

Development of a lab demonstrator to test ionic liquids as phase change materials for energy storage

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Abstract

Phase change materials (PCMs) are an innovative energy storage concept for buildings. Ionic liquids are a new class of such energy storage materials and we present here a lab-scale prototype for their testing and characterization. The design and construction of this lab-scale heat-exchanger and initial results for three newly developed ionic liquids in the prototype are presented, showing their promising PCM properties.

Keywords

Ionic Liquids, Phase Change Materials, Energy Storage

1. Introduction

To reduce energy consumption and the greenhouse gas emissions, innovative energy storage concepts are being developed. One example is the use of phase change material to store thermal energy. These can be used in buildings as temperature stabilization or as a thermal battery with control on the charge/discharge process.

The goals of this project are to evaluate various ionic liquids and to optimize their properties to fit for a PCM application. A small-scale demonstrator is also developed to test the final ionic liquids and to compare their efficiency with a commercial PCM.

2. Phase Change Material (PCM)

Phase change materials are substances that use the heat they absorb and release through their melting and solidifying processes as energy for an external application. For an ideal energy storage, there are some favorable thermophysical properties such as: phase transition temperature suitable for the application, high heat of fusion, high thermal conductivity, density, no tendency to phase separate, good phase-change kinetics (little supercooling, sufficient crystallization rate), chemical stability, low toxicity and low flammability [1].

There are three main categories of PCM that each have their advantages and disadvantages [1]:

- Organic: Large temperature range, no phase separation, stable but volatile and flammable
- Inorganic: High heat of fusion, high thermal conductivity but corrosive and phase separation
- Eutectic: wide liquid temperature range, non-volatile, high storage density but limited data available on their thermo-physical properties

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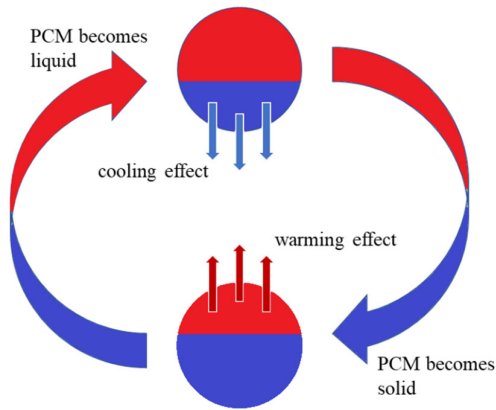


Figure 1: Heating/Cooling scheme for a PCM

3. Ionic Liquid (IL)

An interesting type of compounds are ionic liquids which fit in the eutectic PCM category. These substances are low-melting organic salts, that form liquids entirely comprised of cations and anions. Multiple ILs are bio-based and can therefore be easily produced and are non-toxic. Using these substances could be a step towards more sustainable installations.

It has been shown that ionic liquids can have superior heat transfer properties compared to commercial heat transfer fluids [2]. Advantages are that their properties can easily be tailored by combining various anions and cations to suit the application [2] and the current small scaled production can be easily adapted to large scale productions.

4. Small Scale Demonstrator

To test the ionic liquids for energy storage, a small lab-scale heat-exchanger is developed. After comparing the advantages and disadvantages of multiple set-up ideas, the final prototype presented in Figure 2 is chosen.

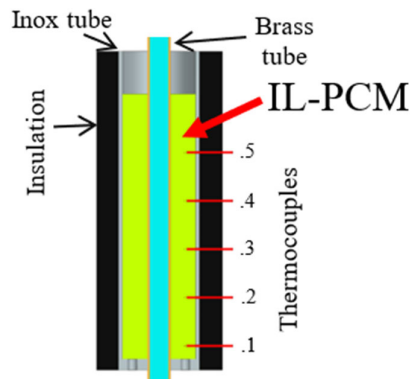


Figure 2: Concept chosen for the small-scale heat exchanger

The system is connected to a Lauda thermostat in a closed loop in order to have a water flow at a controlled temperature. In order to compare two substances in one experiment, two tubes are mounted

in series as shown in **Fehler! Verweisquelle konnte nicht gefunden werden.** All of the thermocouples are connected to a laptop and are read and registered by a LabVIEW program. From the known flowrate, the known mass of PCM and the difference of temperature between the entry and exit of each tube, the power released/absorbed can be calculated. Then by comparing the power measured in tube 1 with that in tube 2, the properties of these material as PCM can be identified.

