Preparation and Properties of Dynamically Cured PP/MAH-*g*-EVA/Epoxy Blends

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ABSTRACT: A method concerning with the simultaneous reinforcing and toughening of polypropylene (PP) was reported. Dynamical cure of the epoxy resin with 2-ethylene-4-methane-imidazole (EMI-2,4) was successfully applied in the PP/maleic anhydride-grafted ethylene-vinyl acetate copolymer (MAH-*g*-EVA), and the obtained blends named as dynamically cured PP/MAH-*g*-EVA/epoxy blends. The stiffness and toughness of the blends are in a good balance, and the smaller size of epoxy particle in the PP/MAH-*g*-EVA/epoxy blends shows that MAH-*g*-EVA was also used as a compatibilizer. The structure of the dynamically cured PP/MAH-*g*-EVA/epoxy blends is the embedding of the epoxy particles by the MAH-*g*-EVA. The cured epoxy particles as organic filler increases the stiffness of the PP/MAH-*g*-EVA blends, and the improvement in the toughness is attributed to the embedded structure. The tensile strength and flexural modulus of the blends increase with increasing the epoxy resin content, and the impact strength reaches a maximum of 258 J/m at the epoxy resin content of 10 wt %. DSC analysis shows that the epoxy particles in the dynamically cured PP/MAH-*g*-EVA/epoxy blends could have contained embedded MAH-*g*-EVA, decreasing the nucleating effect of the epoxy resin. Thermogravimetric results show the addition of epoxy resin could improve the thermal stability of PP, the dynamically cured PP/MAH-*g*-EVA/epoxy stability compared with the pure PP.

Wide-angle x-ray diffraction analysis shows that the dynamical cure and compatibilization do not disturb the crystalline structure of PP in the blends. © 2009 Wiley Periodicals, Inc. J Appl Polym Sci 113: 1986–1993, 2009

Key words: dynamical cure; epoxy resin; PP; MAH-*g*-EVA

INTRODUCTION

Polypropylene (PP) has an important thermoplastic among the synthetic polymers because of its growing commercial applications. However, its application as a structural material is somewhat limited because of its relatively low-impact resistance. The impact toughness of PP can be improved dramatically by the addition of elastomers such as ethylene-propylene rubber,[1] ethylene-propylene diene elastomer,[2,3] ethylene-octene copolymer,[4] styrene-ethylene butylene-styrene (SEBS) triblock copolymer[5] and ethylene-vinyl acetate copolymer (EVA).[6–8] But, the incorporation of elastomers into PP leads to a reduction in the modulus and strength. Therefore, issues concerning with the simultaneous reinforcing and toughening of PP have attracted considerable attention.[9,10] The addition of inorganic filler or short glass fibers into PP/elastomer blends provides an attractive means of maintaining the stiffness-to-toughness balance.[11,12]

The adhesion between the polymer matrix and reinforcing phase plays a decisive role in determining the mechanical properties of the resultant composites. A strong interfacial adhesion gives rise to better tensile and impact properties for the composites. The adhesion between inorganic filler or short glass fibers and PP is very poor, because the surfaces of inorganic filler or short glass fibers are polar but PP is a nonpolar polyolefin. A functional group such as maleic anhydride (MAH) is commonly grafted to PP to enhance the interfacial adhesion of the composites.[13] MAH-grafted SEBS triblock copolymer has been used to improve the compatibility and toughness of phase components of the composites and polymer blends. MAH-*g*-SEBS acts as an impact modifier and a compatibilizer for these materials.[14,15]

Dynamical vulcanization is an effective method to prepare thermoplastic vulcanizates materials.[16,17] It is the process of vulcanizing an elastomer during its melt-mixing with a molten plastics. This technology has led to a significant number of new thermoplastic elastomers during the mid- to late-1980s.[18,19] We have applied dynamical vulcanization to prepare a new type of PP/epoxy blends.[20,21] Dynamical cure of the epoxy resin led to an improvement in the modulus and stiffness of the PP/epoxy blends compared with pure PP.

In this article, the dynamical cure of the epoxy resin in the PP/MAH-*g*-EVA blends gives rise to the

increases in the toughness and stiffness of the blends, and the obtained blends named as dynamically cured PP/MAH-*g*-EVA/epoxy blends. As the epoxy resin and PP were immiscible, MAH-*g*-EVA was acted as not only an impact modifier but also a compatibilizer. The toughness and stiffness of the dynamically cured PP/MAH-*g*-PP/epoxy blends are in a good balance. The morphology, thermal properties, and crystalline structure of the blends were also studied.

EXPERIMENTAL

Raw materials

PP, F401, was produced by Yangzi Petrochemical Co., Ltd. (China), with a melt flow index of 1.9 dg/min (230°C, 2.16 kg). Diglycidyl ether of bisphenol-A resin (DGEBA, M_w: 4500 g/mol) was supplied by Shanghai Resin Co., Ltd. (China). The curing reagent, 2-ethylene-4-methane-imidazole (EMI-2,4) was produced by Shanghai Chemical Reagent Company (China). Maleic anhydride-grafted ethylene-vinyl acetate copolymer (MAH-*g*-EVA) with MAH content of 1% was prepared by Shanghai Sunny New Technology Development Co., Ltd. (China) and contained 28 wt % of VA and had a melt flow index of 6.28 dg/min (230°C, 2.16 kg).

