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NANO INSULATION MATERIALS FOR ENERGY EFFICIENT BUILDINGS

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Abstract: The advanced thermal insulation materials and solutions for improved thermal resistance have been receiving an ever increasing attention due to their significance for sustainable building. Reducing energy consumption and CO_2 emissions by development and deployment of sustainable construction technologies, systems and materials in new and existing buildings will be key to addressing the challenge of a transition to nearly zero-energy buildings in Europe by 2020. Nanotechnology promises to make thermal insulation more efficient, less reliant on non-renewable resources as an important strategy on the pathway to green buildings. The application of nano insulation materials to limit the wall thickness is one of the greatest potential energy-saving characteristics for the existing buildings, as well as for the architectural heritage.

This paper examines the potential advantages of using nanotechnology-based high-performance thermal insulation materials in reducing the life cycle energy, reduction of material usage and enhancing the life span of buildings.

Keywords: thermal insulation, materials, nanotechnology, energy efficiency, buildings.

1. INTRODUCTION

The building sector is responsible for a significant part of global energy consumption, greenhouse gas (GHG) emissions and the generation of solid waste. The Intergovernmental Panel on Climate Change (IPCC), the leading international body for the assessment of climate change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), reports that buildings represent the largest energy-consuming sector with nearly 40% of global electricity consumed, and as a result, they are also responsible for about 36% of global carbon emissions (CO2), mainly due to inefficient thermal insulation systems. While the building sector is still developing, energy consumption will continue to increase. The European Union has also recognized that after the energy sector, construction is a large untapped potential for energy savings in both new and existing buildings.

In order to secure new sources of energy and to reduce greenhouse gas emissions, Europe and the world are focused on increasing the use of renewable energy sources and on improving the energy efficiency, primarily in buildings. The European Union has designated the year 2007 as a turning point in its energy and climate policy and thus became a global leader in meeting the challenges of ensuring sustainable and competitive energy by way of mitigating climate change. The EU has adopted the so-called 2020 climate & energy package as a set of binding legislation with three key targets by 2020: 20% cut in greenhouse gas emissions (from 1990 levels), an increase of 20% renewable energy from renewables in total energy consumption and 20% reduction in consumption energy than the one which is expected, in a worst case scenario, in the case of non-implementation of special measures by 2020 [1].

Considering that the building sector is a particularly large potential for energy savings, the European Commission adopted the 2011 Plan for Energy Efficiency [2], and then a unique Directive 2012/27 / EU of the European Parlia-

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ment and of the Council of 25 October 2012 on energy efficiency was passed as a strategy for energy development in the fight for climate change mitigation [3].

A continuous increase in the price of fossil fuels and the fact that these energy sources are limited, along with the development of environmental awareness and ethics, contributed to the energy optimization of buildings becoming a basic assumption in the overall energy efficiency. Various analyses show that, depending on climate conditions, up to 60% of total energy consumption in buildings is required for heating and 8−15% for cooling and ventilation.

The benefits of energy efficient buildings are numerous. They are most evident in financial savings, but also in a better thermal comfort and longer buildings lifecycle. At the global level, the benefits include preserving natural resources, reduction of harmful gases emission and thus the climate change mitigation. Therefore, the task, which is now set as a priority, is to solve the optimal energy concept of a building and the satisfaction of „3E" formula: energy − economy − ecology.

