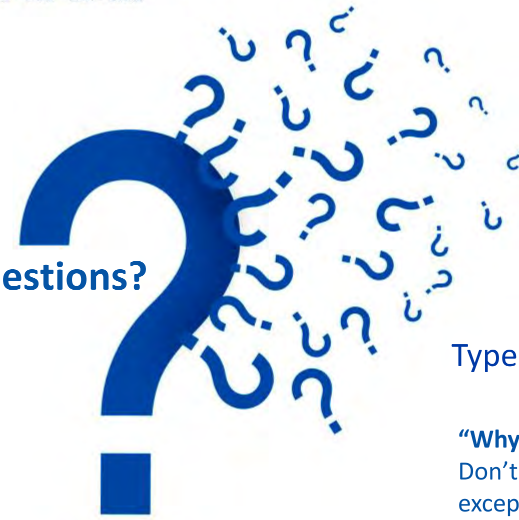
ACS Webinars
CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®



Have Questions?

Type them into questions box!

"Why am I muted?"
Don't worry. Everyone is muted except the presenter and host. Thank you and enjoy the show.

ACS Webinars
CLICK • WATCH • LEARN • DISCUSS

@AmericanChemicalSociety

@AmerChemSociety

@AmerChemSociety

https://www.linkedin.com/company/american-chemical-society

Check out the ACS Webinar Library!

An ACS member exclusive benefit

ACS Chemistry for Life®

Hundreds of presentations from the best and brightest minds that chemistry has to offer are available to you on-demand. The Library is divided into 6 different sections to help you more easily find what you are searching.

Professional Development

▶ View the Collection

Learn how to write better abstracts, deliver more engaging presentations, and network to your next dream job. Brush up on your soft skills and set a new career path by mastering what can not be taught in the lab.

Technology & Innovation

▶ View the Collection

From renewable fuels to creating the materials for the technology of tomorrow, chemistry plays a pivotal role in advancing our world. Meet the chemists that are building a better world and see how their science is making it happen.

Drug Design and Delivery

▶ View the Collection

The Drug Design Delivery Series has built a collection of the top minds in the field to explain the mechanics of drug discovery. Discover the latest research, receive an overview on different fields of study, and gain insight on how to possibly overcome your own med chem roadblocks.

Culinary Chemistry

▶ View the Collection

Why does food taste better when it is grilled or what molecular compounds make a great wine? Discover the delectable science of your favorite food and drink and don't forget to come back for a second helping.

Popular Chemistry

▶ View the Collection

Feeling burdened by all that molecular weight? Listen to experts expound on the amazing side of current hot science topics. Discover the chemistry of rockets, how viruses have affected human history, or the molecular breakdown of a hangover.

Business & Entrepreneurship

▶ View the Collection

How do ideas make it from the lab to the real world? Discover the ins and outs of the chemical industry whether you are looking to start a business or desire a priceless industry-wide perspective.

https://www.acs.org/content/acs/en/acs-webinars/videos.html

3

Learn from the best and brightest minds in chemistry! Hundreds of webinars on diverse topics presented by experts in the chemical sciences and enterprise.

Edited Recordings are an exclusive ACS member benefit and are made available once the recording has been edited and posted.

Live Broadcasts of ACS Webinars® continue to be available to the general public several times a week generally from 2-3pm ET!

A **collection of the best recordings** from the ACS Webinars Library will occasionally be rebroadcast to highlight the value of the content.

www.acs.org/acswebinars

4

Advance YOUR CAREER

ChemIDP™

ChemIDP.org

Discover ACS PUBLICATIONS

Publishing Resources

ACS Reviewer Lab
ACS axial
ACS Author University
ACS Authoring Services

publish.acs.org

Connect WITH CHEMISTS AND OTHER SCIENCE PROFESSIONALS

CAS SciFinder Future Leaders

171 alumni, 35 countries and over 120 institutions

acsoncampus.acs.org/resources

ACS Chemistry for Life® | CAS A Division of the American Chemical Society | ACS Publications Most Trusted. Most Cited. Most Read. | ACS ON CAMPUS

5

From ACS Industry Member Programs

- **Industry Matters Newsletter**

  ACS Member-only weekly newsletter with exclusive interviews with industry leaders and insights to advance your career.

  Preview & Subscribe: acs.org/indnews

- in | ACS Innovation Hub

  Connect, collaborate, and stay informed about the trends leading chemical innovation

  Join: bit.ly/ACSinnovationhub

ACS Career Navigator: Your Home for Career Services

ACS Chemistry for Life®

Whether you are just starting your journey, transitioning jobs, or looking to brush up or learn new skills, the **ACS Career Navigator** has the resources to point you in the right direction.

We have a collection of career resources to support you during this global pandemic:

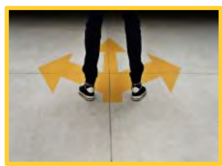
Professional Education

Virtual Career Consultants

ACS Leadership Development System

Career Navigator LIVE!

ChemIDP



College to Career

ACS Webinars

Virtual Classrooms

Visit www.ACS.org/COVID19-Network to learn more!

7

Join us in our efforts to increase the diversity of chemistry.

Valued donors like you have sustained ACS educational programs that are welcoming students from diverse backgrounds into our profession.

www.acs.org/donate

ACS Office of Philanthropy
Chemistry for Life®

8

A Career Planning Tool For Chemical Scientists

ACS Chemistry for Life®

ChemIDP is an Individual Development Plan designed specifically for graduate students and postdoctoral scholars in the chemical sciences. Through immersive, self-paced activities, users explore potential careers, determine specific skills needed for success, and develop plans to achieve professional goals. **ChemIDP** tracks user progress and input, providing tips and strategies to complete goals and guide career exploration.

https://chemidp.acs.org

9

ACS Department of Diversity Programs

Advancing ACS's Core Value of Diversity, Inclusion & Respect

ACS Chemistry for Life®

We believe in the strength of diversity in all its forms, because inclusion of and respect for diverse people, experiences, and ideas lead to superior solutions to world challenges and advances chemistry as a global, multidisciplinary science.

Contact Us:
https://app.suggestionox.com/r/DI_R
Diversity@acs.org

@ACSDiversity

ACS Diversity

ACS Voices Diversity Podcast

acsvoices.podbean.com/

www.acs.org/diversity

10

ACS Webinars
CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

Date: Thursday, November 18, 2021 @ 2-3:15pm ET
Speaker: Elizabeth Tomasino, Oregon State University
Moderator: Brian Guthrie, Cargill

Register for Free!

What You Will Learn:

- What are the compounds associated in smoke and smoke taint in wine
- How smoke taint compounds end up in wine
- How individuals perceive the aroma and flavor of smoke

Co-produced with: ACS Division of Agricultural & Food Chemistry

Fecha: Miércoles, 1 de Diciembre, 2021 @ 2-3pm ET
Ponente: Josep Cornella, Max-Planck-Institut für Kohlenforschung
Moderadora: Ingrid Montes, Recinto de Río Piedras y American Chemical Society

Registrarse Gratuitamente

Lo Que El Público Aprenderá:

- El desarrollo de nuevos reactivos orgánicos que permitan una química orgánica práctica y fácil mediante la agilización de las rutas sintéticas
- El diseño de ligandos que convierten los metales de transición sensibles al aire en complejos robustos con una estabilidad notable frente a la oxidación y la temperatura
- El diseño de elementos p-block, en particular bismuto (Bi), con el objetivo de diseñar nuevos procesos catalíticos redox similares a los metales de transición

Co-producido con: Sociedad Química de México y Chemical & Engineering News

Date: Thursday, December 2, 2021 @ 2-3pm ET
Speakers: Javier García Martínez, IUPAC and Rive Technology / Laura-Isobel McCall, University of Oklahoma / Diego Solis-Ibarra, Universidad Nacional Autónoma de México / Corinna Schindler, University of Michigan
Moderators: Jessica Marshall and Mitch Jacoby, Chemical & Engineering News

Register for Free!

What You Will Learn:

- What were the hottest trends in chemistry research during 2021, according to the experts
- What areas of chemical research do experts think will make the news in 2022
- What molecules caught C&EN editors' attention this year

Co-produced with: Chemical & Engineering News

www.acs.org/acswebinars

11

ACS POLY

ACS Technical Division
Polymer Chemistry (POLY)

UPCOMING EVENTS

Controlled Polymer Radicalization 2021
November 14, 2021 – November 17, 2021
Charleston, SC USA
https://www.polyacs.net/crp2021

POLY Fellows Award
November 30, 2021
https://polyacs.org/poly-fellows

Silicon-Containing Polymers and Composites 2021
December 1, 2021 – December 4, 2021
San Diego, CA USA
https://www.polyacs.net/2018siliconc

MEMBER BENEFITS:

Join the POLY Discussion List
to get informed on job postings, events, workshops, and information exclusive to POLY division members.

We Gladly Thank Our Sponsors!

www.polyacs.org

12

ACS Chemistry for Life®

Co-produced with: POLY | ACS Division of Polymer Chemistry

New Polymers in Space

Long-Term Exploration Beyond Our Planet

FREE Webinar | TODAY at 2pm ET

ACS Webinars CLICK • WATCH • LEARN • DISCUSS

THIS ACS WEBINAR WILL BEGIN SHORTLY...

ACS Webinars CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

New Polymers in Space: Long-term Exploration Beyond Our Planet

Stephanie L. Vivod
Chemical Engineer, Aerospace Polymeric Materials, NASA John H. Glenn Research Center

CHRISTOPHER J. WOHL
Assistant Branch Head and Senior Research Surface Scientist, NASA Langley Research Center

SADEQ MALAKOOTI
Postdoctoral Program Fellow, NASA John H. Glenn Research Center

Presentation slides are available now! The edited recording will be made available as soon as possible.

www.acs.org/acswebinars

This ACS Webinar is co-produced with ACS Division of Polymer Chemistry.

National Aeronautics and Space Administration

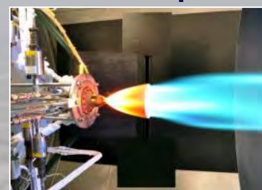
Polymer Aerogels for Lunar Applications and Beyond

Dr. Stephanie Vivod
NASA Glenn Research Center
Cleveland, OH

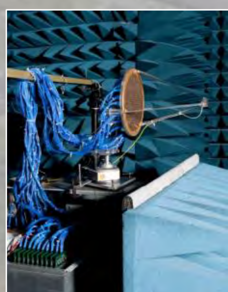
National Aeronautics and Space Administration

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

www.nasa.gov

National Aeronautics and Space Administration

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

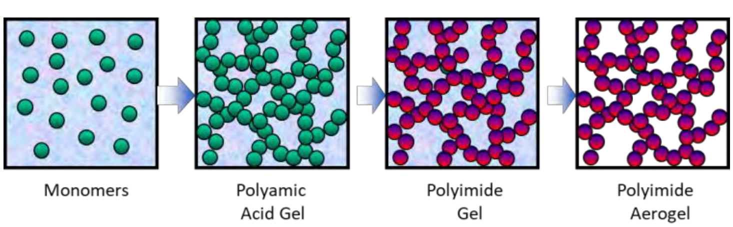
www.nasa.gov 18

Issues and Concerns with Spaceflight and Planetary Exploration

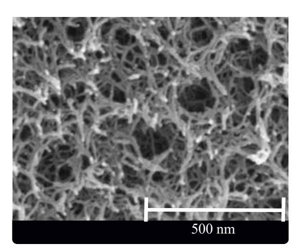
- Orbital debris
- Radiation
- Lunar dust
- Payload weight reduction
- In-situ resource utilization (ISRU)
- Crew health and safety

The Wonderful World of Polymer Aerogels!

