

A STUDY ON MECHANICAL PROPERTIES OF γ -RAY IRRADIATED HDPE FILLED WITH SERICITE-TRIDYMITE-CRISTOBALITE*

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Abstract The effect of γ -ray irradiation on the mechanical properties of high density polyethylene(HDPE) filled with sericite-tridymite-cristobalite(STC) was studied. The experimental results show that γ -ray irradiation can improve the affinity between HDPE and STC, and the dispersion of STC in HDPE matrix. Compared with HDPE/STC (80/20) blend, the yield stress and impact strength of irradiated HDPE (10kGy)/STC (80/20) blend are increased from 22.8 MPa and 70J/m to 28.5 MPa and 144J/m. The yield stress and impact strength of HDPE/irradiated HDPE/STC (48/32/20) are 27.8MPa and 210J/m, respectively.

Keywords γ -Ray irradiation; High density polyethylene; Sericite-tridymite-cristobalite

INTRODUCTION

Polyolefine makes up over 35% of all plastics produced in the world. Polyethylene and polypropylene are the only high-volume polyolefine. The substantial problem for improving the properties of polyolefine based material is how to increase its stiffness at room temperature without loss of toughness, or increase its toughness without loss of stiffness. The toughness of a brittle polymer can be improved by blending it with rubber, however, the modulus, stiffness and heat distortion temperature of the material will be lowered. Some rigid inorganic fillers (RIF) can be used as reinforcing element to increase the stiffness of the materials, however, the toughness, especially notched Izod impact strength will fall down.

The mechanism of oxidation reaction of polyethylene during γ -Ray irradiation in air was studied by Carlsson et al.^[1~3]. Spadaro et al. found that γ -Ray irradiation is conducive for improvement of the compatibility of low density polyethylene with polyamide-6^[4~6]. We observed also that the affinity between linear low

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density polyethylene and alumina trihydrate is improved quite a lot by means of γ -Ray irradiation^[7~8]. The approach adopted in this paper is to introduce some oxygen-containing functional groups onto the molecular chain of HDPE through γ -Ray irradiation within measure, then blending the irradiated HDPE with sericite-tridymite-cristobalite (STC) in hopes of improving both stiffness and toughness of the filled HDPE.

EXPERIMENTAL

Materials

HDPE (DGDA 6098): Qi-lu Petrochemical Co. (China), $\overline{M}_w$ 105400, $\overline{M}_w/\overline{M}_n$ 3.56, MI 0.08g/10 min.

STC: Sichuan Powdering Technology R & D Center (China), sp. gr. 2.7, average particle size 1.6 μ m, it is a kind of natural-born flaky sericite, a heat, weather and corrosion resistant material contains about 70% $KAl_2(AlSi_3O_{10})(OH)_2$, 30% fibroillary silica.

Irradiation of HDPE

Irradiation was carried out in air at room temperature (about 293K), air humidity 60%, cylindrical 50000 Ci ^{60}Co , dose rate 0.1kGy/h, measured by fricke dosimeter.

Contact angle measurement

Contact angle was measured with Erma G-1 contact angle tester at room temperature. The sample thickness is 200 μ m.

Sample preparation and mechanical property testing

HDPE γ -HDPE and STC were blended with a twin roller at $155 \pm 2^\circ C$ for 10 min, then molded to sheets of thickness of 1 mm and 4 mm respectively. The tensile and impact tests were conducted according to GB1040-92 and GB1843-80 with Instron 4302 tension machine and XJ-40A impact tester.

Scanning electron microscopy (SEM) observation

The fractured surface of the impact specimen and the dispersion of STC in matrix were observed with X-650 Scanning Electron Microanalyzer.

RESULTS AND DISCUSSION

Effect of γ -Ray irradiation on HDPE

Oxygen-containing groups (mainly carbonyl group, appeared at 1720 cm^{-1} on

FTIR spectrum) are introduced onto the molecular chain of HDPE during γ -Ray irradiation in air (Fig.1), the polarity of HDPE is thus increased and its contact angle with water becomes smaller. With the increase of irradiation dose on HDPE, the contact angle of HDPE decreases (Fig.2), indicating that the affinity between HDPE and STC gets improved.

