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Crystal structure and magnetic properties of $R_2Co_3Al_9$ compounds (R=Y, Pr, Gd, Tb, Dy, Ho, Er, Tm)

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Abstract

The crystal structure and the magnetic properties of the ternary $R_2Co_3Al_9$ (R=Y, Pr, Gd, Tb, Dy, Ho, Er, Tm) alluminides have been studied from 2 to 300 K under magnetic fields up to 5.5 T. $Y_2Co_3Al_9$ is a Pauli paramagnet while $Pr_2Co_3Al_9$ orders antiferromagnetically at low temperature. $Gd_2Co_3Al_9$ presents two characteristic anomalies around 100 and 20 K.This also occurs with $Tb_2Co_3Al_9$ around 15 and 100 K. $Dy_2Co_3Al_9$, $Ho_2Co_3Al_9$ and $Er_2Co_3Al_9$ order ferromagnetically with low Curie temperatures and $Tm_2Co_3Al_9$ remains paramagnetic down to 2 K.

Keywords: Intermetallics; Crystal structure; Magnetic measurements

1. Introduction

Crystallographic and magnetic properties of the rare earth cobalt gallides have been the subject of our systematic investigations [1–6]. $RCo_{5-x}Ga_x$ (x=1,2) compounds ($CaCu_5$ type structure) show ferromagnetic behavior (light rare earth), while those with the heavy rare earth are ferrimagnetic [1–5]. R_2CoGa_3 compounds (R= Gd, Tb, Dy, Ho, Er and Y) crystallize in the hexagonal $P6_3/mmc$ space group [7] and order ferromagnetically with relatively low Curie temperatures (3 K (Er)$<T_c<$50 K (Gd)) [6]. Finally $RCoGa_4$ compounds (R=Ce, Pr, Nd) crystallize in the orthorhombic *Cmcm* space group [8] and present rather paramagnetic behavior down to 4.6 K [2]. As a continuation of the above study, we report in this paper the crystal structure of $R_2Co_3Ga_9$ (actually $R_{0.66}CoGa_3$) and $R_2Co_3Al_9$ compounds and the magnetic properties of $R_2Co_3Al_9$ compounds.

2. Experimental

All of the samples reported here, were prepared from high purity elements by arc melting under an argon atmosphere and then annealed at 900°C for 10 days to ensure homogeneity. X-ray analysis showed that the compounds $R_2Co_3Al_9$ with R=Y, Gd, Tb, Dy, Ho, Er and Tm were single-phase. Using the Lazy Pulverix program, the lattice parameters were determined on the basis of the orthorhombic *Cmcm* space group and are given in Table 1.

The atom positions are similar to that of the isotypic compound $Y_2Co_3Al_9$ [9], the first alluminide identified with the $Y_2Co_3Ga_9$ structure type [10].

The as cast and after annealing $Pr_2Co_3Al_9$ crystallize in the orthorhombic $LaCoAl_4$ type of structure (space group *Pnma*) [11] and $Nd_2Co_3Al_9$ was identified as two-phase mixture.

Powder X-ray diffraction patterns for all $R_2Co_3Ga_9$ compounds, do not confirm the crystal stucture suggested by Yu.N. Grin et al. [10]. The crystal structure of the $CeCoAl_4$ and $PrCoAl_4$ (orthorhombic structure, space group *Pnma*) looks as more likely [12,13]. Therefore, in order to clarify the space group and atom positions, more investigation is desirable for the $R_2Co_3Ga_9$ compounds.

The magnetic measurements were performed by a SQUID Magnetometer in the temperature range from 2 to 300 K, for fields up to 5.5 Tesla.

Table 1
Crystallographic data for the $R_2Co_3Al_9$ compounds

R	Lattice parameters (A)		
	a	*b*	*c*
Gd	12.757(2)	7.570(5)	9.450(2)
Tb	12.745(3)	7.510(7	9.3709(3)
Dy	12.740(3)	7.522(8)	9.411(4)
Ho	12.746(4)	7.511(5)	9.380(3)
Er	12.738(3)	7.509(7)	9.378(4)
Y	12.740(5)	7.523(8)	9.411(3)

