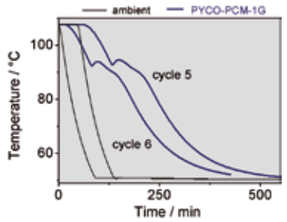
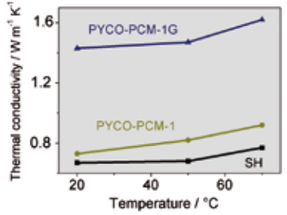
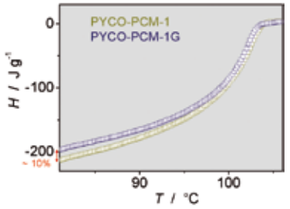


7 *Cooling behavior of 100 g of PYCO-PCM-1G in 3LC*



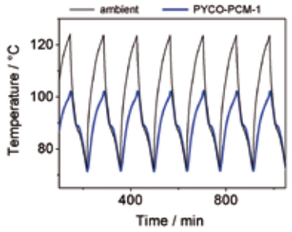
8 *Thermal conductivity – comparison*



9 *Comparison: Enthalpy H(T) of PYCO-PCM-1 and PYCO-PCM-1G*

Thermal Cycle of Stability Test

PYCO-PCM-1 shows an optimal thermal stability when the temperature of heat storage lies between 100 °C and 110 °C. This demonstrates its potential use instead of water in some latent heat storage systems.



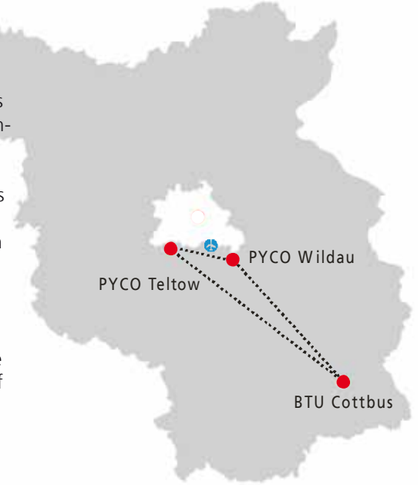
10 *Cycle stability of a sample of PYCO-PCM-1 with a melting point around 89 °C*

Outlook

PYCO will continue with further PCM-developments for other storage temperatures. PYCO is looking for partners that need new latent heat storage systems.

Location Berlin-Brandenburg

New solutions require new approaches: The locations of the research institute in Teltow and Wildau, where the metropolis of Berlin and the federal state of Brandenburg meet, offer optimal conditions for innovative scientific research. Here, the products of tomorrow emerge from ideas and visions. Therefore, the institute's scientists have formed a creative research network with renowned universities, well-known large-scale enterprises, and various innovative medium-sized companies.
Additionally, new synergy arises from the integration in the third largest location of aerospace industry in Germany.



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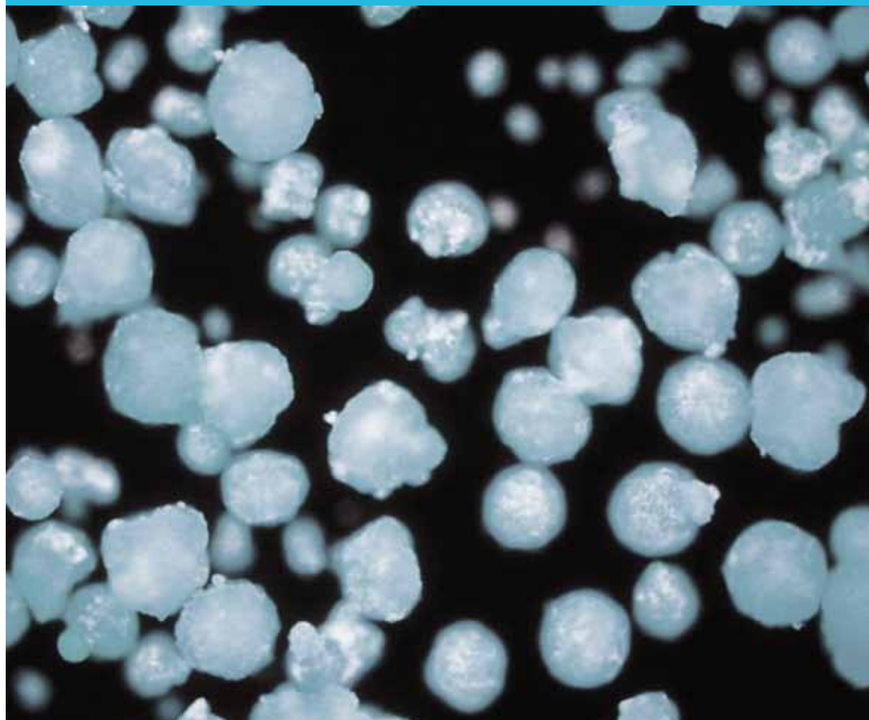
New Innovative Phase Change Materials (PCMs) Based on Salt Hydrates



Motivation

Phase Change Materials (PCM) provide a large heat capacity over a limited temperature range. Such materials store energy by changing phase from solid to liquid (i.e. melting) and release heat by changing phase from liquid to solid (i.e. freezing). Compared to water which is only a sensible heat storage medium at temperatures T > 0 °C or paraffins (125 - 200 kJ dm^{-3}), much better volumetric storage efficiency can be reached with salt hydrates (250 - 400 kJ dm^{-3}).

