MMAtwo

Second Generation MethylMethAcrylate

Concepts of Mechanical Recycling

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CMT Centre for Polymer and Material Technologies

CAPTURE PLASTICS TO RESOURCE

MMAtwo workshop

15/09/2020

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Speaker's introduction

Associate professor Circular Plastics

- Background in polymer science and processing
- Focus on **mechanical recycling** ('same science, different application')
- Interdisciplinary team of 15 researchers

Academic lead of CAPTURE – Plastics to Resource
PI of the mechanical recycling program

CAPTURE

Member of MaTCh – CPMT
Centre for Polymer & Material Technologies

PLASTICS RECYCLING AWARDS EUROPE 2020 FINALIST

Key publications:

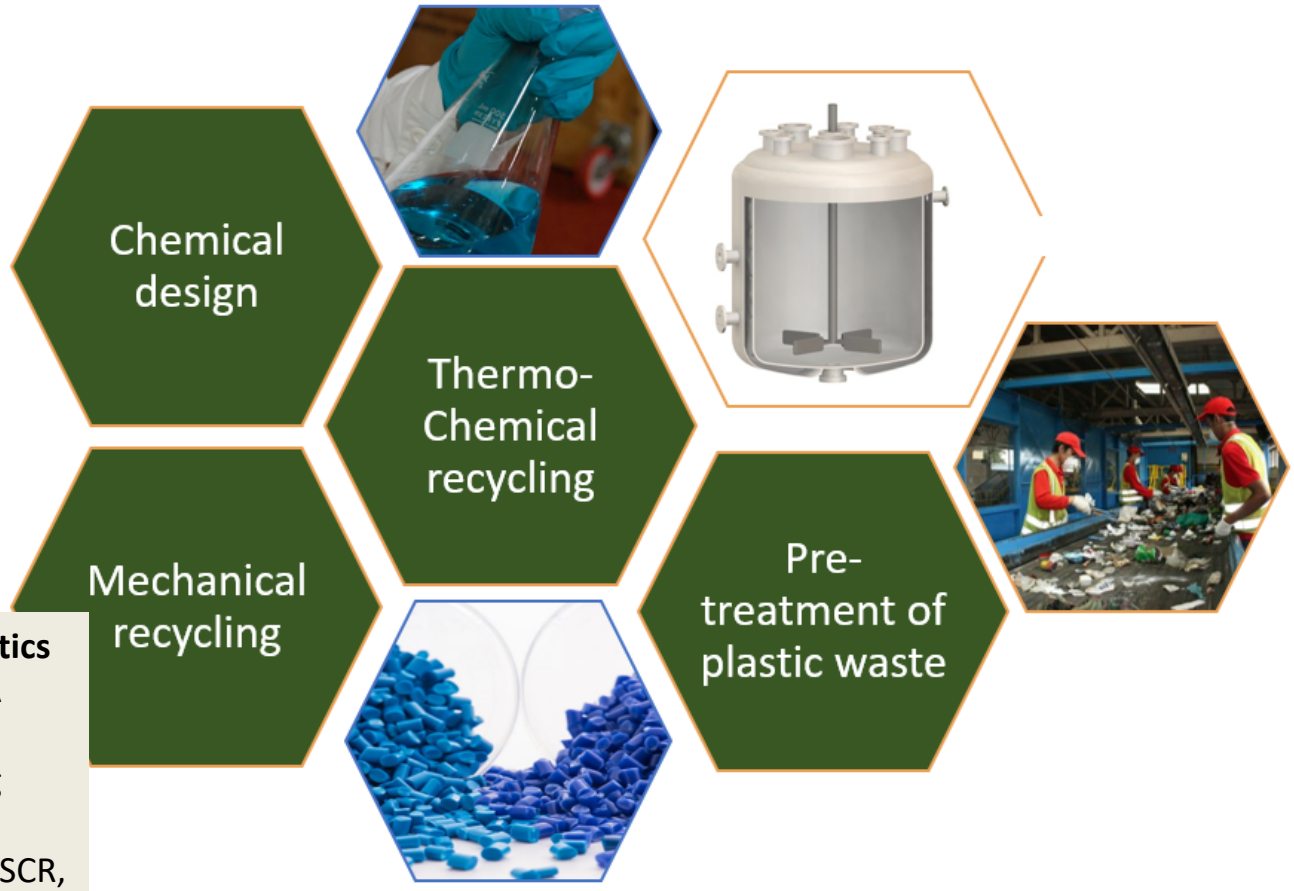
- Astrid Van Belle , ..., and Kim Ragaert. Microstructural contributions of different polyolefins to the deformation mechanisms of their binary blends. (2020) Polymers.
- Kim Ragaert, Sophie Huysveld, Gianni Vyncke, Sara Hubo, Lore Veelaert, Jo Dewulf and Els Du Bois. Design from recycling: A complex mixed plastic waste case study. (2019) Resources, Conservation and Recycling. 155.
- Sophie Huysveld,Sara Hubo; Kim Ragaert; Jo Dewulf. Advancing circular economy benefit indicators and application on open-loop recycling of mixed and contaminated plastic waste fractions, Journal of Cleaner Production 211 (2019) .
- Thoden van Velzen U., Brouwer M., Augustinus A., Soethoudt I., De Meester S. and Ragaert K. Predictive model for the Dutch post-consumer plastic packaging recycling system. Waste Management 71 (2018), 62–854.
- Ragaert K.,Delva L. And Van Geem K. (2017). Mechanical and Chemical Recycling of Solid Plastic Waste. Waste Management 69 (2017) 24–58.
- Sofie Huysman, Jonas De Schaepmeester, Kim Ragaert, Jo Dewulf and Steven De Meester. Performance indicators for a circular economy: A case study on post-industrial plastic waste. Resources, Conservation and Recycling 120 (2017)

- Kim Ragaert. Plastics Rehab. TEDx Vlerick, Ghent, April 2019.

