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Preparation and Preliminary Study on Irradiated and Thermally Treated Polypropylene (PP) - Styrene Butadiene Rubber (SBR) Composite

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Abstract

The tensile strength (TS) and elastic modulus (ES) of non-irradiated (thermally treated) and irradiated Polypropylene (PP) - styrene butadiene rubber (SBR) composites were studied. The content of SBR (mass %) on PP and radiation dose play an important role on tensile strength and modulus of elasticity of PP-SBR composites. Tensile strength (TS) decreased markedly on increasing the SBR content on PP and even on exposing to radiation. The elastic modulus (EM) of PP-SBR composite has a tendency to increase with radiation dose and aging time but decreases with SBR loading. The water uptakes increase with SBR loading which accelerate with aging.

Keywords: Polypropylene; Styrene butadiene rubber; Tensile strength; Elastic modulus.

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1. Introduction

Polypropylene (PP) is a thermoplastic polymer that is widely used in many fields, such as building materials, furniture, automobile and toy industries etc. According to its performance, such as wide property spectrum, easy processability, versatility of applications, high strength and attractive combination of favorable economics, it is a outstanding polymeric materials. But the lacks of sufficient mechanical properties, it is not suitable for many engineering applications. It has relatively poor impact resistance especially in low temperature. We can improve the mechanical properties of PP by adding fillers such as tale, glass fibers etc. [1, 2]. The problem of PP composite with foreign fillers is that it reduces the recyclability as it is difficult to separate the fiber and matrix.

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This problem can be solved by using similar or identical materials for both fillers and matrix.

Polypropylene is now a most usable material in the modern society. But it causes a serious environmental problem due to its poor biodegradability. On the other hand it makes human life so easy that it is quite hard to stop people from using PP. PP fibers and films undergo partial decomposition with loss of mechanical strength only after remaining in air for a year and more. Exacerbation of the environmental problem related to environmental pollution by solid polymer wastes lead to the appearance of a new scientific direction at the junction of physical chemistry, microbiology, materials science, and polymer technology aimed at creating biodegradable polymer materials [3]. Few studies have been done on PP-SBR composites [4-6]. The synergistic incorporation of SiO_2 and SBR nanoparticles into PP can significantly improve the mechanical properties of the PP/SBR/SiO_2 composite and possesses higher thermal stability [4]. PP-SBR composite also can play an important role in this purpose. The rheological properties of PP-SBR composite are dominated by PP and mechanical properties by SBR [5,6].

Styrene butadiene rubber (SBR) is a synthetic rubber made by solution/emulsion polymerization of styrene and butadiene. This rubber is seldom used alone. Generally they are mixed with natural rubber to improve the mechanical property. SBR is superior in aging and ozone resistance. It is also characterized by relatively high hysteresis or heat build up or poor resilience [7]. A comparative study on processing, mechanical properties, thermo-oxidative aging, water absorption and morphology of rice husk and silica fillers in polystyrene/SBR blends have been reported by Ismail *et. al.* [8]. The radiation polymerization has received a great attention from a large number of investigators. It can modify the molecular structure of the polymer as an alternative to traditional methods [9]. Gamma radiation is commonly used as its penetration technique is simple, fast and very effective without significant variation on crystallinity and glass transition temperature. The radiation cross linking and the radiation sterilization of polymers showed comparable development and fulfilling the expectations [10]. Water uptake and swelling represent an important aspect of the characterization of polymers intended for use as degradable medical implants or drug delivery devices [11]. Conventionally, studies of water uptake, swelling, and degradation are being conducted on the macroscopic scale, *e.g.*, by weighing specimens stored in various aqueous media for predetermined periods of time, by measurements of volume, or by determining the total amount of imbibed water by thermal gravimetric analysis (TGA) [12].

The main objective of this work was to make a new PP-SBR composite by using different content of SBR with PP. In addition, this work was extended to obtain the variation of mechanical properties and water absorbed capacity of PP with SBR loading.

