Plastic is considered an all-rounder. Thanks to its versatility, it has proven to be the material of choice for a large number of applications. Polymers enable many products and packaging types that cannot be achieved with alternative materials such as wood, paper, stone or metal. They are lightweight, inexpensive, easy to shape and durable.

The longevity has not only advantages. It has become a global challenge to protect our natural environment from the damage caused to it when plastic products are carelessly disposed of.

Environmentally conscious citizens have brought this topic to all our attention. Since then, many possibilities have been discussed as to how plastic waste can be reduced.

Solutions may be, for example, avoiding waste or improving recycling processes.

Plastics that are intentionally or unintentionally released into our environment pose a serious problem. A risk that can only be overcome through global cooperation between politicians, industry leaders and consumers.

Used plastic can be recycled mechanically, energetically or chemically. Energy recycling is the energy recover process utilizing energy, usually by converting it into e.g. electricity. In chemical recycling, monomers or petrochemical raw materials are recovered and used to manufacture new goods. The third option is mechanical recycling, in which used plastic fractions are converted by extrusion into recylcate. Post-Consumer-Recycling (PCR) refers to the process of manufacturing used plastics. It includes collection, sorting and subsequent extrusion.

PIR (Post-Industrial-Resin) is plastic waste from industrial processes e.g. large packaging.

This brochure presents Lifocolor products that are used at various stages of the thermoplastics recycling process. They help to improve the material qualities of PCRs and thus ensure their recyclability.

"Plastics that enter nature are a serious problem. Only through the global interaction of politics, industry and consumers it can be mastered."
**Recycling companies** want solutions to produce standardised PCRs with reproducible quality from varying batches of used plastics. They are dependent on the colours that ensure the sorting capability of the plastics.

**Plastics processors** are looking for possibilities to increase the proportion of PCR in their products without affecting their quality. They rely on recyclable additives to permanently meet the requirements for colour, stability and function.

For these areas in the recycling process, Lifocolor offers special products. LifoCycle products optimize and support the recycling process.
The recycling industry places high demands on the plastic raw materials used. All contributions to the supply chain are measured by their impact on the recycling process. This process is repeated several times. The associated thermal degradation of plastics creates two necessities for recyclers and processors:

1. The physical properties of the initial polymer before the preceding thermal stress are restored by modifying the process and adding additives. In addition, functions such as content protection or sliding properties are to be guaranteed.

2. Special colour masterbatches were developed which are both suitable for recyclates and for multiple recycling processes.

Two different options can be considered as carriers for the colourants and additives used in PCR applications:

**Option 1: PCR Carrier Systems**

With this option, the market requirement to guarantee the proportion of recylcate at > 95% or better 100% recylcate is taken into account.

Lifocolor currently offers PCR carrier systems for PET, PP and PE masterbatches.

**Option 2: Virgin Polymer Carrier Systems**

The use of virgin material as a carrier for LifoCycle products is associated with consistently high masterbatch quality and precise control of the physical properties.

Virgin polymer carrier systems are particularly suitable when new goods destined for the recycling have to be equipped. This also applies if defined quality masterbatches are to be used in PCR material.

The amount of virgin material that is introduced into a recycled product by such a masterbatch is usually between 0.1% and 2%. This has only a minimal effect on the status of the end product as a > 95% recycling product.
Solutions for Manufacturing

Pellet Size and Dosage

Depending on the process and machine technology, different pellet sizes are used by processors. Criteria that play a role in the selection of the pellet size are dosing quantity, segregation effects, colouring costs and dosing technology.

In volumetric dosing systems, larger pellets are preferred because they are least segregated during conveying in the hopper. Small pellet sizes allow smaller dosages, but usually require separate gravimetric dosing to achieve the greatest possible homogenisation. They favour good statistical pre-distribution during feeding. The lower the dosage, the lower the colouring cost.

Further advantages of a low dosage are:

- Less carrier material input thanks to masterbatch
- Better melting behaviour
- Better statistical distribution in the PCR

Lifocolor offers the following four pellet shapes:

<table>
<thead>
<tr>
<th>Size</th>
<th>Dimensions (mm)</th>
<th>Pellet/g masterbatch</th>
<th>Weight of granules</th>
<th>Volume</th>
<th>Granulation method</th>
</tr>
</thead>
<tbody>
<tr>
<td>micro</td>
<td>1,3</td>
<td>~580</td>
<td>1,7 mg</td>
<td>1,2 mm³</td>
<td>UWP</td>
</tr>
<tr>
<td>micro</td>
<td>Ø 1,8; L: 1,7</td>
<td>~175</td>
<td>6 mg</td>
<td>4 mm³</td>
<td>Strand</td>
</tr>
<tr>
<td>normal</td>
<td>Ø 2,1; L: 3,0</td>
<td>~63</td>
<td>15 mg</td>
<td>10 mm³</td>
<td>Strand</td>
</tr>
<tr>
<td>normal</td>
<td>3,5</td>
<td>~30</td>
<td>32 mg</td>
<td>22 mm³</td>
<td>UWP</td>
</tr>
</tbody>
</table>
SOLUTIONS FOR COLOURING

The Concept

LifoCycle are recyclable masterbatches for polyester (rPET) and polyolefins. They are available on the basis of PCR carriers or on the basis of virgin polymer. Recyclable masterbatches are characterised by the fact that they outlast a large number of recycling runs without noticeable loss in colour. The more stable a colourant is, the less degradation products can occur and accumulate in PCR systems.

Plaques coloured with LifoCycle masterbatch after 1, 5 and 10 extrusion runs

Testing different colourants for suitability in the recycling process

The masterbatches contain carrier systems that are specially adapted to the PCR polymer. This ensures that no additional components other than the colourant and carrier-identical components are introduced into the colourant recylcate. This supports sustainable recycling. Plastics or recycled materials which have been coloured with LifoCycle masterbatches can easily be reprocessed by the recycler, as the ingredients are known and possible dilution losses can be compensated.

LifoCycle for PET

The LifoCycle PET range contains the most recyclable colourants, designed for the process temperatures of PET manufacturing. Due to their selected approval status, they can be used also for sensitive applications in many areas. The range comprises different colourants and is available both on the basis of an rPET carrier and on the basis of virgin PET. Depending on requirements, the products are available in different pellet sizes, so that dosages of up to 0.1% or less are possible. All colourants used have approvals for food applications. The virgin PET-based masterbatches are comprehensively suitable for sensitive applications such as food packaging or toys. In the case of rPET-based masterbatches, approval depends on the rPET type used.
SOLUTIONS FOR COLOURING

LifoCycle for PE and PP

The LifoCycle PE and PP ranges contain colourants which are selected for the processing temperatures of the polyolefins and are also suitable for sensitive applications due to their approval status. LifoCycle masterbatches are available on the basis of rPE or rPP and with virgin material as carrier. The products are available in different pellet sizes depending on the dosage requirements, so that dosages of up to 0.1% or less are possible (see page 6). All colourants used have comprehensive approvals for food applications. The masterbatches based on virgin polymer are comprehensively suitable for sensitive applications such as food packaging or toys. The approvals of PCR based masterbatches depend on the status of the used recyclate.

SOLUTIONS FOR STABILIZING

Additives for the rPET cycle

Due to the recycling economy, the demands placed on the additives used are growing:

- The additives are intended to increase the quality of the end products, especially in the main applications film and bottle.
- High-quality, thermo-stable additives that – once introduced into the material – can survive several recycling runs without losing their effect are required.

LifoCycle-Stab

With the aid of a combination of thermo-stable additive components, the product contributes to the UV stability of the end product (bottle or film). LifoCycle-Stab can also protect UV-sensitive products and contents in the appropriate dosage. With LifoCycle additives, Lifocolor provides special additives optimised for the PET recycling process. All products are available on rPET, aPET or crystallised PET carriers.

IN ADDITION TO LIFOCYCLE-STAB, we are also happy to develop other additives for you, such as lubricants and anti-block masterbatches.
SOLUTIONS FOR SORTING

NIR-detectable Masterbatches

Plastic sorting systems operate in the near infrared (NIR) range. Cameras and high-resolution NIR sensors can simultaneously sort plastic fractions from 2 to 12 millimetres by colour and polymer type. This technology works for all types of plastics. Polymers containing carbon black, for example, are an exception. Carbon black largely absorbs the radiation emitted by the testing device. This prevents signals from entering the detector of the NIR scanner. The result: The plastic remains unrecognised and the item is sorted incorrectly.

Required are now colourants that allow NIR reflection through the polymers and thus enable them to be detected. Lifocolour offers masterbatches for a variety of thermoplastics that ensure NIR detection. The coloured plastic products remain in the recycling loop.

