bottle grade PET, LOTTE CHEMICAL PET COOL with an intrinsic viscosity of 0.74 dl/g and general-purpose PS 1540 granules (GPPS 1540) were purchased from Lotte Chemical Corporation and Tabriz Petrochemical Complex (TPC), respectively. Before any use, the materials were carefully dried under vacuum at 80 °C for 3 days in order to reduce the moisture content. SbB (Kraton™ DX414 J) is a clear, linear block copolymer based on styrene and butadiene with bound styrene of 52% mass. GMA monomer and AIBN (2,2′-Azobis (2-methylpropionitrile, 98%), as the initiator, were provided from Sigma-Aldrich Chemical Co. AIBN half-life time was ca. 7.7 min at 100 °C. Xylene, cyclohexane and methanol solvents were supplied by Merck Chemical Co.

Synthesis of the SbB-g-GMA Graft Copolymer as a Dual Functional Reactive Compatibilizer and Impact Modifier

Graft copolymerization of GMA onto SbB was accomplished at constant stirring in a two-neck round-bottom flask equipped with a backflow condenser and placed in a temperature-controlled thermostat. As the SbB copolymer



Scheme 1 Schematic illustration of the synthesis route of SbB-g-GMA dual functional copolymer

(20 g) dissolved in 50 ml xylene at a constant temperature of 100 °C (this temperature was chosen based on boiling point of xylene solvent (138.4 °C) for controlling steam pressure of xylene and prevention of losing solvent due to evaporation during the reflux condensation), nitrogen purging was done during 10 min, and then, GMA monomer (calculation is done based on GMA/Butadiene molar ratio equal to 1.) and AIBN (2 wt% of Butadiene) simultaneously were introduced into the reaction flask. The synthesis continued for 4 h. After that, the reaction ended when the reaction vessel was opened and air entered. For removing unreacted monomers and homopolymerized GMA, solvent/non solvent precipitation method with xylene/methanol and with xylene/acetone were done 3 times each for removing homopolymers of GMA. For separate the impurities such as un-reacted monomer and formed homopolymers which may remain in solvent/non solvent precipitation step the precipitated graft copolymer was extracted using a Soxhlet extractor with refluxing toluene for 3 days. After 3 days, no precipitate was observed [29]. The toluene-soluble fraction was precipitated in methanol, and finally, the precipitate dried under vacuum at 80 °C overnight. The SbB-g-GMA copolymer weight was 24.36 g. Scheme1 represents the chemical grafting reaction between SbB copolymer and GMA monomer.

Preparation of the Blends

Before preparation of the blends, because of sensitivity towards degradation by moisture, PET granules and PS and SbB-g-GMA compatibilizer were dried at 120 °C for 12 h and at 80 °C for 24 h, respectively, in a vacuum oven to remove their moisture content. All the blends were prepared by melt compounding at 265 °C in a Brabender Plastograph internal mixer at a roller speed of 60 rpm for 7 min. At the end of mixing process in Brabender, the obtained molten bulky materials were immediately placed in between two metallic plates and pressed to form thick solid sheets which were then crushed to small pieces for subsequent compression molding process. Total weight of the materials per batch was 40 g. All the materials were premixed manually before adding to the Brabender chamber. PET polymer in all the blends was 70 per hundred resins by weight (wt%), PS content in the blends was 30 wt%, and consequently, the SbB-g-GMA compatibilizer amount was 0, 3, 5, 7 and 10 phr, which were labelled for instance as 70/30/3 for PET/PS/ SbB-g-GMA.

Characterization of PET/PS Blends

Thermal Analysis

Thermal stability of the blends was evaluated using Thermogravimetric analysis (TGA) and Differential Scanning Calorimetry (DSC) measurements with SDT Q600 V20.9 Build 20 instrument under Argon atmosphere by heating rate of 10 °C/min in the temperature range of 25–600 °C. Three different specimens were measured and averaged.

FT-IR of SbB-g-GMA

The dried SbB-g-GMA graft copolymer was characterized by Fourier transform infrared (FT–IR) spectroscopy using Equinox 55 FT–IR spectrophotometer (Bruker) in the range of 500–4000 cm^{-1}.

NMR Spectroscopy of SbB-g-GMA

^{1}HNMR spectra was done for characterization of the SbB-g-GMA copolymer using a Bruker 500 MHz NMR spectrometer. Dried graft copolymer was dissolved in C_6D_6 as the solvent at 25 °C.

Impact and Tensile Test

Tensile tests were conducted at ambient conditions by a SANTAM Universal Testing Machine, Model STM-50, according to the ASTM D638 method. The dumbbell-shaped samples were prepared by a hydraulic *hot press* machine (Model Schwabenthan 400, Germany) equipped with water *cooling*, under 80 MPa pressure at temperature of 265 °C for 6 min. After molding the press and dumbbell-shape samples were immediately cooled to room temperature. The crosshead speed was 5 mm/min. notched Izod impact strength was measured at ambient conditions according to the ASTM D256 method by an Impact Tester from SANTAM Co. of Iran, Model SIT-20E. The notched Izod impact specimens with sample dimensions of 64 mm × 12.7 mm × 3.2 mm and a standard notch of 2 mm in depth were also obtained by compression molding under 80 MPa pressure at 265 °C for 6 min. Three different specimens were tested and the average value was reported.

Scanning Electron Microscopy

Morphological observation was performed by field-emission scanning electron microscopy (FE–SEM), Model S–4160, Hitachi Co. of Japan. To inhibit charging in SEM, surfaces of specimens were coated with a gold thin film. All the samples were etched by THF solvent for 20 min to dissolve the PS phase out of the blends.

Grafting Yield Measurements

After the synthesis of the grafted SbB copolymer, by comparing weight of the obtained grafted SbB copolymer with original SbB, the grafting yield of the modified SbB was determined using the following equation;

$$Grafting\,yield\,(GY)\,(\%) = \frac{W_g - W_i}{W_i} \times 100 \qquad \text{(Eq. 1)}$$

In this equation, Wg indicates the dry mass of the grafted SbB and W_i indicates the dry mass of initial SbB.

Results and Discussion

The Investigation of PET and PET/PS

Thermogravimetric analysis of PET and PET/PS (70/30) is exhibited in Fig. 1. The thermogram in Fig. 1 clearly shows higher thermal stability of the PET/PS blend than that of PET. The initial degradation temperature (T_{Onset}) of PET/PS was 5 °C higher than that of PET, and the weight loss of PET/PS and PET were 85% and 95%, respectively, indicating that PS contributed to increase thermal stability of PET in the blend.

