Lightweight, Flexible, and Thermal Insulating Polyimide Aerogels for Cryogenic Insulation Applications

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Thermal & Fluids Analysis Workshop
TFAWS 2024
August 26-30, 2024
NASA Glenn Research Center
Cleveland, OH

Cryogenic Systems and Applications

Green aviation as a solution for short-haul aviation.
Image Credit: NASA

Cryogenic Insulation for Liquid Hydrogen Tank
Image Credit: NASA

Space Launch System Cryogenic
Propulsion. Image Credit: NASA

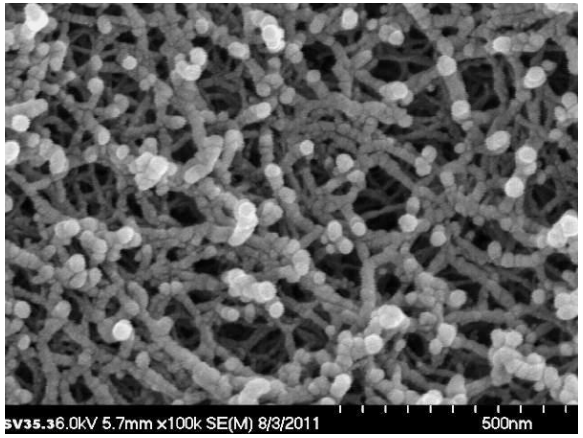
Cryogenic Insulation for Lunar Night Survivability
(50-100 K temp. range). Image Credit: NASA

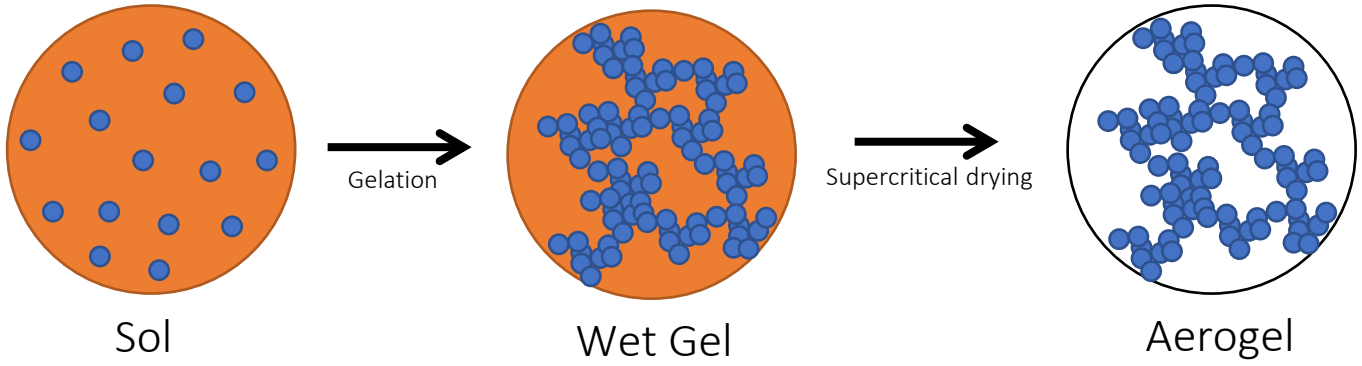
Blue Origin Lunar Lander Baselined Fuel
Cell Power as a primary power source

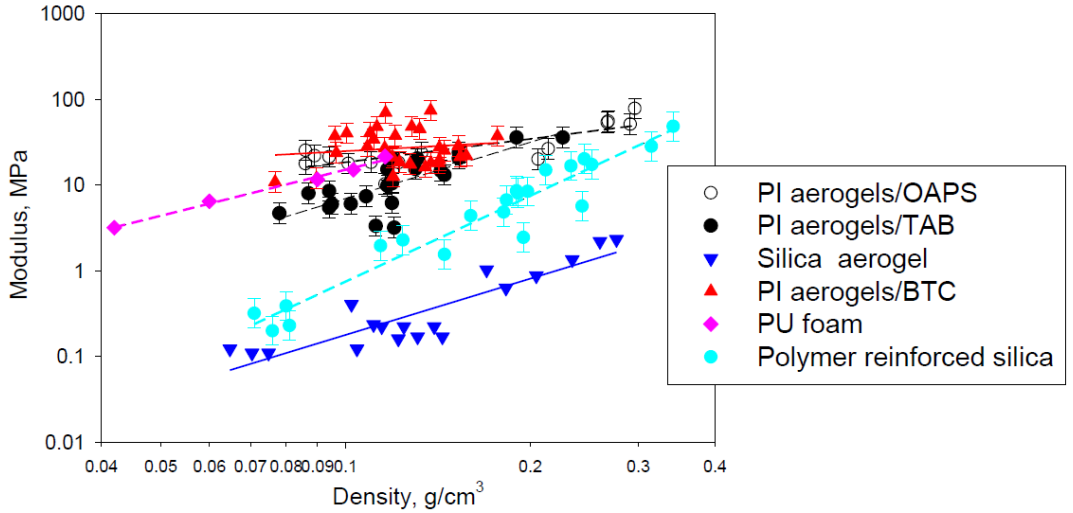
High-Performance Polyimide Aerogels at GRC

