# Supporting Information

## Enhanced flame retardant performance of poly(vinyl alcohol) composites by hydrogen bonding

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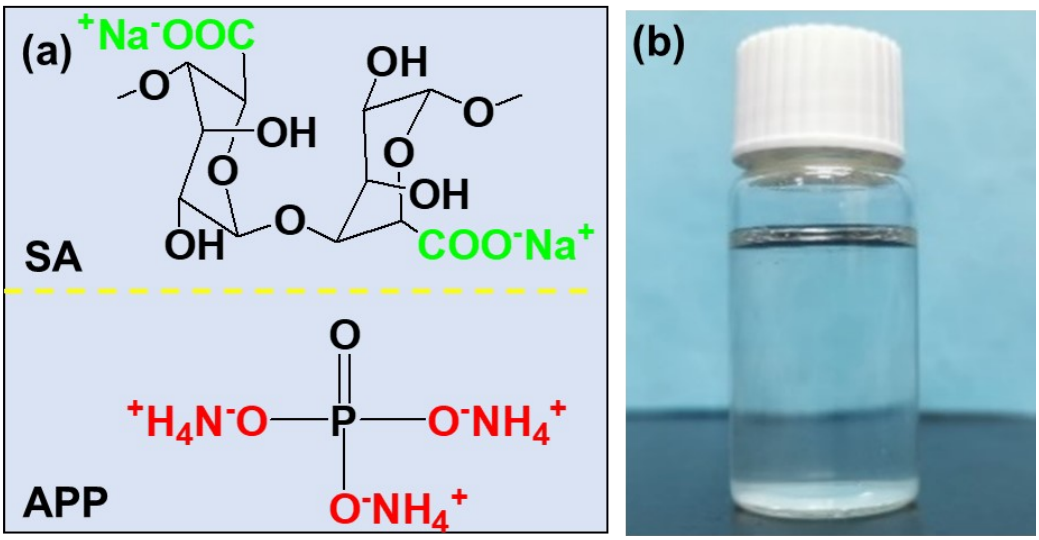