The mechanical properties of the pristine PET and the PET/PS (70/30) blend were investigated under tensile mode, as shown in Fig. 2. The pristine PET and PET/PS (70/30) blend were fractured when the elongation percentage reached ~ 4.6% and ~ 4%, respectively. It shows brittle nature of PET/PS (70/30) during tension in comparison to PET. Moreover, the addition of PS to PET increased the Young's modulus from 2270 MPa ± 103 for neat PET to 3020 ± 110 MPa for PET/PS (70/30), which could be attributed to the higher modulus of PS than that of PET. Furthermore, immiscibility and weak interfacial adhesion between PET and PS and, on the other hand, the sensitivity of elongation at break and toughness to the load transfer between phases are some reasons for reduction of mechanical properties of PET/PS as compared to the neat PET.

It has been proved that reduction of interfacial tension between domains in the blend can upgrade interfacial adhesion and enhance the homogenous dispersion of the dispersed phase in the matrix. So, it was attempted to add a synthetic, inherently rubbery component, as a dual functional reactive compatibilizer, to the PET/PS blend for both modification of interfacial adhesion between PET and PS and obtaining better mechanical properties. Here, GMA monomer was grafted to the SbB copolymer backbone to create a tough component having reactive epoxy groups which can localize at the interface of PET and PS phases in the blend.

The Investigation of the SbB-g-GMA Graft Copolymer

Vibrational Study

The FT-IR spectra of purified SbB-g-GMA copolymer are shown in Fig. 3. The SbB peaks have appeared in 1601 cm $^{-1}$, related to double bond alkene stretching of butadiene blocks, 1448 cm $^{-1}$ and 1492 cm $^{-1}$, ascribed to aromatic double bond stretching vibrations, and 3021 cm $^{-1}$, corresponding to aromatic C-H stretching. Also, two absorption peaks at 910 and 964 cm^{-1} are corresponding to = C-H bending of butadiene units. After the accomplishment of the grafting reaction, the intensity of aliphatic C-H vibration at 2846 and 2924 cm^{-1} became higher than SbB due to insert new hydrocarbon or aliphatic C-H parts onto the SbB double bonds [30]. the appearance of the epoxy group peak in 907 cm $^{-1}$, the most important evidence of grafting, and carbonyl (C = O) and ester groups in 1725 cm $^{-1}$ and 1140 cm $^{-1}$ strongly demonstrate successful grafting of GMA on SbB copolymer.

The other analysis conducted for the characterization of the SbB-g-GMA copolymer was ^{1}HNMR (in $CDCl_3$)

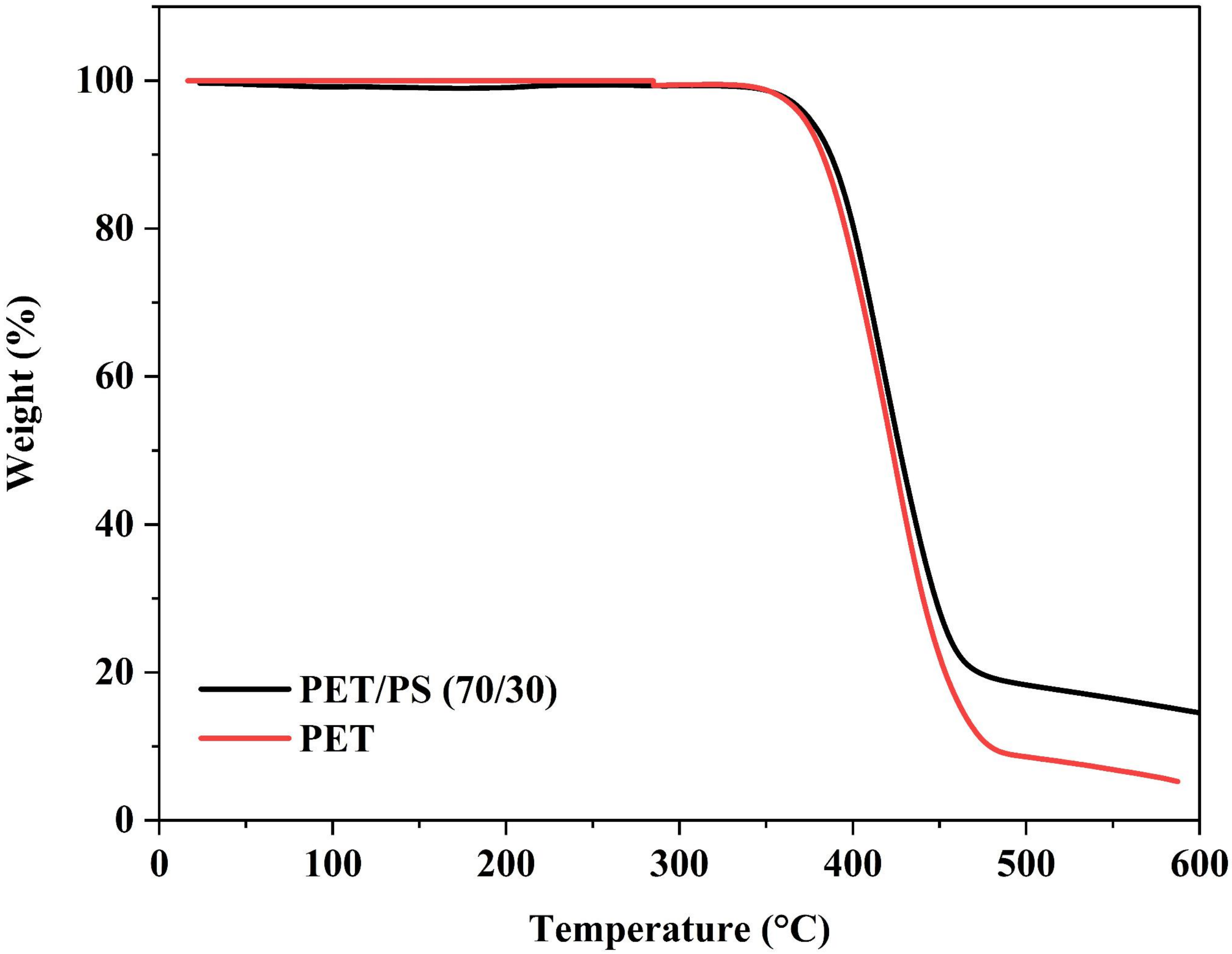


Fig. 1 TGA-curves of the pristine PET, and the PET/PS (70/30) blend

spectrometry technique, by which the micro structure of the SbB-g-GMA copolymer was confirmed. Figure 4 exhibits ^{1}HNMR spectra of the SbB-g-GMA copolymer. Aromatic ring protons exciting in the styrene fraction have appeared in 7.1 ppm, and the reference peak of $CDCl_3$ has emerged in 7.28 ppm. Vinyl group protons for butadiene are also evident at 5 ppm for 1,2 vinyl protons, 5.4 ppm for cis-1,4 vinyl protons and 5.45 ppm for trans-1,4 vinyl protons. Moreover, epoxy ring protons of GMA are shown at 2.5–4.5 ppm. Finely aliphatic group signal in the polymer chain was verified at 0.7–2.2 ppm. Also, the xylene residual wasn't observed in graft copolymer since there wasn't any sharp and clear single peak at 2.29 ppm related to methyl groups on the benzene ring. Accordingly, ^{1}HNMR spectra analysis showed that the copolymer was successfully synthesized [29, 31].

