STUDY OF MAGNETIC REFRIGERATION

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ABSTRACT

Chlorofluorocarbons refrigerants that were used widely today in refrigeration and air conditioning causes the depletion of ozone layer, which is very hazardous to earth. With the goal of making refrigerators and air conditioners more efficient, several groups around the world are developing magnetic-refrigerant materials. A magnetic-cooling system could also be less polluting than current systems because it wouldn't use environmentally harmful chemicals, such as ammonia or chlorofluorocarbons. Instead of ozone-depleting refrigerants and energy-consuming compressors found in conventional vapor-cycle refrigerators, this new style of refrigerator uses gadolinium metal that heats up when exposed to a magnetic field, then cools down when the magnetic field is removed. Magnets are big-time materials, finding roles in products ranging from motors to medical-imaging systems. Now, a team of engineers' improvement of a custom-made magnetic material increases the odds that refrigeration will soon join the roster of magnet-based technologies.

INTRODUCTION :

Magnetic refrigeration technology takes advantage of the magneto caloric effect, the remarkable ability of a magnetic material to heat up in the presence of a magnetic field and cool when the field is removed. Magneto caloric materials store heat energy in the way the atoms vibrate and in the way in which electrons spin within each atom. More heat energy increases the vibrations and also makes the spins more random. In other word, when the party heats up, things get a little crazy. Scientists refer to this "craziness" as entropy, which is a measure of thermodynamic disorder. When a strong magnetic field is applied to the coolant material, the magnetic moments of its atoms become aligned, making the system more ordered. The more ordered material has a lower entropy and compensates for the loss by heating up. But when the strong magnetic field is removed, the party is forced to cool down. The magnetic moments return to their random directions, entropy increases and the material cools. Typically, the temperature of a material can drop by about 10 to 15 degrees C (52 to 59 F), depending on the magnetic field strength. The temperature at which most of the change in magnetic entropy occurs is known as the material's ordering temperature or its Curie point. This is the point where the material changes from being ferromagnetic to paramagnetic, and the farther away from this point the weaker the magneto caloric effect. The useful portion of the magneto caloric effect usually spans about 25 degrees C (77 F) on either side of the material's Curie temperature. Therefore, in order to span a wide temperature range, a refrigerator must contain several different coolants arranged according to their differing ordering temperatures.

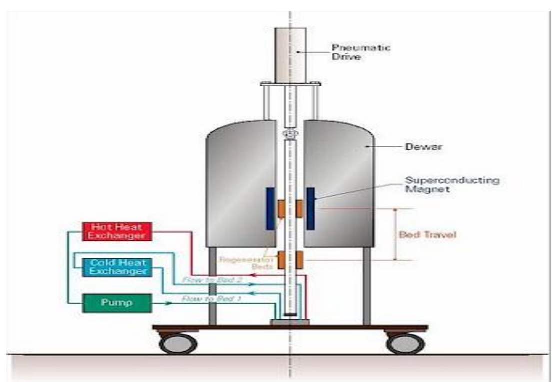
International Engineering Journal For Research & Development

