# Polymers in Space

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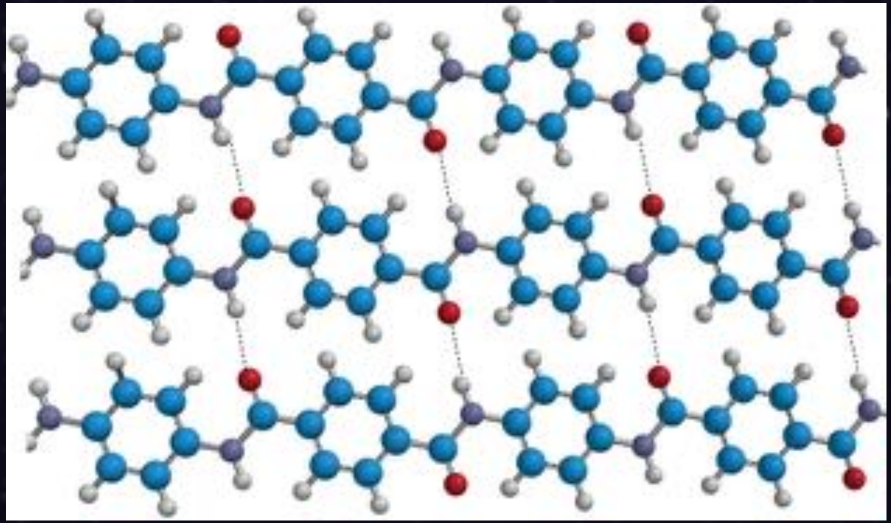
# Requirements for Materials in Space

- Perform intended function in a vacuum
  - Low outgassing to prevent contamination
- Resistance to charged particle radiation
- Resistance to atomic oxygen
- Resistance to micrometeoroids
- Endurance over wide temperature ranges
- Safety
  - Flammability, toxic by products, electrical shorting, optic contamination, etc.

# What is a Polymer?

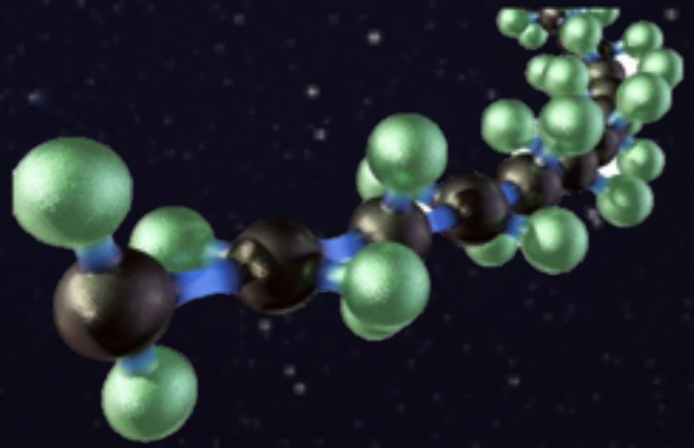
- Materials made of long, repeating chains
- 1869: First synthetic polymer from John Wesley Hyatt
  - Inspired by a New York firm's offer of $10,000 for anyone who could provide a substitute for ivory
  - Treated cellulose from cotton fiber with camphor
- 1907: First fully synthetic polymer
- WWII: Huge expansion



# What is a Polymer?

- Constitute large class of molecules
- Long chain structures and unique molecular architecture
- Can be synthetic or artificial
- Structure, properties, and processing interconnected
- Examples: proteins, DNA, plastics, cotton, rubber, polyester

- “There is a great future in plastics” –The Graduate



# Why Polymers?

- Extreme environments require high quality materials
- Incredibly wide range of uses and easily modified
- Desirable properties:
  - Toughness, resilience, low density, high/low melting points, ductile, electrical resistance, etc.
- Huge research potential
- Help to lower weight while increasing safety, reliability, and functionality