Grafting Yield Measurement

Grafting variables, e.g., concentration of monomer or initiator, and the processing condition, such as time and reaction temperature, affect the degree of functionalization in the final product. After the synthesis of the grafted SbB copolymer by procedure described above, by comparing weight of the obtained grafted SbB copolymer with original SbB, the grafting yield of the modified SbB obtained about 21.78%.

The Investigation of the Compatibilized PET/PS Blends

Compatibilizer efficiency in the PET/PS blend was evaluated using tensile strength and notched Izod impact analysis.

The achieved results of tensile and impact tests are listed in Table 1. Yield strength increased with the addition of 3, 5, 7 phr of compatibilizer in to the PET/PS blend (Fig. 5a). This happened because of the elastomeric nature

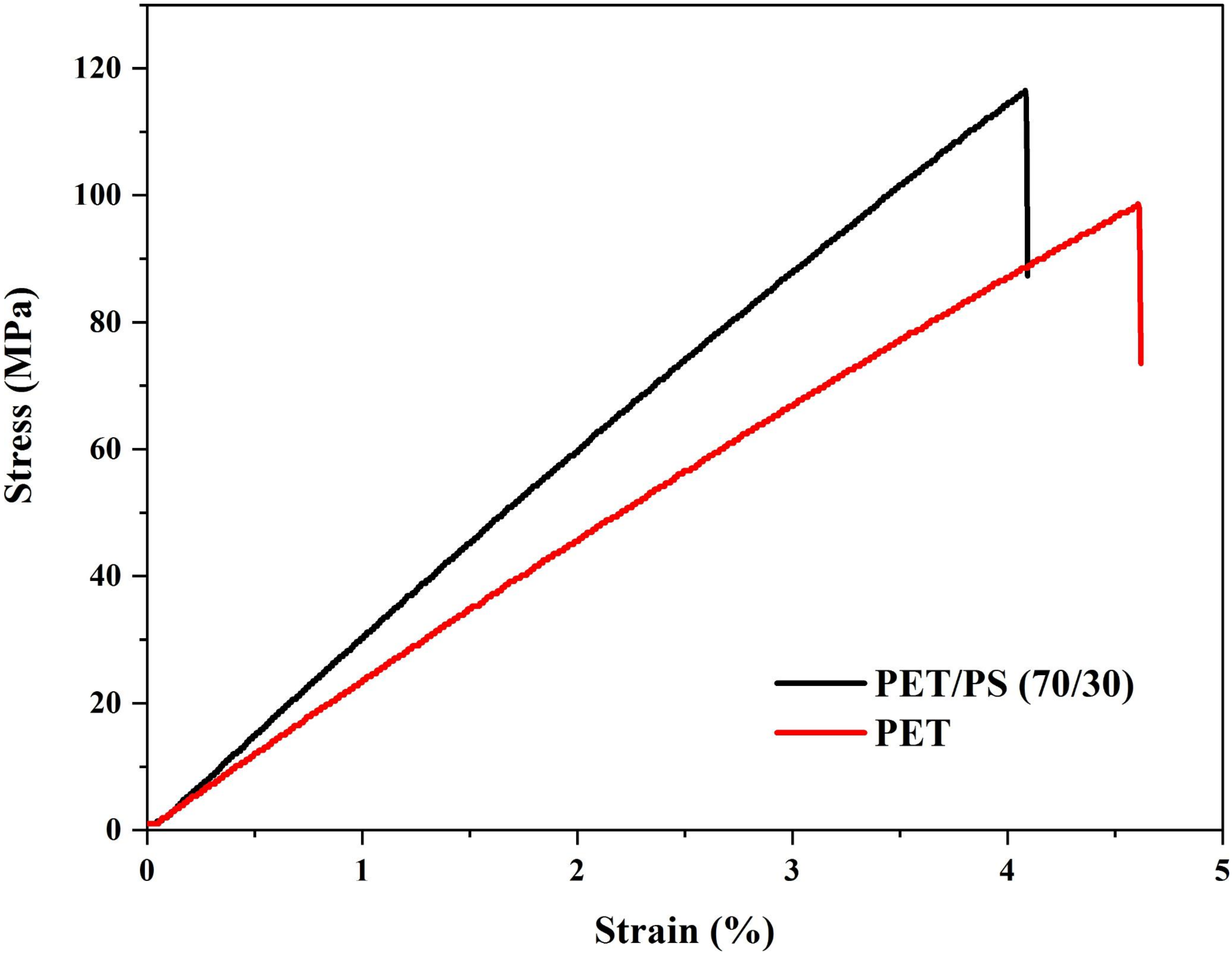


Fig. 2 Stress-strain curve, tensile test for PET and PET/PS (70/30 wt%)

of SbB-g-GMA, having long chains of styrene blocks miscible in the PS phase and, on the other hand, GMA active functional groups ,which are capable of chemically reacting with hydroxyl and carboxyl end-groups of the PET matrix during melt blending, and formed SbB-g-GMA-*co*-PET at the interfacial surface of PET and PS [32]. When the more content of reactive compatibilizer is added to the blend, possibility of crosslinking in high temperature of melt blending between GMA functional groups of the SbB-g-GMA copolymer is high. Furthermore, compatibilized PET/PS with 10 phr SbB-g-GMA (PET/PS/SbB-g-GMA 70/30/10) showed yield strength lower than the PET/PS/SbB-g-GMA 70/30/7 blend. As shown in Fig. 5b, the changes in Izod impact with changing the compatibilizer content were similar to the tensile results. The compatibilizer at the interface of PET and PS acts as impact modifier, which absorbs impact energy and contribute to stress transfer between the matrix and minor domains. Hence, compatibilized PET/PS with 3, 5 and 7 phr of SbB-g-GMA had Izod impact upward, while for compatibilized PET/PS with 10 phr of SbB-g-GMA copolymer, it declined possibly due to crossing the critical micelle concentration and formation of separate phase in the PET matrix. In comparison to mechanical properties of PET/PS/SbB-g-GMA (70/30/5) with PET/PS/SMA 75/20/5 [18] with same percent of compatibilizer, the tensile strength and tensile elongation of PET/PS/SbB-g-GMA 70/30/5 were respectively 3.4 times and 17% more than of the tensile strength and tensile elongation of PET/PS/SMA 75/20/5. Also, the tensile strength of PET/PS/SbB-g-GMA (70/30/10) in this study was 3 times of tensile strength of PET/PS/SMA (75/15/10) as reported by Ming and et al. [33]. In the other word, upgrading mechanical properties can be attributed to the stable and homogenous phase morphology of polymer blends, as also observed in SEM results [26, 34].

