

Closing the loop: pyrolysis of flame- retarded (E)PS

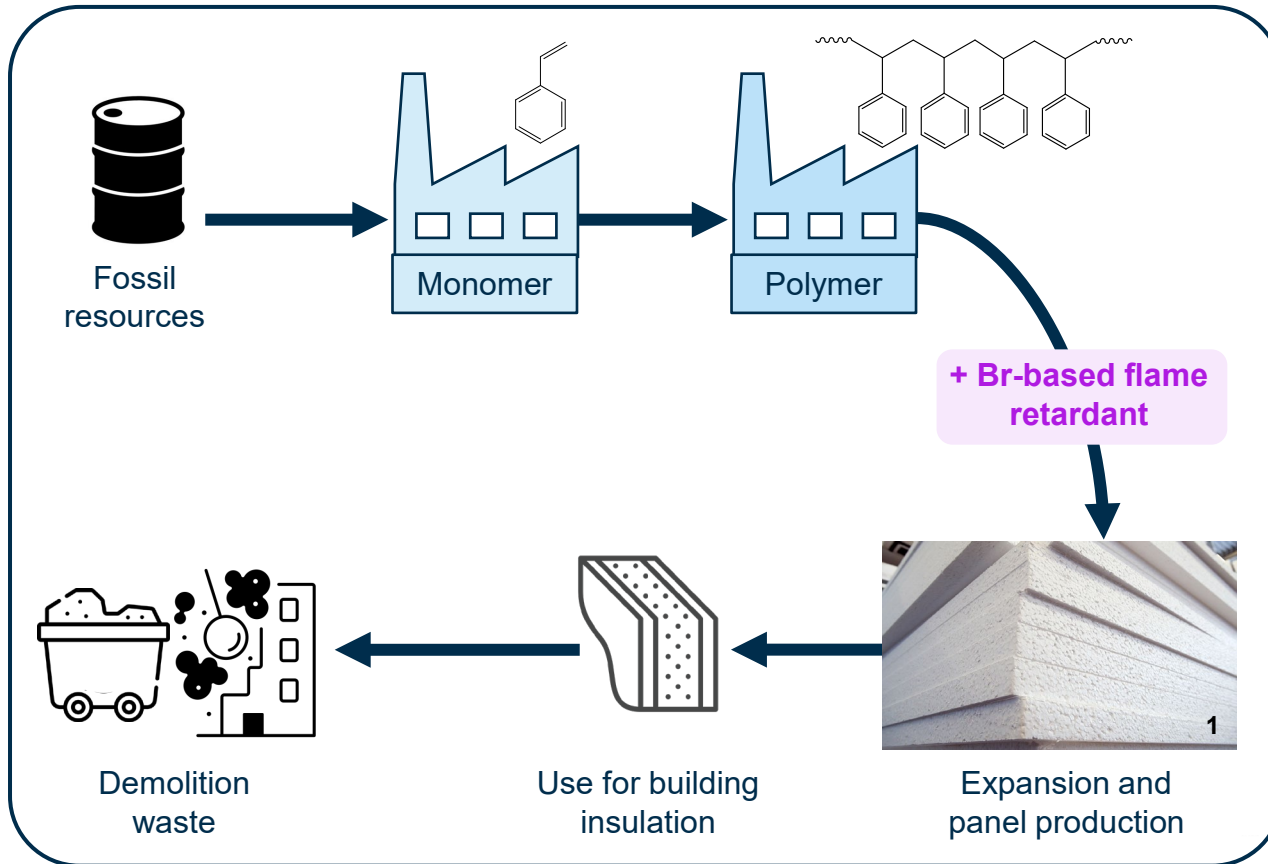
Razan Alshargawi, Daniela Merz, Tim Kurtz, Michael Zeller,
Niklas Netsch, Britta Bergfeldt, Salar Tavakkol, Dieter Stapf

18.03.2025

DECHEMA Fachgruppentreffen 2025, Dresden
Fachgruppe Abfallbehandlung und Wertstoffrückgewinnung
(AuW)

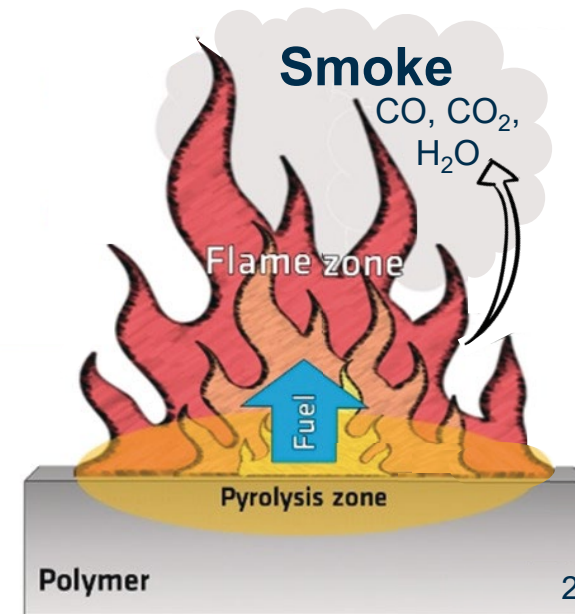


Background

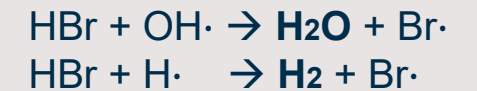


¹ <https://poytherm.com/de/was-ist-eps-und-wei%C3%9Fes-eps/blog/344>, accessed on 10.03.2025

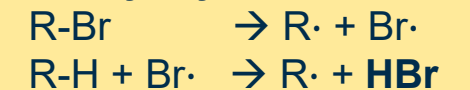
- + **HBr** forms in the pyrolysis zone ⁴
- ? Does HBr affect **EPS pyrolysis**?



Radical scavenging flame inhibition ³



Pyrolysis zone ³



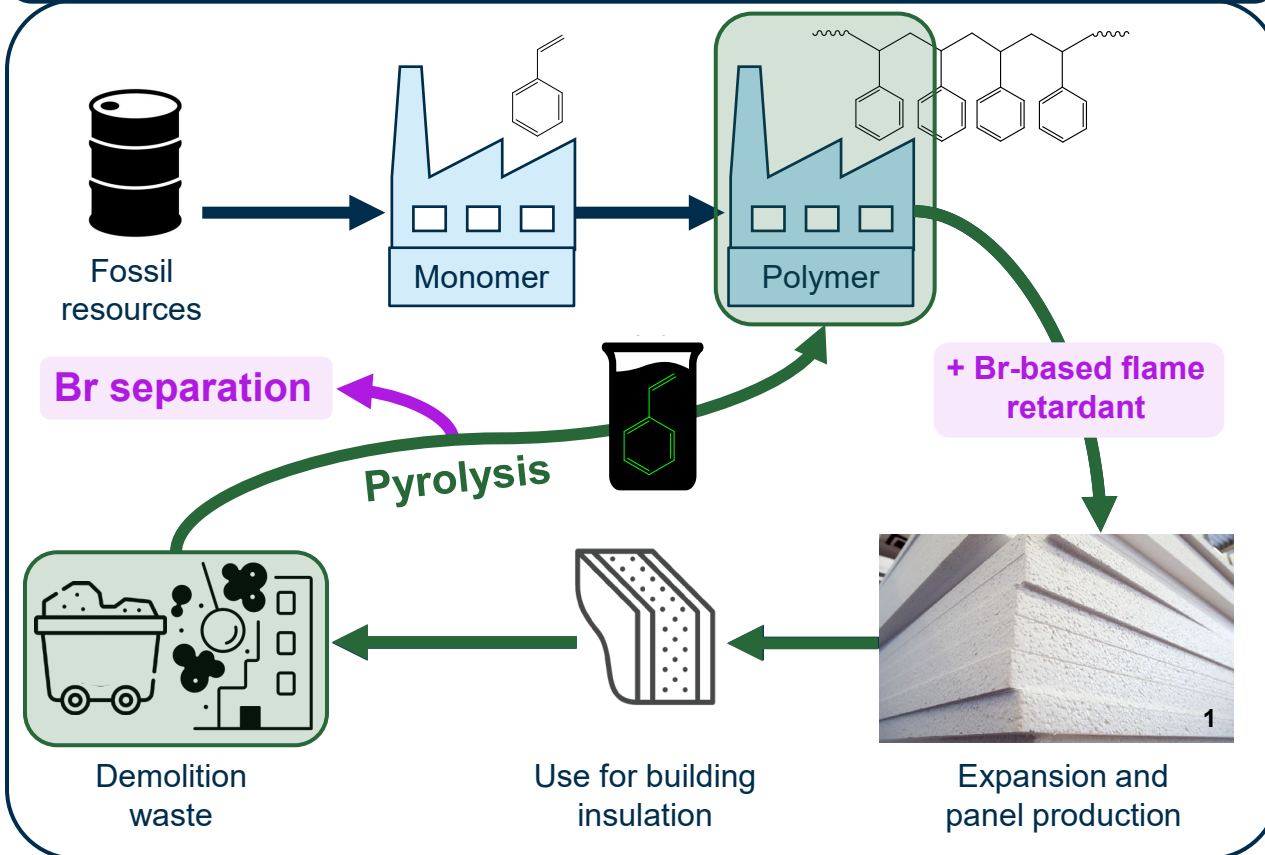
² Adapted and recreated from Velencoso et al., 2018, DOI: 10.1002/anie.201711735

