Eco-Friendly Dye–Porphyrin Copolymer for Organic Solar Cells: From Ternary Donor to Interfacial Layer

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Solar energy, particularly through organic solar cells (OSCs), presents an eco-friendly and promising solution to the challenges of global energy shortages and environmental pollution. OSCs offer notable advantages, including the use of non-critical raw materials, cost-effective production, flexibility, and the potential for large-area, semitransparent fabrication. As a result, significant progress has been made in both the design and synthesis of high-performance materials and the optimization of device architectures to enhance photovoltaic efficiency.

This work focuses on the synthesis and application of two novel conjugated thiophene-based polymers integrated with ionic phosphonium salts, providing enhanced solubility in water/alcohol mixtures. The first material - poly{3-(6-tributylphosphoniumhexyl)thiophene-co-3-[5-(4-phenoxy)-10,15,20-triphenylporphyrinyl]hexylthiophene bromide} (P1buP, ED1) - is a copolymer composed of ionic units and tetraphenylporphyrin dye-functionalized segments, while the second - poly[3,4-(6,6'-tributylphosphoniumhexyloxy)thiophene] bromide (P2buP, ED2) - is a disubstituted homopolymer incorporating ionic groups at the end of hexamethylenic side chains, linked to the main polythiophene backbone via ether bridges. The polymers were processed entirely using green solvents, such as ethanol, and evaluated as photoactive donor materials in ternary bulk-heterojunction (BHJ) OSCs, blended with an alcohol-soluble fullerene derivative (EA). The ternary devices exploit complementary absorption, improved energy level alignment, and a more homogeneous active layer morphology. Notably, the device with a ED1:ED2:EA weight ratio of 0.33:0.67:1 achieved a power conversion efficiency (PCE) of 5.22%, which further increased to 6.03% upon Zn metalation of the porphyrin units, without compromising solubility or film-forming properties. In addition to their role as active layer components, the ionic porphyrin-containing polymer was also successfully employed as an alcohol-soluble cathode interfacial layer, improving charge transport and device stability.

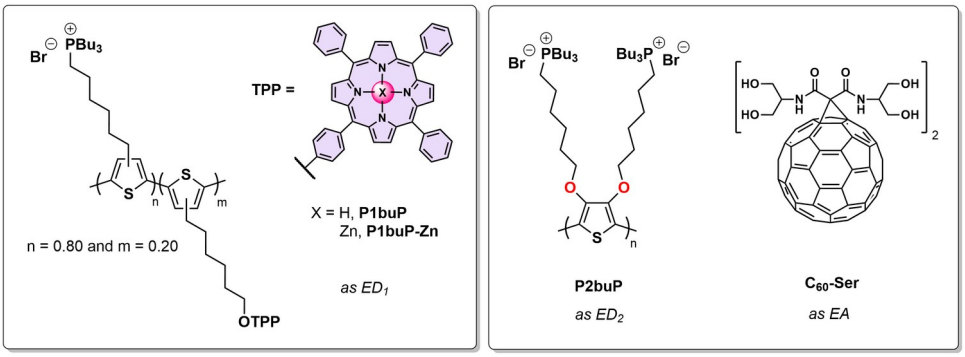

Figure 1. Overview of the synthesized materials.

Acknowledgments

This work was supported by the project "Ecosystem for Sustainable Transition in Emilia-Romagna" (Ecosister), funded under the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.5 - Call for tender No. 3277 of 30/12/2021 of Italian Ministry of University and Research funded by the European Union – NextGenerationEU (project code ECS00000033, CUP D93C22000460001).

References

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