BRIEFING No.3

CONSTRUCTION

NANO-ENABLED INSULATION MATERIALS

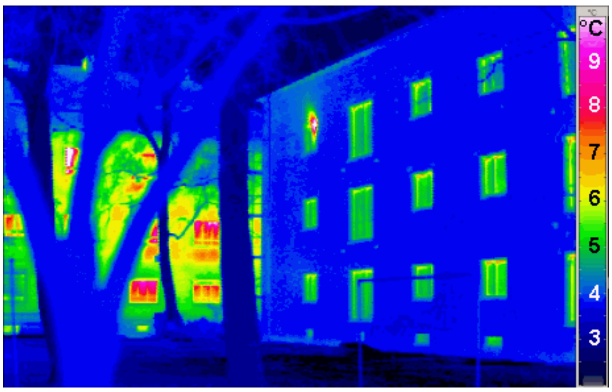
This Briefing provides an overview of the building insulation market, and how nanotechnology is contributing to it. Through nano-porous materials, nano-coatings and nanoparticle enhanced paints, nanotechnology can help society to save energy, and increase comfort and wellbeing within buildings.

The construction sector is the largest energy consumer (40%), and the main contributor to greenhouse gas emissions (GHG), at over 36% in the EU[1]. Around 80% of construction-related energy consumption and GHG emissions is linked to the energy use within the building over its lifetime, whereas only 20% is linked to energy used to produce and transport the materials used in the building. A breakdown of the building use energy consumption shows that heating, ventilation and air conditioning (HVAC) accounts for approximately 36%. As a result, HVAC represents some 10% of EU's energy consumption and greenhouse gas emissions[2].

However, buildings are generally long-lasting, with average lifetimes of greater than 60 years. This makes it difficult to drastically improve the energy efficiency performance of the entire European building stock only through applying superior insulation and thermal management technologies to new buildings. To have a substantial impact within a shorter (10-20 year) timeframe, existing buildings must be upgraded (retro-fitted) in terms of their thermal performance.

Nanotechnology adds value

Currently most building insulators are relatively thick panels or foams made of organic and inorganic porous materials such as fibreglass, mineral wools, polyurethane, and polystyrene, among others. Less traditional insulators include Vacuum Insulation Panels (VIPs) and aerogels, the top performers in the building insulation field, with very high insulative performance, yet with several limitations and high costs.



Thermogram of a Passivhaus building, with traditional building in background - Source: Passivhaus Institut

In order to insulate a building to high standards with commonly used insulation materials, thick layers of these materials are required. For example, a house built according to the Passivhaus standard, which includes a requirement for total energy consumption of less than 120 kWh/m^2/yr, will typically require insulation layers thicker than 30cm in the walls and 50cm in the roof, and triple-pane insulated glazing with air-seals and special window frames[3].

For new buildings these insulation solutions may be relatively feasible, but in the case of existing buildings aspects such as façade modification and reduction of inner square metres can drastically limit their adoption. Considering that 80% of the future 2030 building stock in Europe already exists today and that 30% of today's existing buildings are historical buildings, new solutions specifically designed for existing buildings are required.

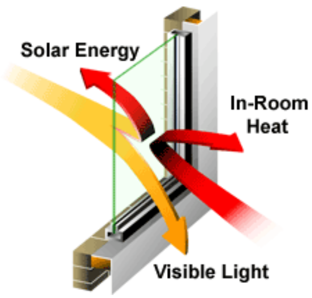
Nanotechnology is enabling the development of novel insulating materials with very high specific insulative performance that can achieve equivalent results to traditional products but with substantially lower thickness, making them very attractive for building retrofitting; examples of these nanomaterials include aerogels, nano-foams and window coatings. However, the high cost of these materials presently limits their adoption.

How does nano help here?

As a general rule denser materials exhibit poorer insulation performance; in porous materials a larger pore size also equates to greater heat transfer and poorer insulation. Nanoporous materials such as aerogels have the lowest known density of any existing solid, in addition to a nanoscale pore size, and therefore act as excellent insulators.

