Macromolecular Materials and Engineering
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Sustainable Macromolecular Materials and Engineering

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This special issue is part of a project across the Macro Journal Family, and sister journals Macromolecular Rapid Communications, Macromolecular Bioscience, Macromolecular Chemistry and Physics, and Macromolecular Reaction Engineering are also focusing on different aspects of sustainability.

Polymers are indispensable materials in our lives, ranging from daily commodities such as drink bottles, to engineering parts such as engine covers, and to speciality components such as precision electronics. These macromolecular materials can be processed, formed and manufactured with various morphologies ranging from solid parts and foams to particles and fibers at different scales. Currently around 370 million tons of plastics are produced worldwide every year, which has grown exponentially from 1.5 million in 1950.[1] Such a growth of the plastics industry plays a critical role in serving the society in terms of economic growth, jobs, quality of life, wellbeing and healthcare. However, it has also brought about issues and challenges. One of the main issues is the waste generated from plastic products at their end of life. More than half of the plastics produced since 1950 has ended up as waste.[2] These plastic wastes are not only depreciating precious resources and lands, but also causing environmental and health concerns. So, how can we reduce the amount of plastic wastes?

Packaging materials, in particular single-use packaging materials, generate the most waste among all plastic wastes. Each year, 80 million tons of packaging waste is produced in the United States alone.[3] To help address this issue, biodegradable polymers have been investigated for compostable packaging applications. In this special issue, mame.202100602 looks at balancing biodegradation behaviour and physical properties of the blends of amorphous poly(D,L-lactide) and semicrystalline poly(L-lactide) (PLLA), which may be attractive for compostable food packaging after modifications for reduced gas permeability. Reduced gas permeability of PLLA film is investigated in mame.202100727 by using synthetic hectorite clay, which also accelerates the biodegradation of the polymer. Mame.202100960 studies the use of post-industrial waste starch to produce biodegradable composites with poly(butylene adipate terephthalate) and mineral fillers for single-use flexible packaging. Mame.202100794 gives a critical review of the sustainability and life cycle analysis of thermoplastic polymers for packaging and points out the challenges associated with the development and use of biobased and biodegradable polymers such as the environmental effects of cultivating agricultural resources and the infrastructure and costs required for composting. Biodegradable polymers can also be developed for other applications. Cellulose acetate is used in a variety of applications such as moulded articles, textiles, membranes and films. To facilitate its application, its long-term biodegradation behaviour is reported in mame.202100951.

Apart from developing biodegradable polymers, how can we improve plastic recycling and reduce the amount of plastic wastes going to landfill? How can we improve the quality of recycled plastics and reduce the amount of plastic wastes going to incineration? Traditionally, recycling plastic waste (*i.e.*, mechanical recycling) involves a series of steps including collection, sorting, washing, shredding, melting, pelletizing, packaging etc. This is complemented by chemical recycling which depolymerizes plastic wastes and turns them back into chemical building blocks. So, to improve plastic recycling and the quality of recycled plastics requires joint efforts from the whole supply chain, including the manufacturers of monomers, polymers and polymer products, users of polymer products/parts, waste collection services, the plastic recycling industry, transport and storage.

Car tyres are another type of product which generate a significant amount of plastic wastes. Each year, approximately 1.5 billion car tyres are discarded globally,[4] which contain about 60% vulcanized natural and synthetic rubbers. In mame.202100944, carbon black from pyrolyzed car tyre waste was used to partially replace common carbon black and reinforce rubbers, which show comparable properties to those prepared from totally common carbon black.

Another major challenge associated with the growth of the plastics industry is the resource used to manufacture polymers. Traditionally polymers are made from fossil oils which are limited and depleting. To tackle this challenge, researchers have turned to natural polymers and synthesized polymers from renewable sources such as biobased feedstocks,[5] and carbon dioxide.[6]

Eugenol-based epoxy is reported in mame.202100833 which shows comparable mechanical properties to their counterpart synthesized using a conventional curing agent. In mame.202100864, biobased epoxy/cellulose and epoxy/flax composites were prepared by frontal photopolymerization, and show similar tensile properties to the composites made from petroleum-based epoxy. Fully biobased recyclable polyamide thermoplastic elastomer/cellulose nanocomposites are investigated in mame.202200120 which possess comparable properties to conventional chemically crosslinked rubbers with low or medium hardness. Renewable polymers for flexible electronics are reviewed in mame.202100978, and cellulose-based soft actuators are reviewed in mame.202200072. In mame.202100902, furan-based polymers are critically reviewed as furan offers a versatile platform for producing various polymers from non-fossil sources and ecological benign processes. While biobased polymers show tremendous promise, the availability of a wide range of building blocks from non-food sources needs to be increased.

