Polypropylene (PP)

Growth through Sustainability and Technical Specialization

Higher mechanical properties with lower density make polypropylene an interesting alternative to polyethylene for a large number of applications. New catalysts and production processes offer a wider range of products. Monolayer films and recycling are under development. In the meantime, China consumes almost one-third of the PP produced worldwide.

The ReOil pilot plant at OMV AG in Schwechat, Austria, converts plastic wastes with poor recycling properties into cracker raw material, and hence into potential monomers (© OMV)

With a global market volume of around 74 million t in 2018, polypropylene is the most widely used plastic in the world, in total surpassed only by the different types of polyethylene (PE, approx. 94 million t). **Figure 1** gives an overview of the further breakdown of the global plastics market with its volume of around 300 million t per year. This is due not least to the vast range of types and applications, and the trend away from standard grades towards specialties for technical application fields is continuing. The average growth rate of around 5 % p.a. is higher than for other standard plastics. While the growth in Europe is slightly below 2 %, the market focus is clearly on Asia, and here in particular on China, which already today consumes almost one-third of the PP produced worldwide. By contrast with PE, however, the production volume is increasing more slowly than the consumption, and this could lead to supply shortages in the coming years [1]. As a result, the prices of PE and PP would appear to be gradually matching each other. What would appear at first sight to be good for the producers of polymers could, in the medium term, prove to be a disadvantage for them. The

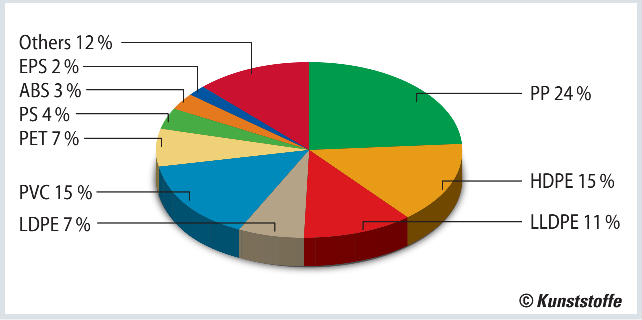

Fig. 1. Global production of different polymers 2018 (source: data from [1] and other sources)

substitution of PP with other materials, in particular other polymers such as PE and polyethylene terephthalate (PET), could become attractive.

Apart from this cost-driven substitution, PP could also be substituted for other reasons. "Plastic" as a packaging material is regarded negatively by many consumers, and the search for alternatives has already begun. This should be seen in the plastics industry as an incentive to devote even more attention to topics such as sustainability and environmental protection. Despite the strong growth, the real market share of biopolymers is still only in the order of 1% [2]. Of these, more than half are non-biologically degradable types, such as bio-PE or bio-PET. It is nevertheless important to remember that a return to traditional materials such as metal, glass or cardboard generally increases the weight and enlarges the CO_2 footprint [3].

Catalyst + Process Technology = Product Diversity

Practically all PP suppliers emphasize the importance of matching production process and catalyst system. It defines not only the breadth of the possible product range, but also the productivity, process economy and the purity of the products with respect to emissions and catalyst residues. Of the catalysts, Ziegler-Natta types continue to dominate, where for example W.R. Grace & Co.-Conn., Columbia, MD/USA, offer Consista catalysts as an example of types without phthalates as internal donors [4]. At least in Europe, a complete changeover to these catalyst types appears to be in process; they are actively advertised, for example, also by Borealis AG, Vienna, Austria, and LyondellBasell Industries N.V., Rotterdam, Netherlands. In these times of globalization, other world regions can almost certainly be expected to follow. A global view of the polymerization processes being employed shows that the substitution of older plants is already well advanced. Bulk and hybrid processes, such as Spheripol and Spherizone from LyondellBasell or Borstar from Borealis account for around 53% of the production volume, while pure gas phase processes such as Unipol from Grace or Novolen from Lummus account for roughly 44% [5]. Slurry processes with solvents are still used for special purposes, such as high-purity products, but have only just 3% market share.

