

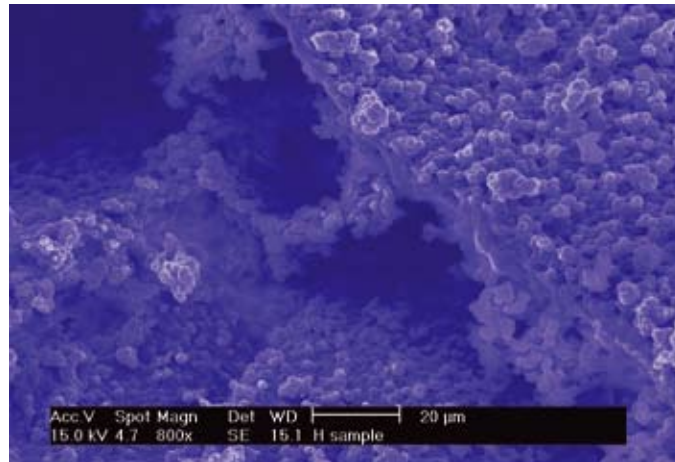
**A**erogels are formed by removing the solvent from the gel at a temperature and pressure above the solvent's critical point. By extracting the solvent at supercritical conditions, strong capillary forces generated by solvent-gas interfaces are eliminated since only one supercritical phase is present and shrinkage of the gel is low or absent. Since shrinkage is low, the structure of the gel is retained in the aerogel and aerogels can be prepared with bulk densities of 0.004 g/cc, surface areas of 1,500 m<sup>2</sup>/g, high porosity (85% or greater) and relatively large pore volumes. The combination of these properties produces a material that has the lowest thermal conductivity values of any solid material.

**Microstructure**

Silica aerogels have open porosity and a microstructure similar to interconnected pearl necklaces with dimensions of 1-5 nm. These nano-sized particles are responsible for the high surface areas of aerogels. Since the particles and pores are smaller than the wavelength of visible light, aerogels can be prepared as transparent, porous solids. Furthermore, their ultra small cell/pore sizes are smaller than the mean free path of air molecules, which makes them excellent

# Aerogel

**Aerogels refer to a unique class of low-density, open-cell materials. Due to their unique structure, they have interesting properties which make them useful in a variety of applications.**



insulators with thermal conductivities about 100 times lower than that observed for fully dense organic polymers. The microstructure also accounts for the low sound velocities observed in aerogels.

A typical aerogel has an average pore diameter of 2 nm-50 nm as

determined from the multipoint nitrogen adsorption curve over a range of relative pressures, typically 0.01-0.99 (gas absorption methods can measure the diameters of pores with diameters of 0.3-300 nm but cannot detect the presence of larger pores), and more than 50% of its total pore volume

consist of pores having a diameter of 2-60 nm. Although larger pores may be present, they cannot easily be detected for methods used to determine the sizes of larger pores usually destroy the aerogel. The gel can be visualized as having been built from many 1-5 nm primary sol particles to form a network structure consisting of clusters of primary particles that range from 20 to 100 nm in size.

**Fabrication**

Inorganic aerogels (e.g. silicon based aerogels), organic aerogels (e.g. resorcinol/formaldehyde aerogels) and inorganic/organic hybrids have been characterized. Inorganic aerogels are prepared from metal alkoxides and include materials, such as silica, titania, zirconia, and alumina. Silica aerogels are traditionally made via the hydrolysis and condensation of silicon alkoxides or via gelation of silicic acid or



of water glass. Organic aerogels include, among

**density** – gęstość  
**cell** – komórka  
**properties** – właściwości  
**solvent** – rozpuszczalnik  
**pressure** – ciśnienie  
**supercritical** – nadkrytyczny  
**force** – siła  
**shrinkage** – kurczenie się, skurcz  
**to retain** – zatrzymać, utrzymać  
**porosity** – porowatość  
**conductivity** – przewodność, przewodnictwo  
**silica** – krzemionka  
**pearl necklace** – naszyjnik z pereł  
**particle** – cząsteczka

**wavelength** – długość fali  
**furthermore** – ponadto, poza tym  
**mean free path** – średnia droga swobodna  
**insulator** – izolator  
**to account for** – być przyczyną  
**sound velocity** – szybkość rozchodzenia się fal dźwiękowych  
**curve** – krzywa  
**diameter** – średnica  
**to consist of** – składać się z  
**to detect** – wykryć, dostrzec  
**sol** – zół  
**cluster** – grupa, skupisko, zbiorowisko

