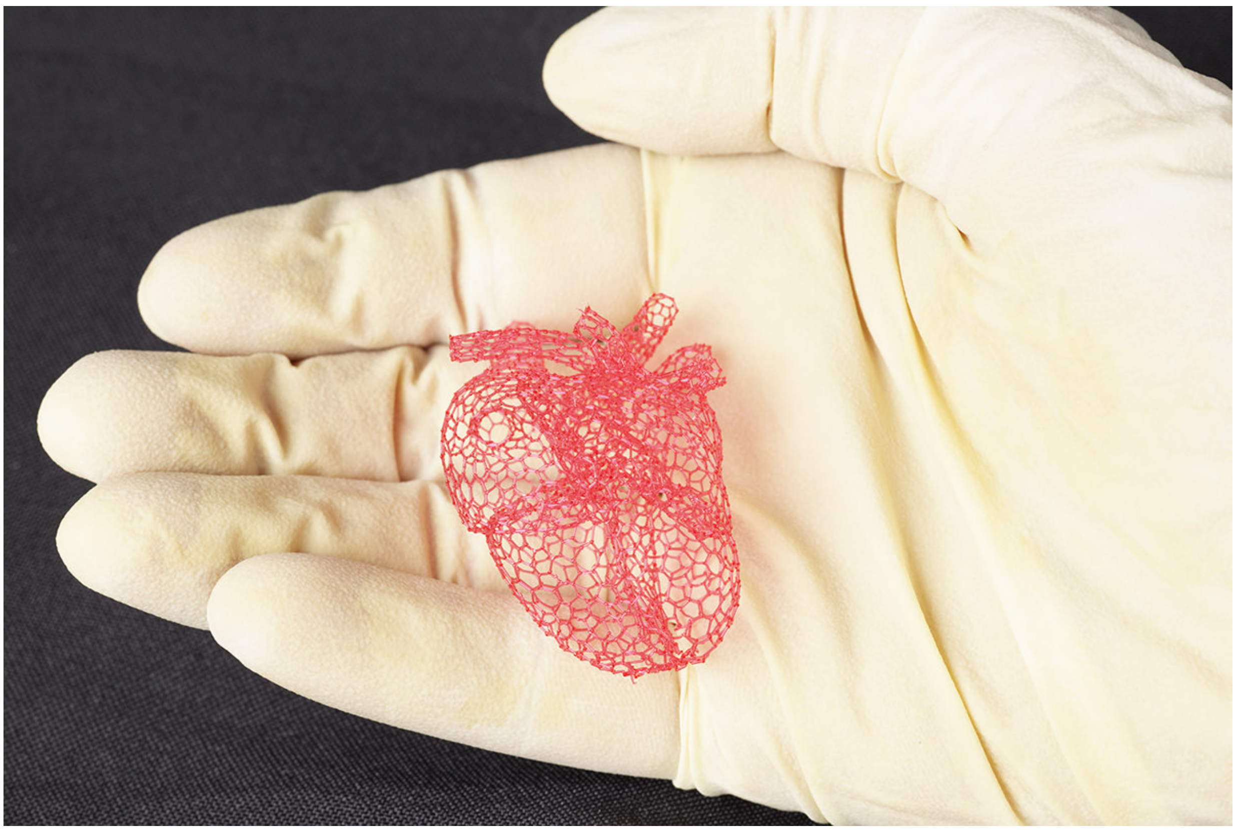
3-D printed sugar scaffolds offer sweet solution for tissue engineering, device manufacturing