# Polymers for Spacecraft Application

- Research at the Jet Propulsion Lab at Cal Tech and Stanford
- 1964-1966
- Materials and Methods Group
- Objective: select polymeric materials to be used in the construction of spacecrafts
- Screened 350 polymers for outgassing (<1% wt. loss)
- Used short-term tests to determine long-term effects under thermal-vacuum conditions

# Space Applications

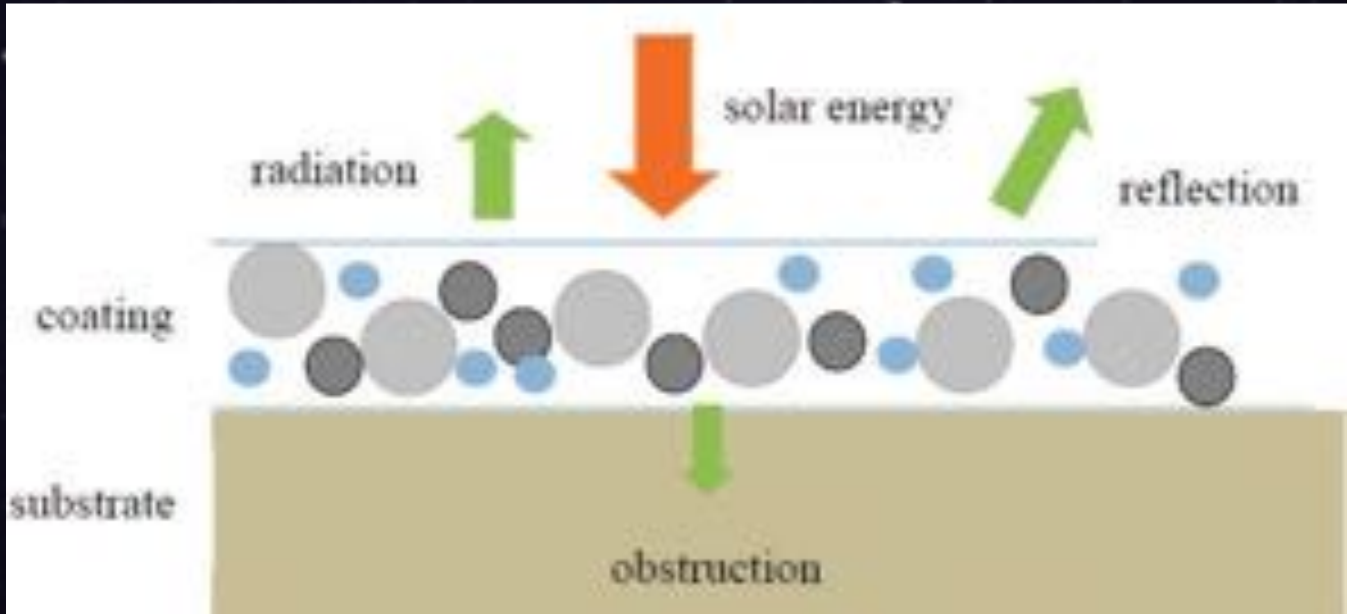
- Thermal Blankets
- Thermal Control Paints
- Adhesives
- Electrical Components
- Helmets
- Structural Components
- And more!

# Thermal Blankets

- Essential for regulating temperature of most spacecraft
- Consist of layers of films
  - Absorb sunlight with carbon black pigment
  - Reflect sunlight with a coating of vapor deposited aluminum
- Films are Dupont products: Mylar (polyethylene terephthalate) or Kapton (polyimide)
- Layers separated by cloths of Nylon

