Two Wastes, One Fiber: Upcycling Expanded Polystyrene and Organosolv Lignin into Electrospun Carbon Fibers

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Abstract

Growing amounts of plastics waste and underused biomass create a need for upcycling methods that convert these resources into valuable materials. Carbon fibers (CF) are attractive because of their low density, high strength, and wide range of applications. Most commercial CF are produced from fossil-based precursors. In this study, expanded polystyrene (EPS) recovered from waste electronic packaging was modified and blended with catalytic organosolv lignin extracted from Miscanthus x giganteus . The blends were electrospun into fibers using a green co-solvent system. Lignin has high carbon content and char-forming ability, but its structure and poor spinnability make fiber production difficult. Polystyrene was used as a fiber-forming polymer to improve spinnability and maintain fiber continuity. Blends containing 30, 50, and 70 wt.% PS were evaluated. The formulation containing 30 wt.% PS showed the best spinnability and produced fibers with an average diameter of 0.90 ± 0.13 μm. FTIR and DSC analyzes indicated compatibility and interactions between polystyrene and lignin. The fibers were stabilized at 180, 250, 280, and 300 ∘C using heating rates of 0.5, 1, 2.5, and 5 ∘C min^{1}. Stabilization between 250 and 300 ∘C at 0.5 and 1 ∘C min^{1} preserved fiber morphology and prevented fusion. The stabilized fibers were then carbonized at 800 and 1100 ∘C using heating rates of 1, 2.5, and 5 ∘C min^{1}. Their average diameter decreased to 0.70 ± 0.10 μm after carbonization. SEM-EDX analysis showed a surface carbon content of 98 at.%. Raman spectroscopy gave ID/IG ratios ranging from 0.81 to 1.00, alongside X-ray diffraction patterns that confirmed the formation of a turbostratic carbon structure. The optimum conditions were stabilization at 300 ∘C and 0.5 ∘C min^{1}, followed by carbonization at 5 ∘C min^{1} leading to a CF diameter of 0.700 ± 0.1 μm. Under these conditions, the fibers maintained their morphology and achieved a carbon yield of 38%, showing the potential of waste-derived polystyrene and lignin as sustainable CF precursors.

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