ALTERNATIVE CHEMICAL RECYCLING APPROACHES FOR TRADITIONAL AND BIODEGRADABLE PLASTICS: TWO CASE STUDIES

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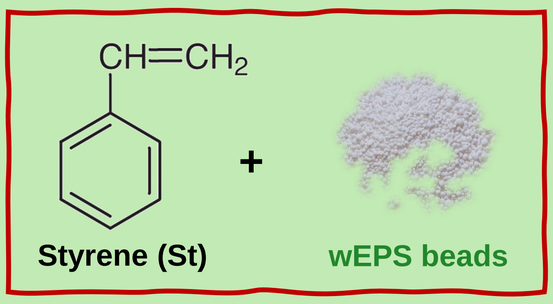
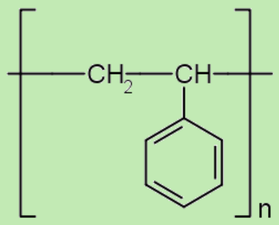
Introduction

To reduce the amount of plastic that ends up in the environment and recover value from wastes, which is nowadays a critical global challenge the transition from the traditional linear economy to a circular economy represents a key solution. However, energy-efficient, eco-friendly, and cost-effective recycling technologies for low-grade plastics are still lacking, as virgin fossil-based plastics remain cheaper to produce. This gap has driven efforts to find methods that address existing plastic waste to achieve new valuable polymer materials that overcome recyclability challenges.

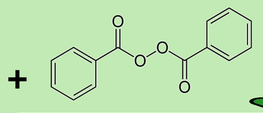
In this study, **waste expanded polystyrene (wEPS)** and a widespread biodegradable polyester, namely **polybutylene adipate terephthalate (PBAT)**, were selected as case-study materials. Consequently, depending on their chemical nature, two different chemical recycling approaches were explored to obtain building-blocks that, in turn, can be used to produce high-molecular-weight polymers and/or polymer-based materials.

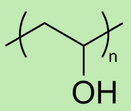
"One-Pot'' recycling technology





BPO

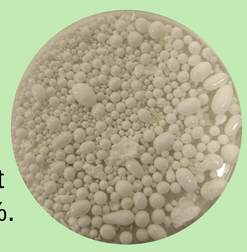
+ 

+ 

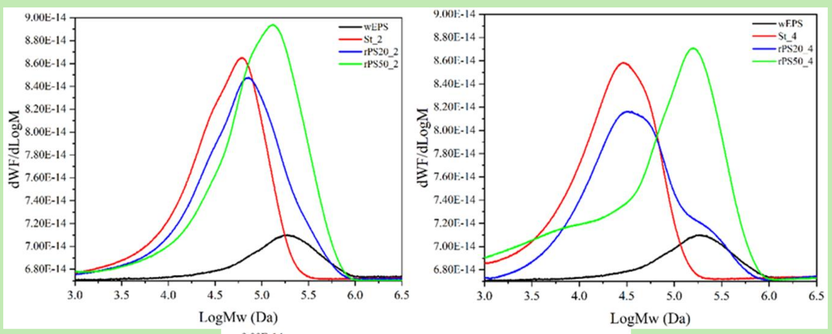
PVA + H_2O

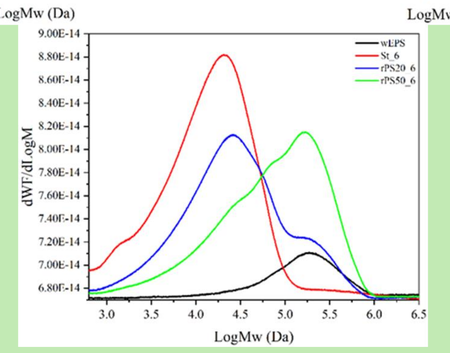
80°C,
800 rpm,
4 h

BPO/St = 2,4,6 wt/wt
wEPS = 0,20,50 wt%.



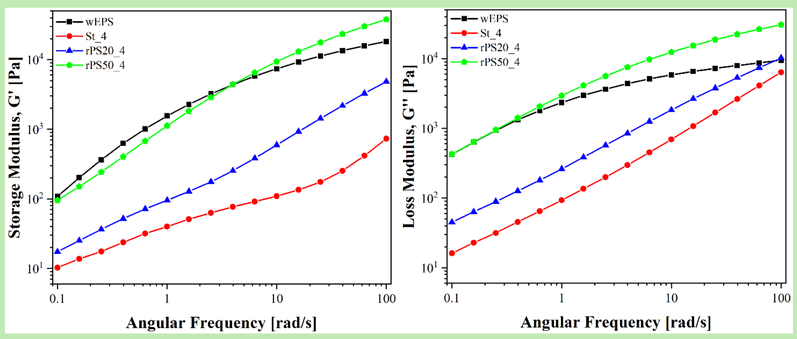
PS-based final product

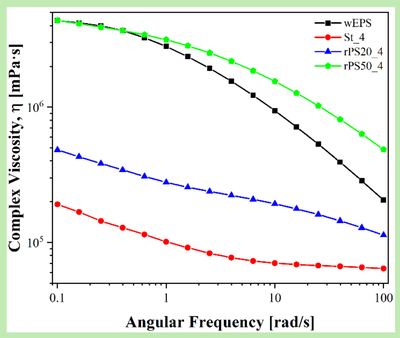




- At the same BPO/St ratio, molecular weight and PDI increase with wEPS amount
- Increasing both BPO/St ratio and wEPS content MWDs broaden, suggesting multiple molecular weight fractions
- The high molecular weight fraction grows with recycled wEPS content