Figure 6 illustrates SEM micrographs of compatibilized and uncompatibilized PET/PS 70/30 blends with solvent etching by THF, as the selective solvent extraction of the

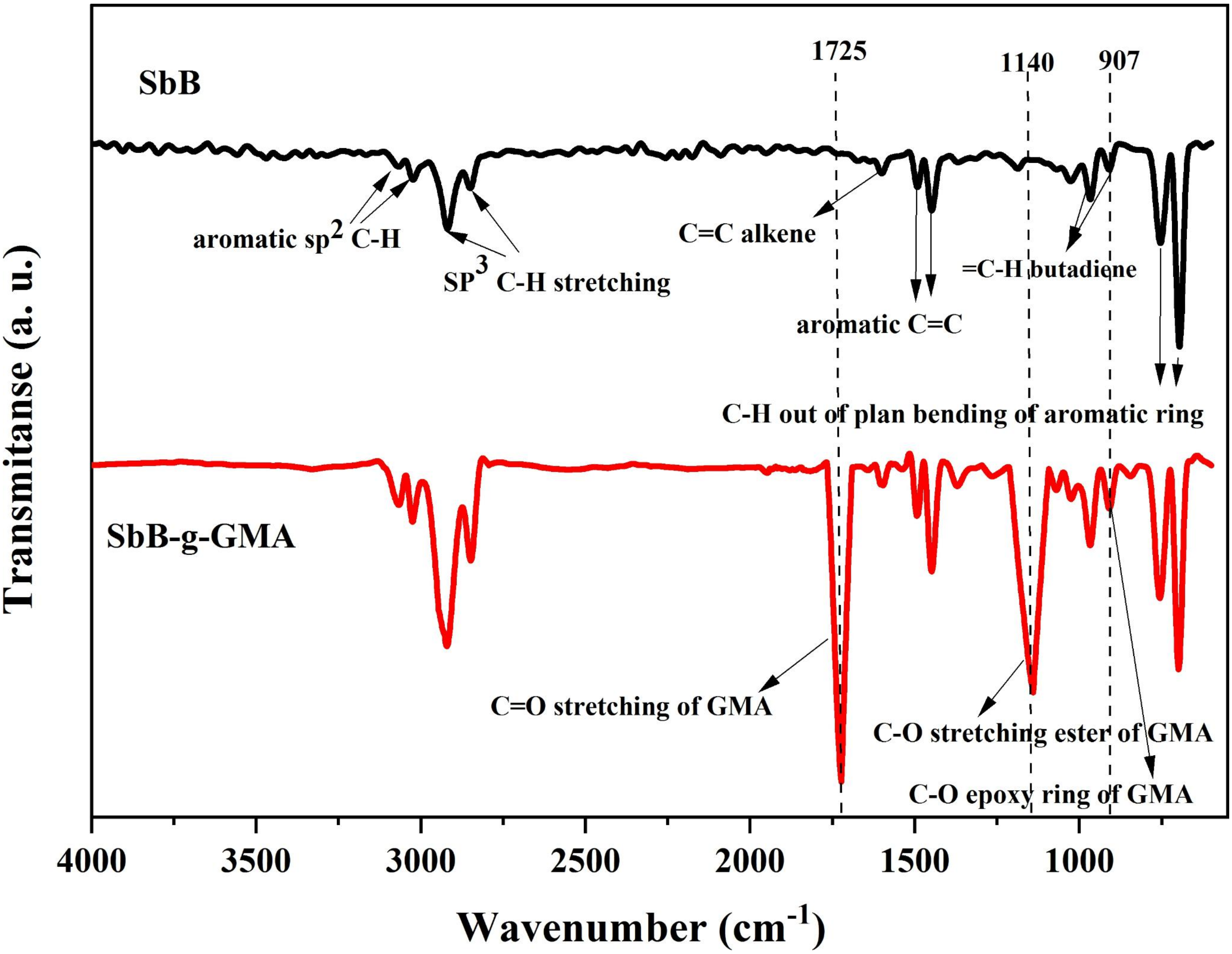


Fig. 3 The chemical structure analysis using FT-IR for the unmodified SbB copolymer and the SbB-g-GMA graft copolymer

PS phase. Spherical-domain (PET)/matrix (PS) morphology is observed for the PET/PS blends. Through increasing the quantity of the SbB-g-GMA compatibilizer, PS large droplets in the uncompatibilized PET/PS blend regularly progressed to reduce in size, and obtained a fine dispersion of PS domains in the PET matrix. For 7 phr compatibilized PET/PS compared to 10 phr PET/PS, the phase dispersion is better and surface morphology is smoother. According to micrographs shown in Fig. 6, in the uncompatibilized blend, co-continuous structure, different size and large spherical PS particles can be easily identified while in the presence of the compatibilizer, the PS phase is well dispersed in the PET matrix and size of PS particles is decreased. Moreover, the phase contrast is not very perspicuously recognized. In fact, the physicochemical affinity of each segment of the SbB-g-GMA copolymer to each immiscible polymer (PET and PS), and the formation of the PET-*co*-GMA-g-SbB copolymer at the interface of the blend during melt compounding lead to stronger interfacial adhesion, greater interfacial area and better miscibility of PET and PS. Establishment of an in situ new graft copolymer that has reciprocal inclination between the PET and PS phases raises the size reduction of the dispersed PS droplets. However, the use of copolymers containing GMA groups always increases viscosity due to the possibility of in situ polymerization. Among the compatibilized blends, the PET/PS/SbB-g-GMA copolymer (70/30/7 phr), even compared to the 70/30/10 phr PET/PS/SbB-g-GMA copolymer blend, has a very small dispersed PS domain and an indistinguishable interfacial area. It would be concluded that the addition of more compatibilizer, because of its affinity to locate at the interface of PET and PS, results in the agglomeration of the compatibilizer at the interface and therefore, the 70/30/10 phr PET/PS/SbB-g-GMA copolymer has a clear phase contrast compared to the PET/PS/SbB-g-GMA copolymer (70/30/7 phr) blend. Furthermore, it was found that the ultimate optimized value of the compatibilizer improved both mechanical and