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



Polyimide Aerogels made using sol-gel synthesis and supercritical fluid extraction



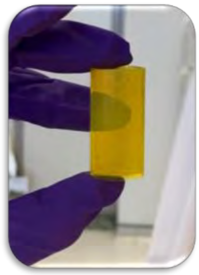
Scanning Electron Micrograph of polymer aerogel matrix

National Aeronautics and Space Administration

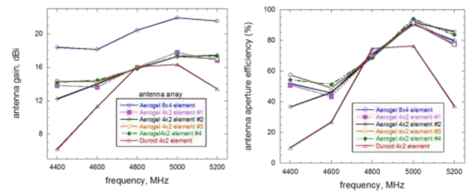
Polymer Aerogel Properties

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)
- Large surface areas (400 – 850 m^2/g)
- Low density (0.05-0.2 g/cm^3)
- Low thermal conductivity (~20mW/m·K)
- Low dielectric (1.1)
- Low refractive index (1.02-1.09)



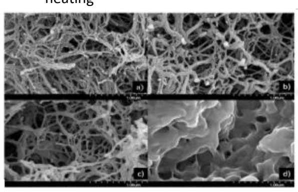
polymer aerogel cylinder (1g)



Low dielectric-Improved gain and efficiency over SOA Duroid antenna substrates

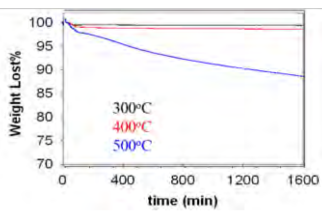
Before heating

After 300 °C

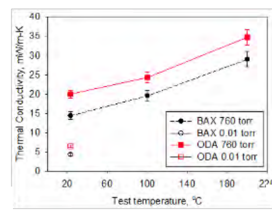


After 400 °C

After 500 °C



Polyimide aerogels-high onset of decomposition (>550° C)



Low thermal conductivity

www.nasa.gov

First Audience Question

When were aerogels first discovered?

- 861 AD
- 1868
- 1931
- 1969

Image credit: NASA

22

National Aeronautics and Space Administration

When were aerogels first discovered?

1. 861 AD- Vikings discover Iceland
2. 1868- Discovery of DNA
3. 1931- First Aerogel made by Samuel Kistler
4. 1969- First man on the moon

National Aeronautics and Space Administration

Aerogel Timeline

SS Kistler
Chemistry professor for College of the Pacific (Stockton, CA)

1930s
First discovery of aerogels, first use of SFE for aerogels

1970s
Resurgence of aerogel work- oxygen and rocket fuel storage

1980s
Use of supercritical CO_2 fluid extraction- increased safety and efficiency

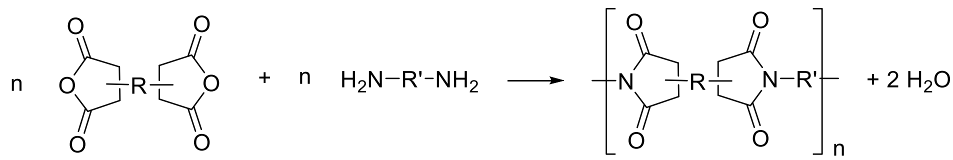
1990s
NASA Space Missions use aerogel-Mars Rover battery and Stardust Mission

2000s
Polymer reinforced silica: x-aerogels, flexible aerogel blankets

2010s
Flexible thin film polyimide, mechanically robust

Current/ Future
3D printed polymer aerogels, Drug delivery, Sensors, Chemical Spills, filtration, tissue engineering, Shape memory

Why Polyimide Aerogels?



dianhydride diamine polyimide repeat unit

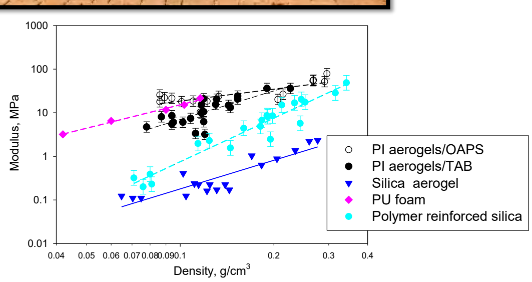
Polyimides

- DuPont-high temperature engineering polymers
- High glass transition (T_g) temp
- Thermal stability (>500 °C)
- Mechanical strength –toughness, flexibility, high tensile strength
- Chemical resistance
- Transparency
- Electrically insulating

Aerogels

- Low density
- High porosity
- High surface area
- Low thermal conductivity

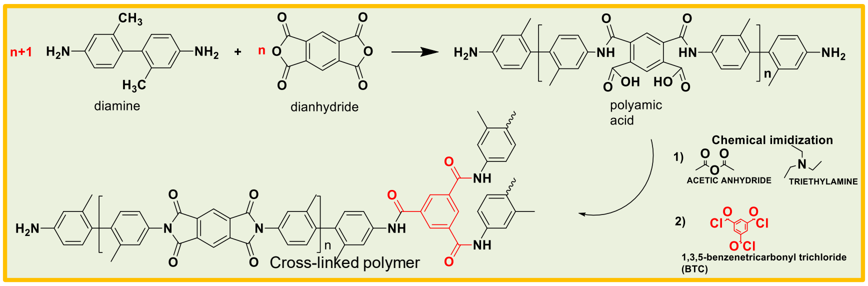
Mechanically Robust Polyimide Aerogels



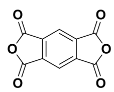
Can be formed into moldable shapes and thin films with excellent mechanical properties and flexibility

H. Guo, et al *ACS Appl. Mater. Interfaces*, **2011**, 546–552

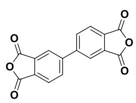
Polyimide Synthesis Mechanism and Monomers



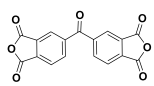
Dianhydrides



Pyromellitic dianhydride (PMDA)

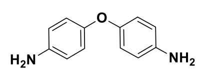


3,3',4,4'-biphenyltetracarboxylic dianhydride (BPDA)

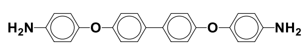


Benzophenone-3,3',4,4'-tetracarboxylic dianhydride (BTDA)

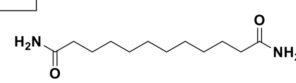
Diamines



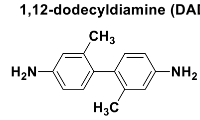
4,4'-oxydianiline (ODA)



4,4'-Bis (4-aminophenoxy) biphenyl (BAPB)

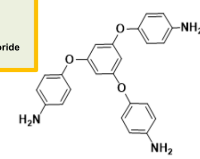


1,12-dodecyldiamine (DADD)

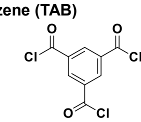


2,2"-dimethylbenzidene (DMBZ)

Cross-linkers



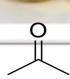
Tris-1,3,5-aminophenoxy benzene (TAB)



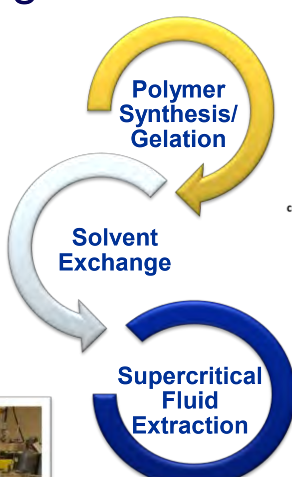
1,3,5-benzenetricarbonyl trichloride (BTC)

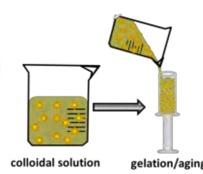
National Aeronautics and Space Administration

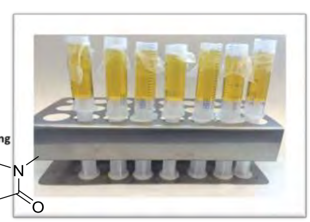
Aerogel Fabrication Process

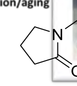


acetone

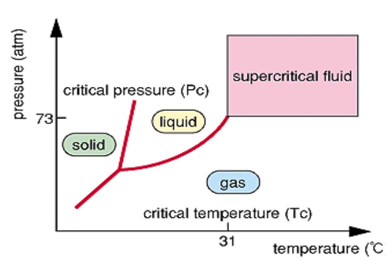








n-methylpyrrolidone (NMP)



www.nasa.gov 28

Second Audience Question

What is a potential application for aerogels?
(Select all that apply)

- Radiation mitigation/filtration
- Thermal/Acoustic Impedance
- Greenhouse gas capture
- Artistic medium


Image credit: NASA

29

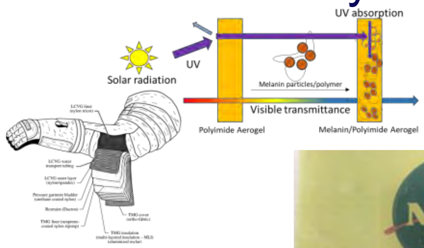
National Aeronautics and Space Administration

