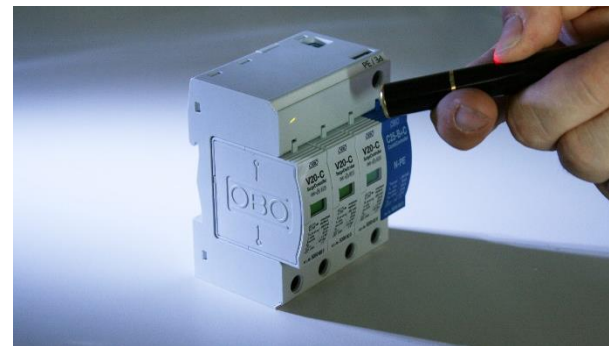


Hamburg T.R.E.N.D. 2020 - Kreislaufwirtschaft am Tropf?, 04.02.2020:
Tracer-Based-Sorting – Verpackungen effizient nach
Spezifikation und Recyclingweg sortieren

Jochen Moesslein, Gründer und Geschäftsführer Polysecure GmbH

- » Technology company focused on innovative marker materials and their detection
 - Inorganic fluorescent marker particles (FMP)
 - Glass-ceramic marker particles with chemical code (GCMP)
 - Encodable polymer taggants (Poltag)
- » Applications (to date):
 - Mobile Authentication and proof of recycled content
 - Smartphone based copy-proof Identification (“Track & Trace”)
 - Material sorting (Tracer-Based-Sorting TBS)
- » Interdisciplinary team & strong IP (~20 patents) to protect marker materials, detection & applications
- » Lab and production infrastructure -> solid state chemistry, electronics, optics, plastic technology
- » Market leaders as first customers -> more than 50.000 tons marked with PS markers

