Melting and Crystallization of Phase Change Materials (PCM) by MicroDSC

Introduction

A phase change material (PCM) is a substance with a high heat of fusion that through melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy (see fig 1). Among other energy savings related applications, PCM are used to design more efficient insulation systems. Indeed, these substances can be encapsulated in building materials such as bricks, or other wall, flooring, roofing, and ceiling materials. By successive melting and crystallization, they can damp the day / night outside temperature variations and allow maintaining acceptable indoor temperatures.

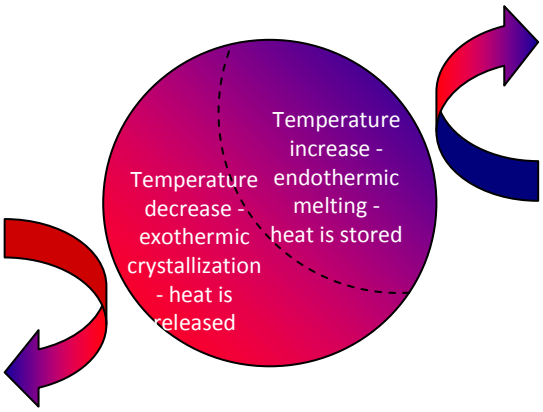

Figure 1 – Principle of a phase change material

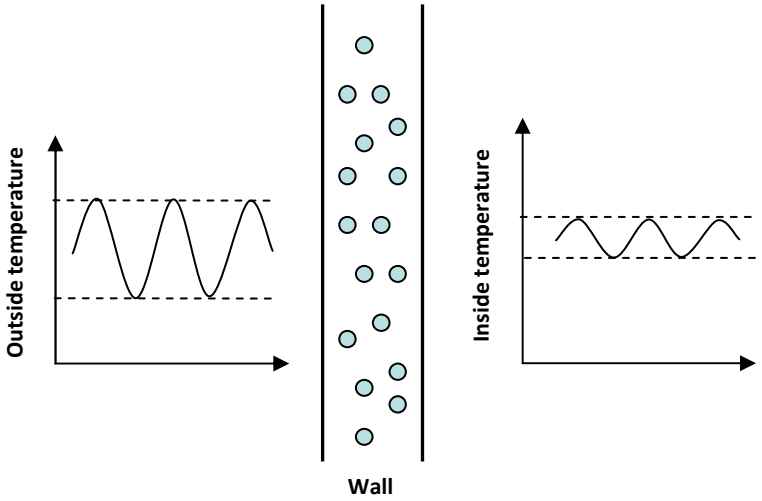

Figure 2 – Application of PCM in the building industry

Fatty acids, paraffins, organic substances, or inorganic salts can be employed if they have high enough latent heat and temperatures of phase change adapted to the application. Moreover, the sensible heat, or the heat capacity change over the temperature range of the considered phase change can play an important role. Of course, those relevant thermal properties have to be known precisely and with a high accuracy. The MicroDSC technique with the capacity of applying very low scanning rates for a better simulation of the process is very well indicated for such a study.

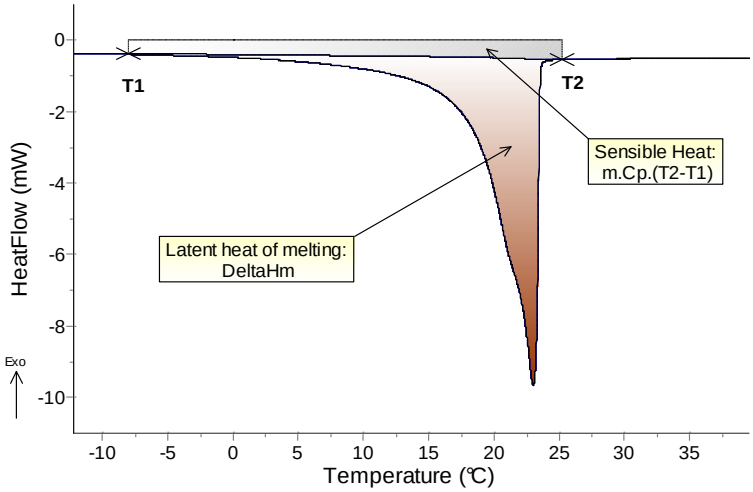

Figure 3 – DSC melting thermogram of a PCM

Property	Organic Paraffin	Organic Non-Paraffin	Inorganic Salt Hydrate	Inorganic Metal Eutectic
h_f (kJ/kg)	230 - 290	120 - 240	170 - 340	30 - 90
h_{fv} ([J/m^3] x 10^6)	190 - 240	140 - 430	250 - 660	300 - 800
ρ (kg/m^3)	~ 810	900 - 1800	900 - 2200	~ 8000
k(W/m°C)	~ 0.25	~ 0.2	0.6 - 1.2	~ 20
Thermal Expansion	High	Moderate	Low	Low
Congruent Melt	Yes	Some Do	Most Do Not	Yes
Supercool	No	No	Most Do	No
Corrosion	Low	Some Are	Highly	Some Are
Toxicity	No	Some Are	Highly	Some Are

