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Effects of Terpolymer Addition on the Thermal and Termomechanical Properties of Poly(Phenylene Sulfide)

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Poly(phenylene sulfide) (PPS) is one of the high-performance engineering polymers and it exhibits superior behavior, such as electrical insulation, dimensional and thermal stability, chemical resistance for various industrial applications. In addition to this, PPS has a high degree of crystallinity and it maintains these properties at high temperatures. These advantageous properties of PPS can be dependent on its chemical structure, composed of phenyl groups linked by a sulfur atom, which gives rigidity to the polymer chains. Owing to these properties, PPS is widely used in electrical and electronic components, automobile industry and mechanical applications. On the other hand, brittleness of PPS restricts its further applications. For this reason, ethylene-acrylic ester-glycidyl methacrylate terpolymer (Lotader®-AX8900) was used to overcome the brittleness of PPS. The effects of terpolymer addition on the thermal and thermomechanical properties of blends were investigated in this study. PPS/Lotader (0, 2, 5, 10 wt.% Lotader®) blends of various compositions were prepared. The blends were prepared by using laboratory scale micro compounder and injection molding machine. Thermomechanical and thermal properties of blends were investigated by means of dynamic mechanic analysis and differential scanning calorimeter test methods. As a result of this study, it was found that increasing loading level of Lotader® significantly decreased the crystallinity and increased glass transition temperature of PPS. On the other hand, Lotader® addition did not affect the melting temperature of PPS considerably. Results of dynamic mechanic analysis test revealed that while damping factor peak and loss modulus values of blends increased with the addition of Lotader®, storage modulus of blends decreased with the increasing loading level of Lotader®. When all test results are considered, it can be concluded that Lotader addition changes the brittle nature of PPS to ductile nature. In addition to this, 2 wt.% Lotader addition to PPS enables the optimum ductility for PPS without deteriorating its other properties.

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1. Introduction

Polyphenylene sulfide (PPS) is a linear, high-performance, semi-crystalline engineering thermoplastic [1, 2]. Sulfur atoms and phenyl rings form the backbone of its macromolecule and give it a number of extraordinary properties. Nonflammability, high hardness and rigidity are some of these inherent properties of PPS. These unique features make this technical plastic suitable particularly for the production of highly mechanically and thermally loadable parts [1, 3].

As known, PPS is mainly used as raw material for connectors, switches, coils and so on, in the electrical and electronic fields, and in the automotive industry, for valves and engine parts. It is also used for manufacturing of cases for pumps, cameras, and instruments in the machinery industry and lastly it is used in aerospace and aviation industry [4, 5]. The request in different industries for PPS will continue to increase, as long as economic growth is lasting. However, the brittleness of PPS, which is derived from the rigid backbone and the crosslinking micro structure, restricts its wider usage. To improve the mechanical properties and to lower the costs, blending, fiber reinforcing, particle filling, and liquid polymer compositing are usually used [6].

Arkema Lotader AX8900 is random terpolymer that contains ethylene-acrylic ester glycidyl-methacrylate terpolymer. Owing to its properties of softness, toughness and reactivity which are deficiencies of PPS, Lotader is preferred as admixture for improving the impact strength, toughness and thermal properties of engineering thermoplastics like polyamide (PA), polyesters (PBT), polycarbonate (PC), acrylonitrile butadiene styrene copolymers (ABS) alloys and polyphenylene sulfide (PPS) [7].

Additionally, glycidyl methacrylate provides reactivity with COOH, OH, and NH_2 groups and leads to optimal dispersion during melt mixing with engineering thermoplastics. By this means, Lotader AX8900 exhibits good adhesion and interaction with PPS [8].

PPS/Lotader AX8900 blends were prepared in this study in order to investigate the thermal and thermomechanical properties of PPS. These properties of blends were investigated by means of dynamic mechanic analysis (DMA) and differential scanning calorimeter (DSC) test methods. Consequently, optimum amount of terpolymer was determined according to thermal test results.

2. Materials and methods

2.1. Materials

Poly(phenylene sulfide) was supplied from Ticona company, Taunus, Germany with Fortron 1200L1 trade name. Lotader AX8900 random terpolymer of

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ethylene-acrylic ester-glycidyl methacrylate was obtained commercially from Arkema Functional Polyolefins, Istanbul, Turkey.

2.2. Preparation of blends

A laboratory scale mini compounder which has corotating twin screw extruder was used for compounding PPS/Lotader AX8900 blends. Blends were mixed at 315 °C barrel temperature, 100 rpm screw speed and mixing time of 3 min. Extruded compounds were subsequently injection molded using a laboratory scale injection molding machine. The barrel temperature and mold temperature were 315 °C and 80 °C respectively. The compounding ratios of components in the blends and code names of specimens are given in Table I. These temperatures were determined referring to foregoing papers.

TABLE I

Blending ratios of components and code names of specimens.

