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

Electrocaloric systems

Efficient cooling and heating without harmful refrigerants

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 often harmful to the environment or to health and sometimes even flammable. The use of these refrigerants is becoming increasingly restricted and regulated, which is why innovative cooling concepts are in demand.

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. These compact, low-noise systems require low maintenance and operate without harmful refrigerants. 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

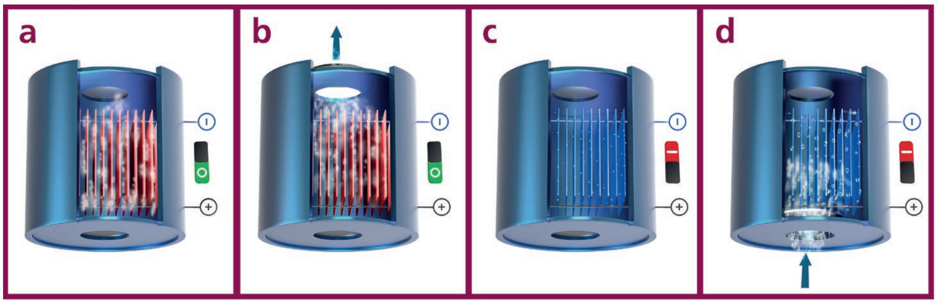
Electrocaloric systems are based on so-called electrocaloric (EC) materials. These are ceramics or polymers that heat up when an electric field is applied and cool down as soon as the field is removed. This effect is reversible to a very high degree and can be established as an electrocaloric cycle. Based on this effect, potentially very energy-efficient cooling systems and heat pumps can be realized (s. schematic diagram reverse page).

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 EC material for heat dissipation. Just like in

Our offer

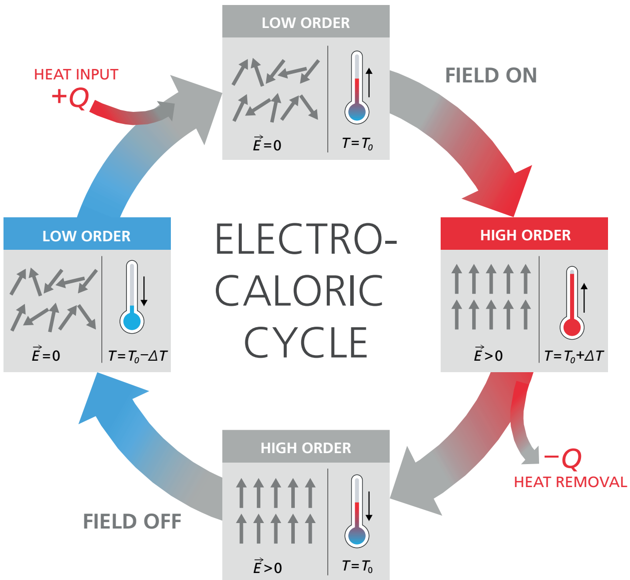
Fraunhofer IPM provides advice and support to companies in the characterization of electrocaloric materials and in the design, development and production of prototypes of magnetocaloric systems.



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).

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 kW/(m² K), and is therefore many orders of magnitude higher than that achieved using existing system concepts. Connecting the electrocaloric segments in series and combining them with a thermal diode produces a temperature spread between the external condenser and the evaporator.



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.

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.

Demonstrator systems

Faster heat transfer enables high system frequencies. An experimental setup at Fraunhofer IPM has already demonstrated the feasibility of the technology with a high power density of approx. 1500 W/kg . This is one order of magnitude more than that achieved by other electrocaloric systems with ceramic components. Adapting the geometry of the EC components and also improving the EC material will further increase power density. Fraunhofer IPM utilizes these levers in the development of demonstrator systems to increase the temperature range and power density.

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