CME NASA STEM SYMPOSIUM

PRES

Polymer Aerogels for Lunar Applications and Beyond

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NASA Glenn Research Center

CME STEM

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www.cme-stem.org

ACS FALL 2021 RESILIENCE OF CHEMISTRY

National Aeronautics and Space Administration

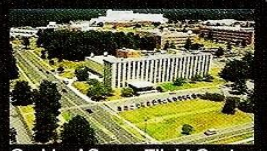
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NASA centers and facilities

www.nasa.gov

PS-00030-0610


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Kennedy Space Center


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Marshall Space Flight Center


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Stennis Space Center

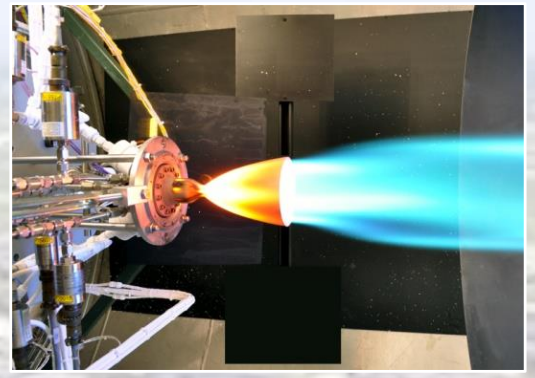

Wallops Flight Facility


White Sands Test Facility

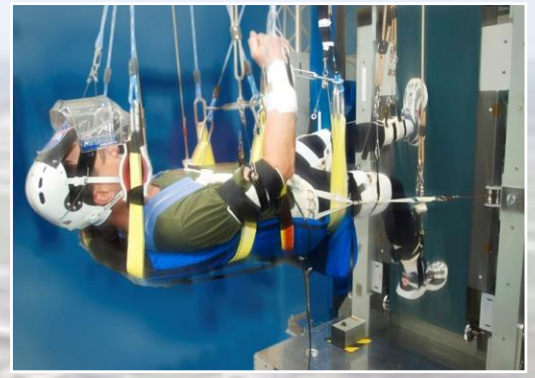
GRC Core Competencies



Air-Breathing Propulsion



In-Space Propulsion and Cryogenic Fluids Management



Physical Sciences and Biomedical Technologies in Space



Communications Technology and Development



Power, Energy Storage and Conversion



Materials and Structures for Extreme Environments

WE'RE GOING BACK!

Artemis Program: Return to moon-2024

https://www.nasa.gov/specials/artemis/

Apollo Program ran from 1961 to 1972

Moon Landing Missions:

- **Apollo 11 (1969)** Neil Armstrong (Commander), Buzz Aldrin, Michael Collins
- **Apollo 12 (1969)** Charles "Pete" Conrad (Commander), Alan Bean, Richard Gordon
- ***Apollo 13 (1970)** James Lovell (Commander), Jack Swigert, Fred Haise
- **Apollo 14 (1971)** Alan Shepard (Commander), Edgar Mitchell, Stuart Rosa
- **Apollo 15 (1971)** David Scott (Commander), James Irwin, Alfred Worden
- **Apollo 16 (1972)** John Young (Commander), Charles Duke, Thomas Mattingly
- **Apollo 17 (1972)** Eugene Cernan (Commander), Harrison Schmitt, Ronald Evans



Apollo 15-Astronaut James B. Irwin, lunar module pilot, works on the Lunar Roving Vehicle

*mission aborted

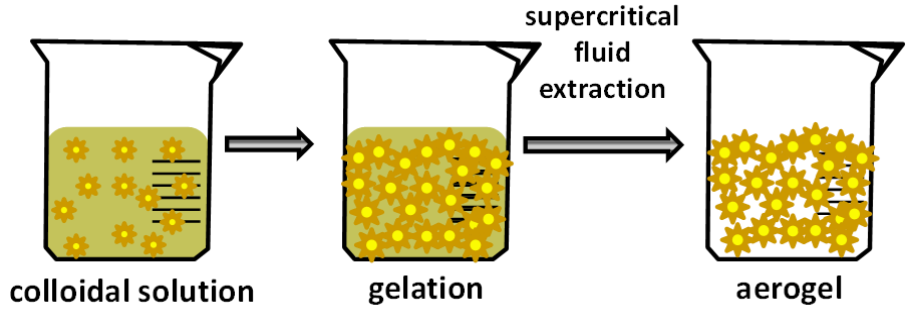
Issues and Concerns with Spaceflight

- Orbital debris
- Radiation
- Lunar dust
- Payload weight reduction
- Crew health and safety
- ISRU

The Wonderful World of Polymer Aerogels!

What is an aerogel?

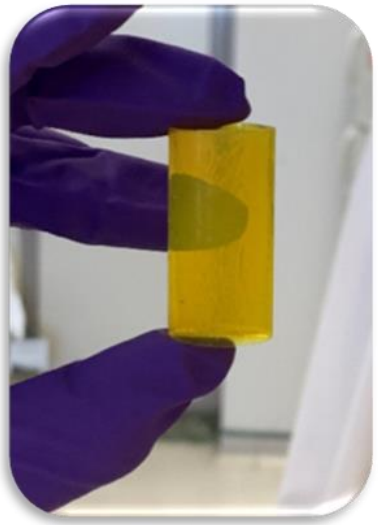
- An open-celled, light weight, porous material derived from a gel in which the liquid is replaced by gas while maintaining the self-assembled three dimensional structure



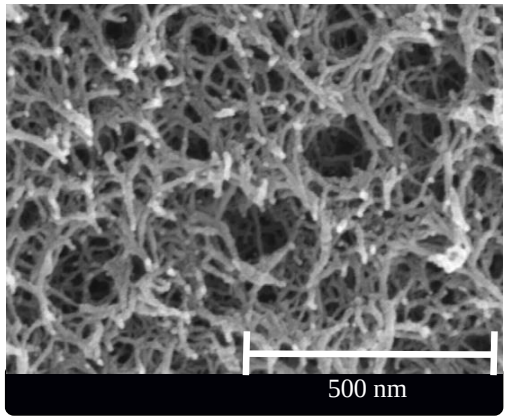
Aerogels made using sol-gel synthesis and supercritical fluid extraction