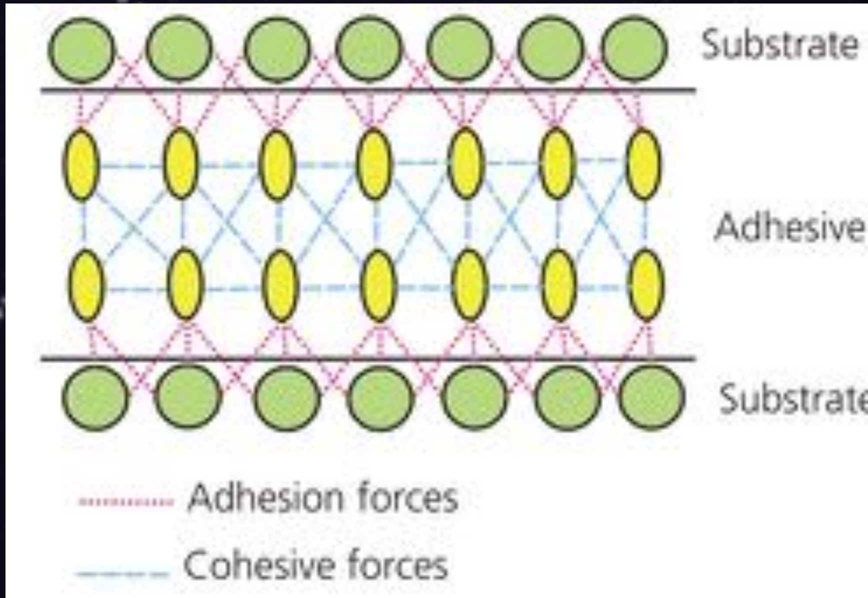
# Thermal Control Paints

- Regulate spacecraft temperature
- Either black or white to absorb/reflect
- Black paints (urethanes) also protect from UV light damage
- White paints (silicones) prevent overheating



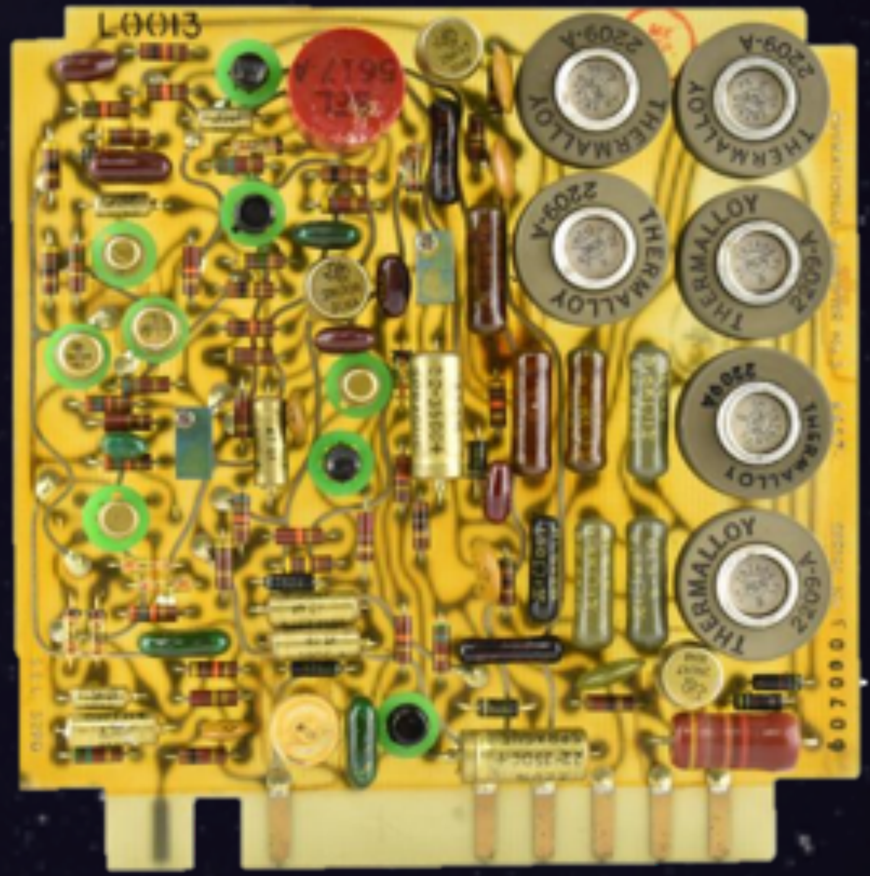
# Adhesives

- Used for structural bonding, wire and cable staking, lamination of optical elements, thread-locking components
- Most common: 2-part epoxies (2 liquid components mixed  and set)
- Modified with fillers, low thermal expansion, excellent adhesion, high temp. capacity,
- Specialty: electrically or thermally conductive
  - Use carbon or silver powders for electrical
  - Fillers of alumina, boron nitride, or diamond dust for thermal coupling



