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Study on the Crystallization and Morphology of HDPE-g-GMA Modified PA66/UHMWPE Blends

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Abstract: By means of melt compounding method, the Glycidyl methacrylate (GMA) grafted HDPE modified Polyamide 66 (PA66) with ultra high molecular weight polyethylene (UHMWPE) blends were prepared via the co-rotating twin screw extruder. The effects of different UHMWPE/HDPE contents on properties of PA66/UHMWPE blends were investigated. Meanwhile, the mechanical properties such as tensile and impact strength etc. were investigated. By using the differential scanning calorimetry (DSC) and scanning electron microscope (SEM), the crystalline and morphology of PA66/UHMWPE blends were analyzed. The results show that UHMWPE toughened PA66 samples exhibit significantly enhanced impact strength and elongation at break comparison with natural PA66. The samples of PA66 with 30% of UHMWPE/HDPE (mass ratio 3/7) blends show impact strength about 2 times and elongation at yield 7 times more than those of natural PA66. The behavior of HDPE-g-GMA shows an effective compatibilizer for PA66/UHMWPE blends, when the mass ratio of PA66/(UHMWPE/HDPE) at 70:30, the blend indicates the best comprehensive property. The investigation on crystallization and morphology of PA66 and their blends show that the behaviors of melting about the two components are independent either PA66 or UHMWPE/HDPE. There are independent melting behaviors, meanwhile, interacted each other between PA66 and UHMWPE. Due to the good compatibility which HDPE-g-GMA contributed, the homogenous PA66/UHMWPE blends could be achieved. The photographs of SEM analysis indicate that the interface action of PA66 and polyethylene is enhanced by compatibilizer HDPE-g-GMA.

Keywords: Polyamide 66; UHMWPE; HDPE-g-GMA; Crystallization; Toughen

Introduction

As engineering plastics, polyamide 66 (PA66) has the good comprehensive performance, but has shortage in impact resistant at dry or lower temperature. This paper aims to use ultra high molecular weight polyethylene (UHMWPE) and high density polyethylene (HDPE) blends to improve the impact strength and water absorption of PA66. The UHMWPE was a new kind of engineering plastics with many excellent properties such as excellent low temperature resistance, toughness and water resistance, due to it has very long molecular chains[1-3]. In order to improve the melt flowability of UHMWPE, it was melt blended suitable HDPE to get the modified UHMWPE (PE_2). By selecting appropriate compatibilizer of HDPE-g-GMA, the PA66/UHMWPE blend was prepared to achieve the comprehensive performance.

Experimental

Materials. PA66 was obtained from USA Solutia. UHMWPE was obtained from Beijing additives plant. HDPE was obtained from CSPC Petrochemical Co., LTD.

Sample preparation. According to certain proportion, the UHMWPE and HDPE were melt blended using co-rotation twin-screw extruder (L/D = 23, Φ = 30mm, HeBei chemical equipment factory). The temperature settings e were 180~200℃.After that, the modified UHMWPE (PE_2)

blending with PA66 to prepared the PA66/UHMWPE blends by means of co-rotation twin-screw extruder at temperature around 250~265℃. The test specimen was prepared via injection molding machine.

Morphology and Crystallization testing. The scanning electron microscopes (SEM) (JSM - LV6380, Japanese electronic company) were employed for observing the morphology of the samples. The crystallization behavior of PA66/UHMWPE blends was examined by differential scanning calorimetry (DSC) at nitrogen atmosphere in 10℃/min.

Results and discussion

Effect of PE_2 proportion on mechanical properties PA66/UHMWPE blends. The figure 1 illustrated that the effect of PE_2 (UHMWPE/HDPE mass ratio 3/7) with different proportion on tensile strength and elongation of PA66/UHMWPE blends, with using the HDPE-g-GMA (12% based on total mass of PA plus PE) as compatibilizer.

Figure 1 showed that the elongation of PA66/UHMWPE blend enhanced with the amount of PE_2 increasing but tensile strength decreased. It indicated that the soften chain of UHMWPE contributed the molecular chain and chain section easy to move during the tensile stress, and the elongation increased. Meanwhile, the modulus and tensile strength decreased. The PE_2 phase as the point of stress concentration, it could easily induce stress crazing around matrix and plastic deformation under external force. With increasing of PE_2 content, there were more point of deformation and stress concentration. The macromolecule chain and chain section were easy to move under external force. As a result, the elongation of PA66/UHMWPE blend could be enhanced.

