Magnetocaloric systems

Efficient cooling and heating without harmful refrigerants

World record: A magnetocaloric cooling system with a specific cooling power of 12.5 W per gram of magnetocaloric material – a milestone in the path to marketable caloric cooling systems.

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. Magnetocaloric cooling systems developed at Fraunhofer IPM achieve a specific cooling power that is an order of magnitude higher compared to state-of-the-art systems. This is due to an innovative heat transfer concept.

Compact design, low noise and maintenance

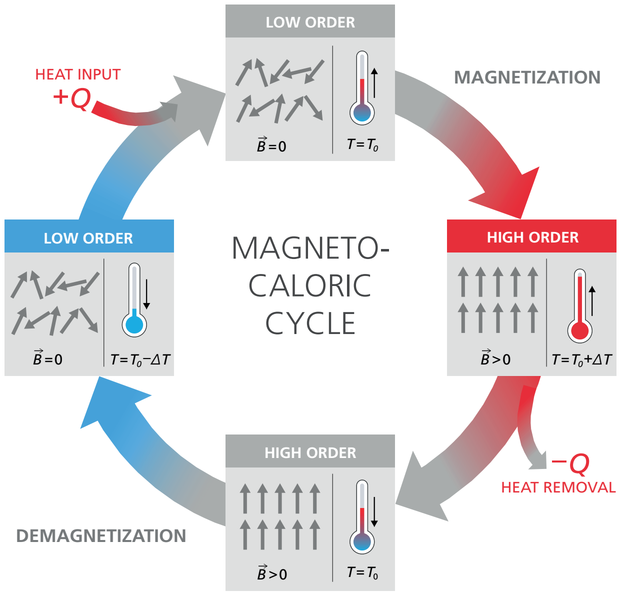
Compressors have been used for cooling for over one hundred years now. But there are some drawbacks with these systems: Compressor technology relies on refrigerants that are harmful to the environment or to health and sometimes even flammable or explosive. New EU regulations are increasingly restricting 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 magnetocaloric cooling systems. In these systems, an innovative heat transfer concept makes a significant contribution to efficiency and power density.

Principle of the magnetocaloric cooling cycle

Magnetocaloric systems are based on what are called magnetocaloric (MC) materials. For its systems, Fraunhofer IPM uses lanthanum-iron-silicon – an alloy which is magnetocaloric even at room temperature. MC materials are magnetizable materials which heat up by a temperature of ΔT when exposed to a magnetic field and cool down again by ΔT when the field is removed. This is how it is possible to implement a cooling cycle. The heated MK material is connected to a heat sink so that heat can be dissipated. If the magnetic field is removed, the material cools down to a temperature below the initial level. Connecting the MK material to a spot to be cooled it can absorb heat. This effect is reversible to a very high degree, enabling highly efficient cooling systems and heat pumps based on MC materials.

High power density thanks to innovative heat transfer concept

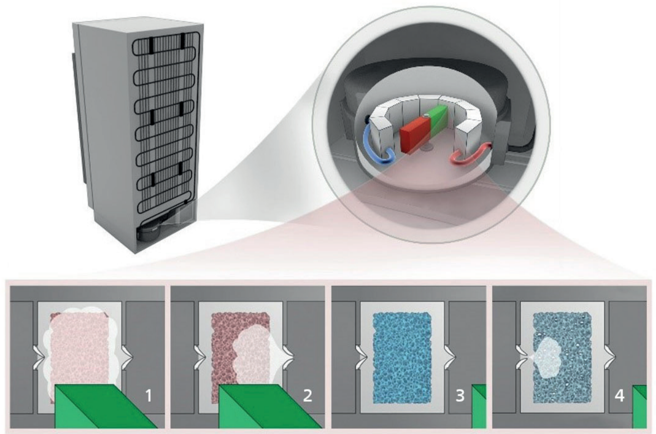
A magnetocaloric cooling system constructed at Fraunhofer IPM with a utilizable cycle frequency of 20 Hz is the first to achieve a specific cooling power of 12.5 W per gram of magnetocaloric material. It is superior to all previously known magnetocaloric systems. This is due primarily to a patented concept of latent heat transfer that is based on heatpipes: A fluid, e. g. water



Magnetization
Magnetocaloric (MC) material is exposed to a magnetic field and heats up due to the generated magnetic order from temperature T_0 to $T_0+\Delta T$.
Heat release
The magnetocaloric (MC) material is connected to a heat sink, the heat produced can be dissipated, the MC material cools down again to temperature T_0.
Demagnetization
If the magnetic field is removed, the MC material cools down and is at a lower temperature $T_0-\Delta T$ than it is at the start of the cycle.
Heat input
The MC material is now connected to the system to the cold side and can absorb heat, until it reaches temperature T_0 again.

evaporates at the warm side of a hermetically sealed pipe and condenses at the cold side of the pipe, the heat sink, allowing heat to be transferred. The individual caloric segments are arranges in series and activated one after another, transfering heat according to the principle of a thermal diode.

In classical concepts of magnetocaloric cooling systems, heat is removed according to the principle of Active Magnetic Regeneration (AMR) by actively pumping liquid through small granules or stacks of caloric material. 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.



Magnetocaloric cooling based on the heat pipe concept
Based on the principle of a thermal diode, the heat is »pushed forward« in only one direction. The heat generated in the magnetic field causes liquid in the magnetocaloric material to evaporate (1). The pressure in the segment increases. The pressure relief valve opens so that vapor enters the neighboring element (2). After switching off the magnet, the magnetocaloric material cools down to below the initial temperature (3). The vapor pressure drops, resulting in a negative pressure compared to the preceding segment. Gaseous fluid flows in, and heat is absorbed from the preceding segment (4).

CALORIC FRIDGE

Contact

Dr. Kilian Bartholomé
Group Manager Caloric Systems
Phone +49 761 8857-238
kilian.bartholome@ipm.fraunhofer.de

Fraunhofer Institute for
Physical Measurement Techniques IPM
Georges-Köhler-Allee 301
D-79110 Freiburg
www.ipm.fraunhofer.de/en