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Preparation and Study of Mechanical and Thermal Properties of Polymer Blends from Recycled Materials of Polystyrene and Polymethylmethacryalate with Different Ratio of Diethylmalonate

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Abstract

Polymer blends of recycled polystyrene (rPS) were obtained from disposable dishes of PS. Also, used the recycled poly (methyl methacrylate) (rPMMA).The blends were made as 1:1 (w/w) weight ratio of r PS: r PMMA with different weight ratios of diethyl malonate, which prepared by casting solvent in the tetrahydrofuran (THF) at 85 °C. The polymer blends were characterized by Fourier transform infrared (FTIR), Differential scanning calorimetry (DSC) and Mechanical properties. The results of FTIR spectra showed that polymer blends of rPS/rPMMA with different ratios of diethyl malonate had no molecular interactions. DSC investigated the thermal behaviour of the produced blends to analyze miscibility behaviour through the glass transition temperature. The DSC analysis of some blends shows that blends have two distinct transitions due to heterophase nature. Mechanical properties were indicated that the best ratio of diethyl malonate was 35% to increase the elongation and forces of polymer blends of rPS/rPMMA. These kinds of blends can be used to synthesize another product with this characteristic by recycling the waste of PS and PMMA.

Keywords: Recycled polystyrene, Recycled polymethylmethacrylate, Diethyl Malonate.

1. Introduction

Polymer blends are an assortment of different copolymer without any covalent bonding between them [1,2,3]; they are grouped as three types, namely, homologous, miscible and immiscible polymer blends [4,5]. Chemically, the polymer mixture consists of one or more polymers and gives an identical and homogeneous mixture, as the mixed polymeric mixtures exhibit single-phase behavior, while unmixed polymer mixture has two or two phase's temperatures. Recently there has been a lot of researches in preparing polymeric blends because they reduce the manufacturing time and are also less expensive than those in the polymer alone [6]. The characterization of a polymeric material can be made better by the option of changing the suitable ingredients and their weight ratios to enhanced physical,

mechanical and chemical properties we can. The blending of two or more polymers having different new properties is usually manufactured as a new polymeric material. These materials may have the properties of jointly the polymers. Some properties such as toughness, strength, etc. have nigh to relationships with polymer blends internal micro phase morphology. PMMA has been found to shape an immiscible blend with polystyrene [7]. Miscibility is not a condition for applications of anew polymer blends; amorphous polymer like Polystyrene is renowned with convenient thermal and radiation-resistant properties [8] which is available with abroad range of formulations and commercially availablein the last years some researcher study different mixture of polystyrene with polymethylmethacrylate and study the anew characterizations, the influence of the addition of polymethyl methacrylate–block polystyrene and PS-b-poly (n-butyl acrylate) diblock copolymer on the mechanical properties of blends were study by Michael Steinert and et al. [9]. K. Kaniappan and S. Latha studied the polystyrene /polymethylmethacrylate blends with different ratios and investigated their glass transition temperature by DSC to analyze miscibility with together behaviour [10]. Superior excellent properties can be achieved by way of a blending of recycled rPMMA with polystyrene. Recycling encompasses breaking the material down into smaller pieces that can be used as feedstock in manufacturing process. rPS and rPMMA are known to be immiscible, exhibiting phase separation and compatibilizer are required. In this work, waste recycled polystyrene (rPS) was obtained from disposable polystyrene dishes and rPMMA blends were prepared with random percent 1:1 % and different weight ratios of diethylmalonate (20%-40%) to investigate their structural features and miscibility behaviour through DSC studies and mechanical properties.

2. Materialsand Instruments

THF and diethylmalonate was purchased from Merck and used as received. The FTIR Spectra were Recorded IR Spectra (as KBr discs) on a JASCO FT/IR 4100 instrument, with a wave number range of 400-4000cm−1. FTER simple technique provided information about the structure and chemical bonding of the material. Mechanical properties were measured by A universal testing machine (Zwick Rell), this device origin (Germany), from type (BTI-FR2.5TN.D14), power operating card (100-129 V / 4, 4-3,7A) at room temperature (RT). it is available at Polymer Research Center, Basrah University, Iraq.

