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The effect of gamma irradiation on mechanical, thermal and morphological properties of glass fiber reinforced polyethylene waste/reclaim rubber composites

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ABSTRACT

Composites of waste polyethylene (WPE), collected from municipal solid waste/recycled waste rubber powder (RWRP) reactive compatibilizing agent, maleic anhydride (MA) and glass fiber (GF) up to 20 wt%, prepared by melting and irradiated with gamma-rays up to 150 kGy have been studied. Tensile strength (T_S), elongation at break (E_b), elastic modulus, hardness, thermal and morphological parameters of the irradiated composites were investigated. The examined mechanical properties have been found to improve largely with filler content. Interesting E_b behavior has been detected for the irradiated composites loaded up to ~10 wt% GF and has been basically discussed in view of matrix crystallinity and morphology. TGA thermograms of unirradiated composites revealed enhanced thermal stability than that reported for the blend whereas comparatively slight improvement has been demonstrated by irradiation. Whereby insignificant alteration in T_m values was observed by loading or irradiation, yet ΔH_m maximum of 3.41 J/g, indicated for the 5 wt% GF irradiated composite with an integral dose of 75 kGy, emphasizes the influence of the relatively moderate load and dose levels on matrix stability. The phenomenon has been confirmed by the respective SEM micrographs.

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1. Introduction

Discarded thermoplastics and waste tires are posing a serious threat to the environment as non-degradable pollutants. Recycling of materials derived from waste streams contributes to solid waste sound management and mitigates intricate environmental pollution. The vulcanization process in the elastomers leads to the formation of a three dimensional cross-linked network, which renders them difficult for recycling. A number of methods [1–5] have been developed for effectively recycling rubber. Recently, Myhre and Mackillop [6], and Adhikari et al. [7] have given a comprehensive summary of all the latest methods for recycling rubber. Currently, composites formed of thermoplastics, rubber and reinforces are widely used in diverse areas such as transportation, construction, electronic and consumer products. They offer an unusual combination of stiffness, strength and weight that is difficult to obtain from individual components. Each specific component of material in a composite is designed to achieve a combination of performance characteristics that cannot easily be found in one material.

Thermoplastic/elastomer blends derived from polyethylene and maleic anhydride grafted ground rubber tire have been reported to be re-processable [8]. The mechanical properties of the blends of reclaimed tire rubber and high-density polyethylene (HDPE) have been studied before and after dynamic vulcanization [9,10]. Different short fibers (glass, carbon, cellulous, polyamide, sisal and polyester) have been added to the thermoplastics/rubber matrix as semirenforcing filler. Where composite-cured properties have showed a remarkable anisotropy.

Ionizing radiation, e.g. gamma rays, offers unique possibilities for application to the problem of recycling polymer [11], due to its ability to cause crosslinking or scission of a wide range of materials without dissolving the sample or having some chemical initiator incorporated in the matrix. Possibilities for using radiation in recycling include: (1) enhancing the mechanical properties of recovered materials or blends, principally through crosslinking, or through surface modification of different phases being combined and (2) decomposition of polymers, particularly through chain scission, leading to recovery of low molecular weight mixtures. Investigation of thermoplastic/rubber reinforced composites in terms of the mechanical and thermal behaviors has been reported on various treatment methods [12–17]. In this context, irradiated thermoplastic/elastomers derived from WPE and WR and their

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composites with glass fiber (GF) have been investigated in our labs for the mechanical, thermal and morphological characteristics; with an objective of producing value-added.

2. Experimental

2.1. Materials

Recycled waste rubber powder (RWRP) of unclassified ground rubber from the tread and sidewalls of: passenger and truck tires was kindly provided by Narobine Company, Cairo, Egypt, of: particle size 80 mesh, the element content of RWRP is: C = 80.92%, H = 6.8%, O = 4.3%, N = 0.38%, S = 1.66%, FTIR bands at 2320 cm^{-1} for –C≡N– of the NBR component, at 1610 cm^{-1} for –C=C– of the SBR component and of the TGA onset temperature of 250 °C. Waste polyethylene (WPE) was obtained from the local market. The reactive compatibilizing agent maleic anhydride (MA) was obtained from Merck, Germany. The used glass fiber (GF), 6 mm, density 2.56 g/cm^3 with less than 1 wt% alkali oxides, is mainly used for glass-reinforced plastics.