³ Sai et al., 2022, DOI: 10.1002/sus2.73

⁴ Barontini et al., 2006, DOI: 10.1016/j.jaap.2006.01.003

Motivation

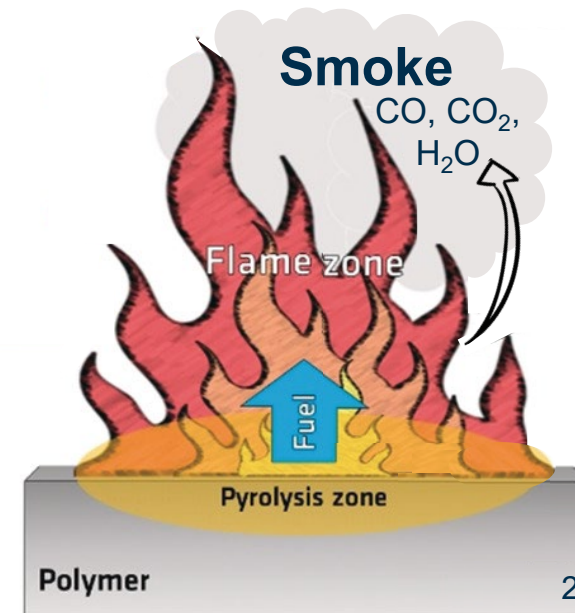
Goals: to **separate Br** and to obtain **Br-free oil**



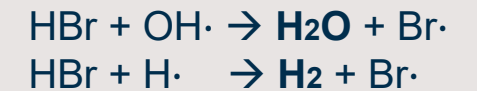
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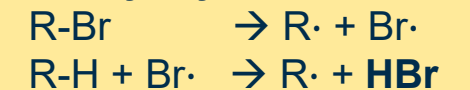
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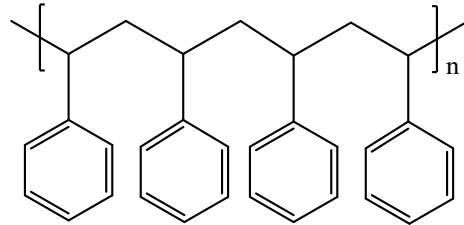


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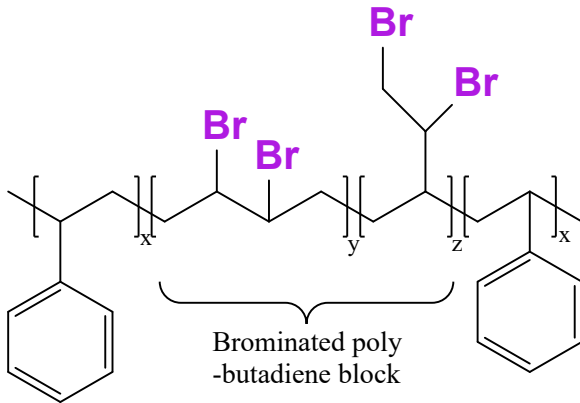
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Test matrix



PolyStyrene (PS)



Brominated butadiene styrene copolymer (PolyFR)

Commercial samples



Mixed samples

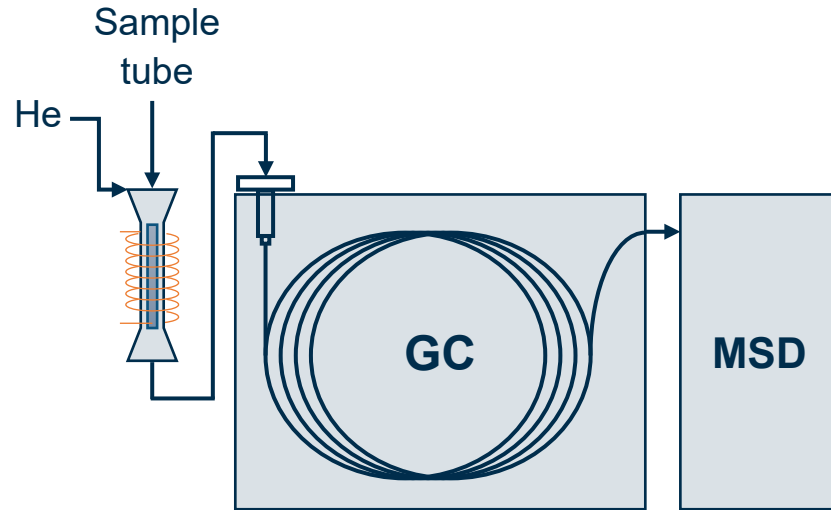


Composition in mass-%

	PS	PolyFR	Br
EPS	100	–	–
EPS-PolyFR	> 99	< 1	0.4 *
PolyFR	–	100	64
PS75PolyFR	25	75	48
PS50PolyFR	50	50	32
PS25PolyFR	75	25	16
PS	100	–	–

* Quantified via combustion ion chromatography (C-IC)

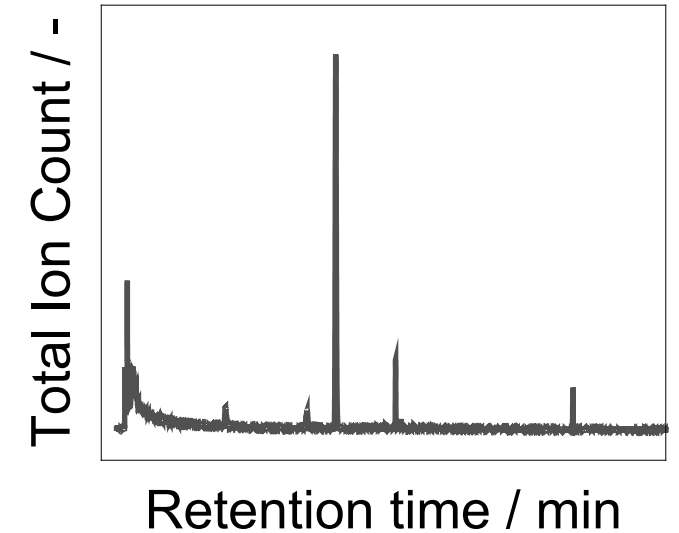
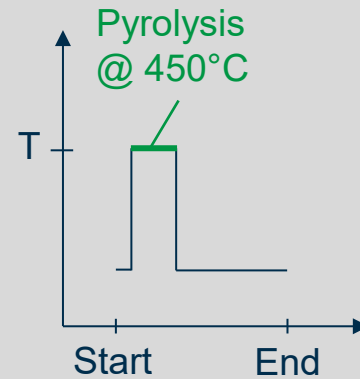
Analysis of pyrolysis products via Py-GC-MS



