Polypropylene (PP): Growth despite Crisis

The Future of Polypropylene Lies in the Circular Economy

PP is a material with good future perspectives. It is attractive as it combines several different properties. It is economical, covers a wide application area – and can be readily recycled. The big PP producers have already established their own product lines for recyclates. The quality of these recyclates has also improved in recent times: even the demands regarding appearance and emissions required for automotive interior uses can be fulfilled.

The "Monobloc" from PP, here in a green version, is one of the most affordable and versatile seating furnitures worldwide (photo from the movie "Monobloc" by Edition Salzgeber). © Boris Mahlau/PIER 53

It is not every day, that someone produces a feature movie about a piece of furniture. However, the "Monobloc," a chair that has been produced from polypropylene in pure or mineral-reinforced form since the mid-1960s, is something really special. As the German movie director Hauke Wendler found out in his research, the Italian company Proserpio alone has so far produced more than 250 million units of this chair. Worldwide, production is estimated at several billion units, making the "Monobloc" the most frequently sold item of furniture. For many people it is also the only affordable one (**Title figure**), and can even be recycled, as it consists of only one material type. Wendler's movie also

Fig. 1. The FFP2 mask by Vprotect, a 100 % daughter company of Grabher Group, mainly consists of meltblown PP by Borealis and can be recycled mechanically. © Grabher

shows the many possibilities of this chair, from repair with diverse materials to its adaptation as a wheelchair.

This movie is therefore a symbol for polypropylene (PP), covering four important aspects of this material:

- PP is globally available in large quantities, with a production of about 75 million t in 2020 [1],
- PP is an economical material,
- with its copolymers and composites, it covers an extremely broad property range,
- PP can be recycled in multiple ways.

Growth despite Crisis: Stronger Demand in Hygiene and Packaging

The production volume of PP has suffered hardly at all from the Covid-19 pandemic, as production declines in areas like the automotive sector were compensated for by stronger demand in hygiene and packaging. One could even say that one article produced from PP – the FFP2 respirator mask – has become a symbol of the pandemic. It is consequently very important that innovations are also related to such mass-produced articles. The masks are produced from PP grades with a melt index (MFR) of more than 1000 g/10 min. via the meltblown process. These materials are available from several producers, such as Sabic and Borealis. These two companies also support recycling of the masks after use. Sabic, together with Procter&Gamble and Fraunhofer, has set up a pilot project for pyrolytic conversion of single-use masks, in which valuable petrochemical raw material is generated. In the collaboration between Borealis and Grabher, a fiber and mask producer, mechanical recycling is used (**Fig. 1**), in which, after sorting, washing, sterilizing and drying, the material is used as filling for pillows and oil absorption applications; a process for re-pelletization is under development.

Market development of PP is, however, distributed unevenly on a global scale. The stronger growth in Asia, and here especially in China, which has already been ongoing for some time, has resulted in a share of over 50 % of the global volume for this region (**Fig. 2**). This development is likely to continue, as the growth of 4 to 6 % per year forecast for the coming years will rather be exceeded by Asian countries [1]. This is explicable by the factors for market growth, such as dynamics in areas of hygiene, healthcare and packaging of convenience products, but also infrastructure and mobility.

EU Recycling Targets Are Becoming a Challenge

However, this positive trend is countered by some factors ranging from a »

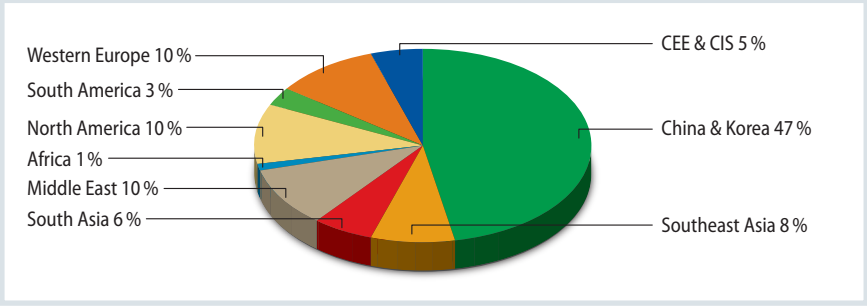

Fig. 2. Distribution of PP production by global regions.

