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Mechanical Behavior of Ultra Violet (UV) Curable Renewable Polymer/Graphite (PG)

Anika Zafiah M. Rus, Nur Munirah Abdullah and M. F. L Abdullah

Sustainable Polymer Engineering, Advanced Manufacturing and Materials Center (SPEN-AMMC), Universiti Tun Hussein Onn Malaysia, Malaysia; zafiah@uthm.edu.my, nurmunirahabdullah87@gmail.com, faiz@uthm.edu.my

Abstract

The mechanical behaviors of the renewable polymer/graphite (PG) films with prolonged UV irradiation exposure were investigated. Renewable PG films were prepared by mixing with varying weight percent of graphite (neat, 10 wt. %, 20 wt. % and 30 wt. %) and crosslinker. Then, casting film solution on square container and cured upon stimulated ultraviolet (UV) irradiation (UV accelerated weathering tester) at different time exposure (0, 250, 500 and 750 hours) was applied. Based on observations, different UV exposure time yield PG with varying tensile strength, tensile modulus and elongation at break. However, the mechanical behavior of resulting PGs gives plateau series due to chemical crosslink and chain scissions within renewable polymer and graphite that shown in infrared spectra (FTIR) of the films. The system indicates that the mechanical behavior of renewable PG can be tailored based on requirements of an application upon UV treatment.

Keywords: Mechanical Behavior, Renewable Polymer Graphite, UV Irradiation

1. Introduction

Ultraviolet (UV)-curing resin system has received increasing attention during recent years due to following characteristics features: financial feasibility, non-thermal, and eco-friendly technology. This photo-initiated cationic ring-opening polymerization has been highlighted as a Green Technology. Rapid polymerization and better physical characteristics features of the final products open a way for multiple applications including synthesis of coating resins[1] photosensitive polymers[2, 3] also in electrical and electronic equipment[4-6] UV-cured resin system mainly composed of UV-cured oligomer (resin), light initiator system, active diluents and additives, etc. Previous SPEN-AMMC research studies mainly focused on influenced of UV irradiation exposure on renewable polymer properties which enhanced by photocatalyst[7-10]. Noted that free radical polymerization of composite based monomers can be initiated by UV exposure; crosslinking and chain scissions. Major performance characteristics of complete system of the resulting films are affected by different process parameters.

In this paper, renewable polymer incorporated with graphite as the conductive filler, cured upon UV irradiation at various time exposure (0, 250, 500 and 750 hours). The impact of the exposure on mechanical behavior of the resulting PGs films is been observed. Variations in its tensile strength, elastic modulus and elongation at break of the films cured under UV with different time irradiation were analyzed. The subsequent changes in chemical functional groups of PGs films also been investigated.

2. Methodology

Free-standing renewable polymer/ graphite (PG) films are made by mixing of virgin cooking oil (VCO) monomer[12, 13] with Methylene Diphenyl Diisocyanate (MDI) and 10-30 wt % of acid treated graphite[14]. The mixture is cast into square container which is then pre-cured at standard room temperature for 1 hour to form gelation

*Author for correspondence

and cured in the UV accelerated weathering tester for various exposure time as simplified in Table 1. UV fluorescent lamps emitting light are used for UV-irradiation of the samples. The infrared spectra of the composites were identified by using Perkin Elmer Fourier Transform Infrared Spectroscopy (FTIR) in the range of 600–4000 cm^{-1} with the resolution of 4 cm^{-1} at room temperature. As for the tensile test; the tensile strength, elongation at break and elastic modulus were measured by Universal Testing Machine. Each experiment report average value of 5 samples as per ASTM D4329[15], EN ISO 4892-3[16] and ASTM D882[17] illustrated in Figure 1.

3. Results and Discussions

3.1 UV Irradiation on Functional Group of PG

The FTIR spectra of UV curable renewable polymer/graphite (PG) composites (PG0, PG10, PG20 and PG30) cured upon different UV irradiation time (0, 250, 500 and 750 hours) are shown in Figure 2. As can be seen, the spectra did not exhibit appreciable changes upon films exposure to UV irradiation, for the range of 1700-4000 cm^{-1} region. All typical transmittance peaks of renewable polymer, such those at 3400- 3500 cm^{-1}(NH), 2800-3100 cm^{-1} (CH_2 and CH_3), 1724 cm^{-1} (C=O), 1030-1230 cm^{-1} (C-N), and 1110 cm^{-1}(C-O-C), indicate the existence of urethane in synthesized renewable PG. Noted that, peaks occurred at 1733 cm^{-1}, 1605 cm^{-1} (C=O), 1540 cm^{-1} (C=C), and 1065 cm^{-1} (C-O), which provide the evidence of interactions between carbonyl and hydroxyl groups from graphite and renewable polymer moieties in PG10, PG20 and PG30. Therefore, stretching vibration band around 2270 cm^{-1} was not observed due to confirmation that the entire isocyanate group was successfully reacted during polymerization.

