THERMOPHYSICAL CHARACTERIZATION OF COMMERCIAL PARAFFIN-BASED PCMS FOR LOW TEMPERATURE THERMAL ENERGY STORAGE APPLICATIONS

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Abstract *Reliable data on the thermophysical properties of commercial Phase Change Materials (PCMs) is fundamental for the design and modelling of low temperature Thermal Energy Storage (TES) applications. However, data provided by manufacturers is often insufficient and uncertain. In this work, an experimental study was conducted to determine the relevant thermophysical properties of some commercial paraffin-based PCMs, providing a valuable and useful database for ongoing and future studies. Two types of PCMs were evaluated, both microencapsulated and in free-form. Latent heat of fusion, specific heat and melting/solidification temperatures were measured by Modulated Differential Scanning Calorimetry (MDSC). High-resolution modulated thermogravimetric analysis (HiRes-MTGA) was also used to evaluate the thermal stability of the tested PCMs. For the thermal conductivity/diffusivity, the Transient Plane Source (TPS) method (HotDisk) was used. The importance of eliminating phase-transition interferences in the measurements and the effect of the polymer shell in the properties of microencapsulated PCMs were analysed. Properties of both type of PCMs were compared, for the same paraffin composition.*

1. INTRODUCTION

The improvement of energy efficiency of buildings is an imposed area of research, with the market/governments demand for new systems that reduce buildings dependency on fossil fuels, by using renewable sources, matching supply and demand (energy storage), while improving indoor thermal comfort in a more sustainable and cost effective way. In this line, PCMs play an important role, contributing for both energy savings and solar energy profit. The assessment of thermophysical properties of PCMs, in particular their change with temperature and physical state, is crucial for the design/modelling of their application in TES, although challenging for conventional techniques.

Cabeza *et al.* [1] reviewed the conventional and unconventional technologies available

for the thermophysical characterization of PCMs. Nowadays, the techniques most commonly used to determine the thermal properties of PCMs are the (conventional) DSC - dynamic and step methods – and the T-history method. In this work, Modulated DSC was used to evaluate the specific heat, the enthalpy curve, the latent heat and the melting/solidification temperatures for several commercial PCMs. The thermal conductivity and diffusivity were evaluated by the TPS method (ISO 22007-2 [2]) from Hot Disk.

2. EXPERIMENTAL

Table 1 summarizes the commercial PCMs studied in this work. Their thermal conductivities/diffusivity was measured using a *Hot Disk TPS 2500 S* equipment in the range 0–50°C. Regarding the evaluation of the specific heat, latent heat of fusion and enthalpy change with temperature, a MDSC equipment from *TA Instruments* (*Q100* model) was used. The thermal stability of the samples was also analysed by HiRes-MTGA with a *TA Instruments Q500* equipment. Finally, the microstructure of microencapsulated PCMs was assessed by a Field Emission Scanning Electron Microscope, model *Merlin Compact/VPCompact FESEM*, from *Zeiss*.

Table 1. Commercial PCMs used in this work ($T_{p,m}$: melting peak temperature).

PCM Ref.[(a)]	**Sample form**	$T_{p,m}$ / °C	**Manufacturer (Supplier)**
PCM 18	Bulk	18	Microtek laboratories
PCM 24	Bulk	24	Microtek laboratories
PCM 28	Bulk	28	Microtek laboratories
RT 25 HC	Bulk	25	Rubitherm
RT 28 HC	Bulk	28	Rubitherm
MPCM 18D	Microencapsulated	18	Microtek Laboratories
MPCM 24D	Microencapsulated	24	Microtek Laboratories
MPCM 28D	Microencapsulated	28	Microtek Laboratories
Micronal® DS 5001 X	Microencapsulated	26	BASF

(a) PCM 18/24/28 use the same paraffin of MPCM 18D/24D/28D, respectively.

3. RESULTS AND CONCLUSIONS

Figures 1 and 2 show representative results of thermal conductivity and specific heat. It is notorious that the thermal conductivity of free-form PCMs is always higher and more differentiated than that of microencapsulated PCMs, which is more pronounced in the solid state. The polymeric component of microencapsulated PCMs contributes to a more regular value in both solid and liquid states, near 0.1 $W \cdot m^{-1} \cdot {}^{o}C^{-1}$. This lower value may reduce the efficiency of this kind of PCMs, since it hinders the heat transfer. Regarding the specific heat results, the influence of the polymer in the broadness and maximum of the peaks during phase transition is noticeable. The position of the peaks of *C*p is consistent with the temperature indicated by the suppliers for the phase change (Table 1), although slightly lower in all cases. Moreover, the phase transition occurs in a wide temperature range.

