FRAUNHOFER INSTITUTE FOR PHYSICAL MEASUREMENT TECHNIQUES IPM

PRESS RELEASE

Fraunhofer flagship project ElKaWe completed

Heat pumps without compressors: Fraunhofer advances electrocalorics

Highly efficient solid-state heat pumps without compressors – that is the vision of Fraunhofer researchers. With the recent completion of the ElKaWe research project, they took a big step towards realizing this vision. The team made great progress in terms of material and system design, and set up the first electrocaloric demonstrators to show the vast potential of this technology.

The demand for refrigeration and air conditioning technology is growing rapidly around the world. Today's heat pumps work on the basis of compressors, and are used for heating and cooling alike. Provided these heat pumps are powered by electricity from renewable sources, they can be a key element of the energy transition. Fraunhofer researchers want to revolutionize heat pump technology with an entirely novel concept: solid-state heat pumps based on electrocaloric materials that do not run on harmful refrigerants and could potentially be more efficient than compressor-based systems. During the recently completed ElKaWe project (ElKaWe is short for electrocaloric heat pump in German), six Fraunhofer institutes worked together on the main technological components of electrocaloric systems. "ElKaWe has generated a leap forward in terms of material, electronic components and heat transfer. While we still have a long way to go, these advances are promising steps towards marketability," says project manager Dr. Kilian Bartholomé of Fraunhofer IPM.

Electrocaloric materials: promising polymers, ceramics and hybrid materials have been identified

The electrocaloric material plays a key role in making electrocaloric heat pumps efficient and durable. The consortium developed and tested various polymer and ceramic materials. A team at Fraunhofer IAP came up with thin, electrocaloric polymer films with a high dielectric strength to make up a component with up to ten layers, setting new international standards. Fraunhofer IKTS developed ceramic multilayer components based on PMN-PT (lead magnesium niobate/lead titanate) that meet the high requirements for dielectric strength and operating frequency. Initial long-term testing showed the ceramic components to be extremely stable: No changes to the electrocaloric effect occurred after 70 million cycles. Additional tests involving components made from other materials are still ongoing. The lead-free barium-strontium-stannate-titanate (BSSnT) proved to be a promising ceramic material for making cost-efficient electrocaloric components that meet current RoHS (Restriction of Hazardous Substances) guidelines.

Editorial notes
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Fast heat transfer through heat pipes, without harmful refrigerants

Up until now, heat dissipation has been a bottleneck in terms of the efficiency of electrocaloric heat pumps: The faster the heat dissipates, the more powerful the system. The team of researchers employed active elastocaloric heat pipes (AEH) to enhance heat transfer rates. Here, latent heat transfer is achieved by the evaporation and condensation of a fluid on the caloric material. The fluids used here were ethanol and water – a great advantage over conventional heat pumps. Within the ElKaWe project, Fraunhofer IPM's patented AEH design was integrated into an electrocaloric system for the first time. The approach based on heat pipes makes for considerably faster cycle frequencies than conventional active pumping of a liquid. The liquid should evaporate and condense on the surface of the electrocaloric material up to ten times per second. This allows a lot of heat to be transported using little material, making it possible to build particularly cost-efficient systems in the future. Fraunhofer FEP developed super-hydrophilic layers that are stable over the long term and make evaporation from the surface particularly efficient. To prevent electrical breakdowns, Fraunhofer LBF also developed a process to embed the electrodes of the electrocaloric segments in epoxy resin.

The high coefficient of performance of caloric heat pumps also depends on it having powerful electrical controls. During the ElKaWe project, Fraunhofer IAF researchers designed a dedicated circuit topology for electrocaloric heat pumps. The GaN-based multilevel DC/DC converter achieves an electrical efficiency of 99.74 percent – setting new global standards in conversion efficiency, which was previously below 90 percent.

A technology with disruption potential

Across three different demonstrator systems, the researchers showed that all the components function together, achieving the expected system performance. According to simulations, the efficiency of electrocaloric heat pumps with today's materials is already equal to that of compressor systems. Analyzing the different classes of materials showed that there is great potential for another increase of the coefficient of performance. Another rise in the efficiency of electrocaloric systems is therefore to be expected. "The interdisciplinary team worked together extremely well, solving key questions. The great potential of electrocaloric technology was clearly demonstrated," says Christian Vogel, who closely supported the research as a member of the project advisory committee.