Previously, on 16 December 2002, the European Parliament and the Council of the European Union, adopted the first Directive 2002/91/EC on the energy performance of buildings [4], which identified the minimum requirements for new and existing buildings: thermal insulation, heating systems, cooling and ventilation, use of renewable energy, as well as the method of calculation of energy efficiency of buildings with the introduction of the energy performance certificate for buildings. It has been replaced with a new *Directive 2010/31/EU on the energy performance of buildings* [5], which, as a realistic solution for reduction of total energy consumption and CO2 emissions, prescribes more stringent commitments to increase energy efficiency of buildings. Compared to the previous passive building standard a much more ambitious concept of nearly zero-energy buildings, was introduced, which requires that from 31 December 2018 new buildings occupied and owned by public authorities must be nearly zero-energy, and from December 31 2020 all new buildings must be nearly zero-energy. A nearly zero-energy building is defined as building that has a very high energy performance, consumes very small amount of energy for heating, cooling, ventilation, air conditioning, hot water and lighting. In these buildings nearly zero or very low amount of energy required should for the most part be covered with the energy from renewable sources, including those produced on-site or nearby. Considering the long life-cycle, both new and existing buildings, should meet the minimum standards when undergoing major renovations. Member States may decide not to determine or implement these requirements for buildings which are officially protected or because of their special architectural or historic significance, but they should fulfill certain minimum requirements of the energy performance with unacceptable changes of their character or appearance, as well for buildings used as places of worship and for religious activities. The Directive lies down that Member States should take the necessary measures during major reconstruction of buildings, to ensure improvement of their energy performance in order to meet the minimum requirements for their energy efficiency. The objective of these prescribed measures is zero emission of greenhouse gases during the life-cycle of the building observed through three main phases: 1. the phase of construction - the building material and construction of a building; 2. use phase of the building and 3. repairs, recycling, demolition and management of construction and demolition waste.

More than towards the programs for energy efficient new buildings, the European Union is now more oriented towards the energy renewal of the existing buildings whose condition and proportion presents the greatest potential for energy savings, but also as a part of the modern concept of urban renewal within the sustainable development strategy. The proposed measures for improving the energy efficiency especially in this segment include: reduction of heat loss by improving the thermal protection of the building; increasing the efficiency of heating, ventilation and air conditioning; increasing the effectiveness of lighting and appliances, and the energy control and management.

The selection of energy, environmentally and economically optimal system involves the physics of a building, energy and process of the energy used, which play a key role in the exploitation of the building in terms of costs, but also of impact on the environment. Namely, in addition to energy for production of building materials and for building construction, an important aspect of energy efficiency implies the use and maintenance of the building, which is why it is necessary to explore the possibilities of reducing energy consumption with passive and active energy systems. An integrated solution must primarily include the systems of building envelope thermal protection, because these include the greatest heat loss.

An adequate thermal insulation is achieved by using building materials of low thermal conductivity, i.e. high thermal resistance, and by avoiding thermal bridges. Thermal rehabilitation of existing buildings represents a particular challenge in the construction sector. Measures of introducing renewable energy sources (solar and wind) in new construction are expected today, but they are far less profitable than installing modern thermal insulation, and for the existing building, it is usually the only way to increase their energy efficiency. Particularly significant is a sensitivity of architectural heritage, where the installation of thermal insulation is a necessary compromise between the conservation interests and a need to increase energy efficiency. In general, rehabilitation and restoration measures should not be applied without taking into consideration the unique needs of historic properties. Searching the right balance between preserving the authenticity of a building and improvement of thermal insulation should be based on the principles and theoretical platforms of official doctrine of protection of architectural heritage, expressed through international standards, charters and declarations, and on the other hand should try to establish satisfactory physical characteristics of the building according to the modern norms and standards. In the area of conservation, the main emphasis is on the shapes and materials visible from the outside (walls, roofs, windows and doors).

Although the EU directives and the national legislations derived from them are not obligatory, the opportunities to increase energy efficiency in the buildings of historical and architectural interest are not to be missed, especially with regard to the architectural heritage of lower categories. It should be taken into account that historic buildings are specific in many ways compared to newer ones, and therefore, the approach to their rehabilitation should be different. Potential conflicts can be avoided with the prudent commitment to technical measures so as not to change the physical appearance and character of the building. As the original historic structures and materials are often not possible either visually or physically, and sometimes even chemically combined with contemporary, one should be careful that interventions into the fabric of the building does not create the preconditions for its faster deterioration. This is especially true with a general rule that the materials and techniques appropriate to the new building should be taken with caution to avoid unwanted side effects when their properties are not completely known compared to the existing structure and the materials. This means that contemporary synthetic, high-tech materials should be used with care, especially for the insulation of the building envelope, in order to ensure sustainability and cost-effectiveness of the rehabilitation interventions.