3. Experimental

Preparation of polymer blends of recycled polystyrene rPS and recycled polymethylmethacryalaterPMMA with diethyl malonate

A series of polymer blends of rPS and rPMMA were prepared from the tetrahydrofuran (THF) as follows, the Polymer blend solutions were prepared by dissolving rPS/rPMMA in random weight ratios (1:1) in THF. The solutions were mixed at 850 °C for 6 hrs., then the different weight ratio of diethyl malonate (0, 20, 25, 30, 35, and 40) % was added and stirred until homogeneous solution was prepared. The solutions were then poured into the glass plates, the solvent THF was slowly evaporated, and the polymer blends were dried in an oven at 70 °C for 24 hrs. Table 1 showed the weight percent of materials and the symbols of the prepared polymer blends. DSC and mechanical properties characterized these materials.

Table (1) Chemical Composite of Polymer Blends.

Materials	Percent of Diethylmalonate %	Number of Symbols
rPS	**0**	**1**
rPMMA	**0**	**2**
rPMMA+ rPS	**0**	**3**
rPMMA+ rPS	**20**	**4**
rPMMA+ rPS	**25**	**5**
rPMMA+ rPS	**30**	**6**
rPMMA+ rPS	**35**	**7**
rPMMA+ rPS	**40**	**8**

4. Results and Discussion

Infrared (FTIR) Spectroscopy Study

The FTIR spectra of r PS are showed in Figure (1), which showed absorption bands at 3465 to aromatic C-H stretching and 2925 $cm^{-1}$for aliphatic C-H stretching. Aromatic C-C stretching showed peaks at 1600 and 1451 cm^{-1}. The C-H deformation vibration band of benzene rings /ring hydrogen has appeared at 757 cm^{-1}. The vibrational bands of 1488 and 1451 cm^{-1} are attributed to CH_2 scissoring and CH_3 asymmetric stretching or deformation of rPMMA. The bands are appearing at 1242 and 846 cm^{-1} identical to C-O-C stretching of r PMMA. The absorption bands related to CH_2 twisting, wagging and rocking of r PMMA appear at 1190, 951 and 750 cm^{-1} respectively. The peaks at 1730 represent the C-O and 1151 cm^{-1} for $–OCH_3$ stretching in all the blends to r PMMA. The peaks at 1644 in all blends for C-C stretching and 665 cm^{-1} in all the blends represent ring of polystyrene. The data of FTIR show the immiscible of polymer blends of r PS and r PMMA and the blends interact by hydrogen bonding, and the table (2) shows the essential bands [11].

Table (2) Bonds wave numbers of r PS and r PMMA polymer blends

Type of bond	Peaks/cm^{-1}
Aromatic C-H	3465
Aliphatic C-H	2925
C-C	1600
CH_3 stretching of r PMMA	1451
C-O-C stretching	1242
CH_2 twisting	1190
C-O bending	1730

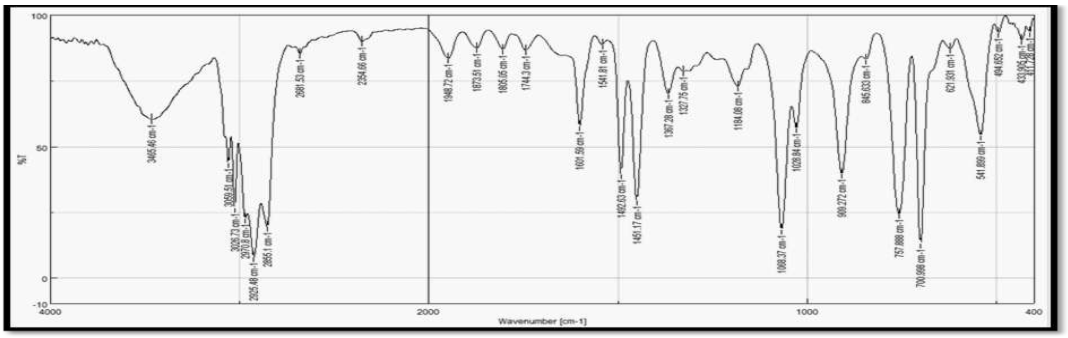

Figure (1): (FTIR) Spectroscopy of polymer blend 1.