Table 1 – Thermal and other properties of common groups of PCM (adapted from [1])

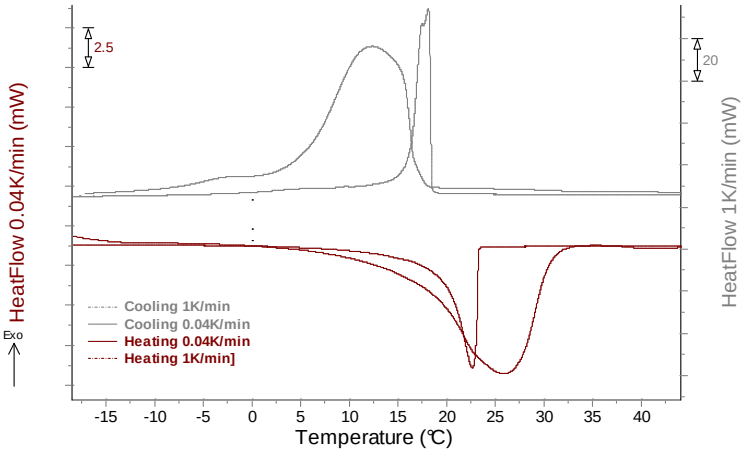

Figure 4 – Experimental DSC melting and crystallization profiles of the tested PCM at 0.04K/min and 1K/min

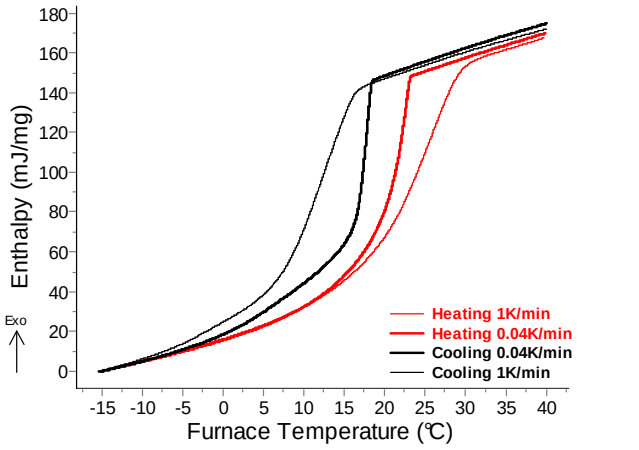

Figure 5 – Enthalpy variations of the tested PCM during heating and cooling at 0.04K/min and 1K/min

Experimental

Sample is a homogeneous blend of polyolefins under the shape of soft beads. It weights 90.39mg of corresponding to about 10 beads. It is heated from -20°C to 50°C followed by cooling from 50°C to -20°C at 1°C.min^{-1} and 0.04 °C.min^{-1}

Results

HeatFlow = f(Temperature) and derived enthalpy variation curves are showed on Figures 4 and 5. Latent heat, onset, offset and peak maximum temperatures are indicated in Table 2. Temperatures at which 90% of the product is crystallized (T90) during cooling operations is also indicated in Table 2.
µDSC3 Evo 3D sensor allows handling large samples, with odd shapes. It can scan temperatures at extremely low rates, that are representative of real conditions of use of PCMs and approach thermodynamically stable conditions necessary for the determination of the heat stored at any temperature [2].

Conditions	T onset (°C)	Tmax (°C)	T offset (°C)	Latent Heat (J/g)	T_{90} (°C)
Heating at 0.04K/min	19.76	22.63	23.27	108.92	N/A
Cooling at 0.04K/min	18.43	18.11	16.21	-108.79	5.61
Heating at 1K/min	16.95	25.85	30.64	105.35	N/A
Cooling at 1K/min	16.87	12.34	4.55	-111.87	1.91

Table 2 – Results

[1] O'Conner, J., and Weber, R., "Thermal Management of Electronic Packages Using Solid-to-Liquid Phase Change Materials", ISPS Proceedings, pp. 72 – 80, 1997.
[2] H. Mehling, H.-P. Ebert, P. Schossig, 7th IIR Conference on Phase Change Materials and Slurries for Refrigeration and Air Conditioning