Journal of Alloys and Compounds 658 (2016) 500–504

Contents lists available at ScienceDirect

Journal of Alloys and Compounds

journal homepage: http://www.elsevier.com/locate/jalcom

Magnetic properties and magnetocaloric effect in metamagnetic $RE_2Cu_2O_5$ (RE = Dy and Ho) cuprates

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ARTICLE INFO

Article history:
Received 12 October 2015
Received in revised form
29 October 2015
Accepted 30 October 2015
Available online 4 November 2015

Keywords:
$RE_2Cu_2O_5$ (RE = Dy and Ho) cuprates
Magnetocaloric effect
Magnetic phase transition
Metamagnetism

ABSTRACT

The magnetic and magnetocaloric properties in $Dy_2Cu_2O_5$ and $Ho_2Cu_2O_5$ cuprates have been investigated. The $RE_2Cu_2O_5$ compounds show a typical paramagnetic (PM) to antiferromagnetic (AFM) transition under low field around 10.3 and 13.5 K for RE = Dy and Ho, respectively. And a field-induced metamagnetic transition from AFM to ferromagnetic (FM) phase was happened with the application of higher magnetic field for both compounds. An inverse MCE under low magnetic field change and at low temperatures together with a normal reversible MCE under high magnetic field change was observed for the present $RE_2Cu_2O_5$ compounds, which is related to the fact of the AFM state and the field-induced first order metamagnetic transition from AFM to FM state, respectively. The maximum values of magnetic entropy change ($-\Delta S_M{}^{max}$) are 12.0 and 12.4 J/kg K under a field change of 0–7 T for $Dy_2Cu_2O_5$ and $Ho_2Cu_2O_5$, with the values of the relative cooling power (RCP) of 273 and 256 J/kg, respectively.

1. Introduction

The magnetocaloric effect (MCE) in various materials has been extensively investigated during the last thirty years, not only due to their potential applications for active magnetic refrigeration but also for further understanding the fundamental properties of these materials [1–13]. MCE is an intrinsic thermal response for all the magnetic materials when applying or removing a magnetic field, which manifests as the magnetic entropy change in an isothermal process, ΔS_M, or/and the temperature change in an adiabatic process, ΔT_{ad}. Magnetic refrigeration technology based on the MCE has many advantages, such as more environmental friendly, higher energy efficiency as compared to the conventional gas compression/expansion refrigeration technology [1–4]. From the viewpoint of applications, search for magnetic materials with large MCE is an important requirement. In recent years, the MCE in some rare earth transition metal oxides have also been carried out, and some of them are found to possess interesting magnetocaloric properties. For examples, a giant MCE has been observed in zircon-type $DyCrO_4$ and $HoCrO_4$ [9]. The $HoVO_3$ orthovanadate undergoes a large negative and conventional MCE around 4 and 15 K, respectively [10]. Large rotating magnetic entropy change, together with large refrigeration capacity and negligible hysteresis in $DyFeO_3$ single crystal has been observed [11]. Very recently, Mo et al. found a giant low field reversible together with large refrigerant capacity in $EuTi_{1-x}Cr_xO_3$ compounds, indicating that these compounds are promising candidates for low temperature magnetic refrigeration [12,13].

In the ternary rare earth RE-Cu-O phase diagram, the series with the stoichiometry $RE_2Cu_2O_5$ arises when RE is smaller than Gd. The crystal structure and some physical properties for $RE_2Cu_2O_5$ have been reported [14–18]. Magnetic studies reveals that the $RE_2Cu_2O_5$ cuprates ordered antiferromagnetically below 17.7, 9.5, 12.3, 25, 16.7, 17.3, and 10.5 K for RE = Tb, Dy, Ho, Er, Tm, Lu, and Y, respectively [14–18]. In the present study, we further investigated the magnetic and magnetocaloric properties in the $Dy_2Cu_2O_5$ and $Ho_2Cu_2O_5$ cuprates. A field induced metamagnetic transition together with a normal and inverse MCE has been observed in both compounds.