Other nanotech-enabled insulation materials include coatings and paints. These materials are especially effective in reducing the radiation-related heat transfer. Every material emits, absorbs and reflects radiant energy; low emissivity materials are materials that emit low levels of radiant energy.

Low emissivity glass has a very thin coating, usually, but not always, made of metal, which reflects thermal radiation or reduces its emissivity, reducing heat transfer through the glass. In winter, radiant heat generated indoors is reflected back inside, while in summer, infrared heat radiation from the sun is reflected away, keeping the interior cool. There are two main production methods for low emissivity coated glass; hard coat involves using atmospheric pressure chemical vapour deposition (APCVD), and soft coat involves the magnetron sputtering vacuum deposition (MSVD) method. An MSVD coated glass offers higher performance than an APCVD coated one; however, the latter is more durable.



Window films are also an interesting alternative to reduce the heat transfer in windows. These films present some advantages when compared to coatings, as they are able to reflect specific wavelengths of light, without reducing the transparency of the glass. These films are made of 200+ nano layers of polymer that act as a filter to ultraviolet (UV) and infrared (IR) light. The main benefits of these films are: their ability to filter UV and IR light while allowing visible light to pass through; the absence of metals that potentially lead to corrosion; and the fact that they can be installed in any existing building. In addition, the embodied energy in window films is substantially lower than that in new low emissivity windows, which means that the CO_2 balance of adding window films to existing windows is substantially better than that of the alternative scenario of replacing existing windows for low emissivity versions.

Impacts

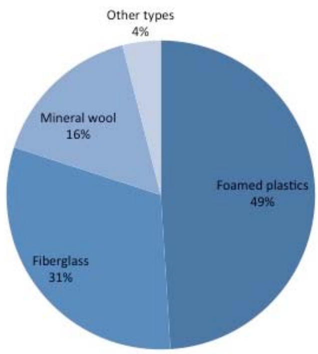
Economic/Industry

At present nanotechnology has a very small business value in the insulation (thermal management) of buildings. Truly nano-enabled products commercialised today are high value, high cost, niche products such as aerogel enabled rooflights or vacuum panel insulation installed in a small number of pilot buildings. However, the sector is clearly growing; the global market for aerogels accounted for $82.9 million in 2008 and is expected to reach $646.3 million in 2013 with a compound annual growth rate of 50.8%[4]. The market is expected to be driven by thermal and acoustic insulation applications. Today, the biggest markets for these nano-enabled insulation materials are found outside of the construction industry: in insulation of deep sea gas and oil pipes; in medical devices; and in the space industry. Some key suppliers of aerogels include Aspen Aerogel Inc (USA) and Cabot (USA).

This is not true for nano-enabled thermal management window coatings, which by now have reached significant market penetration in the high performance flat glass markets and the window film market. Most large flat glass suppliers in the world offer thermal management functionalized glass varieties (Asahi, Pilkington, St Gobain) involving (often nanoscale thickness) metal and/or metal oxide coatings; however, several of them (alone or in collaboration with coating specialists like Beneq (FI), Ferro (USA) or Arkema (FR)) are developing more complex nanotech coatings that offer more tailored performance and wider range of available colours. Low emissivity coatings for flat glass worldwide today represent a $1 billion market, with demand estimated to reach 360 million m^2 by 2015[5].

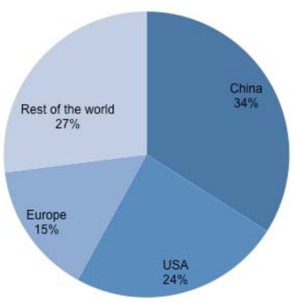
In addition the window film market dominated by players such as Global Window Films (USA), 3M (USA), Bekaert (BE) or Hanita Coatings (ISR) must be considered. The total value today is estimated at some €500 million[6], of which only a part is building glass (the other main market being automotive) and of that, only a very small part is nano-enabled. The main functionality offered by nanotechnology is that of allowing thermal reflection without blocking the entry of light, and/or the ability to have any colour for the windows rather than just one (often mirror like) colour determined by above-nano coating layers.