To improve the service life and reduce the use of resources, self-healable polyurethanes activated by UV/heat are prepared in mame.202100874 by UV crosslinking for applications such as smart coating. Self-healing polymers with dynamic bonds are attractive materials, which may also facilitate the recycling of thermosetting polymers[7] and rubbers[8]. However, many self-healing polymers still show inferior properties compared to their non-self-healing counterparts, which needs to be addressed. Recovery and reuse of some plastic parts from end-of-life products may also help reduce the use of resources.

When manufacturing a polymer product or part, green manufacturing using minimal resources and causing minimal environmental impact, should be considered. A green manufacturing approach is developed in mame.202100823 for the electrospinning of polyurethane nanofibrous membranes with controlled mechanical properties and hydrophobicity by using water as the solvent instead of toxic organic solvents, poly(ethylene oxide) as a water-soluble sacrificing polymer, and tannic acid as a surface modifier, as well as a needleless emitter. Naturally derived cyclodextrin-only nanofibers are prepared in mame.202100891, by pressurized gyration and electrospinning using water as the green solvent for applications such as drug delivery and food science. Such resort to water as a polymer solvent and the increased use of oligosaccharides in polymeric applications will be an impetus to tackling the environmental friendliness, green manufacturing, and sustainability of more traditional polymers.

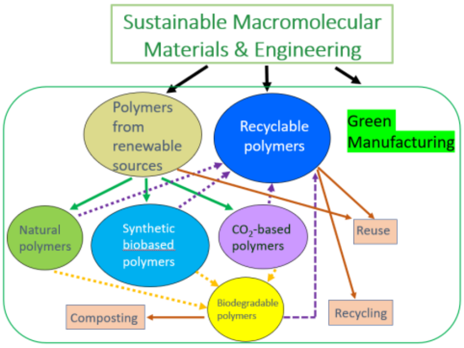

Figure 1. Schematic illustration of sustainable macromolecular materials and engineering

In conclusion, to reduce the generation of plastic wastes and the reliance on limited fossil fuels, we need to encourage circular economy and sustainable macromolecular materials and engineering (**Figure 1**). All stakeholders including researchers, manufacturers, users and policy makers should work together to reduce the use of resources, promote green manufacturing, and facilitate the reuse of plastic products/parts where possible, the recycling of plastic wastes and the production of renewable polymers. Life cycle analysis should be conducted to assess the resource and energy consumption of plastic products during their whole life cycle. Technological challenges associated with sustainable macromolecular materials and engineering should be tackled as a priority.