Speaker's introduction

CAPTURE
PLASTICS TO RESOURCE

www.capture-resources.be/plastics-resource

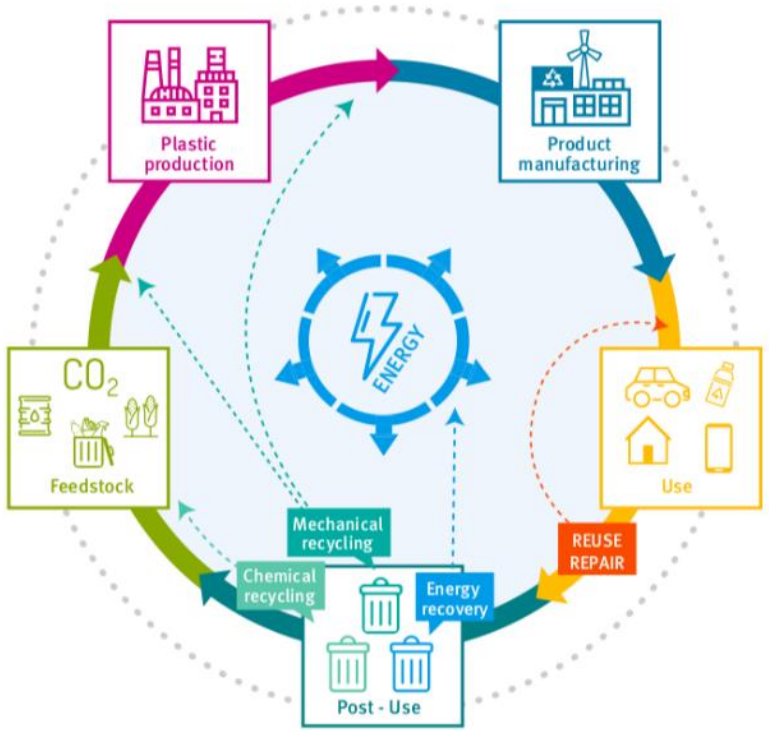


- **'RQ' – Recycling Quality of Contaminated plastics**
- Bring appreciation of technical quality into LCA
- Product design for circularity
- Develop specific structure-property-processing insights from conventional polymer science to solve challenges in mechanical recycling (e.g. ESCR, haze, mulit-to-monolayer, specific issues of ocean plastics,...)
- Develop mechanical recycling of 'new' materials streams: biobased, ocean plastics, vitrimers...

Overview

- Introduction to mechanical recycling
- The different process steps in mechanical recycling
- Relevance for PMMA recycling

Mechanical Recycling in the Circular Economy for Plastics



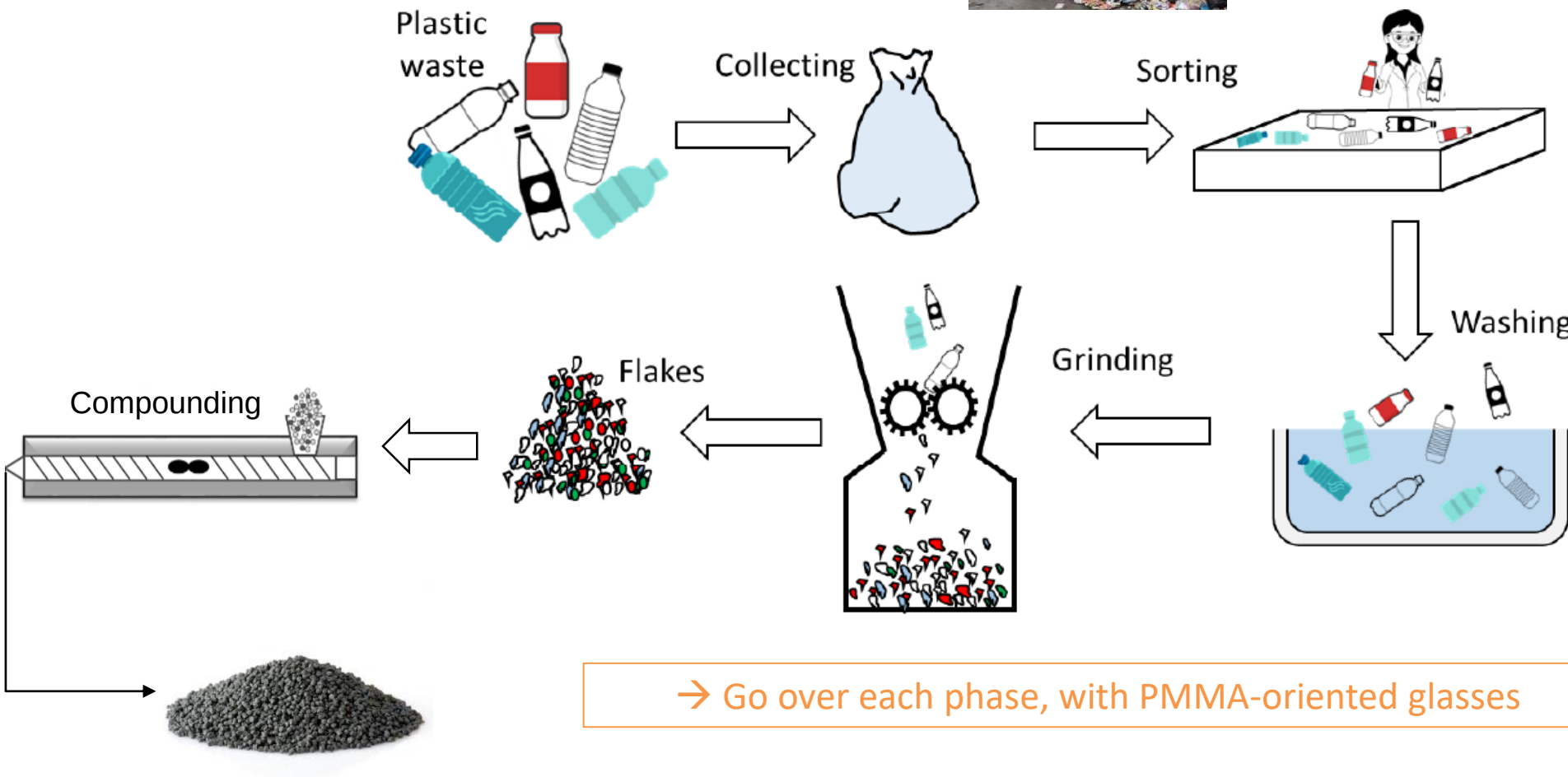
Source: PlasticsEurope, Plastics the Facts 2018