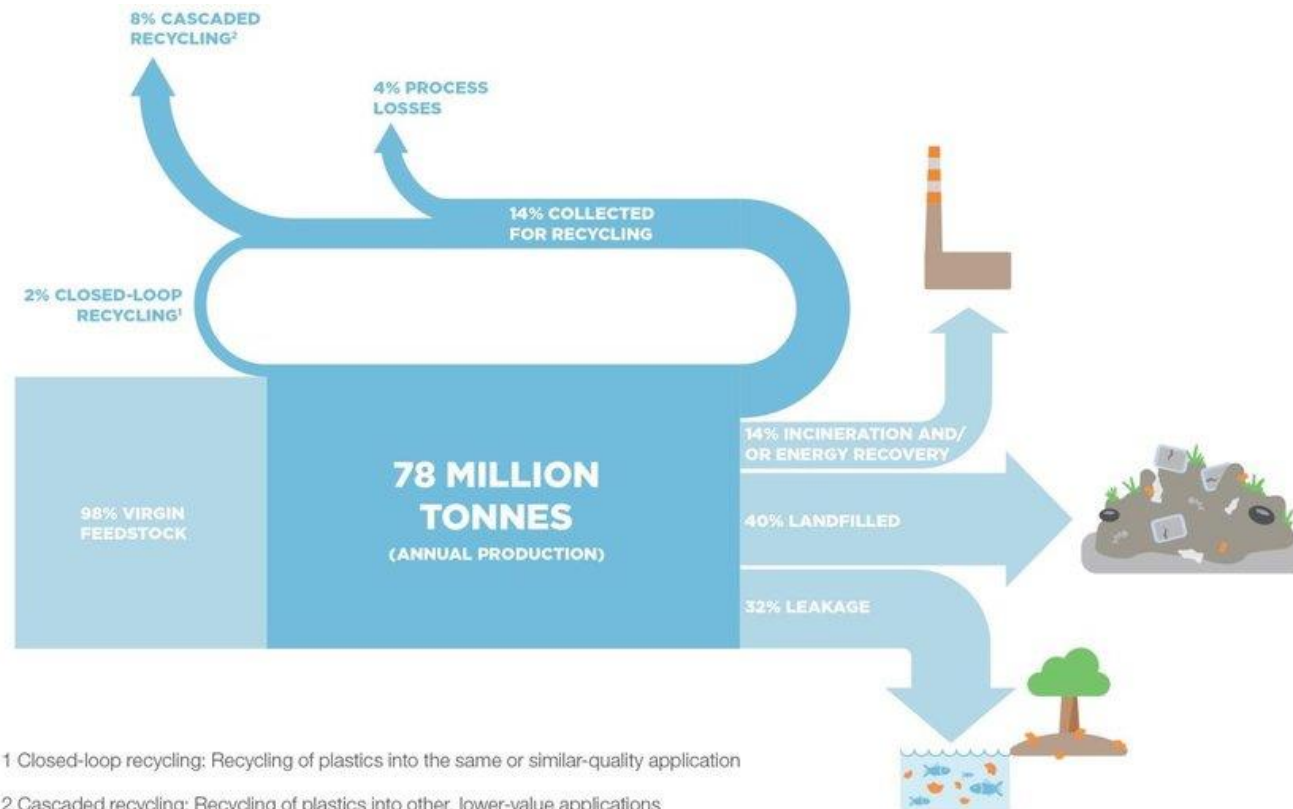


Fluorescence by marker particles in electric switch



FLUOSORT® - TBS flake sorting machine





- » Global setting: Only 10% of packaging waste is recycled, only 2% in a closed-loop... major findings:
 - Dumping waste into nature / landfills is often not banned
 - **Recycling is not competitive against virgin plastics**
- » Germany: After ~30 years of waste management, the recycling rate for plastic waste is still ~20%, while 63% is set by law for 2022... major findings:
 - Too much of the plastic is lost due to sorting difficulties
 - Quality of recyclates is too low due to poor sorting quality
- » Motivation for Tracer-Based-Sorting (TBS) / MaReK:
 - **Can TBS, efficiently applied to plastic packaging, solve the sorting difficulties, lower the costs and increase the quality of recyclates?**
 - Can TBS thereby help increase the recycling rate and thereby create reductions of CO2 and plastic waste in the nature?



Melanie Kamp: Plastic litter on beach in Vietnam



Wikipedia: Manual plastic sorting facility

Development of a **marker** based sorting and **recycling** system for plastic packaging

- » KIT and Polysecure to develop “best possible” new fluorescent materials / tracers (sorting regime, compliance)
- » Polysecure to develop new sorting machine / pilot sorting plant
- » Packaging items are marked with new tracers / sorting code, mixed into typical packaging waste and sorted by TBS pilot line at Polysecure
- » Comprehensive stakeholder process -> brands, packaging manufacturers, converters, utilities, political decision makers etc.

Eine Initiative des Bundesministeriums
für Bildung und Forschung

Plastik
in der **Umwelt**

Quellen • Senken • Lösungsansätze

GEFÖRDERT VOM



What is the overall scenario for packaging / sorting?

- » More **bio-degradable and paper based** packaging will come
 - Disposal by consumers into bio waste / paper fraction -> **no automatic sorting required**
- » More “**design for recycling**”:
 - Packaging which cannot be correctly identified by NIR sorting (i.e. black, multilayer, PET-G-sleeves) will be reduced
- » However, significant share of packaging will **remain plastic**, based on a superior property mix (i.e. flexibility, formability, barrier, hygiene, weight, life cycle balance)
 - Packaging waste should be collected & recycled in a closed-loop
 - **Requires automatic sorting into defined and pure specifications**
- » Current sorting technology: **Cascaded process**, each sorting step diverting the input stream only in two output streams requiring i.e. at least 5 sorting steps for 6 final fractions:
 - **Each additional sorting step creates additional sorting costs -> difficult to base better sorting on further sorting steps**



Landpack GmbH



Denttabs GmbH

What exactly is the sorting challenge?

» How to efficiently & reliably sort trillion of non-uniform objects into well specified & pure fractions which can be easily re-used?



i.e. nonfood HDPE specified for shampoo bottles



i.e. food PET with barrier additive for cheese & meat (no multilayer)



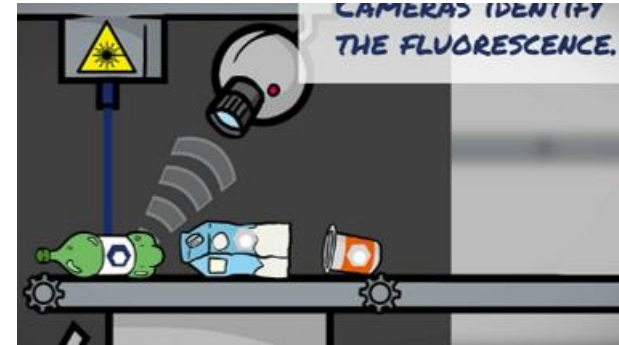
i.e. food PET for mineral water bottles



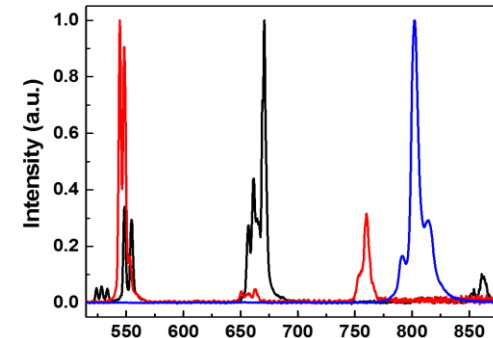
...and further 10 – 40 fractions

How does Tracer-Based-Sorting (TBS) work?

