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Editorial

Green Materials

Editorial: Rethinking green materials: integrating performance, durability and end-of-life management

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The concept of green materials has evolved significantly in recent years. Traditionally, materials have been classified as green based on their origin, such as being biobased or from waste, or on reductions in energy consumption, use of harmful chemicals and emissions during production. While these criteria remain essential, they are no longer sufficient to fully define sustainability. A fundamental question must be addressed: can a material truly be considered sustainable if it fails to deliver long-term performance in real-world applications? Performance, durability, and end-of-life must be considered in a comprehensive lifecycle thinking approach. Moreover, economic and social impacts must be accounted for, as materials must not only be environmentally responsible but also economically viable for producers and acceptable to end users.

Within this context, performance emerges as a central point. Modern green materials are increasingly expected to meet or exceed the functional performance of conventional systems. Closely linked to performance is durability, which plays a critical role in determining the overall environmental impact. Materials that maintain long-term performance and require less frequent replacement help reduce resource consumption and minimize waste generation. Beyond performance and durability, lifecycle thinking provides the framework necessary to evaluate the true sustainability of materials. This holistic perspective considers the cumulative environmental impacts associated with raw material extraction, processing, transportation, use, and end-of-life management. The contributions presented in this issue of *Green Materials* reflect this evolving perspective, moving beyond material origin towards a more integrated concept of sustainability.

The first contribution[1] demonstrates how natural compounds can be engineered to meet functional biomedical requirements, addressing key performance challenges such as dimensional stability, mechanical strength, and antibacterial activity, while maintaining biocompatibility. Another study[2] investigates the formation mechanism of biological calcium carbonate, providing insight into microbially induced calcium carbonate precipitation, an environmentally sustainable technology with applications ranging from crack healing in cement-based materials to soil reinforcement and the treatment of waste and water.

In high-volume sectors such as construction, building and automotive materials, reduced environmental impact can be achieved either through improved performance that enables lower material use, or through the substitution of conventional materials with more environmentally sustainable alternatives. The integration of fiber reinforcement and supplementary cementitious materials (SCMs), such as fly ash, ground granulated blast furnace slag and silica fume, enables reductions in cement consumption while enhancing mechanical performance and durability. Two studies in this area illustrate complementary approaches: one[3] highlights the potential of natural fibers as a more sustainable alternative to synthetic reinforcements for less demanding applications, while another[4] examines the use of locally sourced SCMs in ultra-high-performance concrete. Sustainability considerations are also extended to polymeric materials, where challenges posed by traditional brominated flame retardants in rigid polyurethane foams are addressed through their replacement with environmentally friendly alternatives.[5]

Advances in environmental applications are further illustrated by the development of PVDF/TiO_2/GO composite membranes,[6] which achieve improved mechanical properties and highly efficient oil–water separation. Their high performance and reusability underscore their suitability for use in the fields of oily wastewater treatment and oil spills remediation.

Finally, the last contribution[7] addresses the challenge of managing end-of-life materials, which is becoming urgent in rapidly expanding sectors such as renewable energy. By combining thermal, chemical and green approaches material recovery from end-of-life solar panels is maximized while minimizing the environmental impact.

As the demand for green materials continues to grow, research must not only design environmentally benign materials but also ensure that they are durable and effective throughout their lifecycle, and that their end-of-life management is environmentally sustainable. Achieving a more comprehensive understanding of what it means for a material to be green is not just an academic exercise; it is essential for ensuring a meaningful and lasting impact on the transition toward a more sustainable future.

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