Karlsruhe Institute of Technology

Division III – Mechanical and Electrical Engineering

Institute of Microstructure Technology (IMT)

ZEco Thermal Lab

Sustainable cooling and heating with solid refrigerants

The ZEco-Thermal Lab develops zero-emission, and environmentally friendly (ZEco) cooling and heating technologies based on the elastocaloric effect: the devices use solid materials to change temperature through deformation. They therefore do not require any gaseous climate-damaging refrigerants. The ZEco-Thermal Lab is working on various applications: from micro-scale cooling, for example for electronics, to large appliances such as refrigerators and air conditioning systems. The aim is to provide sustainable cooling and heating solutions for the future.

Around three billion cooling appliances are currently in use worldwide for space cooling. They are responsible for 20 percent of total global electricity consumption. The market is still dominated by conventional vapor compression cooling, a two-century-old technology that relies on gaseous refrigerants with a high global warming potential (GWP). In miniature cooling applications, the growing demand is mainly met by thermoelectric coolers, which are, however, not very energy efficient.

Elastocaloric technology

Elastocaloric cooling, also known as an emerging solid-state cooling, is a promising alternative to conventional cooling. It is based on stress-induced thermal changes in solid-state refrigerants such as superelastic shape memory alloys (SMAs). Solid-state refrigerants have no GWP and therefore does not harm the climate. Superelastic SMAs have an exceptional elastocaloric cooling effect and high material efficiency. Due to these advantages, the European Commission has recognized elastocaloric cooling as the most promising non-vapor-compression technology for future cooling applications.

From micro devices to large appliances

The ZEco Thermal Lab has developed several prototypes of elastocaloric microcooling devices. Its research focuses on the following points: Extending the temperature range for a wider range of applications, increasing the cooling power for different requirements, extending the lifetime by using ultra-low fatigue SMAs, and increasing the efficiency. In addition, the ZEco Thermal Lab is researching cost-effective materials to further develop elastocaloric microcooling for commercialization. The potential applications include thermal management for microelectronics, lab-on-a-chip systems, batteries, sensors and bioanalytical chips.

The research group is also actively developing large-scale elastocaloric cooling and heat pump systems. It is working on new SMA configurations to improve cooling performance and optimize system integration. The upscaling of elastocaloric technologies enables their use in building air conditioning, industrial cooling and district heating systems. The development of advanced regenerators, multistage cooling systems and hybrid systems enable the integration of renewable energies and increase energy efficiency.

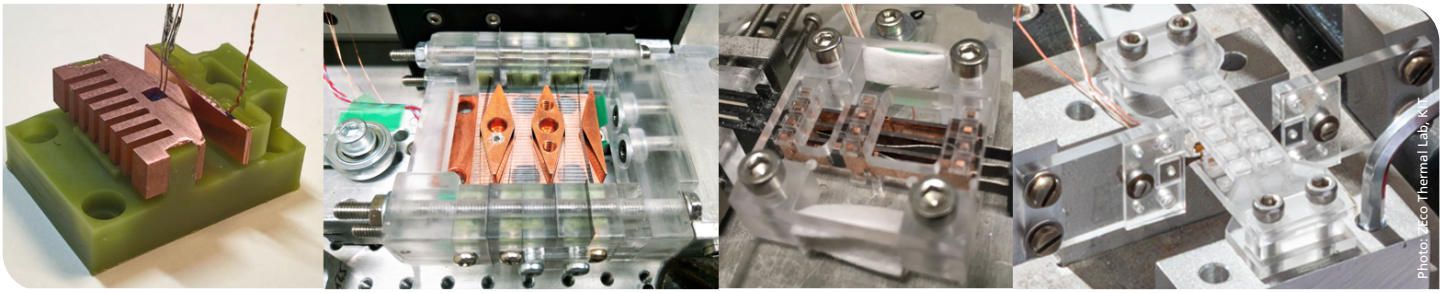

Photo: ZEco Thermal Lab, KIT

Elastocaloric microcooling prototypes (from left): single-stage device as a benchmark, parallel device for increased cooling power, cascade device for an extended temperature range, ultra-long lifetime device with a service life of over ten million cycles.

Use of renewable energies and waste heat

The ZEco Thermal Lab is working on combining elastocaloric cooling and heating with solar thermal, geothermal and waste heat to develop energy-saving and zero-electricity solutions. In this way, elastocaloric systems can provide high-performance cooling and heating devices while significantly reducing energy consumption and greenhouse gas emissions.

