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Hannover Messe: Smart materials offer sustainable cooling and heating solutions for homes, cars and industry

A novel type of air conditioning technology that can cool and heat more sustainably and more economically than current commercial systems is being developed in Saarland, Germany. The technology, which makes use of the elastocaloric effect, works without volatile refrigerants, oil or gas. In elastocaloric systems, heat transfer is achieved simply by mechanically deforming thin wires and sheets of nickel-titanium alloy. The research team led by Professors Stefan Seelecke and Paul Motzki from Saarland University is now developing prototype systems for use in vehicles. The aim is to have achieved commercialization within five years. The team will be at the trade fair Hannover Messe.

Hannover Messe from 31 March to 4 April in Hall 2 (Saarland Innovation Stand B10).

According to physics, cold is simply an absence of heat. To cool something down, you need to remove heat; to warm it up, you add heat. A simple enough idea and one that researchers in Saarbrücken have been able to realize in a particularly innovative way. The team makes use of a special property of the 'shape memory' alloy nickel-titanium ('nitinol' or 'Ni-Ti'). Put simply, by repeatedly pulling bundles of ultrathin nitinol wires or sheets and then letting them relax, heat can be absorbed in one location and then dissipated somewhere else. Based on this elementary principle, the research team led by Stefan Seelecke and Paul Motzki at Saarland University and the Center for Mechatronics and Automation Technology (ZeMA) in Saarbrücken have been developing their novel air conditioning technology in innovative research projects that have received millions in funding.

Elastocaloric technology has been recognized by the EU Commission as one of the most promising alternatives to conventional heating and cooling systems. The World Economic Forum listed the elastocaloric process in its 'Top Ten Emerging Technologies' in 2024. Compared with conventional cooling technologies, which consume a lot of energy and can pollute the environment with climate-damaging refrigerants and greenhouse gases, the technology being developed in Saarbrücken is more energy-efficient and is as clean as the electricity used to power it. Elastocaloric systems dispense with the need for environmentally harmful refrigerants and fossil fuels. The field of elastocalorics, in which Stefan Seelecke and Paul Motzki are among the pioneers, has the potential to play a significant role in addressing the global energy crisis. According to the Federal Environment Agency in Germany, final energy consumption (i.e. the total energy consumed by end users) for heating and cooling accounts for somewhat more than half of Germany's total final energy consumption. What's more, the International Energy Agency (IEA) reports that space cooling alone currently accounts for twelve percent of total global energy demand. 'Forecasts predict that this figure could triple by 2050,' says Paul Motzki, Professor of Smart Material Systems for Innovative Production at Saarland University and Scientific Director/CEO at ZeMA.

Elastocalorics is beginning to move into the mature technology phase. The researchers are keen to translate their findings into practical industrial and commercial solutions. To facilitate knowledge transfer, the German government is investing more than €17 million over a period of nine years in the DEPART!Saar project, which aims to bring together researchers in Saarland with research institutions and industrial partners.

In another project that has just been launched, the team in Saarbrücken is working with Volkswagen AG, the Fraunhofer Institute for Physical Measurement Techniques in Freiburg (IPM) and the company Ingpuls GmbH in Bochum. The aim here is to use elastocaloric technology to develop a lightweight, low-energy air con system for electric vehicles and to develop a means of cooling the traction batteries in EVs. 'The project has been awarded €3.5 million in funding from Germany's Federal Ministry for Economic Affairs and Climate Action and we're currently developing the first prototypes,' explains Paul Motzki.

In yet another new research project, the team is working on an elastocaloric air conditioning system that can be used to cool and heat individual rooms of a residential buildings via ventilation slots in the outer walls. Last year, Paul Motzki and his team were part of a European consortium that won the European Innovation Council's prestigious 'EIC Pathfinder Challenge' worth €4 million. This award is given in recognition of 'visionary, radical new technologies that have the potential to facilitate necessary societal transitions, tackle global challenges and establish new markets'. Over the next three years, a prototype air conditioning system will be developed in the 'SMACool', whose partners include the University of Ljubljana, the University of Naples Federico II and the Irish company exergyn. 'The elastocaloric system acts as both a refrigerator and a heat pump at the same time. With an efficiency some three to five times that of a conventional system, our technology needs significantly less electrical energy to operate,' says Professor Motzki, who is the project's scientific lead.