Figure 1. UV curable renewable PG upon mechanical testing.

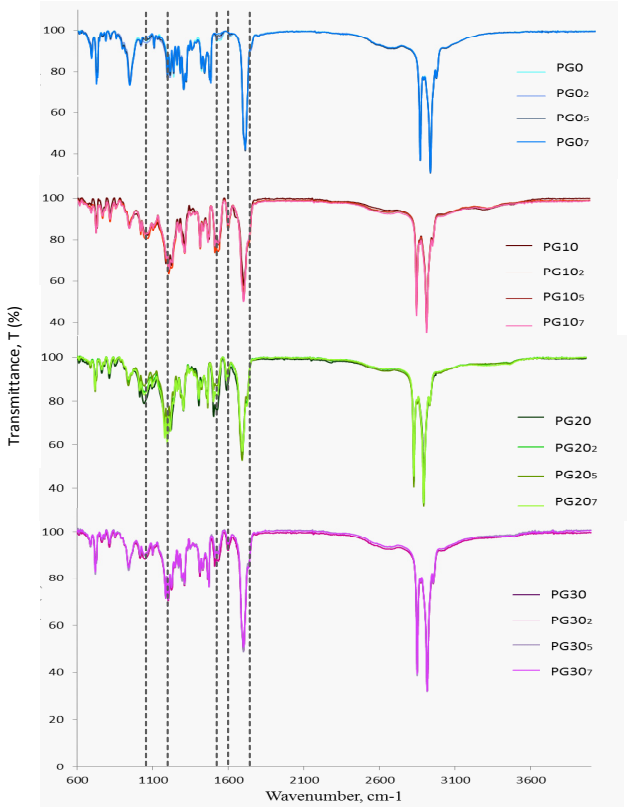

Figure 2. FTIR spectra renewable PG with different curing time upon UV irradiation.

Table 1. Preparation of UV curable renewable PG

Sample			PG0 (neat)	PG10 (10wt.%)	PG20 (20wt.%)	PG30 (30wt.%)
UV irradiation time	Stimulated time (minutes)	Real time (hours)				
	0	0	$PG0_0$	$PG10_0$	$PG20_0$	$PG30_0$
	32	250	$PG0_2$	$PG10_2$	$PG20_2$	$PG30_2$
	64	500	$PG0_5$	$PG10_5$	$PG20_5$	$PG30_5$
	96	750	$PG0_7$	$PG10_7$	$PG20_7$	$PG30_7$

There are significant changes were observed for all resulting PG films that are subjected to UV irradiation. The peaks at 1540 cm^{-1} and 1065 cm^{-1} decrease systematically for PG0 as time upon UV irradiation increased. However, for PG10- PG30, the intensity of the peaks increased at 250 hours upon UV irradiation and then plateau upon remaining exposure. These can be assigned to chain scissions/crosslinking of the soft segment. The crosslinking reaction occurs through a radical mechanism. Previous studies of renewable polymer have showed that radical initiation at 0 to 250 hours, crosslinking above 250 hours, propagation and crosslinking at 500 and 750 hours, and chain scission beyond 3000 hours of the soft segment radical of UV irradiation exposure[18]. Herein, it is confirmed that the polymerization and cross-link occurred concurrently in the presence of UV irradiation by FTIR spectroscopic study.

3.2 UV Irradiation on Mechanical Characteristic of PG

The samples are subjected to different curing time upon UV irradiation, and different material properties (such as mechanical properties) were obtained due to variation in the degree of cure as shown in Figure 3. The tensile strength (Figure 3a) of the resulting films observed a slight increased after the first decreased at 250 hours for PG20 and PG30 with UV irradiation curing time. Meanwhile, the strength of PG0 decreased from 3.56 MPa to 2.11 MPa as the films achieved its limit. According to these results the cross-link reaction may induce at 0, 500, and 750 hours and chain scission at 250 hours between renewable polymer molecules while UV light penetrated into PG film. Moreover, as graphite weight loading increased in the renewable polymer material, thus contributing to the formation of a network-shaped three-dimensional structure[19].