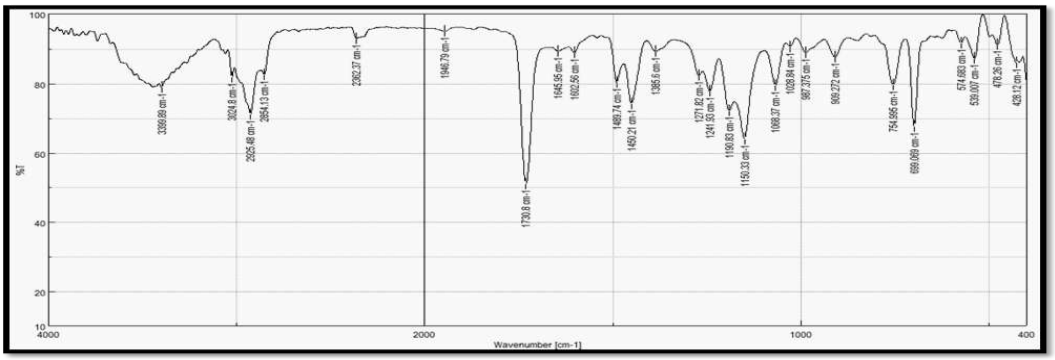

Figure (2): (FTIR) Spectroscopy of polymer blend 2.

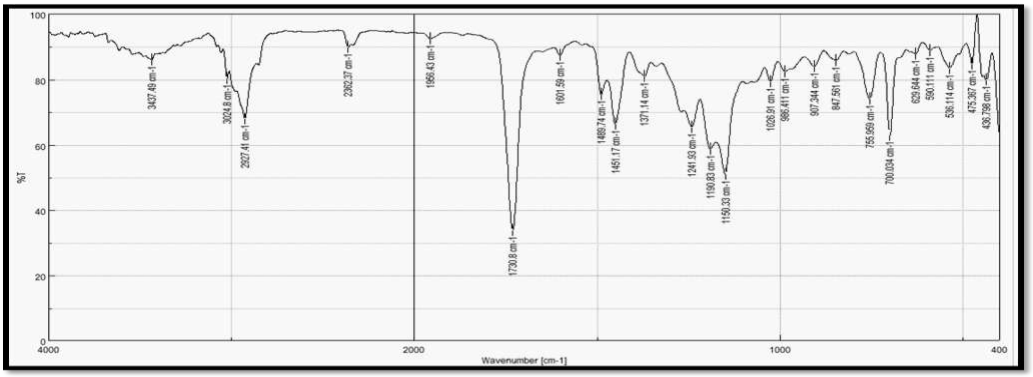

Figure (3): (FTIR) Spectroscopy of polymer blend 3.

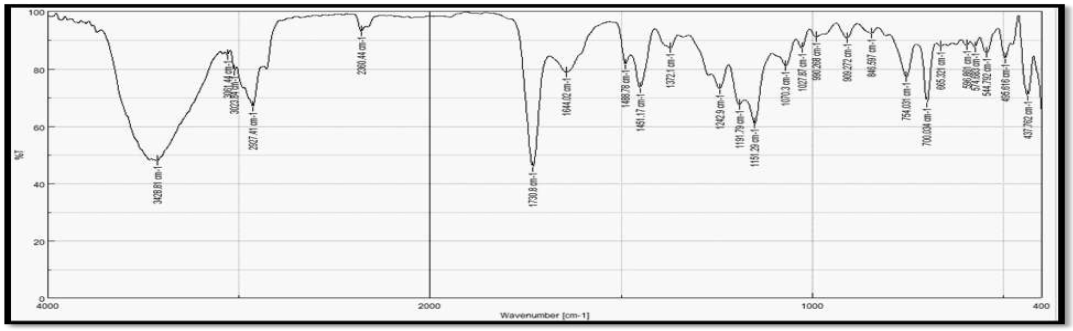

Figure (4): (FTIR) Spectroscopy of polymer blend of blend 4.

