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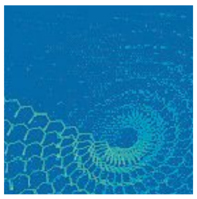

Polymer and Colloid Highlights

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Mesoporous, Colloidal 3D Materials – Trends and Opportunities in Silica Aerogel

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Aerogels are colloidal, open porous, low-density solids classically obtained by sol-gel chemistry and supercritical drying. Originally invented in the 1930s by Kistler,[1] they are currently experiencing a tremendous revival fueled by recent commercialization efforts and a rapidly growing field of applications. Although many colloidal compounds can be obtained in aerogel form, silica is the most widely studied material[2] and the only class of aerogel available in bulk quantities by commercial suppliers.

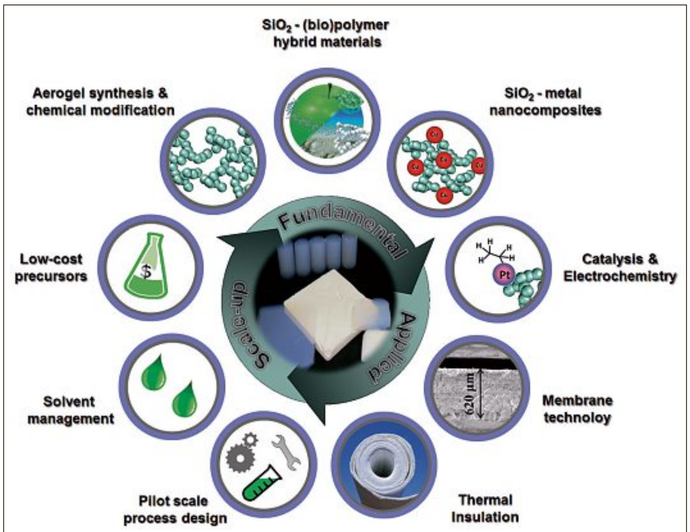

Fig. 1. Silica aerogel science platform and main R&D activities.

Current state-of-the-art research on silica aerogel materials can be classified into three areas, namely i) fundamental research, ii) applied research and iii) scale-up and manufacturing (Fig. 1). Many fundamental research questions of silica aerogel synthesis and chemical modification have been adequately understood,[2] but there remains a need to further advance our understanding of the impact of various synthetic conditions on the final product properties. This is best achieved by carrying out systematic parameter studies which focus on understanding a single process step, for example gel aging or hydrophobization (chemical modification of inner gel surfaces by trimethylsilyl TMS groups).[3] Such an in-depth know-how of individual process steps is essential to develop new process technologies that enable low-cost production. Cost reduction of aerogel materials is essential for this niche industry as there are now first signs of growth slowing down due to the prohibitively high price. Economic industrial aerogel production processes use low cost precursor chemistries, minimize the production time and solvent use and maximize the ability for solvent recycling.[4]

With more effective production technologies underway, we expect a far broader impact of aerogel materials in our daily lives. Aerogel-based thermal superinsulation requires only half the material thickness of conventional insulation and can transform how buildings and industrial installations are insulated. Yet from an applications perspective, there is still significant room for improvement. Today's products tend to be dusty and are mechanically weak. Thus, mechanical strengthening while maintaining the extraordinary thermal performance is an active area of research, for example through the formation of hybrid gels of silica and (bio)polymers such as chitosan or pectin.[5] In addition, new applications arise from the combination of silica gels with metal nanoparticles, which gives access to finely dispersed nanoscale metallic phases on a mesoporous carrier. Such silica nanocomposite hybrid aerogels are being investigated as active materials for a wide range of technical and energy related applications such as heterogeneous catalysis,[6] host matrix for liquid electrolytes in Li-ion batteries[7] or motionless, thermally powered Knudsen pumps[8] to mention just a few examples.

The ability to innovate the next generation silica aerogel-based solutions, *i.e.* to not only invent but also commercialize them, requires an open minded research approach and an efficient interplay of chemical, materials and engineering sciences. Fundamental research on aerogel chemistry using advanced analytical techniques applied to old problems feeds into applied research and enables efficient scale-up of trendsetting materials.

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