To provide context, global demand for insulation materials as a whole is expected to expand by 3.8% annually to reach €29 billion by 2012 (see chart).

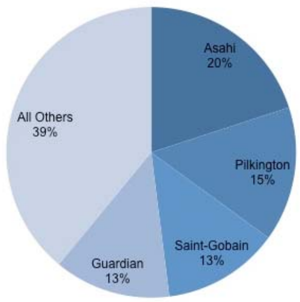


CONSTRUCTION: Nano-enabled Insulation Materials

The annual global demand of flat glass is estimated to grow at 4% reaching $73 billion by 2012. More specifically, glass for architectural uses is expected to grow by 8% annually. Flat glass for construction purposes accounts for 65% of the global annual demand, while the automotive sector represents 25% of the market, and the remaining 10% corresponds to speciality uses such as furniture and mirrors.



Flat glass world demand (tonnes)



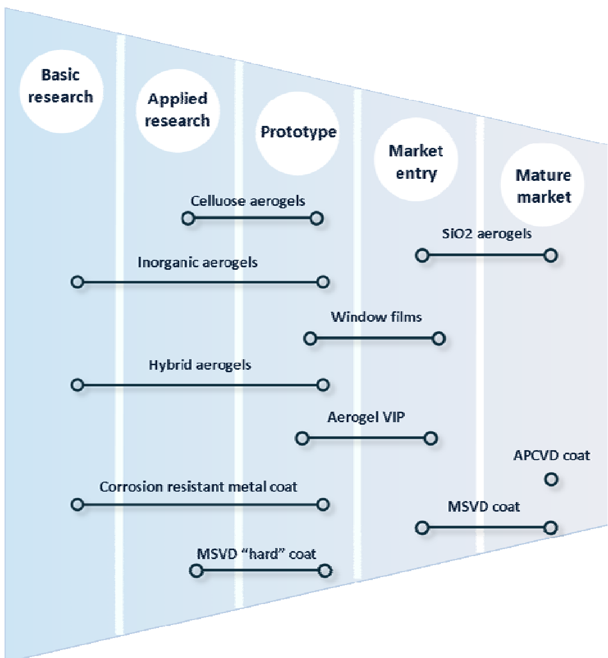
World floating production capacity

Global demand and production is centralised in a few countries and companies, as shown below; Saint-Gobain, Pilkington and Asahi dominate nearly half of the global market.

To adopt nanotechnology, manufacturers of insulation materials such as foams and panels would necessitate completely new machinery and skills. For manufacturers of windows it would require adding new machinery to their current production lines. Both groups of manufacturers say that they would need workers that are skilled in these new fields, and that new handling and safety measures would also need to be implemented.

Technology Readiness Levels

Different nanotechnology-enabled materials are in different stages of development (*see below*).



Societal/Impact on European Citizen

Through the adoption of nano-enabled insulation products, EU citizens will be able to achieve a drastic reduction of the energy consumption of their homes, especially in those buildings that cannot realistically be insulated due to aesthetic or space-loss reasons. Experts claim that for existing buildings, reductions from the current 300 kWh/m^2 to 50 kWh/m^2 per year are achievable. These reductions become increasingly important when fuel prices are expected to rise significantly in the coming years. When it comes to comfort, inhabitants will enjoy a better indoor environment, as temperature gradients are almost eliminated, although mechanical ventilation could be needed. Additionally, the relatively large capital investments needed to insulate a building to high standards is compensated by an increase in the value of the property.

On a societal level, the main impact of nano-enabled insulation solutions is the reduction of GHG emissions through the reduction of HVAC-related energy consumption especially by existing buildings.

