Fraunhofer
IPM

Caloric systems

Solid-state cooling and heating

In Germany, around 50 percent of the total final energy consumption is attributed to heating and cooling. Technological innovations could make a big contribution to protecting the environment and climate.

Cooling systems and heat pumps available on the market today are based almost exclusively on compressors. Compressors have been used for over one hundred years now, mainly for cooling. But there are some drawbacks with these systems. Fraunhofer IPM develops caloric heat pumps for cooling and heating as an alternative to compressor technology.

Cooling technology is one of the fastest growth areas for additional energy demand. In Germany, over 72,000 GWh of electrical power p.a. is consumed for technical cooling. Today's standard compressor-based refrigeration systems dissipate heat via a change in the aggregate state of a refrigerant. Many of these refrigerants are harmful to the climate, toxic or highly flammable and can often only be operated at high pressures. The EU is therefore increasingly restricting the use of these refrigerants. For many applications – such as in commercial refrigerators or cars – small, lightweight and low-noise cooling systems are in demand. These systems should be maintenance-free over long periods of time, insensitive to high temperature fluctuations and vibration, and, above all, operate without harmful refrigerants.

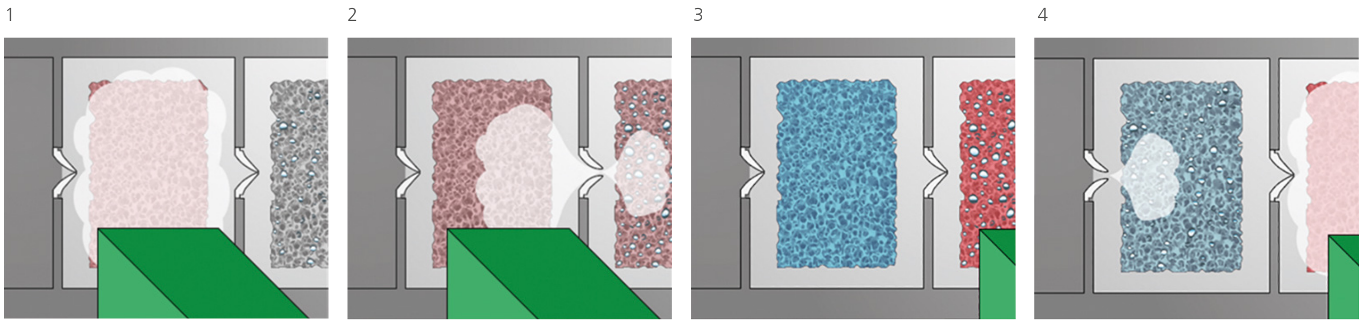
Solid-state cooling systems based on caloric materials are a promising alternative to compressor-based cooling and heating technology. In recent years, a number of magnetocaloric cooling systems have been presented. But heat pumps can also be built with elasto- and electrocaloric materials that outperform conventional cooling systems by up to 30 percent in terms of energy efficiency.

Efficient heat pumps – without harmful refrigerants

Caloric materials show a strong, reversible heat reaction when exposed to a respective field (magnetic field, electric field or mechanical force) and cool down again when this field is removed. Dissipating the heat causes the temperature to drop below the starting temperature. This effect can be utilized to construct a cooling circuit: The heated material is connected to a heat sink in order to dissipate the heat produced. Connecting it to a spot to be cooled, it absorbs heat until the starting temperature is reached. This way, an efficient heat pump with no need for refrigerants can be established.

Advantages

- **Efficient** Increase in efficiency of 20-30 percent possible compared to conventional systems
- **Climate-friendly** No need for harmful refrigerants
- **Low-maintenance** No wear parts
- **Low-noise** Universally applicable

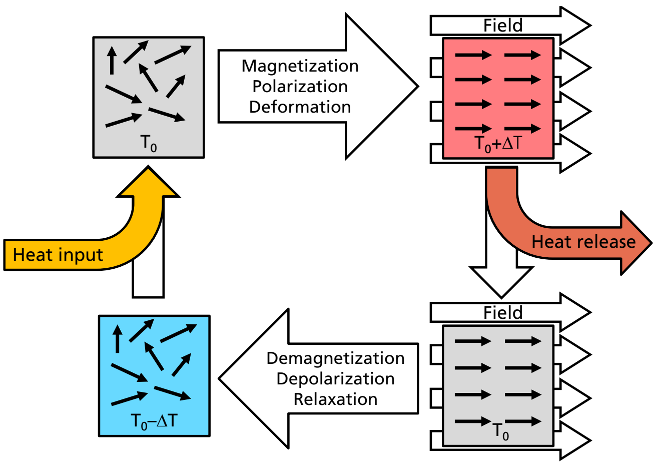


Efficient heat dissipation demonstrated by the example of a magnetocaloric cooling circuit: *The heat is »pushed on« only in one direction according to the principle of a thermal diode. The heat generated in the magnetic field causes fluid in the MC material to evaporate (1). The pressure in the segment increases, opening the pressure-relief valve so that vapor enters the neighboring element (2). When the magnet is switched off, the MC material cools to below the starting temperature (3). The vapor pressure drops. This results in a partial vacuum by comparison with the preceding segment. Gaseous fluid flows in and heat is absorbed from the preceding segment (4).*

Heat transfer with heatpipes boosts efficiency

Various caloric cooling systems, primarily magnetocaloric systems, with high cooling capacities and wide temperature ranges have been realized worldwide in the past few years. Cooling cycles with temperature ranges of up to 50 K or cooling capacities of several kilowatts were achieved. However, these prototypes have not yet demonstrated any increase in efficiency over conventional, compressor-based cooling systems. The crucial factor for the efficiency of caloric cooling circuits is efficient heat transfer. Virtually all prototypes implemented to date are based on the »Active Magnetic Regeneration (AMR)« concept. Here, the material is flushed with a pumped fluid that transfers the heat from the source to the sink. The AMR approach proves to be inefficient owing to the low cycle frequency and the high pump energy required.

Systems developed by Fraunhofer IPM for the first time combine caloric materials with latent heat transfer, analogous to heat pipes, for efficient heat transmission. This patented method involves heat being transferred by the evaporation and condensation of a fluid such as water or ethanol in a hermetically sealed chamber. The principle of this so-called thermosiphon enables heat transfer coefficients which are several orders of magnitude higher than with conventional heat transfer by conduction or convection.



Caloric Cycle

Magnetization / polarization / deformation

The caloric material heats up from the starting temperature T_0 to $T_0 + \Delta T$ when a corresponding field is applied.

Heat release

The caloric material is connected to a heat sink so that the resultant heat can be dissipated. The caloric material cools down to the starting temperature T_0.

Demagnetization / depolarization / relaxation

Once the field is removed, the caloric material cools down and is at a lower temperature $T_0 - \Delta T$ than at the start of the cycle.

Heat input

The caloric material is connected to the system to be cooled and absorbs heat until the starting temperature T_0 is reached.

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