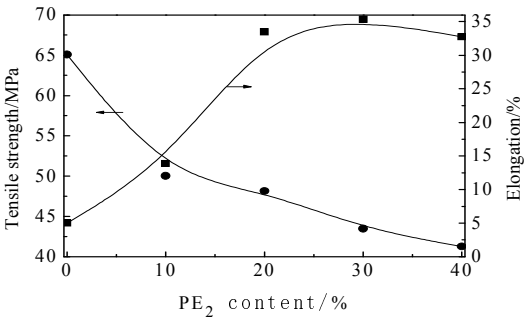


Fig.1 Influence of PE_2 contents on tensile strength of the blends

Figure 2 showed that the effects of PE_2 content on the impact properties of PA66/UHMWPE blend. In Figure 2, the notched impact strength of PA66/UHMWPE blends were significantly enhanced comparison with natural PA66 either at room temperature or minus 18 degree centigrade. At the content around 30% of PE_2, the notched impact strength of PA66/UHMWPE blend was 2.19 times larger than that of natural PA66.

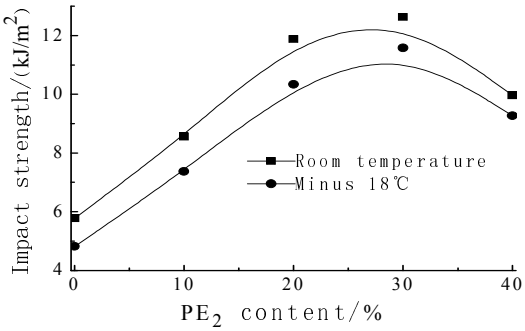


Fig. 2 Influences of PE_2 contents on Notched impact strength of the blends

With the temperature decreasing to -18℃, the impact strength of PA66/UHMWPE blend decreased synchronized. At the 30% content of PE_2, it still achieved larger impact strength than that of others. The samples of PA66 with 30% of PE_2 blends show impact strength about 2 times and elongation at yield 7 times more than those of natural PA66.

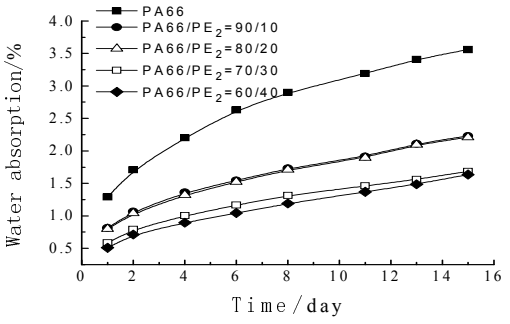


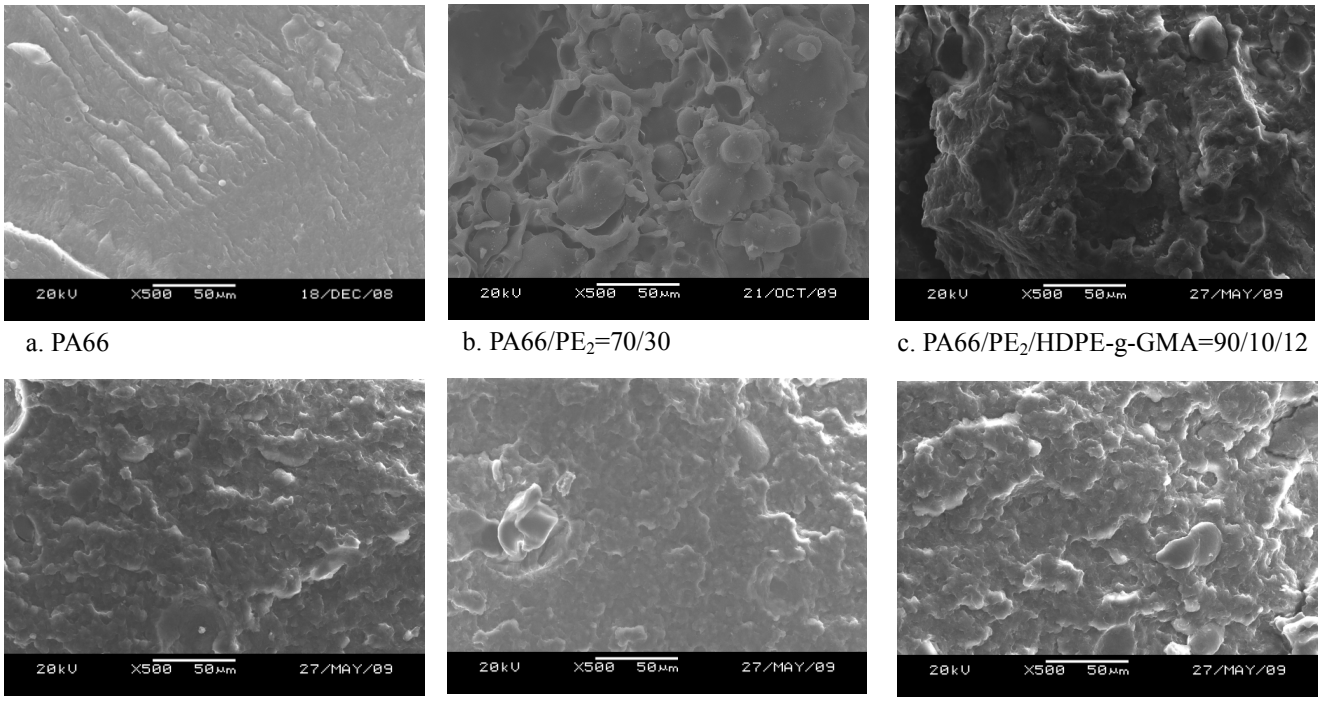
Fig.3 Water absorption vs. time curve of the blends

Effect of PE_2 content on the water absorption property of PA66/UHMWPE blend. Using polyethylene blended into polyamide, it could decrease the water absorption of PA. The figure 3 showed the result of PA66/UHMWPE blends.