Challenges

Aerogels available today in the market are mostly inorganic aerogels; the most common being made of silica. The limitations of these aerogels are their brittleness, poor humidity resistance, and expensive production process. Due to these limitations, new developments in the field of aerogels tend towards hybrid or organic aerogels, and towards novel production processes. Organic aerogels are less brittle, have better mechanical properties, are even lighter than their inorganic counterparts, and perform better as thermal insulators; however, their development is considered to be at an early stage. Hybrid aerogels are organic-inorganic hybrid materials that offer superior characteristics when compared to inorganic-only aerogels. Depending on the materials combination, hybrid aerogels can be up to 100 times more resistant to mechanical stress, can be inert against humidity, and can perform as an effective barrier against thermal radiation. The challenge in this field is to find ways to produce hybrid and organic aerogels at relatively low costs and in large volumes.

The production process of aerogels consists of two main steps: the fabrication of a gel penetrated with solvent, and the removal of the solvent by a specific drying process. Today the most common drying process is supercritical drying, which is an expensive (and energy intensive) fabrication method. In this respect, the challenge now is to develop a subcritical drying process for mass production; this is an economical drying process that can be achieved at atmospheric pressure and at relatively low temperatures.

A main challenge for coatings is to make magnetron sputtering vacuum deposition (MSVD) glass coatings more resistant. Some developments are being achieved in this respect, but APCVD coatings are still the most resistant. A challenge for both hard and soft coatings is to improve the resistance to corrosion mainly due to the inclusion of metals in their composition.

An important policy issue to address is the financing of the investment required to improve energy efficiency as in many cases the builder or owner (and thus investor) of a building is not the beneficiary of the energy savings generated

EU Competitive Position

For window coatings, Europe has a strong position with some small high tech players (like Beneq or Peer+) who are partnering with big global players. Additionally some large EU based players are found including Arkema and BASF. For nano-enabled flat glass, the presence of Pilkington, St Gobain, and Asahi Glass Europe provide EU based research activities and the capability to bring the results of such research to the market.

In Europe, research on nanofoams and aerogels has up to now been below critical mass, despite the collaborations initiated during the Framework Programmes, never reaching substantial markets or mature large volume production capability. However, recently several large chemical industries have increased their interest in these materials, focussing on more robust and less costly polymer nanofoams (also referred to as organic aerogels) and seeking lower cost production routes.

For window films, Solutia, Bekaert and 3M are probably the global leaders; of these Bekaert has its headquarters in Belgium.

EU funding has only recently begun to address the opportunities found here, awarding funding to some projects in recent FP7 calls. Given the size of the market opportunity and the societal relevance of successful research it seems justified to enhance such EU support on research that can overcome key challenges.

From an industry perspective, key companies include Cabot (USA), TAASI (USA), Nanopore (USA), Branch Tech International (USA), Aspen Aerogels (USA), Aerogel Composites (USA), MarkeTech (USA), 3M (USA), DuPont (USA), Arkema (France), BASF (Germany), Beneq (Finland), Bekaert (Belgium), Hanita Coatings (Israel), Solutia (USA) and Research Frontiers, Inc (USA).

Summary

- For nano-enabled insulation materials, the present position of the EU is weak compared to the strong field of US-based industries, though some have production capacity in Germany (Cabot Aerogels). However, the EU chemical industry has the ability and the strategic intent to develop and commercialise organic nanofoams, which are expected to reach the market between 5 to 10 years from now.

- Concerning window coatings, several window players as well as their coating technology suppliers are based in Europe, thus playing a leading role in this business. A similar situation is found in nano-enabled window films; there is at least one global leader based in Europe and the strategic intent and scientific potential to build upon this position. From the academic perspective, few universities or other public research institutes can be identified that show a strong research track record in these specific areas.

- The combined societal impact of nano-enabled low emissivity windows (and window films) combined with that of nano-enabled polymer (or hybrid) foams for building insulation is potentially very large, offering a realistic solution for the existing building stock that will require refurbishment to much higher energy efficiency standards in the future. The ability of EU industry to achieve acceptable cost levels for nano-enabled products will determine whether or not this potential is turned into reality.

Contact

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