

Nanotechnology for Building Solutions and Energy Efficiency: Challenges and issues associated with the Nano Phase Change Materials

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Abstract

The building is a complex thermodynamic system since it is submitted to internal and external climatic conditions, as well as other solicitations. The use of phase change materials (PCMs) in building components to improve the thermal behaviour and to enhance the energy efficiency of the building is an up-to-date challenge. The integration of PCMs into buildings components is designed as thermal energy storage (TES) systems and latent heat thermal energy storage (LHTES) systems.

The PCMs principles and use is simple. The phase change material has the capacity to store energy when changing phase from solid to liquid (endothermic reaction) and to release energy from liquid to solid (exothermic reaction). The great advantage of the use of PCMs is the latent heat capacity besides of the sensible heat of most common construction materials.

The use of nano phase change materials in building materials and solutions face particular challenges in respect to four main issues: i) Thermal properties and manipulation; ii) Compatibility and incorporation matters; iii) Experimental material characterization constraints; iv) Numerical modelling of latent heat phenomenon. There are also other concerns in respect to global material behaviour and specifications in terms of building component directives, as well as the final pricing and market competitiveness.

In respect to thermal properties and manipulation, the PCMs present low thermal conductivity, around $0.2 \text{ [W.m}^{-1}.\text{K}^{-1}]$ (for paraffins) and $0.5 \text{ [W.m}^{-1}.\text{K}^{-1}]$ (for salt hydrates) and this is a strong feature that limits the full potential use of these materials because it slows down the heat transfer reaction associated to the charging and discharging processes. If the PCM mass and selection is not correctly defined the heat needed to melt the PCM could not be enough to store maximum energy capacity or in the case the heat imposed is too strong the PCM could stay in the liquid phase, therefore only a fraction of the PCM is taken advantage of in terms of thermal storage. Another relevant aspect is related to the selection of the appropriate PCM fusion temperature, intrinsically associated to boundary and working conditions [1-3].

Compatibility and incorporation issues, for example are associated to leakage or long-term leakage that can occur if the PCM is not correctly incorporated into other material matrix and the volumetric heat storage capacity is reduced since part of the PCM is replaced by sensible heat material. During the phase change some PCMs suffer volume change and other PCMs are flammable, constraining specific use, and when introduced into some material matrix could present supercooling problems during the phase change [1, 2, 5, 4, 7, 8]. In the case of blended fluids (PCM fluid mixture) an increase of the dynamic viscosity represents higher pump energy consumption for the heat transfer system used [8, 9].

To characterize the thermal behaviour of the PCM it is used a dynamic scan calorimeter (DSC). In this process some features are omitted, as the convection in the sample, representative sampling of mixture limiting the evaluation of the influence of the mass and heating rate in a complete thermal system. The analysis of the process is complex, expensive and cannot be observed visually the phase change phenomenon [1].

Regarding numerical modelling of LHTES and TES systems it is a complex exercise because the PCM has the presence of a moving boundary in the phase change process and due to the non-linear nature of the PCM at the moving interface for which the displacement rate is controlled by the latent heat storage or release [1, 2].

The aim of this research work is to evaluate and discuss the challenges and limitations associated to the incorporation of nano phase change materials into building solutions, analysing a great number of numerical and experimental work carried out in this field.

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