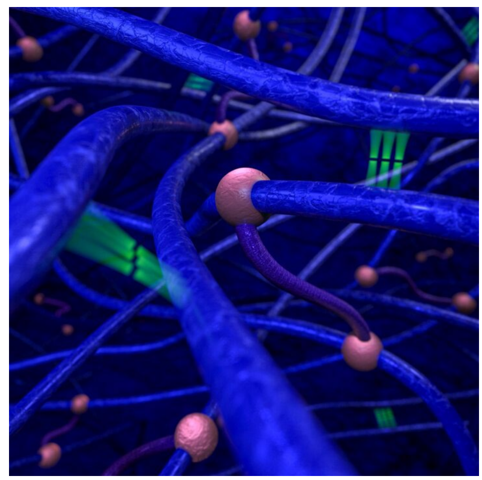
TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

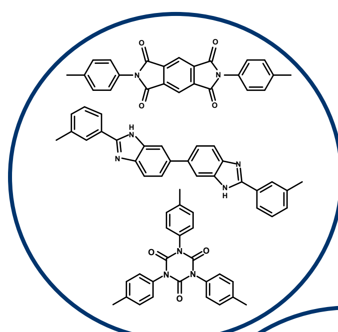
Polymer Performance Materials Group

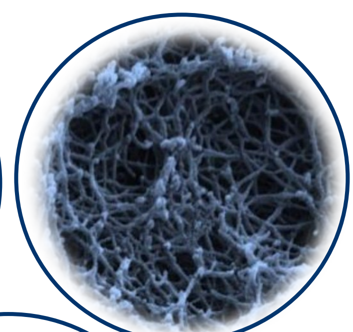
We focus our research on macromolecular chemistry and polymer materials, with a particular emphasis on developing new polymerization strategies and creating innovative polymeric structures. Our goal is to push the boundaries of technological application for these novel macromolecular materials, ultimately leading to the creation of functional and sustainable polymeric materials with industrial relevance.

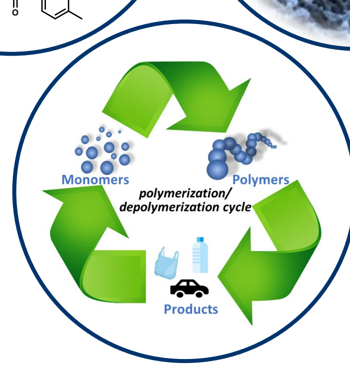


Research at Polymer Performance Materials Group is organized in the following themes:

1. Circular polymer materials
2. Next-generation organic aerogels
3. High-performance polyurethanes







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Polymer Performance Materials

Recyclable epoxy resins

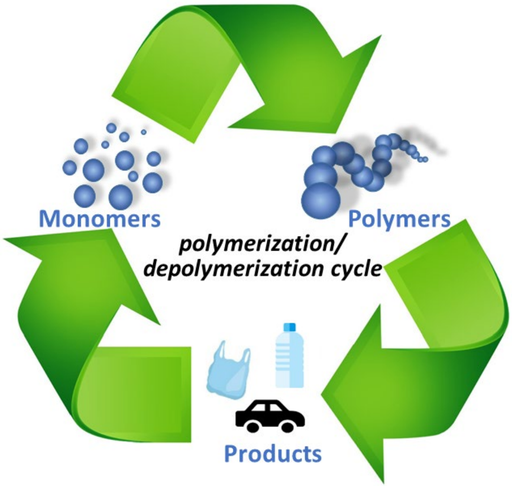
Tankut Türel, Özgün Dağlar, Željko Tomović

Introduction

Epoxy resins constitute a very significant portion of all high-performance plastics due to their excellent thermal and mechanical properties that appear in a wide range of applications. Nevertheless, traditional epoxy networks show limitations regarding chemical recycling due to their covalently crosslinked structures. Development of preferably bio-based, liquid and smartly designed monomers can be polymerized into closed-loop recyclable and/or upcyclable epoxy resins.

Project summary

Smartly functionalized epoxy precursors will be developed, preferably from biomass, which could be cured with commercial diamines under solvent-free, green conditions. The obtained epoxy resins will be reprocessed readily and depolymerized into well-defined and value-added molecules. These precursors will be upcycled into other types of materials.



Project goals

- Synthesis of epoxy resins from bio-renewable resources with mechanical properties similar to commercial epoxy systems
- Full characterization of the smart monomers and epoxy resins using NMR, FTIR, DSC, TGA, DMA and mechanical performance tests
- Depolymerization of the epoxy resins into value-added products which will be upcycled into different types of materials.