In the field of material design, a new edition of the "Polypropylene Handbook" written by Prof. Karger-Kocsis who died in December last year has been published as a standard reference work [6]. The main aspects of the current structure and use of PP materials are presented here in ten chapters, starting from the influence of the polymer chain structure through to composites with fibers and fillers. **Figure 2** shows an example from the chapter on copolymers in which the use of higher α-olefins such as butene and hexene as comonomers is also discussed. Newer catalysts, in particular metallocene types, will make this even more attractive. The diagram shows the differences in the development of the soluble contents with increasing comonomer content that represents a problem for the "normal" statistical copolymers with ethylene as it limits, for example, the use in the food sector. »

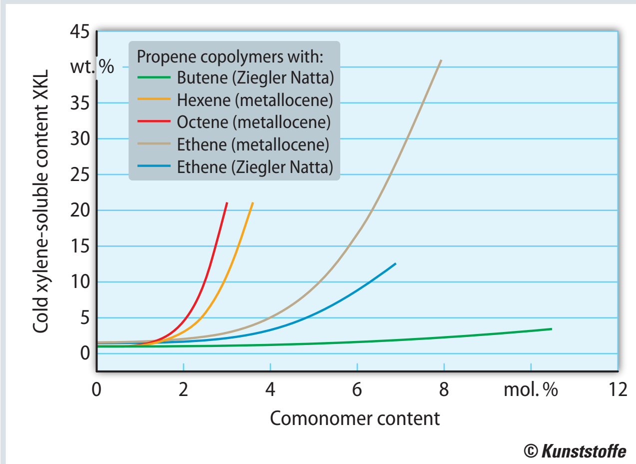

Fig. 2. Influence of type and volume of comonomers on the xylene-soluble contents of random copolymers (source: simplified representation from [4])

Consumer- and Environment-Friendly

Stand-up pouches (SUP) for foodstuff, pet food or detergents is one of the most rapidly growing PP applications of recent years. Due to their complex multi-layer structure, they are proving to be difficult to recycle. A solution here could be a change-over to a mono-material system with a combination of different PP-based materials. **Figure 3** shows an example of a laminate comprising a biaxially oriented PP film (BOPP) and a cast film of PP. The advantage of this combination lies in the very good availability of BOPP, even with high-barrier properties, and the broad spectrum of properties of a PP cast film. The most important properties of PP include dimensional stability at high temperatures (sterilization, hot filling), mechanical strength (high rigidity with high toughness) and very low sealing temperatures.

Such mono-materials can generally only be produced, however, with special PP copolymers. Impact copolymers such as the transparent BC918CF or the extremely tough BD212CF (both from Borealis) are used for the mechanically most relevant main layer. A BOPP layer provides a very good water vapor barrier. Terpolymers such as TD315BF (Borealis) are used in the sealing layer in order to ensure high efficiency and leak-tightness of the packaging. PE plastomers such as Engage (Dow Chemical) or Queo (Borealis) enhance the toughness and extend the sealing window. They can be added in fractions of up to 10 % referred to the total structure without impairing the recycling. If a stronger oxygen and/or CO_2 barrier is required, EVOHs can be added at rates of up to 5 % of the total weight or other barrier layers (preferably SiO_2) can be employed. Such films are also suitable for other flexible packagings, such as tubular bags or lid films. "Design for Recycling" is definitely a current demand that should be laid down in codes of conduct [7]. Recycling thus starts at the beginning of the added-value chain and not only at the end.

Comfort is an important aspect with polymer fibers. PP types for the melt-blown process with improved processability allow softer nonwovens to be produced (**Fig. 4**), also in the typical SMS (spunbonded/meltblown/spunbonded) constructions for hygiene or filtration applications. PP homopolymers with even higher melt flow index (MFI) than to date are now available, such as PP514M12 from Sabic and HL912FB from Borealis. Both products are based on phthalate-free catalysts and have low emissions; HL912FB can also be processed defect-free at higher temperatures.