Advantages

- Easy, 'cheap' and 'low tech'
- Lowest footprint of recycling options
- No discussion on whether it count as recycling
- It's what the collection systems are built for
- Uses the same polymer science as basic compounding, converting
  - Just a little more complicated

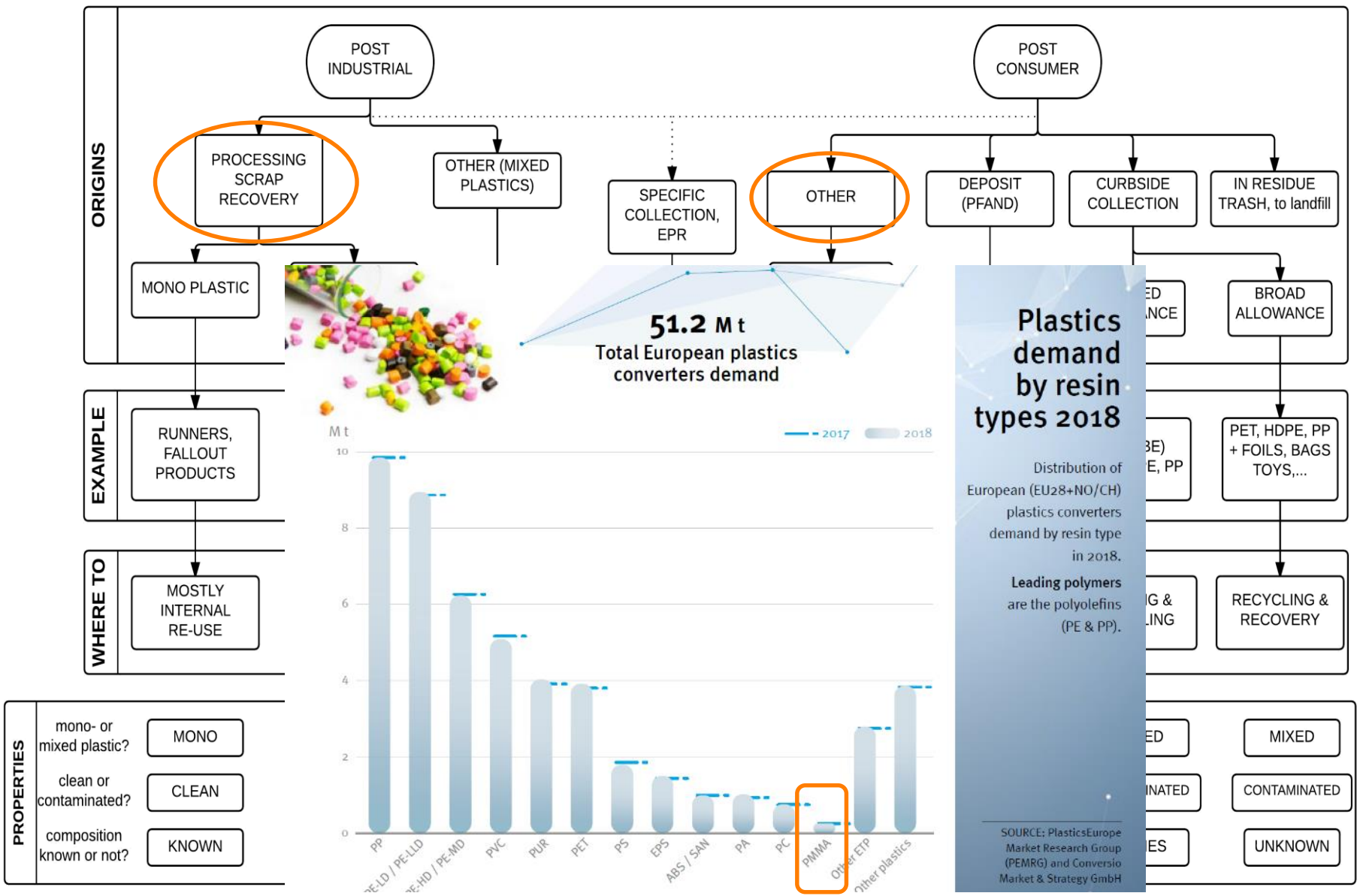
- Still the 'go-to'