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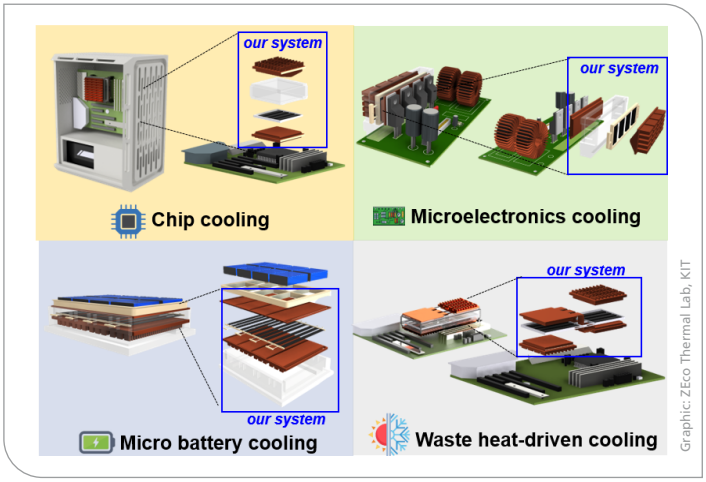
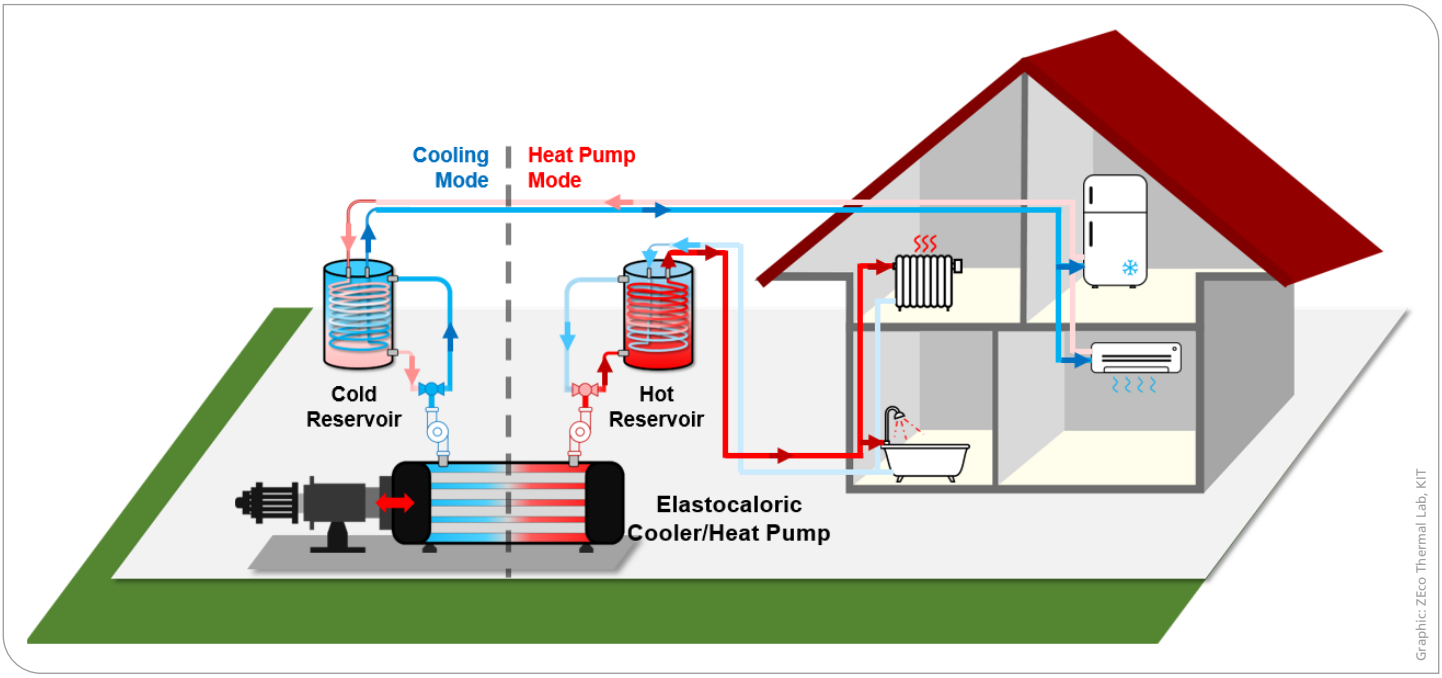


Potential applications and integration of elastocaloric microcooling devices.



A large-scale elastocaloric cooling and heat pump system that demonstrate the potential applications for heating, hot water, refrigeration and air conditioning in buildings.

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Dr. Jingyuan Xu
Phone: +49 721 608-24781
Email: jingyuan.xu@kit.edu
Web: www.imt.kit.edu/3484.php

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