- » Different upconversion fluorescent tracers are integrated in or on materials to be sorted (i.e. plastic packaging)
- » In the sorting device, materials move through a laser curtain which excites the tracers to fluoresce while no other material emits signals
- » As a result: Detector only sees the fluorescence of the tracers, all other material components remain dark -> **optical detection (=sorting) without that there is “noise”** -> **best possible sorting regime** -> see [TBS tech video](#)
- » Sorting into fractions -> the different colors of the tracers (=sorting code) are measured and the detected packaging items are sorted accordingly in one sorting step



Principle of Tracer-Based-Sorting

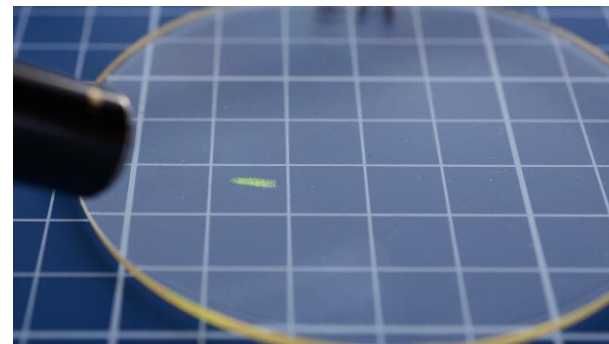


Emission spectrum of 3 different upconversion tracers

- » Individually synthesized crystalline particles with strong fluorescence and characteristic emission / excitation spectrum and dynamic properties
- » Typical particle sizes: 0.1-100µm
- » Good thermal (500-1500°C) and chemical stability plus low solvability (i.e. in acids and bases) -> good biocompatibility
- » Approval for plastic product for drinking water granted, inclusion in positive list for food contact underway
- » As additives of polymer compounds: very robust and usable over practically infinite use cycles and extrusions
- » High external quantum yields
- » Signal strength can be increased by stronger excitation!
- » Exclusive cooperation with [KIT](#)
-> own, partially patented materials & synthesis

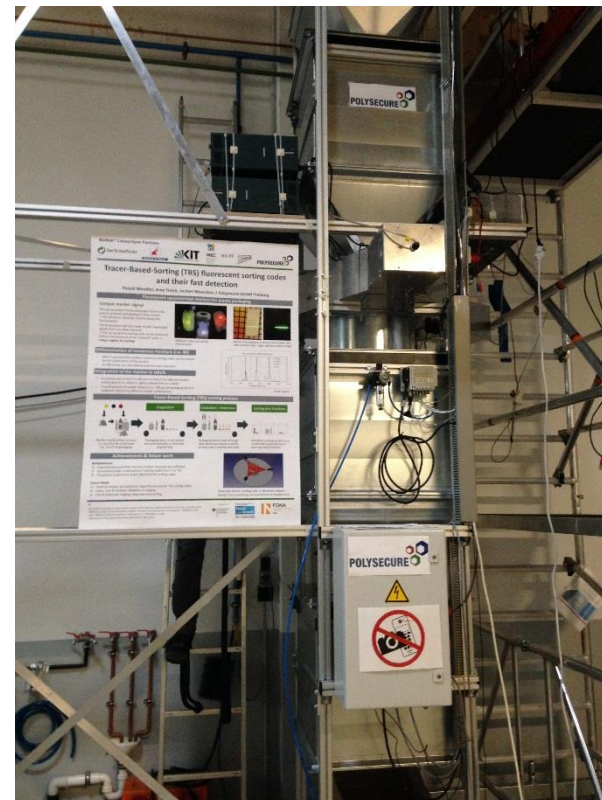
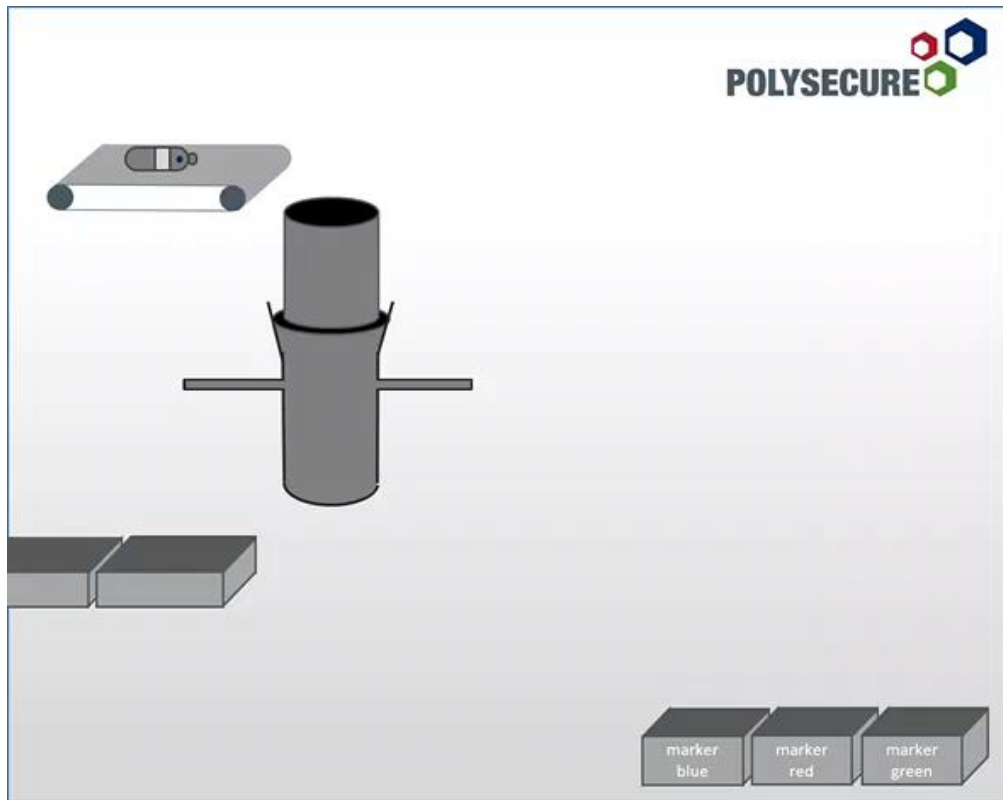


