Novel circular economy business model of high-added value products for energy efficiency: from C&DW to aerogels

F. Ruiz-González[1], D. Nadargi[1], K. Philippe[1], E. Goiti[2], M. Ocejo[2] and I. Vegas[2]

[1] KEEY Aerogel SAS, 68440 Schlierbach France, Phone (+33) 389 390 078;
E-mail: francisco.ruiz@keey-aerogel.com
[2] TECNALIA R&I, Parque Tecnológico de Bizkaia, 48160 Derio Spain

Abstract

Since the Industrial Revolution, humanity's use of natural resources has been basically the same: TAKE, MAKE and THROW AWAY; which consequently led to the indispensable problems of waste materials. Around 461 million tons of Construction & Demolition Waste (C&DW), excluding excavation materials, are yearly generated in EU28. This undoubtedly gives a call to novel closed-loop circular business models which reshape the Eco-system in a way the waste is 'designed out'.

Here, we present a novel closed-loop circular economy model of a high-performance building insulation material from silica containing C&DW materials to silica aerogels with $\lambda \approx 0.015$ W/mK. In the present model, the benefit comes with the use of massive construction waste to a silica precursor and thereby aerogel production guaranteeing at least 40% product cost reduction and 40% reduction in energy consumption in real construction environment.

Keywords: C&DW, aerogel, circular economy, energy efficiency, thermal insulation.

Introduction

Buildings account for almost a third of final energy consumption globally and are an equally imperative source of CO_2 emissions. Around 461 million tons[1] of construction and demolition waste (C&DW), excluding excavation materials, are yearly generated in EU28. Recent studies[2] on the characterization of diverse C&DW samples at European level revealed that the predominant material constituent is concrete with an average value of 52%. The most advanced concrete recycling technologies currently produce upgraded coarse (>4mm) recycled concrete aggregates. However, the fine fraction (0-4 mm), accounting for roughly 40% of the recycled concrete, still faces technical barriers to be incorporated into new concrete and consequently, it is often down-cycled. In global terms, C&DW streams have not yet found technological and business solutions along with their whole circular supply chain, being mostly landfilled. On the other hand, the market for aerogels (the most effective materials known for thermal insulation) as building-insulation materials remain largely underdeveloped due to the high cost of precursor (~80%) associated with industrial scale production. Thus, price is clearly the biggest entry barrier of this material in the building sector.

Therefore, in the present emphasis, both energy consumption and CO_2 emission reductions can be achieved by a novel closed-loop circular economy model of a high-performance building insulation material from silica containing C&DW materials such as recycled siliceous concrete sand, recycled building glass, recycled mineral wool to silica aerogels whose thermal conductivity values is nearly 0.015 W/mK. Aerogels are nanoporous materials with the best thermal insulation performance in ambient conditions. This way a new value chain is created by expanding the size and attractiveness of C&DW recycling and reuse for energy-efficient buildings construction and refurbishment, as shown in Figure 1.

Figure 1. Schematic of closed-loop circular economy business model of high-added value products for energy efficiency.

Description of the concept and the product

The in-line production system integrates the following three steps:

1. Low cost water-glass based precursor production by using silica containing C&DW recycled materials. Using hydrothermal technology is highly efficient silica extraction obtained from silica rich C&DW (Cost reduction over 60%). This process is successfully applied to different natural and alternative silica-rich materials such as quartz sand, glass waste, foundry sands, fume silica and the own aerogel.
2. Gelification/Formation of wet gel by sol–gel chemistry. As a result of hydrolysis and condensation process of the as developed silica precursor, a nanostructured solid network is formed. Aging processes are applied to strengthen the solid skeleton of silica.[3] The silica aerogel will be produced in different forms (granular and impregnated blankets).
3. Drying process/Low Temperature Super Critical Drying (LTSCD). LTSCD is recognized as the most environmental suitable and adequate process to obtain high quality aerogels. Based on recent fundamental knowledge on effective binary diffusion, a continuous multi-solvent LTSCD process has been developed and validated, which shortens the drying cycle up to 40%. This time reduction entails two direct benefits: high reduction of OPEX (by reduction of energy consumption and used solvents) and the reduction of CAPEX by increasing production rates at fixed volumes.