Many characteristics of aerogels are tailored by using various chemistries; however, all aerogels have these Typical Properties:

- High porosity (> 90 %)
- Nano-scale pore sizes (10-40 nm)
- Low density (0.1-0.2 g/cm^3)
- Large surface areas (400 – 850 m^2/g)
- Low thermal conductivity (~20mW/m·K)
- Low dielectric (1.1)
- Low refractive index (1.02-1.09)



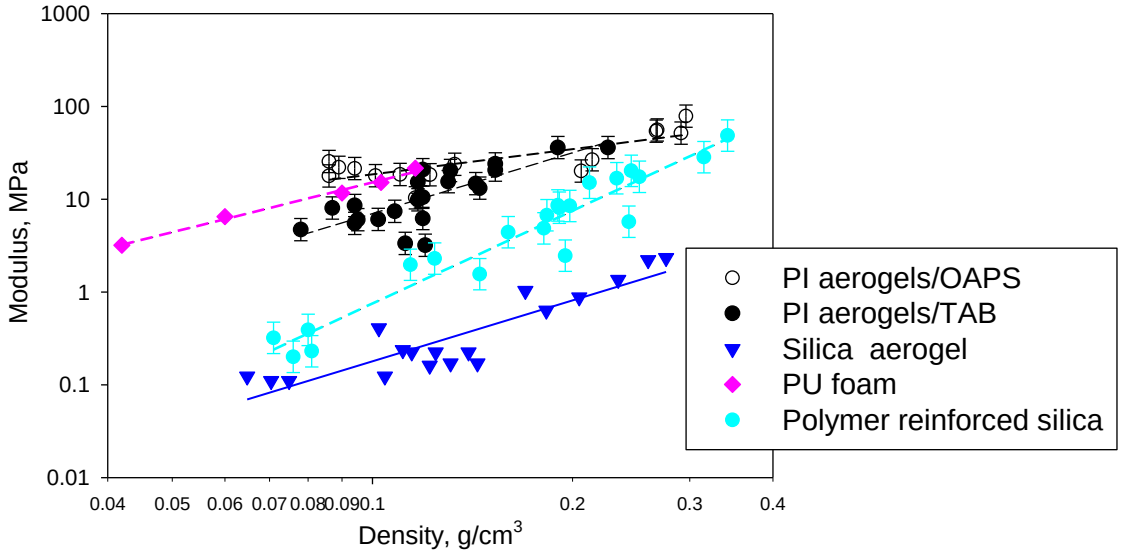
polymer aerogel cylinder (1g) (SA= 850 m2/g)



Scanning Electron Micrograph of polymer aerogel matrix

Strong, Flexible Polyimide Aerogels







Can be formed into moldable shapes and thin films with excellent mechanical properties and flexibility

H.Guo, et al. *ACS Appl. Mater. Interfaces*, **2011**, *3 (2)*, pp 546–552

Multifunctional, Universal Thermal Insulation System

- Current multilayer insulation (MLI) only functions in vacuum
  - Layers of Mylar separated by scrim layers
- Aerogel is best insulation in gaseous environment
- MLI incorporating aerogel in place of scrim reduces TC by 23-37%

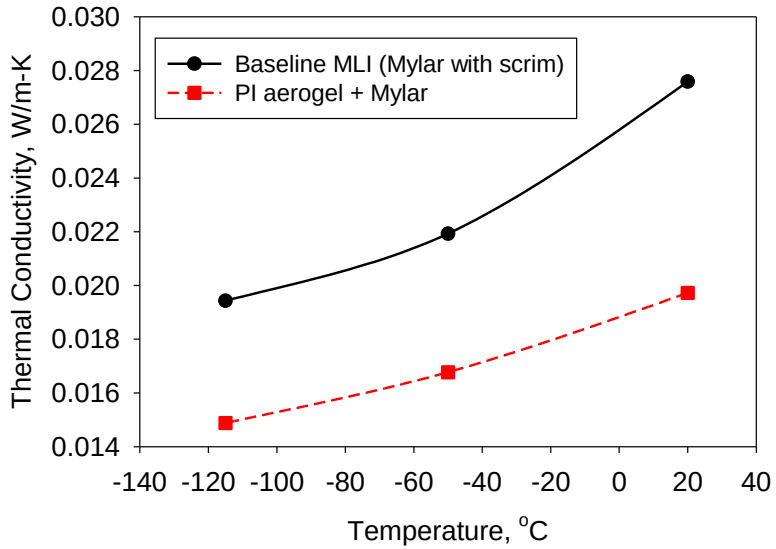




Baseline MLI (Mylar + scrim)



