

Extended Abstract

Reinforcement Strategies of Silica Aerogels for Thermal Insulation Applications [†]

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[†] Presented at the 16th International Symposium “Priorities of Chemistry for a Sustainable Development” PRIOCHEM, Bucharest, Romania, 28–30 October 2020.

Published: 9 November 2020

Keywords: aerogel; silica; mechanical reinforcement; organic modification; silylation; fibers

Silica aerogels are usually known for their distinctive feature of thermal superinsulation. The fine pearl necklace 3D structure of linked nano-sized secondary silica spheres provides an extensive mesoporous network (>90% porosity), 10 times lighter than water and with the ability to avoid the gas-phase heat transfer component of thermal conductivity due to the Knudsen effect [1–3]. Still, this structure is inherently brittle, as expected for a ceramic material, imposing severe constraints on load-bearing applications and the handling of these materials. There are several ways to overcome this “weakness” and reinforcement of the underlying silica structure has been a matter of study that has kept the attention of the scientific community of the field. The main routes are aging methodologies, use of organically modified silanes as silica co-precursors or surface modifying agents, polymers grafting/coating on the silica solid network and use of fibers mats or loose fibers incorporated in the silica matrix. Several reviews of the main strategies to improve the mechanical properties of silica aerogels have been presented in the literature by the authors’ group [1–4], giving, however, more emphasis to the ones tested in project works of the Computation and Materials group (https://www.uc.pt/ctuc/deq/ciepqp/research_groups/cem) of the Chemical Process Engineering and Forest Products Research Centre (CIEPQPF) of University of Coimbra, and always highlighting those which provide superior thermal insulation performance.

Structural reinforcement of silica aerogels with organically modified silica precursors and the introduction of fiber networks are being the main strategies implemented in our projects for improving the mechanical properties of these materials [5,6]. In order to reduce capillary forces and, thus, the shrinkage during evaporative drying of aerogels, an extra silylation step is accomplished in the hydrophobization of the network (substitution of -OH groups of silica by -O-Si(CH₃)₃ groups). Moreover, this surface state prolongs the service life of these hybrid/composite aerogels, since when hydrophilic they exhibit degradation upon exposure to moisture.

Achievements of AerogelDustFree and AeroXTreme projects in terms of novel reinforced and thermal insulating silica-based aerogels are presented in literature [5,6] and summarized in Figure 1 regarding the best systems, and showing the aspect of these materials and their structural/physical and thermomechanical properties.

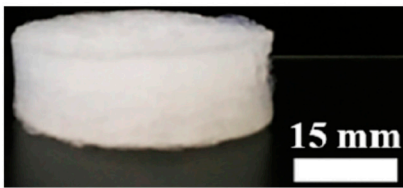
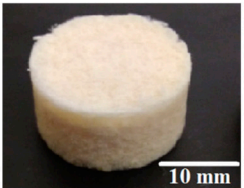
		
	15 mm	10 mm
Silica precursor system:	TEOS/VTMS	TEOS/VTMS
Reinforcement fibers:	Silica mat	Aramid pulp
Silylating agent:	HMDZ	HMDZ
Bulk density (kg m^{-3}):	125 ± 1	214 ± 8
Porosity (%):	93	81
Specific surface area ($\text{m}^2 \text{g}^{-1}$):	762 ± 10	620 ± 6
Thermal conductivity ($\text{mW m}^{-1} \text{K}^{-1}$):	22.9 ± 0.3 (Hot Disk®)	27.9 ± 0.8 (Hot Disk®)
Young's modulus (MPa):	0.06	1.8
Contact angle ($^\circ$):	146 ± 11	156 ± 8

Figure 1. Aerogels from AerogelDustFree (left) and AeroXTreme (right) projects (TEOS—tetraethyl orthosilicate; VTMS—vinyltrimethoxysilane; HMDZ—hexamethyldisilazane).

Acknowledgments: The presented results were obtained from work developed under the projects: (1) AeroXTreme (CENTRO-01-0145-FEDER-029533)—High-performance silica aerogel nanocomposites for insulation under extreme temperature space environments, co-funded by Foundation for Science and Technology (Portugal) and the European Regional Development Fund (ERDF), through the Regional Operational Program of the Center of Portugal (Centro2020); (2) AerogelDustFree—Aerogel for Space applications ISO8 without dust release, Contract No 17815, developed by the consortium Active Aerogels/University of Coimbra, funded by ERDF through the Operational Program for Competitiveness and Internationalization & Centro2020.

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