**Figure S1.** (a) The chemical structure of SA and APP. (b) Optical images of PVA/$APP_{10}$/$SA_5$ solution.

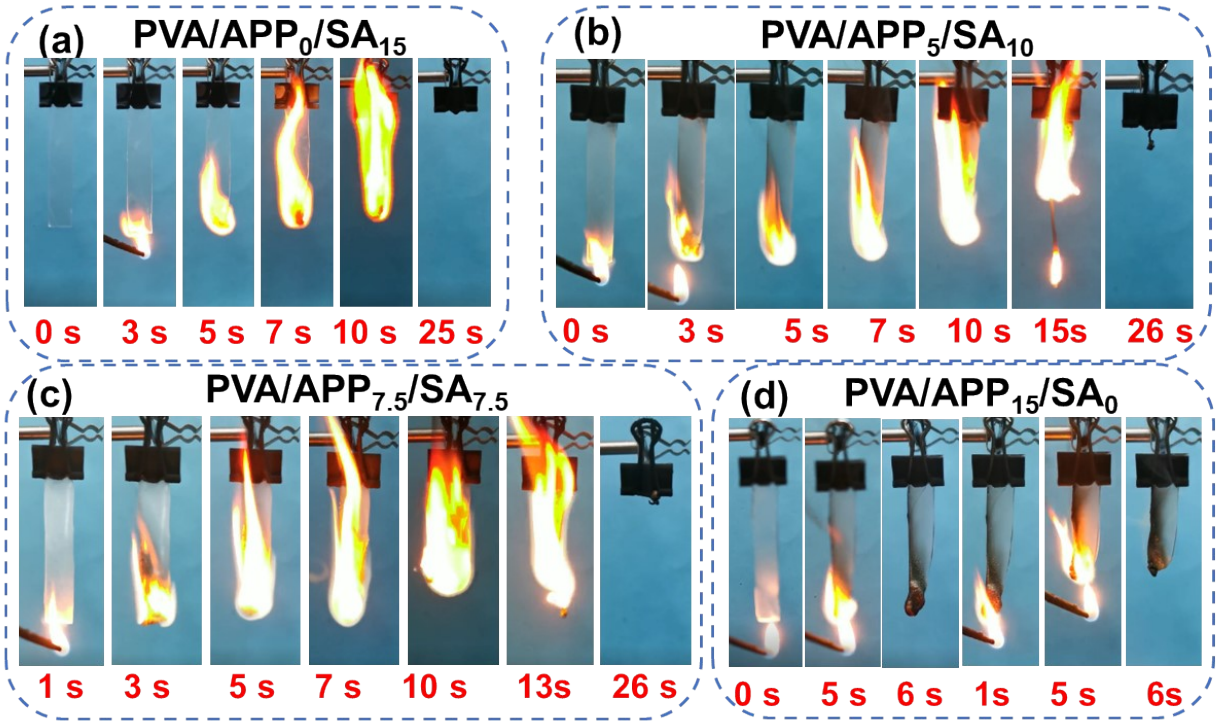


**Figure S2.** Optical images of Vertical combustion for PVA/$APP_0$/$SA_{15}$ (a), PVA/$APP_5$/$SA_{10}$ (b), PVA/$APP_{7.5}$/$SA_{7.5}$ (c) and PVA/$APP_{15}$/$SA_0$ (d) at different time period.