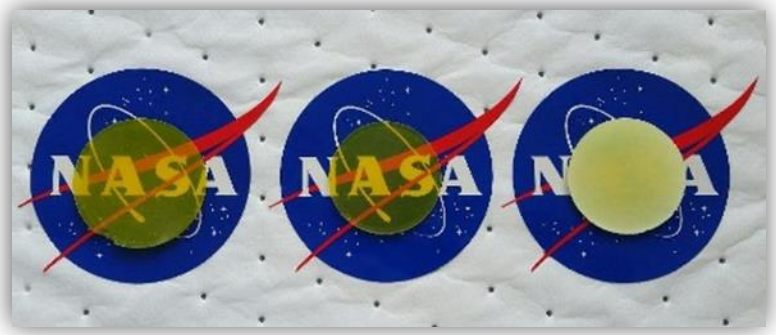
Pi aerogel + Mylar



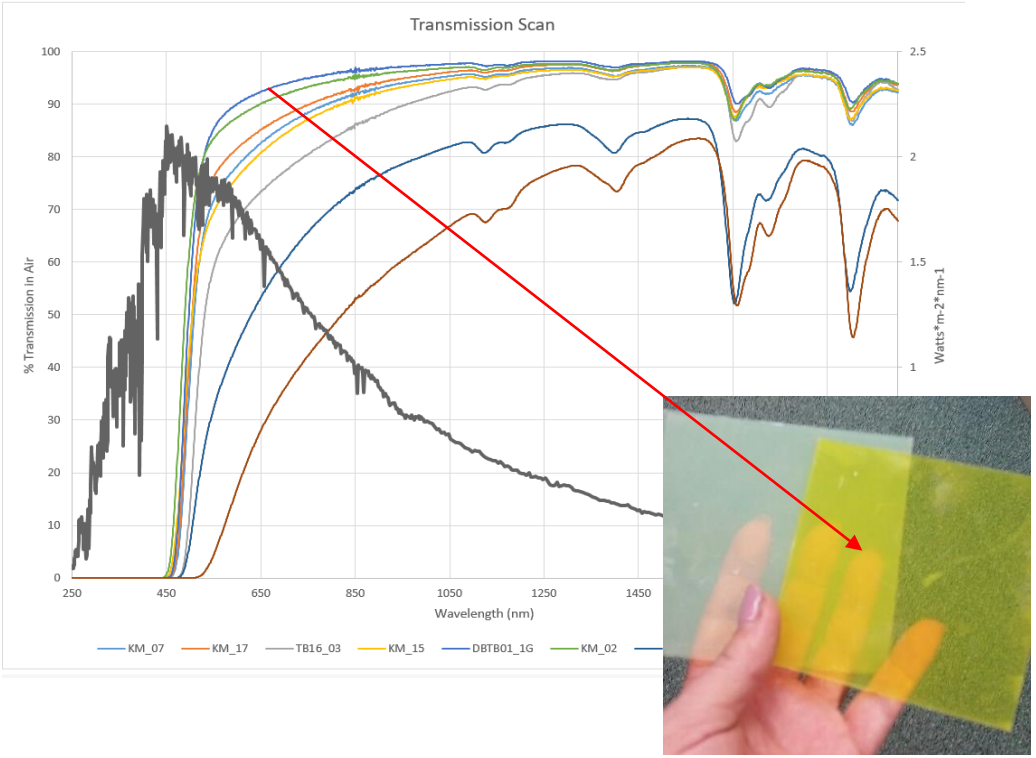
MLI with and without aerogel tested under simulated Mars atmosphere (8 Torr Argon, -120 to 20 °C)

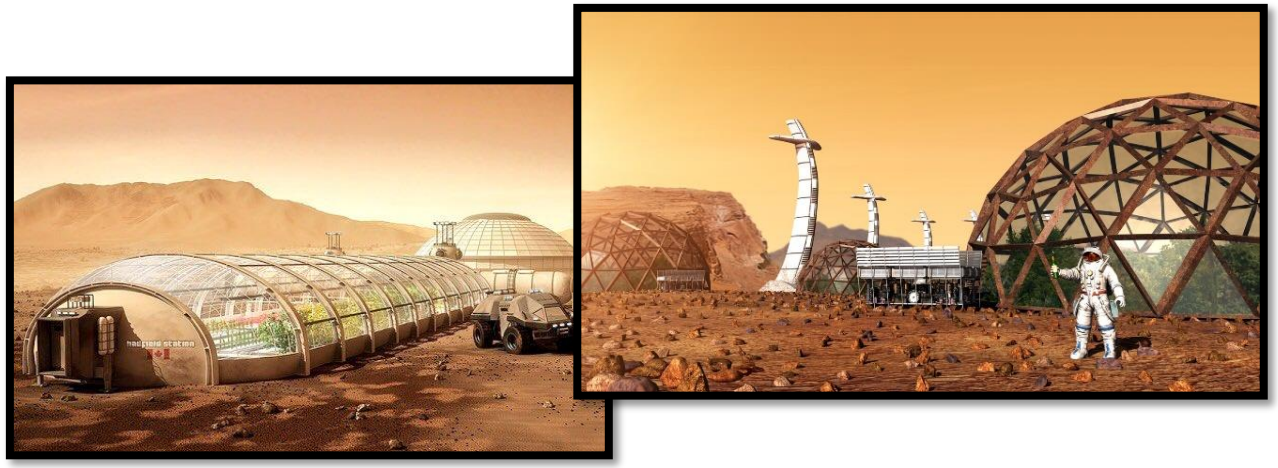
Polymer Aerogels for Passive Thermal Containment