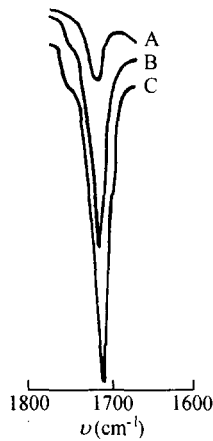


Fig. 1 FT-IR spectra of γ -ray irradiated HDPE (A) 0 kGy (B) 5kGy, (C) 10 kGy

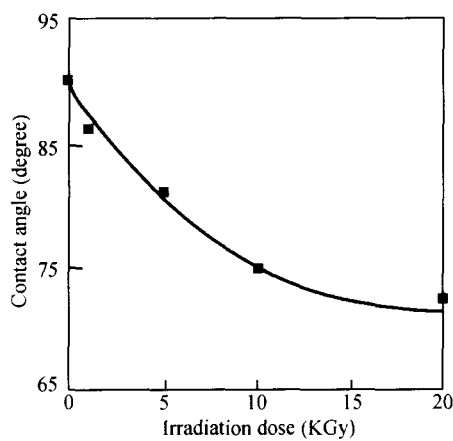


Fig. 2 Contact angle of γ -HDPE HDPE (A) 0 kGy, vs. irradiation dose

Mechanical properties of γ -HDPE/STC blend

Yield stress and elongation at break The yield stress of HDPE/STC blend (Fig. 3) increases and elongation at break (Fig. 4) decreases with increasing STC content. In case of γ -HDPE/STC system, the yield stress increases much faster, the elongation at break decreases more rapidly, indicating the affinity between HDPE and STC is improved through irradiation of HDPE. Data listed in Table 1 show the dependence of the yield stress and elongation at break on irradiation dose. Fig. 5 and 6 show the yield stress and elongation at break of HDPE/STC filled with γ -HDPE. Compared with HDPE/STC (80/20) blend, the yield stress of HDPE/ γ -HDPE/STC (48/32/20) blend is increased from 22.8MPa to 27.8MPa.

Table 1 Yield stress and elongation at break of γ -HDPE/STC (80/20) vs. dosage of irradiation

Irradiation dose (kGy)	Reld stress (MPa)	Elongation at break (%)
0	22.8	603
5	28.3	388
10	28.5	239
20	28.6	220

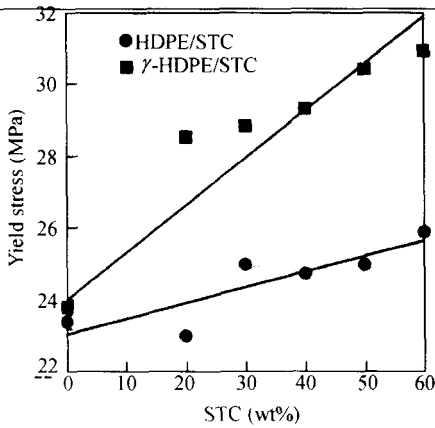


Fig. 3 Yield stress of HDPE/STC and γ -HDPE/STC vs. STC content
 γ -HDPE: 10kGy

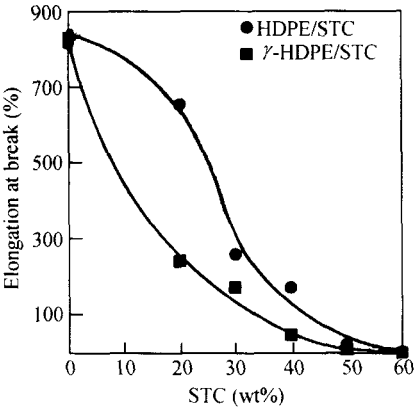


Fig. 4 Elongation at break of HDPE/STC and γ -HDPE/STC vs. STC content
 γ -HDPE: 10kGy

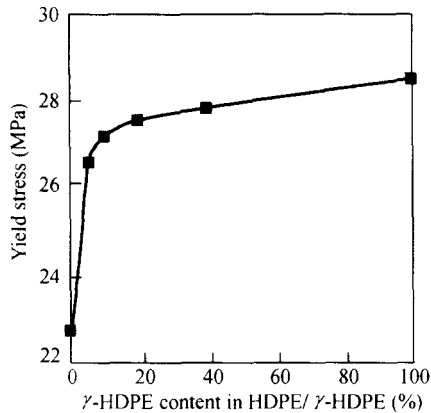


Fig. 5 Yield stress of HDPE/ γ -HDPE/STC (HDPE/ γ -HDPE/20) blend vs. γ -HDPE (10kGy) content in HDPE/ γ -HDPE

