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THE STRENGTH OF THE INTERSUBLATTICE INTERACTION IN THE (Er, Y)Fe₂ COMPOUNDS

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Abstract. - Magnetisation and magnetostriction measurements have been performed on the ferrimagnetic ErₓY₁₋ₓFe₂ (x = 1.0, 0.8, 0.6 and 0.4) compounds. All investigated compounds have a compensation point in the temperature range between 100 K and 500 K. The strength of the Er-Fe interaction has been estimated to be equal to 138 T/μ₉, equivalent to a value for the R-Fe coupling parameter of about 7.8 K.

1. Introduction

The magnetic behaviour of the RₓTₙ compounds (R is a rare-earth element and T a transition-metal element) is largely governed by the intersublattice interaction, especially for the heavy rare-earth elements. A numerical result for this interaction can, in general, be obtained from the Curie temperature, (Tc) [1, 2], or from an analysis of the paramagnetic susceptibility [3]. The ferrimagnetic compounds with a compensation point are also suited for an experimental study of the molecular field, see, for instance, the data reported for the compound ErₓFe₂₃ [4]. High-magnetic-field experiments provide another technique for evaluation of the intersublattice interaction, as has been shown for the series R₂T₇ [5, 6]. Recently, Radwanski [7] has shown that the R-T coupling parameter in the RₓTₙ compounds is rather insensitive to the R or T element as well as to the composition. The aim of the present paper is to evaluate the Er-Fe interaction parameter in the (Er, Y)Fe₂ compounds, by analysing the Curie temperatures and the compensation points.

2. Experimental results and analysis

Polycrystalline samples of the ErₓY₁₋ₓFe₂ compounds (x = 1.0, 0.8, 0.6 and 0.4) were prepared by arc-melting under argon atmosphere. Magnetisation measurements were performed by an induction method, whereas a three-terminal capacitance method was used to measure the magnetostriction. The temperature dependence of the magnetisation of the investigated compounds in an applied field of 0.2 T is presented in figure 1. All compounds are ferrimagnetic as follows from the observed compensation points at a temperature denoted by Tₓ. Values for Tₓ and Tk are collected in table I and table II, respectively. The results for Tk were confirmed by magnetostriction measurements.

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Table I. - Values for the Curie temperature, Tc, the 3d-susceptibility at Tc, χ₃d(Tc), and the iron effective moment, peff, in the ErₓY₁₋ₓFe₂ compounds.

<table>
<thead>
<tr>
<th>x</th>
<th>Tc (K)</th>
<th>χ₃d=10² (μμB/T at.)</th>
<th>peff (μμB/at.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>575</td>
<td>5.05</td>
<td>3.40</td>
</tr>
<tr>
<td>0.8</td>
<td>551</td>
<td>6.55</td>
<td>3.05</td>
</tr>
<tr>
<td>0.6</td>
<td>542</td>
<td>9.20</td>
<td>3.15</td>
</tr>
<tr>
<td>0.4</td>
<td>533</td>
<td>14.50</td>
<td>3.10</td>
</tr>
<tr>
<td>0.0</td>
<td>518</td>
<td>–</td>
<td>3.16</td>
</tr>
</tbody>
</table>

Table II. - Values for the compensation temperature, Tk, the molecular field coefficient, nR₋₃d, and the exchange interaction parameter, Jₓ₋₃d, for the ErₓY₁₋ₓFe₂ compounds.

<table>
<thead>
<tr>
<th>x</th>
<th>Tk (K)</th>
<th>nR₋₃d (T/μμB)</th>
<th>Jₓ₋₃d (T/μμB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>485</td>
<td>24.5</td>
<td>147</td>
</tr>
<tr>
<td>0.8</td>
<td>385</td>
<td>25.0</td>
<td>150</td>
</tr>
<tr>
<td>0.6</td>
<td>296</td>
<td>29.0</td>
<td>172</td>
</tr>
<tr>
<td>0.4</td>
<td>155</td>
<td>30.0</td>
<td>180</td>
</tr>
</tbody>
</table>

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The Curie temperature is described in the so-called s-d model [1, 2, 8, 9] by the following expression:

$$T_c = \left[ N \mu_B^2 J_{R-3d} \right] \chi_d (T_c)$$  \hspace{1cm} (1)

with $J_{R-3d}$ the effective exchange constant, $(g - 1)^2 J (J + 1)$ the De Gennes factor, $\chi_d (T_c)$ the 3d-susceptibility at $T_c$, Avogadro’s number, etc. A value of $138 \ T/\mu_B$ has been derived for the parameter $J_{R-3d}$ of the RFe$_2$ compounds in order to obtain a value of $3.4 \ \mu_B$/at. for the effective moment of iron [9]. The corresponding value for the R-T spin-spin coupling parameter $A_{R-3d}$ amounts to $10.6 \times 10^{-23} \ J$. This result is in good agreement with the value of $9.27 \times 10^{-23} \ J$, reported for all R$_m$T$_n$ intermetallics [6, 7]. Substituting the experimentally derived values for the Curie temperature together with the above-given result for $J_{R-3d}$ in equation (1), we determined values for $\chi_d (T_c)$. The results are listed in table I. Describing the $\chi_d$ values with a Curie-Weiss law with a value for $\theta$ of 518 K (the ordering temperature of YFe$_2$) we deduce values for the effective iron moment decreasing from $3.4 \ \mu_B$/at. for ErFe$_2$ to $3.1 \ \mu_B$/at. in the yttrium-substituted alloys, see table I. A similar decrease of the effective iron moment has also been observed for the (Gd, Y)Fe$_2$ system [11].

The exchange interaction parameter can also be evaluated from the temperature of the compensation point. In this case we approximate the temperature dependence of the rare-earth moment by a Brillouin function:

$$M_R (T) = x g J \mu_B B J \left( g \mu_B n_{R-3d} M_d / k_B T \right)$$  \hspace{1cm} (2)

The value for $M_d$ is determined from experiments. Here, we employ the results from our Mössbauer-spectroscopy investigations at room temperature: $M_d = 1.30 \ \mu_B$. The resulting values for $n_{R-3d}$ are collected in table II. The interaction parameter $n_{R-3d}$, determined in this way, is not sensitive to the exact value for the 3d moment. Decreasing, for instance, $M_d$ from 1.6 $\mu_B$ down to 1.0 $\mu_B$, we calculate a five percent decrease in the value of $n_{R-3d}$ for ErFe$_2$ only.

From the value of $24.5 \ T/\mu_B$ for $n_{R-3d}$ of ErFe$_2$ we deduce a value of $(147 \ T/\mu_B)$ for the parameter $J_{R-3d}$ ($= n_{R-3d} g / (g - 1)$). This value is in satisfying agreement with that deduced from the expression for $T_c$ ($138 \ T/\mu_B$). A refinement in the derivation of $n_{R-3d}$ can be made by taking into account in equation (2) the interactions within the rare-earth sublattice.

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