- G', G'' and complex viscosity increase with recycled wEPS content at a fixed reference temperature

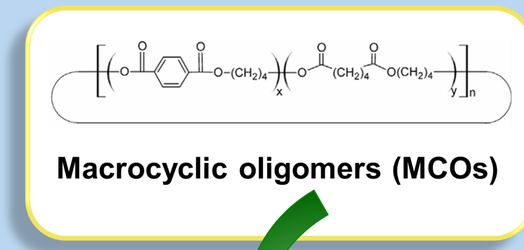




Conclusive remarks

- St seems to polymerize starting from pre-formed wEPS chains
- Viscoelastic properties increase with wEPS amount, reaching or exceeding original wEPS values

Cyclodepolymerization (CDP) HIGH DILUTION



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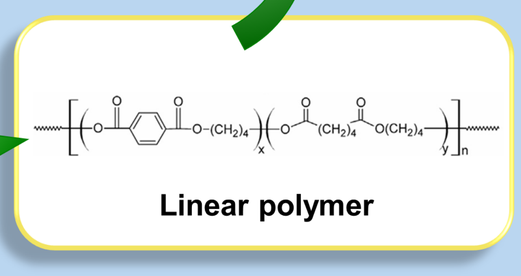


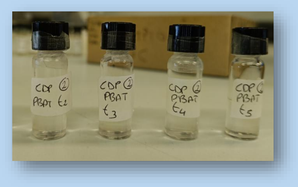
Entropically-driven Ring Opening Polymerization (ED-ROP)
HIGH CONCENTRATION

CDP reactions:
high dilution (1% wt/vol), solvent reflux temperature, 3 mol% catalyst vs.polymer

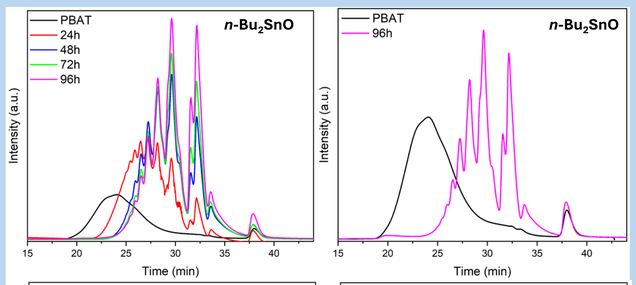
Solvent:
- **$CHCl_3$**
- **2-MeTHF**

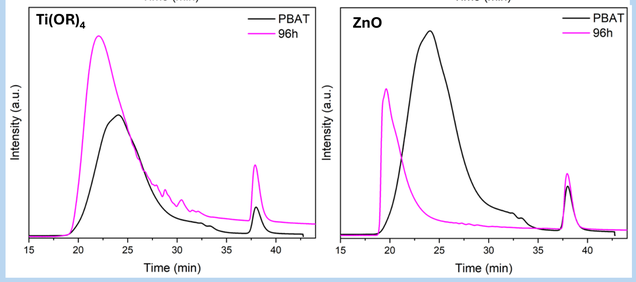
Catalyst:
- ***n*-Bu_2SnO**
- **$Ti(OR)_4$, R = 2-ethylhexyl**
- **ZnO**

Withdrawals at:
24h 48h 72h 96h

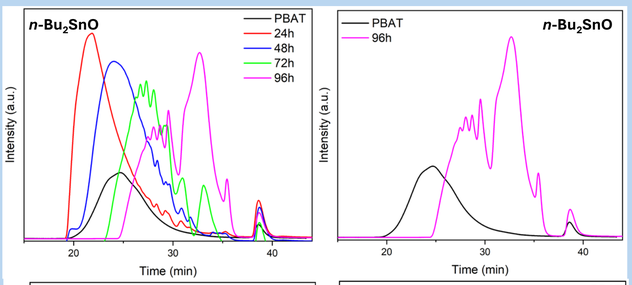


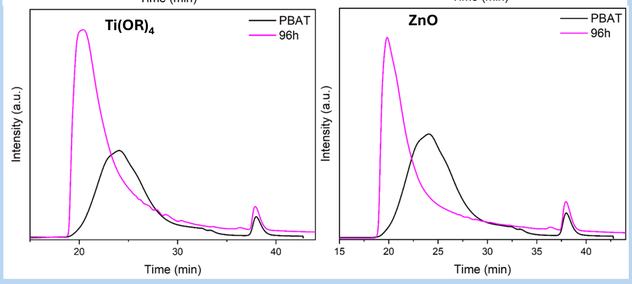
CDP in $CHCl_3$





CDP in 2-MeTHF





** GPC of the parent PBAT (black traces) were performed with the columns set for polymers*

Conclusive remarks

- Widely used *n*-Bu_2SnO remains so far the most efficient catalyst in the explored conditions
- For the CDP in 2-MeTHF, traces of MCOs family together with linear PBAT oligomers/polymers are present at the end of the reaction
- Non-toxic Zn- and Ti-based catalytic systems may be promising for CDP of PBAT performed in the green solvent 2-MeTHF, even though they deserve further investigation

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