# Tracer Based Sorting – Innovative Sorting Options for Post Consumer Products

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ABSTRACT: Tracer Based Sorting is an innovative approach for waste management enabling material or product sorting regardless of their physical properties. The technology is based on applying inorganic marker substances in ppm concentrations in or on the objects to be sorted. These substances can later be detected in the recycling process, serving either to remove contaminants or to recover valuable materials from the waste stream. Five German companies along with two universities and one associated networking partner are working on the pilot development of Tracer Based Sorting for plastic packaging recycling in a collaborative research project.

## 1 INTRODUCTION

Tackling plastic waste from packaging in Germany has become an important topic in recent decades. Starting in 1991 with a mere 1.6 million Mg, in 2013 already 2.8 million Mg or 77 % of plastic packaging waste was collected (Schüler 2015), although in the same period, the mean mass of plastic packaging dropped by 26 % (IK et al. 2015). Future steps will be the development from a packaging to a secondary raw materials collection system and increased recovery rates: German packaging law requires 63 % (w/w) of all plastic packaging to be recycled by 2020 (NN 2017). As the current recovery rate covers both material and energetic recycling, it reaches 99.6 % and this exceeds the current requirement of 60 %, but material recycling still needs to be improved. Out of these 99.6 % merely 41 % are material recycling, 57 % energetic recycling and 1 % feedstock recycling (UBA 2016). Thus the materials recycling quota of 36 % currently required by the German packaging ordinance is clearly met, but for meeting the requirements for 2020 and onward, actions need to be taken.

## 2 TECHNOLOGY DEVELOPMENT REQUIREMENTS

In waste management most spectroscopical sorting processes use the visible and near infrared parts of electromagnetic spectrum, e.g. for lightweight packaging sorting. Modern sorting facilities for these materials use about 15 to 20 of NIR sorters for the separation for PE, PP, PS, or PET. Typical waste management sorting challenges are input quality fluctuations along with increasing quality requirements on the output side, resulting in cascade sorting approaching. Although sensor-based sorting has made remarkable progress, still sorting challenges remain unsolved. These challenges may be subsumed under three different types:

### *2.1 Challenge A: Material Type Distinction*

Current lightweight packaging sorting plants are producing HDPE or PP products which form the basis for HDPE or PP recyclates for specific applications, mixing different material types and thus modifying melt flow and other material properties. More target applications would be opened up if the different polymer types would be separable, enabling an even higher value added. While mixing of these different polymer types does not pose a technical problem for recyclate production, its value decreases in recycling. The value may be retained if a type-specific sorting approach would be available, producing recyclates with much narrower, specifications oriented towards further polymer processing.

### *2.2 Challenge B: Inmiscible Materials Identification*

Plastic packaging solutions might be equipped with properties which are detrimental for recycling. This can result in poor recyclate properties, and these properties may not be separable using conventional sorting processes. Amongst these properties some sub-types might e.g. be components of composite films. These are poorly miscible or not miscible at all with the main packaging material used. Typical problems arise from different components with a high difference in melting temperatures, or an overlap of melting and decomposition temperatures. Another challenge might be components which are not separable by swim-sink sorting after comminution. Moreover glues or labelling solutions which are resistant to conventional recycling washing processes and liquids have to be separated. Typically, materials which have been used energetically in the past might become a higher relevance for materials recycling in future, requiring their improved control and separability.

### *2.3 Challenge C: Filling Materials Identification*

Even completely identical packaging materials might have to be separated in the end-of-life step, e.g. if they have been used for different purposes such as in food and non-food packaging solutions. Other separation requirements might arise from filling materials residues. These might affect the recyclate quality heavily, for example silicone residues in HDPE cartridges for building applications. Hence, sorting approaches cannot rely only on the packaging material identification here. Another example for sorting requirements might be the separation of PET from food and non-food applications.

## 3 TRACER BASED SORTING TECHNOLOGY

Tracer based sorting technology (TBS) might provide an answer to the challenges of plastic packaging mentioned above. This technology uses mineral based materials which show luminescence if exposed to specific visual or infrared irradiation. These materials might be applied in minimal concentrations with the packaging solution and can be used in the sorting processes. Yet, they are completely invisible during the conventional use cycle and do not emit any light e.g. if exposed to sunlight or in house lighting. A current specific challenge that can be met using TBS is the separation of PET beverage bottles with enhanced oxygen barrier (non-deposit bottles) from the conventional PET fraction. In these packaging types, e.g. a PA barrier is used, which in PET recycling leads to PET recyclate discoloration and thus has to be avoided. The Tracer based sorting approach thus enables marking of packaging solutions according to their preferred technical and/or economical recycling route. Marking may be applied on or in the packaging material, or the labels. Tab. 1 shows an overview over the tentative places (Reinig 2017) for marker application along with a technological and waste management experts judgement. It may be stated though that tracer based sorting shows a remarkable potential for materials recycling improvements, as it may provide high quality and single-type plastic material fractions from the end of life plastic packaging sorting steps.

Tab. 1: Places assessment of marker applications in plastic packaging.

| Place of marker substance application | Marker material efficiency | Marker flow control | Marker recoverability | Packaging sortability | Flake sortability | Complexity of implementation |
|---|---|---|---|---|---|---|
| In (bulk) packaging material | - | - | - | + | + | + |
| On (bulk) packaging material | +/- | +/- | +/- | + | + | - |
| Label material | + | + | + | +/- | - | + |
| Glue | +/- | + | + | - | - | + |
| Label Print | + | + | + | +/- | - | + |

+ = advantageous, - = less advantageous, +/- = neutral

Taking the current system as a starting point, miscellaneous options for TBS steps are possible. Selected positions in the material flow are depicted in Fig. 1. The optimal position is amongst others depending on the marker application on the packaging (Tab. 1). Generally speaking, sorting may be carried out on the article (entire packaging) or on the flake level (after grinding the packaging). If position D in Fig. 1 will be chosen for TBS implementation, only markers in or on the bulk packaging materials will be operational. In contrast to that, positions A to C are open both for markers on or in the bulk material as well as for marker use in or on the labels.