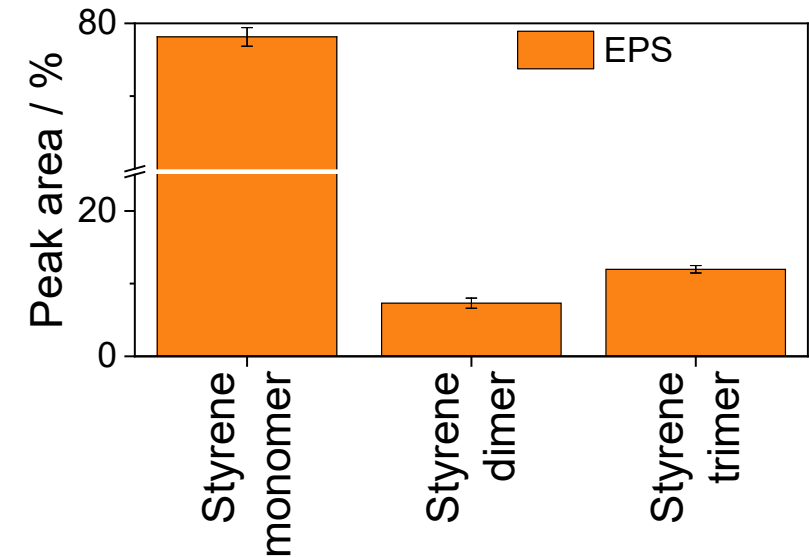
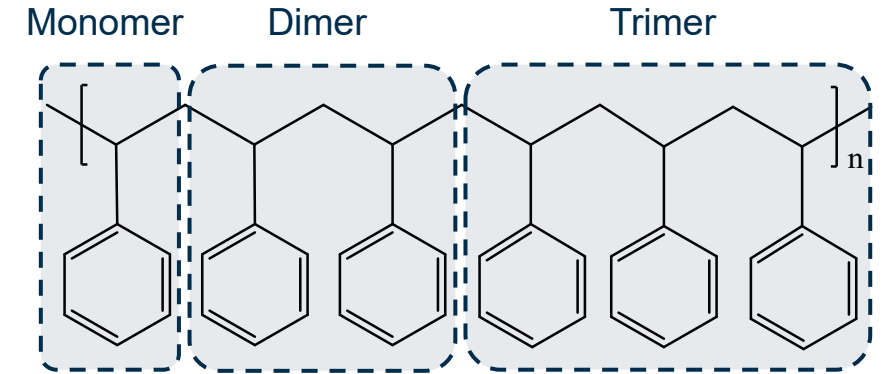
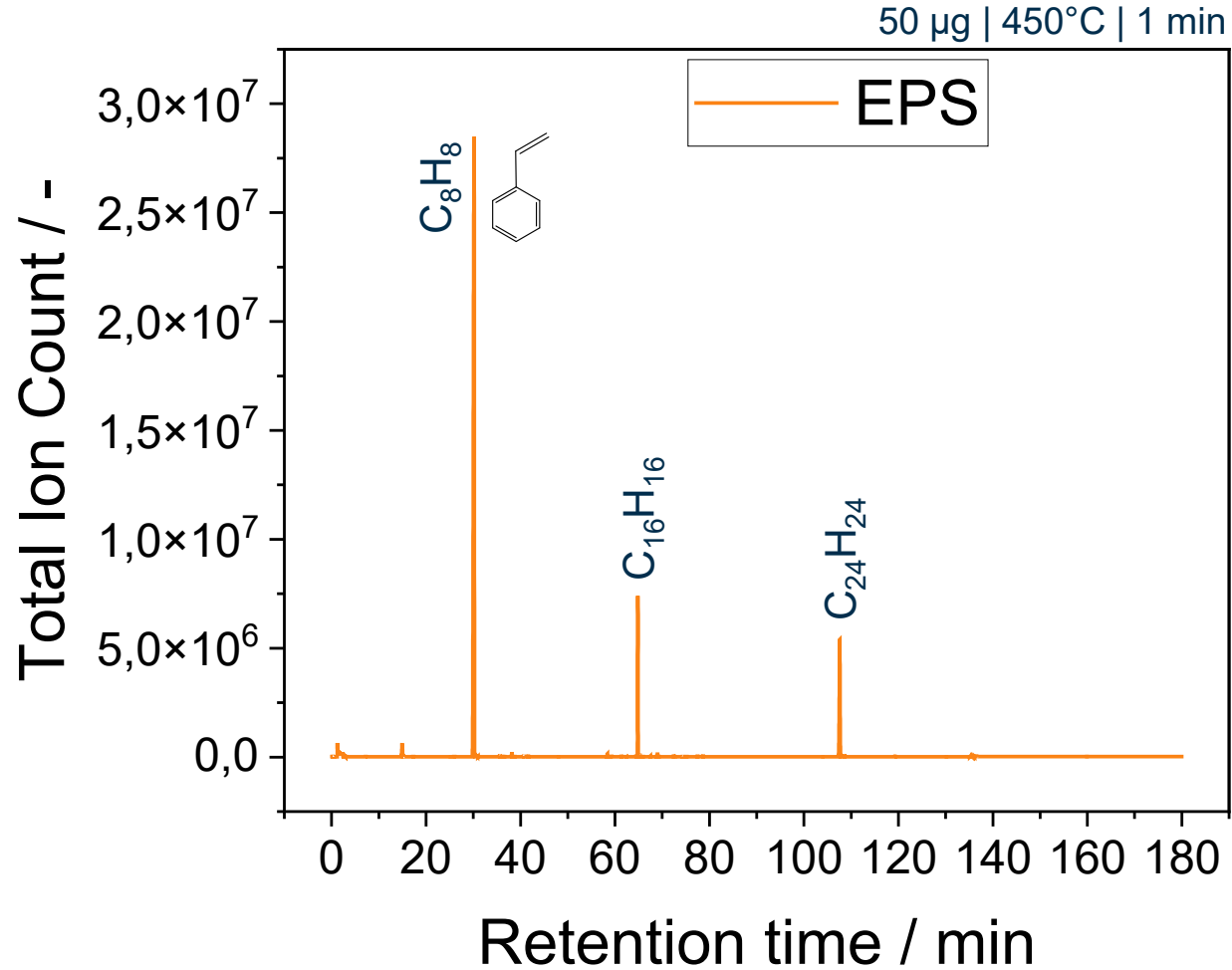
Py-GC-MS

Sample mass: 50 μg
Duration: 1 min
He atmosphere

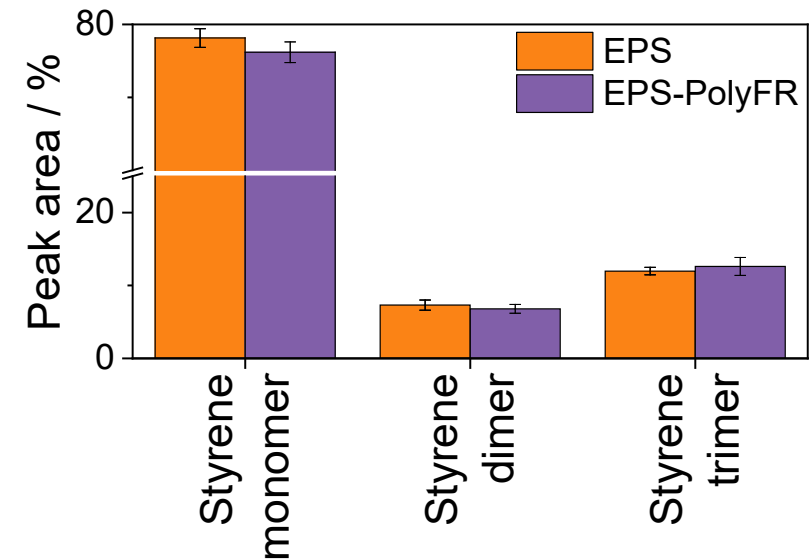
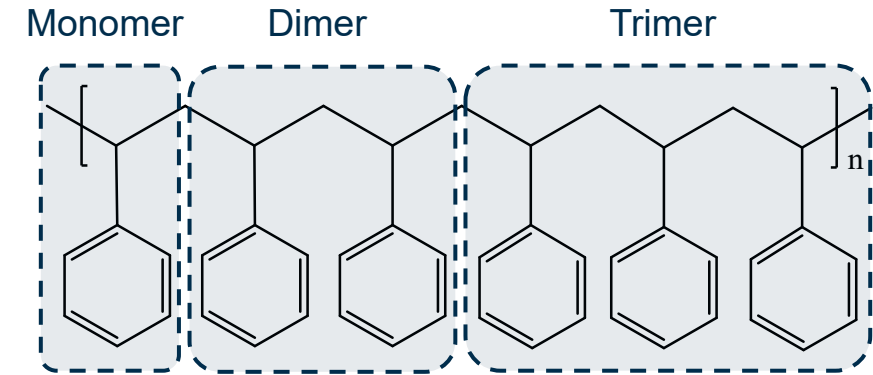
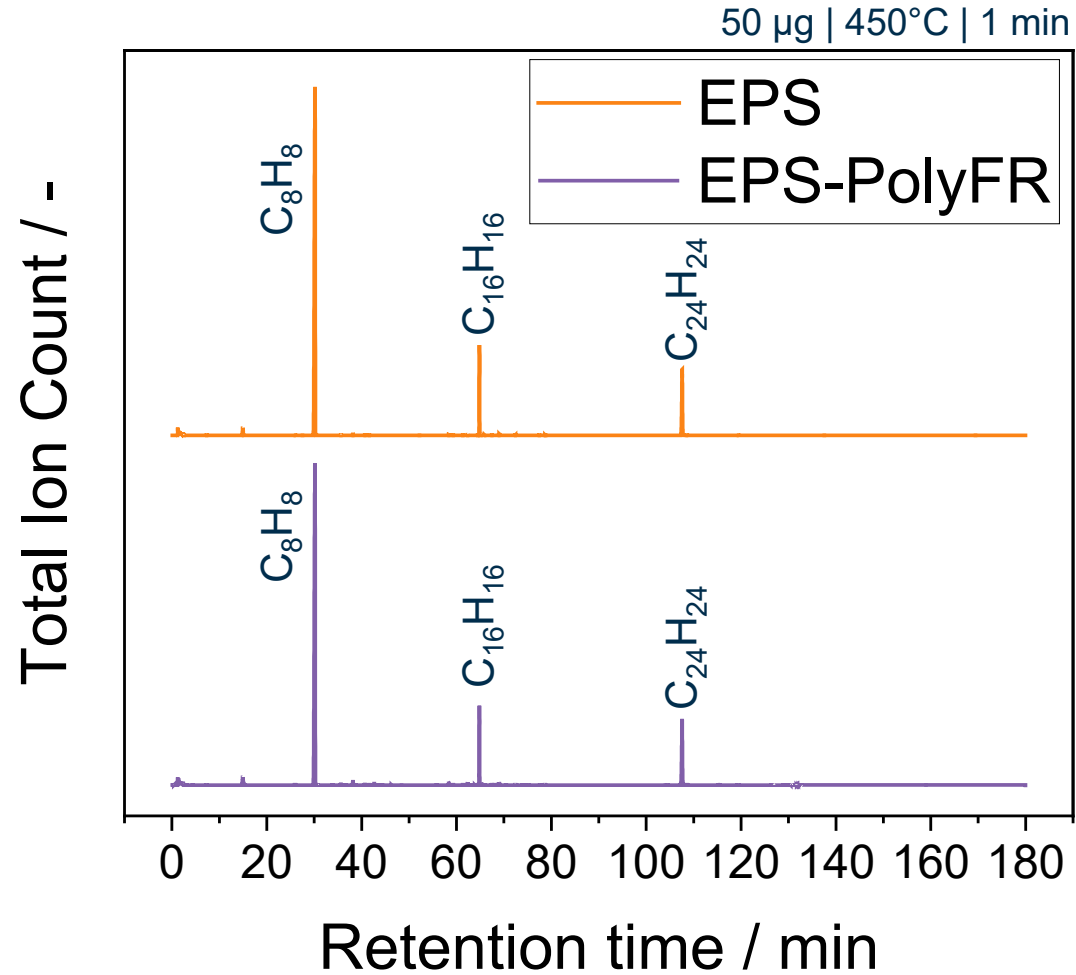
One-shot pyrolysis



