



Controlled degradation of chemically stable polymers via directing group-assisted catalysis

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Abstract

To establish a sustainable society, the development of polymer materials capable of reverting into monomers on demand is crucial. Traditional methods rely on breaking labile bonds such as esters in the main chain, which limits applicability to polymers that consist of robust covalent bonds. We found that the integration of directing groups allowed to engineer resilient polymers with built-in recyclability. Our study showcases phenylene ether-based polymers fortified with directing groups, which can be selectively disassembled under nickel catalysts via selective cleavage of carbon-oxygen bonds. Notably, these polymers exhibit exceptional chemical stability towards acids, bases, and oxidizing agents, while being degradable to well-defined, repolymerizable molecules in the presence of a catalyst.

Background & Results

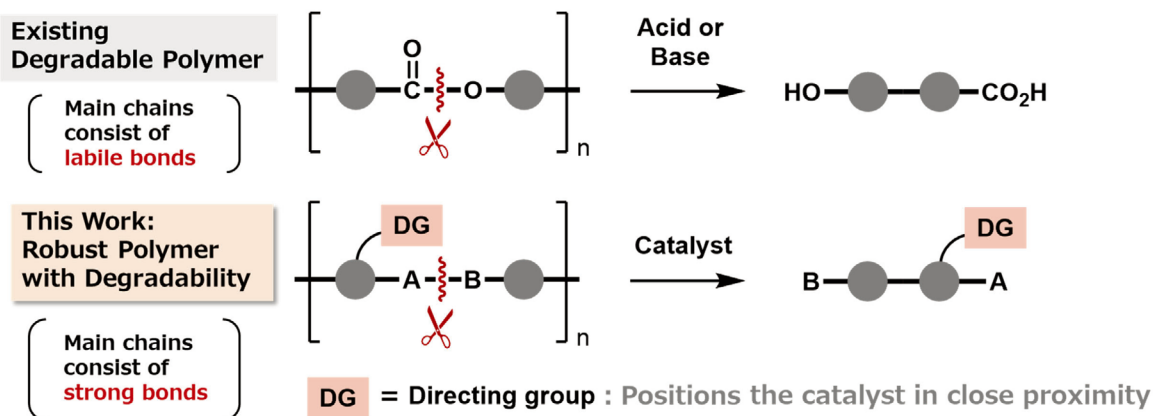
Serious concerns about the long-term environmental impact caused by plastic pollution are prompting us to transition away from single-use plastics toward a more sustainable and circular polymer economy. To this end, mechanical recycling has been implemented on an industrial scale. However, the physical properties of the recycled materials are frequently compromised compared to the original ones, and mechanical recycling cannot be universally applied to all plastics. A more ideal approach is chemical recycling, wherein polymers are transformed back into monomers or other well-defined small molecules that could subsequently be re-

polymerized. Although this approach is appealing in principle, successful examples have primarily been limited to the polymers that contain chemically labile bonds in their main chains encompassing esters, acetals, disulfides, and silyl ethers. Polymers that consist of strong covalent bonds, such as C-C or C(aryl)-O bonds, often exhibit high robustness, which in turn makes depolymerization into monomers a challenge due to the lack of mild methods that could be used to cleave these bonds.

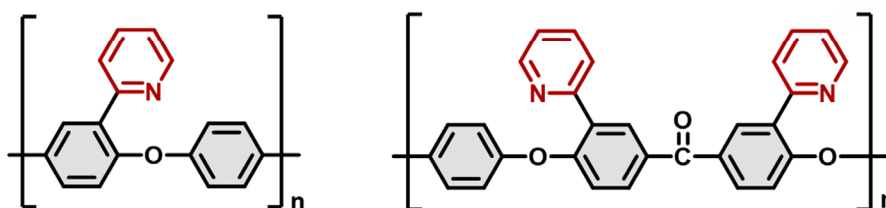
Herein, we introduce a directing group (DG) that serves as a design principle for depolymerizable polymers devoid of labile chemical bonds in their main chain. DGs are strategically used to develop catalytic reactions that involve the activation of strong σ -bonds in low molecular weight compounds. Surprisingly, however, the DG strategy has not been exploited for the cleavage of the main chain of polymeric materials. It is noteworthy that a DG does not fundamentally alter the thermal and chemical stability of neighboring covalent bonds but rather promotes their cleavage only in the presence of a suitable catalyst. Therefore, the robust nature of parent polymers is anticipated to be preserved with the introduction of DGs.

Significance of the research and Future perspective

The introduction of pyridine directing groups did not compromise the chemical stability of the polymers in the absence of a catalyst, which shows promise as a potent strategy for designing robust polymers that are chemically recyclable.



Examples of New Chemically Recyclable and Robust Polymers :



Patent

Treatise

U R L

Keyword

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chemical recycling, high performance polymers, catalyst