Typical properties

- High porosity (>85%)
- Pore size 10-40 nm
- High specific surface area
- Open-cell fibrillar architecture
- High thermal stability
- Tunable hydrophobicity
- Tunable mechanical properties
- Can be cast into flexible thin films

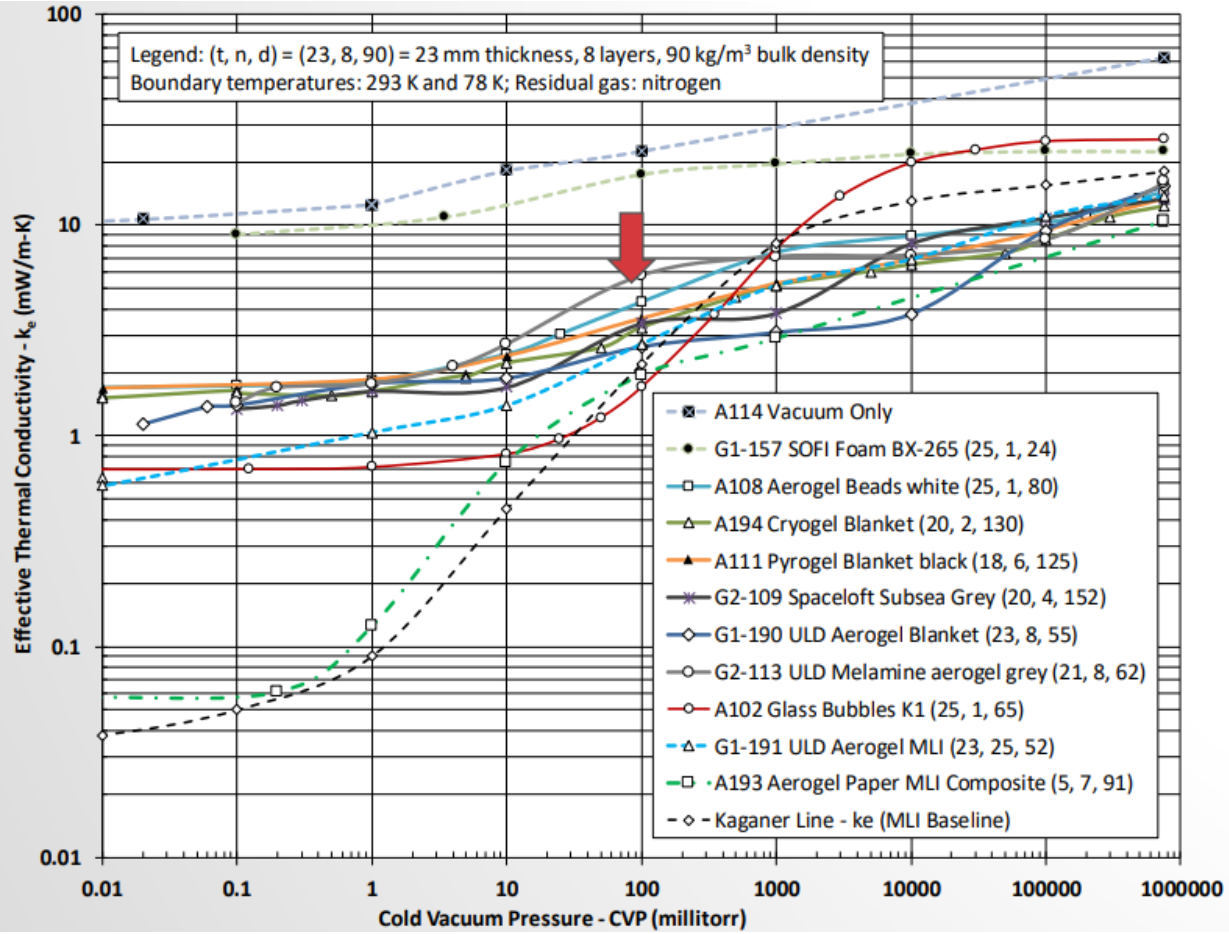






Limited Thermo-physical Data on Aerogels

Cryostat data for silica aerogel-based materials

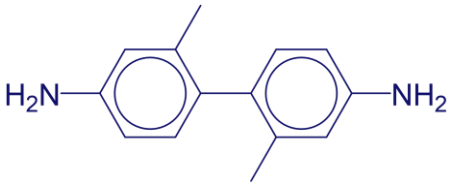


Credit: NASA KSC (J. Fesmire, NTRS 20180006720)

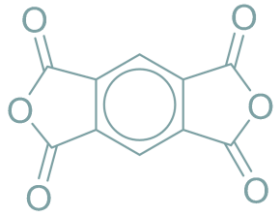
Silica aerogel with fiber matrix reinforcement: Aspen Aerogels, Inc.