Tunable opacity

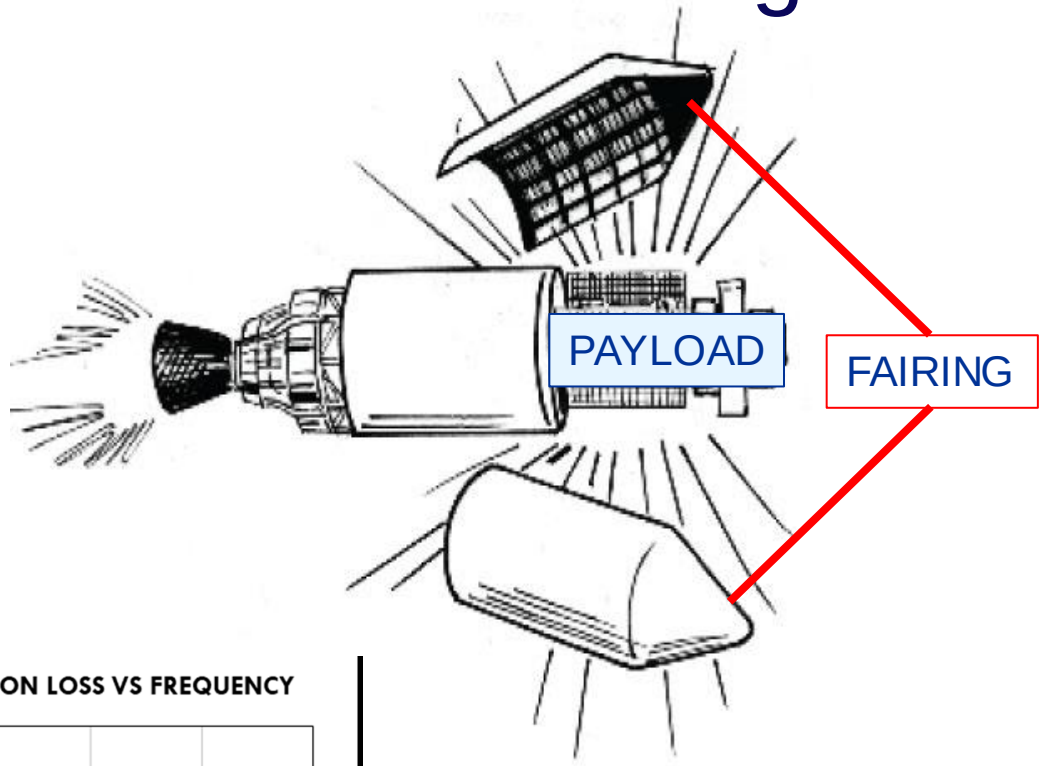


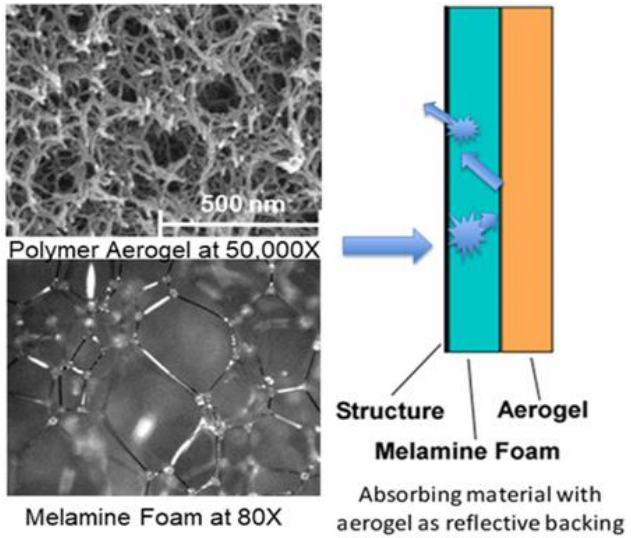


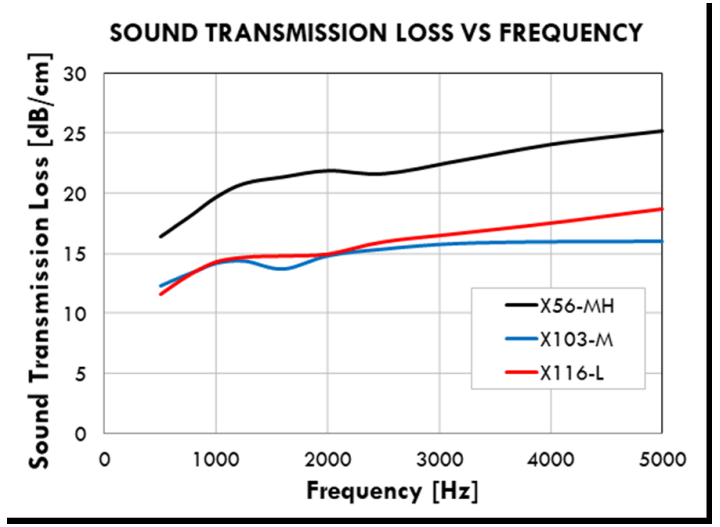
PTC for habitats, greenhouses, terraforming

Advanced Acoustic Materials for Noise Mitigation

- Vibro-acoustic loads pose threat to payload launch survivability
- Aerogels will add damping to the structure, which reduces the amplitude of the vibration and noise transmission in addition to weight reduction

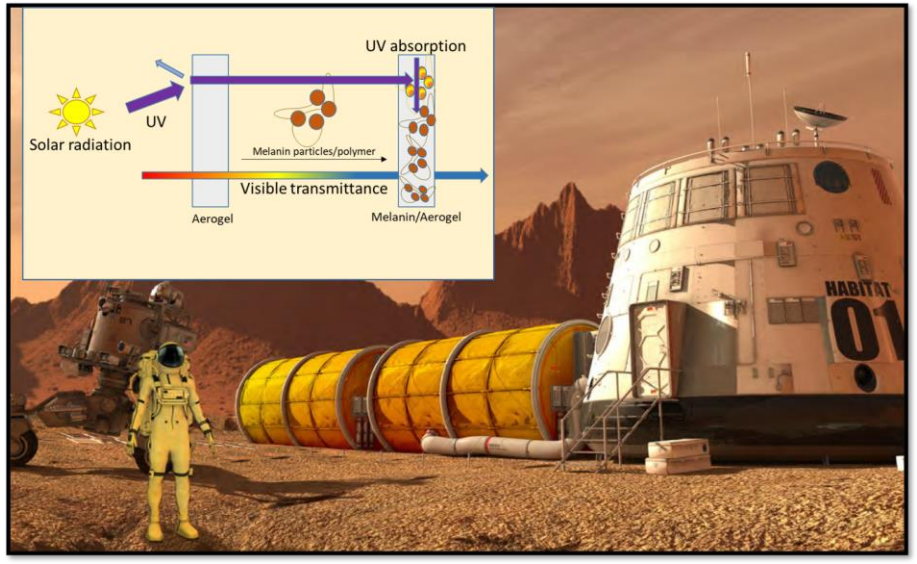


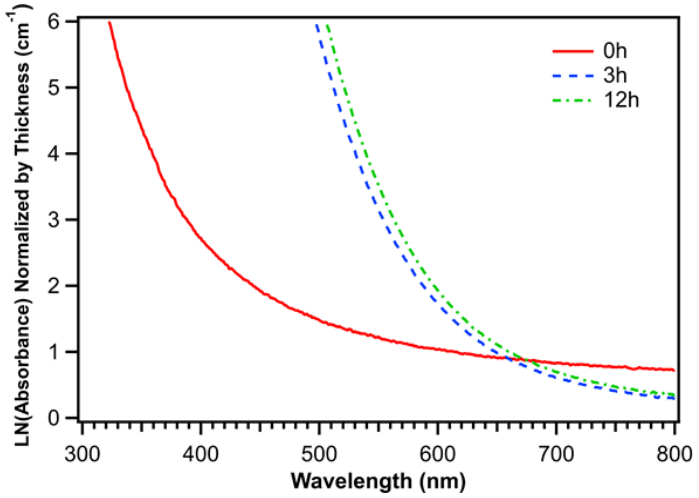




Sound transmission loss vs. frequency for various products from Aerogel Technologies, including X116-L, based on NASA' polyimide aerogel