May 24 2018, by Liz Ahlberg Touchstone



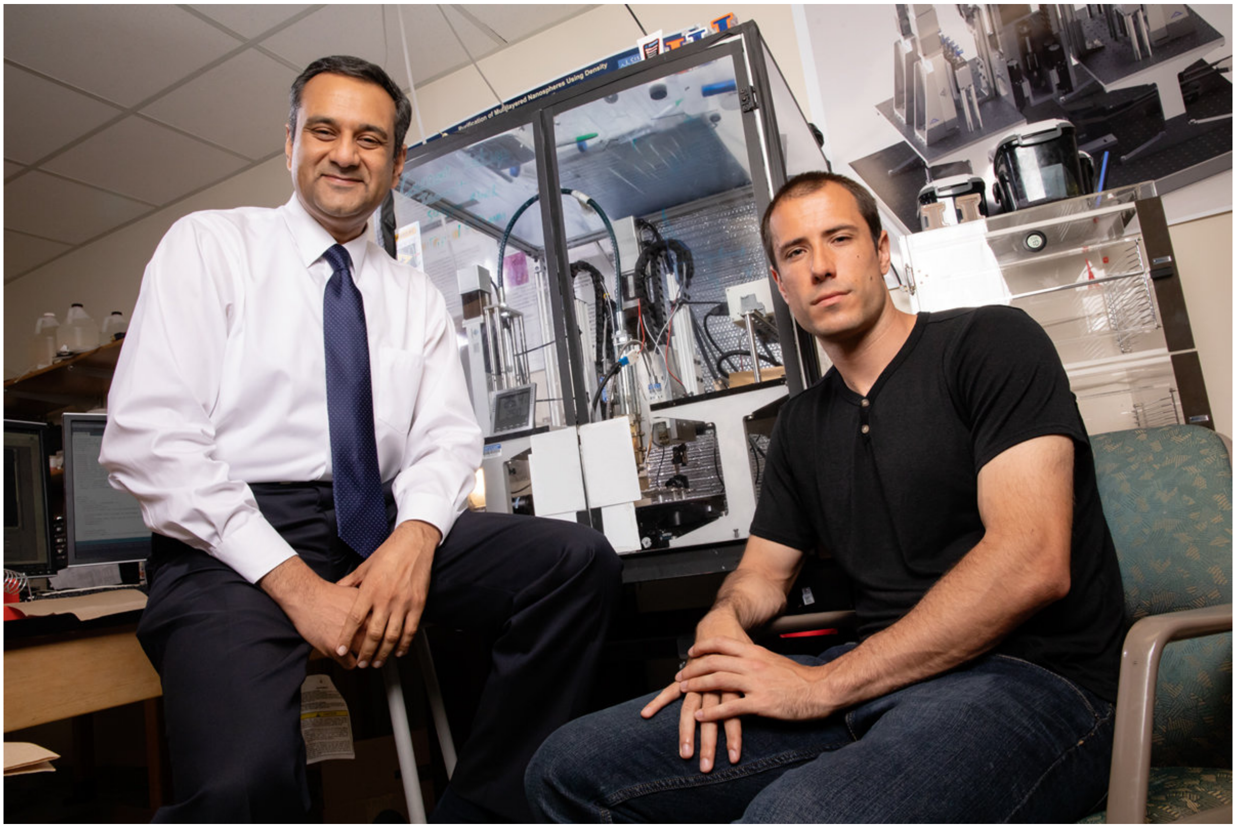
Freeform printing allows the researchers to make intricate structures, such as this model of a heart, that could not be made with traditional layer-by-layer 3-D printing. The structures could be used as scaffolds for tissue engineering or device manufacturing. Credit: Travis Ross, Beckman Institute

University of Illinois engineers built a 3-D printer that offers a sweet solution to making detailed structures that commercial 3-D printers can't: Rather than a layer-upon-layer solid shell, it produces a delicate network of thin ribbons of hardened isomalt, the type of sugar alcohol used to make throat lozenges.

The water-soluble, biodegradable glassy sugar structures have multiple applications in biomedical engineering, cancer research and device manufacturing.

"This is a great way to create shapes around which we can pattern soft materials or grow cells and tissue, then the scaffold dissolves away," said Rohit Bhargava, a professor of bioengineering and director of the Cancer Center at Illinois. "For example, one possible application is to grow tissue or study tumors in the lab. Cell cultures are usually done on flat dishes. That gives us some characteristics of the cells, but it's not a very dynamic way to look at how a system actually functions in the body. In the body, there are well-defined shapes, and shape and function are very closely related."

In a paper published in the journal Additive Manufacturing, the research group described the materials and mechanics of free-form isomalt printing. Free-form means that as the nozzle moves through space, the melted material hardens, leaving a sturdy structure behind – like drawing in midair.