What is a potential application for aerogels?
Choose all that apply

1. Radiation mitigation/filtration
2. Thermal/Acoustic Impedance
3. Greenhouse gas capture
4. Artistic medium

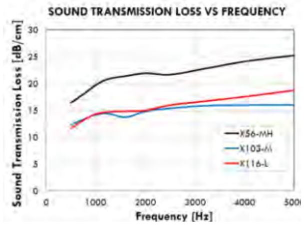
www.nasa.gov 30

Polyimide Aerogel Development

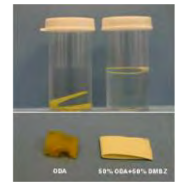


Radiation mitigation

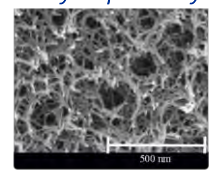
Tunable Transparency



Acoustic impedance

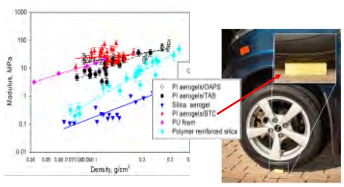


Tailored Hydrophobicity

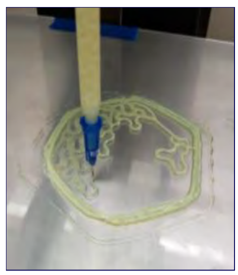


Tunable pore structure

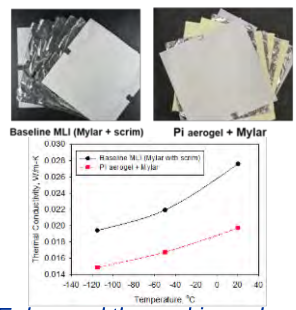
Orbital debris containment



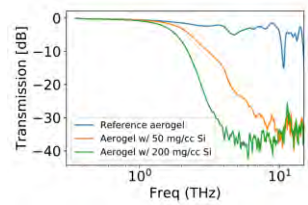
Improved mechanical properties



3D printing

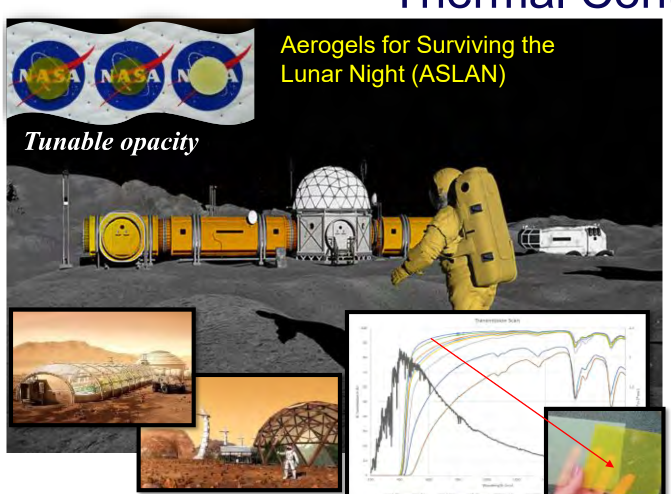


Enhanced thermal impedance



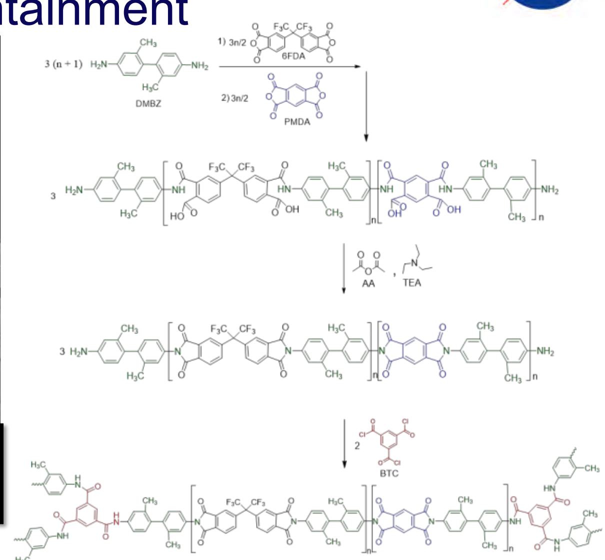
IR filtration

Polymer Aerogels for Passive Thermal Containment



PTC for habitats, greenhouses, terraforming

Higher transmissivity and optical clarity with fluorinated monomer

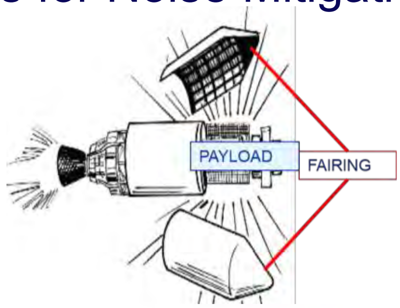


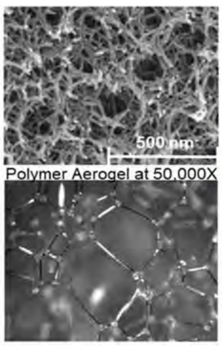
Vivod, et al. ACS Appl. Mater. Interfaces 2020 (7) 8622-8633

National Aeronautics and Space Administration

Advanced Acoustic Materials for Noise Mitigation

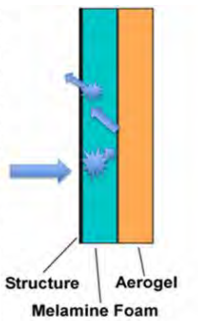
- Vibro-acoustic loads pose threat to payload launch survivability
- Aerogels will add damping to the structure, which reduces the amplitude of the vibration and noise transmission in addition to weight reduction



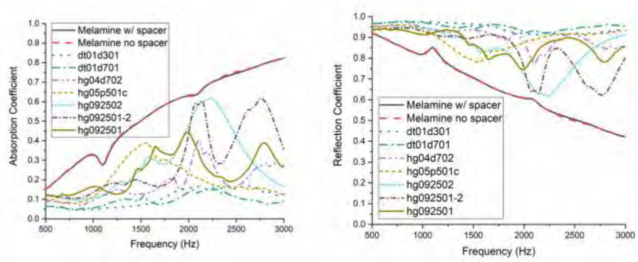


Polymer Aerogel at 50,000X

Melamine Foam at 80X

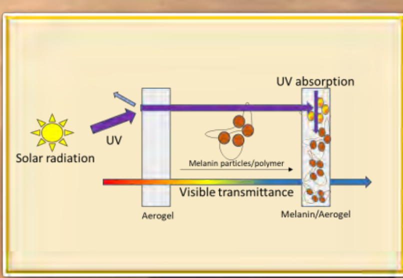


Absorbing material with aerogel as reflective backing



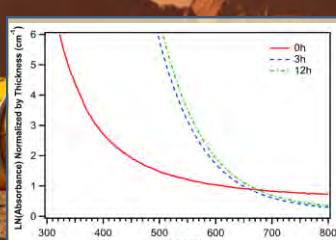
Absorption/Reflection coefficient of polyimide aerogels vs melamine foam

Melanized Aerogel for Radiation Mitigation

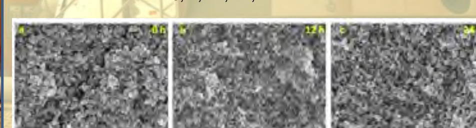


Melanized aerogels exhibit higher absorption over native aerogel with little to no effect on surface area, density, shrinkage, and porosity

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



Representative UV-vis spectra for PDA-coated aerogels at t=0, 3,12



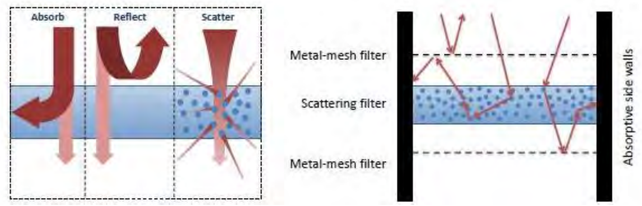
SEM images of the surface morphology of native aerogel (a) and PDA coated aerogel at t=12 h (b) and t=24 h (c)

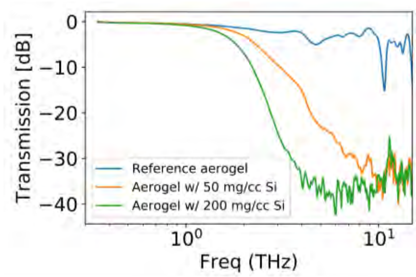
G.Rey, et al. ACS Appl. Mater. Interfaces 2021 13 (34), 41084-41093

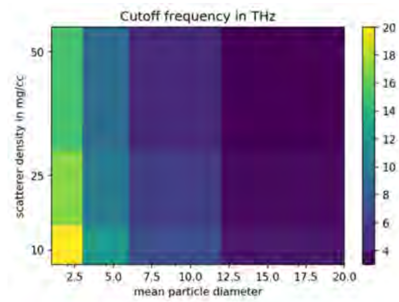
National Aeronautics and Space Administration

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. **2020**, (59) 5439-5446

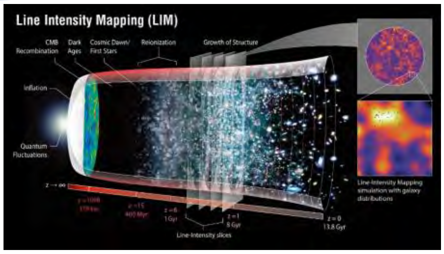
www.nasa.gov 35

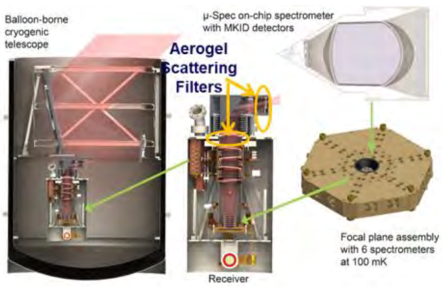
National Aeronautics and Space Administration

Aerogel IR Filter

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



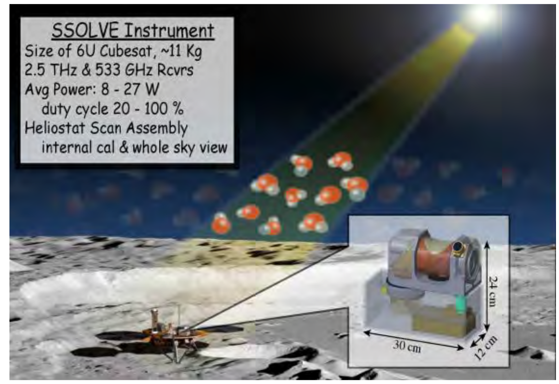


Aerogel scattering filters are the baseline infrared-blocking filter for EXCLAIM

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



- 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 H_2O, OH, and HDO in the lunar atmosphere

PI: Tim Levingood (GSFC)

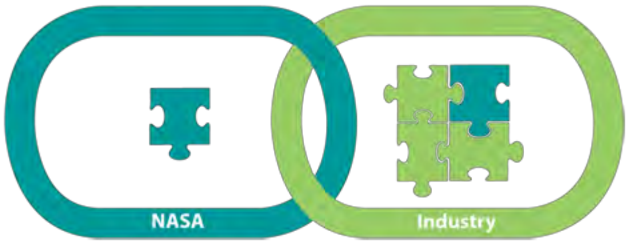
www.nasa.gov 37

Aerogel applications with Industry, Academia, and OGA's

- **Aerogel Technologies, LLC:** Holds the highest number of licenses for NASA aerogel technology
- **UT Dallas:** Auxetic Shape Memory Aerogels
- **Scintilex,LLC/DoE:** Highly transparent aerogel -high energy particle detection
- **Aspen Aerogel-SBIR with NASA**: 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."