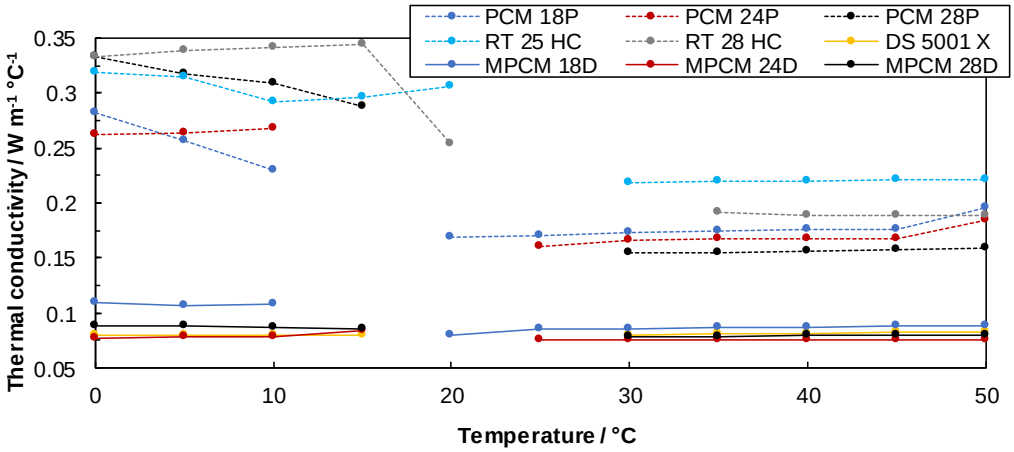

Figure 1. Thermal conductivities of commercial PCMs measured by the TPS method (Hot Disk).

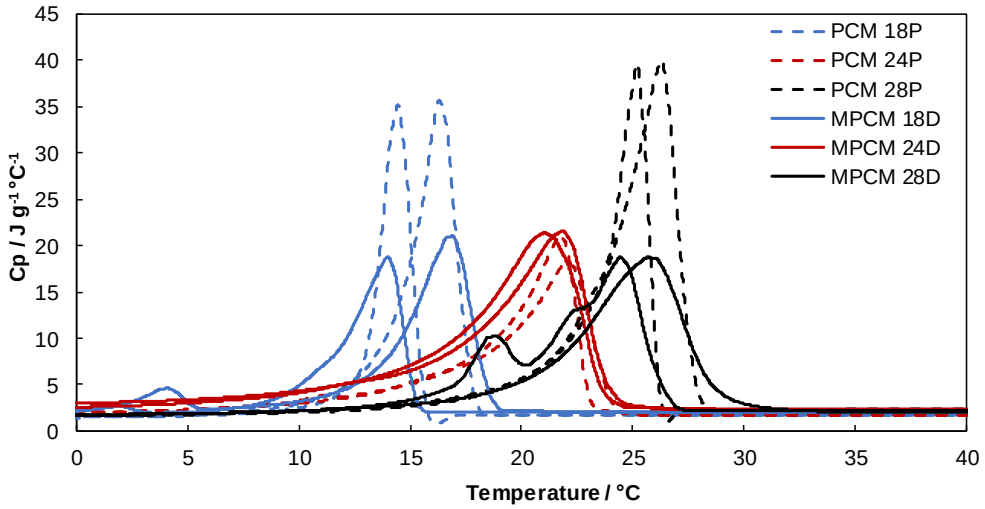

Figure 2. Specific heat of commercial PCMs measured by MDSC (rate: 2 ºC min^{-1}).

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REFERENCES

[1] L.F. Cabeza *et al.* (2915), Unconventional experimental technologies available for phase change materials (PCM) characterization. Part 1. Thermophysical properties, *Renew Sustain Energy Rev* 43 (2015) 1399-1414.

[2] International Standard ISO 22007-2, *Plastics – Determination of thermal conductivity and thermal diffusivity – Part 2: Transient plane heat source (hot disk) method*, 2008.