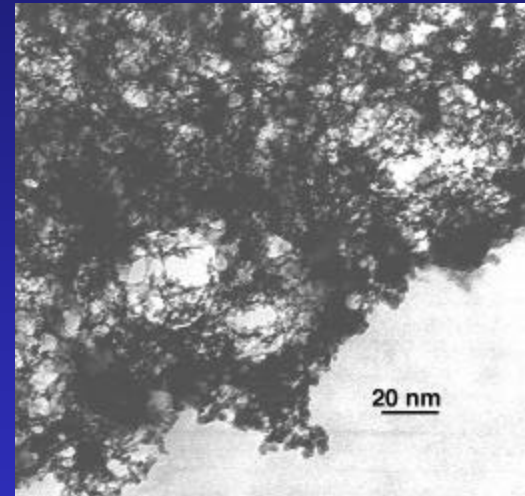
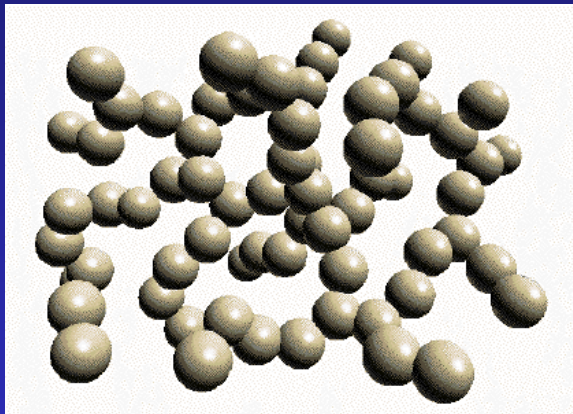


Aerogels and Applications for Thermal Insulation



"The Flower"