2. Experimental

Both the PP and SBR (commercial grade 1502) were purchased from local market (origin: Singapore). The PP and SBR were mixed properly with their desired mass proportions in an extruder (Axon-ab Plastics Machinery, S-26550 NYVANG, Sweden) at an operating temperature range 180°C to 200°C. The mixers were then cooled gradually and cut into pieces. These pieces were made films by heat press machine (WABASH, INDIANA, Model No-3856 S/N 3856-409, U.S.A.) at 176°C temperature. PP granules were used to make PP sheets. Granules were poured in a mould, placed between the plates of the heat press machine (compression moulding machine) and the mould was allowed to cool to prepare PP sheets. A number of films were prepared by changing the compositions of polypropylene and Styrene-Butadiene-Rubber in the composite.

These films were used for measurements of tensile strength and elastic modulus by universal testing machine (Model: Instron- 1011, UK). In addition, they were irradiated with various radiation doses (Gamma Source, Cobalt-60). These films also were aged with various time duration in an aging oven ((Model No. 6327, KASUGA E W LTD., JAPAN) at 100°C temperature.

The samples were cut into specific size (10 mm width and 20 mm in length). The thickness of the films was measured by the thickness reader (2 mm). The tensile-strength and elastic modulus of virgin, mixed, aged, non-irradiated and irradiated films were allowed to measure directly by Instron Machine (ASTM D 638-10, Standard test method for tensile properties of plastics). The machine was operated at a deformation rate 10 mm/min. The machine directly provided the information about the tensile strength (MPa), and Modulus of elasticity (MPa). To study the water adsorption, we take the weight of a small piece of film (1cm X 2cm) before and after water swelling (ASTM D570-98, standard test method for water absorption of plastics). The weight gains with respect to unswell sample represent the water uptake of the composite.

3. Results and Discussion

3.1. *Tensile strength (TS)*

The tensile strength of the PP-SBR composite (σ), is presented in Fig. 1 as a function of SBR content in the composition. As seen from the figure, the tensile strength gradually decreases with an increase in the SBR content in the composition. The tensile strength *vs*. SBR content may be described by an empirical model of the type

$$\sigma = \sigma_0 (1-x)^n \qquad (1)$$

where σ_0 is the tensile strength of the virgin PP, x is the SBR content and n is a constant characterizing the degree of contribution of PP in the PP-SBR composite system. For $n=1$, the contribution of PP in the strength of the composite remains proportional to its mass fraction in the composition. The experimental data of the tensile strength σ is fitted to the Eq. (1) with a curve-fitting program and the fitted value of the parameter n is found to be 2.2±0.2. The value of $n > 1$ indicates that the deterioration of the tensile strength with an increase in the SBR content is higher than that expected for a given composition.

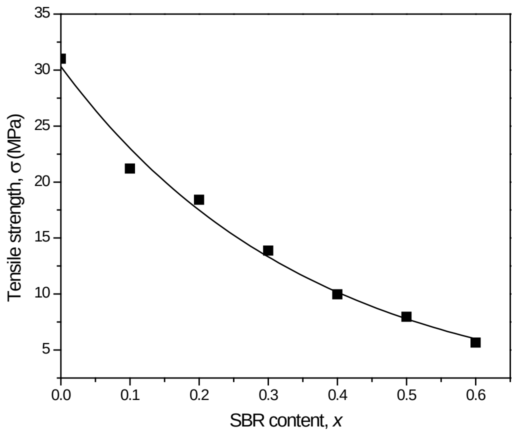

Fig. 1. Tensile strength of the PP-SBR composites.

All virgin PP film and composites are thermally treated, while they were prepared by the treatment in the extruder and heat press machine. So aging is termed as secondary heat treatment in this experiment. Fig. 2 shows no significant effects of aging on tensile strength.