Beverages and Medical Technology, Quick and Clean

A broad field of application for polypropylene are beverage closures, whereby the currently prevailing call for a permanent connection between bottle and closure will give preference to hinge-type closures (**Fig. 5**). The demands made on the material here, such as rigidity for stability and low material input, good impact resistance, resistance to shrinkage and short production cycle times can only be met using specially developed copolymers. Materials for beverage bottle closures of course also have to satisfy the requirements for food contact and for odor and taste neutrality. Here Borealis has brought a type onto the market with RF777MO combining the existing mechanical and organoleptic properties with improved flow properties (MFI 20) and

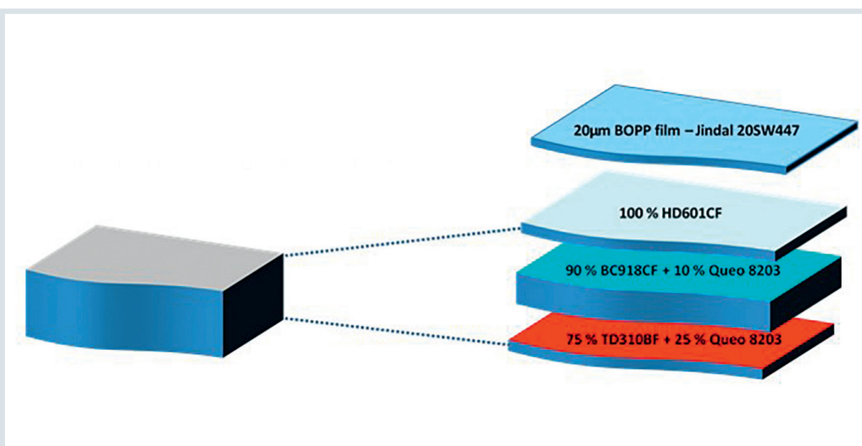

Fig. 3. Layer structure of a flexible film for stand-up pouches of PP-based materials (© Borealis)

Fig. 4. Very soft nonwovens of modern melt-blown PP grades (© Sabic)

Fig. 5. The PP grade RF777MO is particularly suitable for flip-flop beverage bottle closures with hinge function due to its improved flow properties (© Borealis)

Fig. 6. Precision pipette tips of electrically conductive Bormed BJ868MO for medical technology (© Premix Group)

the Borealis nucleation technology (BNT). The reduction in cycle time of up to 10% lowers the processing temperature and energy consumption by up to 5%. This special nucleation also results in dimensional stability, irrespective of the pigments employed. It is therefore a preferred material for use in flip-flop beverage bottle closures, but also in other food packagings, household goods and bottles (ISBM).

In the field of medical technology, the demands are also becoming increasingly complex, and apart from purity and sterilizability, also the precise reproduction of fine component details in injection molding is important. High-flowing copolymer types such as Bormed BJ868MO that combines an MFI of 70 g/10 min with high rigidity and impact strength extend the scope for special applications here, such as modern diagnostic systems (**Fig. 6**). For random copolymers with resistance to electron or gamma radiation used for sterilization, LyondellBasell has introduced a new product with improved flow properties in Purell RP375R. Transparency and low processing temperature simplify the application here.

Various Solutions for Lighter Motor Vehicles

The automotive sector is going through a time of upheaval: new drive concepts and ever stricter emissions regulations are heightening the demand for lighter materials and components. In recent years, the percentage of mineral reinforcing agents has been reduced, and hence the material density lowered. At the same time, efforts have been made to reduce the wall thickness of the parts, an approach that calls for materials with better flow properties and higher »

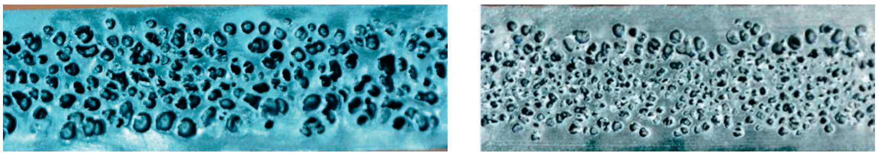

Fig. 7. Foam structure as the basis for mechanical strength and surface quality: finer cells are obtained through a modification of polymer and blowing agent (© Borealis)

rigidity, and hence normally with higher percentages of reinforcing agents. Increasing attention is also being turned, however, to thermoplastic foam injection molding in order to achieve not only good internal part properties, but also a high surface quality. The examples of the foam structure in **Figure 7**, however, show that in addition to the choice of polymer and the process design, great importance also has to be attached to the choice of blowing agent.