Whether using the system for cooling or heating, the team is able to achieve temperature differentials of around 20 °C. 'This applies to a single-stage component,' explains Motzki. 'If we build multi-stage systems, we can achieve much greater temperature differences.' The basis for all of the elastocaloric prototypes being developed in Saarbrücken is the unusual 'shape memory' property of nickel-titanium alloy. Nickel-titanium has two crystal lattices, i.e. two crystallographic phases with slightly different physical dimensions. The term 'shape memory alloy' (SMA) is used to reflect the material's ability to revert to a previous state (crystal lattice structure) via a reversible phase transformation. We all know that water can exist in three physical states or 'phases': solid (ice), liquid (water) and gas (water vapour). But unlike water, the phases in nickel-titanium are both in the solid state. When one of the phases transforms into the other, the SMA wires or sheets absorb heat; when that phase transforms back again, the material dissipates heat to its surroundings. So, air flowing over the nickel-titanium alloy as it undergoes a phase change will either cool down or heat up and this effect can be used, for example, to cool or heat up spaces within buildings. 'Depending on the particular application, we use SMA wires, thin sheets or even 3D-printed components with complex geometries,' explains Motzki.

But while the underlying principle seems fairly straightforward, creating a practical cooling and heating system from these materials requires some clever engineering innovation. The experts in Saarbrücken have built carefully designed prototypes that are able to operate continuously. They have constructed demonstration models that are able to keep inducing phase transformations in metal sheets or wires so that heat can be transferred to or from a medium like air, water or a water-glycol mix that is flowing over the SMA material. Questions being addressed by the team include how best to apply mechanical loads to the nickel-titanium alloy to achieve a desired cooling or heating effect, how to improve process efficiency, how fluid flows can be optimized, which shape of sheet metal or which bundle of wires is best suited for a particular application. The researchers have also developed software that enables them to adjust the heating and cooling technology for different applications and to simulate and plan cooling systems. 'We want to leverage the innovative potential of elastocalorics in a wide range of applications, from household appliances to industrial cooling systems,' says Paul Motzki. The Saarbrücken team is collaborating with other experts in the field, such as Ingpuls GmbH, to examine the entire product lifecycle from raw materials to component manufacture to end-of-life recycling.

The Saarbrücken technology is the fruit of more than 15 years of research in multimillion-euro projects and in doctoral theses that have won several international awards. Results include the world's first demonstration model of the continuous air-to-air elastocaloric effect and the world's first elastocaloric mini fridge.

The research team will be exhibiting the prototype elastocaloric fridge at this year's international trade fair Hannover Messe from 31 March to 4 April in Hall 2 (Saarland Innovation Stand B10).
Demonstrations will be held daily at 10.30 a.m., 1.30 p.m. and 4.30 p.m.

The elastocaloric fridge on show at Hannover Messe has a specially designed, patented cam track that continuously rotates bundles of 200 micron-thin nitinol wires around a circular cooling chamber. As the wire bundles rotate around the circular track, they are pulled (i.e. put under tension) on one side of the circle and allowed to relax again on the other. Air flows past the rotating bundles into the cooling chamber, where the wires relax again (i.e. undergo elastic recovery), which extracts heat from the air. As they continue rotating the warm nitinol wires transport the heat they have absorbed out of the cooling chamber. Once outside the cooling chamber, they transfer this heat to the surroundings. 'Inside the cooling chamber, the air only comes into contact with the unloaded (unstressed) wires. With this prototype we can get down to temperatures of about 15 degrees Celsius,' says Paul Motzki.

'Another important aspect of our technology is that it is self-sensing. Every electrical resistance value corresponds to a particular state of deformation of the wire bundles or sheets. Using artificial intelligence, our system is now able to recognize the precise position efficiently and accurately at all times, even in the event of interference,' explains Professor Motzki.

Background

Shape memory technology
The team researching smart materials at Saarland University and at the Center for Mechatronics and Automation Technology (ZeMA) in Saarbrücken was founded by Professor Stefan Seelecke. Working together Professor Paul Motzki the research work in this field has undergone substantial growth in recent years. The research team is using shape memory technology for a wide range of applications, ranging from robotic grippers to energy-efficient valves and pumps. The technology is being studied in numerous undergraduate, graduate and doctoral research projects. Many of the results have been communicated extensively in high-impact scientific journals, with numerous papers receiving international recognition. The research work has received significant funding from the EU and the German Research Foundation (DFG).

Professors Stefan Seelecke and Paul Motzki have recently founded the 'International Elastocaloric Society`. Based in Saarbrücken, this international scientific society aims to bring together the research community in this emerging research field and to build networks with industry and business with a view to the future commercialization of elastocaloric technology. The second international Elastocaloric Conference will take place in Saarbrücken from 13 to 15 May 2025. In the following years, the conference will rotate to a different host country each year.
To facilitate the transfer of their smart materials technology into the commercial and industrial sectors, the researchers established the company 'mateligent GmbH', which will also exhibiting at the same stand at this year's Hannover Messe.