A careful consideration of all possible options, the establishment of exact monitoring of an interdisciplinary team led by architect conservator, is the only correct approach to decision-making for renovating and rehabilitation of architectural heritage in the direction of greater energy savings and improving their overall sustainability. This involves a series of delicate actions, which must be well thought of and documented. The assessment of the existing features of architectural heritage should always be a primary consideration, because they are much more than their individual building components. At the same time, the basic prerequisite for the success of the project of energy rehabilitation of architectural heritage is a shift away from the obsolete conservation practices and innovative approach to the restoration and protection, which, in addition to traditional materials and techniques, allows the technological innovations. Having said that, the main decisive factors include the significance, value of the ensuing evaluation and the degree of legal protection, which define the type and extent of technical protection measures. While several possible solutions can be generally applied to the building energy renewal, with regards to the historic buildings it can be used only optimally, primarily observed from the conservation interests in order to preserve the monument values and the authenticity as much as possible. This particularly concerns the highest monumental category of buildings. The loss of monumental properties due to excessive and excessively evident alterations to the structure by introducing new materials and constructions, regardless of all the benefits that can be derived from various measures of energy renewal, cannot be a subject of compromises.

2. THERMAL INSULATION OF BUILDINGS

A well insulated building allows the accumulation of heat in the walls so that the building uses less energy for heating in winter and cooling in summer. This reduces the difference in temperatures between the interior surfaces of the walls and indoor air and increases thermal comfort. Insulation extends the lifespan of the building, because it protects the construction materials and prevents condensation of water vapor, which causes decay and corrosion of building materials, thus preventing the formation of micro-organisms, fungi and mold, and results in a better indoor air quality, which is directly related with the concern for the health of people. It is also the path to the overall protection of the environment, reduction of carbon emissions and thus mitigating the global climate change.

In our climate conditions the largest energy consumption is by far for heating of buildings. Since the transmission heat losses are the largest through the building envelope, especially through the walls, finding the best solutions and materials for thermal insulation of walls is a top priority when it comes to energy-efficient buildings.

Requirements for thermal insulation materials include good thermal insulation properties, strength, dimensional stability, fire resistance, hydrophobicity, vapor permeability, chemical neutrality, resistance to aging, decay and vibration and environmental acceptability. The most important parameter that affects the quality of the thermal insulation material is thermal conductivity λ (W/mK), on which depends the thickness of the insulating layer. Present-day most common thermal insulation materials for buildings include mineral wool (glass wool and stone wool), expanded polystyrene (EPS), extruded polystyrene (XPS) and polyurethane foam (PUR). Most of these conventional materials for thermal insulation have a thermal conductivity of λ = 0.030 to 0.045 W/mK (Table 1)

Table 1. Thermal conductivity of most common thermal insulation materials:

MATERIAL	Thermal conductivity (λ) W/mK
Mineral wool	0,030-0,040
Expanded polystyrene (EPS)	0,035-0,040
Extruded polystyrene (XPS)	0,030-0,040
Polyurethane foam (PUR)	0,020-0,030

More stringent requirements for thermal insulation, especially after transition from the passive standards to nearly zero energy buildings, created a need for even thicker layers of insulation. However, in this way usable surface area is lost, which is not only a problem from the architectural and economic perspective, but also from the point of view that the windows, retracted into the mass of the wall, reduce the amount of daylight, and thus the light comfort. Moreover, the increased thickness of thermal insulation, the present-day conventional materials are at least 10 to 20 cm over, means an increase in the produced amount of the building material, which poses a new pressure on natural resources, energy consumption, increased transport, which again leads to an increase of greenhouse gases emissions.

Rehabilitation of the existing buildings, especially those most valuable from architectural stylistic and historical points of view, which are architectural heritage, setting up of such a thick insulation is simply not possible if we want to preserve the authenticity of the dimensions and especially the stylistic elements. But, even though it is not an imperative prescribed by EU directives, it is necessary to allow adequate thermal comfort and thus modern functioning of the buildings, whose occupants and owners cannot be the hostages of cultural monuments. Besides, there are all the advantages of good thermal insulation for protecting building materials and construction from the degradation activity of moisture and corrosion, and also the indoor air quality, especially considering the fact that people in urban areas spend nowadays up to 90% of the day indoors.

