National Aeronautics and Space Administration

The fashion industry is investing in Mango Materials' sustainable fibers made from bioplastic

Methane Bioreactor System Offers Sustainable Plastic Alternative for Earth and Space

Challenge

Recycling and reducing waste are two important operational goals for NASA—both in space and on Earth. In space, recycling is significant as spacecraft have limited storage capacity, and it is costly to launch materials from Earth; it is therefore valuable for spacecraft to use systems that recycle waste products into functional materials.

On the International Space Station, NASA uses a Sabatier system for recycling carbon dioxide and hydrogen—both byproducts of current onboard life-support systems—into water and methane[1]. While the water is used for drinking or split into oxygen for breathing, the methane is produced in unusable amounts for propulsion and is discarded. But what if this methane could be converted into usable material, and what if that solution could be applied to methane on Earth as well?

Solution

Mango Materials, a woman-owned small business based in San Francisco, California, is developing systems to transform methane into biopolymers—plastic alternatives made from biodegradable material. The company was founded by Dr. Molly Morse, Dr. Allison Pieja, and Dr. Anne Schauer-Gimenez. Building on Dr. Morse and Dr. Pieja's Ph.D. research on green, biobased, and biodegradable materials at Stanford University, the team sought to explore plastic alternatives that reduce negative impact on the environment. In 2016, Mango Materials

[1]https://www.nasa.gov/mission_pages/station/research/news/sabatier.html

Project

An end-to-end bioreactor system that produces biopolymer (bioplastic) from methane gas

Mission Directorate

STTR

Follow-on Success

$6 million in total CCRPP funding from NASA STTR and industry investors

Snapshot

Mango Materials partnered with the Colorado School of Mines on NASA STTR awards to adapt a bioreactor system to convert methane into bioplastic for low-gravity environments. In space, methane from carbon dioxide conversion systems and waste treatment can be used to 3D print objects and provide polymers for construction and regolith binding. On Earth, the system can convert methane—a greenhouse gas—into environmentally conscious bioplastic. Mango Materials received $6 million through NASA CCRPP, including funds from fashion investors seeking alternatives to plastic-based textiles.

Mango Materials

Woman-owned small business

San Francisco, CA

mangomaterials.com

proposed to the Phase I solicitation with the Colorado School of Mines. The team received its first Phase I award to help develop a membrane bioreactor system, which produces a biopolymer—or bioplastic—from methane gas through fermentation.

While Mango Materials already created a bioreactor system for Earth, the company proposed to develop the system for deep space. A bioreactor system on the International Space Station could use methane created as a byproduct of recycling carbon dioxide and hydrogen; in addition, a system could be effective on Mars, where the atmosphere is 96% carbon dioxide, and hydrogen exists in frozen surface water.[2] A large-scale bioreactor system could support sustained presence on Mars by printing tools and providing a binding agent for regolith construction on the planet instead of relying on shipments.

After Phase I, the Mango Materials and Mines team received Phase II funding to further advance the technology. In 2019, the Phase II was extended through the STTR **Phase II-E** option to improve the end-to-end system and minimize waste. When the Phase II-E ended in 2020, Mango Materials sought to expand into the marketplace. The STTR **Civilian Commercialization Readiness Pilot Program** (CCRPP) appealed for its emphasis on commercial development and for the STTR dollar match on external investments. In 2021, Mango Materials received $6 million in total CCRPP funds from STTR and investors to optimize and commercialize the biopolymer product.

Business Impact

As of May 2022, the CCRPP has supported the development of the bioreactor system outside of the lab; Mango Materials is working with a wastewater treatment plant to improve its system, using methane created as a byproduct at the plant. Dr. Pieja remarked on how the CCRPP aligned with the company's goals: "It seemed like an amazing opportunity to fund the growth of the business. Commercialization has been our focus on Earth and beyond."

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> – Dr. Allison Pieja
> CTO, Mango Materials

Mango Materials' founders Dr. Molly Morse, Dr. Allison Pieja, and Dr. Anne Schauer-Gimenez are developing systems to convert methane into usable material

The applications on Earth are widespread; in addition to being used for 3D printing, the methane biopolymer also piqued the interest of fashion industry investors. Plastic fibers, such as polyester, are frequently used in the fashion industry, despite being a major source of plastic pollution on Earth.[3] Mango Materials received matching CCRPP funds from fashion industry investors interested in exploring how the methane biopolymer could be a more sustainable alternative to existing fibers.

As Mango Materials pursues its commercial goals, Dr. Junko Munakata Marr, Professor and Department Head of Civil and Environmental Engineering at Mines, also shared her excitement: "I'm an engineer by trade, so I'm very applied by training. I like to work on things that are impactful and have tons of potential in many ways." Through NASA STTR, Dr. Munakata Marr says students have gained insight into small business culture in a real-world setting and the school's space resources program has expanded thanks to the growing relationship with NASA.

The methane bioreactor system developed by the Mango Materials and Mines team has implications for improving life on Earth and in space by reducing waste and recycling materials. As NASA continues to invest in technologies that support its missions, it is important for the agency to prioritize sustainability alongside innovation.

[2]https://www.nasa.gov/press-release/nasa-s-perseverance-mars-rover-extracts-first-oxygen-from-red-planet
[3]https://www.epa.gov/trash-free-waters/what-you-should-know-about-microfiber-pollution