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Effects of Irradiated Recycled Polypropylene Compatibilizer on the Mechanical Properties of Microcrystalline Cellulose Reinforced Recycled Polypropylene Composites

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Abstract

In this study, the potential of irradiated recycled polypropylene (i-rPP), as compatibilizer for rPP reinforced with microcrystalline cellulose (MCC) composites, is evaluated. RPP/MCC composites, with various MCC loadings (5, 20 and 40 wt%) are compounded with melt extrusion, followed by injection moulding. Before compounding, the rPP is exposed to an electron beam irradiation at different doses (10, 20, 30 and 50kGy) and then unirradiated rPP is added at a ratio of 90:10. The mechanical properties of the composites are analyzed using tensile and flexural tests. Both mechanical properties were improved as a result of increased irradiation doses and MCC loadings. However, the optimum results of tensile and flexural properties were obtained at different irradiation doses and MCC loadings. Examination of the fracture surface using Field Emission Scanning Microscopy (FESEM) reveals the presence of good adhesion bonding between rPP matrix and MCC fibre. Gel content analysis exhibits a higher degree of crosslinking with increasing irradiation doses. The occurrence of crosslinking appears to improve the surface adhesion of MCC fibres in the rPP matrix and leads to improved mechanical properties of the composites.

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Keywords: Recycled Polypropylene (rPP); microcrystalline cellulose (MCC); irradiation; tensile properties; surface adhesion; morphology

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1. Introduction

In recent years, natural fibre filled composites have gained demand for automobile and construction markets owing to the growing concern for lightweight and cost effective materials to be reinforced with thermoplastics. Microcrystalline cellulose (MCC) is a type of natural fibre that offers advantages, such as biodegradability, low cost and being abundantly renewable [1]. However, the primary drawback of using natural fibres as polymer matrix reinforcement, is the poor interfacial adhesion between hydrophilic fibres and hydrophobic polymers. As a result, the composites produced will have poor mechanical properties. Typically, chemical coupling agents, such as silane, peroxide, isocyanates and maleic anhydride, are used to improve the adhesion between fibres and the polymer matrix [2]. However, the high cost of coupling agent materials increase production costs.

An alternative method of improving interfacial adhesion is by introducing energy radiation into the materials. Besides being cost effective, the irradiation technique offers solutions to polymer recycling, as it can modify the mechanical properties of recycled polymers by inducing crosslink or chain-scission at appropriate irradiation conditions. Furthermore, this method is clean, energy saving and can induce chemical reactions without requiring any catalysts.

Recycled polypropylene (rPP) has attracted a great deal of interest because it can reduce municipal waste and the usage of virgin polypropylene [3]. However, the blending of hydrophilic MCC fibres and the hydrophobic rPP matrix requires a good compatibilizer to promote good adhesion between them [4].

Therefore, the objective of this study is to determine the effect of irradiated recycled polypropylene, as compatibilizer, on the mechanical properties of the rPP/MCC composite.

2. Materials and methods

2.1. Materials

Recycled polypropylene (rPP), obtained from Top Flow Industry Sdn Bhd, Malaysia, with a density of 1.07g/cm^3 and melt flow index of 1.34 g/10min at 230°C under 2.16 kg load, was used in this study as the matrix polymer. Microcrystalline cellulose (MCC) fibre reinforcement, with an average diameter of 20µm, in powder form, was supplied by Sigma- Aldrich Group, Malaysia.

2.2. Preparation of composites

The rPP and MCC fibres were oven dried at 80°C for 24h to eliminate any moisture. Before that, the rPP pellets were irradiated using an electron beam accelerator (EB 3000) of 3MeV voltage with irradiation doses varying from 10, 20, 30 to 50kGy. The ratio of unirradiated to irradiated rPP pellets was kept constant at 90:10 by weight % before being mixed with the MCC fibre at 5, 20, and 40 wt%. All materials were premixed manually. The rPP/MCC composite, is abbreviated as rPP/MCC-XkGy (where X corresponds to the irradiation dose). The compounding process was carried out using a Brabender twin screw extruder. The barrel temperature was varied from 160 to 175°C, and 180°C at the die; with a constant speed of 100 rpm. The composites were injection moulded using a Battenfield HM 600/850 into rectangular and dumbbell type IV samples.

2.3. Mechanical characterization

Tensile and flexural tests were conducted using a LLYOD (AMETEC) universal testing machine with crosshead speeds of 50mm/min and 5mm/min, respectively. For flexural tests, the span length was 60mm and the samples were prepared using ASTM D790. A total of five readings were taken as an average.

2.4. Gel content analysis

The gel content of neat rPP and rPP/MCC composites was determined using Soxhlet Extraction Test. Samples were weighed and placed into steel nets before being refluxed in xylene solvent for 24h at 130°C. Methanol was