As the walls form the largest building contact area to the outside, here are the single largest losses of heat, and therefore of energy saving opportunities for heating and cooling. The ratio of the surface of transparent and non-transparent elements of external walls is important for thermal quality of the building envelope. Considering that the ratio of openings (windows, doors) compared with a full wall is approximately 1: 3 to 1: 4, thermal insulation of non-transparent wall elements is of primary interest in this work.

3. NANO INSULATION MATERIALS

Demands for energy efficiency, required by the European directives, and then the national building regulations and standards are becoming more stringent, so it is primarily necessary to reduce heat loss through the walls. This can be done either by increasing the thickness of a conventional thermal insulation or by reorientation on high-tech super-insulation materials based on nanotechnology, which, with extraordinary small thicknesses, offer far better effects of isolation.

Nano insulating materials are based on the lawfulness of transfer of energy by collision of molecules of gas. When the pore size in a certain material is reduced to, for example, 200 nm in diameter, on the principle of Knudsen effect, the molecules mostly collide with the walls of the pores, and not with the other molecules of gas. This elimination of intermolecular collisions is basically in reduction of thermal conductivity and efficiency of nano insulation materials.

3. 1. Aerogel

Aerogel is a unique, ultralight material of superior thermal but also acoustic insulation properties. The basic raw material for the production is amorphous silica, with an extremely low thermal conductivity from which the first aerogel in 1931[6] was made, and then also the aerogels based on aluminium, chrome and tin. Carbon aerogels were developed at the end of the last century. In the building sector today silica aerogel dominates, with nanotechnology substantially perfected.

Silica-aerogel is produced by extracting the liquid component from a conventional gel through a supercritical drying process and by filling this place with air. To reduce heat transfer by radiation, before or after supercritical drying special additives are added to aerogel, usually elemental carbon (about 9%). Aerogel is a porous network of silica strands with diameters of a few nanometres. The solid component of the aerogel is from 0.13 to 15%, but mainly 5%, and so 95 to 99.8% by volume is made of the air in nano pores of medium size 20 nm (size of pore varies with the density), thus achieving the maximum limitation of heat transfer [12] (Figure 1).

The International Union of Pure and Applied Chemistry proposed a classification for the porous materials: micropores - up to 2 nm in diameter, between 2 and 50 nm as mesopores and larger than 50 nm as macropores. Silica aerogels possess pores of all three sizes, but predominantly the mesopores, with relatively small micropores, which is very important for the interpretation of high porosity properties of this material [12] (Figure 2).

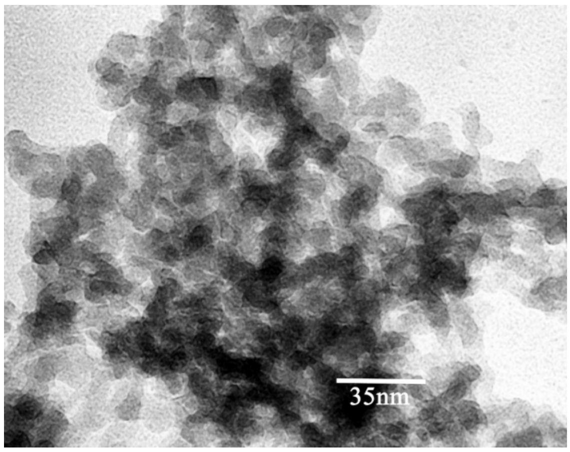

Figure 1. The pore structure of silica aerogel [12]

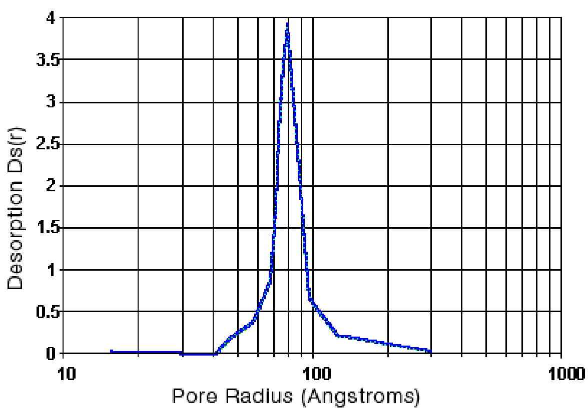

Figure 2. The pore size distribution in the silica aerogel [12]

Because of vacuuming air, the coefficient of thermal conductivity (λ) of aerogel is an average of 0.0014 W/mK, and it is 0.0010 W/mK nowadays. Additionally, the aerogel insulation retains its best performance in the most extreme temperature conditions from - 265˚C to + 650°C. The coefficient of thermal expansion is 2.0 to 4.0 x 10^{-6}, and thermal tolerance is 500° C. Shrinkage begins at about 500° C and melting at more than 1200° C.

