ESR OF Gd^{3+} IN INTERMETALLIC COMPOUNDS $Gd_{1-x}Re_xAl_2$ (Re = Dy, Ho, Er)*

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ESR spectra of $Gd_{1-x}Re_xAl_2$ (Re = Dy, Ho, Er) have been measured in the paramagnetic state. It was found that the changes in the Δg and $dDH/dT(x)$ values cannot be described using the Hasegawa theory.

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1. Introduction

In [1], Hasegawa has analysed an interaction of localised spins with conduction electrons (CE) in diluted alloys. When the relaxation rate of CE to the lattice δ_{eL} is smaller than that of CE to the impurities δ_{ei} the possibility of the "bottleneck" effect has been forseen in ESR. The set of the equations derived in that paper describes the dependence of the g-factor and the thermal broadening of the ESR line dDH/dT on the relaxation rate. This theory gives an explanation of some experimental data for metallic systems with localised moments. The bottleneck effect can be open by the addition of other impurities which relax faster to the lattice or by a diminishing the concentration of localised moments [2].

Thân Trong Nguyên et al. [3] tried to apply the Hasegawa theory to describe ESR in the intermetallic compounds $Gd_{1-x}Dy_xAl_2$ (x: 0–0.2), where the bottleneck effect in $GdAl_2$ was opened by the addition of Dy atoms. The variation of the g values could not be described by this theory. More information could be obtained by analysing experiments for similar compounds. In the present paper the results of the measurements of ESR are shown for $Gd_{1-x}Re_xAl_2$ (where Re = Ho, Dy, Er; x = 0–0.2).

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2. *Experimental*

The alloys investigated were prepared by arc melting of the starting metals Re(3N), Al(5N) in Ar. For all the concentrations of Re the cubic Laves phase C15 was observed. The ESR measurements were performed within the x-band at 90–300 K. Analysis of the asymmetrical lines for Gd^{3+} ions was performed by the method shown by Peter et al. [4].

Fig. 1 shows the dependence of the resonance linewidth DH and the g-factor on the temperature for several values of the concentration x of the Er atoms in $Gd_{1-x}Er_xAl_2$. The dependence $DH(T)$ on the left side of the minimum is connected with the para-ferro-

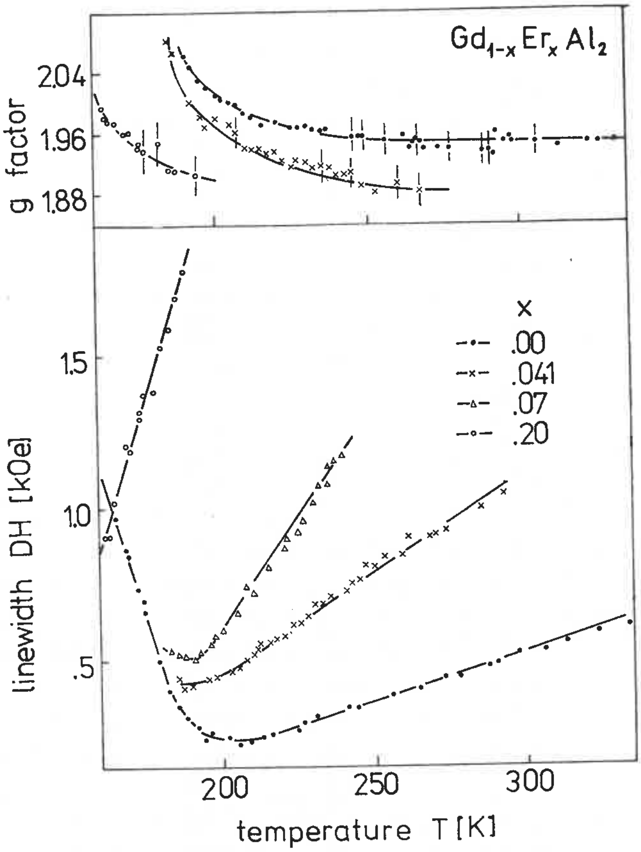

Fig. 1. The temperature dependence of the resonance linewidth and g-factor for different concentrations of Er in $Gd_{1-x}Er_xAl_2$

magnetic transition and has not been analysed. Also the g-factor in the vicinity of the phase transition has not been considered. Fig. 2 and 3 show the dependence of the temperature line broadening and g-factor on the concentration of Re-atoms in $Gd_{1-x}Re_xAl_2$. The x-dependences of the linewidth slope are similar for Er, Ho and Dy. The g-factor decreases with the concentration of Re, but the changes for Ho and Dy are greater than those for Er.

Our results for Dy differ slightly from Nguyên's [3], which may be caused by differences in sample preparation. To avoid similar discrepancies, all our samples have been obtained under the same conditions and all measurements have been performed with the same ESR spectrometer. In this way the relative changes of the investigated quantities have been measured very accurately.