Mechanical Recycling - basically



→ Go over each phase, with PMMA-oriented glasses

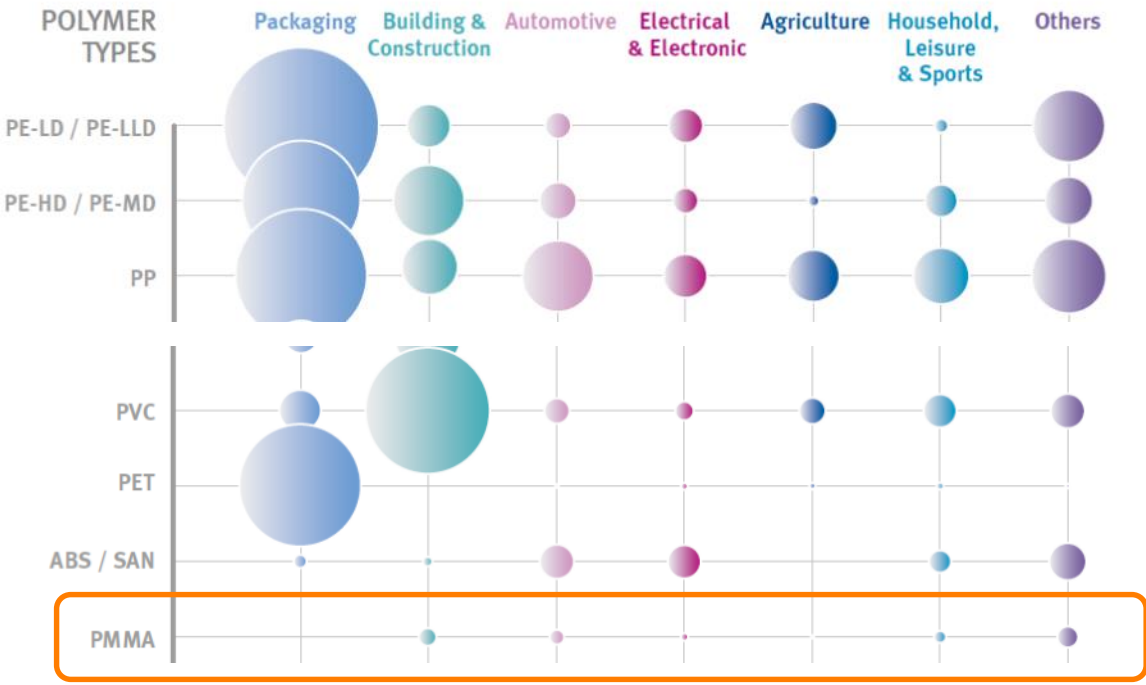
Step 1: the waste



Step 2: collection

Post consumer

1. Packaging waste
   - PET, PP, PE, PS (PVC, PA,…)
2. B&C
   - PVC, HDPE, PP,…
   - PMMA, often mixed up with PC
3. ELV & WEEE
   - PP, ABS, PC, PC/ABS
   - PMMA
4. Agricultural
   - (contaminanted) flexibles
5. Mixed rigids



Source: PlasticsEurope, Plastics the Facts 2019

Post-production

- Production scraps, cut-offs
- Off-specs
- unmixed

Step 3: sorting

Mono streams are always better

MECHANICAL SORTING BY SIZE, SHAPE AND WEIGHT

- ***Wind shifting***
- Ballistic

OPTICAL SORTING

- ***Near infrared*** (NIR) + MIR
- Laser
- Colour or shape

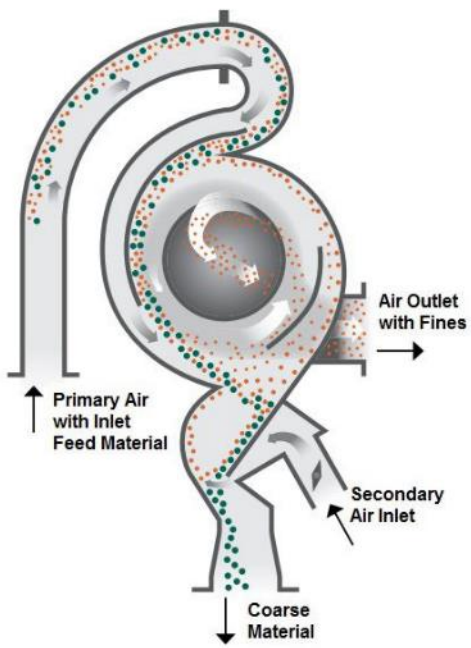
DENSITY SORTING

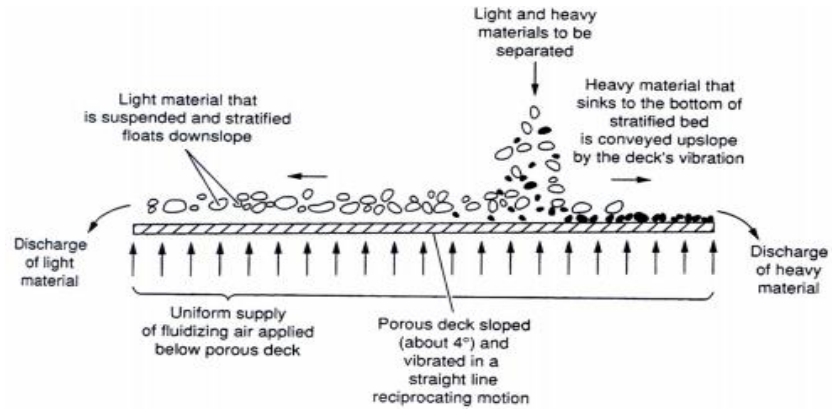
- ***Float-sink tank***
- Centrifuge
- Hydrocyclone