Aerogel is a semi-elastic, especially lightweight material - from 0.003 to 0.35 g/cm^3, but usually 0.1 g/cm^3. Though seemingly frail, aerogel has very good mechanical properties, especially pressure resistance and tension. An important characteristic of aerogel felt is flexibility and thus a simple installation, even for complex geometries walls. The status of permanent hydrophobicity aerogel is extremely important for a longer lifespan of buildings and indoor air quality.

Silica aerogels are generally transparent, and their bluish color is the result of Rayleigh scattering due interaction of the light with inhomogeneity in material. Therefore, with increasing homogeneity of the gel network scattering will be lower, and transparency higher. Since transmission of light is around 80%, transparent aerogels can also be filled in different structural glazing systems (polycarbonate sheets, structural façade glass panels, between two window glass panes of a skylight, as a filling glass partition in the wall panels stairway space, etc.).

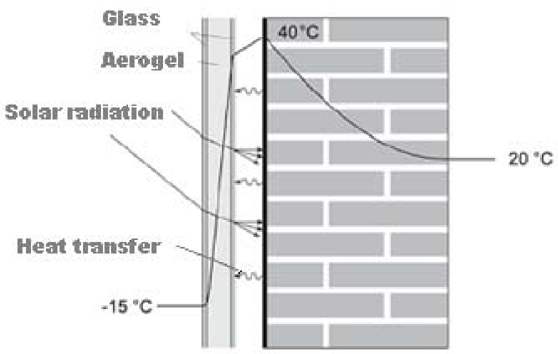

Figure 3. Aerogel filling glass coatings for energy-efficient ventilated wall system

The non-transparent flexible aerogel insulation felts enable to solve problems of thermal bridges in the building envelope, offering a thermal conductivity of about 0.013 W/mK [12].

In addition to having excellent performance for thermal and solar gains, aerogel is a good acoustic insulation material [13]. Speed of the sound at a density of 0.07 g/m^3 is only 100 m/sec, or about 3.5 times less than the speed of the sound in the air [9].

All these characteristics make aerogel insulation material of extraordinary performance. This very thin, durable, hydrophobic, non-flammable, antiseptic modern material has also all the necessary qualities for modern construction, but also for the rehabilitation of existing buildings, especially architectural heritage. However, it is still insufficiently represented because of the high cost in comparison with conventional thermal insulation materials, even though it is eight times more efficient than them.

Nanogels granules can also be added to the mortar and other systems for the treatment of the walls in order to ensure thermal insulation. Thus, in combination with lime, light mineral aggregate, white cement and calcium hydroxide, aerogel granules are used for wall aerogel mortars with high thermal insulation properties, depending on the percentage of aerogel, which ranges from 80-95% [14]. These plasters are water vapor permeable, so that there is no risk of condensation or mold, and because they are water-resistant, no loss of insulating properties due to moisture absorption. Due to its mineral composition they are resistant to algae, fungi and insects, and because of a very porous structure they are good soundproofing. In doing so, they are non-flammable.

Because it is mineral-based, aerogel mortar is very similar to the original building materials of indoor and outdoor surfaces and quite compatible with them. This new material offers a non-invasive method, and is an excellent solution for the rehabilitation of older buildings, and especially for increasing the energy efficiency of architectural heritage, because there are no visible changes in the appearance or dimensions, nor the risk of a subsequent reaction with destructive effects. By comparison, natural plaster (without aerogel) has a thermal conductivity of about 0.50 W/mK, while mortar with aerogel granules, the volume share of 96-99%, offers the best up to date achieved value of thermal conductivity of 0.013 to 0.0018 W/mK [9].

