

## Supporting Information

### **Balanced thermal insulation, flame-retardant and mechanical properties of PU foam constructed via cost-effective EG/APP/SA ternary synergistic modification**

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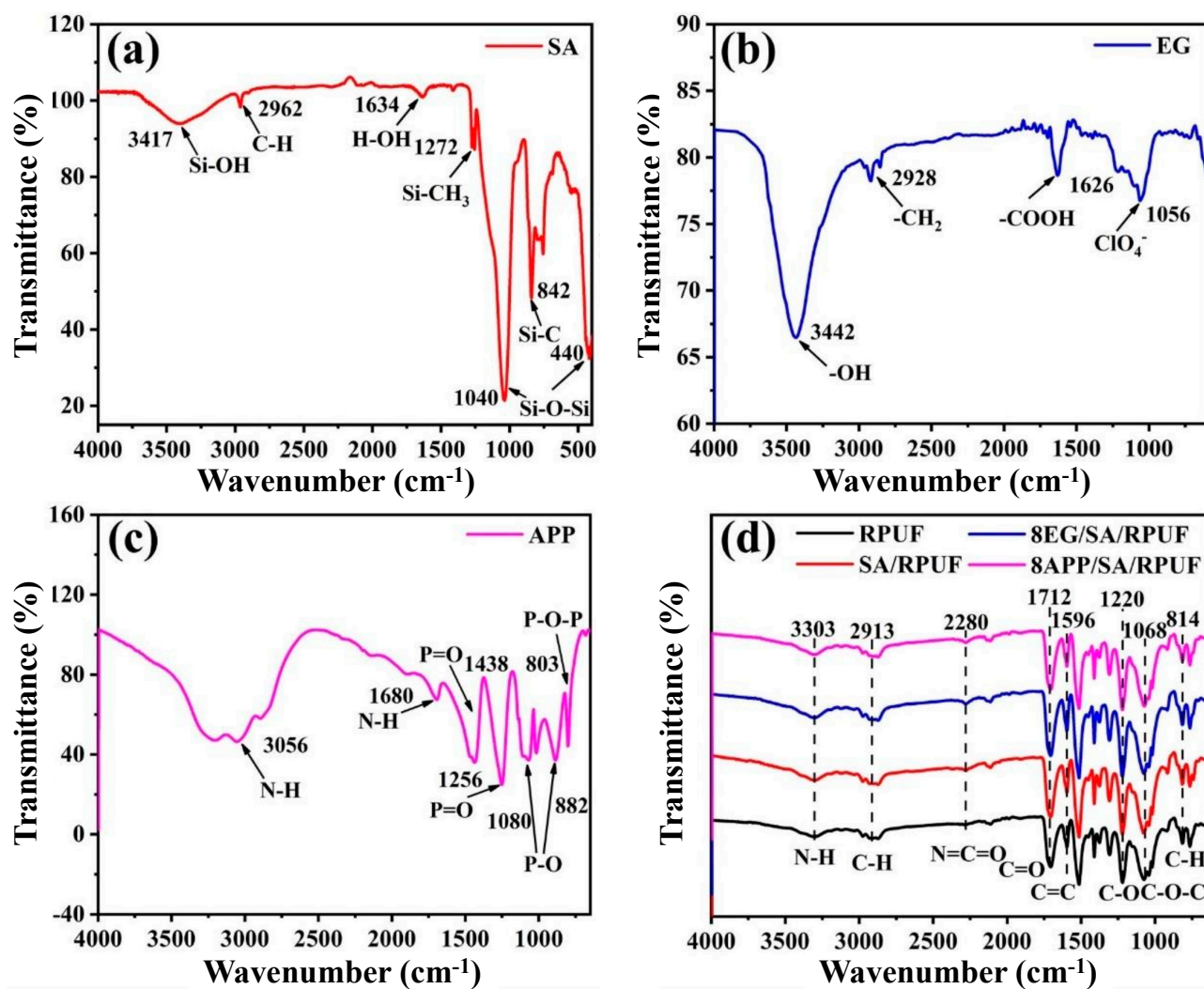
## Chemical structure of EG/APP/SA/RPUFs

The FTIR spectra of the various samples are depicted in Figure S1. It can be observed that the FTIR spectra of all RPUF samples in Figure S1(d) exhibit highly similar curves, indicating minimal occurrence of significant chemical structural changes in the modified RPUF. However, it is noteworthy that the small peak at  $2280\text{ cm}^{-1}$  (typical residual  $\text{N}=\text{C}=\text{O}$  stretching vibration) becomes more pronounced with the addition of SA, EG, and APP. This phenomenon can be attributed to two potential causes: (1) the presence of hydroxyl groups on the filler surfaces, which have the capacity to alter the isocyanate index ( $\text{RNCO}/\text{OH}$ ) [1]; (2) interference arising from the flame-retardant additives, resulting in alterations in the rheological behavior of the reaction mixture or coupling between surface groups and isocyanates, polyols, etc. [2]. In fact, both of these possibilities have the potential to induce lower crosslinking densities and influence the cell morphology as well as the mechanical and thermal insulation properties of the RPUF composite materials, which will be further discussed in subsequent sections.

