New Fast Compostable Polymer without leaving any Traces of Microplastic

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Aim

- Establish a tailor made polymer platform for balancing mechanical properties and degradability.

Concept

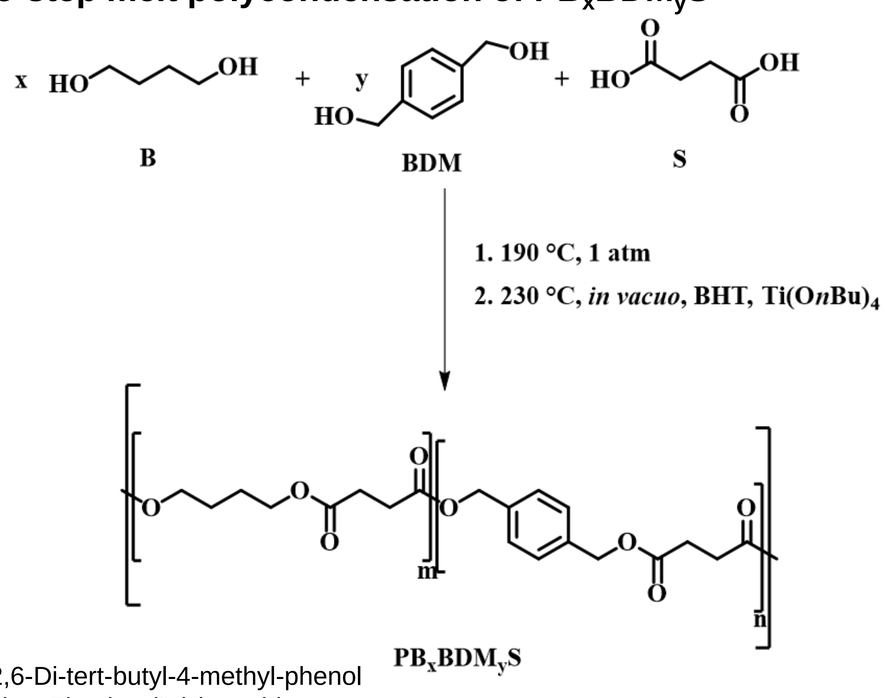
- Achieve desired properties combination by adjusting the molecular composition and structure.

Motivation

- Mechanical stable aromatic polyesters like Polybutylene terephthalate (PBT) are well known for their mechanical strength but are not environmentally degradable.
- Crucial need for fast degradable polymers with appropriate mechanical properties for e.g. packaging and agricultural application.[2]

Synthesis & Characterization

Two-step melt polycondensation of PB_xBDM_yS



BHT = 2,6-Di-tert-butyl-4-methyl-phenol
$Ti(OnBu)_4$ = Titanium(IV) butoxide

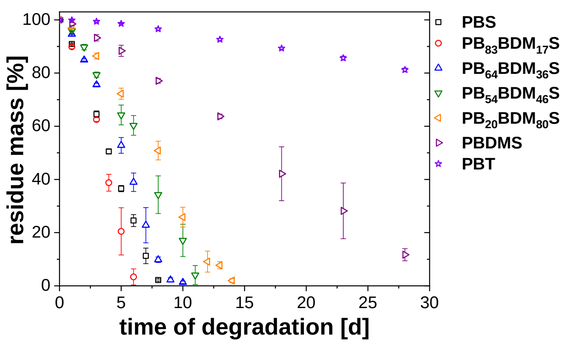
Composition, yield, molecular weight, thermal analysis and crystallinity.

Polymer[a]	Yield [%]	$\bar{M}_n$[b]	$Đ$[b]	T_d[c] [°C]	T_g[d] [°C]	T_m[d] [°C]	ΔH_m[d] [J·g^{-1}]	X_c[e]
PBS	-	75000	2.4	365	-32	116	63	0.44
$PB_{83}BDM_{17}S$	85	63000	2.4	368	-29	90	50	0.42
$PB_{64}BDM_{36}S$	82	74000	2.1	371	-20	69	40	0.25
$PB_{54}BDM_{46}S$	84	66000	2.2	374	-15	66	31	0.16
$PB_{44}BDM_{56}S$	86	58000	2.1	375	-12	47	20	0.14
$PB_{20}BDM_{80}S$	90	43000	2.3	382	-1	72	30	0.30
PBDMS	95	35000	2.8	383	6	100	30	0.31

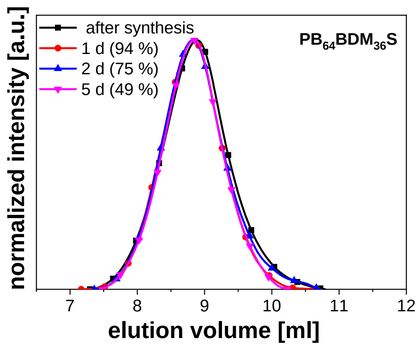
[a]x and y are the molar ratios of B and BDM in the feed; [b]GPC($CHCl_3$, 23°C, PS-standard); [c]onset temperature, TGA(N_2, 25 – 1100 °C, 10 K·min^{-1}); [d]DSC(N_2, 80 – 300 °C, 10 K·min^{-1}); [e]XRD(Cu K_α, 2θ = 5 – 45 °).