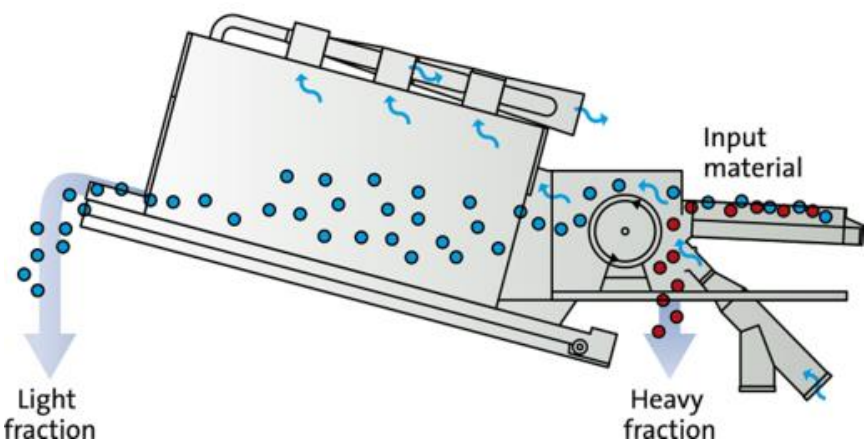
OTHER SORTING

- ***Manual*** (by product)
- Electrostatic (ES)
- X-ray

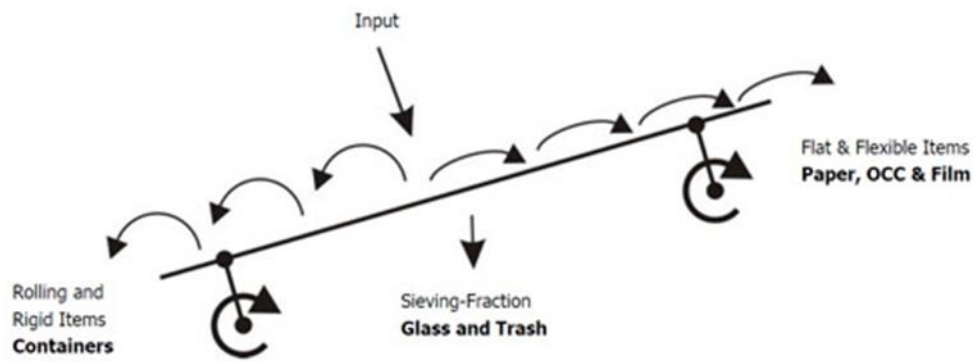
Wind shifting





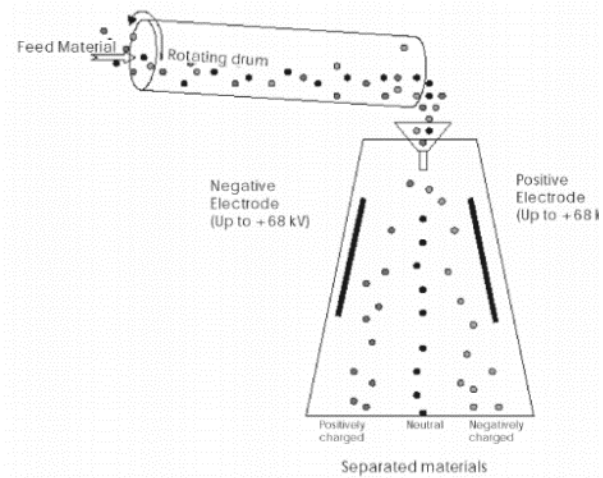


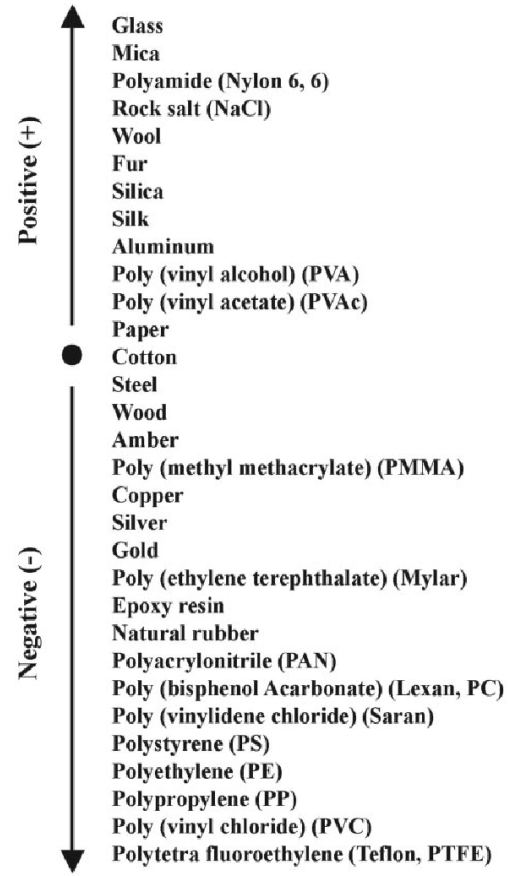
Ballistic separation



Tribo-electric separation

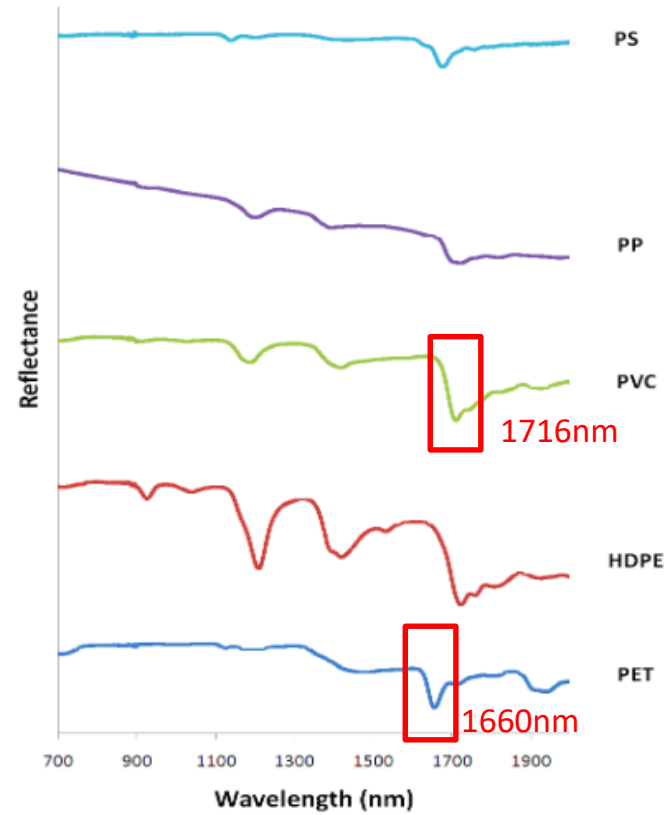
Not usual at sorting plants, but related
(Packaging) Plastic goes more negative, E.g. wood is neutral
Material needs to be dry!

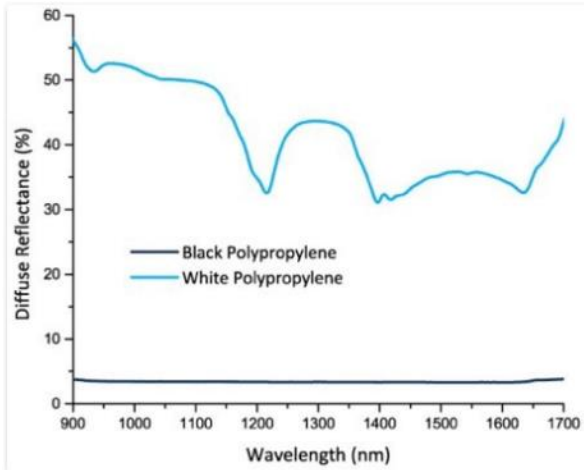




NIR: near InfraRed

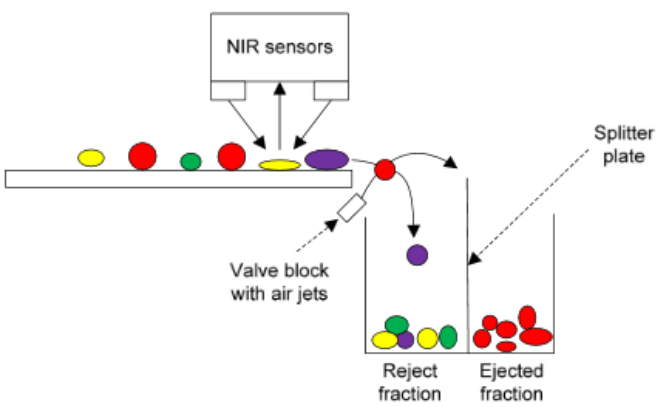
- Optical separation
- Based on infrared spectrum ➔ absorbance of light
- Separation of different types of materials (minerals, plastics, etc.)
- Very powerful technique
- Blacks are currently a bit difficult
- Only surface scanned (<20µm)