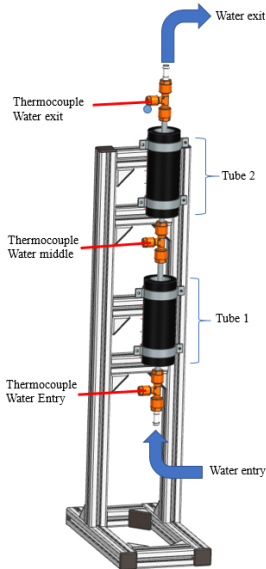


Figure 3: Concept chosen for the small-scale heat exchanger

4.1. Results & Discussion

Three ionic liquids are tested in the demonstrator with water in the second tube as it is the reference material for heating/cooling. A commercially available PCM is also tested in the prototype to compare the efficiency of our ILs with a known PCM.

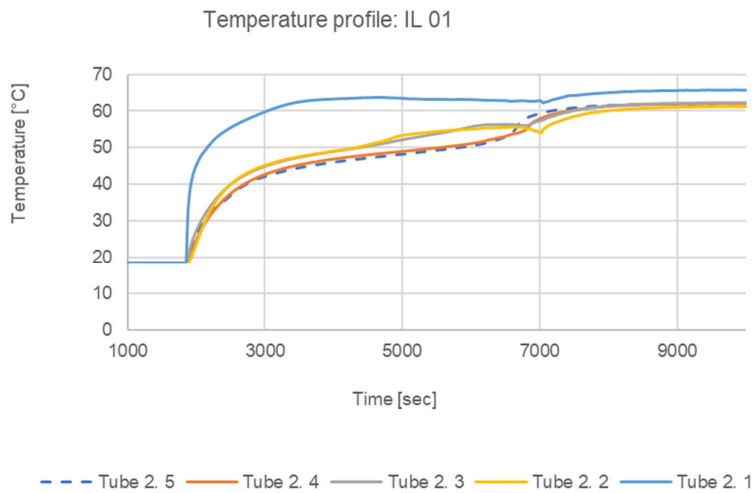


Figure 3: Example of heating experiment: IL 01, temperature measured along tube 2 (5 thermocouples as shown in Figure 2)

First all phase change materials are compared to the values for water. A factor is simply calculated by dividing the PCM's energy by the water's energy. Since not all materials have the same melting point, the difference of temperature during the experiment was also different for each PCM. Therefore, the factor was also corrected by the ΔT for each test. All substances tested are more efficient than water at absorbing energy and the ILs also seem to be more efficient than the commercial PCM as shown in Table 1.

Table 1

Comparison results between PCMs and water

Experiment	Heating [Wh/°C] / [Wh/°C]water
Water	1.00
Commercial PCM	1.79
IL 01	2.81
IL 02	2.50
IL 03	2.76

In a next step, calculations are made to remove the errors that come from the installation and obtain the energy for the PCM itself. This was possible by comparing the measured energy for water with its theoretical value that can be easily determined (see Table 2). The value calculated for the commercial PCM (178 J/ml) is close to the value given by its data sheet (177-187 J/ml) which attests the validity of the calculation.

Table 2

PCM Energies by correcting errors coming from the installation, *Energy divided by ΔT

Experiment	Heating	
	Energy [J/ml]	Energy* [J/(ml*°C)]
Commercial PCM	178 (177-187)	7.4
IL 01	590	13.3
IL 02	458	10.2
IL 03	483	10.7

From these results, all three ILs are more efficient at absorbing energy than the commercial PCM. This is some promising insight for the use of ionic liquids in the application of energy storage. Further tests need to be performed to confirm these primary results and to obtain trustworthy results for PCM cooling experiments.

5. Acknowledgements

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6. References

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