Melanized Aerogel for Radiation Mitigation

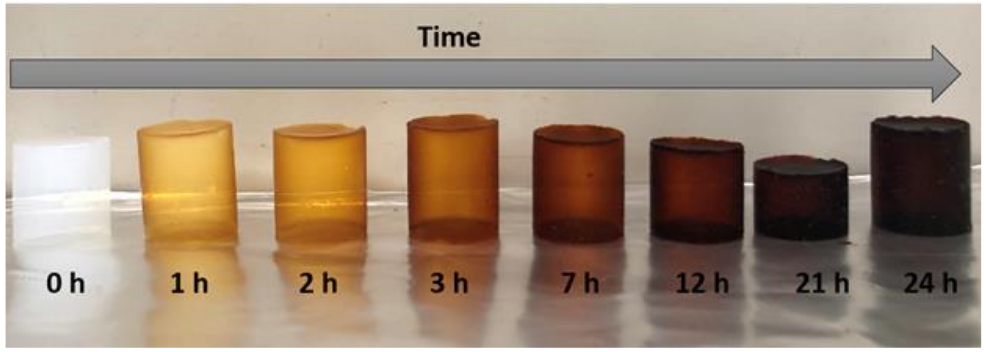




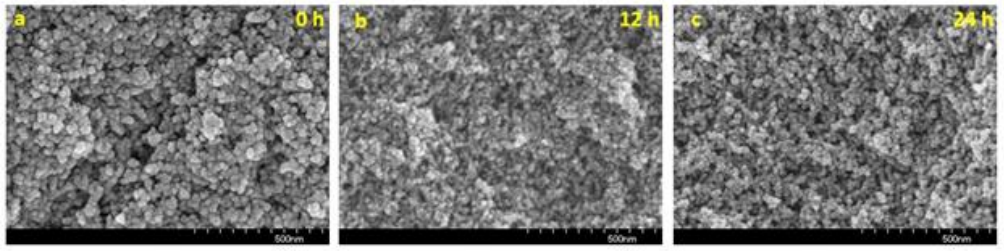
Representative UV-vis spectra for PDA-coated aerogels at t=0, 3,12 h where absorbance is plotted as a function of wavelength.

G.Rey, ACS Appl. Mater. Interfaces, in press, 2021

Melanized aerogels exhibit higher absorption over native aerogel with little to no effect on surface area, density, shrinkage, and porosity



Images of the PDA-coated silica aerogels at coating time (t) t=0, 1, 2, 3, 7, 12, 21, 24 h.

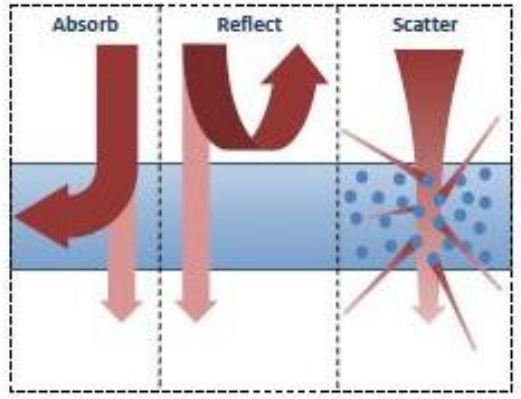


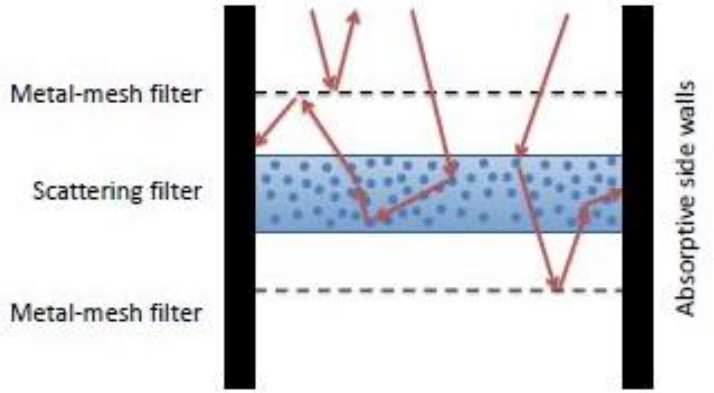
SEM images of the surface morphology of the native aerogel (a) and PDA coated aerogel at t=12 h (b) and t=24 h (c)

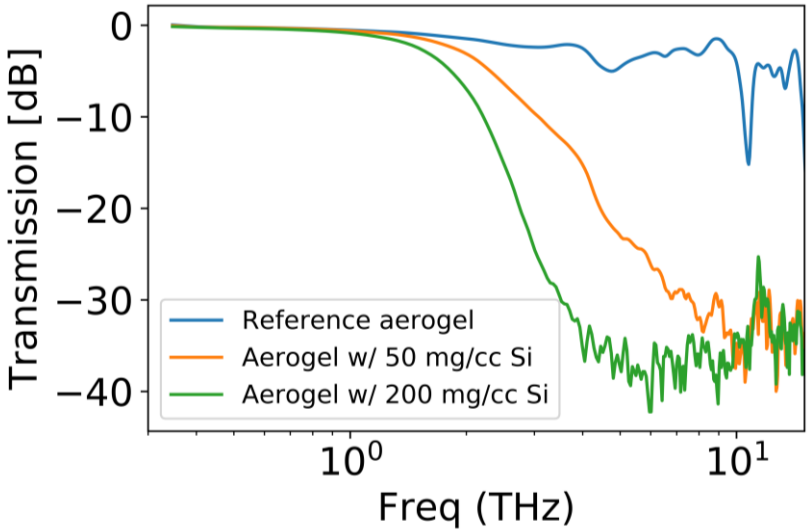
Sample	Porosity	BET Surface Area	Shrinkage	Bulk Density
	(%)	(m^2/g)	(%)	(g/cm^3)
0 h	92.8±0.8	642±45	7±1	0.14±0.02
12 h	92.6±0.9	614±35	7±2	0.13±0.01
24 h	92.4±0.7	658±15	8±1	0.13±0.01

