Editorial: Enabling Research in Smart Sustainable Plastic Packaging

Main text

Polymer-based plastics have revolutionised the world. These materials are ubiquitous in our everyday lives (facilitating communication, computing, entertainment, healthcare, sanitation, and the storage, merchandising, and distribution of a wide variety of fast moving consumer goods, etc.).[1-3] Plastics are produced in high volumes, and their durability (one of the appealing features in plastic product design) is recognised as having a complex combination of positive and negative economic, environmental and social impacts worldwide.[4,5] Various initiatives at a regional and national level have been put in place to: reduce the amount of plastic waste produced, to encourage re-use of plastic items prior to replacement, and ensure the recycling of plastic items whenever possible. The Ellen MacArthur Foundation's Plastics Pact Network is a global manifestation of this effort, with initiatives being undertaken at regional, national, and supranational levels including, but not limited to: the UK Plastics Pact, the Canada-wide Strategy on Zero Plastic Waste, the Australia, New Zealand and Pacific Islands (ANZPAC) Plastics Pact, and the European Strategy for Plastics in a Circular Economy.[6]

Polymer-based plastic packaging represents one class of near ubiquitous everyday items in our global consumer culture, having been integrated in most encounters that we have with the marketplace.[7,8] In this focus section, we have gathered a set of papers to highlight some of the challenges and opportunities in implementing solutions that could support the Plastic Pact Network's ambitions (listed below), and support a circular economy for plastics.[9-12]

The Plastic Pact Network ambitions are to:

- Eliminate unnecessary and problematic plastic packaging through redesign and innovation;
- Move from single-use to reuse.
- Ensure all plastic packaging is reusable, recyclable, or compostable.
- Increase the reuse, collection, and recycling or composting of plastic packaging.
- Increase recycled content in plastic packaging) and a circular economy for plastics.

The contributions to of these papers, from authors around the world, draw on current scholarship in the basic, applied natural and materials sciences, as well as from social science communities. The papers include a variety of perspectives, mini or full reviews, and research papers. Reflecting some of the exciting recent developments in plastic packaging, this section will be of interest to a broad readership. We break down the contributions in a circular order, starting from the point of production and moving to post-consumption resource management, recycling and utilisation.

PRODUCTION PRE-CONSUMPTION/UTILISATION

Wilson and co-workers introduce a design-led approach to polymer research, within the context of "perpetual plastic" being used as single-use plastic packaging for "food to go". They highlight three advantages that could help to overcome these barriers: frame creation as a means for synthesising complex issues towards novel research directions; the potential for changing consumer behaviour through scripted material characteristics; and multidisciplinary working as a facilitator of knowledge generation and transfer.[13]

Polyhydroxybutyrate (PHB) is an exemplar of sustainable polymers that is a promising contender for replacing petroleum-based plastics in food packaging. However, materials produced from natural/synthetic PHB alone tend to have poor mechanical properties (i.e., brittleness) which limits their use. Combining two or more monomers with different physical properties allows the properties of the resulting polymer to be tuned, potentially via controlling the sequence of monomers though design of the metal initiator. Catchpole and Platel examine the copolymerisation of β-butyrolactone and γ-butyrolactone using yttrium amine bis(phenolate) catalysts to generate poly(3-hydroxbutyrate-co-4-hydroxybutyrate) with properties tuneable by monomer feed ratio and catalyst used.[14] Another common approach to tune the properties of materials is to produce composites (e.g., the inclusion of fillers to improve the mechanical properties of PHB composites). However, it is not well understood how fillers affect polymer crystallisation and microstructure, and thus the resulting mechanical properties of the composite. Johnston and co-workers review a combination of computational and experimental studies examining polymer nucleation and crystallisation, and how nucleation is influenced by different types of polymer–filler interface.[15] The data obtained from the literature do not seem to produce strong conclusions about the effect of the degree of crystallinity on the tensile properties of PHB–filler composites, although there are some weak trends that indicate the importance of microstructure, highlighting the necessity for further systematic studies to elucidate the effect of specific filler types and the connection between crystallinity, microstructure and mechanical properties.

FATE POST-CONSUMPTION/UTILISATION

Chen examines some agricultural plastic waste management behaviours and highlights the challenges of reducing plastic waste on farms through the lens of a circular economy. The lack of effective agricultural plastic waste collection services, inequitable enforcement of plastic waste management regulations and rising costs of waste plastic collection in the UK which make it difficult for them to be effectively recycled.[16] Enfrin and Giustozzi investigate the challenges related to the production, performance and durability of plastic modified asphalt in the construction of sustainable asphalt roads using recycled plastic.[17] Challenges include the wide variability in plastic composition/properties after recycling, representative testing procedures. Recent advances in the field are presented and future work to address current research and industrial gaps are highlighted.

While reuse and recycling of plastics is appealing, polymer degradation (deleterious physical/chemical changes of polymers) can complicate reuse/recycling. Designing polymers to impart controlled degradation (when exposed to various stimuli, including enzymes), and designing biodegradable polymers (broken down by bacteria/other organisms with a view to their digestion or compostability) is attractive, in part because it may serve as a source of feedstock chemicals. Polyurethanes are an important class of polymers, however, their degradation under natural conditions is slow/incomplete. Consequently, the discovery of polyurethane-degrading microorganisms and ‘polyurethanase’ enzymes is exciting. Bao, Luo and co-workers review the degradation mechanisms of polyurethanes and recent research on the enzymatic degradation of polyurethanes and biodegradation of polyurethanes via microorganisms.[18] Polyethylene terephthalate (PET) is a very important class of polymer in food packaging that is widely recycled (to the point where deleterious changes in the PETs complicate reuse/recycling). Cochran and co-workers review the use of enzymes sequestered from microbes to enzymatically depolymerise PET in ambient conditions to provide monomeric feedstocks for repolymerization, with a view to achieving the coveted goal of cradle-to-cradle recycling.[19]

A VIEW TO THE FUTURE

The articles in the focus section highlight some of the challenges and opportunities encountered with plastic (a marketplace icon) in consumer culture. The properties of plastics mean they will continue to play a role in society for the foreseeable future, and we believe that the growing appreciation of sustainability and circularity at a global level will see the design and development of novel processes and products involving polymers included in next generation plastics.[20-22] Understanding plastic stock and flows at a global level[23,24] underpins the effective management of these resources within a circular economy.[25-27] We hope this collection inspires scholars from a range of disciplinary backgrounds to engage with the sustainability and circularity agenda.

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