Silica aerogel particles: P100, P200 and P300 by Cabot Corp.

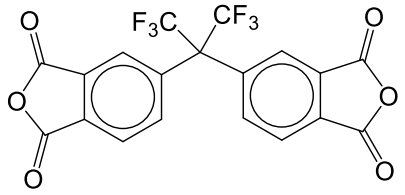
Molecular Engineering of Polyimide Aerogels



2,2'-Dimethyl-4,4'-diaminobiphenyl (DMBZ)

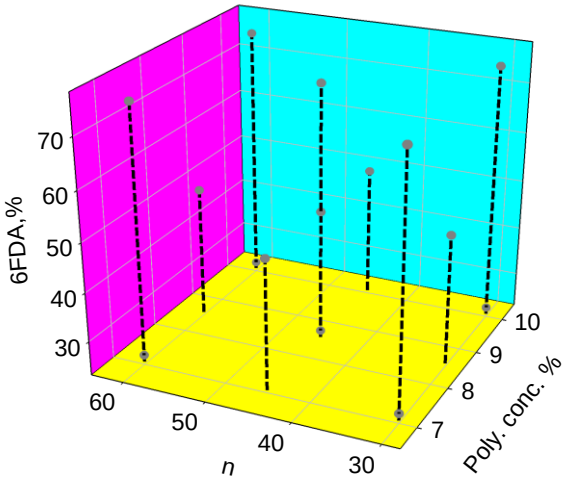


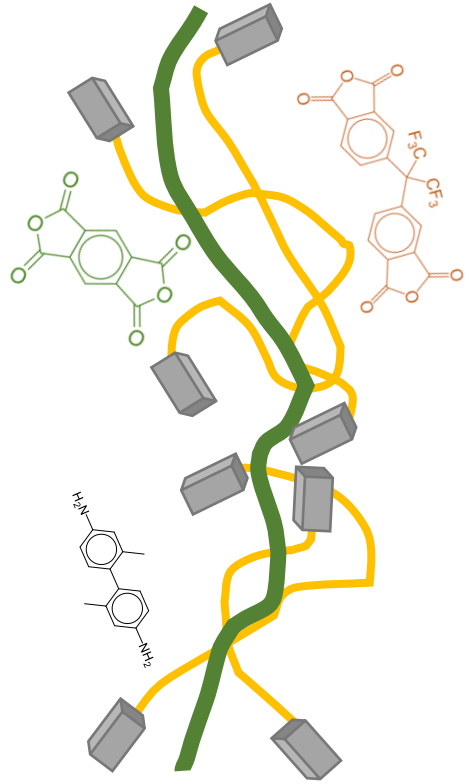
Pyromellitic dianhydride (PMDA)

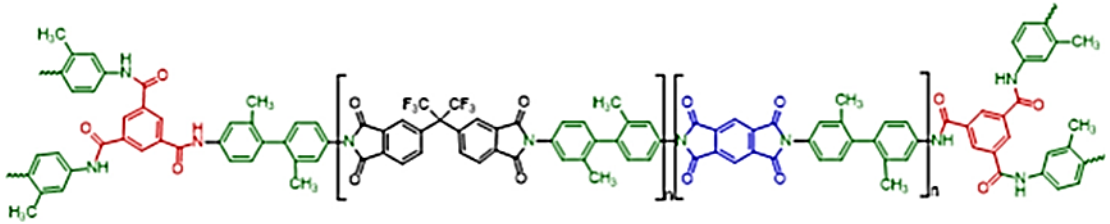


2,2'-Bis-(3,4-Dicarboxyphenyl) hexafluoropropane dianhydride (6FDA)

