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Thermal conductivity measurements for impregnated PCM

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Introduction

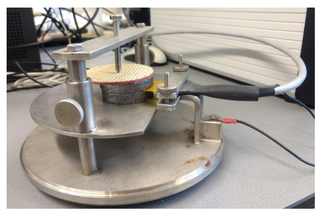
Phase change materials (PCM) can store a large amount of heat in a small temperature interval around the melting temperature. This makes PCM very interesting for industrial heat recovery. However, the low thermal conductivity is a significant barrier to their application.

The present research focuses on improving thermal conductivity of PCMs by impregnation in ENG board (Expanded Natural Graphite). In ENG board, conductivity is strongly anisotropic; in-plane conductivity (perpendicular to pressing direction) is much higher than through-plane (along pressing direction). Since the literature shows a large range of reported values, establishing accurate values for the thermal conductivity of the impregnated PCM-expanded graphite samples, was identified as a critical issue. First tests were carried out using a paraffin PCM as reference material.

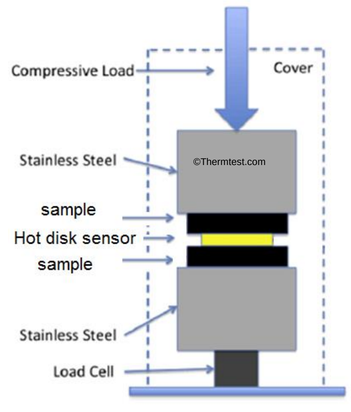
Measurement setup

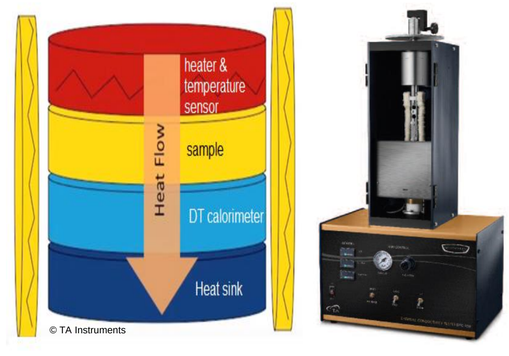
Two types of measurement techniques have been used:

- Hot disk (multidirectional dynamic conductivity measurement)
- Guarded hot plate (unidirectional static conductivity measurement)



Hot disk TPS2500

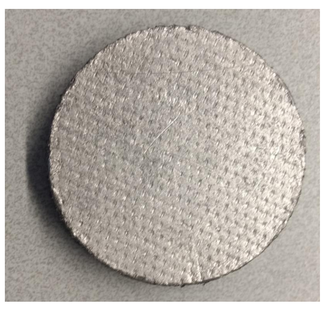




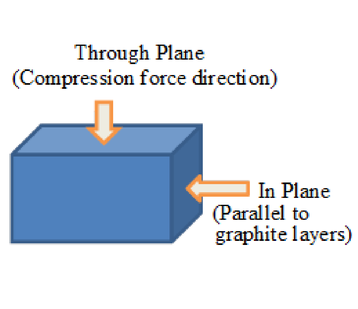
TA instruments Guarded hot plate

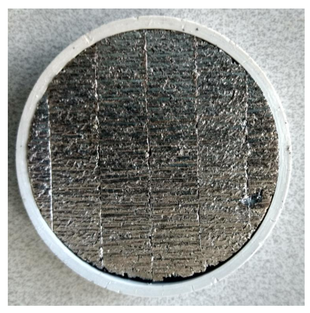
Sample preparation

- PCM: RT70HC (ΔH=260 kJ/kg, k=0.2 W/mK, Tmelt=70°C)
- Graphite Board: SGL Sigratherm L10/750 (ρ=80 kg/m^3) and L10/1500 (ρ=165 kg/m^3). Round samples were cut, diameter 5cm, for both in-plane and through-plane conductivity measurements.