Aerogels are highly efficient state-of-the-art materials with a great potential, whose technology is constantly evolving. For the time being there is no clear quantifiable data on the life cycle of aerogel and its impact on the environment. However, production costs are high, and the energy consumed for its production is very problematic from the energy efficiency perspective, so alternative ways of production are being investigated.

3.2. Vacuum Insulation Panels

Vacuum insulation panels (VIP) are high-tech insulation material with extraordinary properties. VIP is a non-homogeneous insulating panel made of special multi-layer films impermeable to air and moisture and with the insulating core (Figure 4). The porous core - Panel open cell structure made of pressed powder or fibrous material, from which the air is almost completely drawn out and creating the conditions to approximately at least 1/000 of the atmospheric air pressure, that is one millibars (1 mbar or 100 Pa) or so even just 1 or 1/100,000 air pressure). Vacuum-core must be compact enough to withstand the stresses on the air pressure of one bar or 100 kPa.

Material vacuum-core and hermeticaly sealed cover foil have a key role for thermal performances and mechanical properties of the VIPs insulation system. For charging the core various porous materials can be used - fiberglass, polystyrene, polyurethane foam, carbon or silicon carbide. Materials with greater porosity and smaller in size are more able to maintain low thermal conductivity. Most commonly, the core is made from glass fiber without binders, produced in special process, with the value of thermal conductivity of about 32 mW/mK. For building insulation, the core materials of VIP is mainly powder silica, or quartz sand (silica), with open nanoporous structures and the largest cavities of only 200 nm. To further reduce the flow of gas and air, in the integrated core absorbents which absorb gases and moisture and thus prolong the lifetime of VIP. The core is vacuumed and sealed in welded multilayer dense film whose thickness is 100-200 μm [15]

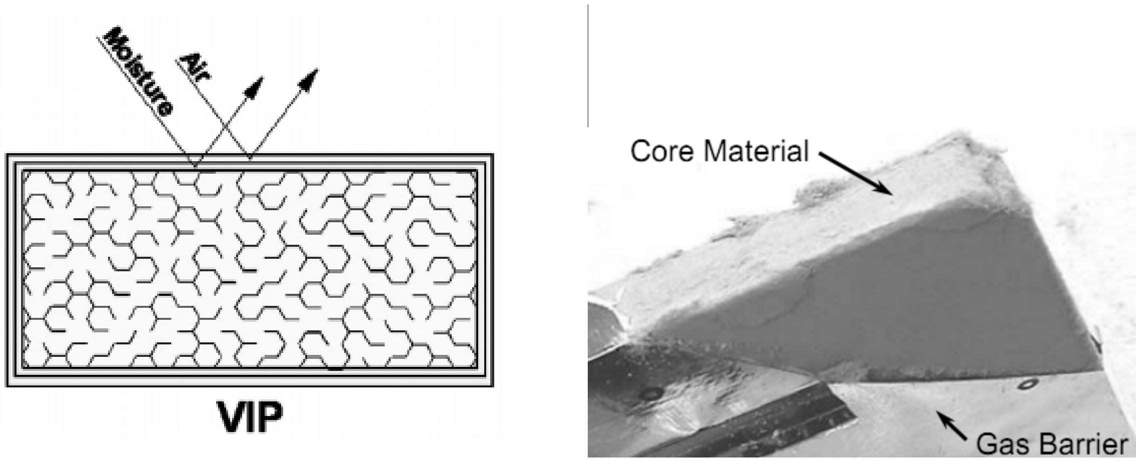

Figure 4. Scheme (left) [12] and a cross section (right) of vacuum insulation panel: the core material (silica, open pores, vacuum) and tight envelope as gas barrier [16]