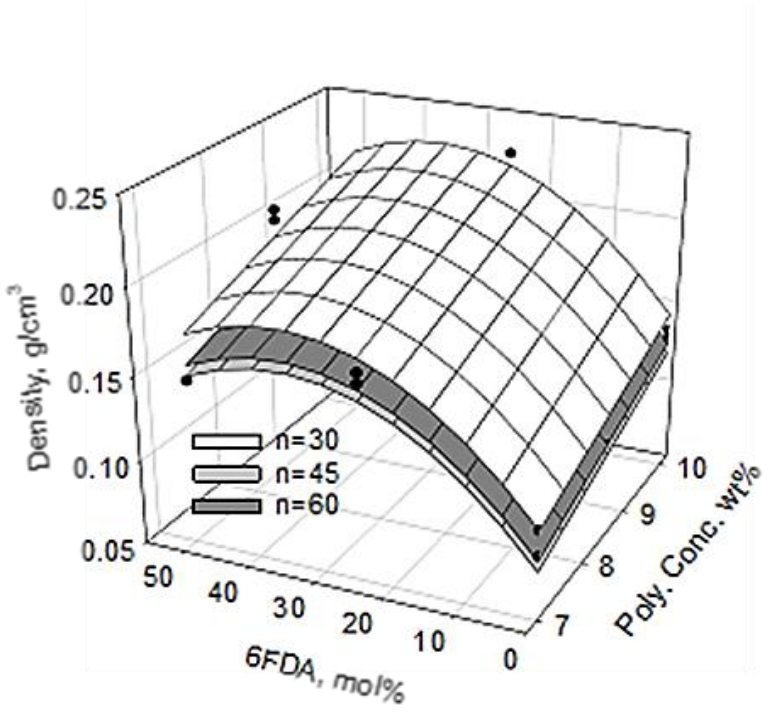
Run	Weight %	Chain length (n)	% 6FDA (remaining % PMDA)	Run	Weight %	Chain length (n)	% 6FDA (remaining % PMDA)
1	7	45	50	11	10	30	25
2	7	30	0	12	8.5	45	50
3	8.5	60	50	13	10	30	0
4	8.5	45	0	14	8.5	45	50
5	7	60	25	15	7	30	25
6	10	60	25	16	7	60	0
7	8.5	30	50	17	8.5	45	50
8	10	45	50	18	8.5	45	25
9	8.5	45	50	19	8.5	45	50
10	8.5	45	50	20	10	60	0