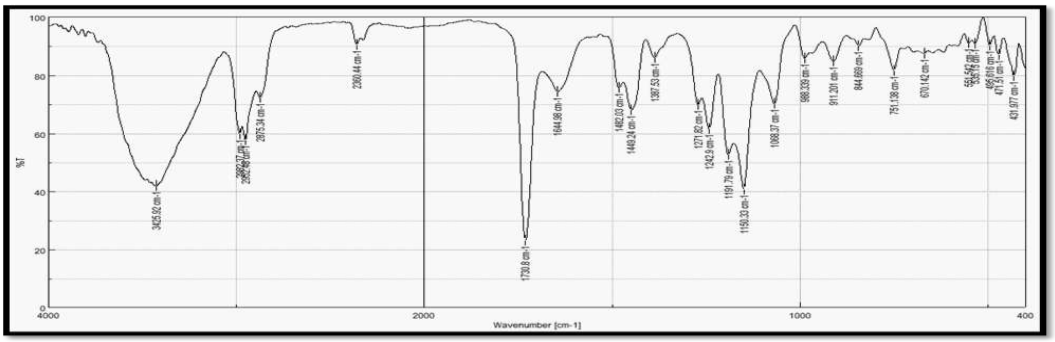

Figure (5): (FTIR) Spectroscopy of polymer blend8.

5. Mechanical Testing Device.

The tensile characteristics were examined according to the ASTM Standard D-638: Standard Analysis Method for Tensile Properties of Plastics polymer. The (stress-strain) behavior for blends of polymer of (rPS) / (rPMMA) shows in Fig. 6 with different ratios of ethyl malonate measured at a constant percentage filling at room temperature. The curve of stress-strain has been depended on the characterization instead of the curve of load elongation because it explains the properties of the material and is little dependent on the sample profile. It is known that polymer belongs to where this behavior has been characterized by low yield stress and young modulus. The curve of strain-stress is epitomized the second behavior of the fracture nominally cold drawing. Three zones can be discovered; the first region is the linear, second region is the yield and the third region is the elongation area is up to the break. In the region of linear where the small deformation, Hook's Law is performed which represents the instantaneous deformation and recoverable associated with the bending and expansion of the chains between the polymer atoms. [12].

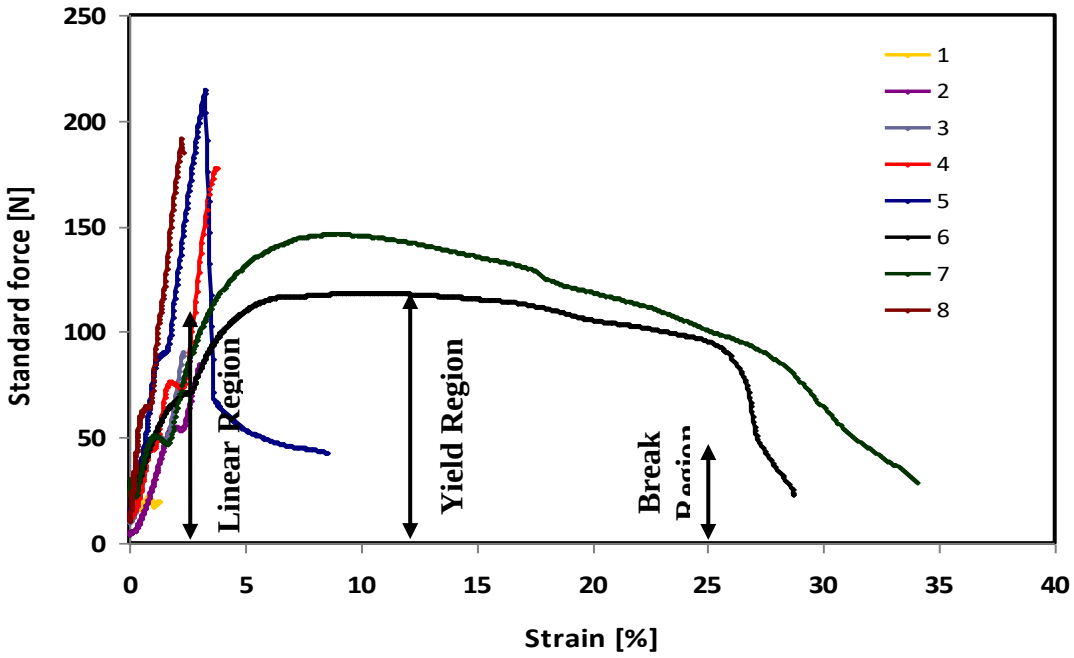

Figure (6): the stress-strain curves of polymer blends of (rPS) and (rPMMA) with different ratio (diethyl malonate).

