

Electrocaloric systems

Efficient cooling and heating without harmful refrigerants

Prototype of an electrocaloric system: Ceramic multilayer components were integrated into a heatpipe for highly efficient heat transfer.

Cooling systems available on the market today are based almost exclusively on compressors. Solid-state cooling systems on the basis of caloric materials are widely regarded as a promising alternative to compressor technology. Fraunhofer IPM develops electrocaloric cooling systems that achieve high system efficiencies and power densities thanks to a novel heat transfer concept.

Compact design, low noise and maintenance

Compressors have been used for cooling for over one hundred years now. But there are some drawbacks with these systems: Compressor technology relies on refrigerants that are harmful to the environment or to health and sometimes even flammable or explosive. New EU regulations are increasingly restricting the use of such harmful refrigerants. Innovative cooling concepts are therefore in urgent demand for many areas of application. Solid-state cooling systems based on caloric materials could prove to be an environmentally friendly alternative to compressor technology in the steadily growing global refrigeration market. Fraunhofer IPM develops electrocaloric cooling systems. In these systems, an innovative heat transfer concept makes a significant contribution to efficiency and cooling and heating power density.

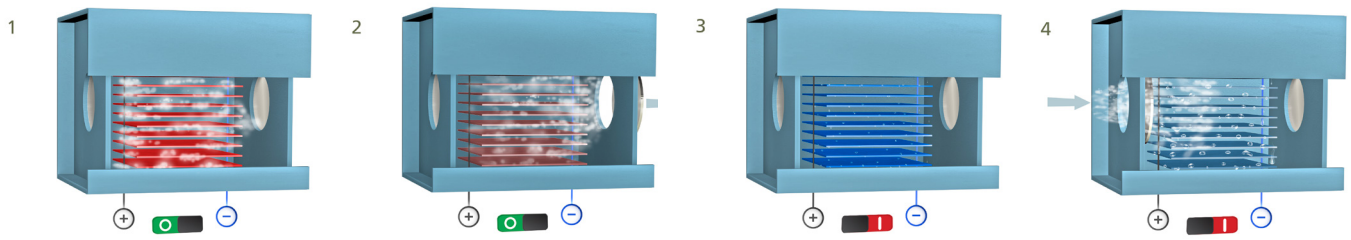
Principle of the electrocaloric cycle

Electrocaloric systems are based on so-called electrocaloric (EC) materials. These are ceramics or polymers that heat up when an electric field is applied and cool down as soon as the field is removed. Based on this effect, potentially very

energy-efficient cooling systems and heat pumps can be realized: The heat generated by applying the electric field is dissipated via a heat sink, causing the material to cool back to its initial temperature. As soon as the electric field is removed, its order reduces and the material cools down to a value below the initial temperature. It can now absorb thermal energy from a heat source. This effect is reversible to a very high degree and can be established as an electrocaloric cycle.

Patented concept for efficient heat transfer

The heat transfer between the EC material and the heat exchanger unit determines the overall efficiency of the electrocaloric system. In a patented concept, Fraunhofer IPM for the first time uses the latent heat produced during the evaporation and condensation of a fluid on the EK material for heat dissipation. Just like in a heat pipe, the fluid (e. g. water) evaporates at the warm side of a hermetically sealed tube and condenses at the cold side of the tube, the heat sink, transferring heat very efficiently: The heat transfer coefficient during evaporation reaches values of up to $100 \text{ kW}/(\text{m}^2 \cdot \text{K})$, and is therefore many orders of magnitude higher than that achieved using existing system concepts.



How does an electrocaloric segment work?

Phase 1: Electric field on

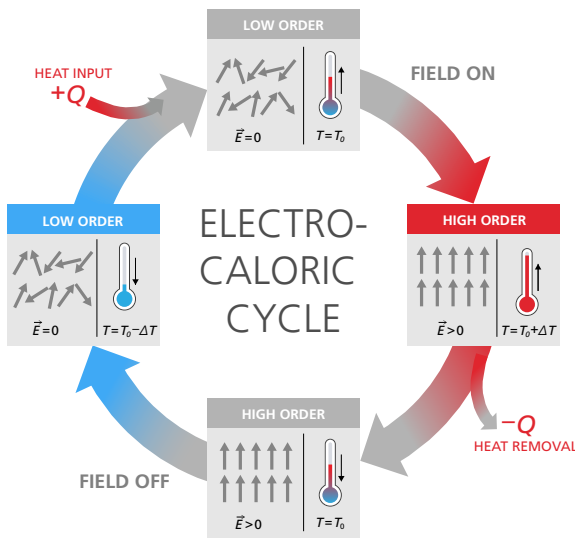
By switching on the electric field, the electrocaloric material heats up and the fluid evaporates. (1) As the fluid evaporates, the pressure in this segment instantly increases, the check valve to the right opens, the gaseous fluid escapes and transfers thermal energy to the next segment by latent heat transfer (2).

Phase 2: Electric field off

By switching off the electric field, the electrocaloric material cools down (3). This causes the fluid to condense on the components, creating a vacuum in relation to the preceding segment. Gaseous fluid flows in, heat is absorbed from the preceding segment (4).

Connecting the electrocaloric segments in series and combining them with a thermal diode produces a temperature spread between the external condenser and the evaporator.

In classical concepts of caloric cooling systems, heat is removed according to the principle of Active Electrocaloric Regeneration (AER), e.g. by actively pumping liquid through spaced stacks of caloric components. This, however, only works up to a certain cycle frequency due to the lower heat transfer. There also is significant pressure loss, which reduces the efficiency of the systems.



Calorics + cycle = heat pump

Electrocaloric material heats up when an electric field is applied. Dissipating the heat to the environment and then removing the field causes the material to cool down so that it can absorb heat. Built up cyclically, the electrocaloric effect can be used to create a heat pump or a cooling system.



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