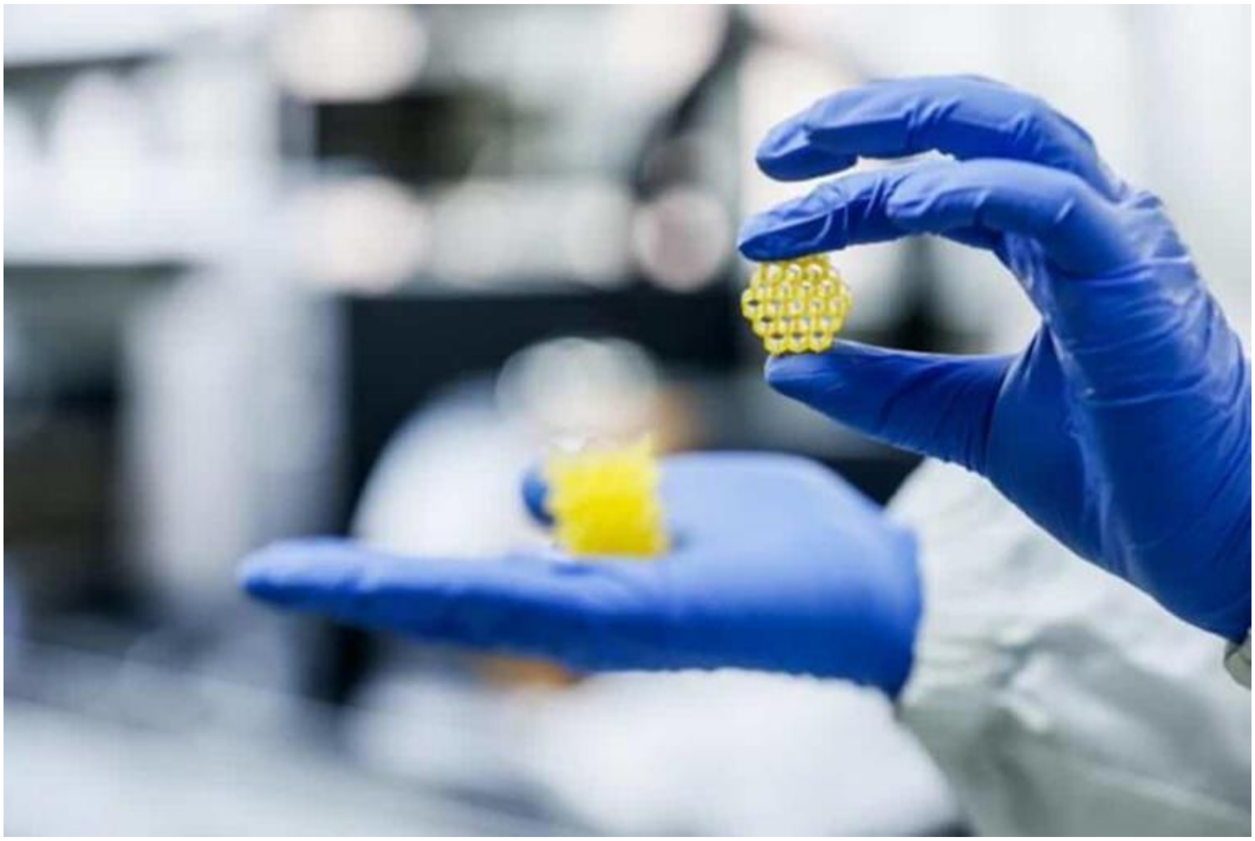
Scientists Created a 3D Printing Resin You Can Reuse Forever



The resin can be used again and again in new 3D printing projects. Credit: Zhejiang University© ZME Science

In a lab at Zhejiang University, a graduate student added a common chemical to a polymer mixture—and got unexpected results. What started as a routine experiment led to the discovery of a recyclable resin that can be printed, broken down, and reused over and over.

Led by Professors Xie Tao and Zheng Ning, the team developed a material that could help tackle one of 3D printing's biggest problems: waste. Their findings were published in *Science*. Photocurable 3D printing builds objects from liquid resin using light, layer by layer. It's like assembling with Lego bricks—except, until now, you couldn't take the bricks apart once the object was done.

Typical 3D printing resins form carbon-carbon bonds during photopolymerization, which are all but impossible to break. That makes recycling difficult, if not impossible.

The Zhejiang team took a different route. Their resin uses dithioacetal bonds, which form under light but break apart with gentle heating. “It’s like disassembling Legos,” said Professor Xie. “The printed object can be recovered at the molecular level and reprinted again and again.”

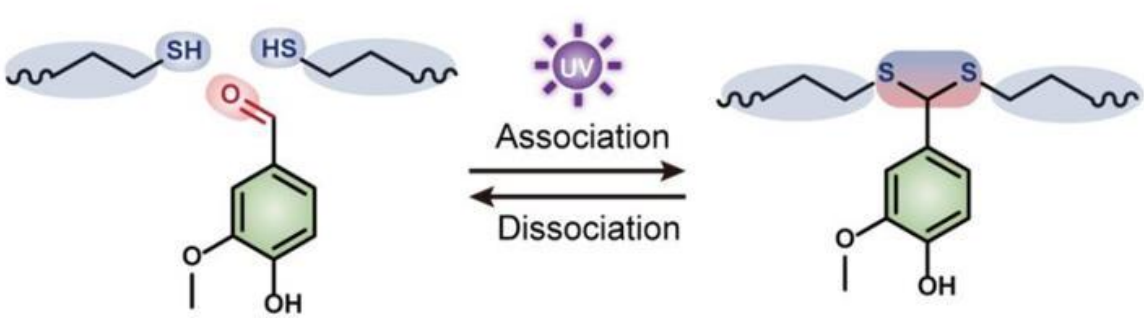
The process hinges on a thermally reversible photo-click reaction, a kind of molecular handshake triggered by light and undone by heat. Once the polymer is heated, its bonds partially dissociate—not fully back to monomers, but into photoreactive oligomers, which can be reused directly. That partial reversal keeps the resin both robust and endlessly recyclable.