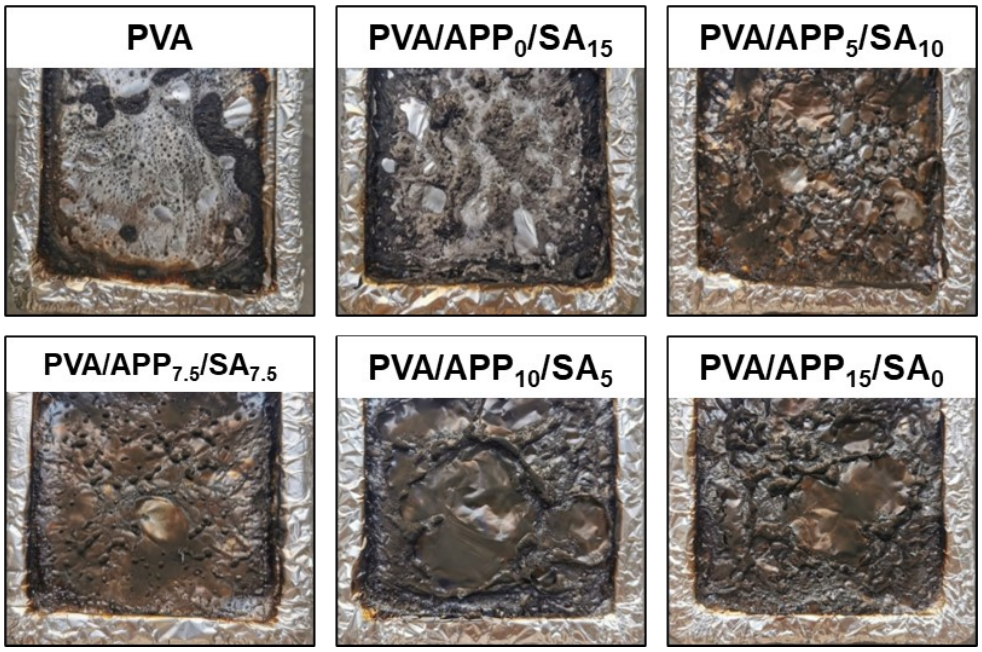


**Figure S3.** Optical images of carbon residue after cone calorimeter test for PVA and PVA composites.

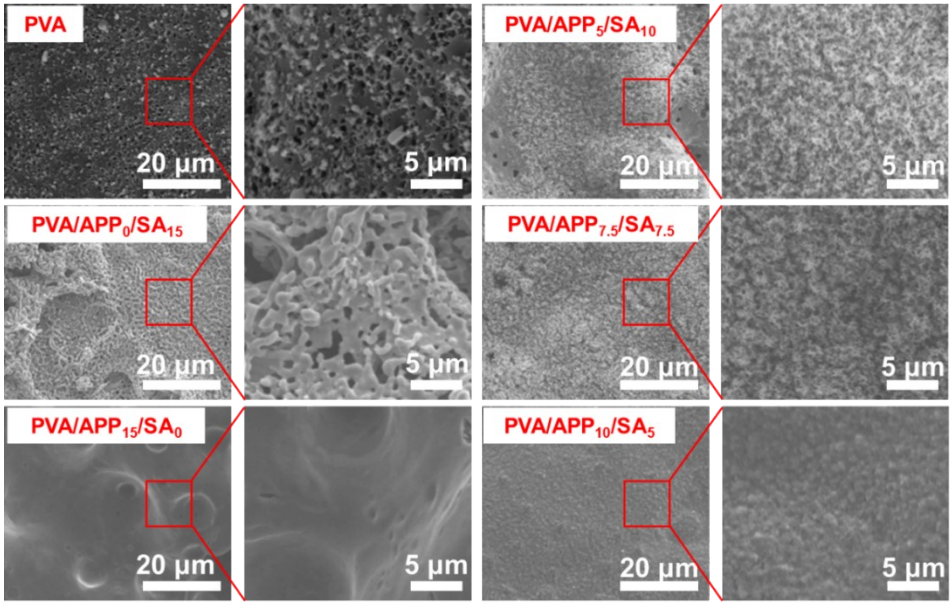


**Figure S4.** The SEM images of carbon residue after cone calorimeter test.

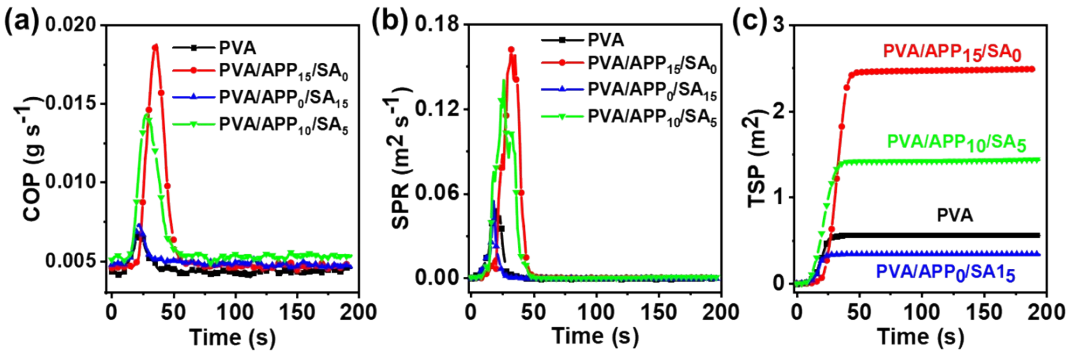


**Figure S5.** (a) CO production, (b) Smoke produce rate and (c) Total smoke release curves of PVA and FR-PVA composites obtained from cone calorimeter test

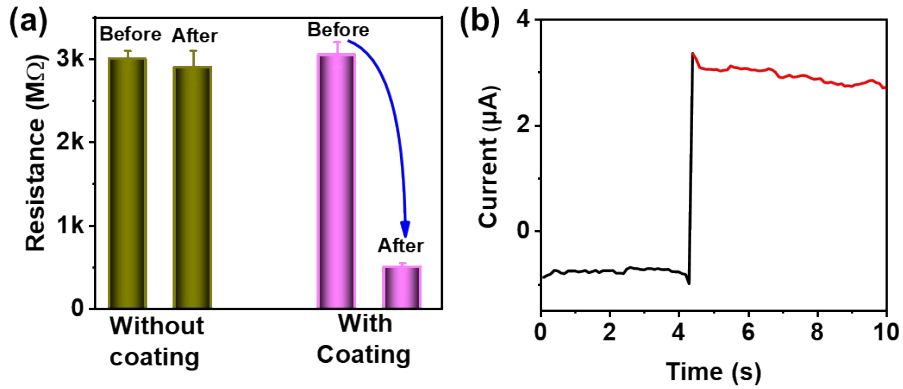


**Figure S6.** (a) The resistance variation of carbon residue before and after combustion for wood without and with FR-PVA coating. (b) Evolution of current of carbon residual during combustion.