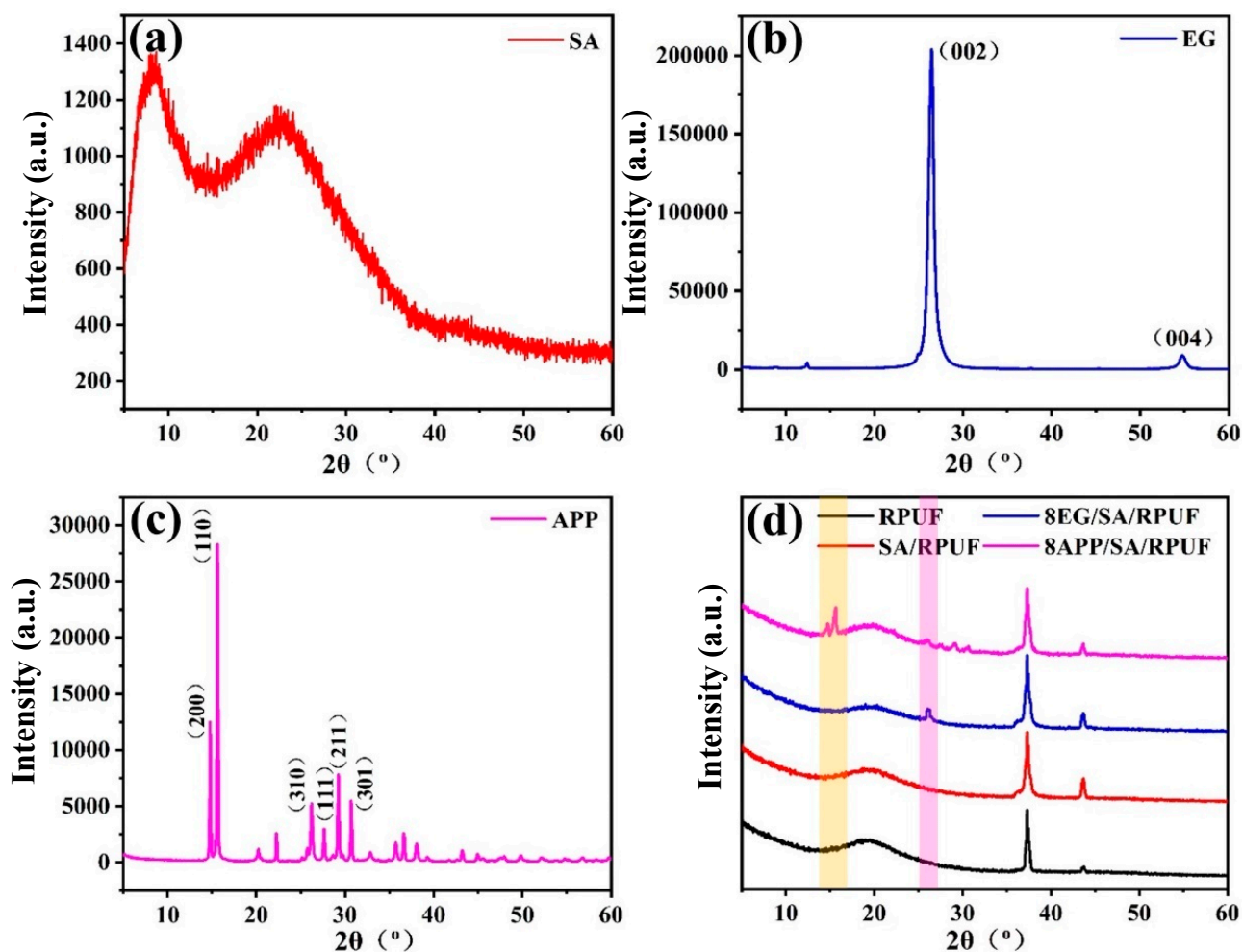
The XRD spectra of the various samples are presented in Figure S2. From Figure S2(d), it can be observed that the XRD spectrum of SA/RPUF exhibits similar curves to neat RPUF, as the XRD spectrum of SA demonstrates broad peaks characteristic of an amorphous phase (Figure S2(a)). However, in the XRD curves of 8EG/SA/RPUF and 8APP/SA/RPUF, some new diffraction peaks are observed in the RPUF composite materials. Specifically, in 8EG/SA/RPUF, a diffraction peak appears at  $2\theta=26.23^\circ$  corresponding to the (002) plane of EG, while in the XRD curve of 8APP/SA/RPUF, characteristic peaks of APP can also be observed. These newly appearing peaks confirm the successful introduction of EG and APP.

More detailed functional groups or crystal planes corresponding to the characteristic peaks in

FTIR and XRD can be found in references [3-6].

