National Aeronautics and
Space Administration

TECHNOLOGY SOLUTION

Manufacturing

3D Printed Polymer Aerogels

Additive manufacturing-enabled rapid fabrication of polymer aerogels with complex, tailored geometries

Aerogels are low density, highly porous, ultra-lightweight materials first invented in the 1930s. More recently, inventors at NASA's Glenn Research Center (GRC) have created a variety of polymer aerogel formulations with broad applications including thermal insulation, acoustic barriers, vibration mitigation, and much more. Conventionally, aerogels are fabricated using a molding process, which requires separate, often costly, manufacturing of the mold itself. The geometry of aerogels that can be fabricated using molding processes are limited in complexity by difficulty removing the gel from mold. This inhibits the ability to rapidly prototype complex, application-specific aerogel structures with tailored geometries (e.g., conformal geometries around existing components), limiting the rate of iterative design and innovation.

To address these challenges, researchers at NASA GRC developed methods to rapidly prototype and fabricate polymer aerogel structures using 3D printing techniques (e.g., direct ink writing) that retain the microstructural, mechanical, and thermal properties of polymer aerogels fabricated via conventional molding processes. 3D printing provides a host of advantages including the ability to produce intricate polymer aerogel architectures with complex geometries in a rapid manner and without the need for a mold.

BENEFITS

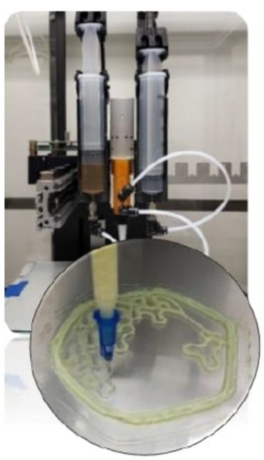
- Enables fabrication of complex polymer aerogel geometries: NASA's 3D printing techniques enable fabrication of polymer aerogel structures with complex, tailored geometries that would be infeasible using molding processes.
- Enables fabrication of complex multi-chemistry polymer aerogels: Using NASA's processes, different polymer aerogel formulations can be layered while in a gel state, chemically bonding (cross-linking) them immediately, eliminating the need for adhesives.
- Allows on-demand, on-site manufacturing: The ability to 3D print polymer aerogels using common additive manufacturing equipment (e.g., direct ink writing printers) enables on-demand fabrication of polymer aerogels at the point-of-use.
- Allows polymer aerogel 3D-printing using existing infrastructure: Many of NASA's polymer aerogel 3D printing techniques can be practiced using conventional direct ink writing printers without the need for additional specialized hardware.
- Eliminates solvent removal step some polymer aerogel formulations: Using NASA's 3D printing techniques, solvent removal (e.g., supercritical fluid extraction) is not required to fabricate some formulations (this would be required using other techniques). Removing this step reduces infrastructure needs, allowing for easier on-demand fabrication.

THE TECHNOLOGY

NASA GRC has developed several different 3D printing techniques to fabricate polymer aerogel structures; different techniques are suitable for different polymer aerogel formulations. In general, the methods entail forming a first liquid comprising a polymer precursor and cross-linker, forming a second liquid comprising a catalyst for reacting a polymer precursor to form a polymer, then 3D printing the aerogel structure with a mixture of the two liquids onto or into a medium.

Specifically, NASA's polymer aerogel 3D printing techniques include: direct syringe printing, dual-syringe printing with static mixing head, direct syringe printing of photocurable formulations, and a unique rapid prototyping method involving a sacrificial bath. The direct syringe process relies upon gelation to occur once the gel is extruded from the print head to the substrate. In the dual-syringe printing process, one syringe contains polyamic acid and the other contains a catalyst. These are mixed in a static mixing head to allow for curing/gelation upon extrusion. For direct syringe printing of photocurable polymer aerogel formulations, a UV pen and array follow the printed gel during extrusion to induce gelation. Finally, the rapid prototyping method uses a bath of highly viscosity, low shear gel that provides a low drag, flexible yet supportive medium in which to print the polymer aerogel. In other embodiments, a bath of polyamic acid is used while cross-linkers and catalysts are introduced via printing, or vice versa (polyamic acid is introduced via printing into a bath of cross-linkers and catalysts).

In addition to complex geometries, these layered 3D printing processes allow for the fabrication of chemically-bonded (cross-linked) structures composed of layers of different polymer aerogel formulations (i.e., fabrication of structures with tailored chemistries / properties). Previously, joining different polymer aerogel formulations into a single structure required the fabrication of different formulations using individual molds and joining them using an adhesive, potentially introducing weak fracture points.



An early embodiment of NASA's dual-syringe printing method demonstrating the fabrication of an intricate aerogel structure.

APPLICATIONS

The technology has several potential applications:

- Thermal insulation (e.g., for electronics, batteries, buildings, spacecraft components, pipelines, aircraft)
- Acoustic insulation (e.g., for aircraft including eVTOL, buildings / architectural acoustics, automotive, aerospace, marine, consumer electronics)
- Vibration mitigation (e.g., for industrial machinery, automotive, aerospace, electronics, buildings, marine applications)
- Construction / Architectural Engineering
- Automotive
- Aerospace
- Antennas
- Sensors
- Energy storage / power devices
- Electronics

PUBLICATIONS

Patent Pending

More Information

National Aeronautics and Space Administration

Agency Licensing Concierge

Glenn Research Center

21000 Brookpark Road
Cleveland, OH 44135
202-358-7432
Agency-Patent-Licensing@mail.nasa.gov

www.nasa.gov

NP-2020-03-2839-HQ

technology.nasa.gov

NASA's Technology Transfer Program pursues the widest possible applications of agency technology to benefit US citizens. Through partnerships and licensing agreements with industry, the program ensures that NASA's investments in pioneering research find secondary uses that benefit the economy, create jobs, and improve quality of life.

LEW-20156-1, LEW-TOPS-171