# Electrical Components

- Circuit boards
- Conductive adhesives
- Wire insulation: insulates and provides radiation protection
- Conformational coatings: resistance to chemical corrosion

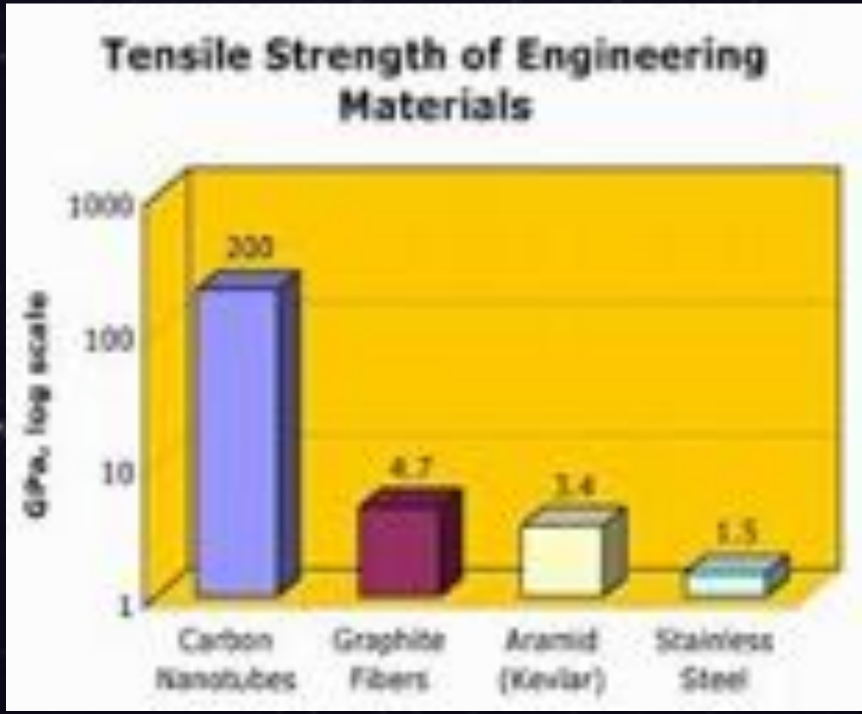


# Helmets

- Composed of plastic shell, 3 eyeshades, 2 visors
- Transparent, durable, keep oxygen in and debris out
- Outer Visor: Sun Visor
  - High temperature polysulfone
  - Filter visible light, UV , IR rays
- Inner Visor: Protective
  - UV stabilized polycarbonate
  - Filters UV, rejects IR

# Structural Components

- Polymers replace aluminum, titanium, and steel in spacecraft with demanding mass and stability requirements
- High impact resistance and low water absorption
- High strength to weight ratio
- Lighter means more efficient and less fuel



