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Influence of Expandable Graphite on Mechanical Properties and Flame Retardant Properties of High Density Polyethylene

Ma Xiuqing [a*], Liu Min [a], Zhai Wenbin [a], Ge Mingjie [a]

[a]*Beijing University of Chemical Technology - Beijing – China*

[*]*maxq@mail.buct.edu.cn*

Abstract. The influence of surface modification for EG, the content and the particle size of EG on the properties of HDPE/EG composite were studied by the tests of tensile strength, notched impact strength, horizontal/vertical combustion and oxygen index of the composite. The results showed that the mechanical properties and flame retardant properties of HDPE/EG composite are both improved after treating the surface of EG with coupling agent, and the mechanical properties and flame retardant properties of HDPE/EG composite after treating the surface of EG with silane coupling agent (KH-550) is better than that with titanate coupling agent (NDZ-201). With the increase of the proportion of EG, the mechanical properties of the composite were reduced while the flame retardant performance was improved. And with the increase of the particle size of EG, the mechanical properties of HDPE/EG composite decreased, and the flame retardant properties improved.

Keywords: high density polyethylene, expandable graphite, mechanical properties, flame retardant properties
PACS: 83.80.Tc

INTRODUCTION

The properties of polymer composite with filled modification are influenced by many factors, such as the surface treatment of inorganic modifiers, the content of inorganic modifiers, the size of inorganic modifiers, and the modified equipment. In this paper, the effects of surface treatment, content, and particle size of EG on the properties of HDPE/EG composite were studied by experiments.

EXPERIMENTS

Experimental Materials

HDPE, 5000s, Petro China Co.,Ltd.; EG, KP5099200/KP8099200/KP10099200/KP15099150, Qingdao Hengrun Da graphite products Co., Ltd.; Silane coupling agent, KH550, Chengdu Chen Bang Chemical Co., Ltd.; Titanate coupling agent, NDZ-201, Chengdu Chen Bang Chemical Co., Ltd.; Absolute ethyl alcohol, Analytical Reagent, Shanghai Wei Chuang Chemical Co., Ltd.; Liquid paraffin, Chemical purity, Wuxi Yatai Chemical Co., Ltd..

Sample Preparation

The experimental formula of HDPE/EG composite is shown in TABLE (1).

TABLE (1). Experiment formulations

Name	HDPE/phr	EG-150/phr	EG-100/phr	EG-80/phr	EG-50/phr	KH-550/phr	NDZ-201/phr
HDPE/EG0	100	20	0	0	0	0	0
HDPE/MEG1	100	20	0	0	0	0	0.3
HDPE/MEG2	100	20	0	0	0	0.3	0
HDPE	100	0	0	0	0	0	0
HDPE/EG10	100	10	0	0	0	0.15	0
HDPE/EG15	100	15	0	0	0	0.225	0
HDPE/EG20	100	20	0	0	0	0.3	0
HDPE/EG25	100	25	0	0	0	0.375	0
HDPE/EG2	100	0	20	0	0	0.3	0
HDPE/EG3	100	0	0	20	0	0.3	0
HDPE/EG4	100	0	0	0	20	0.3	0

Note: The formula of HDPE/EG1 and HDPE/EG20 are the same.

RESULTS AND DISCUSSION

Effect of EG surface treatment on the properties of HDPE/EG composite

FIGURE 1 is the effect of surface modification of EG on the tensile strength of HDPE/EG composite. FIGURE 2 is the effect of EG surface modification on notched impact strength of HDPE/EG composite. As shown in FIGURE 1 and 2, after the surface treatment of the coupling agent, the tensile strength and notched impact strength of the composite are higher than that of the EG without surface treatment. The tensile strength and notched impact stress of the composite after the surface treatment of the silane coupling agent (KH-550) is the largest.

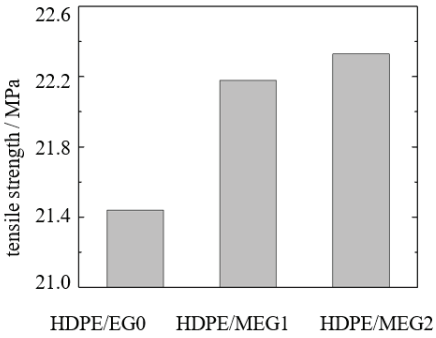

FIGURE 1 Effect of EG surface modification on tensile strength of HDPE/EG composite

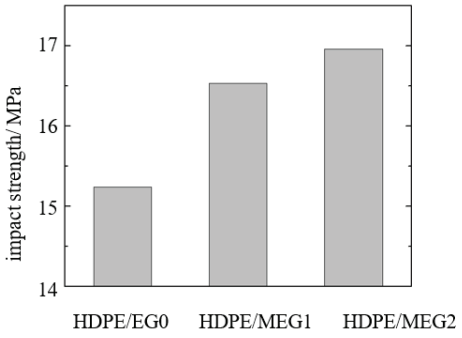

FIGURE 2 Effect of EG surface modification on notched impact strength of HDPE/EG composite

TABLE (2) is the influence of surface modification of EG on the combustion level of HDPE/EG composite. It can be seen in table that the combustion level of three samples is at level FH-3. The average burning rate of composite which EG was surface-treated by coupling agent is lower than that of composite which EG wasn't surface-treated. And the flame retardant properties of composite which EG was surface-treated by KH-550 is excellent.

