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Variation of mechanical and thermal properties of the thermoplastics reinforced with natural fibers by electron beam processing

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Abstract

With restrictions for environmental protection being strengthened, the thermoplastics reinforced with natural fibers (NFs) such as jute, kenaf, flax, etc., appeared as an automobile interior material instead of the chemical plastics. Regardless of many advantages, one shortcoming is the deformation after being formed in high temperature of about 200 °C, caused by the poor adhesion between the natural fibers and thermoplastics. Also, the energy saving in connection with car air-conditioning becomes very important. In this study, the thermal conductivity, tensile strength, and deformation of several kinds of thermoplastic composites composing of 50% polypropylene (PP) and 50% natural fiber irradiated by the electron beam (energy: 0.5 MeV, dose: 0–20 kGy) were measured. The length and thickness of PP and NF are 80 ± 10 mm and 40–120 μm, respectively. The results show that the thermal conductivity and the tensile strength changed and became minimum when the dose of electron beam is 10 kGy, and the deformation after the thermal cycle were reduced by the electron beam.

Keywords: Electron beam irradiation; Thermal conductivity; Thermoplastic composite; Tensile strength

1. Introduction

Natural fibers (NFs) as a substitute for glass fibers in composite components, have gained renewed interest in automotive industries. Car makers are looking increasingly at thermoplastics reinforced with natural fibers to reduce weight and cost in the interior and engine components. Of all the thermoplastic matrices available, polypropylene (PP) shows the most potential benefits when combined with natural fibers in making composites for industrial applications (Jayaraman, 2003).

A notable shortcoming in the natural fiber-thermoplastic system is the poor bonding between the natural fiber and the plastic. This is due to the dissimilar chemical nature, i.e., the surface of the natural fiber is hydrophilic while that of the plastics is generally hydrophobic. In order to develop composites with better mechanical properties, it is necessary to impart hydropobicity to natural fibers by suitable treatments (Mohanty et al., 2002a). The selection of proper coupling agents and electron beam irradiation are important to improve fiber–matrix adhesion so as to produce composite materials with superior strength (Czvikovszky, 1996; Zenkiewicz, 2004). Also, the energy saving in connection with car air-conditioning becomes very important. In this study, the thermal conductivity, tensile strength, and deformation of thermoplastic PP boards reinforced with NF and coupling agents such as maleated polypropylene (MAPP) (Mohanty et al., 2002b) and silane (Maldas et al., 1988) before and after the irradiation of electron beam are investigated.

2. Material preparations

The twin screw co-rotating extruder is prepared for the direct incorporation of 48.5 mass% PP, 48.5 mass% natural fibers, and 3.0 mass% MAPP. MAPP acts as a compatiblizing agent in polymer blends and particularly effective when one polymer is hydrophilic and the other polymer is hydrophobic. The chopped (50–80 mm) length natural

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fibers, e.g., kenaf/hemp/flax/sisal and micron size PP and MAPP powder were used for composite fabrications.

The main motivation of using natural fibers to replace glass fibers includes the low cost (~1/3 of glass fibers), low density (~1/2 of glass), acceptable specific strength properties and enhanced energy recovery, CO_2 sequesterization, and bio-degradability.

Parts of the mats were soaked in 0.3% silane aqueous solution. Individual silane (aminoethylamino-propyltrimethoxy silane or AEAPTMS) coupling agent molecules which are supposed to attach to natural fiber formed a continuous link. Three groups of mats (Group A: PP(50%) + NF(50%), Group B: (48.5%) + NF(48.5%) + MAPP(3%), Group C: Group B soaked in 0.3% silane aqueous solution) were prepared.

All groups of mats were irradiated by the electron beam with a speed of 30 mm s^{-1} with the doses of 0, 5, 10, 15, and 20 kGy. The energy of the electron is 0.5 MeV. The processed mats were subjected to compression molder to be used as the car interior boards, the materials were kept under contact temperature at 200 °C for about 15 min under mild pressure followed by pressing at 350–360 psi pressure for about 2 min followed by cooling under the pressure to obtain the final composite plaques for testing. During the compression, the thickness of the mats was reduced from several centimeter to several millimeters.

Fig. 1 shows the micro-photograph of the sample boards in Group C by compression with different doses of electron beam irradiations. As the dose of electron beam increases to 15 kGy, the cross-linking generated by the mixing of PP, NF, and coupling agents becomes dominant and wider, however, after that the cross-linking disappears by the over exposure of electron beam.