Sample preparation

Before blending, the MAH-*g*-EVA and epoxy resin were dried at 80°C under vacuum for about 8 h. Unless otherwise specified, dynamically cured PP/MAH-*g*-EVA/epoxy blends were prepared in the mixing chamber of a Haake Rheometer RC90 at 190°C and 50 rpm. MAH-*g*-EVA and PP were first mixed for 2 min, then the epoxy resin was added. Two minutes later, the curing reagent was added with the mixing continuing. The total mixing process lasted about 10 min. The composition was moved out and compression molded in a press at 195°C for 10 min, then cold pressed to give samples for testing.

Measurements

The tensile properties were measured using an Instron 4465 Tester at a crosshead speed of 20 mm/min according to ASTM D638. Flexural properties were measured using the Instron 4465 Tester and a three-point loading rig, and the central head was loaded on the specimen at a speed of 1.7 mm/min according to ASTM D790. Notched Izod impact strengths were tested using a Ray-Ran Universal Pendulum Impact Tester at an impacting pendulum speed of 3.5 m/s according to ASTM D256. In each of the tests, at least five samples were tested, and the average results were reported.

A scanning electron microscopy (SEM, HITACHI-S-2150) was used to examine the morphology of the samples. All samples were fractured in liquid nitrogen. The samples of the PP/MAH-*g*-EVA, PP/MAH-*g*-EVA/epoxy, and dynamically cured PP/MAH-*g*-EVA/epoxy blends were etched by toluene at 40°C for 10 min, and then covered with a thin gold layer for further observation.

Capillary rheological measurements were performed at 230°C using an Instron capillary rheometer ($L/D = 40$). End effects were neglected, but the Rabinowitsch correction was applied.[22]

The crystallization behavior of PP and the curing behavior of the epoxy resin in the blends were analyzed using a Perkin-Elmer DSC (Paris 1) (USA) under nitrogen atmosphere. Samples of about 4 mg were taken from the molded plaques. Nonisothermal crystallization was performed as follows: a sample was first heated to 200°C at 50°C /min and then maintained at this temperature for 5 min to eliminate any previous thermal history. The sample was subsequently cooled down to 40°C at a cooling rate of 10°C/min and then heated to 200°C at 10°C/min for data collection. The curing of the epoxy resin in the blends was performed as follows: the sample was heated from 40°C to 200°C at 10°C/min.

The thermogravimetry was performed in a Perkin–Elmer TGA7 (USA). The samples were scanned from 30 to 800°C at a heating rate of 20°C/ min under nitrogen atmosphere.

The X-ray diffraction experiments were performed using a Rigaku Dmax-rC diffractometer (Japan) with Cu target and a rotating anode generator operated at 40 kV and 100 mA. The scanning rate was 2°/min from 5° to 35°. The samples for wide-angle x-ray diffraction (WAXD) measurement were prepared by compression-molded at 200°C and 5 MPa.
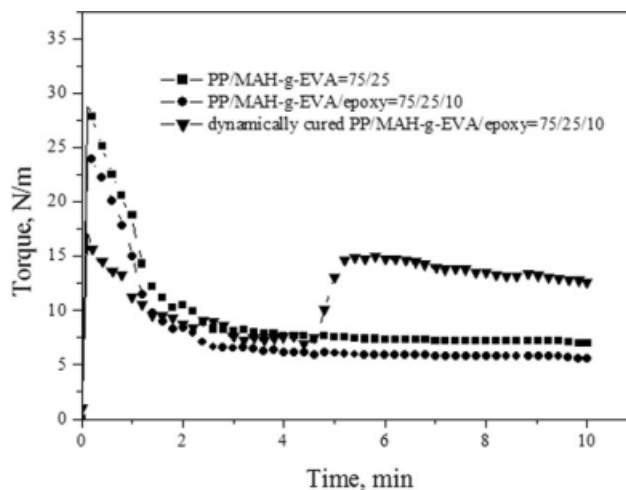

Figure 1 Plot of torque versus time for the PP/MAH-*g*-EVA and PP/MAH-*g*-EVA/epoxy blends at 190°C.
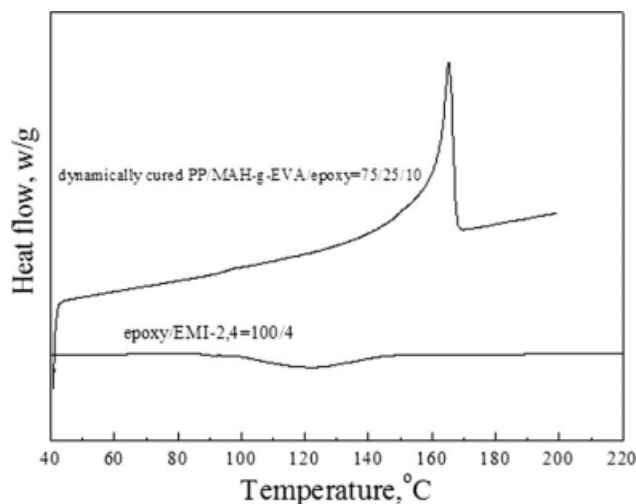
Figure 2 DSC curves of the epoxy/EMI-2,4 and dynamically cured PP/MAH-g-EVA/epoxy blend.

