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Editorial: Recent advances in sustainable polymer materials

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Editorial on the Research Topic
Recent advances in sustainable polymer materials

Polymers are the world's most versatile materials, and nearly everything ranging from high-tech electronics to biomedicine to consumer packaging can be made from polymers. Most of these polymers are derived from petrochemicals and show high persistence in the environment. Most discarded polymers are difficult to recycle or degrade and they often end up in landfills and oceans, resulting in the accumulation of millions of tons of plastic waste every year in the environment. To address plastic pollution, developing sustainable polymer alternatives has been attracting significant attention (Mohanty et al., 2022). Scientific research has focused on chemical design of sustainable polymers, renewable alternatives to replace petrochemically derived resources, and fully recyclable process of waste carbon recourses to build a circular economy. Potential utilization of sustainable polymers is in diverse applications including agriculture, packaging, coatings, automotives and 3D printing. This Research Topic showcases recent work in scientific research on sustainable polymers, composites, and their applications. The Research Topic includes four research articles that cover a wide range of topics from dynamic covalent polymer networks, to semisynthetic biopolymers, to landfill waste derived composites, to functional coatings of food packaging materials.

The incorporation of dynamic covalent bonds into cross-linked polymer networks is emerging as an essential strategy to combat plastic waste. This class of materials, also known as covalent adaptable networks (CANs), use bond exchange processes to enable reuse of cross-linked polymer materials that would otherwise not be recyclable. CANs combine the robust mechanical properties of cross-linked polymers with the ability to reprocess them under the influence of an external stimulus of light, heat, or mechanical force. In Lagron et al., the authors review CAN characterization techniques that range from small molecule techniques to bulk characterization techniques that are used to demonstrate and optimize bond exchange. The review highlights important methods to characterize dynamic bonds on chemical, thermal, mechanical, and reprocessing levels.

Semisynthetic biopolymers are often presented as green and sustainable alternatives to conventional plastic with value-added properties. However, these synthetic modifications may significantly reduce biodegradability, sometimes causing these materials to become a

source of plastic pollution. In Hart-Cooper et al., the authors present a comparative study on the mineralization kinetics of semisynthetic polysaccharides, unmodified cellulose and guar in aerobic wastewater and soil compost environments. Kinetic analysis reveals that synthetically substituted biopolymers tend to have much longer biodegradation time than natural biopolymers, and their degree of persistence is highly dependent on the fraction of polymer substitution. This work provides important guidance for systematic development of semisynthetic biopolymers as sustainable alternatives.

Landfill waste diversion is vital for sustainable and economical practices. The development of useful materials from landfill waste has attracted great interest to maximize landfill diversion of high-volume materials. Ash is commonly generated during the waste to energy process which currently has no market, and the most common disposal method is landfilling. In Mort et al., the authors describe original research on utilizing fly ash waste as fillers in post-consumer recycled plastic for reducing the landfill burden from the plastic and waste to energy industries. A series of polymer composites are compounded from post-consumer recycled polyethylene and fly ash utilizing various compatibilizers. The research demonstrates that the utilization of fly ash in polymer composites can reduce material cost, lower landfill accumulation and add performance value. Such an approach has potential to increase circularity for commodity plastic markets.

Paper and paper board-based materials are considered the ecologically most sustainable materials for packaging applications. However, hydrophilic nature and high porosity in the cellulosic materials tend to absorb moisture, leading to degradation of mechanical performance and functional properties. Polymer coatings are generally required for paper fiber-based materials for food packaging. Kathuria and Zhang review sustainable and repulpable polymer coatings suitable for fiber-based substrates. The review presents strategies for designing degradable polymer coatings and functional nanocomposite coatings for food contact applications which impart improved functional performance such as improved gas barrier, higher dimensional stability, reduced water absorbance, enhanced surface finish, etc. Such coatings either reduce carbon footprint, promote circular economy or mitigate end of the life environmental burden.

In summary, this Research Topic collection reflects recent advances in some central areas of the sustainable polymer materials to address plastic waste issues. The articles in the Research Topic highlight the cutting-edge research to develop new sustainable polymers and composites towards a truly circular economy. We hope this Research Topic serves as a starting point to inspire new ideas and directions in chemical design, characterization methods and energy-efficient processing of sustainable polymer materials.

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