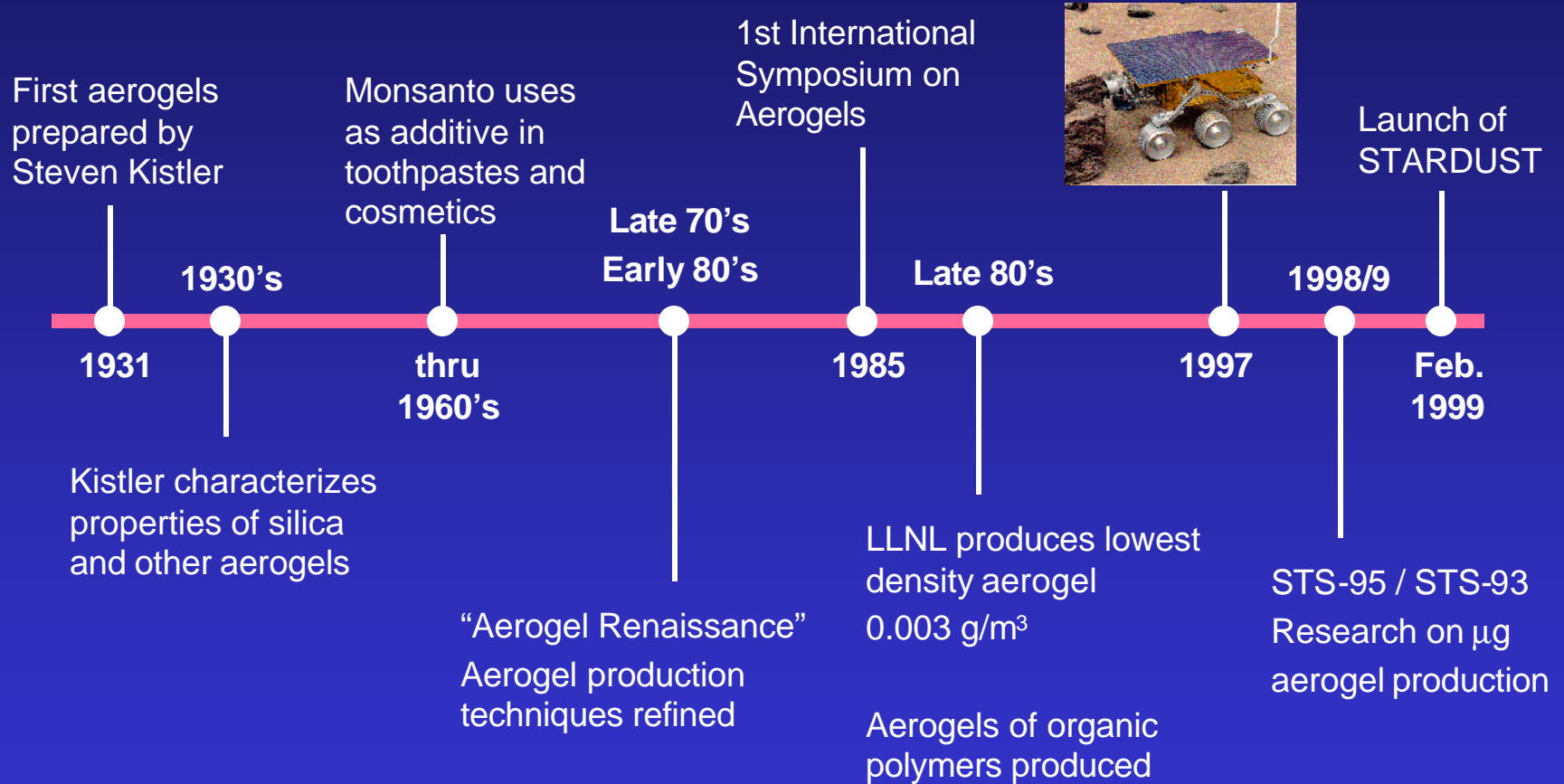


Electron Micrograph
Image

John Creasey
Lockheed Martin - England

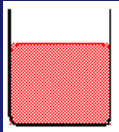


History of Aerogels

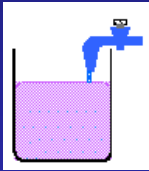




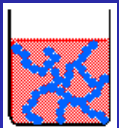
Production of Aerogels Using Sol-Gel Chemistry



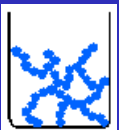
Dissolution of the ingredients
(an alkoxide) in a solvent (an
alcohol)



Hydrolysis by addition of
water



Condensation / Gelation -
formation of three-dimensional
network of colloidal particles



Supercritical drying.
Autoclave pressurized w/ CO_2
(CO_2 critical point, 31°C , 1050
psi)



Supercritical Drying System - 40 L capacity,
square gels 28 cm per side
Berkeley National Labs



Silica Aerogel Properties



- Density: 0.003 - 0.35 g/cm³ (most common density ~0.1 g/cm³)
- Internal Surface Area: 600-1000 m²/g
- Open Pore Network
- Primary Particle Diameter: 2-5 nm
- Mean Pore Diameter: ~20 nm
- Thermal Tolerance: shrinkage begins at 500°C, melting point > 1
- Dielectric Constant: ~1.1
- Index of Refraction: 1.0-1.05
- Nearly transparent; scatters blue light
- Inherently brittle - easily shatters into dust; much more durable under compression
- Destroyed by contact with liquid
- Can be shattered by rapid pressure changes
- Resistant to structural breakdown caused by solar radiation, radioactivity, and ozone
- Non-toxic
- Non-flammable
- Contains no CFC's, HCFC's, HFC's, or other environmentally harmful components
- Can be machined into almost any shape
- No laceration hazard - aerogel particles are smooth and round

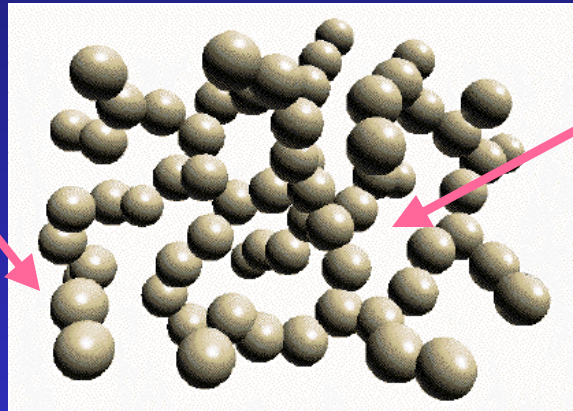


Thermal Conductivity



- Thermal Conductivity = Solid Conductivity + Gaseous Conductivity + Radiative Transmission

