

Effects of Fullerene on the Thermal Stability and Flame Retardancy of

Decabromodiphenyl oxide/Sb₂O₃ Flame-retarded High Density Polyethylene

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Background: Combinations of nanoparticles, such as organically modified clay with brominated flame retardant have exhibited good flame retardant synergy and improved comprehensive properties with overcoming the limitation of the traditional flame retardants, such as the required high loading^[1]. Fullerene (C_{60}) is one of the most widely noticed nanofillers because of its high reactivity towards free radicals ^[2]. The radical trapping effect of C_{60} is considered to be the fundamental reason for their thermal stability and flame retardancy. This is totally different from the barrier effect of clay. This study investigates the ability of C_{60} and brominated flame retardant to impart HDPE with thermal stability and flame retardancy. The goal of this work is to probe in the roles of C_{60} played in the brominated flame retarded high density polyethylene composites and discuss the effect of interactions between C_{60} and brominated flame retardant for the two additives exhibit the radical trapping, hence providing theoretical guidance to scientific research and industry.

Preparation: All samples were prepared via melt blending at 180 °C in a

torque rheometer (Thermohaake rheomixer 600, Germany) with a rotor speed of 60 rpm for 10 min. The ratio of Deca/AO (abbreviated as BFR) was fixed as 4/1 by weight and the formulations are given in Table 1.

Table 1 Conditions during melt blending in co-rotating twin-screw extruder.

Sample	HDPE(wt%)	PE-g-MH(wt%)	BFR(wt%)	C ₆₀ (wt%)
HDPE	100	0	0	0
PE-BFR	87.5	2.5	10	0
PE-BFR/C ₆₀ (9.9/0.1)	87.5	2.5	9.9	0.1
PE-BFR/C ₆₀ (9.5/0.5)	87.5	2.5	9.5	0.5
PE-BFR/C ₆₀ (8/2)	87.5	2.5	8	2
PE-C ₆₀	98	0	0	2

Thermal stability for HDPE and its composites:



Flame retardancy for HDPE and its composites:

		Sample	$t_{\rm PHRR}(s)$	PHRR(kW/m ²)	THR(MJ/m ²)
•		HDPE	210	780	83.1
800 -	$ \begin{array}{c} & & & & \\ & & & & \\ & & & & \\ & & & & $	PE-BFR	205	638	62.8
- 00	$\xrightarrow{PE-BFR/C_{60}(9.5/0.5)}{\xrightarrow{PE-BFR/C_{60}(9/1)}}$ $\xrightarrow{PE-BFR/C_{60}(9/1)}{\xrightarrow{PE-BFR/C_{60}(8/2)}}$	PE-BFR/C ₆₀ (9.9/0.1)	215	707	72.9
nt Release Rate/k		PE-BFR/C ₆₀ (9.5/0.5)	230	666	85.5
ен 200 –		PE-BFR/C ₆₀ (9/1)	250	672	83.3
0 -		$\begin{array}{c} \text{PE-BFR/C}_{60} \\ (8/2) \end{array}$	255	680	87.4
	Time/s	$PE-C_{60}$	210	611	92.4

For PE-BFR, the addition of brominated flame retardant not only prolonged the time to PHRR (t_{PHRR}), but considerably reduced the PHRR and THR. By contrast, a little deterioration of PHRR and THR with the addition of C₆₀. The incorporation of C₆₀, synergy effect were found in t_{PHRR} .

Fig. 1 TG (a) and DTG (b) curves for pure HDPE and HDPE-BFR composites in air.

Table 2 Detailed data obtained from TGA for HDPE, PE-BFR composites in air.

Sample	$T_{\text{onset}}(^{0}\text{C})$	$T_{\rm max}(^{0}{\rm C})$
HDPE	334	407
PE-BFR	349	434
PE-BFR/C ₆₀ (9.9/0.1)	350	423
PE-BFR/C ₆₀ (9.5/0.5)	349	426
PE-BFR/C ₆₀ (9/1)	356	429
PE-BFR/C ₆₀ (8/2)	367	440
$PE-C_{60}$	401	441
BFR	341	443

For PE-BFR, the addition of the brominated flame retardant enhances the thermal stability of HDPE, compared to pure HDPE. When C_{60} was introduced into the brominated flame-retarded system, not only T_{onset} , but also T_{max} were

Mechanisms for the thermal oxidative degradation and

combustion behvaviour of PE-BFR composites:



Fig. 3 Schematic representation of the mechanism for thermal oxidative degradation and combustion behaviour of PE-BFR (a); PE-BFR/C₆₀ composites with low

significantly enhanced especially at higher C_{60} contents with respect to PE-BFR.

concentration of C_{60} (b); PE-BFR/ C_{60} composites with high concentration of C_{60} (c).

Conclusions: The introduction of C_{60} improved the thermal stability of materials. A remarkable increase in the time to PHRR of the composites was found especially at high concentration of C_{60} . PHRR and THR increased were found with partial replacement of BFR by C_{60} . C_{60} trapped the alkyl radicals and bromine radicals in the condense phase, which suppressed the bromine radicals going to the gas phase especially at high concentration of C_{60} . Meanwhile bromine radicals were trapped by C_{60} in the condense phase, which decreased the flame retardancy of BFR.

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References

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