National Aeronautics and Space Administration

Glenn Research Center | NASA TECHNOLOGY TRANSFER PROGRAM



Leverage the outstanding capabilities and accomplishments of NASA's Glenn Research Center for the benefit of both NASA and U.S. taxpayers

COLLABORATIVE EFFORTS TO UTILIZE NASA TECHNOLOGY

- Licensing- NASA's patent portfolio
- Innovative Research Grants
- Cooperative Agreement
- Interagency Transfer

https://technology.grc.nasa.gov

www.nasa.gov

National Aeronautics and Space Administration

A Universe of NASA Opportunities

NASASTEM Engagement

https://intern.nasa.gov/

www.nasa.gov

National Aeronautics and Space Administration

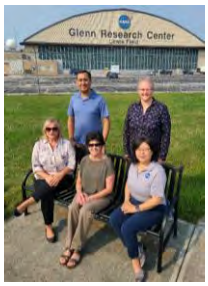
Acknowledgments

–Anne McNelis, Lucas Shearer, Dr. Chris Johnston, Dr. Maria Kuzmarski, Dr. Tom Essinger- Hileman, Dr. Berhanu Bulcha, Dr. Theresa Benyo (NASA)

–Linda McCorkle, Dan Scheiman Frank Bremenour, Spyro Efpraxias (NASA)

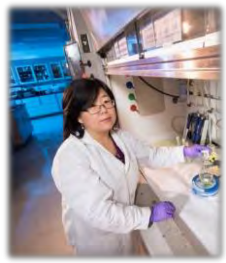
–Dr. Ali Dhinojwala, Gabrielle Rey, Saranshu Singla (University of Akron)

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



Dr. Stephanie Vivod

Dr. Sadeq Malakooti



Dr. Haiquan Guo

Ariel Tokarz

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

www.nasa.gov 41

Polymeric Materials for a Sustained Lunar Presence: Reusable Materials and Lunar Dust Mitigation

Christopher J. Wohl

NASA Langley Research Center, Hampton, VA 23681, USA

ACS Webinars Series
November 17, 2021

42

We are Going back to the Moon … to Stay

Image credit: NASA, "Forward to the Moon: NASA's Strategic Plan for Human Exploration," 4 Sept. 2019.

Third Audience Question

What is the biggest challenge to overcome for long-duration manned lunar surface missions?

- A. Launch vehicle mass and volume restrictions
- B. Construction of infrastructure, power generation, communications, logistics
- C. Dealing with the extreme environment, i.e., UV-VUV, radiation, micrometeoroids, lunar dust
- D. I am lactose intolerant … and the Moon is made of cheese

Image credit: NASA

To Discuss Today:

Long duration exploration missions will require multifunctional materials to increase the period between resupply missions and systems that remain operational in extreme extra-terrestrial environments.

- ❖Project ESPUR: Enabling Sustained Presence Using Recyclables
- ❖Lunar Dust Adhesion Mitigation
  - ❖Passive adhesion mitigation materials technologies
    - ❖Polymeric materials

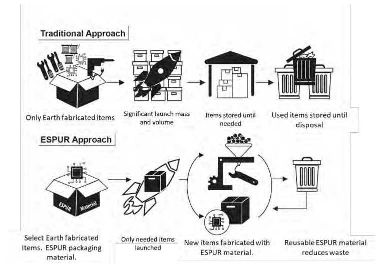



Image credit: NASA

To Discuss Today:

Long duration exploration missions will require multifunctional materials to increase the period between resupply missions and systems that remain operational in extreme extra-terrestrial environments.

- ❖Project ESPUR: Enabling Sustained Presence Using Recyclables
- ❖Lunar Dust Adhesion Mitigation
  - ❖Passive adhesion mitigation materials technologies
    - ❖Polymeric materials

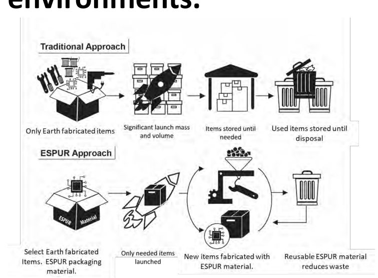



Image credit: NASA

ESPUR Acknowledgements

❖**The Team**

- ❖NASA Langley: Bryce Horvath (Co-I), Interns (lots of them)
- ❖National Institute of Aerospace: Miranda Beaudry
- ❖William & Mary: Prof. Hannes Schniepp, Samantha Applin

❖**NASA Ames Research Center**

- ❖Lauren Abbott

❖**NASA Marshall Space Flight Center**

- ❖Alexander Blanchard, Michael Fisk

Image credit: NASA

47

Reusable Materials for Space Exploration

In-space manufacturing will be critical to enable increased mission endurance and future mission independence from Earth.

❖The Problem: Mission resupply becomes increasingly difficult as we reach further from Earth

- ❖Extended timeline from recognition of need to site arrival
- ❖Risk mitigation is inhibited by launch mass limitations

❖The Need:

- ❖In-space manufacturing capability amenable to a broad array of applications

Quantitative Impact: development of recyclable/reusable material will enable launch mass savings, longer mission duration, and greater mission Earth-independence

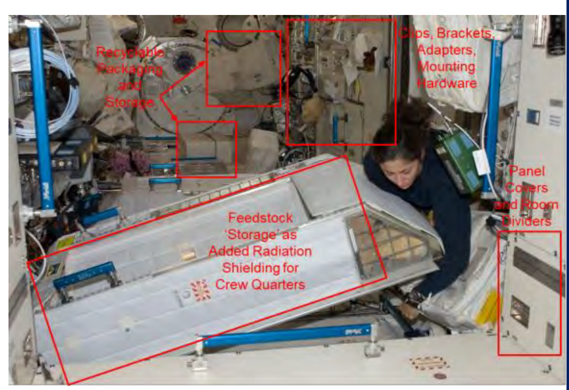


Image credit: NASA

48

Challenge

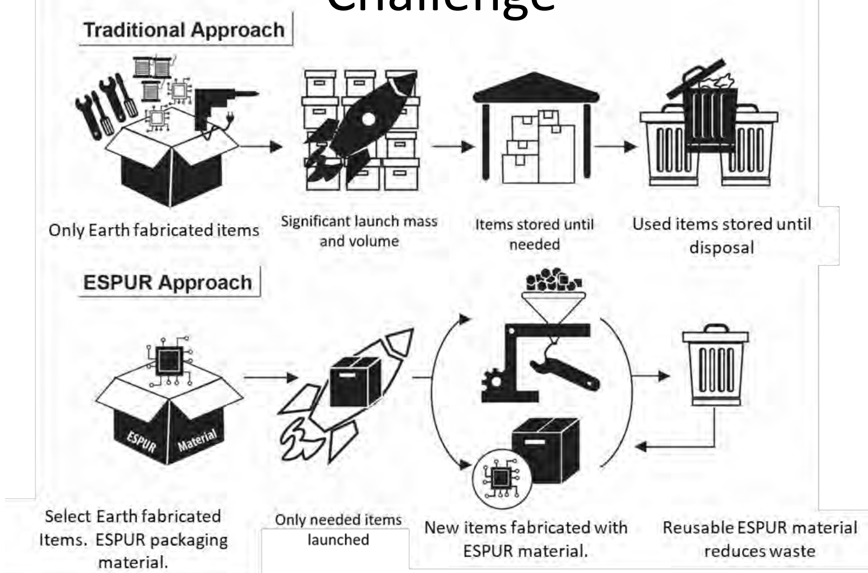
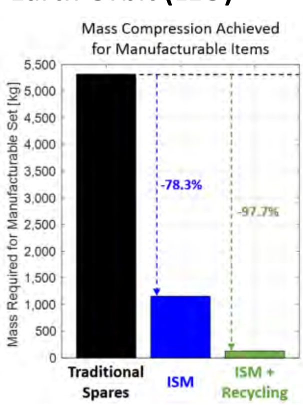


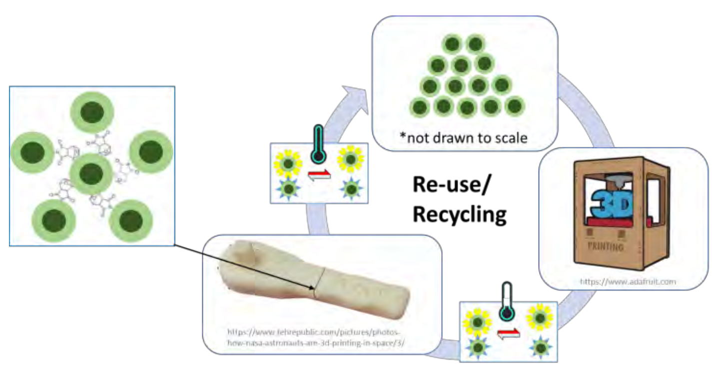
Image credit: NASA 49

The ESPUR Concept

Enable Sustained Presence Beyond Low Earth Orbit (LEO)

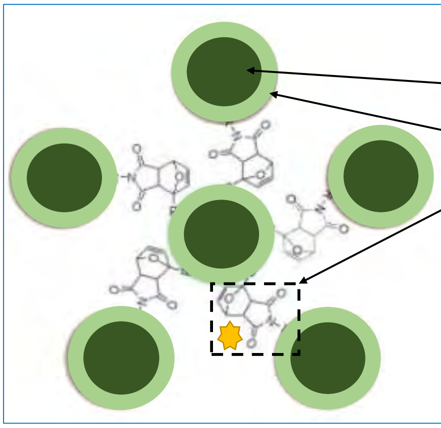


Via Recyclable Feedstocks



Andrew Owens and Olivier De Weck. "Systems Analysis of In-Space Manufacturing Applications for the International Space Station and the Evolvable Mars Campaign", AIAA SPACE 2016, AIAA SPACE Forum, (AIAA 2016-5394)

Components of ESPUR Material



Key

Epoxy Microparticle

Copoly(carbonate-urethane) polymer coating

Diels Alder Functionalities

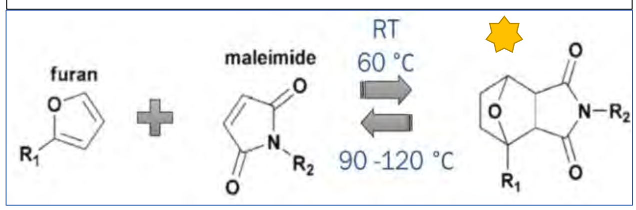
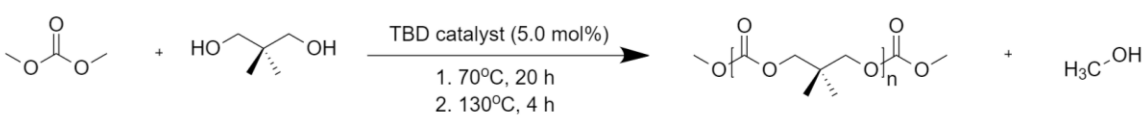