RESULTS AND DISCUSSION

Torque versus time

Torque measurements can be used to give qualitative information concerning the chemical reactivity

and the extent of reaction in the reactively compatibilized blends.[23] Figure 1 gives the relationship between torque and time for the PP/MAH-g-EVA (75/25) and PP/MAH-g-EVA/epoxy blends with or without the curing reagent, EMI-2,4 at 190°C. The addition of the epoxy resin into the PP/MAH-g-EVA (75/25) blend results in a decrease in the torque, which is attributed to the lower viscosity of the epoxy resin compared with MAH-g-EVA. It can be seen that the addition of the curing reagent at the mixing time of 4 min leads to an obvious rise of the torques of the PP/MAH-g-EVA/epoxy blends. This indicates that the epoxy resin has been cured during mixing with the molten PP and MAH-g-EVA, and the obtained blends are named as dynamically cured PP/MAH-g-EVA/epoxy blends.

The curing behavior of the epoxy resin in the blends was generally obtained by analyzed experimental results of DSC curves. Figure 2 shows DSC heating scans of epoxy/EMI-2,4 (100/4) and dynamically cured PP/MAH-g-EVA/epoxy (75/25/10) blend. It shows that there is an obvious exothermal enthalpy of curing reaction of epoxy/EMI-2,4 (100/4) and the curing temperatures range from 90 to
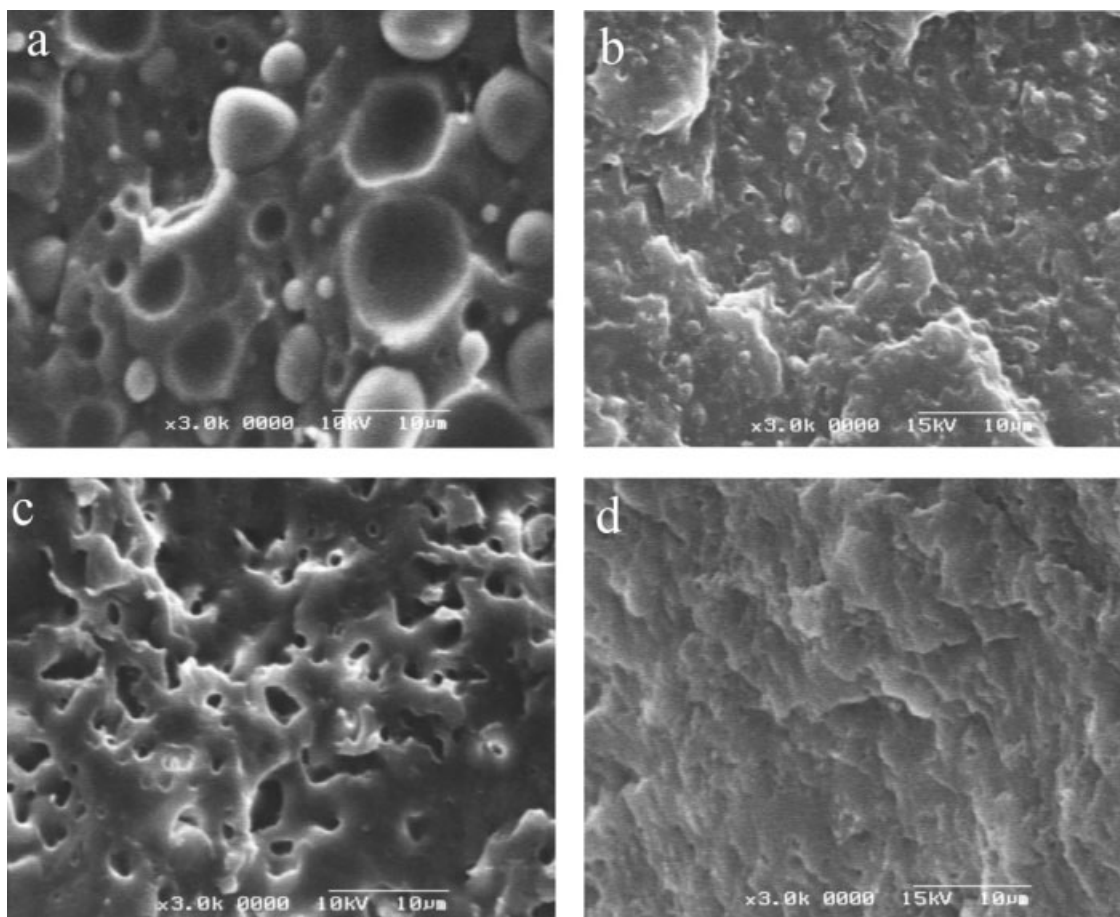

Figure 3 SEM photographs of (a) PP/epoxy = 75/10, (b) PP/MAH-g-EVA/epoxy = 75/25/10, (c) PP/MAH-g-EVA = 75/25 (etched), and (d) dynamically cured PP/MAH-g-EVA/epoxy = 75/25/10 (etched).
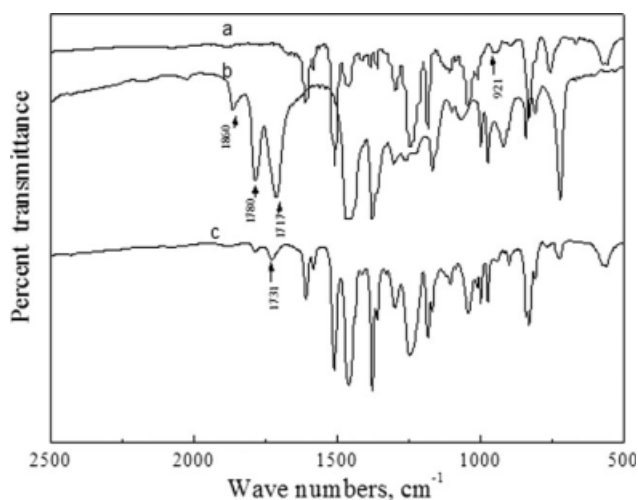
Figure 4 FTIR spectra of (a) epoxy resin, (b) MAH-*g*-EVA, and (c) PP/MAH-*g*-EVA/epoxy = 75/25/10.