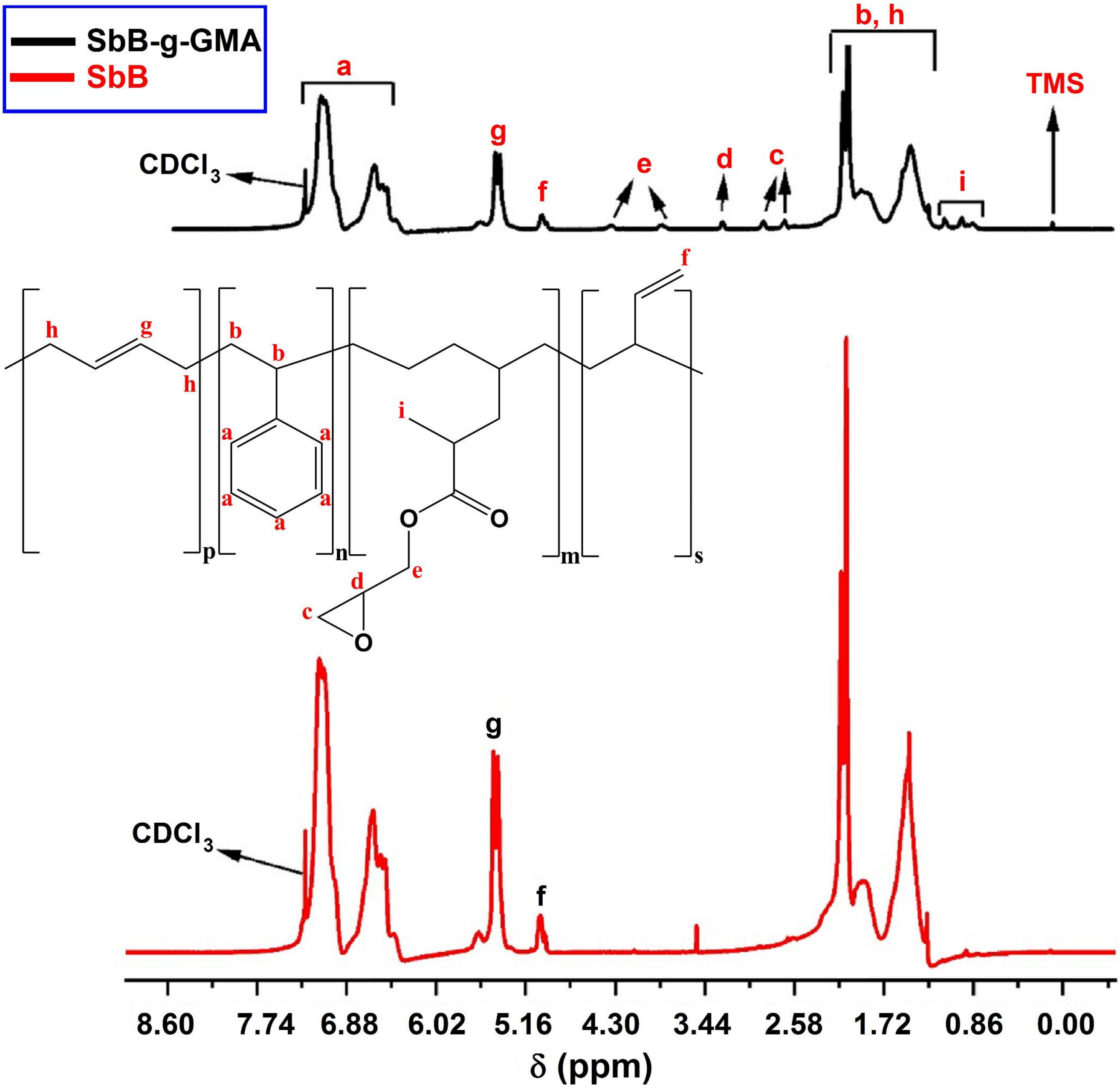


Fig. 4 ^{1}HNMR spectra of the SbB-g-GMA copolymer

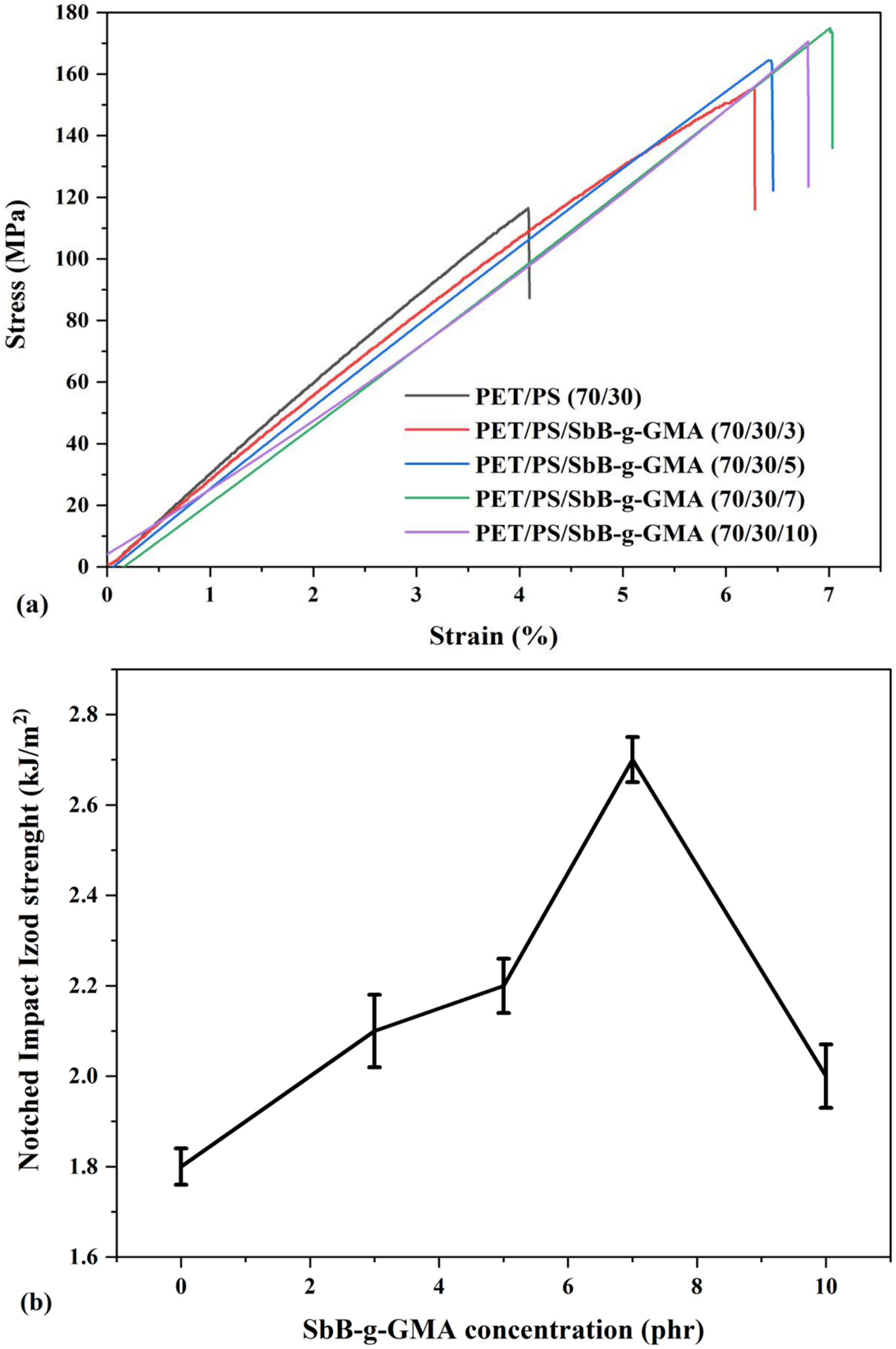
Table 1 Yield stress and elongation at break of PET/PS blends