Proof of concept

Realization of the business model is accomplished by the proof-of-concept of the manufacturing and performance at pilot scale. The idea was firstly executed at laboratory scale with positive and promising results: silica rich recycled concrete aggregates of 0-4mm size range were employed for the synthesis of high quality water-glass which was gelled and dried leading to aerogel samples. Following Figure 2 (a) shows the pilot scale LTSCD process and high-added value product (aerogel granules). Figure 2 (b) highlights the results of different process to obtain the gel at lab scale. The current emphasis is on going to is to implement and test the concept in a continuous manner at pilot scale.

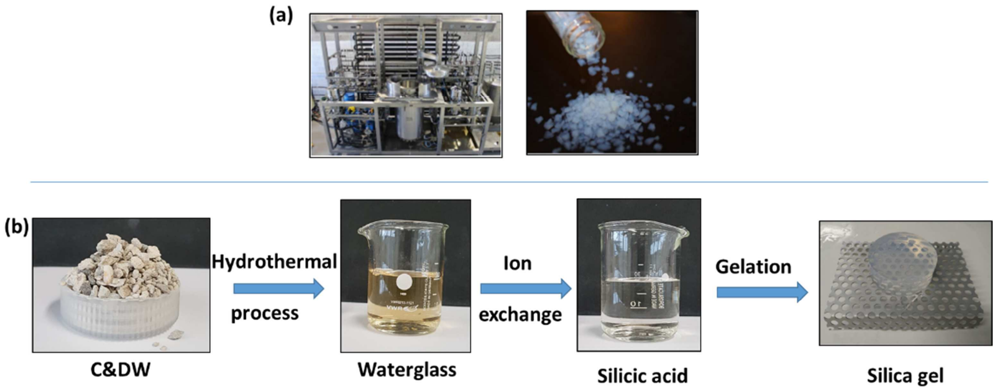

Figure 2. a) Pilot Plant for LTSCD process (left) and manufactured granular aerogel product (right), b) the process to get the gel at lab scale.

Market

New regulation in energy efficiency of new and existing buildings will be imposed in EU28 in 2020. In consequence, thermal insulation and renovation market (over 1,500 billion €. in 2015) will require an improvement in their product portfolio. This "energy efficiency transition is being recognized by the price of performance. In 2014, production of prefabricated components for building or civil engineering has started to grow significantly. As a result, the EU-28 market has reached a value of 24 billion Euro[5]. Out of this figure, 25% is estimated to be the market share of precast concrete insulated wall panels in Europe, which results in a market of 6 billion Euro. Driven by the aforementioned drivers, this market is expected to grow in the next years in order to meet the targets established by Europe for carbon emissions reduction and energy efficiency increase of the building stock.
Within this framework, as produced cost-effective aerogels will be able to compete with current commercial insulation materials for being used in precast concrete insulated wall panels providing superior thermal insulation performance. The main selling point lies especially in the high thermal insulation performance with significantly lower thickness. This position the product as a valid alternative not only to precast concrete insulated wall panels, but also to ETICS (External Thermal Insulation Composite Systems) solutions, plasters, cavity insulation, etc.

Conclusion

In conclusion, the novelty herein comes with the use of massive construction waste to manufacture and integrate high-added value products for energy efficiency. To the date, no technology exists to develop aerogel materials from C&DW. Therefore, novel circular economy business model of high-added value products for energy efficiency is foreseen. The obtained thermal conductivity of as produced aerogels is very low, $\lambda \approx 0.015$ W/mK. New technology will reduce over 40% of manufacturing cost, allowing aerogels to be cost-competitive compared with standard products.

Acknowledgement

The authors gratefully acknowledge for the financial support of this work to European commission through EU project VEEP-723582, "Cost-Effective Recycling of CDW in High Added Value Energy Efficient Prefabricated Concrete Components for Massive Retrofitting of our Built Environment" and to the Spanish Government through Ministerio de Economía y Competitividad and Fondo Europeo de Desarrollo Regional (FEDER) BIA2015-65558-C3-2-R (MINECO/FEDER).

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