150°C. No exothermal enthalpy of curing reaction but an enthalpy of fusion of PP for the dynamically cured PP/MAH-*g*-EVA/epoxy (75/25/10) blend was observed. The result shows that most of the epoxy resin has been cured in the blends as its melting with the molten PP and MAH-*g*-EVA.

SEM analysis

Figure 3(a,b) shows that SEM micrographs of PP/epoxy (75/10) and PP/MAH-*g*-EVA/epoxy (75/25/10) blends. For the PP/epoxy (75/10) blend [Fig. 3(a)], the epoxy resin is dispersed as spherical particles with an average diameter of 2–6 μm in the PP matrix. In the case of PP/MAH-*g*-EVA/epoxy (75/25/10) blend (Fig. 3b), fine epoxy particles with the average diameter of about 0.3–0.8 μm are distributed in the PP matrix. It shows that MAH-*g*-EVA can improve the compatibility between PP and epoxy resin. The FTIR spectra of the MAH-*g*-EVA, epoxy resin, and PP/MAH-*g*-EVA/epoxy (75/25/10) blend are shown in Figure 4. The spectrum of MAH-*g*-EVA shows the characteristic of a saturated ring anhydride. The bands at 1860 cm^{-1} and 1780 cm^{-1} are due to symmetrical and unsymmetrical stretching modes of C=O. The bands at 1717 cm^{-1} belong to the C=O of maleic acid. The characteristic band of the epoxy ring of the epoxy resin was observed at 921 cm^{-1}. In the case of the PP/MAH-*g*-EVA/epoxy (75/25/10) blend, a decrease in intensity for the absorption peak of the C=O of maleic acid at 1717 cm^{-1} shifts to the higher absorption peak (1731 cm^{-1}) that belongs to the C=O of the ester group, and the intensity of epoxide ring at 921 cm^{-1} also decreases. The result shows the maleic anhydride groups of MAH-*g*-PP have reacted with the epoxy resin, the reaction should have taken place in the PP/MAH-*g*-

EVA/epoxy blends to form a graft copolymer to act as a compatibilizer for promoting a fine dispersion of epoxy resin phase.

Figure 3 (c,d) shows the etched SEM micrographs of the PP/MAH-*g*-EVA (75/25) and dynamically cured PP/MAH-*g*-EVA/epoxy (75/25/10) blend. For the PP/MAH-*g*-EVA (75/25) blend, the holes of MAH-*g*-EVA in the PP matrix shows that MAH-*g*-
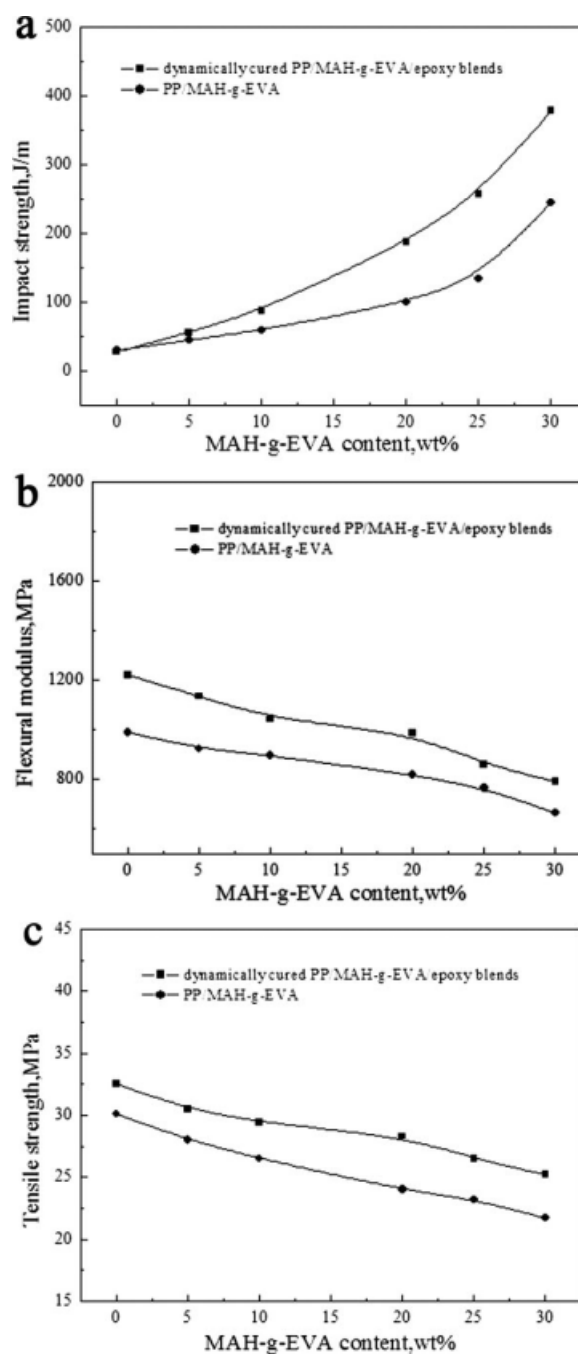