A Happy Accident

Graduate student Yang Bo, the study’s lead author, stumbled into the discovery while experimenting with thiol reagents—sulfur-containing compounds commonly used in organic chemistry. The result caught him off guard.

“The reaction behaved the opposite of what we predicted,” Yang recalls. Further investigation revealed a light-triggered reaction between thiols and aldehydes, a classic reaction that typically needs heat to proceed.

“This was the first time anyone showed that this reaction could occur rapidly under light,” said co-lead Zheng Ning. That unexpected behavior opened a door to a class of recyclable resins that no one had previously imagined.



The dissociative thiol-aldehyde photochemistry. Credit: Zhejiang University© ZME Science

Sustainability often comes with trade-offs. Strong materials are hard to recycle; recyclable materials are often weak. Plastic is a textbook example. But the new resin sidesteps that compromise.

“By establishing a light-responsive dynamic dithioacetal chemistry system, we offer a novel molecular design strategy,” said Professor Xie. “Our research has successfully overcome the longstanding trade-off between mechanical performance and closed-loop recyclability in photocurable 3D printing materials at the molecular level.”

Tests showed that the recycled resin performed just as well as the original. There was no noticeable degradation across print cycles.

By tweaking the polymer backbone, the team could tailor the resin to become soft elastomers, rigid plastics, or even crystalline materials. This modularity expands its range of applications—from dental aligners to engine part molds.

A Step Closer to Zero-Waste Printing

Today’s 3D printing market, from industrial prototyping to hobbyist miniatures, generates tons of unrecyclable waste. Even UV resins marketed as “recyclable” often require laborious chemical treatment—and don’t return to full performance.

“This resin contributes to the ‘circular economy’ in 3D printing,” noted a report in *Tom’s Hardware*, which covered the team’s announcement. “It ensures makers have reliable material with the performance they need while providing a reusability factor that reduces overall cost.”

It’s still early days. No 3D printer on the market currently claims true zero-waste. But this research pushes the field closer.

And while the resin isn’t yet available commercially, the team hopes it will eventually power a new generation of sustainable printers.

“If we could infinitely recycle 3D printing materials,” said Professor Xie, “we’d cut down on both costs and waste—a win-win for both industry and the environment.”

As the world grapples with plastic pollution and the challenges of industrial waste, sometimes the path forward begins in the glow of a beam of light, across a vat of liquid resin, where chemistry behaves in ways no one quite expected.

Circular 3D printing of high-performance photopolymers through dissociative network design

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Editor's summary

Whereas thermopolymers can be remelted and reused, thermoset polymers typically need to be broken back down into monomers for efficient recycling, which is possible only if the polymers are designed with this property in mind. Yang *et al*. explored the potential of lignin-derivable building blocks for making circular resins for three-dimensional (3D) printing (see the Perspective by Lopez de Pariza and Sardon). During printing, the photopolymerization forms dithioacetal bonds. When trying to reuse the material, rather than breaking it down into monomers, the authors reverted the polymers only partially back to photoreactive oligomers using catalytic thermal dissociation of the dithioacetal bonds. This allowed for circular use without loss of properties in each print cycle. —Marc S. Lavine

Abstract

One approach for closed-loop plastics recycling relies on reverting polymers back into monomers because one can then make new plastics without loss of properties. This depolymerization requirement restricts the molecular design to making polymers with high mechanical performance. We report a three-dimensional (3D) printing chemistry through stepwise photopolymerization by forming dithioacetal bonds. The polymerized network can be transformed back into a photoreactive oligomer by dissociation of the dithioacetal bonds. This network-oligomer transformation is reversible, therefore allowing circular 3D printing using the same material. Our approach offers the flexibility of making modular adjustments in the design of the network backbone of a polymer. This allows access to fully recyclable elastomers, crystalline polymers, and rigid glassy polymers with high mechanical toughness, making them potentially suitable for diverse applications.

Reformation by light

Light-driven chemistry enables three-dimensional printing of recyclable polymer parts
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Abstract

The digitalization of manufacturing processes has led to the development of three-dimensional (3D) printing technologies that build objects, layer by layer, starting with a digital model. This type of additive manufacturing is enabling the on-demand production of functional parts with complex geometries (*1*). However, it is also contributing to pollution from end-of-life products, particularly those made from polymers (*2*). Closed-loop recycling of 3D-printed polymers, in which a material is reused indefinitely without losing valuable properties, is a desired solution, but there is an unavoidable trade-off between the mechanical integrity of printed parts and recyclability. On page 170 of this issue, Yang *et al.* (*3*) report a circular additive manufacturing process by which light-induced polymerization produces high-performance polymer parts that can be decomposed into reprintable liquid resins under a specific condition. This represents a major step forward in sustainable light-promoted 3D printing.