E-ISSN No:2349-0721

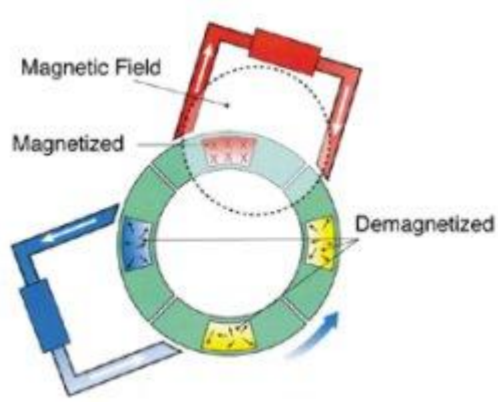
Volume 1 Issue 3

The wheel is arranged to pass through a gap in the magnet where the magnetic field is concentrated. As it passes through this field, the gadolinium in the wheel exhibits a large magneto caloric effect — it heats up. After entering the field, water is circulated to draw the heat out of the metal. As the gadolinium leaves the magnetic field, the material cools further as a result of the magneto caloric effect. A second stream of water is cooled by the gadolinium. This water is then circulated through the refrigerator's cooling coils. The overall result is a compact unit that runs virtually silent and nearly vibration free, without the use of ozone-depleting gases, a dramatic change from the vapor-compression-style refrigeration technology in use today. Researchers can't yet take full advantage of this new material. Each time a magnetic field is applied to the material, it shifts the arrangement of the atoms, changing the material's crystal structure and releasing energy. This shift would reduce the cooling efficiency of any system made with the material.

To eliminate these losses, researchers added iron to the gadolinium-germanium-silicon compound. With just 1 percent of all the atoms in the material consisting of iron, the material no longer changed its crystal structure when exposed to a magnetic field. However, it retained its magnetic-cooling properties. In the June 24 *Nature*, the researchers report that their subtle modification reduced the material's energy losses by almost 95 percent.



Their latest discovery is a new class of alloys with significantly more cooling power than the best existing materials. The new materials are based on gadolinium, an element with two to three times the magnetocaloric effect of a typical ferromagnetic iron and a popular choice for low-temperature ranges.This tremendous breakthrough is going to put magnetic refrigeration in the market.



NEXT GENERATION OF MATERIALS ADVANCES MAGNETIC REFRIGERATION

Scientists at the Department of Energy's (DOE) Ames Laboratory have discovered a new class of materials that represents a significant advance in the cooling power of materials currently used for magnetic refrigeration.

The new materials are made of a gadolinium-silicon-germanium (Gd5Si2Ge2) alloy. Scientists discovered the new class of materials when they lowered the magnetic ordering temperature of the compound, gadolinium-silicon (Gd5Si4), by substituting germanium for silicon. The new compound, Gd5Si2Ge2, exhibits a magnetocaloric effect about twice as large as that exhibited by gadolinium, the best known magnetic refrigerant material for near room temperature applications.

The new material has two advantages over existing magnetic coolants: it exhibits a giant magnetocaloric effect, the ability of certain materials to heat up when placed in a magnetic field and cool when taken back out again; and its operating temperature can be tuned from about 30K (-400 degrees F) to about 290K (65 degrees F) by adjusting the ratio of silicon to germanium -- the more germanium, the lower the temperature.

APPLICATIONS

Define the perfect fuel and it would most likely be one that burns cleanly, poses no harm to the environment and, above all, is renewable or in limitless supply. Liquid hydrogen could prove to be close to a perfect fuel, but first scientists and engineers must jump a few technological hurdles.

One of the biggest hurdles, an efficient method of liquefying hydrogen, has been eliminated by recent developments at Ames Laboratory. Scientists have developed a highly efficient magnetocaloric material that makes magnetic refrigeration technology efficient enough to cheaply produce liquid hydrogen, very likely one of the first major commercial uses of magnetic refrigerators.

Conventional production methods for liquid hydrogen begin by using liquid nitrogen to lower hydrogen gas to minus 196 degrees Celsius (320.8 degrees Fahrenheit). A gas-compression system, similar to the one in your refrigerator at home, is then used to further reduce the temperature to minus 253 C (423.4 F). One drawback to this method, however, is that the inefficiency of the gas-compression cycle cannot economically produce less than five tons of liquefied gas a day. This limits the production sources of liquid hydrogen to large plants that are few and far between.

Researchers nationwide see more than just the liquefaction of hydrogen and other gases on the horizon for magnetic refrigeration technology. Although the history of development for gas-compression cycle refrigerators has given it a head start, the efficiency of the new coolants makes magnetic refrigeration truly competitive with conventional gas-compression technology for the first time. Large-scale applications could soon be developed. Examples include supermarket-sized refrigerators and freezers, air conditioning for large buildings, industrial chemical processing, and waste separation and treatment.