Degradation Tests

Alkaline Hydrolysis:

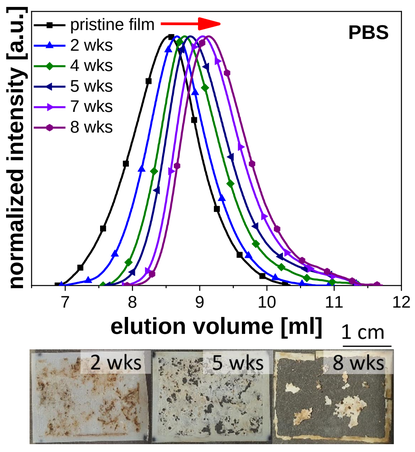


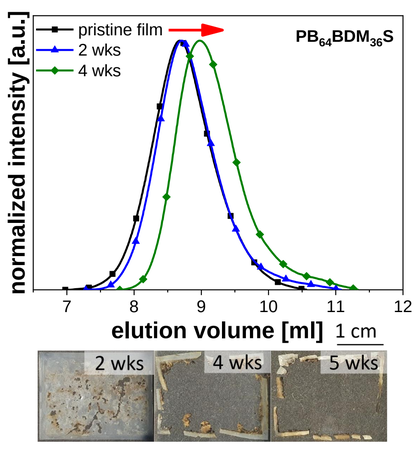
Mass loss over time (1 M NaOH, 50 °C).



GPC at different time intervals.

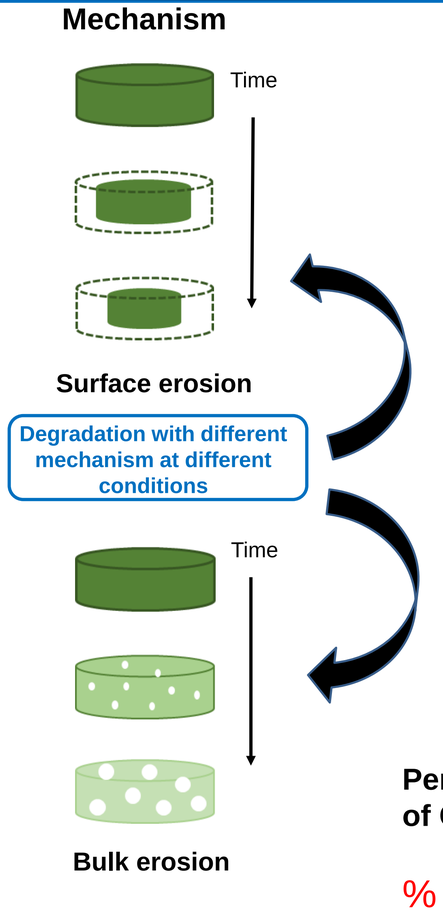
Controlled Composting:





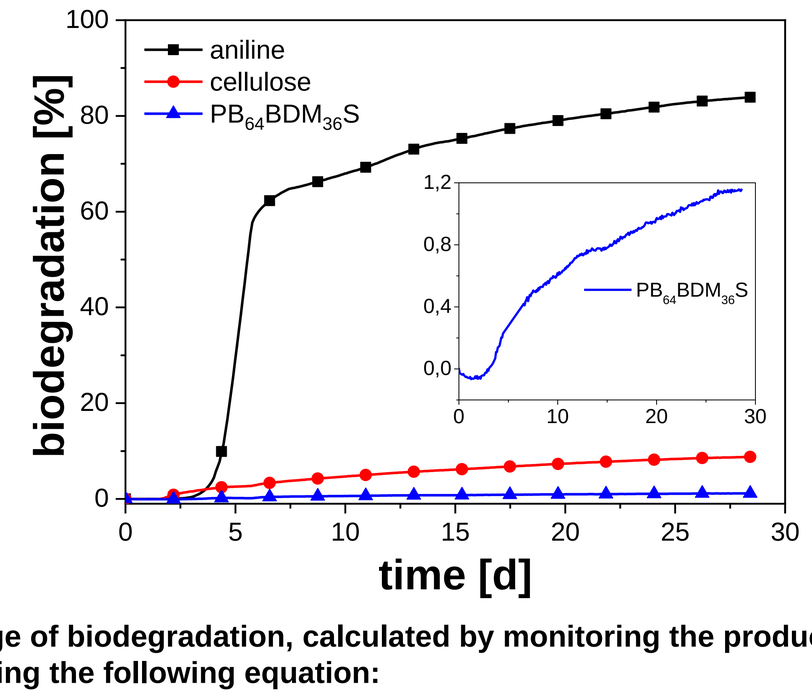
❑ GPC at different time intervals and photos of corresponding films. (Composting at 58 °C and 50% humidity)

Mechanism



Wastewater Degradation:

- Biodegradability test according to ISO 14852 in activated sludge water



Percentage of biodegradation, calculated by monitoring the production of CO_2 using the following equation:

$$\% \text{ Biodegradation} = \frac{(mgCO_2\ produced)_T - (mgCO_2\ produced)_B}{ThCO_2} \times 100$$

Conclusion

- New polymer synthesized with high molar masses.
- Fast chemical hydrolysis and degradation in industrial compost.

Literature

[1] E. Sehl, E. M. Eger, A. Himmelsbach, S. Agarwal, *ACS Appl. Polym. Mater.* **2021**, *3*, 6427−6436.
[2] E.Sehl, R. L. Timmins, D. Ghosh, S. Agarwal, *ACS Appl. Polym. Mater.* **2022**, *4*, 6675−6686.
[3] J. M. Millican, S. Agarwal, *Macromolecules* **2021**, *54*, 4455–4469.

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