Composition of the blend	Tensile modulus (MPa)	Elongation @ break (%)	Impact strength (kJ/m^2)	Peak area (J/g)
PET/PS (70/30)	3020 ± 110	4.00 ± 0.14	1.80 ± 0.17	246
PET/PS/SbB g-GMA(70/30/3)	2801 ± 210	6.27 ± 0.35	2.10 ± 0.08	521
PET/PS/ SbB-g-GMA(70/30/5)	2530 ± 80	6.45 ± 0.24	2.20 ± 0.14	538
PET/PS/SbB g-GMA(70/30/7)	2250 ± 119	7.03 ± 0.41	2.70 ± 0.15	596
PET/PS/SbB g-GMA(70/30/10)	2360 ± 123	6.80 ± 0.22	2.00 ± 0.11	566

morphological properties of PET/PS blends with 7 phr of SbB-g-GMA [18, 33–36].

To further testify the effect of the SbB-g-GMA dual functional compatibilizer content on the thermal stability of the prepared PET/PS composites and as a part of the characterization, TGA curves of pure PET/PS (70/30) and its compatibilized blends were tested and plotted in Fig. 7. The relevant thermal decomposition parameters, such as the onset decomposition temperature (T_{onset}) and the residual weight (%), are listed in Table 2. It can be seen that T_{onset} has gradually increased from 380 °C, for PET/PS (70/30),

Fig. 5 (a) Stress-strain curves, and (b) Notched Izod impact of PET/PS and their compatibilized blends in (70/30/X SbB-g-GMA)



to 406 °C, for PET/PS/SbB-g-GMA with inclusion of 7 phr of SbB-g-GMA to the blend, illustrating that the addition of SbB-g-GMA to PET/PS has enhanced its thermal stability. The addition of 10 phr of SbB-g-GMA to the PET/PS blend not only resulted in higher residual char content due to existence more aromatic structure content in the 70/30/10 blend but also led to lower T_{onset} than the PET/PS blend containing 7 phr of the compatibilizer. It would be concluded that the presence of additional amount of the compatibilizer and the increase in GMA side group led to reduction of T_{onset}. In fact, the association of excess amount of unreacted of GMA side chains in the interphase can weaken the adhesion between compatibilizer and matrix and reduce the thermal stability of blend. Furthermore, all three components of PET/PS/SbB-g-GMA ternary blend have aromatic ring in their structure which helps in char formation. Accordingly, the residual weight of blends increases with an increase in compatibilizer content.