# Specific Polymers

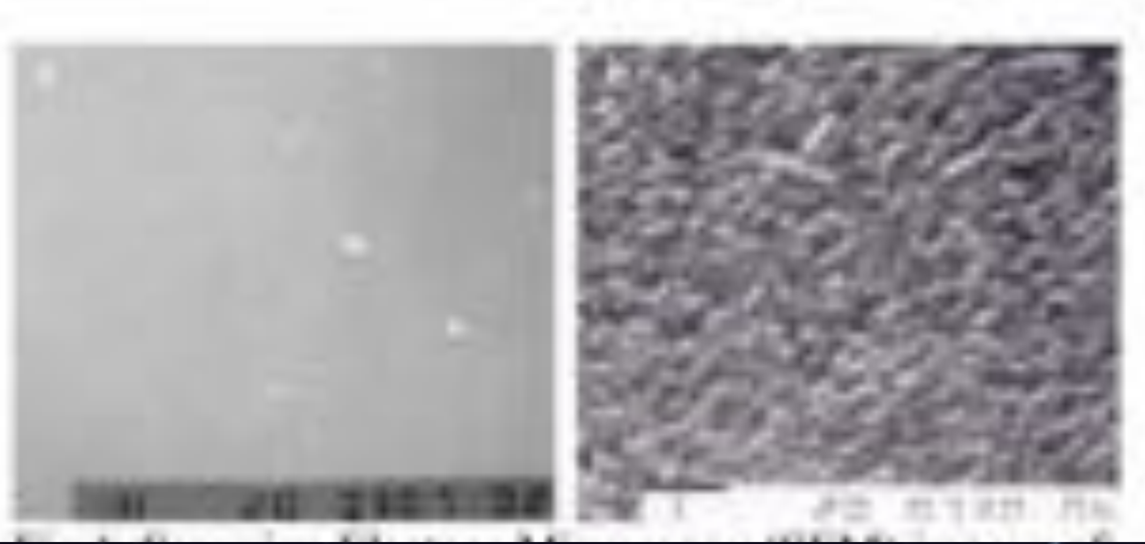
- PEI/PE: Polyetherimide/Polycarbonate
- TOR: Triton Atomic Oxygen Resistant
- Sodium Polyacrylate
- And More!

# PEI/PC: Polyetherimide/Polycarbonate

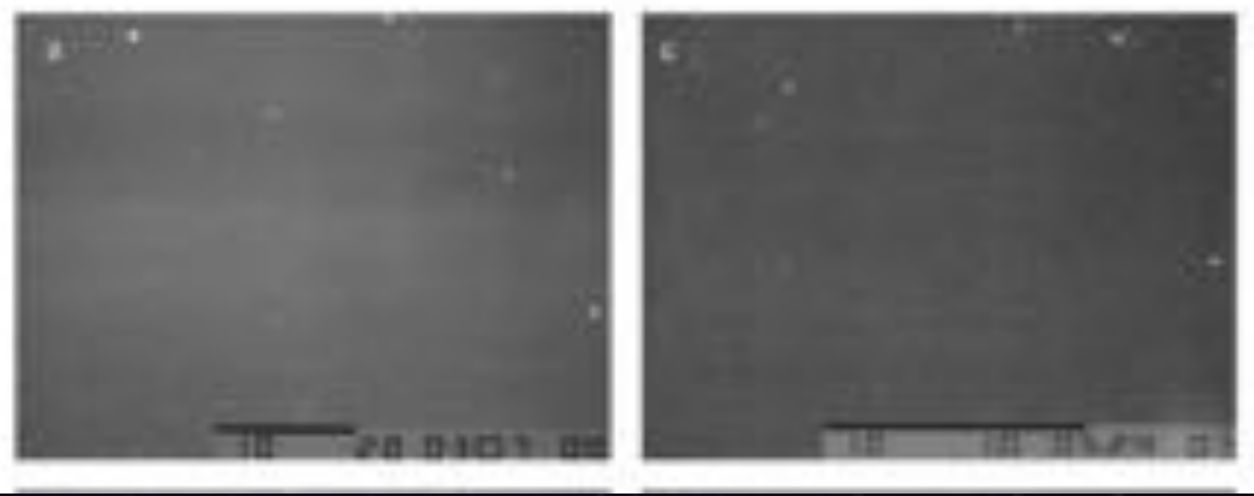
- High heat, solvent, and flame resistant
- High dielectric strength, thermal conductivity, tensile strength
- Used in making satellites and external hardware
- 3D printable aboard the ISS (2017)
  - One of few 3D printable aerospace grade plastics
- Allows for tools, spares, repairs, structures to be created on site, on demand

# TOR: Triton Atomic Oxygen Resistant

- Developed 1999 by Triton Systems
- Protect against erosion caused by atomic oxygen and radiation
- Gives a survival period 10 times longer than other polymers
- Contains Phosphorus to provide this resistance
  - P and O react to produce a protective phosphate layer
- Long lasting barrier means cost savings from repairs and replacements
- Also make excellent high-voltage insulators



