EmPHAti: Tuneable PHA-Based Biodegradable Binder Platform

- Project goal:
  - Development of a biodegradable binder based on *mcl*-PHA
- Project partners:
  - Hanze university of applied sciences
  - Wydo NBD
  - Hochschule Emden-Leer

WYDO
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Hanze

University of Applied Sciences
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eco-friendly materials from poly hydroxy alkanoates tuned for injection moulding
EMPHATI

Interreg
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Why biodegradable binders?

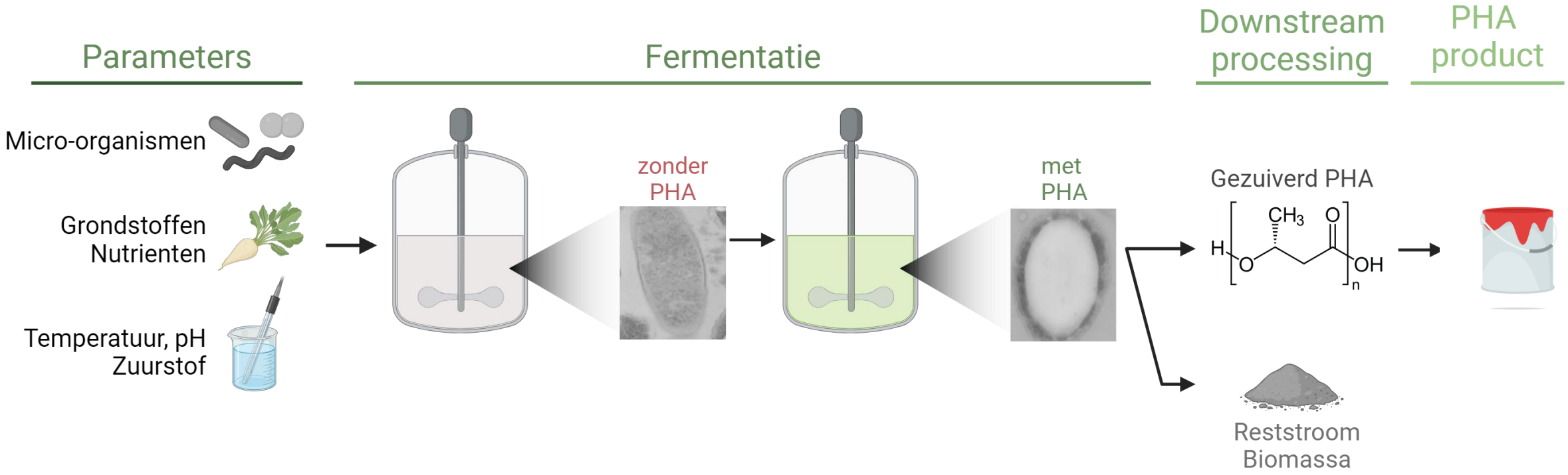
- The use of microplastics is restricted under REACH.
  - **Applies to paints which contain "solid synthetic microparticles" → Polyacrylates.**
- Polyacrylate binders are one of the most used type of binder systems.
- Polyacrylates are already, or will be, forbidden in other product categories
  - Cosmetics (2023);
  - Detergents & agriculture (2028);
  - Crop protection and granulates (playing fields, 2031).
- Degradable polymers are exempt from the restriction.
  - **Polyacrylates are not degradable, and a prohibition for the use in paints is foreseen.**

- New binder technology is necessary
  → **Polyhydroxyalkanoates (PHA's)**

- PHA's
  - Biodegradable polyesters
  - A plural of structures available
    → Tunable properties.
  - Fermentative production from waste streams possible.
  - Tradeoff performance vs biodegradability

We wish to develop renewable, biodegradable binders based on PHA's.

Fermentation of *mcl*-PHA



Which PHA / quality?

- Feed-composition
- Type of micro-organism
- Process conditions
- Down stream processing

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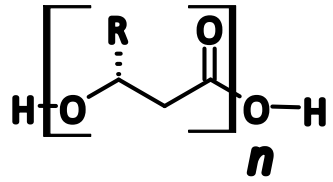
PHA - chemical modification



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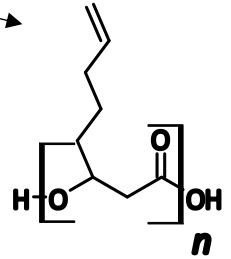
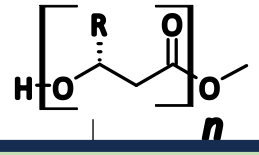
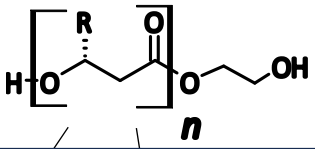
PHA fermentation engineering