2.2. Preparation

The preparation of WPE/RWRP composites was done on a Brabender Plasti-corder PL 2100 Mixer with a volume capacity of about 200 cm^3 at 60 rpm,After melting WPE, RWRP was added into the apparatus, mixed for about 10 min within a temperature range of 170–175 °C to disperse RWRP uniformly into WPE. The glass fiber was thereafter added at various wt% (5, 10, 15, and 20) into the blend. After mixing the samples were hot pressed at about 175 °C under 10 MPa for 5 min into sheets of suitable thickness and size for analysis. The weight ratio of WPE/RWRP in all composites is 3:2. The compatibilizing agent MA was feeded succeeding the addition of RWRP at a ratio of 2 wt%. Testing was performed on three samples each and the mean values were identified as shown in the figures by error bars.

2.3. Gamma irradiation

The composites were submitted to gamma irradiation in air, using gamma cell type 4000 A, India, at the National Center for Radiation Research and Technology, Atomic Energy Authority, Cairo, Egypt, under conditions of room temperature and ambient humidity. The integral absorbed doses were 50, 75, 100, and 150 kGy at irradiation dose rate ≈5 kGy/h.

2.4. Mechanical testing

Tensile properties of the prepared composites were determined by using Hounsfield computer aided testing machine, England. The ISO 37-1977 (E) and ISO 34-1975 (E) standards were followed in measuring tensile strength and elongation at break, respectively. A minimum of three specimens were tested in each case to obtain the average value.

2.5. Hardness measurements

Samples of at least 0.12 mm in thickness with flat surface were cut for hardness test. The measurement was carried out according to ASTM D 2240 using 306L type D Durometer. The unit of hardness is expressed in (D Shore).

2.6. Thermal analysis

The thermal behavior of all developed composites was performed with the DSC Perkin-Elmer equipped with DSC-7 data station, in dry nitrogen flow at a rate of 20 ml/min within the temperature range from ambient to 200 °C at a heating rate of 10 °C/min. Thermogravimetric analysis (TGA) was performed with the Shimadzu TGA-50 system, within the temperature range 20–600 °C at a rate of 20 °C/min under similar gas flow conditions.

2.7. Morphological characterization

The morphological observation of fracture samples was performed using ISM-5400 scanning electron microscope, JEOL, Japan. The examination was carried out on specimens coated with gold by the sputtering technique.

3. Results and discussion

3.1. Mechanical properties

The mechanical properties of GF reinforced composites have been reported to depend critically on the microstructure i.e. aspect ratio of the filler, degree of dispersion of the filler in the matrix, and the adhesion at the filler–matrix interface [18]. The effect of GF content on the T_S of unirradiated blend WPE/RWRP/MA is presented in Fig. 1. It can be seen that the T_S of the composites mainly increased with GF content up to 20 wt%. Opposite trend was reported for a system composed of PP/GF within nearly similar range of fiber load [19]. The enhancement in T_S is related to the formation of a high degree of interphase adhesion between filler particles and PE macromolecules which results in improved interfacial adhesion between the matrix and the fiber [20]. Further, the blend T_S value progressively raised with increasing radiation dose until a certain limit, nearly 50 kGy, where the crosslinking process is suggested to predominate. This trend has been emphasized for a system of E-glass/PP composite. Nearly similar T_S values have been eventually determined for 20 wt% GF unirradiated and up to 100 kGy irradiated composites. The decrease in T_S value with higher doses can be accounted for the radiation induced degradation. These findings are supported by the SEM micrographs.

3.2. Elongation at break

From Fig. 2, elongation at break (E_b) showed maxima within the GF loaded range 5–10 wt% for unirradiated and 50 kGy irradiated specimens. Meanwhile, allover the rest dose range up to 150 kGy elongations exhibited a dramatic decrease within the range

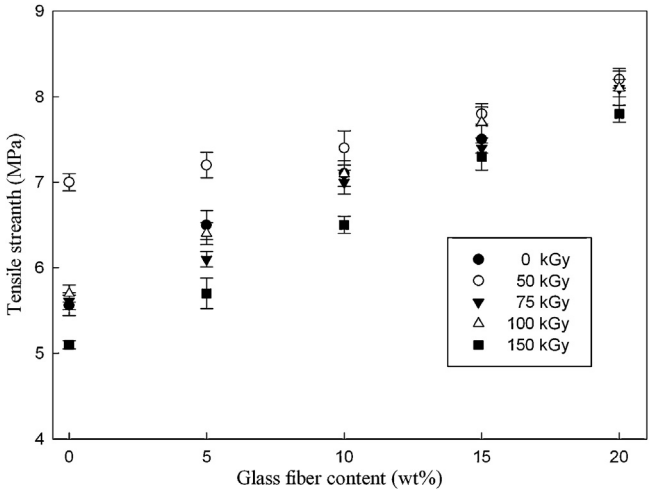

Fig. 1. Effect of glass fiber content % on the tensile strength of WPE/RWRP/MA, 60/40/2 wt%, at various gamma radiation doses.