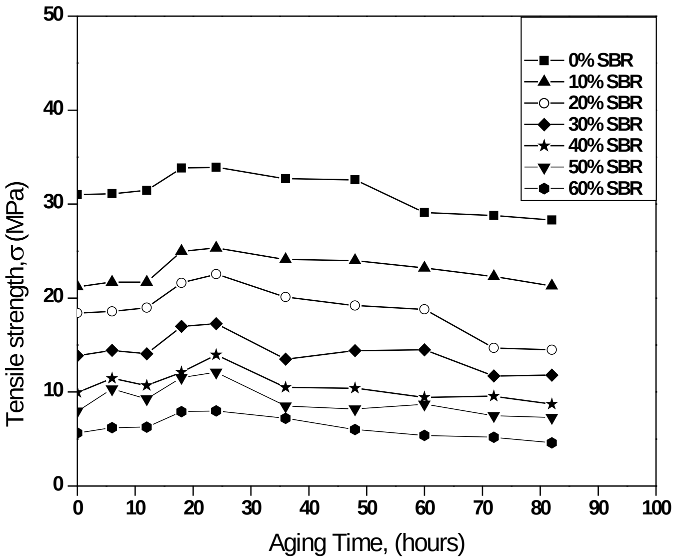

Fig. 2. Presentation of Tensile strength vs. Aging time, (hours) for PP-SBR composites.

The tensile strength of virgin PP film decreased with increasing radiation dose (Fig. 3). The bond strength of PP decreased with increasing radiation dose and it became fragile above 40 kGy radiation dose. SBR loading films showed a little tendency to decrease the TS with increasing radiation dose. The 10, 20 and 30 percent SBR in PP become fragile above 60 kGy radiation dose and for 40 to 60 percent SBR loading, this happens over 100 kGy radiation dose. With the increase in the radiation dosage, two processes are most probable: cross-linking or degradation. The ultimate strength of the polymer depends, which process will dominate. It is presumed that in radiation treatment of PP-SBR system, the cross-linking process is poor. Oxidative degradation is underway in this process and the rate of degradation increases as the dosage increases, resulting in deterioration of tensile strength.

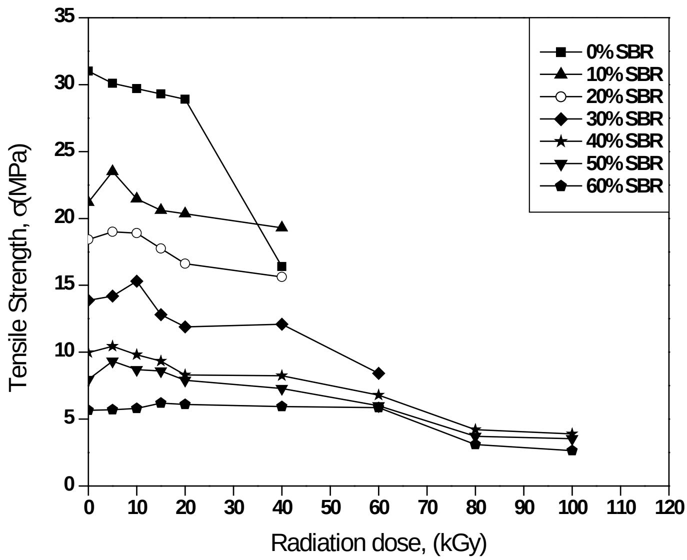

Fig. 3. Tensile strength as a function of Radiation dose, (kGy) for PP-SBR composites.

3.2. *Elastic modulus (EM)*

The elastic modulus *E* is closely related to the bonding forces of atoms in the material. It is a measure for stiffness. Figure (4) presents the elastic modulus of the PP-SBR composite, *E*, as a function of SBR content in the composition. Following the tensile strength vs. SBR content relationship presented in Figure (1), it was presumed that the elastic modulus would monotonously decrease with the increase in the SBR content. This, however, did not happen. The elastic modulus vs. SBR content curve passes through maximum at SBR content of around 20%, indicating that at some critical SBR concentration the interatomic bonding and interaction reaches its highest position.

