CENTRE OF EXCELLENCE OF MULTIFUNCTIONAL ARCHITECTURED MATERIALS
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CEMAM
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IRP4: THERMAL FUNCTIONALIZATION OF BUILDINGS

Nearly half of the energy consumption and roughly a quarter of CO2 emission throughout Europe is used to heat buildings. Significant progresses have already been made, but the latest energy and climate issues induce very demanding thermal standards, like “zero energy” buildings. There is a need for innovations in the insulation and management of transient energy storage. Technological breakthroughs are expected through hierarchically engineered materials that fulfil multifunctional requirements. The following research programs address respectively the two main functions: thermal insulation (including super insulation) and energy storage.

SCIENTIFIC STRATEGIES

The IRP4 is essentially devoted to studying the thermal insulation and energy storage in buildings. The main scientific challenges raised in this IRP are i) Thermo-mechanical behavior of fibrous or porous structures ii) Shape optimization of hybrid structures for strongly non linear problems such as transient thermal conduction including phase change, convective boundary conditions … iii) Degradation of the thermal properties of fibrous or porous or multilayer structures.

VACUUM INSULATING STRUCTURES

The most effective way to improve the insulation capabilities of materials is to organize their structure in a porous manner and benefit from the Knudsen effect. An optimization of the pore size down to the nanometer scale and/or a reduction of the gas and water pressure can even produce solid porous with thermal conductivities significantly bellow that of the vacuum. These structured materials are therefore referred to as “super thermal insulators”.

The first structure that may be considered at atmospheric pressure is composed of, for instance, silica powder for the insulation function and organic fibers for structural properties. Although already processed these materials are in the proof of concept stage. Based on the products employed in traditional insulation (like fiber based or porous materials) and on the gas trapped inside these structures (gas of low thermal conductivity or, even better, vacuum). It requires to tune the mechanical and thermal properties of the structural component for example during the process (partial sintering, joining agent, …) and it requires to ensure the containment of the gas, for which multilayer envelops are necessary to fulfill different requirements (gas confinement, mechanical durability, moisture resistance). Multifunctionality is due to at least an additional function besides the mechanical ones (in compression, creep, …) , water (vapor permeability, sorption …).

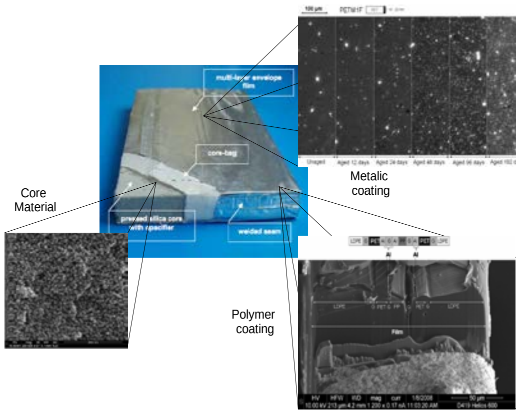

Fig.1 : Hierarchical structure of the insulation panels.




Combining long term competence with short notice reactivity

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THERMAL ENERGY STORAGE WITH PCM

The main idea is store energy during a time of surplus and to release it when needed. A large variety of applications can be targeted. Summer comfort might be improved by damping temperature peaks with latent heat of phase changing materials, reducing the total energy consumption due to air conditioning. On a smaller time scale, solar gain during inter-season could be stored during the day and released at night. In addition, transient energy storing could be made anytime when demand is low and released in peak periods. In the formers cases, Phase Change Materials (PCM) could be an innovative solution. Using PCM efficiently requires following a series of requirements: (i) a specific packaging to avoid leaks of liquefied PCM, (ii) process a large enough mass to store and release the amount of energy needed, (iii) a large enough thermal conductivity to allow a good heat transefert throughout the material. The latter however contrast with the low thermal conductivity required by the application and generally observed with usual PCM (fatty acids, paraffin …). To overcome this drawback one might want to embed the PCM in a more conductive structure (e.g. a metallic honeycomb) and to control the heat propagation by designing the hosting structure and playing on the external conditions (air flux, …). The best choice for such an assembly is currently being addressed in the present program, by developing a methodology to optimize both the architecture of this hybrid material (PCM + hosting structure) and the system (heat exchange and transport through air flux, forced convection …).

In this context, scientific challenges concern a more precise knowledge of PCM candidates (in particular in terms of latent heat, peak temperatures, …), the optimization of the architecture materials (in particular thanks to numerical modeling) , the coupling between the architectured material and the exchange device (Heating pump, pulsed air system, …)

Finally, most of the experimental and theoretical studies presented in the literature concerning the multifunctional materials for building application remain somewhat controversial sometimes on the quantitative and even qualitative point of view. A vivid need is thus identified that represent the three main axis of the CEMAM labex: elaboration, characterization, and modeling. Finally, an extra aim of the Interdisciplinary Research Program IRP4 is also to accompany the most original breakthrough (e.g. development of “sky“cells by opposition to solar cells, …). The packing of the individual components, as well as a better knowledge of the presence, nature and amount of binding agent may also be interesting within the frame of the building application, and beyond.

Fig.2 : example of a hosting structure for a PCM wax : a aluminum honeycomb.

STAFF AND INDUSTRIAL PARTNERSHIP

Full time equivalent staff of about 20 people with close to 10 PHD students and post docs are involved in this Interdisciplinary Research Program.
Industrial collaborations are being developed with EDF, CEA, ETH Zurich, microtherm, Rexor, CSTB, etc.

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