

Electrical transport and magnetic ordering in $R_2Ti_3Ge_4$ ($R = Dy, Ho$ and Er) compounds

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Abstract. New $R_2Ti_3Ge_4$ ($R = Dy, Ho$ and Er) intermetallic compounds have been synthesized and characterized by X-ray diffraction and low temperature ac magnetic susceptibility, electrical resistivity and thermoelectric power measurements were carried out. The compounds crystallize in the parent, Sm_5Ge_4 -type orthorhombic structure (space group $Pnma$) and lanthanide contraction is observed as one moves along the rare-earth series. The changeover from paramagnetic to antiferromagnetic phase happens at low temperatures and the ordering temperature scales with the de Gennes factor. The electrical resistivity is metallic with a negative curvature above 100 K. Thermopower displays a weak maximum at temperatures less than 50 K signifying the possible phonon and magnon drag effects.

Keywords. Intermetallic compounds; magnetic ordering; electrical resistivity; thermoelectric power.

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1. Introduction

In order to develop an efficient, energy saving and environment friendly magnetic refrigeration technology, material scientists are trying to tailor new magnetic materials exhibiting giant magnetocaloric effect in different temperature regions. In particular, $Gd_5(Si_xGe_{1-x})_4$ alloys made a hallmark as their ferromagnetic ordering temperature can be tuned between 20 to 290 K by adjusting Si : Ge ratio [1,2]. These alloys also undergo structural phase transition at their first-order magnetic ordering temperature. Aiming to identify new materials for active magnetic regenerators, effect of substitution at rare-earth site by a suitable rare-earth or transition metal is being investigated. In this context, titanium substitution at rare-earth site has resulted in stable $R_2Ti_3Ge_4$ intermetallic phase. In this paper, magnetic and electrical transport property results obtained on three new $R_2Ti_3Ge_4$ ($R = Dy, Ho$ and Er) compounds will be discussed.

2. Experimental details

The polycrystalline $\text{Dy}_2\text{Ti}_3\text{Ge}_4$, $\text{Ho}_2\text{Ti}_3\text{Ge}_4$ and $\text{Er}_2\text{Ti}_3\text{Ge}_4$ compounds were prepared by electric arc melting under argon atmosphere starting from stoichiometric amounts of high purity constituent elements (Dy, Ho, Er, Ti and Ge – 99.99% pure) followed by vacuum annealing at 1100 K for 8 days. The compounds were characterized by powder X-ray diffraction experiments at room temperature. The dc electrical resistivity measurements were carried out by standard four-probe technique in a Janis closed cycle refrigerator (CCR) in the temperature range of 15 K–300 K. The ac magnetic susceptibility measurements were performed in a bath-type cryostat down to 4.2 K. The thermoelectric power was measured by employing conventional differential technique using copper as a reference material in CCR.

3. Results and discussion

The X-ray diffractograms were analyzed in the isotropic approximation using Rietan programs. The compounds order in Sm_5Ge_4 -type orthorhombic structure (space group Pnma) [3]. The lattice parameters (a , b , c) of the compounds refined at room temperature are given in table 1.

The ac magnetic susceptibility results are given in figure 1. The Dy- and Ho-based compounds undergo from a room temperature paramagnetic to low temperature antiferromagnetic transition at 14 K and 5.6 K respectively. The $\text{Er}_2\text{Ti}_3\text{Ge}_4$ compound does not undergo any magnetic transition down to 4.2 K. The electrical resistivity of these compounds show metallic behavior with a negative curvature at higher temperatures (figure 2). This negative deviation from quasi-linear phonon trend can be ascribed to the s–d scattering

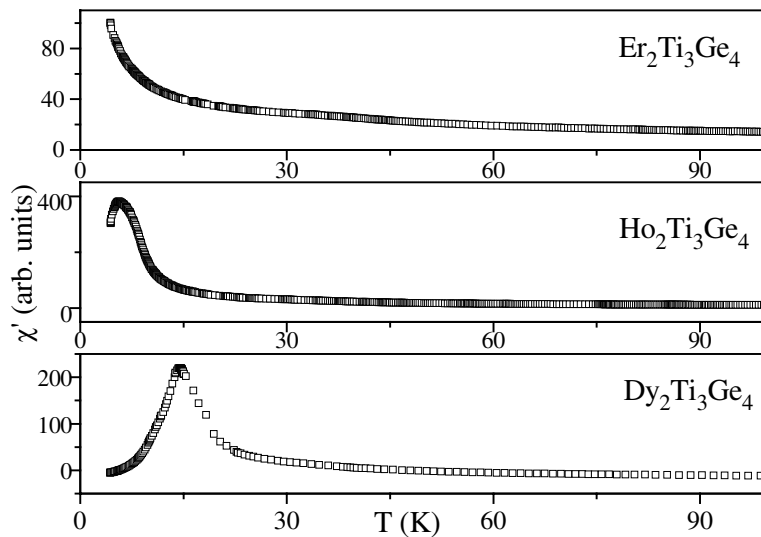


Figure 1. The ac magnetic susceptibility vs. temperature plots for $R_2\text{Ti}_3\text{Ge}_4$ ($R = \text{Dy}, \text{Ho}, \text{Er}$) compounds.