TABLE (2). Effect of EG surface modification on horizontal combustion level of HDPE/EG composite

Composition formula	Horizontal combustion level	Average burning rate ($mm \cdot min^{-1}$)
HDPE/EG	FH-3-18mm/min	17.16
HDPE/EG/NDZ-201	FH-3-17.31mm/min	15.25
HDPE/EG/KH-550	FH-3-13.55mm/min	12.57

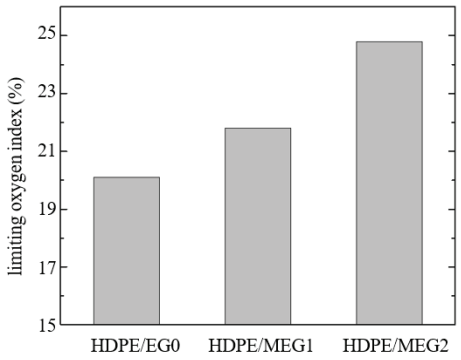

FIGURE 3 Effect of EG surface modification on limiting oxygen index of HDPE/EG composite

Effect of EG content on the performance of HDPE/EG composite

FIGURE 4 is the influence of the content of EG on the tensile strength of the composite. FIGURE 5 is the influence of the content of EG on the notched impact strength of composite. As shown in two figures, the tensile strength and notched impact strength of the HDPE/EG composite decreases with the increase of the content of EG. Because the addition of the flame retardant EG will weaken the inter-acting force of the matrix. When the addition of EG is excess, the EG will agglomerate. When the composite is subjected to external force, the inter acting force is weak and the position where the stress concentrated is easy to slip, which leads to the decrease of the mechanical properties of the composite [3].

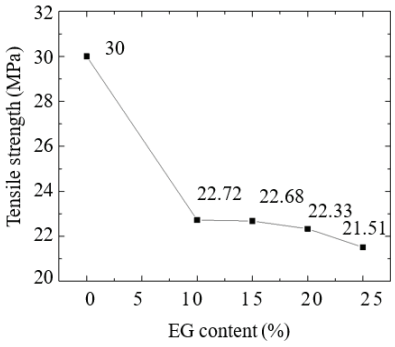

FIGURE.4 The content of EG vs. tensile strength of HDPE/EG composite

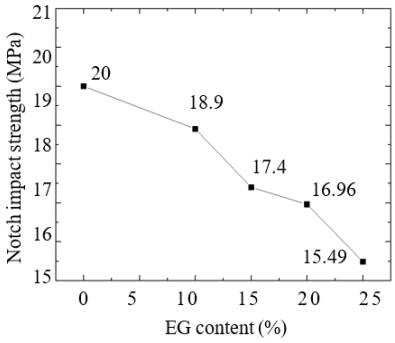

FIGURE. 5 The content of EG vs. notched impact strength of HDPE/EG composite

TABLE (3) is the horizontal combustion level and the average burning rate of the composite with different EG content. It is shown in the table that, without the addition of flame retardant EG, the HDPE level combustion has no grade. The level of the EG occupation is FH-3 level at 10-20wt%, when the EG ratio is 25wt%, the composite reaches the highest level FH-1. The average combustion rate of the composite slows with the higher proportion of EG. TABLE (4) is the vertical combustion level of the HDPE/EG composite with different EG content. It is shown in the table that the addition of EG effectively solves the problem of droplet production in the combustion process of pure HDPE, which can prevent the damage caused by the droplet in the fire. However, only when the proportion of EG is up to 25wt%, the vertical combustion grade of the composite can be reached to the FV-1 level.

TABLE (3). Horizontal combustion level of HDPE/EG composite vs. different proportion of EG

Sample	Composition formula	Horizontal combustion level	Average burning rate ($mm \cdot min^{-1}$)
4#	HDPE	/	-
5#	HDPE/EG10	FH-3-17.31 mm/min	16.85
6#	HDPE/EG15	FH-3-16.01 mm/min	14.01
7#	HDPE/EG20	FH-3-13.55 mm/min	12.57
8#	HDPE/EG25	FH-1	5.31

TABLE.4 Vertical combustion level of HDPE/EG composite vs. different proportion of EG

Sample	Composition formula	Vertical combustion level	Droplet
4#	HDPE	/	√
5#	HDPE/EG10	/	/
6#	HDPE/EG15	/	/
7#	HDPE/EG20	/	/
8#	HDPE/EG25	FV-1	/

FIGURE 6 is the limiting oxygen index of HDPE/EG composite under different EG content. It can be seen that the limiting oxygen index of HDPE/EG composite increases with the increase of the content of EG.