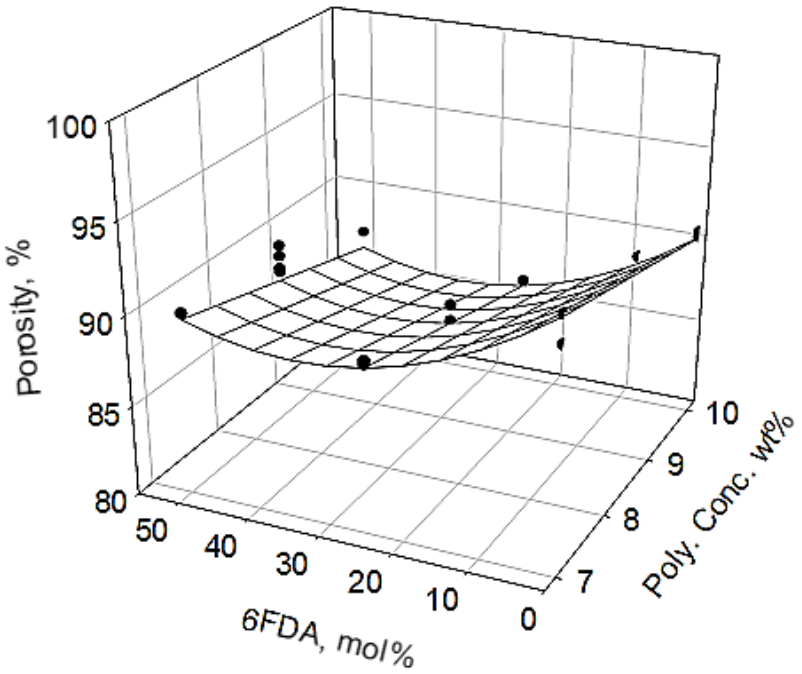


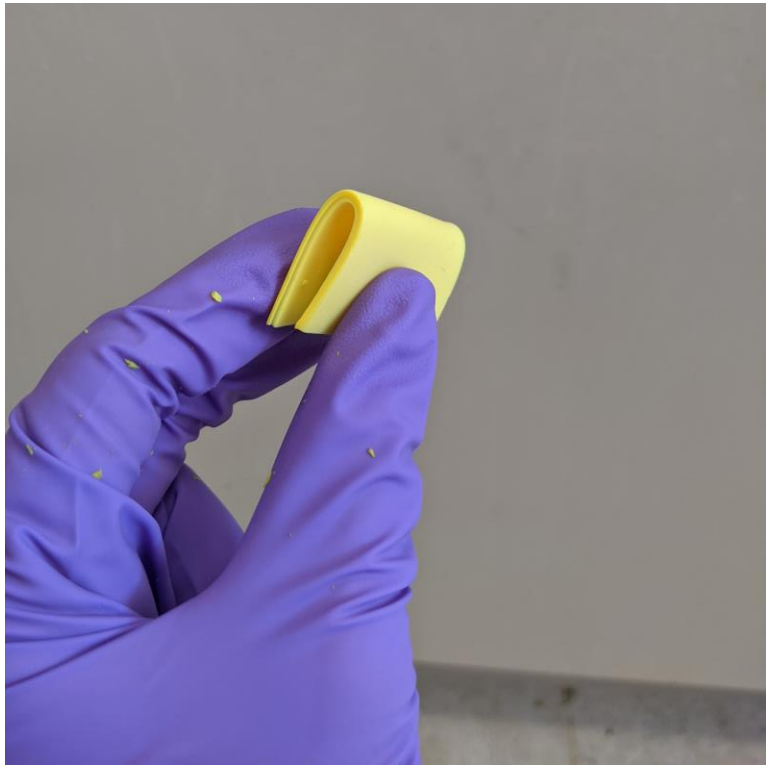




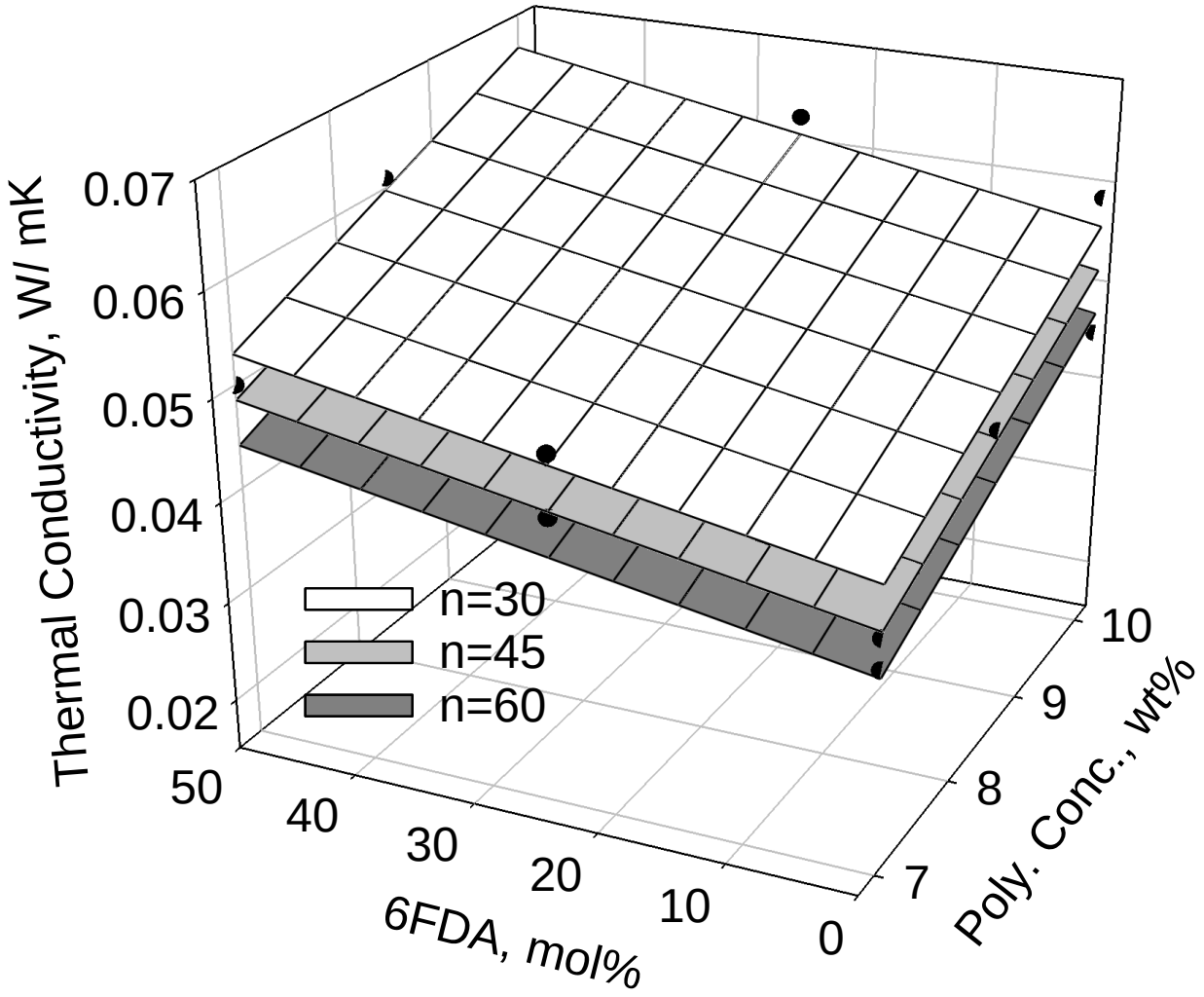
Molecular Engineering of Polyimide Aerogels