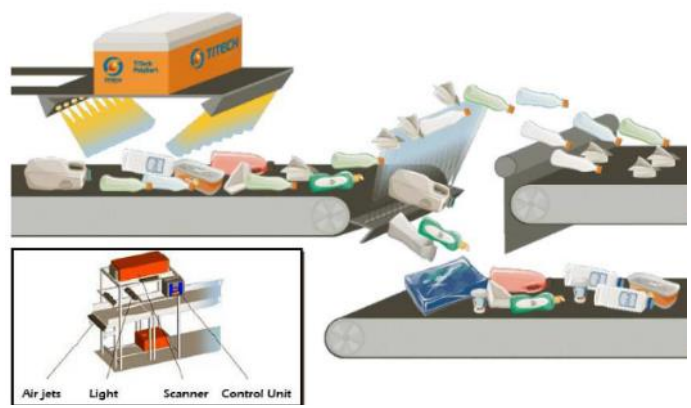




NIR: near InfraRed

NIR has high belt speeds (3m/s)
Because it is so good, companies tend to overload it
Efficiencies are typically around 90%
Best not as ‘first’ separation to get a 10% material out of a mix
Usually done ‘positive’ (e.g. all PE) and then ‘negative’ (e.g. all non PE)



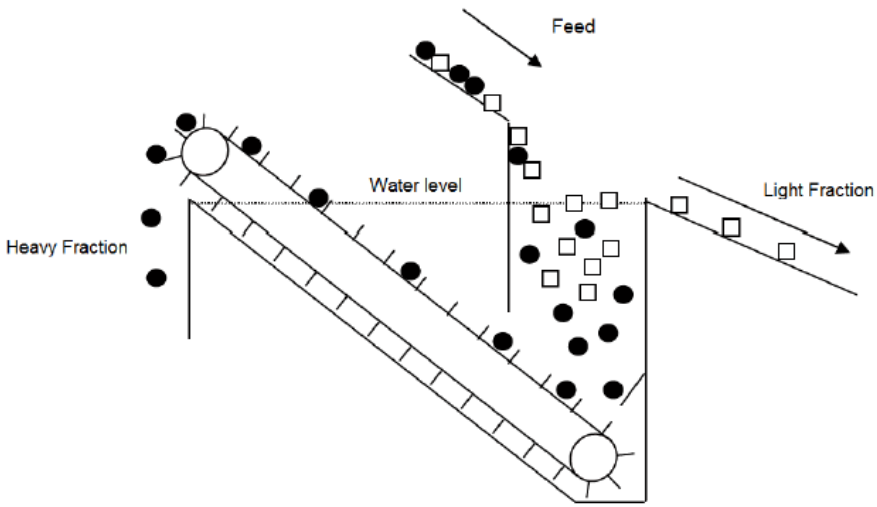


4. *Separate the Most Plentiful Components Early.* Components comprising a large fraction of the feed should be removed first. Clearly, the separation load will depend on the amount of material to be processed. By reducing the amount of this material early in the sequence, processing costs can be cut.

Density separation

Simple?

- Medium
- Process setup
- Particle size and shape



Material	*Specific Gravity*
Polyethylene (low density)	0.917–0.932
Polyethylene (high density)	0.952–0.965
Poly(vinyl chloride)	1.30–1.58
Polytetrafluoroethylene	2.14–2.20
Polypropylene	0.90–0.91
Polystyrene	1.04–1.05
Poly(methyl methacrylate)	1.17–1.20
Phenol-formaldehyde	1.24–1.32
Nylon 6,6	1.13–1.15
Polyester (PET)	1.29–1.40
Polycarbonate	1.20

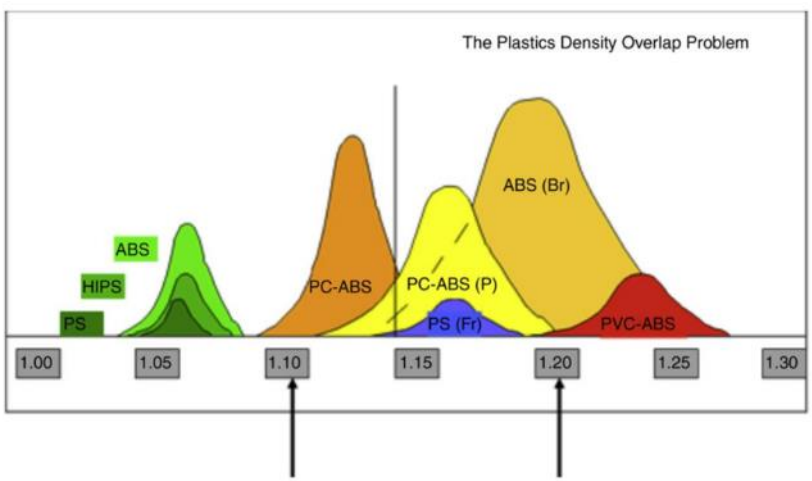
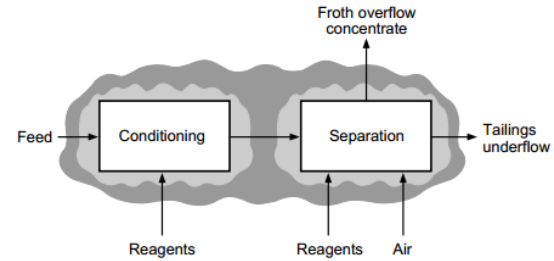