Figure 7 shows the effect of the Diethylmalonate, on (rPS) and (rPMMA) blends on the modulus of elasticity which is defined as a proportion of strain to elongation for solid materials, in fig. 8 showed the decreasing modulus of Young piecemeal with the materials additive concentration. The modulus of elasticity was 6.45 Mpa when the Percent of Diethylmalonate was 0% with rPS, and then decreased to 0.34 MPa when the Percent of Diethylmalonate was 35% with rPMMA+ rPS () [13]. While then maximum values increased to 9.17 Mpa when the Percent of Diethylmalonate was 40% with rPMMA+ rPS , the maybe explains the decrease in the behavior when the Percent of Diethylmalonate was 35% with rPMMA+ rPS of the diethyl malonate to the heterogeneity of the sample although the mixing samples have been in the same conditions, and that mentions that the polymer has a significant elongation (high elasticity) and decline in rigidity at this ratio.

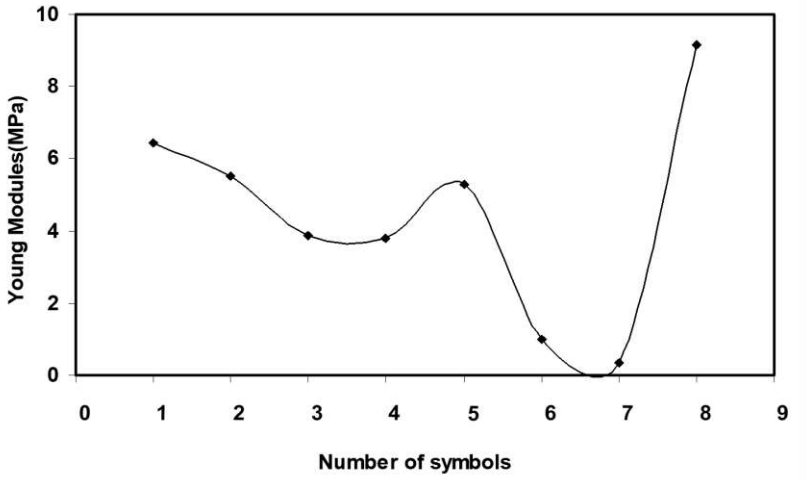

Figure (7): Young modulus of(rPS) and, (rPMMA) blends with different ratio of diethyl malonate.

Figure 8 indicate the relation between the elongation ratio and the diethyl malonate concentration. The polymer blends elongation begin at the number of symbols (1) of the blends of polymer (1.3%) and then increases when the percent of diethyl malonate is (35%) with (rPMMA+ rPS) is (28%), which is a high polymer of flexibility and has a hardness little thereby acting (diethyl malonate), (rPS), and (rPMMA), to fill the spaces between the polymer chains main, thereby the chains polymer limited movement, and then increases to till it arrives the minimum value to them when the ratio of diethyl malonate is (40%) with (rPMMA+ rPS) is (2.3%) [14], and the polymer blend when this ratio less flexibility and high hardness. The chains polymeric that are not constrained by any action as a result of shortage of mixture homogeneity, comprising the nature of the (diethyl malonate, rPS and, (rPMMA), describe by hardness, which in turn increases the polymer rigidity and elongation decreases, which increased the diethyl malonate concentration and worked to increase the polymer stickiness.