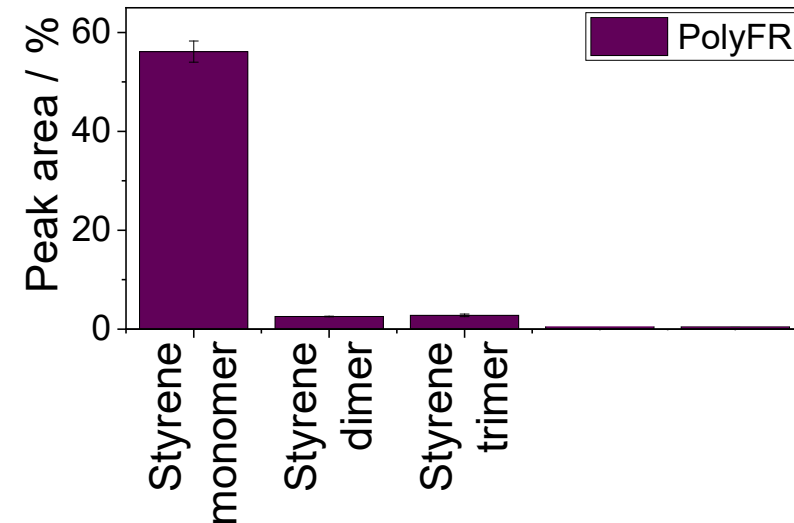
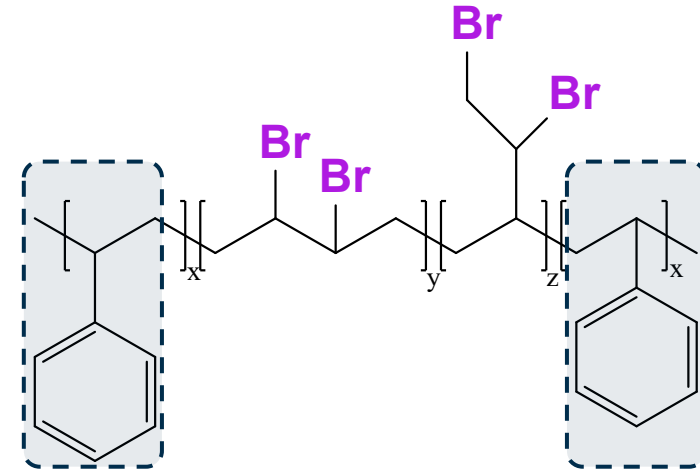
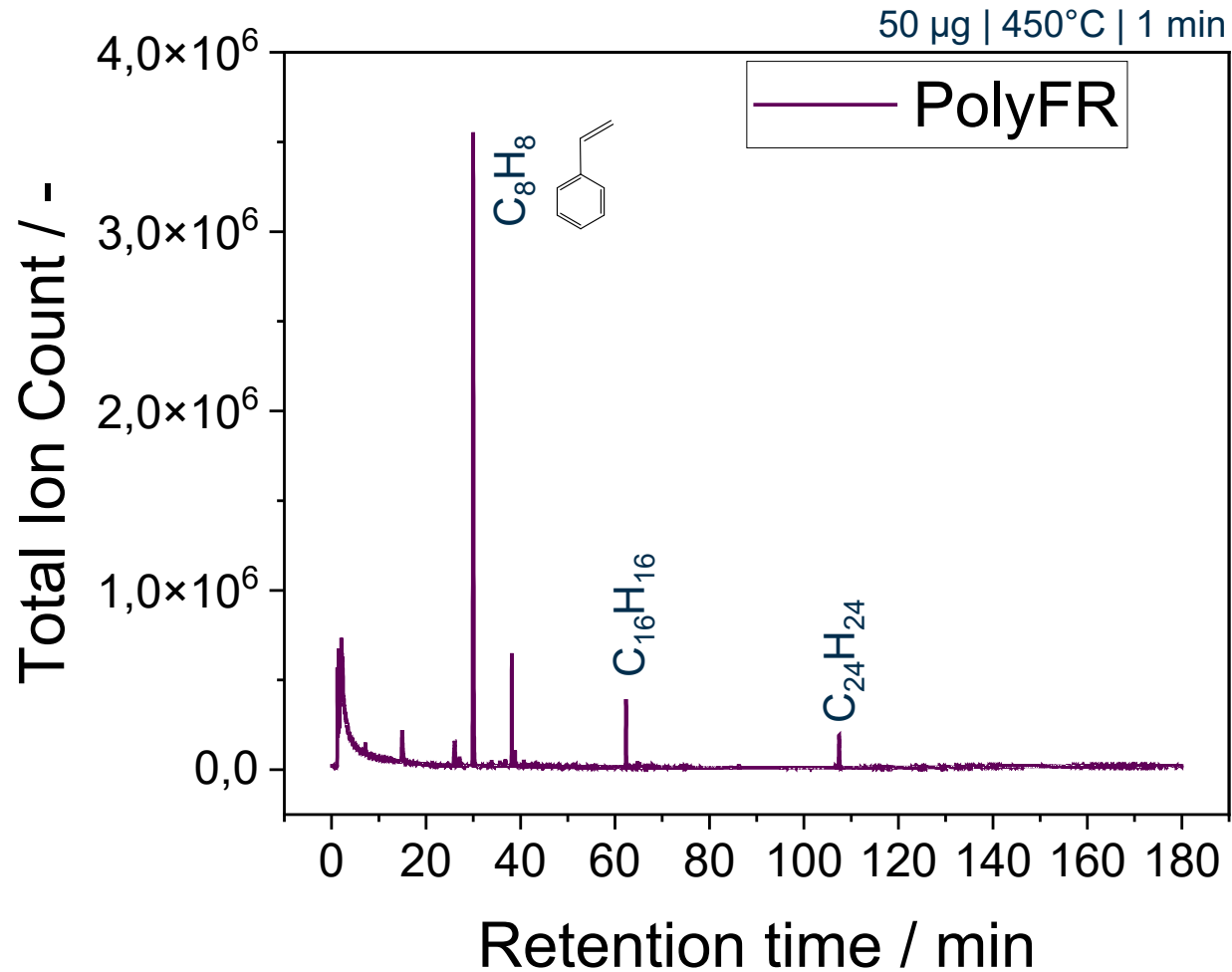
The basics ...



