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Supplementary data

Effects of Modified Layered Double Hydroxides on the Thermal Degradation and Combustion Behaviors of Intumescent Flame Retardant Polyethylene Nanocomposites

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2-carboxy ethyl (phenyl) phosphinic acid (CEPPA) is an efficient phosphorus-containing flame retardant and a reactive component in intumescent flame retardant (IFR). To improve the flame retardant effectiveness of LDH and the reactivity with IFR, CEPPA intercalated LDH (CLDH) was synthesized by regeneration method as shown in Figure S1.

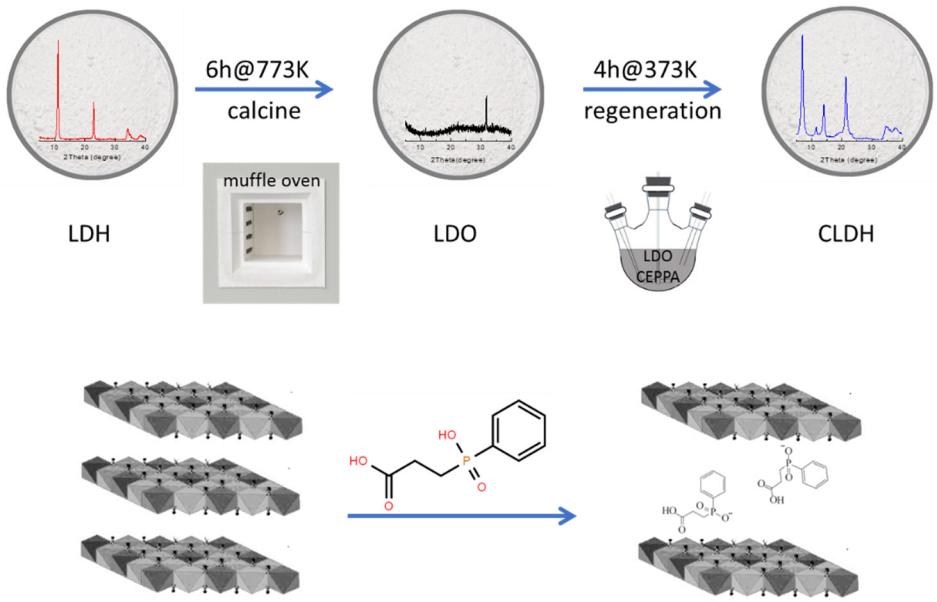

Figure S1. Schematic route to synthesis of CLDH by regeneration method.

CLDH was then compounded with intumescent flame retardant (IFR) to enhance the flame retardancy of polyethylene (PE). The composites were prepared by melt blending according to Table 1. Three kinds of LDHs, including LDH, SDS intercalated LDH (SLDH) and CLDH were used in order to compare the influences of intercalated compounds on the flame retardancy of the composites.

Table S1. Formulations of the flame retardant composites.

Sample	PE (wt.%)	PEgMA (wt.%)	APP (wt.%)	PER (wt.%)	LDHs (wt.%)
PE/IFR	60	10	20	10	--
PE/IFR/LDH	57	10	20	10	3 (LDH)
PE/IFR/SLDH	57	10	20	10	3 (SLDH)
PE/IFR/CLDH	57	10	20	10	3 (CLDH)

As characterized by EDS, the molar percentage of elements in CLDH was shown in Table S2.

Table S2. EDS data of CLDH.

Element	Molar percentage (at.%)
C	36.72
O	40.32
Mg	13.38
Al	6.40
P	2.83
Na	0.35

Thermogravimetric analysis (TGA) was performed at a heating rate of 10 °C/min from 50°C to 700°C in nitrogen atmosphere. TG data of LDHs and IFR/LDHs were shown in Table S3.

Table S3. TG data of LDHs and IFR/LDHs.

Sample	T_5 (°C)	T_{10} (°C)	Peak 1		Peak 2		Residue at 700 °C (%)
			T_{p1} (°C)	R_{p1} (%/°C)	T_{p2} (°C)	R_{p2} (%/°C)	
LDH	189	214	217	0.31	386	0.19	55.6
SLDH	120	193	232	0.82	383	0.10	43.5
CLDH	122	304	378	0.11	535	0.11	61.0
IFR	222	254	232	0.19	521	0.36	30.0
IFR/LDH	211	230	240	0.46	-	-	50.6
IFR/SLDH	204	225	236	0.35	581	0.27	34.6
IFR/CLDH	209	229	228	0.31	538	0.23	40.8

Figure S2. illustrated the ΔWeight curves to further investigate the effects of LDHs on thermal degradation of IFR/LDHs.

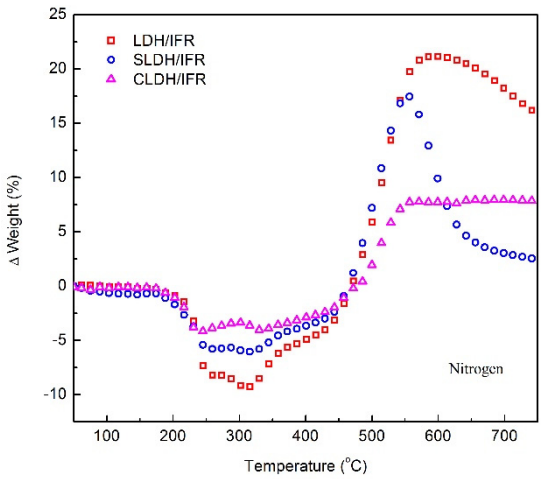

Figure S2. ΔWeight versus temperature curves of IFR/LDHs.

CONE testing was performed on PE/IFR/LDHs composites with three kinds of LDHs. The CONE results were shown in Table S4.

Table S4. Data of CONE.

Sample	PE/IFR	PE/IFR/LDH	PE/IFR/SLDH	PE/IFR/CLDH
TTI (s)	44	51	43	45
Flame out (s)	325	511	335	553
avHRR (kW/m^2)	269	151	231	147
pHRR (kW/m^2)	494	374	418	450
Time to pHRR (s)	264	426	274	462
THR (MJ/m^2)	90	80	87	86
TSR (m^2/m^2)	1840	1507	1475	996

The morphological structure of the char after CONE testing was photographed by digital camera in Figure S3

Figure S3. The digital photographs of the char after CONE Testing of the composites. (**a**) PE/IFR, (**b**) PE/IFR/LDH, (**c**) PE/IFR/SLDH and (**d**) PE/IFR/CLDH.

The char was investigated by XPS and the results were shown in Table S5.

Table S5. Data of XPS.

Sample	PE/IFR	PE/IFR/LDH	PE/IFR/SLDH	PE/IFR/CLDH
C (at.%)	29.68	23.54	32.32	27.91
N (at.%)	2.68	1.58	1.74	1.97
O (at.%)	54.78	57.97	51.82	54.83
Mg (at.%)	0	2.12	1.41	1.59
Al (at.%)	0	0.83	0.79	0.72
P (at.%)	12.86	13.96	11.92	12.98
P:C	0.43	0.59	0.37	0.47
Mg:Al	-	2.55	1.78	2.21
P:Mg	-	6.58	8.45	8.16
Mg:C	-	0.09	0.044	0.057