Alternative Recycling Approaches for the Recovery of Packaging Waste

From Yellow Bags to New Fibers

Currently, PET and PP from heavily contaminated and heterogeneous mixed waste from dual systems are either processed into low-quality recyclates or incinerated. Alternative approaches such as solvent-based recycling or solvolysis could be an important addition to mechanical processing. The Fraunhofer Cluster Circular Plastic Economy is investigating these technologies to enable the use of high-quality recyclates in a wide range of applications.

From mixed plastic waste to recycled PP film and PP multifilament yarn.
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The widespread use of disposable products made of polypropylene (PP) and polyethylene terephthalate (PET) in the packaging sector, as well as the steadily increasing global demand of these materials, are also leading to growing waste streams [1]. Solely in the European Union (EU), 54 million t of plastics were produced in 2023, of which just under 5 % was PET and 16 % was PP [2].

The largest area of application (39 %) for plastics is in short-living packaging materials. In 2022, 18.5 million t of post-consumer packaging waste were generated, of which just under 38 % was recycled, 45 % was used for energy recovery and 17 % was landfilled. To address this challenge of plastic waste accumulation, the EU has taken initial measures with the PPWR (Packaging and Packaging Waste Regulation). The regulation stipulates mandatory recycling quotes, for example, 55 % of plastic packaging waste needs to be recycled by 2030. However, in order to increase the current recycling rate, open-loop concepts such as using recyclates from packaging waste in textiles should be considered.

Complementary Recycling Methods under Scrutiny

High-quality recycling in the packaging sector is currently hampered by the lack of recycling methods available on the market and the high-quality requirements of the packaging sector. The infrastructure for complementary recycling pro-

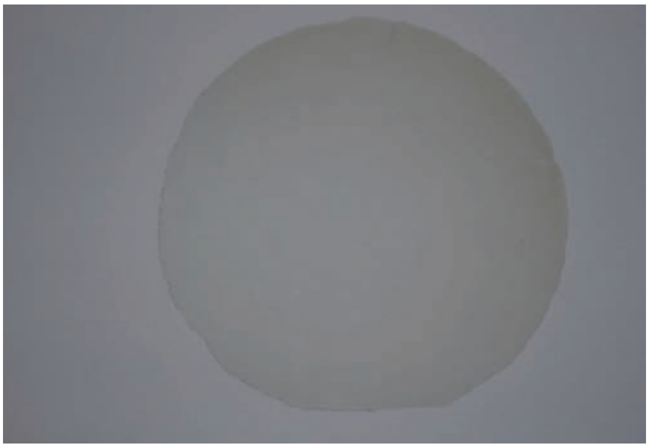

Fig. 1. Film made from 100 % recycled PP. © Fraunhofer IVV

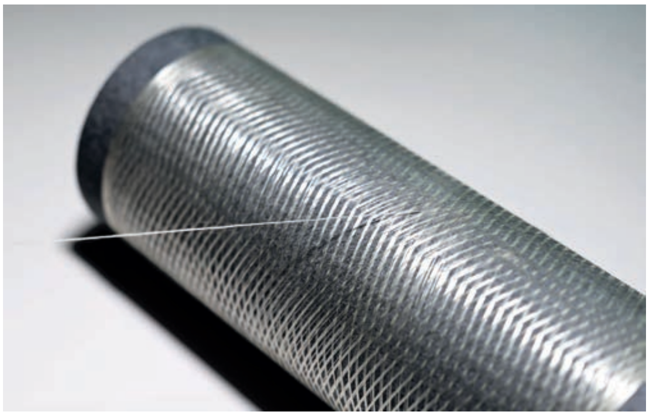

Fig. 2. Manufactured multifilament yarn made from 100 % recycled PP. © Fraunhofer IVV

cesses such as solvent-based and chemical recycling processes must first be developed.

The Fraunhofer Cluster Circular Plastic Economy (CCPE) researches the entire value chain for the circular economy of plastics – from the development of new polymers based on bio-based and recycled raw materials to the development of new business models. As part of the CCPE project "Circular textile Flat Textiles", complementary recycling processes to mechanical methods were developed for previously non-recyclable PP and PET-containing waste streams, and the suitability of the recycled materials obtained, for example for use as geotextiles and films for roofing underlayments, was assessed in technical trials.

Recyclate	Titer [dtex]	Stiffness [cN/tex]	Elastic modulus [cN/tex]	Elongation at break [%]
$rPP_{32f55dtex}$	1.73 ± 0.1	42.1 ± 3.6	454.1 ± 41.9	58.4 ± 10.4
$rPET_{48f46dtex}$	0.95 ± 0.1	45.1 ± 5.7	774.7 ± 80.9	11.9 ± 2.5

Table 1. Tensile properties (single filaments) of the post-stretched rPP and rPET yarns, Favimat testing machine. Source: Fraunhofer CCPE

High-Quality rPP Fibers from Solvent-Based Recycling

The Fraunhofer Institute for Process Engineering and Packaging (IVV) investigated solvent-based recycling for a PP-rich material stream based on a mixed post-consumer plastic film fraction. This technology selectively dissolves PP, removing contaminants such as non-polyolefin plastics, old additives, printing inks and paper. The result is a recyclate that is nearly pure.

To demonstrate the recyclate's purity, a film was produced, which showed no specks or particles and is only slightly discolored (**Fig. 1**). Compared with post-consumer PP recyclates from film waste available on the market, the recyclates obtained via the dissolution process shows a significantly lower degree of contamination.