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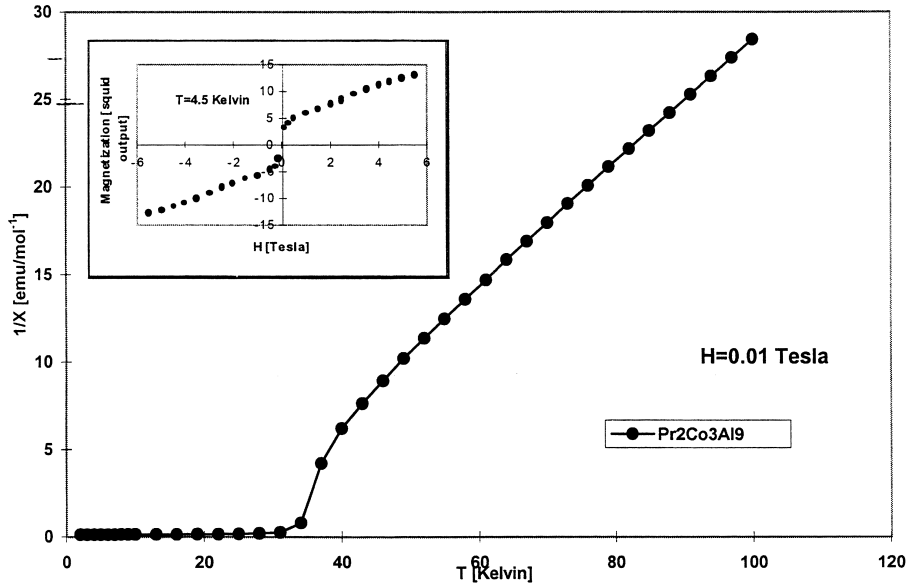

Fig. 1. Inverse magnetic susceptibility for $Pr_2Co_3Al_9$. Insert field dependence of the magnetization at 4.5 K.

3. Results

The $Y_2Co_3Al_9$ compound is a weak Pauli paramagnet with a small susceptibility that is only slightly temperature dependent. In these compounds, the cobalt atoms do not carry any magnetic moment.

$Pr_2Co_3Al_9$ compound orders antiferromagnetically at T_N=37 K (Fig. 1). The result is in agreement with similar results obtained on approximately the same composition $PrCoAl_4$ compound [13]. Curie–Weiss behaviour is reasonably well followed above 40 K. Inset of Fig. 1 presents hysteresis cycle for this compound.

In the case of the Gd sample, we observed two well defined magnetic transitions, one at 25 K and the other around 130 K (Fig. 2). The field dependence of the magnetization at 4.5 K is shown in the inset of Fig. 2.

A jump is observed at about 15 K in the magnetic susceptibility curve for $Tb_2Co_3Al_9$ compound associated with a phase transition (Fig. 3). A second change in the slope occurs at about 100 K. Similar compound Tb_2CoGa_3 orders ferromagnetically with relatively low T_c temperature (27 K) [14]. The anomaly at low temperature in the $\chi(T)$ curve could be associated with the ordering temperature. There is no hysteresis in the magnetization curve, the

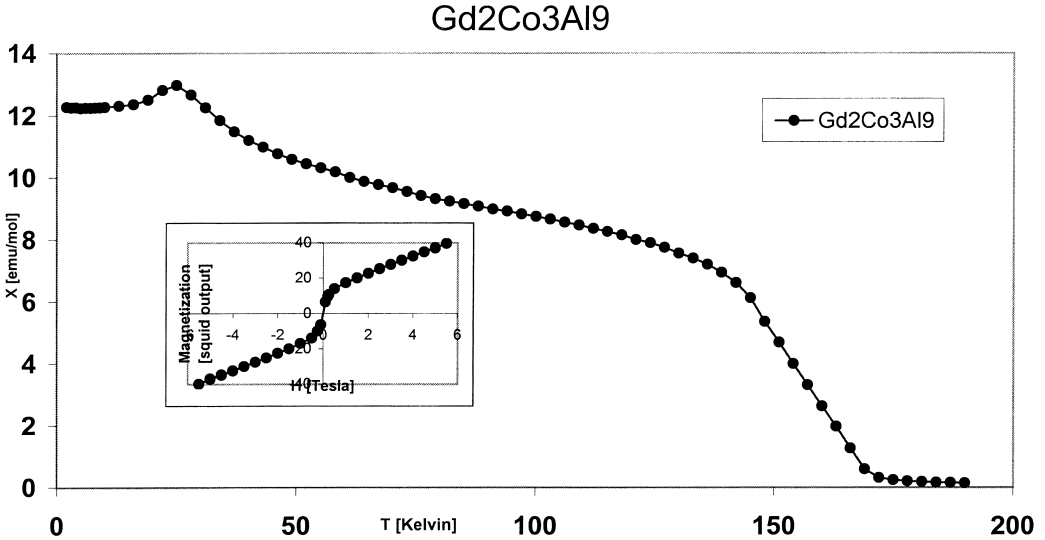

Fig. 2. Magnetic susceptibility for $Gd_2Co_3Al_9$. Insert field dependence of the magnetization at 4.5 K.

