Breakthrough technique speeds up smart tech manufacturing nearly 600 times

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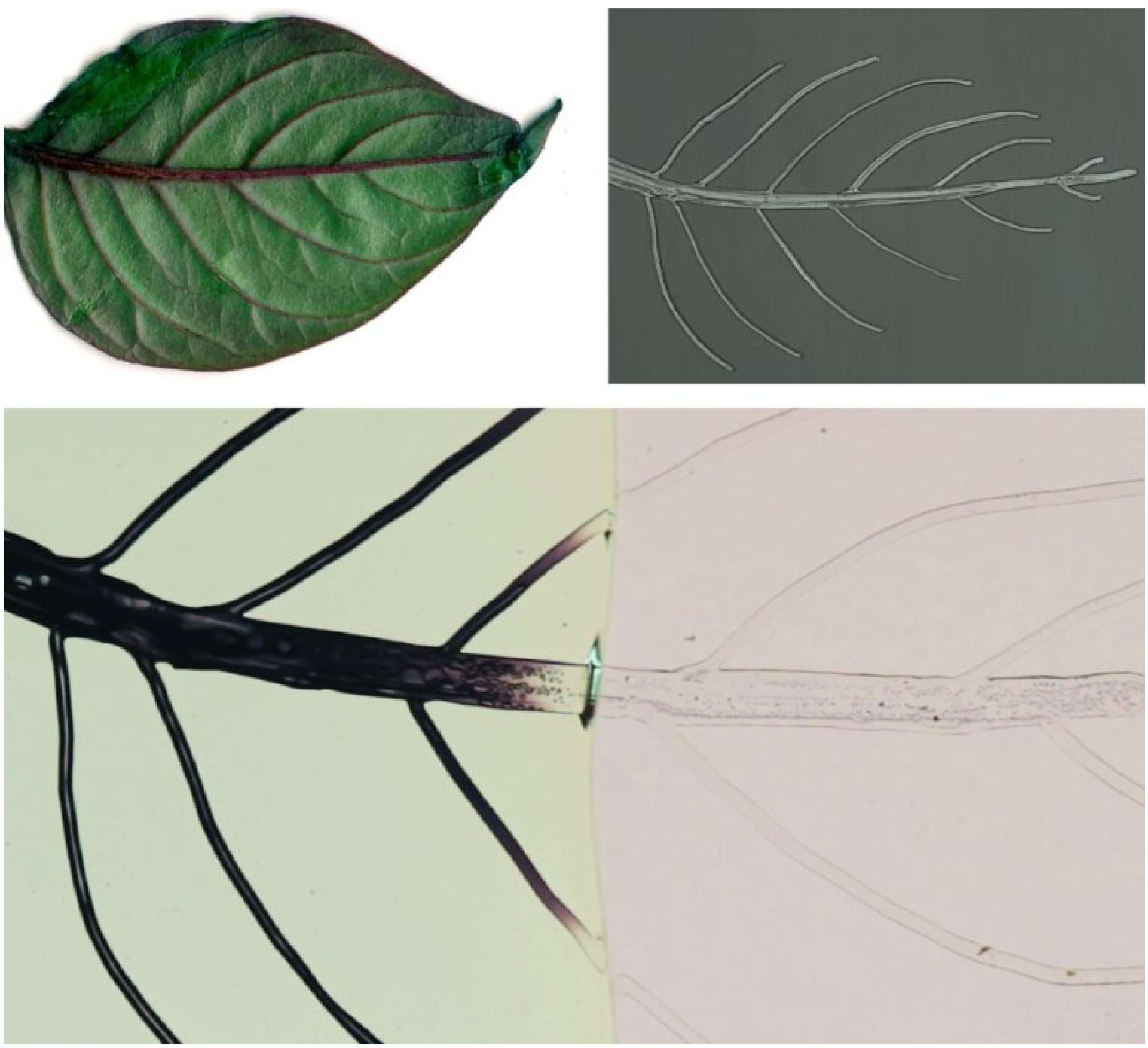

Manufacturing of a vascularized structure using a 3D-printed template that mimics vascular networks of a leaf. Credit: Mayank Garg

Researchers have developed a new polymerization technique to simultaneously cure and vascularize high-performance materials in a matter of minutes instead of days, according to a new paper in *Nature Communications*.

The technique is inspired by biological systems such as human blood vessels or leaves on a plant. By creating microchannels inside structural polymers and composites, scientists can impart multifunctional properties to the host structure—"smart" functionality like self-healing and thermal regulation. Only now, they can do it almost 600 times faster than before.

The breakthrough shortens the manufacturing cycle, from two days of processing under a vacuum at high temperatures to five minutes at room temperature and ambient pressure, without any resources like ovens or pumps.

CSU Assistant Professor Mostafa Yourdkhani was a co-author on the paper, along with several researchers from the Beckman Institute for Advanced Science and Technology. Prior to joining CSU, Yourdkhani was a postdoctoral research associate at the Beckman Institute.

Chemistry and engineering collide

The discovery came about by chance.

The research team had been working on two separate projects for material systems, testing two separate hypotheses. One project examined how to make composites quickly, the other how to turn polymer materials into volatiles in response to triggers.

As the team observed the behavior of the material systems, they began to consider integrating the two projects into one. Could they combine the ideas to create a new manufacturing approach?

The vascular highway

Imagine the vessels in your body or in plants. They transport fluids from one point to another, performing actions such as delivering nutrients, regulating temperature, or healing a wound.

Now imagine an inorganic structure, such as an airplane, with the ability to mimic those actions. The airplane could regulate its temperature or heal itself when there is structural damage. The process is not easy, but it is possible.

Creating vascular materials has historically been a challenging process. Beyond demands of time and heat, the two-step operation involved curing host materials, then vaporizing a sacrificial template to leave behind hollow channels. The more complicated the channel, the longer the process took.

"Each of the material systems used in this idea are unique and disruptive," Yourdkhani said. "On one hand, we have a resin that produces heat for rapid synthesis instead of requiring hours of external heating. On the other hand, we have a solid polymer that turns into volatiles when heated instead of being melted."

Yourdkhani says that the beauty of the work is to see how the combination of these two materials can create internal architectures in structural parts rapidly and without expensive resources.

The discovery of frontal polymerization solves this challenge. The internally created heat solidifies the host while deconstructing the template into gas, leaving behind a vascular network. Combining the two steps into one eliminates the need for an oven and provides greater control to engineers and scientists to explore advanced biological functions and more complex systems.

A boost for smart tech

The discovery paves a new future for efficient smart technology, impacting the aerospace, wind, and automotive sectors. Such industries are increasingly using composite materials in structural parts due to their low density, excellent mechanical properties, and corrosion resistance.

However, composites are prone to internal damages that are not easy to detect. Using vascularized structures allows for delivering beneficial fluids to the damaged site for healing. These self-healing features will enhance the reliability and longevity of structural composites.

"The synergy of chemistry and engineering can lead to interesting and revolutionary design processes," Yourdkhani said. "It worked."

More information: Mayank Garg et al, Rapid synchronized fabrication of vascularized thermosets and composites, *Nature Communications* (2021). DOI: 10.1038/s41467-021-23054-7

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