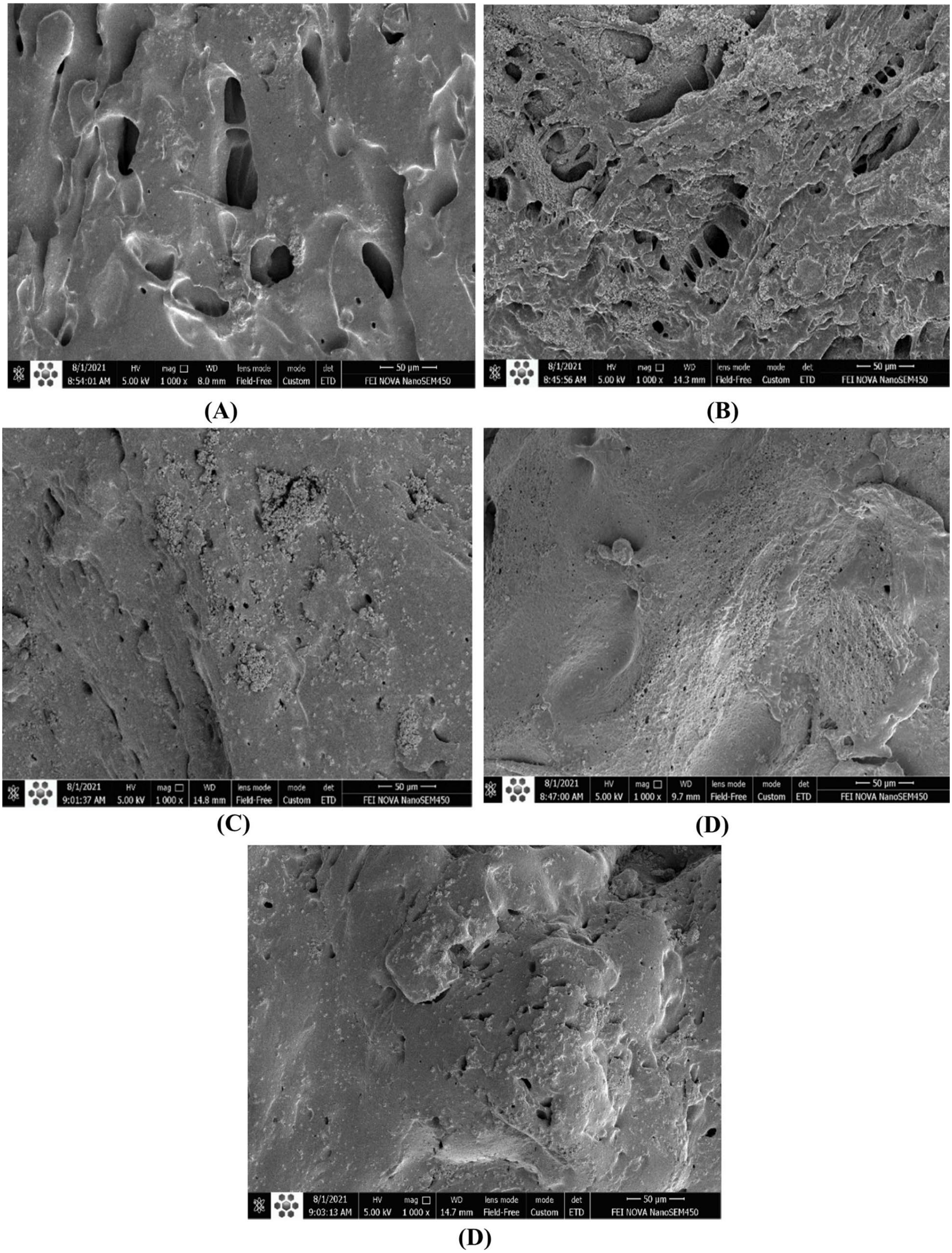


Fig. 6 SEM micrographs of the etched surfaces of (A) PET/PS (70/30) and in presence of (B) 3 phr, (C) 5 phr, (D) 7 phr and (E) 10 phr of the SbB-g-GMA compatibilizer

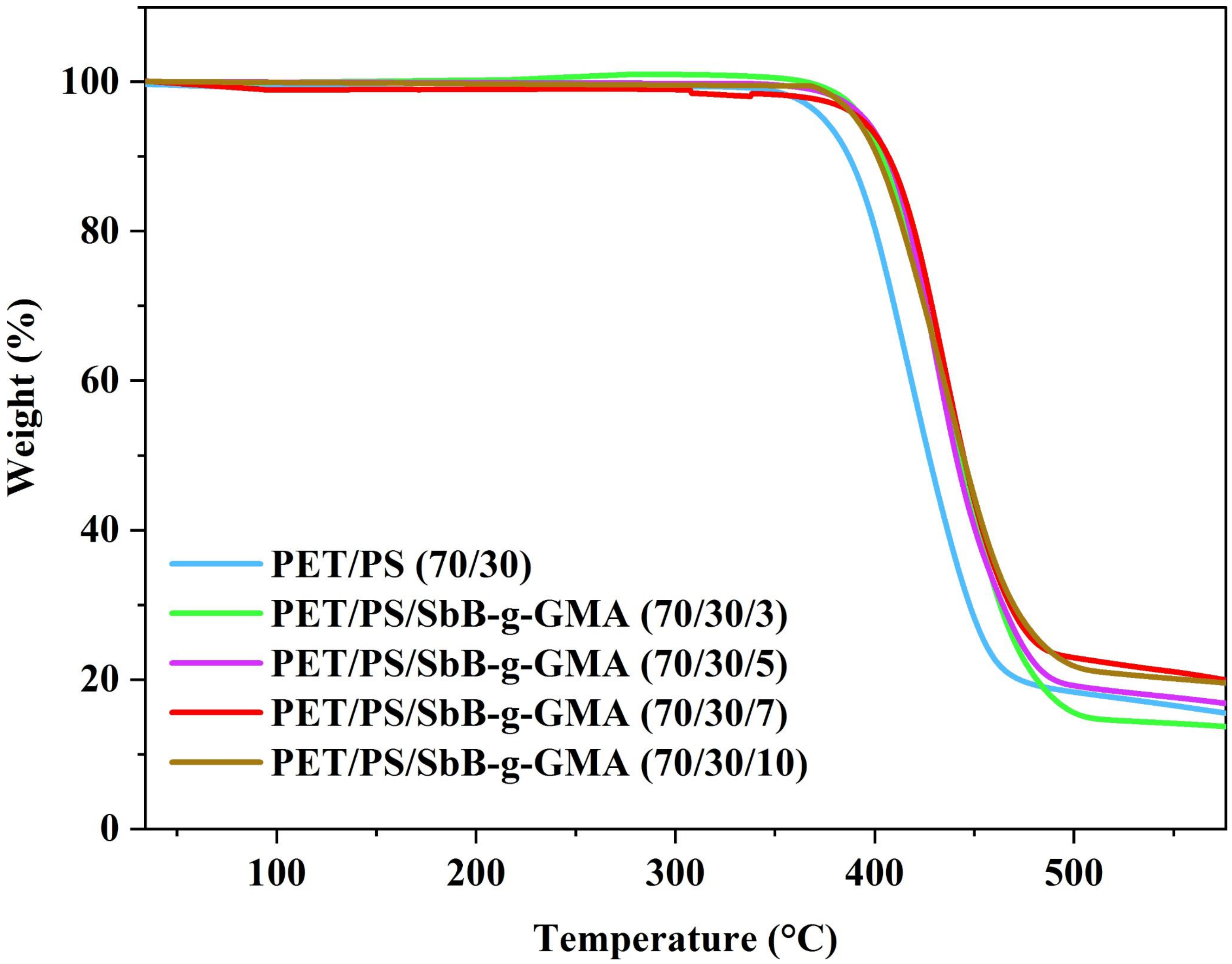


Fig. 7 TGA thermograms of the PET/PS and PET/PS/SbB-g-GMA blends with different contents of the compatibilizer

Table 2 TGA outputs for different compositions of PET/PS.

Composition	T_{onset} (°C)	Residual weight (%)
PET/PS (70/30)	380.0	14.7
PET/PS/SbB-g-GMA (70/30/3)	385.9	13.1
PET/PS/SbB-g-GMA (70/30/5)	399.8	15.8
PET/PS/SbB-g-GMA (70/30/7)	406.1	18.7
PET/PS/SbB-g-GMA (70/30/10)	391.1	19.0

The DSC heating scan for the prepared PET/PS blends before and after compatibilization is represented in Fig. 8. In all cases, the endotherm peaks between the temperature of 100 and 200 °C was attributed to the residual moisture or volatile solvents in the samples. Several peaks appeared about 380 °C are related to thermal decomposition of samples, as seen in the TGA results. For ternary blends in comparison to PET/PS (70/30) blend the number of peaks are more that shows the complexity of decomposition stage in the ternary blends due to a greater number of polymeric components. On the other side the endotherm peak at around 250 °C in all the DSC curves is related to melting peak temperature (T_m) of the PET phase in PET/PS blends. It is clearly observed that T_m of PET has shifted to lower temperatures with the increase in the compatibilizer content. In fact, the crystal imperfections and crystal size distribution parameters may be affecting the melting peak width. On increasing the crystal size distribution, the melting peak is widening. It can be caused by the presence of SbB-g-GMA at the interface and in situ-formation of the graft copolymer have both prevented a perfect crystal growth and impeded the crystallization of the PET component in the compatibilized blends [18, 35, 36].