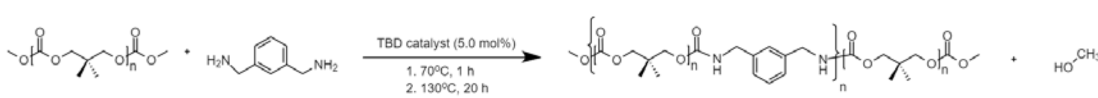
Image credit: NASA

Condensation Polymerization: Copoly(carbonate urethane), **CPCU**

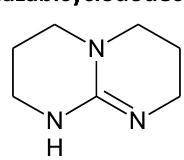
A



B



1,5,7-triazabicyclododecene, TBD

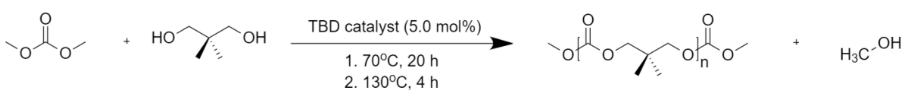


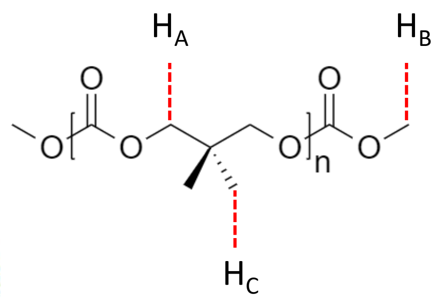
1,3,4,6,7,8-hexahydro-2*H*-pyrimido[1,2-*a*]pyrimidine

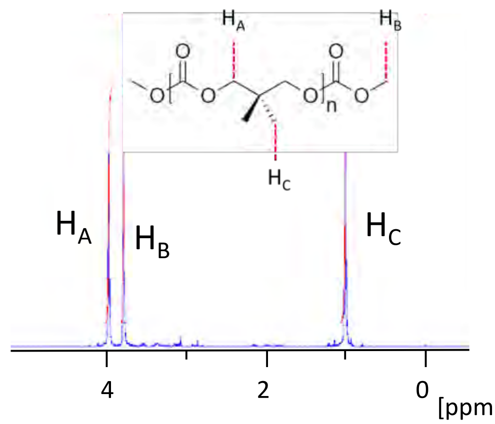
2011, Macromol. Rapid Commun., 32, 1379-1385.
2012, Green Chem., 14, 1728-1735.

Image credit: NASA

CPCU-Carbonate Olgiomer



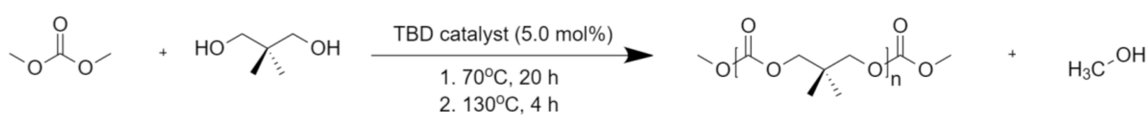




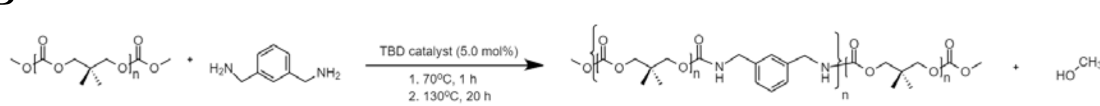
53

Condensation Polymerization: Copoly(carbonate urethane)

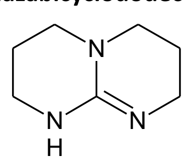
A



B



1,5,7-triazabicyclododecene, TBD



1,3,4,6,7,8-hexahydro-2*H*-pyrimido[1,2-*a*]pyrimidine

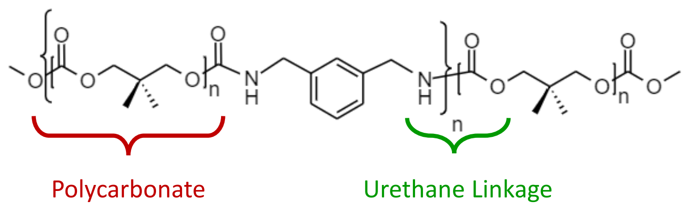
2011, Macromol. Rapid Commun., 32, 1379-1385.
2012, Green Chem., 14, 1728-1735.

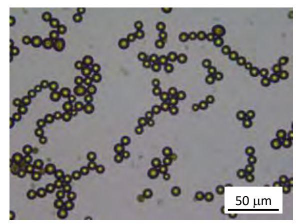
Image credit: NASA

54

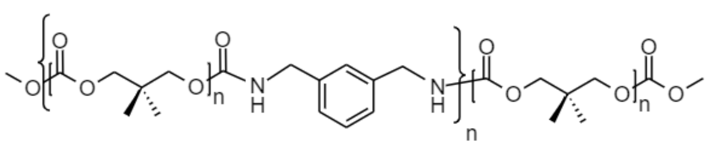
Tunability of ESPUR Material

- ❖Copoly(carbonate urethane) polymer
  - ❖Thermal properties
  - ❖Mechanical properties
  - ❖Rheological properties
- ❖Epoxy microparticles
  - ❖Particle size
  - ❖Particle coating thickness
  - ❖Particle organization





Differential Scanning Calorimetry



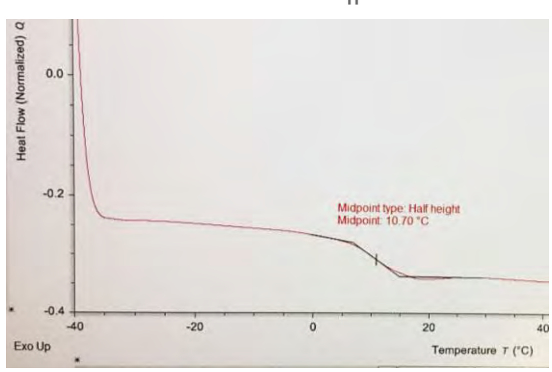
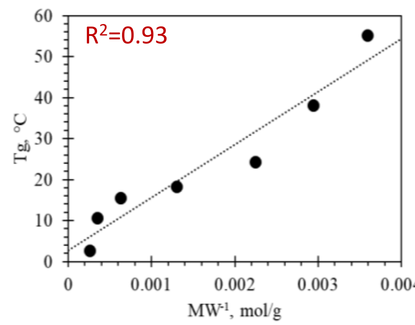


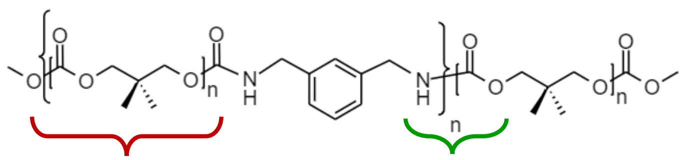
Image credit: NASA

Image credit: NASA

Tunability of ESPUR Material

- Copoly(carbonate urethane) polymer
  - Thermal properties
    - Mechanical properties
    - Rheological properties





Polycarbonate

Urethane Linkage

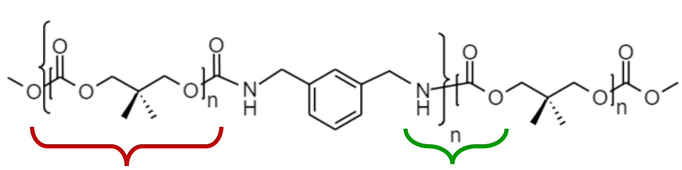
$$T_g(M_n) = T_g(\infty) - \frac{K}{M_n}$$

Flory-Fox Equation

57

Tunability of ESPUR Material

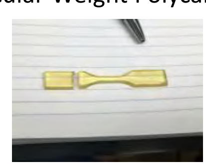
- Copoly(carbonate urethane) polymer
  - Thermal properties
  - Mechanical properties-determined to be dependent on polycarbonate molecular weight
  - Rheological properties



Polycarbonate

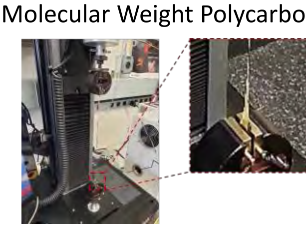
Urethane Linkage

- Low Molecular Weight Polycarbonate



T_g > RT

- High Molecular Weight Polycarbonate



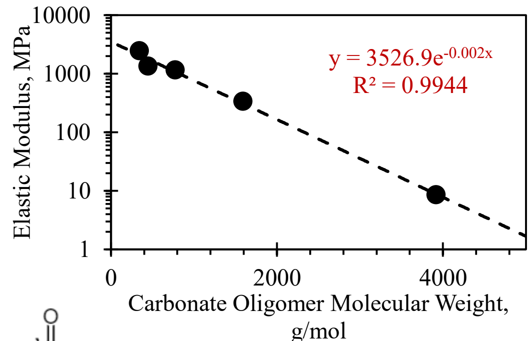
T_g < RT

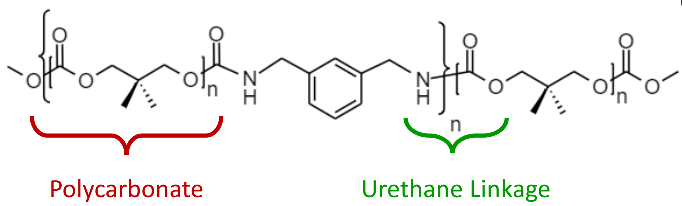
Image credit: NASA

58

Tunability of ESPUR Material

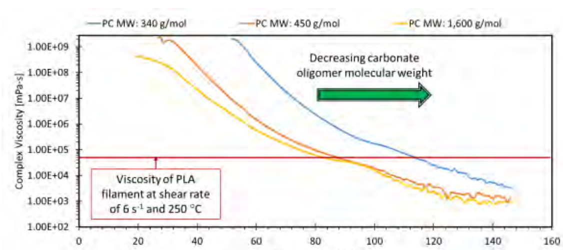
- Copoly(carbonate urethane) polymer
  - Thermal properties
  - Mechanical properties-closely follows a trend enabling estimation of mechanical properties *a priori*
  - Rheological properties



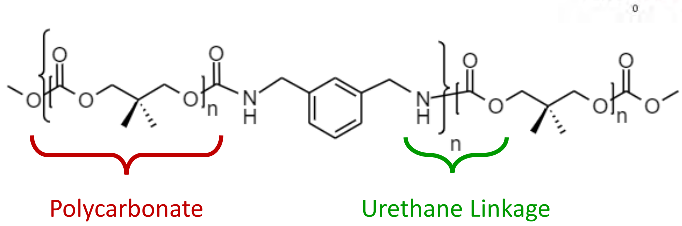


Tunability of ESPUR Material

- Copoly(carbonate urethane) polymer
  - Thermal properties
  - Mechanical properties
  - Rheological properties-properties comparable to PLA at much lower temperatures

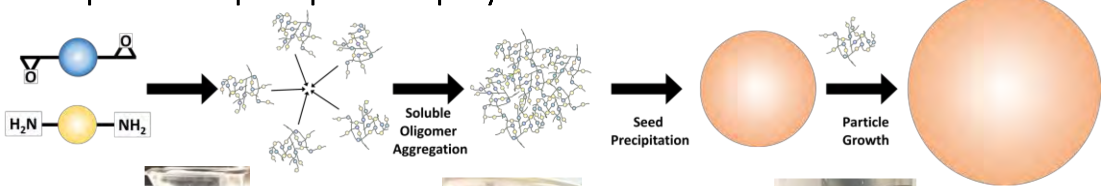


Viscosity of PLA filament from: Zhu, Pu, "Polymer Materials Via Melt Based 3D Printing: Fabrication and Characterization" (2018). All Theses. 2895. https://tigerprints.clemson.edu/all_theses/2895

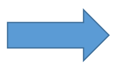


Epoxy Microparticles Synthesized via Precipitation Polymerization

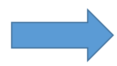
❖Prepared via precipitation polymerization

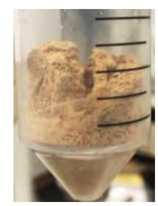


Monomer dissolved PPG (MW: 2000 g/mol)



Quiscent solution heated to 130 °C for 16 h





Particle recovered after acetone wash

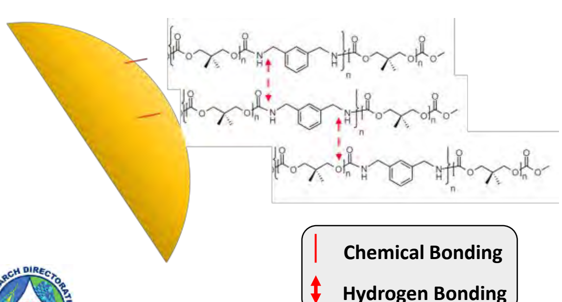
2013, European Polym. J., 49 (3), 579-600.
2012, J. Colloid Interfac Sci., 368, 158-164.

