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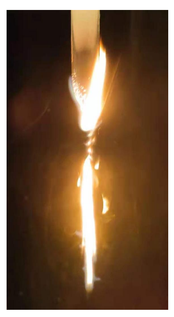
Fire retardancy of polybutylene succinate

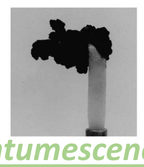
Gaëlle Fontaine [1], Fei Xiao [1,2], Serge Bourbigot [1,3]

[1] Univ. Lille, CNRS, INRAE, Centrale Lille, UMR 8207 - UMET - Unité Matériaux et Transformations, F-59000 Lille, France
[2] School of Safety Science and Emergency Management, Wuhan University of Technology, Wuhan, China, fei.xiao@whut.edu.cn
[3] Institut Universitaire de France (IUF), France

Introduction



PBS: *a biodegradable polymer with high flammability*



Intumescence

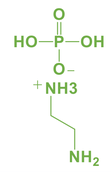
Flame protection

FR

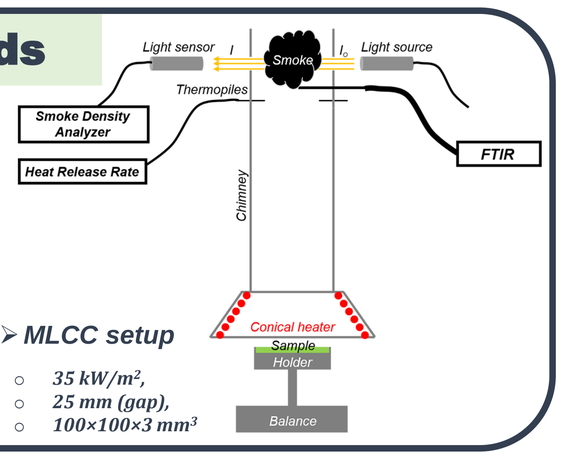
- ✓ Developing new intumescent FR systems
- ✓ Enhancing the flame retardancy of PBS
- ✓ Investigating the FR mechanisms of action

Materials & Methods

- **Biobased PBS:** *Bionolle™1001 MD*
- **Flame retardant:** *ethylenediamine phosphate (EDAP)*
- **Co-additives:** *zinc borate (ZnB), melamine borate (MB), zinc molybdate (ZnMo), and aminated multiwall carbon nanotubes (NH_2-CNT)*
- **10 wt.% total loading and *2 wt.% loading for co-additives***



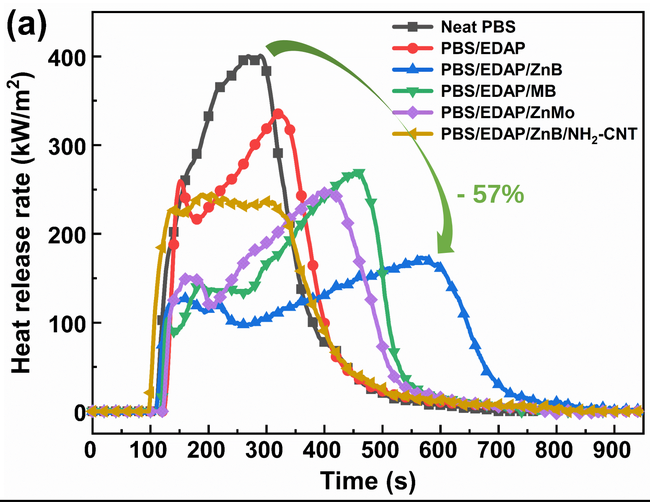
Ethylenediamine phosphate (EDAP)

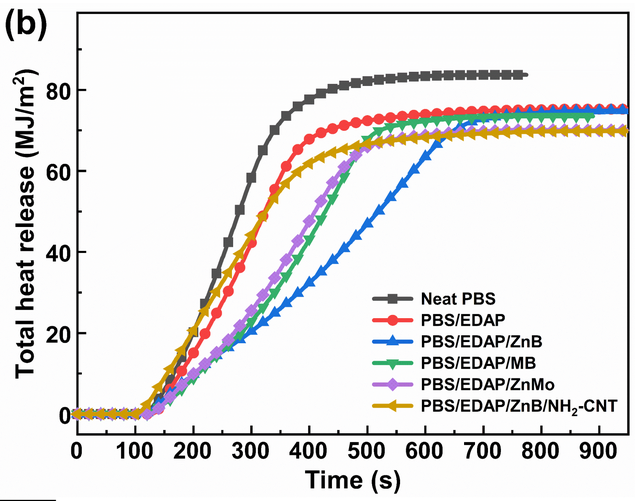


➢ *MLCC setup*

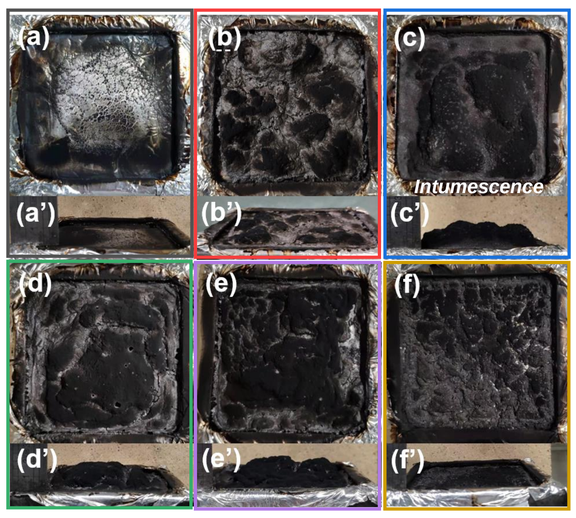
- *35 kW/m²,*
- *25 mm (gap),*
- *100×100×3 mm³*