<table>
<thead>
<tr>
<th>Article no.</th>
<th>Product Name</th>
<th>Suitable for</th>
</tr>
</thead>
<tbody>
<tr>
<td>15150</td>
<td>LIFOCOLOR-BLACK 3080 EST</td>
<td>PBT, PET</td>
</tr>
<tr>
<td>15155</td>
<td>LIFOCOLOR-BLACK 2080 SAN</td>
<td>SAN</td>
</tr>
<tr>
<td>15157</td>
<td>LIFOCOLOR-BLACK 2080 PETG</td>
<td>PET*, PETG</td>
</tr>
<tr>
<td>15158</td>
<td>LIFOCOLOR-BLACK 2080 PS</td>
<td>PS, PS-SB</td>
</tr>
<tr>
<td>15159</td>
<td>LIFOCOLOR-BLACK 2080 PC</td>
<td>PC</td>
</tr>
<tr>
<td>9005576</td>
<td>LIFOCOLOR-BLACK 9005576 PE</td>
<td>PE, PP</td>
</tr>
<tr>
<td>9005084</td>
<td>LIFOCOLOR-BLACK 9005084 PP</td>
<td>PP</td>
</tr>
</tbody>
</table>

* preliminary test required

Comparison of conventional black (left) to NIR-Black (right); hardly any visual difference to be noticed.

Beiersdorfer confirms the recycling capability of LIFOCOLOR BLACK 9005084 in a certificate.
SOLUTIONS FOR RECYCLERS AND PROCESSORS

LifoCycle Clear Masterbatches for the Production and Processing of High-Quality PCR

As the proportion of applications involving PCR is increasing, the properties of such materials need to be as close as possible to those of natural products. Processors expect the recyclers to deliver consistent quality that enables trouble-free processing without major process changes.

But even with optimised sorting processes, there are fluctuations in the colour, transparency and physical and mechanical properties of the PCRs.

Examples of different PCR qualities

The recyclers are expected to offer products of consistent quality that enable trouble-free processing without major process changes.

After addition of 1% LifoCycle Clear (left) and without LifoCycle Clear (right)

Advantages of the LifoCycle Clear Product Series in rPET

• It enables the recycler and the processor to achieve consistent colouration of its PCR type.

• Small pellet sizes allow low dosages of up to 0.1% to be achieved with good statistical pre-distribution. The introduction of foreign material into the PCR system is minimized.

• With the help of LifoCycle products, the processor can optimise the PCR used in each case to achieve their target colour. It allows to react to market availability or quality fluctuations of the PCR types.
PRODUCT SAFETY

Safety in the Cycle

An essential task in keeping raw materials safely in the recycling is to identify and eliminate contaminated batches from the cycle that have a negative impact on the product. Therefore, it is necessary to control the used raw materials and PCRs.

Due to the complex material flows, every single batch must be checked. A fast and automatable analysis possibility for the raw materials used is absolutely necessary.

Gas chromatography (GC-headspace), which is an established analytical method for quality control in the case of PET, is the ideal solution. It enables the identification of volatile substances with a low molecular volume.

Due to their ability to diffuse and migrate, they can migrate out of the packaging material very quickly. They therefore represent the greatest risk of contamination.

Automated control of all raw materials and PCRs used can increase security in the supply chain and in the cycle.

By setting up an automated GC-headspace analysis, Lifocolor has already established quality control for raw materials and masterbatches at an early stage. This method enables the verification of constant raw material batches.

This allows suspicious raw materials to be identified. Raw materials that are recycled several times in the recycling can contain NIAS (Non Intentionally Added Substances).

NIAS are caused by contamination with foreign materials and degradation reactions of the base polymer. The processor must keep these NIAS in mind for safe further use in order to be able to assess possible risks. In sensitive applications, the assessment of these substances is an essential part of the conformity work for PCR-based systems.
SUMMARY

The LifoCycle portfolio offers solutions for users in the plastics recycling:

- Solutions for **BRAND OWNERS**
- Solutions for **PRIVATE LABELS**
- Solutions for **PROCESSORS**
- Solutions for **RECYCLERS**

WHAT LIFOCYCLE PRODUCTS ACHIEVE

- The LifoCycle product portfolio consists of basic masterbatches, which are specially designed for the recycling process. These can be combined to formulate individual colour tones.

- The targeted selection of raw materials for the basic masterbatches ensures safe repeated recyclability. This is achieved by using highly temperature-stable and migration-resistant colourants and additives.

- For converters, retailers and brand owners who operate their own recycling, it is possible to compensate colour losses in the recycled material without the need for foreign material.

- For recyclers, there are opportunities to standardise their PCR qualities in terms of colour.

- The LifoCycle masterbatches are available for PP, PE and PET systems.

- The masterbatches can be supplied in micro or normal pellets.

- The use of the LifoCycle portfolio in sensitive applications can be supported by our own product analytics.