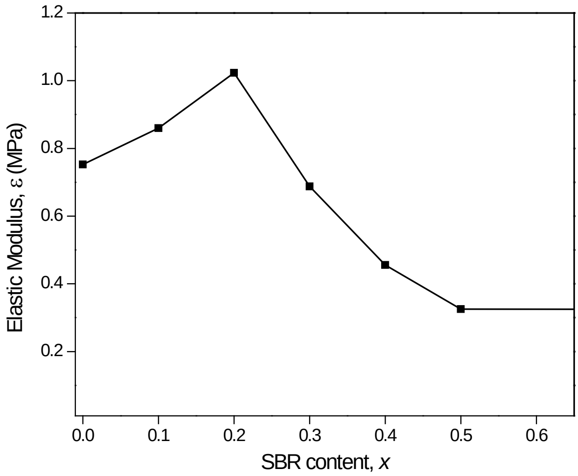

Fig. 4. Elastic modulus (EM) of PP-SBR composites.

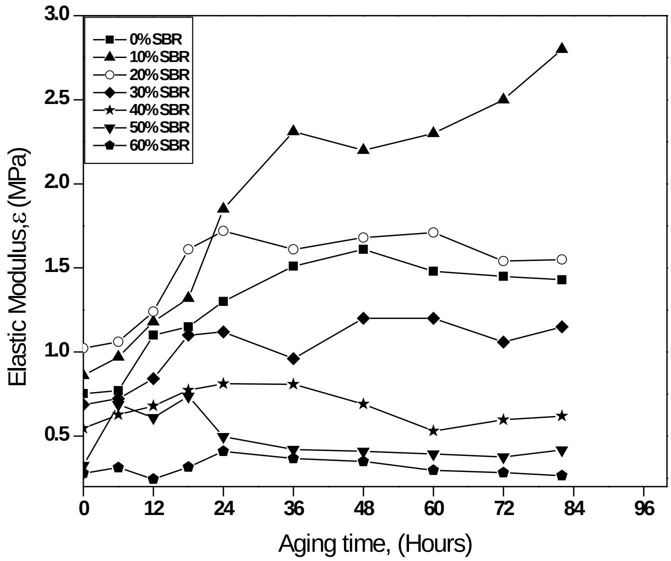

Fig. 5. Modulus of elasticity is a function of Aging time, (hours) for PP-SBR composites.

Fig. 5 shows elastic modulus with aging time of all types of films. Virgin PP and all composite showed the increase the EM with aging time upto 30% SBR loading. Rest of the three films (40, 50, and 60% SBR loading) showed the insignificant effects of aging time on EM. Practically, aging is a degradation process and in almost all cases, the mechanical properties are deteriorated upon aging. In some cases, cross-linking also may take place leading to loss of the flexibility of the materials. For this reason on aging the elastic properties usually varies. The elastic modulus of all films increased with radiation dose (Fig. 6) and became brittle at higher radiation dose.

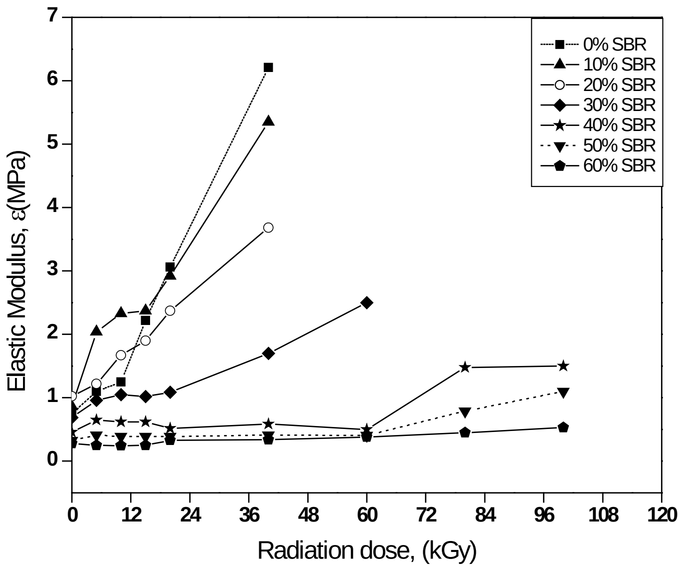

Fig. 6. Modulus of elasticity vs. Radiation dose, (kGy) for PP-SBR composites.