Image credit: NASA

Coating Epoxy Microparticles

❖Particle coating thickness-

- ❖Controlled by concentration of reactive species with polymerization occurring in the presence of particles



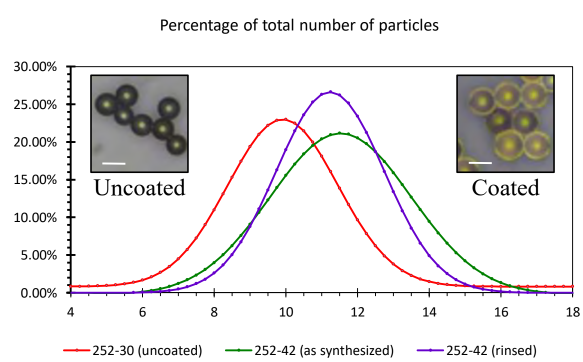
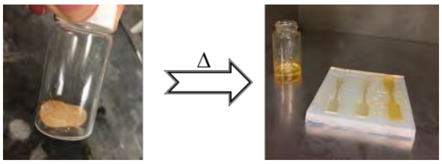


Image credit: NASA

Materials Forms

Polymer as Filament



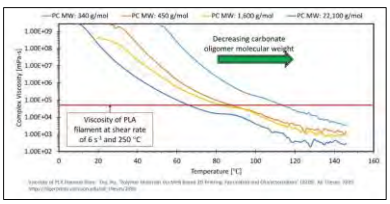


Image credit:
Matterhackers.com
Green MH P-Series Polylacticacid Filament

Technology as Paste

Image credit:
3Dpotter.com, "Dueling Scaras" https://youtu.be/3Q72nOSKyww

63

Conclusions/Next Steps

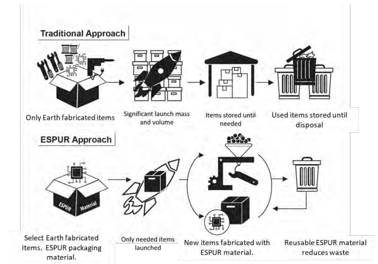
- ❖In-space manufacturing can be a game-changing approach to realize long duration missions beyond low Earth orbit (LEO)
- ❖Utilization of recyclable feedstocks to extend mission lifetimes and reduce risk seems like a natural extension
- ❖Next Steps
  - ❖Need to develop CPCU formulations for filament extrusion toward 3D printing applications
  - ❖Need to evaluate the efficacy of click-chemistry functionalities integrated into CPCU
  - ❖Need to demonstrate reversible assembly

64

To Discuss Today:

Long duration exploration missions will require multifunctional materials to increase the period between resupply missions and systems that remain operational in extreme extra-terrestrial environments.

- ❖Project ESPUR: Enabling Sustained Presence Using Recyclables



- ❖Lunar Dust Adhesion Mitigation
  - ❖Passive adhesion mitigation materials technologies
    - ❖Polymeric materials


Image credit: NASA

65

NASA Langley Research Center — ACS Webinar 11.17.21 — Advanced Materials and Processing Branch

Fourth Audience Question

Why is lunar dust such a big problem?

- A. It is incredibly abrasive, chemically reactive, electrostatically charged, potentially magnetic
- B. It was a huge nuisance during the Apollo missions
- C. It will present a huge challenge for mission completion in every phase of Artemis and beyond
- D. It is not a big problem, Chris just wants to play in the dirt


Image credit: NASA

66

Why is Lunar Dust so Problematic?

Apollo missions demonstrated that dust was a limiting factor for lunar surface operation and posed a health concern when it penetrated habitable spaces. Dust mitigation (DM) is required to enable ARTEMIS.

- The Problem: Hazards associated with hard, sharp, fine, chemically reactive lunar dust
  - Impact on people:
    - Potential inhalation health hazard
    - Embeds in, abrades soft materials
    - Reduces visibility through optical surfaces by scatter and scratching
  - Impact on habitats, equipment, and mission operations:
    - Reduces performance efficiency of solar arrays and radiators
    - Compromises sealing of critical, gas-tight surfaces
    - Accelerates wear on and increases jamming of moving surfaces
    - Variable with lunar locations and specific dust characteristics

Apollo astronaut glove covered in lunar dust
Image credit: NASA

- The Need:
  - Reduce health hazard associated with incidental exposure
  - Improve functioning and increase equipment lifetime
  - Expand lunar surface mission options, longer lifetime for deployed systems, minimize risk of lunar system capability loss (i.e., magnitude and duration) and increase system reliability, and create a greater probability of mission success
  - DM is needed to support NASA's Plan to Return to the Moon by 2024 and Lunar Sustainability by 2028 (LSII project)

<u>Quantitative Impact: preliminary studies show adhesion reductions of 80% to 95% for various removal techniques.</u>

Flanagan and Goree, Dust release from surfaces exposed to plasma, Physics of Plasma 13, 123504, 2006. Schwan, J., et al., The charge state of electrostatically transported dust on regolith surfaces, Geophy. Res. Lett., 44, 3059, 2017. Godyak. V,. Ferromagnetic enhanced inductive plamsa source. J. Phys. D: Appl. Phys., 46, 283001, 2013. Wang. X et al. https://sservi.nasa.gov/articles/video-dust-charging-and-mobilization/

Where is Lunar Dust Mitigation Important?

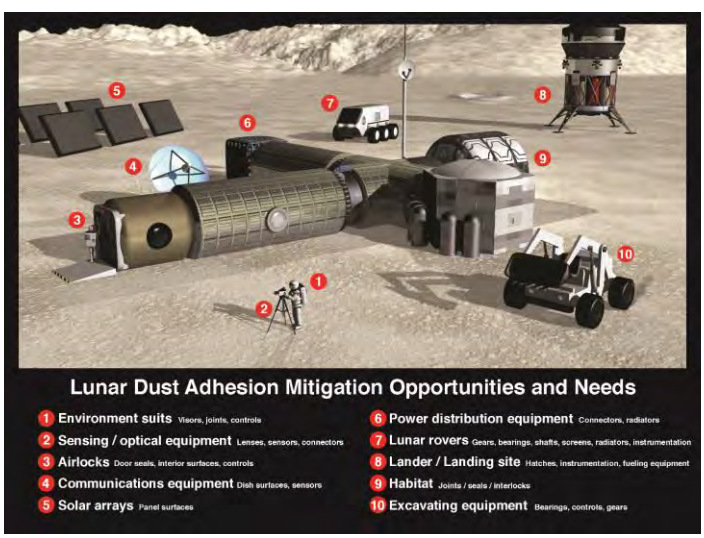


Image credit: NASA

Lunar Dust Mitigation Acknowledgements

❖**The NASA Langley Team**
- ❖Lopamudra Das
- ❖Valerie Wiesner
- ❖Keith Gordon
- ❖Glen King
- ❖Jonathan Hernandez
- ❖John Connell
- ❖And of course … interns

❖**NASA Glenn Research Center**
- ❖Erica Montbach **(Project Manager)**
- ❖Sharon Miller, Bruce Banks, Emily Naim **(ERA)**

Virtual Interns on "Hat Day" Summer 2020

❖**NASA Jet Propulsion Laboratory (JPL)**
- ❖Ulf Isrealsson, Inseob Hahn **(Dust Lofting)**
- ❖Joel Schwartz, Robert Kowalczyk **(Solar Array)**

Image credit: NASA

Image credit: NASA

Surface Modifying Agents

❖Surface modifying agents (SMA)s are great examples of entropy vs enthalpy.

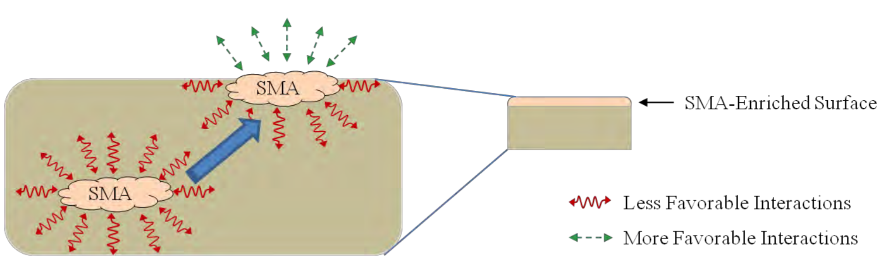
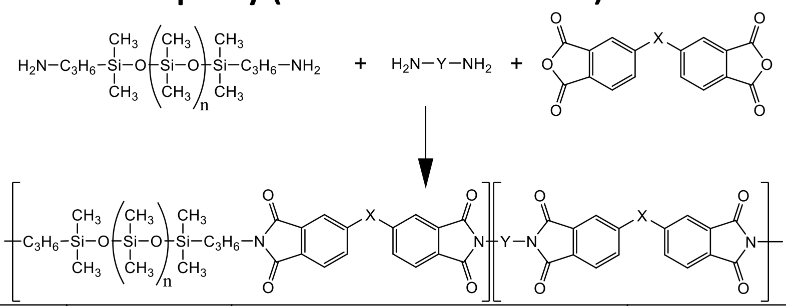


Image credit: NASA

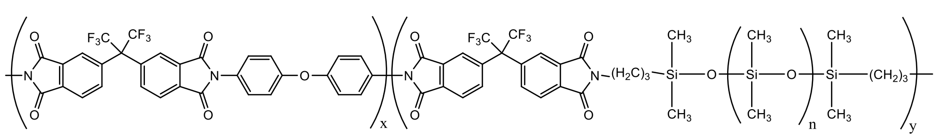
Condensation Polymerization: Copoly(imide siloxane)

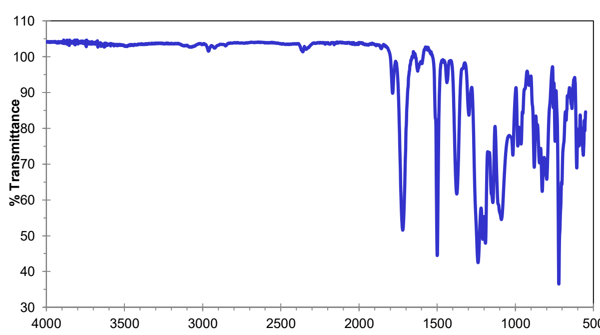


Siloxane	Designation	Molecular Weight (g mol^{-1}) Reported	^{1}H NMR Analysis	Number of repeat units
Disiloxane	S1	249	249	1
DMS-A11	S2	875	1150	12
DMS-A15	S3	3000	2980	37
DMS-A21	S4	5000	6150	80
DMS-A32	S5	30000	35800	480

All copoly(imide siloxane)s were generated at siloxane oligomer content from 1-10 wt%.