Table 1. Crystal structure parameters of $R_2Ti_3Ge_4$ ($R = Dy, Ho$ and Er) compounds.

Compound	a (nm)	b (nm)	c (nm)	V (nm ³)	R_F (%)
Dy ₂ Ti ₃ Ge ₄	0.6987(1)	1.3409(2)	0.7122(1)	0.66727	4.1
Ho ₂ Ti ₃ Ge ₄	0.6981(1)	1.3400(2)	0.7117(1)	0.66577	3.4
Er ₂ Ti ₃ Ge ₄	0.6962(1)	1.3367(2)	0.7099(1)	0.66063	3.6

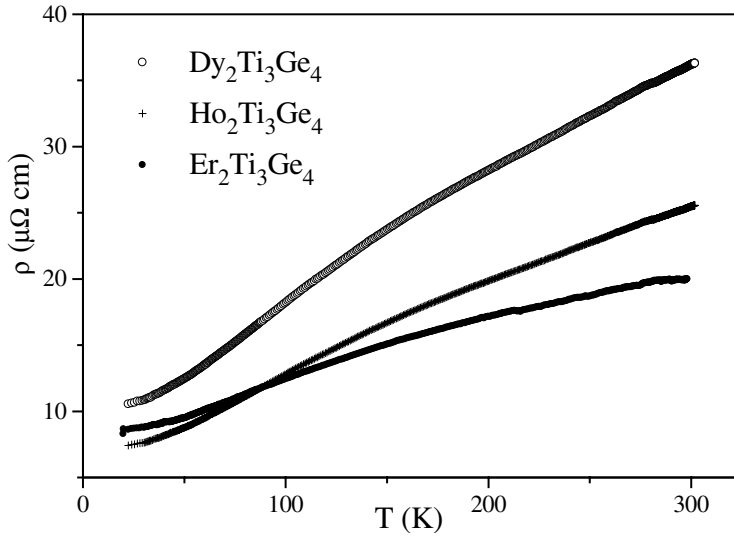


Figure 2. Variation of electrical resistivity ρ with temperature for Dy₂Ti₃Ge₄, Ho₂Ti₃Ge₄ and Er₂Ti₃Ge₄.

mechanism indicating d-like Fermi surface. Thermoelectric power (S) of these materials increases more or less linearly from a small negative value at room temperature showing a peak around 30 K, below which the value of S falls (figure 3). The absolute values of resistivity and thermoelectric power at typical temperatures are listed in table 2.

Table 2. Magnetic and transport property data of $R_2Ti_3Ge_4$ ($R = Dy, Ho$ and Er) compounds.

Compound	T_N (K)	ρ (280 K) ($\mu\Omega$ cm)	ρ (30 K) ($\mu\Omega$ cm)	S (280 K) ($\mu V/K$)	S (30 K) ($\mu V/K$)
Dy ₂ Ti ₃ Ge ₄	14	34.7	11	-1.2	6.0
Ho ₂ Ti ₃ Ge ₄	5.6	24.4	7.7	-0.9	12.2
Er ₂ Ti ₃ Ge ₄	N	19.8	8.9	-1.0	15.1

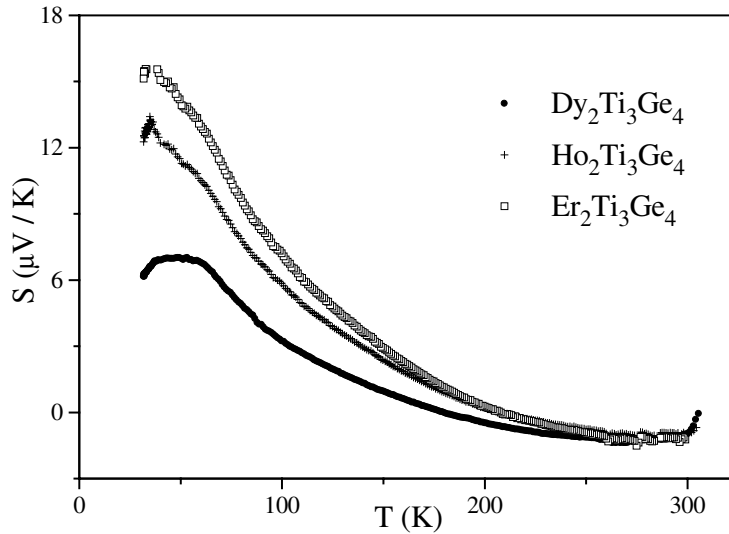


Figure 3. Thermoelectric power S vs. temperature for $\text{Dy}_2\text{Ti}_3\text{Ge}_4$, $\text{Ho}_2\text{Ti}_3\text{Ge}_4$ and $\text{Er}_2\text{Ti}_3\text{Ge}_4$.

4. Conclusion

Titanium substitution at rare-earth site of R_5Ge_4 compounds retains the antiferromagnetic nature of the ground state and the magnetic transition temperature values scale with de Gennes factor. The electrical resistivity is metallic and the absolute resistivity at room temperature is more for Gd compound [4] and it decreases systematically for heavier rare-earth containing compounds.

References

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