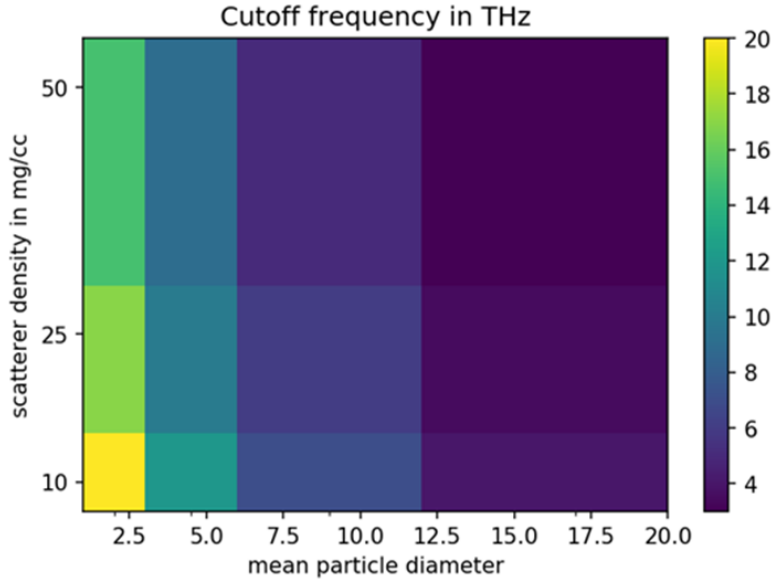
Aerogel IR Scattering Filters for mm and Sub-mm Astrophysics (Origin of Life Studies)

- IR blocking filters made by embedding scattering particles in an aerogel substrate
- Maximizing the sensitivity of millimeter and sub-millimeter instruments requires rejection of infrared (IR) light.









T. Essinger-Hileman,et al. Appl. Opt. 59, 5439-5446 (2020)



M16 ▪ Eagle Nebula
Hubble Space Telescope ▪ WFC3/UVIS/IR

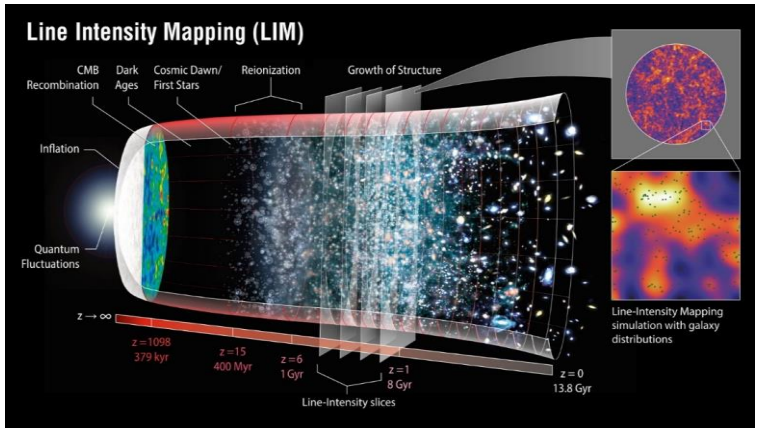
NASA and ESA

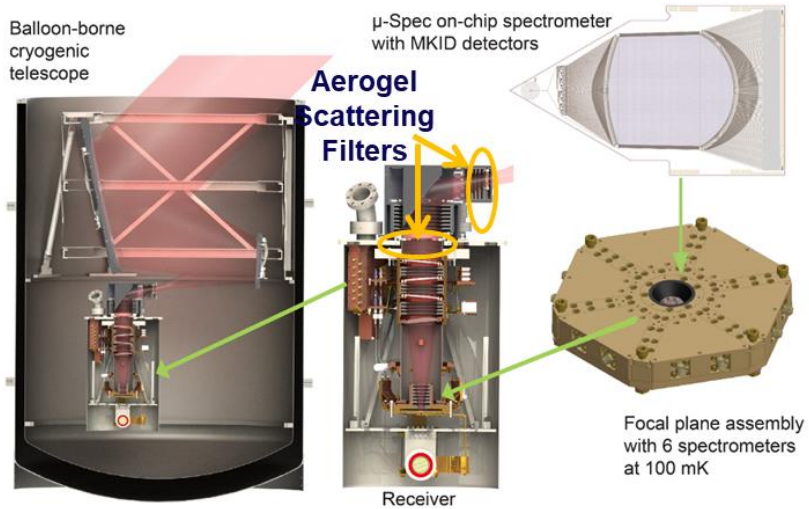
STScI-PRC15-01c

EXCLAIM:

The EXperiment for Cryogenic Large-Aperture Intensity Mapping

EXCLAIM will try to map CO and ionized carbon [CII] at redshifts of 0 < z < 3.5 (depending on the line) to try to understand star formation over cosmic time





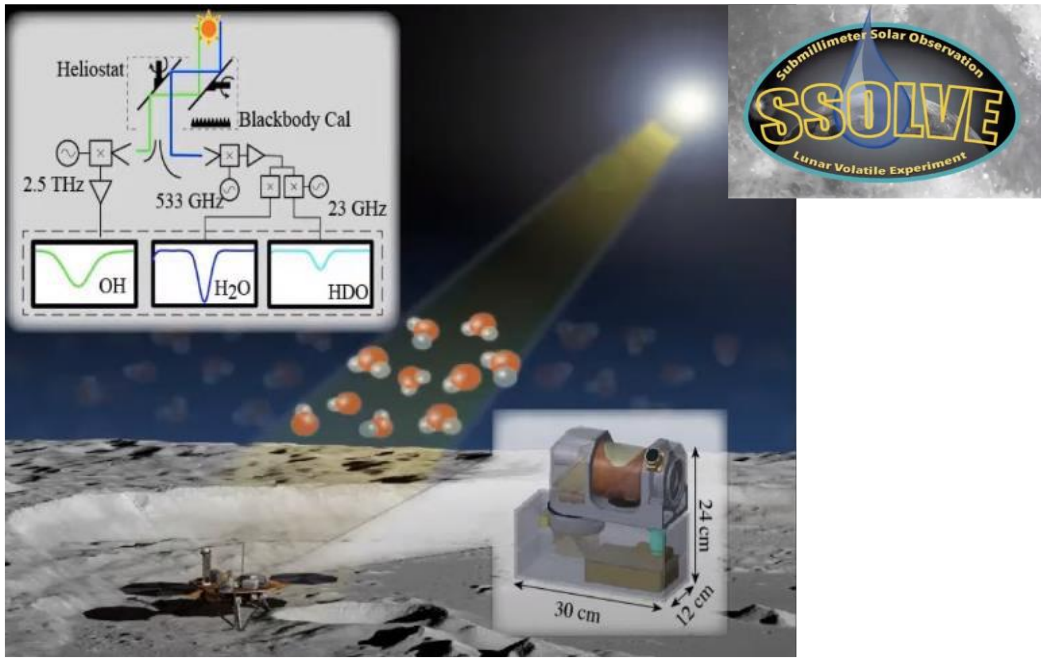
Aerogel scattering filters are the baseline infrared-blocking filter for EXCLAIM