Conclusion

Possibility of recycling of PET and PS was investigated via a melt mixing approach using a dual functional compatibilizer. For enhancing the blends properties,

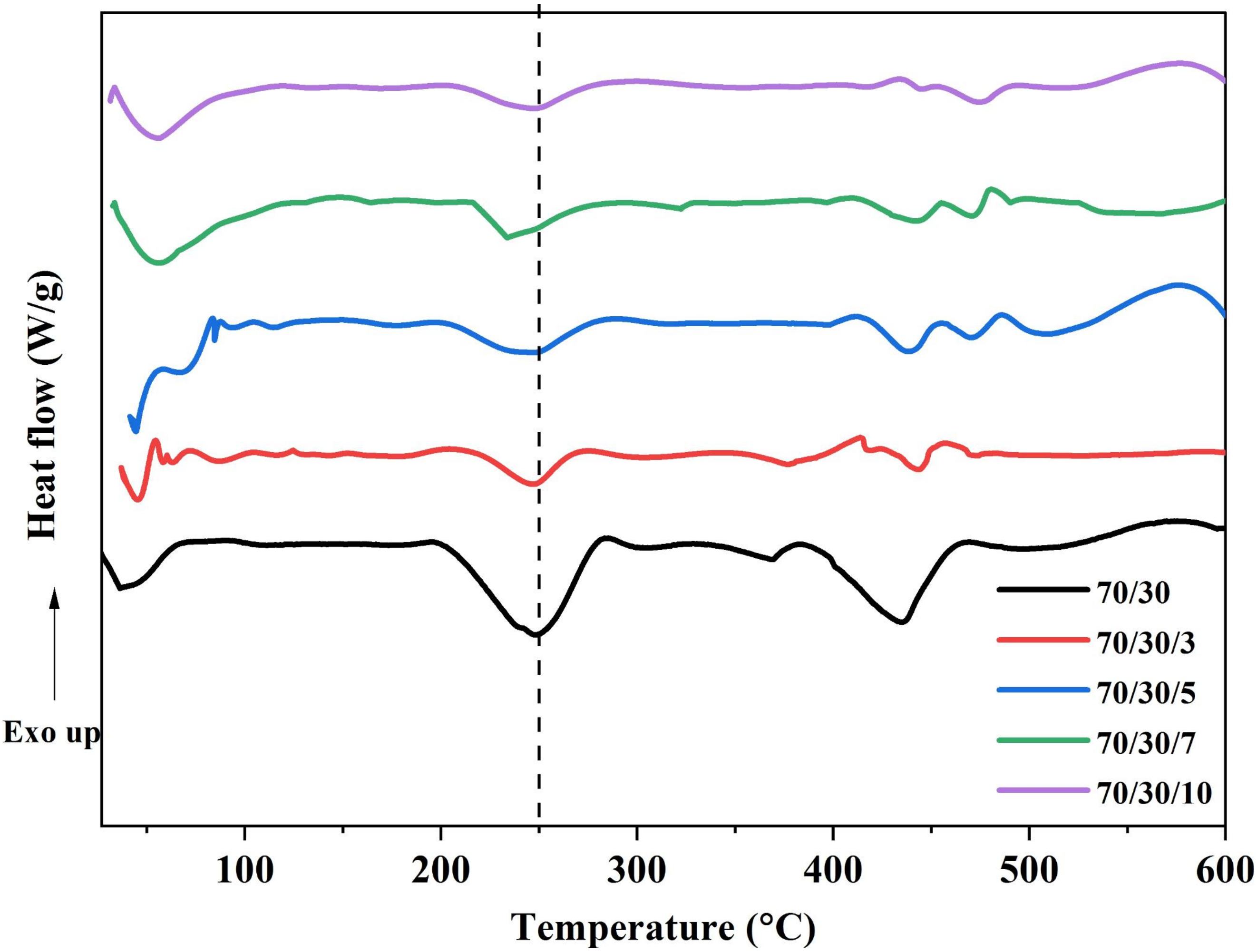


Fig. 8 DSC heating curves of PET/PS and PET/PS/SbB-g-GMA blends (At heating rate: 10 °C/min)

glycidyl methacrylate-grafted styrene-block-butadiene (SbB-g-GMA) as a dual purpose reactive compatibilizer and impact modifier was first synthesized via grafting GMA onto SbB, and then, added to the blends in order to obtain a stable morphology with no distinct phase separation and with improved impact properties. Different blends with various amount of compatibilizer were prepared, and their thermal, morphological and mechanical properties were investigated. It was found that through the incorporation of 7 phr of the SbB-g-GMA compatibilizer, into the blend, as the optimum value, the best tensile and notched Izod impact strength as well as the highest thermal stability could be achieved as compared to the blend with no compatibilizer and with those having different loadings of the compatibilizer. Additionally, FESEM results indicated that although the unmodified PET/ PS blend was composed of large PS droplets, the PS droplets size was significantly minimized in the compatibilized blends, especially in the blend with 7 phr of the SbB-g-GMA compatibilizer, indicating better miscibility, and therefore, superior thermal and mechanical properties. As mentioned before, in the developed ternary blends of PET/PS/SbB-g-GMA, the PET plays the role of matrix. So the developed PET/PS/SbB-g-GMA blend can be utilized in wide range of applications in automotive industry such as fabrication of engine cover, wiper arm and gear housings, head lamp retainer, and connector [37] in addition to houseware,, it can be utilized in building and constructions and packaging applications too.

Abbreviations

PET	Polyethylene terephthalate
PS	Polystyrene
SbB	Styrene-butadiene block copolymer
GMA	Glycidyl methacrylate
AIBN	2,2’-Azobis(isobutyronitrile)
SbB-g-GMA	Styrene-butadiene grafted GMA

Contributions **F. Tahmasebi** did formal analysis and investigation and wrote original draft, **S.H. Jafari** did conceptualization, supervision and reviewed the manuscript, **S. Morteza F. Farnia** did review and editing.

Declarations

Conflict of interest The author declares that they have no conflict of interest.

Consent for publication All authors agreed to publish.

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