Figure 5 Effect of MAH-*g*-EVA content on the mechanical properties of the PP/MAH-*g*-EVA and dynamically cured PP/MAH-*g*-EVA/epoxy blends (formulation: (PP+MAH-*g*-EVA) 100, epoxy resin 10, EMI-2,4 0.4, MAH-*g*-EVA variable).
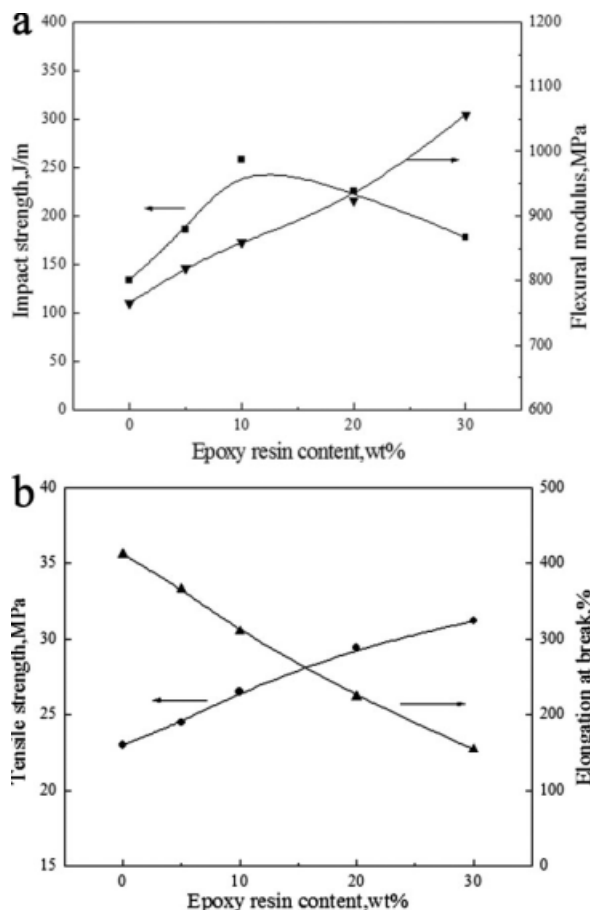
Figure 6 Effect of the epoxy resin content on the mechanical properties of dynamically cured PP/MAH-g-EVA/epoxy blends (formulation: PP 75, MAH-g-EVA 25, epoxy and EMI-2,4 variable).

EVA is a dispersed phase in the blends. But, a few smaller epoxy particles with diameters of about 0.20 μm and a number of smaller holes representing etched MAH-g-EVA were observed in the dynamically cured PP/MAH-g-EVA/epoxy (75/25/10) blend. It shows that the structure of the dynamically cured PP/MAH-g-EVA/epoxy blends is the embedding of the epoxy particles by the MAH-g-EVA. The epoxy particles could be embedded in MAH-g-EVA, and form the structure of core-shell complex phase and PP continuous phase in the blend. When MAH-g-EVA were etched by dimethylbenzene, a lot of epoxy particles were detached along with the MAH-g-EVA. Similar structures of three-component polymer/elastomer/fillers have been reported by other authors.[24,25]

Effect of MAH-g-EVA content

Figure 5 shows the effect of MAH-g-EVA content on the mechanical properties of the PP/ MAH-g-EVA and dynamically cured PP/MAH-g-EVA/epoxy blends. When MAH-g-EVA is added into the PP ma-

trix, the impact strength increases greatly, whereas the tensile strength and flexural modulus decrease. Although the addition of MAH-g-EVA improves the toughness of PP, it decreases the stiffness. When 10 wt % epoxy resin was dynamical cured in the PP/ MAH-g-EVA (75/25) blend, the impact strength is 258 J/m, increases by 100% compared with PP/ MAH-g-EVA (75/25) blend. In the condition of the same content of the MAH-g-EVA, the impact strength of dynamically cured PP/MAH-g-EVA/epoxy blends are higher than that of the PP/MAH-g-EVA blends (shown in Fig. 5). The result shows that the dynamical cure of the epoxy resin in the PP/ MAH-g-EVA blends improves not only the stiffness of the blends but also their toughness. The stiffness and toughness of the dynamically cured PP/MAH-g-EVA/epoxy blends are in a good balance. We thought that the cured epoxy particles as organic filler increases the stiffness of the PP/MAH-g-EVA blends, and an increase in the toughness is attributed to the embedded structure consisted of epoxy particles encapsulated with MAH-g-EVA. The epoxy particles led to finer dispersion with MAH-g-EVA domains of 0.5–1 μm in the dynamically cured PP/ MAH-g-EVA/epoxy blends, which is much smaller than that in PP/MAH-g-EVA blends.Wilkinson et al.[26] studied the phase structure in PP/PA6/SEBS blends, the use of reactive MAH-g-SEBS resulted in the formation of dispersed phases consisted of PA6 particles encapsulated with SEBS, and the core-shell PA6/SEBS particles led to an increase in impact strength compared with the PP matrix. Faulkner[27] studied the impact behavior of PP/mica/elastomer composites and tried to optimize stiffness and toughness, he also thought that the embedded structure had a better impact resistance.
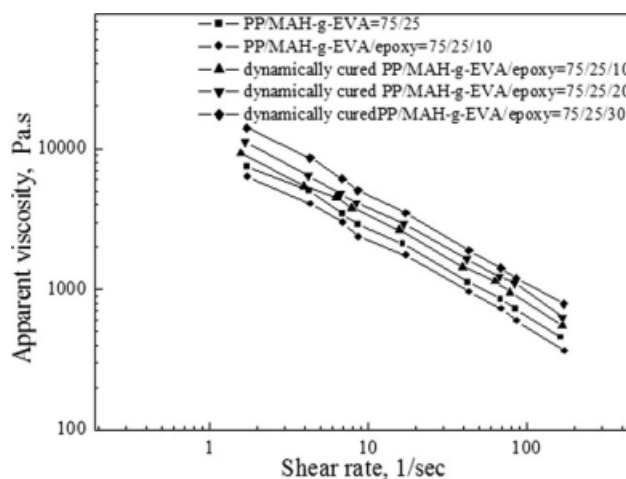