For mechanical processes, the waste material generally has to be very pure and contain only a few contaminants. The selective dissolution process, however, can handle a high degree of contamination. Although the project's waste stream contained 67 % foreign plastics (10 % PE, 7 % PS, 10 % PA, 23 % PET, 11 % insoluble non-plastics, 6 % other), the polyolefin (PO) fraction could be purified effectively. The process succeeded in reducing both the non-PO plastics and the PE content by 80 %, leaving the residual PE content below 2 %.

The rPP obtained was then spun into a yarn with 32 filaments at the Fraunhofer Institute for Applied Polymer Research (IAP) (**Fig. 2**). The flow and stretching properties of the recycled material enabled stable control of the spinning process and high stretchability of the filaments down to the microfiber range. In the post-stretching process, the sample spools were stretched by a factor of 1.6 and prepared for tensile testing.

High-Quality rPET from the Solvolysis Process

The PET waste stream was treated by solvolysis at the Fraunhofer Institute for Chemical Technology (ICT). The waste fraction originated from the mixed PET 90/10 fraction (**Fig. 3**). At the current stage of the project, most of this is incinerated and mechanically recycled only to a limited extent due to excessive contamination. The fraction consisted of 87 % PET. The remaining 13 % was PP, PVC, paper, aluminum, etc.

In solvolysis, the plastics are specifically broken down into their respective monomers or monomer derivatives using a depolymerization reagent. This process is particularly suitable

Fig. 3. Shredded post-consumer PET mixed fraction. © Fraunhofer ICT

for polyaddition and polycondensation polymers. In the case of PET, the process of glycolysis, a special case of solvolysis using ethylene glycol, was applied.

The PET fraction was used without any further pre-treatment. In the process, PET is broken down into bishydroxyethyl terephthalate (BHET) as the monomer (**Fig. 4**). The PET waste was almost completely converted.

All other components of the waste fraction were filtered out as insoluble material after the reaction. One of the advantages of this process is that the recycled monomer rBHET can be easily recrystallized. This allows for easy separation of foreign substances and additives, and the monomer can be isolated with good purity and moderate yield.

The recrystallized rBHET was then converted into high-quality rPET for textile applications at the Fraunhofer Institute for Applied Polymer Research (IAP). The rPET was processed into multifilament yarn with 48 filaments on a pilot melt spinning line (**Fig. 5**). This was achieved with very good spinning stability and high stretchability of the material down to the microfiber range. The yarn was then stretched on a stretching machine with a stretch factor of 1.8 and its mechanical properties were examined.

Fiber Properties and Application Potential

The fiber samples produced exhibit very good mechanical properties for textile applications. The fine rPP and rPET single filaments of the yarns have a property profile (**Table 1**) that makes them suitable for a wide range of applications.

The quality of the recycled materials also allows them to be processed directly into spunbonded nonwovens. This manufacturing process places almost identical demands on the material as fiber production using the melt spinning process. This could open up further high-revenue markets with products such as

Fig. 4. Recycled bishydroxyethyl terephthalate from the PET mixed fraction. © Fraunhofer ICT

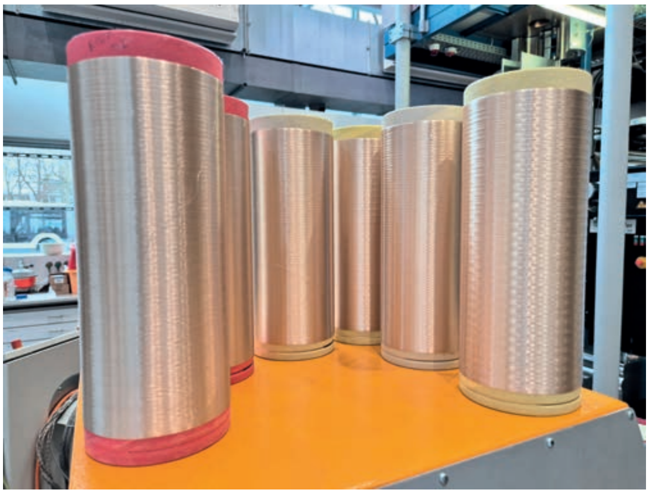

Fig. 5. Manufactured multifilament yarn made from 100 % recycled PET. © Fraunhofer IAP

roofing underlayments or geotextiles. In addition, the rPP yarn is suitable for applications such as filters, carpets, artificial turf or awnings. The rPET yarn, on the other hand, could be used to manufacture clothing, home textiles, tent fabrics or upholstery fabrics for furniture and the automotive industry.

Conclusion and Outlook

The selective dissolution process for PP makes it possible to effectively separate impurities such as foreign substances or additives and obtain a high-quality recyclate that is almost as good as virgin material. The technology thus creates the conditions for a true circular economy and a more sustainable future for the plastics industry.

Solvolysis has proven to be a suitable method for the recycling of PET packaging waste. It enables the recovery of the monomer BHET. The robustness of the process is crucial here. Project work carried out by Fraunhofer CCPE has shown that contaminated waste streams do not impair process stability. This makes solvolysis an ideal complementary technology to mechanical recycling of PET, which relies on clean material streams.

The developments at CCPE show that only through the integration of advanced processes such as solvent-based and chemical recycling a true circular economy with optimized resource utilization can be achieved. Targeted support from industry and politics is now needed to bring the technologies to market maturity and ensure a sustainable future for plastics. ■

Info

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References

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