SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

# 2013 HIGHLIGHTS

# SHC Task 42
# Thermal Energy Storage: Material Development for System Integration

## THE ISSUE

To reach high solar fractions, it is necessary to store heat or cold efficiently for longer periods of time. At this time, there are no cost-effective compact storage technologies available. For high solar fraction systems, hot water stores are expensive and require very large volumes of space. Alternative storage technologies, such as phase change materials (PCMs), sorption materials and thermochemical materials (TCMs) are only available at the laboratory scale, and more R&D is needed before they are available commercially.

## OUR WORK

The objective of this joint Task with the IEA Energy Conservation through Energy Storage (ECES) Programme is to develop advanced materials for compact storage systems, suitable not only for solar thermal systems, but also for other renewable heating and cooling applications such as solar cooling, micro-cogeneration, biomass, or heat pumps. The Task covers phase change materials (PCMs), thermochemical materials (TCMs), and composite materials and nanostructures. It includes activities on material development, analysis, and engineering, numerical modelling of materials and systems, development of storage components and systems, and development of standards and test methods.

The main added value of this Task is to combine the knowledge of experts from materials science with that of experts in solar/renewable heating and energy conservation.

This is a joint effort with the IEA Energy Conservation through Energy Storage Progamme's Annex 29.

**PARTICIPATING COUNTRIES**

Australia
Austria
Belgium
Denmark
France
Germany
Italy
Japan
Netherlands
New Zealand
Slovenia
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

**Task Date** 2013-2016

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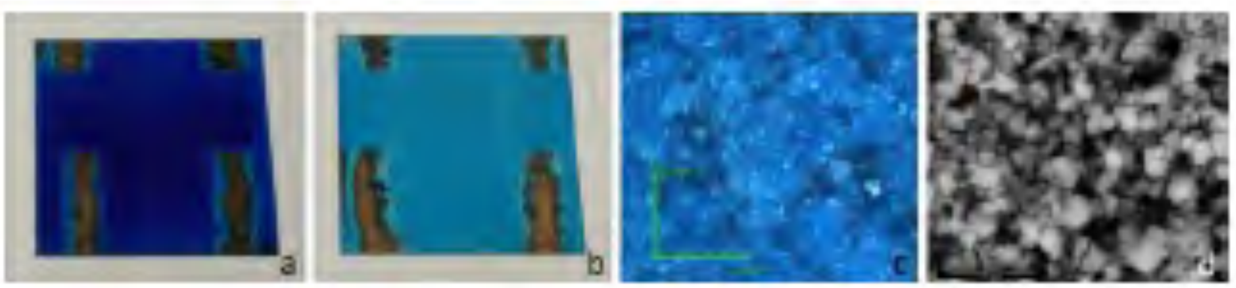
## KEY RESULTS OF 2013

### Material Development

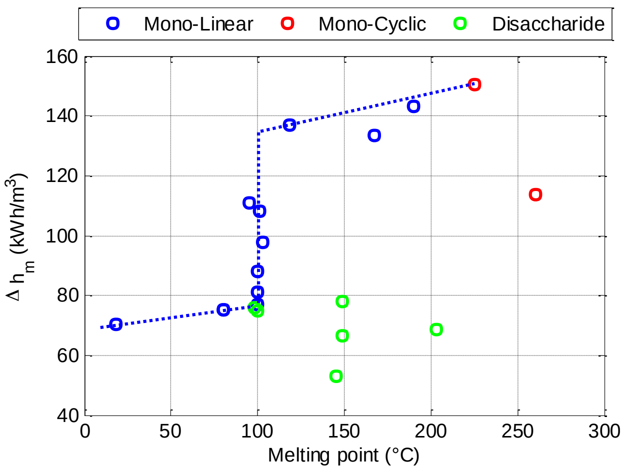
The Leuphana University in Luneburg, Germany is investigating the properties of composite materials, in which salt hydrates are impregnated in different carrier materials, like expanded vermiculite, expanded graphite powder, silicagel and activated carbon. The carrier materials function is to increase the rather low thermal conductivity of the salt hydrate and to stabilize the salt. Introducing the passive carrier material reduces the net energy storage density, and especially the carbon carrier composites have good energy storage densities.

Also in Germany, in Freiburg, the Fraunhofer Institute for Solar Energy is working on methods to cover the surface of metal fins with poly-crystalline layers of metal-organic frameworks (MOFs). The first aim is to have better performing heat exchangers in adsorption heat pumps, but the material development is also important for thermal storage applications. It was found that with these materials, the deposition growth rate was unprecedented.




*Optical image of the obtained coated sheets*

At the University of Bordeaux, France, research is underway on the possibility of making sugar alcohols suitable as phase change materials for temperatures lower than 100° C. To this end, first a screening was done of candidate materials and then composite mixtures are being investigated trying to find a mixture with optimal properties. Ideally, this mixture should have a high melting enthalpy at temperatures below 100° C.