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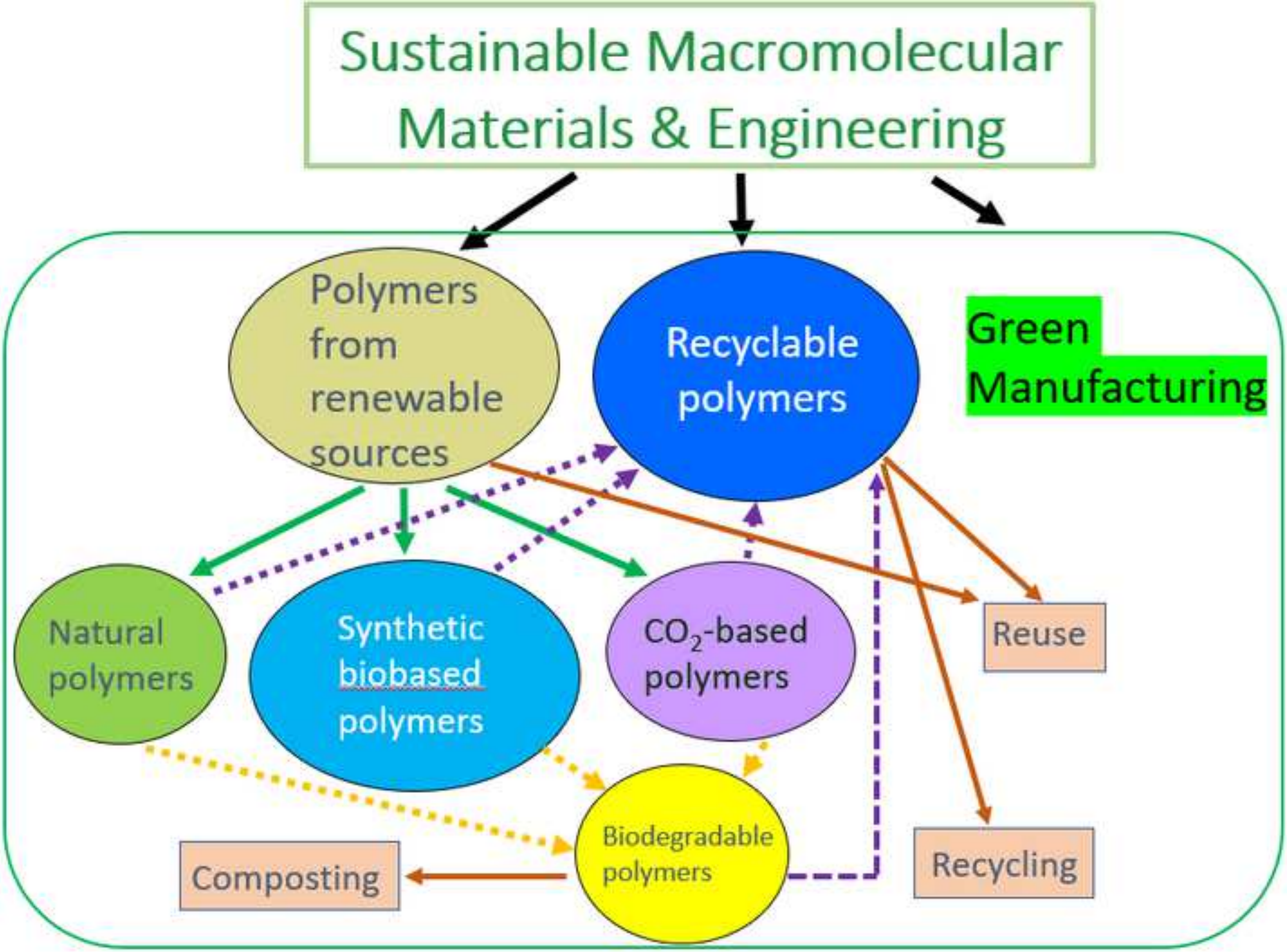
Short Biography

Biqiong Chen is a Professor of Polymer Engineering at the School of Mechanical and Aerospace Engineering, Queen's University Belfast. She obtained her PhD in Materials Science from Queen Mary, University of London. Her current research interests are mainly focused on the synthesis, processing and characterization of smart sustainable polymers and multifunctional polymer nanocomposites for applications such as healthcare, stretchable electronics, packaging, sealing, transport and energy.

Suprakas Sinha Ray is a Chief Researcher at the Council for Scientific and Industrial Research with a PhD in Physical Chemistry from the University of Calcutta in 2001, Manager of the Centre for Nanostructures and Advanced Materials, and Director of the DSI-CSIR Nanotechnology Innovation Centre. He is also associated with the University of Johannesburg as a Distinguished Visiting Professor of Chemical Sciences. Ray's current research focuses on polymer-based advanced nanostructured materials and their applications.

Mohan Edirisinghe is Bonfield Chair of Biomaterials in UCL Mechanical Engineering. He has published over 500 journal papers. His research on macromolecular manufacturing for healthcare has won numerous grants and prizes, including recently, The UK Royal Academy of Engineering Prize for excellence in Materials Engineering and the Premier UK IOM3 Chapman Medal for distinguished research in Biomedical Materials. In the Queen's New Year National Honours 2021 he was appointed OBE for his services to Biomedical Engineering.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Materials & Engineering
Polymers from renewable sources
Recyclable polymers
Green Manufacturing
Natural polymers
Synthetic biobased polymers
CO_2-based polymers
Reuse
Biodegradable polymers
Composting
Recycling