Marker with strong upconversion fluorescence

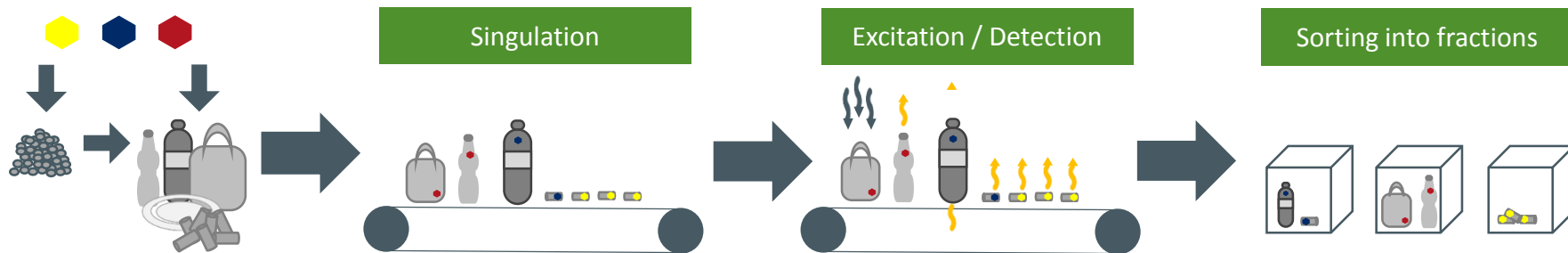


Fluorescent particle in transparent lens

TBS detection: inexpensive devices enabled by tracers



How does the TBS “complete” process look like?