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Polymer Performance Materials

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Closed-Loop Recycling & Upcycling of Polyurethane and Epoxy Systems

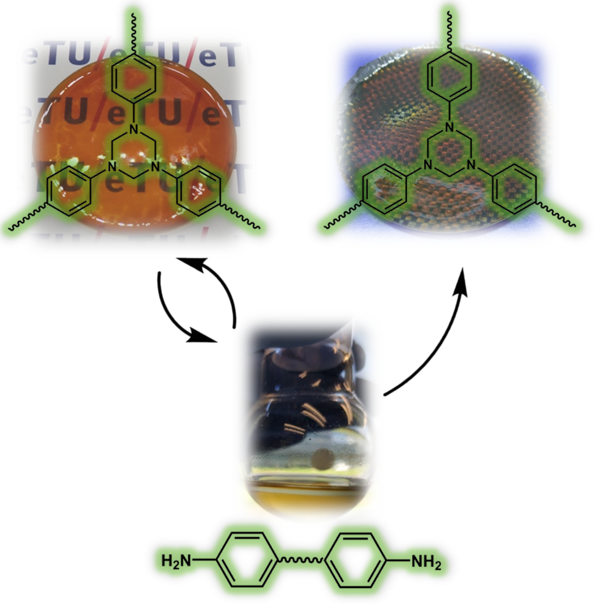
Özgün Dağlar, Patrick Schara, Yi-Ru Chen, Željko Tomović

Introduction

The extensive use of plastics, which is essential in many areas, including industrial applications and even our daily life, is increasing rapidly today. However, the measures taken to reduce their use remain limited so far. In this context, the most important step to reduce the use of plastics would be to draw a roadmap on how polymers can be recycled from the very beginning. Therefore, the design of recyclable polymers and, more importantly, smart monomers has become one of the most crucial strategies for solving this problem.

Project summary

Polyurethanes and epoxy systems constitute one of the most important stakeholders of the polymer family. This project will focus on the synthesis, recycling, and upcycling of these polymeric systems. As the first step, hexahydro-triazine-based aromatic, smart monomers and polymers based on these monomers will be synthesized. The depolymerization of these polymers will be performed by exploiting their acid-labile behavior. Lastly, repolymerizing the depolymerized molecules to the initial polymers and/or upcycling them into value-added new polymeric materials will be targeted.



Project goals

- Preparation of acid-labile triazine-based monomers
- Syntheses and characterizations of the polymers (NMR, Tensile, DMA, DSC, and TGA)
- Selective depolymerization of the polymers.
- Recycling and upcycling of recovered products.

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CHEMICAL ENGINEERING AND CHEMISTRY

Polymer Performance Materials

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Upcycling of plastic waste

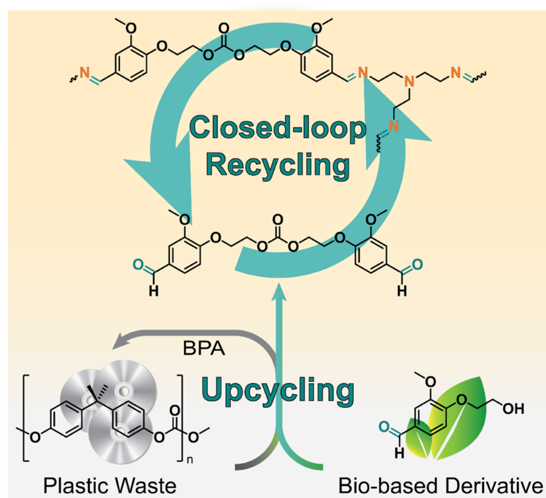
Keita Saito, Tankut Türel, Fabian Eisenreich, Željko Tomović

Introduction

Recycling of polymeric materials is a major scientific challenge of modern society as the ever-increasing production of plastic goods and their predominant linear use cause severe environmental burden. Thus, creating a circular economy for plastics is an auspicious strategy to counteract the current take-make-waste consumption model. Recently, chemical upcycling strategy has been considered as an attractive path, which allows for the generation of value-added monomers from traditional polymers and thus provides access to upcycled polymeric materials with superior properties.

Project summary

In this project, we will perform chemical upcycling of plastic waste to create innovative molecules and materials. To elevate the sustainability of our approach, we perform the selective depolymerization of traditional polymer using bio-based resources instead of petrochemical reagents. The upcycled molecules will further be used as building blocks to prepare various types of polymeric materials. Interestingly, plastic waste can be transformed into materials that can achieve closed-loop recycling as shown in the figure.



