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Resource recovery from waste polystyrene via thermo-catalytic depolymerization

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1. Introduction

Background:

- Chemical recycling can be applied to convert waste plastics into their monomers and/or other valuable chemicals
- Thermal and thermo-catalytic pyrolysis are considered as promising processes for the chemical recycling of plastics
- Operating conditions and reactor configuration along with the catalytic material can influence the monomer recovery
- Additives present in different plastics may also affect the product distribution

Aims:

- Perform thermal and thermo-catalytic pyrolysis of pure, recycled and waste polystyrene
- Investigate the effect of operating conditions and feedstocks on the product distribution
- Identify the operating conditions for enhanced recovery of styrene monomer

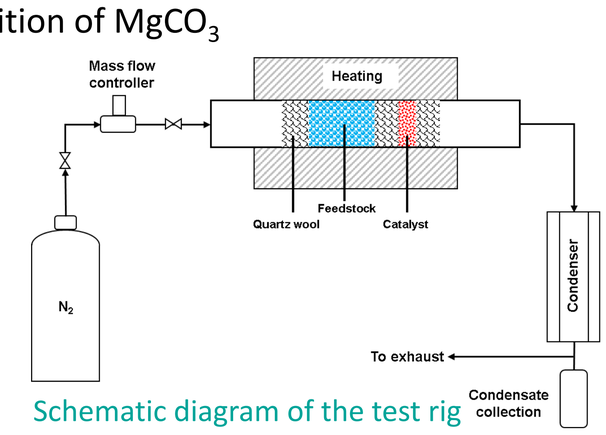
2. Materials and methods - I

Base Catalyst:

- MgO pellets from powder form
- MgO powder from thermal decomposition of $MgCO_3$

Test rig:

- Batch and semi-batch configuration
- Glass tube reactor
- Temperature = 400-500 °C
- Catalyst to feed ratio = 1:10
- N_2 flow rate = 50 ml min^{-1}



Schematic diagram of the test rig

Analysis:

- GC-MS analysis of pyrolysis oil for the following components: Benzene (BEN), Toluene (TOL), Ethylbenzene (ETB), Styrene monomer (SM), Alpha methyl styrene (AMS) and the oligomers

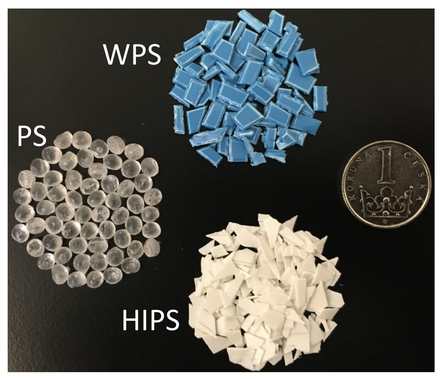
3. Materials and methods - II

Feedstocks:

1. Pure PS (PS) with a molecular weight of 192,000 g mol^{-1}
2. High Impact Polystyrene (HIPS)
3. Waste Polystyrene (WPS)

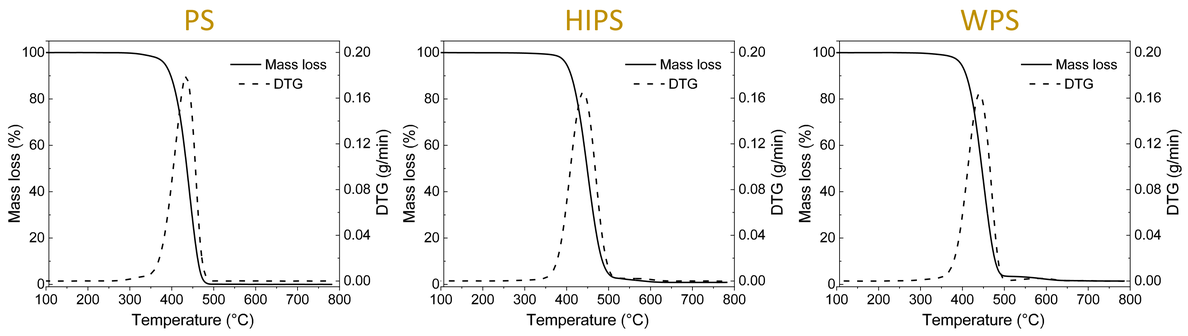
Feedstock sources:

- PS: Sigma Aldrich
- HIPS: SOLLAU CZ
- WPS: from the packing of toner cartridge



Photograph of the feedstocks

Thermogravimetric analysis (TGA) performed on three different feedstocks:

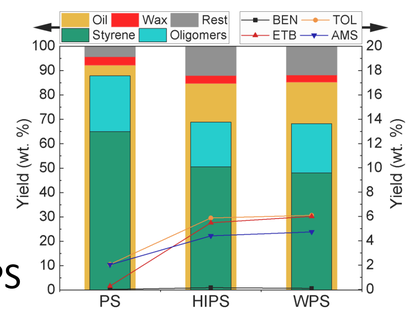


Similar TG and DTG curves shown by HIPS and WPS

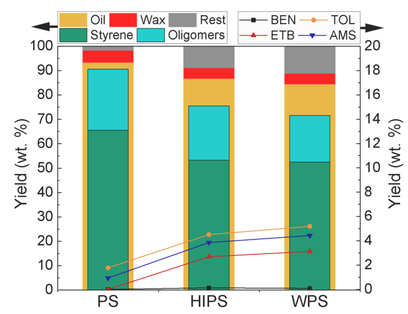
4. Results and discussion

Pyrolysis at 400 °C:

- The carrier gas flow (semi-batch) influenced the product yields
- Significant amounts of minor products were produced only in the pyrolysis of HIPS and WPS
- The additives present in HIPS and WPS might have a catalytic effect



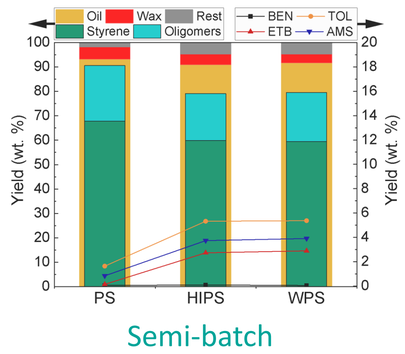
Batch (no carrier gas)
Thermal



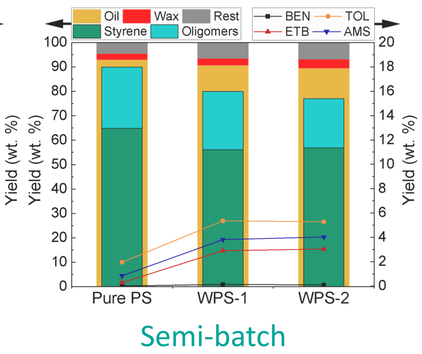
Semi-batch
Thermal

Pyrolysis at 500 °C:

- Enhanced styrene monomer recovery as compared to 400 °C
- MgO slightly increased the oligomers and decreased the styrene yield



Semi-batch
Thermal



Semi-batch
Thermo-catalytic

5. Conclusion and outlook

- Thermal and thermo-catalytic pyrolysis were performed on samples of pure (PS), recycled high impact polystyrene (HIPS) and waste polystyrene (WPS)
- HIPS and WPS showed a similar behavior in TGA and gave similar product distributions in the thermal and thermo-catalytic pyrolysis experiments
- The recovery of styrene monomer as well as the product distribution in the pyrolysis oil obtained was influenced mainly by temperature and the carrier gas flow
- Both the increase in temperature and the use of carrier gas increased the yield of styrene monomer, whereas the addition of MgO catalyst produced slightly less styrene but more oligomers
- The minor products such as toluene, ethylbenzene and alpha methyl styrene were produced in significant amounts only in the pyrolysis of HIPS and WPS
- In order to determine any catalytic role of the additives present in HIPS and WPS, further study would be required
- Further experiments on the thermal and thermo-catalytic pyrolysis of waste polystyrene from different sources will be carried out

6. References

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[2] Okan, M., Aydin, H.M., Barsbay, M., Current approaches to waste polymer utilization and minimization: a review. J. Chem. Technol. Biotechnol. (2019)

[3] Mo, Y., Zhao, L., Wang, Z., Chen, C.L., Tan, G.Y.A., Wang, J.Y., Enhanced styrene recovery from waste polystyrene pyrolysis using response surface methodology coupled with Box-Behnken design. Waste Manag. (2014)

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