Upcycling Waste Polyvinyl Chloride (PVC) To Prepare Value-Added Dienes

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BACKGROUND

Making productive use of PVC waste is a challenge. Mechanical recycling is difficult because different PVC products each contain different blends of plasticizers, stabilizers, and other additives; combining these additives leads to diminished mechanical properties.Meanwhile, incineration of PVC is an issue because it produces corrosive HCl and toxic chlorinated dioxins, a class of persistent organic pollutants. Changing regulations also present an issue: harmful plasticizers such as diethylhexylphthalate (DEHP) still present in legacy PVC products are now banned in newly made (or newly recycled) PVC in the EU. In the US, DEHP is restricted in childcare articles and food packaging. Vinyloop®, a plant designed to recycle PVC from mixed waste by selective dissolution/precipitation, was shut down in 2018 due to its inability to remove phthalates. Lead stabilizers found in legacy PVC products are similarly banned in new products, complicating recycling.

Chemical recycling and upcycling of polymers is a growing field of interest with the goal of creating a circular economy. Breaking down a polymer into monomer or other useful small molecules allows purification of the products and avoids the downcycling phenomenon seen in mechanical recycling. Polymers with labile ester or amide bonds in their backbone are more amenable to this treatment than polymers with an all-carbon backbone. For instance, polyethylene terephthalate and polyurethane can both be depolymerized by hydrolysis, alcoholysis, or aminolysis; the monomers or short oligomers obtained can be repolymerized to form the original polymer or other high-performance polymers. Polymers with all-carbon backbones are more challenging to controllably cleave, but many methods have been developed to break down polyethylene, polypropylene, and polystyrene into light hydrocarbon fuels, benzene derivatives, or H_2 gas. However, even small amounts of PVC can contaminate these reactions and deactivate the catalyst, requiring PVC to be separated out first.

Chemical upcycling of PVC is underdeveloped compared to that of other polymers, despite the fact that it is the third-most produced plastic in the world. Most PVC degradation procedures explored have been carried out at high temperatures (200-900 ^{o}C) and focus on pyrolysis to small hydrocarbons or oxidation to carboxylic acids. Pyrolysis of PVC is complicated by the release of HCl, which can corrode the equipment and deactivate catalysts. Solutions to this include pre-treatment with base, or pyrolysis in the presence of base or bio-waste. In some cases, products are a mixture of acetone, benzene, and other aromatics. In other cases, alkanes or syngas (CO and H_2) are produced.

There remains a need for new approaches to chemically break down PVC. Expanding the toolbox of reactions that can controllably degrade PVC will allow a wider range of products to be made, and bring the world closer to the goal of harvesting plastic waste as a resource.

TECHNOLOGY DESCRIPTION

The technology involves a method of chemically degrading PVC in two steps. The first step involves a partial elimination with an alkali base that removes some chlorines in the PVC to form a salt and creates carbon-carbon double bonds. The second step involves olefin cross metathesis in conjunction with an added partner alkene. This cleaves cleaves the carbon-carbon double bonds of the polymer backbone. The resulting products are a mixture of PVC polymers with reduced molecular weights and small molecule dienes that correspond to the substituents of the partner alkene.

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OTHER INFORMATION

KEYWORDS

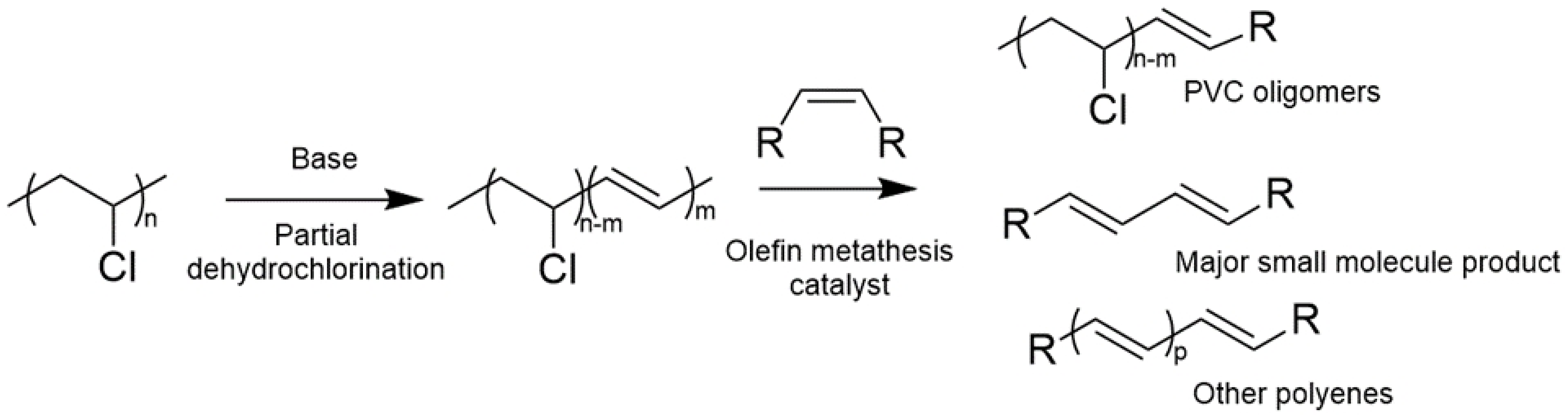
Depolymerization, PVC, Polyvinyl chloride, Breakdown, Plastics, Dehydrochlorination, Grubbs Catalyst, Dienes, Upcycling, Upcycled PVC, Synthetic rubber

CATEGORIZED AS

- **Environment**
  - Remediation
- **Materials & Chemicals**
  - Polymers

RELATED CASES

2021-987-0



In summary, this reaction quickly and simply transforms waste polyvinyl chloride (PVC) into upcycled, value added dienes that can be used in synthetic rubbers (e.g. neoprene, polybutadiene) and other polymers with no toxic byproducts or CO2 production.

APPLICATIONS

- Upcycling of PVC waste into dienes
- Dienes can be made into synthetic rubbers (e.g. neoprene, polybutadiene) and other polymers

ADVANTAGES

- Simple, two step, low temperature reaction (~55 °C)
- Carbon neutral
- No other harmful by-products of reaction
- Scalable to industrial level

INTELLECTUAL PROPERTY INFORMATION

Patent Pending

RELATED MATERIALS

- Degradation of Polyvinyl Chloride by Sequential Dehydrochlorination and Olefin Metathesis - 05/16/2023

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