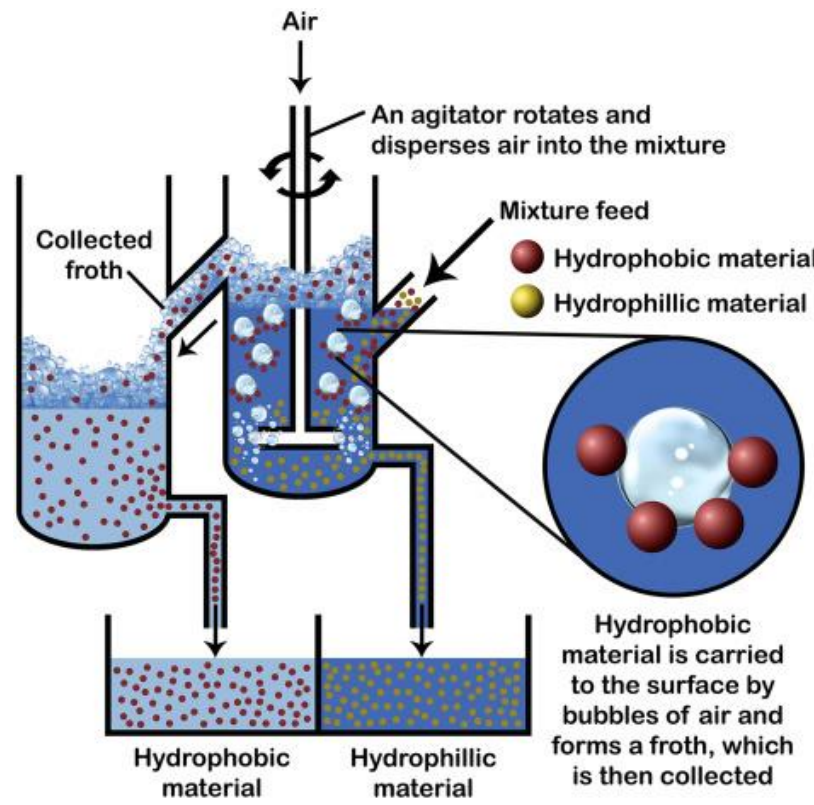
Figure 3.14 *Overlapping plastic density [19].*

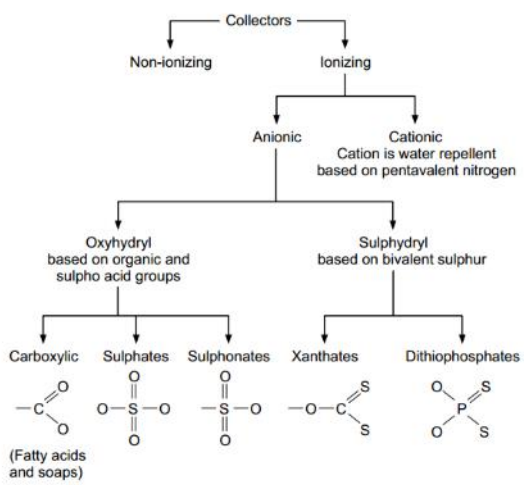
Dense liquid	Density (g/cm^3)
H_2O	1.0
$NaCl + H_2O$	1.2
$ZnCl_2$	1.75
$CaCl_2 + H_2O$	1.5
Bromoform	2.89
Acetone: TBE = 0.27:1	2.5
TBE	2.96
Clerici solution	4.28

Froth flotation

Introduce air bubbles
Density + hydrofobicity
Surface chemistry adjusted by collectors
Frothers stabilise foam layer







Step 4: washing

- Typically friction washers
- Most common detergent NaOH
- Cold or warm
- Current technology can remove dirt, organic contamination
- Remains challenging: odour, ink

- Not required in most post-production scrap

Step 5: size reduction

Why?

- Homogenisation
- Better handling
- Increase surface to volume area

3 options: shear, impact, cut

Important - brittle materials will:

- Produce a lot of fines
- Have more losses in shredding

Step 6: compounding

- From flake to granulate (uniformity of processing)
- Homogenization
- Re-additivation (stabilizers, clarifiers, colours,…)
- Optional blending with virgin

- Is a thermo-mechanical loading in itself
- Often uses melt filtration

- YOU GET OUT WHAT YOU PUT IN

Mechanical Recycling in the Circular Economy for Plastics

Disadvantages

- Challenging to obtain food contact for anything except PET
- Progressive thermomechanical degradation → you will always need virgin influx
- Very dependent on input qualities
  - Especially for optically clear
- Pricing competition with virgin

- Mechanical recycling alone will not get us to the ambitious EU targets in time

Advantages

- Easy, 'cheap' and 'low tech'
- Lowest footprint of recycling options
- No discussion on whether it count as recycling
- It's what the collection systems are built for
- Uses the same polymer science as basic compounding, converting
  - Just a little more complicated

- Still the 'go-to'

Mechanical recycling for PMMA?

Collection: where will we get it?

Relevant to all types of PMMA recycling:

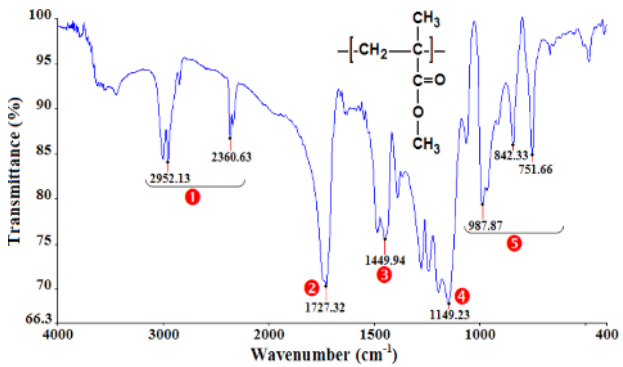
- There exists no post-consumer collection and/or sorting that targets PMMA
- If existing systems were to be expanded in that direction → B&C is most likely candidate, with cross-contamination from clear PC

