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Development of Transparent and Opaque Vacuum Insulation Panels for Energy Efficient Buildings

Esra Kucukpinar[a,*], Oliver Miesbauer[a], Yoash Carmi[b], Marc Fricke[c], Leif Gullberg[d], Can Erkey[e], Roland Caps[f], Malcolm Rochefort[g], Araceli Galvez Moreno[h], Clara Delgado[i], Michael Koehl[j], Paul Holdsworth[k],Klaus Noller[a]

[a]*Fraunhofer Institute for Process Engineering and Packaging, Freising, 85354, Germany*
[b]*Hanita Coatings, Kibbutz Hanita, Israel*
[c]*BASF Polyurethanes GmbH, Lemfoerde, 49448, Germany*
[d]*Airglass AB, Staffanstorp, SE-24522, Sweden*
[e]*Koç University, Chemical and Biological Engineering Department, Istanbul, 34450, Turkey*
[f]*va-Q-tec AG, Würzburg, 97080, Germany*
[g]*Kingspan Insulation Limited, Herefordshire, HR6 9LA, UK*
[h]*Acciona Infraestructuras S.A., Madrid, 28108, Spain*
[i]*Gaiker Centro Tecnológico, Bizkaia, 48170, Spain*
[j]*Fraunhofer Institute for Solar Energy Systems, Freiburg, 79110, Germany*
[k]*Pera Innovation Limited, Leicestershire LE13 0PB, United Kingdom*

Abstract

One reason for heat losses in buildings is inadequate insulation. Vacuum Insulation Panels (VIPs) is emerging as a promising solution, being more energy efficient than conventional insulation materials, thinner and lighter. A VIP is made by placing a core insulation material inside a gas-barrier envelope and evacuating the air from inside the panel. The limitations to wide-scale VIP commercialization lie in lack of low-cost and high-volume processes to turn them into products suitable for use in buildings, and their short in-service lifetimes. These drawbacks were researched in a European funded project "NanoInsulate", and this paper gives an overview of results.

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Keywords: Transparent Vacuum Insulation Panels, Opaque VIPs, energy consumption reduction, aerogel, nanofoam, high barrier envelopes

* Corresponding author. Tel.: +49 8161 491 507; fax: +49 8161 491 555.
E-mail address: esra.kucukpinar@ivv.fraunhofer.de

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1. Introduction

Nearly 40% of total EU energy consumption is due to heat losses through buildings and windows, which is a significant contributor to greenhouse gas emissions. The successful entry of new nanotechnology-based insulation products to the transportation and refrigeration fields indicates that innovative insulation products should be explored in the building and construction sector, which accounts for over 40% of all energy usage. Among these innovative products, the development and use of VIPs is particularly advantageous as they are not only more energy efficient than conventional commercial counterparts but are also thinner and lighter and, thus, more resource-efficient than standard insulation systems. Furthermore, they are suitable not only for use in new buildings, but also for retrofitting older buildings, where installation space and simple component design are a premium. Robustness (both physical and in long term performance) and lower cost are key to success in the construction field. The NanoInsulate - Development of Nanotechnology-based High-performance Opaque & Transparent Insulation Systems for Energy-efficient Buildings" project has developed durable, robust, cost-effective opaque and transparent VIPs incorporating new nanotechnology-based core materials (such as nanofoams and aerogel composites) and high-barrier films, resulting in panels that are more energy efficient than current solutions.

2. Materials

A VIP is manufactured by packing core insulation materials such as fiber glass, silica, perlite, aerogel, open-celled extruded polystyrene, or open celled polyurethane in a high gas/water vapor barrier envelope. These core materials, upon evacuation in a vacuum-tight envelope (e.g. barrier films) lead to very low thermal conductivity values. The optimization of material performance (e.g. inhibition of thermal aging, inner pressure tolerance etc.) is critical in maintaining the thermal and mechanical performance in service. Issues with handling the products and increase of inner pressures with time and cost are also factors that need to be considered and evaluated. The novel VIP core materials developed within NanoInsulate project are organic nano-porous foam and nano-monolithic composites of inorganic silica aerogels. The properties of these new VIP core materials and the high barrier envelopes developed are summarized in this section.

2.1. Novel VIP core materials: Organic nano-porous foam

The organic nano-porous material development was performed by the project partner BASF SE, Germany. The developed materials have low thermal conductivities below 5 mW/(m·K) under vacuum at a density of below 180 g/l. Producing this type of material in a cost-efficient manufacturing process could be a real breakthrough for commercialization and would allow wide-scale commercialization of VIPs feasible for the building and construction sector. It has been shown by BASF that careful selection of a number of synthetic pathways leads to ideal material performance with the opportunity of mass production. Based on that, the development of an industrial-scale product and process seems feasible.

Sol-gel chemistry has been shown to potentially give access to nano-porous materials with sufficient mechanical properties and a sufficiently low thermal conductivity. Suitable catalyst combinations were identified that achieved gelation speeds according to the technical requirements, without impact on the material property profile [1]. Screenings for suitable chemical building blocks, resin concentrations and monomer ratios were carried out to identify a parameter range leading to mechanically stable nano-porous materials after solvent removal and drying. These recipes led to materials which were successfully converted to laboratory-scale VIPs. Furthermore these materials passed the B2 fire-rating test. The lowest thermal conductivity values reached with large-scale VIPs are shown in Table 1. These VIPs were produced at the project partners Kingspan Insulation Limited, UK and va-Q-tec A.G., Germany with BASF nano-porous foam and the thermal conductivities were measured.

Due to the shrinkage and deformation problems after the evacuation, further optimization of the material mechanical properties was required. This resulted in flake-like material morphology with a similar density and a higher compressive strength (Figure 1, Table 2). The thermal conductivity has increased slightly after the material optimization. This material has been selected as one of the VIP core materials for the production of VIPs to be installed at the mock-ups in Spain and Poland at the project partner ACCIONA Infraestructuras SA facilities.