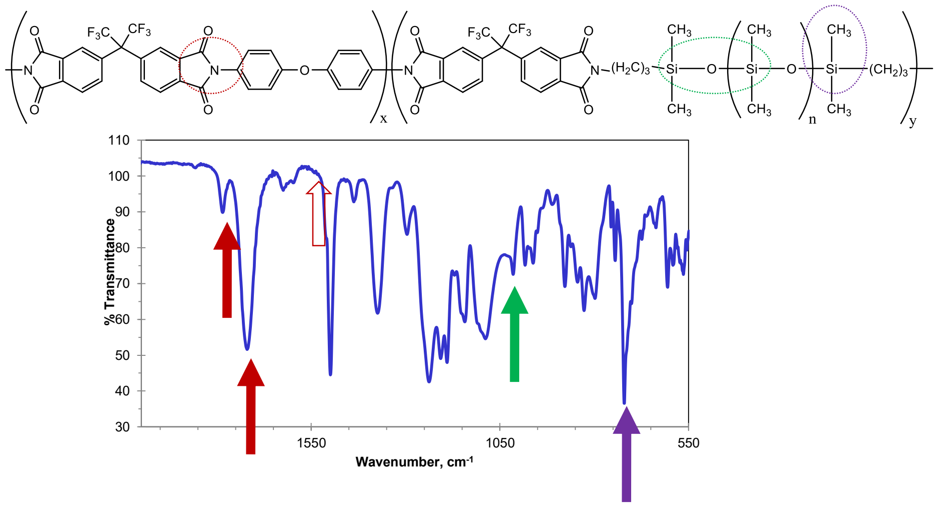
Copoly(imide siloxane)s ATR-IR





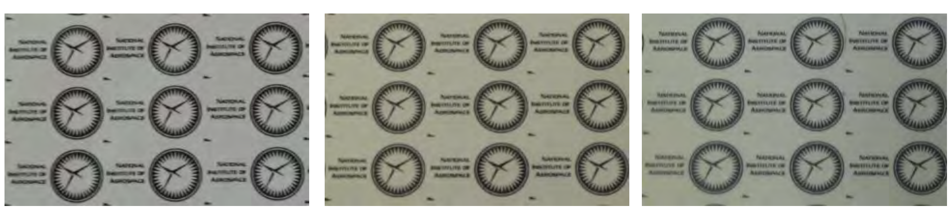
6FDA:4,4'-ODA:DMS-A21 (5 wt%)

Copoly(imide siloxane)s ATR-IR

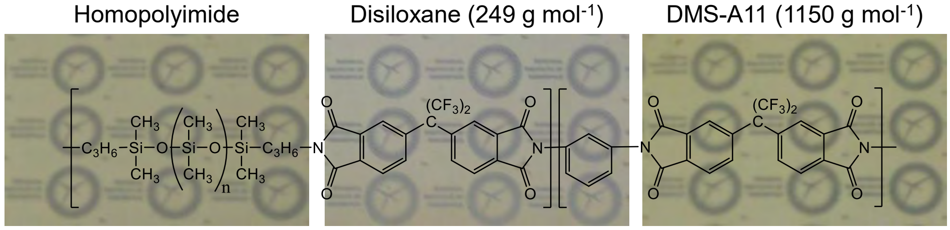


6FDA:4,4'-ODA:DMS-A21 (5 wt%)

Copoly(imide siloxane) Film Optical Clarity



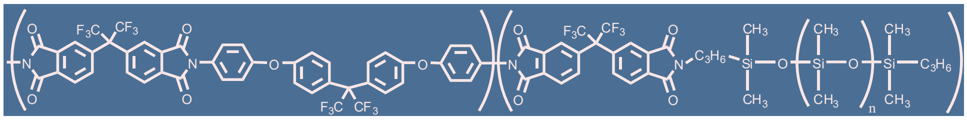
Homopolyimide | Disiloxane (249 g mol^{-1}) | DMS-A11 (1150 g mol^{-1})

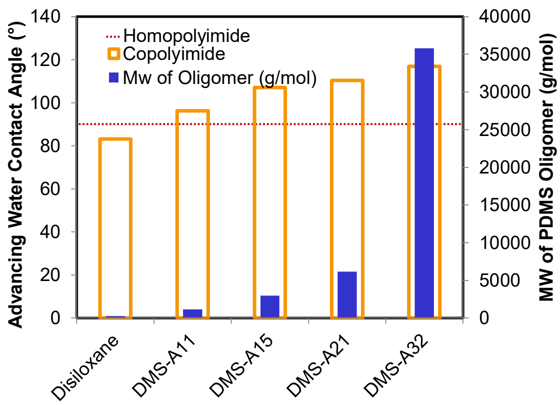


DMS-A15 (2980 g mol^{-1}) | DMS-A21 (6150 g mol^{-1}) | DMS-A32 (35800 g mol^{-1})

Image credit: NASA

Copoly(imide siloxane) Contact Angle Values



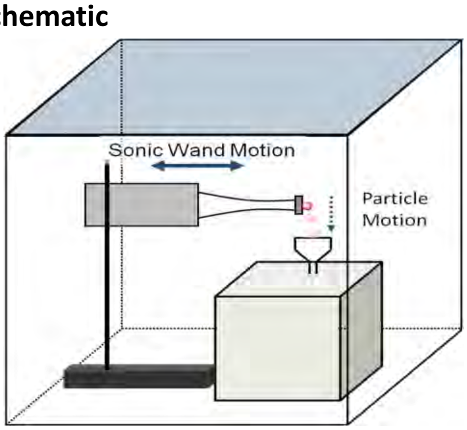


- Change in advancing water contact angle for 6FDA:4-BDAF copoly(imide siloxane)s upon increasing molecular weight of PDMS oligomer

Lunar Dust Adhesion Testing

Adhesion Test Chamber

Schematic



Actual Instrument

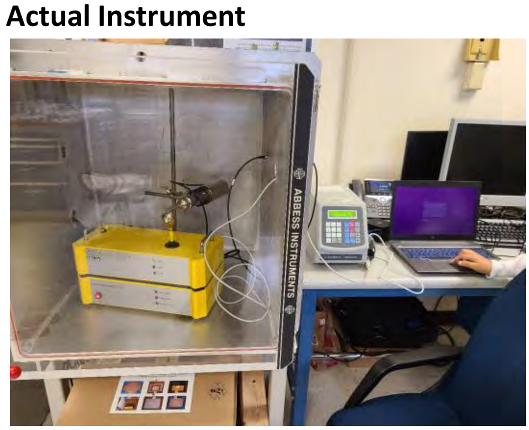
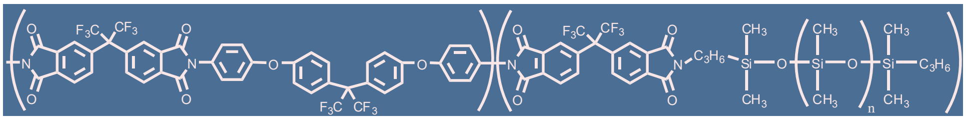
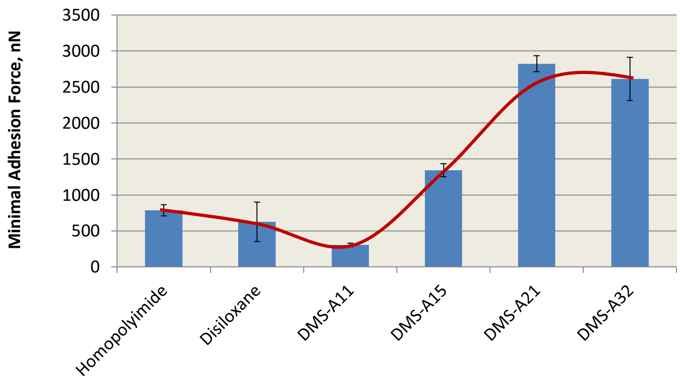


Image credit: NASA

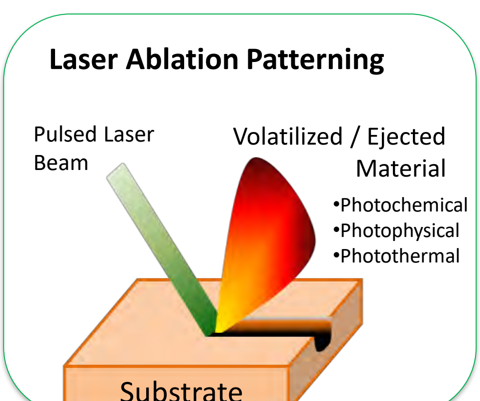
Copoly(imide siloxane) Simulant Adhesion Results





77

Surface Topographic Modification: Laser Ablation Patterning



90° cross-hatch pattern

Cross-section of Ablation Patterned Polymer Film

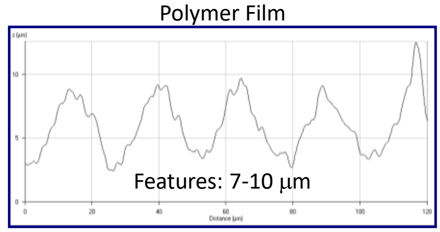
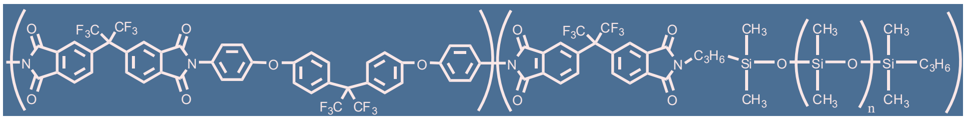
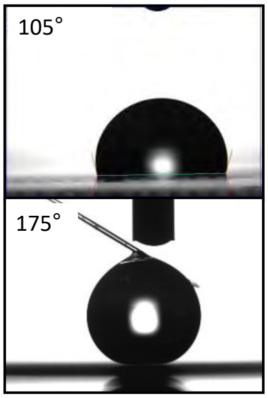


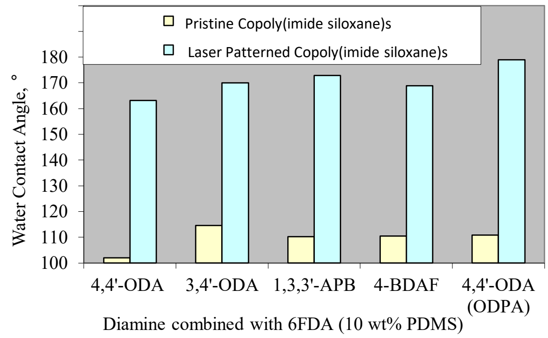
Image credit: NASA

78

Surface Topographic Modification: Laser Ablation Patterning





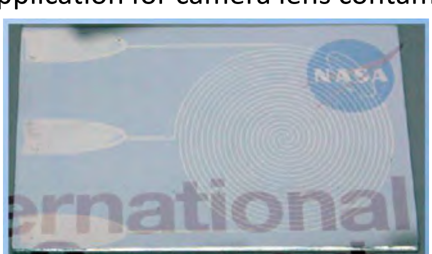


2012, High Performance Polym., 24(1), 40-49.

