3D-printing formula may transform future of foam

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Credit: University of Texas at Dallas

From seat cushions to mattresses to insulation, foam is everywhere—even if we don't always see it. Now, researchers at The University of Texas at Dallas have fused chemistry with technology to create a 3D-printed foam that is more durable and more recyclable than the polymer foam found in many everyday products.

The research, published in *RSC Applied Polymers*, focused on creating a sturdy but lightweight foam that could be 3D-printed, a method that is still largely unexplored in commercial manufacturing, said the study's co-lead author, UT Dallas doctoral student Rebecca Johnson BS'20.

"This is probably the longest project I've ever done," said Johnson, who plans to complete her Ph.D. in chemistry in May. "From start to finish, it was a little over two years. A lot of it was trying to get the polymer formulation correct to be compatible with the 3D printer."

Although making new materials that are compatible with 3D technology is challenging, Johnson said, the 3D-printing process allowed the researchers to create complex shapes that could be customized in manufacturing applications. To demonstrate the proof-of-concept, they produced foam in the shape of a balloon dog. They also described their work in a YouTube video.

"The goal of the project was to address some limitations in 3D printing in terms of making polymer foam," said Dr. Ron Smaldone, associate professor of chemistry and biochemistry in the School of Natural Sciences and Mathematics and the corresponding author of the study. "One of the main uses, or interests, of 3D-printable foams is insulation and shock absorption."

With more research and experimentation, Smaldone said, this type of foam and process could be used for high-impact absorption items such as motorcycle or football helmets, car bumpers or armor. He also noted that 3D printing enables the creation of more complex structures, such as fine lattices, which can increase the physical flexibility of the material and provide more versatility for applications.

Chemistry doctoral student Rebecca Johnson BS'20 holds a tiny dog-shaped piece of sturdy, lightweight 3D-printed foam she and her colleagues developed. Credit: University of Texas at Dallas

The researchers also examined how to make a material that could be 3D-printed into a consistent final product without a lot of defects. Most commercial foam is thermoset, meaning it undergoes a chemical reaction during molding that permanently locks its structure in place, preventing it from being reshaped, melted or dissolved. As a result, most polymer foam cannot be recycled and ultimately ends up in landfills, Smaldone said.

The UT Dallas researchers developed their durable foam using special reversible bonds, called dynamic covalent chemistry. Although the foam cannot be completely melted and reshaped like plastic, these bonds allow the material to repair itself when damaged, making it more versatile and longer lasting.

"We're certainly not the only ones trying to do this," Smaldone said. "The novelty is using dynamic chemistry to print really great foam material. The next question to address will be, how do we tune the properties and use this new kind of knowledge to fit a variety of different needs?"

Johnson and the study's other co-lead author, chemistry doctoral student Ariel Tolfree BS'23, developed their ideas after studying similar research in the field. Tolfree, who credits Johnson as her mentor, plans to expand on the research by examining how to make the foam more recyclable and exploring the foam's sustainability potential.

Tolfree said creating a foam balloon dog as one of the group's test objects was a natural choice.

"It's a simple shape but perfectly represents our foams," Tolfree said. "A balloon seems ordinary until it's twisted into something new, almost defying expectations. Our foams are the same—unassuming at first, but once expanded and transformed, they become something remarkable."

More information: Rebecca M. Johnson et al, 3D printable polymer foams with tunable expansion and mechanical properties enabled by catalyst-free dynamic covalent chemistry, *RSC Applied Polymers* (2025). DOI: 10.1039/D4LP00374H

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