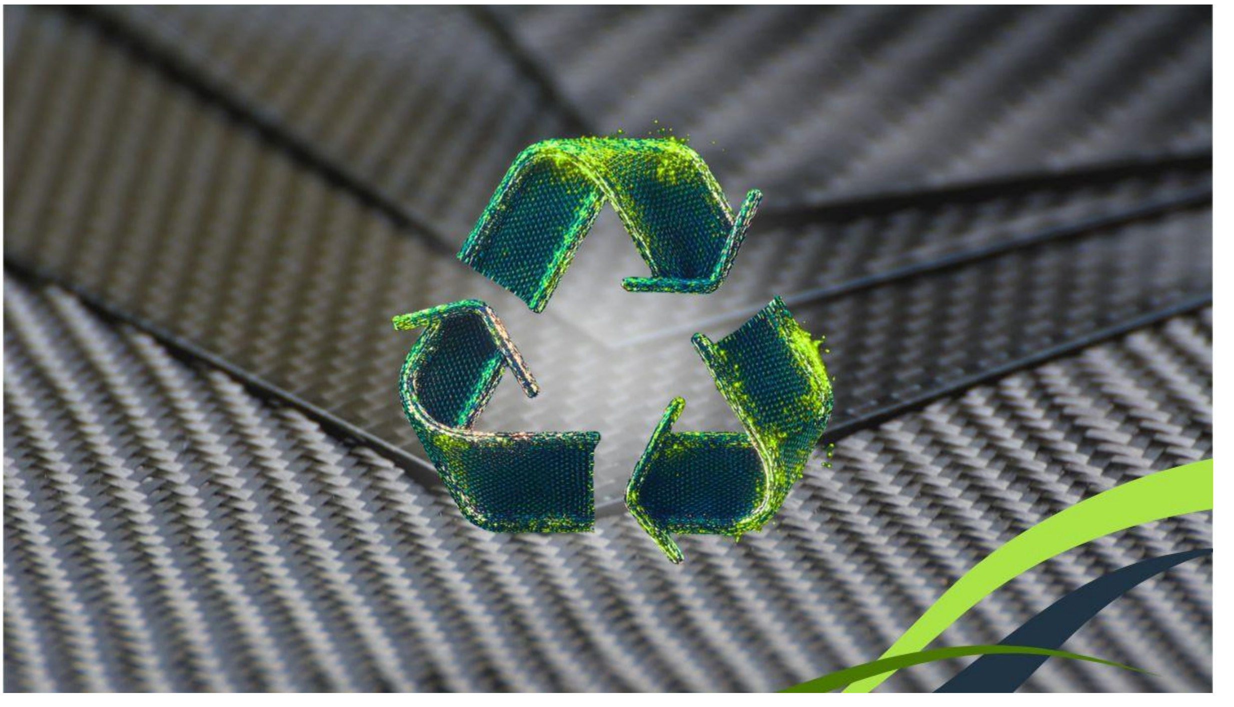
Covalent Adaptable Network to solve-out the end-of-life issue of thermoset materials



AUTHORS

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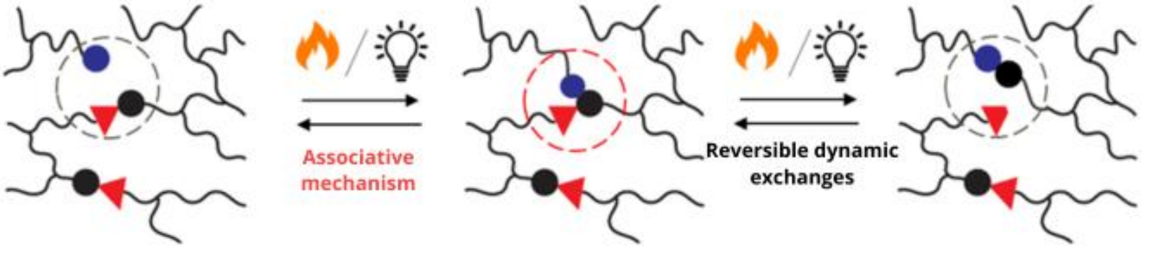
DATE

June 2025

Despite their advantageous properties in terms of longevity and resistance, thermosets contribute significantly to the global synthetic polymer production of 140 million tons annually, with less than 10% being recycled. This limitation stems from the difficulty in breaking down crosslinked network. As a result, thermosets often end up in landfills or incinerators, contributing to environmental pollution. Current recycling methods, such as chemical or mechanical processes, are often inefficient, expensive, and involve aggressive chemicals or high temperatures above 400°C, leading to substantial production costs and resource wastage.

Addressing these challenges requires innovative approaches to improve recycling technologies and reduce environmental impact while maintaining the beneficial properties of thermoset materials.

