From waste to innovation: Sol-gel strategies for the synthesis of multifunctional polymer-based composites containing biowastes and their derivatives

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The incorporation of biowastes into high-performance polymer-based composites offers a promising route to enhance sustainability while exploiting sol-gel chemistry for multifunctional design [1]. This presentation reviews recent advances where biowastes are combined with hybrid polymer matrices or sol-gel architectures to improve thermal, mechanical, and flame retardant properties. Humic acids represent an abundant biowaste, its direct reuse as a functional additive can be feasible by the previous modification of epoxy with a silane coupling agent [2]. Silanized epoxy chains can rearrange in amphiphilic systems, enabling the excellent dispersion of the biowaste. While humic acids do not affect the mechanical response of final composites, they promote char formation in the condensed phase by synergistically acting with phosphorus-based additives and inorganic moieties. Since most of the biowastes are very hydrophilic and exhibit poor thermal stability, their thermo-chemical conversion into biochar or hydrochar allows to finely disperse them throughout the polymer matrix and improve the fire behavior of final composites. That's the case of spent coffee grounds; the coffee waste-derived biochar can easily distribute in a silanized epoxy and give self-extinguishing response, thanks a synergism with well-designed sol-gel ternary inorganic oxides [3]. The hydrothermal liquefaction of municipal sewage sludge produces a hydrochar that, when combined with functionalized whisker-like sol-gel silica particles, makes possible the preparation of self-extinguishing epoxy-based composites with high hydrophobicity [4]. Similarly, hydrochar from tannery sludge imparts fire resistance and an organic look to thermoplastic decorative panels, when used with sol-gel-tailored hazelnut shells and other additives. Overall, sol-gel approaches reinforce waste-to-wealth material design and support circular economy principles by reducing dependence on conventional flame retardants and fillers.

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References

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