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Thermodynamic features of magnetization and magnetocaloric effect near the magnetic ordering temperature of Gd

Y.I. Spichkin[a,*], A.V. Derkach[b], A.M. Tishin[b], M.D. Kuz'min[c], A.S. Chernyshov[d], K.A. Gschneidner Jr[d], V.K. Pecharsky[d]

[a] *Advanced Magnetic Technologies and Consulting Ltd., Moscow 117393, Russia*
[b] *Physics Faculty of M.V. Lomonosov Moscow State University, Moscow 119992, Russia*
[c] *Leibniz-Institut fur Festkorper und Werkstoffforschung, IFW Dresden, PF 270116, D-01171 Dresden, Germany*
[d] *Ames Laboratory and Department of Materials Science and Engineering, Iowa State University, Ames, IA 50011-3020, USA*

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Abstract

The magnetic field and temperature dependences of the adiabatic temperature change (ΔT) were measured in single-crystalline and polycrystalline gadolinium (Gd) near the Curie point (T_C) by a direct method while continuously changing magnetic field (H) at different rates and the more conventional stepping of the magnetic field from 0 to 1.2 T. The $\Delta T(H)$ behavior has a tendency towards saturation at high magnetic fields, which is similar for both the polycrystal and the single crystal (in the latter case, the magnetic field vectors was parallel to the c-axis of the crystal). The Curie temperature of Gd was determined from Belov–Goryaga (Arrott) plots using isothermal magnetization data and a similar technique using adiabatic temperature change isotherms. In the latter case, T_C was about 9 K higher than in the first case. Possible reasons for the observed difference are discussed.

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In recent years, research on the magnetocaloric effect (MCE) enjoys a steady increase [1–5]. This is related mainly to a potential of the phenomenon for practical application in efficient, energy saving technology—magnetic cooling. Because MCE reaches its highest values near magnetic phase transitions, the behavior of the MCE in this region is of particular importance. Moreover, MCE can provide additional information about the mechanisms of magnetic phase transitions, which makes studying the MCE important from a fundamental point of view. The MCE occurs when a magnetic field (H) is applied to a magnetic material. The effect has two manifestations—the adiabatic temperature change (ΔT) and the isothermal magnetic entropy change (ΔS_M). The adiabatic temperature change can be experimentally determined indirectly—from specific heat as function of temperature and magnetic field, and by direct measurements of the temperature change caused by the change of the magnetic field. Although $\Delta T(H)$ dependences can be determined indirectly, direct measurements carried out while continuously sweeping magnetic field are rarely, if ever, performed. At the same time, such investigations can provide important additional information, which would be especially useful from a practical point of view. It also should be noted that $\Delta T(H)$ field sweep measurements should be performed first on several well-studied materials in order to compare the obtained results with other MCE data available today and check the reliability of the technique. In this work, we investigate $\Delta T(H, T)$ dependences of single-crystalline and polycrystalline gadolinium (Gd) metal with continuous magnetic-field sweeps performed in the vicinity of the Curie point (T_C) in order to reveal peculiarities of the MCE behavior in this temperature range and establish their relationships with the behavior of magnetization (σ).

*Corresponding author. Tel./fax: +7 495 7878178.
E-mail address: spichkin@NdFeB.ru (Y.I. Spichkin).

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