Example of upcycling. Closed-loop recycling of poly(imine-carbonate) derived from plastic waste and bio-based resources. *Angew. Chem. Int. Ed*. **2022**, 61, e202211806.

Project goals

- Design and synthesis of value-added molecules through upcycling of plastic waste (*e.g.,* polycarbonate and polyesters)
- Synthesis of different types polymers based on the upcycled building blocks
- Analytical characterization using several techniques including NMR, FT-IR, GPC, DSC, TGA, DMA.

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Polymer Performance Materials

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Recyclable high-performance aerogels

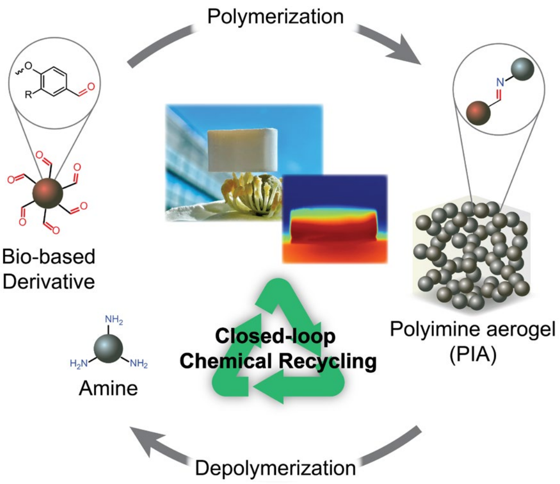
Changlin Wang, Christos Pantazidis, Fabian Eisenreich, Željko Tomović

Introduction

Organic aerogels are an intriguing class of highly porous and ultralight materials with widespread applications in thermal insulation, energy storage, and chemical absorption. However, these crosslinked polymeric networks pose environmental concerns as they are made from fossil-based feedstock, and their closed-loop recycling is virtually impossible. A reversible crosslinking approach can be applied to overcome these obstacles, enabling cleavage of the network on demand.

Project summary

We aim to prepare next-generation organic aerogels, which are recyclable and produced using bio-based resources. The parameters affecting the sol-gel process will be studied carefully. The synthetic pathway will thus be optimized to obtain recyclable aerogels with high performance properties, such as high mechanical strength, thermal and chemical stability, and superior insulation efficiency.



Closed-loop recycling of bio-based aerogels.
Adv. Mater. **2022**, 2209003.

Project goals

- Synthesis of monomers and crosslinkers
- Investigation of the sol-gel process
- Aerogel production through supercritical CO_2 drying
- Characterization of the materials by N_2 physisorption, SEM, TGA, NMR, and FTIR
- Closed-loop chemical recycling of aerogels

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CHEMICAL ENGINEERING AND CHEMISTRY

Polymer Performance Materials

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Recycling of Polymers with light

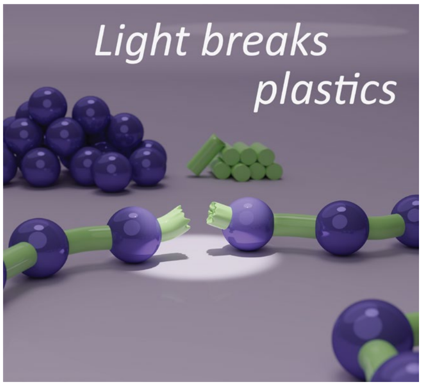
Bengi Şentürk, Ahsen Yalın, Željko Tomović, Fabian Eisenreich

Introduction

Plastics have become a leading product in the customer marketplace since their development in the 1930s. Accordingly, it would be accurate to describe the era we live in as the age of plastic. The surplus consumption of this revolutionary, but at the same time disposable material overwhelms the world's ability to deal with it and results in a pressing environmental crisis. The field of chemistry plays a crucial role to render the use of plastics sustainable. In recent years, light has become a promising energy source in polymer recycling since photochemical processes provide more efficient and precise chemical transformations than conventional thermal processes. In addition, light has other advantageous features, such as being abundant, safe, and easily tunable regarding intensity and wavelength.

Project summary

Our research focuses on the design of multi-responsive smart monomers and their (de)polymerizations using light as a green energy source. We also aim to establish closed-loop recycling of traditional polymers through photo-catalysis. Accordingly, our motivation is to cleave stable chemical bonds within the backbone of polymers by exploiting light.



Project goals

- ✓ Synthesizing and characterizing multi-responsive smart monomers
- ✓ Light-controlled (de)polymerizations of these monomers using LED equipment
- ✓ Performing closed-loop recycling of polymers *via* photocatalysis

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