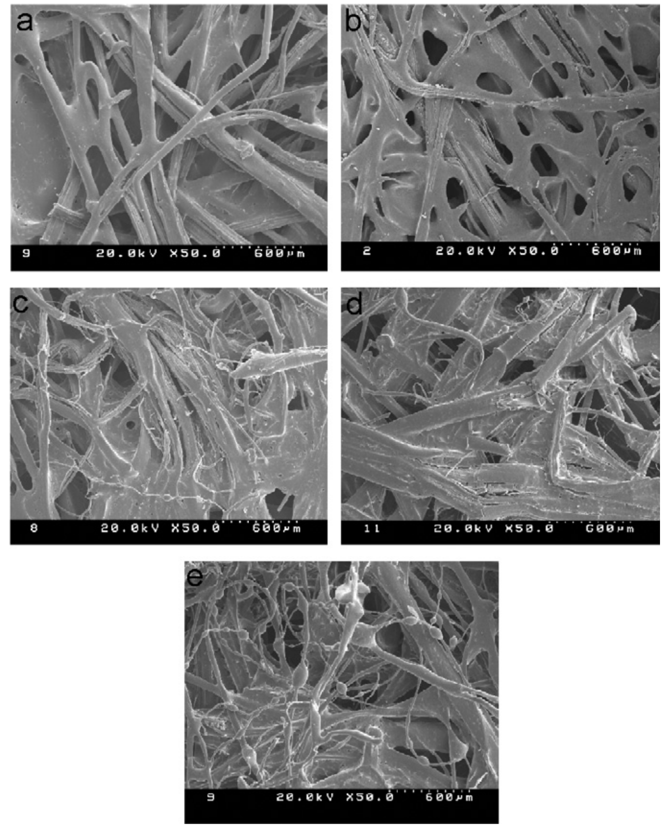

Fig. 1. The micro-photograph of the sample boards by compression molding in group C with different doses of electron beam irradiations: (a) 0 kGy, (b) 5 kGy, (c) 10 kGy, (d) 15 kGy, and (e) 20 kGy.

3. Experiments and results

3.1. Thermal conductivity

The thermal conductivity of all the above samples were measured by the heat flow meter apparatus (RK-30) following ASTM-C 518; standard test method for steady-state thermal transmission properties by means of the heat flow meter apparatus and ISO 8301; thermal insulation, determination of steady-state thermal resistance and related properties. The thermal conductivity can be calculated from the temperatures of hot plate, cold plate, the flowed heat from hot plate to cold plate, and the thickness of the sample (Kuhn et al., 1992). The measurements were made five times. The sample size is 300×300 mm, and thickness is 1.8–2.5 mm.

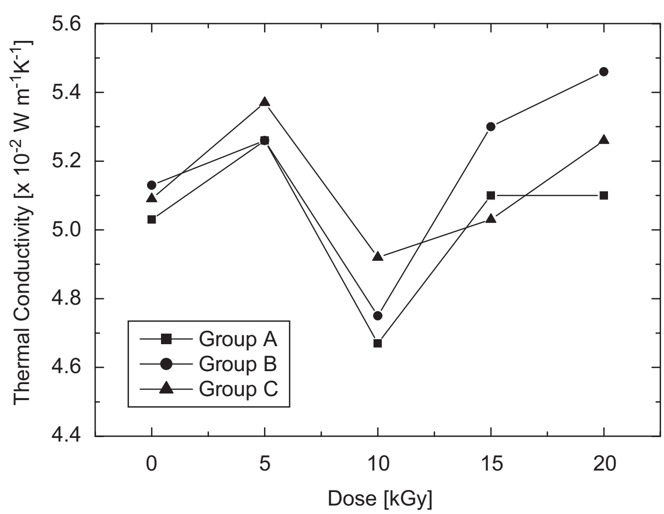

Fig. 2. The obtained thermal conductivities of three groups of sample boards for different doses of electron beam.

The average values of the thermal conductivity obtained in the present study are shown in Fig. 2. The thermal conductivities are in 4.6×10^{-2} to 5.4×10^{-2} W m^{-1} K^{-1} range. All the groups of the samples show similar trends for the increment of the dose of electron beam. At first, the thermal conductivities increase and become maximum when the dose is 5 kGy and then start to decrease and become minimum at 10 kGy. The reason for this is assumed to be the weak cross-linking of NF and PP caused by the electron beam processing even though it does not looks clear in the figure. By increasing the dose of electron beam, the thermal conductivity was increased and recovered the initial values. We also think that not only the