

Solid state cooling based on magnetocaloric, electrocaloric, and mechanocaloric materials advancing to replace present environmentally damaging refrigeration technologies

Current cooling technology, such as that found in fridges and air conditioning systems, exploits the changes in temperature when gases are compressed and expanded. This technology often uses environmentally damaging greenhouse gases.

The search for materials with large caloric effects has become a major challenge in material science due to their potential in developing near room-temperature solid-state cooling devices, which are both efficient and clean, and that can successfully replace present refrigeration technologies.

There are three main families of caloric materials: magnetocaloric, electrocaloric, and mechanocaloric. They are classified based on whether thermal changes occur in response to a magnetic, electrical or mechanical field – with each displaying its own unique behaviour. Many research groups are developing prototype and proof-of-principle coolers based on these solid-state materials.

While magnetocaloric and electrocaloric materials have been studied intensively in the last few decades, mechanocaloric materials are only very recently receiving a great deal of attention. These mechanical stresses can either be uniaxial stress or hydrostatic pressure from a gas or liquid.

The different materials also differ in the strength of their response to the applied field. "For example, magnetocaloric materials work well and they have been studied extensively over the past 20 years, however for them to show a large temperature change a very large magnetic field must be applied. This makes it expensive and challenging to use magnetocaloric materials in real world applications.

As a result research into electrocaloric and mechanocaloric materials is blossoming and we're still finding out a lot about them," said Dr Xavier Moya whose team is researching caloric materials in which thermal changes are brought upon by application of external field. Further Electrocaloric materials require extremely thin sample, make them impractical for a cooling device.

"Application of an external field can be used to drive a phase transition in a material. A phase transition results in a change in the internal structure of the material which, in turn, alters its thermodynamic properties. This change in thermodynamic properties means that the temperature of the system changes and heat can be exchanged," said Dr Xavier Moya, of the University of Cambridge.

"Mechanocaloric materials have a few other advantages the most obvious being that only a mechanical force is required to drive the effect, which is straightforward to generate. I believe that mechanocaloric materials could play a part in some important technologies in the future," said Dr Moya.

Dr Moya explains, "A simple example of this would be the thermal changes that occur in the natural rubber found in party balloons. In the balloons resting state the rubber polymer chains are disordered and scrambled together. However, when the balloon is stretched the polymer chains are all pulled tightly and straighten up along the direction of the stretching force. This represents a change from a disordered system to an ordered system and, as the order of the system is

changed there is a change in entropy which results in a heat transfer. “ The process is similar for an electrocaloric material – a phase change (for example, paraelectric to ferroelectric) occurs when applying an electric field, and there is a transfer of heat.

Solid-state cooling technology will still take some time to develop to a point that may compete with fridges and air-conditioners that use vapour compression.

References and Resources also include:

<http://www.azom.com/article.aspx?ArticleID=13453>