3.3. *Water uptake*

Fig. 7 presents water uptake of the PP-SBR composite as a function of SBR content in the composition for a period of 24 hours. Both the PP and cross-linked SBR are completely hydrophobic materials and reasonably, it is expected that the both the material individually or in composite form will show insignificant trend of water uptake. The virgin PP samples really show practically nil water uptake. With an increase in the SBR content, water uptake increases indicating appearance of pores in the composition due to the loose adhesion of the components in the composites. As stated in Yang and Otsuka *et. al.* [13, 14], PP and SBR are miscible on melting and separate out a heterogeneous phases at low temperature. Then the bond between PP and SBR is lose and leads to the formation of vacuoles in this structure. This will increase water uptake upon SBR content.

The water uptake with respect to aging time for all composites was shown in Fig. 8. For the PP-SBR composites, it is increasing with aging time upto 120 hours. After that the aging time is not more effective on water uptake. The radiation dosage is not much effective on the water uptake properties of PP-SBR composite.

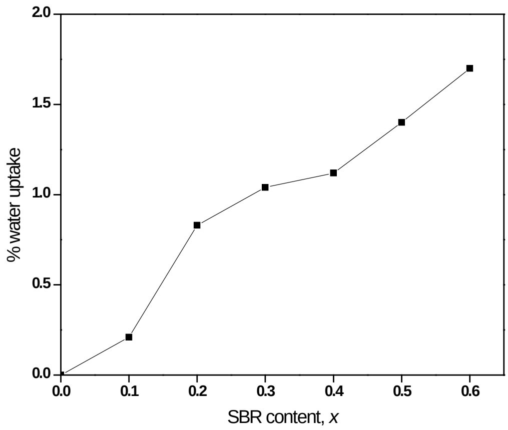

Fig. 7. Percentage of water uptake is a function of SBR present in PP-SBR composites.

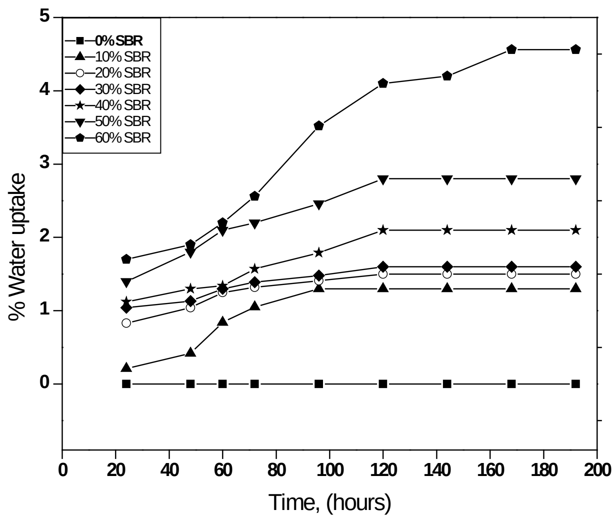

Fig. 8. Percentage water uptake by various PP-SBR composites with time.

4. Conclusions

The production of PP-SBR composites have not yet been developed in a significant level. If some agencies take initiative, PP-SBR based industries could be established, which would be helpful both for economic growth as well as friendly environment. In the present study PP-SBR composites were prepared and their tensile strength, elastic modulus and water uptake in normal forms and gamma radiation treated form were observed. Aging time in the preparation of PP-SBR composite plays an important role for increasing the elastic modulus but not for tensile strength. TS decreases and EM increases with the increase of radiation doses. This may be due to the development of degradation of crosslink between PP and SBR. Water uptake increases on increasing the SBR content. Considering all experimental results, stability and effectiveness of the approach of gamma ray radiation method for synthesis of degradable polymer could prove to be a development of this technology.

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