2. Experimental

Polycrystalline samples of $Dy_2Cu_2O_5$ and $Ho_2Cu_2O_5$ were prepared by solid–state reaction method from dried high-purity

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http://dx.doi.org/10.1016/j.jallcom.2015.10.289
0925-8388/

Dy_2O_3, Ho_2O_3, and Cu_2O powders. The powders with the stoichiometric composition were mixed, grinding thoroughly and calcined at 900 °C for 24 h in air with intermediate grinding. The products were pressed into pellets and sintered at 915 °C for 48 h. The final heat treatment of the sintered precursors was at 930 °C for 48 h. Both samples were proved to be a single phase by X-ray powder diffraction (XRD), and the lattice parameters *a*, *b*, and *c* were calculated to be 10.83, 3.512, and 12.45 Å for $Dy_2Cu_2O_5$; and to be 10.81, 3.493, and 12.46 Å for $Ho_2Cu_2O_5$, respectively. The magnetization measurements were performed with a commercial vibrating sample magnetometer (VSM) which is an option of physical property measurement system (PPMS-9, Quantum Design).

3. Results and discussion

The temperature dependence of the zero field cooled (ZFC) and field cooled (FC) magnetization (*M*) under the magnetic fields of 0.2 T for $Dy_2Cu_2O_5$ and $Ho_2Cu_2O_5$ are shown in Fig. 1(a) and (b), respectively. No difference can be observed in ZFC and FC *M*–*T* curves for both compounds, indicating no thermal hysteresis. The *M*–*T* curves of $RE_2Cu_2O_5$ exhibits a maximum around 10.3 and 13.5 K for *RE* = Dy and Ho, respectively, which is a typical characteristic of paramagnetic (PM) to antiferromagnetic (AFM) transition, being consistent with previously reported results [14,17]. A series of temperature dependence of magnetization under different external field from 0.5 to 3 T for $Dy_2Cu_2O_5$ and $Ho_2Cu_2O_5$ are measured, and the results are shown in Fig. 2(a) and (b), respectively. Both compounds show a similar behaviour, i. e. AFM ordering for $H \leq 1.5$ T, whereas ferromagnetic (FM) or FM-like magnetic ordering for $H \geq 2$ T. The temperature dependence of the magnetization *M* (left scale) and the reciprocal susceptibility $1/\chi$ (right

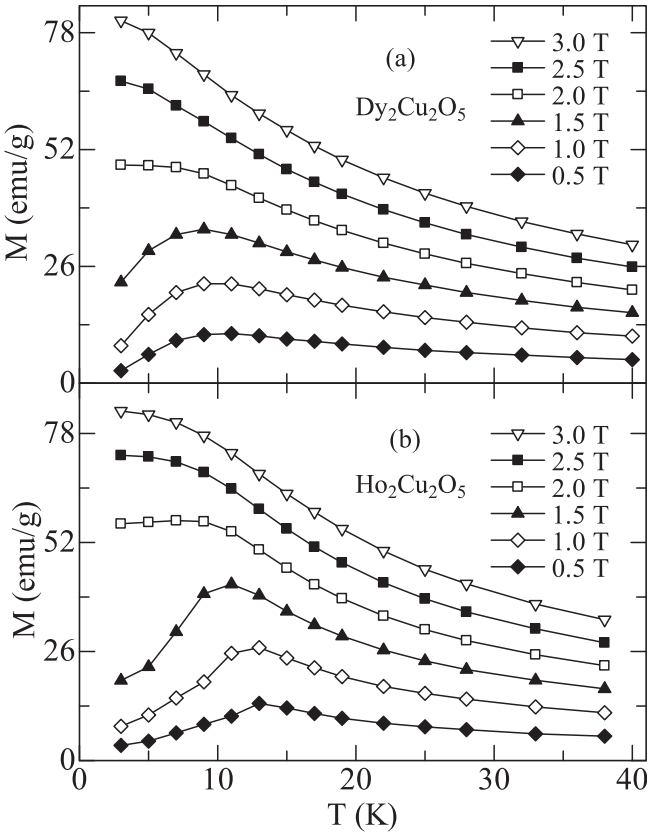

Fig. 2. Temperature dependence of magnetization (*M*) under different external field from 0.5 to 3 T for (a) $Dy_2Cu_2O_5$ and (b) $Ho_2Cu_2O_5$.