Application of TRACER onto packaging

Integration of tracer onto packaging via routine printing process or label

→ small spot of 10x10 mm is sufficient

→ 20–200 µg tracer is sufficient

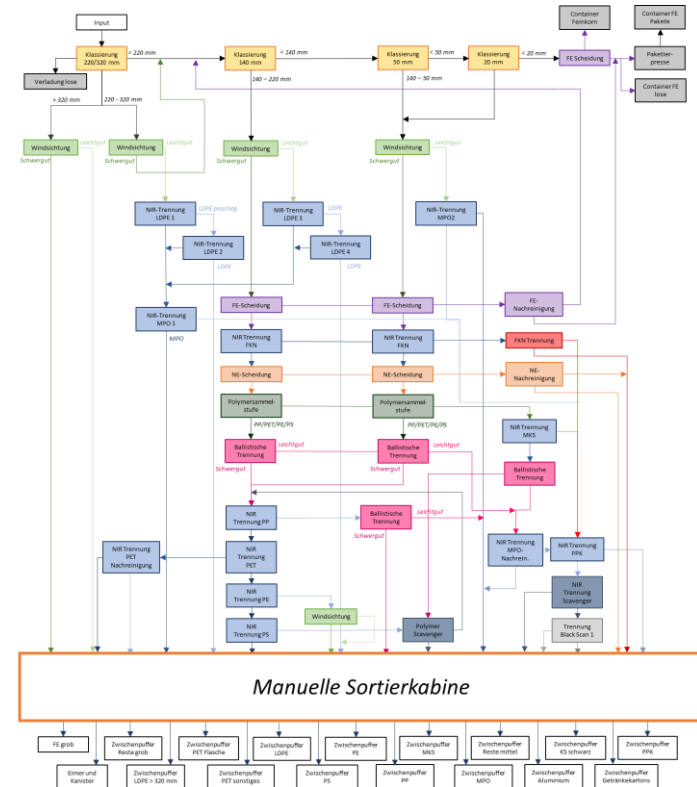
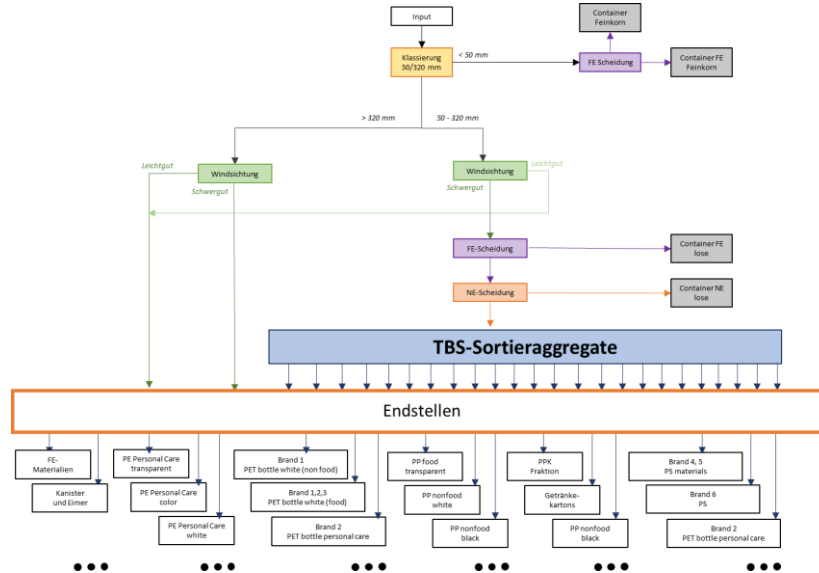
Detection

all coded fractions and colors are detected in one step, within one cost-efficient device

Sorting

all fractions are sorted into final bins
→ i.e. 45 codes into 45 fractions / bins

Process layout: TBS (left) versus state of the art (right)



Tracer integration by printing ink

- » Most preferred marking option at present: Disperse marker mix in **light printing ink** and likewise embed sorting tracer on the label or on the packaging directly
- » **Sorting tracer is then extracted** with the label or printing ink from the plastic packaging material



Separated fractions after TBS flake sorting process

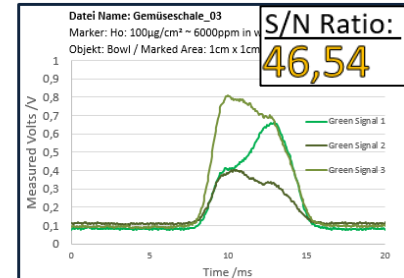
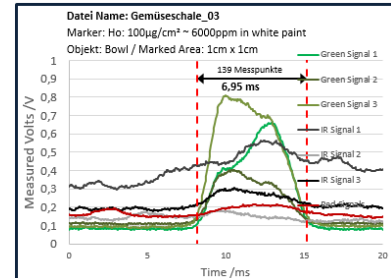
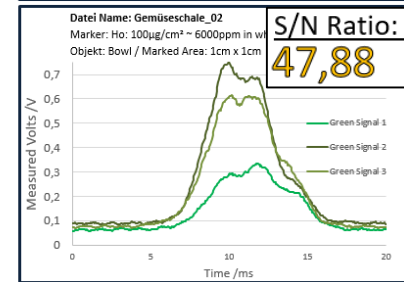
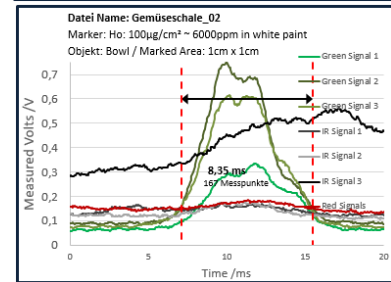
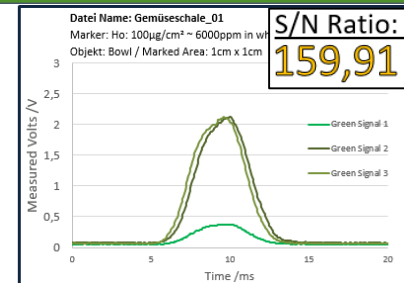
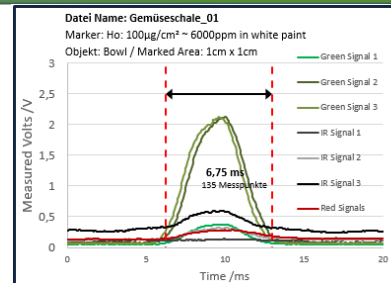