**silicon** – krzem  
**alkoxide** – alkoholan  
**titania** – tlenek tytanu  
**zirconia** – tlenek cyrkonu  
**alumina** – tlenek glinu  
**gelation** – żelatynizacja, żelowanie  
**acid** – kwas  
**alkaline conditions** – środowisko zasadowe  
**evaporation** – parowanie  
**subcritical** – podkrytyczny  
**alkoxy group** – grupa alkoksylowa  
**methacrylate** – metakrylan  
**to disperse** – rozpraszać (się)  
**to encompass** – zawierać,

obejmować  
**ormocer** – skrót: ceramika zmodyfikowana organicznie  
**coating** – powłoka, pokrycie  
**bulk** – masa  
**bead** – kulka  
**acoustic attenuation** – tłumienie dźwięku/hałasu  
**fiber reinforced** – wzmocniony włóknem szklanym  
**blanket** – tu: mata  
**rigid** – sztywny  
**to sinter** – spiec  
**abundantly** – licznie, obficie, hojnie

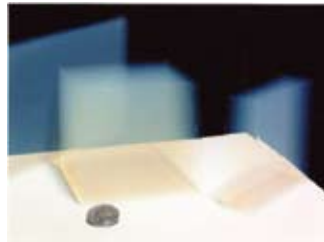
others, urethane aerogels, polyisocyanate, resorcinol-formaldehyde aerogels (RF), polyolefin aerogels, melamineformaldehyde aerogels and phenol-furfural aerogels. Organic aerogels, such as RF aerogels,



are typically made by the condensation polymerization of resorcinol and formaldehyde under alkaline conditions. Xerogels (evaporation of sol-gel solvent), ambigels (evaporation of an alkane solvent) and aerogels (supercritical drying) can be prepared from the gel and the drying conditions determine the final properties of the material. Each type of material involves the formation of a gel and drying of the gel by evaporation, subcritical extraction or supercritical extraction. Xerogels and ambigels are prepared by evaporative drying and aerogels by a supercritical extraction process to preserve the structure of the gel state. Although methods to prepare aerogel-like materials have been

reported using evaporative drying processes, such materials are only aerogel-like and experience higher shrinkages and have higher densities than typical supercritically dried aerogels.

Organic/inorganic hybrid aerogels can be considered to be ORMOSIL (Organically Modified SILica) aerogels. Typically, ormosils are formed through the co-hydrolysis and condensation of organically modified silanes, such as  $R-Si(OR')_3$  and an alkoxide precursors,  $Y(OR')_4$ , where  $OR'$  represents a alkoxy group and  $Y$  represents a metal. The  $R$  group in  $R-Si(OR')_3$  may be any organic group,



such as methyl, ethyl, propyl, butyl, isopropyl, methacrylate, vinyl, etc. The organic components may be chemically bonded to the silica network or be dispersed throughout the material as a second interpenetrating phase. The term "ormosil" encompasses the foregoing materials as well as other



organically modified ceramics, sometimes called "ormocers." Ormosils are often used as coatings where an ormosil film is cast over a substrate material through, for example, the sol-gel process. Ormosil films are not classified as an aerogel since the polymer is not gelled nor supercritically dried.

### Applications

Aerogels can also be classified by their bulk properties. Monolithic, bead, particle, granule, powder, coating, or thin film aerogels are classes of aerogels. Thin film aerogels can be defined as a film less than 100 nm thick while coatings are generally thicker and can be as thick as several millimeters. In general, monolithic aerogels have advantages over thin film, powder, or granular aerogels because they can be used for a wide variety of applications where using thin films or granular aerogels would not be practical. For example, most thermal

insulation, acoustic attenuation and kinetic applications require thicker insulating material than can be provided by films or coatings. Fiber reinforced aerogel blankets have the similar insulating properties as monolithic aerogels but are flexible and can be installed in layers to provide the thickness required for the application.

Aerogels are considered to be the best solid thermal insulators, with thermal conductivities of c.10-15 mW/mK at 100°F and are better insulators than the best rigid foams. They function as thermal insulators primarily by minimizing conduction, convection and radiation. Depending on the formulation, aerogels are excellent cryogenic insulators and can also function well at elevated temperatures up to 550-650°C. At temperatures above 800°C, silica aerogels begin to sinter and rapidly lose surface area and insulating properties as the temperature increases. Aerogel materials also display many other interesting acoustic, optical, mechanical and chemical properties that make them abundantly useful.



## SPECJALISTYCZNE TŁUMACZENIA ZWYKŁE I PRZYSIĘGŁE



AGENCJA  
TŁUMACZEŃ  
SPECJALISTYCZNYCH



KONTAKT  
(22) 852 49 50  
(22) 852 49 55  
www.tts-szkolenia.pl  
WYCENA TŁUMACZEŃ  
biuro@tts-szkolenia.pl

PROFESJONALNIE ■ ODPOWIEDZIALNIE ■ NA CZAS