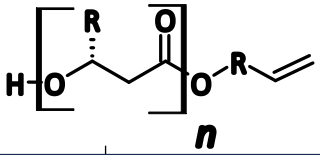


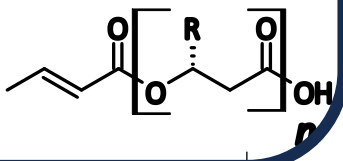
Transesterification

Thermal degradation



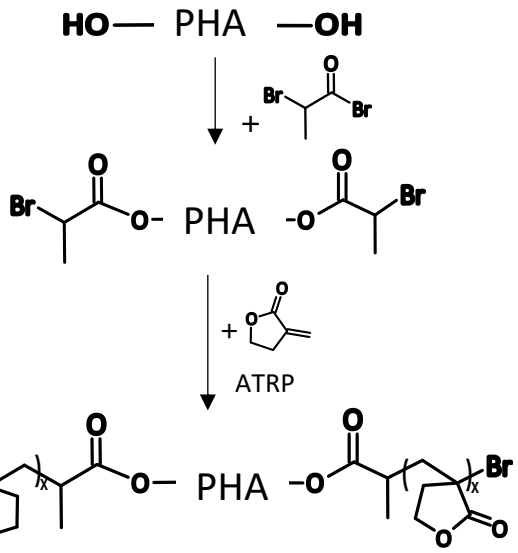






Macroinitiators

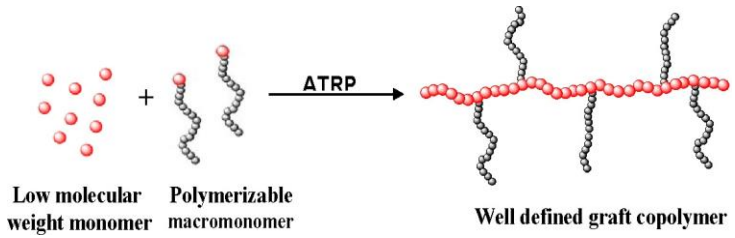
Copolymerization to form linear copolymers.



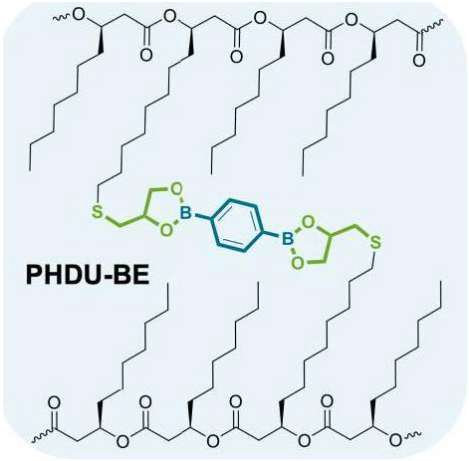
Copolymerization to form (random)block-copolymers.

Polyester synthesis, Copolymer synthesis with other natural polymers.

Macromonomers for graft copolymerization with suitable (biobased) monomers or cyclic ketene acetals for radical ring-opening polymerization.

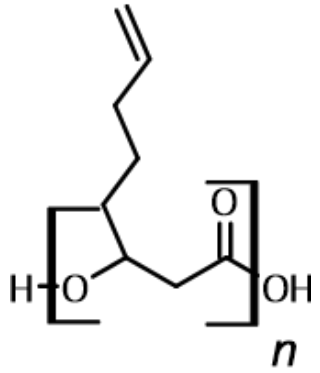


Vitrimer forming through thiol-ene click chemistry, oxidative cross-coupling or other mechanism.

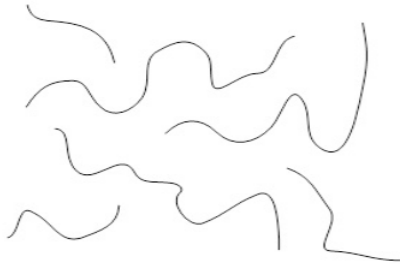


PHA cross-linking
the perfect picture

Fermentation process



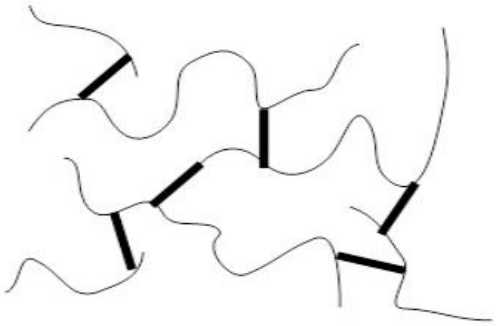
Engineered *mcl*-PHA
Vinyl or another functional group



Functional group modification

Cross-linking of functional groups

Cross-linked polymer network =
Novel coating



PHA – analysis and chemical modification

Analytics

- DSC
- IR

- GPC (with standards or triple detection)
- titrations
  - saponification value
  - acid value
  - iodine value
  - (hydroxyl value?)
- (LC)-MS

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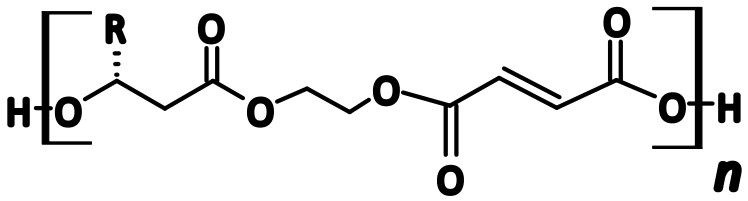
PHA Modification

- only transesterification

  ("classic" or lipase-catalyzed)



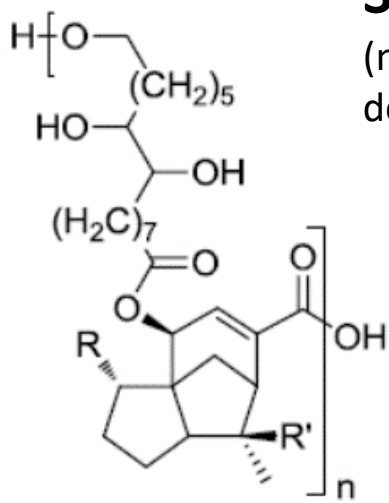
PHA-ethylene glycol-maleic anhydride copolymer

- without crosslinking

  ethylene glycol/carbonate + maleic/itaconic acid (-anhydride)

- with crosslinking

  glycerol + …., shellac, colophony



Shellac
(natural polymer derived from lice)

R = CHO, CO_2H
R' = CH_2OH, CH_3
n = 1 - 4