Intermetallics 85 (2017) 69–73

Contents lists available at ScienceDirect

Intermetallics

journal homepage: www.elsevier.com/locate/intermet

Large reversible magnetocaloric effect in the $RECoC_2$ (RE=Ho and Er) compounds

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ARTICLE INFO

Article history:
Received 2 January 2017
Received in revised form
13 January 2017
Accepted 4 February 2017

Keywords:
$HoCoC_2$ and $ErCoC_2$ compounds
Magnetocaloric effect
Magnetic properties
Magnetic refrigeration

ABSTRACT

The crystal structure, magnetic properties and magnetocaloric effect (MCE) of $HoCoC_2$ and $ErCoC_2$ have been investigated. They both crystallize in orthorhombic $CeNiC_2$-type structure with $Amm2$ space group and a second-order paramagnetic to ferromagnetic phase transition around the Curie temperature T_C ~11 K and ~14 K occurred in them. Under the magnetic field change (ΔH) of 0–5 T, the maximal values of magnetic entropy change, refrigerant capacity and relative cooling power are 15.6 J/kg K, 183 J/kg, 242 J/kg for $HoCoC_2$ and 17.2 J/kg K, 243 J/kg, 375 J/kg for $ErCoC_2$, respectively.

1. Introduction

On the basis of the magnetocaloric effect (MCE), magnetic refrigeration is regarded as an alternative refrigeration technology on account of its advantages like environmental friendliness, higher efficiency, smaller, quieter and more reliable as compared with the traditional gas compression cooling method [1–6]. All magnetic materials exhibit magnetocaloric effect (MCE) and it is an intrinsic phenomenon which usually manifests as adiabatic temperature change (ΔT_{ad}) and isothermal magnetic entropy change (ΔS_M). Searching for new highly efficient and reliable magnetic materials with excellent MCE performances is considered to be the main mission in the research of magnetic refrigeration. In recent years, some of the rare-earth based intermetallic compounds have gained a lot of attention and been investigated for potential application at low temperature around 20 K, which are eligible to be applied for hydrogen liquefaction [7–18].

The existing intermetallics $RETC_2$ (RE stand for heavy rare earth element and T stands for transition metal Co and Ni) exhibit interesting physical and chemical properties and have attracted lots of attention. Schäfer et al. have reported that all the $RECoC_2$ compounds order ferromagnetically [19–25]. Among the $RETC_2$ compounds, only the MCE in $GdCoC_2$ and $TbCoC_2$ have been reported and the maximal value of magnetic entropy change ($-\Delta S_M^{max}$) are 28.4 J/kg K and 15.3 J/kg K under the magnetic field change of 0–5 T, respectively [14,16]. In the present study, we continue the investigation of MCE in $RETC_2$ and investigated the MCE in $HoCoC_2$ and $ErCoC_2$. The values of $-\Delta S_M^{max}$ are 15.6 J/kg K and 17.2 J/kg K for the magnetic field change of 0–5 T, respectively.

2. Experimental details

The samples of $HoCoC_2$ and $ErCoC_2$ were synthesized by the method of arc melting high-purity (99.99%) elements Ho, Er, Co and C. For purpose of compensating the loss in the melting, 3% extra carbon were added. The samples were turned over and melted for three or four times under an argon atmosphere in order to have good homogeneity. Then the samples were annealed at 900 °C for nine days in evacuated quartz tubes and rapidly quenched in ice water. The samples were characterized by X-ray powder diffraction (XRD) measurement by Rigaku D/MAX 2550 using Cu Kα radiation. The measurements of magnetization were performed by a commercial superconducting quantum interference device based vibrating sample magnetometer (SQUID-VSM) by Quantum Design.

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http://dx.doi.org/10.1016/j.intermet.2017.02.006
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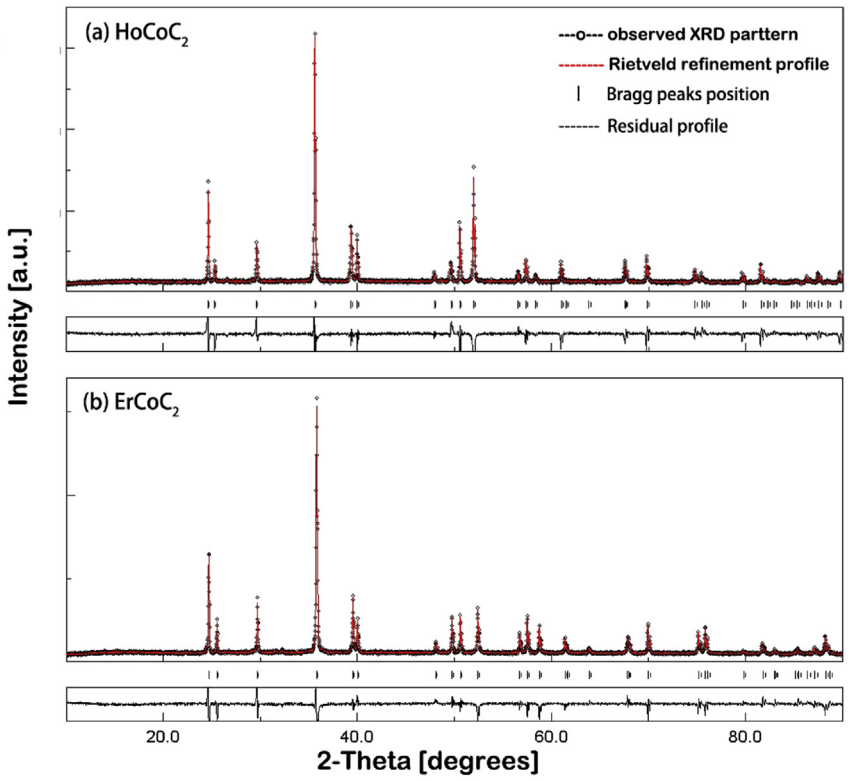