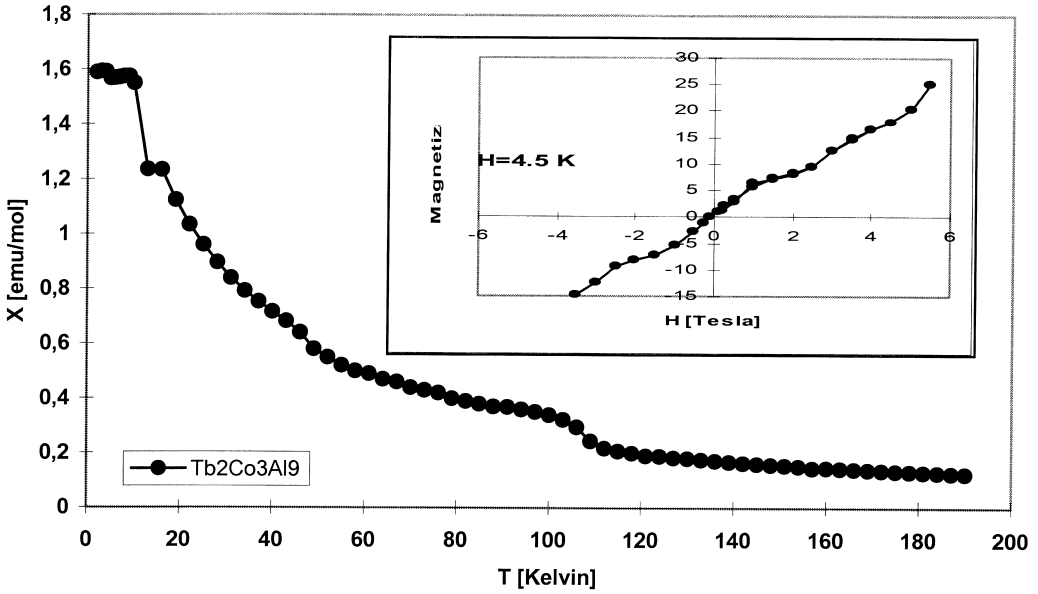

Fig. 3. Magnetic susceptibility for $Tb_2Co_3Al_9$. Insert field dependence of the magnetization at 4.5 K.

measurements with increasing and decreasing field being coincident. This curve exhibits two transitions at 2.5 and 5 T.

$Dy_2Co_3Al_9$, $Ho_2Co_3Al_9$ and $Er_2Co_3Al_9$ compounds order ferromagnetically with low Curie temperatures, 13, 10 and 5 K, respectively (Fig. 4). $Tm_2Co_3Al_9$ remains paramagnetic down to 2 K. The reciprocal susceptibility curves vs. T of the $R_2Co_3Al_9$ compounds (R=Dy, Ho, Er, Tm) follow Curie–Weiss law above about 30 K (inset of Fig. 4). The paramagnetic Curie temperatures θ_p are positive or near zero.

R_2CoGa_3 (R=Dy, Ho, Er) compounds present similar behaviour [6].

The nature of the magnetic transitions of the $R_2Co_3Al_9$ compounds will be the subject of neutron diffraction studies planned in the near future.

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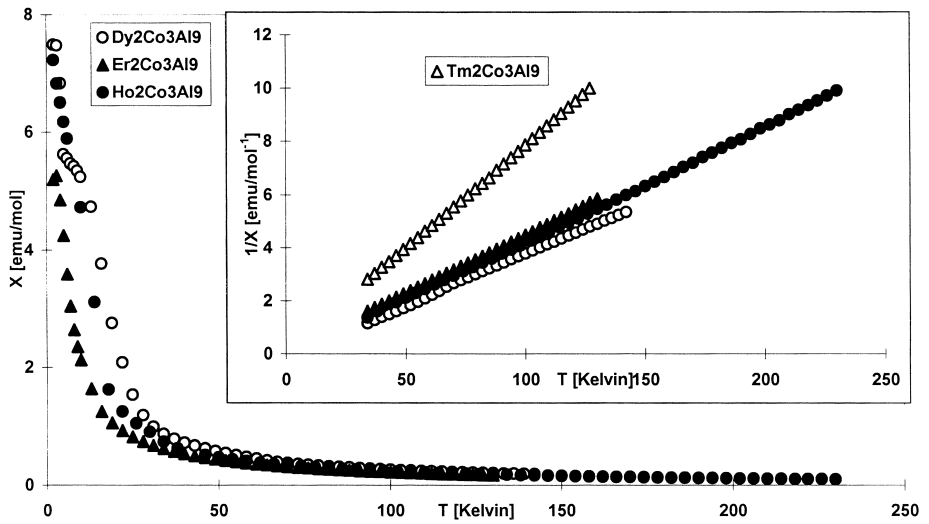

Fig. 4. Magnetic susceptibilities for $R_2Co_3Al_9$ compounds (R=Dy, Ho, Er) in a 0.01 T field. Insert shows inverse magnetic susceptibilities for R=Dy, Ho, Er and Tm.

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