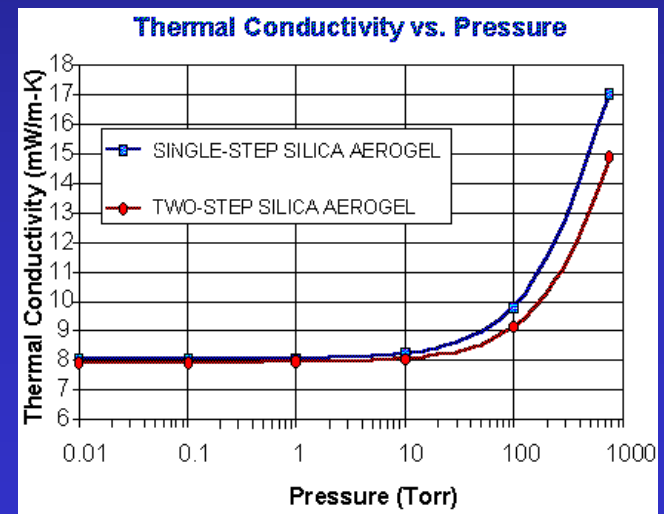
3-D network with a lot of dead ends



Mean free path of gas > pore diameter

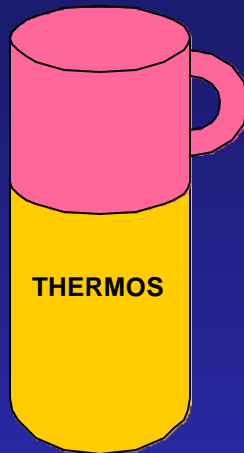
Elemental carbon can help absorb infrared radiation

Reduce pressure to lengthen mean free path
 $k = 0.008 \text{ W/mK}$ at $\sim 50 \text{ torr}$





Dewar's Flask versus VIP



VACUUM INSULATION PANEL

- No gas molecules to transport heat - R250 or better
- No support structure
- Wall material must be specially treated glass or metal -> heat conducted where walls joined
- Shape limited to round, oval, or cylindrical
- Internally coated w/aluminum (radiant heat barrier)
- R values from 20 to 140
- Core material provides structure
- Core material can be aerogel, fiberglass, silica, or open-cell foams (polyurethane, polystyrene)
- Membrane film forms wall of VIP
- Can consist of up to 9 layers of various plastics
- Aerogel core material acts as getter and desiccant



Available Products



- Aspen Systems
 - Developed under NASA SBIR contract
 - Flexible aerogel / fiber matrix composites
 - Final product - blanket, sheet, sleeve, or clamshell unit
 - R140/inch at high vacuum (10e-5 torr), R14/inch at ambient pressure, ΔT of 203 K
- Glacier Bay - Ultra-R VIP
 - R50/inch at 0.5 torr (0.0097 psi). R9/inch if punctured
 - Encased in tough polypropylene housing
 - 25-year warranty
 - Focused on marine refrigeration market
- MarkeTech
 - Customized aerogel production - physical properties controlled by density and microstructure
 - Products available in monoliths, thin films, or powder
 - Silica, R-F (Resorcinol-Formaldehyde), and Carbon aerogels
- Others - Nanopore, Hoechst, Airglass (Sweden), JPL

Material	"R" value per inch
Aluminum	0.001
Glass	0.2
Expanded Polystyrene	3.6
Polyurethane Foam	5.9
Air	6.2
MarkeTech	
Silica Aerogel	7
RF Aerogel	11
Carbon Aerogel	12
VacuPanel VIP	20
Glacier Bay Ultra-R	50 / 9
Aspen Systems	140 / 14
Total Vacuum	250