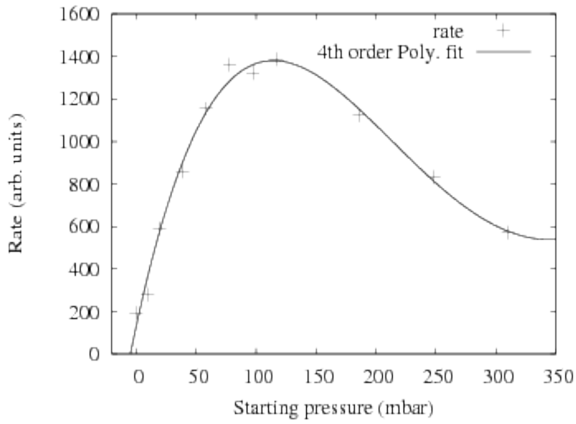



*Enthalpy change by melting of polyols as a function of the melting point.*

*Blue points: Linear monosaccharide polyols*
*Red point: Cyclic or ramified monosaccharide polyos*
*Green points: Disaccharide polyols.*

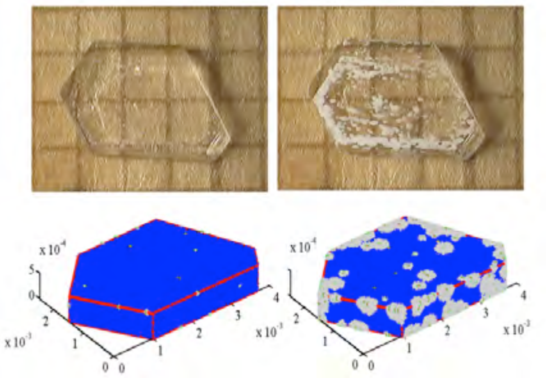
### Numerical Simulation

At the Eindhoven University of Technology, The Netherlands, a number of numerical models are being developed to calculate the materials behavior from principles. One class of models is molecular dynamic simulations, that are performed to study the dehydration behavior of epsomite (magnesium sulphate hepta hydrate, $MgSO_4.7H_2O$). The famous Topley-Smith effect observed in the dehydration process is reproduced in the simulation. The reason for the effect still remains unclear. The influence of crystal density, porosity and crystallinity seems to have little or no influence on the Topley-Smith effect. It appears that the temperature of the crystal is increasing as the water vapor pressure is increased. Thus the Topley-Smith effect may be related to the decreased self-cooling as proposed by Boris L'vov.




*Dehydration rate as a function of starting water vapor pressure. This curve shows the Topley-Smith effect.*

On a crystal grain scale, a model was developed to calculate the dehydration process in a lithium sulphate crystal. The model is based on nucleation growth theory, and there was good agreement between the experiments and the model results.



*Evolution of dehydration process of a Li2SO4•H2O crystal both from experiment (top) and simulation (bottom).*

## Systems development for TCM Storage

Several institutes have conducted work on new types of reactors for Thermochemical Energy Storage. The active volume of this generation of reactors is in the order of several tens of liters, making it possible to see the effects of using larger quantities of the active thermochemical storage material. These reactors are the step towards larger systems that will be built in 2014.

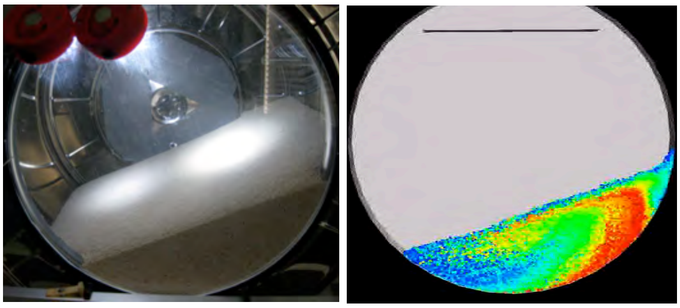
**Switzerland.** EMPA is working on a prototype seasonal storage system based on liquid sorption with sodium hydroxide. They finalized the design of the sorption reactor and the prototype was built. The figure on the left is a design sketch of the reactor.

*EMPA's liquid sorption reactor with enhanced*

**Austria.** ASiC built a prototype for a completely new reactor type for storage purposes that has the active material transported slowly trough a rotating drum. The first series of experiments were carried out with this set-up. It was found that ventilation of moist air through the rotating drum filled with dry zeolite spheres leads to a significant lift of the air temperature. Taking into account the ventilating rate, heat capacity of the air, storage material, and experimental setup as well as the thermal losses of the drum its self, several operation parameters (thermal power, humidity uptake efficiency, COP, etc.) can be calculated and will be validated with the experiments.

Below are a few examples of the research and development work of the groups participating in the Task. The most important publications about Compact Thermal Energy Storage R&D was assembled by the experts in the group and can be found on the Task website: http://task42.iea-shc.org/publications.

*ECN's bulk type open sorption prototype reactor.*



*ASiC's slow rotating drum and a simulation image of grain movement in the drum.*

*TNO's prototype sorption reactor with solid sorption material attached to the fins of the heat exchanger.*