Our research involves making new PCMs based on salt hydrates with efficient thermo-physical properties including the phase change behavior, the thermal stability, the storage capacity and the thermal conductivity.

The PYCO-PCM-1 salt hydrate presented here is an ideal candidate which can be incorporated in latent heat storage systems for efficient and effective handling of thermal energy around 100 °C. The thermal properties of commercial salt used as starting material in the development are presented for comparison.

Advantages of the PYCO-PCM-1

- Low cost materials
- Stable performance throughout the phase change cycles
- Limited subcooling
- Non-flammable
- Possible adjustment of the thermal properties:
  - Phase change temperature from 88 °C to 94 °C
  - High energy storage density of up to 250 - 300 MJ m^{-3} for ΔT = 20 K
  - Maximal operation temperature variable between 100 °C and 110 °C

Potential Applications of PYCO-PCM-1

- District heating
- Automotive industry
- Recovery of waste heat from industrial processes
- Thermal control in applications involving electronic devices

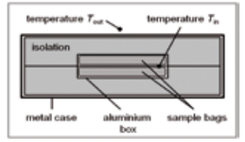
Heat storage materials	unit	Water	Paraffin - RT100	PYCO-PCM-1
Storage capacity (ΔT = 20 K)	kJ kg^{-1}	84	137	200
	MJ m^{-3}	84	105,5	300
	kWh m^{-3}	23,33	29,30	83,33

1 *Comparison of storage capacities of heat storage materials working around 100 °C*

Characterization Method

The standard measurement method to characterize the PCMs is the Differential Scanning Calorimetry (DSC). The required sample size of about 20 mg is too small to correlate well with conditions encountered in practice. To obtain reliable thermophysical properties results, we therefore used an improved 3-Layer-Calorimetry (3LC) method which allows bigger samples (typically 100 g).
Measurements are made over a temperature interval chosen within the phase change transition temperature range. Thermal stability measurements are performed in a Cyclic Test Device (CTD). The cycle time is about 3 to 4 hours for a sample mass of 50 g to 100 g.

2 *View into an open 3-Layer-Calorimeter*

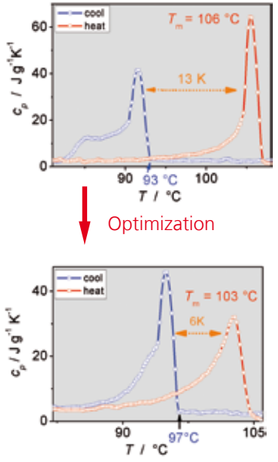


3 *Schematic Setup*

Manufacturing of the PYCO-PCM-1

PYCO-PCMs with efficient thermal performance are prepared by adding suitable additives (types, quantities) to commercial salt hydrates. Here the effectiveness of our method of preparation is demonstrated by comparing the specific heat $c_p(T)$ obtained (a) before and (b) after optimization of the properties of a commercial salt hydrate.

(a) Commercial salt hydrate, 45 cycles



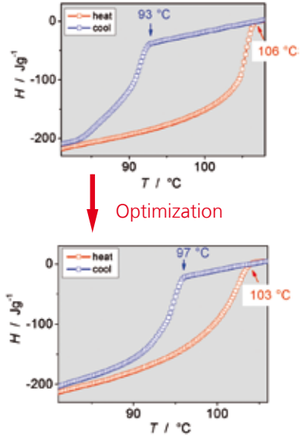
(b) PYCO-PCM-1, 62 cycles

4 *Variation of the specific heat with the temperature after several cycles in the CTD*

Storage Capacity

The thermal reliability of the PYCO-PCMs is studied by measuring the storage capacity after subjection to several repeated cycles. According to the enthalpy-temperature curves evaluated from the $c_p(T)$-data of 4 and presented in 5, the PYCO-PCM-1 has a storage capacity which is deviated of less than 10% of that of the starting salt hydrate. This shows once again the efficiency of the method of preparation.

(a) Commercial salt hydrate, 45 cycles

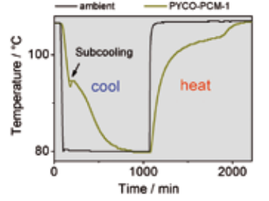


(b) PYCO-PCM-1, 62 cycles

5 *Enthalpy variation with the temperature after several cycles in the CTD*

Phase Change Temperature

Here the temperature profile registered during recovery and storage experiments carried out in the 3LC is shown in 6. As can be seen, only a slight subcooling effect appears before the release of the heat during the cooling.



6 *Temperature variation with the time in the 3LC (measurement range: 80 °C – 107 °C, after 62 cycles in the CTD, 100 g)*

Thermal Conductivity

It is possible to increase the thermal conductivity of PYCO-PCM-1 by adding graphite without affecting the phase change behavior of the material (see 7). An increase of at least 40% of the thermal conductivity in the solid state is observed for a sample containing 5% of graphite (PYCO-PCM-1G) (see 8).
The deterioration observed in the storage capacity of about 10% falls in the range of the measurement error (see 9).