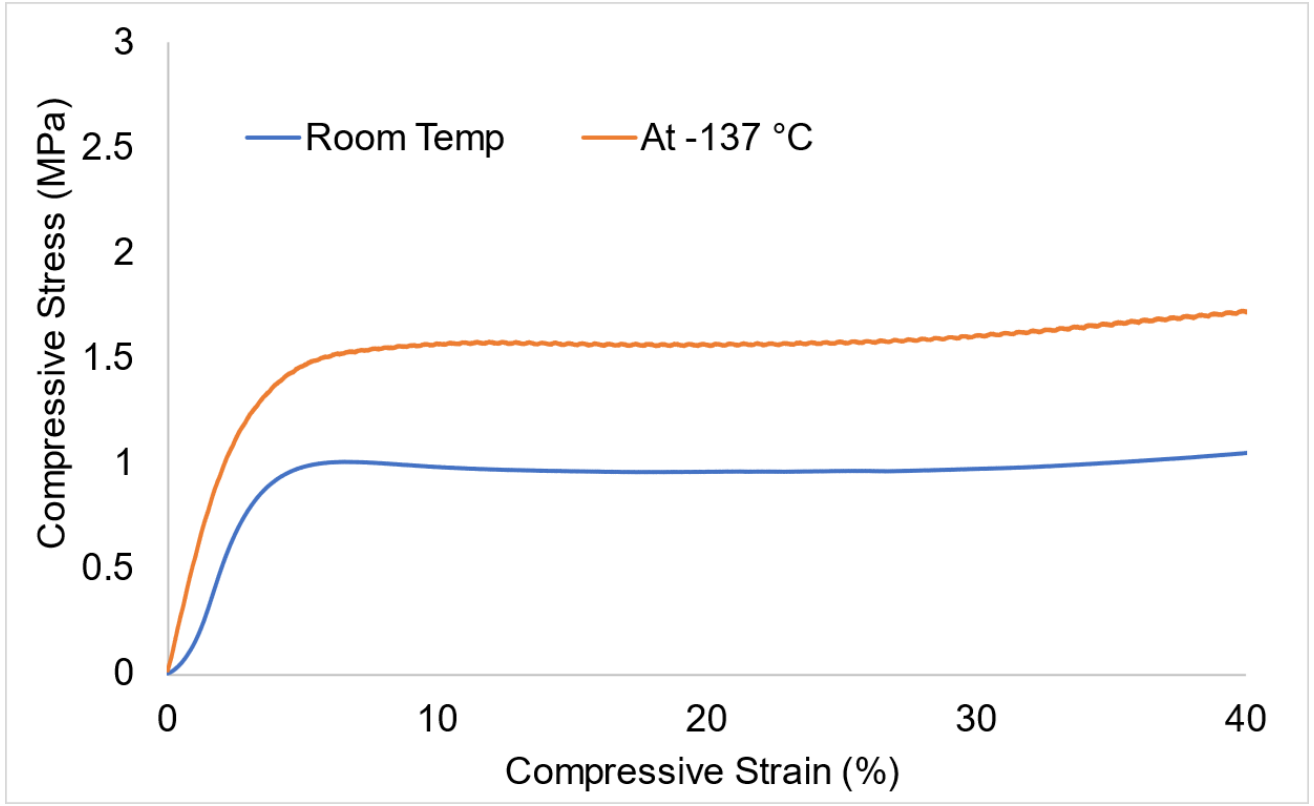
Thermal Conductivity Measurements at Room Temp



Modified Transient Plane Source (ASTM D7984-16)

