Multiple Layers – Multiple Problems?

Approaches and Unresolved Problems in the Mechanical Recycling of Flexible Multilayer Packaging

The challenges associated with recycling food packaging are particularly great in the flexible-packaging sector. Multilayer composites are often a hindrance to mechanical recycling, yet are irreplaceable in many applications. Replacements will not be found until recyclable and ecologically sustainable packaging solutions are devised.

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Multilayer composites, which can consist of up to 12 layers, are mostly non-recyclable. This prevents material loops from being closed (**Fig. 1**), as the materials cannot be recycled to reusable secondary material for higher-value applications.

However, multilayer composites are an established packaging system, they now account for about 10 wt.% of the global packaging market [1] and they offer many advantages. The fact that different combinations of materials are possible affords a way to exploit their morphology and associated properties. Even thin layers are capable of acting as a barrier that will adequately protect the contents. Polarity, crystallinity, tacticity (the recurring sequence of side chains in the polymers), molecular weight distribution – each material has a characteristic constitution and thus has different application possibilities [2].

Closing the Material Loop through Mechanical Recycling

The entire value chain now has to do a rethink. The EU's strategic goal of only putting recyclable or reusable packaging into circulation by 2030 is essentially unassailable. If the material loop is to be closed via mechanical recycling, new recycling solutions will have to be found and tested.

One solution under consideration is the use of mono-material instead of multi-material. This raises the question as to whether mono-material composites can serve as replacements for specialized multilayer composites. This is because any one material on its own is usually unable to act as a barrier against different

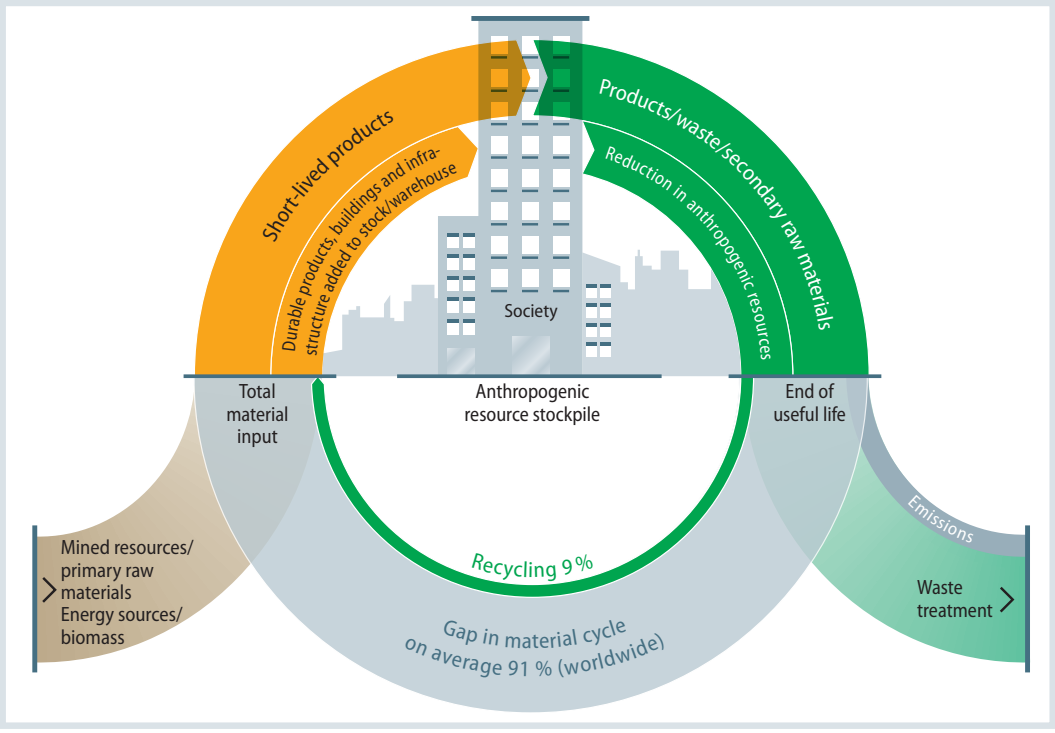

Fig. 1. Gap in the circular economy: the pathway followed by resources is only 9 % circular on average worldwide. Just 91 % of the 92.8 billion t of minerals, fossil fuels, metals and biomass entering the economy each year is not recycled Source: Altstoff Recycling Austria, EU, graphic: © Hanser

environmental factors. Should a product, say, need to be protected against both water-vapor and oxygen, one limitation soon manifests itself in the morphology: non-polar polyolefins will protect against water-vapor, yet be permeated by oxygen [2]. So how can we continue to provide proper protection for products (such as crispy snacks which are vulnerable to oxidation) that have a wide range of requirements?