Figure 7 Apparent viscosities of the PP/MAH-g-EVA and PP/MAH-g-EVA/epoxy blends as a function of shear rate at 230°C.
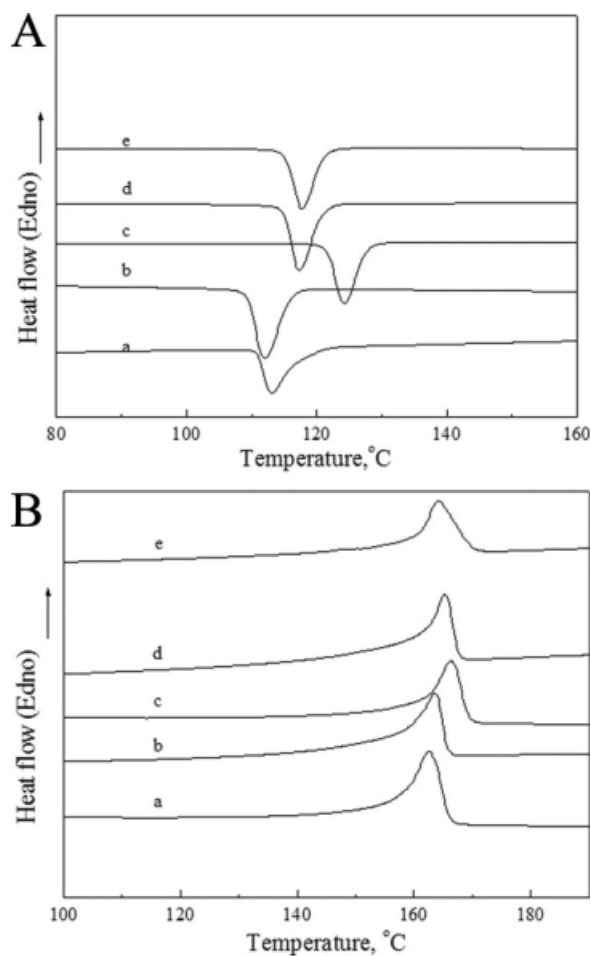
Figure 8 DSC thermograms at first cooling (A) and second heating (B). (a) PP; (b) PP/MAH-*g*-EVA = 75/25; (c) PP/epoxy = 75/10; (d) PP/MAH-*g*-EVA/epoxy = 75/25/10; and (e) dynamically cured PP/MAH-*g*-EVA/epoxy = 75/25/10.

Effect of epoxy resin content

Figure 6 shows the effect of epoxy resin content on the mechanical properties of the dynamically cured PP/MAH-*g*-EVA/epoxy blends. With increasing epoxy resin content, the tensile strength and flexural modulus of the dynamically cured PP/MAH-*g*-EVA/epoxy blends increase gradually, but the elongation at break deceases. Compared with PP/MAH-*g*-EVA (70/25) blend, the tensile strength and flexural modulus of the dynamically cured PP/MAH-*g*-EVA/epoxy (70/25/5) blend are 24.5 MPa and 820 MPa, respectively, increase by 7 and 8%, but elongation at break decreases by 11%. The impact strength increases with the dynamically cured PP/MAH-*g*-EVA/epoxy blend increasing the epoxy resin content (0–10 wt %) and has a maximum of 258 J/m at the epoxy resin content of 10 wt %. When the epoxy resin content is more than 10 wt % the impact strength decreases. We thought excessive epoxy particles give rise to thin layers of MAH-*g*-EVA, leading to an inability to relieve strain

constraint and subsequently unable to promote the toughness. It results also show that the dynamically cured PP/MAH-*g*-EVA/epoxy blends has the embedded structure with epoxy particles containing embedded MAH-*g*-EVA, which obviously improves the stiffness and toughness, and the stiffness and toughness of the blends increases with increasing epoxy resin content (0-10 wt%), whereas a higher epoxy resin content (10 wt %) impairs the toughness.

Capillary rheometry

Figure 7 illustrates the apparent viscosity versus shear rate for the PP/MAH-*g*-EVA (75/25) PP/MAH-*g*-EVA/epoxy (75/25/10) and dynamically cured PP/MAH-*g*-EVA/epoxy blends at 230°C. All the molten blends present non-Newtonian fluid and shear-thinning behavior. It shows that the addition of the epoxy resin into the PP/MAH-*g*-EVA (75/25) blend results in a decrease in the apparent viscosity. The apparent viscosity of the dynamically cured PP/MAH-*g*-EVA/epoxy blends is higher than that of the PP/MAH-*g*-EVA/epoxy (75/25/10) blend, and increases with increasing epoxy resin content. An increase in the apparent viscosity of the dynamically cured PP/MAH-*g*-EVA/epoxy blends shows that the epoxy resin has been cured in the blends.

