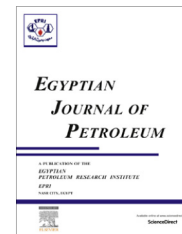


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FULL LENGTH ARTICLE

Flammability properties of polypropylene containing montmorillonite and some of silicon compounds

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Abstract New polypropylene (PP) blends were prepared using phenyltrimethoxysilane (PTMS), glycidoxypolytrimethoxysilane (GPTMS) and potassium-montmorillonite (K-MMT). Polymers A (K-MMT/PTMS), B (MMT/GPTMS) and C (modified-MMT) were prepared using sol-gel technique then incorporated in the PP matrix by different concentrations. Fourier transform infrared spectroscopy (FTIR), thermogravimetric analysis (TGA), and differential scanning calorimeter (DSC) were used to investigate the structure and thermal stability. The mechanical properties (tensile strength/TS and elongation/%) were measured. The flame-retardant properties of the unblended and blended (PP/A, PP/B and PP/C) were estimated by limiting oxygen index (LOI), flame chamber (UL/94) and oxygen bomb calorimeter (OBC) tests, whereas the thermal stabilities were investigated using TGA were carried flammability out to detect the properties of the blended PP.

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1. Introduction

Polypropylene/polypropene (PP) is a thermoplastic polymer and has different applications as automobiles, textiles, medicine, furniture, electronic casings, automotive products, interior decoration, and relatively low cost [1–5]. The melting point of PP is ranged from 145 to 195 °C [6]. Due to the chemical constitution of the polymer it is easily flammable and so flame retardancy becomes an important requirement for PP

[7]. At temperature above 100 °C polypropylene dissolves in aromatic hydrocarbons, such as benzene and toluene. Montmorillonite (MMT) can be defined as an aluminosilicate layer mostly present in clays and most often used in the preparation of polymer nanocomposite. The surface of MMT is hydrophilic and therefore not suitable for the preparation of nanocomposites with most of the commercial polymers. To ensure good intercalation the surface of MMT platelets has to be modified. There are several ways of modifying MMT, but the most common method is to use a cation. New polymers can be generated by adding MMT at different amounts. These polymers can be characterized by decreasing at the peak heat release rate (pHRR), an increase in the percentage of ash residue after the combustion and the change in the char structure [8–19].

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Also, modified polymer/clay materials increase physical, thermal and mechanical properties radically [20–27]. The sol-gel process involves the growth of inorganic networks through the formation of a colloidal suspension (sol) while gel can be formed during the sol gelation and form a network in a continuous liquid phase [28,29]. The sol-gel derived products have numerous applications such as: synthesis of the lightest materials and some of the toughest ceramics, optics, and electronics [30–32]. The technique of the sol-gel process depends on two steps: hydrolysis and condensation reactions [28]. The mechanisms of hydrolysis and condensation, and the factors (organic radical of the OR-group, solvent, catalyst, concentration and temperature) that have a bias toward linear or branched structures are the most critical issues of sol-gel science and technology [33,34]. In the present work, the PP/A, PP/B and PP/C blends have been prepared and their mechanical (tensile and elongation), thermal stability (TGA and DSC) and flammability (LOI and UL/-94) tests have been investigated. This study showed that, as the percentage of K-MMT, PTMS and GPTMS polymers increased compared to PP, the ignition properties increased, and vice versa.

2. Experimental

2.1. Materials

Polypropylene was purchased as pellets from the Oriental Petrochemicals Company (OPC), Egypt. Its specifications are shown in Table 1. Potassium montmorillonite (K-MMT, with a cation exchange capacity of 97 meq/100 g) were kindly provided by Ke Yan Company. Glacial acetic acid (99%) and ethanol were purchased from Fluka, while GPTMS (97%) and PTMS (94%) were purchased from Alfa Aesar and Aldrich, respectively.

2.2. Polymer preparation

The sol-gel technique was used to prepare the Polymers. Distilled water (2.5 ml), ethanol (2 ml), acetic acid (1 ml) and the clay (K-MMT, 7 gm) or silane coupling agents (PTMS, 7 gm or GPTMS, 7 gm) were mixed together in a round flask using a magnetic stirrer for 24 h to form A, B and C-polymers, respectively, then washed with ethanol several times and left to dry at 80 °C for 1 h.

2.3. Blended polymer preparation

Different percentage of A, B and C-polymers were blended with PP using Newplast twin screw extruder (made in India)

at zone temperatures 185 °C, 190 °C, and 190 °C for zone 1, zone 2, and zone 3, respectively, then blend them together with twin screw at speed 35 rpm, then preheat using a Morgan press injection instrument (made in USA) at 160 °C for nozzle zone and barrel zone and were injected with 120 MPa of injection pressure, 90 MPa of holding pressure, holding time of 20 s and cooling time was taken as 10 s to produce $7.5 \times 7.5 \times 0.2 \text{ cm}^3$ and $10 \times 1 \times 0.2 \text{ cm}^3$ molds. Samples of pure PP were processed in the same way and used for comparison.

2.4. Fourier transform infrared analysis (FTIR)

FTIR spectra for samples performed using Nicolet 380 Spectrometer-USA that is equipped with zinc selenide crystal in the spectral range $4000\text{--}400 \text{ cm}^{-1}$ [39]. To ensure reproducible contact between the crystal face and the fabric, a pressure of about 18 kPa [40] was applied to the crystal holder. The FTIR absorbents frequencies for the treated samples are recorded with an average of 32 scans using a resolution of 4 cm^{-1} .

2.5. Thermo-gravimetric analysis (TGA)

TGA was used to determine the mass loss of a sample exposed to prominent temperatures using DTG-50 thermal analyzer (Shimadzu) after placing the sample in open platinum pan in nitrogen gas. The sample is heated by a furnace while the loss or gain of sample weight is monitored by a sensitive balance. Weight, temperature, and furnace calibrations were carried out within the range of the TGA (25–850 °C) at scan rates of 10 °C/min [41–43].

2.6. Differential scanning calorimeter (DSC)

DSC instrument was used to characterize the thermophysical properties of polymers such as; glass transition (T_g), melting temperature (T_m), and heat of melting (ΔH_m), using DSC-50 Shimadzu Instrument-Japan. The heating rate was 10 °C/min , a flow rate of 30 ml/min, nitrogen gas was used as a carrier gas. Scans were carried out at a temperature range of $30\text{--}650 \text{ °C}$ [44].

2.7. Mechanical tests

Tensile strength and elongation break, % tests were carried out in a universal testing machine, model Z010, Zwick, Germany with load cell of 10 kN according to ASTM D638-02 [45].

2.8. Limiting oxygen index (LOI)

According to ISO 4589 LOI was determined for all samples. The lower concentration of oxygen required to sample ignition was measured using a Rheometric oxygen index instrument [46]. Both nitrogen and oxygen were connected to the apparatus through pressure regulators. Mixture of N_2/O_2 atmospheres was continuously sent through the glass chamber. Samples were cut with dimension $15 \times 5 \text{ cm}^2$, and then clamped in the holder vertically in the center of the combustion

Table 1 Specification of polypropylene [35–38].

Properties	Value	Unit
Density @ 23 °C	0.905	g/cm^3
Melt flow (210 °C)	12	g/10 min
Tensile strength @ Yield (50 mm/min)	33	MPa
Tensile elongation @ Yield (50 mm/min)	8	%
Flexural modulus (1% Secant), @ 1.3 mm/min	1350	MPa
Heat deflection temp. @455 kPa	104	°C

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