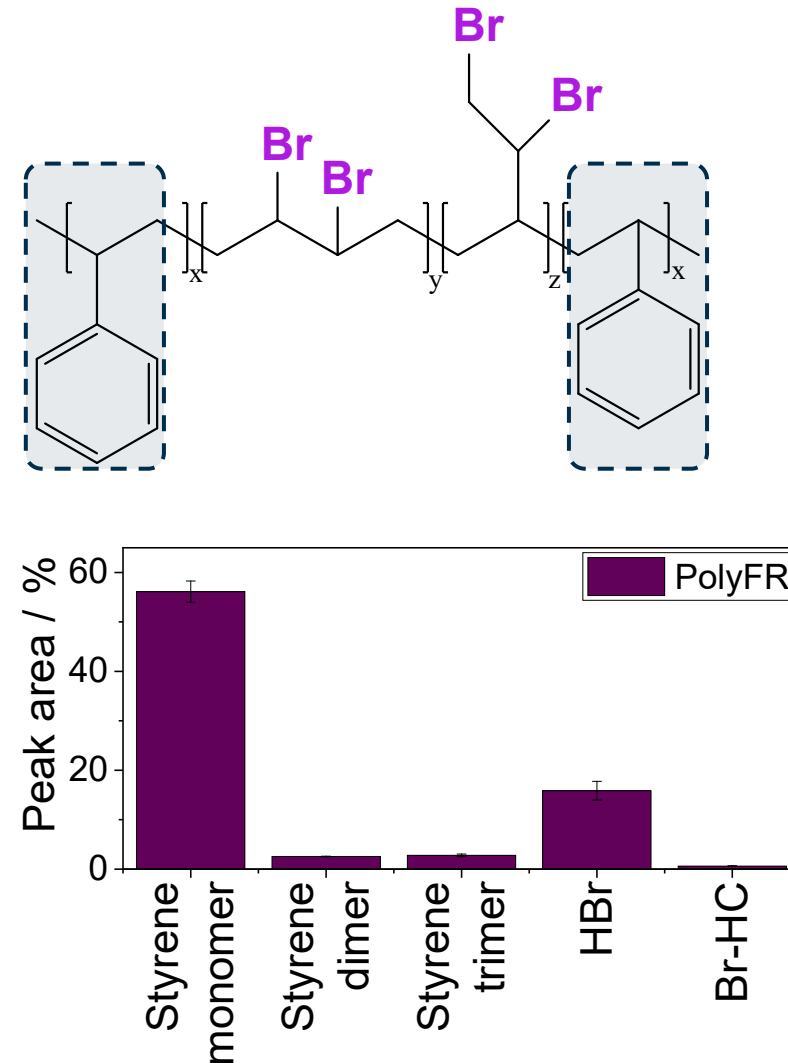
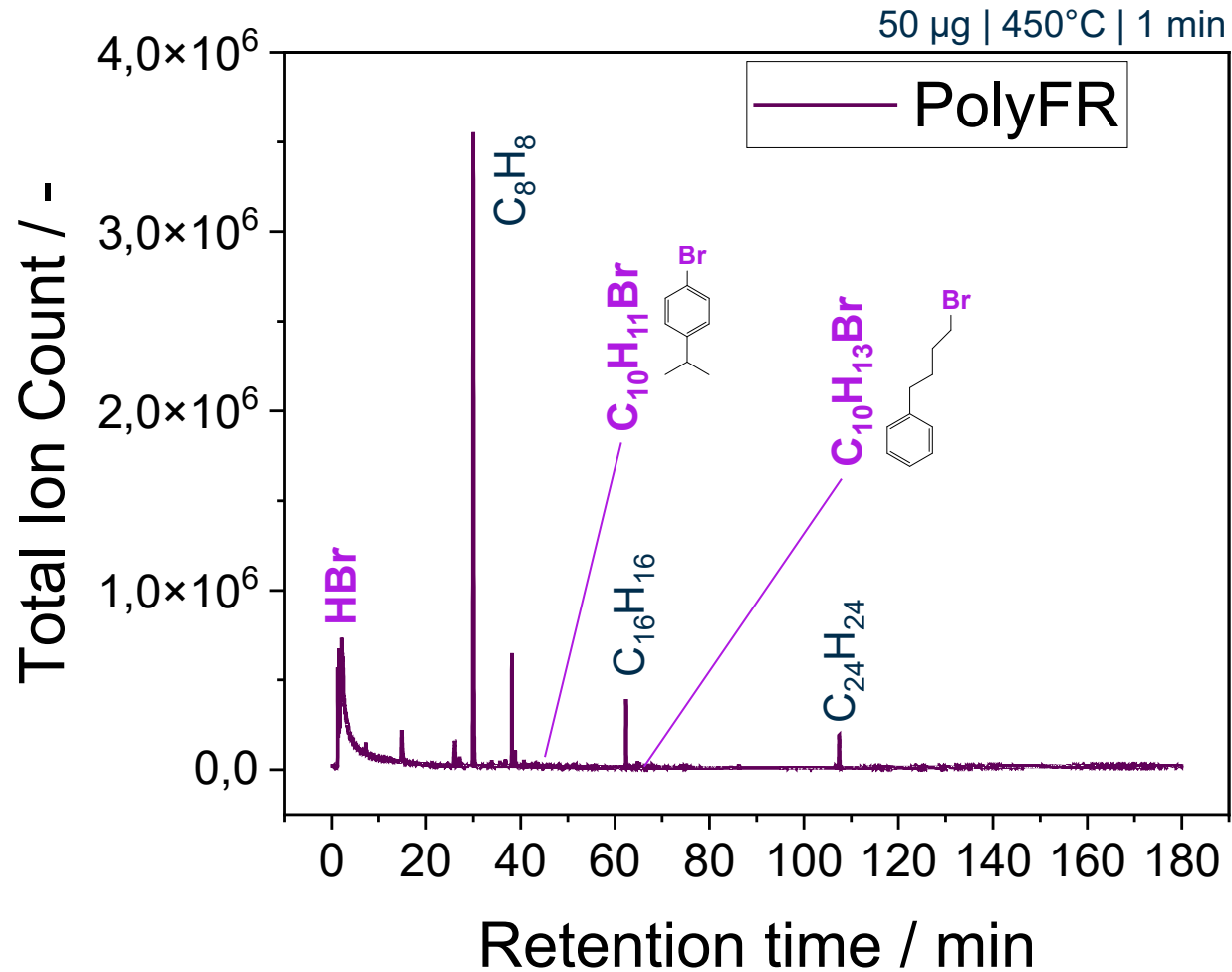
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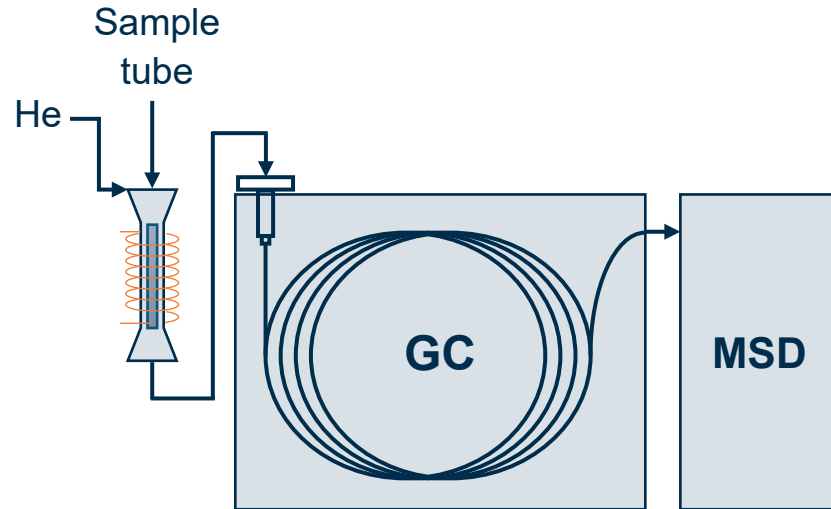
What about bromine?



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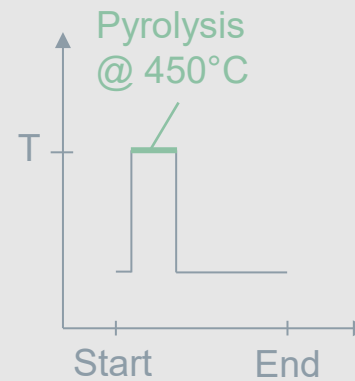
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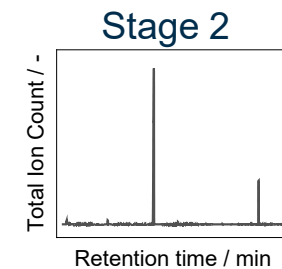
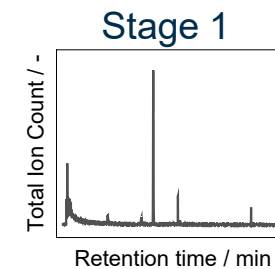
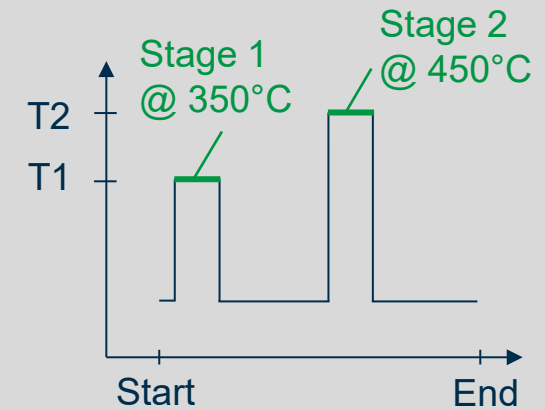
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He atmosphere