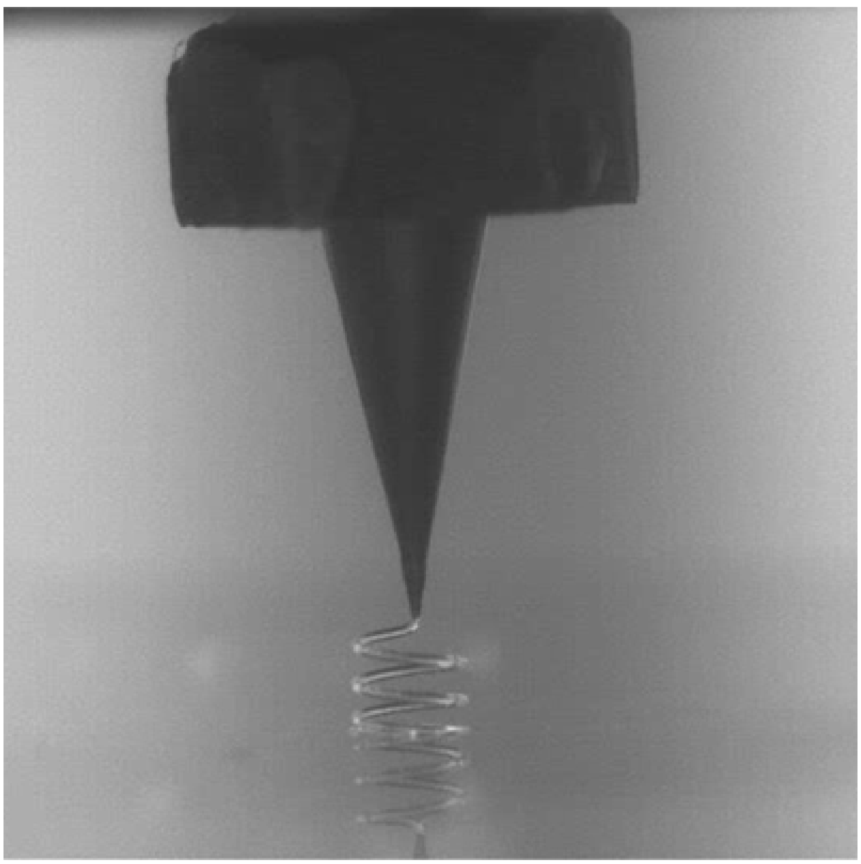


Illinois professor Rohit Bhargava, left, and Ph.D. graduate Matthew Gelber developed a free-form 3-D printer that can create scaffoldings out of sugar for tissue engineering and manufacturing applications. Credit: University of Illinois at Urbana-Champaign

Other types of sugar printing have been previously explored, but have problems with the sugar burning or crystallizing, said Matthew Gelber, the first author of the paper who recently graduated from Bhargava's group with a Ph.D.

The Illinois team found that the sugar alcohol isomalt could work for printing applications and is less prone to burning or crystallization. Then they had to build a printer that would have the right combination of mechanical details to print stable isomalt structures – the right temperature, pressure to extrude it from the nozzle, diameter of the nozzle, and speed to move it so it prints smoothly but then hardens into a stable structure.