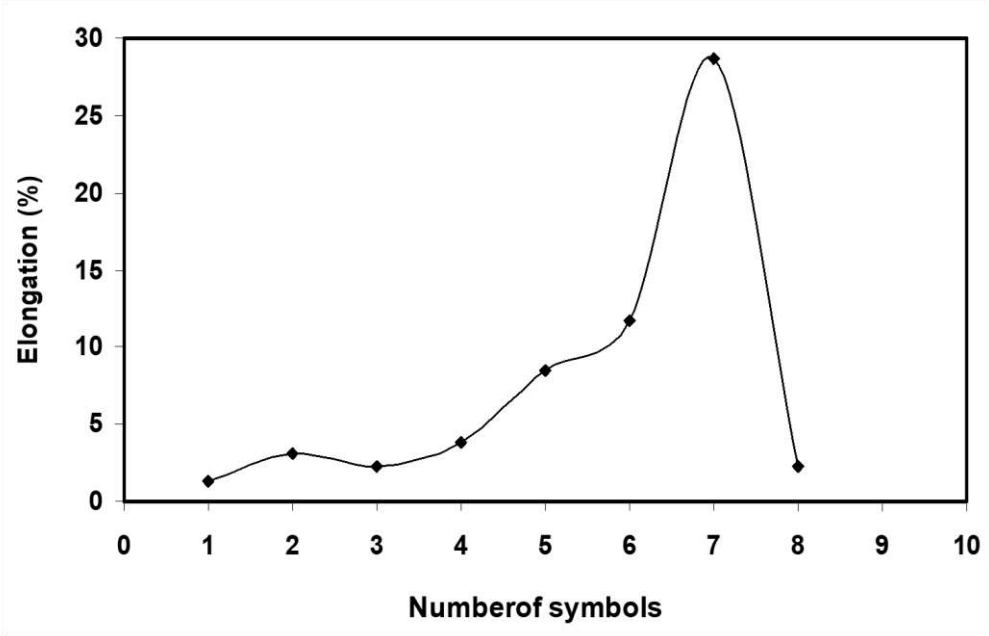

Figure (8): Elongation of rPS and, rPMMA blends with ratio ofdiethyl malonate.

Figure 9 show the connection between the Stress with a percentage of diethyl malonate added to the polymer blend. The behaviour of stress at yield starts the low influence when the ratio of (rPS) of the diethyl malonate, and The behavior then increase to (16.5 MPa) when the percent of diethyl malonate is (0%) with (rPMMA) [15], and also we note from fiq.(9) the behavior of stress decreases and increases when you increase the ratio of adding the diethyl malonate, rPS and, rPMMA, and the behavior of yield strength highest increases when the percent of diethyl malonate is (40%) with (rPMMA+ rPS) is (21.1 MPa). This shows that diethyl malonate works to improve the hardness of polymer blends (and elongation) at the same time at the percentage of (6%) when the polymer rigidity stretches at this average of the impact of the distribution of homogeneous solid material nature.

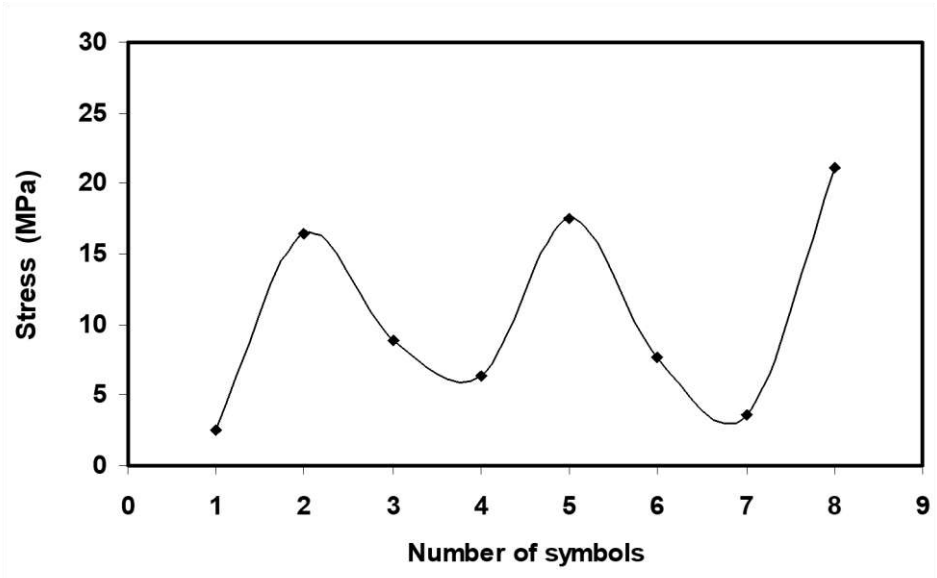

Figure (9): Stress at yieldof rPS and, rPMMA blends with ratio of diethyl malonate.

Differential scanning calorimetryDSC study.

Polymer blends are miscible if their ingredients form a single homogeneous phase at the molecular scale, or immiscible if they display several distinct phases [16-20]. The DSC thermo gram of the representative rPS/rPMMA blend shows one distinct glass transitions Thus, the addition of diethyl malonate to the blend would increase the molecular mobility of tow polymers and data showed that addition of diethyl malonate to the rPS/rPMMA polymer blends change itsTg. Thus, the obtained results show that diethyl malonate, a good effect for rPS/rPMMAblends. The DSC of the waste polystyrene and the waste polymethyl methacrylate and 1: 1weight ratio of both polymers is shown in Figures (10-12).