Source: data based on[1,3]; graphic: © Hanser

general skepticism about single-use plastic articles to legal requirements, as for example resulting from the EU strategy for plastics [2]. For PP this mostly means that the demand for recycled material will increase. This is presently at about 7 % of the overall market (higher in Europe, significantly lower in North America), but it should double in the foreseeable future. This development will also be required for meeting the recycling target of the EU of 65 % by 2030 (together with a landfilling rate of only 10 %) [3]. The trend towards recycling is presently also supported by the price development, with an increase of about 25 % from 2019 to 2021 [1].

Producers Starting Large Chemical Recycling Projects

The currently predominant mechanical recycling operations will therefore need to be supplemented with chemical processes, for which several important polymer producers have announced large projects [4]. It is important here that processes targeted at direct production of monomers or at least valuable intermediates for monomer production have especially high requirements for cleanliness and composition of the respective raw material [5]. Targeted collection and pre-sorting will therefore very likely remain a necessity, and the decision about the chosen recycling path should be based on objective criteria such as energy demand and emissions in the process. It is, however, clear that the decarbonization of the polymer industry necessary for protecting the climate requires a shift in the raw material base for monomer production from natural oil and gas (as well as coal, at least in China) towards plastic waste and renewable sources.

Dedicated Product Lines for Recyclates

Regarding the latter, some of the major PP producers have already defined dedicated product lines – Borcycle (for recyclates) and Bornewables (for production from regenerative sources) at Borealis, Circulen at LyondellBasell, Trucircle at Sabic and Exxtend at ExxonMobil. The definitions are somewhat different, but both have the same two targets: international certification such as via ISCC, which verifies the material balance and raw materials source, and guarantees identical performance. The latter was proven several times in recent years, for example by Greiner Packaging. Here, Bornewables grades were processed in thin-wall injection molding with in-mold labeling for certification first (**Fig. 3**), and a joint project with Emmi for "Caffè Latte" cups has since been started on that basis, but also a Circulen grade has been successfully tested for coffee capsules.

The possibility of recycling should, however, already be considered when designing articles and assemblies based on PP [6]. A reduction of material diversity is required here, and there are some encouraging examples of this. The "Pure Line" films of the packaging producer Südpack received the German packaging award in the sustainability category. These are based on mono-materials and are consequently easy to recycle, but still show the typical packaging properties (such as barrier against oxygen and carbon dioxide). One step further was taken by Radici in designing single-use protective overalls: Radipeople Eco is the first fully recyclable protective gear from 100 % polypropylene, as the fabric, coating, zipper and even sewing thread are made from this single material (**Fig. 4**).

Why Price Development Does Not Affect Sales Volumes

In the period between December 2020 and May 2021 the price for standard PP in Western Europe increased by 80 to 100 % and is now in the range of 2 EUR/kg [1]. As the development has taken place in parallel for

Fig. 3. Prototype cup for yogurt packaging with in-mold labeling, produced from bio-circular PP Copolymer Bornewables by Borealis.

© Greiner Packaging

Fig. 4. The single-use protective overall Radipeople Eco from 100 % polypropylene. © Radici

nearly all plastic types, this has neither retarded growth nor resulted in substitution. However, the already mentioned trend towards increased use of recyclates has clearly been supported, and the rising prices in this segment, too, are fueling the expansion of the production plant volumes. Here, too, cooperations are considered in many cases, frequently between polymer producers and disposal and sorting specialists. Examples are the acquisition of QCP by LyondellBasell and Suez, or the joint pilot plant of Borealis und Tomra established in Germany. A high degree of automation, such as sorting using infrared sensors, and the adaptation of grinding and purification to the base material allow the production of recyclates of much better quality than in earlier years.

Hardly Any Spectacular Innovations, as the Spectrum Is Already Broad

In the development of primary produced PP materials the number of spectacular innovations is limited for several reasons. First, a transition to catalysts systems without phthalates has become necessary in recent years, and, second, the available property spectrum is already very broad today. **Figure 5** shows this for the mechanical performance of PP copolymers with ethylene. It should be considered here that the E-modulus range for PP homopolymers extends up to more than 2 GPa (2000 MPa), and for compounds and composites to more than 13 GPa.