**Table S1.** Comparison of flame retardance of As-designed FR-PVA with previous PVA counterparts.

| Flame retardant system | Add (%) | LOI (%) | ΔLOI (%) | pHRR (kW $m^{-2}$) | ΔpHRR (%) | Residue (wt%) | ref |
|---|---|---|---|---|---|---|---|
| Graphene nanosheets | 2 | 22 | 13.4 | 193 | 60.9 | * | [Qiu et al. 2020] |
| Carbon nanoparticles | 3 | * | * | 225 | 32.0 | 2.36 | [Zahid et al. 2020] |
| Phosphate cellulose | 15 | 34.0 | 88.8 | 255.4 | 33.8 | 18.6 | [Wei et al. 2021] |
| α-zirconium phosphate | 20 | 29.8 | 61.9 | 105.7 | 82.3 | 35.0 | [Zhang et al. 2020] |
| Boron nitride and ammonium polyphosphate | 28.6 | 29.5 | 48.2 | 153 | 71.1 | 26 | [Zhang et al. 2019] |
| Calcium bis(dihydrogenphosphate) and hexachlorocyclotr-iphosphazene | 30 | 25.6 | 42.2 | 117.1 | 75 | 39.5 | [Zhang et al. 2021] |
| Sodium alginate and Pyrovatex CP | 41.2 | 30.4 | 58.3 | * | * | 27 | [Wang et al. 2020] |
| Agarose macromolecules | 50 | * | * | 170.76 | 37 | * | [Yan et al. 2021] |
| Sodium alginate and ammonium polyphosphate | 15 | 30.2 | 67.8 | 306.25 | 30.6 | 17.28 | This work |

**Table S2.** The samples composition table of FR-PVA composites.

| Samples | PVA (g) | APP (g) | SA (g) |
|---|---|---|---|
| PVA | 8.5 | 0 | 0 |
| $PVA/APP_{15}/SA_0$ | 8.5 | 1.5 | 0 |
| $PVA/APP_0/SA_{15}$ | 8.5 | 0 | 1.5 |
| $PVA/APP_{10}/SA_5$ | 8.5 | 1.0 | 0.5 |
| $PVA/APP_{7.5}/SA_{7.5}$ | 8.5 | 0.75 | 0.75 |
| $PVA/APP_5/SA_{10}$ | 8.5 | 0.5 | 1.0 |

## Reference


Qiu, M. H., Wang, D., Zhang, L. P., Li, M., Liu, M. M., & Fu, S. H. (2020). Electrochemical exfoliation of water-dispersible graphene from graphite towards reinforcing the mechanical and flame-retardant properties of poly (vinyl alcohol) composites. Materials Chemistry and Physics, 254, 123430.

Zahid, M., Ali, S., Saleem, S., Salman, M., & Khan, M. (2020). Carbon nanoparticles/polyvinyl alcohol composites with enhanced optical, thermal, mechanical, and flame-retardant properties. *Journal of Applied Polymer Science*, 137(41), 49261.

Wei, J. X., Zhao, C. X., Li, Y. C., Li, Y. T., Sun, Z. M., Xiang, D., & Li, H. (2021). A simple and green strategy for preparing poly(vinyl alcohol)/phosphate cellulose aerogel with enhanced flame-retardant properties. *Polymer Engineering & Science*, 61(3), 693−705.

Zhang, Z. H., Ma, Z. Y., & Wang, Y. H. (2020). Green and facile fabrication of α-zirconium phosphate-based core-multishell nanoparticles for enhancing fire retardant performance of poly(vinyl alcohol). *ACS Applied Nano Materials*, 3(9), 8708−8718.

Zhang, Q. R., Wang, X. Y., Tao, X. J., Li, Z. W., Li, X. H., & Zhang, Z. J. (2019). Polyvinyl alcohol composite aerogel with remarkable flame retardancy, chemical durability and self-cleaning property. *Composites Communications*, 15, 96−102.

Zhang, D., Meng, D. H., Ma, Z. Y., Zhang, Z. H., Ning, H. Z., & Wang, Y. H. (2021). Synthesis of a novel organic-inorganic hybrid flame retardant based on Ca(H2PO4)2 and hexachlorocyclotriphosphazene and its performance in polyvinyl alcohol. *Journal of Applied Polymer Science*, 138(13), 50099.

Wang, Q. Q., Liu, J., Zhang, L., Ci, M. Y., Zhang, X. Y., Jiang, Z. M., & Zhu, P. (2020). Preparation and characterization of polyvinyl alcohol/sodium alginate/Pyrovatex CP composite fibers. Ferroelectrics, 562(1), 125−125.

Yan, T. T., Zou, Y. H., Zhang, X. H., Li, D. H., Guo, X. X., & Yang, D. J. (2021). Hydrogen bond interpenetrated agarose/PVA network: A highly ionic

66 conductive and flame-retardant gel polymer electrolyte. ACS Applied Materials
67 & Interfaces, 13(8), 9856−9864.