

Supercooling Suppression in Fatty Alcohol Phase Change Slurries

ID 186


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Motivation

Phase Change Slurries (PCS/PCME) are an efficient medium for isothermal energy storage and transportation. In small dispersion droplets, supercooling decreases the available heat capacity in a specific temperature range. Since Phase Change Materials (PCM) are predestinated for use in applications with a narrow operating temperature interval, supercooling can lead to its entire unusability in the worst case ¹.

- Supercooling in organic PCS with particle diameters below 4 μm
 - Crystallization delayed
 - Melting unaffected

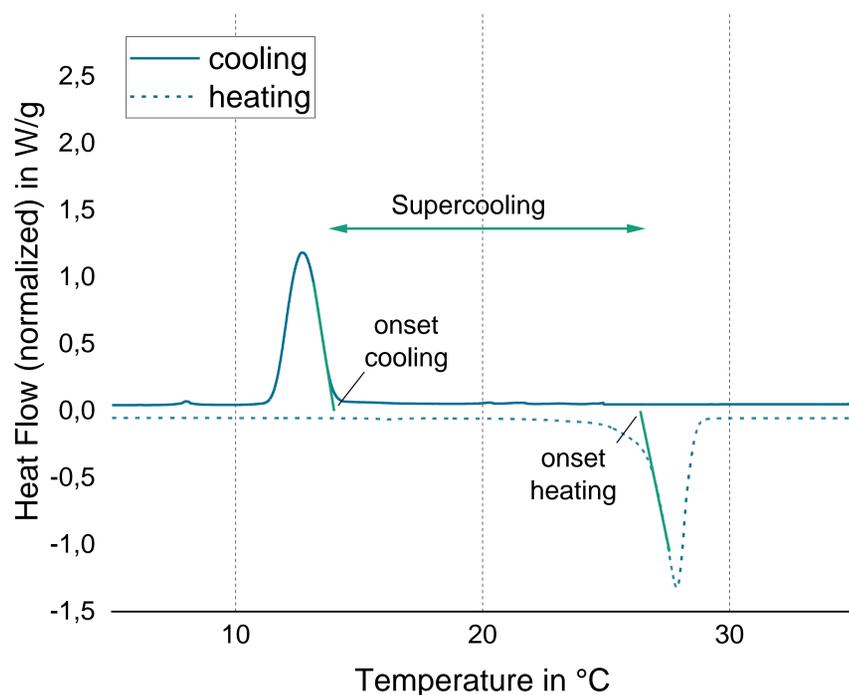


Figure 1: Supercooling in n-Octadecane.

Objectives

- Minimize supercooling to maximize latent heat capacity in a narrow temperature range
- Understand crystallization process for improving controllability

Methods

- Addition of nucleation agents
- Differential Scanning Calorimetry for determination of latent heat capacity and supercooling
- X-ray diffraction for characterization of crystal structures

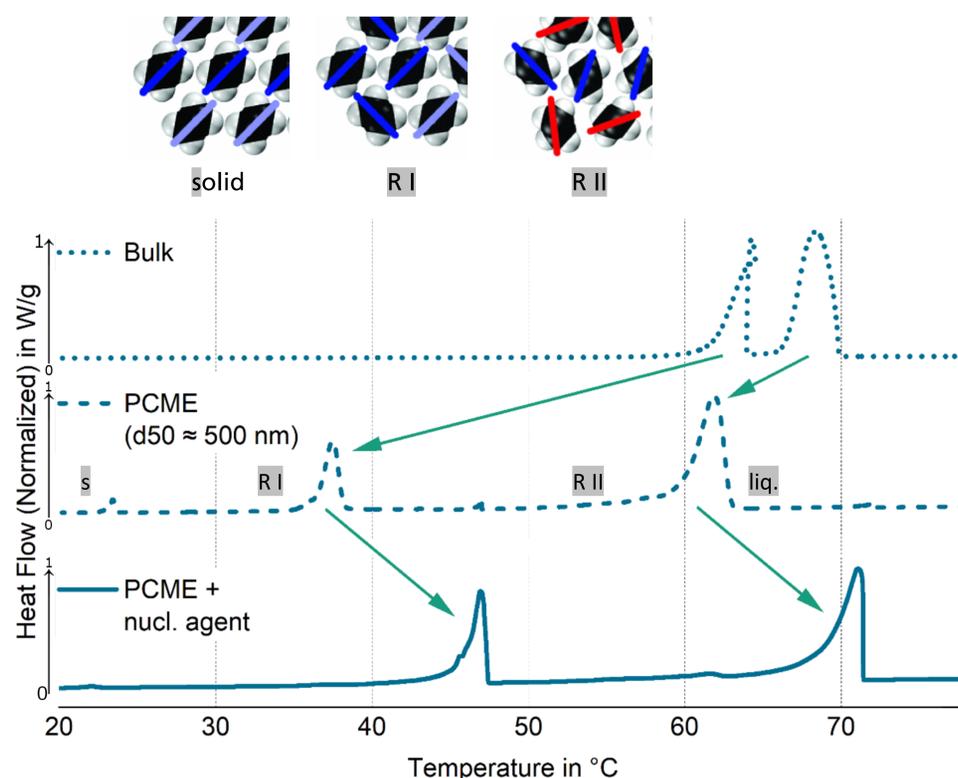


Results

- Phase transition(s) split and shift to different degrees
- Molecular structures of involved materials play a key role
 - PCM compatibility with nucleation additive on molecular scale
 - PCM rotation phases R I and R II
 - Surfactant constitution

Adding nucleation agents

- Suppressed supercooling from liquid to solid (liq. \rightarrow R II, fig. 2) and
- Shifts the solid-solid transition equally (R II \rightarrow R I, fig. 2).


 Figure 2: Phase transitions and rotation phases² of 1-Docosanol PCM(E) with different degrees of supercooling. Melting at approx. 70 °C not shown.

Summary

Based on experiments with different PCM, nucleation additives and surfactants, a model for the crystallization was developed:

- PCM chains and nucleation additives require structural match
- Surfactant must not inhibit PCM crystallization
- Supercooling can only be avoided partially

Acknowledgments

We gratefully acknowledge the collaboration with our partners from ZAE Bayern, the financial support from the Federal Ministry for Economic Affairs and Climate Action (BMWK) and appreciate the cooperation with Projektträger Jülich.

¹ Safari, A.; Saidur, R.; Sulaiman, F. A.; Xu, Yan; Dong, Joe (2017): A review on supercooling of Phase Change Materials in thermal energy storage systems. In Renewable and Sustainable Energy Reviews 70, pp. 905–919. DOI: 10.1016/j.rser.2016.11.272.
 Zahir, Md. Hasan; Mohamed, Shamseldin A.; Saidur, R.; Al-Sulaiman, Fahad A. (2019): Supercooling of phase-change materials and the techniques used to mitigate the phenomenon. In Applied Energy 240, pp. 793–817. DOI: 10.1016/j.apenergy.2019.02.045.
² Reproduced with permission from Wentzel, Nathaniel; Milner, Scott T. (2011): Simulation of multiple ordered phases in C23 n-alkane. In The Journal of Chemical Physics 134 (22), p. 224504. DOI: 10.1063/1.3589417.