Driven by the growing demand for sustainable materials, self-healable, thermos-reversible, and recyclable cross-linked polymers are gaining increasing attention. Among them, polymers with dynamic covalent bonds, known as Covalent Adaptable Networks (CANs), stand out for combining the reprocessability of thermoplastics with the mechanical strength of thermosets.



These dynamic systems can rearrange their network structure through reversible bond exchange under external stimuli like heat, pH, or UV light. As a result, CANs can be repaired, reprocessed, and recycled without compromising performance. They are generally categorized into two types based on their exchange mechanism: dissociative and associative. Dissociative CANs temporarily break their cross-links upon heating, reducing network density during rearrangement. Associative CANs, on the other hand, maintain constant connectivity by only forming new bonds as others break.

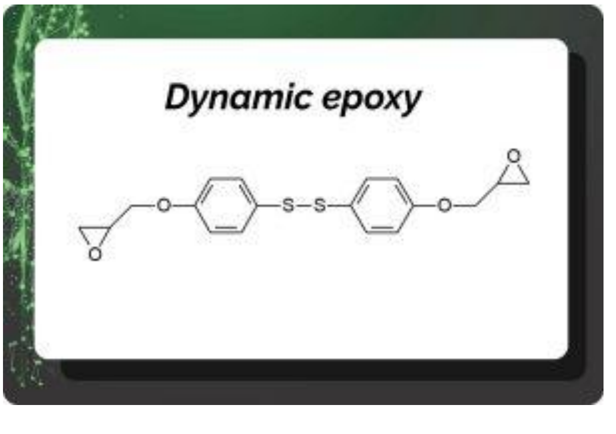
This special behavior, particularly in associative CANs, is similar to how inorganic glass behaves. Because of this, these materials were named *vitrimers*.

Vitrimers – Our range of dynamic building-blocks to enhance thermoset recyclability

Within vitrimers, dynamic covalent bonds allow reversible exchange reactions that can occur without compromising the overall structure of the material. Thanks to this dynamic nature, vitrimers can be reshaped, repaired, or recycled when exposed to certain conditions, most commonly heat, positioning them as a promising solution for more sustainable and circular materials.

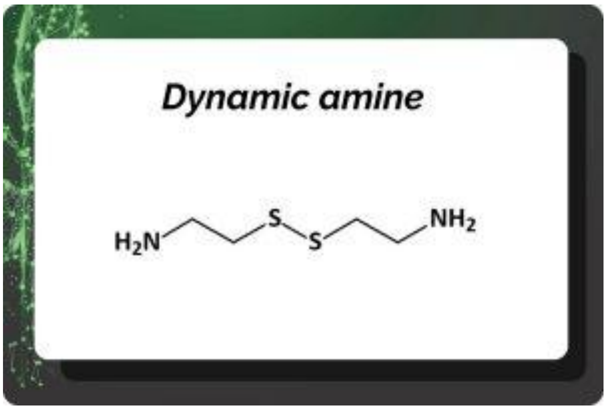
SPECIFIC POLYMERS has been involved for more than 10 years in the development of innovative material building-blocks containing dynamic bonds and enabling the design of dynamic thermosets. All designed dynamic building-blocks contain both reactive moieties to ensure classical crosslinking reactions (epoxy, amine, (meth)acrylate, vinyl ether, etc.) but also dynamic linkages to promote recyclability.

Please discover below our range of dynamic building blocks for R&D purposes :