Sample for Through-plane measurements

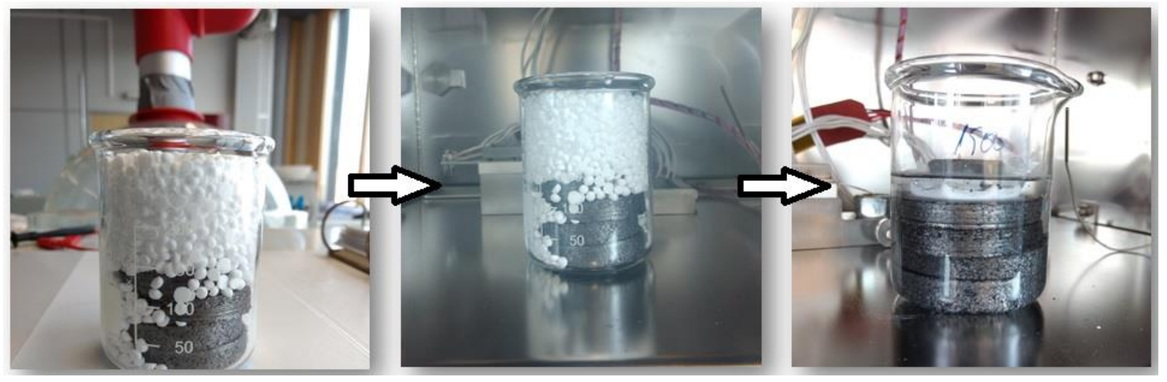




Sample for In-plane measurements (cut and positioned sideways)

Sample preparation

ENG samples were soaked overnight in molten RT70HC at 90°C. Based on increase in mass, about 85-95% pore utilization was realized, resulting in a mass ratio RT70/ENG in the sample of 900% for L10/750 and 550% for L10/1500.



Impregnation with molten RT70HC

Results –Conductivity measurement & hot disk

Below, results are shown for sample conductivity at room temperature (solid phase), measured with the hot disk setup. A problem was the large scatter in the anisotropic conductivity determined by the hot disk software; the values below result from fitting the temperature curve with Comsol. The in-plane conductivity was confirmed to be substantially higher than the through-plane conductivity and higher density ENG resulted in higher conductivity.

ENG	Direction	Mean (Average)	Population Standard Deviation
ENG 750 (non-impregnated)	Through-plane	0.57	0.34
	In-plane	2.94	1.36
ENG 1500 (non-impregnated)	Through-plane	0.87	0.12
	In-plane	2.83	1.55
ENG 750 RT70HC	Through-plane	2.67	1.83
	In-plane	12.22	5.83
ENG 1500 RT70HC	Through-plane	4.33	2.16
	In-plane	16.67	7.82

Results – Conductivity measurement & guarded hot plate

In the guarded hot plate measurements, typical results for the RT70HC through-plane were ~0.6-1 W/mK, and in-plane ~1-1.4 W/mK at room temperature. These results are much lower than for the hot disk measurements. It is likely that the hot plate results were influenced by contacting issues, especially for the in-plane measurements (uneven surface). However, the trends are similar, showing increasing conductivity with increasing graphite density and higher in-plane than through-plane conductivity.

Finally, in the guarded hot plate measurements, a significant increase in measured conductivity was observed with increasing temperature. This effect was not expected. Possibly, this is related to improved thermal contact on softening and melting of the PCM, in agreement with the observation above.

Conclusions & Outlook

- A significant anisotropy was found comparing in-plane and through-plane impregnated samples, as expected from literature
- The anisotropy was measured by hot disk measurements, but considerable inaccuracy resulted on trying to separate in-plane and through-plane conductivity. On the other hand, the guarded hot plate results were influenced by contacting issues, resulting in rather low measured values.
- The RT70 impregnated samples were estimated to have conductivity improvement of ~10-20 times compared to the original PCM.

Overall, the impregnation of PCM in ENG seems to be a promising route of increasing the heat transfer in PCM heat storage.

Acknowledgements

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