DSC analysis

PP can crystallize rapidly, even under quenching conditions. Figure 8 (A,B) shows the first cooling and second heating DSC scans of PP, PP/MAH-*g*-EVA (75/25), PP/epoxy (75/10), PP/MAH-*g*-EVA/epoxy (75/25/10), and dynamically cured PP/MAH-*g*-EVA/epoxy (75/25/10), respectively. Table I gives a summary of the crystallization and melting data from the DSC thermograms. The crystallinity of the PP component in the blends was calculated by using the following equation:

$$X_c(\%) = (\Delta H / \Delta H_0) \times (100/x) \tag{1}$$

where X_c is the crystallinity of PP, ΔH is the measured heat of crystallization of the blend, ΔH_0 (=170

TABLE I
DSC Analysis Results of PP and PP/Epoxy Blends (T_m: Peak Melting temperature; T_p: Peak Crystallisation Temperature; X_c: the Crystallinity of PP)

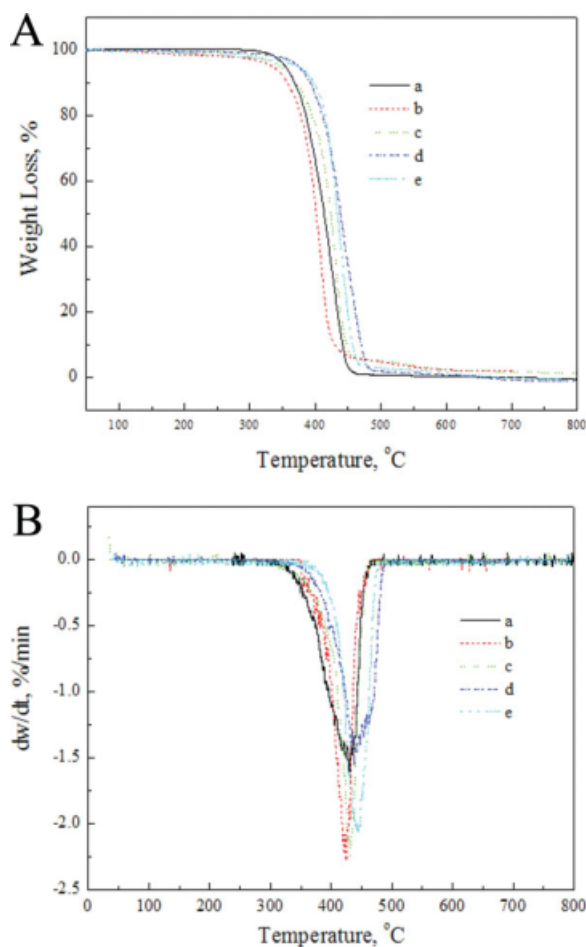| Composition	T_m, °C	T_p, °C	X_c, wt %
PP	162.4	113.1	56.1
PP/MAH-*g*-EVA = 75/25	163.2	112.0	57.5
PP/epoxy = 75/10	166.2	124.2	56.7
PP/MAH-*g*-EVA/epoxy = 75/25/10	165.2	117.4	57.9
dynamically cured PP/MAH-*g*-EVA/epoxy = 75/25/10	164.9	118.0	59.1

Figure 9 TG (A) and DTG (B)curves of (a) PP; (b) PP/MAH-*g*-EVA = 75/25; (c) PP/epoxy = 75/10; (d) PP/MAH-*g*-EVA/epoxy = 75/25/10; and (e) dynamically cured PP/MAH-*g*-EVA/epoxy = 75/25/10. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

J/g) is the heat of crystallization of 100% crystalline isotactic PP,[2] and *x* is the mass fraction of PP in the blend.

Only a single crystallization peak (T_p) could be seen for PP, PP/MAH-*g*-EVA, PP/epoxy, PP/MAH-*g*-EVA/epoxy, and dynamically cured PP/MAH-*g*-EVA/epoxy blends. The T_p of PP is 113.1°C, the T_p of PP in PP/MAH-*g*-EVA (75/25) was about 112°C, i.e., lower than that of the PP/epoxy (75/10), which is about 124.2°C. A shift of the T_p to a higher temperature suggests that epoxy resin in the blends can act as nucleating agents, accelerating the crystallization of PP.

The T_p of dynamically cured PP/MAH-*g*-EVA/epoxy (75/25/10) was about 118°C, which is similar to that of PP/MAH-*g*-EVA/epoxy (75/25/10), but lower than that of the PP/epoxy (75/10). It shows the epoxy particles embedded MAH-*g*-EVA decrease its nucleating effect. Premphet et al.[25] also found that the nucleating effect of calcium carbonate on PP

in PP/CaCO₃/elastomers became worse when the $CaCO_3$ was embedded in the elastomer. In all cases, the crystallinity of PP in the blends was slightly higher than that of pure PP, and the increase in the melting temperature of PP in the blends was directly related to the size of the PP crystals.[28]

