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To cite this article: C Barreneche *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **251** 012111

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# PCM/wood composite to store thermal energy in passive building envelopes

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**Abstract.** The development of new materials to store thermal energy in a passive building system is a must to improve the thermal efficiency by thermal-regulating the indoor temperatures. This fact will deal with the reduction of the gap between energy supply and energy demand to achieve thermal comfort in building indoors. The aim of this work was to test properties of novel PCM/wood composite materials developed at Riga Technical University. Impregnation of PCM (phase change material) in wood increases its thermal mass and regulates temperature fluctuations during day and night. The PCM used are paraffin waxes (RT-21 and RT-27 from Rubitherm) and the wood used was black alder, the most common wood in Latvia. The PCM distribution inside wood sample has been studied as well as its thermophysical, mechanical and fire reaction properties. Developed composite materials are promising in the field of energy saving in buildings.

## 1. Introduction

Phase change materials (PCMs) are latent thermal energy storage materials that can be used in building construction elements for regulating temperature fluctuations during day and night [1, 2]. Storage of thermal energy using PCMs integrated within building materials is efficient and rational way of handling available energy resources. Since the energy consumption and its cost are increasing everyday [3], the interest about the development and understanding of PCM impregnated building materials is growing. In this study, impregnation of wood with PCM was the main goal. This study is focused on a characterization of a novel hybrid material for building made with wood, paraffinic PCM and polymer coating.

Wood materials are cheap and widely used in buildings for various applications (used in floors, ceiling, walls etc.), which make them particularly interesting for impregnation with PCM. Nevertheless wood is naturally occurring porous material and introduction of various substances to improve its properties has long been known [2]. In literature practically all attention is devoted to PCM impregnation in man made porous construction materials such as concrete, plaster, wallboards [1,2]. However, Li et. al. [4] has designed novel material for thermal energy storage consisting of micro-encapsulated PCM, high density polyethylene and wood flour.



This study is focused on novel wood/PCM composite material characterization for perspective use in buildings. Wood/PCM composite material consists of wood, impregnated PCM and polymer coating. Characterization was done by means of Fourier transform infrared spectroscopy (FT-IR) and differential scanning calorimetry (DSC).

## 2. Materials and methodology.

In this study black alder wood (*Alnus Glutinosa*) was impregnated with paraffins RT21, RT27 - PCMs manufactured by Rubitherm GmbH. Size of wooden samples was 30×15×5 mm.

Paraffinic PCM were chosen because they are chemically inert, thermally stable, no phase segregation occurs and there is negligible subcooling effect. Again commercial paraffins are cheap and with moderate thermal storage densities and wide range of melting temperatures [2, 3]. RT21 was selected for the study because its phase change temperature is 20-21°C, which is near to suggested room temperature in heating-dominated climate. While wood/RT27 composites were studied because its phase change temperature 25-27°C is near to suggested room temperature in cooling-dominated climate.

### 2.1. Fabrication of composites

Wood impregnation with PCM to prepare wood/PCM composite was performed by applying vacuum. Before impregnation wood samples were dried at 105°C. Three composite materials of each PCM used were prepared, each with approximately 10, 20 or 30wt% of PCM (total 6 samples).

Structural stability of wood/PCM composites was achieved by using polystyrene that retains PCM when it is in liquid state. At first samples were impregnated and then coated with polystyrene solution in organic solvent. After evaporation of solvent smooth coating of polystyrene was formed. Figure 1. shows wood/PCM composite with polystyrene coating. Table 1 summarizes the samples under study.

