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Magnetocaloric effect near a second-order magnetic phase transition

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Abstract

The temperature and magnetic field dependences of the magnetocaloric effect (adiabatic temperature change ΔT) were measured in single crystalline and polycrystalline Gd near the Curie point (T_C) using direct method with continuously changing magnetic field (H) at different rates and the more conventional stepping of the magnetic field. The peculiarities in ΔT(H) behavior are discussed. The Curie temperature of Gd was obtained by means of Belov–Goryaga (Arrott) plots on the basis of magnetization and magnetocaloric data, and from AC susceptibility measurements. The differences in the obtained values and possible reasons of the differences are discussed.

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The interest in the magnetocaloric effect (MCE) research has grown recently [1–5]. This is due to not only fundamental interest, but future practical applications in magnetic refrigeration. Moreover, MCE makes it possible to obtain additional information about the nature of magnetic phase transitions.

Potential applications of MCE are rather broad, including instrumentation development, medical applications and thermo-magnetic engines. The thermo-magnetic engine is remarkable for its simple design. Here, thermal energy of a hot gas produced by combustion of fuel is converted into mechanical energy due to phase transition of a material of a rotor from a high-magnetization state to a low-magnetization state and back. Nevertheless, the development of magnetic refrigerators remains the major potential use of MCE.

Magnetic refrigeration has been used for the first time in 1930s. At that time, the temperature of 0.25 K was reached by means of adiabatic demagnetization of a paramagnetic salt (hydrate of $Gd_2(SO_4)_3$). Now, a similar method of cooling (adiabatic demagnetization) is used in the laboratory for obtaining ultra low temperatures.

Magnetic refrigerators have such advantages compared to their household analogues, which use liquid coolants, as their durability, lowered energy consumption, and ecological benignity. Certainly, the first place, where magnetic refrigerators find their application, will be high efficiency devices with a narrow-working temperature intervals. One example is condensation of moisture from air. It is supposed that the magnetic refrigerator will be powered by solar cells. For condensation of moisture, the greater energy, and consequently, the greater the efficiency of the cooling device is required. At present, the usual air conditioners do not have such properties.

At present, there are several methods of estimating the MCE, such as from magnetization, heat capacity, etc. Not only these methods are indirect, but are they quasi-static as well. In all devices described above a cyclic process is used. Thus, it is necessary to investigate the dynamic MCE. No research has been devoted to this issue in the past, and basically this work is the first attempt of such a research. It is

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