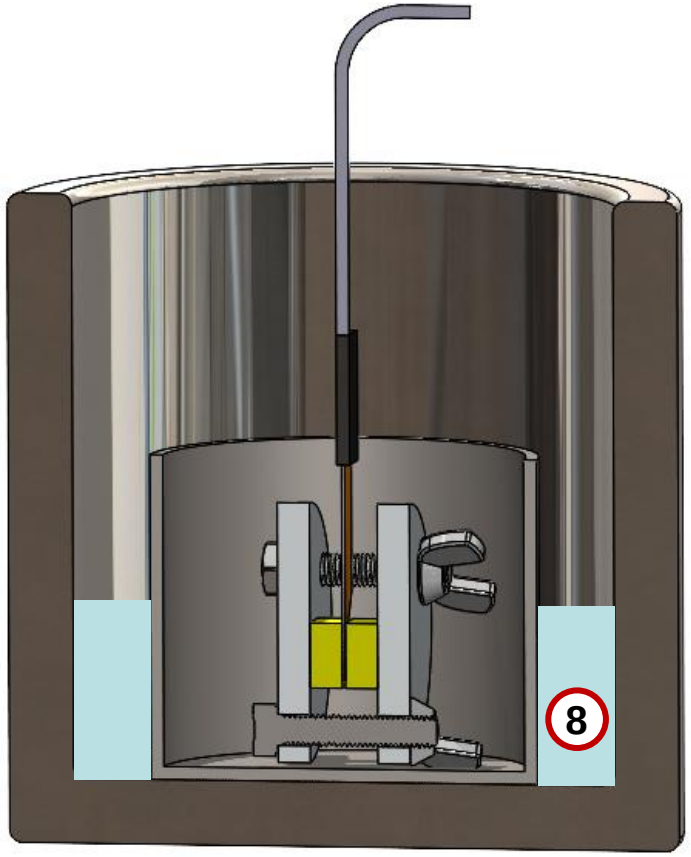
C-Therm Trident thermal conductivity instrument (C-Therm Technologies Ltd., Fredericton, Canada)