Fig. 1. XRD patterns of $HoCoC_2$ (a) and $ErCoC_2$ (b) together with the Rietveld refinement profiles, Bragg peak positions and Residual profiles.

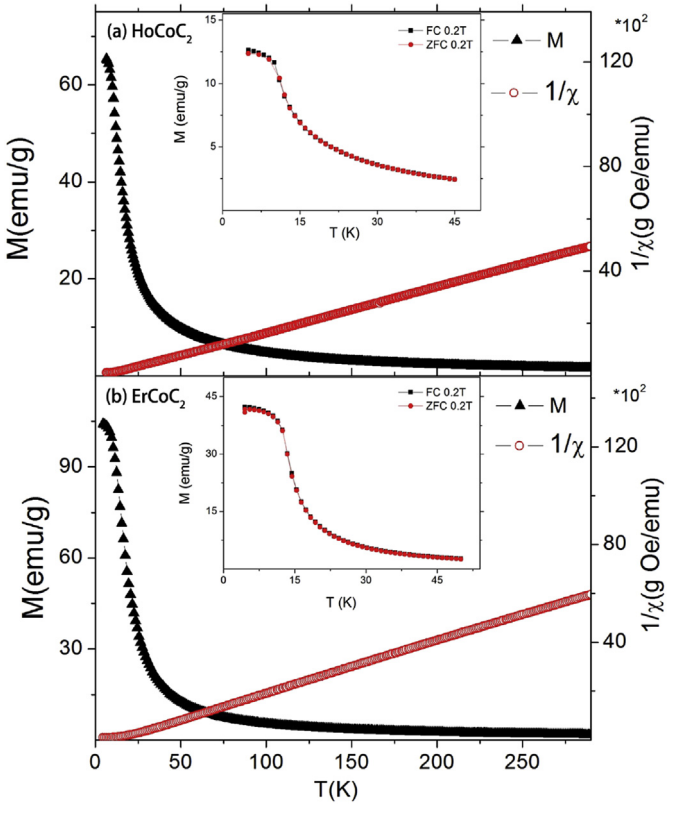

Fig. 2. Temperature dependence of the inverse susceptibility $1/\chi$ (right scale) and magnetization (left scale) of $HoCoC_2$ (a) and $ErCoC_2$ (b). Inset: the ZFC and FC magnetization-temperature curve under the magnetic field of 0.2 T.

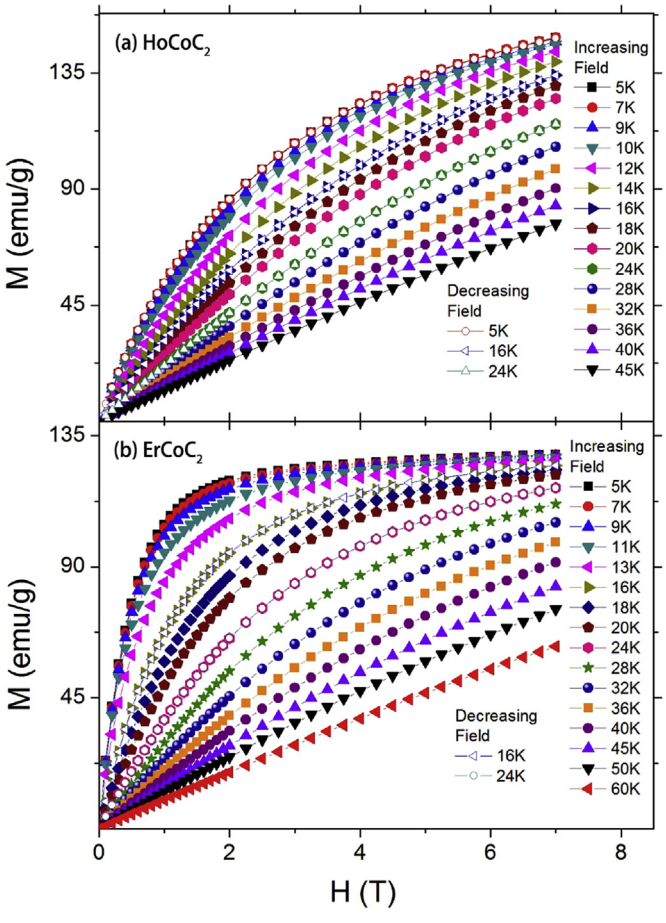

Fig. 3. Magnetic isotherms of $HoCoC_2$ (a) and $ErCoC_2$ (b) at selected temperatures.