Magnetic Room Temperature Cooling Using Stacks of Gadolinium Plates

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INTRODUCTION

Refrigeration is estimated to take up 15-20% of the energy consumption in western countries. Thus massive energy savings can be obtained from an optimization of the cooling process, resulting in reduction of the global carbon dioxide emission and the economic expenses in households and the industry.
It is estimated that magnetic refrigeration can yield an energy efficiency 20-40% higher than conventional refrigeration that make use of the vapor compression cycle. It has several other advantages compared to conventional refrigeration, for instance a lower noise level.

MAGNETIC REFRIGERATION

The cooling process is based on the magnetocaloric effect, i.e. the property of magnetic materials to change temperature when exposed to a changing magnetic field.
The magnetocaloric effect can be described by thermodynamic considerations. When magnetic materials are magnetized in a field, the individual spins in the material are aligned with the direction of the field. Thus the entropy of the system is decreased. The second law of thermodynamics tells us that the entropy of a closed system tends to increase over time. This is obtained by a drop in the temperature.
Magnetic refrigeration is now being used to low temperature cooling, where a powder of magnetic material is demagnetized and hence cooled down. A fluid is then pushed through the powder after which the fluid is used to cool the sample. A lot of power is required to push the fluid through the powder. This process can be optimized by substituting the powder with stacks of plates of magnetic materials.

IMPLEMENTING STACKS OF MAGNETIC PLATES

When a magnetic material is inserted in a magnetic field, it changes the field around it. By finding the right configuration of the magnetic plates, the demagnetizing field of one plate can intensify the field at the sites of the other plates, thus reducing the amount of magnetic material required. This project aims to describe the effect of stacking magnetic plates. It is experimentally measured how the magnetocaloric effect changes when the following 3 parameters are changed:

- Number of plates: The temperature change is measured for stacks of 1 to 11 plates.
- Plate spacing: The temperature changed is measured for 3 different spacings between the plates in a stack.
- Angle of field: The temperature change is measured for plates parallel and perpendicular to the field.

The experimental results are compared to a simulation model based on the mean field theory. The optimal configuration for a prototype is determined from the results.