Before and after AO exposure without Phosphorus



Before and after AO exposure with Phosphorus

http://adsabs.harvard.edu/full/2003ESASP.540..473I

# Sodium Polyacrylate

- Super Absorbent Polymer (SAP)
- Used in NASA's Maximum Absorbency Garment (space diaper)
- Capable of locking in 400 times its weight in water
- Allows MAG to soak up to 2 liters of liquid, astronauts only have to change every 8-10 hours
- NASA did not invent disposable diapers, adult diapers, sodium polyacrylate, or SAPS

# Other Useful Polymers

- Velcro
  - Developed by Swiss scientists
  - Used for convenience in zero gravity
- Teflon
  - Developed by Dupont
  - Used in heat shields, space suits, and cargo hold liners
  - Best known for use in nonstick pans

# NASA Polymer Spinoffs

- PS300
- Temper Foam
- LZR Racer
- And More!

# PS300

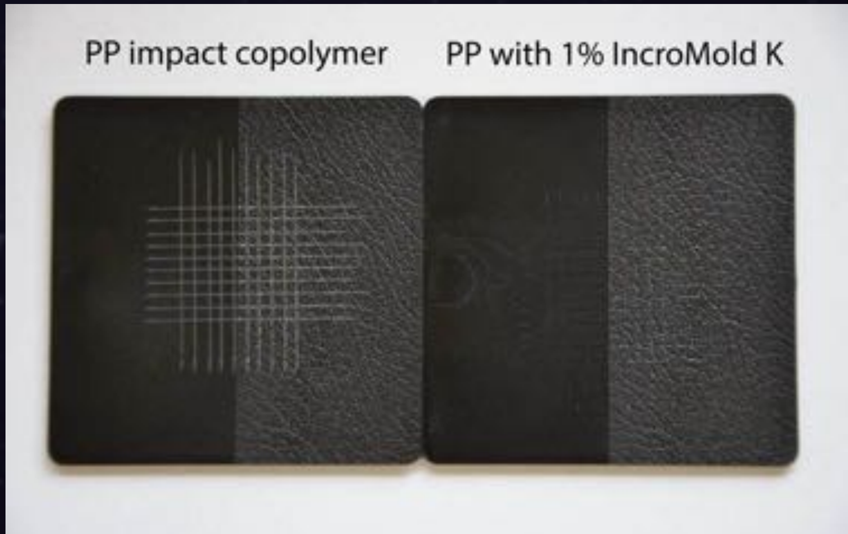
- Developed by NASA in 2003
- Solid lubricant coating deposited by thermal spraying to protect foil air bearings
- Lowers friction and wear, reduces emissions, reduces maintenance
- Functional from 20-650°C in oxidizing and reducing environments
- Saves manufacturing industry millions

# Temper Foam (Memory Foam)

- Developed in 1981 at Ames Research Center with Expanded Rubber & Plastics Corporation
- High energy absorption but remains soft and pliable
- Provides better impact protection and distributes body weight and pressures evenly over entire contact area
- Used in astronaut’s seats
- Helmets, mattresses, prosthetics, seats, shoes, etc.

# Scratch Resistant Lenses

- Elastic recovery upon removal of applied stress
- Idea from NASA scientist Dr. Wydeven working on spacecraft water purification, coated filter with plastic film
- Research continued with abrasion-resistant helmet coatings
- Better than glass: better optics, shatter-resistant, lighter, absorb UV lighter better



# LZR Racer

- Developed with Speedo at Langley Research Center
- Used wind tunnel testing facilities and fluid flow analysis
- Reduces skin friction by 24%, 4% increase in speed
- Goals: 1) Minimize friction 2) Maximize support to muscles 3) Without constraining motion
- LZR Pulse Fabric: Microfibers of nylon and spandex with different composite layers with thin panels of polyurethane (more rigid than base layers)

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