Plastic bottles with small marked label

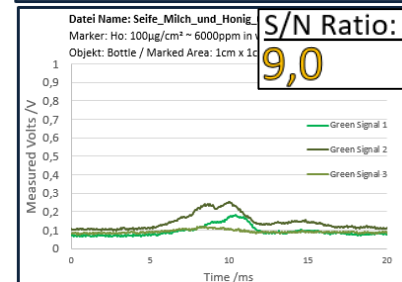
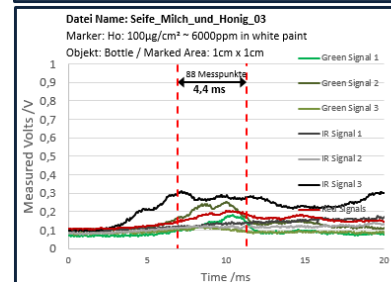
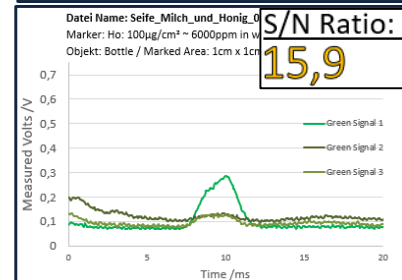
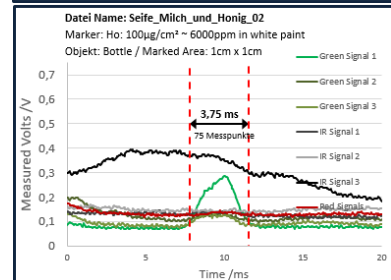
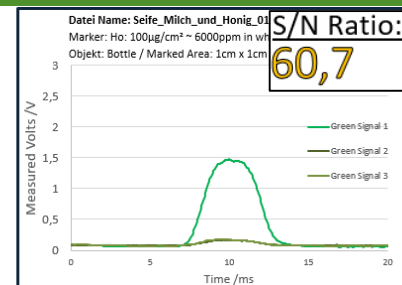
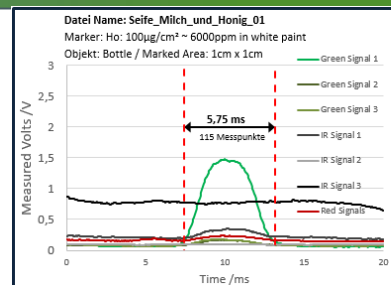
TBS sorting trials with real samples -> dirty, deformed, crushed, black...



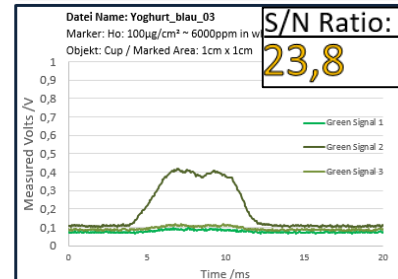
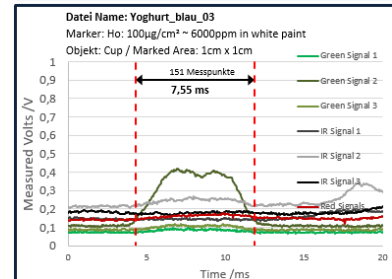
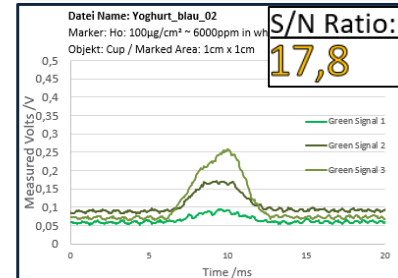
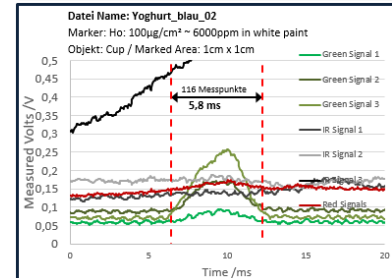
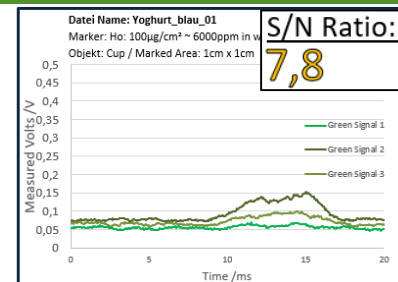
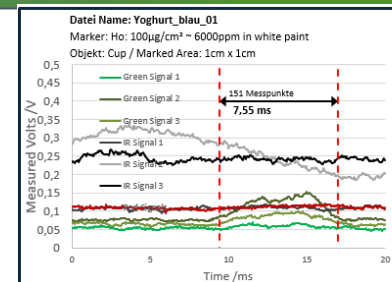
Sample #1: dirty, crushed, deformed -> reliable detection