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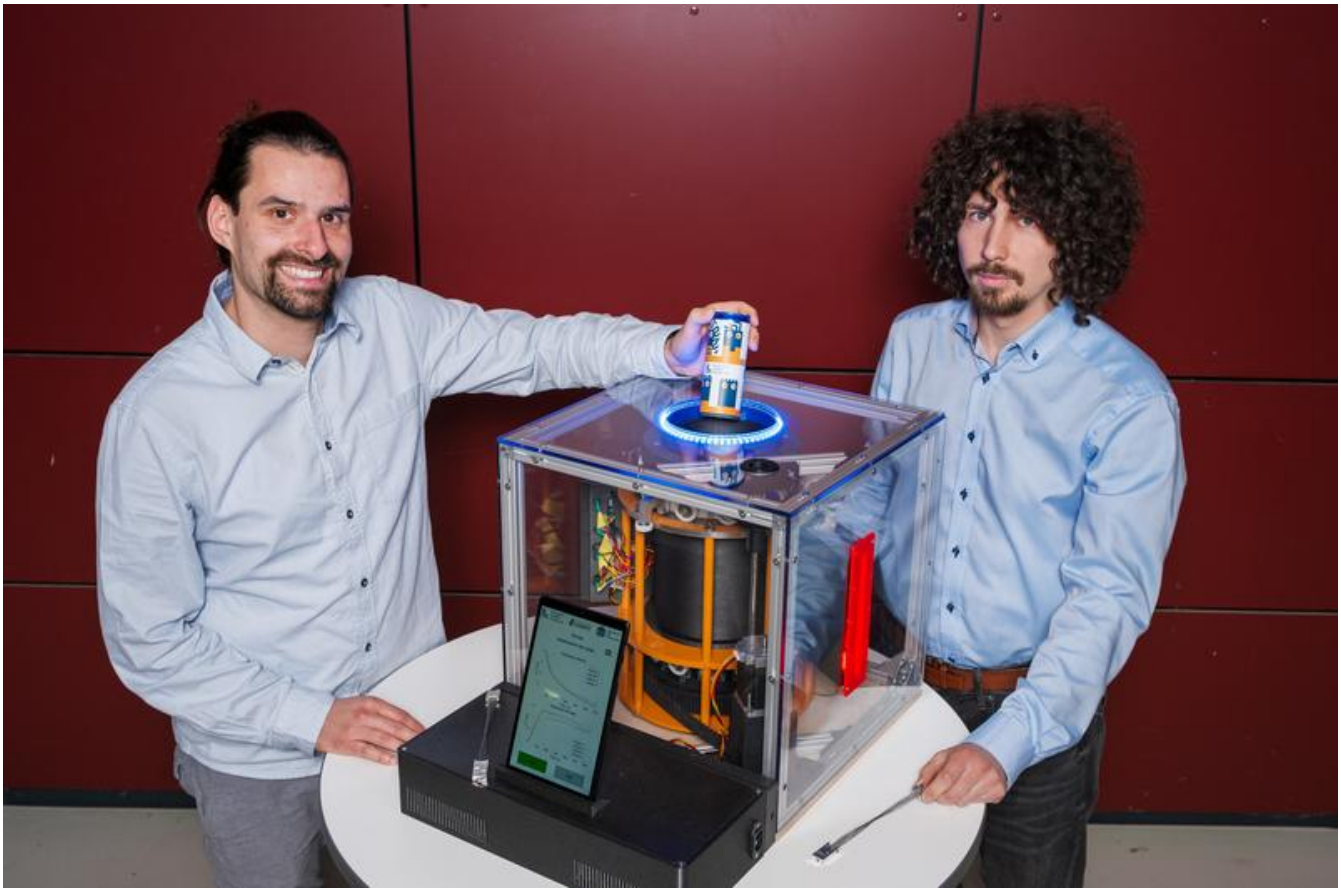
URL zur Pressemitteilung: https://zema.de – Center for Mechatronics and Automation Technology (ZeMA)



The team will be showcasing their prototype mini fridge at this year's Hannover Messe. PhD students Lukas Ehl (left) and Ivan Trofimenko (right) are researching ways to optimize this innovative cooling technology.
Credit: Oliver Dietze
Saarland University

Paul Motzki, Professor of Smart Material Systems for Innovative Production at Saarland University and Managing Director at the Center for Mechatronics and Automation Technology (ZeMA).
Credit: Oliver Dietze
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