Use of Aerogels in Space Experimentation



- Benefits
 - Relaxes other design constraints
 - Increased chamber volume / Less support hardware
 - Larger ΔT 's
 - Useful in extra-vehicular experiments (e.g. AG-Pod)
 - Reduced volume requirement for insulation
 - Transparent insulator (if desired)
- Challenges
 - Physical integration with other subsystems
 - Customized shapes
 - Flexibility of material
 - Cost



Other Aerogel Applications



Particle Physics Research
(radiation detection)

Low Dielectric Coating -
thin films in high-speed,
integrated digital and
microwave circuitry

Protective Materials
(absorb kinetic energy)

Energy-efficient
Windows

Fire-retardant
Packing Materials

Sound Insulator

Waste Gas Capture
before emission to
atmosphere

Lightweight Composites

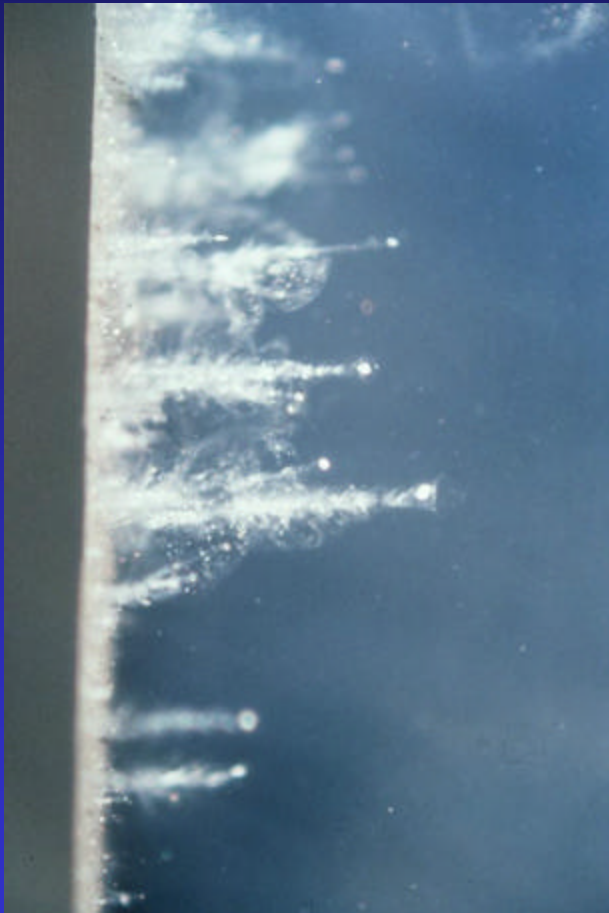
Super Capacitors

Crucible material for
microgravity solidification
research

Active and Passive
Components in Optical
Sensors

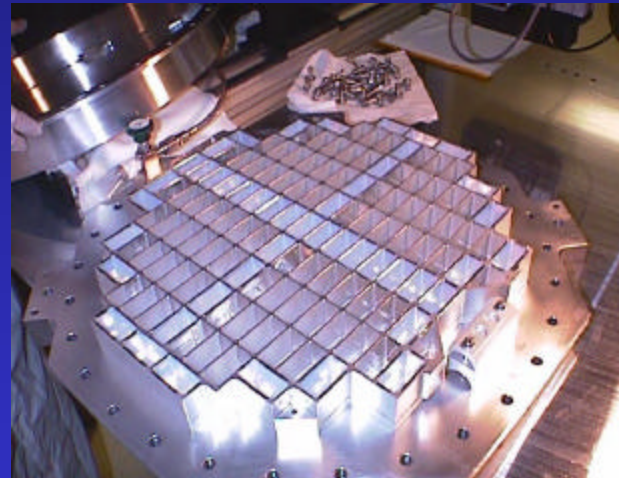


Particle Capture



Particle Tracks in Aerogel

- Collapse of solid network occurs gradually, spreading the force of impact out over a longer time



STARDUST Dust Collector
Silica Aerogel (1000 cm²) mounted in
modular Aluminum cells