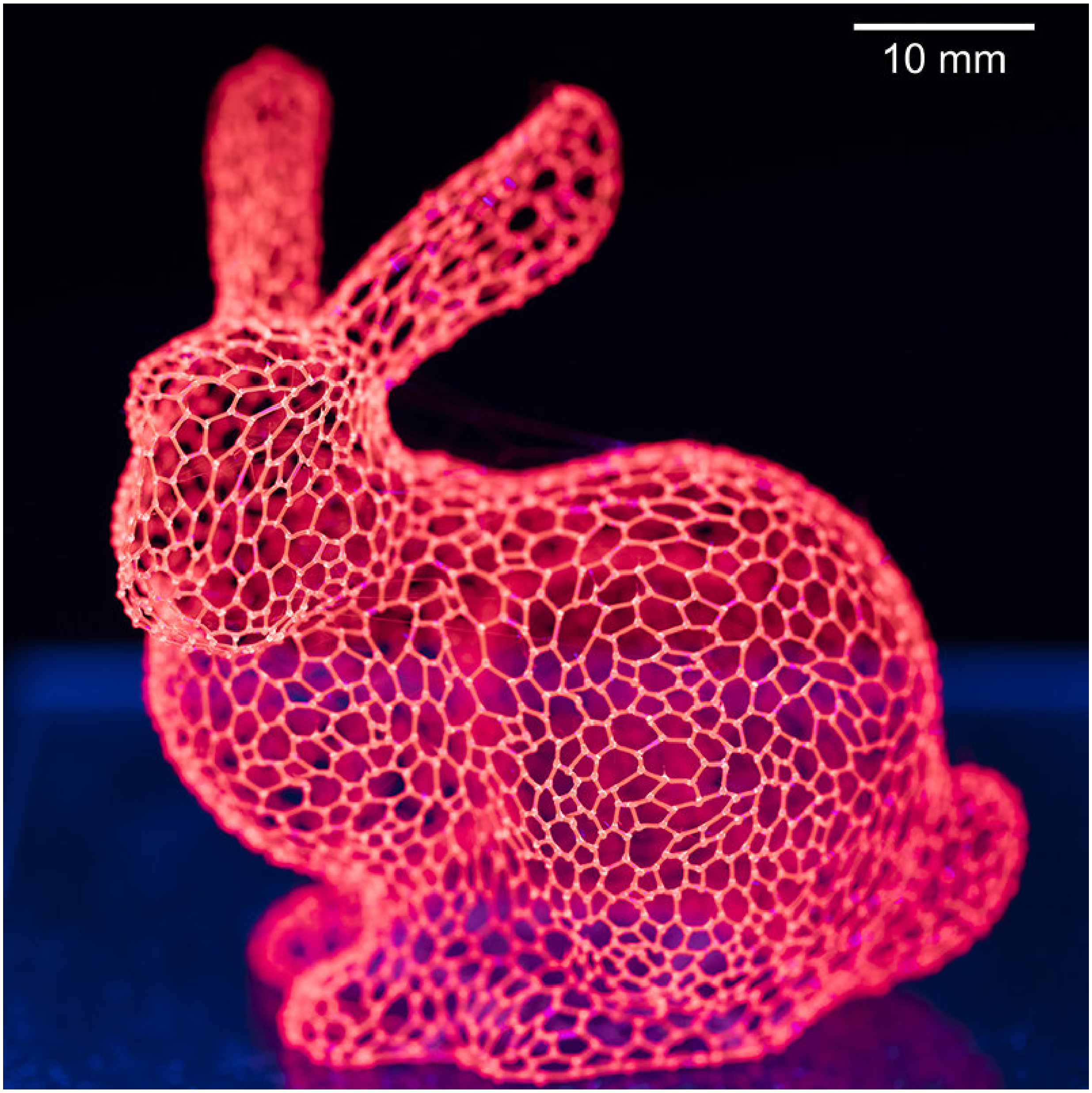
"After the materials and the mechanics, the third component was computer science," Gelber said. "You have a design of a thing you want to make; how do you tell the printer to make it? How do you figure out the sequence to print all these intersecting filaments so it doesn't collapse?"



The machine prints free-form, the melted sugar hardening in the air as it prints. Credit: Matthew Gelber

The Illinois researchers partnered with Greg Hurst at Wolfram Research in Champaign to create an algorithm to design scaffolds and map out printing pathways.

One advantage such free-form structures hold is their ability to make thin tubes with circular cross-sections, something not possible with conventional polymer 3-D printing, Bhargava said. When the sugar dissolves, it leaves a series of connected cylindrical tubes and tunnels that can be used like blood vessels to transport nutrients in tissue or to create channels in microfluidic devices.



A 3-D printed bunny made of isomalt sugar mixed with a glowing red dye used in biomedical imaging. Credit: Troy Comi

Another advantage is the ability to precisely control the mechanical properties of each part of the structure by making slight changes in the printer parameters.

"For example, we printed a bunny. We could, in principle, change the mechanical properties of the tail of the bunny to be different from the back of the bunny, and yet be different from the ears," Bhargava said. "This is very important biologically. In layer-by-layer printing, you have the same material and you're depositing the same amount, so it's very difficult to adjust the mechanical properties."

Bhargava's group is already using the scaffolds in a variety of microfluidic devices and cell cultures, and it is working to develop coating for the scaffolds to control how quickly they dissolve. The Additive Manufacturing paper is part of a series of publications based on Gelber's thesis work that details how to build the printer and the planning algorithms necessary to operate it, as the researchers hope that others can use their models to build printers and explore various applications for isomalt structures.

"This printer is an example of engineering that has long-term implications for biological research," Bhargava said. "This is fundamental engineering coming together with materials science and computer science to make a useful device for biomedical applications."

More information: M.K. Gelber et al. Model-guided design and characterization of a high-precision 3D printing process for carbohydrate glass, *Additive Manufacturing* (2018). DOI: 10.1016/j.addma.2018.04.026

Provided by University of Illinois at Urbana-Champaign