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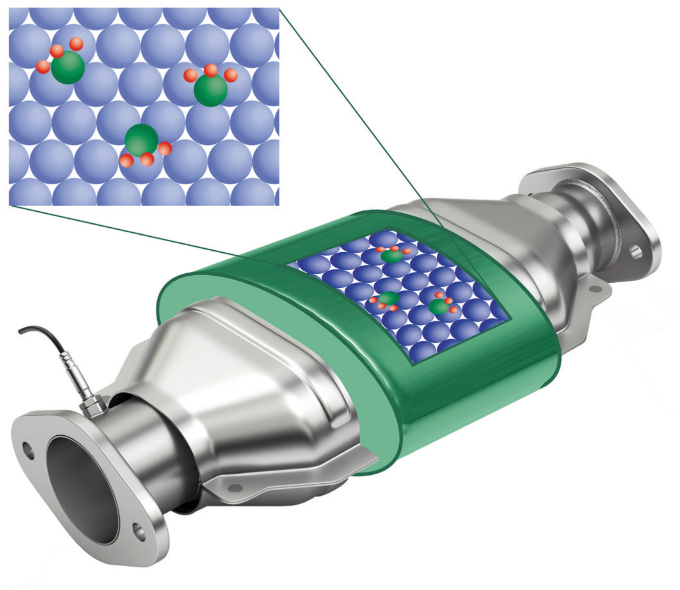
High-performance thermal energy storage

Thermo-chemical energy storage system for utilising waste heat from 150°C to 400°C – highly dynamic, easy-to-handle, compact

With a combustion engine, the emissions after a cold start can be around 10 times higher than those exhausted when at operating temperature. These can be largely eliminated if the catalytic converter is pre-heated accordingly. Forty per cent of all car journeys in Germany and Austria are less than 5 km long and therefore do not usually benefit from the cleaning effect of the catalytic converter. Heating devices, industrial production and power generating utilities regularly lose an enormous amount of heat energy without benefiting from it. This waste energy could be used efficiently via intermediate storage and utilization of heat at lower temperature levels. This would minimize the overall energy consumption as well as the CO_2 footprint. All of these emissions could be significantly reduced with low-loss thermal energy storage systems, which make it possible to bridge the time – and also the physical distance if necessary – between the availability of waste heat and the need for useful heat. These emissions are associated with waste heat at temperatures of between 150 and 400°C – and there are currently no suitable thermal energy storage systems available for this large range. By contrast, there are already systems for the low temperature range (up to 200°C) and the high temperature range (from 400°C). These store latent heat (e.g. in water or sand) or utilise the phase transition between solid and liquid (e.g. heat pads for the winter, and other organic phase change materials).

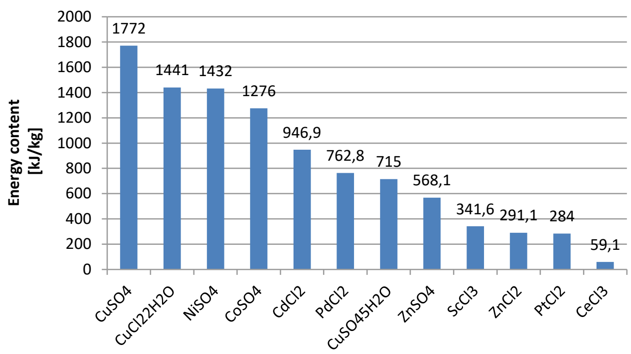
Objective

To be able to significantly reduce emissions from industry, transport and the energy sector, and utilise waste heat even more intelligently and efficiently than is currently possible, a new type of thermal energy storage system is required. The research groups headed by Dr Peter Weinberger (Institute of Applied Synthetic Chemistry) and Prof. Andreas Werner (Institute of Energy Systems and Thermodynamics) aimed to develop a storage system which could withstand thousands of charge and discharge cycles without losses, was easy to handle from a technical perspective, and was compact and cost-effective. Ideally, it needed to be able to react quickly, store the waste heat at different temperatures and release heat at various, adjustable temperatures. This would also allow cascading use, which is associated with particularly high recovery rates for waste heat.



Approach

The researchers at TU Wien decided to investigate materials expected to give thermochemical reactions in greater detail – for example, when you add water to quicklime, heat develops, spontaneously. These enable compact systems based on solids for long-term, loss-free storage with a high energy density. Thanks to the special structuring and spatial arrangement, it is possible to influence the reaction kinetics of the solids in a targeted manner. Basic research identified some 5000 chemical reactions capable of storing heat in solids. Once the storage density, reaction dynamics, cycle stability, technical handling, and costs of the substances had been taken into account, a dozen promising pairs of substances remained.



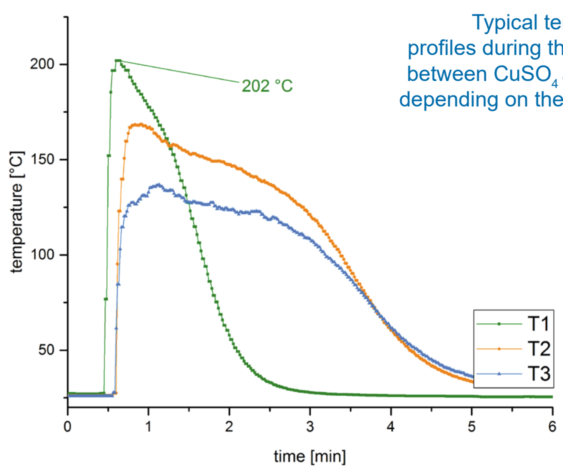
Storage density of different metal ammines in relation to the mass

Result

With 1.8 MJ/kg, copper sulphate ($CuSO_4$) exhibited the greatest thermal storage density and reacted fully reversibly with low amounts of ammonia (NH_3). The $CuSO_4$ is applied to a porous and chemically inert carrier substance and brought into contact with NH_3 to release the heat. For regeneration, the ammine is heated by the waste heat, which releases the NH_3 from the solid again. A simple piece of equipment, which works like a vacuum pump, transports the ammonia into a storage chamber, where it is kept in readiness for the next cycle.

The system is highly dynamic and even gives off heat at the highest temperature level, which can be over 300°C, within a few seconds already after the ammonia hits the solid. This temperature level can be influenced in a targeted manner through the structuring and geometry of the carrier substance and the technology selected for heat transfer. The same holds true with heat absorption.

The system makes it possible to separate the accrual of waste heat and the release and utilisation of stored heat both temporally and – if the compact storage device is transported – also physically.



Typical temperature profiles during the reaction between $CuSO_4$ and NH_3 – depending on the geometry

As the temperature levels at which the heat is released or absorbed can be calibrated specifically, provisions can be made to adapt the storage system for cascaded heat use and/or cascaded charging, if required.

Taking into account the actual purpose and the given spatial and physical conditions the appropriate thermal energy storage device can be designed and built, based on the know-how of TU Wien.

Advantages

- first highly dynamic storage system for utilising waste heat between 150°C and 400°C
- high energy density of 1.82 MJ/kg
- highly dynamic heat output – at peak temperature in just a few seconds
- provides heat at a high temperature level of over 300°C
- short charging time of just a few minutes
- high cycle stability
- adjustable temperature profiles for heat absorption and output
- unique and cost-effective materials
- also suitable for use as a long-term storage system – over several months

Applications

- to prevent emissions given off by a cold start of a combustion engine – for cars, lorries, ships, construction machinery, traction engines
- to utilise waste heat in heat-intensive manufacturing and processing industries
- the energy sector

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