

Supplementary information

Functionalized graphene oxide /phosphoramidate oligomer
nanocomposites flame retardant prepared via in situ polymerization
for improving the fire safety of polypropylene

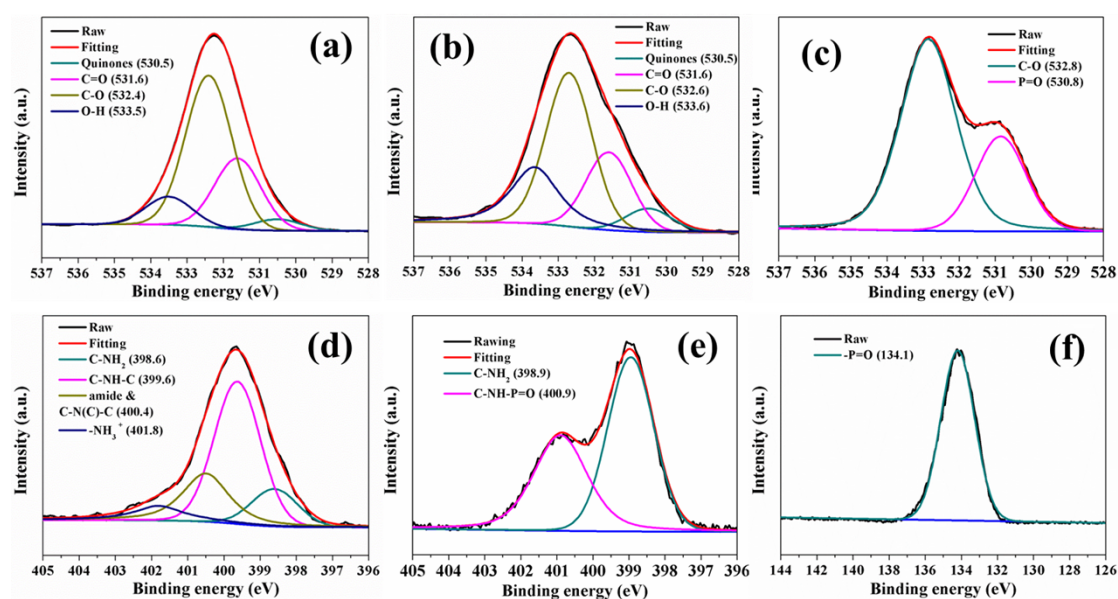


Fig. S1 XPS O1s spectra of (a) GO, (b) FGO and (c) FRs-FGO and N1s spectra of (d) FGO and (e) FRs-FGO and P2p spectra of (f) FRs-FGO.

Table S1 Analysis of the deconvoluted C1s peaks obtained from XPS and the FWHM of the different C1s peaks as well as the relative area percentages for GO, FGO and FRs-FGO

Sample	C1s fitting			
	Binding energy (eV) (Relative area percentage %, FWHM eV)			
	C-C	C-O	C=O	C-N
GO	284.6 (42.2, 1.45)	286.6 (50.4, 1.45)	288.4 (7.4, 1.45)	/
FGO	284.6 (68.4, 1.45)	286.8 (17.9, 1.45)	288.4 (4.9, 1.45)	285.6 (8.8, 1.45)
FRs-FGO	284.2 (56.0, 1.45)	286.3 (25.9, 1.45)	/	285.6 (18.1, 1.45)

FWHM: Full width at half maximum

Table S2 Atomic percentages of C, O, N and P for GO, FGO and FRs-FGO

Sample	C1s (%)	O1s (%)	N1s (%)	P2p (%)
GO	63.2	36.8	/	/
FGO	88.8	8.1	3.1	/
FRs-FGO	55.2	30.6	5.4	8.8

The XPS O1s spectra of (a) GO, (b) FGO and (c) FRs-FGO and N1s spectra of (d) FGO and (e) FRs-FGO and P2p spectra of (f) FRs-FGO are shown in Fig. S1. In Fig. S1a, the O1s spectra of GO can be curve-fitted into four peaks, which are corresponding to quinones (530.5 eV), C=O (carbonyl and carboxyl, 531.6 eV), C-O (epoxy and hydroxyl, 532.4 eV) and O-H (carboxyl, 533.5 eV) respectively.¹ After modification of GO, the O1s spectra of FGO presents the similar four peaks. Moreover, it can be seen from Table S2 that the atomic percentages of O in FGO is significantly decreased compared to that of GO, suggesting that the chemical reduction of GO was accomplished successfully. The XPS O1s spectra of FRs-FGO (Fig. 1Sc) can be curve-fitted into two peak components with binding energy at about 532.8 and 530.9 eV, attributable to the C-O and P=O species, respectively.² In the N1s spectrum of FGO (Fig. S1c), four peaks are observed. These peaks at 398.6 eV, 399.6 eV, 400.4 eV and 401.6 eV are assigned to primary amines (the free ends of the grafted DDM), secondary amines (the grafted ends of the DDM), amide and tertiary amines (generated via dehydration of proximal surface alcohols) and protonated primary amine, respectively.³⁻⁵ As can be seen from the N1s spectrum of FRs-FGO, the low binding energy at 389.9 eV is assigned to nitrogen of the amine group in the terminal position of FRs chains, and the peak at 400.9 eV is attributed to nitrogen of phosphamide group.⁶ As shown in Fig. 1Sf, only a singlet at 134.1 eV appears in the P2p spectra of FRs-FGO, indicating the presence of only one kind of chemical environment of phosphorus, which is consistent with the structure of FRs. All the descriptions abovementioned indicate that GO is successfully modified and

reduced by DDM and the FGO is incorporated into FRs to form the phosphamide nanocomposites flame retardant.

Table S3. Comparison of flame retardancy and preparation methods of PP nanocomposites

Literature	Nanofiller (wt. %)	FRs (wt. %)	TTI (S)	PHRR (kW·m ⁻²)	THR (MJ·m ⁻²)	Preparation method
PP/Gs–NiCe _x O _y Hong ⁷	2.0	/	~ (-) 16%	~ (-) 37%	~ (-) 17%	Melt blending
PP-FR/5.0FG Dittrich ⁸	5.0	/	~ (-) 39%	~ (-) 76%	~ (-) 19%	Melt blending
PP/5.0TRGO Dittrich ⁹	5.0	/	~ (-) 30%	~ (-) 73%	~ (-) 8%	Melt blending
PP-FR + TRGO Hofmann ¹⁰	5.0	/	/	~ (-) 74%	~ (-) 10%	Melt blending

-: decrease

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