For random copolymers, RACOs, there is a new review [7] which highlights the possibilities for varying these transparent materials by changes in »

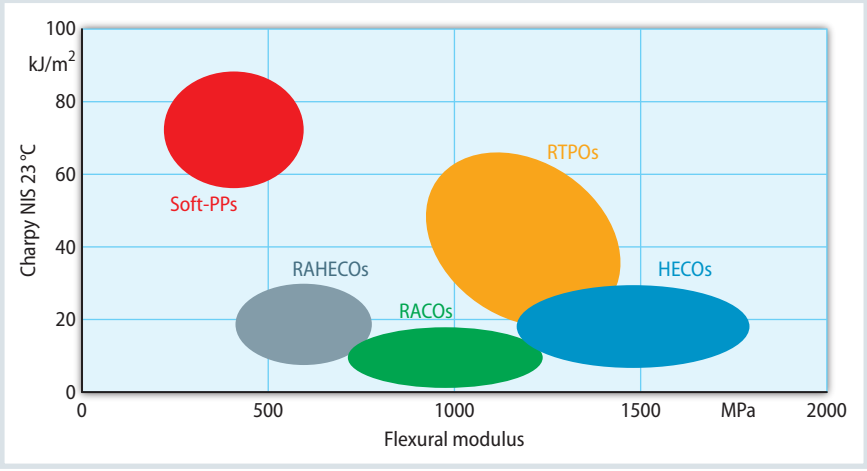

Fig. 5. Mechanical profile of different classes of ethylene-propylene copolymers (HECOs – heterophasic copolymers, RTPOs – reactor-based thermoplastic PO-elastomers, RACOs – random copolymers, RAHECOs – random-heterophasic copolymers, softPPs – special copolymers like Adflex or Borsoft). Source: Borealis; graphic: © Hanser

the catalyst system and multimodal distribution of comonomer or molecular weight. A recent example of this is the bimodal BorPure RF777MO of Borealis for bottle closures with film hinges (MFR 13 g/10 min., **Fig. 6**), which excels through shorter cycle times and improved toughness. RACOs are also playing an important role in medical technology, such as Purell RP375R of LyondellBasell (MFR 25 g/10 min.) with its resistance against sterilization by γ- or electron irradiation.

For soft PP copolymers with RACO-matrix and C2C3-elastomer, RAHECOs and SoftPPs, quite different products can be found in the market today. Depending on modulus and transparency, these are used in the technical area of roofing membranes and thermoplastic cable insulation, but also for pharmaceutical packaging as films or blow-molded containers. There are hardly new developments right now, but the foreseeable need to replace plasticized PVC could generate new dynamics in this field.

Classical high-impact copolymers, HECOs and RTPOs, have an extremely wide application area, both as pure materials and in the formulation of compounds with reinforcements and fibers. The full design spectrum can only be realized with modern production plants consisting of two or more reactors, which can be controlled individually, and a catalyst with a long "lifespan". "Post-phthalate"-types are equally well suited here, as can be seen from patents [8] and publications [9]. But also products based on renewable resources have been tested, such as BorECO BH381MO of Borealis (MFR 35 g/10 min.) or Flowpact FPC45 of Sabic (MFR 45 g/10 min.) – both well suited for thin-wall injection molding and food contact.

E-Mobility Pushes Compounds and Composites

Especially the automotive sector has proven a source of constant inspiration for innovation in recent years, and »

