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ACCEPTED MANUSCRIPT

PLASTICALLY DEFORMED GD-X (X= Y, In, Zr, Ga, B) SOLID SOLUTIONS FOR MAGNETOCALORIC REGENERATOR OF PARALLEL PLATE GEOMETRY

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ABSTRACT

Despite significant progress in the study of materials undergoing first-order magnetic phase transitions accompanied by the so-called giant magnetocaloric effect (MCE), Gd metal still remains the most widely used material in prototypes of magnetic refrigerators due to its significant MCE, good machinability and reasonable mechanical and chemical stabilities. Alloying of Gd enables fine-tuning the Curie temperature of Gd-based solid solutions (all show second-order phase transitions), for graded magnetocaloric materials. Commonly, Gd packed spheres are used as a magnetocaloric working substance in the active magnetic regenerator (AMR) cycle. In this work, we show that the optimized stacking parallel-plate geometry of AMR bed made of Gd is more effective for application at frequencies 1-10 Hz then the packed spheres. We also give a short review on magnetocaloric properties of cold-rolled Gd-X (X = Y, In, Zr, Ga, B) solid solutions. These materials can be produced in the form of thin (~ 100 μm) foils/plates to ensure rapid heat exchange between to the heat transfer fluid. Although the magnetocaloric effect decreases in the as-rolled foils, it can be recovered by thermal treatment of the final stacked-plates regenerators. Gd-Y, Gd-In and Gd-Zr solid solutions have magnetocaloric properties, comparable to the MCE of pure Gd in a wide temperature working span up to 37 K, 36 K, and 16 K respectively, which makes them suitable magnetocaloric material systems for testing the fundamental heat exchangers geometries at ambient temperature and in frequencies of 1-10 Hz.

Keywords: magnetocaloric effect, magnetic refrigeration, ferromagnets, gadolinium solid solutions, rare earth alloys, plastic deformation.
DOI:

1. INTRODUCTION

Triggered by the discovery of the giant magnetocaloric effect (MCE) in the compound $Gd_5Si_2Ge_2$ [1], there have been many research efforts in finding new intermetallics suitable for energy efficient magnetic refrigeration at ambient temperature. Since that time, a large number of compounds with impressive magnetocaloric characteristics have been found [2], however, the theoretical limit for the adiabatic temperature change of 18 K/T [3] is still an elusive quantity, even for the materials with a first-order magnetostructural phase transition.

In order to use a magnetocaloric material in a magnetic refrigerator, the material should be machined into a heat exchanger or regenerator, which is essentially a porous structure with fine and straight channels designed to provide the largest possible contact surface area to the heat transfer liquid. This issue requires magnetocaloric materials with outstanding MCE, excellent mechanical integrity, chemical stability, high thermal conductivity and tunable transition temperature.

Some intermetallic phases that exhibit magnetostructural or itinerant electron transitions demonstrate exceptional magnetocaloric properties [2], but they are rather brittle, and, under cycling in alternating magnetic field, they can decrepitate due to a large volume change accompanying the magnetic phase transition [4]. That is the one reason why the rare earth element Gd is still one of the widely used materials in magnetic cooling devices [5]. The Gd reveals good adiabatic temperature change ΔT_{ad} and specific entropy

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