In this experimental work, no trend could be established for films exposed to UV irradiation. The elastic modulus (Figure 3b) and the elongation at break (Figure 3c) of UV curable renewable PG gives plateau series respectively. Therefore upon UV exposure time, double bonds were triggered and meet possible modification of the films, contributing to the chemical crosslinking/sliding of the molecular chains in the film. Thus, a suitable PG can be chosen according to the particular requirements.

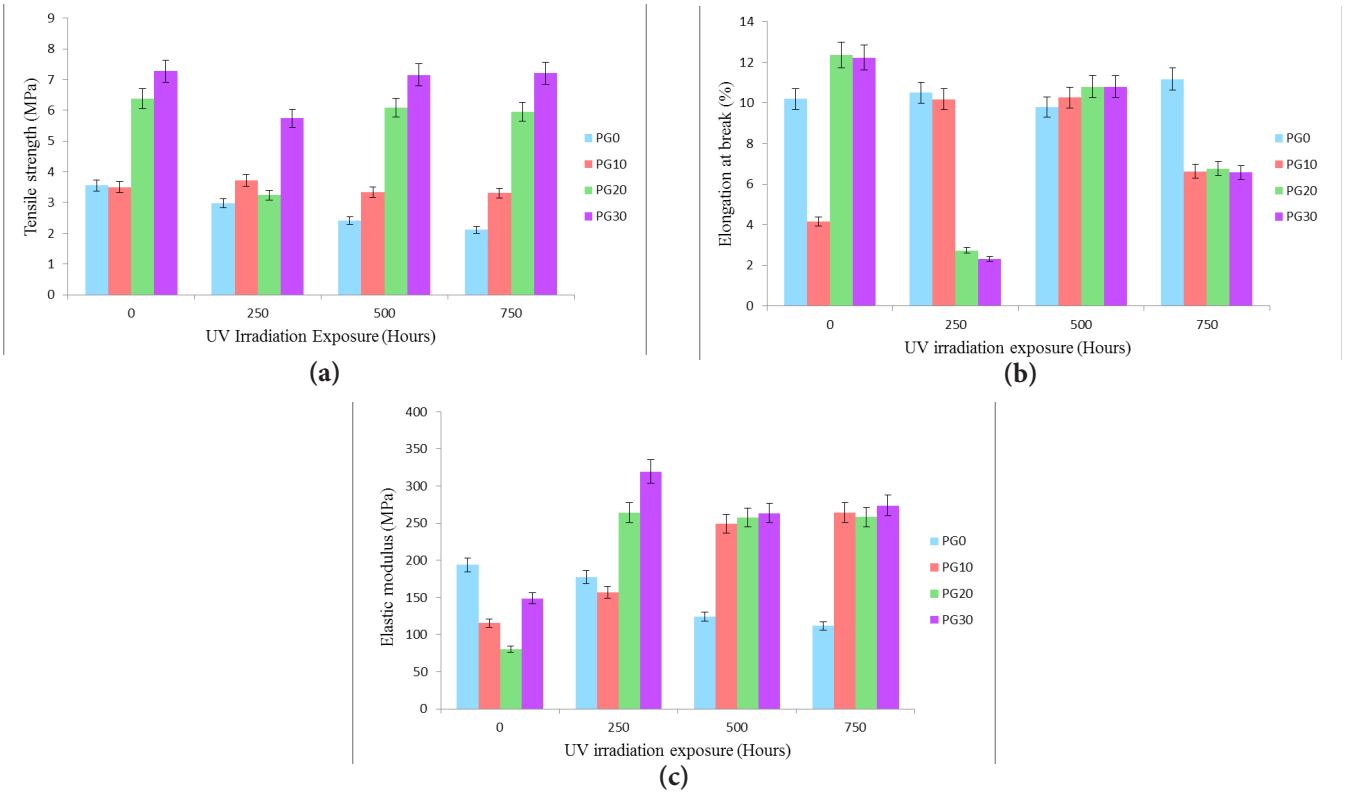

Figure 3. Mechanical behavior of renewable PG with different curing time upon UV irradiation; **(a)** Tensile strength, **(b)** Tensile modulus and **(c)** Elongation at break.

4. Conclusion

In conclusion, this paper has demonstrated that UV curable renewable PG were prepared with neat (PG0), 10 wt.% (PG10), 20 wt.% (PG20) and 30 wt.% (PG30) of graphite weight loading and cured upon 0, 250, 500 and 750 hours of UV irradiation. The infrared spectra have indicated that the UV light had triggered free radical causing chain scissions and crosslinking in the resulting PG films. The result pointed out that the mechanical behavior of renewable PG can be improved due to variation in the degree of cure up to certain limit of UV exposure respectively.

10. Acknowledgements

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