**Table 1.** PCM concentration in wood/PCM composites.

PCM	Concentration of PCM (wt.%)
RT21	10.5
	20.5
	28.6
RT27	12.8
	19.0
	29.9

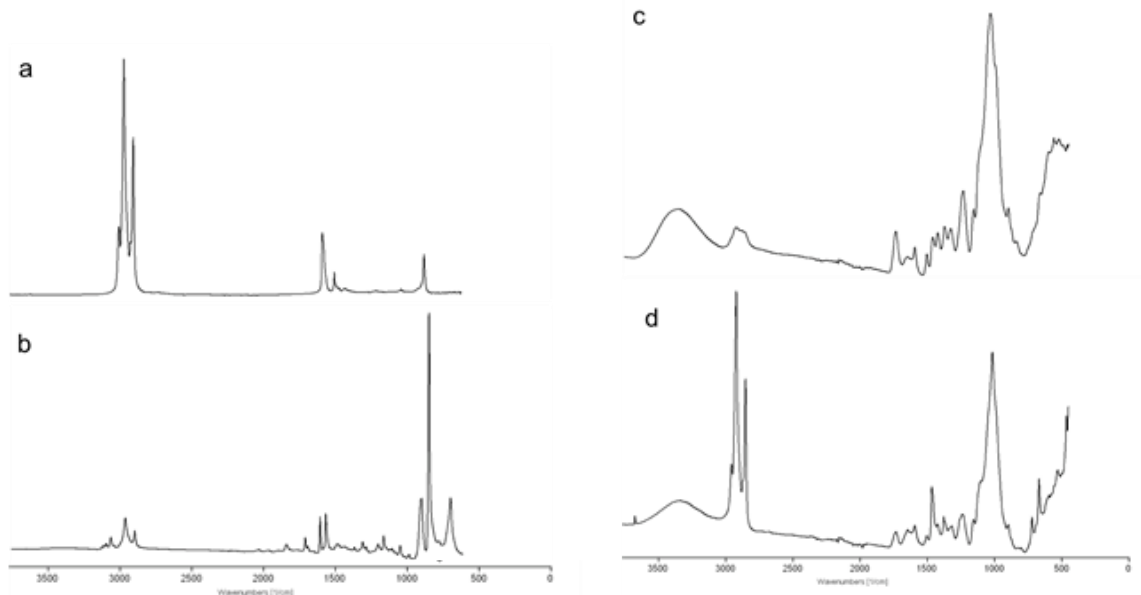
### 2.2. Methodology

Chemical structure and composition: ATR Fourier transform infrared spectroscopy (ATR-FTIR) is convenient and non-destructive method for sample characterization. For ATR-FTIR measurements 6 samples with different PCMs and PCM concentrations and a reference sample without PCM were used. Samples for ATR-FTIR measurements were prepared by cutting samples impregnated with PCM in thin slices. ATR-FTIR spectra were collected with PerkinElmer Spectrum Two spectrometer with UATR Two accessory. Spectral resolution was 4 cm<sup>-1</sup>, number of scans was 4. Moderate pressure was applied to the samples to ensure good contact with diamond crystal, which is relevant to achieve qualitative results. The spectra were baseline corrected and normalized using the Spekwin32 software.

Thermophysical properties: Differential scanning calorimetry (DSC) measurements were performed on the same samples as for FTIR-ATR analysis. Samples for DSC technique were prepared by cutting a thin slice from the whole sample. Slice was taken from the middle of the sample. Also DSC curves of pure RT21 and RT27 were taken into account. Heating rate was following: 0.5°C/min. Data evaluation was performed with STARe Software (vers. 11.00a) from Mettler Toledo.

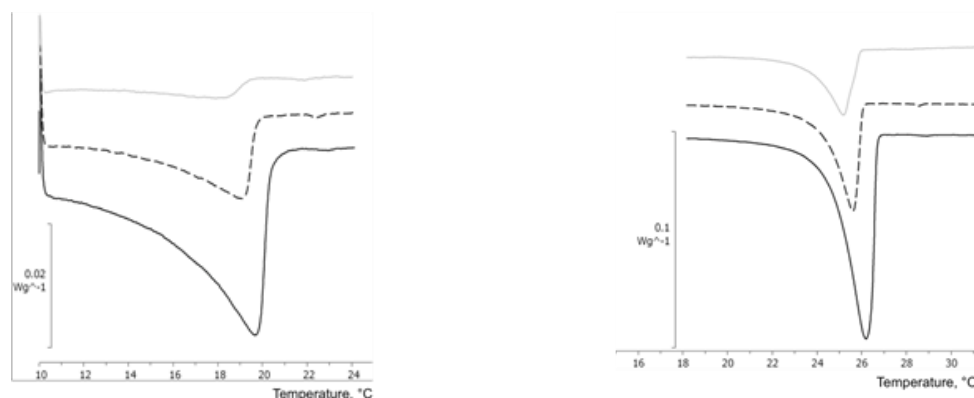
### 3. Results

Spectra of PCM, polystyrene and wood without PCM were collected for better understanding and comparison of results. Spectra of wood/PCM composite and its individual components are shown in Figure 1.



**Figure 1.** ATR-FTIR spectra of individual components: (a) PCM, (b) polystyrene, (c) black alder wood, and wood/PCM composite with polystyrene coating.

Introduction of PCM in wooden matrix gives rise to absorption bands in the wavenumber region of 3000 - 2800  $\text{cm}^{-1}$ . These bands correspond to methyl and methylene group stretching, as RT21 and RT27 are saturated hydrocarbons with molecular formula  $\text{C}_n\text{H}_{2n+2}$ . Wood adds characteristic absorption bands of cellulose, hemicellulose and lignin to the wood/PCM composite spectra. Bands of polystyrene usually appear of composite layers closer to surface or ends of the sample. In Figure 1 (d) no new absorption bands appear and it can assume that PCMs are not chemically bonded with wood. Characteristic DSC melting curve of RT21 in wood/RT21 composite is presented in Figure 2.



**Figure 2.** a) DSC curve of RT21 melting in wood/RT21 composite; b) DSC curve of RT27 melting within wood/RT27 composite.

PCM gives endothermic melting peak. Melting temperature range is broader of wood/RT21 composites in comparison with wood/RT27 composites. Comparison of DSC curves of wood/PCM

composites with different amounts of PCM shows that increase of PCM content broadens PCM melting temperature range. Table 2 listed the DSC results of the samples under study.

**Table 2.** Melting characteristics of wood/PCM composites with different PCM concentration.

PCM	Concentration of PCM (wt.%)	Peak (°C)	Melting enthalpy (J/g)
	10.5	18.33	2.41
	20.5	19.09	8.80
	28.6	19.67	18.85
	12.8	25.17	9.68
	19.0	25.59	12.84
	29.9	26.18	20.62

#### 4. Conclusions

Novel wood/PCM composite material containing various amounts of PCM was characterized with ATR-FTIR and DSC for perspective application in building construction elements. In summary the main conclusions of this study are that both impregnation and coating of polystyrene is necessary to retain PCM during phase change; ATR-FTIR spectroscopy showed that there is no chemical bonding between PCM and wood; because of latter statement desirable phase change effect can be observed with differential scanning calorimeter (DSC) and developed wood/PCM composite materials functions as expected.

#### Acknowledgements

The research leading to these results has received funding from the European Commission Seventh Framework Programme (FP/2007-2013) under grant agreement n° PIRSES-GA-2013-610692 (INNOSTORAGE) and from the European Union's Horizon 2020 research and innovation program under grant agreement No 657466 (INPATH-TES). The authors would like to thank the Catalan Government for the quality accreditation given to their research group DIOPMA (2014 SGR 1543). This work has been partially funded by the Spanish government (ENE2015-64117-C5-2-R (MINECO/FEDER)). Dr. Camila Barreneche would like to thank Ministerio de Economía y Competitividad de España for Grant Juan de la Cierva FJCI-2014-22886.

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