Figure 13 shows the DSC of polymer blend with 20% of diethylmalonate, Tg value of polymer blends with different the ratio of diethyl malonate were less than the r PS and r PMMA and the blend of r PS/r PMMA(1:1) and the Figures (14-17) show the DSC of polymer blends with different ratio of diethylmalonate.DSC studies Thermal characterization of rPS/rPMMA polymer blends are well-known method for placement the miscibility of polymer blends. The DSC thermo r PMMA and r PS polymer blends with different ratio of diethylmalonate were allowed molecular rearrangement to occur and decrease Tg values.

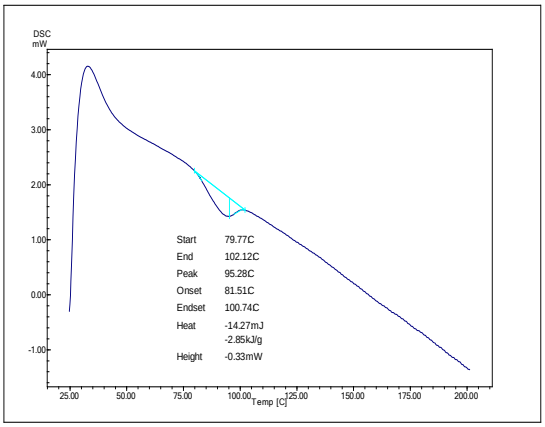

Figure (10):DSC curve of 1.

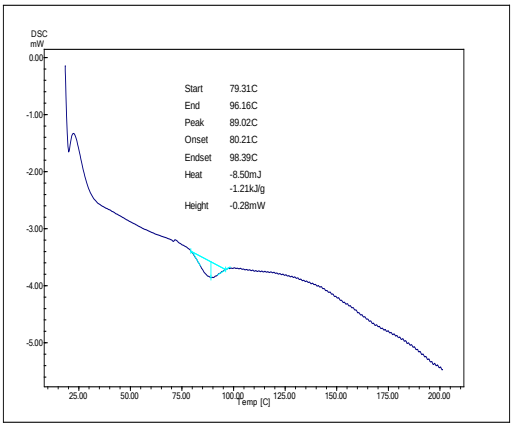

Figure (11): DSC curves of 2.

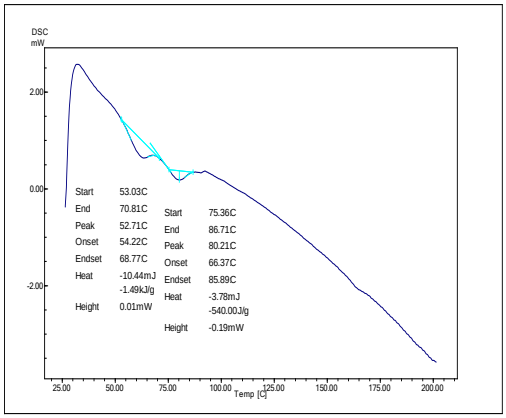

Figure (12) DSC curves of blend3.

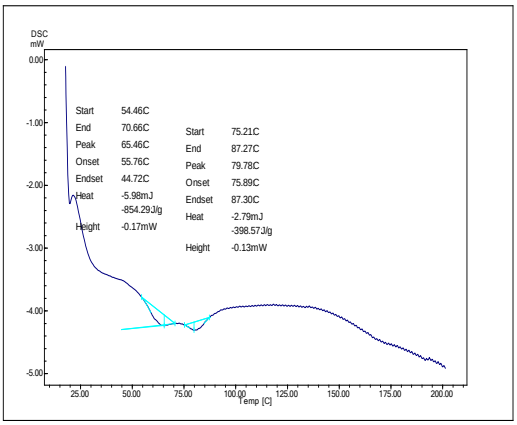

Figure (13) DSC curves of blend 4.