The figure 3 illustrated that, pure PA66 absorption rate reached maximum 3.56%. Along with the increase of PE_2 content, blends absorption rate decreased gradually. When PA66/PE_2 = 60/40, the blends absorption rate was better than other, absorption rate maximum was 1.64%. Between pure PA66 and PA66/PE_2=90/10, the absorption rate changed larger. With the increase of PE_2 content, absorption rate was increasingly less, as can be seen from Figure 3.

PA66 molecular contains strong polar groups, easily formed hydrogen bond with the water molecule. UHMWPE and HDPE were nonpolar with excellent hydrophobic property. When the PA66 blends mixed with PE_2 uniformly dispersed in the matrix, it could hinder water molecules diffused and internal migration into PA66 matrix. So with the increase of PE_2 content, the absorption rate of PA66 will be declined.

Effect of PE_2 content on micro structure of PA66 blends. The SEM photos of fracture section were illustrated in figure 4.



a. PA66 b. PA66/PE_2=70/30 c. PA66/PE_2/HDPE-g-GMA=90/10/12

d. A66/PE2/HDPE-g-GMA=80/20/12 e. PA66/PE_2/HDPE-g-GMA=70/30/12 f.PA66/PE_2HDPE-g-GMA=60/40/12

Fig.4 The fracture section SEM photographs of impact specimen

From view of Figure 4, it was indicated that the effect of PA66/PE_2 blends with different proportion on micro structure of fracture section. The figure 4(a) represents the fracture surface of natural PA66. It was rough surface, and that the natural PA66 fracture was belonged to ductile fracture, but still too gently. So impact strength of natural PA66 was relatively lower. In Figure 4(b), when PA66 blended with PE_2, PA66 continuous phase matrix contained some PE_2 particles, there were many cavities and protruded globular particles, these holes and protrusions size were large, irregular distribution and the interface between two phases was clear. This was mainly because large different polarity between PA66 and PE_2 phases. In Figure 4(c)-(f) shows that cavities and particle in the fracture surface significantly reduced, and the two phase interface were obscured. So the compatibilizer HDPE-g-GMA could improve the phase interface action and bonding, effectively modify the PA66 and PE_2 phase compatibility and played the important role of toughening effectively [4-5].

Effect of PA66/PE_2 different proportion on blends melt and crystallization

In Figure 5 DSC melting curves, PA66 and UHMWPE components had melting peaks in their pure component of the melting temperature range, and the melting point had no change too much. It indicated there was good compatibility between UHMWPE and HDPE, meanwhile, they were incompatible system for PA66 with polyethylene. But by means of general blend melting equipment and conditions, although the two phases of PA66 and PE_2 formed hardly uniform formation for the viscosity difference, but due to good compatibility which HDPE-g-GMA contributed, the homogenous PA66/UHMWPE blends could be achieved.

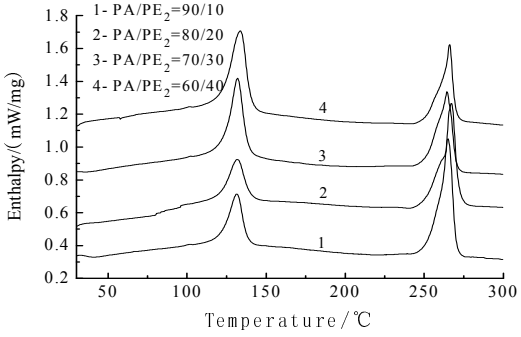


Fig.5 The DSC curves of different ratio of PA66/PE_2 under heating rate of 10℃/min

Conclusions

(1)PA66/PE_2 ratio between 80/20 and 70/30, blends comprehensive performance was better. PE_2 phase dispersion in the PA66 matrix and two-phase interface action situation were analyzed by the SEM. It indicated that the interface action of PA66 and polyethylene was enhanced by compatibilizer HDPE-g-GMA.

(2) Adding PE_2 effectively improved the PA66/UHMWPE blends adsorptive properties. Along with the increase of PE_2 content, PA66/UHMWPE blends absorption rate decreased gradually, and down to 1.64%.

(3) The investigation on crystallization and morphology of PA66 and their blends show that the behaviors of melting about the two components are independent either PA66 or UHMWPE/HDPE. There are independent melting behaviors, meanwhile, interacted each other between PA66 and UHMWPE. Due to the good compatibility which HDPE-g-GMA contributed, the homogenous PA66/UHMWPE blends could be achieved.

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