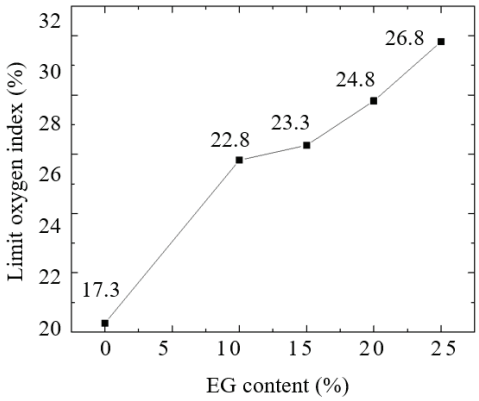

FIGURE 6 The proportion of EG vs. limit oxygen index of HDPE/EG composite

Effect of particle size of EG on the performance of HDPE/EG composite

FIGURE 9 is the relationship between the particle size of EG and the tensile strength of the composite. FIGURE 10 is the relationship between the particle size of EG and the notched impact strength of composite. As shown in two figures, the tensile strength and notched impact strength of the HDPE/EG composite decreases with the increase of EG particle size. It is inferred that the bond force between the EG and matrix is weakened on one hand with the increase of the particle size of EG. On the other hand, with the increase of the particle size of EG, the forced area of the matrix on the cross section of the composite becomes smaller, which leads to the gradually decreasing of the mechanical properties of the HDPE/EG composite [4].

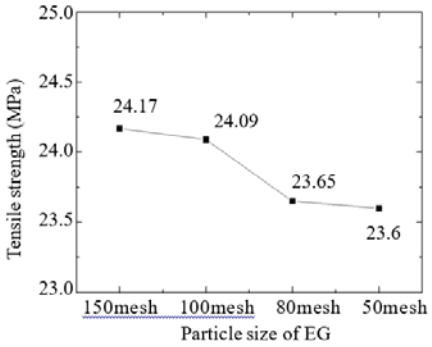

FIGURE 7 EG particle size vs. tensile strength of HDPE/EG composite

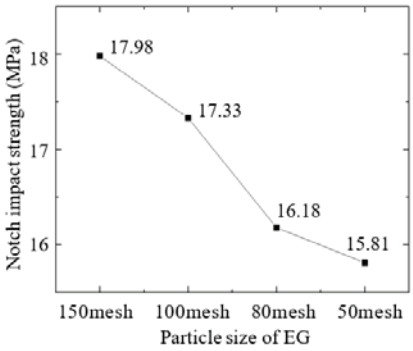

FIGURE 8 EG particle size vs. notched impact strength of HDPE/EG composite

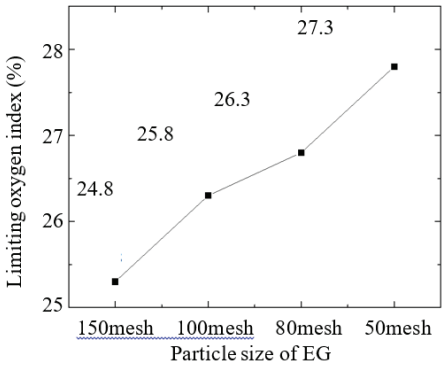

FIGURE 9 EG particle size vs. limiting oxygen index of HDPE/EG composite

TABLE (5) is the horizontal combustion level and the average burning rate of the composite with different EG particle sizes. As shown in table that the level of combustion of the HDPE/EG composite increases with the increase

of the particle size of EG, and the average combustion rate decreases. FIGURE 9 is the limiting oxygen index of the composite with different EG particle sizes. As shown in the figure that the limiting oxygen index of the HDPE/EG composite increases with the increase of the particle size of the EG, that is, the flame retardancy of the composite increases with the increase of the particle size of the EG. This is that the particle size of EG is an important factor affecting the expansion ratio. The smaller the particle is, the smaller the expansion ratio is [5], the less the surface space and the burning point of the covered HDPE are, the larger the burning area.

TABLE (5). Horizontal combustion level of composite vs. different paticle of EG

Sample	Composition formula	Horizontal combustion level	Average burning rate ($mm \cdot min^{-1}$)
9#	HDPE/EG_1（150Mesh）	FH-3-10.47 mm/min	-
10#	HDPE/EG_2（100Mesh）	FH-1	7.61
11#	HDPE/EG_3（80Mesh）	FH-1	6.21
12#	HDPE/EG_4（50Mesh）	FH-1	5.91

CONCLUSION

The effects of EG surface modification, EG content and particle size on the properties of HDPE/EG composite were studied by experimental research. The results indicated that:

The mechanical and flame retardant properties of composite which EG was surface-treated is better.

With the increase of the content and particle size of EG, the flame retardant properties of composite increases obviously, but the mechanical properties of composite decreases clearly. So, the content and particle size determination of EG should be considered with both mechanical properties and flame retardant properties.

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