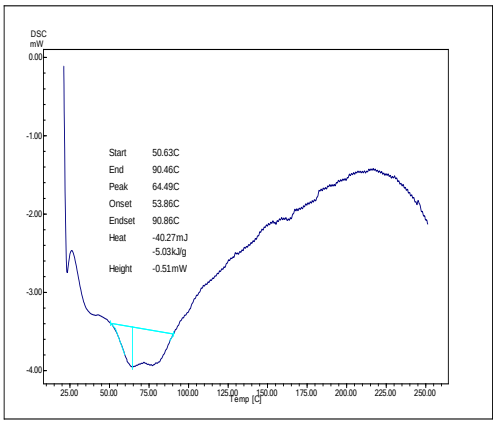

Figure (14): DSC curve of blend 5.

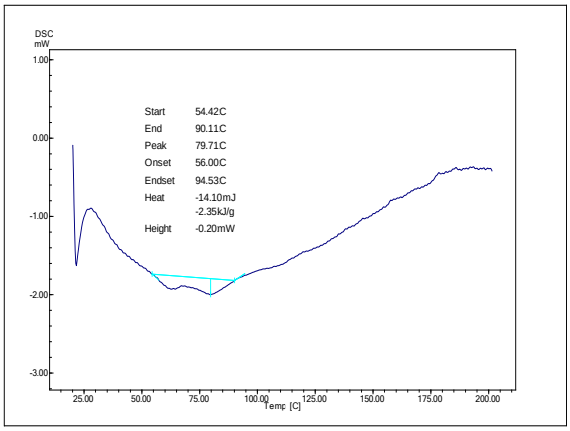

Figure (15): DSC curves of blend 6

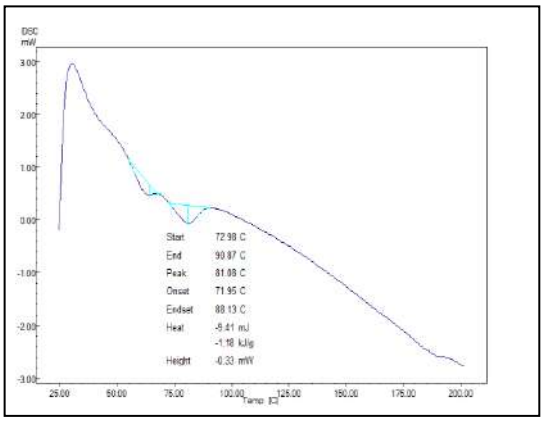

Figure (16): DSC curves of blend 7.

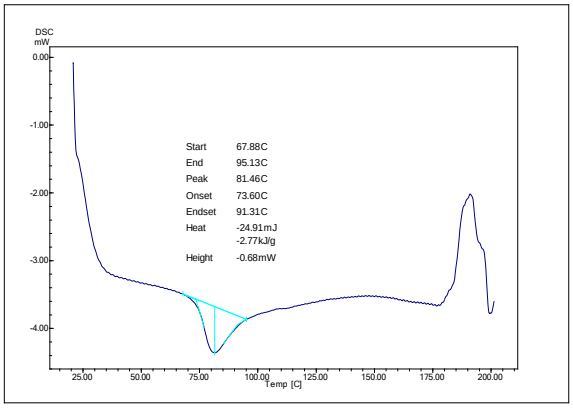

Figure (17): DSC curves of blend 8.

6. Conclusions

Modified blends of rPS/rPMMA were prepared by the Solvent casting technique with different weight percentages (0, 20, 25, 30, 35, and40wt. %) of diethyl malonate. FTIR spectra characterized the prepared blends and the essential peaks are found at 1730 and 1151cm^{-1} in all the blends representing the C-O and –OCH_3 stretching of rPMMA. The peaks at 1604and 965 cm^{-1} in all the blends represent the C–C stretching and ring deformation of polystyrene. Further, the mechanical study was found that the tensile strength and modulus enhanced as a function of diethyl malonate concentration. Among all the composites, 6 wt. % of rPS–rPMMA blends indicates high tensile modulus of3.8 GPa. The increase in the elongation tensile indicatesthat the diethyl malonate significantly improves the mechanical property. DSC confirms that the melting point change withan increase in diethyl malonate in rPS/rPMMA blends. DSC confirmed the immiscible character of the polymer blends and the results evidenced that blend system was heterophase due to two distinct glass transitions. Hence, rPS/rPMMA/diethylmalonate blends were immiscible and no specific intermolecular interactions were observed, which make the possibility to recycle anew materials from the waste.

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