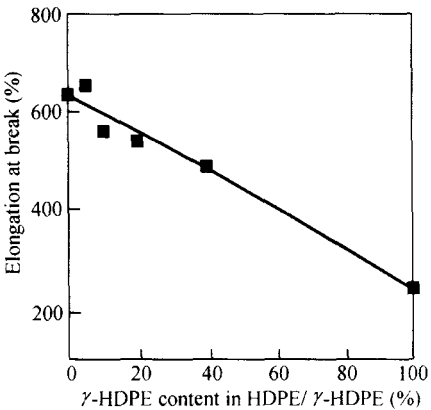


Fig. 6 Elongation at break of HDPE/ γ -HDPE/STC (HDPE/ γ -HDPE/20) blend vs. γ -HDPE (10kGy) content in HDPE/ γ -HDPE

Table 2 Impact strength of γ -HDPE/STC (80/20) vs. dosage of irradiation	
Irradiation dose (kGy)	Impact strength (J/m)
0	70
5	148
10	144
20	105

Impact strength The impact strength of γ -HDPE/STC is much higher than that of HDPE/STC (Table 2). The impact strength of HDPE/STC decreases rapidly with the increase of STC content; in case of γ -HDPE/STC, the downtrend of the

curve is pretty slow (Fig. 7). The impact strength of HDPE/STC (80/20) containing about 40% γ -HDPE amounts to 210J/m (Fig. 8).

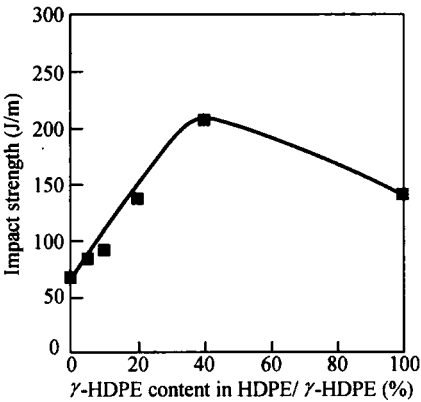
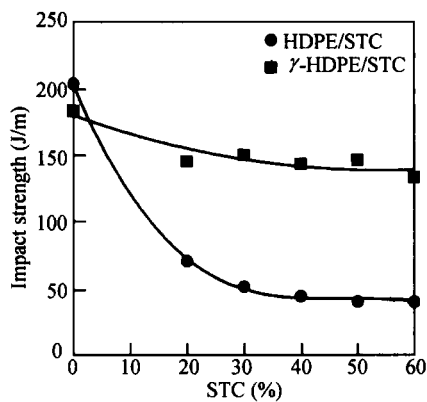


Fig. 7 Impact strength HDPE/STC and γ -HDPE/STC vs. STC content
 γ -HDPE: 10kGy

Fig. 8 Impact strength of HDPE/ γ -HDPE/STC (HDPE/ γ -HDPE/20) blend vs. γ -HDPE (10kGy) content in HDPE/ γ -HDPE

SEM analysis As shown in Fig. 9A, STC particles disperse unevenly in HDPE/STC blend. In the presence of γ -HDPE, STC particles in the blend are wrapped by γ -HDPE (Fig.9B, 9C), indicating the presence of interactions between STC and γ -HDPE.



Fig. 9 SEM of liquid nitrogen frozen fractured surface of specimens

CONCLUSION

By means of γ -Ray treatment in air, some oxygen-containing functional groups are introduced on the molecular chains of HDPE. The affinity between HDPE and STC, the yield stress and impact strength of HDPE/STC blends are distinctly

improved. The yield stress of γ -HDPE (10kGy)/STC (80/20) is increased from 22.8MPa to 28.5MPa, impact strength from 70J/m to 144J/m. The yield stress and impact strength of HDPE/ γ -HDPE (10 kGy)/STC (48/32/20) are 27.8 MPa and 210J/m, respectively.

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