Further information

How does an electrocaloric heat pump work?

If an electric field is applied to electrocaloric materials, the electric dipole moments in the field are aligned. This additional order is accompanied by heating of the material according to the laws of thermodynamics. The resulting heat is dissipated via a heat sink so that the material cools down again to the initial temperature. If the electric field is removed, the order is reduced and the material cools down to a temperature below the initial temperature – again in accordance with the laws of thermodynamics. Now it can absorb thermal energy from a heat source. The effect is reversible. In this way, a cycle can be set up that functions as an efficient heat pump for cooling or heating.

The ElKaWe project

In the Fraunhofer flagship project »ElKaWe«, six Fraunhofer Institutes under the direction of Fraunhofer IPM have been working on the development of electrocaloric heat pumps for heating and cooling. Today, heat pumps work almost exclusively based on compressor technology. Electrocaloric heat pumps promise significantly higher efficiency and do not require harmful refrigerants. As part of the project, the scientists developed ceramic and polymer-based electrocaloric materials and worked on an innovative system concept that enables particularly efficient heat dissipation.

Participating Fraunhofer-Institutes

- Fraunhofer Institute for Physical Measurement Techniques IPM (Project Coordinator)
- Fraunhofer Institute for Electron Beam and Plasma Technology FEP
- Fraunhofer Institute for Applied Solid State Physics IAF
- Fraunhofer Institute for Applied Polymer Research IAP
- Fraunhofer Institute for Ceramic Technologies and Systems IKTS
- Fraunhofer Institute for Structural Durability and System Reliability LBF

Fraunhofer flagship projects

Fraunhofer is tackling the current challenges facing industry head on. Its lighthouse projects put the focus on strategic objectives with a view to developing practical solutions from which economies such as Germany's can benefit. The topics these projects address are geared towards economic requirements. By pooling their expertise and involving industrial partners at an early stage, the Fraunhofer Institutes involved in the projects aim to turn original scientific ideas into marketable products as quickly as possible. (learn more)

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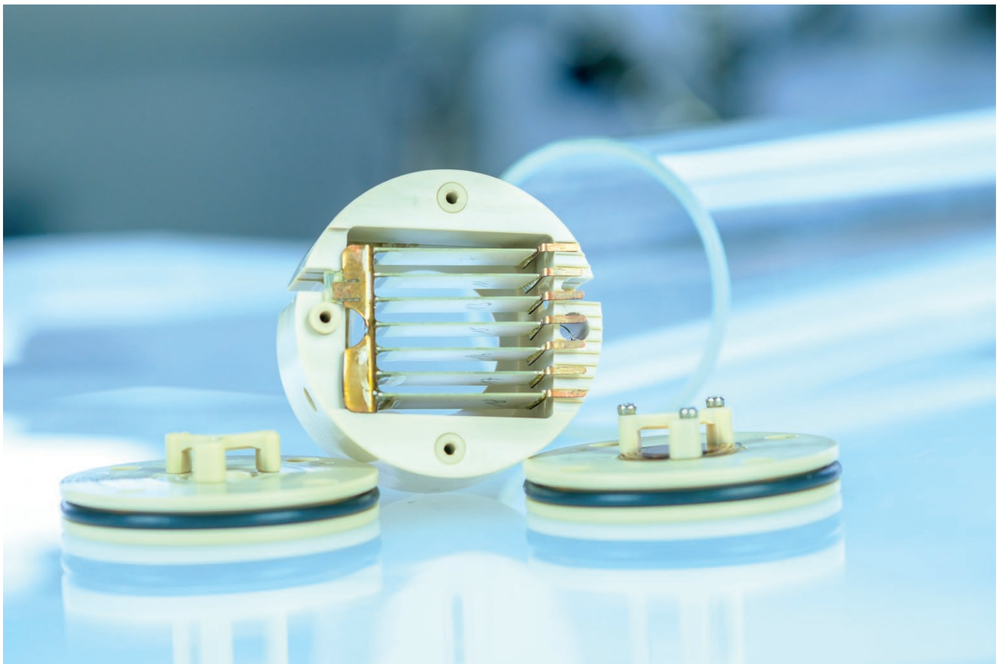

Electrocaloric segment: Heat pumps based on electrocaloric materials could provide a more efficient and environmentally friendly heating and cooling solution in the future. Three demonstrator systems comprising up to four segments each were assembled during the project. © Fraunhofer IPM

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