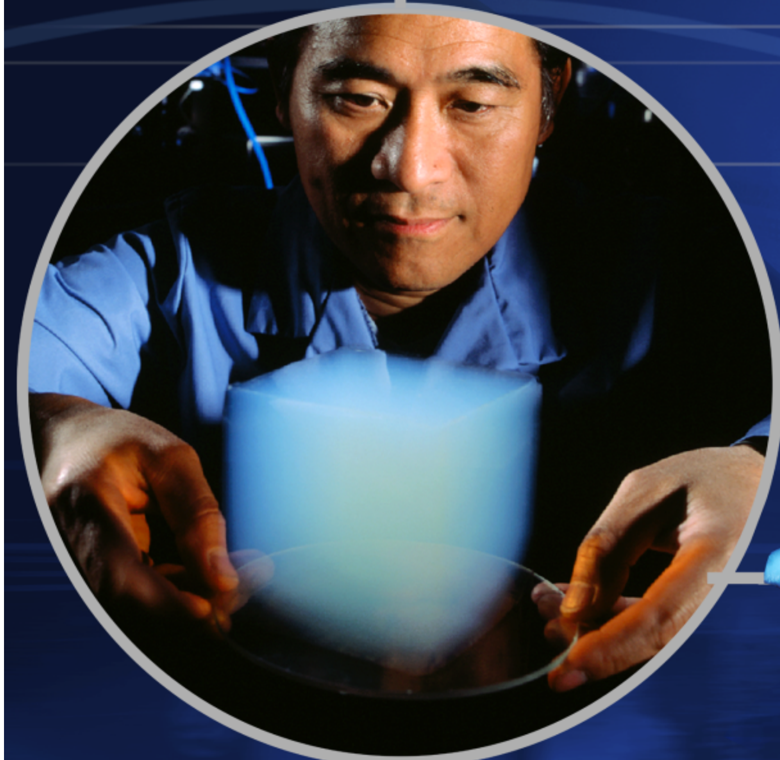
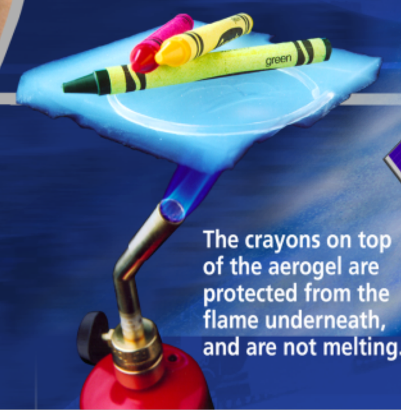
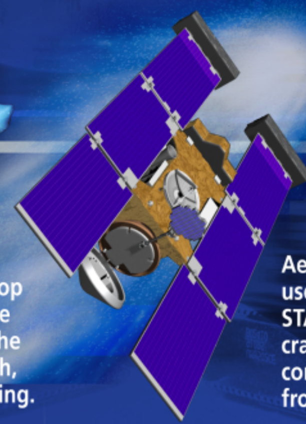


Aerogel *Mystifying Blue Smoke*

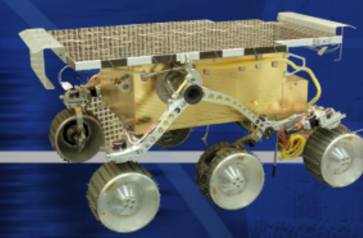
At first glance aerogel resembles a hologram. It's deceiving whether it's really there or not. A highly porous solid material, aerogel has the lowest density of any solid known to man. One thousand times less dense than glass, aerogel has earned the nickname, "solid blue smoke."



The crayons on top of the aerogel are protected from the flame underneath, and are not melting.



Aerogel will be used on the STARDUST spacecraft to capture comet particles from Comet Wild 2.



Aerogel is strong and easily survives launch and space environments. It has been used for the Mars Pathfinder and other rover missions.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Chemistry

Mixed with silicon dioxide and a solvent, aerogel is 99.8% air, and is 1,000 times less dense than glass.

Capability

Particles traveling six times faster than a rifle bullet can be stopped by a block of aerogel.

High Temperature

Aerogel can withstand high temperatures. Some types of aerogel provide 39 times more insulation than fiberglass.

Support

Despite weighing only 3 milligrams per cubic centimeter, aerogel can support up to 4,000 times its own weight.

Aerogel

Mystifying Blue Smoke

At first sight, aerogel resembles a hologram. An excellent insulator, aerogel has the lowest density of any known solid — one form of this extraordinary substance is actually 99.8 percent air and 0.2 percent silica dioxide (by volume). Aerogels have open-pore structures similar to honeycomb, but in fact they are low-density, solid materials with extremely fine microstructures. Typically silicon-based like ordinary glass, or carbon-based like common organic synthetics, aerogels possess unique physical properties (see table). The unique characteristics of aerogels are being applied to meet new technological demands.

Aerogel was discovered in the late 1930s by chemist Samuel S. Kistler. Since then, numerous attempts have been made to further understand and develop it. At NASA's Jet Propulsion Laboratory (JPL), aerogel technology has found two primary applications. The first is the capture of dust particles from comet Wild 2 (pronounced "Vilt 2") by the Stardust sample return mission. The particles gradually decelerate as they bore deeper into the threadlike silica network of Stardust's gradient-density aerogel, so that the samples sustain minimal damage while being collected for return to Earth for scientific study in 2006.

JPL's second application of aerogel is spacecraft insulation. Because aerogel is mostly air, an effective thermal insulator is contained within its porous silica network. This presents an excellent thermal barrier to protect the spacecraft against the extreme cold of deep space. The Mars Pathfinder mission used aerogel to protect the electronics of the Sojourner rover against the frigid Martian environment during Sojourner's 1997 travels on the red planet. Each of the twin Mars Exploration Rovers, scheduled to land on Mars in early 2004, employs aerogel for thermal insulation of the battery, electronics, and computer in the chassis, or warm electronics box.

JPL is currently investigating a variety of future applications for aerogel. Discussions and experiments are ongoing regarding its use as a thermal insulation material for light aircraft and spacecraft. Aerogel's large surface area makes it a potential basis for chemical sensors. Aerogel may also find a home in areas such as sporting equipment and architectural design through corporate and academic contacts.

For more information about aerogel, visit http://stardust.jpl.nasa.gov

Property	Silica Aerogel	Silica Glass
Density (kgm^3)	5 – 200	2300
Specific Surface Area (m^2/g)	500 – 800	0.1
Refractive Index at 632.8 nm	1.002 – 1.046	1.514 – 1.644
Optical Transmittance at 632.8 nm	90%	99%
Coefficient of Thermal Expansion 1/C at 20–80 deg C	~2×10^{-6}	10×10^{-6}
Thermal Conductivity (W/mK) at 25 deg C	0.016 – 0.03	1.2
Sound Velocity (m/s)	70 – 1300	5000 – 6000
Acoustic Impedance (kg/m^2/s)	10^4	10^7
Electric Resistivity (ohm-cm)	1×10^{18}	1×10^{15}
Dielectric Constant at 3–40 GHz	1.008 – 2.27	4.0 – 6.75

Development Timeline

1930 Aerogel discovered.

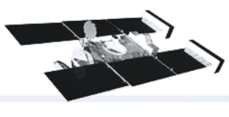
1940 Aerogel first marketed commercially.

1980 Scientific uses of aerogel.

1997 Sojourner insulation.

1999 Stardust launch.

2004 Mars Exploration Rovers.



2004 Stardust encounter with comet Wild 2.

2006 Stardust sample returns to Earth.

2008 Future uses.

JPL 400-1119 9/03