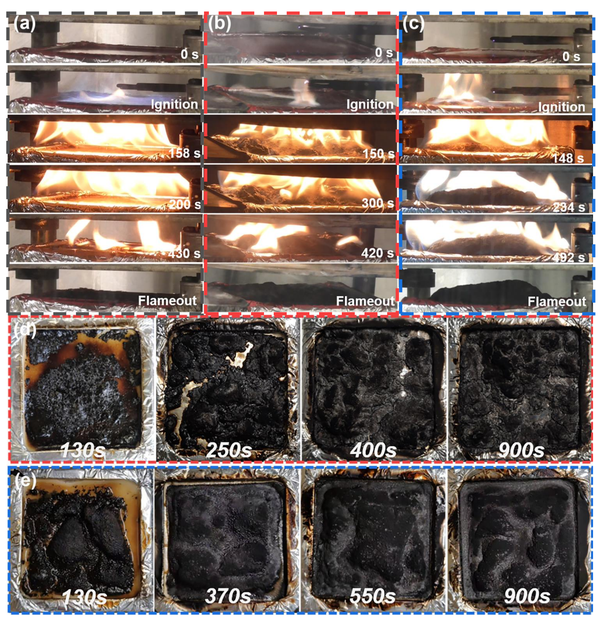
Fire & smoke behaviors





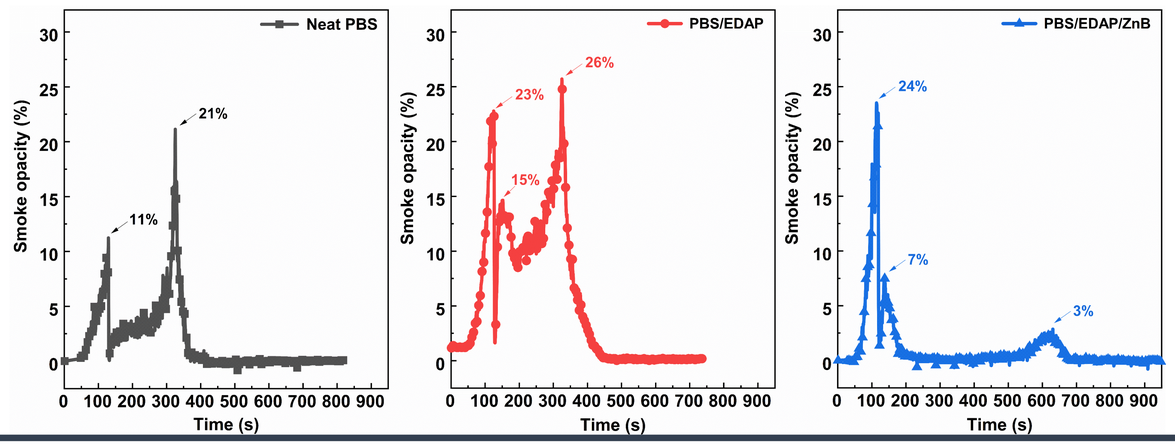
Sample	TTI [s]	$t_{Flameout}$ [s]	pHRR [kW/m²]	THR [MJ/m²]	Residue [wt.%]	FIGRA [kW/(m²s)]	FRI [/]	MARHE [kW/m²]
Neat PBS	109	493	401	83.7	2.0	1.69	/	206
PBS/EDAP	125	476	336	74.6	7.7	1.72	1.54	172
PBS/EDAP/ZnB	110	737	173	74.9	8.0	0.90	2.61	108
PBS/EDAP/MB	118	537	269	73.4	6.9	0.81	1.84	133
PBS/EDAP/ZnMo	122	578	248	70.1	8.0	0.94	2.16	136
PBS/EDAP/ZnB/NH_2-CNT	100	517	245	69.3	8.4	1.70	1.81	158