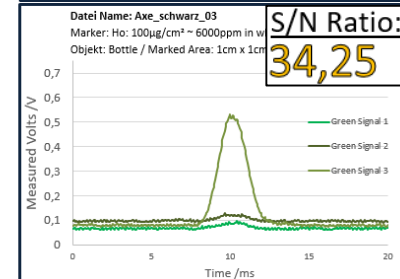
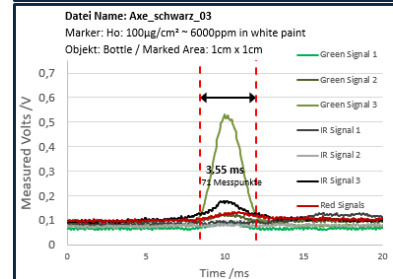
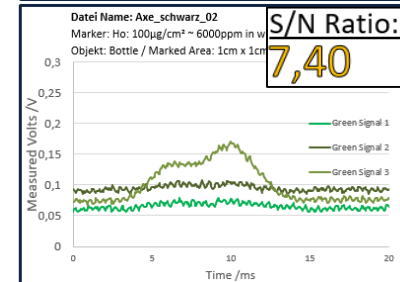
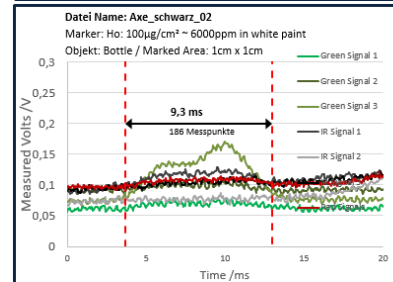
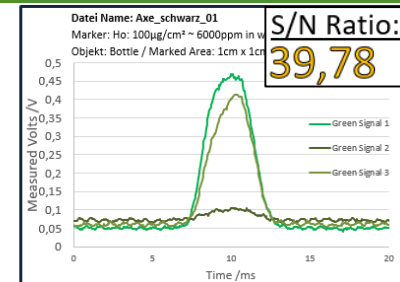
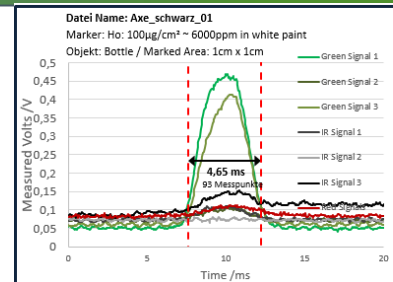
Sample #2: dirty, crushed, deformed -> reliable detection



Sample #3: dirty, crushed, deformed -> reliable detection



Sample #4: black -> reliable detection



TBS packaging waste logistics by reliable process as for letters, parcels...



Automatic infeed: USPS / Distrisort

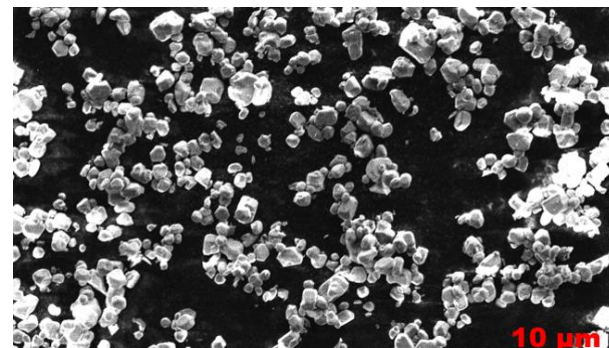
Post NL - Sorting line with [automatic parcel infeed](#)



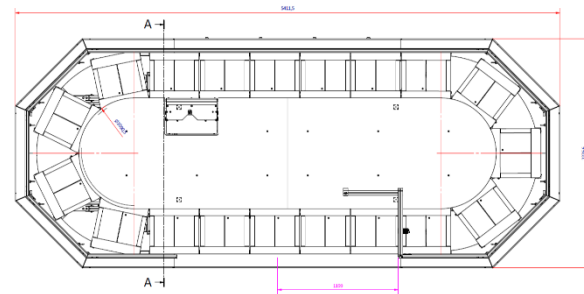
Plastic packaging items are transported by split tray sorter to the conveyer belt or bin of their individual fraction -> quality of sorted fractions is key

Courtesy of
Distrisort

- » New efficient, inorganic, biocompatible upconversion fluorescent marker materials developed
- » Efficient synthesis & post-treatment established
- » Practical marker integration developed -> best option: marker via light ink on label -> tracer is then washed off with label / ink
- » Experimental proof that very low tracer amounts are sufficient for fast & reliable detection
- » **Crucial advantage: Works for all packaging types, even when dirty, crushed, deformed or black!**
- » Developed inexpensive & fast detection device
- » Transport of typical packaging items successfully tested with split tray sorter