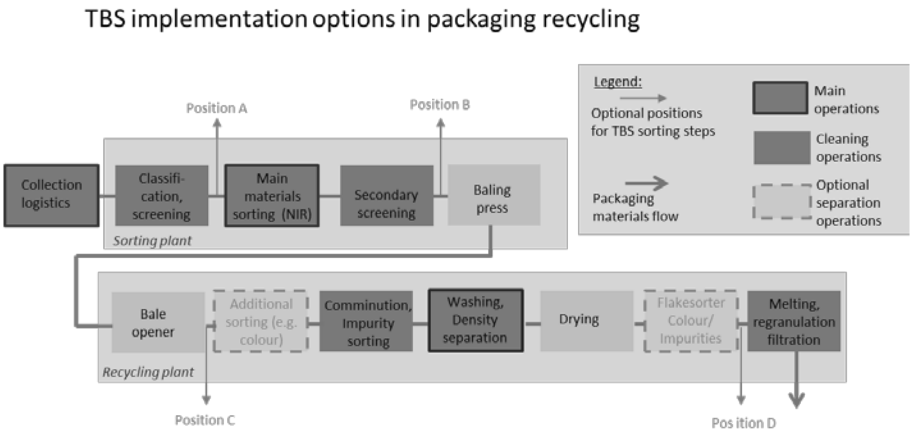


Fig. 1: Tracer based sorting as an addition to conventional plastic packaging recycling.

## 4 THE PHYSICS OF TBS

TBS uses the luminescence effect which is easily generated by electromagnetic irradiation using e.g. laser diodes or LED, and which can be detected using simple detector technology such as CCD camera chips. Excitation and detection only take milliseconds and are carried out in a non-destructive process. The excitation wavelength used are in the invisible spectrum while the luminescence occurs in form of visible light. The materials used show a high quantum efficiency, rendering traces of a concentration of 1 – 100 ppm is sufficient for a proper luminescence signal in order to detect materials or products.

The approach used by TBS so far is the “Anti-Stokes” or upconversion luminescence. In this physical effect the excitation wavelength is longer (carries less energy) than the emissions/luminiscence wavelength. Thus by these upconversion materials, two or more photons are collected first, and subsequently one photon on a higher energy level is released. This process may use e.g. infrared irradiation for excitation, and emit in the visible spectrum. Although efficiency ranges in the one digit percentage range, with a very narrow wavelength distribution this upconversion effect offers very promising options for detection and sorting. This can be attributed to the specificity of excitation and emission wavelength, which are unique and may be specifically tailored for each material or product, as no other effect nor material in nature are known which exhibit this behavior. Consequently no optical background noise is observed in the upconversion process, so an excellent signal-to-noise ratio is found here.

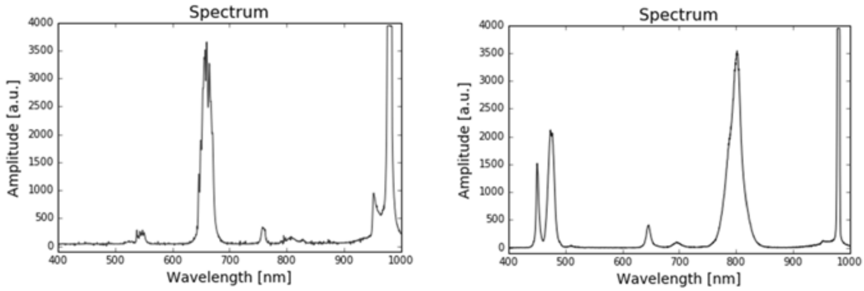


Fig. 2: Upconversion emission spectra (picture provided by Polysecure GmbH)

Recent years saw the development of numerous inorganic fluorescent materials, usually based on an inorganic host lattice, dopants (activators, sensitizers) and defects and impurities and produced by complex synthesis processes. For fluorescence, activators are crucial, which are converting energy by electron transfers. Sensitizers support the energy absorption process by providing adequate electron transfer steps. To enhance quantum efficiency, defects and impurities have to be strictly controlled. With a thorough knowledge of dopants and formulation specific wavelength emissions may be created (cf. Fig. 2). Thus from a portfolio of merely five different emissions (wavelengths) the combinatory distinctive discrimination of 31 (25 - 1) codes created by upconversion markers is possible.

## 5 THE MAREK PROJECT

In the collaborative research project “Marker-based sorting and recycling system for plastic packaging” („Markerbasiertes Sortier- und Recyclingsystem für Kunststoffverpackungen (MaReK)“), seven partners work together under the lead of the Institute for Industrial Ecology (INEC) at Pforzheim University. Also in this partnership, the German companies Polysecure GmbH (Freiburg), Werner & Mertz GmbH (Mainz), Der Grüne Punkt – Duales System Deutschland GmbH (Köln) and the Karlsruhe Institute for Technology (KIT) conduct research with the contractors CMO-SYS GmbH and Nägele Mechanik GmbH and the associated partner Umwelttechnik BW GmbH (Stuttgart) with the goal to develop a demonstration case for TBS. The technological core of the project is a harmonized packaging and sorting technology development to recover high quality secondary polymer packaging from packaging wastes.

## 6 GRANT SUPPORT

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