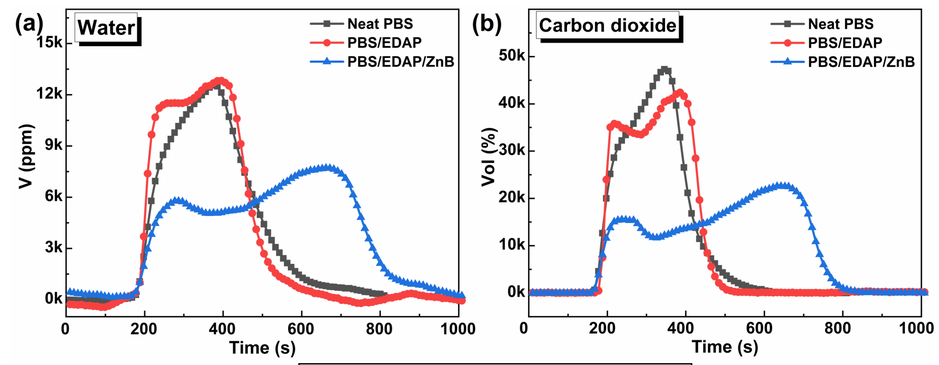
❖ *Residue morphology of (a) neat PBS, (b,d) PBS/EDAP, and (c,e) PBS/EDAP/ZnB*

❖ Smoke opacity



Gas phase

❖ MLCC-FTIR analysis

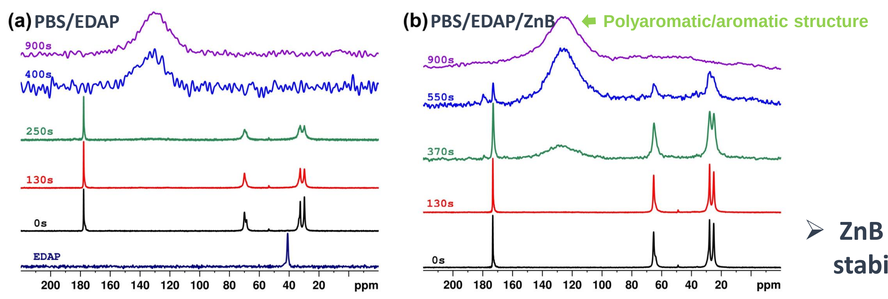


➢ Water and carbon dioxide ➡ similar shapes to HRR curve;

➢ Addition of ZnB retards the release of gases (e.g. CO_2, H_2O, CO, …).

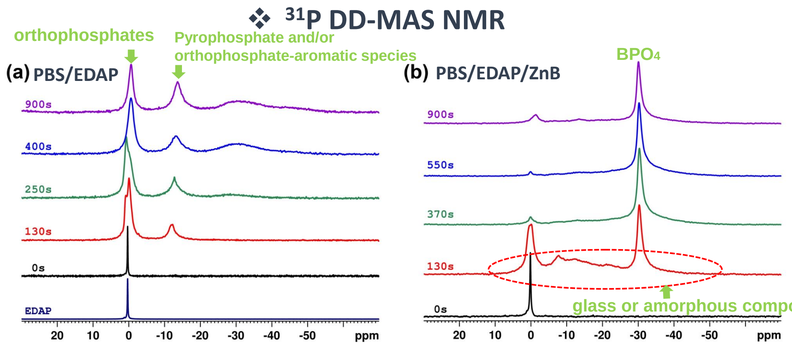
Condensed phase

❖ ^{13}C CP-MAS NMR



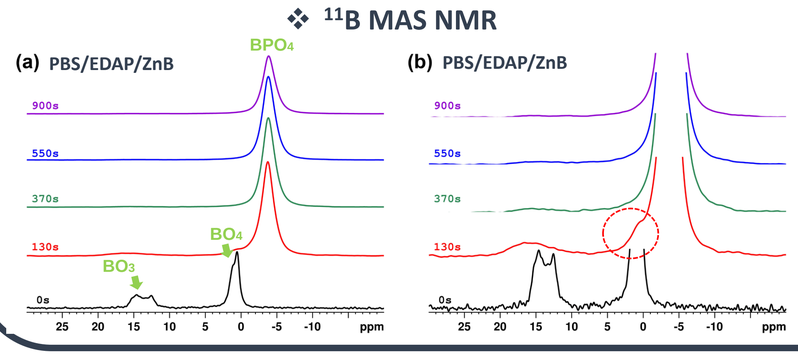
➢ ZnB enhances the stability of residue

❖ ^{31}P DD-MAS NMR



➢ BPO_4 and glassy structures are formed

❖ ^{11}B MAS NMR



➢ BPO_4 is detected

Conclusion

- ➢ Combination of EDAP and ZnB (10 wt.% total loading) leads to an improvement of flame retardancy;
- ➢ The addition of ZnB promotes the formation of an intumescent char, and the PHRR is reduced by 57 %;
- ➢ The presence of inorganic residue (e.g. BPO_4) provides an additional barrier effect and stabilizes the char.

References

1. *J. Alongi, Z. Han, S. Bourbigot, Intumescence: Tradition versus novelty. A comprehensive review, Prog. Polym. Sci. 51 (2015) 28-73.*
2. *S. Bourbigot, M. Le Bras, S. Duquesne, M. Rochery, Recent advances for intumescent polymers, Macromol. Mater. Eng. 289(6) (2004) 499-511.*
3. *F. Xiao, G. Fontaine, S. Bourbigot, Recent developments in fire retardancy of polybutylene succinate, Polym. Degrad. Stab. 183 (2021) 109466.*