The EXCLAIM band is 420-540 GHz and the filters should effectively block radiation above 1 THz

PI: Eric Switzer (GSFC)

SSOLVE:

Submillimeter Solar Observation Lunar Volatiles Experiment

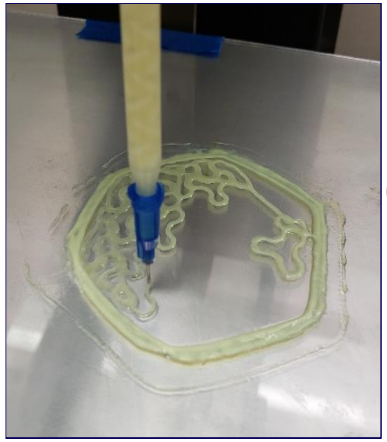


- SSOLVE will measure water vapor to learn which source(s) of water dominates the lunar atmosphere.
- Operate submillimeter spectrometers from a lander, using a heliostat to target the Sun and to measure the column abundance of H2O, OH, and HDO in the lunar atmosphere

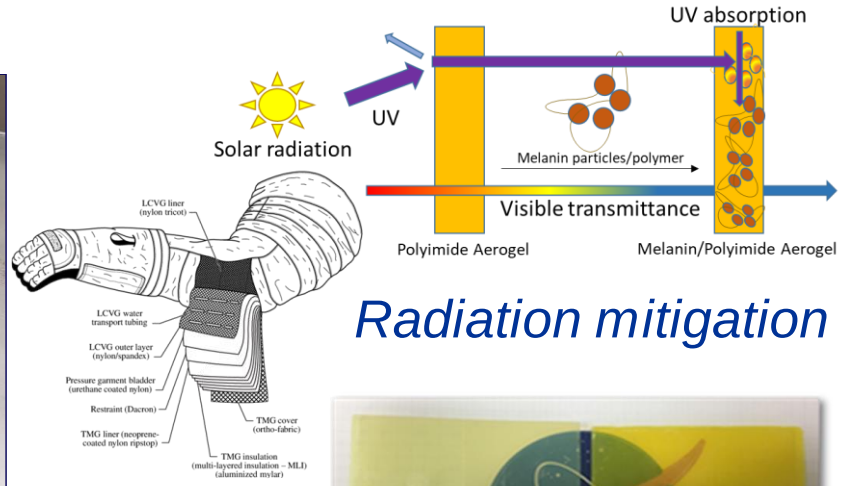
EPSC Abstracts, Vol. 13, EPSC-DPS2019-1173-1, 2019

PI: Berhanu Bulch (GSFC), Tim Levingood (University of Maryland)