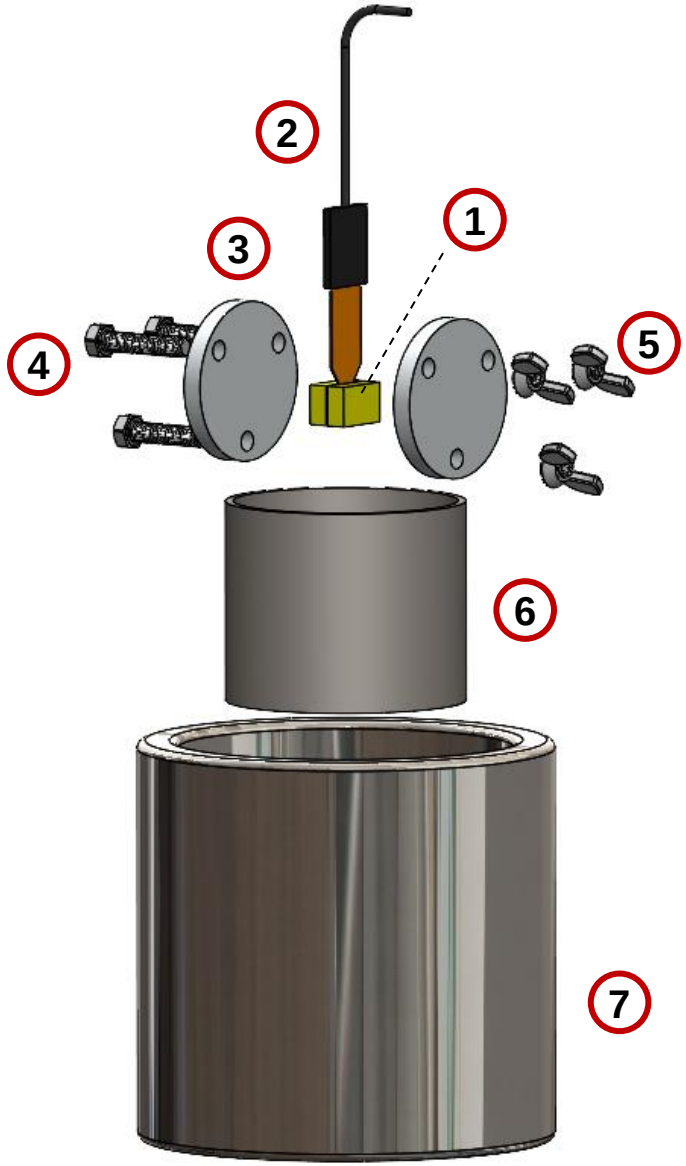
Compression Test at LN2 Temp



Cryogenic Quasi-static Compression Experiment at -137 °C

Thermal Conductivity Measurements at LN2 Temp

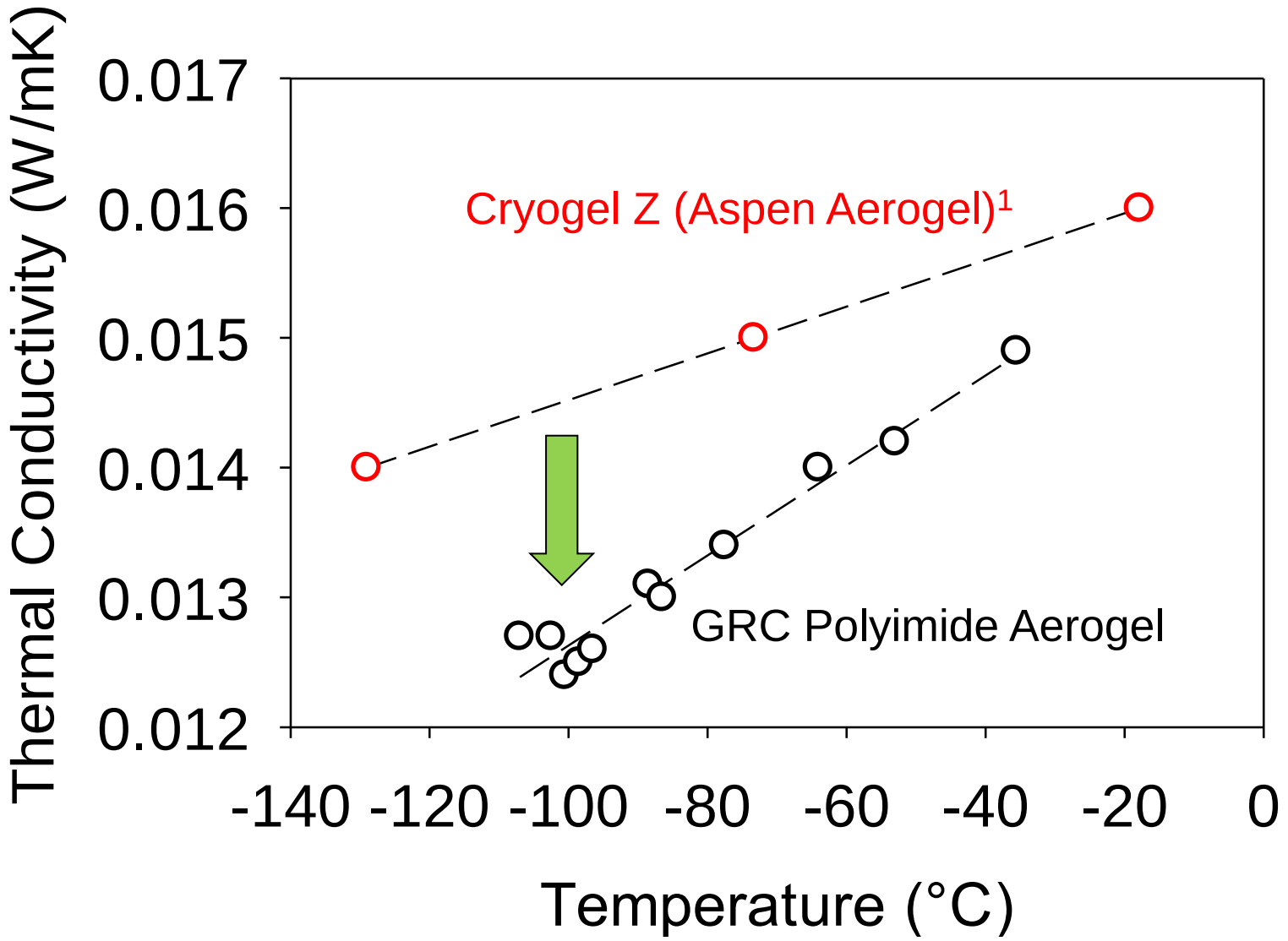




(1) Aerogel sample
(2) TPS sensor (C-Therm, 0.5 in OD)
(3) Aluminum sample holder
(4) Hex bolt
(5) Wing nut
(6) Aluminum cup
(7) Dewar
(8) Liquid nitrogen

Ref: Transient Plane Source Method (ISO 22007-2)

Thermal Conductivity Measurements at LN2 Temp



Transient Plane Source
(ISO 22007-2)

C-Therm Trident thermal conductivity instrument (C-Therm Technologies Ltd., Fredericton, Canada)

Cryogel Z (Aspen Aerogel)
- Thickness = 5 mm
- Density = 0.16 g/cm^3

GRC Polyimide Aerogel
- Thickness = 2.5 mm
- Density = 0.11 g/cm^3

Note: Thermal conductivity values in mW/mK at 200 K
- N_2: 0.0183
- Air: 0.0185

Ref: Lemmon et al., Int. J. Thermophys. 25, 21, 2004

[1]aerogel.com/cryogel

Acknowledgments

NASA GRC Aerogel Team

- Dr. Stephanie L. Vivod
- Dr. Haiquan Guo
- Dr. Michael Chauby
- Trevor Hagen (Intern)

NASA Glenn Research Center

- Dr. Vadim Lvovich
- Wesley Johnson
- Daniel Scheiman
- Linda McCorkle

NASA Aeronautics Research Mission Directorate (ARMD)