To advance space colonization, team explores 3D printing in microgravity

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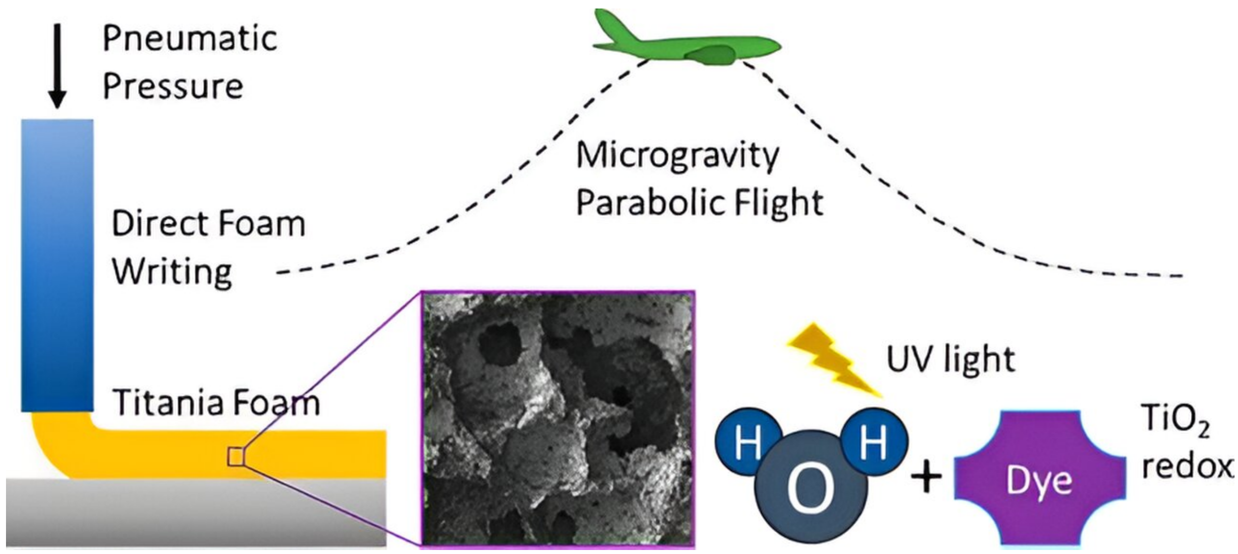

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Research from West Virginia University students and faculty into how 3D printing works in a weightless environment aims to support long-term exploration and habitation on spaceships, the moon or Mars.

Extended missions in outer space require the manufacture of crucial materials and equipment onsite, rather than transporting those items from Earth. Members of the Microgravity Research Team said they believe 3D printing is the way to make that happen.

The team's recent experiments focused on how a weightless microgravity environment affects 3D printing using titania foam, a material with potential applications ranging from UV blocking to water purification. ACS Applied Materials and Interfaces published their findings.

"A spacecraft can't carry infinite resources, so you have to maintain and recycle what you have and 3D printing enables that," said lead author Jacob Cordonier, a doctoral student in mechanical and aerospace engineering at the WVU Benjamin M. Statler College of Engineering and Mineral Resources. "You can print only what you need, reducing waste. Our study looked at whether a 3D-printed titanium dioxide foam could protect against ultraviolet radiation in outer space and purify water."

"The research also allows us to see gravity's role in how the foam comes out of the 3D printer nozzle and spreads onto a substrate. We've seen differences in the filament shape when printed in microgravity compared to Earth gravity. And by changing additional variables in the printing process, such as writing speed and extrusion pressure, we're able to paint a clearer image of how all these parameters interact to tune the shape of the filament."

Cordonier's co-authors include current and former undergraduate students Kyleigh Anderson, Ronan Butts, Ross O'Hara, Renee Garneau and Nathanael Wimer. Also contributing to the paper were John Kuhlman, professor emeritus, and Konstantinos Sierros, associate professor and associate chair for research in the Department of Mechanical and Aerospace Engineering.

Sierros has overseen the Microgravity Research Team's titania foam studies since 2016. The work now happens in his WVU labs but originally required taking a ride on a Boeing 727. There, students printed lines of foam onto glass slides during 20-second periods of weightlessness when the jet was at the top of its parabolic flight path.

"Transporting even a kilogram of material in space is expensive and storage is limited, so we're looking into what is called 'in-situ resource utilization,'" Sierros said. "We know the moon contains deposits of minerals very similar to the titanium dioxide used to make our foam, so the idea is you don't have to transport equipment from here to space because we can mine those resources on the moon and print the equipment that's necessary for a mission."

Necessary equipment includes shields against ultraviolet light, which poses a threat to astronauts, electronics and other space assets.

"On Earth, our atmosphere blocks a significant part of UV light—though not all of it, which is why we get sunburned," Cordonier said. "In space or on the moon, there's nothing to mitigate it besides your spacesuit or whatever coating is on your spacecraft or habitat."

To measure titania foam's effectiveness at blocking UV waves, "we would shine light ranging from the ultraviolet wavelengths up to the visible light spectrum," he explained. "We measured how much light was getting through the titania foam film we had printed, how much got reflected back and how much was absorbed by the sample. We showed the film blocks almost all the UV light hitting the sample and very little visible light gets through. Even at only 200 microns thick, our material is effective at blocking UV radiation."

Cordonier said the foam also demonstrated photocatalytic properties, meaning that it can use light to promote chemical reactions that can do things like purify air or water.

Team member Butts, an undergraduate from Wheeling, led experiments in contact angle testing to analyze how changes in temperature affected the foam's surface energy. Butts called the research "a different type of challenge that students don't always get to experience," and said he especially valued the engagement component.

"Our team gets to do a lot of outreach with young students like the Scouts through the Merit Badge University at WVU. We get to show them what we do here as a way to say, 'Hey, this is something you could do, too,'" Butts said.

According to Sierros, "We're trying to integrate research into student careers at an early point. We have a student subgroup that's purely hardware and they make the 3D printers. We have students leading materials development, automation, data analysis. The undergraduates who have been doing this work with the support of two very competitive NASA grants are participating in the whole research process. They have published peer-reviewed scientific articles and presented at conferences."

Garneau, a student researcher from Winchester, Virginia, said her dream is for their 3D printer—custom designed to be compact and automated—to take a six-month trip to the International Space Station. That would enable more extensive monitoring of the printing process than was possible during the 20-second freefalls.

"This was an amazing experience," Garneau said. "It was the first time I participated in a research project that didn't have predetermined results like what I have experienced in research-based classes. It was really rewarding to analyze the data and come to conclusions that weren't based on fixed expectations.

"Our approach can help extend space exploration, allowing astronauts to use resources they already have available to them without necessitating a resupply mission."

More information: G. Jacob Cordonier et al, Direct Writing of a Titania Foam in Microgravity for Photocatalytic Applications, *ACS Applied Materials & Interfaces* (2023). DOI: 10.1021/acsami.3c09658

Provided by West Virginia University