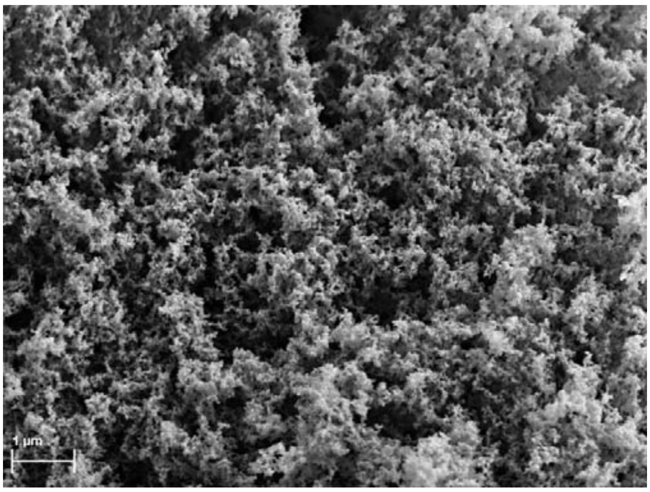

Figure 5. The largest cavities in the panels made of fumed silica are only around 200 nm in size © ZAE Bayern [17]

The durability of VIP mostly depends on the film quality, especially its welded joints provided by vacuum. The film has a layered structure with at least one layer of metal (aluminum, stainless steel or other metal foil), and the outer layers. Because of low permeability of air and moisture, the effective casing, mainly uses aluminum composite films consisting of an aluminium film with a layer thickness between 6 and 12 μm and two plastic foils with the outer sides of polyethylene (PT, PET, HDPE) or polypropylene (PP). All layers of the casing are connected to each other by gluing and then welded.

The panels can be made with standard surfaces and thicknesses (from 5 to 40 mm), and after being manufactured dimensions must not be altered in any way, since vacuum would be destroyed which basically represents high-performance of VIPs. The core is then encapsulated in a correspondingly sized envelope evacuated in a vacuum chamber, the size of which is determined by the maximum possible dimensions of the panel (e.g. 2m x 1m) [18]. This reduces the flexibility of VIP already in the manufacturing process.

Consequently, in particular it is impossible to adjust them to the object, so they can only be used in the manufacturing sizes and the best for large flat surfaces (walls, floors and ceilings). Since VIP panels are very vulnerable they must be handled particularly carefully during transport, storage and assembly, in order to prevent any potential mechanical damage, because their efficiency and durability depend on the preservation of vacuum. Their installation must be carried out with particular care and under constant surveillance. No mechanical attaching, drilling are allowed and even a small scratch can permanently damage the protective film. On the facades with VIPs basic mortar is reinforced with mesh, and then finished.

Vacuum insulation panels have an extremely high thermal resistance and require substantially less thickness than conventional thermal insulation with the same thermal properties and can be used for indoor and outdoor thermal insulation of buildings (walls, roofs and terraces). It is one of the most effective heat insulation materials in the future. Thermal conductivity (λ) of VIP is in the range of only 0.003 to 0.004 W/mK as a fresh, which is ten times better than conventional materials such as mineral or glass fibers or polystyrene whose λ is in the average 0.036 W / mK. Since the same quality of thermal insulation requires small thickness of VIPs, it makes them very attractive from the aspect of saving of usable space in buildings, and is especially preferred in the renovation of older buildings.

Thus, for the sake of comparison, the insulating properties of only 2 cm thick panel are equal to 24 cm thick styrofoam panel. At lower temperatures, thermal insulation properties are improved, which is particularly important for colder climate. However, with time, moisture and air penetrate in the core, and after 25 years the coefficient of thermal conductivity can fall to 0.008 W/mK. In the case of mechanical damage of VIP it loses vacuum, and λ can fall to 0.020 W/mK [19, 20].

Thermal conductivity of these high-tech insulations is excellent, but their prices are by far higher than conventional thermal insulations. That is why it is not realistic to expect that they become their substitute, but as a complementary addition − where the use of conventional insulation is impossible or difficult to apply - for the internal thermal insulation of the existing building, in the floor heating systems, for low or almost zero energy buildings and generally where space is precious. Because of low thickness and high efficiency, vacuum insulating panels present a good solution for rehabilitation of architectural heritage, where, because of significant alteration of original dimensions, it is not possible to install a large layer thickness insulation − either in or out.