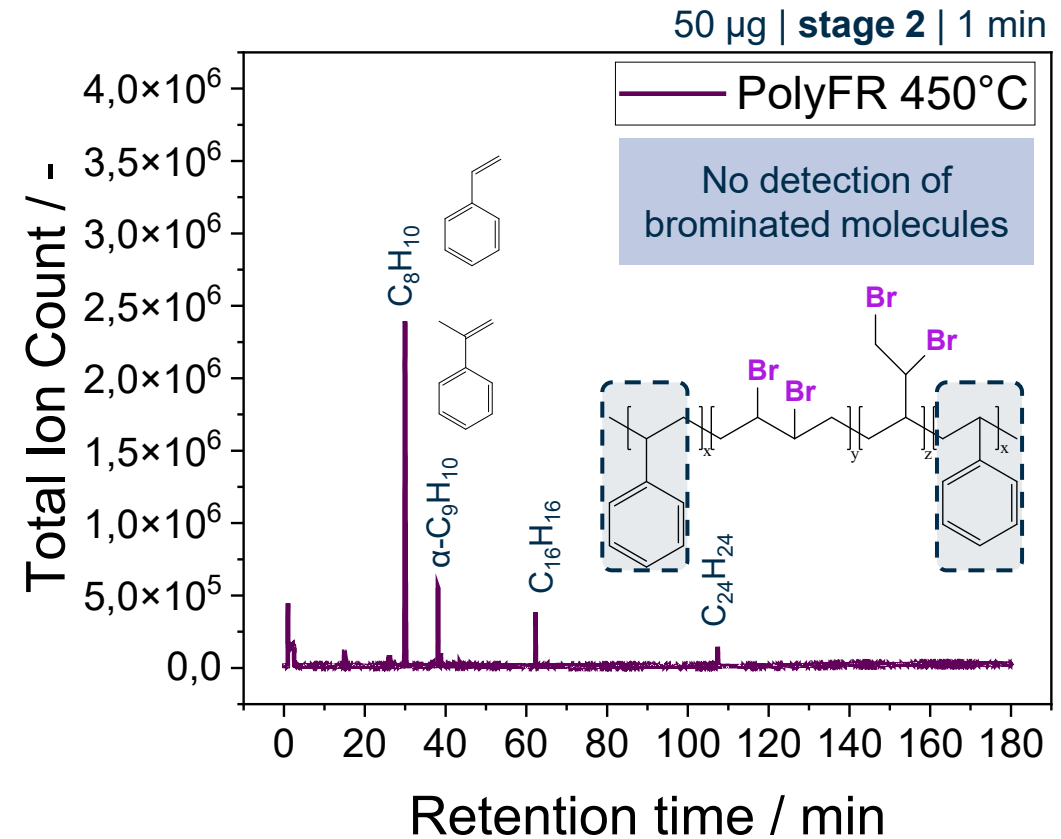
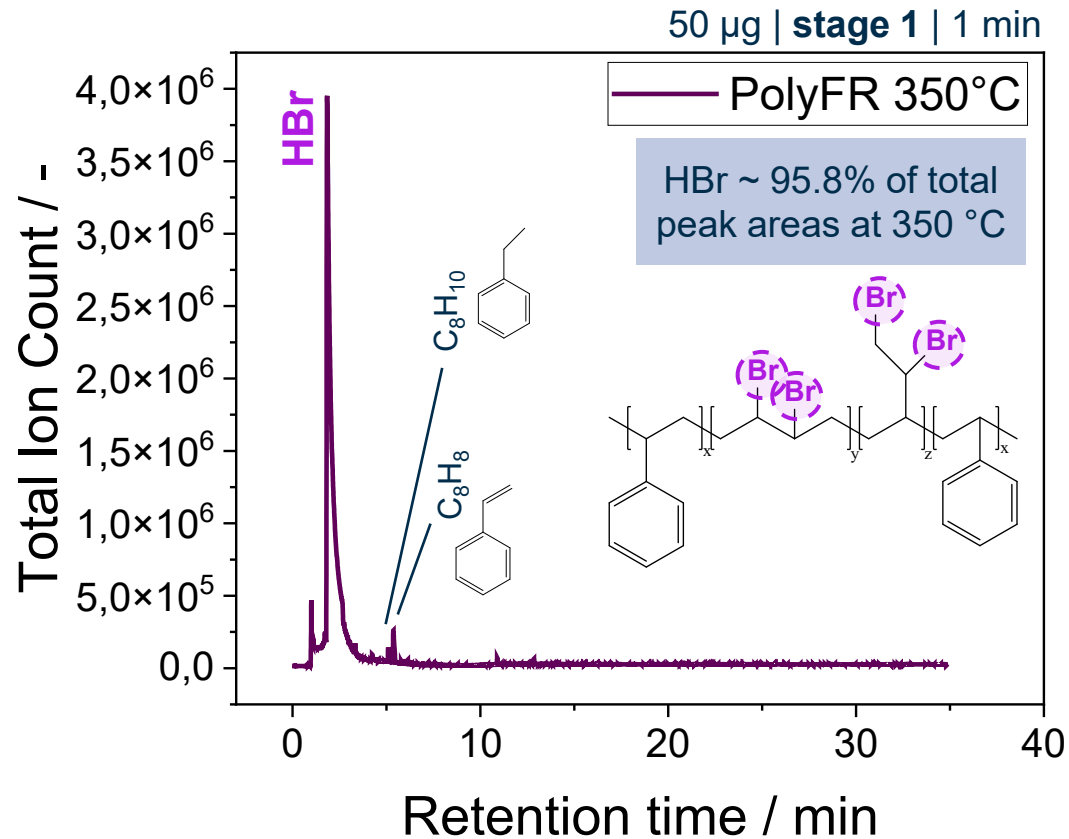
One-shot pyrolysis



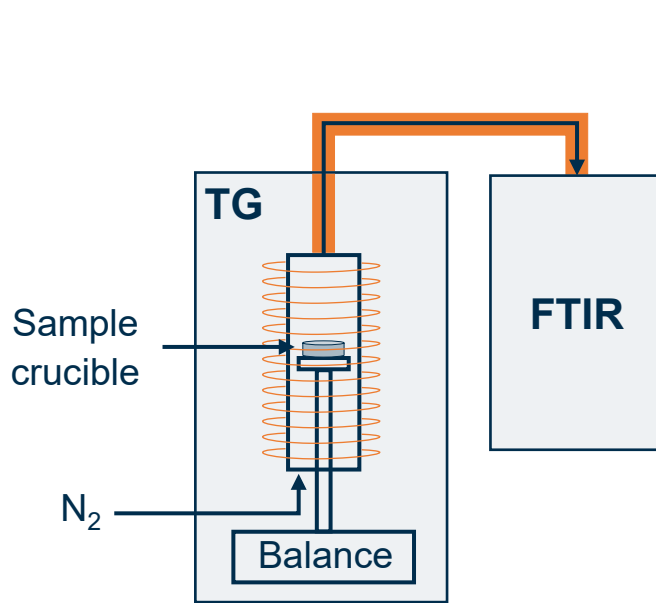
Temperature-staged pyrolysis



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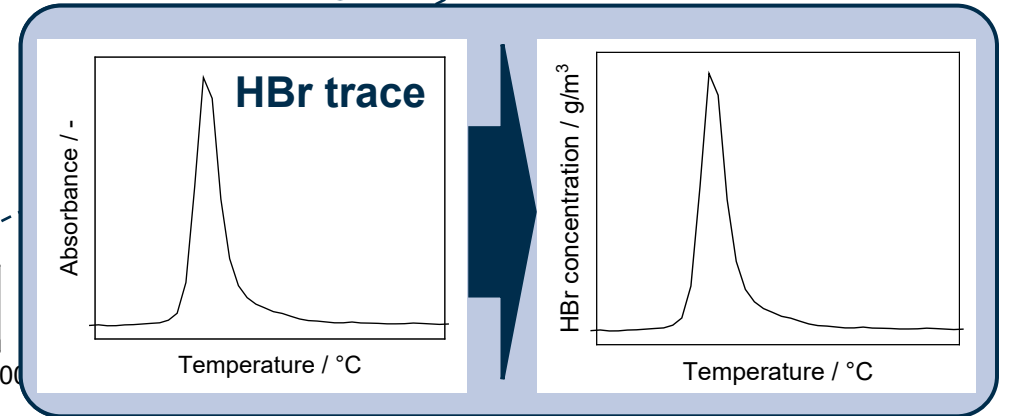
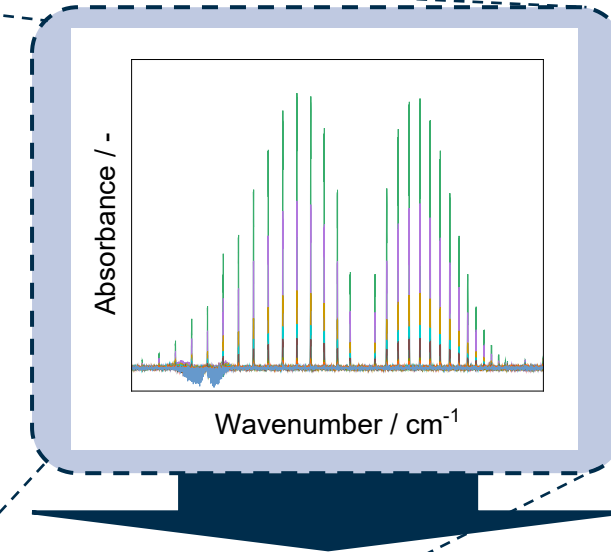
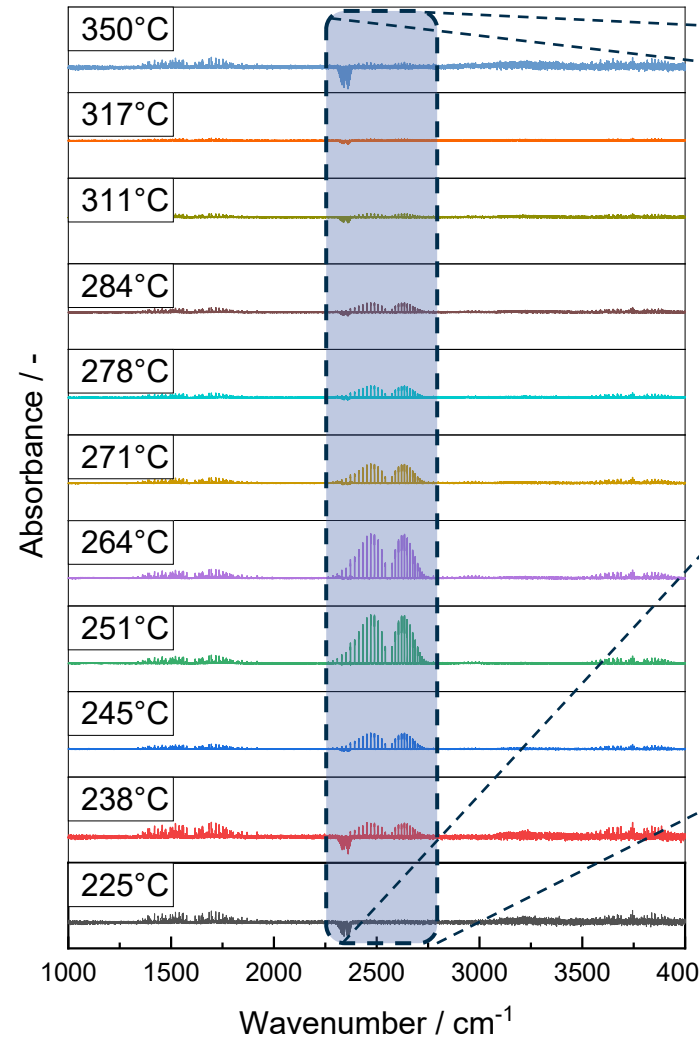