Fig. 6. Cosmetics closure with film hinge from BorPure RF777MO. © Borealis

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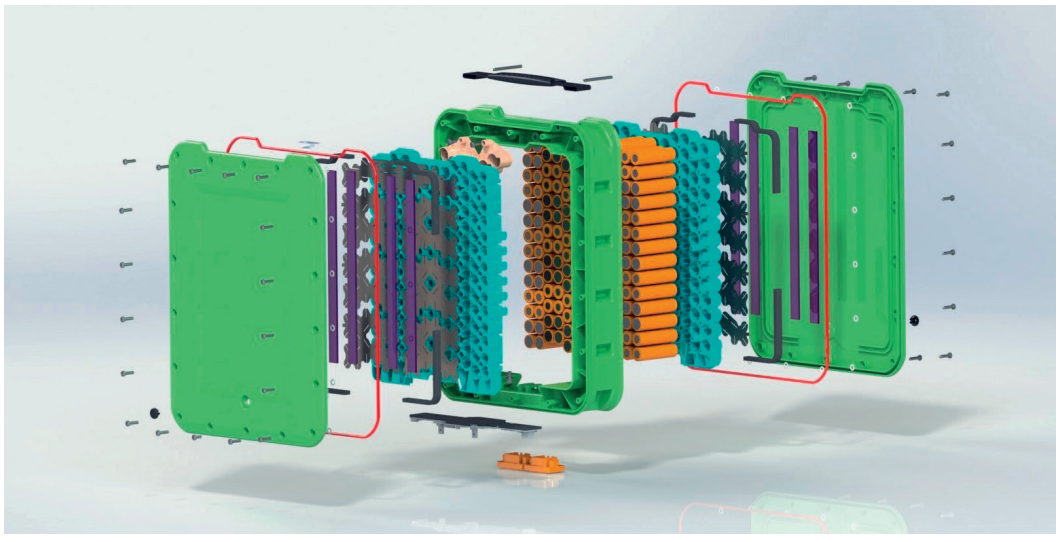

Fig. 7. The new GreenPack 2.0, 2nd generation battery-pack system by Ansmann in a casing from flame retardant PP composites by Borealis. © Ansmann

the trend towards electromobility has further heightened the requirements regarding weight reduction [10]. In terms of mechanical strength, the focus is clearly on long glass fiber composites (PP-LGF), which require special processing technique but yield the highest elastic modulus. For extreme requirements these can be combined with unidirectional glass-fiber tapes, as demonstrated by Sabic with Stamax for the toolboxes of trucks, for example.

But even without further reinforcement, Fibremod GB416LF of Borealis with 40 % glass fibers, for example, achieves a tensile modulus of more than 10 GPa, allowing novel designs: in the new Volkswagen Multivan T7 this enables the largest so far realized tailgate structure from PP-LGF alone, contributing significantly to design freedom and weight reduction. A key advantage is the good surface quality, eliminating the need for post-treatment or painting. This combination is clearly trending, as also shown by the use of Celstran LFT of Celanese in the VW ID.3 [11].

But this is just one of many positive contributions, which PP can deliver for E-mobility. At Ansmann AG, for example, the second generation of the GreenPack rechargable battery system is presently being developed (**Fig. 7**), for which Borealis has designed a halogen-free flame-retardant compound with glass fibers. The combination of electrical insulation and fire resistance with high mechanical strength and warpage-free processing is achieved here with a special polymer base and 20 to 30 % of glass fibers. For these exchangeable battery backs, dimensional stability even at elevated temperatures and drop resistance are decisive. Compared to polyamide or polycarbonate/ABS blends, the production carbon footprint is also reduced massively.

Recyclates Also Used in Automotive Applications

Compounds are also playing an important role for mechanical recycling, where requirements are becoming more diverse and complex. Borealis Brazil has recently presented Borcycle ME1490SYB, a compound with 47 % recyclate and 10 % talc for automotive applications. The grade has been approved by Stellantis and is used in the new Fiat Strada, a bestseller in the small pickup category in the South American market (**Fig. 8**).

So far, the use of recyclate in cars has been mostly limited to exterior applications, as the demands on appearance and emissions for interior use hardly seemed accessible. Better sorting and cleaning in combination with targeted post-treatment allows innovations also here, as in the case of Borcycle EE1300SY, which offers bright colors, high toughness and scratch resistance at a content of 30 % recycled polymer – and even fulfills low emission and odor levels. With this, the pathway towards "renewable plastics in the car" seems already very realistic. ■

Fig. 8. Fiat Strada, a pickup with components from Borcycle ME1490SYB. © Stellantis