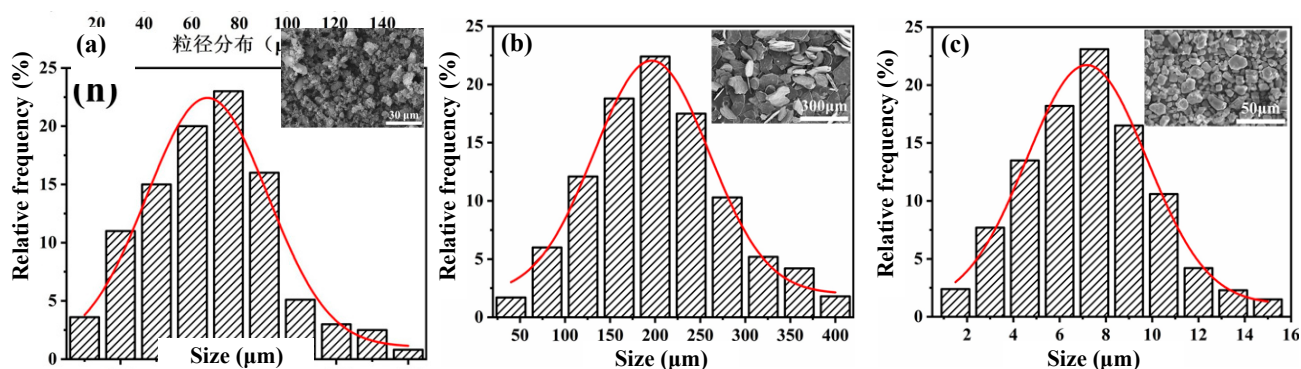


**Figure S1.** The FT-IR spectra of (a) SA, (b) EG, (c) APP, and (d) neat RPUF, SA/RPUF and EG or APP modified SA/RPUF



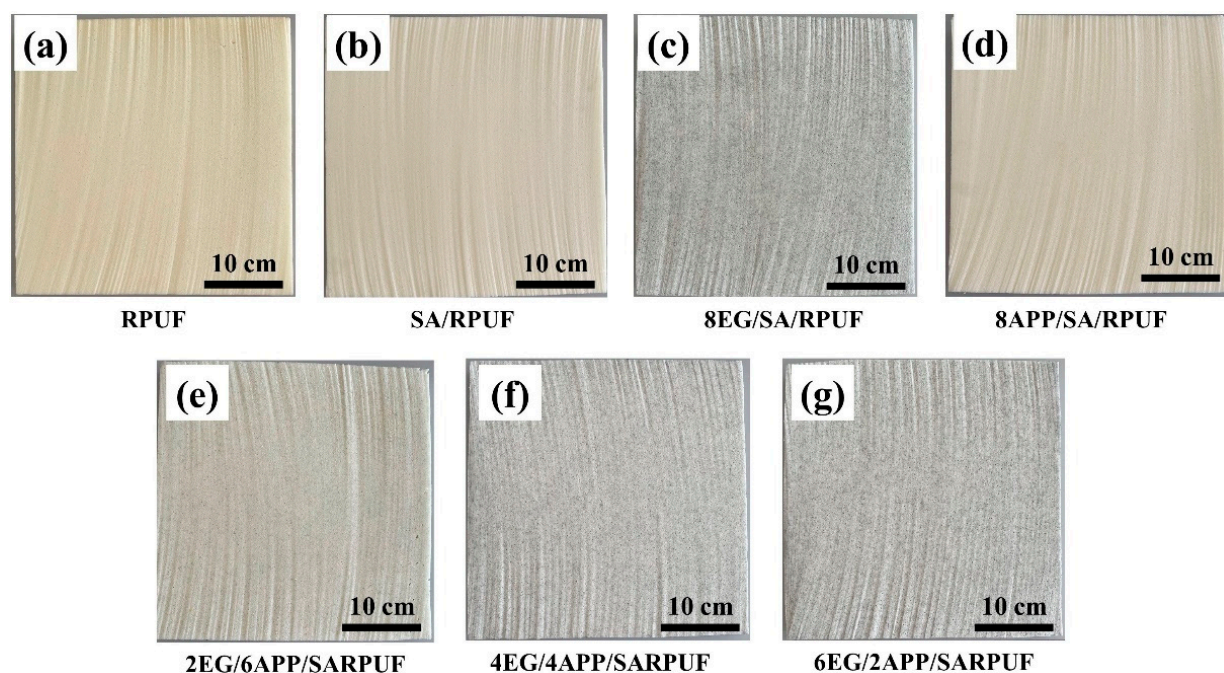
**Figure S2.** The XRD spectra of (a) SA, (b) EG, (c) APP, and (d) neat RPUF, SA/RPUF and EG/RPUF or APP modified SA/RPUF

### Microstructure of SA, EG, APP



**Figure S3.** Morphology and size of (a) SA, (b) EG, and (c) APP raw materials

## Microstructure of EG/APP/SA/PRUFs



**Figure S4.** Digital photographs of (a) neat RPUF, (b) SA/RPUF, (c) 8EG/SA/RPUF, (d)

8APP/SA/RPUF, (e) 2EG/6APP/SA/RPUF, (f) 4EG/4APP/SA/RPUF, and (g) 6EG/2APP/SA/RPUF

## References

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