HBr quantification via TG-FTIR

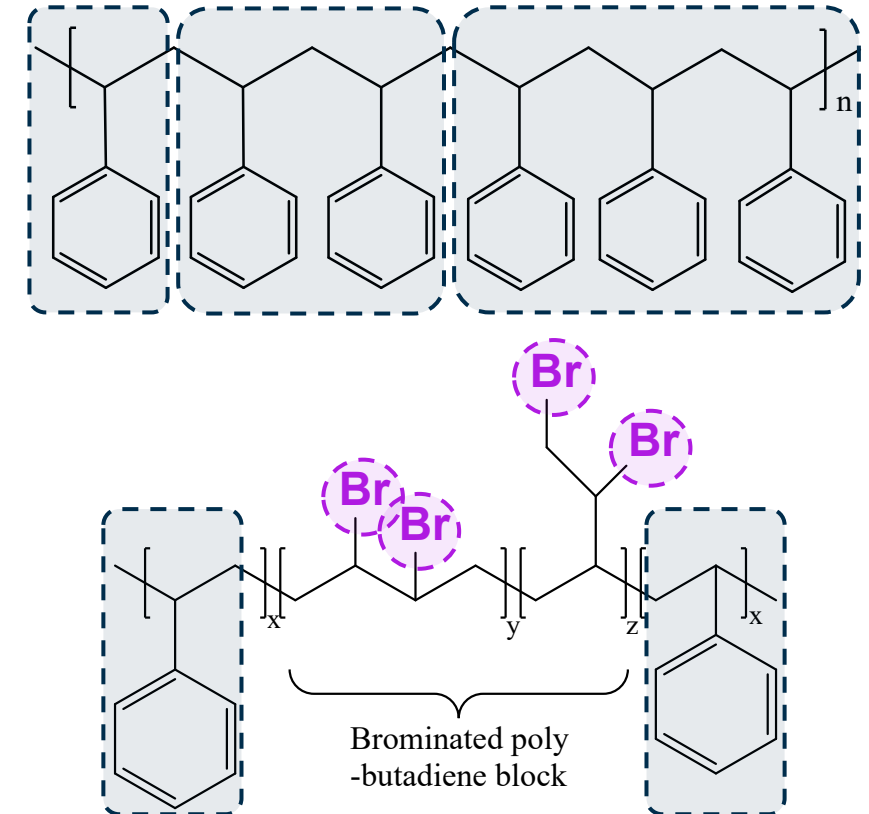
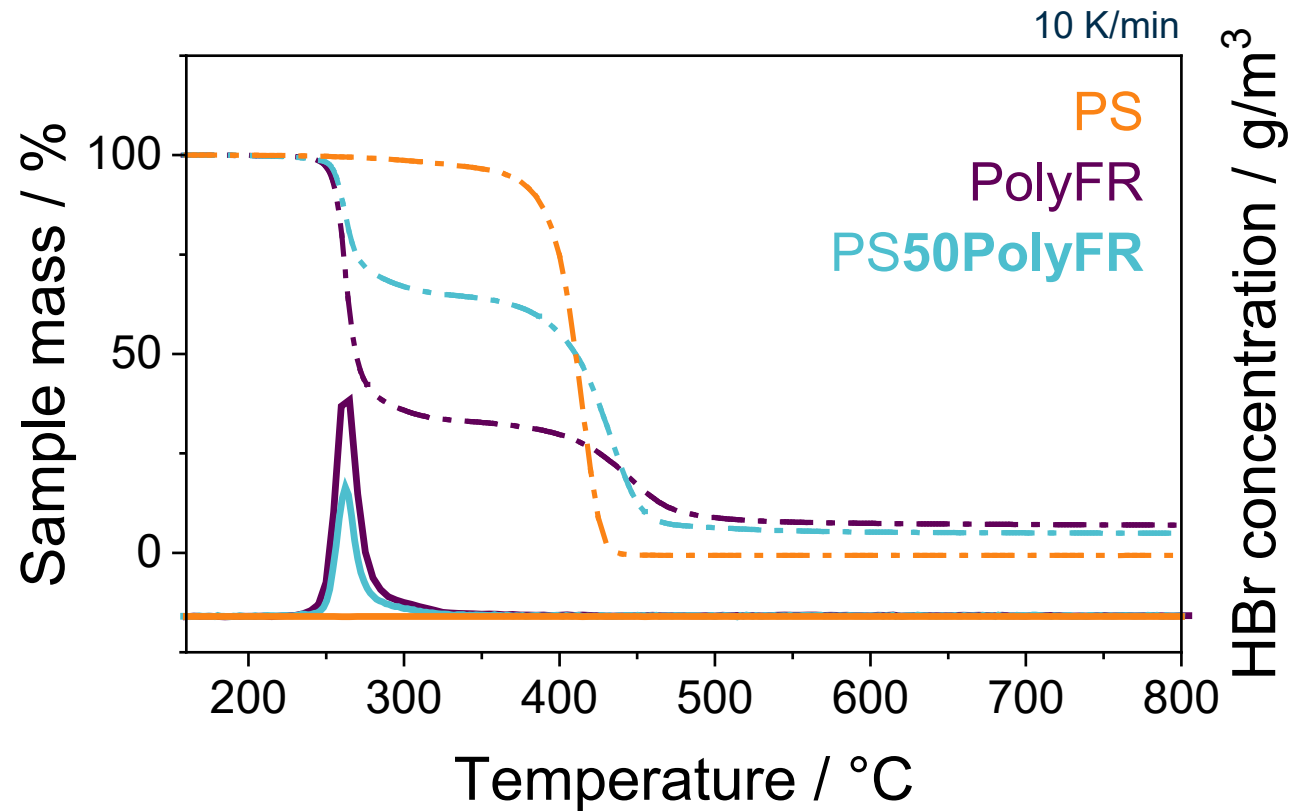


TG-FTIR

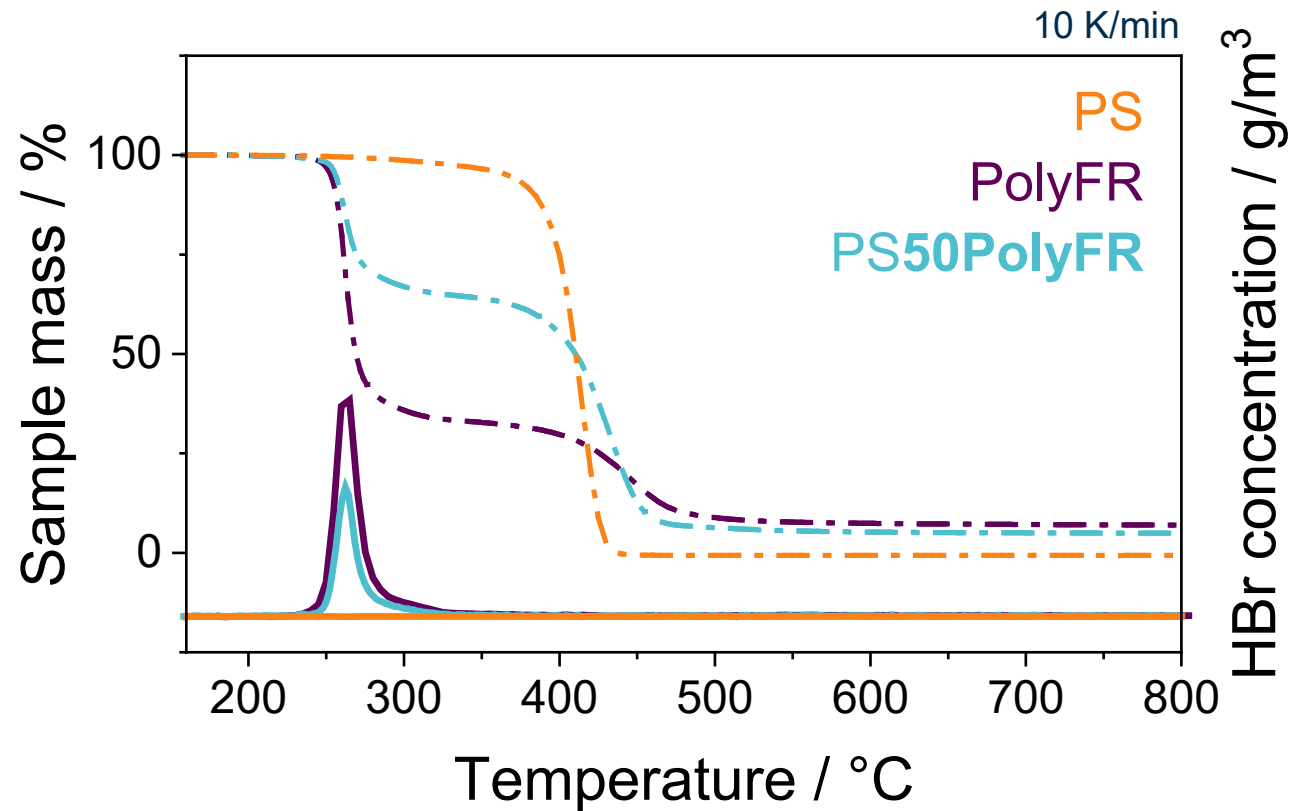
Sample mass: 5, 10 mg
Heating rate: 10, 100 K/min
N₂ atmosphere