Mono-Material Approach Must be Developed Further

Mono-material solutions are every recycler's dream, as they can usually be recycled without problems. Very thin coatings of metal oxides or of aluminum in thicknesses of 100 nm or less usually do not disrupt mechanical recycling. It has also been shown that EVOH polyolefin composites with an EVOH content of less than 5 % are easily recyclable. The plastic content of common combinations of plastics with sandwiched layers of aluminum (aluminum layer thicker than 5 µm) or paper is typically not mechanically recyclable. The same is true of composite beverage cartons, where usually only the paper content is recycled.

According to [3], theoretically recyclable combinations currently include composites comprising

- Coatings of silicon oxide (SiO_x) or aluminum oxide (Al_2O_3) for PP, PE and PET,
- EVOH in a proportion of up to 5 wt. % for PP and PE,
- PA in a proportion of up to 5 wt. % in PET, and
- metallized foils, provided that they do not interfere with the sorting process.

In practice, economic reasons largely preclude these film grades from being either collected or mechanically recycled. What is more, there are many other packaging materials on the market that are still non-recyclable.

Recyclable Barrier Solutions in Practice

A trawl of online platforms reveals that some manufacturing companies already offer recyclable solutions for flexible food packaging and are substituting the recyclable composites mentioned above for previously used multilayer composites: mono-PE for muesli, mono-PP for fruit puree and muesli bars, metallized PP for nuts and seeds, vapor-deposited silicon oxide on PP for heatable convenience packaging. Also available are coated paper solutions which, if they are coated on one side only and they contain less than 5% plastic, can be licensed and recycled as paper. »

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Fig. 2. Redesign required: about 30 % of plastic packaging (measured by weight) cannot be mechanically recycled without a fundamental redesign Source: Ellen MacArthur Foundation, graphic: © Hanser

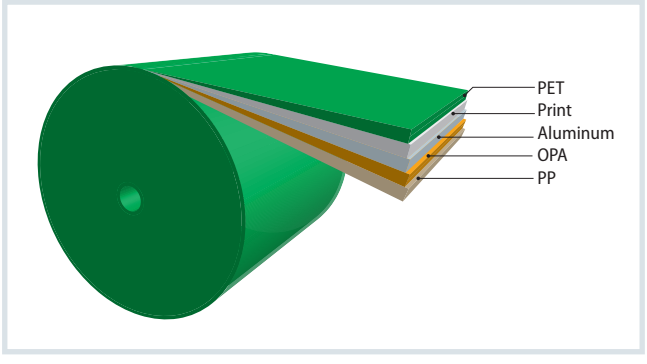

Fig. 3. Stand-up pouch: typical composition of a non-mechanically recyclable pouch bag for wet feed
Source: Constantia Flexibles; graphic: © Hanser

However, recyclable barrier solutions currently have low market penetration (**Fig. 2**). In the case of individual food product classes, such as sausage and cheese slices or animal feed, the market is dominated by non-recyclable multilayer composites, because no other solutions exist that meet all the requirements of these product classes (**Fig. 3**). The issues here are machinability, sterilizability and even puncture resistance. Further developments are still necessary in this area.

Simply transitioning from non-recyclable multilayer composites to recyclable combinations will not close the loop (or more precisely: loops). This is because recycling of flexible packaging has been hindered up to now by a number of technical challenges, such as the diversity of polymers and combinations thereof, contaminants and residues, overlaps and assignability, and size allocations. Also standing in the way of recycling and reuse as secondary material are systemic problems relating to a lack of collection and recovery infrastructure, absence of economic viability, restrictive use permits, low sustainability, etc.

Complex Systemic Impediments

In some instances, systemic impediments are more complex than the technical ones. The bulk of scientific publications over the last ten years on the subject of recyclable flexible multilayer packaging report that one of the challenges is the fragmentation and lack of transparency of the value chain. This is made up of many players pursuing their own small-scale developments and projects and creating a huge patchwork of potential solutions. If larger reusable material flows are to be achieved, however, it is necessary for standardized approaches and (material) goals to be adopted as far as possible. Loops can still remain small, but they must be profitable from all aspects of sustainability (ecological, economic, social). It is becoming increasingly important to interlink all the elements in this value chain because there is no compelling case, from any aspect of sustainability, in favor of mechanically recycling flexible multilayer plastic films in their current composition.

A further problem arises in the case of ecological sustainability, for example. Although it may not be recyclable, nonetheless, highly specialized thin – and thus lightweight – flexible multilayer packaging is highly efficient, consumes very few resources and has a low carbon footprint. Replacing these materials with alternatives would nearly always entail higher resource consumption and greater environmental impact. With regard to plastic film recycling, the question also arises as to whether this is also ecologically justified if, say, the high effort entailed in collecting, sorting and recycling leads to a negative environmental footprint.

Conclusion

It is clear that our economy must move towards a circular model. However, this is not an end in itself, but rather should mitigate the negative environmental impact of our actions – as measured, e.g., in terms of resource consumption and carbon footprint. In this context, "recyclable" does not automatically equate with "more sustainable". ■