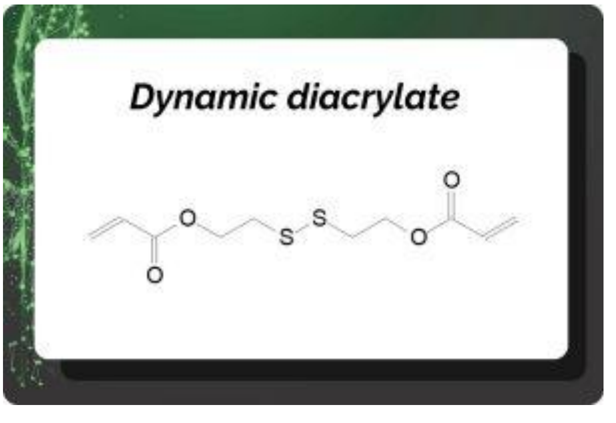
Bis(4-glycidoxyphenyl) disulfide

SP-3-65-004



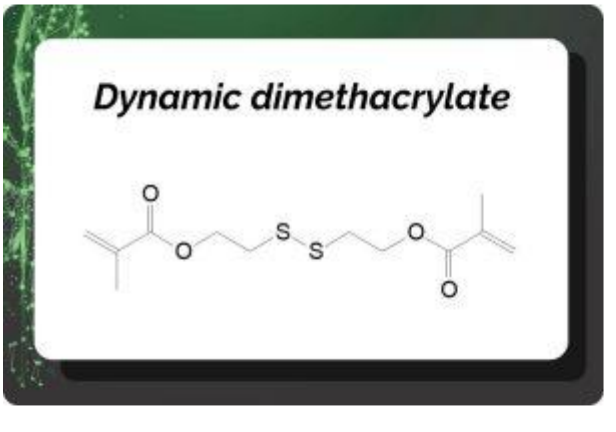
Cystamine

SP-2-4-001



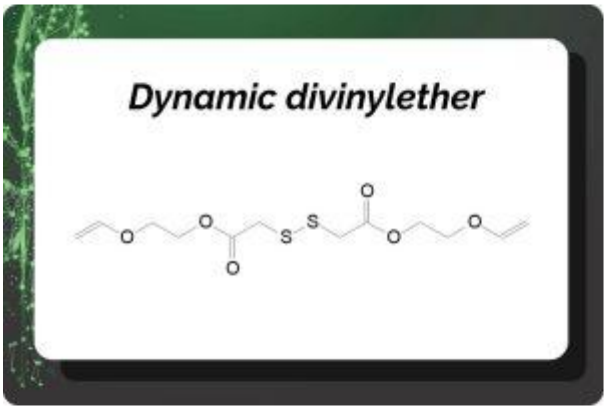
2,2'-Dithiodiethanol diacrylate

SP-43-6-001



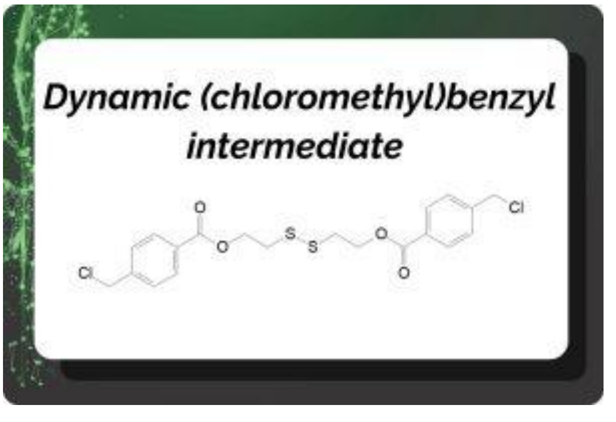
Dithiodi-2,1-ethanediyl bis(methacrylate)

SP-43-6-002



Bis[2-(vinyloxy)ethyl] 2,2'-disulfanediyldiacetate

SP-43-6-003



Dithiobis(ethane-2,1-diyl)-bis[4-(chloromethyl)benzoate]

SP-19-011

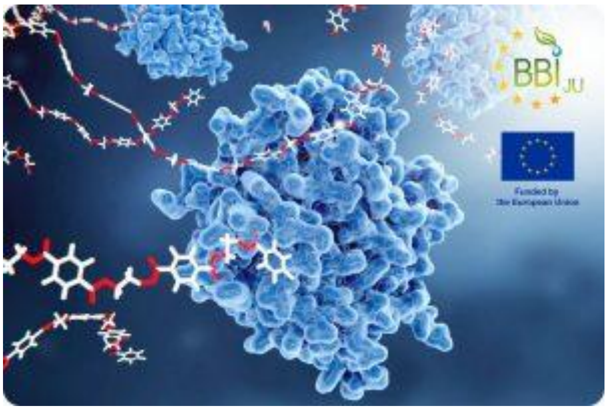
All these products are commercially available in laboratory-scale quantities (typically from 5 g to 250 g, depending on the reference). For quantities beyond those listed, we are also open to discussing bulk requests. Furthermore, it is worth noting that for our flagship reference in this range (SP-2-4-001 Cystamine), we have recently improved our production process and can now offer 250 g batches.

Incorporating vitrimers into thermoset matrices allows manufacturers to improve product lifecycle sustainability while minimizing environmental impact. These dynamic materials facilitate more efficient end-of-life management through controlled degradation and reprocessing, supporting a circular economy model.

In addition to our portfolio of dynamic building blocks, we offer custom design and synthesis services to develop bespoke solutions. We also formulate resin systems on demand, tailored to meet our clients' specific needs and performance objectives.

Related collaborative Projects

Beyond the sale of R&D materials, Specific Polymers is actively involved in several collaborative projects focused on this emerging field. These partnerships aim to co-develop vitrimer resin formulations based on the specifications provided by processing partners and end-users. The ongoing developments target various applications, including structural materials, coatings, and adhesives, where durability and recyclability are both critical. Such collaborations not only enable us to tailor our solutions to real industrial needs but also allow us to advance the technological maturity of our vitrimer platform. Our long-term objective is to bring to market vitrimer-based resin formulations that offer equivalent performance to current benchmark resins, while adding the key advantage of recyclability.



BIZENTE

VIBES

BIO-UPTAKE

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