HBr formation during pyrolysis



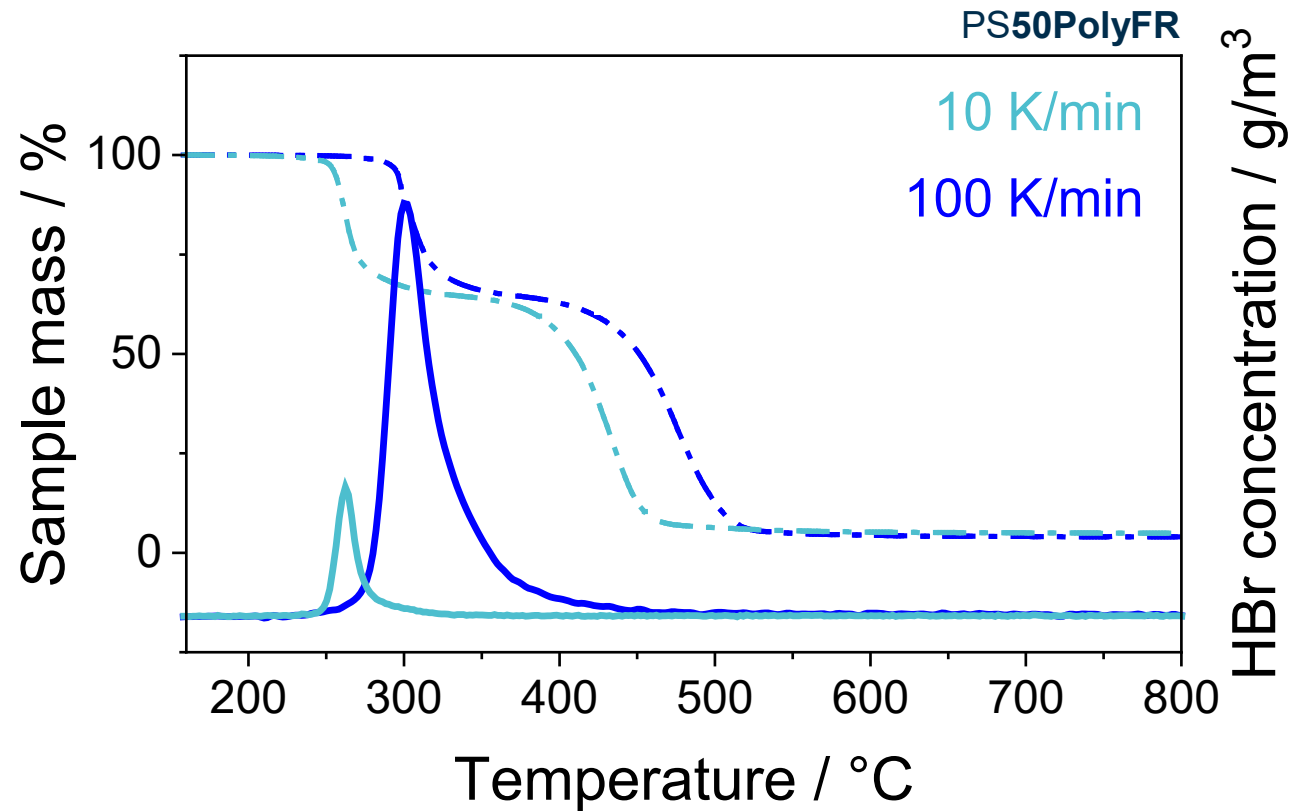
HBr formation during pyrolysis



Br as HBr / mass-%	
PolyFR	89.0 ± 2.2
PS75PolyFR	89.8 ± 0.9
PS50PolyFR	87.2 ± 1.2
PS25PolyFR	92.3 ± 2.5

HBr formation and release are independent of PolyFR loading

One-shot vs. Temperature-staging



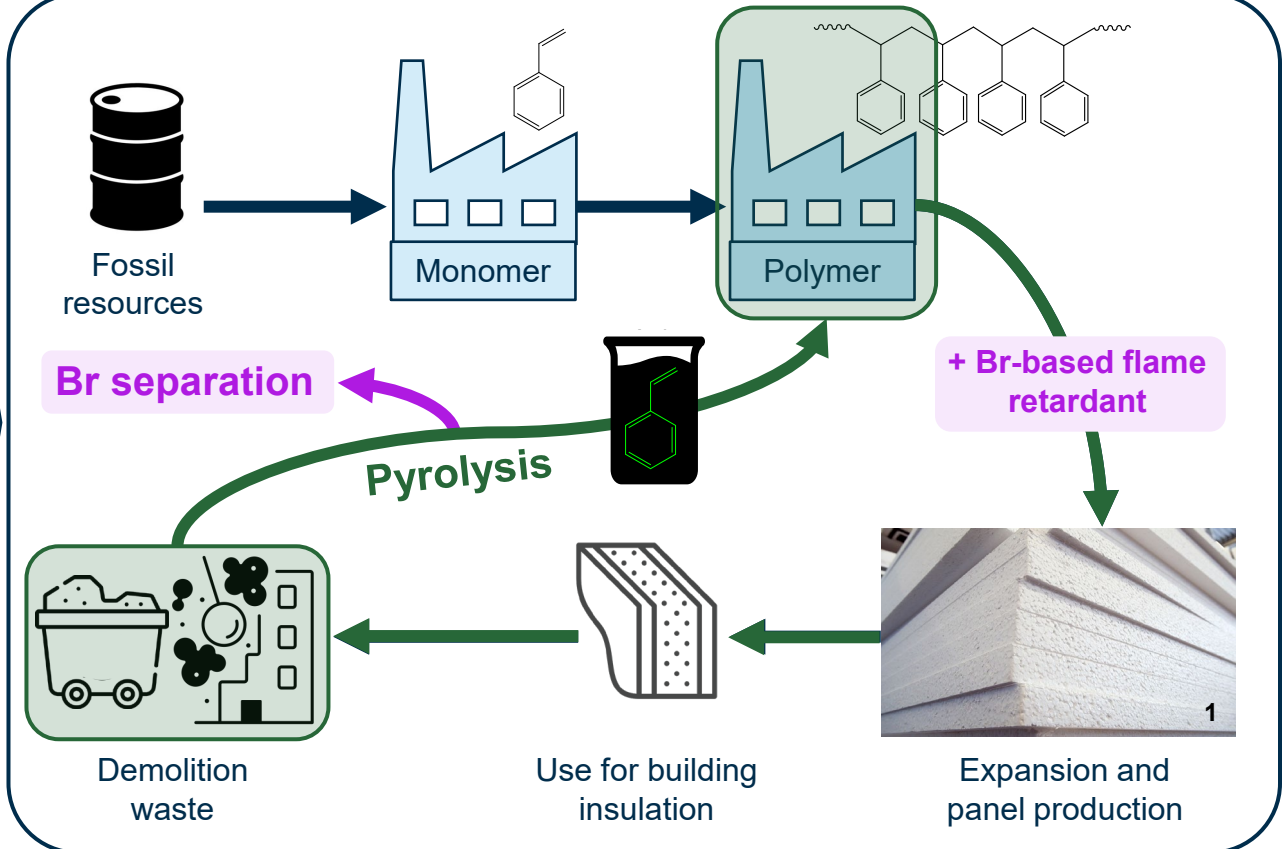
PS50PolyFR	Br as HBr / mass-%
10 K/min	87.2 ± 1.2
100 K/min	70.3 ± 0.9

**HBr formation and release
vary with heating rate**

Conclusion

- ✓ Commercial EPS and EPS-PolyFR primarily yield styrene monomer
- ✓ PolyFR primarily releases Br as HBr
- ✓ HBr formation occurs $< 350^{\circ}\text{C}$
- ✓ PS decomposition occurs around 400°C
- ✓ HBr formation and release are independent of PolyFR loading
- ✓ HBr formation and release vary with heating rate

Goals: to **separate Br** and to obtain **Br-free oil**



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Thank you for your attention.

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