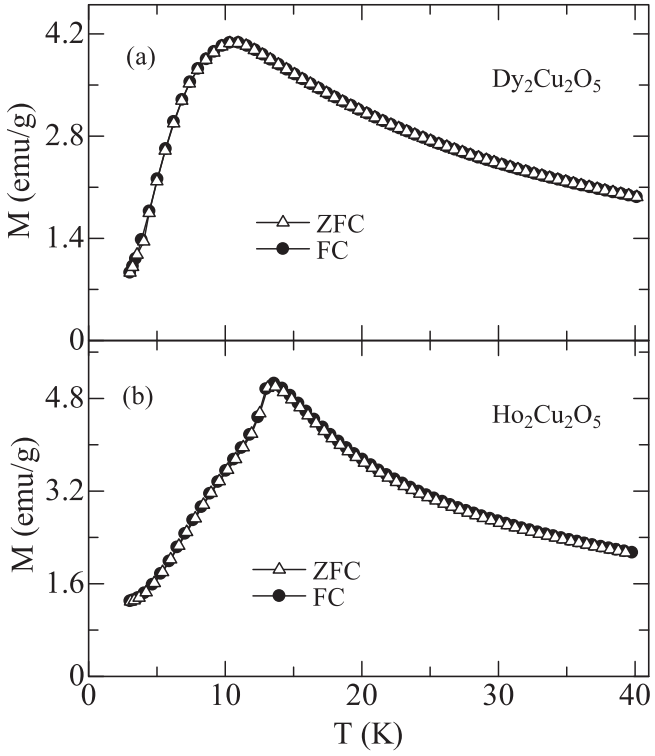

Fig. 1. Temperature dependence of the zero field cooled (ZFC) and field cooled (FC) magnetization (*M*) under the magnetic fields of 0.2 T for (a) $Dy_2Cu_2O_5$ and (b) $Ho_2Cu_2O_5$.

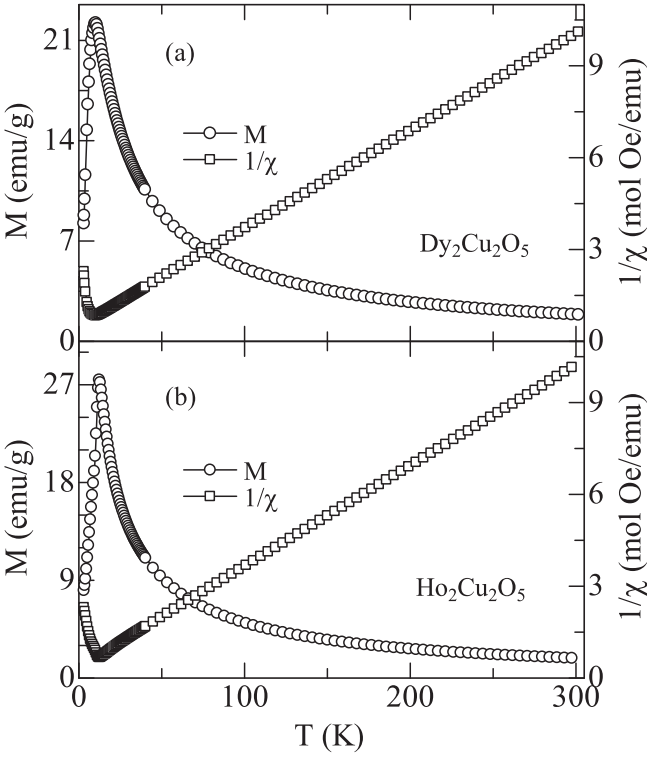

Fig. 3. Temperature dependence of the magnetization *M* (left scale) and the reciprocal susceptibility $1/\chi$ (right scale) under a magnetic field $H = 1$ T for $Dy_2Cu_2O_5$ and $Ho_2Cu_2O_5$.