Thermal stability

Polymer degradation is generally an undesirable process involving a deterioration of their properties. One of the most accepted methods for studying the thermal properties of polymeric materials is thermogravimetry which by means of integral and derivative thermogravimetric curves provide information about the nature and extent of degradation of the polymeric materials.[29] Thermograms of the PP, PP/MAH-*g*-EVA (75/25), PP/epoxy (75/10), PP/MAH-*g*-EVA/epoxy (75/25/10), and dynamically cured PP/MAH-*g*-EVA/epoxy (75/25/10) blends are shown in Figure 9(A). The degradation of PP started at 347°C and finished at 473°C. In the case of the PP/MAH-*g*-EVA (75/25) and PP/epoxy (75/10) blends, the incorporation of 25 wt % MAH-*g*-EVA into the pure PP decreases the initial degradation temperature (T_0) from 347°C to 328°C, but the addition of epoxy resin increases T_0 from 347°C to 380°C. The dynamically cured PP/MAH-*g*-EVA/epoxy (75/25/10) blend has the higher T_0 compared with the PP and PP/MAH-*g*-EVA/epoxy (75/25/10) (shown in Table II). It shows that dynamical cure of epoxy resin in the blends obviously could further improve the thermal stability. The temperature of maximum rate of mass loss (T_{max}) for PP, PP/MAH-*g*-EVA (75/25), PP/epoxy (75/10), PP/MAH-*g*-EVA/epoxy (75/25/10), and dynamically cured PP/MAH-*g*-EVA/epoxy (75/25/10) blends was obtained by derivative thermogravimetric (DTG) curves (shown in Figure 9B), T_{max} has the same tendency as T_0. The result is that the addition of epoxy resin could improve the thermal stability of PP, and dynamically cured PP/MAH-*g*-EVA/epoxy blends have a good thermal stability.

TABLE II
TG and DTG Analysis Results of PP and PP/Epoxy Blends (T_0: Initial Degradation Temperature; T_f: Final Degradation Temperature, T_{max}: Temperature of Maximum Rate of Mass Loss)

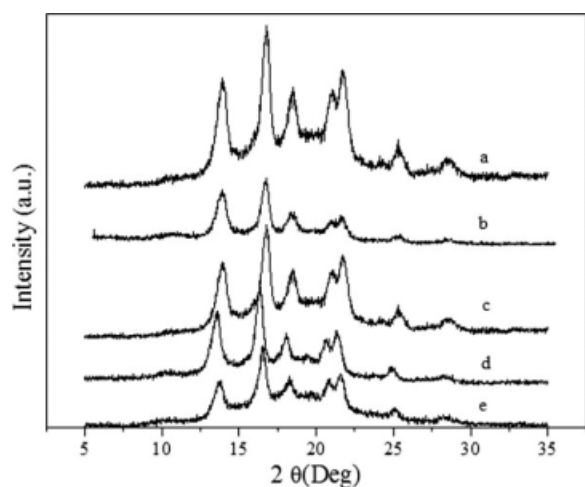| Composition	T_0, °C	T_f, °C	T_{max},°C
PP	347	473	424
PP/MAH-*g*-EVA = 75/25	328	470	423
PP/epoxy = 75/10	380	502	458
PP/MAH-*g*-EVA/epoxy = 75/25/10	356	492	430
dynamically cured PP/MAH-*g*-EVA/epoxy = 75/25/10	383	497	448

Figure 10 WAXD curves of (a) PP; (b) PP/MAH-*g*-EVA = 75/25; (c) PP/epoxy = 75/10; (d) PP/MAH-*g*-EVA/epoxy = 75/25/10; and (e) dynamically cured PP/MAH-*g*-EVA/epoxy = 75/25/10.

Wide-angle x-ray diffraction analysis

To investigate whether the crystalline structure formed by one component of the blend can be affected by the other component or the compatibilizer, X-ray diffraction studies were made on the corresponding PP and the blends. Figure 10 shows the WAXD patterns of PP, PP/MAH-*g*-EVA (75/25), PP/epoxy (75/10), PP/MAH-*g*-EVA/epoxy (75/25/10), and dynamically cured PP/MAH-*g*-EVA/epoxy (75/25/10). Several reflections in both the blends and PP are observed at $2\theta = 13.9°$, $16.7°$, $18.3°$, $20.9°$, $21.8°$, which belong to the identical monoclinic α form of the PP component. The result shows that the dynamical cure of epoxy resin and compatibilization do not disturb the crystalline structure of PP in the blends.

CONCLUSIONS

The epoxy resin was dynamical cured in the PP/MAH-*g*-EVA blends, and the obtained blends named as dynamically cured PP/MAH-*g*-EVA/epoxy blends. Because the epoxy resin and PP were immiscible, MAH-*g*-EVA was also used as a compatibilizer. SEM analysis shows that the dynamically cured PP/MAH-*g*-EVA/epoxy blends with the structure of the embedding of the epoxy particles by the MAH-*g*-EVA. The cured epoxy particles in the PP/MAH-*g*-EVA blends improve not only the stiffness of the blends but also the toughness. The tensile strength and flexural modulus of dynamically cured PP/MAH-*g*-EVA/epoxy blends increase with increasing the epoxy resin content, and the impact strength exhibits a maximum of 258 J/m at the epoxy resin content of 10 wt %. The stiffness and toughness of dynamically cured PP/MAH-*g*-EVA/epoxy blends are in a good balance. The cured epoxy particles as

organic filler increases the stiffness of the PP/MAH-*g*-EVA blends, and the improvement in the toughness is attributed to the embedded structure in the dynamical cured PP/MAH-*g*-EVA/epoxy blends. DSC analysis shows that the epoxy particles the dynamically cured PP/MAH-*g*-EVA/epoxy blends could have contained embedded MAH-*g*-EVA, decreasing the nucleating effect of the epoxy resin. Thermogravimetric results show the addition of epoxy resin could improve the thermal stability of PP, the dynamically cured PP/MAH-*g*-EVA/epoxy blends have a good thermal stability compared with the pure PP. WAXD analysis shows that the dynamical cure and compatibilization do not disturb the crystalline structure of PP in the blends.

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