Polyimide Aerogel Development



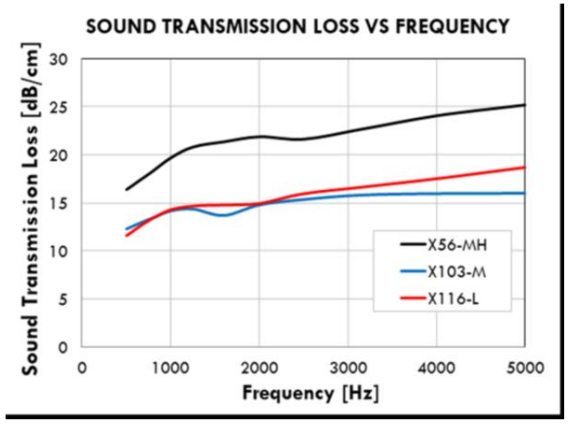
3D printing



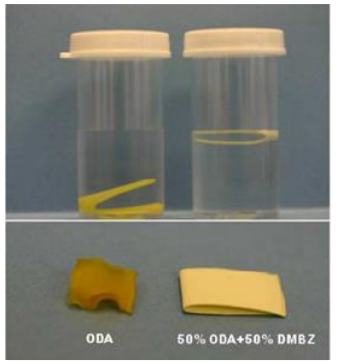
Radiation mitigation



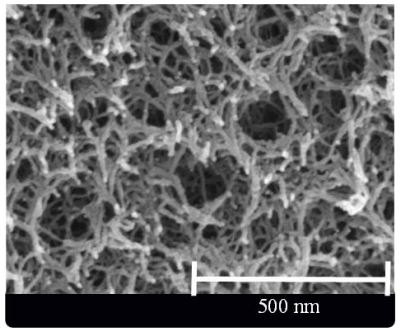
Tunable Transparency



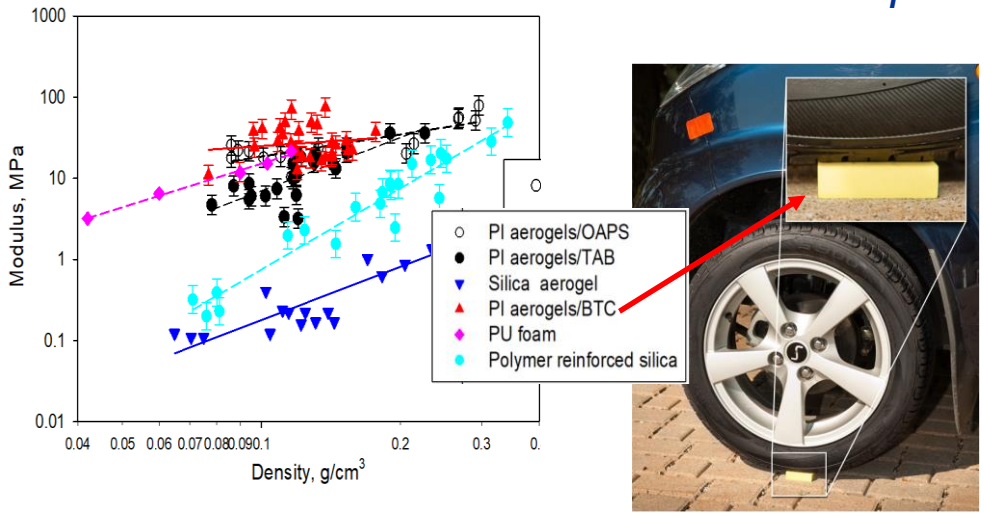
Acoustic impedance



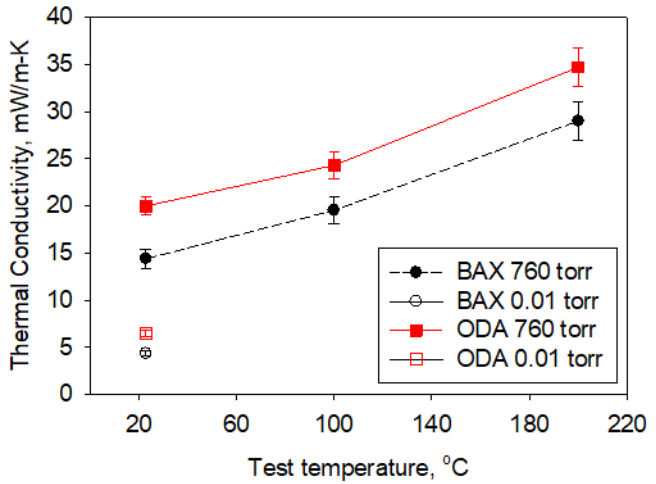
Tailored Hydrophobicity



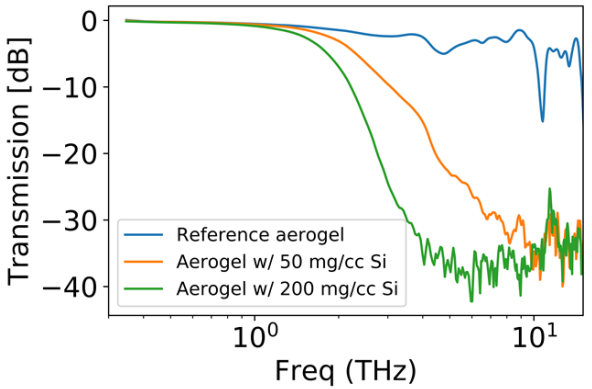
Tunable pore structure



Improved mechanical properties



Enhanced thermal insulation



IR filtration

Aerogel applications with Industry, Academia, and OGA's

- **Aerogel Technologies, LLC:** Holds the highest number of licenses for NASA aerogel technology
- **UT Austin/NSF:** ultralight carbon aerogel electrodes to increase energy density of rechargeable batteries
- **Scintilex,LLC/DoE:** **Highly** transparent aerogel -high energy particle detection
- **Aspen Aerogel-SBIR with NASA**: Thin Aerogel as a Spacer in Multi-Layer Insulation. Fixed-Wing and Rotary-Wing Aircraft Thermal, Acoustic, IR & Fire Protection
- **US DoD/ Lockheed Martin**: Nanocellulose Aerogels for UAV applications
- **Washington State University**: 3D-printed LH2 Tank-Aerogel Insulation
- **Bremont Watch Co(UK)/Boeing**: Wristwatches and chronometers featuring Boeing aeroplane material (aerogel)
- **Designer Claire Choisne**: Boucheron's Goutte de Ciel, which translates as "taste of the sky."









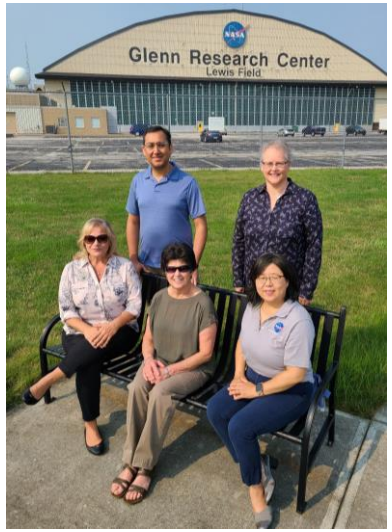
Acknowledgments

–Dr. Haiquan Guo, Dr. Sadeq Malakooti, Matt Deminico, Anne McNelis, Lucas Shearer, Dr. Tom Essinger- Hileman, Dr. Berhanu Bulcha, Ariel Tokarz, Dr. Theresa Benyo, Alyssa Barlis, Dr. Mary Ann Meador

–Linda McCorkle, Dan Scheiman Frank Bremenour, Spyro Efpraxias

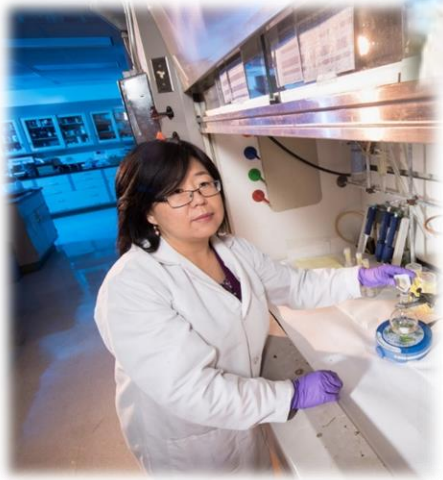
–Dr. Ali Dhinojwala, Gabrielle Rey, Saranshu Singla (University of Akron)

–Dr. Stephen Steiner, Justin Griffin, Moriah Buckwalter (Aerogel Technologies)











Funding

SMD Astrophysics Research and Analysis (APRA) Program
STMD Game Changing Development Program (GCDP) ACO
NASA Center Innovation Fund (CIF)
NASA Independent Research and Development (IRAD) Program

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