PPS/ Lotader AX8900	PPS weight [%]	Lotader weight [%]
PPS	100	0
PPS_2L	98	2
PPS_5L	95	5
PPS_10L	90	10

2.3. Methods

DMA tests were performed in order to obtain elastic properties of specimens and to investigate how they change with increasing temperature. DMA tests were applied by using TA Instruments DMA Q800 tester between 25–150 °C at 3 °C/min heating speed.

DSC test is a method that provides crystallinity degree, melting temperature and glass transition temperature. Glass transition temperature is an indicator of continuous working temperature, because if temperature gets higher than that value, material gets soft and fluid. Crystallinity degree, on the other hand, directly influences the tensile strength. DSC tests were applied by using TA Instruments Q200 tester between 20–340 °C at 3 °C/min heating speed.

3. Results and discussion

According to Fig. 1, crystallization energy decreased with Lotader addition, with respect to that of pure PPS, but increasing ratio of Lotader does not affect that change. Low crystallization energy means low crystallinity degree and that means weaker tensile strength but higher elongation at break [9]. Another data that was obtained from this test is glass transition point T_g. Table II shows that T_g gets higher with Lotader addition but it is not effected by the ratio of addition. Melting point, on the other hand, gets about 2 °C lower than that of pure PPS with Lotader addition and it is not effected by the ratio at all. Column % in Table II contains data of the change in the crystallinity degree for each tested material.

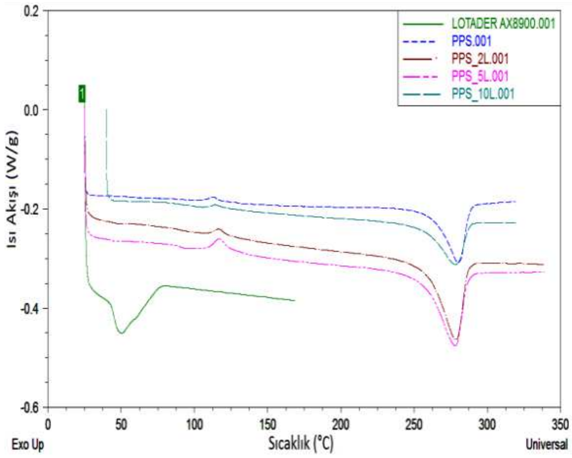

Fig. 1. DSC test graphs of studied specimens.

TABLE II

DSC test data.

Specimen	Melting energy [J/g]	T_g [°C]	T_m [°C]	%
PPS	38.717	87.81	280.2	0
PPS_2L	31.1826	90.82	278.66	-19.46
PPS_5L	31.272	90.63	278.06	-19.22
PPS_10L	32.23	89.83	278.45	-16.76

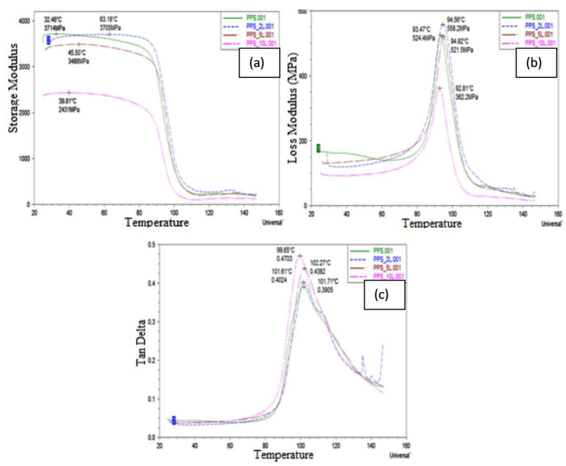

Fig. 2. Temperature dependencies of the DMA test of specimens, (a) storage modulus, (b) loss modulus, (c) tan delta.

Figure 2 shows DMA results of manufactured specimens. The storage and loss modulus are important parameters, however their ratio, "tan delta" is the most important data, which is obtained from DMA test. Figure 2a shows how much of applied energy is recovered and Fig. 2b shows how much is absorbed by the specimen.

Figure 2c shows the ratio of the absorbed/recovered by these specimens energy. According to Fig. 2 Lotader addition affected negatively elastic properties of PPS. That means that specimen absorbs more energy by inner fractions, so it gets tougher [10]. Blends got more ductile than the pure PPS.

Specimen containing 2 wt.% of Lotader, on the other hand, has shown properties very close to those of pure PPS, but was still tougher enough. DMA tests show that 2 wt.% Lotader-containing blend has the most proper compound ratio to reach the purpose of this study.

4. Conclusions

- In this research, it was found that glass transition point of PPS increased slightly with addition of LOTADER AX8900.
- Melting point decreased by about 2 °C at all blend compositions.
- Crysatllinity degree of blends decreased by about 20% with respect to pure PPS.
- DMA tests show that elastic properties of PPS were affected negatively after Lotader addition.
- Investigation shows that optimum thermal, thermomechanical and mechanical properties, according to DMA and DSC tests, were obtained in the 2 wt.% Lotader containing blend.

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