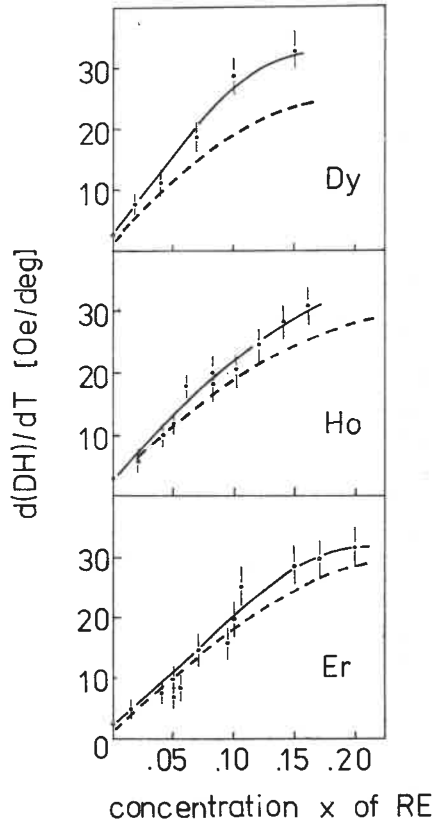

Fig. 2

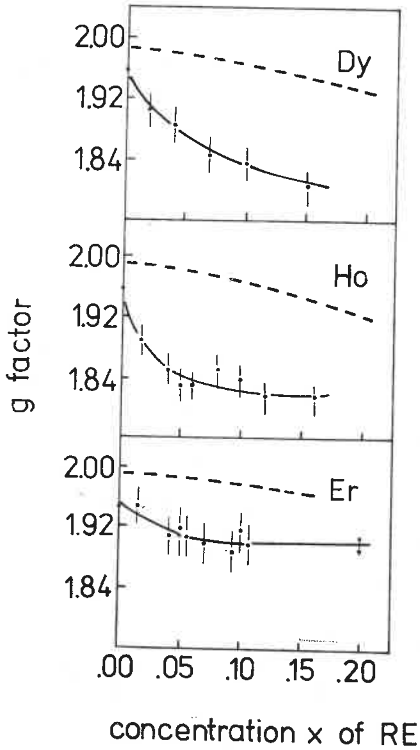

Fig. 3

Fig. 2. The thermal broadening linewidth as a function of Re concentration in $Gd_{1-x}Re_xAl_2$. The dashed lines are the results of fitting the (3) terms to the data

Fig. 3. The dependence of the g-factor on Re concentration. The dashed lines are obtained from formula (4)

3. *Discussion*

The aim of this work was to check how the Hasegawa theory describes the change of the Δg and dDH/dT values in $Gd_{1-x}Re_xAl_2$ compounds. When one neglects the dynamical effects $[(\gamma\lambda\chi_i H/\delta_{ei})^2 \ll 1]$ for systems with the bottleneck effect $(\delta_{eL}/\delta_{ei} \ll 1)$ the

Hasegawa theory gives the following formulas for DH and Δg:

$$DH \approx \frac{\delta_{eL}/\delta_{ei}}{(\delta_{eL}/\delta_{ei})+1} DH_k, \tag{1}$$

$$\Delta g \approx \frac{(\delta_{eL}/\delta_{ei})^2}{[(\delta_{eL}/\delta_{ei})+1]^2} \Delta g_k, \tag{2}$$

where DH_k and Δg_k are the Korringa linewidth and the Korringa shift [5]. Assuming [3] that: (*i*) the relaxation rate of CE to Gd is $\delta_{ei} = \delta^0_{ei}(1-x)$ (where δ^0_{ei} = rate for $GdAl_2$), (*ii*) the relaxation rate of CE to Re is $\delta_{eR} = \delta^0_{eR}x$, and (*iii*) the rate of CE to the lattice $\delta_{eL} = \delta^0_{eL}+\delta^0_{eR}x$ we can write the formulas (1) and (2) in the following form:

$$\frac{dDH}{dT} = \frac{(\delta^0_{eL}/\delta^0_{ei})+x(\delta^0_{eR}/\delta^0_{ei})}{(\delta^0_{eL}/\delta^0_{ei})+x(\delta^0_{eR}/\delta^0_{ei})+(1-x)} \frac{dDH_k}{dT}, \tag{3}$$

$$\frac{\Delta g}{\Delta g_k} = \left(\frac{dDH}{dT}\bigg/\frac{dDH_k}{dT}\right)^2. \tag{4}$$

The formulas (3) and (4) do not contain the magnetic interaction between Gd and Re. The only effect which is taken into account is the opening of an additional path of energy transfer from CE to the lattice caused by the presence of the impurity Re.

The dashed lines in Figs 2 and 3 are the results of fitting the (3) and (4) terms to the data and the parameters obtained for the best fit of $dDH/dT(x)$ are shown in Table I. The δ_{eL}/δ_{ei} changes by one order of a magnitude for different sequences. This quantity refers

TABLE I

Re in $Gd_{1-x}Re_xAl_2$	$\frac{\delta^0_{eL}}{\delta^0_{ei}}$	$\frac{\delta^0_{eR}}{\delta^0_{ei}}$	dDH_k/dT [Gs/deg]
Dy	0.022	5.7	48
Ho	0.047	5.0	49
Er	0.0031	5.7	49

to the pure $GdAl_2$ and this should not depend on the impurities. To estimate the Δg shift it has been assumed [3] that the g-factor for the high concentration of the Dy atoms is equal to the unbottlenecked g_k. This question arises if the system is already completely bottlenecked in this range of concentration. From the considerations presented it seems that the experimental results cannot be explained by the existing Hasegawa theory. It has been suggested previously [6] that the observed effects could be connected, for instance, with the reversing of the position Re$-8a$ and Al$-16d$ in $Gd_{1-x}Re_xAl_2$. The observed effects can also be influenced by the magnetic interaction of Gd and Re which has not been taken into account. In order to avoid this difficulty an experiment with a non-magnetic impurity is necessary. Such an experiment is in progress with $GdAl_2$ doped La atoms. It is very probable that the negative shift Δg can be explained on the basis of the "two-band" model.

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