Image credit: NASA

Integration into Electrodynamic Dust Shields (EDS)

- ❖Collaborative activity with NASA Kennedy Space Center
  - ❖EDS utilizes multiple embedded, integrated electrodes operating with differences in phase to generate a non-uniform electric field
  - ❖Contaminants, i.e., lunar dust, will be electrostatically charged and propelled off the surface
- ❖Application for camera lens contamination protection



EDS generated in ITO on a silica substrate

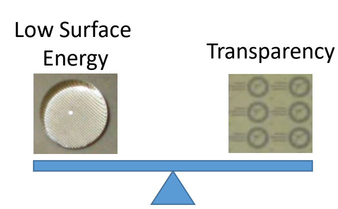


Image credit: NASA

Interns at NASA Langley Research Center

Image credit: NASA

NASA Interns Can Help Advance NASA Missions!

Eligibility Requirements:

- ✓ US Citizen
- ✓ Enrolled in a degree-granting program (note: can apply up to 6 months after graduation)
  - High school, undergraduate, graduate, and educators are eligible
- ✓ Minimum 3.0 GPA on 4.0 scale
- ✓ Minimum 16 years of age

Internship Sessions

Students are competitively selected for three sessions per year.

Fall
16 Weeks
Begins late August to early September

Spring
16 Weeks
Begins mid to late January

Summer
10 Weeks
Begins late May to early June

Image credit: NASA

The Selection Process & Timeline

- Apply to internships the semester before at **intern.nasa.gov**
- Apply to up to 15 projects across all centers per session
- Mentors & Center Intern Program Coordinators collaborate to identify candidates for selection
- If selected, you will be contacted by the Coordinators

Follow us on Social Media!

Get the latest on NASA Internships social media!

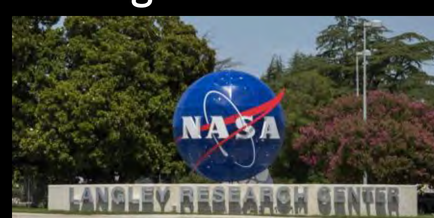
- Facebook.com/*NASAInterns*
- Instagram - *@nasainternships*
- Twitter - *@NASAInterns*
- Blog – *blogs.nasa.gov/interns*
- Email – *nasa-internships*@mail.nasa.gov

85

STEM TAKES FLIGHT
at Virginia's Community Colleges

STEM Takes Flight NASA Research Experience Program

- In partnership with NASA, the VSGC and the Virginia Community College System, funding covered 10-week paid on-site/virtual NASA Research Experiences for STF student researchers between 2015 and 2021.
  - 177 Student Researchers have participated to date.
  - 27 placements will be funded for the 2022 summer session.
  - $5K Stipend for 40 hrs/wk. (22-LaRC; 5-WFF).
  - Program Dates: June 6 – August 12, 2022.
  - Applicants must be a Virginia community college student; rising, current or recently graduated (not sooner than May of 2022) sophomore; US citizen; 18 years old; 2.5 GPA
  - For the 2nd year of the COVID-19 pandemic, NASA shipped computers to all students.
  - NASA Center Director, Clayton Turner, encourages the students to always be passionate about their goals and never give up.



A 2021 Closing Ceremony was held for the students. Many shared the impact of the experience had changed their lives. The impact is real!

VCCS and VSGC announced the program will continue through at least 2023.
The 2022 application is coming soon!

Virginia Space Grant Consortium

Image credit: NASA

ACS Chemistry for Life®

Co-produced with: POLY | ACS Division of Polymer Chemistry

New Polymers in Space

Long-Term Exploration Beyond Our Planet

FREE Webinar | TODAY at 2pm ET

ACS Webinars CLICK • WATCH • LEARN • DISCUSS

ASK YOUR QUESTIONS AND MAKE YOUR COMMENTS IN THE QUESTIONS PANEL NOW! 97

ACS Webinars CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

New Polymers in Space: Long-term Exploration Beyond Our Planet

Stephanie L. Vivod
Chemical Engineer, Aerospace Polymeric Materials, NASA John H. Glenn Research Center

CHRISTOPHER J. WOHL
Assistant Branch Head and Senior Research Surface Scientist, NASA Langley Research Center

SADEQ MALAKOOTI
Postdoctoral Program Fellow, NASA John H. Glenn Research Center

Presentation slides are available now! The edited recording will be made available as soon as possible.

www.acs.org/acswebinars

This ACS Webinar is co-produced with ACS Division of Polymer Chemistry. 98

98

ACS POLY

ACS Technical Division
Polymer Chemistry (POLY)

UPCOMING EVENTS

Controlled Polymer Radicalization 2021
November 14, 2021 – November 17, 2021
Charleston, SC USA
https://www.polyacs.net/crp2021

POLY Fellows Award
November 30, 2021
https://polyacs.org/poly-fellows

Silicon-Containing Polymers and Composites 2021
December 1, 2021 – December 4, 2021
San Diego, CA USA
https://www.polyacs.net/2018siliconc

MEMBER BENEFITS:

Join the POLY Discussion List
to get informed on job postings, events, workshops, and information exclusive to POLY division members.

We Gladly Thank Our Sponsors!

www.polyacs.org

ACS Webinars

CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

Date: Thursday, November 18, 2021 @ 2-3:15pm ET
Speaker: Elizabeth Tomasino, Oregon State University
Moderator: Brian Guthrie, Cargill

Register for Free!

What You Will Learn:

- What are the compounds associated in smoke and smoke taint in wine
- How smoke taint compounds end up in wine
- How individuals perceive the aroma and flavor of smoke

Co-produced with: ACS Division of Agricultural & Food Chemistry

Fecha: Miércoles, 1 de Diciembre, 2021 @ 2-3pm ET
Ponente: Josep Cornella, Max-Planck-Institut für Kohlenforschung
Moderadora: Ingrid Montes, Recinto de Río Piedras y American Chemical Society

Registrarse Gratuitamente

Lo Que El Público Aprenderá:

- El desarrollo de nuevos reactivos orgánicos que permitan una química orgánica práctica y fácil mediante la agilización de las rutas sintéticas
- El diseño de ligandos que convierten los metales de transición sensibles al aire en complejos robustos con una estabilidad notable frente a la oxidación y la temperatura
- El diseño de elementos p-block, en particular bismuto (Bi), con el objetivo de diseñar nuevos procesos catalíticos redox similares a los metales de transición

Co-producido con: Sociedad Química de México y Chemical & Engineering News

Date: Thursday, December 2, 2021 @ 2-3pm ET
Speakers: Javier García Martínez, IUPAC and Rive Technology / Laura-Isobel McCall, University of Oklahoma / Diego Solis-Ibarra, Universidad Nacional Autónoma de México / Corinna Schindler, University of Michigan
Moderators: Jessica Marshall and Mitch Jacoby, Chemical & Engineering News

Register for Free!

What You Will Learn:

- What were the hottest trends in chemistry research during 2021, according to the experts
- What areas of chemical research do experts think will make the news in 2022
- What molecules caught C&EN editors' attention this year

Co-produced with: Chemical & Engineering News

www.acs.org/acswebinars

ACS Webinars®
CLICK • WATCH • LEARN • DISCUSS

Learn from the best and brightest minds in chemistry! Hundreds of webinars on diverse topics presented by experts in the chemical sciences and enterprise.

Edited Recordings are an exclusive ACS member benefit and are made available once the recording has been edited and posted.

Live Broadcasts of ACS Webinars® continue to be available to the general public several times a week generally from 2-3pm ET!

A **collection of the best recordings** from the ACS Webinars Library will occasionally be rebroadcast to highlight the value of the content.

www.acs.org/acswebinars

101

ACS Webinars
CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

ACS Webinars® does not endorse any products or services. The views expressed in this presentation are those of the presenter and do not necessarily reflect the views or policies of the American Chemical Society.

Contact ACS Webinars ® at acswebinars@acs.org

102

ACS Webinars
CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

Date: Thursday, November 18, 2021 @ 2-3:15pm ET
Speaker: Elizabeth Tomasino, Oregon State University
Moderator: Brian Guthrie, Cargill

Register for Free!

What You Will Learn:

- What are the compounds associated in smoke and smoke taint in wine
- How smoke taint compounds end up in wine
- How individuals perceive the aroma and flavor of smoke

Co-produced with: ACS Division of Agricultural & Food Chemistry

Fecha: Miércoles, 1 de Diciembre, 2021 @ 2-3pm ET
Ponente: Josep Cornella, Max-Planck-Institut für Kohlenforschung
Moderadora: Ingrid Montes, Recinto de Río Piedras y American Chemical Society

Registrarse Gratuitamente

Lo Que El Público Aprenderá:

- El desarrollo de nuevos reactivos orgánicos que permitan una química orgánica práctica y fácil mediante la agilización de las rutas sintéticas
- El diseño de ligandos que convierten los metales de transición sensibles al aire en complejos robustos con una estabilidad notable frente a la oxidación y la temperatura
- El diseño de elementos p-block, en particular bismuto (Bi), con el objetivo de diseñar nuevos procesos catalíticos redox similares a los metales de transición

Co-producido con: Sociedad Química de México y Chemical & Engineering News

Date: Thursday, December 2, 2021 @ 2-3pm ET
Speakers: Javier García Martínez, IUPAC and Rive Technology / Laura-Isobel McCall, University of Oklahoma / Diego Solis-Ibarra, Universidad Nacional Autónoma de México / Corinna Schindler, University of Michigan
Moderators: Jessica Marshall and Mitch Jacoby, Chemical & Engineering News

Register for Free!

What You Will Learn:

- What were the hottest trends in chemistry research during 2021, according to the experts
- What areas of chemical research do experts think will make the news in 2022
- What molecules caught C&EN editors' attention this year

Co-produced with: Chemical & Engineering News

www.acs.org/acswebinars

103