Also, the new coolants may eliminate the need for the superconducting magnets associated with earlier cry coolers. This opens the way for small-scale applications of this technology, such as car and home air conditioners.

Magnetic-cooling systems could have uses beyond refrigerators and other household appliances. One of the things that is really limiting the development of all-electric cars is the fact that they don't have an air conditioner .They can't generate enough power to run it. An efficient magnetic-cooling system could solve that problem, he predicts.

Household fridges and magnets have long had a surface relationship. Now, they may be warming up—actually, cooling off—to a more intimate involvement. Researchers have unveiled a new cooling system that chills by means of magnets, operates at room temperature, and can fit inside home appliances.

The discovery may also launch totally new applications for efficient refrigerators at very low refrigeration powers since gas compression technology cannot be scaled down to such low cooling powers and since thermoelectric cooling is very inefficient (30 times less than magnetic refrigerants).

With the goal of making refrigerators and air conditioners more efficient, several groups around the world are developing magnetic-refrigerant materials. A magnetic-cooling system could also be less polluting than current systems because it wouldn't use environmentally harmful chemicals, such as ammonia or chlorofluorocarbons. What's more, the technology requires few moving parts, so it can be simple, silent, and reliable. When a magnetic-refrigerant material is exposed to a magnetic field, the field forces the spins of electrons in the material to align. As a result, the material heats up. Removing the field permits the electrons to relax into less-ordered states, and the material cools down. By cycling the material through these hot and cold states and venting away the heat, the system can generate an overall cooling effect.

Magnetic refrigerators and air conditioners promise to be more efficient than conventional ones. Also, magnetic appliances would circulate water or relatively benign antifreeze fluids instead of ozone-depleting refrigerants, he adds.

Not a new technology, magnetic cooling has been used for more than 50 years by cryogenics specialists to chill already ultra cold substances to even lower temperatures. A few years ago, a team of researchers demonstrated a magnetic refrigeration unit that operated at room temperature. However, the device required a cryogenically cooled, electrically powered superconducting magnet, making it impractical for homes.

The permanent magnets and the gadolinium don't require any energy inputs to make them work, so the only energy it takes is the electricity for the motors to spin the wheel and drive the water pumps.

The efficiency of the new materials make magnetic refrigeration even more competitive with conventional gas-compression technology by replacing complex and costly superconducting magnets with permanent magnets in refrigerator designs. The elimination of superconducting magnets may also open the way for small-scale applications of this technology, such as climate control in cars and homes, and in home refrigerators and freezers

CONCLUSION:

At the same time, Ames Lab researchers have designed a permanent magnet configuration capable of producing a stronger magnetic field. The new magnet can produce a magnetic field nearly twice as high as that produced by the magnet used in the initial refrigerator; this is an important advance since the output and efficiency of the refrigerator is generally proportional to the strength of the magnetic field. The group has filed patent applications on both the gadolinium alloy process and the permanent magnet.

Currently another Ames Laboratory group to find practical means of processing the new materials and with Astronautics to design, construct and test a variety of magnetic refrigerators, which span temperatures from 20K (-425 degrees F) to 300K (80 degrees F) and have cooling powers ranging from one watt to 50,000 watts.

Continuing research into even more efficient coolant materials could narrow the gap. The new knowledge will allow us to improve existing materials and point the way to new and better ones, which will ensure the success of magnetic refrigeration as a viable energy-saving and environmentally safe technology in the next century. The limitations of magnetic refrigeration are only in the minds of scientists and engineers.

These are important advances, but it will require additional testing to see how much they will enhance refrigeration capabilities. Progress (in this field) is measured in small steps, and this is just another of those steps. However, we've come a long way since first announcing the giant magnetocaloric alloy five years ago.

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