Aerogels & Composites: From Concept to Applications

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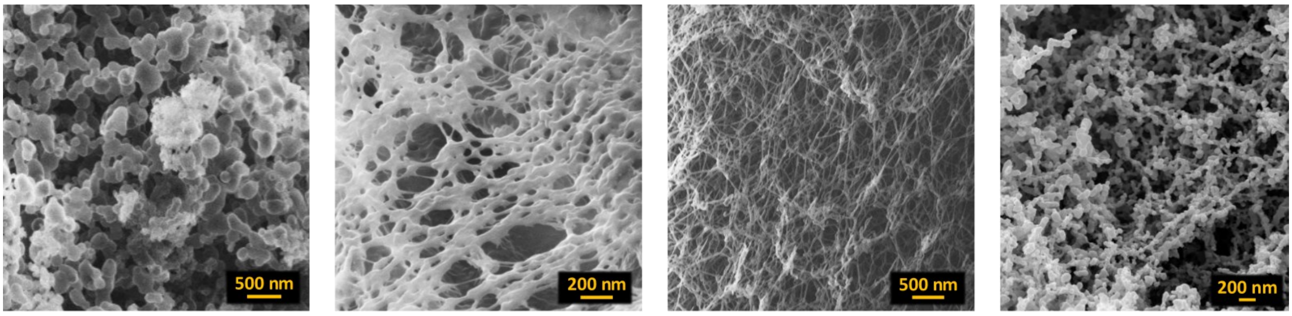
Abstract

This work focuses on introducing a new concept for generating aerogel powders and fibrils based on a disruptive patented technology[1,2] which does not require the gelation, nor cross-linking of polymers, nor time-consuming solvent exchange steps. The technology is called Pressurized Gas eXpanded liquid (PGX) Technology and utilizes supercritical CO_2 expanded ethanol to precipitate polymers from aqueous solutions, while also removing the water from the formed porous morphology to ultimately form aerogels.

PGX Technology offers several key advantages over conventional drying and purification technologies. It can be used to quickly process one or several temperature-sensitive, high-molecular-weight, water-soluble biopolymers. PGX Technology is ideally suited to make high-value, ultra-light, open-porous, homogenous, fine-structured polymer aerogels[3-8] (Figure 1) on a semi-continuous basis, which is not possible using today's conventional technologies.



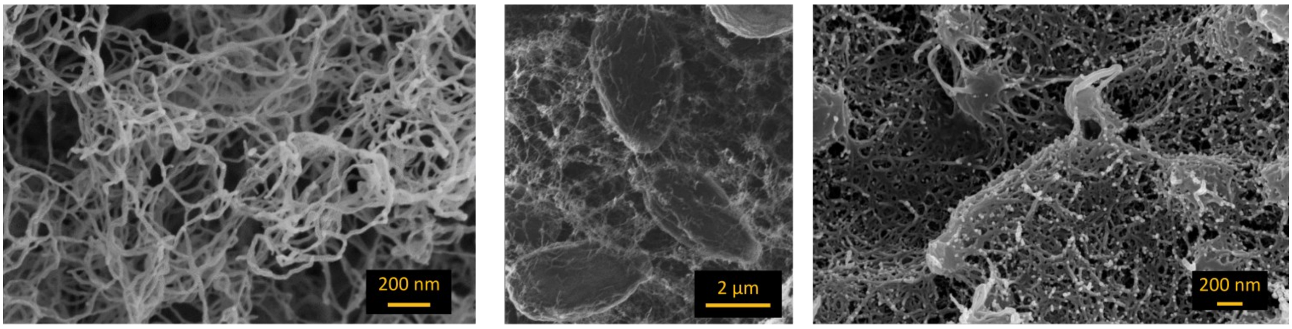
(a) (b) (c) (d)

Figure 1. Helium Ion Microscope images of aerogels produced by the PGX Technology. (a) Gum Arabic (65 m^2/g), (b) Oat β-glucan (24 m^2/g), (c) Sodium Alginate (164 m^2/g), (d) Corn Starch (17 m^2/g).

To conduct PGX Technology processing, an aqueous polymer slurry or solution is injected together with a gas expanded liquid (SC-CO_2 + Ethanol, the PGX fluid), typically at 40°C and 100 bars, through a coaxial nozzle into a collection chamber. The polymer is rapidly precipitated, and water is removed with the PGX fluid by gradually changing its composition while avoiding the two-phase region.

The PGX Technology also facilitates the generation of novel bioactive aerogel composites. For that purpose, aqueous polymer solutions or suspensions can be simply mixed, at any polymer ratio, prior to PGX processing. This can lead to the generation of many different morphologies and composites. For instance, the resulting aerogel can consist of intertwined fibrils, as it is the case when an aqueous solution of both pectin and alginate is PGX processed (Figure 2a). However, when PGX processing an aqueous mixture of water-soluble or dispersible polymers (*e.g.* sodium alginate and nanocrystalline cellulose[5]) with non-water-soluble particulate material (*e.g.* yeast beta glucan ghost cells and Polyhydroxybutyrate beads), the resulting aerogel is an exfoliated nano-composite (Figure 2b, Figure ***2***c).

During this presentation, we will illustrate that PGX aerogel fibrils and composites can be shaped into flat sheets or thin strips (Fig. 3, left) maintaining the porous structure (Fig. 3, right), and loaded with bioactives utilizing adsorptive precipitation[3] for generation of novel nutraceuticals[4,6], drug delivery, or wound healing applications[7]. While PGX Technology does not require cross-linking, nor gelation of polymers to generate porous structures, this can also be implemented. For example, PGX sodium alginate aerogels can be cross-linked after shaping the aerogel and loading drugs to form hydrogels with tunable drug release profiles[7].



(a) (b) (c)

Figure 2. PGX processed aerogel composites: (a) Sodium Alginate and Pectin, (b) Sodium Alginate and Yeast Beta Glucan ghost cells, (c) Nanocrystalline Cellulose and Polyhydroxybutyrate.

Figure 3. Fast dissolving strips (size 2x3 cm) made from PGX Sodium Alginate aerogel, the specific surface area of the strips is tunable ranging from about 100 to 200 m^2/gram - shown strip has 5 m^2 - (left). The open-porous structure is maintained in the strip (right).

Besides providing the basic concepts of the PGX Technology, the presentation will feature many of the possible aerogels that have been successfully processed so far spanning from single component aerogels to multicomponent aerogel composites and exfoliated nano-composites. Finally, some of the possible applications currently under development will be presented, including wound healing dressings, nutraceutical oral strips, and bioactive delivery systems.

References

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