The interiors of modern cars are dominated by low-emission and odor-neutral polymer types with very high scratch resistance and surface quality. Modified polymers and lower filler content reduce weight and complexity, as illustrated by the new Skoda Scala (**Fig. 8**). Door panels, glove compartment, center console and instrument panel demonstrate the versatility of modern PP materials [8]. One of the main areas of concern for the exterior is an improved paintability. PP types such as PPC 8500 from Sabic and Daplen ED113AE from Borealis combine primer-less painting with high rigidity and low shrinkage. More complex part constructions and increasing numbers of integrated sensors (driver assistance systems and autonomous driving) necessitate materials with good flow properties and minimum coefficient of linear expansion. Apart from classic applications, such as bumpers, sills and spoilers, whole tailgate modules are being produced from PP in the meantime, with frame structures of long glass fiber-reinforced material and a painted outer skin of mineral-reinforced PP.

If an even higher elastic modulus is required, e.g. in order to substitute polyamide or metal, then glass fibers continue to be the standard for reinforcement. The Fibremod portfolio from Borealis extends up to 40 wt.% glass fiber for Fibremod GB477HP and even 50 wt.% for Fibremod GD577SF that is in widespread use, for example, for front-end modules. A combination with sheathed metal or organosheets based on woven long fibers can further increase the rigidity and generally replace metal and massively reduce component weight. Carbon fibers [9] are to be preferred for high-end reinforcement that, for example for CB201SY, offer a modulus level of around 10,000 MPa. These materials enable modern electric cars such as the NIO ES8 (**Fig. 9**) to achieve greater ranges and better efficiency.

On the Road to Sustainability

Foam molding is an important topic not only in the automotive sector, as evidenced by the success of the EcoCore process from Bockatech Ltd., Huntingdon, Great Britain, in cooperation with Borealis. This foam injection molding process allows particularly light and thermally stable products to be manufactured. The most important product is currently the re-usable "Corretto" coffee cup (**Fig. 8**) which, thanks to the use of 100 % PP as material, is also extremely easy to recycle. It is an inexpensive, break-proof alternative to the currently widely criticized disposable cups made from coated cardboard. In cooperation with Borealis, the types BH381MO (high-rigidity copolymer) and Daploy WB140HMS (long chain-branched homopolymer) were selected for production by foam injection molding that allows low material input and short process cycle times. Due to their high strength, packagings produced in this way are suitable for e.g. deposit and return systems that have proved to be successful with their recovery rates of up to 94 %.

Sustainability and recycling are becoming general necessities in the plastics industry. PP has good chances here thanks to its low specific energy consumption during production, low density and good long-term stability. Several leading manufacturers have recently launched initiatives for mechanical recycling. Total has taken over the French recycler Synova (20 kt/a), Borealis has built up a volume of 70 kt/a with the two companies mtm plastics, Niedergebra, Germany, and Ecoplast Kunststoffrecycling Ges.m.b.H, Wildon, Austria, and Lyondell-Basell and the Suez Group have completed the joint takeover of the

Fig. 8. The interior of the new Skoda Scala unites various assemblies based on the same polymer concept, and always with low emissions (© Skoda Auto)

Service

References & Digital Version

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German Version

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Fig. 9. The electric SUV NIO ES8 with components of Fibremod CB201SY (© NIO)

Dutch plastics recycler Quality Circular Polymers (QCP) that processes plastic wastes into PE and PP reclaim.

A massive expansion of mechanical recycling as demanded by national and supra-national legislators [10], however, also necessitates significant growth in the fields of application of the materials thus produced. Here again, it is a question of convincing the ultimate user. Designers and processors also have to know that modern PP reclaim such as the new Borcycle MF1981SY is suitable for far more than just park benches. Recent plastic recycling figures show Europe to be on the right road, but with still significant differences between the member states [11].

Chemical recycling is also seen as a complementary solution [12] in order to no longer have to dump or incinerate in future. Here, for example, Sabic is working together with the British company Plastic Energy on the production of "Tacoil" as the basis for monomer production. Borealis is cooperating with the Austrian company OMV that is already producing raw material for the cracker on an expanded pilot plant for its ReOil process with a capacity of 100 kg per hour (**Title figure**). Other companies, such as Braskem, are employing in-house developments or, like LyondellBasell, are working together with research institutes. In the medium term, such processes could become a major source of raw materials. ■

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Fig. 10. Re-usable and recyclable "Corretto" coffee cup produced using the Bockatech EcoCore process (© Bockatech)