Morphology of new upconversion fluorescent particles



Design of split tray sorter

Conclusions for Tracer-Based-Sorting of packaging

- » **Sorting for any specification possible**, defined by the most valuable recycling pathway
- » **Sorting for brands** possible -> brands can get back their known & specified materials -> makes re-use easy and enables reaching recycling targets
- » Separation of materials which cannot be identified with NIR technology: i.e. multilayer, PET-G sleeves, **food versus nonfood**, black plastics, impurities (i.e. HDPE silicon cartridges) ...
- » Sorting tracer could be part of registration -> **free-riders** are systematically sorted out
- » **TBS generates well specified, pure material fractions** -> allows less sorting / lower costs at recycler and high quality recyclates at <<1000 Euro per ton (competitive to virgin plastics)
- » **Economics of TBS process**
 - Based on efficient “physics”: low tracer concentration -> low tracer costs ~ 30 Euro per ton of packaging
 - Enables sorting in one step -> better scalability, better flexibility for new fractions
- » Significant **increase of recycling rate** -> **large CO₂-reduction by a cost-efficient measure!**
 - Germany -> substitution of ~1m ton of virgin plastic possible -> 2.5m ton of CO₂-equivalent
 - World -> 100m / 250m ton of CO₂-equivalent

Thank you very much for your attention!

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79111 Freiburg / Germany



What are other technology options to sort packaging waste?

» NIR reflection spectrometry (state of the art):

- Limited to differentiate main polymers: PE, PP, PS, PET etc.
- Multilayer, sleeved bottles, black plastics, wet & reflective surfaces etc. cannot be correctly identified
- Differentiation of food / nonfood, brands and subclasses of main polymer is not possible

» Digital Watermarks:

- Integration of watermark in artwork of packaging, use and adoption of NIR sorter
- Optical measurement of watermark at high speeds requires minimum flat surface without dirt, wrinkles, deformation -> challenge to achieve high identification rates in waste stream

» TBS “light” with NIR sorter:

- Integration of fluorescent tracer on packaging, use and adoption of NIR sorter
- Excited fluorescence has to be distinct against strong background noise from different optical processes -> challenge to generate reliable sorting codes at low tracer costs per packaging

» TBS “complete” with dedicated Polysecure TBS sorting device:

- Integration of tracer on packaging, sorting by upconversion fluorescent codes without any ambient noise
- Enables low tracer costs and reliable sorting for defined fractions, but requires shielded sorter without ambient light



How do current sorting technology options compare?

Sorting technology	Detection mechanism	Sortable fractions	Abundance of background noise during detection?	Independence from pack. mat., label, artwork?	Robust against wrinkles, deformation etc?	Robust against dust etc on the surface of packaging?	Reliability of correct identification?	Enough codes to cover sorting needs?	Control over freeriders who do not register and pay?	Cost reduction potential for quality recycles?
NIR reflection spectroscopy	reflection spectrum of polymer	limited to main polymers: PE, PP, PS, PET, PA, PVC	↓	↓	↑	→	↓	no	↓	↓
Watermarks in packaging	optical color pattern recognition	any fraction defined by specific watermark	↓	→	↓	↓	?	?	→	↓
Watermarks in label / artwork	optical color pattern recognition	any fraction defined by specific watermark	↓	→	↓	↓	?	?	→	↓
Stokes tracers on packaging (TBS light)	characteristic emission spectrum	any fraction defined by specific tracer	↓	→	↑	↑	→	?	↑	↓
Upconversion tracers on pack. (TBS complete)	color of upconversion fluorescence	any fraction defined by specific tracer	↑	↑	↑	↑	↑	yes	↑	↑

First industrial TBS application: PVC flake sorting

- » Separation of shredded flakes from PVC window profiles with and without glass fiber
- » PVC window profiles with glass fiber are lighter, have better properties than pure PVC -> attractive product
- » On the other side, the glass fiber must not enter the general PVC material flow, otherwise all PVC manufacturers would have to adopt to the handling of glass fiber -> glass fiber containing PVC has to be separated.
- » Polysecure solution: PVC with glass fiber is marked with specific fluorescent tracer from Polysecure and separated in new sorting machine -> see [TBS video](#)



Post consumer PVC window profiles



Polysecure's FLUOSORT® TBS sorting machine

Technical results of PVC flake sorting with TBS

- » Conveyor band width: 1m, conveyor speed: 3 m/s, throughput: ~10000 to/a; particle size: 2-8mm
- » Reduction of glass fiber PVC from 10% to 1% by one sorting pass -> good sorting quality!
- » Marker stays in the marked fraction and survives multiple extrusions without problem -> good economic efficiency by multiple use
- » Some 10000 tons have been marked in series production -> dosing and processing of marker without problem



Inside Polysecure's FLUOSORT® TBS flake sorting machine



Separated fractions after TBS flake sorting process