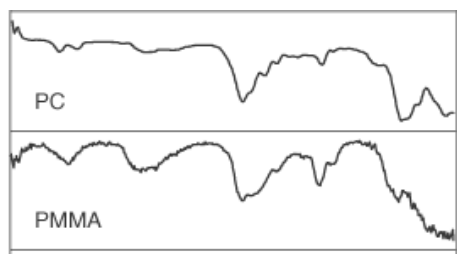
Currently:

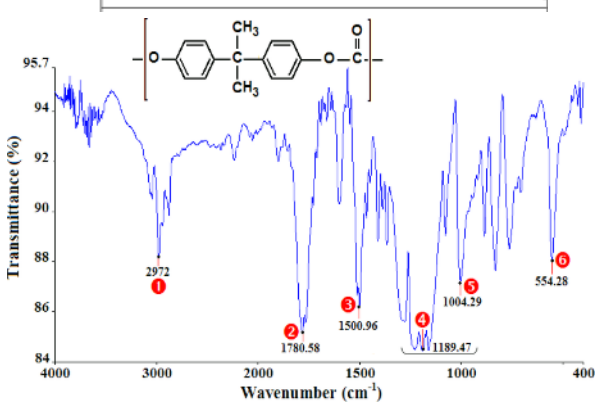
- Post industrial streams only

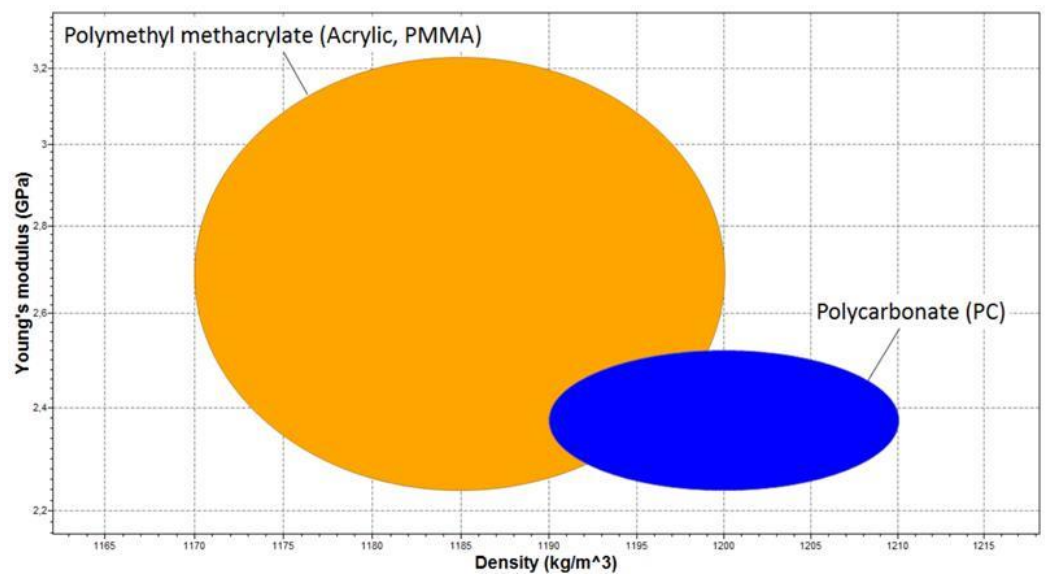
Mechanical recycling for PMMA?

If we get it mixed, how will we sort it?







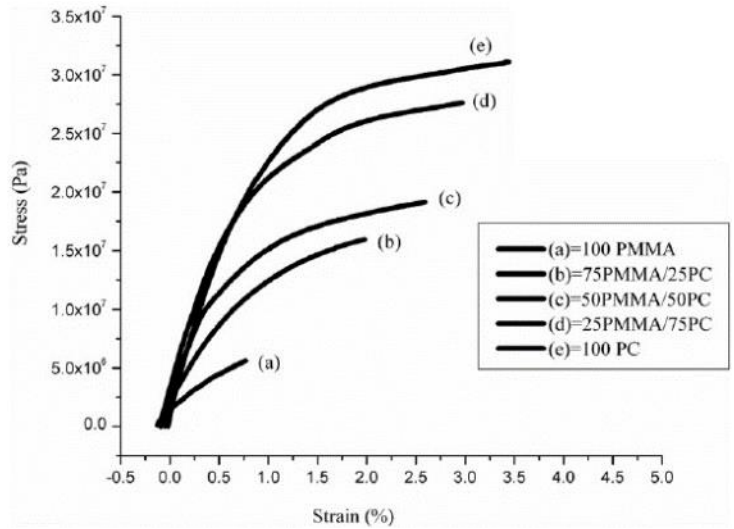


Ghorbel et al. 2014. Materials. Characterization of Thermo-Mechanical and Fracture Behaviors of Thermoplastic Polymers

Mechanical recycling for PMMA?

How will PMMA behave in process?

- In shredding: brittle behaviour (the toughness comes from the elasticity, not plasticity)
- In compounding: PMMA has good thermal stability
- ‘you get out what you put in’: optical clarity is challenging if input is not pure



Mechanical recycling for PMMA?

Anything else?

Methyl methacrylate

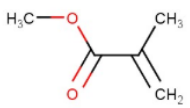
Regulatory process names 6 Translated names 46 CAS names 1 IUPAC names 21 Trade names 25 Other identifiers 10

Substance identity

EC / List no.: 201-297-1

CAS no.: 80-62-6

Mol. formula: C5H8O2



Hazard classification & labelling

Danger! According to the **harmonised classification and labelling** (CLP00) approved by the European Union, this substance is a highly flammable liquid and vapour, causes skin irritation, may cause an allergic skin reaction and may cause respiratory irritation.

Additionally, the classification provided by companies to ECHA in **REACH registrations** identifies that this substance may be harmful if inhaled and is harmful to aquatic life.

All these considerations together lead to the fact that (today),
PMMA is not mechanically recycled.

If and when it is recycled, it is done via pyrolysis or (emerging)
depolymerization.

MMAtwo

Second Generation MethylMethAcrylate

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Mechanical Recycling of Polymers for Dummies

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