With all the obvious strengths and weaknesses, VIPs require a lot of research in order to further improve and spread commercial use in construction. Particularly considering new stricter regulations on energy efficiency buildings, set by Directive 2010/31 / EU as well as the goals set in „Climate & Energy“ for CO_2 emissions reduction to 80-95% by 2050. Retaining all the advantages of VIP, the research is trying to find a better economic alternative to materials and production technologies.

At Iowa State University and the US Department of Energy's Ames Laboratory research is carried out aimed at obtaining a new generation of high-tech insulation [21]. As the production of silicon nano-particles, that form the core of VIPs, is an intensive process in terms of energy and costs, new research has focused on finding lower cost alternatives for making the core. Thus ash and diatomaceous earth are proposed, which is the most promising, since it consists of fossilized remains widespread unicell algae silicate diatoms. These studies have already offered some promising results, and certainly not only one along that way.

An ambitious project of VIP4ALL Group "Highly Effective and Sustainable Production of Innovative Low Cost Vacuum Insulation Panels for Zero Carbon Building Construction" is currently underway [22]. The VIP4ALL Group proposes to bring to the market a new generation of more superior, low cost, highly sustainable and energy efficient thermal insulation panels as a new solution for renovation actions. In relation to the VIPs it is more accessible, uses renewable natural minerals and recycled products more environmentally friendly, and thus has significantly lower emissions of greenhouse gases.

4. CONCLUSION

The development of sustainable energy efficient building concepts has shown a significant growth in recent years, and this trend will continue in the future. Insulating building materials play a key role in meeting the requirements to increase the energy efficiency and to achieve EU standards of nearly zero-energy buildings.

In the research and development sector, significant research activities are being undertaken in order to improve the properties of materials in commercial use and to introduce the most advanced thermal insulation materials with high nanotechnology-based performance . However, it is necessary in future to seek alternative technologies in order to reduce costs and environmental impacts. It is necessary to make a shift from the current practice and in a completely transparent way make Life Cycle Assessment (LCA) of each new product, assessing at the same time energy savings, conservation resources, greenhouse gas emissions, recyclability and the management of potentially hazardous construction waste. The current difficulty concerning the assembling Life Cycle Assessment of nano-products is that the information about their properties and actual composition is often missing because producers do not publish them, justifying it by confidentiality.

So, for most of nano building products, there are currently no analyses of their total life cycle, and thus no evaluation of their eco balances in comparison to conventional insulation materials, in order to be able to objectively quantify all the potential advantages and risks in relation to their environmental acceptability. However, the results of previous partial analysis of nanomaterials life cycle show that their environmental impacts are relatively high, even appreciating their low thermal conductivity.

The use of nano insulation materials offers a number of advantages because of their unique properties. But their disadvantages during production include intensive energy consumption and high CO_2 emission. Not every nano-product is environmentally sustainable by definition. And whatever the great hope in the nano-technology, new and optimized products and production processes of insulating materials, which should contribute significantly to solving our energy problems and climate protection in the future, the global and long-term responsibility requires that the emphasis should be on the total potential environmental sustainability of nano insulation materials.

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НАНО ИЗОЛАЦИОНИ МАТЕРИЈАЛИ ЗА ЕНЕРГЕТСКИ ЕФИКАСНЕ ЗГРАДЕ

Сажетак: Напредни термоизолациони материјали и рјешења за побољшање топлотне отпорности, добијају све већу пажњу због своје важности за одрживо грађење. Смањење потрошње енергије и емисија CO_2 развојем и имплементацијом одрживих грађевинских технологија, система и материјала за нове и постојеће зграде биће кључни у рјешавању изазова преласка на зграде готово нулте потрошње енергије до 2020. године у Европи. Нанотехнологија обећава ефикаснију топлотну изолацију, мање зависну од необновљивих ресурса, као важне стратегије на путу према зеленој градњи. Примјена нано изолационих материјала за ограничење дебљине зидова један је од највећих потенцијала уштеде енергије за постојеће зграде, међу њима и за градитељско насљеђе.

Овај рад истражује потенцијалне предности кориштења на нанотехнологији заснованих термоизолационих материјала високих перформанси у смањењу животног циклуса енергије, смањењу кориштења материјала и повећање животног вијека зграда.

Кључне ријечи: изолација, материјали, нанотехнологија, енергетска ефикасност, зграде.

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